UDC 523.11:524.827:539.12:524.854:530.11

Bukalov A.V.

THE EQUATIONS OF GENERAL RELATIVITY AS EQUATIONS OF GRAVITATIONAL SUPERCONDUCTIVITY AND GEOMETRIC QUANTIZATION OF THE GRAVITATIONAL FLOW

The Centre for Physical and Space Research, International Institute of Socionics, Kyiv, Ukraine, bukalov.physics@socionic.info

The cosmological model with superconductivity (CMS), proposed by the author, makes it possible to obtain the observed value of the density of dark energy. From CMS follows also the system of equations for gravitational-fermionic superconductivity, which includes the equations of general relativity for primary fermions with Planck mass, supplemented by quantum equations. From the gravitational equations of superconductivity, describing the motion of the primary fermions, follows the quantization of the gravitational flow, which has a geometric nature. For a black hole the number of quanta of gravitational flow corresponds to the Bekenstein-Hawking entropy. The presence of dark matter in the coronas of galaxies can be explained by the existence of macroscopic gravitational vortex of superfluid condensate of paired primary fermions.

Keywords: superconducting cosmology, gravitation, time, fermions, dark energy, general relativity.

1. Introduction

Dark energy is one of the most important factors in cosmology (Karachentsev et al., 2009; Bisnovatyi-Kogan & Chernin, 2012; Chernin et al., 2013; Bukalov, 2015). In the author's paper (Bukalov, 2016), it was shown that the observed value of the dark energy density ρ_{DE} can be obtained within the vacuum superconductivity model in which primary b-fermions condense into Cooper pairs. This condensation process reduces the energy density by 120 orders of magnitude in comparison with the Planck energy density usually obtained in field theory:

$$\rho_{DE} = \frac{M_P^4}{256\pi^3 e^{2\lambda^{-1}}} = \frac{M_P^4}{256\pi^3 e^{2\alpha_{em}^{-1}}} = \frac{c^5}{256\pi^3 G_N^2 \hbar e^{2\alpha_{em}^{-1}}}\,, \tag{1}$$

$\rho_{DE} \approx 6.09\cdot 10^{-27}\,\text{kg/m}^3$, where $\lambda \approx \alpha_{em}$, α_{em} is the fine structure constant. Therefore, the Universe can be considered as condensate fermion system in which phase transitions occur in the superconducting state. The condensate of primary fermions forms different phases, evolving according to different laws, depending on the coupling constant λ_i, λ_j. In view of this, we can consider currents flowing in such structure, consisting of normal and superfluid component, and obtain the equations of the macroscopic theory of superconductivity for the Universe.

2. The equations of superconductivity as electromagnetism and gravitation

For electron superconductivity, according to Londons (London & London, 1935; Feynman, 1972), at electron density n, mass m_e, charge of electron e, the motion of electrons in an electric field E is described by equation $-eE = m_e\ddot{x}$, current density is $j = -ne\dot{x}$. In a magnetic field for a superconductor $-\Lambda_e(A-A_0)=j$, where $-\Lambda_e = ne^2/(m_e c)$=const. At $A_0 = 0$ $j = -\Lambda_e A$, at $divA = 0$, $A\vec{n} = 0$,

$$rot\ rotA = \nabla^2 A = 4\pi\Lambda_e A / c\,. \tag{2}$$

Therefore, the magnetic field $A \sim e^{\pm\sqrt{4\pi\Lambda/c}\,x}$ penetrates into the sample to depth $r \sim \sqrt{c/4\pi\Lambda_e}$. Let us now consider the equations of the general theory of relativity:

$$G_{\mu\nu} - 8\pi\Lambda g_{\mu\nu} = R_{\mu\nu} - 2^{-1} g_{\mu\nu} R - 8\pi\Lambda g_{\mu\nu} = -8\pi G_N c^{-5} T_{\mu\nu}\,. \tag{3}$$

At $T_{\mu\nu} = 0$ equation (3) transforms into equation $G_{\mu\nu} = 8\pi\Lambda g_{\mu\nu}$. We transform the metric tensor into a tensor potential as an analog of the electromagnetic vector potential: $g_{\mu\nu}c^2G_N^{-1/2} = B_{\mu\nu}$. Then $c^2G_N^{-1/2}G_{\mu\nu} = \ = 8\pi\Lambda_s B_{\mu\nu} = 8\pi J_{\mu\nu}^{(s)}$, where $J_{\mu\nu}^{(s)}$ is a tensor current of the superfluid component of the current formed by the primary fermions. In such record, the equations of general relativity with the cosmological constant are analogous to the London equation(2). At $T_{\mu\nu} \neq 0$

$$c^2G_N^{-1/2}G_{\mu\nu} = -8\pi J_{\mu\nu}^{(m)} + 8\pi J_{\mu\nu}^{(s)}, \quad (4)$$

where $8\pi J_{\mu\nu}^{(m)} = 8\pi T_{\mu\nu}G_N^{1/2}/c^2$. The equation (4) is equivalent to the GTR equation (3) and shows that the gravitating matter and the dark energy can be considered as a normal and superfluid components of the currents formed by the primary fermions. According to Londons, the quantum mechanical expression for the electric current in a magnetic field, with the momentum operator $p + eA/c$, is

$$\begin{aligned} j_s &= -\frac{e}{2m_e}\left\{\psi^*\left(\frac{\hbar}{i}\nabla + \frac{eA}{c}\right)\psi + \left[\left(\frac{\hbar}{i}\nabla + \frac{eA}{c}\right)\psi\right]^*\psi\right\} = \\ &= -\frac{\hbar e}{2im_e}\left(\psi^*\nabla\psi - (\nabla\psi)^*\psi\right) - \frac{e^2A}{m_e c}\psi^*\psi = j_p + j_d, \end{aligned} \quad (5)$$

where j_p is a paramagnetic current component, j_d is a diamagnetic current component , me is electron mass. It is obvious that equations (4) and (5) are analogous. Taking into account that the wave function of the condensate particle of the Cooper pair is $\psi(r) = 2^{-1/2}e^{i\Phi}n_s^{1/2}$, we obtain $\hbar\nabla\Phi = 2m_e v_s$. When a particle with a mass of $2m_e$ and a charge $2e$ moves in a magnetic field, the particle momentum is $\hbar\nabla\Phi = 2mv_s + 2eA/c$. Then the density of the superconducting electron current

$$j_s = n_s e v_s = \frac{\Lambda}{c}\left(\frac{\Phi_0}{2\pi}\nabla\Phi - A\right), \quad (6)$$

where $\Phi_0 = \pi\hbar c/e$ is magnetic flux quantum (Pitaevskii & Lifshitz, 1980; Feynman, 1972). Adding a quantum equation, an analog of the Schrödinger equation $\alpha\Psi + \beta\Psi|\Psi|^2 + \frac{1}{4m}\left(i\hbar\nabla + \frac{2e}{c}A\right)^2\Psi = 0$, where α=const, β=const, gives a system of Ginzburg-Landau equations for the macroscopic theory of superconductivity [1]. In this case, $c^2G_N^{-1/2}G_{\mu\nu} = -8\pi n_G G_N^{1/2} m_0 c^{-2} U_\mu U_\nu + 8\pi\Lambda_s B_{\mu\nu}$, where n_G is generalized density of gravitational charges as a function of density and pressure, m_0 is a mass, Q_G is gravitational charge, U_μ is 4-velocity. For a wave function $\Psi_b(r) = (\tilde{n}_G/2)^{1/2}\cdot e^{i\theta}$ of a condensate particle *b*-fermion of Cooper pair with effective mass m_x, $\hbar\nabla_\mu\theta/m_x = U_\mu$, $\hbar\nabla_\nu\theta/m_x = U_\nu$.

$$c^2G_N^{-1/2}G_{\mu\nu} = -8\pi n_G Q_G \hbar^2 m_x^{-2} c^{-2}\nabla_\mu\theta\nabla_\nu\theta + 8\pi\Lambda_s B_{\mu\nu} \quad (7)$$

Thus, the gravitational equations arise for the superconducting current of fermions, which in form and sense are analogous to the equations of London and Landau-Ginzburg (Pitaevskii & Lifshitz, 1980). We can write them in quantum form:

$$\begin{aligned} c^2G_N^{-1/2}G_{\mu\nu} &= -\frac{8\pi\hbar^2 Q_x}{(2m_x)^2c^2|\psi_b|^2}(\psi_b^*\nabla_\mu\psi_b - \psi_b\nabla_\mu\psi_b^*)\cdot \\ &\cdot(\psi_b^*\nabla_\nu\psi_b - \psi_b\nabla_\nu\psi_b^*) + 8\pi\frac{2Q_x^2|\psi_b|^2 B_{\mu\nu}}{m_x c} \end{aligned} \quad (8)$$

at $\Lambda_s = n_s Q_x^2/m_x c^2$. The second equation can also be written analogously to the equation for paired electrons:

$$\sigma\psi_b + \varsigma\psi_b|\psi_b|^2 + E_b\psi_b = 0, \quad (9)$$

where E_b is the energy of paired primary fermions, $\sigma = \text{const}$, $\varsigma = \text{const}$.

From this point of view, Einstein's equations of gravity with a Λ-member can be considered as a description of the motion of the normal and superfluid components of the primary fermion currents in the gravitational field. Equation (8) can also be written in the form

$$G_{\mu\nu} = -8\pi\Lambda_s \left(\frac{\Phi_B(0)}{4\pi} \nabla_\mu \theta \nabla_\nu \theta - g_{\mu\nu} \right). \quad (10)$$

where $\Phi_B(0) = 4L_P^2$ is an elementary geometric quantum of the gravitational flow is an analog of the quantum of the magnetic flux, which is a quantum of the event horizon area in the Bekenstein-Hawking formula. $S = \pi R^2 / L_P^2$ (Bekenstein, 1974; Hawking, 1975). It is possible that the "para-gravitational" component $J_{\mu\nu}^{(s)} = n_v Q_v \nabla_\mu \theta \nabla_\nu \theta$ contributes to the effects associated with the action of directly unobservable "dark matter" in the form of vortices possessing an effective gravitational mass. Thus, Λs expresses, on the one hand, the depth of penetration of the external gravitational field into the Universe as a superconductor, and on the other hand, the mass that gravitons acquire $\Lambda_s = m_G^2$, as a result of the interaction of the superconducting current with the external field, similar to the appearance of photons mass in an electromagnetic superconductor. Similar to the Meissner effect, the superconducting current of primary fermions pushes out the external gravitational field, so it manifests itself as antigravitation. In the era of inflation and the Big Bang, the external field penetrates into the primary, the initial Universe, which leads to a phase transition with the release of heat, like electric superconductors. In this case, the time component of the penetration of the external field into the Universe is observed as an anti-gravity effect and acceleration of the expansion of the Universe. Therefore, the dynamic de Sitter and Friedmann-Lemaître equations describe aspects of the second-order phase transition as the evolution of the Universe.

3. Conclusion

The quantum macroscopic equations of gravitational superconductivity explain not only the equations of general relativity at the quantum level, but also describe matter and vacuum as elements of the gravitating ("para-gravitational") and anti-gravity ("diagravitational") current components in the superconducting structure of the universe.

References:

1. Bekenstein J. D.: 1974, *Phys. Rev.* **D 9** 3292.
2. Bisnovatyi-Kogan G.S., Chernin A.D.: 2012, *Astrophys. Space Sci.*, **338**, 337.
3. Bukalov A.V.: 2015, *Odessa Astron. Publ.*, **28 (2)**, 114.
4. Bukalov A.V.: 2016, *Odessa Astron. Publ.*, **29 (1)**, 42.
5. Chernin A.D. et al.: 2013, *Astron. Astrophys.*, **553**, 101.
6. Feynman R.P.: 1972, Statistical mechanics. A set of lectures. (W.A. Benjamin Inc., Massachusetts).
7. Hawking S. W.: 1975, *Commun. Math. Phys.*, **43**, 199.
8. Karachentsev I.D. et al.: 2009, *MNRAS*, **393**, 1265.
9. London F., London H.: 1935, *Proc. Roy. Soc.*, **A149**, 71.
10. Pitaevskii L.P., Lifshitz E.M.: 1980, Statistical Physics. Part 2, (Nauka, Moskow).

Статья поступила в редакцию 20.11.2017 г.

Букалов А.В.

Уравнения общей теории относительности как уравнения гравитационной сверхпроводимости и геометрическое квантование гравитационного потока

Предложенная автором космологическая модель с сверхпроводимостью (CMS) позволяет получить наблюдаемое значение плотности темной энергии. Из CMS следует также система уравнений для гравитационно-фермионной сверхпроводимости, включающая уравнения общей теории относительности для первичных фермионов с массой Планка, дополненные квантовыми уравнениями. Из гравитационных уравнений сверхпроводимости, описывающих движение первичных фермионов, следует квантование гравитационного потока, имеющее геометрический характер. Для черной дыры число квантов гравитационного потока соответствует энтропии Бекенштейна-Хокинга. Наличие темной материи в коронах галактик можно объяснить наличием макроскопического гравитационного вихря сверхтекучего конденсата парных первичных фермионов.

Ключевые слова: сверхпроводящая космология, гравитация, время, фермионы, темная энергия, общая теория относительности.