ULTRALIGHT GRAVITONS WITH TINY ELECTRIC DIPOLE MOMENT ARE SEEPING FROM THE VACUUM

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Abstract
Mass and electric dipole moment of graviton, which is identified as dark matter particle, are estimated. This change the concept of dark matter and can help to explain the baryon asymmetry of the universe. The calculations are based on quantum modification of the general relativity with two additional terms in the Einstein equations, which takes into account production/absorption of gravitons. In this theory, there are no Big Bang in the beginning (some local bangs during the evolution of the universe are probable), no critical density of the universe, no dark energy (no need in cosmological constant) and no inflation. The theory (without fitting) is in good quantitative agreement with cosmic data.
Key words: graviton; cosmology; age of the universe; interface between gravitons and ordinary matter.

Quantum modification of the general relativity (Qmoger), which takes into account production/absorption of dark matter by the vacuum, was introduced in [1] and developed in [2-4]. These works were presided by invention of new type of fluid, namely, dynamics of distributed sources/sinks [5]. The Qmoger equations differ from the Einstein equations by two additional terms [1]:

$$R_i^k - \frac{1}{2}\delta_i^k R = 8\pi G_* T_i^k + \lambda_N \delta_i^k,\ T_i^k = w u_i u^k - \delta_i^k p,\ w = \varepsilon + p, \quad (1)$$

$$\lambda_N = \lambda_0 + \beta \frac{d\sigma}{ds} + \gamma\sigma^2,\ \sigma = \frac{\partial u^k}{\partial x^k} + \frac{1}{2g}\frac{dg}{ds},\ \frac{d}{ds} = u^k \frac{\partial}{\partial x^k} \quad (2)$$

Here R_i^k is the curvature tensor, p, ε and w are pressure, energy density and heat function, respectively, $G_* = Gc^{-4}$(G- gravitational constant, c- speed of light), u^k - components of velocity (summation over repeated indexes is assumed from 0 to 3, $x^0 = \tau = ct$), λ_0 is CC (which we will put zero), σ is the covariant divergency, β and γ are nondimensional constants (which we will put $\beta = 2\gamma = 2/3$) and g is the determinant of the metric tensor. With $\beta = \gamma = 0$ we recover the classical equations of GR. Let us note that curvature terms in lhs of (1) and additional terms $d\sigma/ds$ and σ^2 all contain second order (or square of first order) derivatives of metric tensor, which make these terms compatible. The importance of σ also follows from the fact that it is the only dynamic characteristic of media, which enters into the balance of the proper number density of particles $n : dn/ds + \sigma n = q$, where q is the rate of particle production (or absorption) by the vacuum. So, if n is constant (see the exact analytical solution

(3) below) or changing slowly, than the σ-effect is, certainly, very important in quantum cosmology.

Qmoger equations reproduce Newtonian gravitation in the nonrelativistic asymptotic, but gravitational waves propagate with speed, which is not necessary equal to the speed of light [2]. That give us a hint that gravitons may have finite mass.

Qmoger equations (with $\lambda_0 = 0, \beta = 2\gamma = 2/3$) have exact Gaussian solution for the scale factor [2-4]:

$$a(\tau) = a_0 \exp[H_0\tau - 2\pi(\tau/L_*)^2],\ L_* = (G_*\varepsilon_0)^{-1/2} \tag{3}$$

Here subscript 0 indicates present epoch ($\tau = 0$) and H_0 is the Hubble constant. Solution (3) corresponds to continuous and metric-affecting production of matter out of vacuum, with its density ρ_0 being retain constant during the expansion of spatially flat universe. With this solution, we get rid of major controversies [critical density of the universe, cosmological constant (dark energy) and inflation], which is a kind of relief. Formula (3) does not have any fitting parameters and shows good quantitative agreement with cosmological observations (SnIa, SDSS-BAO and reduction of acceleration of the expanding Universe [6]) [2, 3].

The solution (3) is shown [2] to be stable in the regime of cosmological expansion until $t_{\max}$ about 34 billion years from now. After that time, the solution becomes unstable and characterizes the inverse process of dark matter particle absorption by the vacuum in the regime of contraction of the universe. This can imply the need for considering the change of regime (3) at $t > t_{\max}$ to a different evolutionary regime, possibly, with the more general model from [1].

In this theory, the mass m_0 of dark matter particles (DMP), which we considered as gravitons, is estimated by comparing characteristic scale L_* from (3) with the relativistic uncertainty of particle position [7] (or Compton wavelength) $\hbar/m_0c$:

$$m_0 = \hbar(G_*\rho_0)^{1/2} \sim 0.5 \cdot 10^{-66} gram \tag{4}$$

Here $\hbar$ is the Planck constant, and ρ_0 is averaged mass density of the universe. According to WMAP data, we use $\rho_0 \approx 0.26 \cdot 10^{-29} gcm^{-3}$, which includes dark and ordinary matter, but not dark energy. In this theory, flatness of the universe is supported by the divergency terms in Qmoger equations (1, 2).

According to (4), DMP are ultralight and their uncertainty of position $L_* \approx$ 76 billion light years (bly) is of the same order as size of the visible universe $a_0 \approx 46,5$ bly. So, we can say, that mass m_0 predetermined the size of universe (see details below). It also means that universe has a halo of DMP. This halo potentially can influence the visible part of universe, producing effects similar to influence of hypothetical multiverse.

Concentration of particles n and characteristic scale l are:

$$n = \rho_0/m_0 \sim 0.5 \cdot 10^{37} cm^{-3},\ l = n^{-1/3} \sim 0,27 \cdot 10^{-12} cm. \tag{5}$$

In this theory there is no Big Bang at the beginning, but some local bangs during the evolution of the universe are probable (see below). From (3) it was calculated [4] that $a(\tau_1) = l_P = (G_* \hbar c)^{1/2}$ (Planck scale) corresponds to $t_1 \approx -327$ billion years. After that it took about 43 billion years of "incubation" (see below) to accommodate universe for production of particles with mass m_0, when $a(\tau_2) = l$ [4].

It seems interesting to identify dark matter particles with gravitons (see also recent paper [8]). So, gravitons have small, but finite mass (4) and huge concentration (5). The "ordinary" matter (OM) in this theory was synthesized from dark matter in galaxies [4]. Averaged concentration (5) is not only enormous, but also constant. It means, that these particles somehow communicate with each other and polarize vacuum in order to maintain averaged distance l (5). Remember, that we are dealing with unusual fluid [5]. The thermal de Brogle wavelength for the temperature of the universe $T \approx 2.73K$ is substantially bigger than l: $\hbar c(lk_B T)^{-1} \approx 3 \cdot 10^{11}$ (k_B - Boltzmann constant). This estimate is for massless particles. For nonrelativistic gravitons with mass m_0 the scale factor is $\hbar l^{-1}(m_0 k_B T)^{-1/2} \approx 7 \cdot 10^{13}$. So, the quantum effects, such as Bose-Einstein condensate, can dominate, even for high temperature. In the areas of gravitational condensation (future galaxies) the density was much higher than (5). With certain critical density, we can expect local bangs of multiple collisions with formation of new particles in some sort of "natural selection". During the steady and stable expansion of the universe, the ordinary matter (OM) was synthesized in this way, probably, starting with light particles.

These processes were accompanied by radiation, which is reflected in CMB. The eqilibrium character of CMB and the small global curvature are naturally explained by the large amount of time available for the evolution. Some peculiarities of CMB can be associated with synthesis of various particles in expanding universe. Particularly, the observed anisotropy of CMB can be connected with nonsynchronous processes in galaxies.

In context of the type of evolution, which is described by exact solution (3), what we call ordinary matter is, in fact, an exotic matter, which was synthesized from gravitons and, so far, constitute about 15% of the total mass of the universe (standard 4% corresponds to inclusion of dark energy). The theory of elementary particles should be modified by considering gravitons as primary basis for all particles. Moreover, we can not be sure that gravitons obeys all the rules of the conventional quantum theory. It is possible, that gravitons produce some quantum effects for "ordinary" matter (see new interpretation of quantum theory [9]).

In this theory, the baryonic asymmetry of the universe can be explained if gravitons have nonzero electric dipole moment (EDM). It will also help to explain synthesis of some particles from the dipole Bose-Einstein condensate. From mass m_0 (4), Planck scale $l_P = (\hbar G/c^3)^{1/2}$ and c we have unique expression for EDM:

$$d \sim m_0^{1/2} l_P^{3/2} c \sim 2 \times 10^{-72} gram^{1/2} cm^{5/2} \sec^{-1} \tag{6}$$

There is also scale $l_0 = m_0 G c^{-2} \sim 4 \cdot 10^{-95} cm$, which is much smaller than l_P. So, we have small nondimensional parameter $\nu = l_0/l_P \sim 2.5 \cdot 10^{-62}$ and more general formula $d = m_0^{1/2} l_P^{3/2} c N(\nu)$. We will get (6), assuming that $N(0)$ is finite. Using ν, we have spectrum of mass: $m(\alpha) = m_0 \nu^{\alpha}$. Scale l_0 and particles with masses smaller than m_0 (for $\alpha > 0$) can be related to early evolution, including indicated above "incubation" period, and to mediators between gravitons and OM particles (see below).

Let us note, that presented calculations of mass (4) and EDM (6), actually, do not require the full acceptance of the QMOGER theory. It is sufficient to assume, that ρ_0 is an important parameter.

In the described theory we got that gravitons constitute omnipresent background in the universe. As a result of gravitational condensation, from that background emerged OM. The indicated above mediators can be produced spontaneously, or during collisions. The "plasma" of gravitons and mediators produces ordinary matter, including photons. So, we got interface between dark and ordinary matter (IDOM). Such interface very likely exists not only in cosmos, but everywhere, including our body and our brain [10]. A model of IDOM is described in [12]. From that model it follows that our subjective experiences are manifestations of IDOM and can be used as a natural detector of interaction between gravitons and ordinary matter.

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[10] It did not escape my attention, that this approach has important philosophical consequences. Particularly, nonmaterial entities can be considered as interfaces (or collections of interfaces) between different types of matter. Also, the approach can be imbedded in a mathematical structure, similar to the category theory [11], with morphisms and formalized interfaces, but that is another story.

[11] See an excellent review: J. C. Baez and M. Stay, arXiv:0903.0340

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