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NATURE OF COSMOLOGICAL TIME: FROM THE MACROSCOPIC EQUATIONS OF GENERAL RELATIVITY TO QUANTUM MICROSCOPIC DYNAMICS

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The application of the principles of the cosmological model with superconductivity to the equations of general relativity makes it possible to describe the macroscopic dynamics of the evolution of the Universe through coherent dynamics on microscopic Planck scales. It is obtained a hierarchical system of equations, showing how the parameter of cosmological time depends on the microscopic dynamics of fermions at the Fermi surface for the Planck crystal-like structure of space-time.

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

1. Introduction

At the present time the dark energy manifests itself as anti-gravity, not only on a cosmological scale, but on the scale of galaxy groups (Karachentsev et al., 2009; Bisnovatyi-Kogan & Chernin, 2012; Chernin et al., 2013; Bukalov, 2015). Using the principles of the quantum theory of superconductivity, the author previously obtained the value of the density of dark energy ρ_{DE}, which determines the effective value of the cosmological constant (Bukalov, 2016).

$$\rho_{DE} = \frac{1}{4\pi G_N \left(8\,\pi p t_P e^{1/\lambda_i}\right)^2} \tag{1}$$

$$\rho_{DE} = \frac{1}{256\pi^3 G_N^2} \frac{c^5}{\hbar e^{2\alpha_{em}^{-1}}} = 6.09 \cdot 10^{-27}\,\text{kg/m}^3 \tag{2}$$

where $\lambda = \alpha_{em} = e^2/\hbar c$ is the electromagnetic constant of a fine structure or its "dark" analog, and $\alpha_x = \alpha_{em}$. The critical density of the Universe is

$$\rho_c = \frac{9}{8\pi^2 G_N}\left(\frac{1}{8\pi t_P e^{\alpha_j^{-1}}}\right)^2, H_0 = \left(8\pi\left(\frac{\pi}{3}\right)^{1/2} \cdot e^{\alpha_j^{-1}} t_P\right)^{-1} \tag{3}$$

At $\alpha_j \cong \alpha_{em}$ $H_0 = 68.2\,\text{km}\cdot\text{s}^{-1}\cdot\text{Mpk}^{-1}$, which is in good agreement with the PLANK data (Planck Collaboration, 2015).

The time parameter is a function of a second-order phase transition analogous to the transition in the theory of superconductivity, $t_U \sim t_H = 8\pi t_P e^{\alpha_j^{-1}}$. And α_j^{-1} is the coupling parameter of the fermion interaction, an analog of the fine structure constant, but dynamically changing, which determines the course of cosmological time t_H. In the present era $\alpha_j^{-1} \cong \alpha_{em}^{-1} = 137.03599...$. This equality determines the proximity of the value of the density of "dark energy" and matter in this era and explains the phenomenon of "cosmic concordance" (coincidence).

2. From the classical dynamics of the equations of general relativity and Friedmann to microscopic quantum dynamics

Since the dynamics of the change of the fine structure α_j^{-1} is determined by the relation

$$\alpha_i^{-1} = \alpha_0^{-1} - \beta \ln\left(2m_e / Q_i\right) / 2\pi, \tag{4}$$

where Q_i varies from kT_{GUT} to $2m_e c^2$, then the density of dark energy varies according to the law:

$$\rho_{DE} = \frac{3}{8\pi} G_N \frac{1}{8\pi e^{\alpha_i^{-1}} t_P} \left(\frac{Q_i}{2m_e} \right)^{\beta/2\pi}, \tag{5}$$

where Q_i is impulse of quantum of radiation.

Similarly critical density evolves:

$$\rho_c = \frac{3}{8\pi} H_0^2 = \frac{3}{8\pi G_N} \left(\frac{1}{8\pi e^{\alpha_j^{-1}} t_P} \right)^2 \left(\frac{Q_i}{2m_x} \right)^{\beta/2\pi}, \tag{6}$$

where Q_i is an impulse, and m_x is a mass, that are forming the observed dynamics of the Universe, but located in another "energy zone", if we use the analogy of the "crystal" (Fomin, 1990), or in other dimensions additional to the dimensions space-time of the observed Universe. Different models of multidimensional universes have been considered by many authors.We now turn to the consideration of Friedmann's equations. First we consider the De Sitter vacuum solution for $\rho = -p$, $\ddot{a} = \Lambda_1 a / 3$, $a = a_0 \exp((\Lambda_1/3)^{1/2} t)$, at $(\Lambda_1/3)^{1/2} t = \alpha_i^{-1}$. In the quantum theory of superconductivity, the fermion interaction constant α is defined as $\alpha^{-1} = \pi\hbar / p_F |b|$, where $p_F = m \cdot v_F$ is an impulse of a fermion near the Fermi surface, expressed in terms of mass and velocity, $|b|$ is fermion scattering length (Pitaevskii & Lifshiz, 1980). Therefore at $\alpha^{-1} = \alpha_{em}^{-1} = \pi\lambda_F / |b|$ scale factor a is:

$$a = a_0 \cdot e^{\pi\lambda_F/|b|} = a_0 \cdot e^{\alpha_{em}^{-1}} \left(\frac{2m_e}{Q_i} \right)^{\beta/2\pi} = a_0 \cdot e^{\pi\lambda_0/|b|} \left(\frac{2m_e}{Q_i} \right)^{\beta/2\pi} \tag{7}$$

Obviously, when $\sqrt{\Lambda_1/3} \sim \pi/|b|$, $\lambda_F \sim ct$, and the cosmological time is determined by the dynamics of the change in the fermion wave length at the Fermi surface, or by the change in the radiation energy impulse in the radiation-dominant evolution stage of the Universe. So far as $\sigma g_{eff} T^4 = 3 \cdot (32\pi G_N t_H^2)^{-1}$ and $Q_i \sim kT \sim t_H^{-1/2}$, then

$$a = a_0 \cdot e^{\pi\lambda_F/|b|} (2m_e t_H^{1/2})^{\beta/2\pi}, \tag{8}$$

and all dynamics are determined by the time parameter $t_H \sim \lambda_F$. In this case, we can represent the dynamics of time t_H variation as follows:

$$t_H = 8\pi e^{\pi\lambda_0/|b|} \left(\frac{2m_x}{Q_j} \right)^{\beta/2\pi} \cdot t_P = 8\pi e^{\alpha_{0em}^{-1}} \left(\frac{2\tau^{1/2}}{\lambda_x} \right)^{\beta/2\pi} \cdot t_P, \tag{9}$$

where t_P is the Planck time.

According to (8) and (9) dynamics of cosmological time change can be inferred from the vacuum-type equation

$$\frac{d^2 t_H}{d\tau^2} = \Lambda_2 t_H \text{ or } \frac{d^2 t_H}{d\tau^2} = \left(\frac{\pi}{|b|} \right)^2 t_H \tag{10}$$

as an analog of the Friedmann equation. In general:

$$\frac{1}{t} \frac{d^2 t_H}{d\tau^2} = \frac{8\pi}{3} G_N (\rho^* + 3p^*) + \frac{\Lambda_2}{3} \tag{11}$$

From (11) it follows:

$$\frac{1}{t^2} \left(\frac{dt_H}{d\tau} \right)^2 = \frac{8\pi}{3} G_N \rho^* + \frac{\Lambda_2}{3} - \frac{k_2}{t^2}, . \tag{12}$$

where $\rho^* = 3 / 8\pi G_N \tau_H^2$, τ_H is a microscopic quantum time parameter for fermions near Fermi surface.

Thus, we obtain the dynamics of the change of cosmological time at the microscopic quantum level. Because $\Lambda^{-1/2} = 8\pi e^{\alpha_j^{-1}} L_P \cdot \Omega_\Lambda^{-1/2}$, then

$$a_\Lambda = a_0 \cdot e^{\sqrt{\frac{\Lambda}{3}}\,t} = a_0 \cdot e^{\frac{8\pi e^{\alpha_j^{-1}} t_p}{8\pi e^{\alpha_i^{-1}} t_p} \cdot (3\Omega_\Lambda)^{1/2}} = a_0 \cdot e^{(3\Omega_\Lambda)^{1/2} \left(\frac{2m_x}{Q_j} \cdot \frac{Q_i}{2m_e} \right)^{\beta/2\pi}} .$$

At $Q_j = 2m_x$ and $Q_i = 2m_e$, $a_\Lambda = const$, $t = 0.485$ s $a_\Lambda = a_0 e^{\alpha_0^{-1}}$. Given that $t \sim t_H \sim \lambda_F(\tau)$, equations (11)–(12) are transformed into the following:

$$\begin{aligned} &\frac{1}{\lambda_F(\tau)} \frac{d^2\lambda_F(\tau)}{d\tau^2} = -\frac{4\pi}{3} G_N \left(\rho^* + 3p^* + \frac{\Lambda_2}{3} \right); \\ &\frac{1}{\lambda_F^2(\tau)} \left(\frac{d\lambda_F(\tau)}{d\tau} \right)^2 = -\frac{8\pi}{3} G_N \rho^* + \frac{\Lambda_2}{3} - \frac{k_2}{\lambda_F^2(\tau)} \end{aligned}, \qquad (13)$$

where $t \sim \lambda_F(\tau)$ plays the role of a scale factor in the microscopic quantum dynamics of fermions near the Fermi surface. A hierarchy of dynamic levels appears in which the variable $\tau \sim \lambda_F(\tau)$ controls the time variable $t_\Lambda = f(\tau) = f(\tau(\eta))$, and the corresponding hierarchy of both Friedmann equations and Einstein's equations of general relativity, corresponding to the dynamics of hierarchically interdependent variables, corresponding spaces and metrics. We can consider the macroscopic dynamics of our and other universes on a microscopic, quantum level, replacing $ct^0 \to \lambda^0$, $x^\mu \to \lambda_F^\mu = \lambda^\mu$. At $\alpha^{-1} = \alpha_{em}^{-1} = g / e = \pi\lambda_F / |b|$ $|b| / \pi = L_P$, $\lambda_F = \alpha_{em}^{-1} |b| / \pi$. This means that the macroscopic dynamics of the universe corresponds to microscopic quantum dynamics on Planck scales.

3. Conclusion

The transition from macroscopic classical dynamics of general relativity to microscopic fermion dynamics at the Fermi surface shows that the real structure and dynamics of space-time are described by coherent quantum processes. In particular, the parameter of evolutionary cosmological time is determined by the dynamics of microscopic quantum processes on Planck scales. The macroscopic nature of the observed space-time is provided by a factor $e^{\alpha^{-1}}$, which varies in the interval from 1 to $3.26 \cdot 10^{59}$ and determines the scale of the coherence of quantum processes.

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Природа космологического времени: от макроскопических уравнений общей теории относительности к квантовой микроскопической динамике

Применение принципов космологической теории со сверхпроводимостью к уравнениям общей теории относительности позволяет описать макроскопическую динамику эволюции Вселенной через когерентную динамику на микроскопических планковских масштабах. Получена иерархическая система уравнений, показывающая, как параметр космологического времени зависит от микроскопической динамики фермионов на поверхности Ферми для планковской кристаллоподобной структуры пространства-времени.

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