Low-energy quantum gravity

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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. In this case, 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. It 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.

A quantum mechanism of classical gravity based on an existence of this sea of gravitons is described for the Newtonian limit. This mechanism needs graviton pairing and "an atomic structure" of matter for working it, and leads to the time asymmetry. If the considered quantum mechanism of classical gravity is realized in the nature, then an existence of black holes contradicts to Einstein's equivalence principle. It is shown that 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. In this approach, every massive body would be decelerated due to collisions with gravitons that may be connected with the Pioneer 10 anomaly. Some unsolved problems are discussed, so as possibilities to verify some conjectures in laser-based experiments.

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. In this contribution, I would like to describe a very unexpected possibility to consider gravity as a very-low-energy stochastic process. I enumerate those discoveries and observations which may support this my opinion.

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 experiment.

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. 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.

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. The main results of author's research in this approach are described here briefly (it is a short version of my summarizing paper [6]). Starting from a statistical model of the graviton background with a low temperature, it is shown - under the very important condition that gravitons are super-strong interacting particles - 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.

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2 Passing photons through the graviton background [5, 7]

If the isotropic graviton background exists, then it is possible photon scattering on gravitons, if one of the gravitons is virtual. 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. 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 $\bar{\epsilon}$ 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, 7]:

$$dE = -aEdr, \tag{1}$$

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. The expression (1) is true if the condition $\bar{\epsilon} << E(r)$ 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. Perhaps, the last one is the cosmic microwave background.

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. We get for the factor b (see [9]):

$$b = \frac{4}{\pi}(\int_0^{\pi/4} 2\cos^2\theta d\theta + \int_{\pi/4}^{\pi/2} \sin^2 2\theta d\theta) = \frac{3}{2} + \frac{2}{\pi} \simeq 2.137. \tag{2}$$

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

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following luminosity distance D_L :

$$D_L = a^{-1}\ln(1+z) \cdot (1+z)^{(1+b)/2} \equiv a^{-1}f_1(z), \qquad (3)$$

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

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. [10], we can use the fact that f_1 is the luminosity distance in units of c/H. In Figure 1, the graph of f_1 is shown; observational data (82 points) are taken from Table 5 of [10]. Observations of [10] are transformed as $\mu_0 \rightarrow 10^{(\mu_0-c_1)/5}$ with the constant $c_1 = 43$. The predictions fit observations very well for roughly $z < 0.5$. It excludes a need of any dark energy to explain supernova 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 would be explained in
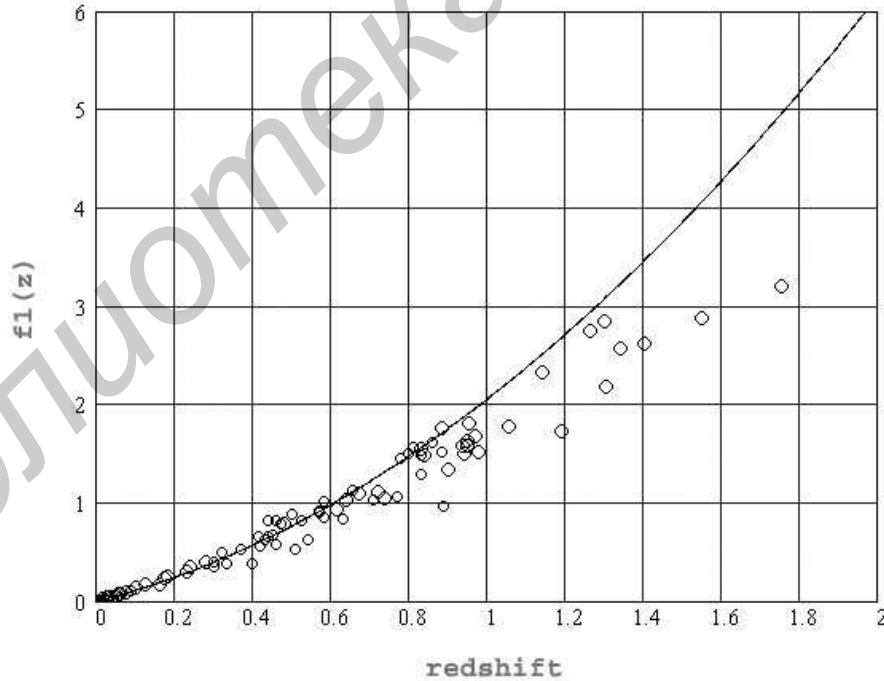

Figure 1: Predicted values of $f_1(z)$ (solid line) and observations (points) from [10] transformed to a linear scale

the model as a result of specific deformation of SN spectra due to a discrete

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character of photon energy losses. Today, a theory of this effect does not exist.

In this model, the Hubble constant may be computed. Let us consider that a full redshift magnitude is caused by an interaction with single gravitons, and $\sigma(E, \epsilon)$ is a cross-section of interaction by forehead collisions of a photon with an energy E with a graviton, having an energy ϵ. Let us introduce a new dimensional constant D, so that for forehead collisions:

$$\sigma(E, \epsilon) = D \cdot E \cdot \epsilon. \qquad (4)$$

Then

$$H = \frac{1}{2\pi} D \cdot \bar{\epsilon} \cdot (\sigma T^4), \qquad (5)$$

where $\bar{\epsilon}$ is an average graviton energy. Assuming $T \sim 3K$, $\bar{\epsilon} \sim 10^{-4}$ eV, and $H = 1.6 \cdot 10^{-18}$ s^{-1}, we get the following rough estimate for $D : D \sim 10^{-27}$ m^2/eV^2, that gives us the phenomenological estimate of cross-section by the same and equal E and $\bar{\epsilon}$: $\sigma(E, \bar{\epsilon}) \sim 10^{-35}$ m^2.

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 NASA cosmic probes (the Pioneer anomaly). We get for the body acceleration $w \equiv dv/dt$ by a non-zero velocity:

$$w = -ac^2(1 - v^2/c^2). \qquad (6)$$

For small velocities: $w \simeq -Hc$. If the Hubble constant H is equal to $2.14 \cdot 10^{-18} s^{-1}$ (it is the theoretical estimate of H in this approach), a modulus of the acceleration will be equal to $|w| = 6.419 \cdot 10^{-10}$ m/s^2, that has the same order of magnitude as a value of the observed additional acceleration $(8.74 \pm 1.33) \cdot 10^{-10} m/s^2$ for NASA probes [1].

3 Gravity as the screening effect

It was shown by the author [8, 13, 14] 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

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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.

3.1   Pressure force of single gravitons

If masses of two bodies are m_1 and m_2 (and energies E_1 and E_2), $\sigma(E_1, \epsilon)$ is a cross-section of interaction of body 1 with a graviton with an energy $\epsilon = \hbar\omega$, where ω is a graviton frequency, $\sigma(E_2, \epsilon)$ is the same cross-section for body 2. Then the following attractive force will act between bodies 1 and 2 :

$$F_1 = \int_0^\infty \frac{\sigma(E_2, <\epsilon>)}{4\pi r^2} \cdot 4\sigma(E_1, <\epsilon>) \cdot \frac{1}{3} \cdot \frac{4f(\omega, T)}{c} d\omega. \tag{7}$$

If $f(\omega, T)$ is described with the Planck formula, 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), $P(n, x)$ is a probability of that in a realization of flat wave a number of gravitons is equal to n, we shall have for $<\epsilon>$ the following expression (for more details, see [6]):

$$<\epsilon> = \hbar\omega(1 - P(0, x))\bar{n}^2 \exp(-\bar{n}). \tag{8}$$

A quantity $<\epsilon>$ 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. Then an attractive force F_1 will be equal to:

$$F_1 = \frac{4}{3} \frac{D^2 E_1 E_2}{\pi r^2 c} \int_0^\infty \frac{\hbar^3 \omega^5}{4\pi^2 c^2} (1 - P(0, x))^2 \bar{n}^5 \exp(-2\bar{n}) d\omega \tag{9}$$

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

where $I_1 = 5.636 \cdot 10^{-3}$. When $F_1 \equiv G_1 \cdot m_1 m_2/r^2$, the constant G_1 is equal to:

$$G_1 \equiv \frac{1}{3} \cdot \frac{D^2 c(kT)^6}{\pi^3 \hbar^3} \cdot I_1. \tag{10}$$

By $T = 2.7\ K : G_1 = 1215.4 \cdot G$, 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 of scattered gravitons will create a repulsive force F_1' acting on body 2 and equal to $F_1' = F_1$. So, for bodies which elastically scatter gravitons, screening a flux of single gravitons does not ensure Newtonian attraction. But for black holes which absorb any particles and do not re-emit them, 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 stays in force for the case of graviton pairing, too.

3.2   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 [8]. If such pairs are destructed by collision with a body, then quantities $< \epsilon >$ 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:

$$\bar{n}_2 = \frac{1}{\exp(2x) - 1}, \tag{11}$$

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. The question arises: how many different modes, i.e. spin projections, may graviton pairs have? We assume here that the background of initial gravitons consists of two modes. For massless transverse bosons, it takes place as by spin 1 as by spin 2. If graviton pairs have

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maximum spin 2, then single gravitons should have spin 1. But from such particles one may constitute four combinations: ↑↑, ↓↓ (with total spin 2), and ↑↓, ↓↑ (with total spin 0). All these four combinations will be equiprobable if spin projections ↑ and ↓ are equiprobable in a flat wave (without taking into account a probable spin-spin interaction).

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

$$\lim_{x \to 0} \frac{\bar{n}_2}{\bar{n}} = 1/2, \tag{12}$$

then by $x \to 0$ 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 $x \to 0$, because of that, the numbers of modes are equal, too, if the background is in the thermodynamic equilibrium with surrounding bodies. The above reasoning does not allow to choose a spin value 2 or 0 for composite gravitons. A choice of namely spin 2 would ensure the following proposition: all of gravitons in one realization of flat wave have the same spin projections. From another side, a spin-spin interaction would cause it.

The spectrum of composite gravitons is also the Planckian one, but with a smaller temperature $T_2 \equiv (1/8)^{1/4}T = 0.5946\ T$.

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.

3.3 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*

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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 $\sigma(E_2, <\epsilon_2>)$, where $<\epsilon_2>$ 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 at a body ($<\epsilon_2>$ is an analog of $<\epsilon>$). 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 graviton pairs:

$$<\epsilon_2> \sim 2\hbar\omega(1 - P(0,2x))\bar{n}_2^2\exp(-\bar{n}_2). \tag{13}$$

This expression does not take into account only that beside pairs there may be single gravitons in a realization of flat wave. To reject cases when, instead of a pair, a single graviton runs against a body (a contribution of such gravitons in attraction and repulsion is the same), we add the factor $P(0,x)$ into $<\epsilon_2>$:

$$<\epsilon_2> = 2\hbar\omega(1 - P(0,2x))\bar{n}_2^2\exp(-\bar{n}_2) \cdot P(0,x). \tag{14}$$

Then a force of attraction of two bodies due to pressure of graviton pairs, F_2, - in the full analogy with (19) - will be equal to[1]:

$$F_2 = \int_0^\infty \frac{\sigma(E_2, <\epsilon_2>)}{4\pi r^2} \cdot 4\sigma(E_1, <\epsilon_2>) \cdot \frac{1}{3} \cdot \frac{4f_2(2\omega, T)}{c}d\omega = \tag{15}$$

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

where $I_2 = 2.3184 \cdot 10^{-6}$. The difference F between attractive and repulsive forces will be equal to:

$$F \equiv F_2 - F_2' = \frac{1}{2}F_2 \equiv G_2\frac{m_1 m_2}{r^2}, \tag{16}$$

where the constant G_2 is equal to:

$$G_2 \equiv \frac{4}{3} \cdot \frac{D^2c(kT)^6}{\pi^3\hbar^3} \cdot I_2. \tag{17}$$

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

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[1]In initial version of this paper, factor 2 was lost in the right part of Eq. (15), and the theoretical values of D and H were overestimated of $\sqrt{2}$ times

If one assumes that $G_2 = G$, then it follows from (17) that by $T = 2.7K$ the constant D should have the value: $D = 0.795 \cdot 10^{-27} m^2/eV^2$.

We can use (5) and (17) to establish a connection between the two fundamental constants, G and H, under the condition that $G_2 = G$. We have for D:

$$D = \frac{2\pi H}{\bar{\epsilon}\sigma T^4} = \frac{2\pi^5 H}{15k\sigma T^5 I_4}; \tag{18}$$

then

$$G = G_2 = \frac{4}{3} \cdot \frac{D^2 c(kT)^6}{\pi^3 \hbar^3} \cdot I_2 = \frac{64\pi^5}{45} \cdot \frac{H^2 c^3 I_2}{\sigma T^4 I_4^2}. \tag{19}$$

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

$$H = (G\frac{45}{64\pi^5} \frac{\sigma T^4 I_4^2}{c^3 I_2})^{1/2} = 2.14 \cdot 10^{-18} \; s^{-1}, \tag{20}$$

or in the units which are more familiar for many of us: $H = 66.875 \; km \cdot s^{-1} \cdot Mpc^{-1}$.

This value of H is in the good accordance with the majority of present astrophysical estimations [2, 15, 16] (for example, the estimate (72 ± 8) km/s/Mpc has been got from SN1a cosmological distance determinations in [16]), but it is lesser than some of them [17] and than it follows from the observed value of anomalous acceleration of Pioneer 10 [1].

3.4 Restrictions on a geometrical language in gravity

The described quantum mechanism of classical gravity gives Newton's law with the constant G_2 value (17) and the connection (19) for the constants G_2 and H. We have obtained the rational value of H (20) by $G_2 = G$, if the condition of big distances is fulfilled:

$$\sigma(E_2, <\epsilon>) \ll 4\pi r^2. \tag{21}$$

Because it is known from experience that for big bodies of the solar system, Newton's law is a very good approximation, one would expect that this condition is fulfilled, for example, for the pair Sun-Earth. But assuming $r = 1 \; AU$ and $E_2 = m_\odot c^2$, we obtain assuming for rough estimation $<\epsilon> \to \bar{\epsilon}$:

$$\frac{\sigma(E_2, <\epsilon>)}{4\pi r^2} \sim 4 \cdot 10^{12}.$$

It means that in the case of interaction of gravitons or graviton pairs with the Sun in the aggregate, the considered quantum mechanism of classical gravity could not lead to Newton's law as a good approximation. This "contradiction" with experience is eliminated if one assumes that gravitons interact with "small particles" of matter - for example, with atoms. If the Sun contains of N atoms, then $\sigma(E_2, <\epsilon>) = N\sigma(E_a, <\epsilon>)$, where E_a is an average energy of one atom. For rough estimation we assume here that $E_a = E_p$, where E_p is a proton rest energy; then it is $N \sim 10^{57}$, i.e. $\sigma(E_a, <\epsilon>)/4\pi r^2 \sim 10^{-45} \ll 1$.

This necessity of "atomic structure" of matter for working the described quantum mechanism is natural relative to usual bodies. But would one expect that black holes have a similar structure? If any radiation cannot be emitted with a black hole, a black hole should interact with gravitons as an aggregated object, i.e. this condition for a black hole of sun mass has not been fulfilled even at distances $\sim 10^6 \ AU$.

For bodies without an atomic structure, the allowances, which are proportional to D^3/r^4 and are caused by decreasing a gravitonic flux due to the screening effect, will have a factor $m_1^2 m_2$ or $m_1 m_2^2$. These allowances break the equivalence principle for such the bodies.

For bodies with an atomic structure, a force of interaction is added up from small forces of interaction of their "atoms":

$$F \sim N_1 N_2 m_a^2/r^2 = m_1 m_2/r^2,$$

where N_1 and N_2 are numbers of atoms for bodies 1 and 2. The allowances to full forces due to the screening effect will be proportional to the quantity: $N_1 N_2 m_a^3/r^4$, which can be expressed via the full masses of bodies as $m_1^2 m_2/r^4 N_1$ or $m_1 m_2^2/r^4 N_2$. By big numbers N_1 and N_2 the allowances will be small. The allowance to the force F, acting on body 2, will be equal to:

$$\Delta F = \frac{1}{2N_2} \int_0^\infty \frac{\sigma^2(E_2, <\epsilon_2>)}{(4\pi r^2)^2} \cdot 4\sigma(E_1, <\epsilon_2>) \cdot \frac{1}{3} \cdot \frac{4f_2(2\omega, T)}{c} d\omega \quad (22)$$

$$= \frac{2}{3N_2} \cdot \frac{D^3 c^3 (kT)^7 m_1 m_2^2}{\pi^4 \hbar^3 r^4} \cdot I_3,$$

(for body 1 we shall have the similar expression if replace $N_2 \to N_1$, $m_1 m_2^2 \to m_1^2 m_2$), where $I_3 = 1.0988 \cdot 10^{-7}$.

Let us find the ratio:

$$\frac{\Delta F}{F} = \frac{DE_2 kT}{N_2 2\pi r^2} \cdot \frac{I_3}{I_2}. \quad (23)$$

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Using this formula, we can find by $E_2 = E_\odot$, $r = 1$ AU :

$$\frac{\Delta F}{F} \sim 10^{-46}.$$ (24)

An analogical allowance to the force F_1 has by the same conditions the order $\sim 10^{-48} F_1$, or $\sim 10^{-45} F$. One can replace E_p with a rest energy of very big atom - the geometrical approach will left a very good language to describe the solar system. We see that for bodies with an atomic structure the considered mechanism leads to very small deviations from Einstein's equivalence principle, if the condition of big distances is fulfilled for microparticles, which prompt interact with gravitons.

For small distances we shall have:

$$\sigma(E_2, <\epsilon>) \sim 4\pi r^2.$$ (25)

It takes place by $E_a = E_p$, $<\epsilon> \sim 10^{-3}$ eV for $r \sim 10^{-11}$ m. This quantity is many orders larger than the Planck length. The equivalence principle should be broken at such distances.

4   Some cosmological consequences of the model

If the described model of redshifts is true, what is a picture of the universe? It is interesting that 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) [18, 19]. 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 : $D_L(z)/r(z) = (1 + z)^{(1+b)/2}$, which does not depend on the Hubble constant. An outer part of the universe will drown in a darkness. 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 [20, 8].

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 [21]). 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. The renormalization group approach to gravity leads to modifications of the theory of general relativity on galactic scales [22, 23], and a growth of Newton's constant at large distances takes place, too. Kepler's third law receives quantum corrections that may explain the flat rotation curves of the galaxies.

5 How to verify the main conjecture of this approach in a laser experiment on the Earth

I would like to show here (see [24, 6]) a full realizability at present time of verifying my basic conjecture about the quantum gravitational nature of redshifts in a ground-based laser experiment. Of course, many details of this precision experiment will be in full authority of experimentalists.

It was not clear in 1995 how big is a temperature of the graviton background, and my proposal [11] to verify the conjecture about the described

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local quantum character of redshifts turned out to be very rigid: a laser with instability of $\sim 10^{-17}$ hasn't appeared after 10 years. But if $T = 2.7K$, the satellite of main laser line of frequency ν after passing the delay line will be red-shifted at $\sim 10^{-3}$ eV/h and its position will be fixed (see Fig. 2). It will be caused by the fact that on a very small way in the delay line only a
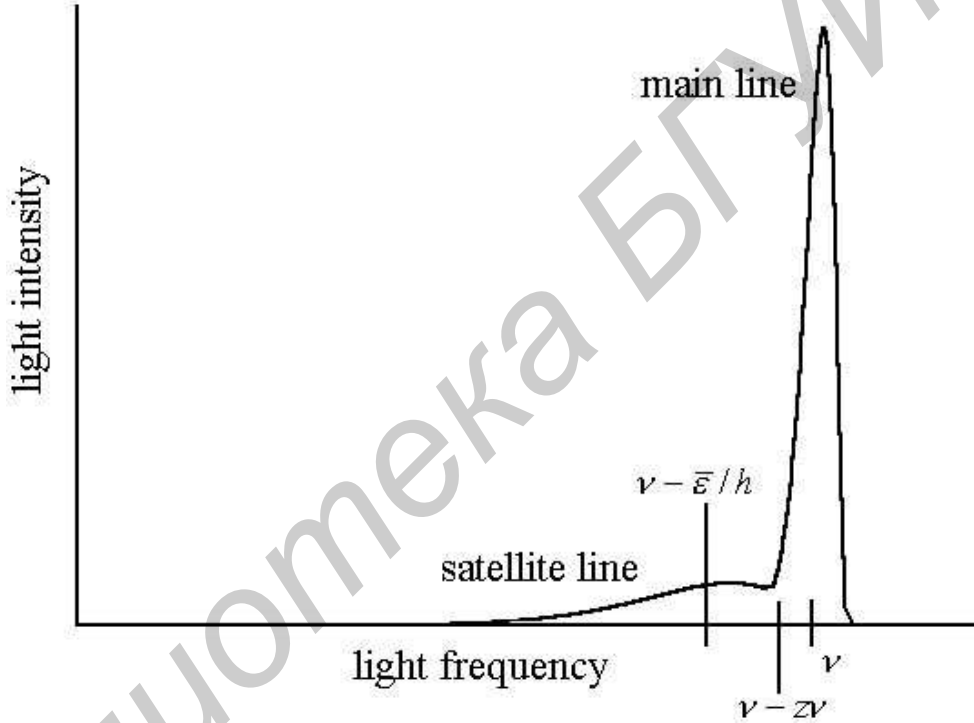

Figure 2: The main line and the expected red-shifted satellite line of a stable laser radiation spectrum after a delay line. Satellite's position should be fixed near $\nu - \bar{\epsilon}/h$, and its intensity should linear rise with a path of photons in a delay line, l. A center-of-mass of both lines is expected to be approximately near $\nu - z\nu$.

small part of photons may collide with gravitons of the background. The rest of them will have unchanged energies. The center-of-mass of laser radiation spectrum should be shifted proportionally to a photon path. Then due to the quantum nature of shifting process, the ratio of satellite's intensity to main line's intensity should have the order: $\sim \frac{h\nu}{\bar{\epsilon}} \frac{H}{c} l$, where l is a path of laser photons in a vacuum tube of delay line. It gives us a possibility to plan a laser-based experiment to verify the basic conjecture of this approach with

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much softer demands to the equipment. An instability of a laser of a power P must be only $\ll 10^{-3}$ if a photon energy is of ~ 1 eV. It will be necessary to compare intensities of the red-shifted satellite at the very beginning of the path l and after it. Given a very low signal-to-noise ratio, one could use a single photon counter to measure the intensities. When q is a quantum output of a cathode of the used photomultiplier (a number of photoelectrons is q times smaller than a number of photons falling to the cathode), N_n is a frequency of its noise pulses, and n is a desired ratio of a signal to noise's standard deviation, then an evaluated time duration t of data acquisition would have the order:

$$t = \frac{\bar{\epsilon}^2 c^2}{H^2} \frac{n^2 N_n}{q^2 P^2 l^2}. \tag{26}$$

Assuming $n = 10$, $N_n = 10^3$ s^{-1}, $q = 0.3$, $P = 100$ mW, $l = 100$ m, we would have the estimate: $t = 200,000$ years, that is unacceptable. But given $P = 300$ W, we get: $t \sim 8$ days, that is acceptable for the experiment of such the potential importance. Of course, one will rather choose a bigger value of l by a small laser power forcing a laser beam to whipsaw many times between mirrors in a delay line - it is a challenge for experimentalists.

6 Gravity in a frame of non-linear and non-local QED? - the question only to the Nature

From thermodynamic reasons, it is assumed here that the graviton background has the same temperature as the microwave background. Also it follows from the condition of detail equilibrium, that both backgrounds should have the Planckian spectra. Composite gravitons will have spin 2, if single gravitons have the same spin as photons. The question arise, of course: how are gravitons and photons connected? Has the conjecture by Adler et al. [25, 26] (that a graviton with spin 2 is composed with two photons) chances to be true? Intuitive demur calls forth a huge self-action, photons should be endued with which if one unifies the main conjecture of this approach with the one by Adler et al. - but one may get a unified theory on this way.

To verify this combined conjecture in experiment, one would search for transitions in interstellar gas molecules caused by the microwave background, with an angular momentum change corresponding to absorption of spin 2 par-

ticles (photon pairs). A frequency of such the transitions should correspond to an equivalent temperature of the sub-system of these composite particles $T_2 = 0.5946\ T$, if T is a temperature of the microwave background.

From another side, one might check this conjecture in a laser experiment, too (see [12, 6]). Taking two lasers with photon energies $h\nu_1$ and $h\nu_2$, one may force laser beams to collide on a way L (see Fig. 3). If photons are self-interacting particles, we might wait that photons with energies $h\nu_1 - h\nu_2$, if $h\nu_1 > h\nu_2$, would arise after collisions of initial photons. If we *assume (only*
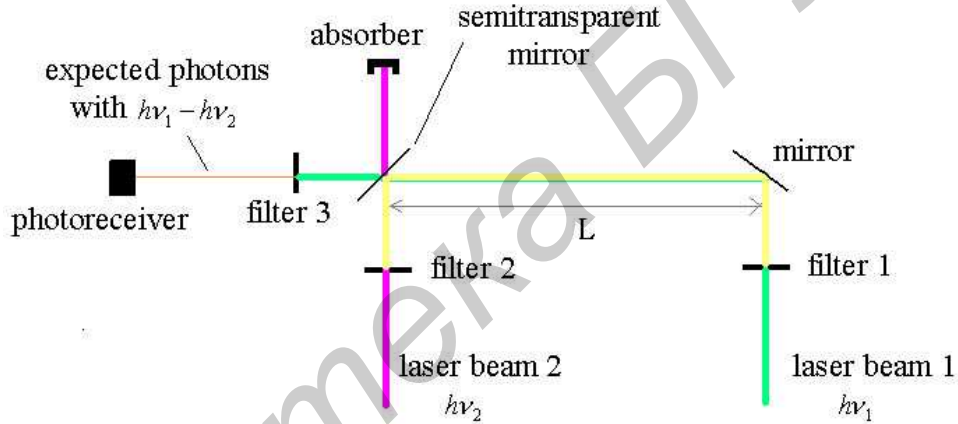

Figure 3: The scheme of laser beam passes. Two laser beams 1 and 2 collide into the area with a length L. An expected beam of photons with energies $h\nu_1 - h\nu_2$ falls to a photoreceiver.

here) that single gravitons are identical to photons, it will be necessary to take into account the following circumstances to calculate an analog of the Hubble constant for this experiment: an average graviton energy should be replaced with $h\nu_2$, the factor $1/2\pi$ in (5) should be replaced with $1/\varphi$, where φ is a divergence of laser beam 2, and one must use a quantity P/S instead of σT^4 in (5), where P is a laser 2 power and S is a cross-section of its beam. Together all it means that we should replace the Hubble constant with its analog for a laser beam collision, H_{laser}:

$$H \rightarrow H_{laser} = \frac{1}{\varphi} \cdot D \cdot h\nu_2 \cdot \frac{P}{S}. \qquad (27)$$

Taken $\varphi = 10^{-4}$, $h\nu_2 \sim 1\ eV$, $P \sim 10\ mW$, and $P/S \sim 10^3\ W/m^2$, that is characterizing a He-Ne laser, we get the estimate: $H_{laser} \sim 0.06\ s^{-1}$. Then

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photons with energies $h\nu_1 - h\nu_2$ would fall to a photoreceiver with a frequency which should linearly rise with L (proportionally to $\frac{H_{laser}}{c} \cdot L$), and it would be of $10^7 \; s^{-1}$ if both lasers have equal powers $\sim 10 \; mW$, and $L \sim 1 \; m$. It is a big enough frequency to give us a possibility to detect easy a flux of these expected photons in IR band.

If this tentative non-linear vacuum effect exists, it would lead us far beyond standard quantum electrodynamics to take into account new non-linearities (which are not connected with the electron-positron pair creation) and an essential impact of such a non-locally born object as the graviton background.

7 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 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. Cosmological models with the inversion of the time arrow were considered by Sakharov [27]. Penrose has noted that a hidden physical law may determine the time arrow direction [28]; it will be very interesting if namely realization in the nature of Newton's law determines this direction.

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

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much bigger than the Planck length, needs to be described only in some unified manner.

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