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MODELING OF AN APPEARANCE OF PARTICLE-WAVES AND THE UNIVERSE AS EXTREME WAVE RESONANT EVENTS

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The importance of nonlinear and resonant processes in the origin of quantum particles and our Universe is emphasized. On this basis, definitions are introduced for virtual and real quantum particle-waves (quantum particles). The resonant solutions describing the particle-waves of the scalar field (ϕ^4 field) are being connected with certain parameters of the origin and evolution of the Universe. A very simplified (qualitative) scheme of such unification and some illustrations to it is proposed.

The idea is used that elementary quantum particles are not point objects, but are local oscillations of fields, which are described by resonant solutions of the nonlinear Klein-Gordon equation (NKGE). The indicated approximate solutions qualitatively describe the appearance and motion, as well as certain properties of the particle-waves. On this basis, an attempt is made to explain the quantum entanglement and smallness of the vacuum energy. Quantum particles and antiparticles are described. The birth of the particle is not symmetric, although cases when they can annihilate each other are considered. The data of experiments based on the Casimir effect and described the appearance of elementary quantum particles are presented. In particular, in these experiments the appearance of particle-waves is associated with a resonant amplification of vacuum fluctuations in resonators. It is emphasized that similar processes could have taken place during the origin and evolution of the Universe. When considering the evolution of the Universe, it is assumed that resonant processes take place everywhere and constantly in all kinds of resonators of outer space. There, the balance of the appearance of real and virtual particles changes all the time and is, possibly, in the vicinity of zero. It is assumed that virtual particles determine the energy of the vacuum and the expansion of the space of the Universe. Real particles determine the compression of this space. Oscillations of the balance in the vicinity of zero give the predominance of the influence of compression or expansion of the space. As a result, the Universe may oscillate in the process of the expansion.

Key words: theoretical imitation; quantum particles; the Universe; scalar fields; Casimir effect; vacuum fluctuations; annihilation; quantum entanglement; quantum coupling; quantum action; asymmetry; false and true vacuums.

1. Modeling of particles – waves and some properties of quantum scalar fields.

Let us look at NKGE as a foundation for description of quantum particle – waves. We will construct a solution to this equation not by the perturbation method, but using, let it be a very rough, but initially nonlinear approximation [1–5]. Namely, we are looking for a solution that describes some spherical wave packets.

1.1. Approximate solutions for a scalar quantum field.

Until now obtaining of elementary particle images were notoriously difficult. It can be assumed that the particles are spherical. In particular, electrons are traditionally considered to be spherical. A group called ACME, led by David D. of Yale University and John D. and Gerald G. of Harvard University, found that the electron looks spherical with an accuracy of 0.00000000000000000000000000001 centimeter [6].

We write NKGE as follows

$$\Phi_{tt} - c_*^2 \sum_{n=1}^{N} \Phi_{x_n x_n} + m_1\Phi - \lambda_1\Phi^3 = 0. \qquad (1)$$

It can be assumed that this equation describes various scalar quantum fields and elementary quantum particles when coefficients c_*^2, m_1 and λ_1 have different values. Generally speaking, these coefficients are dependent on quantum fluctuations. However, this will not be taken into account considering the solutions of Eq. (1). We will take this

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dependence into account only analyzing consequences of the solutions (see sections 1.2–1.5 and 3). We introduce variable

$$r = R^2 - \sum_n^N (x_n - c_n t)^2 . \tag{2}$$

Here

$$R = R_0 + l\cos\Omega t \text{ and } R_t = -l\Omega\sin\Omega t . \tag{3}$$

and $R_0 >> l$. The variable (2) allows us to describe wave packets having spherical shapes. Since

$$\Phi_{tt} = [(R^2)_t + 2\sum_n^N (x_n - c_n t)c_n]^2 \Phi_{rr} +$$

$$+[(R^2)_{tt} - 2\sum_n^N c_n{}^2]\Phi_r ,$$

$$\varphi_{x_n x_n} = 4\varphi_{rr}[(x_n - c_n t)]^2 + 2\varphi_r \tag{4}$$

the equation (1) yields

$$\Phi_{rr}\{[(R^2)_t + 2\sum_n^N (x_n - c_n t)c_n]^2 -$$

$$-4c_*^2 \sum_n^N (x_n - c_n t)^2\} - [2c_*^2 N - (R^2)_{tt} + \tag{5}$$

$$+2\sum_n^N c_n{}^2]\Phi_r = -m_1\Phi + \lambda_1\Phi^3.$$

We shall consider a very strongly localized near points $R_0^2 = \sum_n^N (x_n - c_n t)^2$ solutions of (5).

It is assumed that the function Φ is a very fast variable in comparison with the coefficients of Eq. (5), which are considered below as weakly variable quantities C_1 and C_2:

$$C_1 = \left[\left(R^2\right)_t + 2\sum_n^N \left(x_n - c_n t\right)c_n\right]^2 - 4c_*^2 \sum_n^N \left(x_n - c_n t\right)^2,$$

$$C_2 = 2c_*^2 N - \left(R^2\right)_{tt} + 2\sum_n^N c_n^2. \tag{6}$$

In Eq. (5) quantities quantities C_1 and C_2 are considered as constants. As a result, Eq. (5) is rewritten as

$$C_1\Phi_{rr} + C_2\Phi_r = m_1\Phi - \lambda_1\Phi^3. \tag{7}$$

We obtained an ordinary nonlinear equation containing a viscous term. The solution of the linearized equation (7) is well known. It can be written as follows

$$\Phi = e^{-\gamma\omega r}(A_1 e^{i\omega\sqrt{1-\gamma^2}r} + A_2 e^{-i\omega\sqrt{1-\gamma^2}r}). \tag{8}$$

Here $\gamma = C_2 / 2\omega C_1$, $\omega = \sqrt{-m_1 / C_1}$. In the case $C_2 \neq 0$ this solution shows no oscillatory periodical wave but rather an exponential decay of the wave. In particular, solution (8) can describe the curves shown in Fig. 1.

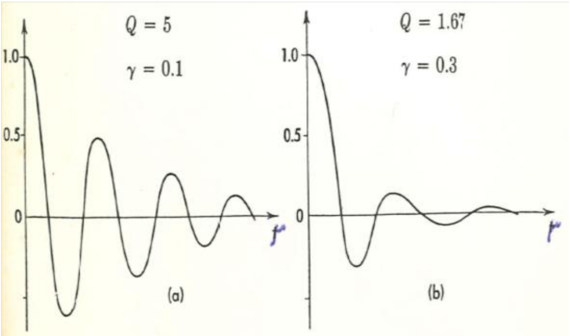


Fig. 1. Examples of damped harmonic oscillations, $Q = 1/2\gamma$

Further we will consider two expressions (namely (9) and (18)), as approximate solutions of Eq. (7). Both of these solutions qualitatively correspond to the linear solution (8).

1. Let [4, 5]

$$\Phi = A\,\mathrm{sech}\,Br\sin\bar{B}(r + \phi). \tag{9}$$

Here B, A, $\bar{B}$ are unknown constants, and ϕ is an arbitrary constant. Expression (9) determines the solution in the form of a sphere-like wave packet moving in a certain direction.

The solution (9) is intentionally written in the form of the oscillating soliton. In (9) $\sin\bar{B}(r+\phi)$ is the oscillating part of the wave packet, and $\mathrm{sech}\,Br$ is the envelope. Now we can find

$$\begin{aligned}\Phi_{rr} &= 2AB^2(1 - \mathrm{sech}^2 Br)\,\mathrm{sech}\,Br\sin\bar{B}(r+\phi) - \\ &- AB^2\,\mathrm{sech}\,Br\sin\bar{B}(r+\phi) \\ &- 2AB\bar{B}\,\mathrm{sech}^2 Br\sinh Br\cos\bar{B}(r+\phi) - \\ &- A\bar{B}^2\,\mathrm{sech}\,Br\sin\bar{B}(r+\phi).\end{aligned} \tag{10}$$

The expressions (9) and (10) are substituted in (7). Next, we equate the terms containing $\mathrm{sech}\,Br\sin\bar{B}(r+\phi)$ and find a following expression

$$B^2 - \bar{B}^2 = m_1 C_1^{-1}. \tag{11}$$

Equating the terms containing $\mathrm{sech}^3 Br\sin\bar{B}(r+\phi)$ we find three values

$$A = 0,\ A_\pm = \pm B\sqrt{8C_1\lambda_1^{-1}/3}. \tag{12}$$

Here the expression for $A_\pm$ can be real or imaginary, depending on the coefficients C_1, C_2, m_1 and λ_1 in Eq. (7).

Obviously, two real quantities $A_\pm$ determine 2 types of connected (similar) solutions (9). They describe two particle-waves existing at the same time. We emphasize that in solution (9) the value is ϕ an arbitrary constant. In other words, we can take for one particle-wave the following expression

$\Phi_+ = A_+ \operatorname{sech} Br \sin \bar{B}(r+\varphi_+)$ and

$$r = R^2 - \sum_n^N (x_n - c_n t)^2 . \qquad (13)$$

For another particle-wave we have

$\Phi_- = A_- \operatorname{sech} Br \sin \bar{B}(r+\varphi_-)$ and

$$r = R^2 - \sum_n^N (x_n - c_n t)^2 . \qquad (14)$$

In the general case, solutions (13) and (14) do not indicate any preferred localization of the place of the considered particle-waves. These wave particles can exist at the same point in space. They can be located as far from each other as desired. They can annihilate each other if they are located in the same place and $\varphi_+ = \varphi_-$. They can also weaken or strengthen each other, depending on the values of arbitrary constants ϕ_+ and ϕ_-.

We hope that the solutions (9), (11) and (12) give a qualitative description of the shape of wave packets (particle-waves) and the law of the motion of their in space. They contain several indeterminate constants and are limited, of course, by the ranges of application of using above assumptions and the initial equation (1).

If the scalar field and the scalar potential is known, one can calculate the energy pressure *p* and energy density ρ of this field according to expressions [7, 8]

$$p = \tfrac{1}{2}\Phi_t^2 - \tfrac{1}{6}(\nabla\Phi)^2 - V(\Phi), \qquad (15)$$

$$\rho = \tfrac{1}{2}\Phi_t^2 + \tfrac{1}{2}(\nabla\Phi)^2 + V(\Phi). \qquad (16)$$

We use the scalar potential $V(\Phi)$ presented as

$$V(\Phi) = \tfrac{1}{2} m_1 \Phi^2 - \tfrac{1}{4}\lambda_1 \Phi^4 + \bar{C}. \qquad (17)$$

Here $\bar{C}$ is a constant.

2. Let

$$\Phi = A \operatorname{sech}[B \sin \bar{B}(r+\phi)] \operatorname{sech}[B(r+\phi)]. \qquad (18)$$

Further we will only consider terms containing $A \operatorname{sech}[B \sin \bar{B}(r+\phi)] \operatorname{sech}[B(r+\phi)]$ or $A \operatorname{sech}^3[B \sin \bar{B}(r+\phi)] \operatorname{sech}[B(r+\phi)]$ in the expression for Φ_r and Φ_{rr}. The discarded terms are considered negligible. Then approximately

$$\Phi_r = -A \operatorname{sech}[B \sin \bar{B}(r+\phi)] B \sinh[B(r+\phi)],$$

$$\Phi_{rr} = \tfrac{1}{2} AB^2 \bar{B}^2 \{\operatorname{sech}[B \sin \bar{B}(r+\phi)] - 2 \operatorname{sech}^3[B \sin \bar{B}(r+\phi)]\} \operatorname{sech}[B(r+\phi)] - AB^2 \operatorname{sech}[B \sin \bar{B}(r+\phi)] \operatorname{sech}[B(r+\phi)]. \qquad (19)$$

The expressions (18) and (19) are substituted in (7). Next, we equate the terms containing $\operatorname{sech}[B \sin \bar{B}(r+\phi)] \operatorname{sech}[B(r+\phi)]$ and find a following equation

$$\tfrac{1}{2} C_1 AB^2 \bar{B}^2 - AC_1 B^2 - C_2 AB = m_1 A. \qquad (20)$$

Equating the terms containing $A \operatorname{sech}^3[B \sin \bar{B}(r+\phi)] \operatorname{sech}[B(r+\phi)]$ we find three real values

$$A = 0, \; A_\pm = \pm B\bar{B}\sqrt{C_1 \lambda_1^{-1}} . \qquad (21)$$

If $\bar{B} >> B$, then (20) and (21) yield

$$\tfrac{1}{2} C_1 B^2 \bar{B}^2 = m_1 \text{ and } A = 0,$$

$$A_\pm = \pm B\bar{B}\sqrt{C_1 \lambda_1^{-1}} . \qquad (22)$$

It is obvious that $A_\pm$ (22) defines two similar (related) solutions (18) of Eq. (7). In other words, we assume that (18) defines 2 types of related (similar) solutions. The first

$$\Phi_+ = A_+ \operatorname{sech}[B \sin \bar{B}(r+\varphi_+)] \operatorname{sech}[B(r+\varphi_+)]$$

$$\text{and } r = R^2 - \sum_n^N (x_n - c_n t)^2 . \qquad (23)$$

The second

$$\Phi_- = A_- \operatorname{sech}[B \sin \bar{B}(r+\varphi_-)] \operatorname{sech}[B(r+\varphi_-)]$$

$$\text{and } r = R^2 - \sum_n^N (x_n - c_n t)^2 . \qquad (24)$$

There is an analogy between solutions (9), (13), (14) and (18), (23), (24). Therefore, the comments related to solutions (9), (13), (14) and presented above fully apply to solutions (18), (23), (24). We emphasize that the solutions obtained above are so important for this study that we will devote special sections 1.2, 1.3, 1.4 and 1.5 to them.

1.2. Double quantum particles and quantum entanglement [9–12].

Recall that expressions (12) and (21) for $A_\pm$ can be real or imaginary depending on the coefficients C_1, C_2, m_1 and λ_1 included in Eq. (7). Thus, we assume that these coefficients are all the time under the influence of random quantum fluctuations, in the same way as an electron rotating in an atom is under the influence of random quantum fluctuations all the time. The creation of a pair of quantum particles is associated here with such quantum fluctuations, that instantly makes the quantity $A_\pm$ real (Fig. 2).

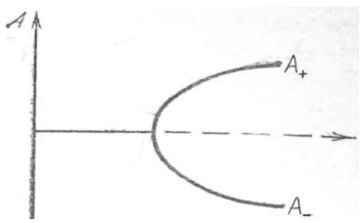


Fig. 2. Qualitative illustration of the results of section 1.1. At some values C_1, C_2, m_1 and λ_1 there is an change in the nature of solutions to Eq. (1). Instead of the zero solution, two real solutions appear describing a quantum particle Φ_+ and a quantum antiparticle Φ_-

Thus, we obtained two approximate solutions (9) and (18) describing various quantum wave packets, which we interpret as particle-waves. The expression (9) corresponds to a sign changing group of waves propagating in space. The expression (18) corresponds to a group of waves having positive or negative sign. These expressions can be associated with quantum particles and antiparticles.

Let us dwell on these particles. It is known that the main equation of quantum wave mechanics is the Schrödinger equation. It describes a wave function that, when interpreted probabilistically, approximates a set of experimental data. One of the limitation on the use of the Schrödinger equation is well known. It is not applicable if the speed of the quantum particle is close to the speed of light. To describe relativistic particles, one must use the Dirac equation (it was obtained in 1928 by the English physicist Paul Dirac). It turned out that the Dirac equation has two solutions with different signs: a solution with a plus sign corresponds to the positive energy, a solution with a minus sign – the negative energy. Dirac, in order to explain the existence of the second solution, suggested that in addition to particles, there are so-called antiparticles. Later it turned out that Dirac's solutions correspond to two real particles – an electron and a positron.

It also turned out that two solutions are inherent not only to the Dirac equation, but also to other equations describing relativistic particles. Sometimes it turns out that the particle is the antiparticle of itself. It takes place if the two solutions of the equation coincide. For example, if $\phi_+ = 0$ and $\phi_- = \pi$, then expressions (13) and (14) begin to describe the same particle. It is known also that the simplest and most well-known NKGE describes solitary waves (solitons). Moreover, there are two solutions that differ only in sign. So that they do not annihilate each other, Galiev suggested that they may have some spatial or temporal shift relative to each other [4, 5]. This shift can occur due to quantum uncertainty, both the localization and the lifetime of the specified wave particles (the Heisenberg uncertainty principle states that it is impossible to know the position and momentum of a particle with absolute accuracy. The more accurately you measure one quantity, the less you know about another quantity). Thus, according to the equations of Dirac and NKGE, particles can exist only in pairs. Moreover, the mathematical expressions for them can differ in only one parameter, for example, a sign. Consequently, if we have determined the properties of one particle from the pair, then we can determine the parameters of another particle from the pair without capturing or studying it specially!

Let us explain this situation using a well-known interpretation (analogy). Namely, a pair of solutions to the Klein-Gordon equation may be considering as a pair of gloves. If we find somewhere one glove of the pair, then when we find another glove corresponding to it, we do not even need to consider it, since we know its shape in advance. Moreover, the accuracy of such a prediction is 100%. There is no uncertainty (probability) in this prediction.

The resulting result may have to do with the quantum teleportation. The quantum teleportation is the ability to transfer the quantum state of one particle of a pair to another particle of a pair instantly at any distance. Thus, it is implicitly assumed that it is possible to transmit an information faster than the speed of light. Many experiments confirm the possibility of the quantum teleportation. However, the theory of it is based on the probabilistic interpretation of quantum mechanics and the results of the experiments violate the principle of locality. According to it the state of an object can be influenced only by its close environment.

This "contradiction" is associated with Einstein – Podolsky – Rosen paradox (EPR paradox) and constitutes one of the main conceptual difficulties of quantum mechanics (at least in its Copenhagen interpretation). Thus, if we proceed from NKGE (1) and reject the probabilistic interpretation of the wave function in quantum mechanics, then the effect of quantum entanglement of particle-waves is explained by the results presented above. If we have a particle-wave described by solution (13) (or (23)), then we should not be surprised that we also know the parameters of the particle-wave corresponding to solution (14) (or (24)) (see also section 1.5). Thus, our purely approximate study supports the point of view EPR, not the Copenhagen school on the issue of the quantum entanglement.

1.3. Quantum energy of vacuum (energy of virtual particles).

Generally speaking, the scalar fields described by NKGE (1) can be different and describe different particles which can have different energies. Particle – waves are produced in pairs (positive and negative), as is known for fermions. Their sum may be nonzero. The possibility of the specified existence of a nonzero value of the sum can be called virtual.

It is known that the energy of quantum vacuum fluctuations in total can be unimaginably large, close to infinity [12, 13]. It is very interesting that if a positive value is attributed to the total vacuum energy, then its action in space will manifest itself in the form of a force of universal repulsion. Thus, the vacuum energy can be associated with Einstein's cosmological constant Λ, which is included in Einstein's equations and explains the nonstationarity of the Universe. This value can be measured experimentally. It turned out that this constant has an order of 10^{-120}. Thus, there is a colossal large discrepancy between the theoretically determined vacuum energy and the cosmological constant. This discrepancy is one of the greatest mysteries of modern cosmology [12, 13].

We will come back to this puzzle in sections 1.5 and 4.

1.4. Calculations illustrating the obtained solutions and describing particle-waves.

We received the approximate solutions that can be physically interpreted in different ways. It was assumed that these solutions describe certain quantum waves which correspond to so-called quantum particles (particle-waves). Examples of such quantum particles constructed according to solution (18) for five instants are shown in Fig. 3.

It is important that Fig. 3 models a particle – wave having a spherical shape and a rectilinear trajectory of motion. Let us consider the movement and interaction of these particles. Three moments of the movement of a particle-wave (left) and interaction of particle-waves (right) are shown in Fig. 4.

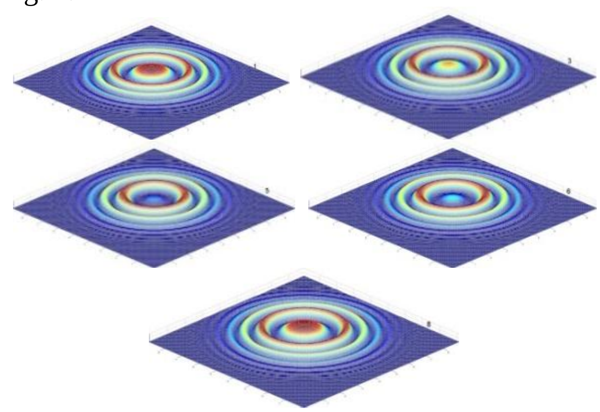


Fig. 3. Two-dimensional presentation of the wave packet calculated for five moments of the time

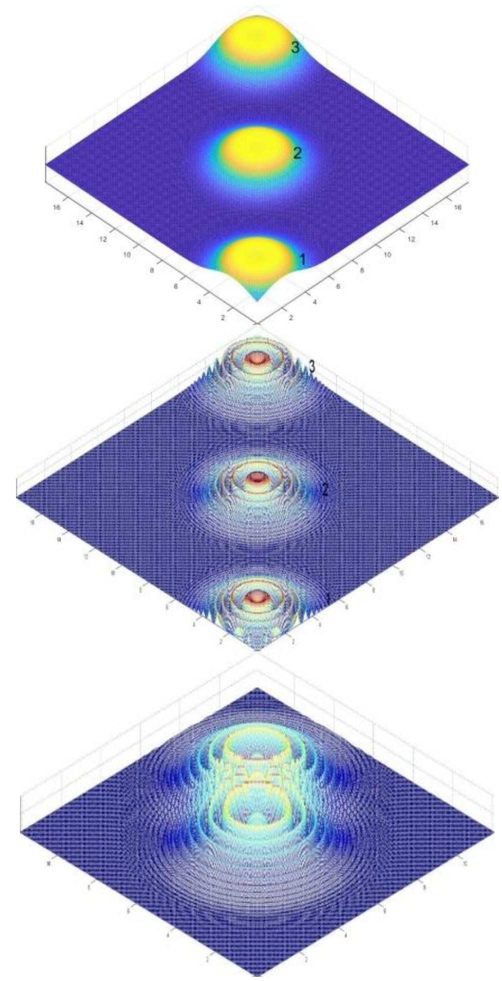


Fig. 4. 2D picture of particle (its envelop) motion calculated for 3 instants of the time (upper). 2D picture of wave packet motion calculated for 3 instants of the time (centre). 2D picture of the interaction of two wave packets (bottom)

It can be seen from Fig. 4 that the motion of quantum particles and interaction of them may be presented as the motion and interaction of the particle-waves. Thus, it was shown that it might be possible to model certain aspects of quantum theory on the basis of self-consistent, scalar fields, where quantum particles are only concentrations of density of the fields. We remind that the words “quantum mechanics” mean “wave quantum mechanics”.

We emphasise that the wave function (Figs. 3 and 4) does not correspond to the wavefunction well- known in quantum mechanics (solutions of the Schrödinger’s equation). It is not also some kind of “pilot wave” (de Broglie-Bohm model). It is a nonlinear wave with a periodically oscillating centre which is strongly localized near centre. According to Fig. 3 during the half-cycle the wave packet can be approximately considered as a particle, during the next half-period it is a typical wave packet. According to our approach any wave packet (“particle”) influences the whole Universe and all “particles” of the Universe influence the wave packet.

Generally speaking, we can find the “mass” m of the wave packet according to de Broglie’s theory ($m = \hbar\lambda^{-1}v^{-1}$, $\hbar$ is the Planck’s constant, λ is the wave length and v is the wave speed).

One can see that we do not agree with the Copenhagen interpretation of quantum theory, developed in the 1920s mainly by physicists Niels Bohr and Werner Heisenberg. They treat the wavefunction as nothing more than a tool for predicting the results of observations, and cautions physicists not to concern themselves with what the reality looks like underneath.

1.5. Are these illustrations to quantum entanglement and quantum coupling?

Here we associate the vacuum energy with the particle-waves. In general, they can also be virtual. Moreover, the particles appear in pairs and they can have different signs. Therefore, on the one hand, they can unnihilate each other. In this case, the vacuum energy is zero. However, some random, temporal or spatial, very small, shift of the arising particles from each other is possible. As a result, a certain finite, of course very small (but not zero), energy value may appear. This value characterizes the result of the interaction of the particles of the pair under consideration.

Thus, the location of particle-waves (9) is known approximately up to Planck's constant (the same for particle-waves (18)). Consequently, these two solutions fluctuate randomly relative to each other all the time. In order to get at least some idea of virtual particles, we give the results of calculations based on the solution (9) using this fact. We will assign the sign + to the positive wave packet, and assign the sign – to the negative wave packet. The results of the calculations are shown in Fig. 5.

Thus, the vacuum energy resulting from the partial annihilation of the particles of these pairs can be very small. It can correspond to the cosmological constant included in Einstein's equations. If this is accepted, then we are extending a bridge in a certain sense connecting the general theory of relativity with quantum wave mechanics.

We have considered some of the consequences from Eq. (1). The birth of particle-waves from "nothing", which we have considered, looks somewhat unusual from the point of view of classical physics. But for quantum mechanics, this result is not very new. We have already mentioned Dirac's solutions. The experiments described below (section 3) also confirm this possibility. Let us emphasize that there are developed theories describing the birth of the Universe from “nothing” [12, 13].

Note that in the context of the Universe, apparently, Fred Hoyle was the first to point out the possibility of the formation of matter from "nothing". This idea underlies his theory of a stationary universe which he successfully opposed the Big Bang theory for almost 20 years, namely, from about 1948 to 1968 (Steady State Cosmology) [14].

In addition to the one considered here, we will mention another option for elimination of the annihilation of the pairs. Near the black hole, one particle from the pair will be "eaten" by the black hole, and the second will be able to escape according to the theory of Stephen Hawking

At the same time, we are wondering – maybe the existence of the expressions like solutions (9) and (18) is somehow connected with the quantum entanglement and quantum coupling.

Remark. According to Fig. 5, virtual fluctuations are determined by two peaks – positive and negative. They can be qualitatively described by an expression $\varphi(\Phi) = \operatorname{sech}^2 \bar{\xi} \sinh \bar{\xi}$ (see the right part of Fig. 5). We will use this expression in Eq. (29) (see also (31)).

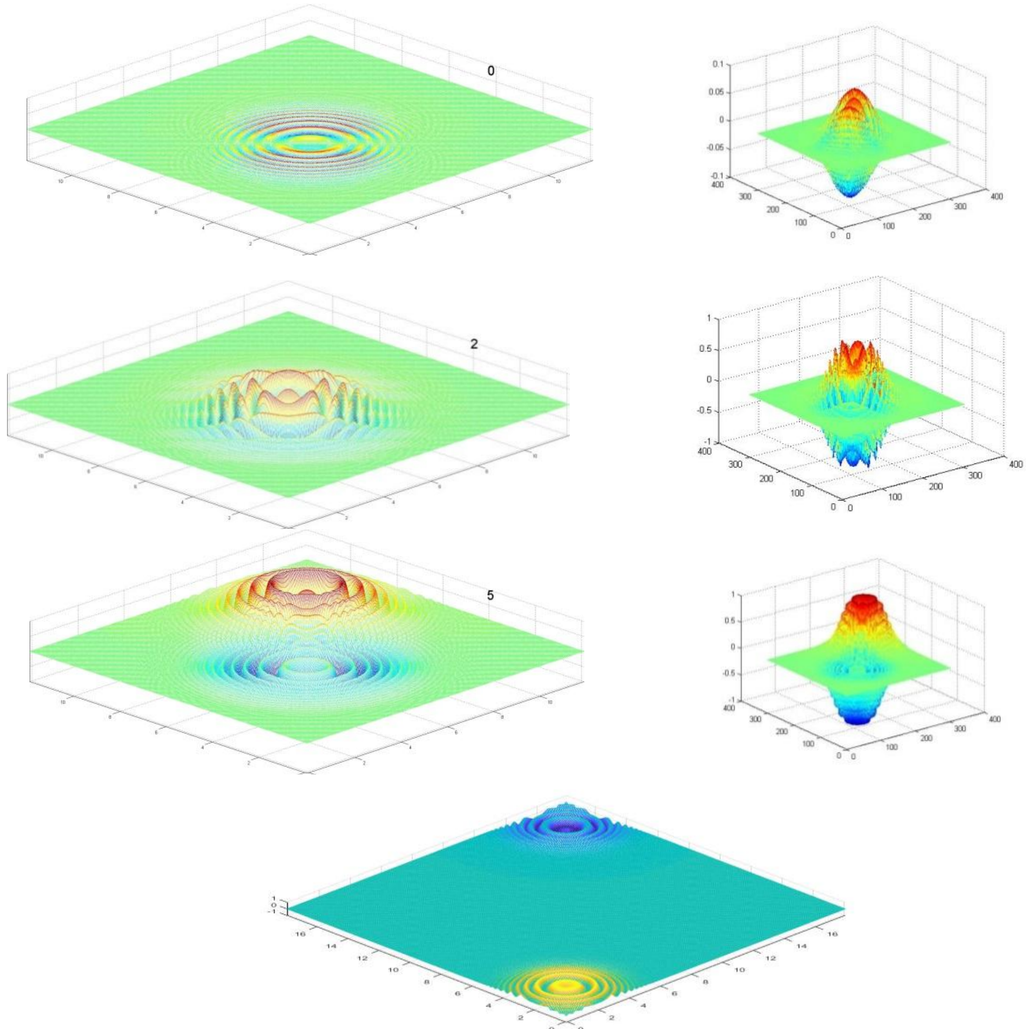


Fig. 5. Above 3 versions of particles-waves having different space shifts of the corresponding solutions are presented. The sum has zero energy if the shift is zero. The sum can begin to exhibit properties of energy if the shift of the solutions has the Planck length order. At the bottom is the example of the particles-waves separated by large space. Cases when particles, that give birth as a pair only partially annihilate, are considered as cases of the birth of virtual quantum particles. The case when the particles, that give birth as a pair, do not interact in any way (no annihilation), corresponds to the birth of a particle and an antiparticle (Dirac's case)

2. Modelling of quantum actions.

It is known, that the vacuum is not “empty”, but filled with virtual particles that are very difficult to register, but under certain conditions they become real – for example, when an external field of high energy is applied or when high speed particle-waves interact.

The problem is to describe the influence of the quantum fluctuations on the scalar field. How can we introduce a quantum action to describe the evolution of an element of the scalar field?

Recall that we began to consider this issue in section 1. It was shown that expressions (12) and (22) for $A_\pm$ can be real or imaginary depending on the coefficients C_1, C_2, m_1 and λ_1 included in Eq. (7). The origin of a pair of quantum particles is associated with such quantum fluctuation that instantly yields the values $A_\pm$.

Here we will develop above results using the idea of Hawking [15].

He introduced quantum fluctuations in the right side of the wave equation. As a result, he got $(-\Box+\mu^2)G(x,y)=\delta(x,y)-(3/8\pi^2)H^4$. In general, this equation does not contradict modern ideas. For example, an equation similar to the Hawking equation and resembling Eq. (1) is discussed in [16, 17]. The equations of scalar fields containing quantum fluctuations are considered in books [18, 19].

We use the idea of Hawking following [4, 5].

2.1. Theory.

We will assume that the initial value of the scalar field is equal to zero to simplify as much as possible the study of the appearance of particle-waves.

The question is posed, how the zero solution Φ=0 ((12) and (21)) transforms into cases Φ≠0. For mathematical modeling of the problem, we introduce the variable

$$\xi = Br. \qquad (25)$$

Then Eg. (7) gives

$$C_1\Phi_{\xi\xi} + C_2B^2\Phi_\xi + m^2\Phi - \lambda\Phi^3 = 0. \qquad (26)$$

Here

$$m^2 = m_1B^2 \text{ и } \lambda = \lambda_1 B^2. \qquad (27)$$

Let us take as the most important assumption that the appearance of quantum particles is associated with very local and short-term quantum fluctuations at a point $\overline{\xi} = Br_0$ and its vicinity [1–5, 20, 21]. Consider a point $\overline{\xi} = Br_0$ and a very small neighbourhood of it. In this region, we will approximate solutions (9) and (18) as

$$\Phi = A\operatorname{sech}\xi. \qquad (28)$$

Thus, we will neglect the presence of field oscillations inside the particle-wave at the moment of its emergence from "nothing" due to quantum fluctuations. That is, we keep the envelope (see Fig. 4) of solutions (9) and (18) in order to qualitatively show the possibility of their occurrence.

In the case of the action of a quantum perturbation on a point $\overline{\xi} = Br_0$, Eq. (26) can be rewritten as

$$C_1\Phi_{\xi\xi} + C_2B^2\Phi_\xi + m^2\Phi - \lambda\Phi^3 = \varphi(\Phi)\tilde{A}\delta(\overline{\xi}). \qquad (29)$$

Here $\overline{\xi}$ is a point subjected to the quantum action ϕ(Φ), $\delta(\overline{\xi})$ is the Dirac delta function, $\tilde{A}$ is the amplitude of the quantum fluctuation. The function ϕ(Φ) is arbitrary.

Expression (28) is substituted into Eq. (29). We will consider the field in the vicinity of $\overline{\xi}$. It is assumed that there the value of the field can change discontinuously as a result of the quantum kick (fluctuation). This discontinuous change in the field is computed by integrating (29) from $\xi_j = \overline{\xi} - \varepsilon$ to $\xi_{j+1} = \overline{\xi} + \varepsilon$:

$$\begin{aligned} &C_1[\Phi_\xi(\overline{\xi}+\varepsilon) - \Phi_\xi(\overline{\xi}-\varepsilon)] + \\ &+C_2B^2[\Phi(\overline{\xi}+\varepsilon) - \Phi(\overline{\xi}-\varepsilon)] \\ &+\int_{\overline{\xi}-\varepsilon}^{\overline{\xi}+\varepsilon}(m^2A\operatorname{sech}\xi - \lambda A^3\operatorname{sech}^3\xi)d\xi = \\ &= \tilde{A}\int_{\overline{\xi}-\varepsilon}^{\overline{\xi}+\varepsilon}\varphi(\Phi)\delta(\overline{\xi})d\xi. \end{aligned} \qquad (30)$$

This equation is rewritten using (28). Let

$$\varphi(\Phi) = \operatorname{sech}^2\overline{\xi}\sinh\overline{\xi}. \qquad (31)$$

As a result we have

$$\begin{aligned} &C_1[-(A\operatorname{sech}^2\xi\sinh\xi)_{\overline{\xi}+\varepsilon} + (A\operatorname{sech}^2\xi\sinh\xi)_{\overline{\xi}-\varepsilon}] \\ &+C_2B^2[-(A\operatorname{sech}\xi)_{\overline{\xi}+\varepsilon} + (A\operatorname{sech}\xi)_{\overline{\xi}-\varepsilon}] \\ &+2m^2[(A\operatorname{argtan}(\exp\xi))_{\overline{\xi}+\varepsilon} - (A\operatorname{argtan}(\exp\xi))_{\overline{\xi}-\varepsilon}] \\ &-\tfrac{1}{2}\lambda[(A^3\operatorname{sech}^2\xi\sinh\xi)_{\overline{\xi}+\varepsilon} - (A^3\operatorname{sech}^2\xi\sinh\xi)_{\overline{\xi}-\varepsilon}] \\ &-\lambda[(A^3\operatorname{argtan}(\exp\xi))_{\overline{\xi}+\varepsilon} - (A^3\operatorname{argtan}(\exp\xi))_{\overline{\xi}-\varepsilon}] = \\ &= \tilde{A}\int_{\overline{\xi}-\varepsilon}^{\overline{\xi}+\varepsilon}\operatorname{sech}^2\overline{\xi}\sinh\overline{\xi}\delta(\overline{\xi})d\xi. \end{aligned} \qquad (32)$$

Let ε→0. Further we will study only cases when $(A)_{\overline{\xi}+\varepsilon} >> (A)_{\overline{\xi}-\varepsilon}$. Thus the cases will be considered when, at some value C_1, the amplitude A experiences a jump. Before the jump, we have that $(A)_{\overline{\xi}+\varepsilon} >> (A)_{\overline{\xi}-\varepsilon}$. If ε is extreme close to zero, then the right side of (32) yields $\tilde{A}\operatorname{sech}^2\overline{\xi}\sinh\overline{\xi}$.

First we collect the terms with

$$(\operatorname{sech}^2\xi\sinh\xi)_{\overline{\xi}+\varepsilon}. \qquad (33)$$

As a result we have an equation linking $A_{\overline{\xi}}$ and $\tilde{A}$,

$$A_{\overline{\xi}}^3 + 2\lambda^{-1}C_1A_{\overline{\xi}} + 2\tilde{A}\lambda^{-1} = 0. \qquad (34)$$

Then we collect the terms with

$$\operatorname{argtan}(\exp\xi)_{\overline{\xi}+\varepsilon}. \qquad (35)$$

In this case the equation (32) approximately yields that

$$m^2 = \tfrac{1}{2}\lambda(A_{\overline{\xi}})^2. \qquad (36)$$

Thus, we have the algebraic equation (34) coupling the nonlinear properties of the field, the amplitude of the quantum action and coefficient $2C_1$. If $\tilde{A} = 0$, then (34) yields the solution similar to the former solutions (12) and (22) for the field (see Fig. 2 too).

However, generally speaking, Eq. (34) can have discontinuous solutions. Of course, the discontinuous solutions are only for certain values of the coefficient $2C_1$ and $\tilde{A}$, λ^{-1}. Let us consider conditions determining an origin of the discontinuous solutions.

Remark. We wrote the quantum fluctuation in (29) as (31). This presentation is in qualitative agreement with the analysis of section 1.5 (see right pictures in Fig. 5).

2.2. Eruption of a quantum particle as a jump in a scalar field.

Our aim in this section to study the influence of $2C_1$ and $\tilde{A}$ on solutions of the equation (34). Effects of λ^{-1} are also analysed [1-5].

Instant jump. We recall that R, x_n, c_n and c_* in (6) are arbitrary values which determine the coefficient $2C_1$. This coefficient will be considered as a variable. The solutions of (34) also depend strongly on effects of nonlinearity (the coefficient λ) and $\tilde{A}$.

If $\tilde{A} = 0$, then we have from (34) the zero solution $A_{\bar{\xi}} = 0$, as well as two real solutions, if $2\lambda^{-1}C_1 < 0$, or two imaginary solutions, if $2\lambda^{-1}C_1 > 0$. In general, the case $\tilde{A} = 0$ gives results similar to those presented in section 1 (see (12) and (22)). The situation changes if there is an action of quantum fluctuations ($\tilde{A} \neq 0$). In this case, it becomes possible the existence of discontinuous solutions to Eq. (34), and the amplitude of the jump depends on the amplitude of the quantum action $\tilde{A}$.

A scheme of the described situation is shown in Fig. 6, where the value $2C_1$ is plotted along the horizontal axis. We assume that $\lambda^{-1} > 0$ [22]. Recall that if $\tilde{A} = 0$, then we have from (34) the zero solution $A_{\bar{\xi}} = 0$, as well as two real solutions, if $2C_1 <$ 0, or two imaginary solutions, if $2\lambda^{-1}C_1 > 0$.

Now consider a very weak quantum effect when $\tilde{A} = 10^{-21}$. In this case, Eq. (34) has real solutions for practically any $2C_1$. Namely, one solution if $2C_1 > 0$ and three solutions, if $-2C_1 > 10^{-18}$ (see Fig. 6A). In this case, there is a rather weak jump on the curve consisting from segments 1, 4 and 5 of Fig. 6A.

The situation changes for strong enough quantum actions ($\tilde{A} = 10^{-19}$). In this case, we can construct discontinuous multivalued solutions of (34) with strong jump (see a composite discontinuous curve consisting from segments 1, 4 and 5 or a composite discontinuous curve consisting from segments 2, 4 and 5 in Fig. 6B). These discontinuous multivalued curves (solutions) are also illustrated by the corresponding smooth segments in Fig. 6C.

Full typical nonlinear picture of roots of the equation (34) is shown in Fig. 6. We assumed that $\tilde{A} = 10^{-19}$ (B and C). If approximately $-2C_1 > 4\cdot10^{-18}$, there are three different real solutions of (34) (segments 1, 2 and 3). If approximately $-2C_1 < 4\cdot10^{-18}$, the solution is determined by one curve, which is composed from the segments 4 and 5 (see Fig. 6B and C). The jump takes place approximately at the point $2C_1 = -4\cdot10^{-18}$.

It is important that the jump to the positive values experiences fields having negative amplitudes (segments 1 and 2). It is seen that values of these fields (segments 1 and 2) may be very different. However, during the jump, these fields coalesce, and begin to interact in such a way that they form a new field corresponding to the segments 4 and 5. For them $-2C_1 < 4\cdot10^{-18}$ (Fig. 6B).

So we have presented in Fig. 6 the curves determining the amplitude of the function $\Phi = A\,\text{sech}\,\xi$ (28) for some value ξ. Generally speaking, the equation (34) determines the amplitude A as a function of the parameters included in C_1 (6). These parameters link ξ with time t and coordinates x_i (see (25) and (2)). Depending on the coefficient $2C_1$ Eq. (34) can define five different segments. The segments 1, 2 and 3 correspond to three different real roots of Eq. (34).We will call these roots as A_1, A_2 and A_3. They were found for $\lambda = 10^{-15}$. In this case, we found that the action ($\tilde{A} = 10^{-19}$) increases instantly the amplitude of the function $\Phi = A\,\text{sech}\,\xi$ up to the order of 0.1. On the contrary, if quantum action is small enough ($\tilde{A} = 10^{-21}$), the dynamic part remains practically unchanged. The jump is very small or it is missing (see, as an example, Fig. 6A).

The field amplification depends strongly on the coefficient of nonlinearity λ. The smaller λ, the larger amplification. For example, if $\lambda = 10^{-80}$ and $\tilde{A} = 10^{12}$ then $A_{\bar{\xi}}$ is of the order of 10^{31}. If $\lambda = 10^{-120}$ and $\tilde{A} = 10^{12}$ then $A_{\bar{\xi}}$ is of the order of 10^{44} (Fig. 7).

We studied also the influence of the nonlinearity and the amplitude $\tilde{A}$ on the size of the discontinunuous jump. According to our calculations, the field reaches the values of the order of 10^{-7}, when $2/\lambda = 10^4$ and $\tilde{A} = 10^{-25}$. If $2/\lambda = 10^{20}$ and $\tilde{A} = 10^{-18}$, then the jump was of order 10. If $2/\lambda = 10^{-20}$ and $\tilde{A} = 10^{-38}$, then the jump was of order 10^{-19}. Thus, the jump depends strongly on $\tilde{A}$ and λ. At the same time, we found that the jump amplification of the scalar field was proportional to $2\tilde{A}/\lambda$. For any λ^{-1} this amplification can change approximately from $10^{20}\tilde{A}$ to $10^{17}\tilde{A}$. Thus, the scalar field can be greatly amplified as a result of weak-enough quantum action.

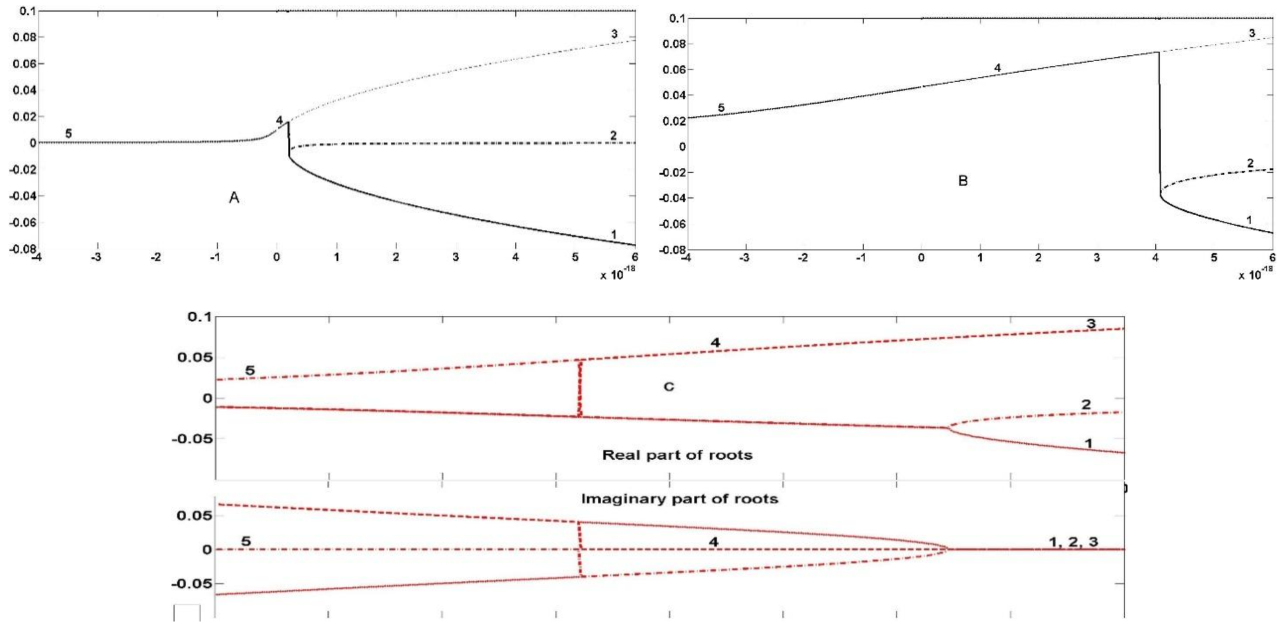


Fig. 6. Typical nonlinear picture of the amplitudes of the dynamic part calculated for $\lambda=10^{-15}$, different values $2C_1$, $\tilde{A}=10^{-21}$ (A) or $\tilde{A}=10^{-19}$ (B and C). The curves show and explain the formation of the discontinuous solutions of (34)

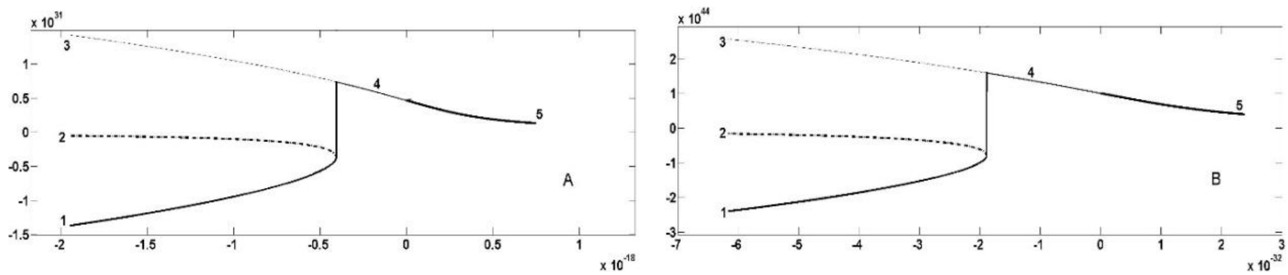


Fig. 7. Examples of extreme amplification of the amplitude of the dynamic part calculated for $\lambda=10^{-80}$ (A) and $\lambda=10^{-120}$ (B) when $\tilde{A}=10^{12}$. The horizontal axis corresponds to different values of $-2C_1$. The curves show and explain the formation of the discontinuous solutions of Eq. (34)

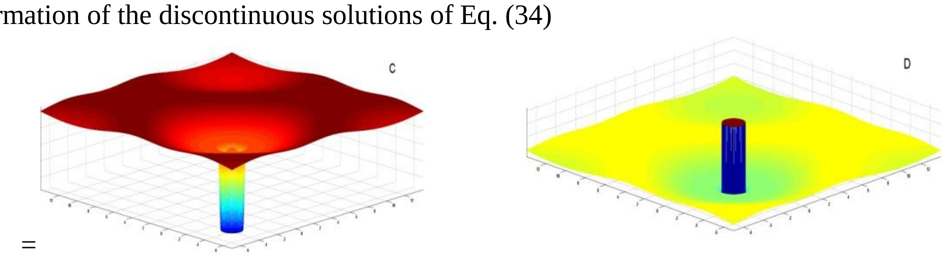


Fig. 8. Rough scheme of the jump. The pictures demonstrate the scalar landscape before the jump (C) and the results of the jump (D)

Imitation of the origin of the particle-waves. Let us qualitatively illustrate the jumps of the scalar field. Of course the landscape of the scalar field is changed at the moments of the jump. We tried to give an idea of this change in Fig. 8.

We recall that basic laws of quantum mechanics are applicable for our analysis. In particular, it is well known [7, 8] that the energy density and the energy pressure of the scalar field depend on derivatives, and the scalar potential (see (15), (16) and (17)). Thus, the density and pressure can increase infinitely in the points of discontinuity.

Remark. Coefficient C_1 (6) depends on the initial parameters of the field, which can also vary due to quantum uncertainty. Thus, the creation of a particle is a completely random process, but it takes place only when some of the most important, in our opinion, condition for the coefficient C_1 is fulfilled. With it, a jump takes place. Let us call this condition – resonance.

2.3. Non-symmetry of quantum particles and antiparticles

Consider Fig. 5–7 from a slightly different point of view. Recall that the solutions of section 1 describe particles and anti-particles, which, in the cases indicated there, can annihilate each other when they arise. It is remarkable that such possibility disappears if the quantum fluctuations manifest itself perturbing the coefficients in Eq. (1). Quantum fluctuation can also manifest itself as the right-hand term in Eq. (29). In this case, Eq. (29) has one real solution plus two complex solutions or three real solutions (Figs. 6 and 7). Thus, this equation shows the possibility of the emergence of one quantum particle or three quantum particles. Moreover, two of the last three particles have the same sign!

This result is fundamentally different from the one obtained in section 1 on the basis of Eq. (1). In particular, all real roots shown in Figs. 6 and 7 are nonzero.

Thus, from the results of section 2 follow that one quantum particle (see curves 4 and 5) or three quantum particles (see curves 1, 2 and 3) can appear in the Universe at the same time. At any pair consisting from a particle and an antiparticle, the contribution of the particle is always greater than the contribution of the antiparticle.

This result can qualitatively explain the weak presence of antimatter in the Universe. On the other hand, this result, possibly, is somehow related to the presence of "dark" matter in the Universe.

At the same time, in the case of very weak quantum fluctuations, the results of sections 1 and 2 practically coincide. Apparently, in the modern Universe, scalar fields are so weak that, basically, quantum particles appear according to Paul Dirac.

3. The Casimir effect and the resonant nature of the particle-wave generation from vacuum

Next, we will consider experiments in which the fact of the emergence of quantum particles from vacuum (from "nothing") is firmly established. We emphasised that during the experiments the particles move almost in a vacuum (for example, 10^{-8} mbar in [23]).

In 1948 year, Dutch theorist Hendric Casimir predicted that a generalized version of van der Waals forces would arise between two metal plates (or conducting materials) due to quantum fluctuations of the electromagnetic field (Fig. 9). When Casimir first calculated the effect, he used perfect "ideal" conductors. Later, more detailed calculations showed the effect for realistic conductors, and in 1997 the effect was confirmed experimentally. The most recent experiments get results to within 1% of the theoretical result. Strange as it is, the Casimir effect is very real. The Casimir effect is a great example the strangeness of quantum theory, and how even some of its strangest predictions turn out to be true [24–26].

Photons (energy) from nothing. More recently, Chris Wilson et al. [24] have tried to prove another eccentric prediction: that it is possible to use the effect to release latent energy. Instead of allowing the fluctuations to tug on the plates, you rapidly force the plates together to squeeze their wavelengths – and force out photons (see Fig. 9).

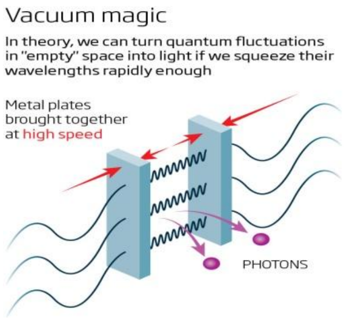


Fig. 9. This scheme illustrates a prediction on how to pull energy from empty space and produce light [25]

Generally speaking, in this experiment vacuum fluctuations manifests itself only indirectly. However, possibly, taking into account nonlinear and resonant coupling of purely virtual particles allow to detect effects origination of them [26].

The acoustic Casimir force. The term acoustic Casimir force (ACF) refers to the force between two parallel plates when they are placed in an acoustic random field [26]. This is a classical analogue of the quantum Casimir force that results from quantum vacuum fluctuations. Unlike the unbounded spectrum of the quantum case, the ACF has very interesting physical consequences. The most significant being that the ACF changes from attractive to repulsive depending on the plate separation and the frequency bandwidth.

It might be considered the schemes shown in Figs. 9 and 10, as some sources of the real particle-waves. If we excite one plate with certain resonant frequency of the system, perhaps, the real particles will be radiated in this case more effectively.

Conclusions and comments on sections 1–3: A. We emphasise that during certain time, when the interaction is absent, all particles move in a vacuum. Thanks to the uncertainty principle, the vacuum buzzes with particle-antiparticle pairs popping in and out of existence. Pairs include, among many others, electron-positron pairs and photons, which are their own antiparticles. Ordinarily, those "virtual" particles cannot be directly captured. But like some spooky Greek chorus, they exert subtle influences on the "real" world. For example, the virtual photons fitting in and out of existence produce a randomly fluctuating electric field. In particular, in 1947, physicists found that the field shifts the energy level of an electron inside a hydrogen atom and hence the spectrum of radiation the atom emits. Thus, the vacuum is not "empty", but filled with virtual particles that are very difficult to register, but under certain conditions they become real – for example, when an external field of high energy is applied or when high speed particle-waves interact. According to our theory cases when particles, that give birth as a pair only partially annihilate, are considered as cases of the birth of virtual quantum particles. The case when the particles, that give birth as a pair, do not interact in any way (no annihilation), corresponds to the birth of a particle and an antiparticle (Dirac's case).

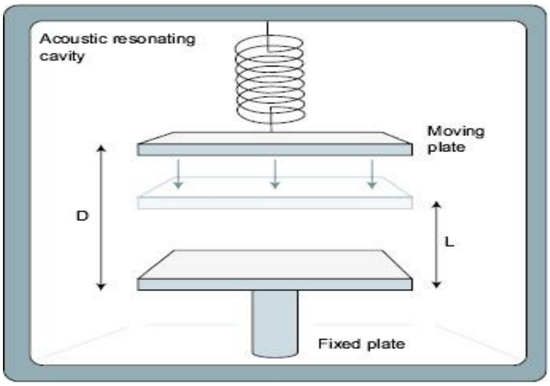


Fig. 10. Simple-lumped one-degree-of-freedom system considered in the calculation of the acoustic Casimir force [26]

B. It can also be assumed based on the experiments presented above that the production of particles is associated with the resonance effect and resonators. If the plates move away from each other, the effect disappears (at high modes it usually weakens and disappears).

C. According to section 1, we can assume that when a real quantum particle appears in the resonator (for example, between the plates), then its twin may appear somewhere in a neighbouring galaxy. Those are as far away as you like. Or maybe this explains the inequality of particles and antiparticles observed in the Universe.

D. Outside the resonators, the virtual vacuum particles randomly oscillate with respect to each other, and the virtual vacuum particles all the time arise and disappear randomly. It is seen from the Casimir effect. Chaotic quantum oscillations become more ordered in the resonators. Therefore, there vacuum field gains energy, mass, and pressure. The field obtains certain parameters that are outside the resonator almost zero. Perhaps the situation resembles the situation with electromagnetic waves. It took their resonant amplification in the experiment Hertz. Only then did they show up. However, the vacuum energy resulting from the partial annihilation of the particles can be very small. It can correspond to the cosmological constant included in Einstein's equations. If this is accepted, then we are extending a bridge in a certain sense connecting the general theory of relativity with quantum wave mechanics.

E. At the same time, we are wondering – maybe the existence of the expressions like solutions (9) and (18) is somehow connected with the quantum entanglement and quantum coupling.

F. Virtual particles and the normal matter are interrelated environments.

G. The possibility of the absence of symmetry in the birth of quantum particles has been shown in sections 1 and 2. Perhaps this asymmetry explains the weak presence of antimatter in the observable Universe. On the other hand, this result, possibly, is somehow related to the presence of "dark" matter in the Universe.

4. Imitation of the origin of the Universe

We have considered the motion and appearance of elementary quantum particles in a certain rough approximation. It was assumed that particles arise in a vacuum due to quantum fluctuations. Based on the solutions given and Fig. 6 and 7, we can represent the appearance of a particle as an instantaneous receipt of significant energy by a certain finite volume of a field. This sharply distinguishes this volume from the rest of the field and corresponds to the birth of a real particle-wave (Fig. 8). According to section 1, pairs of quantum particles can arise that are spatially arbitrarily far from each other. The resulting volume can have tremendous energy, which is determined both by the resonance condition, and by the initial energy of the field itself and the nature of the quantum fluctuation.

In [1–5, 20, 21, 27, 28] an attempt is made to extend the approach described above to the case of the origin of the Universe from the pre-universe. It is assumed that the material of the pre-universe has a very high nonlinearity, very high density and energy. It is difficult to say anything about the speed of light in such a medium (the speed of light corresponds to the speed of photons), but, in principle, its speed can be even less than the speed of sound. Perhaps this material has some similarities with Bose – Einstein condensate (in terms of nonlinear properties and the speed of light) and with the plasma of the very early Universe, in which, apparently, the speeds of light and sound were of the same order of magnitude.

There are not many problems in science, the ways of solving which are absolutely not visible. These include the problem of the origin of the observable Universe. It is emphasized that 4 Nobel prizes have been awarded for achievements in the study of the early Universe over the past two decades, however there are many problems with its origin. To a large extent, this is due to the fact that an experimental repetition of this event is impossible, and the observational data cannot be interpreted unambiguously. Therefore, the researchers are building and investigating mathematical models of the origin. There are many theories of the origin of the Universe, which can be approximately divided into 3 groups. 1st. Universe is unique and emerged from a singularity or some finite volume; 2. May be many universes. The observable Universe emerged from the pre-universe or a metaverse. 3. The Universe arose out of nothing [2, 13, 14, 29].

It is important that the recent results of the Planck satellite and other observations [8, 29, 30] are favorable for modeling the earliest Universe using the wave equations, in particular, nonlinear equation of the Klein-Gordon type [15, 32–35]. Indeed, at the early stage of the existence of the Universe, waves existed (appeared) in it, similar to waves in resonators [36–44].

Thus, the very early Universe vibrated like certain condensed matter in some kind of resonator (figuratively speaking, like a spherical bell). Is it possible that the very fact of the origin of the Universe is associated with wave and resonance effects that took place in the pre-universe [2–5, 27, 34, 35, 37–45]? In [1, 3, 20, 21], it was proposed to use a simple scalar wave field model to describe the origin of the Universe from some pre-universe, using certain ideas from the theory of extreme waves [2, 4, 5, 27, 45].

It is proposed to use the same equation of the scalar field (ϕ^4 field), both for describing the pre-universe, and for describing the tunnelling from it of a finite clot of field, which, after some evolution to four dimensional space-time, begins to rapidly expand due to the formation of more and more "elementary" particle-waves [1–3]. The main assumptions and stages of the evolution of the Universe from the pre-universe are: 1. The pre-Universe exists in multidimensional space-time. This pre-Universe is described by a scalar field that has its own structure. The field is roiled by the quantum fluctuations; 2. At any moment the pre-universe gives birth to billions of ‘seeds’ of rapidly evolving universes, one of which accidentally evolved into our Universe; 3. The Universe sprang into existence due to quantum fluctuations that fragment some multidimensional scalar ‘seed’ into vibrating elements having very high energy. 4. The elements are modelled as one-dimensional strings; 5. Highly nonlinear oscillations (waves) of those elements emitted very heavy particles of mass and energy which formed the four-dimensional spacetime. Our Universe appeared with huge energy, mass and the finite size; 6. The spacetime began to spread very rapidly as more and more particles appeared and the heavy particles began breaking up into lighter particles and the energy continued to transform into mass. It was the Universe’s rapid growth spurt [33].

Thus, a strict sequence of stages in the evolution of the Universe arising from the pre-universe is being built. Namely, solutions of NKGE are found that describe billions of "seeds" of rapidly developing universes. Most of them are Planck-sized ‘flicker’ universes, which blink in and out of existence. However, there are some universes that evolve to a large size. One of them accidentally formed our Universe with the fundamental parameters that we have. We rejected the starting point of the Universe from a singularity. The pre-history of the Universe is introduced instead of the singularity.

Apparently every element of the model has some analogue in the modern theories of cosmology. However, the continuous picture of the origin is constructed.

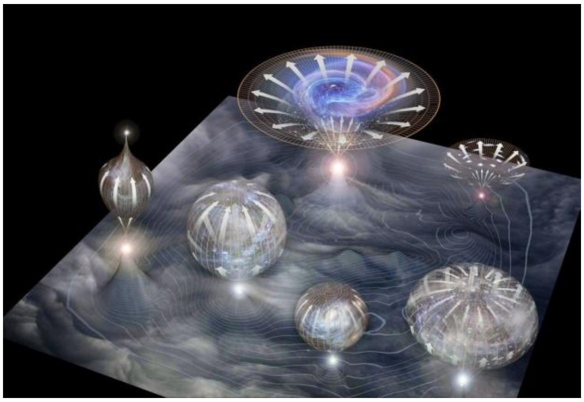
Of course, the picture described is highly dependent on the accuracy of the NKGE solutions used and their interpretation.

4.1. Imitation of the origin of the Universe

The above analysis of the appearance of quantum particles is applicable to the case of origin of the Universe. This possibility was highlighted ([45], page 493 and [5], page 485). It is assumed that the scalar field exists which is described by Eq. 1. This equation contains 3 coefficients that can characterize the field and solutions. We assume that they can vary over a very wide range to describe different types of scalar fields and vacua. In particular, according to Vilenkin [13], there are 3 types of vacuum: electro-weak vacuum, the grand-unified vacuum and the ordinary (true) vacuum. The electroweak vacuum and the grand-unified vacuum have an unimaginably high energy density and, perhaps, do not take place in our Universe. They are named a false vacuum. This vacuum can exist in the pre-universe.

It is impossible to indicate the constants in Eq. (1) for this case. However, in order to somehow deal with them, we assume that the equation and its coefficients correspond to the energy density of the electroweak vacuum. This energy corresponds to the density of the pre-universe material of the order 10^{19} tons per cubic centimeter. The space dimension is much higher than our 4-dimensional space-time. Thus, n in (1) is much more than 3.

The theory of origin of the Universe based on the use of NKGE is presented in [1–3, 45]. It describes a pre-universe that has some stationary structure consisting of the energy wells. Clots of a scalar field vibrate in them. These clots jump out (tunnel) from potential energy wells under the action of quantum fluctuation if a certain resonance condition is met. It is important that the equation describing this process differs from (29) only in coefficients. The corresponding jumping out of the energy clot from the multidimensional pre-universe is also described by an equation of the form (34) and the corresponding curves do not differ qualitatively from those presented in Figs. 6 and 7. We can consider Figs. 6, 7 and 8 as the extremely crude scheme of this origin. According to (15)–(17), the Universe can emerge having practically infinite energy and mass due to the jump. It is interested to note that the scheme reminds the drawings presented in Fig. 11.



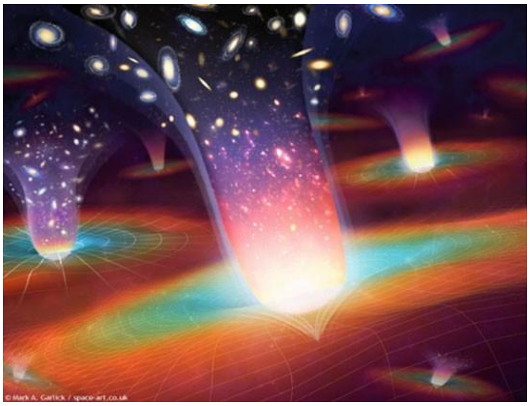
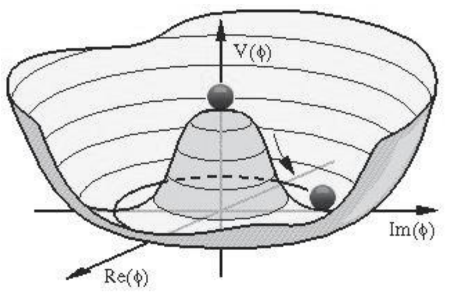
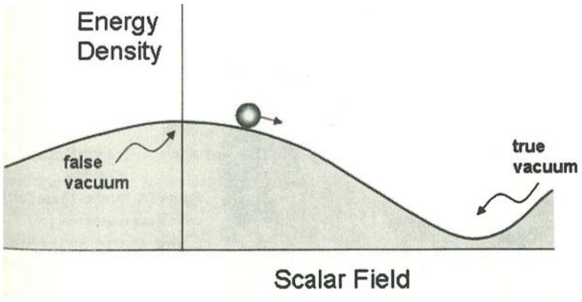


Fig. 11. Rough schemes of “eruption” of universes from a pre-universe. The left image is taken from http://news.nationalgeographic.com/news/2014/03/140318-multiverse-inflation-big-bang-science-space. The right image was presented in a few sources, for example in [2]



A



B

Fig. 12. As a result of the jump the clot of energy appears on the energy hill (A). The Universe arises in the process of rolling of the clot and its oscillations at the bottom of the landscape determined by the value of the true vacuum (B) [2, 13]

As a result, we get a starting point for the implementation of one of the scenarios of the inflationary theory proposed by Linde [33]. The key idea of Linde's theory is that the clot of energy of the scalar field is located on a hilltop at the very beginning of the Universe (Fig. 12). This is the starting point for inflation. Linde and other researchers do not indicate how the clot got to the top of the hill. We can assume that this is the result of a quantum jump (tunneling) of the clot from the pre-universe according to Eq. (34) [1–3]. Thus, a very small volume of the material, similar to an electroweak vacuum, changes to a new vacuum state like grand-unified vacuum (Fig. 12). It is possible that a result the density increases approximately by a factor 10^{48}. According to Vilenkin [13] the space of this grand-unified vacuum, of course, instantly disintegrates.

Thus, the multidimensional quantum space in a particle – wave loses its stability and it disintegrates into a set of particle-waves having a lower dimension. In papers [1–3], the case of instantaneous appearance of a cloud of one-dimensional particle-waves is considered. They have such a high energy that they cannot exist in isolation, and on scales larger than the Planck length they form 4-dimensional space-time [13].

The process could be visualised by imagining a three-dimensional drop of oil impacting the surface of water. As a result of the impact the oil drop is separated into many elements (particles) which spread over the two-dimensional surface of water. These elements of oil occupy in the two-dimensional space much bigger volume than they had in the initial moment. It is important that the elements became more isolated from each other comparing to when they were inside the drop.

The spacetime appeared as some sort of large scale construction of more fundamental elements. The spacetime properties appear from the underlying physics of its constituents, just as water's properties emerge from the particles that comprise it. The Universe had properties that could not be found in the individual elements forming it.

Thus, at the moment of the start, the Universe had dimensions much larger than the Planck length. Subsequently, a very rapid slide of the Universe from the top of the energy hill takes place and its long evolution. It is largely identical to that described for the cosmic inflation and the theory of the Big Bang.

Let us dwell on one more extremely important point of view. It can be assumed that the matter of the pre- universe consists of negative matter (antimatter) corresponding to a very energetically strong scalar field. Let it corresponds to curve 1 in Figs. 6 and 7. Consider the effect of quantum fluctuations on this field. Then, according to the equation (34), the solution corresponding to curve 1 can instantly jump onto the curve 4 and be at the top of the energy hill (Fig. 12) having a positive sign!, that is, correspond to the normal matter. Of course, in the process of the subsequent evolution of particles of normal matter, particles of antimatter could arise. However, their number can be expected to remain much less than the amount of normal matter, as is observed in the modern Universe.

Scheme of the Universe evolution after the jump. The evolution scenario of the scalar field subjected to a quantum fluctuation presented above can be viewed as describing the origin of the Universe. The Universe appeared as a result of the jump of the clot from a pre-universe. The Universe instantly obtained almost infinite energy. At the same time the space dimensions of the Universe lost the stability. During this process the initial field was being fragmented into almost infinite quantity of highly energetic one-dimensional elements which oscillated at resonant frequencies. The waveforms of these resonant oscillations were highly nonlinear and emitted particles of energy and matter. The individual elements noted above were only one-dimensional 'shards' of space and time. The three-dimensional space and time emerged only after the appearance of enough matter forming this spacetime.

The appearance of time and the three-dimensional space did not mean that the expansion of the Universe stopped. It continued to possess a huge amount of energy. High energy elements vibrating with resonant frequencies continued to generate particles of matter. Of course, the energy of those vibrations kept reducing. Therefore the particles appeared with less and less energy. On the other hand the high-energy particles that appeared earlier were breaking up into smaller-energy particles. As a result the Universe was being filled by the particles more and more familiar to us. The temperature and the primordial matter of the very early Universe appeared. Evolution and interaction of different particles of this matter were described by different interacting scalar fields [2].

4.2. Oscillating Universe

Let us try to describe and illustrate some of the properties that the very early Universe possessed and globally represent the path of its evolution based on the results presented above for particle-waves.

Due to the disintegration of the false vacuum space at the start moment, the Universe had dimensions much larger than the Planck length. In particular, atoms and atomic clusters begin to form resonators of different sizes almost immediately.

Experiments based on the Casimir effect show that virtual quantum particles and real quantum particles appear in natural resonators (see Figs. 5 and 8–10). Apparently, in the depths of intergalactic space, where there is almost no normal matter (resonators), these effects do not manifest themselves.

Indeed, it is known that approximately 1 cubic meter of intergalactic space contains on average 1 proton and 200,000,000 photons. There are no resonators in similar vacuum, so virtual particles appear in pairs and almost always unnihilate each other. Therefore, the energy of the true vacuum is practically zero. Almost complete symmetry is fulfilled there. At the same time there are millions of different type resonators in Nature – from the Universe to microwave cavities and atoms. It was emphasised that the symmetry is broken in resonators, so real (material) particles can appear there. Consequently, they arise near and inside stars and planets. The influence of natural resonators can become noticeable there. For example, for plates having the size of a playing card and located 0.0001 cm apart, the force (Casimir force) is approximately equal to the weight of one dew drop. Such forces can occur in a variety of resonators. However, apparently, given the colossal volume of vacuum in the Universe, the influence of the appearance of virtual particles in cosmic resonators on the energy of the entire Universe is extremely small. It is important for us that it is possible to link the existence of the cosmological constant with the appearance and disappearance of these virtual particles in the resonators.

At the same time, particles of normal matter also appear all the time in resonators, ensuring the emergence of more and more matter and resonators in the expanding Universe. The situation is reminiscent of Fred Hoyle's stationary model of the Universe. The model, despite expansion, remains practically static due to the constant appearance of matter in space. Hoyle did not provide an explanation for the origin of this matter.

Thus, we associate the emergence of new matter in the proposed model of a nonstationary Universe with the creation of quantum particles in cosmic resonators. We again emphasize that at the same time the virtual particles appear in the resonators, which determine the cosmic constant, which pushes (increases) the space of the Universe. This is hindered by the constantly emerging matter. According to what has been said, there is always a struggle of two opposite tendencies in the Universe. This is the tendency to contraction, associated with the birth of new matter in space (in resonators), and the tendency to expand space, associated with the birth of virtual particles in resonators and the cosmological constant determined by them. We believe that the struggle between these two trends can lead to the fact that the process of expansion of the Universe can have an oscillatory character (Fig. 13).

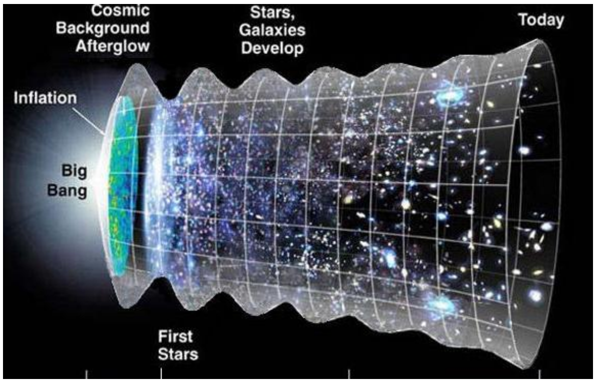


Fig. 13. The Universe itself may be oscillating through billions of years of cosmic time [46]

Let us emphasize a certain analogy between the indicated oscillations of the Universe and the motion of some galaxies. It is known that the motion of galaxies is determined by both attraction of them and repulsion according to the Hubble law. Therefore, nearby galaxies, if the mutual attraction is large enough, can approach each other, although globally the systems of galaxies are constantly moving away from each other. For some cases of such close galaxies, the sum of approach and expansion can change sign with time. It is the same way as the sum of the above opposite tendencies associated with the appearance of particles in cosmic resonators changes. Variation of the last sum can determine noted oscillations of the Universe.

Concluding comments. Of course, many researchers are getting used to the oddities of the quantum world, especially the researchers who have been working with the concepts for many years! But still this is a very, very strange world [47]! And over the years this situation has not been simplified. Quantum mechanics suggests that nature seethes with nonlocal “spooky actions”. Remote, apparently disconnected things can be “entangled”, influencing each other in mysterious ways. On the other hand, there are the oddities associated with the origin of the Universe!

May be need to consider these oddities together? Maybe the oddities of the quantum world can shed light on the oddities of the origin of the Universe? An attempt is made here to jointly consider some oddities. We based on the previously developed theory of extreme waves [2, 4, 5, 45].

We have presented an example of a unified theory describing certain phenomena in quantum theory and in space, as resonant and nonlinear phenomena. In the theory, there are no infinities, instead of the equations of general relativity, the equation of a scalar field is used, and quantum effects correct Steady State Cosmology and determine the birth of the Universe.

Of course, certain results, ideas and pictures like Figs. 8 and 11–13 may be considered as some wild speculations connected with unsolved problems of science. Indeed, some cosmological theories may appear crazy. But the society should get accustomed to them. The pictures like 11 and 13 should help us to understand better those crazy ideas. On the other hand the scientific art which were showed in Figs. 11 and 13 could popularize scientific ideas and results which are not supported up to this moment fully by experiments and observations [8, 11–13, 29, 31, 32, 33, 44, 47].

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МОДЕЛИРОВАНИЕ ОБРАЗОВАНИЯ ЧАСТИЦ-ВОЛН И ВСЕЛЕННОЙ КАК ЯВЛЕНИЙ ЭКСТРЕМАЛЬНОГО ВОЛНОВОГО РЕЗОНАНСА

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В статье подчеркивается значение нелинейных и резонансных процессов в процессе образования квантовых частиц и нашей Вселенной. На основе этого вводятся определения виртуальных и реальных частиц-волн (квантовых частиц). Резонансные решения, описывающие частицы-волны скалярного поля (ϕ^4 поле), связываются с некоторыми параметрами возникновения и эволюции Вселенной. Предложены упрощенная (качественная) схема подобной связи и ряд иллюстраций к ней. Применена идея о том, что элементарные квантовые частицы представляют собой не точечные объекты, а локальные колебания полей, описываемые резонансными решениями нелинейного уравнения Клейна–Гордона. Указанные апроксимальные решения качественно описывают возникновение и движение частиц-волн, а также некоторые их свойства. Исходя из этого, сделана попытка объяснить квантовую запутанность и малую величину энергии вакуума. Описаны квантовые частицы и античастицы. Рождение частиц не симметрично, хотя возможны случаи их взаимного аннигилирования. Приводятся экспериментальные данные, основанные на эффекте Казимира и описывающие образование элементарных квантовых частиц. В частности, в этих экспериментах возникновение частиц-волн объясняется резонансным усилением вакуумных флуктуаций в резонаторах. Указано, что подобные процессы могут также иметь место при возникновении и эволюции Вселенной. При рассмотрении эволюции Вселенной выдвинуто предположение, что резонансные процессы постоянно происходят в любых резонаторах космического пространства. При этом все время меняется баланс возникающих реальных и виртуальных частиц, возможно, в окрестности нуля. Известно, что виртуальные частицы определяют энергию вакуума и расширение пространства Вселенной. Реальные частицы определяют сжатие этого пространства. Колебания баланса в окрестности нуля обусловливают преобладающее влияние либо сжатия, либо расширения. Таким образом, не исключено участие колебаний в процессе расширения Вселенной.

Ключевые слова: теоретическое подражание, квантовые частицы, Вселенная, скалярные поля, эффект Казимира, колебания вакуума, аннигиляция, квантовая запутанность, квантовая связь, квантовое действие, асимметрия, ложный и истинный вакуум.