

## BRIGHT MATTER

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"Suppose, for simplicity, there is the God. Yes. The question is, why He will do explosions? Why show a bad example to future terrorists on Earth?.." ( E. A. Novikov, essay "God and explosions", 2012).

### Abstract

Quantum modification of general relativity (Qmoger) is supported by cosmic data (without fitting). Qmoger equations consist of Einstein equations with two additional terms responsible for production/absorption of matter. In Qmoger cosmology there was no Big Bang and matter is continuously producing by the Vacuum. Particularly, production of the ultralight gravitons with tiny electric dipole moment (EDM) was started about 284 billion years ago. Quantum effects dominate interaction of these particles and they form the quantum condensate. Under influence of gravitation, the condensate is forming galaxies and producing ordinary matter, including photons. As one important result of this activity, it recently created us, the people, and continues to support us. Particularly, our subjective experiences are a result of an interaction between the background condensate and the neural system of the brain. The action potentials of neural system create traps and coherent dynamic patterns in the dipolar condensate. So, our subjective experiences are graviton-based. Some problems with the origin of life can also be clarified by taking into account the background dipolar condensate. It seems natural to call this graviton condensate **bright matter**. It not only produced ordinary matter, including light, but also produced and nurturing conscious life, as we know it, and, perhaps, some other forms of life in the universe. EDM of gravitons is small and existing telescopes can not see them, but we actually see bright matter in our subjective experiences. So, cosmology and brain science must work together to investigate bright matter, which will be the most important enterprise of humankind,

The level of a civilization, to a high degree, is determined by its cosmology. To the oldest question - Who we are?- this article, based on the described below quantum modification of general relativity (Qmoger), gives the answer: "We are creatures of the cosmic quantum condensate of ultralight dipolar gravitons - particles, which started to seep from the Vacuum about 284 billion years ago". How it sound?

Let us take it slowly. First of all, in Qmoger the matter/energy is produced continuously. This is in contrast with the conventional Big Bang cosmology [1] with singular release of energy about 14 billion years ago. Some problems with Big Bang theory are described in Ref. 1, 2. Additional critical analysis of the old cosmology and main results of new cosmology, supported by cosmic data (without fitting, see below), were presented in Ref. 3, 4 and references

there. In the new cosmology, our universe was quietly born in the infinite past (mathematically speaking). At those times there was nothing but the Vacuum with small quantum fluctuations. Than, about 327 billion years (*by*) ago an embryonic universe was born with size about Planck length  $l_P = (G_* \hbar c)^{1/2} \sim 1.6 \times 10^{-37} cm$  ( $G_* = Gc^{-4}$ ,  $G$  - gravitation constant,  $c$  - speed of light,  $\hbar$  - Planck constant) and mass:

$$M_1 = \rho_0 l_P^3 \approx 10^{-128} gram, \quad (1)$$

where  $\rho_0$  is the current averaged mass density of the universe. At this stage, one may naturally ask two questions: why 327 *by* and why  $\rho_0$ ? To answer these questions, here comes exact analytical solution of the Qmoger equations (see Appendix):

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

Here  $a(\tau)$  is the time dependent averaged size of the universe (scale factor), subscript 0 indicate initial (current) value,  $\varepsilon_0 = \rho_0 c^2$  is the energy density,  $H_0$  is Hubble constant - current value of  $H(\tau) = \dot{a}/a$ , where dot indicate differentiation with respect to  $\tau$ . Solution (2) corresponds to constant energy density  $\varepsilon(\tau) = \varepsilon_0$ . That is why we have  $\rho_0$  in (1). According to WMAP data [5], we use  $\rho_0 \approx 2.6 \cdot 10^{-30} gram \cdot cm^{-3}$ , which includes dark and ordinary matter, but not the so called dark energy, which we do not need in our theory.

In fact, problems with dark energy (cosmological constant) were a major motivation for the Qmoger theory, presented originally in Ref. 6. This work was presided by invention of new type of fluid, namely, dynamics of distributed sources/sinks [7,8], which in turn where presided by exact analytical solution of the (1+1)-dimensional Newtonian gravitation [9]. I love to simplify things and to get analytical solutions (second motivation for Qmoger). In Ref. 9 it was shown, particularly, that Newtonian gravitation leads to singularities in spacial dimensions 1 and 2. So, the third motivation for Qmoger was to get rid of singularities, particularly, from Big Bang - see, how smooth is function (2).

Solution (2) formally gives beginning of the universe at infinite past with  $a(-\infty) = 0$ . But, physically speaking, it seems natural to start with size  $l_P$ , when we can expect formation of smooth spacetime metric. Putting  $a(\tau) = l_P$  in (2), we get equation for  $\tau$ . Solution of this equation, corresponding to the past, gives 327 *by* [10, 4].

According to (2), evolution of the universe is determined by characteristic physical scale  $L_* \approx 76$  billion light years (*bly*), which is comparable with the size of the visible universe  $a_0 \approx 46.5$  *bly*. It seems natural to assume that mass  $m_0$  of the dark matter particles (DMP), which fill out the universe, is determined by condition that the relativistic uncertainty of partial position [11] (or Compton wavelength)  $\hbar/m_0 c$  is of order of  $L_*$ . This gives:

$$m_0 = \hbar(G_* \rho_0)^{1/2} \sim 5 \cdot 10^{-67} gram. \quad (3)$$

These ultralight particles we call gravitons, because only gravity field was used in the theory. Concentration of gravitons  $n$  and characteristic scale  $l$  (averaged distance between them) are:

$$n = \rho_0/m_0 \sim 0.5 \cdot 10^{37} cm^{-3}, \quad l = n^{-1/3} \sim 0,27 \cdot 10^{-12} cm. \quad (4)$$

To determine when universe started to produce gravitons, we put  $a(\tau) = l$  into (2), solve equation for  $\tau$  and got the result: 284 *by* ago [10, 4]. So, it took 43 *by* of "incubation" to accommodate universe for production of gravitons.

Formula (2) 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 [12]). Comparison with observational data was made in Refs. 13, 14, 3, see also Fig.1 below.

Gravitons have small, but finite mass (3) and huge concentration (4). The "ordinary" matter (OM) in this theory was synthesized from dark matter in galaxies [3, 4]. Averaged concentration (4) 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  $l$  (4). Remember, that we are dealing with unusual fluid [7, 8]. The thermal de Broglie wavelength [15] for the temperature of the universe  $T \approx 2.73K$  is substantially bigger than  $l$ :  $\hbar c/(k_B T) \approx 3 \cdot 10^{11}$  ( $k_B$  - Boltzmann constant). This estimate is for massless particles. For nonrelativistic gravitons with mass  $m_0$  the relation 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 (4). With certain critical density, we can expect local bangs (recall Ref. 9) with multiple collisions and 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 cosmic microwave background (CMB). The equilibrium character of CMB and the small global curvature of the universe 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 (2), 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). Taking into account the history of the universe and indicated below spectrum of mass and mediators between gravitons and OM, we can not be sure that graviton is elementary particle. Moreover, we can not be sure that gravitons obeys all the rules of the conventional quantum theory. It is possible, that gravitons and mediators produce some quantum effects for "ordinary" matter (see new interpretation of quantum theory [16]).

In Qmoger the baryonic asymmetry of the universe ( prevalence of matter over antimatter ) can be explained if gravitons have nonzero electric dipole moment (EDM). Indeed, EDM of primary particles can break the reflection symmetry and give advantage to matter over antimatter. It will also help to explain synthesis of some particles from the dipolar quantum condensate. From mass  $m_0$  (3),  $l_P$  and  $c$  we have unique expression for EDM:

$$d \sim m_0^{1/2} l_P^{3/2} c \sim 2 \times 10^{-72} \text{gram}^{1/2} \text{cm}^{5/2} \text{sec}^{-1} \quad (5)$$

There is also scale  $l_0 = m_0 G c^{-2} \sim 4 \cdot 10^{-95} \text{cm}$ , 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 (5), assuming that  $N(0)$  is finite. Using  $\nu$ , 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.

Let us note, that presented calculations of mass (3) and EDM (5), actually, do not require the full acceptance of the Qmoger theory. It is sufficient to accept, that  $\rho_0$  is an important parameter.

In the described theory we got that gravitons constitute omnipresent background in the universe. As a result of gravitation, 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<sup>1</sup>). A model of IDOM is described in Ref. 17. From that model it follows that our subjective experiences (qualia) are manifestations of IDOM and can be used as a natural detector of interaction between gravitons and ordinary matter. The typical action potentials (say,  $30mV$ ) [18] of neural system can easily create traps and coherent dynamic patterns in the dipolar condensate with obtained above values of particle mass (3) and EDM (5). The necessary for qualia enormous number of degrees of freedom is supplied by huge concentration of gravitons (4). So, our subjective experiences are graviton-based. It can open new directions of research in biology and medicine. It also justify the given above answer to the big question: Who we are?

Some problems with the origin of life can also be clarified by taking into account the background dipolar condensate. It seems natural to call this graviton condensate bright matter. It not only produced ordinary matter, including light, but also produced and nurturing conscious life, as we know it, and, perhaps, some other forms of life in the universe. EDM of gravitons is small and existing telescopes can not see them, but we actually see bright matter in our subjective experiences. So, cosmology and brain science must work together to investigate bright matter, which will be the most important enterprise of humankind,

### **Appendix: Quantum modification of general relativity (Qmoger)**

Qmoger equations, introduced in Ref. 6, differ from the Einstein equation by two additional terms responsible for production/absorption of matter by the

vacuum:

$$R_i^k - \frac{1}{2}\delta_i^k R = 8\pi G_* T_i^k + \lambda_N \delta_i^k, \quad T_i^k = w u_i u^k - \delta_i^k p, \quad w = \varepsilon + p, \quad (\text{A1})$$

$$\lambda_N = \lambda_0 + \beta \frac{d\sigma}{ds} + \gamma \sigma^2, \quad \sigma = \frac{\partial u^k}{\partial x^k} + \frac{1}{2g} \frac{dg}{ds}, \quad \frac{d}{ds} = u^k \frac{\partial}{\partial x^k} \quad (\text{A2})$$

Here  $R_i^k$  is the curvature tensor,  $p$ ,  $\varepsilon$  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,  $x^0 = \tau = ct$ ),  $\lambda_0$  is CC (which we will put zero),  $\sigma$  is the covariant divergency,  $\beta$  and  $\gamma$  are nondimensional constants<sup>2)</sup> (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 equation of GR. Let us note that curvature terms in lhs of (A1) and additional terms  $d\sigma/ds$  and  $\sigma^2$  all contain second order (or square of first order) derivatives of metric tensor, which make these terms compatible. The importance of  $\sigma$  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 (5) below) or changing slowly, than the  $\sigma$ -effect is, certainly, very important in quantum cosmology.

Some exact analytical solutions of equations (A1, A2) were obtained in Ref. 6. On the basis of these solutions, it was concluded that the effect of spacetime stretching ( $\sigma$ ) explains the accelerated expansion of the universe and for negative  $\sigma$  (collapse) the same effect can prevent formation of singularity. Equations (A1, A2) reproduce Newtonian gravitation in the nonrelativistic asymptotic, but gravitational waves can propagate with speed, which is not necessary equal to speed of light [13]. This give us a hint that gravitons may have finite mass.

In the case  $\beta = 2\gamma$  equations (A1, A2) can be derived from the variational principle by simply replacing the cosmological constant  $\lambda_0$  (in the Lagrangian) by  $\lambda = \lambda_0 - \gamma\sigma^2$ [13].

The natural next step was quantitative comparison with cosmological data and choice of nondimensional constants  $\beta$  and  $\gamma$ . Let us consider equations for the scale factor  $a(\tau)$  in homogeneous isotropic universe (Eq. (8,9) in Ref. 6):

$$(2 - 3\beta) \frac{\ddot{a}}{a} + (1 + 3\beta - 9\gamma) \left(\frac{\dot{a}}{a}\right)^2 + \frac{k}{a^2} - \lambda_0 = -8\pi G_* p, \quad (\text{A3})$$

$$-\beta \frac{\ddot{a}}{a} + (1 + \beta - 3\gamma) \left(\frac{\dot{a}}{a}\right)^2 + \frac{k}{a^2} - \frac{\lambda_0}{3} = \frac{8\pi}{3} G_* \varepsilon. \quad (\text{A4})$$

Here points indicate differentiation over  $\tau$ , the discrete curvature parameter  $k = 0, +1, -1$  corresponds to flat, closed and open universe, respectively.

With indicated in Ref. 6 unique choice  $\beta = 2\gamma = 2/3$ , these equations take simple form:

$$\frac{k}{a^2} = \lambda_0 - 8\pi G_* p, \quad (\text{A5})$$

$$\dot{H} = \frac{3k}{2a^2} - \frac{\lambda_0}{2} - 4\pi G_* \varepsilon, \quad H \equiv \frac{\dot{a}}{a} \quad (\text{A6})$$

From (A5) with  $\lambda_0 = 0$ , we see that sign of curvature is opposite to sign of pressure. From observations we know that global curvature is close to zero. So, the dust approximation ( $p = 0$ ) is natural for this theory with  $\lambda_0 = 0$  and  $\beta = 2\gamma = 2/3$ .

In the dust approximation with  $\lambda_0 = 0, k = 0$ , two special cases for system (A3, A4) have been indicated [6]: 1) for  $\beta = 2/3$  and  $\gamma \neq 1/3$  stationary solution exist; 2) for  $\beta = 2\gamma$  the global energy is conserved, except for  $\beta = 2\gamma = 2/3$ . The choice  $\beta = 2\gamma = 2/3$  is exceptional and in the dust approximation with  $\lambda_0 = 0, k = 0$ , equation (A5) is identity and from (A6) we have exact analytical Gaussian solution:

$$a(\tau) = a_0 \exp[H_0 \tau - 2\pi(\tau/L_*)^2], \quad L_* = (G_* \varepsilon_0)^{-1/2} \quad (\text{A7})$$

Here subscript 0 indicate present epoch ( $\tau = 0$ ) and  $H_0$  is the Hubble constant. In the analogous solution, obtained in [13], instead of  $\varepsilon_0$  was  $w_0 = \varepsilon_0 + \lambda_0/8\pi G_*$ , for generality.

Solution (A7) corresponds to continuous and metric-affecting production of dark matter (DM) particles out of vacuum, with its density  $\rho_0 = \varepsilon_0 c^{-2}$  being retain constant during the expansion of spatially flat universe. In this solution there is no critical density of the universe, which is a kind of relief.

The solution (A7) is shown [13] 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.

<sup>1)</sup> 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 [19], with morphisms and formalized interfaces, but that is another story.

<sup>2)</sup> More general case [20] considered in connection with formation of galaxies.

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Fig.1. Comparison of exact analytical solution (2) with results of two observational projects and with some parametric models (details in Ref. 13, 14).

