Low-Energy Quantum Gravity Leads to Another Picture of the Universe

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Abstract. If gravitons are super-strong interacting particles and the low-temperature graviton background exists, the basic cosmological conjecture about the Dopplerian nature of redshifts may be false: a full magnitude of cosmological redshift would be caused by interactions of photons with gravitons. Non-forehead collisions with gravitons will lead to a very specific additional relaxation of any photonic flux that gives a possibility of another interpretation of supernovae 1a data - without any kinematics. These facts may implicate a necessity to change the standard cosmological paradigm. Some features of a new paradigm are discussed. In a frame of this model, every observer has two different cosmological horizons. One of them is defined by maximum existing temperatures of remote sources - by big enough distances, all of them will be masked with the CMB radiation. Another, and much smaller, one depends on their maximum luminosity - the luminosity distance increases with a redshift much quickly than the geometrical one.

If the considered quantum mechanism of classical gravity is realized in the nature, then an existence of black holes contradicts to the equivalence principle. In this approach, the two fundamental constants - Hubble's and Newton's ones - should be connected between themselves. The theoretical value of the Hubble constant is computed. Also, every massive body would be decelerated due to collisions with gravitons that may be connected with the Pioneer 10 anomaly.

1. INTRODUCTION

An opinion is commonly accepted that quantum gravity should manifest itself only on the Planck scale of energies, i.e. it is a high-energy phenomenon. The value of the Planck energy $\sim 10^{19}$ GeV has been got from dimensional reasonings. Still one wide-spread opinion is that we know a mechanism of gravity (bodies are exchanging with gravitons of spin 2) but cannot correctly describe it.

In a few last years, the situation has been abruptly changed. I enumerate those discoveries and observations which may force, in my opinion, the ice to break up.

1. In 1998, Anderson's team reported about the discovery of anomalous acceleration of NASA's probes Pioneer 10/11 [1]; this effect is not embedded in a frame of the general relativity, and its magnitude is somehow equal to $\sim Hc$, where H is the Hubble constant, c is the light velocity.

2. In the same 1998, two teams of astrophysicists, which were collecting supernovae 1a data with the aim to specificate parameters of cosmological expansion, reported about dimming remote supernovae [2, 3]; the one would be explained on a basis of the Doppler effect if at present epoch the universe expands with acceleration. This explanation needs an introduction of some "dark energy" which is unknown from any laboratory experiments.

3. In January 2002, Nesvizhevsky's team reported about discovery of quantum states of ultra-cold neutrons in the Earth's gravitational field [4]. Observed energies of levels (it means that and their differences too) in full agreement with quantum-mechanical calculations turned out to be equal to $\sim 10^{-12}$ eV. The formula for energy levels had been found still by Bohr and Sommerfeld. If transitions between these levels are accompanied with irradiation of gravitons then energies of irradiated gravitons should have the same order - but it is of 40 orders lesser than the Planck energy by which one waits quantum manifestations of gravity.

The first of these discoveries obliges to muse about the borders of applicability of the general relativity, the third - about that quantum gravity would be a high-energy phenomenon. It seems that the second discovery is far from quantum gravity but it obliges us to look at the traditional interpretation of the nature of cosmological redshift

critically. An introduction into consideration of an alternative model of redshifts [5] which is based on a conjecture about an existence of the graviton background gives us odds to see on the effect of supernova dimming as an additional manifestation of low-energy quantum gravity. Under the definite conditions, an effective temperature of the background may be the same one as a temperature of the cosmic microwave background, with an average graviton energy of the order of $\sim 10^{-3}$ eV.

In this contribution (it is a short version of my summarizing paper [6]), the main results of author's research in this approach are described. It is shown that if a redshift would be a quantum gravitational effect then one can get from its magnitude an estimate of a new dimensional constant characterizing a single act of interaction in this model. It is possible to calculate theoretically a dependence of a light flux relaxation on a redshift value, and this dependence fits supernova observational data very well at least for $z < 0.5$. Further, it is possible to find a pressure of single gravitons of the background which acts on any pair of bodies due to screening the graviton background with the bodies [7]. It turns out that the pressure is huge (a corresponding force is ~ 1000 times stronger than the Newtonian attraction) but it is compensated with a pressure of gravitons which are re-scattered by the bodies. The Newtonian attraction arises if a part of gravitons of the background forms pairs which are destructed by interaction with bodies. It is interesting that both Hubble's and Newton's constants may be computed in this approach with the ones being connected between themselves. It allows us to get a theoretical estimate of the Hubble constant. An unexpected feature of this mechanism of gravity is a necessity of "an atomic structure" of matter - the mechanism doesn't work without the one.

Collisions with gravitons should also call forth a deceleration of massive bodies of order $\sim Hc$ - namely the same as of NASA's probes. But at present stage it turns out unclear why such the deceleration has *not* been observed for planets. The situation reminds by something of the one that took place in physics before the creation of quantum mechanics when a motion of electrons should, as it seemed by canons of classical physics, lead to their fall to a nucleus.

So, in this approach we deal with the following small quantum effects of low-energy gravity: redshifts, its analog - a deceleration of massive bodies, and an additional relaxation of any light flux. The Newtonian attraction turns out to be the main statistical effect, with bodies themselves being not sources of gravitons - only correlational properties of *in* and *out* fluxes of gravitons in their neighbourhood are changed due to an interaction with bodies. There does still not exist a full and closed theory in this approach, but even the initial researches in this direction show that in this case quantum gravity cannot be described separately of other interactions, and also manifest the boundaries of applicability of a geometrical language in gravity.

2. PASSING PHOTONS THROUGH THE GRAVITON BACKGROUND [5]

Let us introduce the hypothesis, which is considered in this approach as independent from the standard cosmological model: there exists the isotropic graviton background. Photon scattering is possible on gravitons $\gamma + h \rightarrow \gamma + h$, where γ is a photon and h is a graviton, if one of the gravitons is virtual. The energy-momentum conservation law prohibits energy transfer to free gravitons. Due to forehead collisions with gravitons, an energy of any photon should decrease when it passes through the sea of gravitons.

From another side, none-forehead collisions of photons with gravitons of the background will lead to an additional relaxation of a photon flux, caused by transmission of a momentum transversal component to some photons. It will lead to an additional dimming of any remote objects, and may be connected with supernova dimming.

We deal here with the uniform non-expanding universe with the Euclidean space, and there are not any cosmological kinematic effects in this model.

2.1. Forehead collisions with gravitons: an alternative explanations of the redshift nature

We shall take into account that a gravitational "charge" of a photon must be proportional to E (it gives the factor E^2 in a cross-section) and a normalization of a photon wave function gives the factor E^{-1} in the cross-section. Also we assume here that a photon average energy loss $\bar{\varepsilon}$ in one act of interaction is relatively small to a photon energy E. Then average energy losses of a photon with an energy E on a way dr will be equal to [5]:

$$dE = -aEdr, \qquad (1)$$

where a is a constant. If a *whole* redshift magnitude is caused by this effect, we must identify $a = H/c$, where c is the light velocity, to have the Hubble law for small distances [8].

A photon energy E should depend on a distance from a source r as

$$E(r) = E_0 \exp(-ar), \tag{2}$$

where E_0 is an initial value of energy.

The expression (2) is just only so far as the condition $\bar{\varepsilon} << E(r)$ takes place. Photons with a very small energy may lose or acquire an energy changing their direction of propagation after scattering. Early or late such photons should turn out in the thermodynamic equilibrium with the graviton background, flowing into their own background. Decay of virtual gravitons should give photon pairs for this background, too. Perhaps, the last one is the cosmic microwave background [9, 10].

It follows from the expression (2) that an exact dependence $r(z)$ is the following one:

$$r(z) = ln(1+z)/a, \tag{3}$$

if an interaction with the graviton background is the only cause of redshifts. It is very important, that this redshift does not depend on a light frequency. For small z, the dependence $r(z)$ will be linear.

The expressions (1) - (3) are the same that appear in other tired-light models (compare with [11]). In this approach, the ones follow from a possible existence of the isotropic graviton background, from quantum electrodynamics, and from the fact that a gravitational "charge" of a photon must be proportional to E.

There are two difficulties in this model: (i) possible blurring of point sources, and (ii) the rise to fall time of the light curve for SN1a sources (the relativistic time dilation effect) [12] is in apparent conflict with the ideas here and of any "tired light" explanation of effect. The problems are now open. I think that for (i), a solution will be based on the following: an average graviton energy is not equal to zero, and after multiple non-forehead collisions, photons should be rejected from the registered flux - without a loss of definition of the source. For (ii), a discrete character of photon energy losses (for some more details, see the very end of subsection 2.3) would lead to a deformation of the light curve and may give something like to time dilation - but now, it is only the idea.

2.2. Non-forehead collisions with gravitons: an additional dimming of any light flux

Photon flux's average energy losses on a way dr due to non-forehead collisions with gravitons should be proportional to $badr$, where b is a new constant of the order 1. These losses are connected with a rejection of a part of photons from a source-observer direction. Such the relaxation together with the redshift will give a connection between visible object's diameter and its luminosity (i.e. the ratio of an object visible angular diameter to a square root of visible luminosity), distinguishing from the one of the standard cosmological model.

Let us consider that in a case of a non-forehead collision of a graviton with a photon, the latter leaves a photon flux detected by a remote observer (an assumption of a narrow beam of rays). The details of calculation of the theoretical value of relaxation factor b which was used in author's paper [5] were given later in the preprint [13]. So as both particles have velocities c, a cross-section of interaction, which is "visible" under an angle θ (see Fig. 1), will be equal to $\sigma_0|\cos\theta|$ if σ_0 is a cross-section by forehead collisions. The function $|\cos\theta|$ allows to take into account both front and back hemispheres for riding gravitons. Additionally, a graviton flux, which falls on a picked out area (cross-section), depends on the angle θ. We have for the ratio of fluxes:

$$\Phi(\theta)/\Phi_0 = S_s/\sigma_0,$$

where $\Phi(\theta)$ and Φ_0 are the fluxes which fall on σ_0 under the angle θ and normally, S_s is a square of side surface of a truncated cone with a base σ_0 (see Fig. 1).

Finally, we get for the factor b :

$$b = 2 \int_0^{\pi/2} \cos\theta \times (S_s/\sigma_0) \frac{d\theta}{\pi/2}. \tag{4}$$

By $0 < \theta < \pi/4$, a formed cone contains self-intersections, and it is $S_s = 2\sigma_0 \times \cos\theta$. By $\pi/4 \le \theta \le \pi/2$, we have $S_s = 4\sigma_0 \times \sin^2\theta \cos\theta$.

After computation of simple integrals, we get:

$$b = \frac{4}{\pi}\left(\int_0^{\pi/4} 2\cos^2\theta d\theta + \int_{\pi/4}^{\pi/2} \sin^2 2\theta d\theta\right) = \frac{3}{2} + \frac{2}{\pi} \simeq 2.137. \tag{5}$$
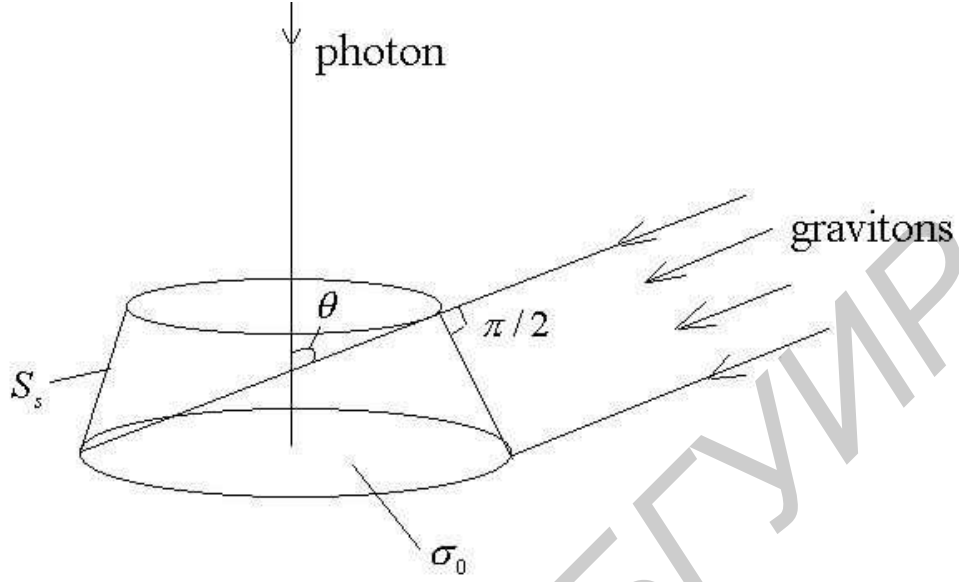
FIGURE 1. By non-forehead collisions of gravitons with a photon, it is necessary to calculate a cone's side surface square, S_s.

In the considered simplest case of the uniform non-expanding universe with the Euclidean space, we shall have the quantity

$$(1+z)^{(1+b)/2} \equiv (1+z)^{1.57}$$

in a visible object diameter-luminosity connection if a whole redshift magnitude would caused by such an interaction with the background (instead of $(1+z)^2$ for the expanding uniform universe). For near sources, the estimate of the factor b will be some increased one.

The luminosity distance (see [2]) is a convenient quantity for astrophysical observations. Both redshifts and the additional relaxation of any photonic flux due to non-forehead collisions of gravitons with photons lead in our model to the following luminosity distance D_L:

$$D_L = a^{-1}\ln(1+z) \times (1+z)^{(1+b)/2} \equiv a^{-1}f_1(z), \qquad (6)$$

where $f_1(z) \equiv \ln(1+z) \times (1+z)^{(1+b)/2}$.

2.3. Comparison of the theoretical predictions with supernova data

To compare a form of this predicted dependence $D_L(z)$ by unknown, but constant H, with the latest observational supernova data by Riess et al. [14], one can introduce distance moduli $\mu_0 = 5\log D_L + 25 = 5\log f_1 + c_1$, where c_1 is an unknown constant (it is a single free parameter to fit the data); f_1 is the luminosity distance in units of c/H. In Figure 2, the Hubble diagram $\mu_0(z)$ is shown with $c_1 = 43$ to fit observations for low redshifts; observational data (82 points) are taken from Table 5 of [14]. The predictions fit observations very well for roughly $z < 0.5$. It excludes a need of any dark energy to explain supernovae dimming.

Discrepancies between predicted and observed values of $\mu_0(z)$ are obvious for higher z: we see that observations show brighter SNe that the theory allows, and a difference increases with z. It is better seen on Figure 3 with a linear scale for f_1; observations are transformed as $\mu_0 \rightarrow 10^{(\mu_0-c_1)/5}$ with the same $c_1 = 43$.[1] It would be explained in the model as a result of specific deformation of SN spectra due to a discrete character of photon energy losses. Today, a theory of this effect does not exist, and I explain its origin only qualitatively [15]. For very small redshifts z, only a small part of photons transmits its energy to the background (see Fig. 8 in [6]). Therefore any red-shifted narrow

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[1] A spread of observations raises with z; it might be partially caused by quickly raising contribution of a dispersion of measured flux: it should be proportional to $f_1^6(z)$.
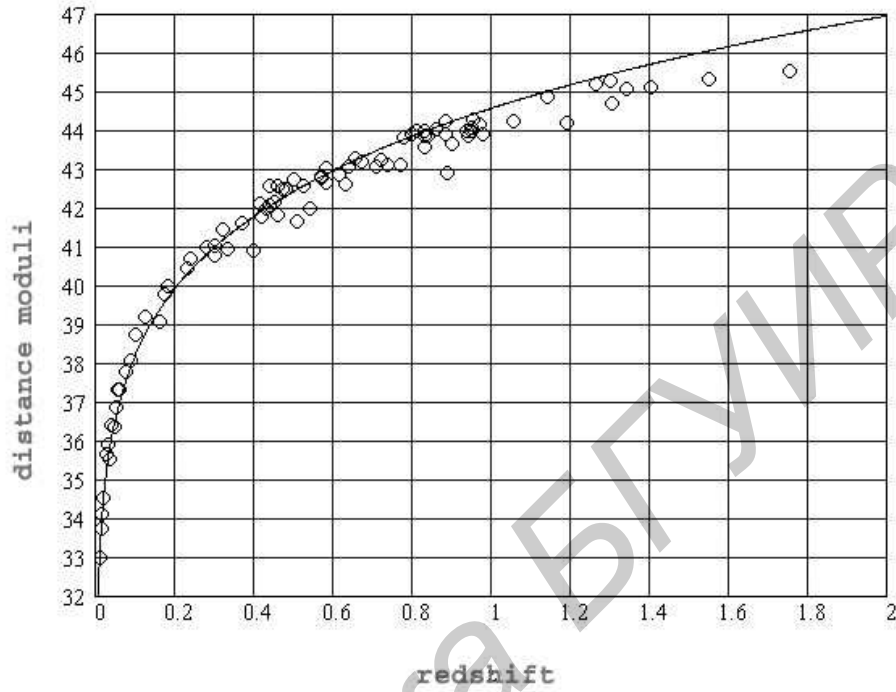
FIGURE 2. Comparison of the theoretical values of distance moduli $\mu_0(z)$ in author's model (solid line) with observations (points) from Table 5 of [14] by Riess et al.

spectral strip will be a superposition of two strips. One of them has a form which is identical to an initial one, its space is proportional to $1 - n(r)$ where $n(r)$ is an average number of interactions of a single photon with the background, and its center's shift is negligible (for a narrow strip). Another part is expand, its space is proportional to $n(r)$, and its center's shift is equal to $\bar{\varepsilon}_g/h$ where $\bar{\varepsilon}_g$ is an average energy loss in one act of interaction. An amplitude of the red-shifted step should linear raise with a redshift. For big z, spectra of remote objects of the universe would be deformed. A deformation would because of multifold interactions of a initially-red-shifted part of photons with the graviton background. It means that the observed flux within a given passband would depend on a form of spectrum: the flux may be larger than an expected one without this effect if an initial flux within a next-blue neighbour band is big enough - due to a superposition of red-shifted parts of spectrum. Some other evidences of this effect would be an apparent variance of the fine structure constant [16] or of the CMB temperature [17] with epochs. In both cases, a ratio of red-shifted spectral line's intensities may be sensitive to the effect. Also, this effect should be taken into account when one analyzes a temporal evolution of supernova spectra to detect the relativistic "time dilation" effect [12].

2.4. Computation of the Hubble constant

Let us consider that a full redshift magnitude is caused by an interaction with single gravitons. If $\sigma(E,\varepsilon)$ is a cross-section of interaction by forehead collisions of a photon with an energy E with a graviton, having an energy ε, we consider really (see (1)), that

$$\frac{d\sigma(E,\varepsilon)}{Ed\Omega} = const(E),$$

where $d\Omega$ is a space angle element, and the function $const(x)$ has a constant value for any x. If $f(\omega,T)d\Omega/2\pi$ is a spectral density of graviton flux in the limits of $d\Omega$ in some direction (ω is a graviton frequency, $\varepsilon = \hbar\omega$), i.e. an intensity of a graviton flux is equal to the integral $(d\Omega/2\pi)\int_0^\infty f(\omega,T)d\omega$, T is an equivalent temperature of the
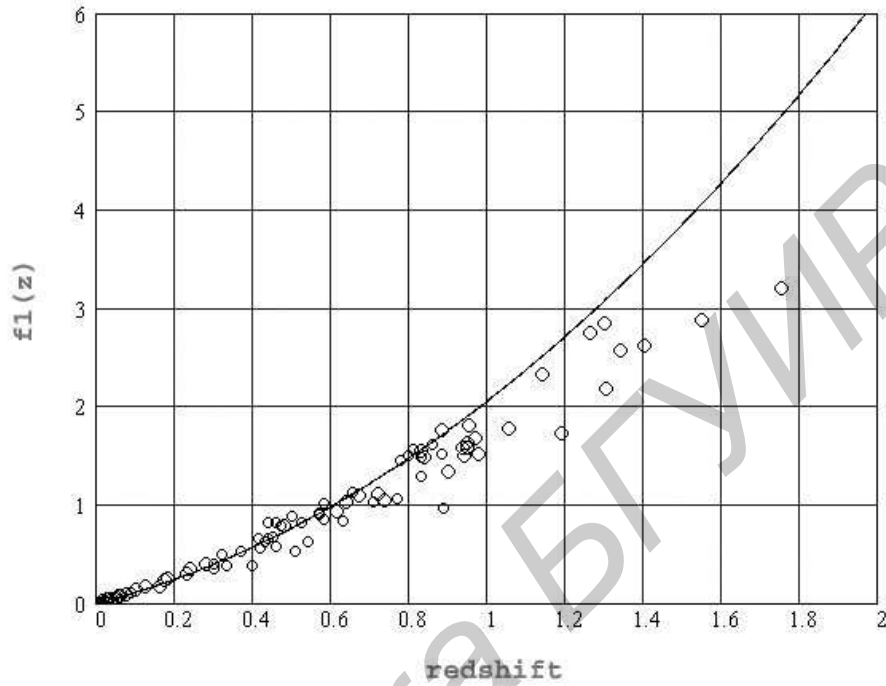
FIGURE 3. Predicted values of $f_1(z)$ (solid line) and observations (points) from [14] transformed to a linear scale

graviton background, we can write for the Hubble constant $H = ac$, introduced in the expression (1):

$$H = \frac{1}{2\pi} \int_0^\infty \frac{\sigma(E, \varepsilon)}{E} f(\omega, T) d\omega.$$

If $f(\omega, T)$ can be described by the Planck formula for equilibrium radiation, then

$$\int_0^\infty f(\omega, T) d\omega = \sigma T^4,$$

where σ is the Stephan- Boltzmann constant. As carriers of a gravitational "charge" (without consideration of spin properties), gravitons should be described in the same manner as photons , i.e. one can write for them:

$$\frac{d\sigma(E, \varepsilon)}{\varepsilon d\Omega} = const(\varepsilon).$$

Now let us introduce a new dimensional constant D, so that for forehead collisions:

$$\sigma(E, \varepsilon) = D \times E \times \varepsilon. \tag{7}$$

Then

$$H = \frac{1}{2\pi} D \times \bar{\varepsilon} \times (\sigma T^4), \tag{8}$$

where $\bar{\varepsilon}$ is an average graviton energy. Assuming $T \sim 3\text{K}$, $\bar{\varepsilon} \sim 10^{-4}$ eV, and $H = 1.6 \times 10^{-18}\,\text{s}^{-1}$, we get the following rough estimate for D :

$$D \sim 10^{-27}\ \text{m}^2/eV^2,$$

(see below Subsection 4.3 for more exact estimate of D and for a theoretical estimate of H) that gives us the phenomenological estimate of cross-section by the same and equal E and $\bar{\varepsilon}$:

$$\sigma(E, \bar{\varepsilon}) \sim 10^{-35}\ \text{m}^2.$$

3. DECELERATION OF MASSIVE BODIES: AN ANALOG OF REDSHIFTS

As it was reported by Anderson's team [1] , NASA deep-space probes (Pioneer 10/11, Galileo, and Ulysses) experience a small additional constant acceleration, directed towards the Sun (the Pioneer anomaly). Today, a possible origin of the effect is unknown. It must be noted here that the reported direction of additional acceleration may be a result of the simplest conjecture, which was accepted by the authors to provide a good fit for all probes. One should compare different conjectures to choose the one giving the best fit.

We consider here a deceleration of massive bodies, which would give a similar deformation of cosmic probes' trajectories [5]. The one would be a result of interaction of a massive body with the graviton background, but such an additional acceleration will be directed against a body velocity.

It follows from a universality of gravitational interaction, that not only photons, but all other objects, moving relative to the background, should lose their energy, too, due to such a quantum interaction with gravitons. If $a = H/c$, it turns out that massive bodies must feel a constant deceleration of the same order of magnitude as a small additional acceleration of cosmic probes.

Let us now denote as E a full energy of a moving body which has a velocity v relative to the background. Then energy losses of the body by an interaction with the graviton background (due to forehead collisions with gravitons) on the way dr must be expressed by the same formula (1):

$$dE = -aE\,dr,$$

where $a = H/c$. If $dr = v\,dt$, where t is a time, and $E = mc^2/\sqrt{1 - v^2/c^2}$, then we get for the body acceleration $w \equiv dv/dt$ by a non-zero velocity:

$$w = -ac^2(1 - v^2/c^2). \tag{9}$$

We assume here, that non-forehead collisions with gravitons give only stochastic deviations of a massive body's velocity direction, which are negligible. For small velocities:

$$w \simeq -Hc. \tag{10}$$

If the Hubble constant H is equal to $2.14 \times 10^{-18} \text{s}^{-1}$ (it is the theoretical estimate of H in this approach, see below Subsection 4.3), a modulus of the acceleration will be equal to

$$|w| \simeq Hc = 6.419 \times 10^{-10} \text{ m}/s^2, \tag{11}$$

that has the same order of magnitude as a value of the observed additional acceleration $(8.74 \pm 1.33) \times 10^{-10} \text{m}/s^2$ for NASA probes.

I must emphasize here that the acceleration w is directed against a body velocity only in a special frame of reference (in which the graviton background is isotropic). I would like to note that a deep-space mission to test the discovered anomaly is planned now at NASA by the authors of this very important discovery [18].

It is very important to understand, why such an acceleration has not been observed for planets. This acceleration will have different directions by motion of a body on a closed orbit, and one must take into account a solar system motion, too. As a result, an orbit should be deformed. The observed value of anomalous acceleration of Pioneer 10 should represent the vector difference of the two accelerations [7]: an acceleration of Pioneer 10 relative to the graviton background, and an acceleration of the Earth relative to the background. Possibly, the last is displayed as an annual periodic term in the residuals of Pioneer 10 [19]. If the solar system moves with a noticeable velocity relative to the background, the Earth's anomalous acceleration projection on the direction of this velocity will be smaller than for the Sun - because of the Earth's orbital motion. It means that in a frame of reference, connected with the Sun, the Earth should move with an anomalous acceleration having non-zero projections as well on the orbital velocity direction as on the direction of solar system motion relative to the background. Under some conditions, the Earth's anomalous acceleration in this frame of reference may be periodic. The axis of Earth's orbit should feel an annual precession by it. This question needs a further consideration.

4. GRAVITY AS THE SCREENING EFFECT

It was shown by the author [7] that screening the background of super-strong interacting gravitons creates for any pair of bodies both attraction and repulsion forces due to pressure of gravitons. For single gravitons, these forces are

approximately balanced, but each of them is much bigger than a force of Newtonian attraction. If single gravitons are pairing, an attraction force due to pressure of such graviton pairs is twice exceeding a corresponding repulsion force if graviton pairs are destructed by collisions with a body. In such the model, the Newton constant is connected with the Hubble constant that gives a possibility to obtain a theoretical estimate of the last. We deal here with a flat non-expanding universe fulfilled with super-strong interacting gravitons; it changes the meaning of the Hubble constant which describes magnitudes of three small effects of quantum gravity but not any expansion or an age of the universe.

4.1. Pressure force of single gravitons

If gravitons of the background run against a pair of bodies with masses m_1 and m_2 (and energies E_1 and E_2) from infinity, then a part of gravitons is screened. Let $\sigma(E_1, \varepsilon)$ is a cross-section of interaction of body 1 with a graviton with an energy $\varepsilon = \hbar\omega$, where ω is a graviton frequency, $\sigma(E_2, \varepsilon)$ is the same cross-section for body 2. In absence of body 2, a whole modulus of a gravitonic pressure force acting on body 1 would be equal to:

$$4\sigma(E_1, <\varepsilon>) \times \frac{1}{3} \times \frac{4f(\omega, T)}{c}, \tag{12}$$

where $f(\omega, T)$ is a graviton spectrum with a temperature T (assuming to be Planckian), the factor 4 in front of $\sigma(E_1, <\varepsilon>)$ is introduced to allow all possible directions of graviton running, $<\varepsilon>$ is another average energy of running gravitons with a frequency ω taking into account a probability of that in a realization of flat wave a number of gravitons may be equal to zero, and that not all of gravitons ride at a body.

Body 2, placed on a distance r from body 1, will screen a portion of running against body 1 gravitons which is equal for big distances between the bodies (i.e. by $\sigma(E_2, <\varepsilon>) \ll 4\pi r^2$) to:

$$\frac{\sigma(E_2, <\varepsilon>)}{4\pi r^2}. \tag{13}$$

Taking into account all frequencies ω, the following attractive force will act between bodies 1 and 2 :

$$F_1 = \int_0^\infty \frac{\sigma(E_2, <\varepsilon>)}{4\pi r^2} \times 4\sigma(E_1, <\varepsilon>) \times \frac{1}{3} \times \frac{4f(\omega, T)}{c} d\omega. \tag{14}$$

Let $f(\omega, T)$ is described with the Planck formula:

$$f(\omega, T) = \frac{\omega^2}{4\pi^2 c^2} \frac{\hbar\omega}{\exp(\hbar\omega/kT) - 1}. \tag{15}$$

Let $x \equiv \hbar\omega/kT$, and $\bar{n} \equiv 1/(\exp(x) - 1)$ is an average number of gravitons in a flat wave with a frequency ω (on one mode of two distinguishing with a projection of particle spin). Let $P(n, x)$ is a probability of that in a realization of flat wave a number of gravitons is equal to n, for example $P(0, x) = \exp(-\bar{n})$.

Then we get for an attractive force F_1 :

$$F_1 = \frac{4}{3} \frac{D^2 E_1 E_2}{\pi r^2 c} \int_0^\infty \frac{\hbar^3 \omega^5}{4\pi^2 c^2} [1 - P(0, x)]^2 \bar{n}^5 \exp(-2\bar{n}) d\omega \tag{16}$$

$$= \frac{1}{3} \times \frac{D^2 c(kT)^6 m_1 m_2}{\pi^3 \hbar^3 r^2} \times I_1,$$

where

$$I_1 \equiv \int_0^\infty x^5 (1 - \exp\{-[\exp(x) - 1]^{-1}\})^2 [\exp(x) - 1]^{-5} \exp\{-2[\exp(x) - 1]^{-1}\} dx \tag{17}$$

$$= 5.636 \times 10^{-3}.$$

This and all other integrals were found with the MathCad software.

If $F_1 \equiv G_1 \times m_1 m_2 / r^2$, then the constant G_1 is equal to:

$$G_1 \equiv \frac{1}{3} \times \frac{D^2 c(kT)^6}{\pi^3 \hbar^3} \times I_1. \tag{18}$$

By $T = 2.7$ K : $G_1 = 1215.4 \times G$, that is three order greater than the Newton constant, G.

But if single gravitons are elastically scattered with body 1, then our reasoning may be reversed: the same portion (13) of scattered gravitons will create a repulsive force F_1' acting on body 2 and equal to $F_1' = F_1$, if one neglects with small allowances which are proportional to D^3/r^4.

So, for bodies which elastically scatter gravitons, screening a flux of single gravitons does not ensure Newtonian attraction. But for gravitonic black holes which absorb any particles and do not re-emit them (by the meaning of a concept, the ones are usual black holes; I introduce a redundant adjective only from a caution), we will have $F_1' = 0$. It means that such the object would attract other bodies with a force which is proportional to G_1 but not to G, i.e. Einstein's equivalence principle would be violated for them. This conclusion, as we shall see below, stays in force for the case of graviton pairing, too.

4.2. Graviton pairing

To ensure an attractive force which is not equal to a repulsive one, particle correlations should differ for *in* and *out* flux. For example, single gravitons of running flux may associate in pairs [7]. If such pairs are destructed by collision with a body, then quantities $< \varepsilon >$ will be distinguished for running and scattered particles. Graviton pairing may be caused with graviton's own gravitational attraction or gravitonic spin-spin interaction. Left an analysis of the nature of graviton pairing for the future; let us see that gives such the pairing.

To find an average number of pairs $\bar{n}_2$ in a wave with a frequency ω for the state of thermodynamic equilibrium, one may replace $\hbar \rightarrow 2\hbar$ by deducing the Planck formula. Then an average number of pairs will be equal to:

$$\bar{n}_2 = \frac{1}{\exp(2x) - 1}, \tag{19}$$

and an energy of one pair will be equal to $2\hbar\omega$. It is important that graviton pairing does not change a number of stationary waves, so as pairs nucleate from existing gravitons.

It follows from the energy conservation law that composite gravitons should be distributed only in two modes. So as

$$\lim_{x \rightarrow 0} \frac{\bar{n}_2}{\bar{n}} = 1/2, \tag{20}$$

then by $x \rightarrow 0$ we have $2\bar{n}_2 = \bar{n}$, i.e. all of gravitons are pairing by low frequencies. An average energy on every mode of pairing gravitons is equal to $2\hbar\omega\bar{n}_2$, the one on every mode of single gravitons - to $\hbar\omega\bar{n}$. These energies are equal by $x \rightarrow 0$, because of that, the numbers of modes are equal, too, if the background is in the thermodynamic equilibrium with surrounding bodies.

The spectrum of composite gravitons is also the Planckian one, but with a smaller temperature of $0.5946T$. An absolute luminosity for the sub-system of composite gravitons is equal to $\frac{1}{8}\sigma T^4$, where σ is the Stephan-Boltzmann constant. It is important that the graviton pairing effect does not change computed values of the Hubble constant and of anomalous deceleration of massive bodies: twice decreasing of a sub-system particle number due to the pairing effect is compensated with twice increasing the cross-section of interaction of a photon or any body with such the composite gravitons. Non-pairing gravitons with spin 1 give also its contribution in values of redshifts, an additional relaxation of light intensity due to non-forehead collisions with gravitons, and anomalous deceleration of massive bodies moving relative to the background.

4.3. Computation of the Newton constant, and a connection between the two fundamental constants, G and H

If running graviton pairs ensure for two bodies an attractive force F_2, then a repulsive force due to re-emission of gravitons of a pair alone will be equal to $F_2' = F_2/2$. It follows from that the cross-section for *single additional scattered* gravitons of destructed pairs will be twice smaller than for pairs themselves (the leading factor $2\hbar\omega$ for pairs should be replaced with $\hbar\omega$ for single gravitons). For pairs, we introduce here the cross-section $\sigma(E_2, < \varepsilon_2 >)$, where $< \varepsilon_2 >$ is an average pair energy with taking into account a probability of that in a realization of flat wave a number of graviton pairs may be equal to zero, and that not all of graviton pairs ride a body ($< \varepsilon_2 >$ is an analog of $< \varepsilon >$). This

equality is true in neglecting with small allowances which are proportional to D^3/r^4. Replacing $\bar{n} \to \bar{n}_2$, $\hbar\omega \to 2\hbar\omega$, and $P(n,x) \to P(n,2x)$, where $P(0,2x) = \exp(-\bar{n}_2)$, we get for a force of attraction of two bodies due to pressure of graviton pairs [2], F_2:

$$F_2 = \int_0^\infty \frac{\sigma(E_2, <\varepsilon_2>)}{4\pi r^2} \times 4\sigma(E_1, <\varepsilon_2>) \times \frac{1}{3} \times \frac{4f_2(2\omega, T)}{c} d\omega \tag{21}$$

$$= \frac{8}{3} \times \frac{D^2 c(kT)^6 m_1 m_2}{\pi^3 \hbar^3 r^2} \times I_2,$$

where

$$I_2 \equiv \int_0^\infty \frac{x^5(1 - \exp\{-[\exp(2x)-1]^{-1}\})^2 [\exp(2x)-1]^{-5}}{\exp(2(\exp(2x)-1)^{-1}) \exp\{2[\exp(x)-1]^{-1}\}} dx \tag{22}$$

$$= 2.3184 \times 10^{-6}.$$

The difference F between attractive and repulsive forces will be equal to:

$$F \equiv F_2 - F_2^{'} = \frac{1}{2} F_2 \equiv G_2 \frac{m_1 m_2}{r^2}, \tag{23}$$

where the constant G_2 is equal to:

$$G_2 \equiv \frac{4}{3} \times \frac{D^2 c(kT)^6}{\pi^3 \hbar^3} \times I_2. \tag{24}$$

Both G_1 and G_2 are proportional to T^6 (and $H \sim T^5$, so as $\bar{\varepsilon} \sim T$).

If one assumes that $G_2 = G$, then it follows that by $T = 2.7$K the constant D should have the value:

$$D = 0.795 \times 10^{-27} \text{m}^2/\text{eV}^2. \tag{25}$$

An average graviton energy of the background is equal to:

$$\bar{\varepsilon} \equiv \int_0^\infty \hbar\omega \times \frac{f(\omega, T)}{\sigma T^4} d\omega = \frac{15}{\pi^4} I_4 kT, \tag{26}$$

where

$$I_4 \equiv \int_0^\infty \frac{x^4 dx}{\exp(x)-1} = 24.866 $$

(it is $\bar{\varepsilon} = 8.98 \times 10^{-4}$eV by $T = 2.7$K).

We can use (8) and (24) to establish a connection between the two fundamental constants, G and H, under the condition that $G_2 = G$. We have for D:

$$D = \frac{2\pi H}{\bar{\varepsilon}\sigma T^4} = \frac{2\pi^5 H}{15k\sigma T^5 I_4}; \tag{27}$$

then

$$G = G_2 = \frac{4}{3} \times \frac{D^2 c(kT)^6}{\pi^3 \hbar^3} \times I_2 = \frac{64\pi^5}{45} \times \frac{H^2 c^3 I_2}{\sigma T^4 I_4^2}. \tag{28}$$

So as the value of G is known much better than the value of H, let us express H via G:

$$H = (G \frac{45}{64\pi^5} \frac{\sigma T^4 I_4^2}{c^3 I_2})^{1/2} = 2.14 \times 10^{-18} \text{ s}^{-1}, \tag{29}$$

or in the units which are more familiar for many of us: $H = 66.875 \text{ k}m \times s^{-1} \times Mpc^{-1}$.

This value of H is in the good accordance with the majority of present astrophysical estimations [2, 20, 21] (for example, the estimate (72 ± 8)k$m/s/Mpc$ has been got from SN1a cosmological distance determinations in [21]), but it is lesser than some of them [22] and than it follows from the observed value of anomalous acceleration of Pioneer 10 [1].

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[2] In initial version of this paper, factor 2 was lost in the right part of Eq. (21), and the theoretical values of D and H were overestimated of $\sqrt{2}$ times

5. SOME COSMOLOGICAL CONSEQUENCES OF THE MODEL

If the described model of redshifts is true, what is a picture of the universe? In a frame of this model, every observer has two own spheres of observability in the universe (two different cosmological horizons exist for any observer) [24, 25]. One of them is defined by maximum existing temperatures of remote sources - by big enough distances, all of them will be masked with the CMB radiation. Another, and much smaller, sphere depends on their maximum luminosity - the luminosity distance increases with a redshift much quickly than the geometrical one. The ratio of the luminosity distance to the geometrical one is the quickly increasing function of z:

$$D_L(z)/r(z) = (1+z)^{(1+b)/2}, \qquad (30)$$

which does not depend on the Hubble constant. An outer part of the universe will drown in a darkness.

By the found theoretical value of the Hubble constant: $H = 2.14 \times 10^{-18} \text{ s}^{-1}$ (then a natural light unit of distances is equal to $1/H \simeq 14.85$ light GYR), plots of two theoretical functions of z in this model - the geometrical distance $r(z)$ and the luminosity distance $D_L(z)$ - are shown on Fig. 4 [24, 25]. As one can see, for objects with $z \sim 10$, which are observable now, we should anticipate geometrical distances of the order ~ 35 light GYR and luminosity distances of the order ~ 1555 light GYR in a frame of this model. An estimate of distances to objects with given z is changed, too: for example, the quasar with $z = 5.8$ [27] should be in a distance approximately 2.8 times bigger than the one expected in the model based on the Doppler effect.
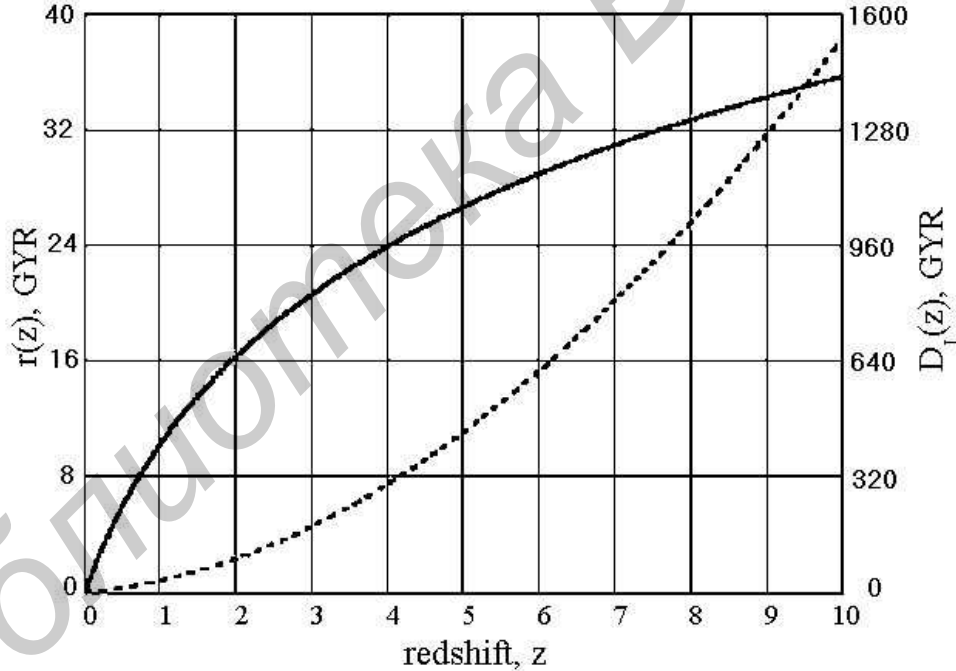

FIGURE 4.   The geometrical distance, $r(z)$, (solid line) and the luminosity distance, $D_L(z)$, (dashed line) - both in light GYRs - in this model as functions of a redshift, z. The following theoretical value for H is accepted: $H = 2.14 \times 10^{-18} \text{s}^{-1}$.

We can assume that the graviton background and the cosmic microwave one are in a state of thermodynamical equilibrium, and have the same temperatures. CMB itself may arise as a result of cooling any light radiation up to reaching this equilibrium. Then it needs $z \sim 1000$ to get through the very edge of our cosmic "ecumene".

Some other possible cosmological consequences of an existence of the graviton background were described in [7, 26]. Observations of last years give us strong evidences for supermassive and compact objects (named now supermassive black holes) in active and normal galactic nuclei [28, 29, 30, 31, 32]. Massive nuclear "black holes" of $10^6 - 10^9$ solar masses may be responsible for the energy production in quasars and active galaxies [28]. In a frame of this model, an existence of black holes contradicts to the equivalence principle. It means that these objects should have another nature; one must remember that we know only that these objects are supermassive and compact.

There should be two opposite processes of heating and cooling the graviton background [26] which may have a big impact on cosmology. Unlike models of expanding universe, in any tired light model one has a problem of utilization

of energy, lost by radiation of remote objects. In the considered model, a virtual graviton forms under collision of a photon with a graviton of the graviton background. It should be massive if an initial graviton transfers its total momentum to a photon; it follows from the energy conservation law that its energy ε' must be equal to 2ε if ε is an initial graviton energy. In force of the uncertainty relation, one has for a virtual graviton lifetime $\tau : \tau \le \hbar/\varepsilon'$, i.e. for $\varepsilon' \sim 10^{-4}$ eV it is $\tau \le 10^{-11}$ s. In force of conservation laws for energy, momentum and angular momentum, a virtual graviton may decay into no less than three real gravitons. In a case of decay into three gravitons, its energies should be equal to ε, ε'', ε''', with $\varepsilon'' + \varepsilon''' = \varepsilon$. So, after this decay, two new gravitons with ε'', $\varepsilon''' < \varepsilon$ inflow into the graviton background. It is a source of adjunction of the graviton background.

From another side, an interaction of gravitons of the background between themselves should lead to the formation of virtual massive gravitons, too, with energies less than ε_{min} where ε_{min} is a minimal energy of one graviton of an initial interacting pair. If gravitons with energies ε'', ε''' wear out a file of collisions with gravitons of the background, its lifetime increases. In every such a collision-decay cycle, an average energy of "redundant" gravitons will double decrease, and its lifetime will double increase. Only for ~ 93 cycles, a lifetime will increase from 10^{-11} s to 10 Gyr. Such virtual massive gravitons, with a lifetime increasing from one collision to another, would duly serve dark matter particles. Having a zero (or near to zero) initial velocity relative to the graviton background, the ones will not interact with matter in any manner excepting usual gravitation. An ultra-cold gas of such gravitons will condense under influence of gravitational attraction into "black holes" or other massive objects. Additionally to it, even in absence of initial heterogeneity, the one will easy arise in such the gas that would lead to arising of super compact massive objects, which will be able to turn out "germs" of "black holes". It is a method "to cool" the graviton background.

So, the graviton background may turn up "a perpetual engine" of the universe, pumping energy from any radiation to massive objects. An equilibrium state of the background will be ensured by such a temperature T, for which an energy profit of the background due to an influx of energy from radiation will be equal to a loss of its energy due to a catch of virtual massive gravitons with "black holes" or other massive objects. In such the picture, the chances are that "black holes" would turn out "germs" of galaxies. After accumulation of a big enough energy by a "black hole" (to be more exact, by a super-compact massive object) by means of a catch of virtual massive gravitons, the one would be absolved from an energy excess in via ejection of matter, from which stars of galaxy should form. It awaits to understand else in such the approach how usual matter particles form from virtual massive gravitons.

There is a very interesting but non-researched possibility: due to relative decreasing of an intensity of graviton pair flux in an internal area of galaxies (pairs are destructed under collisions with matter particles), the effective Newton constant may turn out to be running on galactic scales. It might lead to something like to the modified Newtonian dynamics (MOND) by Mordehai Milgrom (about MOND, for example, see [33]). But to evaluate this effect, one should take into account a relaxation process for pairs, about which we know nothing today. It is obvious only that gravity should be stronger on a galactic periphery.

6. CONCLUSION

It follows from the above consideration that the geometrical description of gravity should be a good idealization for any pair of bodies at a big distance by the condition of an "atomic structure" of matter. This condition cannot be accepted only for black holes which must interact with gravitons as aggregated objects. In addition, the equivalence principle is roughly broken for black holes, if the described quantum mechanism of classical gravity is realized in the nature. Because attracting bodies are not initial sources of gravitons, a future theory must be non-local in this sense to describe gravitons running from infinity. The Le Sage's idea to describe gravity as caused by running *ab extra* particles was criticized by the great physicist Richard Feynman in his public lectures at Cornell University [34], but the Pioneer 10 anomaly [1], perhaps, is a good contra argument pro this idea.

The described quantum mechanism of classical gravity is obviously asymmetric relative to the time inversion. By the time inversion, single gravitons would run against bodies to form pairs after collisions with bodies. It would lead to replacing a body attraction with a repulsion. But such the change will do impossible the graviton pairing.

A future theory dealing with gravitons as usual particles should have a number of features which are not characterizing any existing model to image the considered here features of the possible quantum mechanism of gravity. If this mechanism is realized in the nature, both the general relativity and quantum mechanics should be modified. Any divergencies, perhaps, would be not possible in such the model because of natural smooth cut-offs of the graviton spectrum from both sides. Gravity at short distances, which are much bigger than the Planck length, needs to be described only in some unified manner.

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