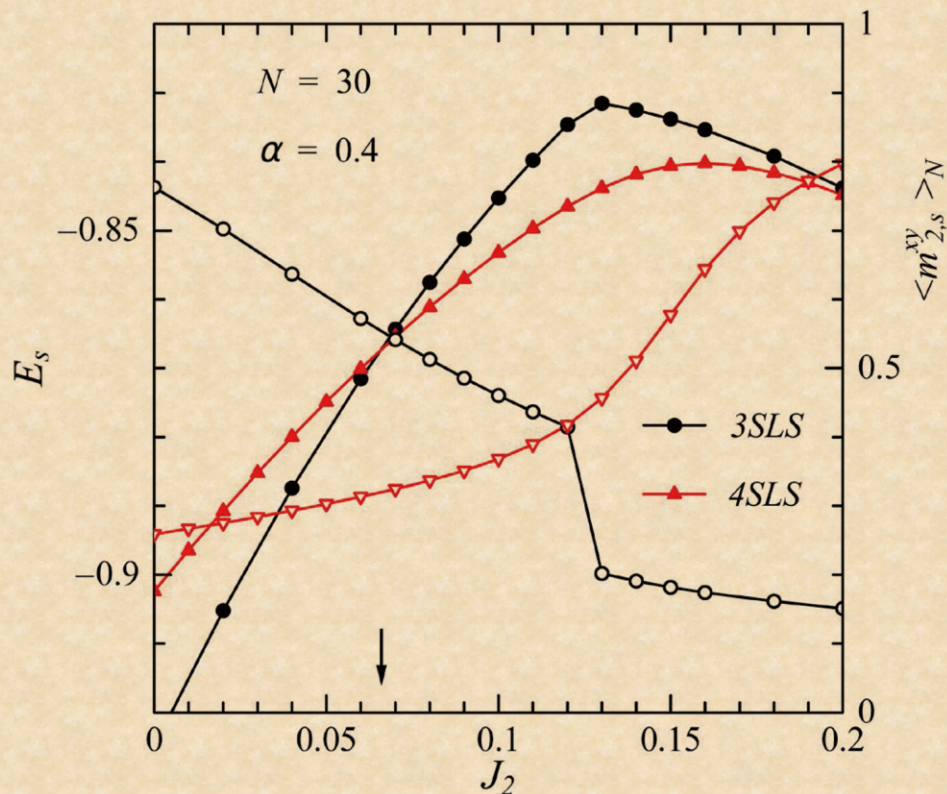


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On the Nature of π and μ Mesons

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Abstract

Earlier it was shown [1], that neutrino is a specific magnetic γ -quantum, which as any γ -quantum carries away the reaction energy. This allows taking a fresh look at the chain of reactions $\text{pion}^+ \rightarrow \text{muon}^+ \rightarrow e^+$, which is accompanied by the emission of three neutrinos, but in which no other particles are generated. Since the role of neutrinos is a throwing away the energy of the initial particles, it is easy to conclude that both pion and muon are excited states of electron. The introduction of an additional assumption about the possible mechanism of the excited state of an elementary particle allows us to estimate the mass of these excited states. The obtained estimates are in good agreement with the experimentally measured values of the pion and muon masses.

Keywords

Neutrino, Pion, Muon, Electron

1. Introduction

According to modern concepts, mesons are an integral part of the Standard model.

It is assumed that μ -mesons, being leptons, do not have a quark structure and do not participate in reactions with strong interaction, unlike charged π -mesons, which consist of quarks and are characterized by strong interaction with other particles.

However, it is important that there is a characteristic chain of transformations:

$\text{Pion}^- \rightarrow \text{muon}^- \rightarrow \text{electron}$, in which these particles are connected only by successive radiation of several neutrinos (**Figure 1**).

Therefore, the key to understanding the nature of pions and muons is given by neutrino physics.

Neutrinos are fundamental neutral stable particles with extremely high penetrating

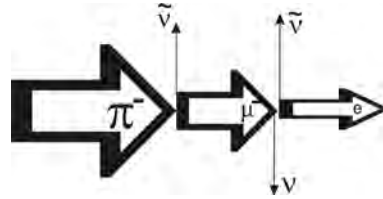


Figure 1. Schematic representation of the chain of π^- -meson transformations into μ^- -meson and then into an electron together with accompanying neutrinos.

power. This property distinguishes them from all other particles.

The fact that neutrinos propagate through space at the speed of light suggests that they have a unique specific electromagnetic nature.

Radiation and propagation of electromagnetic excitations in the ether with all the completeness and accuracy has been studied by classical electrodynamics.

The question about fields generated by oscillating electric or magnetic moments is considered in detail in all courses of classical electromagnetic theory.

However, these courses do not address the issue of radiation, which should accompany the very quickly (relativistically quickly) turn on of the magnetic moment. The reason for this, apparently, is that it is technically impossible to turn on a magnetic moment relativistically quickly.

However, this phenomenon exists in nature.

The magnetic moment arises relativistically quickly at beta decay when an electron is ejected from the decaying nucleus, since the electron has a large (on the microcosm scale) magnetic moment.

Let consider briefly the description of electromagnetic wave radiation in vacuum, which is given by the standard Maxwell theory.

2. Radiation of Electromagnetic Waves in Vacuum

For simplification we will assume that electric charges and their currents, electric dipoles and quadrupoles are absent initially.

Let the only source of electromagnetic fields in the subsequent consideration be the time-varying magnetic dipole moment $\mathbf{m}(t)$.

The time-varying electromagnetic field created by a wavering magnetic dipole can be represented by its vector potential [2]

$$\mathbf{A}(R, t) = \frac{[\dot{\mathbf{m}}(t^*) \times \mathbf{n}]}{cR}, \quad (1)$$

(to account for the delay of the electromagnetic signal, the retarded time is entered here $t^* = t - \frac{R}{c}$).

By definition ([2], Eq.46.4), in the absence of free charges (*i.e.* at $\varphi = 0$), the electric field of the electromagnetic wave

$$\mathbf{E}(R, t) = -\frac{1}{c} \frac{d\mathbf{A}(R, t)}{dt^*} = -\frac{1}{c^2 R} [\ddot{\mathbf{m}}(t^*) \times \mathbf{n}]. \quad (2)$$

The magnetic field in this wave

$$\mathbf{H}(R, t) = \text{rot} \mathbf{A}(R, t) = \left[\nabla \times \frac{\dot{\mathbf{m}}(t^*) \times \mathbf{n}}{cR} \right] = \frac{1}{c} \left[\nabla \times [\dot{\mathbf{m}}(t^*) \times \mathbf{n}] \cdot \frac{1}{R} \right] \quad (3)$$

That is, the magnetic field in the electromagnetic wave generated by the magnetic dipole

$$\mathbf{H}(R, t) = -\frac{1}{c^2 R} \left[\mathbf{n} \times [\ddot{\mathbf{m}}(t^*) \times \mathbf{n}] \right] + \frac{1}{cR^2} \left[\mathbf{n} \times [\dot{\mathbf{m}}(t^*) \times \mathbf{n}] \right] \quad (4)$$

2.1. Ordinary Electromagnetic Waves

The problem of electromagnetic wave generation by a magnetic dipole, whose oscillations are described by a differentiable function from time, is considered in electrodynamics courses in detail. A typical example of this movement is the harmonic oscillation of the dipole $\mathbf{m}(t) = \mathbf{m} \cdot \sin \omega t$.

In this case, in the wave zone, *i.e.* if the distance R is much greater than the wavelength $\lambda = c/\omega$, the relation exists

$$\frac{\ddot{\mathbf{m}}(t)}{\dot{\mathbf{m}}(t)} \approx \frac{R}{\lambda} \gg 1. \quad (5)$$

Therefore, in the wave zone, the electromagnetic wave (photon) has electric and magnetic fields of equal intensity

$$\mathbf{E}(R, t) = -\frac{1}{c^2 R} [\ddot{\mathbf{m}}(t^*) \times \mathbf{n}] \quad (6)$$

$$\mathbf{H}(R, t) = -\frac{1}{c^2 R} \left[\mathbf{n} \times [\ddot{\mathbf{m}}(t^*) \times \mathbf{n}] \right] \quad (7)$$

and only they are turned relative to each other by 90 degrees.

Tasks where the oscillations of the magnetic moment are described by more complex formulas have the same solution if spectra of these oscillations can be decomposed into harmonic components.

2.2. Magnetic Excitation of the Aether

The task on generation of electromagnetic radiation in vacuum, at the very rapid birth of the magnetic moment earlier in the courses of electrodynamics has never been considered.

An example of such a phenomenon is β -decay of neutron, in which a free electron bearing a large (in microcosm scale) magnetic moment arises relativistically quickly.

Another example is the transformation of π^- -meson into μ^- -meson and then into electron.

π -meson has no magnetic moment, but μ -meson and electron have it.

The uncertainty relation makes it possible to estimate the time of π -meson into μ -meson transformation:

$$\tau_{\pi \rightarrow \mu} \approx \frac{\hbar}{(M_{\pi} - M_{\mu})c^2} \approx 10^{-23} \text{ sec} \quad (8)$$

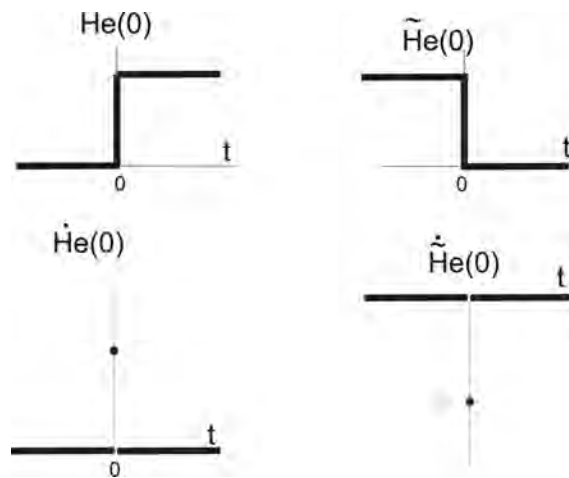


Figure 2. Two Heaviside's step functions—up and down—responsible for the birth of neutrinos and antineutrinos. Below are derivatives of these functions in time.

Thus, the vacuum excitation that occurs at β -decay due to the birth of the magnetic moment should be classified as a kind of particle, since it is characterized by a very short time interval.

The process of birth (or disappearance) of the magnetic moment can be described by the Heaviside's step function (Figure 2).

The first time derivative of the Heaviside's step function is δ -function, and the second derivative, due to the exceptional brevity of the process, is zero. So for this case from Equations (2) and (4) we receive

$$E(R, t) = 0 \quad (9)$$

$$H(R, t) \sim \dot{m}(t^*) \quad (10)$$

An unusual property, which should have such a particle, which can be called a magnetic γ -quantum, occurs due to the lack of magnetic monopoles in nature. The fact that normal photons, with the electric component, scattered and absorbed in matter with electrons. In the absence of magnetic monopoles, the magnetic γ -quantum of small energy should interact extremely weakly with the substance and its free path in the medium should be approximately two dozen orders of magnitude greater than that of a conventional photon [3].

In addition, being circularly polarized, a photon having both a magnetic and an electric component has a spin equal to \hbar . It seems natural to assume that a circularly polarized magnetic photon devoid of an electrical component should have a spin equal to $\hbar/2$.

The existence of two types of Heaviside's steps (up and down) suggests that there should be two types magnetic gamma-quanta (forward and reverse).

Since magnetic γ -quanta arise at β -decay, they can be identified with neutrinos (or antineutrinos), since all their basic physical properties coincide.

3. Mesons as Excited States of Electron

The chain of transformations $\text{pion}^+ \rightarrow \text{muon}^+ \rightarrow \text{electron}^+$ gives rise to three an-

tineutrino-neutrino. That is, three times there is a removal of energy, which is carried away by these particles. The fact that there are no products other than neutrinos and antineutrinos in these reactions means that the pion and muon are excited states of the electron. This circumstance makes it possible to calculate their masses [1].

How can you imagine electron in an excited state? It can be assumed that the excitation energy of an electron is the kinetic energy of its internal motion.

We can assume that a quasi-stable excited state can be created when the electron rotates along a circle of radius R provided that the ratio of the length of its de Broglie wave to the length of this circle is equal to an integer (the same condition that determines the motion of electron in Bohr atom):

$$\frac{\lambda_{dB}}{2\pi R} = k. \quad (11)$$

Given that the de Broglie wavelength is determined by the electron momentum p_e

$$\lambda_{dB} = \frac{2\pi\hbar}{p_e} \quad (12)$$

we obtain a condition for the existence of an excited state of electron which can be hypothetically quasi-stable :

$$R \cdot p_e = \frac{\hbar}{k}. \quad (13)$$

The generalized particle momentum depends on the vector potential A

$$p_e^* = p_e - \frac{e}{c} A. \quad (14)$$

In the case of relativistic circular motion, the vector potential A is determined by the magnetic moment of the circular current μ_0

$$A = \frac{\mu_0}{R^2 \sqrt{1-\beta^2}} \quad (15)$$

Since for a circular current

$$\mu_0 = \frac{eR\beta}{2} \quad (16)$$

finally, for the case $\beta \rightarrow 1$, we obtain an expression for the generalized electron momentum

$$p_e^* = p_e - \gamma \frac{\alpha \hbar}{2R}. \quad (17)$$

where

$$\gamma = \frac{1}{\sqrt{1-\beta^2}} \text{ is the relativistic factor of electron,}$$

$$\alpha = \frac{e^2}{\hbar c} \text{ — the fine structure constant.}$$

Since the generalized momentum of rotation (spin) of the particle

$$S = R \times p_e^* \quad (18)$$

from condition (13) we have

$$S = \hbar \left| \frac{1}{k} - \frac{\alpha\gamma}{2} \right| \quad (19)$$

3.1. π -Meson

Spin of π -meson

$$S_\pi = 0 \quad (20)$$

If we assume that for this case $k=1$, we obtain the mass of the particle close to the mass of π^\pm -meson:

$$m_{calc} = \gamma_{s=0, k=1} m_e = 274.08 m_e \quad (21)$$

3.2. μ -Meson

Spin of μ -meson

$$S_\mu = \frac{\hbar}{2}. \quad (22)$$

If we choose $k=4$ for this case, then by simple calculations we obtain the mass of the particle close to the mass of μ^\pm -meson:

$$m_{calc} = \gamma_{s=\frac{1}{2}, k=4} m_e = 205.56 m_e. \quad (23)$$

For clarity, the results of this simulation are summarized in **Table 1**.

4. Conclusions

The concept of neutrinos as magnetic excitations of ether [1] explains all basic of their properties:

- extremely weak interaction with substance is the result of absence of magnetic monopoles in nature,
- spin neutrinos is equal to $\hbar/2$ due to the fact that they have only the magnetic component,
- the birth of neutrinos in beta-decays is due to the fast appearance of magnetic moments of the generated particles,
- the existence of neutrino and antineutrino is explained by the presence of two types of Heaviside's steps.

At the same time, the awareness of the electromagnetic nature of neutrinos

Table 1. The results of model calculations of meson masses.

		meson mass		calculated mass	
meson	spin	M_m	k	m_{calc}	$\frac{m_{calc} - M_m}{M_m}$
π	0	$273.13 m_e$	1	$274.1 m_e$	3.5×10^{-3}
μ	$\hbar/2$	$206.77 m_e$	4	$205.6 m_e$	-5.8×10^{-3}

makes it possible to take a fresh look at the nature of mesons, which is an important step in understanding the microcosm.

In the 20th century at the study of the microcosm a new method was formed. The construction of various tables (as table of quark structure of Gell-Mann particles or standard model of Weinberg-Salam particles) played an important role in it. These tables seem informative and beautiful. And at first glance seems quite reliable. But any theoretical construction should be based on experimental data confirming this construction [4].

The very possibility of building a classification is not a confirmation of its correctness, because the uniqueness of such construction is not proved.

The fact that the Gell-Mann's quark model has not found an experimental confirmation is clear at least because, that no fractional-charge quarks were found. The confinement model cannot save this situation, because it does not satisfy the principle that in the natural Sciences there cannot be objects that are fundamentally unobservable as angels of medieval beliefs.

In addition, the neutron is not an elementary particle [5], since all measurements of its properties proof that it is a kind of Bohr hydrogen atom, but with a relativistic electron. Since the reaction of neutron \rightarrow proton transformation is the cornerstone of the Gell-Mann model, the loss of the neutron from this construction simply makes it meaningless.

The exclusion of neutrinos, neutrons and charged mesons from the number of independent elementary particles should also lead to a change in the Weinberg-Salam table.

What tau-neutrino and neutral mesons have to do with this concept remains unclear.

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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Phase Diagram of an $S = 1/2$ J_1 - J_2 Anisotropic Heisenberg Antiferromagnet on a Triangular Lattice

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Abstract

We study the ground state of an $S = 1/2$ anisotropic α ($\equiv J_z/J_{xy}$) Heisenberg antiferromagnet with nearest (J_1) and next-nearest (J_2) neighbor exchange interactions on a triangular lattice using the exact diagonalization method. We obtain the energy, squared sublattice magnetizations, and their Binder ratios on finite lattices with $N \leq 36$ sites. We estimate the threshold $J_2^{(t)}(\alpha)$ between the three-sublattice Néel state and the spin liquid (SL) state, and $J_2^{(s)}(\alpha)$ between the stripe state and the SL state. The SL state exists over a wide range in the α - J_2 plane. For $\alpha > 1$, the xy component of the magnetization is destroyed by quantum fluctuations, and the classical distorted 120° structure is replaced by the collinear state.

Keywords

Quantum Spin, Triangular Lattice, Quantum Fluctuation, Spin Liquid, Exact Diagonalization

1. Introduction

Over the past three decades, the low temperature properties of low-dimensional quantum systems have been studied because of the exotic spin states that can arise from quantum fluctuations. The quantum antiferromagnetic Heisenberg (QAFH) model on a triangular lattice is a typical quantum frustrated system. This involves a generalized model with an antiferromagnetic nearest-neighbor (NN) interaction $J_1 (> 0)$ and a next-nearest-neighbor (NNN) interaction J_2 ,

the model Hamiltonian of which given by

$$H = 2J_1 \sum_{\langle i,j \rangle} [S_i^x S_j^x + S_i^y S_j^y + \alpha S_i^z S_j^z] + 2J_2 \sum_{\langle\langle i,j \rangle\rangle} [S_i^x S_j^x + S_i^y S_j^y + \alpha S_i^z S_j^z], \quad (1)$$

where S_i^v is the v component ($v = x, y, z$) of the quantum spin $S = 1/2$ at lattice site i , $\alpha (\equiv J_z/J_{xy})$ is an exchange anisotropy, and the sums $\langle i, j \rangle$ and $\langle\langle i, j \rangle\rangle$ run over all NN and NNN pairs of sites, respectively. Hereafter we set $J_1 = 1$ as the unit of energy scaling. The ground state (GS) of an isotropic QAFH model ($\alpha = 1$) with $J_2 = 0$ is the central issue of the model. Anderson proposed a resonating-valence-bond state or a spin liquid (SL) state as the GS of the model [1]. Since then, many authors have used various methods to study the model [2]-[16]. The GS of the model is now widely believed to have the classical long-range-order (LRO) in the form of the 3-sublattice structure (120° Néel state). However recent experiments on model compounds such as κ -(ET)₂Cu₂(CN)₃ [17], EtMe₃Sb[Pd(dmit)₂]₂ [18], and Ba₃IrTi₂O₉ [19] have observed no LRO down to very low temperatures. Motivated by this discrepancy, the present authors [14] (hereafter referred to as SMFS) reexamined the GS of *an anisotropic QAFH model with* $0 \leq \alpha < \infty$ on finite lattices having used an exact diagonalization technique, and found that the classical LRO is absent for $0.55 \lesssim \alpha \lesssim 1.67$. This includes the GS of the isotropic model ($\alpha = 1$) with $J_2 = 0$, i.e., it has no LRO and is the SL state.

In the present paper, we consider the effect of the NNN interaction J_2 on the anisotropic QAFH model. The isotropic QAFH model with J_2 was studied recently using approximations such as a variational Monte Carlo (VMC) method [20], a many-variable VMC (mVMC) method [21], a coupled cluster method (CCM) [22], and a density matrix renormalization group method [23] [24]. These approaches showed that the 120° Néel state occurs for $J_2 < J_2^{(t)}$ and that a four-sublattice antiferromagnetic LRO state (stripe Néel state) occurs for $J_2 > J_2^{(s)}$, i.e., the SL state appears between them, $J_2^{(t)} \lesssim J_2 \lesssim J_2^{(s)}$. The thresholds have been estimated as $J_2^{(t)} \sim 0.06$ and $J_2^{(s)} \sim 0.16$ [20] [22] [23] [24], although the mVMC method suggested a smaller region of the SL state, i.e., $J_2^{(t)} \simeq 0.10$ and $J_2^{(s)} \simeq 0.135$ [21]. However, an exact result for finite lattices by SMFS [14] suggested $J_2^{(t)} < 0$. No studies have been carried out on $J_2^{(t)}$ and $J_2^{(s)}$ using the exact diagonalization technique. We therefore apply the same method used by SMFS to the model extended with J_2 . We calculate exactly the squared sublattice magnetization of finite lattices, and we estimate $J_2^{(t)}$ and $J_2^{(s)}$ using their Binder ratios over a wide range of α and try to draw the phase diagram in the α - J_2 plane.

In Section 2, we present our method with the finite lattices. In Section 3, we estimate the threshold $J_2^{(t)}(\alpha)$ between the 120° Néel state and the SL state. In Section 4, we consider the stripe Néel state and its threshold $J_2^{(s)}(\alpha)$ with the SL state. In Section 5, we propose a phase diagram of the model.

2. Method

It is known that the GS of the classical model is a 120° Néel state when

$J_2 < J_2^{(clas)}$, and the stripe Néel state when $J_2 > J_2^{(clas)}$, where $J_2^{(clas)} = 1/8$ for $\alpha \leq 1$ and tends to zero as $\alpha \rightarrow \infty$. The unit cells of these states are shown in **Figure 1**. Although a similar LRO may be expected to appear in the anisotropic QAFH model, the classical ordered state is not a good quantum state. Therefore a remarkable difference may exist in the phase transition between the classical and quantum models.

We first consider this problem. Hereafter we refer to the spin space of a lattice with $N = 3n$ sites with three-sublattice symmetry as the three-sublattice space (3SLS), where n is a natural number. Similarly, we refer to the spin space of a lattice with $N = 4n$ sites with four-sublattice symmetry as the four-sublattice space (4SLS). The minimum energies per site in the 3SLS and 4SLS are labeled as E_{tri} and E_{str} , respectively. The spin state is in the 3SLS when $E_{tri} < E_{str}$ and in the 4SLS when $E_{str} < E_{tri}$. In the classical model, the threshold of $J_2^{(clas)}$ is one at which the spin space changes from one to the other, and the phase transition at $J_2^{(clas)}$ is of the first order. In the quantum model, although the spin space changes at some threshold $J_2^{(quan)}$, no phase transition will take place at $J_2^{(quan)}$, because there would be no LRO in those spin spaces at $J_2 \sim J_2^{(quan)}$. We must then consider the thresholds and natures of the phase transitions in the 3SLS and in the 4SLS, separately.

For the 3SLS, we consider the lattices with $N = 18 - 30$ (and partly $N = 36$) sites with periodic boundary conditions suitable for the three-sublattice structure (**Figure 2(a)**).

For the 4SLS, we consider the lattices with $N = 24, 28$, and 32 sites with periodic boundary conditions suitable for the stripe structure (**Figure 2(b)**).

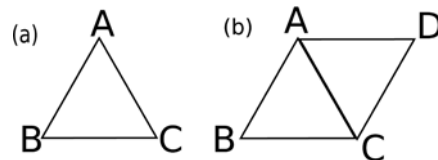


Figure 1. (a) Sublattices A, B, and C in the three-sublattice state; (b) Sublattices A, B, C, and D in the four-sublattice state.

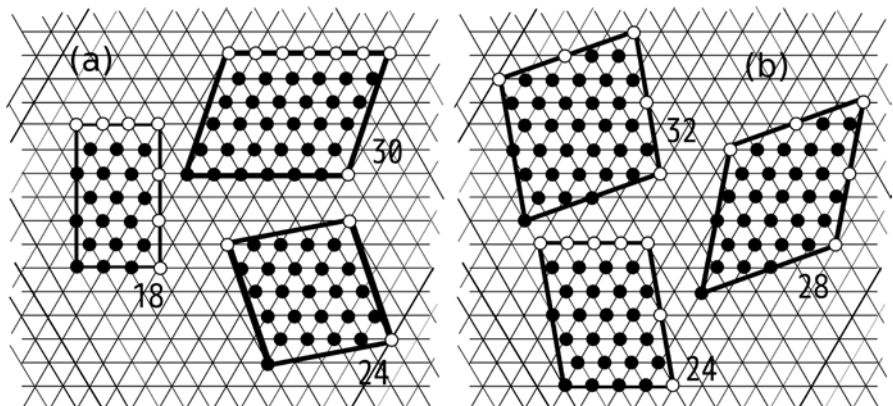


Figure 2. (a) The lattices with three-sublattice symmetry (3SLS). The lattices of $N = 21, 27$, and 36 appear in Ref. [10]; (b) The lattices with four-sublattice symmetry (4SLS).

In either case, we obtain the GS eigenfunction $|\psi_{sG}\rangle_N$ of the N sites using the Lanczos method, where $s = tri$ or str for the 3SLS or 4SLS, respectively. The ν component of the magnetization on the Ω_l sublattice is defined as

$$\mu_l^\nu = \frac{2N_{sub}}{N} \sum_{i \in \Omega_l} S_i^\nu, \quad (2)$$

where $N_{sub} = 3$ and $l = A, B$, and C for the 3SLS, and $N_{sub} = 4$ and $l = A, B, C$, and D for the 4SLS. The operators of the z , xy , and xyz components of the squared sublattice magnetization are defined as

$$m_2^z = \frac{1}{N_{sub}} \sum_l (\mu_l^z)^2, \quad (3)$$

$$m_2^{xy} = \frac{1}{N_{sub}} \sum_l \left((\mu_l^x)^2 + (\mu_l^y)^2 \right), \quad (4)$$

$$m_2^{xyz} = \frac{1}{N_{sub}} \sum_l \left((\mu_l^x)^2 + (\mu_l^y)^2 + (\mu_l^z)^2 \right). \quad (5)$$

We calculate the ζ component the squared sublattice magnetization, $\langle m_{2,s}^\zeta \rangle_N$, as

$$\langle m_{2,s}^\zeta \rangle_N = {}_N \langle \psi_{sG} | m_2^\zeta | \psi_{sG} \rangle_N \quad (6)$$

where $\zeta = z, xy$, or xyz .

We study the Binder ratios [25] that are used by SMFS [14] to estimate the threshold α of the model with $J_2 = 0$. At the critical point, the Binder ratio is size invariant. If there is a LRO, the Binder ratio is expected to increase with the system size. In contrast, in the paramagnetic or SL state, the Binder ratio decreases with the system size. This means that the size dependence of the Binder ratio is different from each other with and without a LRO. The z , xy , and xyz components of the Binder ratio can be defined as

$$B_s^z(N) = \left(3 - \langle (m_{2,s}^z)^2 \rangle_N / \langle m_{2,s}^z \rangle_N^2 \right) / 2, \quad (7)$$

$$B_s^{xy}(N) = 2 - \langle (m_{2,s}^{xy})^2 \rangle_N / \langle m_{2,s}^{xy} \rangle_N^2, \quad (8)$$

$$B_s^{xyz}(N) = \left(5 - 3 \langle (m_{2,s}^{xyz})^2 \rangle_N / \langle m_{2,s}^{xyz} \rangle_N^2 \right) / 2. \quad (9)$$

Before estimating $J_2^{(t)}$ and $J_2^{(s)}$, we should examine that no phase transition will take place at $J_2^{(quan)}$. **Figure 3** shows E_{tri} and E_{str} together with $\langle m_{2,tri}^{xy} \rangle_N$ and $\langle m_{2,str}^{xy} \rangle_N$ for the case of $\alpha = 0.4$. As mentioned above, the spin space changes at $J_2 = J_2^{(quan)}$ (~ 0.065), whereas no signal of a change in the magnetic state is seen at this point. We consider the 3SLS for $J_2 < J_2^{(quan)}$ and the 4SLS for $J_2 > J_2^{(quan)}$. A remarkable point is that $\langle m_{2,tri}^{xy} \rangle_N$ ($\langle m_{2,str}^{xy} \rangle_N$) changes markedly around J_2^{peak} , at which E_{tri} (E_{str}) has its maximum value. In the 3SLS, a bending of E_{tri} accompanied by a discontinuous drop of $\langle m_{2,tri}^{xy} \rangle_N$ indicates exchange in the GS between the lowest and next-lowest energy eigenstates at J_2^{peak} . However, we reason that this says nothing about the

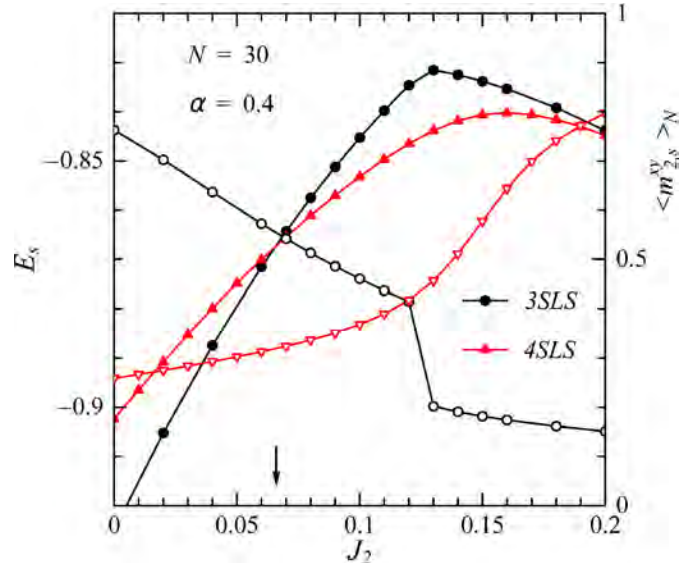


Figure 3. The GS energies E_s and the squared sublattice magnetizations $\langle m_{2,s}^{xy} \rangle_N$ of the 3SLS ($s = tri$) and the 4SLS ($s = str$). The data of the 4SLS for $N = 30$ are averages of those of $N = 28$ and $N = 32$. The solid and open symbols are E_s and $\langle m_{2,s}^{xy} \rangle_N$, respectively. An arrow represents the positions of $J_2^{(quan)}$.

phase transition between the 120° Néel state and the SL state because $J_2^{peak} > J_2^{(quan)}$. The phase boundary should be estimated by a different method. In contrast, we expect $J_2^{(s)}$ to be near J_2^{peak} , because $J_2^{(quan)} < J_2^{peak}$. In Section 4, we consider J_2^{peak} together with the Binder ratio B_{str}^ζ in order to estimate $J_2^{(s)}$.

3. Three-Sublattice Néel State

In this section, we estimate the threshold $J_2^{(t)}$. We consider $\langle m_{2,tri}^\zeta \rangle_N$ in the GS of the 3SLS. Special attention should be paid to the $M^z (= \sum_i S_i^z)$ subspace in which the GS belongs. For $\alpha \leq 1$, the GS is in the minimum $|M^z|$ subspace. For $\alpha > 1$, however, the GS may not be restricted to the minimum $|M^z|$ subspace depending on J_2 . We then consider the cases $\alpha \leq 1$ and $\alpha > 1$ separately.

3.1. XY-Like Case ($\alpha \leq 1$)

For $\alpha \leq 1$, the LRO has the 120° Néel state symmetry, and $\langle m_{2,tri}^{xy} \rangle_N$ and $\langle m_{2,tri}^{xyz} \rangle_N$ are calculated for various α . For $\alpha < 1$, because the spins lie in the xy plane, we consider the $\zeta = xy$ component, whereas the $\zeta = xyz$ component for $\alpha = 1$. In **Figures 4(a)-(d)**, we present $\langle m_{2,tri}^\zeta \rangle_N$ for $\alpha = 0.0, 0.4, 0.8$, and 1.0 as functions of J_2 , respectively. As J_2 is decreased, $\langle m_{2,tri}^\zeta \rangle_N$ increases revealing the development of the 120° spin correlation. For small $\alpha (= 0.4)$, the finite-size effect (FSE) for $J_2 \lesssim 0.05$ is rather weak implying the occurrence of the 120° Néel state. As α is increased, the FSE becomes stronger. In the isotropic case of $\alpha = 1.0$, we can see a strong FSE even for $J_2 < -0.1$.

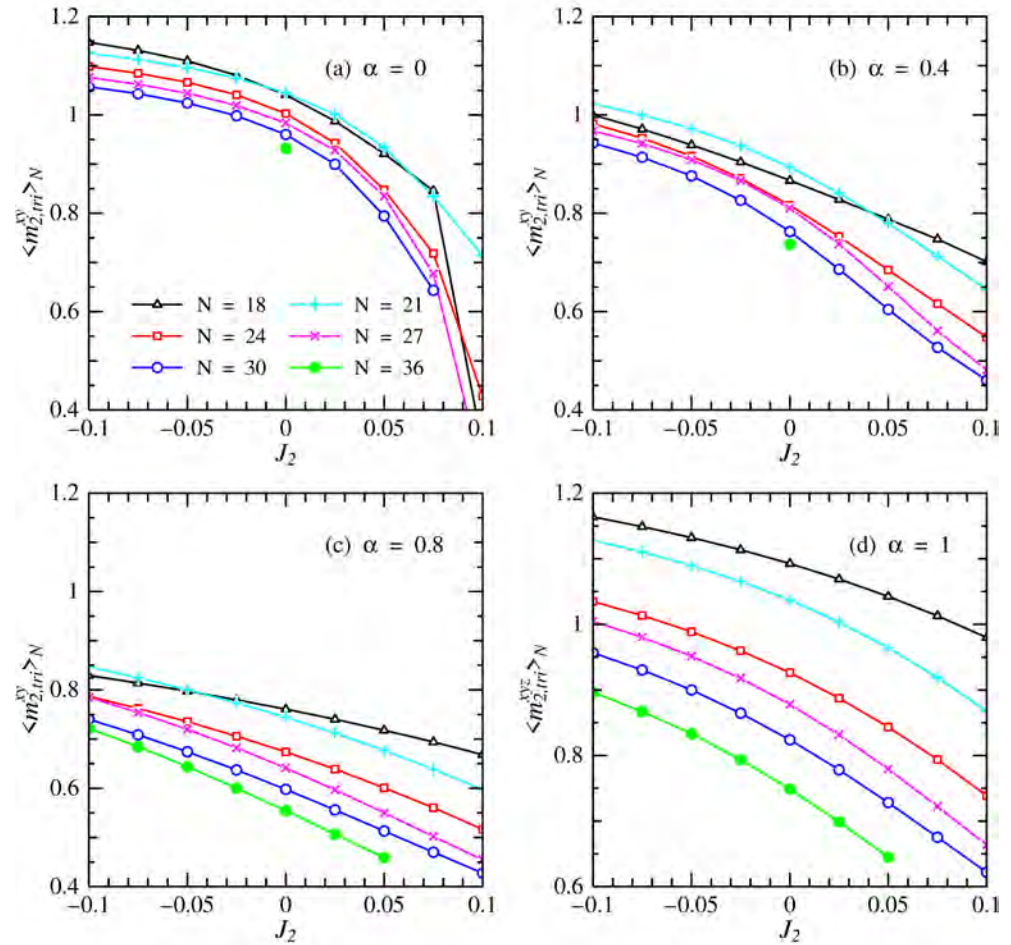


Figure 4. The squared three-sublattice magnetizations (a)-(c) $\langle m_{2,tri}^{xy} \rangle_N$ and (d) $\langle m_{2,tri}^{xyz} \rangle_N$ as functions of J_2 . Note that for $\alpha = 1.0$, $\langle m_{2,tri}^{xyz} \rangle_N = (3/2)\langle m_{2,tri}^{xy} \rangle_N$.

We consider the Binder ratio $B_{tri}^{\zeta}(N)$ [25] [14]. In **Figures 5(a)-(d)**, we show $B_{tri}^{\zeta}(N)$ for different even N as functions of J_2 for $\alpha = 0, 0.4, 0.8$, and 1.0 , respectively. For a large J_2 , $B_{tri}^{\zeta}(N)$ decreases with increasing N , which reveals that LRO is absent. As J_2 is decreased, $B_{tri}^{\zeta}(N)$ increases and the values for different N are close to each other. For $\alpha \sim 0$, $B_{tri}^{\zeta}(N)$ for different N intersect at almost the same J_2 (see **Figure 5(a)** and **Figure 5(b)**). That is, $J_2^{(t)}(0) = 0.06 \pm 0.01$ and $J_2^{(t)}(0.4) = 0.01 \pm 0.01$. As α is increased, the intersection points scatter, as seen in **Figure 5(c)**. In this case, we consider a lower bound J_2^l and an upper bound J_2^u of $J_2^{(t)}(\alpha)$ according to the hypotheses described in Sec. II: the LRO is present when the Binder ratio $B_s^{\zeta}(N)$ increases with N , whereas it is absent when $B_s^{\zeta}(N)$ decreases with increasing N . We evaluate J_2^l and J_2^u , and tentatively estimate $J_2^{(t)}(\alpha)$ as their average value. In this way, we get the thresholds as $J_2^{(t)}(0.6) = -0.01 \pm 0.01$, $J_2^{(t)}(0.8) = -0.05 \pm 0.04$, and $J_2^{(t)}(0.9) = -0.10 \pm 0.06$.

In the case of $\alpha = 1.0$, $B_{tri}^{\zeta}(N)$ exhibits a somewhat different behavior from those for $\alpha < 1.0$. Although $B_{tri}^{\zeta}(N)$ increases with decreasing J_2 , its increment

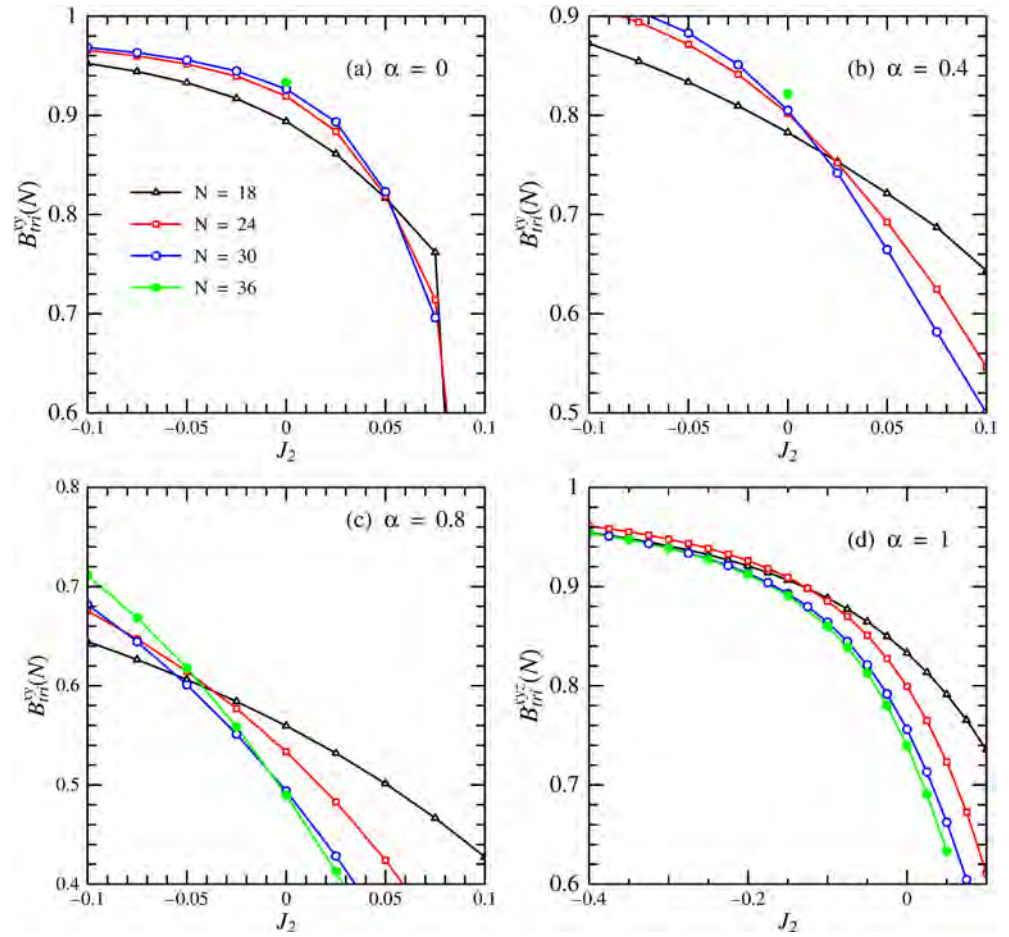


Figure 5. Binder ratios (a)-(c) $B_m^{xy}(N)$ and (d) $B_m^{yz}(N)$ of the squared 3-sublattice magnetization as functions of J_2 .

depends only very weakly on N , especially for $J_2 < 0$. We could see no definite intersection point of $B_m^z(N)$ for $N \geq 24$ down to $J_2 = -0.4$, *i.e.*, we could not evaluate J_2^l . Therefore we believe $J_2^{(l)}(1) < -0.1$, because $J_2^u \sim -0.1$.

3.2. Ising-Like Case ($\alpha > 1$)

For $\alpha > 1$, we are interested in $\langle m_{2,tri}^z \rangle_N$ and $\langle m_{2,tri}^{xy} \rangle_N$ because a distorted 120° Néel state occurs in the classical model. We obtain the eigenfunction $|\psi(M^z)\rangle_N$ with the minimum energy $E(M^z)$ for each M^z subspaces. Note that we consider only the subspaces of $M^z \leq N/6$ because the GS is in the $M^z = N/6$ subspace for $J_2 \rightarrow -\infty$. The GS eigenfunction $|\psi_{sG}\rangle_N$ of the system is one which gives the lowest value among $E(M^z)$'s. When $J_2 \geq 0$, the GS eigenfunction $|\psi_{sG}\rangle_N$ is $|\psi(0)\rangle_N$. As J_2 is decreased, $|\psi_{sG}\rangle_N$ successively changes to $|\psi(1)\rangle_N, |\psi(2)\rangle_N, \dots, |\psi(N/6)\rangle_N$ at $J_2^{(1)}, J_2^{(2)}, \dots, J_2^{(N/6)}$, respectively. Using $|\psi_{sG}\rangle_N$, we obtain $\langle m_{2,tri}^z \rangle_N$ and $\langle m_{2,tri}^{xy} \rangle_N$ for various α . A typical result of these is shown in **Figure 6** for $\alpha = 1.25$. For $J_2 \sim 0$, both $\langle m_{2,tri}^z \rangle_N$ and $\langle m_{2,tri}^{xy} \rangle_N$ exhibit a strong N dependence which reveals that $\langle m_{2,tri}^{xy} \rangle_N, \langle m_{2,tri}^z \rangle_N \rightarrow 0$ for $N \rightarrow \infty$. As J_2 is decreased, $\langle m_{2,tri}^z \rangle_N$ and $\langle m_{2,tri}^{xy} \rangle_N$

show different behaviors from each other. For $\langle m_{2,tri}^{xy} \rangle_N$, they remain almost constant down to $J_2^{(1)}$ and drop at $J_2^{(1)}, J_2^{(2)}, \dots, J_2^{(N/6)}$. For the whole range of J_2 , we see a strong N dependence, that suggests that $\langle m_{2,tri}^{xy} \rangle_N \rightarrow 0$ for $N \rightarrow \infty$. In contrast, $\langle m_{2,tri}^z \rangle_N$ gradually increases down to $J_2^{(1)}$ and discontinuously jumps at $J_2^{(1)}, J_2^{(2)}, \dots, J_2^{(N/6)}$. It exhibits its own N dependence in different ranges of J_2 . For 1) $J_2 < J_2^{(N/6)}$, $\langle m_{2,tri}^z \rangle_N$ is almost independent of N . We believe that the classical ferrimagnetic state arises in this range, because $\langle m_{2,tri}^z \rangle_N \sim 1$ and $\langle m_{2,tri}^{xy} \rangle_\infty = 0$. For 2) $J_2^{(N/6)} < J_2 < J_2^{(1)}$, $\langle m_{2,tri}^z \rangle_N$ increases with N revealing the occurrence of the LRO of the z component of the spin. However, for 3) $J_2^{(1)} < J_2$, $\langle m_{2,tri}^z \rangle_N$ slightly decreases with increasing N . Note that we also obtain the similar results for $\alpha = 1.67$ and 2.5.

In **Figure 7(a)** and **Figure 7(b)**, we plot the Binder ratio $B_{tri}^z(N)$ as a function

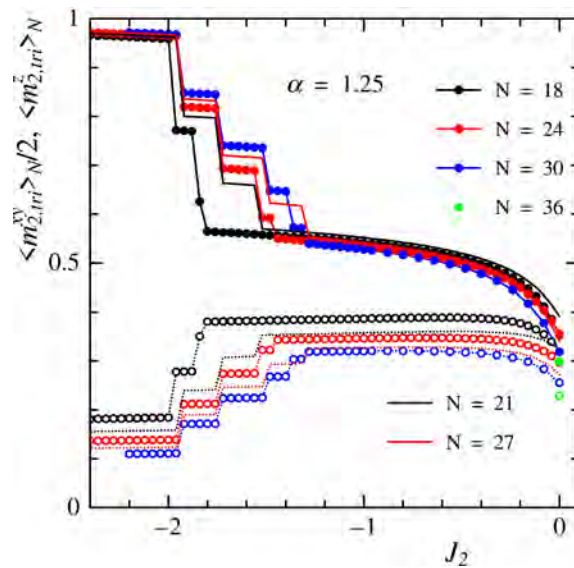


Figure 6. Squared three-sublattice magnetizations $\langle m_{2,tri}^z \rangle_N$ (solid symbols) and $\langle m_{2,tri}^{xy} \rangle_N$ (open symbols) as functions of J_2 . Jumps in those quantities occur at $J_2^{(1)}, J_2^{(2)}, \dots, J_2^{(N/6)}$ from the right.

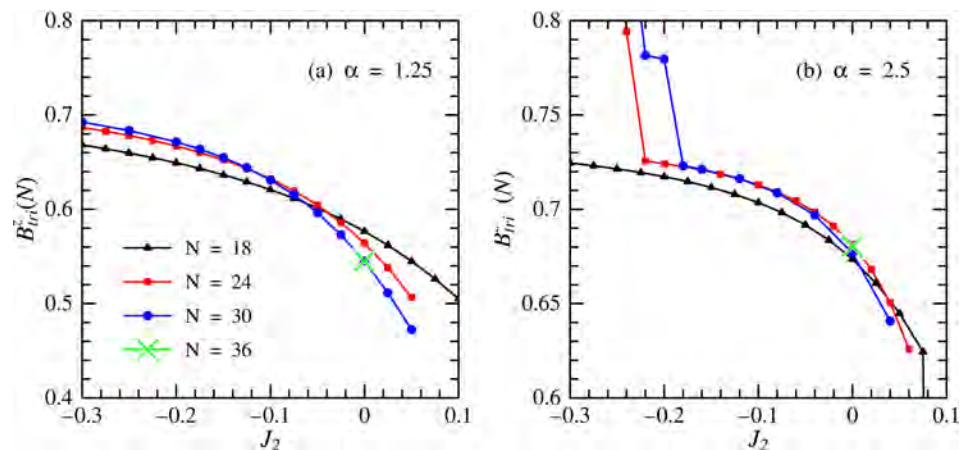


Figure 7. Binder ratios $B_{tri}^z(N)$ as functions of J_2 for (a) $\alpha = 1.25$ and (b) $\alpha = 2.5$.

of J_2 for $\alpha = 1.25$ and $\alpha = 2.5$, respectively. For (a) $\alpha = 1.25$, we evaluate the lower and upper bounds of $J_2^{(i)}$ as $J_2^l \sim -0.15$ and $J_2^u \sim 0$, i.e., $J_2^{(i)}(1.25) \sim -0.08 \pm 0.08$. For (b) $\alpha = 2.5$, we estimate $J_2^l \sim -0.08$ and $J_2^u \sim 0.04$, i.e., $J_2^{(i)}(2.5) \sim -0.02 \pm 0.06$. Note that we also examined $B_{iri}^{xy}(N)$ to confirm the speculation given above and found that, in fact, $B_{iri}^{xy}(N)$ decreases with increasing N for the whole range of J_2 .

To close this subsection, we emphasize that the distorted 120° Néel state is absent in the QAFH model, in contrast to the classical model. We find that, when $J_2 < J_2^{(i)}$, the LRO of the z component of the spin occurs. A question remains as to what the value of $J_2^{(i)}$ for $N \rightarrow \infty$, $J_{2,\infty}^{(i)}$. If $J_{2,\infty}^{(i)} = J_2^{(i)}(\alpha)$, the LRO of the z component of the spin occurs for $J_2 \leq J_2^{(i)}(\alpha)$. If not, two possibilities exist in the range $J_{2,\infty}^{(i)} < J_2 < J_2^{(i)}(\alpha)$: either there is still the LRO, or the system is in a critical state that is similar to the spin state of the Ising model with $J_2 = 0$. Further studies are necessary to answer this question.

4. Stripe State

In this section, we consider the stripe state. We obtain the GS as the eigenfunction $|\psi_{strG}\rangle_N = |\psi(0)\rangle_N$ with energy E_{str} because the stripe state belongs to the $M^z = 0$ subspace. In **Figure 8(a)** and **Figure 8(b)**, we show these quantities as functions of J_2 for $\alpha = 0.4$ and $\alpha = 1.25$, respectively. We readily see that the results for the $N = 24$ system are quantitatively different from those of the $N = 28$ and 32 systems, which lead us to consider mainly data for $N \geq 28$ in order to evaluate $J_2^{(s)}$. We see similar properties in the cases of $\alpha < 1$ and $\alpha > 1$. The magnetization $\langle m_{2,stri}^z \rangle_N$ rapidly increases around the peak position J_2^{peak} of E_{str} that implies the occurrence of the phase transition. When $J_2 < J_2^{peak}$, $\langle m_{2,stri}^z \rangle_N$ is small and its N dependence is strong which reveals that the stripe state is absent. When $J_2 > J_2^{peak}$, $\langle m_{2,stri}^z \rangle_N$ is large, although its N dependence is still considerable especially for $\alpha < 1$. Then we examine the

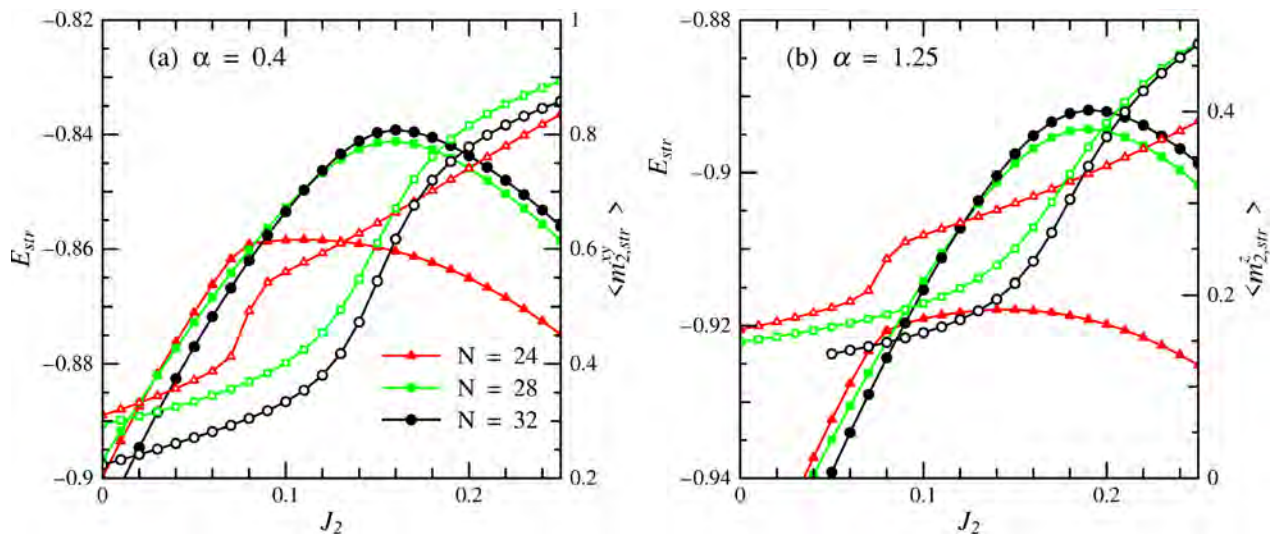


Figure 8. The GS energies E_{str} and four-sublattice magnetizations $\langle m_{iri}^z \rangle_N$ as functions of J_2 .

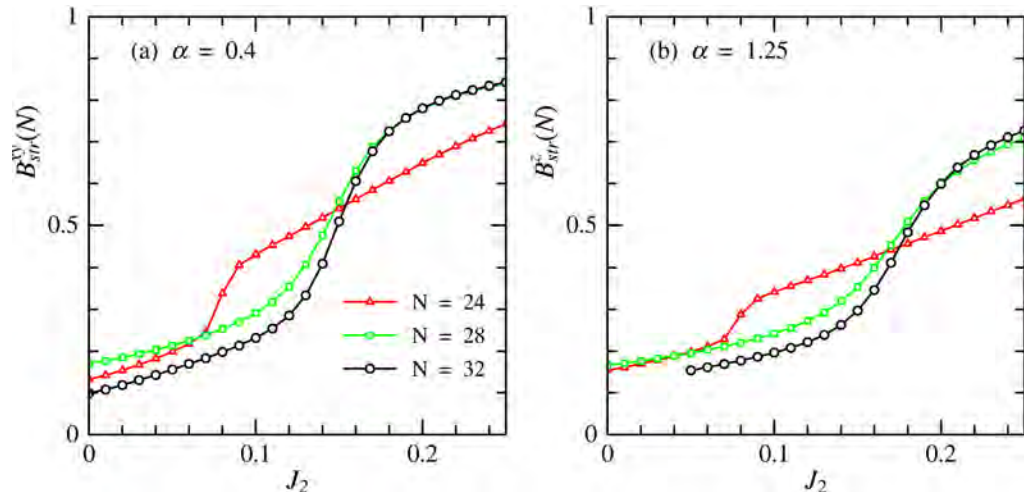


Figure 9. Binder ratios as functions of J_2 .

Binder ratio $B_{str}^z(N)$. In **Figure 9(a)** and **Figure 9(b)**, we plot $B_{str}^{xy}(N)$ and $B_{str}^z(N)$ as functions of J_2 for $\alpha=0.4$ and $\alpha=1.25$, respectively. For $\alpha=0.4$, when $J_2 \gtrsim 0.19$, $B_{str}^{xy}(N)$ increases with N , suggesting the presence of the stripe state, *i.e.*, $J_2^u=0.19$. In contrast, the lower bound of $J_2^{(s)}$ is evaluated from $J_2^{peak} \sim 0.16$ of the $N=32$ system because J_2^{peak} increases slightly with N . Therefore we estimate $J_2^{(s)}(0.4)=0.18 \pm 0.02$. Similarly, we estimate $J_2^{(s)}(1.25)=0.195 \pm 0.010$.

We have also examined $J_2^{(s)}$ for $\alpha=1$. We may evaluate the lower bound of $J_2^l = J_2^{peak} \sim 0.20$. However, we could not evaluate J_2^u because $B_{str}^{xyz}(32) < B_{str}^{xyz}(28)$ even up to $J_2 = 0.3$ [26].

5. Summary

We have studied the $S=1/2$ anisotropic antiferromagnetic model ($\alpha \equiv J^z/J^{xy}$) with nearest-neighbor (J_1) and next-nearest-neighbor (J_2) interactions on a triangular lattice using the exact diagonalization method. We have obtained the ground-state energy and the sublattice magnetizations for systems of different size N . We have examined Binder ratios to investigate the stability of the long-range order of the system. The N -dependences of Binder ratios suggest the threshold $J_2^{(t)}(\alpha)$ between the three-sublattice Néel state and the disordered state, *i.e.*, the spin liquid (SL) state, and the threshold $J_2^{(s)}(\alpha)$ between the stripe state and the SL state. The results are summarized in the phase diagram shown in **Figure 10**. For $\alpha < 1$, the classical 120° phase or the stripe phase occurs in the xy plane. For $\alpha > 1$, the xy component of the sublattice magnetization vanishes, *i.e.*, the distorted 120° state is replaced by the collinear (up up down) antiferromagnetic state because of quantum fluctuations.

We have suggested that the SL state exists over a wide range in the α - J_2 plane in contrast with recent approximation studies [20] [22] [23] [24] which give $J_2^{(t)}(1)=0.06-0.10$ and $J_2^{(s)}=0.135-0.16$. The discrepancy will come from either the finite-size effect or approximations. Further studies are necessary to

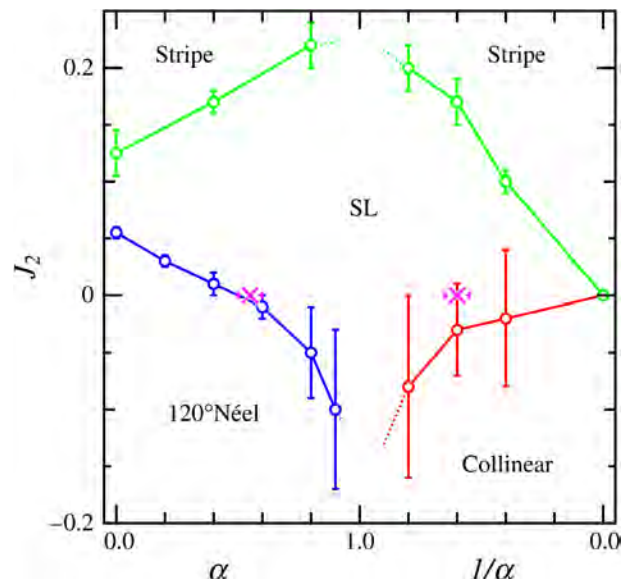


Figure 10. The α - J_2 phase diagram of the J_1 - J_2 anisotropic Heisenberg model on a triangular lattice. Cross symbols are those estimated in SMFS [14].

establish the thresholds for $\alpha \sim 1$.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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An Analogy between the Properties of “Dark Energy” and Physical Vacuum Consisting of Quantum Harmonic Oscillators Characterized by Zero-Point Energy

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Abstract

In quantum field theory, the physical vacuum, free from magnetic and electric fields (without regard to gravitational energy), is defined not as an empty space but as the ground state of the field consisting of quantum harmonic oscillators (QHOs) characterized by zero-point energy. The aim of this work is to show that such physical vacuum may possess the properties similar to the properties of dark energy: the positive density, the negative pressure, and the possibility of so-called accelerated expansion. In the model discussed, the mass of QHOs determines the positive density of dark energy. The observed electric polarization of physical vacuum in an electric field means the existence of electric dipole moment of QHO, which, in turn, suggests the existence inside the QHO of a repulsive force between unlike charges compensating the attractive Coulomb force between the charges. The existence of such repulsive force may be treated as the existence of omniradial tensions inside every QHO. In terms of hydrodynamics, it means that the vacuum with this property may be regarded as a medium with negative pressure. The electric dipole-dipole interaction of QHOs under some condition may result in the expansion of physical vacuum consisting of QHOs. It is shown also that the physical vacuum consisting of QHOs is a luminiferous medium, and based on this concept the conditions are discussed for the emergence of invisibility of any objects (in particular, dark matter). The existence of luminiferous medium does not contradict the second postulate of special relativity (the principle of constancy of the velocity of light in inertial systems), if to take into account the interaction of photons with QHOs and with virtual photons (the virtual particles pairs) created by quantum entities that constitute the inertial systems.

Keywords

Dark Energy, Dark Matter, Zero-Point Energy, Quantum Harmonic Oscillator, Cosmic Microwave Background

1. Introduction

According to contemporary cosmological models, near 70 percent of the total mass-energy of the universe is in the form of so-called dark energy or “quintessence” which is characterized by the homogeneous distribution of positive density, by negative pressure and by the possibility of accelerated expansion [1] [2] [3]. At present, there is no generally accepted physical model of dark energy. In this work, it is shown that the physical vacuum consisting of quantum harmonic oscillators (hereafter called QHOs) characterized by zero-point energy may have all the properties of dark energy.

In quantum field theory, the physical vacuum, free from magnetic and electric fields (without regard to gravitational energy), is defined not as an empty space but as the ground state of the field consisting of QHOs characterized by non-zero energy equal to $h\nu/2$. The concept of zero-point energy was developed in Germany in 1913 by a group of physicists, including M. Planck, A. Einstein, and O. Stern [4], using the formula derived by Planck [5] for energy ε of atomic oscillator vibrating with frequency ν : $\varepsilon = h\nu/2 + h\nu/(\exp(h\nu/(kT)) - 1)$, where h is the Planck constant, k is the Boltzmann constant, T is temperature. The properties of the physical vacuum consisting of QHOs as a continuum are determined by the properties of QHOs [6]. The mass of QHOs associated with their energy determines the positive density of the physical vacuum. The observed electric polarization of physical vacuum in an electric field means the existence of electric dipole moment of QHO, which, in turn, suggests the existence of a repulsive force between unlike charges inside the QHO, which may be treated as the existence of omniradial tensions inside the QHO. In terms of hydrodynamics, it means that the vacuum with this property may be regarded as a medium with negative pressure [7]. The electric dipole-dipole interaction of QHOs may result in the so-called accelerated expansion of the physical vacuum consisting of QHOs. It is shown as well that the physical vacuum consisting of QHOs is a luminiferous medium, and based on this concept the conditions are discussed for the emergence of invisibility of any objects (in particular, dark matter). Due to possibility of emergence of spin supercurrent between QHOs the background electro-magnetic emission may exist in the physical vacuum consisting of QHOs. The cosmic microwave background (CMB) may be such an emission.

The work below consists of three sections. In Section 2, the properties of physical vacuum consisting of QHOs are considered, in particular: the connection of speed of motion of such vacuum and magnetic phenomena. In Section 3, the following is discussed: the emergence of the wave-vortex-spin (electromagnetic)

process in the physical vacuum, equalizing the speed of light in inertial systems, the condition of disappearance of wave-vortex-spin process (the condition of invisibility of objects). In Section 4, the electric dipole-dipole interaction of QHOs, which results in a change in the distance between these QHOs, is discussed.

2. The Properties of Physical Vacuum Consisting of QHOs

2.1. The Equation Describing the Physical Vacuum, Consisting of QHOs, in a Stationary State

Based on the characteristics of QHOs mentioned in Introduction, the following conclusions can be made about the properties of the physical vacuum consisting of QHOs (the vacuum being in a stationary state): the positive density created by the mass of QHOs and negative pressure. As it will be shown in Section 4, the density of the physical vacuum is slightly dependent on speed u at small u/c (c is the speed of light). The negative pressure is due to the existence of electric dipole moment of QHO, that is, the existence of a repulsive force between unlike charges inside the QHO, compensating the attractive Coulomb force between these charges. The existence of such repulsive force may be treated as the existence of omniradial tensions inside the QHO [7]. Taking into account the dissipation-free motion of celestial bodies, such as the planets of the solar system, that is the absence of shear viscosity, it may be assumed that the physical vacuum consisting of QHOs in a stationary state is analogous to ideal incompressible liquid, and can be described by the following Equation [7] [8]:

$$\rho u^2/2 - p = \text{const}, \quad (1)$$

where ρ and p are respectively the density and pressure of the physical vacuum consisting of QHOs.

2.2. The Connection of the Speed of Motion of Physical Vacuum Consisting of QHOs with Magnetic Phenomena

It is shown in [7], that there is a complete analogy between the structures of formulas describing the magnetic interactions of current-carrying wires and the structures of formulas describing the interactions of vortices in an ideal incompressible liquid with positive density and negative pressure, that is, in the liquid described by Equation (1) in a stationary case.

Let us deduce the relationship between the speed of QHOs and magnetic induction by comparing the characteristics of the magnetic field and both force and kinematic characteristics of physical vacuum consisting of QHOs [7].

The magnetic induction \mathbf{B} generated by a loop with current I [9] is determined by the Biot-Savart law and in the CGSE system of units it is determined as:

$$\mathbf{B} = \frac{I}{c} \int_{L'} \frac{d\mathbf{l} \times \mathbf{r}}{r^3}, \text{ where } L' \text{ is the length of the loop, } d\mathbf{l} \text{ is the wire element, } \mathbf{r} \text{ is}$$

a radius vector from $d\mathbf{l}$ to the point of observation. The field of velocities \mathbf{u} generated by a closed vortex line having circulation Γ along an arbitrary loop

enclosing the vortex line is defined [7] as: $\mathbf{u} = \frac{\Gamma}{4\pi} \int_{L'} \frac{d\mathbf{l} \times \mathbf{r}}{r^3}$, where $d\mathbf{l}$ is an in-

infinitesimal vector element of the vortex line, L' is the length of the line. Equating the expressions for \mathbf{B} and \mathbf{u} we obtain the relationship between Γ and I :

$$\Gamma = I\sqrt{4\pi}/(c\sqrt{\rho}). \quad (2)$$

Thus, Equation (2) establishes a relationship between the current and circulation of vortex line produced by moving electric charges that form the current (in detail see Section 2.3).

The force F_Γ acting on a unit length of either of the two infinite mutually parallel vortex lines having the same values of circulation Γ equals [7]: $F_\Gamma = \rho\Gamma^2/(2\pi r_w)$, where r_w is the distance between the vortex lines with circulation Γ . The force F_I acting on a unit length of either of the two infinite mutually parallel current-carrying wires having the same values of current I (in the CGSE system of units) equals [9]: $F_I = 2I^2/(r_w c^2)$, where r_w is here the distance between the current-carrying wires. Equating the expressions for F_Γ and F_I and taking into account Equation (2), we obtain.

$$\mathbf{B} = \mathbf{u}\sqrt{4\pi\rho}. \quad (3)$$

There is indirect experimental evidence of validity of Equation (3). The term “indirect” is used because in the experiments in question the evidence refers to the neutrino whose properties are mysterious in some respects. At present, the concept of massive neutrino with its magnetic moment aligned with its spin is considered to be most acceptable to physicists. From observations it follows that the spin of a left-handed neutrino moving relative to the “cosmic” vacuum is oriented opposite to its velocity \mathbf{v} ; according to Equation (3), this motion is equivalent to placing the neutrino in the magnetic field with magnetic induction $\mathbf{B} = -\mathbf{v}\sqrt{4\pi\rho}$. It is in accordance with that in an external magnetic field (whose magnetic induction in the experiments was much greater than that of the Earth) the neutrino spin got oriented in the magnetic induction direction [10] [11].

2.3. Electric Current as a Vortex Line in the Physical Vacuum Consisting of QHOs

According to postulates of quantum mechanics, a quantum entity (its characteristics are determined by the wave function) that is a singularity in electric or magnetic fields (electric charge or/and magnetic dipole) creates a virtual photon (pair of virtual particles) [12] [13]. The virtual photon is characterized by spin S_v precessing with frequency ω_v (that is, the virtual photon is a spin vortex), mass m_v , electric dipole moment \mathbf{d}_v and circulation Γ_v (Figure 1). Let us consider the properties of virtual photons in detail.

Spin. As the virtual photon is a spin vortex, then by the analogy with (real) photon the following holds [8] [14] with respect to spin S_v and electric dipole moment \mathbf{d}_v :

$$\mathbf{d}_v \uparrow\downarrow S_v. \quad (4)$$

Taking into account that electric field \mathbf{E}_v inside the electric dipole is antiparallel

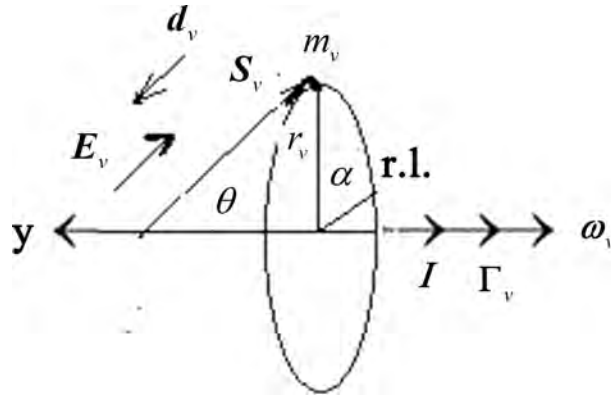


Figure 1. The characteristics of a virtual photon created by electron: S_v is spin, d_v is the electric dipole moment, E_v is the electric field inside the electric dipole, Γ_v is circulation, ω_v is the precession frequency, I is electric current, y is the velocity of electron, θ is the deflection angle between ω_v and S_v , α is the precession angle, r_v is the radius of circle by which mass m_v performs circulation motion, on the premise that the mass is point-like, r.l. is a reference line.

to its electric dipole moment, $E_v \uparrow \downarrow d_v$ [9], we have:

$$E_v \uparrow \uparrow S_v. \quad (5)$$

Precession frequency. As follows from the study by L. Boldyreva [15], the precession frequency ω_v of spin of the virtual photon (pair of virtual particles) created by a quantum entity equals the frequency ω_q of the wave function of the entity: $\omega_q = \omega_v$. In Schrodinger's wave function the value of ω_q is determined by energy U_q of quantum entity: $\omega_q = U_q / \hbar$, consequently:

$$\omega_v = U_q / \hbar. \quad (6)$$

Let us consider the case where energy U_q of quantum entity equals its kinetic energy:

$$U_q = m_q y^2 / 2, \quad (7)$$

where m_q and y are respectively mass and speed of the quantum entity. Then from Equations (6) and (7) it follows:

$$\omega_v = m_q y^2 / (2\hbar). \quad (8)$$

If a virtual photon is created by electrically charged quantum entity, then electric field E_q of this entity acts on the virtual photon as on an electric dipole; the emerging moment M_q is determined [9] as $M_q = d_v \times E_q$. Because of the action of moment M_q , the orientation of ω_v shall be determined by the sign of the quantum entity. Taking into account that direction of velocity y is the single preferential direction for virtual photon, we may assume:

$$\omega_v \uparrow \uparrow \eta y, \quad (9)$$

where $\eta = 1$ for positively charged quantum entity and $\eta = -1$ for negatively charged quantum entity, that is:

$$\omega_v \uparrow \uparrow I, \quad (10)$$

where I is the current created by the moving charged quantum entity.

Electric dipole moment. The electric dipole moment of virtual photon d_v may be determined [14] as:

$$d_v = q_v \tilde{\lambda}_q, \quad (11)$$

where q_v is the charge of every virtual particle in the virtual photon; $\tilde{\lambda}_q$ is the wave function wavelength of quantum entity creating the virtual photon and it is determined [16] as:

$$\tilde{\lambda}_q = \hbar / (m_q y). \quad (12)$$

Let us deduce the expression for d_v for the virtual photon created by an electron, assuming that the specific charge of the virtual particle in the virtual photon is proportional to the specific electron charge e/m_e (e and m_e are respectively the electric charge and mass of electron). Note that the experiments conducted by W. Kaufmann on deflection of beta-rays emitted by radium make one believe that the mass of electron is purely of electromagnetic nature [17]. Thus $q_v = m_v e / (2m_e)$; the virtual photon mass m_v , taking into account Equation (7) and classical relationship between mass and energy, is determined as:

$$m_v = m_q y^2 / (2 \cdot c^2). \quad (13)$$

Using the above considered expression for q_v , Equation (13) and the expression for Bohr's magneton ($\mu_B = e \cdot \hbar (2 \cdot m_e \cdot c)$) in Equation (11) we obtain:

$$d_v = \frac{\mu_B \cdot y}{2 \cdot c}. \quad (14)$$

If for the virtual particles pair created by electron moving at velocity y ($y \ll c$) it holds that $d_v \uparrow \uparrow y$, then from Equation (14) it follows that in the electric field E the moment M acting on the electric dipole, $M = d_v \times E$, is determined as: $M = \frac{\mu_B}{2 \cdot c} (y \times E)$; the right side of expression for M is the same as that for maximum value of the spin-orbit interaction energy of the electron in a hydrogen atom: $(U_{s-o})_{\max} = \left| \frac{\mu_B}{2 \cdot c} (y \times E) \right|$. Thus at $y \ll c$ the condition $d_v \uparrow \uparrow y$ holds true. Taking into account conditions (4) and (9), and that for photon spin S_{ph} the following is valid: $S_{ph} \perp c$ (c is the velocity of light) [14] [18], we may introduce the following equation for deflection angle θ between the precession frequency of virtual photon and its spin:

$$\sin \theta = y/c. \quad (15)$$

The circulation. Using the above-considered expressions for characteristics of virtual photon let us analyze the circulation motion of mass m_v that is performed as a result of precession motion of spin S_v . The circulation Γ_v characterized by this circulation motion is defined [7] as:

$$\Gamma_v = 2\pi \omega_v r_v^2, \quad (16)$$

where r_v is the radius of circle by which mass m_v performs circulation motion, on the premise that the mass is point-like. From Equations (8), (10) and (16) it

follows: $\Gamma_v = \mathbf{I} \pi m_q y^2 r_v^2 / (I \hbar)$. Thus the moving charged quantum entity creates a vortex line in the physical vacuum consisting of QHOs with circulation directed along the current created by motion of this quantum entity. The circulation Γ_l created by electric current \mathbf{I} is determined as sum of Γ_v for all charged quantum entities that constitute the electric current. It should be noted that virtual photons created by charged quantum entities, the speed \mathbf{v} of which is directed along the same axis, have equal precession angles α . This equalization of precession angles α along the vortex line created by electric current is performed by spin supercurrent. Let us consider it in detail.

Spin supercurrent. Spin supercurrent was discovered while investigating the characteristics of superfluid $^3\text{He-B}$ [19] [20] [21]. For example, the value of spin supercurrent j_z in the direction of orientation (axis \mathbf{z}) of precession frequencies of spins of ^3He atoms is determined as follows:

$$j_z = -g_1 \partial \alpha / \partial z - g_2 \partial \theta / \partial z, \quad (17)$$

where α is the precession angle (phase), θ is the deflection angle. The spin supercurrent tends to equalize the respective characteristics of spins of interacting spin structures: angles (phases) of precession and angles of deflection. For example, after action of spin supercurrent J_z between spin structures with precession angles α_1 and α_2 , and deflection angles θ_1 and θ_2 the following takes place:

$$|\alpha_1 - \alpha_2| > |\alpha'_1 - \alpha'_2|, \quad (18)$$

$$|\theta_1 - \theta_2| > |\theta'_1 - \theta'_2|, \quad (19)$$

where α'_1 and α'_2 are respectively the values of precession angles α_1 and α_2 after the action of spin supercurrent; θ'_1 and θ'_2 are respectively the values of deflection angles θ_1 and θ_2 after the action of spin supercurrent.

Virtual photon and QHOs. The photon may decay into a pair of oppositely charged particles in the electric field of heavy nuclei [16]. In this case, the total spin of emerging particles equals the photon spin, which suggests that the principle of conservation of angular momentum holds true in the physical vacuum where the photon emerges. Consequently, the creation of virtual photons having precessing spin by a quantum entity while saving the value of its own spin testifies that the spin of virtual photon is formed by spins of particles that constitute the physical vacuum: in particular, by spins of QHOs. (The analogous conclusion may be made for “real” photons as well while analyzing the Cherenkov effect [22]: the production of photons having spin by an electron moving at a superluminal speed while saving the value of its own spin. It should be noted that spin of “real” photon in pure state performs precession motion with frequency of photon.) Thus QHO as a harmonic oscillator having precessing spin might be classified as a spin vortex, and the frequency of oscillations Ω_{QHO} may be the precession frequency of spin of QHO. Consequently, QHO may possess the properties of such spin vortex as the virtual photon and the expressions similar to (4)-(5), (9) and (14)-(15) hold true as well for QHO, that is:

$$\mathbf{d}_{\text{QHO}} \uparrow \downarrow \mathbf{S}_{\text{QHO}}, \quad (20)$$

$$\mathbf{E}_{\text{QHO}} \uparrow \uparrow \mathbf{S}_{\text{QHO}}, \quad (21)$$

$$\boldsymbol{\Omega}_{\text{QHO}} \parallel \mathbf{u}, \quad (22)$$

$$d_{\text{QHO}} \approx \gamma \cdot u, \quad (23)$$

$$\sin \theta = u/c, \quad (24)$$

where \mathbf{d}_{QHO} is the electric dipole moment of QHO, \mathbf{S}_{QHO} is spin of QHO, u is the speed of QHO, γ is a proportionality factor, θ is the deflection angle between \mathbf{S}_{QHO} and frequency $\boldsymbol{\Omega}_{\text{QHO}}$ of its precession.

3. The Wave-Vortex-Spin Process in the Physical Vacuum Consisting of QHOs

3.1. The Equation Describing the Wave-Vortex-Spin Process in the Physical Vacuum Consisting of QHOs

Due to the existence of interactions of QHOs (the electric dipole-dipole interaction and that owing to spin supercurrents), the physical vacuum consisting of QHOs should feature the rotational viscosity, which manifests itself in a nonstationary case, in particular, the transformation of macrorotation in microrotation and vice versa. It is shown that the wave-vortex-spin process may arise in the physical vacuum (see also [23]). It should be noted that the vortices in the physical vacuum may terminate in the bulk of the physical vacuum due to complete transfer of the angular momentum of vortex to intrinsic motions (to intrinsic degrees of freedom) of the physical vacuum.

The first Equation describing the wave-vortex-spin process

Due to conservation of angular momentum in the physical vacuum, the Einstein-de Haas effect takes place in this vacuum [24]: a change of spin \mathbf{S} ($\partial \mathbf{S} / \partial t \neq 0$) of a unit volume of physical vacuum consisting of QHOs results in the rotation of the vacuum ($\text{curl} \mathbf{u} \neq 0$). That is the following holds true:

$$\partial \mathbf{S} / \partial t = -(1/k_1) \cdot \text{curl} \mathbf{u}, \quad (25)$$

where t is time, $k_1 > 0$ is a proportionality factor.

The second Equation describing the wave-vortex-spin process

According to Equations (22) and (24), at the emergence of $\partial \mathbf{u} / \partial t$ in the physical vacuum consisting of QHOs the following cases may take place:

1) at a change in the direction of velocity \mathbf{u} , the precession motion of \mathbf{S} relative to a new direction of \mathbf{u} arises;

2) at a change of only the value of u , the angle θ changes.

In both cases, a change in deflection angle θ takes place, which, in turn, results in emergence of $\text{curl} \mathbf{S}$. That is, the following equation should be taken to be true:

$$\partial \mathbf{u} / \partial t = k_2 \text{curl} \mathbf{S}, \quad (26)$$

where $k_2 > 0$ is a proportionality factor. To make it clear that Equations (25) and (26) describe the wave-vortex-spin process in the physical vacuum consist-

ing of QHOs let us introduce the following factor χ :

$$\chi = \sqrt{k_2/k_1} \quad (27)$$

Using Equation (27) in Equations (25) and (26) we obtain:

$$\frac{\partial(\chi k_1 \mathbf{S})}{\partial t} = -\chi \text{curl} \mathbf{u}, \quad (28)$$

$$\frac{\partial \mathbf{u}}{\partial t} = \chi \text{curl}(\chi k_1 \mathbf{S}). \quad (29)$$

The dimension of factor χ is the same as that of speed. The Equations (28) and (29) describe the wave-vortex-spin process in which transformation of energy is performed as follows: the specific kinetic energy of motion of physical vacuum $\rho u^2/2$ transforms into energy W_s of spin system of the vacuum that creates the spin vortex; in turn, the energy W_s transforms into the kinetic energy of motion of the physical vacuum. The energy W_s may be detailed if to introduce the following notation in Equations ((28), (29)):

$$\mathbf{Y} = -k_1 \chi \mathbf{S}. \quad (30)$$

Then

$$\frac{\partial \mathbf{Y}}{\partial t} = \chi \cdot \text{curl} \mathbf{u}, \quad (31)$$

$$\frac{\partial \mathbf{u}}{\partial t} = -\chi \cdot \text{curl} \mathbf{Y}. \quad (32)$$

Let us consider the physical meaning of variable \mathbf{Y} , which, according to (30), is directed oppositely to \mathbf{S} , is proportional to the magnitude of \mathbf{S} and has the dimension of velocity. It may be supposed that \mathbf{Y} is a velocity of motion of positive charges of QHO (simultaneously, negative charges of QHO move at velocity— \mathbf{Y}), see **Figure 2**. Such motions result in creation of electric field \mathbf{E} inside QHO. Then W_s is the kinetic energy of motion of charges inside QHO at speed Y , that is in the wave-vortex-spin process the transformation of energy is performed as follows: the specific *kinetic* energy of motion of physical vacuum $\rho u^2/2$ around the vortex transforms into specific *kinetic* energy of motion of physical vacuum $\rho Y^2/2$ inside the vortex.

As electric field \mathbf{E} emerges inside QHO due to motion of charges inside QHO at speed Y , the specific kinetic energy of this motion ($\rho Y^2/2$) transforms in the specific energy of emerging electric field \mathbf{E} ($E^2/(8\pi)$). It follows from equality of those energies:

$$\mathbf{E} = -Y \sqrt{4\pi\rho}. \quad (33)$$

Using Equations (3) and (33) in Equations (31) and (32), we obtain the equations describing the electromagnetic process:

$$\frac{\partial \mathbf{E}}{\partial t} = \chi \cdot \text{curl} \mathbf{B}, \quad (34)$$

$$\frac{\partial \mathbf{B}}{\partial t} = -\chi \cdot \text{curl} \mathbf{E}. \quad (35)$$

Consequently, the physical vacuum consisting of QHOs may be considered as a luminiferous medium.

Note. In emerging electric field \mathbf{E} the moment \mathbf{M}_E acts on QHO as on electric dipole: $\mathbf{M}_E = \mathbf{d}_{\text{QHO}} \times \mathbf{E}$. Simultaneously, according to condition (20), \mathbf{M}_E acts as well on spin \mathbf{S}_{QHO} of QHO. Thus in an electric field the electric and spin polarizations of physical vacuum consisting of QHOs characterized by zero-point energy emerge.

3.2. The Equalization of Speed of Wave-Vortex-Spin Process in Inertial Systems

The existence of a luminiferous medium does not contradict the second postulate of special relativity; this principle of the constancy of the velocity of light states: “in all *inertial systems* the velocity of light has the same value when measured with length—measures and clocks of the same kind” [25].

In this Section (see also ref. [14]), it will be shown that this postulate may be due to the interaction of the photons with QHOs constituting the physical vacuum and with the virtual photons (virtual particles pairs) created by quantum entities that constitute the inertial system (and determine, in fact, its inertial properties). One of the first works containing the physical interpretation of the equalization of the speed of light in inertial systems to a definite value is the work by Fox [26]. The studies by Fox were directed at supporting the Ritz emission theory, according to which the fundamental constant c is the speed of light with respect to the source in the vacuum and the Galilean addition of velocities holds [27]. Fox used the extinction theorem of Ewald and Oseen [28]. The theorem states that if an incident electromagnetic wave traveling at a speed c appropriate to vacuum enters a dispersive medium, its fields are cancelled by part of the fields of the induced dipoles (macroscopically, by the polarization) and replaced by another wave propagating with a phase velocity characteristic of the medium. The incident wave is extinguished by interference and replaced by another wave. The motion of the source and the speed of light relative to it are irrelevant in this theorem. There are, however, some experiments that are not explained by the extinction theorem, for example the experiment performed at CERN, Geneva, in 1964 [29]. In this experiment, photons were produced by the source moving at speed of $0.99975c$ relative to the measurement devices. Photons' speed was measured by time of flight over paths up to 80 meters; within the experimental error it was found that the speed of the photons was equal to c relative to the same measurement devices. The extinction theorem, in which the interaction of a photon and a medium takes place due to the magnetic and electric components of photon, does not explain the results of the experiment. The equalization of the speed of light found in experiments indicates the existence of some other interactions. In particular, it is necessary to take into account the interaction of photons with QHOs that constitute the physical vacuum and with virtual photons (the virtual particles pairs) created by quantum entities that constitute the inertial systems.

3.3. The Condition of Disappearance of Wave-Vortex-Spin Process

Equation (28) describing the wave-vortex-spin process contains $\partial S/\partial t$. Consequently, this process could not spread in the region where the orientation of spins of QHOs that constitute the physical vacuum cannot change, *i.e.* spins can be considered to be “frozen”:

$$\partial S/\partial t \equiv 0. \quad (36)$$

This may take place, for example, in the following cases: 1) at the emergence of spin supercurrents causing a definite orientation of spins and suppressing any disturbances producing a change in the orientation of spins; 2) at rotation of physical vacuum consisting of QHOs, which due to the Barnett effect [30] creates a definite orientation of spins of QHOs that constitute this vacuum.

One of the most striking examples demonstrating the effect of visibility loss is a series of experiments conducted by J. Searl in 1940-1950 [31]. In the experimental setup a rotating nonlinear magnetic field could be created. At the critical value of speed of rotation the invisibility of the setup is observed. This may be interpreted as follows: according to Equation (3), the rotation of magnetic field means the rotation of physical vacuum consisting of QHOs and consequently, due to the effect of Barnett, gives rise to a definite orientation of spins of QHOs that constitute this vacuum.

In the standard Lambda-CDM model of cosmology, near 27% of the total mass-energy of the universe consist of dark matter [32]. At present, the invisibility is explained in particular by that the strong gravitation field of the matter does not allow photons to leave the location of the matter. The model of physical vacuum consisting of QHOs considered in this work accounts for the invisibility by emergence of “freezing” of spins (Equation (36)) of those QHOs at the location of this matter. This “freezing” may take place as a result of rotation of dark matter and due to low temperature characterizing dark matter. Let us consider the influence of temperature in detail.

The temperature T determines the velocity v ($v = \sqrt{2KT/m}$) of thermal chaotic motion of quantum entities (with mass m) that constitute “dark” matter and consequently the velocity of motion of virtual photons (virtual particles pairs) created by those entities. The speed of quantum entities influences the following characteristics of virtual photons: the value of the deflection angle, see Equation (15); the direction and the value of precession frequency ω_v , see Equations ((8), (9)). As the virtual photon is a vortex in the physical vacuum consisting of QHOs, the changes in characteristics of virtual photons mean the changes in the characteristics of QHOs as well. Thus, the thermal chaotic motion may prevent the “freezing” of spins of QHOs that constitute the physical vacuum.

4. The Electric Dipole-Dipole Interaction of QHOs That Constitute the Physical Vacuum

Let us consider the projections of electric dipole moment of QHO, d_{QHO} , on the

direction of velocity \mathbf{u} of QHO, $(d_{\text{QHO}})_u$, and on the direction perpendicular to \mathbf{u} , $(d_{\text{QHO}})_{\perp u}$, see **Figure 2**. According to conditions (20) and (22), the projections $(d_{\text{QHO}})_u$ and $(d_{\text{QHO}})_{\perp u}$ are determined as:

$$(d_{\text{QHO}})_u = d_{\text{QHO}} \sqrt{1 - \sin^2 \theta}, \quad (37)$$

$$(d_{\text{QHO}})_{\perp u} = d_{\text{QHO}} \sin \theta. \quad (38)$$

According to Equations (17)-(19), spin supercurrent equalizes both the precession angles α and the deflection angles θ of QHOs, whose precession frequencies Ω_{QHO} and velocities \mathbf{u} are directed along the same axis \mathbf{z} (see **Figure 2**). Consequently: first, the components $(d_{\text{QHO}})_{\perp u}$ of QHOs moving along the same axis \mathbf{z} are parallel to each other, and, secondly, these QHOs have equal components $(d_{\text{QHO}})_{\perp u}$ and equal components $(d_{\text{QHO}})_u$ respectively. As a result, the attractive force $F_{\text{QHO}\parallel}$ and repulsive force $F_{\text{QHO}\perp}$ act between those QHOs [9]. According to Equations (24) and (37)-(38), we have:

$$F_{\text{QHO}\parallel} = \frac{6d_{\text{QHO}}^2(1 - u^2/c^2)}{r^4}, \quad (39)$$

$$F_{\text{QHO}\perp} = \frac{3d_{\text{QHO}}^2 u^2}{c^2 r^4}, \quad (40)$$

where r is the distance between the QHOs. The expression for resulting force $F_{\text{QHO}} = F_{\text{QHO}\parallel} - F_{\text{QHO}\perp}$ with taking into account Equations (39) and (40) may be written in the form: $F_{\text{QHO}} = 3d_{\text{QHO}}^2(2 - 3u^2/c^2)/r^4$. Using Equation (23), F_{QHO} may be expressed in the form:

$$F_{\text{QHO}} = 3\gamma^2(2u^2/c^2 - 3u^4/c^4)/r^4. \quad (41)$$

Consequently, that force F_{QHO} is repulsive under condition $u > c\sqrt{2/3}$.

Let us estimate the influence of components of force F_{QHO} on the density of the physical vacuum consisting of QHOs characterized by zero-point energy. The force component $F_{\text{QHO}\parallel}$, being an attractive force, tends to decrease the distance between QHOs moving along the same axis \mathbf{z} and consequently to increase the concentration of QHOs in the physical vacuum. The force component

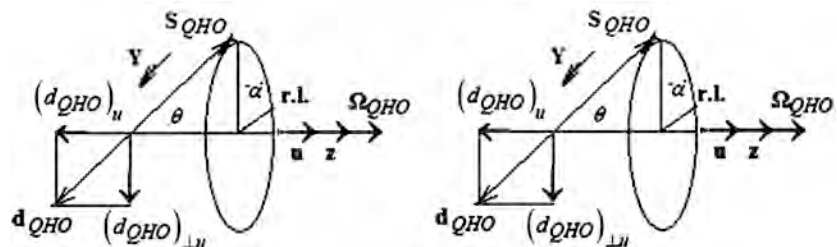


Figure 2. The characteristics of quantum harmonic oscillators (QHOs): S_{QHO} is spin, d_{QHO} is the electric dipole moment, Ω_{QHO} is the frequency of spin, $(d_{\text{QHO}})_{\perp u}$ is the projection of d_{QHO} on the direction perpendicular to velocity \mathbf{u} , $(d_{\text{QHO}})_u$ is the projection of d_{QHO} on the direction \mathbf{u} , θ is the deflection angle, α is the precession angle, r.l. is a reference line, \mathbf{Y} is the velocity of positive charges that constitute QHO.

$F_{\text{QHO}\perp}$, being a repulsive force, tends to increase the distance between QHOs moving along the same axis z and consequently to decrease the concentration of QHOs in the physical vacuum. It follows from Equation (41) that in the first order of $\beta = u/c$ the resulting force F_{QHO} and consequently the concentration of QHOs does not depend on the speed of physical vacuum. Since there is no information available on the connection of mass of QHO with the speed of the latter, it may be assumed that only the concentration of QHOs determines the dependence of density of physical vacuum on the speed. And consequently it may be assumed that the density does not depend on the speed of physical vacuum at small β .

5. Discussion. Cosmic Microwave Background (CMB)

The QHOs that constitute the physical vacuum have precessing spin. Spin supercurrent emerging between QHOs influences the characteristics of the precession (the angles of precession and deflection) changing thus the orientation of spin in space. According to Equations ((28), (29)), this means the possibility of emergence in the physical vacuum of wave-vortex-spin process that, according to Equations ((34), (35)), is also an electromagnetic process. Thus, the background electro-magnetic emission may exist in the physical vacuum consisting of QHOs. The cosmic microwave background (CMB) may be such an emission.

6. Conclusions

The properties of physical vacuum consisting of quantum harmonic oscillators (QHOs) characterized by zero-point energy are identical to the properties of dark energy, *i.e.*:

- the positive density associated with mass of QHOs;
- the negative pressure caused by that in a QHO a separation of the substance of vacuum into positive and negative charges takes place;
- the possibility of increase in distance between QHOs, *i.e.* of the “expansion” of physical vacuum; it is due to electric dipole-dipole interaction of QHOs;
- the physical vacuum consisting of QHOs having zero-point energy may be classified as “dark”, since light propagates in it as a process. The existence of luminiferous medium does not contradict the second postulate of special relativity (the principle of constancy of the velocity of light in inertial systems) if to take into account the interaction of photons with QHOs and with virtual photons (the virtual particles pairs) created by quantum entities that constitute the inertial systems.

Due to possibility of emergence of spin supercurrent between QHOs the background electro-magnetic emission may exist in the physical vacuum consisting of QHOs. The cosmic microwave background (CMB) may be such an emission.

The model of physical vacuum consisting of QHOs considered in this work

may account for the invisibility of dark matter due to “freezing” of spins of the QHOs at the location of this matter. The “freezing” might take place for example at a large angular speed of rotation of this matter and at low temperature (the latter is characteristic of dark matter).

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Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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A Two-Higgs-Doublet Model without Flavor-Changing Neutral Currents at Tree-Level

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Abstract

The flavor-changing neutral current (FCNC) problem at tree-level is a very critical defect of the two Higgs doublet extension of standard model (SM). In this article, a two-Higgs-doublet model (2HDM) in which such defects do not exist at all is to be demonstrated. The general pattern of matrix pairs which can be diagonalized simultaneously by a same unitary transformation is proposed without extra constraints like symmetries or zeros in M matrices. Only an assumption of the hermiticity of mass matrices is employed in the derivation. With this assumption, number of parameters in the mass matrix of a specific fermion type is reduced from eighteen down to five. Eigenvalues and eigenvectors are analytically derived and it is surprising that unitary transformation matrix thus derived depends on only two parameters. It is a very general and elegant way to solve the tree-level FCNC problem radically and it includes previous similar models as special cases with specific parameter values.

Keywords

Two-Higgs-Doublet Model, CP Violation, 2HDM

1. Introduction

In the standard model (SM) of electro-weak interactions CP symmetry can be violated explicitly by ranking the Yukawa couplings between fermions and Higgs fields suitably and expect them to generate complex phases in the Cabibbo-Kobayashi-Maskawa (CKM) matrix. But, no one knows how these Yukawa couplings should be arranged to give a satisfactory CKM matrix. Though in SM the vacuum expectation value (VEV) of its Higgs doublet also provided a complex phase when the gauge symmetry was spontaneously broken. However, CP symmetry can't be violated spontaneously in SM since the only phase generated in this way can always be rotated away. Thus, an extension of SM with one extra Higgs doublet was proposed [1], through which, one expects the phases in the VEVs may unlikely be rotated

away simultaneously and a non-zero phase difference between them might survive so as to bring in CP-violation spontaneously. However, a definite way regarding how CP-violation can be generated in such a model is still missing.

Besides failing to solve the CP problem, this extra Higgs doublet also brought in an extra problem of flavor-changing neutral currents (FCNCs) at tree level. This problem arises if those two components M_1 and M_2 of the quark mass matrix $M = M_1 + M_2$ corresponding to Higgs doublets Φ_1 and Φ_2 respectively were not diagonalized simultaneously by a same unitary transformation U . Respective non-zero off-diagonal elements of diagonalized UM_1U^\dagger and UM_2U^\dagger in the mass eigenstate lead to flavor-changing-neutral (FCN) interactions mediated by neutral Higgs scalars at tree level.

At the beginning, people were not aware of the danger of such interactions too much. But, as the energy and accuracy of experiments increase and no such effects were detected until 2005 [2], the need of hypotheses to explain the smallness of such interactions emerged. Owing to the smallness of detected such interactions, it is natural for people to consider them as loop corrections. If one considers them as loop corrections, that means such interactions won't appear at tree-level. In such a manner, there should be matrix pairs which can be diagonalized simultaneously and how to find such matrix pairs becomes the key to solve the FCNC problem.

In [3] two Natural-Flavor-Conservation (NFC) models were proposed by employing a Z_2 discrete symmetry to forbid both Higgs doublets to couple with a same quark type simultaneously. These two models are usually referred to as the Type-I and Type-II NFC models or just Type-I and Type-II 2HDMs. In the Type-I model, only one of the Higgs doublets couples with both quark types and the other completely does not. In the Type-II model, up- and down-type quarks couple with different Higgs doublets respectively. Surely they are free of FCNCs since for a specific quark type either $M_1 = 0$ or $M_2 = 0$ guarantees the absence of FCNCs. Besides these two models, there are also similar models which are usually referred to as the Type-III and -IV models, sometimes the -X and -Y models, or the lepton-specific and flipped 2HDMs. However, these models are just extensions of Type-I and -II models to include leptons [4–7, and references therein].

Besides models mentioned in last paragraph, there are also several 2HDMs in which both M_1 and M_2 are assumed non-zero. But these models do not have proper dynamic explanations for their assumptions. For instance, in Fritzsch-ansatz [8] [9] and its consequent developments several elements of the mass matrices were assumed zero to simplify the pattern of mass matrices down to an analytically manageable level. In the Aligned Two-Higgs-Doublet model (ATHDM or A2HDM) [5], an assumption of M_1 and M_2 are proportional was employed as an *ad-hoc* constraint. However, they are in fact special cases of the model to be presented in this article. It is noticeable that most of these models also assume the M matrices are Hermitian in addition to these imposed constraints.

Besides the FCNC-free 2HDMs mentioned above, there is another type of 2HDM which is also referred to as Type-III 2HDM [10–15, and references therein] and usually causes confusions with the one mentioned above. Such models do not deny the existence of FCNCs at tree level. It just assumes that tree-level FCNCs are highly suppressed or can be canceled by loop corrections down to empirical values.

In 2HDMs mentioned above, except for the one allows for tree-level FCNCs, assumptions or forbiddance were employed to simplify the patterns of fermion mass matrices. However, theoretically, a model with fewer *ad-hoc* constraints is better since it will be more general and natural. Forbidding couplings between specific fermion types and Higgs doublets is a very strong constraint. In usual, physicists prefer a general model applies to wider fields to special models constrained by special conditions or symmetries. Thus, a model in which neither M_1 , M_2 nor any elements in them has to be assumed zero will be a better one.

Theoretically, a 2HDM in which both M_1 and M_2 are nonzero and can be diagonalized simultaneously should exist. If such a model does exist, it is obviously more general than the Z_2 -symmetric ones or those assuming zeros in mass matrices. At the mean time, assumptions of highly suppressed tree-level FCNCs or loop corrections as strong as zeroth-order interactions in Type-III models are no longer needed. In such a model, FCNCs at tree-level are no more problems since they do not exist at all. Now the only problem is how to find them and what will they looks like.

In fact, such matrix pairs do exist and the first one had been discovered in a S_3 -symmetric 2HDM [16–18] decades ago. The matrix pair derived there were

$$M_1 = \begin{pmatrix} A & B & B \\ B & A & B \\ B & B & A \end{pmatrix}, \quad M_2 = i \begin{pmatrix} 0 & -D & D \\ D & 0 & -D \\ -D & D & 0 \end{pmatrix}, \quad (1)$$

and the unitary transformation which diagonalize them simultaneously was derived analytically as:

$$U = \begin{pmatrix} 1/\sqrt{3} & (-1 - i\sqrt{3})/2\sqrt{3} & (-1 + i\sqrt{3})/2\sqrt{3} \\ 1/\sqrt{3} & (-1 + i\sqrt{3})/2\sqrt{3} & (-1 - i\sqrt{3})/2\sqrt{3} \\ 1/\sqrt{3} & 1/\sqrt{3} & 1/\sqrt{3} \end{pmatrix}. \quad (2)$$

In recent years, three more such FCNC-free matrix pairs were derived by extending the S_3 -symmetric pattern to three $(S_3 + S_2)$ -symmetric patterns [19]. In this article, a very general pattern of such FCNC-free matrix pairs is derived without any symmetries or assumptions except the hermiticity of mass matrices. It not only includes the S_3 - and $(S_3 + S_2)$ -symmetric matrix pairs as special cases in it, but also the Z_2 -symmetric, Fritzsch ansatz and A2HDM.

At the beginning of section II, a FCNC-free condition for a 2HDM which was firstly given in [20] is discussed and improved. With this condition, number of free parameters in a mass matrix is substantially reduced from eighteen down to five. Thus, analytical solutions of the eigenvalues and eigenvectors are derivable. It is amazing that derived unitary transformation matrix U which diagonalize both M_1 and M_2 simultaneously is extremely simple. It depends on only two of the five parameters in each quark type. Conclusions and some discussions on its application on generating CP violation will be given in section III.

2. A General Pattern for FCNC-Free Mass Matrices

Theoretically, finding matrix pairs which can be diagonalized by a same U matrix simultaneously is a better way to solve the FCNC

problem since that will be more general than those imposing symmetries [16–19], forbiddance [3] or zeros in mass matrices [8, 9]. In usual, physicists prefer a general model applies to wider fields to special models apply only under certain conditions.

Following this hypothesis, we would like to start the study from a very general basis without any imposed symmetries, forbiddance or zeros. We try to keep it as general as possible in the following derivations. However, as to be shown below, a Hermitian assumption of the M matrix is still needed for simplifying the M matrix down to a manageable level. This Hermitian assumption firstly reduce the number of parameters in a most general M matrix from eighteen down to nine. Then, with the help of an interesting condition between M_1 and M_2 which is to appear in Equation (7), the parameter number is further reduced down to five. Thus, eigenvalues and corresponding U matrix are now achievable analytically. In what follows, the procedure of derivations will be presented step by step.

For a 2HDM, the Yukawa couplings of Q quarks can be written as

$$-\mathcal{L}_Y = \bar{Q}_L(Y_1^d\Phi_1 + Y_2^d\Phi_2)d_R + \bar{Q}_L\epsilon(Y_1^u\Phi_1^* + Y_2^u\Phi_2^*)u_R + h.c., \quad (3)$$

where Y_i^q are 3×3 Yukawa-coupling matrices for quark types $q = u, d$ and Higgs doublets $i = 1, 2$, respectively, and ϵ is the 2×2 antisymmetric tensor. Q_L are left-handed quark doublets, and d_R and u_R are right-handed down- and up-type quark singlets, respectively, in their weak eigenstates. The mass matrices can then be expressed as

$$M^{(u,d)} = M_1^{(u,d)} + M_2^{(u,d)} = Y_1^{(u,d)}\langle\Phi_1\rangle + Y_2^{(u,d)}\langle\Phi_2\rangle, \quad (4)$$

where $\langle\Phi_i\rangle \equiv v_i e^{i\theta_i}/\sqrt{2}$, $i = 1$ and 2 , are vacuum expectation values of the Higgs doublets. Here, a basis in which $\theta_1 = 0$ will be chosen and only the phase θ_2 is left non-zero.

Neglecting the hyper-indices of M , the most general pattern of a 3×3 mass matrix can always be written as

$$M = M_1 + M_2 = \begin{pmatrix} A_1 + iD_1 & B_1 + iC_1 & B_2 + iC_2 \\ B_4 + iC_4 & A_2 + iD_2 & B_3 + iC_3 \\ B_5 + iC_5 & B_6 + iC_6 & A_3 + iD_3 \end{pmatrix}, \quad (5)$$

where A, B, C and D are all real and each of them may receive contributions from both M_1 and M_2 arbitrarily. Such a pattern is the most general one for a 3×3 matrix since it contains nine elements and each of them has one real and one imaginary components. Thus, if no constraints were imposed, there are eighteen parameters in such a M matrix in total.

It is obvious that eighteen parameters are too many to have such a matrix be diagonalized analytically. That's why physicists employed various constraints in previous 2HDMs to simplify the M pattern. However, as to be shown below, a Hermitian assumption is already enough to simplify the M pattern down to an analytically manageable level. Constraints like Z_2, S_N symmetries or imposed zeros in M matrix are in fact unnecessary.

If one assumes the mass matrix M were Hermitian, the D parameters will be all zero and Equation (5) becomes

$$M = \begin{pmatrix} A_1 & B_1 + iC_1 & B_2 + iC_2 \\ B_1 - iC_1 & A_2 & B_3 + iC_3 \\ B_2 - iC_2 & B_3 - iC_3 & A_3 \end{pmatrix}, \quad (6)$$

with $B_4 = B_1$, $B_5 = B_2$, $B_6 = B_3$, $C_4 = -C_1$, $C_5 = -C_2$ and $C_6 = -C_3$.

In [20], a condition

$$M_1 M_2^\dagger - M_2 M_1^\dagger = 0, \quad (7)$$

was given for a matrix pair which can be diagonalized by a same U matrix if they were both Hermitian. This can be easily proved since $U M_1 U^\dagger = U M_1^\dagger U^\dagger = M_1^{diag.}$ and $U M_2 U^\dagger = U M_2^\dagger U^\dagger = M_2^{diag.}$, where $M_1^{diag.}$ and $M_2^{diag.}$ are diagonal. If one applies U onto Equation (7), one will receive

$$\begin{aligned} & (U M_1 U^\dagger)(U M_2^\dagger U^\dagger) - (U M_2 U^\dagger)(U M_1^\dagger U^\dagger) \\ &= M_1^{diag.} M_2^{diag.} - M_2^{diag.} M_1^{diag.} = 0. \end{aligned} \quad (8)$$

Thus, if one can find a matrix pair which satisfies Equation (7), the FCNC problem at tree-level is solved automatically.

Based on this, it is instinctive for one to divide the Hermitian matrix in Equation (6) into two Hermitian components and substitute them into Equation (7). The simplest way for doing so is to divide them into one purely real component and one purely imaginary component as

$$M_R = \begin{pmatrix} A_1 & B_1 & B_2 \\ B_1 & A_2 & B_3 \\ B_2 & B_3 & A_3 \end{pmatrix}, \quad M_I = i \begin{pmatrix} 0 & C_1 & C_2 \\ -C_1 & 0 & C_3 \\ -C_2 & -C_3 & 0 \end{pmatrix}. \quad (9)$$

Substitute Equation (9) into Equation (7), we receive

$$M_I M_R^\dagger = i \begin{pmatrix} B_1 C_1 + B_2 C_2 & A_2 C_1 + B_3 C_2 & B_3 C_1 + A_3 C_2 \\ B_2 C_3 - A_1 C_1 & B_3 C_3 - B_1 C_1 & A_3 C_3 - B_2 C_1 \\ -A_1 C_2 - B_1 C_3 & -B_1 C_2 - A_2 C_3 & -B_2 C_2 - B_3 C_3 \end{pmatrix},$$

$$M_R M_I^\dagger = i \begin{pmatrix} -B_1 C_1 - B_2 C_2 & A_1 C_1 - B_2 C_3 & A_1 C_2 + B_1 C_3 \\ -A_2 C_1 - B_3 C_2 & B_1 C_1 - B_3 C_3 & B_1 C_2 + A_2 C_3 \\ -B_3 C_1 - A_3 C_2 & B_2 C_1 - A_3 C_3 & B_2 C_2 + B_3 C_3 \end{pmatrix} \quad (10)$$

The diagonal elements give us following conditions

$$B_1 C_1 = -B_2 C_2 = B_3 C_3 \quad (11)$$

and the off-diagonal ones give us other three

$$(A_1 - A_2) = (B_3 C_2 + B_2 C_3)/C_1, \quad (12)$$

$$(A_3 - A_1) = (B_1 C_3 - B_3 C_1)/C_2, \quad (13)$$

$$(A_2 - A_3) = -(B_2 C_1 + B_1 C_2)/C_3. \quad (14)$$

But, substituting Equation (11) into the sum of Equation (12) and Equation (13) will receive Equation (14). So we have in fact only four equations to reduce the number of independent parameters down to five.

For simplicity, one may leave A_3 , B_3 , C_3 , B_1 and B_2 independent and replaces A_1 , A_2 , C_1 and C_2 by

$$\begin{aligned} A_1 &= A_3 + B_2(B_1^2 - B_3^2)/B_1 B_3, \\ A_2 &= A_3 + B_3(B_1^2 - B_2^2)/B_1 B_2, \\ C_1 &= B_3 C_3/B_1, \quad C_2 = -B_3 C_3/B_2, \end{aligned} \quad (15)$$

and Equation (5) now becomes

$$M = \begin{pmatrix} A + xB(y - \frac{1}{y}) & yB + i\frac{C}{y} & xB - i\frac{C}{x} \\ yB - i\frac{C}{y} & A + B(\frac{y}{x} - \frac{x}{y}) & B + iC \\ xB + i\frac{C}{x} & B - iC & A \end{pmatrix}, \quad (16)$$

if one lets $A \equiv A_3$, $B \equiv B_3$, $C \equiv C_3$ and $x \equiv B_2/B_3$, $y \equiv B_1/B_3$.

Subsequently, the mass eigenvalues can be derived analytically as

$$M^{diag.} = \begin{pmatrix} A - B\frac{x}{y} - C\frac{\sqrt{x^2+y^2+x^2y^2}}{xy} & 0 & 0 \\ 0 & A - B\frac{x}{y} + C\frac{\sqrt{x^2+y^2+x^2y^2}}{xy} & 0 \\ 0 & 0 & A + B\frac{(x^2+1)y}{x} \end{pmatrix}, \quad (17)$$

with the U matrix given as

$$U^{(u)} = \begin{pmatrix} \frac{-\sqrt{x^2+y^2}}{\sqrt{2(x^2+y^2+x^2y^2)}} & \frac{x(y^2-i\sqrt{x^2+y^2+x^2y^2})}{\sqrt{2}\sqrt{x^2+y^2}\sqrt{x^2+y^2+x^2y^2}} & \frac{y(x^2+i\sqrt{x^2+y^2+x^2y^2})}{\sqrt{2}\sqrt{x^2+y^2}\sqrt{x^2+y^2+x^2y^2}} \\ \frac{-\sqrt{x^2+y^2}}{\sqrt{2(x^2+y^2+x^2y^2)}} & \frac{x(y^2+i\sqrt{x^2+y^2+x^2y^2})}{\sqrt{2}\sqrt{x^2+y^2}\sqrt{x^2+y^2+x^2y^2}} & \frac{y(x^2-i\sqrt{x^2+y^2+x^2y^2})}{\sqrt{2}\sqrt{x^2+y^2}\sqrt{x^2+y^2+x^2y^2}} \\ \frac{xy}{\sqrt{x^2+y^2+x^2y^2}} & \frac{y}{\sqrt{x^2+y^2+x^2y^2}} & \frac{x}{\sqrt{x^2+y^2+x^2y^2}} \end{pmatrix} \quad (18)$$

if we consider here the up-type quarks.

Surprisingly, all elements of this matrix are independent of A , B and C . They depend only on two parameters x and y . Similarly, the matrix $U^{(d)}$ for down-type quarks should have the same pattern and one may express it simply by replacing all parameters in $M^{(u)}$ and $U^{(u)}$ with primed ones A' , B' , C' , $x' \equiv B'_2/B'_3$ and $y' \equiv B'_1/B'_3$, respectively.

Though this pattern was achieved by dividing M into two real and imaginary components. However, any combinations of M_R and M_I like $(pM_R + qM_I)$ with p and q arbitrary numbers, even complex, can be assigned to M_1 or M_2 and still be diagonalized by the same U . Thus, any matrix pairs

$$M_1 = pM_R + qM_I \quad \text{and} \quad M_2 = rM_R + sM_I, \quad (19)$$

where p , q , r and s are arbitrary numbers, will also be diagonalized by the same U and free of tree-level FCNCs naturally. Besides, the derivation demonstrated above did not employ any symmetries like Z_2 in [3], S_3 in [16–18] or $(S_3 + S_2)$ in [19] except for the only assumption of hermiticity of quark mass matrices. Such a matrix pattern is a very general one. Even, it includes all previous NFC models as special cases in it.

For instance, in Type-I and -II models some of the M_i^q components are assigned zero by the Z_2 discrete symmetry. That can be achieved by letting either $A = B = 0$ or $C = 0$ for corresponding quark type. The S_3 pattern in Equation (1) can be achieved by letting $x = y = 1$ (firstly achieved in [16–18] or the case-1 in [19]). Those three patterns achieved in the $(S_3 + S_2)$ model correspond to $x = y = -1$ (case-2), $x = -y = 1$ (case-3) and $x = -y = -1$ (case-4), respectively. Even the Fritzsch ansatz [8, 9] and the aligned two-Higgs doublet model (ATHDM) are also included. One may achieve the Fritzsch ansatz simply by letting $A_1 = A_2 = B_2 = 0$. For ATHDM, that is the $p \cdot s = q \cdot r$ case in this model.

3. Conclusions and Discussions

The matrix pattern achieved in this article is a very general one since no symmetry is employed during the derivation. The only assumption employed is the hermiticity of quark mass matrices. Besides, it is derived analytically from an very fundamental theory of electro-weak interactions. Thus, it includes almost previous 2HDMs in it, except for the type-III models. That provides us with a very rational and general aspect to realize the nature of FCNCs and CP violation.

In this model all possible freedom in the Yukawa sector gets parameterized in terms of five parameters A , B , C , x and y for a quark type. But, corresponding unitary transformation matrix $U^{(u)}$ depends only on two of them. Assuming $U^{(d)}$ has similar FCNC-free pattern and assigning its corresponding parameters as x' and y' , the CKM matrix thus derived will depend on merely three of the four x , y , x' and y' parameters if one considers the unitarity of CKM matrix. That provides us with a new aspect to realize the explicit origin of CP violation.

Theoretically, of course, there could be other FCNC-free matrix pairs than those presented in this article. For instance, there could be matrix pairs which are not respectively Hermitian but still can be diagonalized simultaneously. Surely they will not satisfy Equation (7) and the number of free parameters in them will be many more than five for each fermion type.

Besides, the mass matrix M itself could be non-Hermitian, too. In that case, the number of free parameters surely will be many more than five. Both cases are far beyond our ability of analytical derivation for now.

Beyond the 2HDM scope of this article. It is interesting that these matrix patterns also apply to Standard Model and an even extended model with three Higgs doublets. The detailed study on them is now still underway.

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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Uniqueness and Reproducibility of Semantic Intelligence: New Approach to the Notion of Self-Organization

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Abstract

A novel notion of self-organization whose major property is that it brings about the execution of semantic intelligence as spontaneous physico-chemical processes in an unspecified ever-changing non-uniform environment is introduced. Its greatest advantage is that the covariance of causality encapsulated in any piece of semantic intelligence is provided with a great diversity of its individuality viewed as the properties of the current response and its reproducibility viewed as causality encapsulated in any of the homeostatic patterns. Alongside, the consistency of the functional metrics, which is always Euclidean, with any metrics of the space-time renders the proposed notion of self-organization ubiquitously available.

Keywords

Self-Organization, Concept of Boundedness, Point-Like Approach to Response, Semantic Intelligence, Algorithmic Intelligence, Metrics

1. Introduction

So far the dominant concept of the interdisciplinary science is that the hierarchy of complexity of natural systems develops as decentralized form of self-organization which is going bottom up. This short statement implies that since each and every complex system is comprised by atoms and molecules, its emergent behavior can be derived as a decentralized self-organization of constituting atoms and molecules subject to simple rules. Despite the promising results about the development of pattern formation and swarm intelligence, this idea suffers serious weakness in a number of key points and needs serious modification. Thus, the grounding idea of swarm intelligence, namely the emergence of collective beha-

behavior out of decentralized simple rules, is inherently contradictory since a successful self-organization involves a rule called *cohesion* whose implementation needs permanently information about the current center of mass of the corresponding system. This, however, implies that the rule *cohesion* is not a simple dynamical rule but it is also an emergent on higher levels of complexity rule typical for a rather mindful behavior. The inherent contradiction of pattern formation scenario will be considered in Section 3.

Another weak point of the above idea is that the emergent from simple rules behavior cannot explain the autonomous way in which the natural semantics is accomplished. This is a result of the fact that emergent behavior commencing from the traditional setting of self-organization is accomplished as a short transit to a steady asymptotic. Thus, neither form of intelligence can proceed autonomously in the frame of such view on self-organization.

There are other weak points of the above idea of self-organization some of which will be discussed later in the paper and more of them can be found in the author's recent book [1]. The major conclusion drawn from those weaknesses is that the idea of self-organization needs fundamental revision. I find that the problem so serious that its resolution requires a fundamentally novel view on it. The revision started with the introduction of the idea that there exists general operational protocol supervising dynamical behavior of stable natural systems which I called boundedness. Putting in a nutshell, it means that a stable system develops so that both amplitudes and rates of exchange of matter, energy and information with its environment are kept permanently bounded within specific to its margins. A systematic development of that idea is presented in [1]. The theory successfully resolves the major difficulties which the behavior of complex systems challenges the present day interdisciplinary science. However, the major advantage of that theory is the substantiation of a new type of intelligence, called by me semantic intelligence, whose major property is autonomous creation and comprehension of information in an ever-changing non-uniform environment. The new type of intelligence is viewed as an emergent dynamical phenomenon where the autonomy of semantics is implemented by means of spontaneous motion among different steady patterns each of which stands for a semantic unit. The novel, and to the much extent surprising, grounds for the existence of steady spatio-temporal patterns in a non-uniform ever-changing environment is the central for the entire theory of boundedness proof of the called by me decomposition theorem. The latter asserts that for each and every bounded irregular sequence (BIS) there exists presentation basis (which turns to be power spectrum) where the spectrum additively decomposes into two parts: a specific steady spatio-temporal pattern, called homeostasis, and a universal "noise" component so that both the details of the pattern and the shape of the noise component are robust to details of the statistics of the BIS.

There are several major outcomes of the decomposition theorem:

- 1) The first one is that this decomposition makes possible to distinguish the causal relations encapsulated in the homeostatic patterns from the non-causal

ones encapsulated in the noise term. Thus, the response viewed as a bounded irregular sequence of current response is unique while its decomposition in the corresponding power spectrum provides the reproducibility of the corresponding semantics viewed as a system of steady causal relations encapsulated in the corresponding homeostatic pattern.

2) Since each and every homeostatic pattern is an extended in space and time object, it poses the question about the character of the dynamical rules that produce that behavior.

The importance of the latter problem stems from the controversy with another basic idea of the traditional science: that of point-like approach to response. In a nutshell, the latter implies that in equilibrium, the response of a system or any of its sub-unit to a uniform steady environment is applied to a single spatial point called center of mass and remains the same forever if not other forces are applied. Thus, the formation of a response is set up by a single spatio-temporal point. This requirement commences from the mechanical view that a system in equilibrium does not rotate. The steady in the time behavior commences from the Newton's third law. The above considerations make clear where the name point-like response comes for.

These basic mechanical views are extended to systems of different nature and different levels of complexity through generalizing the idea of mechanical equilibrium to the idea of thermodynamic equilibrium viewed as a general Law of Nature. This idea consists of assertion that to be in thermodynamic equilibrium, the response of each and every system to any environmental impact proceeds as the development of the corresponding spontaneous fluctuation. Further, it is taken for granted that the process of development of any fluctuation in the course of time is irrelevant, because it is taken for granted that the thermodynamic equilibrium is a global attractor for all initial states. In turn, this suggests that any deviation from the thermodynamic equilibrium is due to damp out in a finite time in a spontaneous way. This assumption serves as grounds for adoption the idea that all fluctuations (and accordingly the responses to environmental impacts) can be presented as instantaneous independent events subject to probability distribution and so they become subjects of the Central Limit Theorem. As a result, this generalization culminates in the validation of the Central Limit Theorem as the most widespread tool for studying spatio-temporal phenomena of different origin.

Little or no attention has been paid to the fact that this generalization holds only for steady uniform environment. It is also taken for granted that: 1) all fluctuations damp out spontaneously and irrespectively to their amplitude; 2) no constraints on the amplitude of fluctuations (and correspondingly to the environmental impact) are imposed.

The major and non-overwhelming difficulty of that generalization is the fact that the subject of the Central Limit Theorem is generically irreconcilable with any form of intelligence, since the latter always is viewed as a sequence of de-

pendent from one another event while the Central Limit Theorem holds only for independent events.

Now it becomes evident that the decomposition theorem is more adequate frame for any form of intelligence. On the other hand, however, it's subject is completely different from the subject of the Central Limit Theorem. Indeed, while the subject of the decomposition theorem are bounded irregular variables (yet not independent), the subject of the Central Limit are independent variables (yet not bounded). It should be stressed on the fact that the subjects of both theorems have not cross-section because any form of permanent boundedness implies long-term correlations.

Outlining, the decomposition theorem sets the general frame for substantiation of the long-term correlations among semantic units. Now we face the major problem how to modify the idea about the point-like approach to response and the idea of self-organization so that to match physically the proceeding of semantic intelligence in the autonomous way. It will be demonstrated that an appropriate modification of certain basic notions and ideas of physics and certain modification of the idea of self-organization, provides the targeted physical implementation of the semantic intelligence. It will be seen that this issue is crucially related to the problem about uniqueness and reproducibility of the semantic intelligence.

2. Point-Like Approach to Response: Critical Overview

The goal of the present section is to provide a critical analysis of all pro and cons of one of the grounding ideas of the nowadays interdisciplinary science, namely the idea of point-like approach to response. In a nutshell the notion of point-like approach to response has two-fold meaning:

1) To be in a mechanical equilibrium it is necessary that each and every single object does not rotate. This is possible if only all mechanical forces are applied in a single point called center of mass and all forces acts at the same time. The next important point is that the location of the center of mass does not change its position within the corresponding object. The greatest advantage of that idea is that it provides time translational invariance of the physical laws that governs the dynamics of any object as well as its spatial covariance, *i.e.* the independence of those laws from the reference frame chosen for description of the corresponding motion.

2) To be in thermodynamic equilibrium, it is supposed that the response to any environmental impact matches the development of the corresponding spontaneous fluctuation. This is the assertion of the so call fluctuation-dissipation theorem. Since the notion of thermodynamic equilibrium implies that it is a global attractor for all initial conditions, it is taken for granted that the development of any fluctuation in the course of time and in space is irrelevant because the fluctuations are supposed to develop coherently throughout a system. This assumption serves as grounds for adoption the idea that all fluctuations (and accordingly the

responses to environmental impacts) can be presented as instantaneous independent events subject to a probability distribution and so they become subjects of the Central Limit Theorem. It is worth noting that what is tacitly implied about these assumptions is that the environment is supposed uniform and steady; fluctuations damp out spontaneously and irrespectively to their amplitude; no constraints on the amplitude of fluctuations (and correspondingly to the environmental impact) are imposed.

The idea of mechanical equilibrium is developed further into the idea that the environment of any object provides a specific time-independent Hamiltonian which turns out to be the bearer of identity of the corresponding object. The admissible states of the object are defined by means of imposing specific initial and boundary conditions to the dynamical rule which comprises the corresponding Hamiltonian. This setting commences from the idea that there exists presentation basis such that all dynamical interactions are considerable as isolated from one another events. In turn the latter renders spatial and temporal dimension of any isolated interaction irrelevant for the outcome of its processing, hence the name of point-like approach to response.

Further, to this general protocol, the assumption that steady motion is available only on those trajectories where the action is stationary is added. Thus, the latter idea selects that single trajectory which provides stationarity of the corresponding action. It should be stressed that so far the stationarity of the action is always derived from the constraint of some extermination such as being the shortest path, being the trajectory where the energy losses are minimal, the trajectory where the entropy is maximal and so on. A persistently overlooking fact is that this renders the succession of states which a trajectory, subject to stationary action, passes through mutually dependent.

However the latter result is apparently incompatible with the Central Limit Theorem. Indeed, the latter is grounded on the fluctuation-dissipation theorem viewed as assertion that the fluctuations and correspondingly all responses are independent from one another events and thus each of them can precede and/or succeed any other one. Put it in more formal terms it asserts that any succession of fluctuations/responses forms a Markov process. To remind that indeed the notion of a Markov process implies that a succession of jumps has memory of bounded radius. Thus, all events, or blobs of events, are to be considered as independent from one another events and thus each and every Markov process is subject to the Central Limit Theorem. The idea of Markovianity implies that all trajectories are admissible which, however, is incompatible with the idea about stationarity of the action viewed as the general protocol which selects the sub-set of admissible trajectories from the set of all available. So far the dominant concept is that of the Markovianity. It, however, is not able to substantiate any form of semantic and/or algorithmic intelligence, because the fundamental difference between any piece of semantics and/or algorithm on the one hand, and a random sequence on the other hand, implies inter-dependence among the succession of the constituting events in the former case and its lack in the case of ran-

dom sequences.

The greatest value of the point-like approach is that it provides time-translational invariance of the laws of Nature and their independence from the reference frame chosen for their description. However, the revealed in the Introduction and in the present section inherent contradictions and incapability for explaining the uniqueness and reproducibility of any semantics, viewed as a specific sequence of mutually dependent events, call for necessity of a fundamental revision. A successful revision should provide not only the time-translational invariance of the laws of Nature and their independence from a reference frame, but altogether it should provide a consistent with them explanation of the uniqueness and reproducibility of semantics.

3. Self-Organization: Critical Analysis in a Nutshell

Formal definition of semantic intelligence as well as its major properties is provided in Chapter 10 of [1]. There the semantic intelligence is viewed as a new form of intelligence whose major property is autonomous creation and comprehension of information. The latter property provides the demarcation line with the algorithmic intelligence which serves as ground for all types of modern-day computers and artificial intelligence. The major property of algorithmic intelligence is that its execution is possible only in artificially designed and artificially maintained environment. The main reason why the algorithmic intelligence cannot be executed by spontaneous processes in the frame of the point-like approach to response is that the very idea of execution of any form of intelligence is incompatible with the idea of thermodynamic equilibrium viewed as global attractor for all initial conditions. Consequently, whatever the initial state is, after a short transit, each and every closed system approaches it and stays there forever if no other forces applied. However, the notion of intelligence is grounded on the suggestion that logically different states are associated with physically different states and any algorithm is executed as a specific sequence of “jumps” among these states. This consideration poses the major question whether it is possible to execute a given form of intelligence by means of spontaneously executed physico-chemical processes.

Since the second half of 20-th century most promises for resolving this problem have been put on the idea that emergent macroscopic properties spontaneously commence from simple dynamics and/or from spontaneous pattern formation out of simple reaction-diffusion systems. However, the most fundamental inherent contradiction of that idea is that, on the one hand, the emergent behavior and emergent patterns are asymptotically stable and thus they are generically consistent with the idea of thermodynamic equilibrium and on the other hand, they exist only in specific narrow range of control parameters which parametrize the impact of a well-defined steady uniform environment.

Most hopes have been put on the idea that different emergent patterns can be designed so that to operate simultaneously and coherently. However, this idea

faces both technical and fundamental difficulties. The technical difficulties commence from the fact that different patterns emerge at fine-tuning to different ranges of values of the control parameters which, however, makes most unlikely their simultaneous emergence and simultaneous maintenance. Along with this technical difficulty, another, more crucial one challenges this scenario. It consists of the fact that neither form of intelligence would be adaptable to environmental changes in this framework because the performance of any piece of intelligence would repeat exactly the same. Put the latter in other words, the response of any such system would look more like to a physical law viewed in its traditional setting than to any form of intelligence whose major property is highly non-trivial interplay between uniqueness of any piece of semantics along with its reproducibility viewed as self-sustaining intact the specific causal relations encapsulated in it.

Another non-overwhelming difficulty consists of the fact that any form of self-organization through fine tuning is extremely vulnerable to the tiniest perturbations of the environment.

Outlining, the above considered issues render the idea about appropriate modification of the notion of self-organization so that to make possible the execution of a semantic-like response as a stable spontaneous physical process an ultimate goal.

4. General Operational Protocol for Execution of Semantic Intelligence by Means of Spontaneous Processes

One of the major requirements to any form of spontaneously executed intelligence is its stable operation in the course of time and in any environment. That is why I put this requirement in the following setting: namely the setting of un-specified non-uniform ever-changing environment subject to the mild constraint of boundedness alone. The major pay-off of the latter will be that the boundedness of rates and amplitudes alone turns sufficient to provide the substantiation of the decomposition theorem whose exclusive property is to provide grounds for the implementation of semantic intelligence by means of spontaneously executed physico-chemical processes. Thus, the major goal of the present section is to provide delineation of the grounds for the general operational protocol aimed towards sustaining of boundedness of rates and amplitudes, introduced in [1], from the grounds of the point-like approach to response.

Since, as proven by the decomposition theorem, the permanent sustaining of boundedness of rates and amplitudes is sufficient to provide long-term stability of any complex system, let me start with the question how to characterize stability of a system of coexisting homeostatic patterns put in a non-uniform ever-changing environment. It is obvious that no global parameter (e.g. intensity of the impact) is available since different patterns (and their sub-units as well) are put in different local environment; thus, even identical entities respond dif-

ferently being located at distant spatio-temporal points. This property is generic for all heterogeneous systems and it holds true even for an initially uniform system.

My assertion is that the stability of any system put in a non-uniform ever-changing environment holds true if and only if the interplay of the interactions that proceed in it is able to sustain Euclidean metrics among the distinctive functional properties of all entities and on each and every hierarchical level. Crucial for the substantiation of this assumption is the view on Euclidean metrics as single-size Voronoi tessellation. The latter tacitly presupposes existence of bounded both from below and above ranges of admissible deviations from any given homeostatic pattern so that the pattern properties to stay intact. The bounds of any such range are derived from the requirement that homeostatic patterns on lower hierarchical levels appears as “fine structure” to the higher levels ones. This requirement commences from the necessary condition for sustaining long-term stability of a system: that is the necessity for substantiating a ban over resonances among different patterns. Alongside, keeping an appropriate “distance” from one another renders patterns that come from different hierarchical levels well defined in a long run.

The necessity of keeping both local and global functional metrics Euclidean suggests the idea that the latter is plausible only if the interactions in each and every system are constrained so that to vary within specific margins. The major pay-off is that thus the constraint of boundedness provides holding of the decomposition theorem. Next I will demonstrate that the general operational protocol, introduced in [1], which supervises dynamic processes so that locally accumulated extra energy and matter to dissipate throughout a system serves as grounds for physical implementation of the boundedness of rates and amplitudes. It will be demonstrated also that this protocol operates steadily only when the extra matter and extra energy in every locality does not exceed specific margins imposed so that to provide that corresponding deviations of the local functional metrics stays within the range of the admissible ones.

I start the justification of this idea with the consideration how the notion of a Hamiltonian is to be modified so that to retain the property of being the bearer of identity of the corresponding species in an ever-changing non-specified and non-uniform environment. It is obvious that neither the Hamiltonian nor initial and boundary conditions are steady because the neighborhood of any species which forms it permanently varies put in an ever-changing non-uniform environment. This prompts suggestion that any Hamiltonian and the corresponding initial and boundary conditions vary according to the changes in its neighborhood. Yet, in order to sustain its identity, the variations of the shape of that Hamiltonian must be bounded to be within a specific “strip” “wrapped” around a time-independent steady “skeleton”. Initial and boundary conditions are also bounded in specific strips each of which is to be associated with a given state of the time-independent skeleton. Further, in order to sustain the identity of the

corresponding Hamiltonian, the strips around different states should not overlap. This, however, immediately implies that the changes in initial and boundary conditions and the changes of the corresponding Hamiltonian are correlated. This in turn renders that the changes in the position, momentum, energy and the duration of any transition are also vary bounded within specific margins. In turn, the changes in the current shape of a Hamiltonian and corresponding initial and boundary conditions trigger transitions and so the corresponding species is never in rest. Since this restlessness is generic for any non-steady Hamiltonian, these transitions serve as grounds for implementation of spontaneous processes.

It should be stressed on the high non-triviality of the above assumption. Jumping ahead, the subordination of those variations to the general operational protocol which provides the boundedness of rates and amplitudes renders formation of steady homeostatic patterns of the transitions so that those patterns to appear as emergent ones to the corresponding Hamiltonian's "skeleton"; for example, it includes appearance of extra lines, forbidding certain transitions etc., phenomena well established in condensed matter spectroscopy. Another exclusive property is that it opens the door for a variety of synergetic and antagonistic phenomena whose generic properties is that they are not proportional to the intensity of the corresponding impact.

Before considering the ingredients of the general operational protocol for sustaining boundedness of rates and amplitudes let me remind how the boundedness of rates substantiates the idea for "coordination" of the spontaneous processes which take place at different spatio-temporal points so that to produce long-range correlations among them.

As it has been already established, in order to sustain the identity of species, the changes of all characteristics of any non-steady Hamiltonian due to spontaneous transition must be bounded so that to stay within specific margins. Thus, in order to keep this boundedness permanent, there must be specific constraint imposed on successive transitions. It is worth noting that the constraint imposed on successive transitions substantiates the notion of boundedness of rates. As suggested in Chapter 7 of [1] boundedness of rates is implemented by the stationarity of the corresponding action. A very important property of the proposed stationarity of the action is that it is not associated with any form of extremization and/or optimization. On the contrary, its exclusive property is that it selects those paths where the sequence of transitions does not violate the boundedness of rates. And since, there is no optimization imposed, these paths are generically more than one.

Outlining, two conclusions are of major importance: 1) the first one is that the paths selected by the stationarity of the action provide long-term stable correlations among the transitions which occur on any of those paths. In turn, semantic intelligence can be substantiated in a stable and reproducible way only on those paths; 2) being more than one, the existence of different paths substantiates di-

versity of semantics.

Let us now remind in details how long-term correlations among events happening at distant spatio-temporal appear due to the boundedness of rates and amplitudes. The importance of that issue arises from the fact that their substantiation justifies the basic premise of the decomposition theorem, namely the premise that the latter is available for bounded, and thus long-term correlated, events. The consideration goes as delineation with the point-like approach to response whose major premise substantiates independence of successive events from one another and thus provides grounds for the availability of the Central Limit Theorem.

I start this consideration with the reminder that the point-like approach to response implies that the latter depends on the current impact and the current state of a system only irrespectively to the previous and future states. To remind that the point-like response gathers its name after the assumption that space and time dimension of the development of any response and/or fluctuation is irrelevant. On the contrary, according to the concept of boundedness, any current response depends explicitly on the current impact and current state but it also implicitly depends on the whole chain of previous states because the realization of any given transition depends on whether the entire chain of all previous ones have been selected from the corresponding subsets of the admissible transitions where the subsets of admissible transitions are selected by the boundedness of rates from the set of all possible ones. In turn, the boundedness of rates produces correlations and inter-dependences among successive events whose generic property is that their memory radius is infinite. In turn, the latter substantiates the fundamental difference with the Markov processes whose hallmark is that the memory radius is always finite. It is worth noting that this difference mathematically substantiates the delineation of the subject of the decomposition theorem (infinite memory radius; hence bounded variables) from the subject of the Central Limit Theorem (finite memory radius; hence independent variables) so that there is no cross-section of both subjects. It is worth reminding that one of the far-going consequences of that delineation is that any form of intelligence is compatible only with the decomposition theorem while the Central Limit Theorem is incapable to provide difference between any sequences of random events from any one which brings any information.

It is worth noting that the replacement of the idea about Markov property of successive responses with the idea of stationarity of the action viewed as an implement for providing boundedness of rates in a long run is free from one of the major controversies of the point-like approach to response discussed in section 2. In turn, its farthest going consequence is that this release renders the grounds for shifting from Central Limit Theorem to the decomposition theorem and thus provides grounds for substantiation for execution of semantic intelligence by means of spontaneous processes.

Further, the stationarity of the action is sustained by a highly non-trivial in-

terplay among transitions executed on different hierarchical levels because they operate both simultaneously and in sequence but each of them is subject to the constraint of stationarity of the action. In turn, the latter interplay verifies the idea proposed in [1] that the hierarchy of a semantic response is bidirectional, *i.e.* it operates not only bottom up but top down as well.

It should be stressed that since the stationarity of action is derived from the boundedness of rates, it is obvious that on each and every admissible trajectory it could vary within specific margins set up by it. The stationarity of the action is spontaneously maintained by means of the considered next general protocol which provides that any local accumulation of extra matter and extra energy, which does not exceed specific margins, dissipates throughout the system irrespectively to the chemical nature of the species and their physical properties. In turn, the admissible trajectories associated with each stationary action turns out to be also bounded in a strip “wrapped” around stationary “skeleton”. In turn, the fact that the admissible trajectories associated with each and every stationary action are generically more than one enormously expands the range for substantiation of the uniqueness of the semantic response and its diversity.

Outlining, the above suggested idea that the stability of response is substantiated only on paths selected by the permanently imposed constraint of stationarity of the action constitutes the replacement of the controversial notion of point-like approach to response with the idea that in an ever-changing non-uniform environment, the spontaneous processes are executed in a stable way if and only if all changes are kept permanently bounded along the admissible trajectories. In turn, this renders holding of the decomposition theorem which as already has been mentioned provides existence of stable homeostatic patterns.

The next point is to demonstrate that the boundedness of rates and amplitudes and the motion on selected by stationarity of the action trajectories is maintained by means of the existence of a general operational protocol which supervises spontaneously executed dissipation of extra energy and matter accumulated in any given location. It is implemented by putting forward a new general frame for the interactions and wave emission. These frames are introduced in [1] are turns to be ubiquitous because they are insensitive to the chemical nature of the corresponding units and their physical properties and they are insensitive to the details of the simple rules that govern the behavior of those units as well.

Let me start with the ground with the new frame for interactions. I put forward the notion that the interactions are generically non-isolated events and thus their spatial and temporal dimension becomes of key importance. An example of that new notion are the introduced by me in Chapter 3 of [1] non-unitary interactions. They commence as a result of involvement of an extra species in the process of an initially unitary interaction. Since the moment of arrival of the extra species is un-specified, the outcome of the corresponding interaction is different for different moments. It is worth reminding that namely the

idea that dynamical interactions are isolated from one another serves as grounds for the point-like approach. Its major characteristic is the insignificance of the temporal and the spatial dimension of any isolated interaction for the outcome of its proceeding. I replace the notion about isolation of the dynamical interactions with the notion that dynamical interactions are generically non-isolated. The fundamental difference which this replacement brings about is that temporal and spatial dimension of any interaction become relevant for the outcome because the characteristics of the latter explicitly depend on the moment of intervention of extra species. In turn the cross-section of that interaction becomes a multi-valued function each selection of which corresponds to a given moment of extra-species intervention.

The key implement which provides spontaneous dissipation of any locally accumulated extra-energy is the proposed by me in Chapter 3 of [1] feedback between any non-unitary interaction and appropriate collective modes (*i.e.* acoustic phonons). Its major property is insensitivity to the chemical nature of the participating species and their physical properties which in turn makes the feedback ubiquitously available for systems of different nature and for every environment. The ubiquity of that feedback is constrained only by the necessity of subordinating its stable operation to the admissible deviations from local functional metrics because the collective modes are well-defined only if the corresponding local deviations from the metrics do not exceed specific margins dictated by the admissible deviations from the metrics. To remind the admissible deviations from the metrics are those which do not compromise the Euclidean metrics viewed as single size Voronoi tessellation. In turn, this provides the operational margins for the feedback between the non-unitary interactions and the collective modes.

The next new general frame considers a new type of waves emitted so that to provide the dissipation of any local accumulation of extra matter. These new waves commence as a new type of solution of non-linear non-autonomous partial differential equations and are mathematically derived by me in Chapter 7 of [1]. The general premises of that derivation are as follows: any local accumulation of extra matter causes a local disturbance of the flow which passes through that spatio-temporal point. The crucial novelty is that this disturbance is parametrized as deviation from the local metrics. This notion is suggested by the very important property of the feedback between the non-unitary interactions and the collective modes which consists of sustaining constant relative velocity among species irrespectively to the chemical nature and the physical properties of participating species [2]. In turn the latter provides a flow to be permanently laminar and sustains the notion of concentration well defined. This consideration justifies the association of any local disturbance of matter balance with a specific local deviation of the diffusion coefficient. In turn, the generic dependence of the diffusion coefficient on deviations of the local concentration provides a new type of solution of the governing reaction—diffusion equation which turns out to be the emission of a matter wave so that its direction is determined

by the properties of the corresponding gradient of the diffusion coefficient.

It is important to stress on the relation between the conditions for the matter wave emitting and the corresponding metrics. This relation confines the matter wave emitting to be available only when the corresponding deviations from the local metrics belong to the admissible deviations from the corresponding functional metrics. To remind that the feedback between non-unitary interactions and collective modes which provides dissipation of any locally accumulated extra-energy is also constrained by the margins of the admissible deviations from the functional metrics.

Outlining, the operational margins of the general protocol for spontaneous dissipation of locally accumulated extra-energy and extra-matter are explicitly related to the admissible deviations from the corresponding functional metrics. In turn, this implements an explicit relation of the notion of boundedness of rates and amplitudes with the long-term stability of the corresponding system.

Summarizing, I replace the notion of point-like approach to response with the notion about existence of general operational protocol which supervises dynamics so that to sustain permanently boundedness of rates and amplitudes by means of spontaneously executed dissipation of extra-matter and extra-energy in any given locality. The ubiquity of this protocol is controlled by the general condition for subordination of the extra-energy and extra-matter amount to match the admissible deviations from the local functional metrics. Further, the substantiation of that protocol is grounded on the notion about non-isolated interactions and matter wave emitting where the latter is viewed as a new type of solution of non-linear non-autonomous partial differential equations. These novel notions render the spatial and temporal dimension of any initially unitary interaction of key importance which culminates in the exclusive property of the corresponding cross-section to become a multi-valued function. As a result, the response of any complex system is executed as spontaneous non-stop jumps between successive homeostatic patterns. This result is fundamentally different from the notion of thermodynamic equilibrium viewed as a global attractor for all initial conditions which notion is central for the point-like approach to response. Put it in other words, I replace the notion of thermodynamic equilibrium viewed as a global attractor with the notion of stability implemented by a general operational protocol for providing boundedness of rates and amplitudes through spontaneous dissipation of locally accumulated extra-matter and extra energy if only the latter is bounded within specific margins set by the admissible deviations from local functional metrics.

5. Implementation of Causal Relations: New Approach to the Notion of Self-Organization

The major idea put forward in the previous section is that there exists general operational protocol which supervises the interactions so that make possible keeping permanent boundedness of rates and amplitudes on selected trajectories

where the action is stationary. In turn, the sustaining of boundedness of rates and amplitudes onto certain trajectories provides holding of the decomposition theorem which in turn provides existence of specific steady homeostatic patterns for each and every location where these trajectories pass through. The major property of any of these patterns is that its properties do not exactly match the properties of the corresponding structure. In turn, the lack of one-to-one correspondence between the properties of, for example, the corresponding Hamiltonian's "skeleton" and the emergent functional properties could give rise to, appearance of extra lines, could forbid certain transitions etc., phenomena well established in condensed matter spectroscopy. Another exclusive property is that it opens the door for a variety of synergetic and antagonistic phenomena whose generic properties is that they are not proportional to the intensity of the corresponding impact.

Other generic property of the homeostatic patterns is that they may be different on different trajectories. This property is exclusive for the setting of boundedness and has no analog at the current science where the requirement about optimization selects a single match between structural and functional properties.

Further, the boundedness of action, viewed as implement for permanent sustaining of the boundedness of rates, also renders existence of specific homeostatic patterns associated with each trajectory. In turn this provides "fine structure" of the diversity of semantics. Thus, the existence of a "fine structure" specific for each trajectory, enormously increase the range of diversity of semantics by means of setting up the grounds for "hierarchy" of that diversity. Alongside, it enormously expands the range for substantiation of the uniqueness of the semantic response.

Thus, the ubiquitous existence of homeostatic patterns whose major property is insensitivity to the details of environmental fluctuations opens the door to a new form of causality viewed as emergent steady functionality. Thus, in [1] I have introduced the notion of the meaning of a semantic unit as the performance of a non-mechanical engine built on the corresponding trajectory for the purpose to make the corresponding causality irreducible to the set of the binary relations among the constituents and to view it as an emergent property. This comes on the contrary to the traditional algorithmic theory where causality is viewed as reducible to steady binary relations among successive states of hardware only. The major weak point of the current view is two-fold: 1) the reduction of causality to binary relations implies lack of continuity in causality which in turn renders truly causal relations indistinguishable from a random sequence; 2) being steady relations until an external intervention takes place, there is no route for spontaneous execution of any sequence of causal relations.

The greatest advantage of the withdrawal from the reducibility of causality to steady binary correlations is provided by the exclusive property of even the simplest form of causality viewed as emergent steady pattern that is to be covariant with respect to time-translational invariance and independent from the refer-

ence frame chosen for its description. This is an exclusive property provided by the decomposition theorem according to which, any homeostatic pattern viewed as a piece of causality, is additively superimposed onto a noise component so that both the shape of the latter and structure of the former turn out insensitive to the details of the current environment. Consequently, the homeostatic pattern is insensitive to positions on the arrow of time of both the initial and the final moments of its execution. The same insensitivity holds for the specific location of any homeostatic pattern in the space. In turn, the insensitivity of the properties of any homeostatic pattern to its current spatio-temporal position justifies the covariance of the causality encapsulated in each and every homeostatic pattern.

Thus, the decomposition theorem enormously expands the grounds for time translational invariance of causality and its independence from the reference frame rendering them available for complex systems put in a non-uniform ever-changing environment. To compare, the point-like approach to response provide these properties for steady uniform environment only.

It is worth noting that the above established covariance of causality is an exclusive property of the self-organized functionality only. A crucially important consequence consists of the fact that the latter allows it's commence from structures of different spatio-temporal metrics. Note however, that while the spatio-temporal metrics could be any (Euclidean, Riemann etc.), the metrics of any stable functional organization is always Euclidean. In turn, this once again justifies the idea proposed in [1] that the functionality is an emergent phenomenon which commences from highly non-trivial specific interplay among many different interactions supervised by the above discussed general operational protocol for sustaining boundedness.

The fact that the functionality signifies an emergent phenomenon makes possible to put forward a novel prospective on self-organization: it is substantiated by means of spontaneous motion among a hierarchy of steady homeostatic patterns. The ultimate goal of this motion is to "adjust" the response of a system, viewed as specific self-organized functionality, so that to provide its long-term stability in an ever-changing non-uniform environment.

There are three exclusive properties of thus modified notion of self-organization:

- 1) The emergent behavior is characterized by the fact that, although the properties of any homeostatic pattern are derived from the structure, the generic lack of optimization renders no single match and no one-to-one correspondence between structure and functionality. Put it in other words, the functionality is "emergent" with respect to the structure. In turn, this justifies the view put forward in [1] statement that the most effective semantics must not to be associated every time with the fastest computers and/or those ones whose maintenance requires least losses.

- 2) A great advantage of this type of self-organization is that it operates steadily at any concrete specification of ever-changing non-uniform environment let

alone the latter is bounded. Thus, semantics is not constrained to the narrow range of appropriate values of the corresponding control parameters selected by the process of fine-tuning as the present-day views on it prescribe.

3) The hierarchy of response is bi-directional which means that it goes both bottom up and top down. Its exclusive property is that both directions are entangled in a highly non-trivial interplay because their simultaneous operation makes them supervise each other.

6. Conclusions

The major goal of the present paper is to consider an adequate modification of the current idea of self-organization so that to put grounds for execution of certain new form of intelligence through spontaneous physico-chemical processes. It has been demonstrated that this idea challenges the very fundament of the current interdisciplinary science. A systematic overcoming of those difficulties is achieved in the setting of the recently proposed by the author concept of boundedness [1].

The focus in the present paper is to establish the physical grounds for a novel concept of self-organization. It is demonstrated that: 1) the basics of the point-like approach to response, widely adopted in the current science, are inherently contradictory and are unable to provide spontaneous execution of any form of intelligence; 2) it is demonstrated that there exists general operational protocol supervising the dynamical behavior of any complex system which turns sufficient to provide the execution of semantic intelligence by means of spontaneous physico-chemical processes in an unspecified ever-changing non-uniform environment let alone the latter is bounded.

The greatest advantage of the novel notion of self-organization is the covariance of causality encapsulated in any piece of semantics because it is provided with a great diversity of individuality viewed as the properties of the current response and reproducibility viewed as causality encapsulated in any of the homeostatic patterns which the current non-mechanical engine is built on. Alongside, the consistency of the functional metrics, which is always Euclidean, with any metrics of the space-time renders the proposed in the present paper notion of self-organization ubiquitously available. It is now available for systems ranging from nano-objects, living organisms to cosmological ones.

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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Intra-Atomic Gravitational Shielding (Lensing), Nuclear Forces and Radioactivity

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Abstract

The discovery by the author of real magnetic charges and true anti-electrons in the atomic structures allowed him to establish that the gravitational field (GF) in reality is the vortex electromagnetic field. Depending on the vector conditions the gravitational fields can be either paragravitational (PGF) or ferrogravitational (FGF). Masses (atoms, nucleons, etc.) emitting PGF manifest so-called attraction to each other. In fact, this process is the pressing of atoms or nucleons to each other by the forces of gravitational “Dark energy”. Namely the gravitational “Dark energy” which is formed between the masses emitting PGF and compressing of nucleons in atomic nuclei is the main factor determining the formation of nuclear forces. Masses that emit FGF are repelled from PGF sources, for example, from the Earth. The last gravitational manifestation, discovered by the author, this is of the effect of the gravitational levitation. The atomic shell and atomic nucleus are autonomous sources of gravitational field in atomic compositions. The gravitational fields emitted these sources, by its physical parameters, are different gravitational fields, what associated with differences in the magnitudes charges of magnetic and electric particles in their compositions. The noted differences in the parameters of the GF are of reason that in atoms the process of extrusion of foreign gravitational field from the region of given gravitational source is realized. This effect should be called the effect of intra-atomic gravitational shielding (IAGS). Within the framework of this effect the shell of the atom is a kind of gravitational “insulator” that prevents the PGF of the nucleons from leaving beyond of the atom. As result of the IAGS effect, the concentration PGF of nucleons is realized only in the region of the nucleus, which leads to an increase in nuclear forces. However, the resistance of the marked “insulator” is finite and if the critical voltage PGF on the nucleus is exceeded, the complete shielding of the nucleon fields by the atomic shell is broken. As

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result of the leakage of a part of the PGF of nucleons beyond the atom, the density of this field in the region of the nucleus decreases significantly, which leads to a weakening of the nuclear forces and often leads to radioactivity. The effect of gravitational shielding is directly related to such a well-known concept as the mass defect of the nucleus. It is the exclusion of the gravitational field formed by the nucleons in the composition of the atomic nucleus as a result of the full IAGS effect that creates the illusion of atomic mass defect.

Keywords

Magnetic Charges, Antielectrons, Magnetons, Antimagnetons, Bispinors, Physical Mass, Negative Masses, Vortex Electromagnetic (Gravitational) Field, Paragravitation and Ferrogravitation, “Dark Energy”, Gravitational Shielding (Lensing), Defect of Mass, Nuclear Forces

1. Introduction in Real Physics of Magnetic and Electric Charges, Gravitational Field and “Dark Energy”

Experimental and theoretical studies of the author (the period from 1968 to the present time) have shown that magnetic spinor particles (magnetic charges) are real structural components of atoms and substance and are the direct sources of all magnetic fields in Nature [1] [2]. It should note that initial experiments which prompted the author to studies’ problem of participation magnetic charges in the structures of atoms and substance were his experiments with magnetic scattering of neutrons in the ferrimagnetic crystals [3]. In addition, the author’s research has allowed establishing that in atoms and substance as the structural components “work” and such of real Antimatter particles as true anti-electrons with charge e^+ . These last particles are neither positrons nor Dirac’s “holes”. The real particles, noted above, for more than hundred years are not recognized by official physical science. The introduction of these particles into the basic physical concepts significantly changes the interpretation of a huge number of physical effects, and also allows us to discover new physical manifestations and patterns.

1.1. Magnetic and Electrical Charges in Structures of Atomic and Nucleonic Shells

The results of the author’s research showed that the shells of atoms are electromagnetic, and not electronic as commonly believed. Magnetic and electric charges forming atomic shells exist in the compositions of corresponding dipoles circulating on atomic orbits. The number of magnetic charges in the compositions of shells is approximately equal to the number of electric charges. The values of charges of the spinor particles in atomic shells correspond to the condition $e = g$, where g is the charge of magnetic particle. Magnetic dipoles consist of

magnetons, *i.e.* material magnetic particles with charge g^- and antimagnetons, *i.e.* particles Antimatter with charge g^+ . These magnetic particles are magnetic analogs of electrons and antielectrons. The magnetic charges presented above emit magnetic fields exclusively because of their magnetic nature which has nothing to do with electrical particles. In other words, magnetism and electricity are physically independent natural manifestations [4].

It is important to note here that the first person who observed real magnetic charges (in his opinion, magnetic ions) was Felix Ehrenhaft, who made his remarkable discoveries at beginning of the 20th century [5]. The reasons which, more than one hundred years, inhibit the recognition of valid conclusions of F. Ehrenhaft were discussed in detail in the publications of the author (see, for example, [2]).

It should be noted such interesting topic of the theoretical physics as magnetic monopoles. Under the concept “magnetic monopole” is commonly understood as theoretical electrified structures that are designed to create a magnetic field. The basis for the design of these structures, as a rule, is the theory of Dirac’s magnetic monopole [6]. However, this monopole is capable of emitting exclusively the vortex magnetic field, which is described by the vortex vector $\text{rot}\mathbf{H}$ [7]. For this reason the Dirac monopole and its derivatives cannot have any relation to real magnetic poles emitting the polar magnetic field, natural to them, with field strength \mathbf{H} . By their physical nature real magnetic charges are magnetic analogues of electrons, as well as other fundamental electrical particles. Given the physical irreducibility of real magnetic charges and theoretical magnetic monopoles, the author considers it pointless to draw any logical Parallels between them.

In atomic structures, in composition of electric dipoles, there are true anti-electrons, *i.e.* of real Antimatter particles with charge e^+ . Note, that these anti-electrons no direct relation to the positrons and has nothing to do with the so-called electron vacancies or Dirac “holes” [8].

The author in the publication [9] showed that nucleons (proton and neutron) are of the atomic-shaped electromagnetic structures, *i.e.* like of atoms include the nucleon shell and nucleus. The magnitude of the electric and magnetic charges in the nucleon shells are, according to the author’s research, 1/2 or less of the magnitude charges in atomic shells.

It is important to note that the basic (unperturbed) state of the spinor particles is the state of bispinor. In this state the charges in pairs + and – are tightly pressed together by the forces of “Dark energy” what leads to compensation of the external activity of their spins. Such pair does not manifest itself by external spinor field and, in practice, is not detected. The process of dense compression of a particle and an antiparticle described above and the exclusion of this pair from the information sphere provoked the emergence of such a fictitious concept as the annihilation of particles in the existing physical theory. This concept was formed on basis of observed interaction of electron and positron, as result of which only gamma quanta are detected. The positron is not is elementary spinor particle but is the varieties of mass, that is, it is the electromagnetic

structure atomic-shaped form. A true antielectron “sits” in the positron structure as its nucleus. Upon contact of electron and positron the electron connects with the antielectron, *i.e.* that is, with the positron nucleus with the formation of bispinor. As for the electromagnetic (quark) shell of the positron, it actually annihilates, and the evidence for its destruction is the observed gamma quanta. At the same time, the main protagonists of the so-called annihilation of particles (electron and true antielectron) do not annihilate, but remain unchanged in the composition bispinor.

1.2. The Electromagnetic Vortex (Gravitational) Fields and Essence of Physical Mass

The author's research has shown that electric and magnetic charges forming atomic and nucleonic shells exist in the compositions of the corresponding dipoles which rotate on atomic and nucleonic orbits. Namely the electromagnetic shells of atoms are the natural sources (generators) of gravitational field (GF) which, in reality, is of vortex electromagnetic field [10]. The elementary source of gravitational field is the spinor electromagnetic quasi-particle which received the name S-Graviton (S from “source”). The composition of S-Graviton: two spinors (electric and magnetic) and two antispinor corresponding to them. The S-Graviton is combination of the electric and magnetic dipole rotating in anti-phase at same atomic or nucleonic orbit. The model representation of the atomic orbital electromagnetic current or S-Graviton can be written in following form: $\text{rot}[\mathbf{J}_e - \mathbf{J}_g]$ where \mathbf{J}_e and \mathbf{J}_g are vectors of density instantaneous currents of electric (e) and magnetic (g) charges in corresponding of orbital flows. Then the equation process gravitational field formation by means the atomic S-Graviton can be presented in the form: $k \text{rot}[\mathbf{J}_e - \mathbf{J}_g] = \text{rot}[\mathbf{E} - \mathbf{H}]$ where \mathbf{E} and \mathbf{H} are vectors of the instantaneous electric and magnetic field strength in structure of the vortex electromagnetic (gravitational) field, k is the proportionality coefficient.

If the polarization of vortex vectors $\text{rot}[\mathbf{J}_e - \mathbf{J}_g]$ of S-Gravitons is realized in structures of Physical masses (in atoms, nucleons, substance *et al.*) that is accompanied by polarization corresponding of vortex vectors $\text{rot}[\mathbf{E} - \mathbf{H}]$, then by analogy with magnetic fields of the ferromagnetics, the gravitational fields being emitted by these masses can be called the ferrogravitational fields (FGF). The gravitational fields formed by masses in the absence polarization of the vortex vectors of S-Gravitons in their compositions are tensor or quasi-scalar fields. And again, by outward analogy with magnetism, such fields can be defined as para-gravitational fields (PGF).

The mathematical expression corresponding to the states of FGF is have the form $\langle \text{rot}[\mathbf{E} - \mathbf{H}] \rangle \neq 0$. The gravitational fields corresponding to the condition: $\langle \text{rot}[\mathbf{E} - \mathbf{H}] \rangle = 0$, by analogy with the paramagnetism can be defined as para-gravitational field.

The physical masses which emit the ferrogravitational fields will push off from

masses-sources of the paragravitational fields, for example, from Earth. This last effect discovered by the author of the article called as the effect Gravitational levitation [11]. It is important to note that the masses emitting FGP are so-called negative masses. The well-known representative of the “negative mass” is the atom of ordinary hydrogen or protium.

In his publications, since 2001, author tried to explain that all varieties of Physical Mass are the electromagnetic structures of atomic-shaped type consisting of electric and magnetic spinor particles. Main characteristic property of all varieties of mass is ability to emit the gravitational field that is formed as the result joint orbital currents of electric and magnetic charges and is the vortex electromagnetic field. In addition, the author showed that the formation of photons also falls, exclusively, within the competence of mass [12].

It is necessary to emphasize that Physical Mass and, for example, Matter are completely different physical categories. By the Physical masses, for example, are atoms, nucleons, substance. It is especially important to note that the individual spinor particles as electric, so and magnetic are massless, because mass is the result their joint structural union. For example, the electron is massless particle and no “divine bosons” can’t give it mass.

1.3. “Dark Energy” Is Global Force Factor That Is Responsible for All the So-Called Interactions between Masses and Charges

The results research of real magnetic charges allowed the author to formulate the conception of the World Physical Triad (PT) according which the real World consists of three fundamental phases: of the Matter, Antimatter and Energo-phase (Energo-medium) [13] [14].

The Phase of Matter is inhabited with magnetic and electric spinor particles with negative charge, and the Antimatter is formed by electric and magnetic particles with positive charge. Particles Antimatter constitute half all of real spinor particles, *i.e.* charged particles in real World, and their absence in the physical representations is determined by Physics their of confinement in the atoms and substance which is radically different from the confinement, for example, of electrons.

In the basic (undisturbed) state the Energo-phase (Energo-medium) is the isotropic high-density gas-like (possibly also quasi-fluid) medium formed by its own fundamental particles referred to as the energions which are spinless and massless. These particles are very small, they move in all directions at speeds close to the speed of light and can only be of two types: the Left and Right what linked with the appropriate direction of their own rotation. Super-high mobility and not-inertial behavior of the energions allow the particles and masses to move relatively freely in Energo-medium when this medium is in basic (undisturbed) state.

According to the Physical Triad Concept all forces direct action on the par-

ticles and masses, which are implemented in the real World are the forces of the so-called “Dark energy” (“DE”) which are determined by non-equilibrium states in the “Energo-medium” in the form of oblasts of local pressures P_ε created by energions (ε). The formation of “Dark Energy” in Energo-medium is induced by spinor fields, *i.e.* fields of charged particles. All variety of spinor fields, including gravitational fields, don’t have any real of power significance. They only play the role of intermediaries exerting influence on state of the Energo-medium and inducing formation of “Dark Energy” in it. Namely “Dark Energy” is real forces factor, performing the dynamics and the so-called interactions of masses and charged particles as in the scale of the Universe (the movement of galaxies, stars, planets and other objects) so and in the microcosm, for example, the dynamics of the spinor particles within a Physical masses of such as in atoms, nucleons, etc.

The gravitational fields radiated by masses (bodies) create in the area between them zones of negative or positive “Dark energy”. Forces of negative “DE” (F_{DE}^-) which realized between masses emitting the paragravitational field is determines all physical manifestations within the framework of the law of Universal Gravitation. As for the positive “DE”, so it is formed between the masses emitting PGF and FGF. The forces of the positive “DE” repel bodies from each other and are responsible for such an important effect as gravitational levitation.

The “Dark energy” realized in practice can associate with spinor fields which formed its, and therefore you can define the “Dark energy”, for example, as the gravitational “DE” or electrostatic “DE”. Considering that the gravitational field is the vortex electromagnetic, *i.e.* the spinor field, for the present study it is important to find out the mechanisms formation of the gravitational “Dark energy” and the features of it effect on the masses (bodies).

2. Gravitational Shielding in Hydrogen Atoms

Section 1.2 of this article showed that the gravitational fields of the masses (atoms, nucleons, etc.), in depending on the ordering of the vortex vectors $\text{rot}[\mathbf{E} - \mathbf{H}]$ in the compositions of the gravitational fields (GF) emitted by them, can be both paragravitational (PGF) and ferrogravitational (FGF). The classical source of GF is the electromagnetic quasiparticle consisting of two coupled dipoles (electric and magnetic) rotating in one atomic or nucleon orbit. S-Graviton is the shell of all hydrogen atoms (protium, deuterium and tritium).

Diagram of structure of the atom so-called lightweight hydrogen (protium) is shown in **Figure 1**. Recall that the atomic shells of all elements, like the shell of hydrogen atoms, are electromagnetic, and not electronic, as is now commonly believed. The magnitudes of the charges of the electric and magnetic spinor particles constituting the atomic shells of all the elements correspond to the condition $e = g$. The considering that S-Graviton is an elementary source of a gravitational field, the shell of a hydrogen atom emits namely FGF. As for the proton (p^+), which is located in the center of the atom and performs the function of the nucleus, it emits a PGF. It is known that the proton is attracted, more precisely,

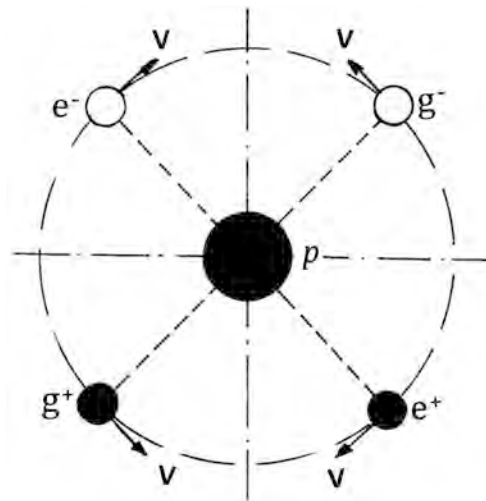


Figure 1. Scheme the electromagnetic device of atom protium. Through white circles in the **Figure 1** are shown of negative charged electric and magnetic spinors: electron (e^-) and magneton (g^-), and black circles denote of positively charged antispinors corresponding to them with charges e^+ and g^+ . The vectors instantaneous velocity \mathbf{v} is indicate the direction rotation of the magnetic and electrical dipoles in the same orbital of the hydrogen atom.

pressed to the Earth by the forces of the gravitational “DE”, what is unequivocal sign of its PGF.

In the composition of the atom protium is coexist two autonomous sources of GP: shell emitting FGF and nucleus-proton emitting PGF. However, in gravitational interactions, protium manifests itself as the source of FGF, which, we recall, is generated by its EM-shell. In favor of the latter statement is testifies by the known volatility of protium which is determined by the effect of gravitational levitation discovered and studied by the author.

The most probable cause that does not allow proton PGF to go beyond the atomic shell of the protium atom and manifest itself in gravitational interactions is the effect of intra-atomic gravitational lensing (IAGL). Through the term “gravitational lensing” in physics all types of deviations by masses of EM-fields are defined. Within this broad theme its physical subsections can be distinguished [15]. So, for example, IAGL processes, which are realized in atoms, should, as more accurate, be called as processes of the intra-atomic gravitational shielding (IAGS) the field of nucleus by atomic shell. This last definition we will use in article.

The gravitational field emitted by the nucleus-proton under the conditions of the IAGS realization cannot go beyond the atomic shell of protium and exists in closed oblast in the zone of nucleus. The atomic shell, in this case, is a kind of gravitational “insulator” preventing exit the field of nucleus from escaping beyond the atom. As for the FGF which emit the shell of hydrogen atom, it again, as a result of IAGS, manifests itself in external space and is not detected on the atomic nucleus.

The above-described manifestation, which is defined as the full IAGS of the

nucleus field, is shown in **Figure 2(a)**, which shows the areas of gravitational fields formed by sources in the composition protium atom: FGF of shell which appears beyond limit atom (indicated by straight hatching) and PGF of core (indicated in white) which, due of the IAGS effect, cannot go beyond the limits of the atomic shell. In addition, at the bottom of **Figure 2(a)** is shown the Earth as the third source of GP, taking part in the described gravitational influences. With the participation of the Earth, which is a powerful source of PGF is revealed all the circumstances of the gravitational scenarios related to IAGS. Since under conditions of full IAGS, the gravitational field of the nucleus cannot go beyond the atom, the gravitational interaction of the protium atom with the Earth determines exclusively the FGF emitted by the atomic shell. Between the FGF and PGF sources, *i.e.* between the protium atom and the Earth, the effect of gravitational levitation is realized, as a result of which these sources repel each other by the forces of positive “Dark energy” (shown in **Figure 2(a)** as F_{DE}^+).

The situation with the IAGS effect, described above in relation to protium, changes significantly in the case of the hydrogen isotope—deuterium or so-called heavy hydrogen. The nucleus of deuterium, which is called deytion, consists of one proton and one neutron. It is important to note that deytion is a loosely coupled nucleus with a nucleon binding energy of just 2.22457 MeV. Unlike protium, deuterium atoms do not exhibit volatility, but are pressed against the Earth what defines the name “heavy”.

The noted effect of changing the sign of the gravitational interaction of deuterium with the Earth is explained by the violation of the process of full gravitational screening of the PGF of deytion by the atomic shell. The neutron, like a proton, is a source of PGF. At inclusion of neutron in the composition of the nucleus of hydrogen atom, the intensity of PGF on the nucleus (denoted, conventionally, as EH) practically doubles. As for the shell, the value of its gravitational resistance R_G for breakdown PGF remains the same as that of protium.

Thus, the shell that consists of single S-Graviton cannot provide complete shielding of deytion’s PGF. Namely, the release (leakage) of the PGF of the nucleus beyond the atom limits leads to the compensation of the gravitational manifestation FGF of shell and is accompanied by a change in the volatility of the hydrogen atom to its so-called attraction to Earth. In this case, two opposing forces are formed between the Earth and the deuterium atom: repulsion of bodies by means of the F_{DE}^+ forces formed by FGF of shell and PGF of Earth and pressing them to each other by the F_{DE}^- forces resulting from the superposition of the PGF of the Earth and the PGF of deytion which burst beyond the shell of deuterium. The resulting force F_{DE} which presses the deuterium atom to Earth is defined as the difference between the marked forces $F_{DE} = F_{DE}^- - F_{DE}^+$.

A diagram of the distribution of gravitational fields emitted by the shell and the nucleus and the “DE” force effects induced by them in the case of deuterium is shown in **Figure 2(b)**. It is important to note that the breakdown of the gravitational resistance R_G of the hydrogen shell and the release of the PGF of deytion

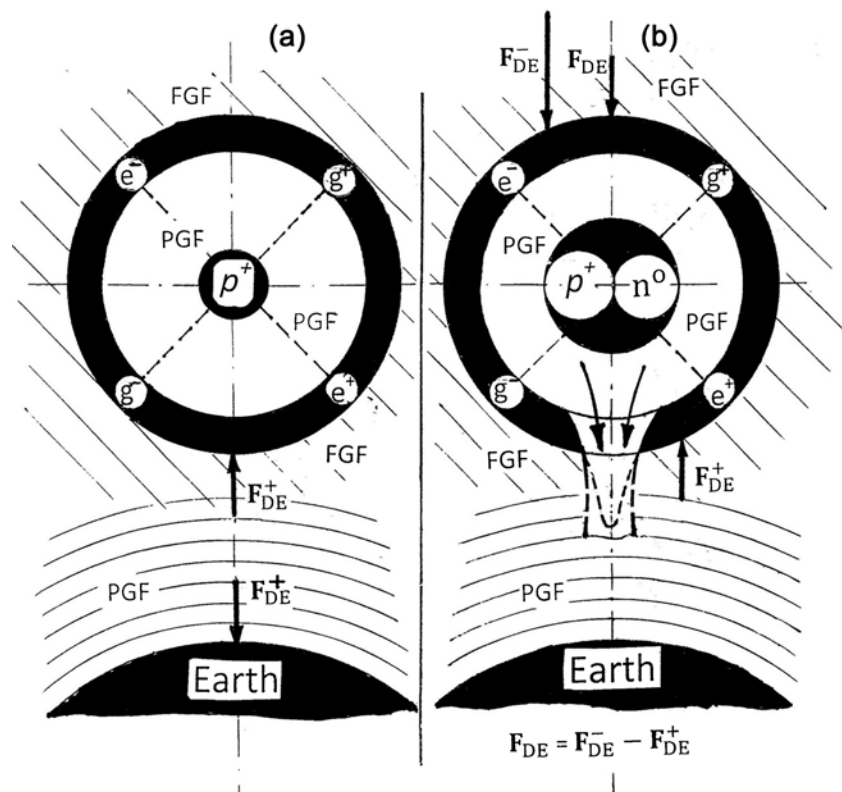


Figure 2. Schemes of distribution FGF and PGF under is conditions of realization of IAGS in the protium atom 2(a) and deuterium atom 2(b). By black color in **Figure 2**, stand-alone sources of GP are indicated: electromagnetic atomic shells emitting FGF and their nuclei, *i.e.* proton 2(a) and deytion 2(b), emitting PGF. The concentric lines indicate the Earth's PGF. The forces of the “Dark Energy” F_{DE}^- and F_{DE}^+ , as well as their resultant force F_{DE} under the IAGS conditions of the deuterium atom, are also shown in **Figure 2(a)**. Note: In order to simplify **Figure 2(b)** the diagram does not show the “DE” forces by which the deuterium atom presses the Earth to itself. These forces are antisymmetric to the forces shown in **Figure 2(b)** and is equal to them in magnitude.

beyond the atom limits significantly reduces the density of this field on the deuterium nucleus, which is accompanied by a decrease in the magnitude of the nuclear forces connecting the proton and neutron. It is this circumstance that explains the weak coupling of nucleons in the deuterium nucleus noted above. However, deuterium belongs to the category of stable isotopes of hydrogen.

The distribution of the PGF of deytion, shown in **Figure 2(b)**, is in the opinion of the author, the most possible option that is realized when the IAGS effect is violated, what accompanied by the output of the PGF beyond of the atom deuterium. The intensity of the PGF of the deytion, most likely, does not greatly exceed the critical value of the intensity EH_{cp} , necessary for the breakdown of the “insulator”, *i.e.* to overcome the gravitational resistance of the R_G shell. Therefore, in the case of deuterium, it is most likely that only one gravitational “language” of the PGF will go beyond the atom. As for the direction of the PGF exit, it is determined by the gravitational field of the source interacting with the deuterium, *i.e.* of the earth. In general, as such a source can be atoms of various

elements.

The shape and parameters of the field of PGF, which is formed outside the atom in violation of the full IAGS, require additional studies. These parameters should correspond to the necessary concentration of the nucleus field for the breakdown of shell resistance and autonomous existence beyond the atom. It is also necessary to take into account the possible processes of gravitational focusing of the PGF of the nucleus as it passes through the electromagnetic density of the shell, as well as the conditions for its interaction with the PGF of the Earth and the FGF shell beyond the deuterium atom. The dotted in **Figure 2(b)** shows the possible configurations of the “language” of the PGF of the deuterium nucleus outside atomic shell.

The addition of second neutron to the nucleus of deuterium leads to the formation of a third isotope of hydrogen with the name tritium, which, as is known, is a radioactive element with a half-life of 12.32 years. The cause of radioactivity is a significant leakage of the PGF of the nucleus as a result of its release beyond the shell of tritium and the corresponding minimization of nuclear forces in its core.

According to the findings of the author the main reason for the formation of the IAGS effect is physical apartness, both of the sources and their gravitational fields in the atomic compositions. The gravitational fields emitted by the shell and the nucleons in the composition of the atom are, by their physical parameters are different gravitational fields what is determined by the differences in the values of the charges that form them. These fields cannot physically correlate in the total atomic composition, which leads to the screening by a gravitational source of an alien GP. This important circumstance is discussed in more detail below in Chapter 3.

According to the results of our study of IAGS effect in hydrogen atoms we can draw the following conclusions.

- 1) The effect of complete shielding of the gravitational field of the nucleus is implemented in the protium atom. In this case, the field of the proton nucleus is completely disconnected from the external gravitational manifestation of the atom, which is determined solely by the atomic shell which generates FGF.
- 2) The principle of shielding the gravitational field of the nucleus is determined by the physical isolation of the atomic sources of the GF, which manifests itself both in its atomic geometry and in a part of the gravitational fields emitted by them.
- 3) The IAGS process determines and regulates the density of the GF emitted by the nucleons in the region of the nucleus. Nuclear forces are determined by the density (intensity) of PGF on the core, *i.e.* the higher the density of the field, the stronger the bond between the nucleons in the nuclei. The leakage of PGF from the nucleus region, in the case of a partial removal of the gravitational “blockade”, leads to a sharp weakening of the nuclear binding forces of the nucleons. This is precisely the reason for the super-weak coupling between the proton and the neutron in the deuterium nucleus, as well as the radioactivity of

tritium.

3. Gravitational Shielding in Atoms as Main Reason for Change in Magnitude of Nuclear Forces

It is not difficult to foresee that the IAGS effect is a universal intra-atomic process which is implemented in the atoms of all elements. As noted above, the IAGS processes have a significant impact on the magnitude of the nuclear forces. It is important to emphasize once again that gravitational shielding is realized in the compositions of the masses (atoms, nucleons, etc.) formed by autonomous sources of gravitational fields, which differ in their physical parameters.

The magnitudes the electric and magnetic charges quarks that form the atomic shells of nucleons are more than two times smaller than the charges of the shell of atoms. The gravitational field emitted by the shells of nucleons is described by the vortex vector $\text{rot}[\mathbf{E}_n - \mathbf{H}_n]$, where \mathbf{E}_n and \mathbf{H}_n are the electric and magnetic field strength vectors in the composition of the nucleon gravitational field. Herewith magnitudes of the marked of the vectors correspond to the conditions $E_n(H_n) < E_a(H_a)$, where the indices n and a refer these quantities to the nucleon and atomic shells, respectively. Namely, the differences in the physical parameters of gravitational fields emitted by autonomous sources in the composition of atoms underlie the IAGS effects described in the article.

In the article [8], the author stated that the nuclear forces are determined primarily by gravitational forces of “DE”, which are realized under the influence PGF of nucleons. Since the proton and the neutron are sources of PGF, the forces of the gravitational “DE” are realized between them, which press (but do not attract) the nucleons to each other. It is these forces of “DE”, according to the author, that are responsible for the formation of nuclear forces. However, the effect of IAGS, which significantly affects the situation with the magnitude of nuclear forces, was not known to the author at that time. The discovery of this effect and its introduction into basic concepts substantially complement the author’s earlier assumptions regarding the nature and variability of nuclear forces.

The effect full IAGS in results in high concentration of PGF of nucleons in the region of the atomic nucleus. In the mathematical representation the distribution function of the gravitational field of free nucleon, which extends from 0 to ∞ , convolve into function of this field in a narrow region of space from 0 to R , where R is the radius of the nucleus. Quite roughly, such a change in the density of the gravitational field can be defined as $>10^2$ times. Ultrahigh density (intensity) of the PGF between nucleons in the nucleus, which is formed as a result of the full IAGS effect, accompanied by the formation of the corresponding level of negative gravitational “Dark energy” which is manifested by well-known of nuclear forces. As for the GF emitted by the atomic shell it is responsible for external processes, for example, the condensation of atoms into the composition of the substance, *i.e.* for the formation of a chemical bond. In other words, there is rational division of “labor” between the gravitational sources of the atom.

The division of “labor” noted above implies an obligatory territorial isolation between the marked sources of gravitational fields in the composition of the atoms. The latter, in turn, implies the existence of forces that push these sources apart from each other for some distance and do not allow the so-called “electrons” fall to nucleus.

Everything noted above in this section was related, mainly, to the atoms of the natural stable elements that make up the periodic system of elements. At the same time, there is a huge package of atoms in whose structures the processes of screening the PGF of the nucleus are not fully performed. Such atoms are numerous isotopes of elements, on the nuclei of which, as a result of the addition of additional neutrons, supercritical values of the PGF intensity are realized. Since, in this case, the atomic shell is not able to completely shield the gravitational field of the nucleus, there is a partial release (leakage) of the field formed by the nucleons beyond the atom. As a result of this leakage, the PGF intensity at the nuclei significantly decreases compared with conditions full IAGS. The latter circumstance leads to a weakening of the nuclear forces and is manifested, for example, in such processes as the radioactivity of the nuclei.

It is important to note that the electric fields of the nucleons suspected of organizing the connection between the shell and the nucleus are most likely not directly related to the processes of gravitational shielding.

As is known, the elements in the Periodic System of Mendeleev are arranged in accordance with the increase in the size of their atomic masses or atomic weights. As for the atomic weight of any element, it is determined by the magnitude of the force of the gravitational “Dark energy” with which the atom is pressed against the Earth. It is important to note that this force is induced by a gravitational field emitted mainly by the atomic shell. In this case, as a rule, there is no contribution of the atomic nucleus to the marked “DE” force, which presses the atom to the Earth. It is this circumstance that brought about such a thing as an atomic mass defect, which is defined as the difference between the sum of the individual masses of free nucleons of a nucleus and the mass of a nucleus as a single entity. In other words, the mass of the atomic nucleus turns out to be significantly smaller than the sum of the individual masses of nucleons (protons and neutrons) in its composition. The marked decrease (defect) of the nuclear mass Δm is determined in the existing theory by the corresponding nuclear connection energy of the nucleons W_{nc} which relate as $W_{nc} = \Delta mc^2$. Mathematical support of the problem with the atomic mass defect can be found in textbooks on physics, as well as on Wikipedia. It is important to note that the concept of mass defect itself does not have any intelligible physical explanation, apart from its numerical definition through the value of W_{nc} .

The discovery by the author of real magnetic charges in the structures of atoms and substance, the discovery of the electromagnetic nature of the gravitational field and the mechanism of its formation, made it possible to determine the general physical essence of the concept of atomic mass defect. Namely, the

above-described intra-atomic shielding by the atomic shell of the gravitational fields of nucleons in the composition of atomic nuclei is the physical process that is responsible for the so-called defect of mass. Herewith the gravitational field of the nucleus, which is PGF, completely or partially, is disconnected from the so-called gravitational interaction with the Earth, which and manifests itself as the defect mass of the nucleus.

Since the gravitational “DE” is the main force factor that determines the physics of chemical bonding of atoms, chemistry, as the science of the problem of the condensation of atoms into compounds and substances, can be called gravitational chemistry. An exception here is the ionic bond, in the physics of which the participation of the electrostatic “Dark energy”. However, in the processes of chemical bonding of ions, in addition to electrostatic “DE” the forces of gravitational “DE” are involved, since the ions are, as a rule, the source of PGF

There are grounds to assume that the IAGS effect is not a purely atomic effect. In his publications (see, for example, [9]), the author showed that nucleons are the small atoms, which consist of nucleon shells and nuclei. The source of GF in nucleon nuclei is the well-known positron, which is a type of mass. The positron participates in the classical gravitational interaction, *i.e.* shows so-called attraction to Earth. The latter implies that the positron is a source of PGF.

Since the electric and magnetic charges in the compositions of the shells of nucleons and in the structures of positrons differ significantly in magnitude, it should be assumed that the PGF emitted by marked sources in the compositions of the nucleons are different PGF. Therefore, by analogy with IAGS, one should expect the manifestation of the effect of gravitational shielding and in the structures of nucleons. This effect in the composition of nucleons should be referred to as intra-nucleon gravitational shielding (INGS). However, at the moment it is impossible to determine whether this effect is full INGS or partial.

4. Conclusions

Detection of the effect of IAGS described in this article turned out possible solely as result of the discovery and investigation by the author of real magnetic charges, as well as true anti-electrons in the structures of atoms and nucleons. Paradoxically, but these real particles, which make up three quarters of all real spinor particles, *i.e.* of charged particles in atoms and substance, more than hundred years, are not recognized by the official physical science. The introduction of the above-mentioned real particles into the basic physical concepts allowed the author to clarify, for example, such crucial questions of fundamental physics as the true nature of the gravitational field and the physical essence of mass. In addition, it is extremely important that the author managed to find out the real physics of “Dark energy” and to explain the peculiarities of its participation in the numerous effects and manifestations of the real World. In his publications it is shown that namely the forces “DE” is responsible for the dynamics and the so-called interaction of particles and masses in the Universe. So, for

example, the gravitational “Dark energy” is the main force factor determining the Law of Universal Gravitation [16].

The main reason for ignoring all these real particles in physical science is the conditions of their retention in the structures of atoms and substances, which are fundamentally different from the retention of electrons. However, the Physics of confinement is not the only reason which blocks the path to confess these real particles by physical science. A huge negative factor on this path was Maxwell’s electric magnetism (EMM), embedded in the minds of humanity in 1873 [17]. It is important to emphasize that EMM arose, exclusively, as result of superficial perception by Maxwell of famous experience Oersted’s. Namely the “ingenious” guess of the Great Physicist: “electrons moving in a conductor are direct sources of the magnetic field”, for more than a hundred year hindered the fruitful development of world physical science. Based on the last conclusion, the equation was written: $k\mathbf{J}_e = \text{rot}\mathbf{H}$ known as the first Maxwell equation. The piquancy of the situation with EMM is that this “magnetism” is easily obtained in practice. It is enough to have an electric battery, conductor and a magnetic needle (compass). External simplicity and clarity formation of the magnetic field in the Oersted Experience did not suggest the need for deep thinking about its source. It was Maxwell’s conclusion and his famous equation that made magnetic charges, in general, unnecessary; since and without them, using such theoretical surrogates as magnetic moments and electronic vacancies, almost everything was more or less explained.

The effect of IAGS is a universal physical effect, which necessarily manifests itself in atoms and nucleons and, therefore, concerns the physics of all varieties of mass. Physical processes such as the chemical bonding of atoms in matter, nuclear forces, and radioactivity physics are directly dependent on the IAGS effect. The article noted that such important physical concept as an atomic mass defect does not have a clear theoretical explanation. The effect of IAGS, presented in the article, allows us to quite clearly imagine which physics is behind this concept in reality. At the same time, the introduction of the IAGS effect into physical representations implies numerous revisions of existing interpretations of physical effects and even established physical laws. It is also important to note that with the use of the IAGS effect, there are ample opportunities to detect new physical effects and manifestations.

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Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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Novel Features of Classical Electrodynamics and Their Connection to the Elementary Charge, Energy Density of Vacuum and Heisenberg's Uncertainty Principle—Review and Consolidation

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Abstract

The paper provides a review and conciliation of the results pertinent to the energy and action associated with electromagnetic radiation obtained using classical electrodynamics and published in several journal papers. The results presented in those papers are based on three systems that generate electromagnetic radiation, namely, frequency domain antennas, time domain antennas and decelerating (or accelerating) charged elementary particles. In the case of radiation generated by a frequency domain antenna, the energy dissipated as radiation within half a period, U , satisfies the order of magnitude inequality $U \geq h\nu \rightarrow q \geq e$ where q is the magnitude of the oscillating charge in the antenna, e is the elementary charge, ν is the frequency and h is the Planck constant. In the case of transient radiation fields generated by time domain antennas or the radiation emitted by decelerating (or accelerating) charged elementary particles, the energy dissipated by the system as radiation satisfies the order of magnitude inequality $U\tau_r \geq h/4\pi \rightarrow q \geq e$ where U is the energy dissipated as radiation by the system, τ_r is the duration of the energy emission and q is either the charge in the current pulse in the case of the time domain antenna or the charge of the elementary particle giving rise to the radiation. These results are derived while adhering strictly to the principles of classical electrodynamics alone. These results were interpreted in different papers in different ways using different assumptions. In this paper, we provide a unified interpretation of the results, and combining these results with two simple quantum mechanical concepts, expression for the

elementary charge as a function of other natural constants and the energy density of vacuum is derived. The expressions predict the elementary charge to an accuracy higher than about 1%.

Keywords

Classical Electrodynamics, Electromagnetic Radiation, Electron, Elementary Charge, Vacuum Energy, Dark Energy, Hubble Radius, Heisenberg's Uncertainty Principle

1. Introduction

In several recent publications, Cooray and Cooray [1] [2] [3] [4] [5] investigated the features of electromagnetic radiation generated by antennas working in both frequency and time domain when the radiating charge in the antenna is reduced to the elementary charge. These authors studied the same problem from a different angle by studying the electromagnetic radiation generated by a decelerating charged elementary particle when it strikes an impenetrable perfectly conducting boundary [6]. These studies revealed the existence of several remarkable features associated with the electromagnetic radiation fields as predicted by classical electrodynamics. Even though these studies were conducted independent of each other, the derived results had several similar features. The goal of this paper is to place all investigations in the same framework, review the results, and provide unified conclusions concerning these predictions of classical electrodynamics. Thus, the concepts used here are already presented in the six papers mentioned above. The mathematical expressions related to the energy, momentum, and action of the radiation fields are identical to those presented previously in the papers mentioned above. For this reason, final equations are obtained directly from the respected papers without presenting the derivations. However, some of the definitions of the parameters used here are slightly different from the ones used in those papers and this was done to achieve uniformity in the method of analysis utilized in different studies. Moreover, in the case of the transient antenna, the problem analyzed in the previous paper is a dipole antenna whereas here, a monopole located over a perfectly conducting ground plane is examined.

In Section 2 we will show the results obtained purely based on classical electrodynamics. In Section 3 and 4 it is shown how the results obtained in Section 2 can be combined with the known concepts of quantum mechanics to extract expressions for the elementary charge in terms of other natural constants and the energy density of vacuum. Section 5 presents a summary of the results and conclusions.

2. Analysis

2.1. Frequency Domain Antenna

As the radiating system we will consider an antenna of length L located over a

perfectly conducting ground plane. The perfectly conducting plane coincides with the x-y plane with $z = 0$. The antenna is located along the z-axis and is fed by a sinusoidal current from the ground end (*i.e.* $z = 0$). The material to be given below is obtained directly from reference [2].

The power generated by the antenna takes place in bursts of duration $T/2$, where T is the period of oscillation. Under ideal conditions when all the losses associated with the current propagation along the antenna can be neglected, the median value of the energy radiated within a single burst of duration $T/2$ is given by the equation

$$U_{med} = \frac{q_0^2 \pi \nu}{4\epsilon_0 c} \{ \gamma + \ln(4\pi L/\lambda) \} \quad (1)$$

In Equation (1), γ is Euler's constant, which is equal to 0.5772, q_0 is the magnitude of the oscillating charge, λ is the wavelength, and ν is the frequency of oscillation. For a given charge q_0 , the median energy increases with increasing length of the antenna and decreasing wavelength. Let us consider the limits of L and λ . The smallest possible value of the wavelength that one can plug into the equation is in the order of the antenna radius. In the analysis to follow, we assume that the smallest possible radius of an antenna that can exist in nature is equal to the Bohr radius a_0 . We also presume that the largest possible value of the antenna length that one can have in nature is equal to the ultimate radius of the universe that is in causal contact with the observer. This radius is estimated as follows. Consider an observer in an expanding universe. The objects in this universe which are not bound to the observer by any other forces such as gravitational, electromagnetic or nuclear are receding with respect to the observer with a certain speed which increases with the distance from the observer to the object. Consequently, as the distance between the observer and the object increases, there is a certain distance where the objects recede from the observer with the speed of light. This distance is called the "Hubble radius". The space located beyond the Hubble radius expands faster than the speed of light and the observer cannot receive any information from events happening beyond the Hubble radius. Thus, the maximum spatial distance available for the observer within the space that is in causal contact with him is the Hubble radius. The Hubble radius varies with the age of the universe and in the present epoch of the universe the Hubble radius increases with the age of the universe. However, the presence of vacuum energy will provide an upper asymptotic limit to the Hubble radius, a steady state value. Thus, in our universe the maximum length of an antenna that an observer can achieve is limited by this steady state value of the Hubble radius. Let us denote this steady state value of the Hubble radius by R_∞ . Using this as the ultimate limit of the antenna length, the upper limit of the median energy dissipated within a single power burst of duration $T/2$ for a given charge is given by,

$$U_{max} = \frac{q_0^2 \pi \nu}{4\epsilon_0 c} \{ \gamma + \ln(4\pi R_\infty/a_0) \} \quad (2)$$

Consider a photon of frequency ν . The energy associated with such a photon is given by $h\nu$, where h is the Planck constant. The charge that corresponds to a median energy equivalent to a single photon is given by

$$q_0 = \pm \sqrt{\frac{4\varepsilon_0 hc}{\pi \left\{ \gamma + \ln(4\pi R_\infty / a_0) \right\}}} \quad (3)$$

Now, the steady state or the ultimate value of the Hubble radius is given by

$$R_\infty = c^2 \sqrt{\frac{3}{8\pi G \rho_\Lambda}} \quad (4)$$

In the above equation, G is the gravitational constant and ρ_Λ is the energy density of the vacuum. The current estimate of the vacuum energy density is about $6 \times 10^{-10} \text{ J/m}^3$ [7]. Substituting this in the above equation we find that the final value of the Hubble radius *i.e.* R_∞ is about $1.55 \times 10^{26} \text{ m}$. Substituting the expression for R_∞ from Equation (4) in Equation (3), we obtain

$$q_0 = \pm \sqrt{\frac{4\varepsilon_0 hc}{\pi \left\{ \gamma + \ln \left[\frac{4\pi c^2}{a_0} \sqrt{\frac{3}{8\pi G \rho_\Lambda}} \right] \right\}}} \quad (5)$$

If we substitute numerical values to the parameters in the above equation we find that $q_0 = \pm 1.603 \times 10^{-19}$ which is equal to the elementary charge to an accuracy of 0.1%. This indicates that in an oscillatory antenna radiating at its maximum capacity which is limited only by the natural dimensions, an oscillating charge with magnitude equal to the elementary charge will generate, in a single burst of radiation, an energy equivalent to a single photon. If the length of the antenna is smaller or the radius of the antenna is larger than the natural limits, a charge larger than an elementary charge is needed to radiate an equivalent amount of energy in a single burst. Moreover, since the antenna losses will reduce the amount of energy dissipation for a given charge, if one includes the antenna losses in the analysis, a larger charge will be necessary to compensate for the losses. The results can be summarized by the following inequality: $U \geq h\nu \rightarrow q \geq e$. In this inequality, U is the energy associated with a single burst of radiation, h is the Planck constant, q is the magnitude of the oscillating charge, and e is the elementary charge. Note that q_0 (*i.e.* the smallest value of q) is not exactly equal to e . Thus, this inequality has to be treated as an order of magnitude relationship. Observe that the reverse of this inequality is not valid because $q \geq e$ does not lead to $U \geq h\nu$.

2.2. Time Domain Antenna

Consider a long and vertical conductor located over a perfectly conducting ground plane. As in the previous case the perfectly conducting plane coincides with the plane x - y with $z = 0$. A current is injected into this antenna from the ground end ($z = 0$). Recall that, as before, we are considering the ideal case without any losses. That is, we neglect all the losses such as thermal, dispersive

and radiative. In this case the pulse propagates along the antenna without attenuation and dispersion. We consider the case in which the current pulse gets absorbed when it reaches the end of the antenna.

The current waveform propagating along the antenna is assumed to be a Gaussian pulse of the form $e^{-t^2/2\sigma^2}$. The duration of this pulse is denoted by τ . In order to make the analysis general, we define a non-dimensional parameter η as follows:

$$\eta = \tau/(L/c) \quad (6)$$

Note that η denotes the ratio between the duration of the current and the time of travel of the current along the antenna. Following the same procedure used in references [1] [3] and [4], the energy dissipated by the antenna can be written as

$$U = \frac{q^2}{8\pi^{3/2}\sigma\epsilon_0 c} \ln\left(\frac{2}{\eta}\right) \quad (7)$$

Let us now consider the action associated with this energy burst. The action is defined as the product of the dissipated energy and the time over which the energy is dissipated. The temporal variation of power associated with the radiation burst varies as $e^{-t^2/2\sigma_r^2}$ where $\sigma_r = \sigma/\sqrt{2}$. We define the duration of the energy burst τ_r , as the time interval within which 95% of the energy is dissipated. With this definition we obtain $\tau_r \approx 4\sigma_r = 2^{3/2}\sigma$. Obviously, one can use slightly different definitions for the duration of the energy burst [see references [1] [3] and [4]] but such choices will not change the order of magnitude of the results to be obtained. Thus, the action associated with this radiation burst is given by

$$A = \frac{\tau_r q^2}{8\pi^{3/2}\sigma\epsilon_0 c} \ln\left(\frac{2}{\eta}\right) \quad (8)$$

Substituting for τ_r and after simplification we obtain

$$A = \frac{2^{3/2} q^2}{8\pi^{3/2}\epsilon_0 c} \ln\left(\frac{2}{\eta}\right) \quad (9)$$

After substituting for η the action can be written as

$$A = \frac{2^{3/2} q^2}{8\pi^{3/2}\epsilon_0 c} \ln\left(\frac{2L}{\tau c}\right) \quad (10)$$

As per this equation, the action associated with a given charge q increases with increasing L and with decreasing τc . Let us consider the natural limits of these parameters. Now, the radiation field as given earlier is valid when τc is on the order of the radius of the conductor or larger. This is the case because if this condition is not satisfied the radiation fields generated from different parts of the cross section will interfere destructively reducing the amplitude of the radiation field. Thus, the maximum value of the radiation, and hence the action is obtained, when $\tau c \approx a$, where a is the radius of the conductor. For a given radius, the maximum value of the action is then given by

$$A = \frac{2^{3/2} q^2}{8\pi^{3/2} \epsilon_0 c} \ln \left(\frac{2L}{a} \right) \quad (11)$$

Using the same arguments as in the case of frequency domain analysis, the maximum value of the length of the conductor that one can have is equal to R_∞ and the smallest radius is equal to the Bohr radius. Thus, the maximum action associated with a given charge is

$$A_m = \frac{2^{3/2} q^2}{8\pi^{3/2} \epsilon_0 c} \ln \left(\frac{2R_\infty}{a_0} \right) \quad (12)$$

Now, the natural unit that is being used to measure the action is $\hbar/2\pi$ or $\hbar/4\pi$. The charge necessary to make the action equal to $\hbar/4\pi$ is given by

$$q_0 = \pm \sqrt{\frac{\hbar \pi^{1/2} \epsilon_0 c}{2^{1/2}} \left[1 / \ln \left(\frac{2R_\infty}{a_0} \right) \right]} \quad (13)$$

Substituting numerical values for the parameters in the above equation we find $q_0 = \pm 1.61 \times 10^{-19}$ C. This shows that as the charge decreases the action decreases and when the charge reaches the elementary charge the action becomes comparable to $\hbar/4\pi$. Since Equation (12) gives the maximum action possible in nature for a given charge, one can summarize the results by the following inequality: $A \geq \hbar/4\pi \rightarrow q \geq e$ where A is the action associated with a burst of radiation generated by the antenna and q is the charge associated with the current. Observe that the reverse of this inequality is not valid. That is, $q \geq e$ does not lead to $A \geq \hbar/4\pi$. Note that this result is based purely on classical electrodynamics without burrowing any features from quantum electrodynamics.

2.3. Radiation Fields Generated by a Decelerating Charged Elementary Particle or Transition Radiation

In the previous sections we have analyzed the radiation fields generated by transmitting antennas, both in the frequency domain and time domain, when their dimensions are pushed to limits allowed by nature. In this section, we will summarize the results obtained in reference [6] for the radiation fields generated when a fast-moving charged elementary particle is incident on a perfectly conducting ground plane. As before the perfectly conducting plane is located along an x-y plane with $z = 0$. A charged elementary particle moves in the direction of negative z-axis with uniform velocity v and is incident on the ground plane. The deceleration of the particle during this encounter gives rise to a pulse of electromagnetic radiation. If one treats the elementary particle as a point particle the radiation goes to infinity. Thus, to calculate the radiation field, we will treat the charged elementary particle as a charge distribution and consider the movement of the particle as a propagation of a current pulse. The temporal variation of the current pulse is assumed to be Gaussian. The energy dissipated during the encounter between the charged particle and the perfect conductor is given by (with $\beta = v/c$);

$$U = \frac{q^2 \beta^2}{16\pi^{3/2} \epsilon_0 c \sigma} \left[\frac{1+\beta^2}{\beta^3} \ln \left(\frac{1+\beta}{1-\beta} \right) - \frac{2}{\beta^2} \right] \quad (14)$$

As in the previous case, the temporal variation of the power emission is given by e^{-t^2/σ^2} , and as before the duration of the energy emission $\tau_r = 2^{3/2} \sigma$. Thus, the action associated with this radiation energy burst is given by

$$A = \tau_r U = \frac{q^2 \beta^2 2^{3/2}}{16\pi^{3/2} \epsilon_0 c} \left[\frac{(1+\beta^2)}{\beta^3} \ln \left(\frac{1+\beta}{1-\beta} \right) - \frac{2}{\beta^2} \right] \quad (15)$$

In our study, we are interested in the values of β where $(1-\beta) \ll 1$, *i.e.* $\beta \approx 1$. Under these conditions, the action reduces to

$$A = \frac{q^2 2^{3/2}}{8\pi^{3/2} \epsilon_0 c} \left[\ln \left(\frac{2}{1-\beta} \right) - 1 \right] \quad (16)$$

Observe that the action reaches infinity when β goes to unity; *i.e.* when the speed of the particle reaches the speed of light. Due to relativistic change of mass of the particle its speed can never become equal to the speed of light. However, in principle, there is no restriction for the speed of the particle to reach values which are infinitesimally close to the speed of light. Assume that the particle is moving with speed of light along the z-direction. Since, the speed of light is the maximum ever possible speed of the charged particle, this indicates that the speed of the particle in any direction along the x-y plane is equal to zero. However, this contradicts the Heisenberg's position-momentum uncertainty principle. Since the particle is confined inside the Hubble sphere, according to Heisenberg's uncertainty principle the speed of the particle in any given direction could not be equal to zero. Perivolaropoulos analyzed this problem in reference [8], and according to the results there is a minimum momentum associated with the particle in any given direction, and the speed v_{\min} of the particle associated with this minimum momentum is given by [8]

$$v_{\min} = \frac{3\sqrt{3}}{8} \frac{h}{\pi m_e R_\infty} \quad (17)$$

Thus, the maximum speed of the particle in any given direction in space is limited to a value v_{\max} given by

$$v_{\max} \approx c - v_{\min} \quad (18)$$

This will limit the minimum value of $(1-\beta)$, $(1-\beta)_{\min}$, to

$$(1-\beta)_{\min} = \frac{3\sqrt{3}}{8\pi} \frac{h}{m R_\infty c} \quad (19)$$

In the above equation m is the mass of the charged elementary particle. Substituting this in Equation (16) we obtain the maximum value of the action associated with any given charge as

$$A_m = \frac{q^2 2^{3/2}}{8\pi^{3/2} \epsilon_0 c} \left[\ln \left(\frac{16\pi m R_\infty c}{3\sqrt{3}h} \right) - 1 \right] \quad (20)$$

The charge necessary for this action to be equal to $h/4\pi$ is given by

$$q_0 = \pm \sqrt{\frac{h\pi^{1/2}\varepsilon_0 c}{2^{1/2} \left[\ln \left(\frac{16\pi m R_\infty c}{3\sqrt{3}h} \right) - 1 \right]}} \quad (21)$$

Consider a charged elementary particle having the mass identical to an electron. Replacing the mass m in Equation (21) by the mass of the electron m_e and re-writing the equation in terms of well-known atomic parameters we obtain

$$q_0 = \pm \sqrt{\frac{h\pi^{1/2}\varepsilon_0 c}{2^{1/2} \left[\ln \left(\frac{8R_\infty}{3\sqrt{3}\alpha a_0} \right) - 1 \right]}} \quad (22)$$

In the above equation, α and a_0 are the fine structure constant and the Bohr radius respectively. Equation (22) gives the charge necessary in an elementary particle having a mass equal to that of an electron so that the action becomes comparable to $h/4\pi$. Substituting numerical values for the parameters in the above equation, we find $q_0 \approx \pm 1.58 \times 10^{-19}$ C. This shows that when the charge of the elementary particle having a mass equal to that of an electron reaches the elementary charge, the action becomes comparable to $h/4\pi$. Since the Equation (20) gives the maximum action possible in nature for a given charge of magnitude q , the results can be summarized by the following inequality: $A \geq h/4\pi \rightarrow q \geq e$. Observe that this relationship is valid for an elementary particle having the mass of an electron. Also note the condition $A = h/4\pi \rightarrow q \approx e$ is satisfied when the elementary charged particle travels with the maximum possible speed allowed by nature for a particle located inside the Hubble sphere. Moreover, observe again that the reverse of this inequality is not valid. That is, $q \geq e$ does not lead to $A \geq h/4\pi$.

The results presented above are obtained for an elementary particle having a mass equal to that of an electron. The other charged elementary particles are Quarks, muons and taus. However, quarks are not free and confined inside the nucleus. Both muons and taus decay rapidly to electrons. Muons decay to electrons within about 2.2×10^{-6} seconds and taus decay to electrons within about 10^{-13} seconds. However, the relationship is approximately satisfied also by both muons and taus, thanks to the fact that the mass of the particle appears inside the logarithmic term.

3. Discussion

3.1. Frequency Domain Antenna

In the analysis, we have assumed the length and radius of the radiating antenna have the extreme limits allowed by nature. Let us refer to such an antenna as the “ultimate antenna”. It is important to note that if the antenna length is decreased or the antenna radius is increased from these extreme values, the magnitude of

the radiation will decrease. In other words, to reach the same level of radiation as the extreme antenna, more charge is necessary in the radiating antenna. The same is true if we include the losses associated with the current propagation. The effect of these losses is to reduce the magnitude of the radiation fields, and more charge is necessary in the radiating system to reach the same level of radiated energy. This means that the condition $U \geq h\nu \rightarrow q \geq e$ is valid for an antenna of any length or radius and even when losses are included. In other words, it is a universal condition. The condition $U \geq h\nu \rightarrow q = e$ is satisfied by the ultimate antenna and the condition $U \geq h\nu \rightarrow q \geq e$ is satisfied by any other antenna. Observe that this relationship is obtained using classical electrodynamics alone. It is important to point out that this relationship does not prove that the minimum charge that can oscillate in the antenna is the elementary charge. It only shows that if, and only if, $U \geq h\nu$ then $q \geq e$. If we wish to prove that the smallest possible oscillating charge in the antenna is the elementary charge, we have to show that the condition $U \geq h\nu$ is satisfied by the electromagnetic radiation. Let us consider this point in more detail.

In the inequality, U is the energy dissipated within the time $T/2$. According to quantum mechanical interpretation electromagnetic radiation consists of photons. If any electromagnetic energy is dissipated within the time duration $T/2$, then at least one or more photons should be released by the radiator during this time interval. Since the energy of a photon cannot be smaller than $h\nu$, the energy released during the time period $T/2$ cannot be smaller than $h\nu$. In other words, the quantum mechanical nature of electromagnetic radiation gives rise to inequality $U \geq h\nu$. This shows that the condition $q \geq e$ is a consequence of the quantum nature of the electromagnetic fields.

Equation (5) is derived using pure classical electrodynamics and it indicates q_0 is almost equal to the elementary charge. If we assume that q_0 is exactly equal to the elementary charge, then, Equation (5) can be written as

$$e = \sqrt{\frac{4\epsilon_0 hc}{\pi \left\{ \gamma + \ln \left[\frac{4\pi c^2}{a_0} \sqrt{\frac{3}{8\pi G \rho_\Lambda}} \right] \right\}}} \quad (23)$$

Using the above expression for the elementary charge one can express the fine structure constant α as

$$\alpha = \frac{2}{\pi \left\{ \gamma + \ln \left[\frac{4\pi R_\infty}{a_0} \right] \right\}}} \quad (24)$$

In terms of the vacuum energy density the fine structure constant is given by

$$\alpha = \frac{2}{\pi \left\{ \gamma + \ln \left[\frac{4\pi c^2}{a_0} \sqrt{\frac{3}{8\pi G \rho_\Lambda}} \right] \right\}}} \quad (25)$$

Note that even though Equations (5) and (23) are almost equivalent they are

based on very different assumptions. In Equation (5) q_0 is the charge necessary in the ultimate antenna so that the median energy dissipated over half a period, U , is equal to $h\nu$. This is a result based purely on classical electrodynamics. The value of q_0 is almost equal to the elementary charge (to an accuracy less than 1%) and we assume that $q_0 = e$. However, the condition $q_0 = e$ is valid only if the value of U does not go below $h\nu$. However, classical electrodynamics does not place any restrictions on the value U and accordingly, it can take any value larger than zero. Indeed, one has to appeal to quantum mechanics to show that the minimum value of U cannot be less than $h\nu$. The statement $q_0 = e$ is based, therefore, on quantum nature of the electromagnetic radiation. Thus, Equation (23) is a result of the fact that electromagnetic radiation consists of photons.

Equation (23) can be rewritten while making ρ_Λ the subject as

$$\rho_\Lambda = \frac{3}{8\pi G \left\{ \frac{a_0}{4\pi c^2} \exp \left[\frac{4\varepsilon_0 hc}{e^2 \pi} - \gamma \right] \right\}^2} \quad (26)$$

Equation (26) is an expression for the energy density of vacuum in terms of well-known physical constants. If we substitute numerical values to these constants, we find $\rho_\Lambda = 4 \times 10^{-10} \text{ J/m}^3$ which is close to the measured value $6 \times 10^{-10} \text{ J/m}^3$. Indeed, this is the value we need in Equation (5) to make $q_0 = e$. Equation (26) can be considered as an alternative expression for the vacuum energy density.

In a glance, it is difficult to understand how the charge of an electron and the size of the steady state (or the ultimate) Hubble radius, as indicated by Equations (5) and (23), are connected. We believe that the relationship between the size of the universe and the elementary charge is a secondary relationship. As per Equations (5) and (23), the true primary connection is probably associated with the energy density of the vacuum and the elementary charge.

3.2. Time Domain Antenna

The results presented here are based on the work presented in references [1] [3] and [4]. However, there are a few differences in the definition of the parameters. For example, here, the duration of the radiation field is defined by analyzing the temporal variation of the power of the radiation field whereas in references [1] [3] [4] and [6] the duration is defined using the current waveform. This difference in the definition of the duration of the energy burst had caused a few percent change in the calculated value of q_0 . One more difference is the fact that in references [1] [3] and [4] the radiating antenna consists of a dipole whereas here a monopole antenna over a perfectly conducting ground is used. The aim here was to evade the problem of two current waveforms taking part in the radiation.

As in the case of the frequency domain antenna, a reduction in length of the antenna or an increase in the radius of the antenna will lead to a reduction in the energy dissipation. That means, to generate the same level of radiation as the ul-

ultimate antenna, the charge associated with the current has to increase. Thus, the relationship $A \geq h/4\pi \rightarrow q \geq e$ is satisfied by all time-domain radiating antennas. The relationship $A = h/4\pi \rightarrow q = e$ is valid for the ultimate antenna and the relationship $A > h/4\pi \rightarrow q > e$ is valid for any other antenna. Since the losses will decrease the amount of radiation generated by a given antenna, an antenna with losses requires a larger charge to maintain the same level of energy emission. Thus, the relationship $A > h/4\pi \rightarrow q > e$ is valid for all antennas even when the losses are included. One can indeed claim that the condition is universally satisfied by time domain antennas. It is vital to stress here again that these results are based purely on classical electrodynamics.

As in the previous case, one cannot conclude that the smallest free charge that can radiate is equal to the elementary charge by solely depending on the results obtained from classical electrodynamics. Actually, the quantization of the charge is observed about 30 years after the development of classical electrodynamics, and it is not a requirement in that theory. If we are interested in proving from the above relationship that the smallest free charge available in nature is the elementary charge, it is necessary to prove that the condition $U\tau_r \geq h/2\pi$ is satisfied by the radiated energy. Let us now investigate whether one can prove the condition $U\tau_r \geq h/2\pi$ is satisfied by the radiation emitted by the time domain antenna.

Consider an experiment in which the radiation emitted by a time domain antenna is utilized to estimate the location of the antenna. Now, for values of $1/\eta$ which are larger than about 10^5 , which indeed is the case under consideration, the z-component of the momentum transported by radiation is given by U/c [5]. Note that due to symmetry, the net momentum has only a z component. Let ΔU be the uncertainty in U . Then the uncertainty in the z-component of the momentum transported by the radiation is $\Delta U/c$. As the radiation is emitted, an equal but opposite momentum is transferred to the antenna. Consequently, the uncertainty in the z-component of the momentum of the antenna, Δp_z , will also be $\Delta U/c$. Recall also that the duration of the power emitted by the antenna is τ_r and under the conditions mentioned earlier this power is dissipated mainly along the z-direction. For this reason, the antenna can be located in the z-direction only to an accuracy of about $c\tau_r$, i.e. $\Delta z = c\tau_r$. These uncertainties must satisfy the position momentum uncertainty principle, i.e. $\Delta z \Delta p_z = h/4\pi$. Substituting for Δz and Δp_z in the latter we obtain $\tau_r \Delta U = h/4\pi$. Now, when the charge responsible for the radiation is on the order of the elementary charge, the uncertainty in the energy is comparable to the energy itself. This is the case, because the elementary charge is the smallest possible charge that can radiate. As a result, when the charge associated with the current is comparable to the elementary charge, the Heisenberg's uncertainty principle leads to $\tau_r U = h/4\pi$. When the charge associated with the radiation is larger than the elementary charge, the uncertainty in the energy becomes larger than the minimum uncertainty given above, and one can write $\tau_r U \geq h/2\pi$. Based on this

analysis, one can conclude that the condition $q \geq e$ is a consequence of the Heisenberg's uncertainty principle (see also reference [5]).

In deriving the above relationship, one had to make several assumptions concerning the definition of the duration of the radiation burst and the shape of the current pulse. For these reasons the inequality derived here can be considered as an order of magnitude approximation. It is important to point out that the results presented here are based on a Gaussian current pulse. Since we ultimately reduce the charge to an electron, the Gaussian pulse could be the most reasonable approximation to represent the charge associated with an electron. However, one can represent the current with other waveforms such as finite step, exponential decay etc. As pointed out in references [1] even with other current waveforms the order of magnitude of the relationship still holds. Note also that the smallest value of q for a give radiation level is obtained for the largest value of the Hubble radius. As the Hubble radius decreases, the value of q increases and hence the above inequality is not disturbed even when using a Hubble radius smaller than the steady state one (we will take up this point later).

In the analysis the current pulse is assumed to propagate with the speed of light along the antenna. It is vital to point out that what is propagating with the speed of light is the current pulse and not the individual charges themselves.

3.3. Transition Radiation

While estimating the maximum speed that a particle can have when confined to the Hubble radius we had to appeal to results obtained using quantum mechanics (*i.e.*, Heisenberg's uncertainty principle). Other than that, the derivation is based purely on classical electrodynamics. Following are the other significant points to be considered:

In the case of transition radiation, we have concluded that if $A \geq h/4\pi$ then $q \geq e$. As in the case of the transient antenna, one can show independently that the constraint $A \geq h/4\pi$ is satisfied by the transition radiation. The existence of such a constraint in nature can be understood by appealing again to the Heisenberg's uncertainty principle. Consider the charged elementary particle that will give rise to the transition radiation. The particle is moving along the z-axis with a well-defined speed and hence momentum. Due to Heisenberg's uncertainty principle its location is largely uncertain. At a particular time, the particle will interact with the perfectly conducting plane and gives rise to the transition radiation. Let us consider a hypothetical or "Gedanken" experiment in which the transition radiation itself is used to locate the position of the particle. Since the particle is moving very close to the speed of light, most of the radiation is emitted along the z-axis and the z-component of the momentum associated with the radiation is given by U/c . Due to the removal of energy as radiation from the particle, its momentum in the direction of z-axis will become uncertain by an amount equal to U/c . That is, the z-momentum uncertainty, Δp_z , of the particle will be about U/c . Let us now consider the accuracy with which the loca-

tion of the particle can be estimated. Since the transition radiation is generated over a time interval equal to τ_r , the z-location of the particle as estimated using this radiation will be uncertain by an amount equal to $v\tau_r$. That is, $\Delta z = v\tau_r$. These two uncertainties should satisfy the position-momentum uncertainty principle, and therefore

$$\tau_r v \frac{U}{c} \geq \frac{h}{4\pi} \quad (27)$$

For values of v close to the speed of light, it reduces to the equation

$$\tau_r U \geq \frac{h}{4\pi} \quad (28)$$

To obtain the uncertainty in the location of the particle, one can also appeal to the following argument. If one uses electromagnetic radiation of wavelength λ to locate a particle, it can be located only to an accuracy on the order of λ . Transition radiation, however, is a time domain pulse and its *effective wavelength* is about $\tau_r c$. Thus, the uncertainty in the position of the particle in the z-direction as estimated from the transition radiation is about $\tau_r c$. Use of this uncertainty in position and the uncertainty in the z-momentum estimated earlier in the uncertainty principle will also lead to Equation (28). In the previous section we showed that “if” the condition $A \geq h/4\pi$ is valid then $q \geq e$. Equation (28) indicates that the condition $A \geq h/4\pi$ indeed is satisfied by radiated energy. This makes it possible for us to derive an expression for the magnitude of the smallest free charge available in nature in terms of other physical parameters. For example, since the condition $A \geq h/4\pi$ is satisfied by the emitted radiation, we can consider Equation (22) as an expression for the magnitude of the smallest free charge available in nature. This equation predicts the elementary charge to an accuracy close to 1%.

4. Effects of Including the Time Dependent Hubble Radius

In our analysis, we assumed that the analysis of radiation from antennas and transition radiation is conducted in an epoch of the universe where the Hubble radius remains constant. Based on this assumption and appealing to two quantum mechanical concepts, we have derived several expressions for the elementary charge and the predictions of these equations agree within 1% with the measured value. We believe that this is the correct assumption to be made because in this epoch we will have a truly constant “Hubble constant” and Hubble radius. Moreover, such an assumption links the elementary charge to the energy density of vacuum which is a local parameter of the fabric of space in which the electrons are located. However, it is of interest to find out the consequences on the results if this assumption is relaxed. Assume that the radiation is analyzed in an epoch where the Hubble radius is still increasing with time. In this case, the expressions obtained for the magnitude of the elementary charge can be written as (with $R(t)$ denoting the Hubble radius at time t)

$$q_0 = \sqrt{\frac{4\varepsilon_0 hc}{\pi \{ \gamma + \ln(4\pi R(t)/a_0) \}}} \quad (29)$$

$$q_0 \approx \sqrt{\frac{\varepsilon_0 \pi^{1/2} ch}{2^{1/2} \ln\left(\frac{2R(t)}{a_0}\right)}} \quad (30)$$

$$q_0 \approx \sqrt{\frac{\varepsilon_0 \pi^{1/2} ch}{2^{1/2} \left[\ln\left(\frac{8R(t)}{3\sqrt{3}\alpha a_0}\right) - 1 \right]}} \quad (31)$$

Note that we have used the approximately equal sign (*i.e.* \approx) in Equations (30) and (31) because in deriving these two equations we had to appeal to the Heisenberg's uncertainty principle which provides an order of magnitude estimation of relevant quantities. Using the Friedmann equation, one can calculate how the Hubble radius varies as a function of time [9] [10]. **Figure 1(a)** presents the results of this calculation. The smallest age of the universe used in the calculation is 0.1 million years.

The Hubble radius increases with time and reaches a constant value decided by the vacuum energy density. If the values of q_0 in all the three examples are estimated using the Hubble radius corresponding to each epoch, the resulting values of q_0 as a function of the age of the universe for the three examples considered in this paper are depicted in **Figure 1(b)**. Even if we consider the variation of q_0 as a function of the age of the universe, one can still treat the relationships $U \geq h\nu \rightarrow q \geq e$ and $\tau_r U \geq h/4\pi \rightarrow q \geq e$ as the order of magnitude estimates. Further, the smallest value of q for a give radiation level is obtained

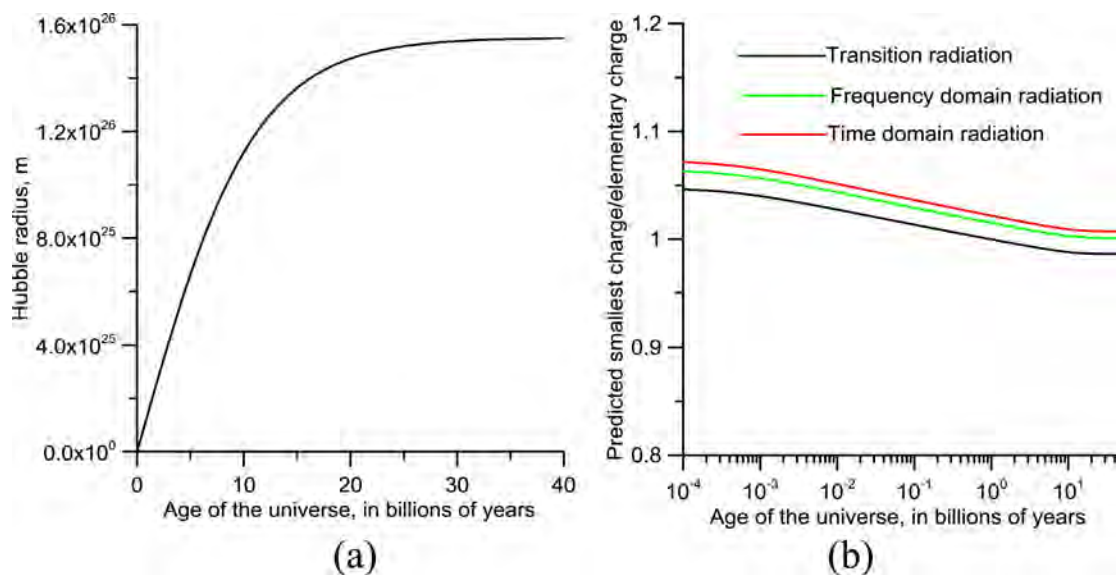


Figure 1. (a) The variation of Hubble radius with the age of the universe. (b) The variation of the estimated minimum charge, q_0 , for the three cases considered when the Hubble radius corresponding to the age of the universe is utilized. Note that the charge in **Figure 1(b)** is given as a fraction of the elementary charge. Also note that the current age of the universe is about 13.8 billion years.

for the largest value of the Hubble radius. As the Hubble radius decreases the value of q increases and for this reason the above inequalities are not disturbed when using a Hubble radius smaller than the steady state one. Of course, one can make the predicted charge and the fine structure constant to be independent of the age of the universe or the size of the Hubble radius by treating the speed of light as a variable inversely proportional to the Hubble radius while the impedance of free space remains constant. That is $cR(t) = \text{constant}$ and $\sqrt{\mu_0/\epsilon_0} = \text{constant}$. In this case, the speed of light will have a high value close to the beginning of the universe and decreases as the universe ages. We believe, however, that the correct procedure is to use the steady state Hubble radius in the calculation because this is the largest spatial radius in the universe that an observer can have within which the events taking place are in causal contact. In this case we predict a direct relationship between the elementary charge and the energy density of vacuum. This connection appears logical to us because the radiating electrons are located in a space and time controlled by the vacuum energy which in turn controls the ultimate size of the universe.

5. Summary and Conclusions

At present, the radius of the universe as given by the Hubble radius increases with time. Thanks to the vacuum energy this radius reaches a steady value as the time increases. This is the maximum value of the Hubble radius ever possible in the current universe. Let us denote this steady and maximum Hubble radius by R_∞ . The radiating systems to be considered here are located within R_∞ . The main results obtained for these radiating systems can be summarized as follows:

1) Consider an ideal antenna located over a perfectly conducting ground plane containing a sinusoidally oscillating current. Increase the length of the antenna to R_∞ and decrease the radius of the antenna to the Bohr radius. Now, reduce the magnitude of the oscillating charge in the antenna to the elementary charge. Then the energy generated within half a period will be reduced to $h\nu$. Based on this result, one can show that for any antenna with oscillating currents the radiated energy satisfies the inequality $U \geq h\nu \rightarrow q \geq e$ where U is the energy dissipated as radiation within half a period of the antenna and q is the oscillating charge in the antenna. It is also possible to utilize the results to extract an expression that connects the energy density of the vacuum to the elementary charge.

2) Consider an ideal antenna located over a perfectly conducting ground plane through which a current pulse propagates with speed of light in free space. Increase the length of the antenna to R_∞ and decrease the radius of the antenna to the Bohr radius. Let U be the energy radiated by the antenna and τ_r is the time over which this radiation is generated. Now, reduce the magnitude of the current so the charge associated with it becomes equal to the elementary charge. Then the action associated with the radiation $U\tau_r$ reduces to $h/4\pi$. Based on this result, one can show that for any antenna with transient currents the ra-

diated energy satisfies the inequality $U\tau_r \geq h/4\pi \rightarrow q \geq e$ where q is the charge in the transient current.

3) Consider a charged elementary particle that is moving with the maximum possible speed in the universe at a time when the Hubble radius has reached its steady value R_∞ . The particle strikes a perfectly conducting ground plane and the deceleration of the charged particle during this encounter gives rise to transition radiation. Let U be the energy dissipated in the transition radiation and τ_r is the time over which this radiation is generated. It can be proved that when the charged particle is an electron the action associated with the radiation $U\tau_r$ reduces to $h/4\pi$. Based on this result, one can show that the transition radiation generated by an accelerating or decelerating charged elementary particle satisfies the order of magnitude inequality $U\tau_r \geq h/4\pi \rightarrow q \geq e$ where q is the charge of the elementary particle. The inequality is satisfied to a high degree of accuracy by an electron. As far as an order of magnitude relationship, it is also satisfied by other elementary charged particles, namely muons and taus.

The inequalities derived in this paper are valid even if one considers any other epoch of the universe where the Hubble radius is still increasing and it is less than the steady state value. Based on the results, one can conclude that all radiating systems that generate frequency domain radiation satisfy the condition $U \geq h\nu \rightarrow q \geq e$ and all radiating systems that generate transient electromagnetic radiation satisfy the condition $U\tau_r \geq h/4\pi \rightarrow q \geq e$. These results, obtained purely using classical electrodynamics, when combined with basic quantum mechanical concepts show that the elementary charge and the vacuum energy are intimately connected.

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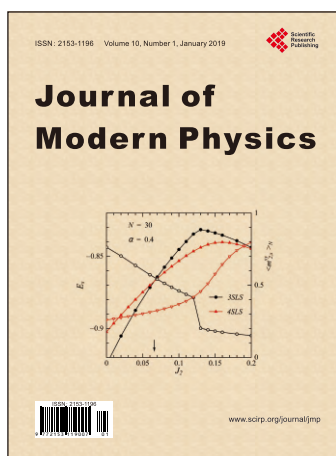
Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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