A NEW APPROACH TO STUDY OF QUANTUM VACUUM - DARK ENERGY

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Short contents

Quantum vacuum and dark energy

Quintessence is a hypothetical form of dark energy, more precisely a scalar field postulated as an explanation of the observation of an accelerating rate of expansion of the universe, rather than due to a true cosmological constant. The first such scenario was proposed by *Ratra and Peebles (1988)*.

According to the approval of modern quantum field theory, quantum vacuum is the place of fluctuating particles and fields of all types, where, however, the mean value of both is zero.

Hence it can be concluded that the vacuum is a specific energetic medium that is characterized by physical parameters and a structure that continuously permeates the entire length of the universe.

Now, the question is how to describe the vacuum?

Our main goal is to substantiate the equation for describing a quantum vacuum and to prove the possibility of the existence of massless particles, from which the quintessence must consist.

The quantum equation of a single photon

Using the obvious similarity between a neutrino and a photon, the following two first order equations of the Weyl type can be written for a photon in an ordinary vacuum:

$$i\hbar\,\partial_t \boldsymbol{\Psi}^{\pm}(\mathbf{r},t) \mp c_0\big(\mathbf{S}\cdot\frac{\hbar}{i}\boldsymbol{\nabla}\big)\boldsymbol{\Psi}^{\pm}(\mathbf{r},t) = 0, \qquad \partial_t \equiv \partial/\partial t, \tag{1}$$

and also;

$$\nabla\cdot\boldsymbol{\Psi}^{\pm}(\mathbf{r},t) = 0. \tag{2}$$

where c_0 denotes the speed of light, $\boldsymbol{\Psi}^{+}$ and $\boldsymbol{\Psi}^{-}$ denote the wave functions of photons of both helicities, a left-hand $+1$ and right-hand -1, respectively. In addition, $\boldsymbol{S} = (S_x, S_y, S_z)$ denotes the set of matrices consisting of components:

$$S_x = \begin{pmatrix} 0 & 0 & 0 \\ 0 & 0 & -i \\ 0 & i & 0 \end{pmatrix}, \quad S_y = \begin{pmatrix} 0 & 0 & i \\ 0 & 0 & 0 \\ -i & 0 & 0 \end{pmatrix}, \quad S_z = \begin{pmatrix} 0 & -i & 0 \\ i & 0 & 0 \\ 0 & 0 & 0 \end{pmatrix}.$$

Recall that the wave function has the following form:

$$\boldsymbol{\Psi}^{\pm}(\mathbf{r},t) = \frac{1}{\sqrt{2}}\left\{\frac{\mathbf{D}(\mathbf{r},t)}{\sqrt{\epsilon_0}} \pm i\,\frac{\mathbf{B}(\mathbf{r},t)}{\sqrt{\mu_0}}\right\}, \qquad c_0 = \frac{1}{\sqrt{\mu_0\epsilon_0}}, \tag{3}$$

Using the equations (1) and the representation (3), Maxwell's equations for electromagnetic fields in ordinary vacuum can be obtained:

$$\begin{aligned} &\partial_t \mathbf{D} - \nabla \times \mathbf{H} = 0, \qquad \nabla \cdot \mathbf{E} = 0, \\ &\partial_t \mathbf{B} + \nabla \times \mathbf{E} = 0, \qquad \nabla \cdot \mathbf{H} = 0, \end{aligned} \tag{4}$$

where ϵ_0 and μ_0 describe the dielectric and magnetic constants of the vacuum, respectively. It is important to note that the dielectric and magnetic constants provide the following equations:

$$\mathbf{D} = \epsilon_0 \mathbf{E}, \qquad \mathbf{B} = \mu_0 \mathbf{H}.$$

Recall that the only difference between equations (1) and (4) is that, the system of Maxwell equations does not take into account the spin of the photon, that will be important for further reasoning.

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$$\mathbf{D} = \epsilon_0 \mathbf{E}, \qquad \mathbf{B} = \mu_0 \mathbf{H}.$$

Recall that the only difference between the equations of (1) and (5) is that, the system of Maxwell equations does not take into account the spin of the photon, that will be important for further reasoning.

Equations of unperturbed quantum vacuum fields

Let us consider of vector fields:

$$\boldsymbol{\psi}^+(\mathbf{r},t) = \begin{bmatrix} \psi_x^+(\mathbf{r},t) \\ \psi_y^+(\mathbf{r},t) \\ \psi_z^+(\mathbf{r},t) \end{bmatrix}, \qquad \boldsymbol{\psi}^-(\mathbf{r},t) = \begin{bmatrix} \psi_x^-(\mathbf{r},t) \\ \psi_y^-(\mathbf{r},t) \\ \psi_z^-(\mathbf{r},t) \end{bmatrix}, \tag{6}$$

which satisfy a system of equations of the type (2). In this connection, the key question arises, namely, whether the system of equations can describe the *bound state*. Substituting (6) into (2) and taking into account (1)-(2), we can find two independent equations system:

$$\begin{aligned} ic^{-1}\partial_t\psi_x^+ &= \partial_y\psi_z^+ - \partial_z\psi_y^+, \qquad & ic^{-1}\partial_t\psi_x^- &= \partial_z\psi_y^- - \partial_y\psi_z^-, \\ ic^{-1}\partial_t\psi_y^+ &= \partial_z\psi_x^+ - \partial_x\psi_z^+, \qquad & ic^{-1}\partial_t\psi_y^- &= \partial_x\psi_z^- - \partial_z\psi_x^-, \\ ic^{-1}\partial_t\psi_z^+ &= \partial_x\psi_y^+ - \partial_y\psi_x^+, \qquad & ic^{-1}\partial_t\psi_z^- &= \partial_y\psi_x^- - \partial_x\psi_y^-. \end{aligned} \tag{7}$$

In addition, the following additional equations can be found from (2):

$$\begin{aligned} \partial_x\psi_x^+ + \partial_y\psi_y^+ + \partial_z\psi_z^+ &= 0, \\ \partial_x\psi_x^- + \partial_y\psi_y^- + \partial_z\psi_z^- &= 0, \end{aligned} \tag{8}$$

c is the propagation velocity of fields, which can differ from c_0.

The second order equations for vacuum fields

Recall that for a bound state the four-dimensional interval is zero, and the points of Minkowski space (events) are connected by a light cone:

$$s^2 = c^2 t^2 - r^2 = 0, \qquad r^2 = x^2 + y^2 + z^2. \tag{9}$$

It is clear that the time of propagation of the field in the such system must be periodic $t \in [0, T]$. Using the equations (7) and (8) we can obtain the following equations for vacuum fields $\boldsymbol{\psi}^+ = (\psi_x^+, \psi_y^+, \psi_z^+)$:

$$\begin{aligned}
\Box\psi_x^+ &= c^{-1}c_{;y}\left(\partial_x\psi_y^+ - \partial_y\psi_x^+\right) - c^{-1}c_{;z}\left(\partial_z\psi_x^+ - \partial_x\psi_z^+\right) - c_{;t}c^{-3}\partial_t\psi_x^+,\\
\Box\psi_y^+ &= c^{-1}c_{;z}\left(\partial_y\psi_z^+ - \partial_z\psi_y^+\right) - c^{-1}c_{;x}\left(\partial_x\psi_y^+ - \partial_y\psi_x^+\right) - c_{;t}c^{-3}\partial_t\psi_y^+,\\
\Box\psi_z^+ &= c^{-1}c_{;x}\left(\partial_z\psi_x^+ - \partial_x\psi_z^+\right) - c^{-1}c_{;y}\left(\partial_y\psi_z^+ - \partial_z\psi_y^+\right) - c_{;t}c^{-3}\partial_t\psi_z^+,
\end{aligned} \tag{10}$$

where $\Box = \triangle - c^{-2}\partial_t^2$ denotes the D'Alembert operator, $\triangle$ is the Laplace operator, while $c_{;\sigma} = \partial c/\partial\sigma$. In addition, using the equation (9), we can find the explicit form of the coefficients in the equations (10):

$$c_{;t} = -c^2 r^{-1}, \quad c_{;x} = c\,xr^{-2}, \quad c_{;y} = cyr^{-2}, \quad c_{;z} = czr^{-2}.$$

Taking into account the circumstance that in considered problem the space-time is homogeneous and isotropic and all fields are symmetric, the following additional conditions can be superimposed on the field components:

$$\begin{aligned}(c_{;z} - c_{;y})\partial_t\psi_x^+ &= c_{;z}\partial_t\psi_y^+ - c_{;y}\partial_t\psi_z^+,\\ (c_{;x} - c_{;z})\partial_t\psi_y^+ &= c_{;x}\partial_t\psi_z^+ - c_{;z}\partial_t\psi_x^+,\\ (c_{;y} - c_{;x})\partial_t\psi_z^+ &= c_{;y}\partial_t\psi_x^+ - c_{;x}\partial_t\psi_y^+.\end{aligned} \tag{11}$$

It is easy to verify that these conditions are symmetric with respect to the components of the field and are given on the hypersurfaces of four-dimensional events. Finally, using the conditions (11), the system of equations (10) can be reduced to the following canonical form:

$$\begin{aligned}\left\{\Box + [i(c_{;z} - c_{;y}) + c_{;t}c^{-1}]c^{-2}\partial_t\right\}\psi_x^+ &= 0,\\ \left\{\Box + [i(c_{;x} - c_{;z}) + c_{;t}c^{-1}]c^{-2}\partial_t\right\}\psi_y^+ &= 0,\\ \left\{\Box + [i(c_{;y} - c_{;x}) + c_{;t}c^{-1}]c^{-2}\partial_t\right\}\psi_z^+ &= 0.\end{aligned} \tag{12}$$

Note that the equations for fields of an unperturbed quantum vacuum (QV) must satisfy the conditions of autonomy, ie:

$$\psi_\sigma^+(\mathbf{r},t) = \exp\left(\frac{\mathcal{E}_\sigma t}{\hbar}\right)\phi_\sigma^+(\mathbf{r}), \qquad \sigma = x, y, z, \tag{13}$$

where $\mathcal{E}_\sigma < 0$ is the energy of one mode. It is obvious that the symmetry of the problem assumes the equality of the modes energies $\mathcal{E}_x = \mathcal{E}_y = \mathcal{E}_z = \mathcal{E} < 0$. Finally, using (13) and (14) from (7), we can obtain the following system of equations:

$$\begin{aligned}
&\Big\{\triangle + \lambda\Big[-\lambda - \frac{1}{r} + i\frac{z-y}{r^2}\Big]\Big\}\phi_x^+(\mathbf{r}) = 0,\\
&\Big\{\triangle + \lambda\Big[-\lambda - \frac{1}{r} + i\frac{x-z}{r^2}\Big]\Big\}\phi_y^+(\mathbf{r}) = 0,\\
&\Big\{\triangle + \lambda\Big[-\lambda - \frac{1}{r} + i\frac{y-x}{r^2}\Big]\Big\}\phi_z^+(\mathbf{r}) = 0,
\end{aligned} \tag{14}$$

where $\lambda = (\mathcal{E}/c\hbar) < 0$, in addition, parameter $|\lambda|$ has dimensionality of inverse distance.

We consider the equation for the field component $\phi_x^+(\mathbf{r})$. Representing the wave function in the form; $\phi_x^+(\mathbf{r}) = \phi_x^r(\mathbf{r}) + i\phi_x^i(\mathbf{r})$, from the first equation of the system (14), we can obtain the following two real equations:

$$\begin{aligned} &\Big\{\triangle - \lambda\Big(\lambda + \frac{1}{r}\Big)\Big\}\phi_x^r(\mathbf{r}) - \lambda\frac{z-y}{r^2}\phi_x^i(\mathbf{r}) = 0, \\ &\Big\{\triangle - \lambda\Big(\lambda + \frac{1}{r}\Big)\Big\}\phi_x^i(\mathbf{r}) + \lambda\frac{z-y}{r^2}\phi_x^r(\mathbf{r}) = 0. \end{aligned} \tag{15}$$

Using symmetry properties $\phi_x^r(\mathbf{r}) \mapsto \phi_x^i(\mathbf{r})$ and $\phi_x^i(\mathbf{r}) \mapsto -\phi_x^r(\mathbf{r})$, from (15) two independent equations can be obtained:

$$\begin{aligned} &\Big\{\triangle - \lambda\Big[\lambda + \frac{r-y+z}{r^2}\Big]\Big\}\phi_x^r(\mathbf{r}) = 0, \\ &\Big\{\triangle - \lambda\Big[\lambda + \frac{r+y-z}{r^2}\Big]\Big\}\phi_x^i(\mathbf{r}) = 0. \end{aligned} \tag{16}$$

Now we consider the solution for the real term $\phi_x^r(\mathbf{r})$ on a given plane:

$$r - y + z = \mu r, \tag{17}$$

where μ is a some parameter.

The real part of the wave function

Substituting (17) into the first equation of the system (16), we get:

$$\Big\{\triangle + \big[-\lambda^2 - \bar{\mu} r^{-1}\big]\Big\}\phi^r_x(\mathbf{r}) = 0, \qquad \bar{\mu} = \lambda\mu. \tag{18}$$

For further study of the problem, it is useful to rewrite equation (25) in a spherical coordinate system $(x, y, z) \mapsto (r, \theta, \varphi)$:

$$\left\{\frac{1}{r^2}\left[\frac{\partial}{\partial r}\left(r^2\frac{\partial}{\partial r}\right)+\frac{1}{\sin^2\theta}\frac{\partial^2}{\partial\varphi^2}+\frac{1}{\sin\theta}\frac{\partial}{\partial\theta}\left(\sin\theta\frac{\partial}{\partial\theta}\right)\right]-\left[\lambda^2-\frac{\bar{\mu}(\theta,\varphi)}{r}\right]\right\}\phi^r_x = 0. \tag{19}$$

Representing the wave function in the form:

$$\phi^r_x(\mathbf{r}) = \chi(r)Y(\theta,\varphi), \tag{20}$$

we can conditionally separate the variables in the equation (26):

$$r^2\chi^{''} + 2r\chi^{'} + \big[-\lambda^2 r^2 - \bar{\mu}(\theta,\varphi)r - \nu\big]\chi = 0, \qquad \chi^{'} = d\chi/dr, \tag{21}$$

and, respectively;

$$\frac{1}{\sin\theta}\left\{\frac{1}{\sin\theta}\frac{\partial^2}{\partial\varphi^2} + \frac{\partial}{\partial\theta}\left(\sin\theta\frac{\partial}{\partial\theta}\right)\right\}Y + \nu Y = 0. \tag{22}$$

Note, that ϱ is a constant, which is convenient to represent in the form $\nu = l(l+1)$, where $l = 0, 1, 2...$

As for the equation (21), we will solve it for a fixed value μ, which is equivalent to the plane cut of the three-dimensional solution. We will seek a solution $\chi(r)$ tending to finite value for $r \to 0$ and, respectively, to zero at $r \to \infty$. Writing the equation (17) in spherical coordinates, we obtain the following trigonometric equation:

$$\mu(\theta, \varphi) = 1 - \sin\theta \sin\varphi + \cos\theta. \tag{23}$$

As the analysis of the equation (23) shows, the range of variation of the parameter μ for real angles is $\mu \in [(1-\sqrt{2}),(1+\sqrt{2})]$.
For a given parameter μ_0, we can write the equation (21) in the form:

$$\frac{d^2\chi}{d\varrho^2} + \frac{2}{\varrho}\frac{d\chi}{d\varrho} + \left[-\beta^2 + \frac{2}{\varrho} - \frac{l(l+1)}{\varrho^2}\right]\chi = 0, \tag{24}$$

where $\varrho = r/a_p$ is the dimensionless distance, $a_p = 2/(|\lambda|\mu_0)$ some characteristic spatial distance and $\beta = 2/\mu_0$. This equation can have a solution describing the *bound state* if the following condition is satisfied:

$$n_r + l + 1 = n + l = \frac{1}{\beta}, \qquad n_r = 0, 1, 2..., \tag{25}$$

where n_r is the radial quantum number, while n is the principal quantum number.

As can be seen from the equation (25), there is only one value $\beta = 1$ or, that the same one value $\mu_0 = 2$, satisfying the equation. Proceeding from the foregoing, we can write a slice of the solution (real part of the wave function) on the chosen plane $S^r_{(\theta,\varphi)}$:

$$\phi^r_x(r,\theta,\varphi) = \chi_{nl}(r) Y_l^m(\theta,\varphi), \tag{26}$$

with the help of which on the 2D surface for the "ground state"we obtain the following solution:

$$\chi_{10}(r) = \frac{1}{2a_p^{3/2}} e^{-r/a_p}, \qquad Y_0^0(\theta,\varphi) = \frac{1}{2}\sqrt{\frac{1}{\pi}}.$$

Note that the plane $S^r(\theta,\varphi)$ in a $3D$ -space can have only such orientations whose angles satisfy the following trigonometric equation:

$$1 + \sin\theta \sin\varphi - \cos\theta = 0. \tag{27}$$

Obviously, the possible orientations of plane in 3D space forms a continuum. The imaginary part of the wave function $\phi^i_x(r,\theta,\varphi)$ is calculated in analogous way, only in this case the plane $S^i_{(\theta,\varphi)}$ is perpendicular to the plane $S^r_{(\theta,\varphi)}$. Let us note, as the calculations shows, the excited states for this hypothetical formation are unstable.

As the basic equations describing the fields QV, we will use complex stochastic equations of the Langevin type:

$$\partial_t \bar{\psi}^+(\mathbf{r},t) + c\big(\mathbf{S}\cdot\boldsymbol{\nabla}\big)\bar{\psi}^+(\mathbf{r},t) = \boldsymbol{\eta}^+(s),$$
$$\partial_t \bar{\psi}^-(\mathbf{r},t) - c\big(\mathbf{S}\cdot\boldsymbol{\nabla}\big)\bar{\psi}^-(\mathbf{r},t) = \boldsymbol{\eta}^-(s), \qquad (28)$$

where $\boldsymbol{\eta}^+(s) = (\eta_x^+, \eta_y^+, \eta_z^+)$ and $\boldsymbol{\eta}^-(s) = (\eta_x^-, \eta_y^-, \eta_z^-)$ are generators, which describe random charges and currents that depend on the four-dimensional relativistic interval, $ds^2 = c^2 dt^2 - dr^2$. For further study it is useful to write these equations in the matrix form:

$$\begin{bmatrix} ict & -z & y \\ z & ict & -x \\ -y & x & ict \end{bmatrix} \cdot \begin{bmatrix} \dot{\bar{\psi}}_x^+ \\ \dot{\bar{\psi}}_y^+ \\ \dot{\bar{\psi}}_z^+ \end{bmatrix} = \begin{bmatrix} s\eta_x^+ \\ s\eta_y^+ \\ s\eta_z^+ \end{bmatrix},$$

and, respectively,

$$\begin{bmatrix} ict & z & -y \\ -z & ict & x \\ y & -x & ict \end{bmatrix} \cdot \begin{bmatrix} \dot{\bar{\psi}}_x^- \\ \dot{\bar{\psi}}_y^- \\ \dot{\bar{\psi}}_z^- \end{bmatrix} = \begin{bmatrix} s\eta_x^- \\ s\eta_y^- \\ s\eta_z^- \end{bmatrix}, \qquad (29)$$

where $\dot{\bar{\psi}}_\sigma^+ = \partial\bar{\psi}_\sigma^+/\partial s$ and $\dot{\bar{\psi}}_\sigma^- = \partial\bar{\psi}_\sigma^-/\partial s$, in addition, $\sigma = (x, y, z)$.

The stochastic field equations in canonical form

The systems of equations (29) can be reduced to the canonical form:

$$\dot{\bar{\psi}}^{+}_{\sigma}(s;\mathbf{r},t) = \{a^{+}_{\sigma}(\mathbf{r},t) + b^{+}_{\sigma}(\mathbf{r},t)\} s^{-1}\eta^{+}(s),$$
$$\dot{\bar{\psi}}^{-}_{\sigma}(s;\mathbf{r},t) = \{a^{-}_{\sigma}(\mathbf{r},t) + b^{-}_{\sigma}(\mathbf{r},t)\} s^{-1}\eta^{-}(s), \qquad (30)$$

where

$$a^{+}_{x}(\mathbf{r},t) = -a^{-}_{x}(\mathbf{r},t) = y - z, \quad b^{\pm}_{x}(\mathbf{r},t) = (c^2t^2 - x^2 - xy - xz)(ct)^{-1},$$
$$a^{+}_{y}(\mathbf{r},t) = -a^{-}_{y}(\mathbf{r},t) = z - x, \quad b^{\pm}_{y}(\mathbf{r},t) = (c^2t^2 - y^2 - xy - yz)(ct)^{-1},$$
$$a^{+}_{z}(\mathbf{r},t) = -a^{-}_{z}(\mathbf{r},t) = x - y, \quad b^{\pm}_{z}(\mathbf{r},t) = (c^2t^2 - z^2 - xz - yz)(ct)^{-1},$$
$$(31)$$

Note that when deriving equations (30) it is suggested that:

$$\eta^{+}_{x} = \eta^{+}_{y} = \eta^{+}_{z} = \eta^{+}, \qquad \eta^{-}_{x} = \eta^{-}_{y} = \eta^{-}_{z} = \eta^{-},$$

which looks quite natural in the context of considered problem.

Now assuming that random generators satisfy the following correlation properties:

$$\langle \eta(s) \rangle = 0, \qquad \langle \eta(s)\eta(s') \rangle = 2\epsilon\delta(s-s'), \tag{32}$$

where $\eta(s) = s^{-1}\eta^{-}(s) = s^{-1}\eta^{+}(s)$ and ϵ denotes the fluctuations power. For further study of the problem, we can represent the joint probability distribution of vacuum fields in the form:

$$\mathcal{P}(\{\bar{\psi}\}, s; \mathbf{r}, t) = \prod_{\alpha,\sigma} \Big\langle \delta\big(\bar{\psi}^{\alpha}_{\sigma}(s; \mathbf{r}, t) - \psi^{\alpha}_{\sigma}(0; \mathbf{r}, t)\big)\Big\rangle, \qquad \alpha = +, -. \tag{33}$$

where $\{\bar{\psi}\} = (\bar{\psi}^{+}_{x}, ..., \bar{\psi}^{-}_{z})$ denotes the set of fields with $+1$ and -1 spins taking into account relaxation in the environment consisting of infinite number similar formations. Using the stochastic equations (30), it is easy to obtain the following regular equation for probability distribution:

$$\Big\{\frac{\partial}{\partial s} - \frac{1}{2}\sum_{\alpha,\sigma} \epsilon^{\alpha}_{\sigma}(\mathbf{r}, t)\frac{\partial^2}{\partial(\bar{\psi}^{\alpha}_{\sigma})^2}\Big\}\mathcal{P} = 0, \tag{34}$$

where $\epsilon^{\alpha}_{\sigma}(\mathbf{r}, t) = a^{\alpha}_{\sigma}(\mathbf{r}, t) + b^{\alpha}_{\sigma}(\mathbf{r}, t)$, in addition, it is necessary to note that in this equation $\epsilon^{\alpha}_{\sigma}(\mathbf{r}, t)$ are external parameters and, therefore, when solving the equation, they can be considered as constants.

Joint probability of scalar fields with zero spin

As it is not difficult to notice, the expression (33) is the distribution of wave function of formation consisting of two bound states, respectively, with $+1$ and -1 spins. In other words, we are talking about the distribution of the wave function of a hypothetical particle of scalar field with zero spin and without mass (particle of quintessence-dark energy field).

The general solution of the equation (34) can be represented in the form:

$$\mathcal{P}(\{\bar{\psi}\}, s; \mathbf{r}, t) = \int_{\Xi^6} \check{\mathcal{P}}(\{\psi\}) \prod_{\alpha,\sigma} \exp\left\{-\frac{\left(\psi^{\alpha}_{\sigma} - \bar{\psi}^{\alpha}_{\sigma}\right)^2}{2s\epsilon^{\alpha}_{\sigma}}\right\} \frac{d\psi^{\alpha}_{\sigma}}{\sqrt{2\pi s\epsilon^{\alpha}_{\sigma}}}, \qquad (35)$$

where $\Xi^6 \in \{\psi\}$ is the six dimensional Hilbert space and $\{\psi\} = (\psi^{+}_{x}, ...,$ $\psi^{-}_{z})$ denotes the set of fields with $+1$ and -1 spins.

In the expression (35), the function $\check{\mathcal{P}}(\{\psi\})$ is the boundary condition of equation (34) for $s = 0$. On the basis of physical considerations, it is obvious that as such a function one can choose the probability density of the "ground state"of a scalar field with spin zero, which can be represented in the form $\check{\mathcal{P}}(\{\psi\}) = \prod_{\alpha,\sigma} |\psi^{\alpha}_{\sigma}|^2$.

With consideration of fluctuations, spontaneous transitions to the continuous spectrum with different realizations of fields and particles arise.

Conclusion

1. A new microscopic theory has been developed that makes it possible to prove the possibility of forming a hypothetical particle without mass and with zero spin in the region of negative energies.

2. As shown, there is a high probability that a hypothetical particle with another similar particle, but with the opposite spin, can form a stable pair with zero spin and, accordingly, become a good candidate for a scalar field's particle.

3. The developed representation allows to predict new fundamental phenomena, in particular, to discover new and more effective mechanisms of light-light interaction, vacuum polarization at low energy impacts, and so on.

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