# Gravitons as super-strong interacting particles, and low-energy quantum gravity

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**Abstract**

It is shown by the author that 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. A new dimensional constant which characterizes one act of interaction is introduced and estimated. 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. Of course, all of these facts may implicate a necessity to change the standard cosmological paradigm. Some features of a new paradigm are discussed here, too.

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. It is shown that the predicted and observed values of deceleration are in good agreement. Some unsolved problems are discussed, so as possibilities to verify some conjectures in laser-based experiments.

# 1 Introduction

By a full coincidence of the forms of Coulomb's and Newton's laws, which describe an interaction of electric charges and a gravitational interaction of bodies, we see a dramatic difference in developing the pictures of these interactions on a quantum level. Constructed with pillars on multiple experiments QED is one of the most exact physical theories and an archetype for imitation by creation of new models. While the attempts to quantize the remarkable in its logical beauty theory of general relativity, which describes gravitation on a classical level so fully and delicately, (see review [1]) not only have not a hit until today but gave a specific side psychological effect - there exists conceptualization that quantum gravity may be described only by some sophisticated theory. An opinion is commonly accepted, too, 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. If an apple from the legend about Newton's afflatus can imagine all these complications, it would hesitate to fall to the ground so artlessly as it is accepted among the apples.

Perhaps, physicists would be able to refuse easier the preconceived stereotypes which balk - as it seems to me - to go ahead in understanding quantum gravity if experiments or observations would give more essential meat for reasonings. But in this area, at least up to recent years, there was observed nothing that may serve if not Ariadne's clew but such a simple physical contradiction that an aspiration to overcome it would advantage introduction of new ideas and revision of the "inviolable".

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 [2]; 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 [3, 4]; 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 [5]. 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 [6] which is based on a conjecture about an existence of the graviton background gives us odds to see in the effect of dimming supernovae 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 $\sim 10^{-3}$ eV.

In this chapter, the main results of author's research in this approach are described. Starting from a statistical model of the graviton background with 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. 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 [8]. It turns out that the pressure is huge (a corresponding force is $\sim 1000$ 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.

Because the very unexpected hypothesis founded into the basis of this approach is a super-strong character of gravitational interaction on a quantum level, I would like to explain my motivation which conduced namely to such the choice. Learning symmetries of the quantum two-component composite system [9], I have found that its discrete symmetries in an 8-space may be interpreted by an observer from a 4-dimensional world as the exact global symmetries of the standard model of particle physics if internal coordinates of the system (the composite fermion) are rigidly fixed. This conclusion was hard for me and took much enough time. But to ensure almost full fixation of components of the system, an interaction connecting them should be very strong. Because of it, when a choice arise - an amount of gravitons or an intensity of the interaction, - I have remembered this overpassed earlier barrier and chose namely the super-strong interaction. Without this property, the graviton background would not be in the thermodynamical equilibrium with the cosmic microwave background that could entail big difficulties in the model.

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 [6, 7]

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 $\gamma$ 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 $\bar{\epsilon}$ 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 [6, 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 [10].

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 $\bar{\epsilon} << E(r)$ 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. Decay of virtual gravitons should give photon pairs for this background, too. Perhaps, the last one is the cosmic microwave background [11, 12].

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 [13]). 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 $E$.

## 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 [6] were given later in the preprint [14]. So as both particles have velocities $c$, a cross-section of interaction, which is "visible" under an angle $\theta$ (see Fig. 1), will be equal to $\sigma_0|\cos\theta|$ if $\sigma_0$ 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 $\theta$. We have for the ratio of fluxes:

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

where $\Phi(\theta)$ and $\Phi_0$ are the fluxes which fall on $\sigma_0$ under the angle $\theta$ and normally, $S_s$ is a square of side surface of a truncated cone with a base $\sigma_0$ (see Fig. 1).

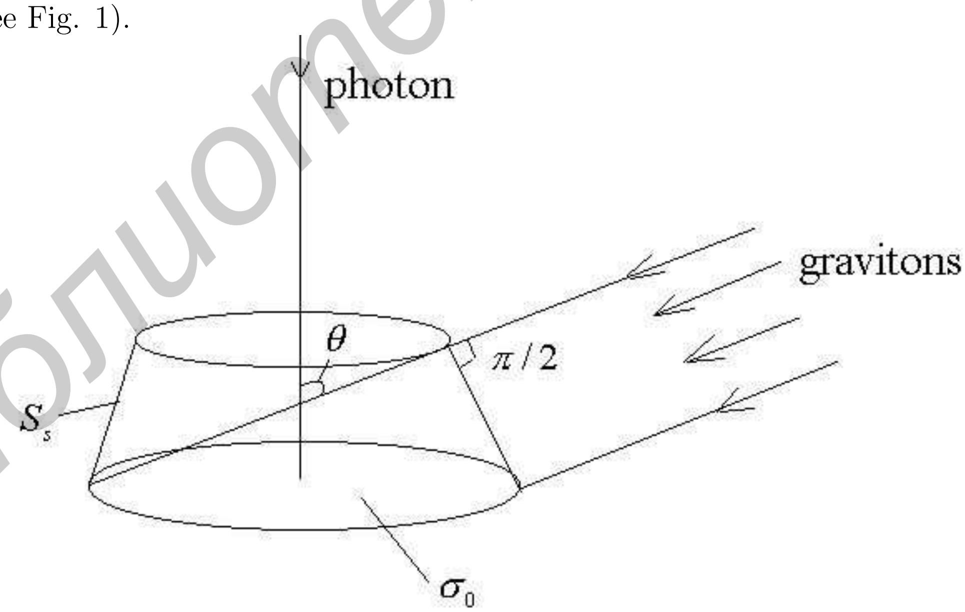


Figure 1: By non-forehead collisions of gravitons with a photon, it is necessary to calculate a cone's side surface square, $S_s$.

Finally, we get for the factor $b$ :

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

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

After computation of simple integrals, we get:

$$b = \frac{4}{\pi}(\int_0^{\pi/4} 2\cos^2\theta d\theta + \int_{\pi/4}^{\pi/2} \sin^2 2\theta d\theta) = \frac{3}{2} + \frac{2}{\pi} \simeq 2.137. \quad (5)$$

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 [3]) 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 $D_L$ :

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

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

## 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. [15], 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 [15]. The predictions fit observations

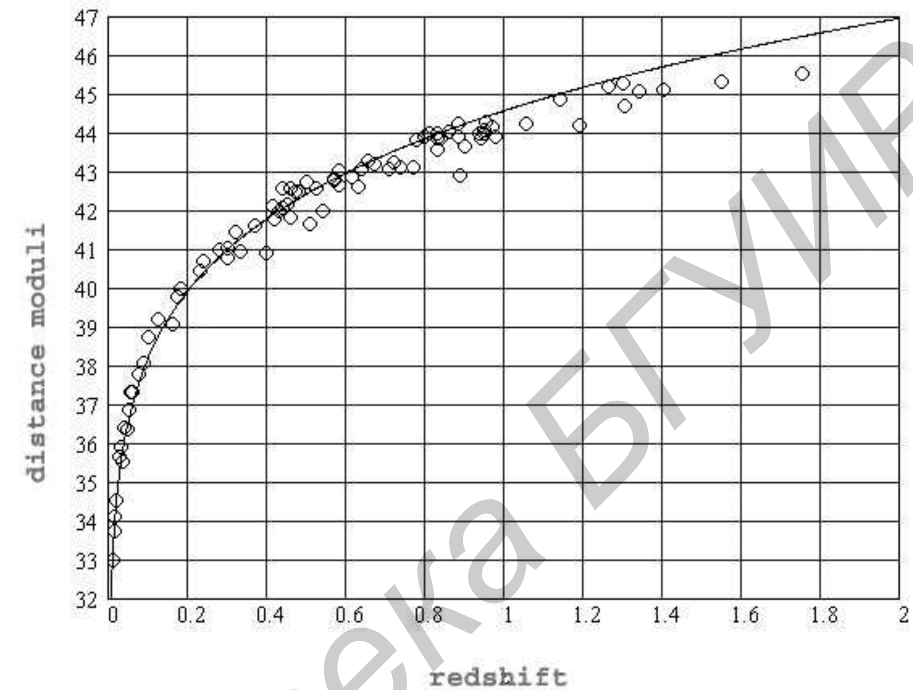


Figure 2: Comparison of the theoretical values of distance moduli $\mu_0(z)$ (solid line) with observations (points) from [15] by Riess et al.

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 [16]. For very small redshifts $z$, only a small part of photons transmits its energy to the background (see below Fig. 8 in Section 6). Therefore

[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 $f_1^6(z)$.

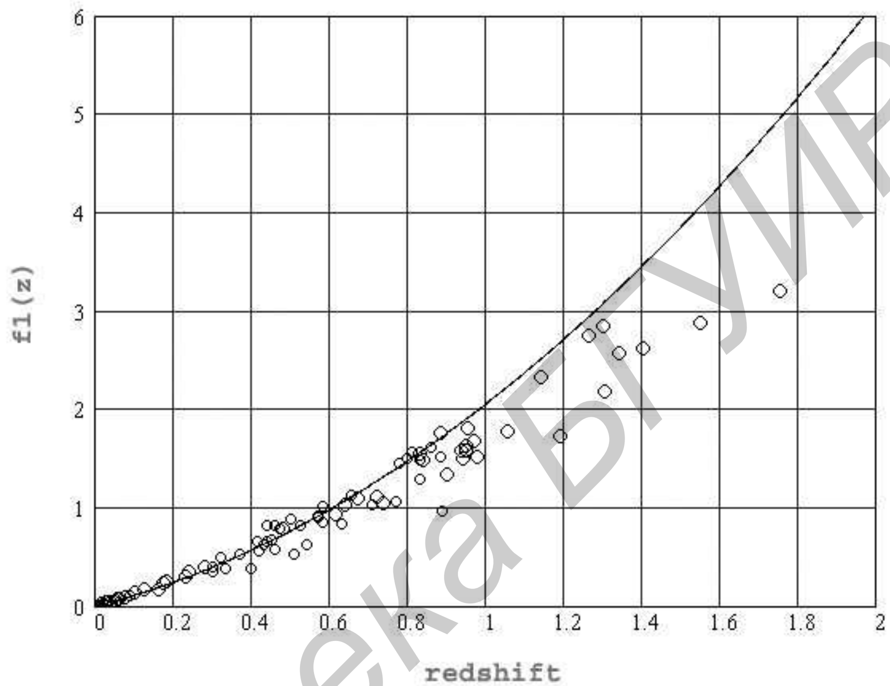


Figure 3: Predicted values of $f_1(z)$ (solid line) and observations (points) from [15] transformed to a linear scale

any red-shifted narrow spectral strip will be a superposition of two strips. One of them has a form which is identical with 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 $\bar{\epsilon}_g/h$ where $\bar{\epsilon}_g$ 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 appear 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 [17] or of the CMB temperature [18] with epochs. In both cases, a ratio of red-shifted spectral line's intensities may be sensitive to the effect.

This comparison with observations is very important; to see some additional details, we can compute and graph the ratio $f_{1obs}(z)/f_1(z)$, where $f_{1obs}(z)$ is an observed analog of $f_1(z)$ (see Fig. 4) [19]. An expected value of the ratio should be equal to 1 for any $z$.

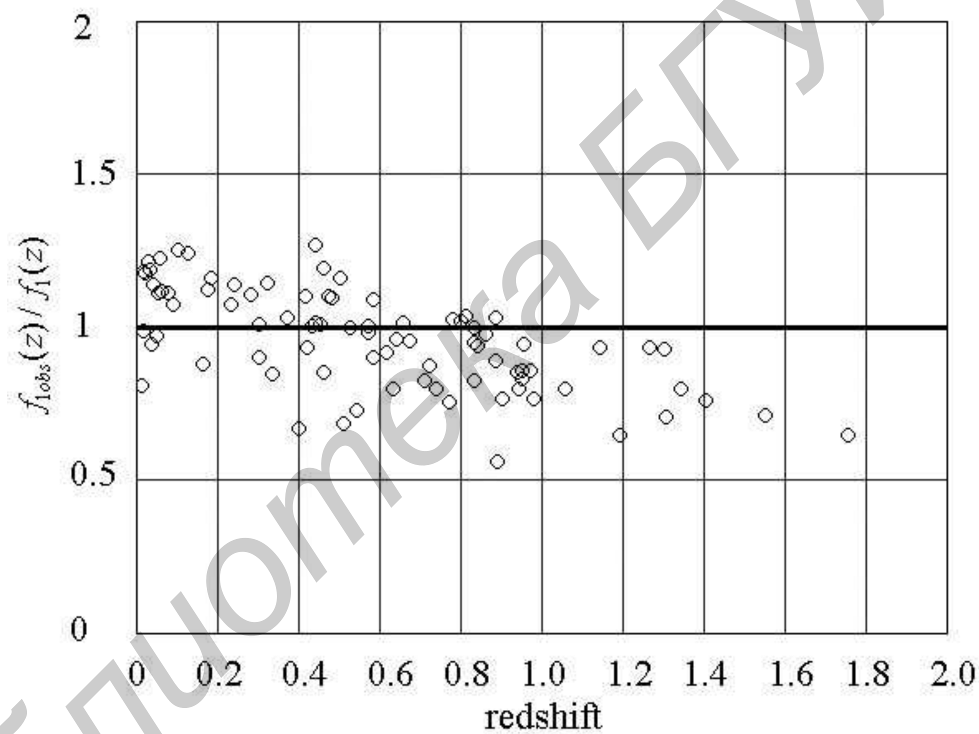


Figure 4: The ratio of observed to theoretical functions $f_{1obs}(z)/f_1(z)$ (dots); observational data are taken from Table 5 of [15]. If this model is true, the ratio should be equal to 1 for any $z$ (solid line).

## 2.4 Computation of the Hubble constant

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

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

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 ($\omega$ is a graviton frequency, $\epsilon = \hbar\omega$), 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 graviton background, we can write for the Hubble constant $H = ac$, introduced in the expression (1):

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

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 $\sigma$ 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 (compare with [20]), i.e. one can write for them:

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

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

$$\sigma(E,\epsilon) = D \cdot E \cdot \epsilon. \qquad (7)$$

Then

$$H = \frac{1}{2\pi} D \cdot \bar{\epsilon} \cdot (\sigma T^4), \qquad (8)$$

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 $D$ :

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

(see below Section 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 $\bar{\epsilon}$:

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

## 2.5 Some new constants from dimensional reasonings

We can introduce the following new constants (see [6]): $G_0$, $l_0$, $E_0$, which are analogues, on this new scale, of classical constants: the Newton constant $G$, the Planck length $l_{Pl}$, and the Planck energy $E_{Pl}$ correspondingly. Let us accept from dimensional reasonings that

$$D \equiv (l_0/E_0)^2 = (G_0/c^4)^2,$$

where $l_0 = \sqrt{G_0 \hbar / c^3}$, $E_0 = \sqrt{\hbar c^5 / G_0}$. Then we have for these new constants:

$$G_0 \sim 1.6 \cdot 10^{39} m^3/kg \cdot s^2, \; l_0 \sim 2.4 \cdot 10^{-12} m, \; E_0 \sim 1.6 \; keV.$$

If one would replace $G$ with $G_0$, then an electrostatic force, acting between two protons, will be only $\sim 2 \cdot 10^{13}$ times smaller than a gravitational one by the same distance (a theoretical finding of the Newton constant $G$ is given below in Section 4.3).

Using $E_0$ instead of $E_{Pl}$, we can evaluate the new non-dimensional "constant" (a bilinear function of $E$ and $\epsilon$), $k$, which would characterize one act of interaction: $k \equiv E \cdot \epsilon / E_0^2$. We must remember here, that a universality of gravitational interaction allows to expect that this floating coupling "constant" $k$ should characterize interactions of any particles with an energy $E$, including gravitons, with single gravitons. For $E \sim 1eV$ and $\epsilon \sim 10^{-4} eV$, we have $k \sim 4 \cdot 10^{-9}$. But for $E \sim 25 \; MeV$ and $\epsilon \sim 10^{-3} \; eV$, we shall have $k \sim 10^{-2}$, i.e. $k$ will be comparable with QED's constant $\alpha$. Already by $E \sim \epsilon \sim 5 \; keV$, such an interaction would have the same intensity as the strong interaction ($k \sim 10$).

# 3 Deceleration of massive bodies: an analog of redshifts

As it was reported by Anderson's team [2] , 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 [6]. 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):

$$dE = -aEdr,$$

where $a = H/c$. If $dr = vdt$, 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 $2.14 \cdot 10^{-18} s^{-1}$ (it is the theoretical estimate of $H$ in this approach, see below Section 4.3), a modulus of the acceleration will be equal to

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

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

We 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). In other frames, we may find its direction, using transformation formulae for an acceleration (see [24]). We can assume that the graviton background and the microwave one are isotropic in one frame (the Earth velocity relative to the microwave background was determined in [25]).

To verify my conjecture about the origin of probes' additional acceleration, one could re-analyze radio Doppler data for the probes. One should find a velocity of the special frame of reference and a constant probe acceleration $w$ in this frame which must be negative, as it is described above. These two parameters must provide the best fit for all probes, if the conjecture is true. In such a case, one can get an independent estimate of the Hubble constant, based on the measured value of probe's additional acceleration: $H = \mid w \mid /c$. 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 [26].

Under influence of such a small additional acceleration $w$, a probe must move on a deformed trajectory. Its view will be determined by small seeming deviations from exact conservation laws for energy and angular momentum of a not-fully reserved body system which one has in a case of neglecting with the graviton background. For example, Ulysses should go some nearer to the Sun when the one rounds it. It may be interpreted as an additional acceleration, directed towards the Sun, if we shall think that one deals with a reserved body system.

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 [8]: 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 [27]. 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 [8, 21, 22] 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 $\sigma(E_1, \epsilon)$ is a cross-section of interaction of body 1 with a graviton with an energy $\epsilon = \hbar\omega$, where $\omega$ is a graviton frequency, $\sigma(E_2, \epsilon)$ 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:

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

where $f(\omega, T)$ is a graviton spectrum with a temperature $T$ (assuming to be Planckian), the factor 4 in front of $\sigma(E_1, <\epsilon>)$ is introduced to allow all possible directions of graviton running, $<\epsilon>$ is another average energy of running gravitons with a frequency $\omega$ 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 $\sigma(E_2, <\epsilon>) \ll 4\pi r^2$) to:

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

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

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

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 $\omega$ (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 $P(0, x) = \exp(-\bar{n})$.

A quantity $<\epsilon>$ must contain the factor $(1 - P(0, x))$, i.e. it should be:

$$<\epsilon> \sim \hbar\omega(1 - P(0, x)), \tag{16}$$

that let us to reject flat wave realizations with zero number of gravitons.

But attempting to define other factors in $<\epsilon>$, we find the difficult place in our reasoning. On this stage, it is necessary to introduce some new assumption to find the factors. Perhaps, this assumption will be well-founded in a future theory - or would be rejected. If a flat wave realization, running against a finite size body from infinity, contains one graviton, then one cannot consider that it must stringent ride at a body to interact with some probability with the one. It would break the uncertainty principle by W. Heisenberg. We should admit that we know a graviton trajectory. The same is pertaining to gravitons scattered by one of bodies by big distances between bodies. What is a probability that a single graviton will ride namely at the body? If one denotes this probability as $P_1$, then for a wave with $n$ gravitons their chances to ride at the body must be equal to $n \cdot P_1$. Taking into account the probabilities of values of $n$ for the Poisson flux of events, an additional factor in $< \epsilon >$ should be equal to $\bar{n} \cdot P_1$. I have admitted in [8] that

$$P_1 = P(1, x), \tag{17}$$

where $P(1, x) = \bar{n} \exp(-\bar{n})$; (below it is admitted for pairing gravitons: $P_1 = P(1, 2x)$ - see Section 4.3).

In such the case, we have for $< \epsilon >$ the following expression:

$$< \epsilon >= \hbar\omega(1 - P(0, x))\bar{n}^2 \exp(-\bar{n}). \tag{18}$$

Then we get for an attractive force $F_1$ :

$$F_1 = \frac{4}{3} \frac{D^2 E_1 E_2}{\pi r^2 c} \int_0^\infty \frac{\hbar^3 \omega^5}{4\pi^2 c^2} (1 - P(0, x))^2 \bar{n}^5 \exp(-2\bar{n}) d\omega = \tag{19}$$

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

where

$$I_1 \equiv \int_0^\infty x^5 (1 - \exp(-(\exp(x) - 1)^{-1}))^2 (\exp(x) - 1)^{-5} \exp(-2(\exp(x) - 1)^{-1}) dx = \tag{20}$$

$$5.636 \cdot 10^{-3}.$$

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

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

$$G_1 \equiv \frac{1}{3} \cdot \frac{D^2 c (kT)^6}{\pi^3 \hbar^3} \cdot I_1. \tag{21}$$

By $T = 2.7\ K$ :

$$G_1 = 1215.4 \cdot G, \tag{22}$$

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

$$F_1^{'} = F_1, \tag{23}$$

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. The conclusion cannot be changed with taking into account of Hawking's quantum effect of evaporation of black holes [23].

## 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 [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 $\omega$ 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:

$$\bar{n}_2 = \frac{1}{\exp(2x) - 1}, \tag{24}$$

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

But it is happened that, if expression (24) is true, it follows from the energy conservation law that composite gravitons should be distributed only in two modes. So as

$$\lim_{x \to 0} \frac{\bar{n}_2}{\bar{n}} = 1/2, \tag{25}$$

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; it has the view:

$$f_2(2\omega, T)d\omega = \frac{\omega^2}{4\pi^2 c^2} \cdot \frac{2\hbar\omega}{\exp(2x) - 1} d\omega \equiv \frac{(2\omega)^2}{32\pi^2 c^2} \cdot \frac{2\hbar\omega}{\exp(2x) - 1} d(2\omega). \tag{26}$$

It means that an absolute luminosity for the sub-system of composite gravitons is equal to:

$$\int_0^\infty f_2(2\omega, T)d(2\omega) = \frac{1}{8}\sigma T^4, \tag{27}$$

where $\sigma$ is the Stephan-Boltzmann constant; i.e. an equivalent temperature of this sub-system is

$$T_2 \equiv (1/8)^{1/4} T = \frac{2^{1/4}}{2} T = 0.5946T. \tag{28}$$

The portion of pairing gravitons, $2\bar{n}_2/\bar{n}$, a spectrum of single gravitons, $f(x)$, and a spectrum of subsystem of pairing gravitons, $f_2(2x)$, are shown on Fig. 5 as functions of the dimensionless parameter $x \equiv \hbar\omega/kT$.

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

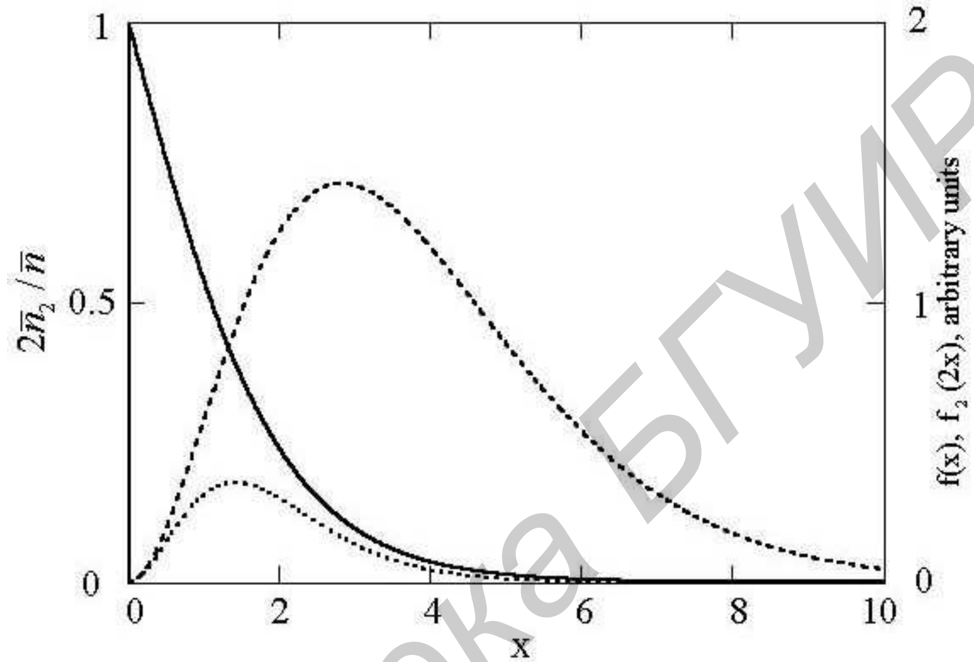


Figure 5: The portion of pairing gravitons, $2\bar{n}_2/\bar{n}$, (solid line), a spectrum of single gravitons, $f(x)$, (dashed line), and a spectrum of graviton pairs, $f_2(2x)$, (dotted line) versus the dimensionless parameter $x$.

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 $\sigma(E_2, <$

$\epsilon_2 >$), 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 $< \epsilon >$). This equality is true in neglecting with small allowances which are proportional to $D^3/r^4$ (see Section 4.4). 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 graviton pairs:

$$< \epsilon_2 > \sim 2\hbar\omega(1 - P(0,2x))\bar{n}_2^2 \exp(-\bar{n}_2). \tag{29}$$

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 $< \epsilon_2 >$:

$$< \epsilon_2 > = 2\hbar\omega(1 - P(0,2x))\bar{n}_2^2 \exp(-\bar{n}_2) \cdot P(0,x). \tag{30}$$

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 [2]:

$$F_2 = \int_0^\infty \frac{\sigma(E_2, < \epsilon_2 >)}{4\pi r^2} \cdot 4\sigma(E_1, < \epsilon_2 >) \cdot \frac{1}{3} \cdot \frac{4 f_2(2\omega, T)}{c} d\omega = \frac{8}{3} \cdot \frac{D^2 c (kT)^6 m_1 m_2}{\pi^3 \hbar^3 r^2} \cdot I_2, \tag{31}$$

where

$$I_2 \equiv \int_0^\infty \frac{x^5 (1 - \exp(-(\exp(2x) - 1)^{-1}))^2 (\exp(2x) - 1)^{-5}}{\exp(2(\exp(2x) - 1)^{-1}) \exp(2(\exp(x) - 1)^{-1})} dx = 2.3184 \cdot 10^{-6}. \tag{32}$$

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

$$F \equiv F_2 - F_2^{'} = \frac{1}{2} F_2 \equiv G_2 \frac{m_1 m_2}{r^2}, \tag{33}$$

where the constant $G_2$ is equal to:

$$G_2 \equiv \frac{4}{3} \cdot \frac{D^2 c (kT)^6}{\pi^3 \hbar^3} \cdot I_2. \tag{34}$$

[2]In initial version of this paper, factor 2 was lost in the right part of Eq. (31), and the theoretical values of $D$ and $H$ were overestimated of $\sqrt{2}$ times

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

If one assumes that $G_2 = G$, then it follows from (34) that by $T = 2.7K$ the constant $D$ should have the value:

$$D = 0.795 \cdot 10^{-27} m^2/eV^2. \tag{35}$$

An average graviton energy of the background is equal to:

$$\bar{\epsilon} \equiv \int_0^\infty \hbar\omega \cdot \frac{f(\omega, T)}{\sigma T^4} d\omega = \frac{15}{\pi^4} I_4 kT, \tag{36}$$

where

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

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

We can use (8) and (34) to establish a connection between the two fundamental constants, $G$ and $H$, under the condition that $G_2 = G$. We have for $D$ :

$$D = \frac{2\pi H}{\bar{\epsilon}\sigma T^4} = \frac{2\pi^5 H}{15k\sigma T^5 I_4}; \tag{37}$$

then

$$G = G_2 = \frac{4}{3} \cdot \frac{D^2 c(kT)^6}{\pi^3 \hbar^3} \cdot I_2 = \frac{64\pi^5}{45} \cdot \frac{H^2 c^3 I_2}{\sigma T^4 I_4^2}. \tag{38}$$

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

$$H = (G \frac{45}{64\pi^5} \frac{\sigma T^4 I_4^2}{c^3 I_2})^{1/2} = 2.14 \cdot 10^{-18}\ s^{-1}, \tag{39}$$

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 [3, 28, 29] (for example, the estimate $(72 \pm 8)$ km/s/Mpc has been got from SN1a cosmological distance determinations in [29]), but it is lesser than some of them [30] and than it follows from the observed value of anomalous acceleration of Pioneer 10 [2].

### 4.4 Restrictions on a geometrical language in gravity

The described quantum mechanism of classical gravity gives Newton's law with the constant $G_2$ value (34) and the connection (38) for the constants

$G_2$ and $H$. We have obtained the rational value of $H$ (39) by $G_2 = G$, if the condition of big distances is fulfilled:

$$\sigma(E_2, <\epsilon>) \ll 4\pi r^2. \tag{40}$$

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 the condition (40) 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 $<\epsilon> \rightarrow \bar{\epsilon}$ :

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

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. the condition (40) 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:

$$\Delta F = \frac{1}{2N_2}\int_0^\infty \frac{\sigma^2(E_2, <\epsilon_2>)}{(4\pi r^2)^2} \cdot 4\sigma(E_1, <\epsilon_2>) \cdot \frac{1}{3} \cdot \frac{4 f_2(2\omega, T)}{c} d\omega = \tag{41}$$

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

(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

$$I_3 \equiv \int_0^\infty \frac{x^6(1-\exp(-(\exp(2x)-1)^{-1}))^3(\exp(2x)-1)^{-7}}{\exp(3(\exp(x)-1)^{-1})} dx = 1.0988 \cdot 10^{-7}.$$

Let us find the ratio:

$$\frac{\Delta F}{F} = \frac{D E_2 kT}{N_2 2\pi r^2} \cdot \frac{I_3}{I_2}. \tag{42}$$

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

$$\frac{\Delta F}{F} \sim 10^{-46}. \tag{43}$$

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 (40) is fulfilled for microparticles, which prompt interact with gravitons.

For small distances we shall have:

$$\sigma(E_2, <\epsilon>) \sim 4\pi r^2. \tag{44}$$

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.

Under the condition (44), big digressions from Newton's law will be caused with two factors: 1) a screening portion of a running flux of gravitons is not small and it should be taken into account by computation of the repulsive force; 2) a value of this portion cannot be defined by the expression (13).

Instead of (13), one might describe this portion at small distances with an expression of the kind:

$$\frac{1}{2}(1+\sigma(E_a,<\epsilon>)/\pi r^2-(1+\sigma(E_a,<\epsilon>)/\pi r^2)^{1/2}) \tag{45}$$

(the formula for a spheric segment area is used here [31]). Formally, by $\sigma(E_a,<\epsilon>)/\pi r^2 \to \infty$ we shall have for the portion (45):

$$\sim \frac{1}{2}(\sigma(E_a,<\epsilon>)/\pi r^2-(\sigma(E_a,<\epsilon>)/\pi)^{1/2}/r),$$

where the second term shows that the interaction should be weaker at small distances. We might expect that a screening portion may tend to a fixing value at super-short distances, and it will be something similar to asymptotic freedom of strong interactions. But, of course, at such distances the interaction will be super-strong and our naive approach would be not valid.

# 5 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) [32, 33]. 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 $z$ :

$$D_L(z)/r(z)=(1+z)^{(1+b)/2}, \tag{46}$$

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: $H = 2.14 \cdot 10^{-18}\ s^{-1}$ (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.

6 [32, 33]. As one can see, for objects with $z \sim 10$, which are observable now, we should anticipate geometrical distances of the order $\sim 35$ light GYR and luminosity distances of the order $\sim 1555$ 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 $z = 5.8$ [35] should be in a distance approximately of 2.8 times bigger than the one expected in the model based on the Doppler effect.

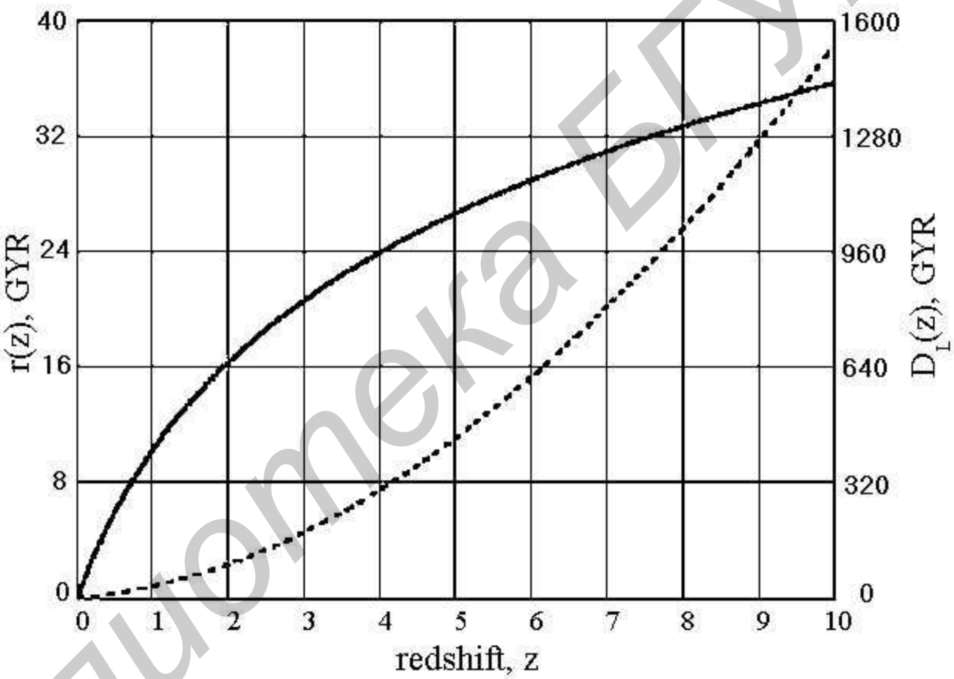


Figure 6: The geometrical distance, $r(z)$, (solid line) and the luminosity distance, $D_L(z)$, (dashed line) - both in light GYRs - in this model as functions of a redshift, z. The following theoretical value for $H$ is accepted: $H = 2.14 \cdot 10^{-18} s^{-1}$.

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" (see Fig. 7).

Some other possible cosmological consequences of an existence of the graviton background were described in [34, 8]. Observations of last years give

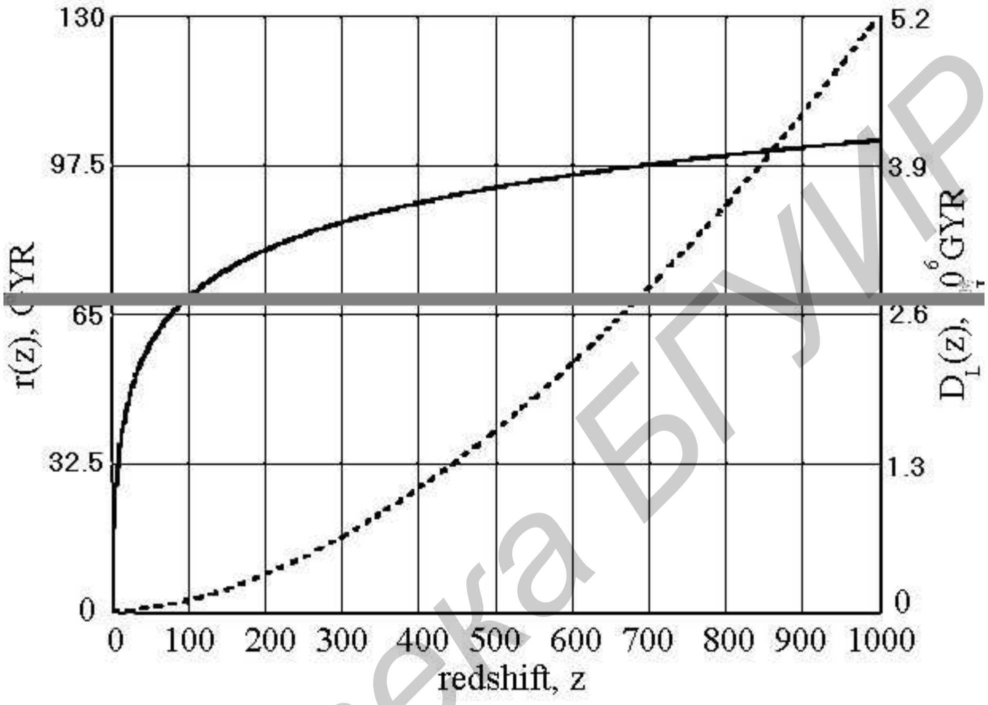


Figure 7: The same functions as on Fig. 6 (all notations are reserved), but for the huge range of $z$.

us strong evidences for supermassive and compact objects (named now supermassive black holes) in active and normal galactic nuclei [36, 37, 38, 39, 40]. Massive nuclear "black holes" of $10^6 - 10^9$ solar masses may be responsible for the energy production in quasars and active galaxies [36]. 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 [34] 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 $\epsilon'$ must be equal to $2\epsilon$ if $\epsilon$ is an initial graviton energy. In force of the uncertainty relation, one has for a virtual graviton lifetime $\tau$ : $\tau \leq \hbar/\epsilon^{'}$, i.e. for $\epsilon^{'} \sim 10^{-4}\ eV$ it is $\tau \leq 10^{-11}\ s$. 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 $\epsilon,\ \epsilon^{''},\ \epsilon^{'''}$, with $\epsilon^{''} + \epsilon^{'''} = \epsilon$. So, after this decay, two new gravitons with $\epsilon^{''},\ \epsilon^{'''} < \epsilon$ 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 $\epsilon_{min}$ where $\epsilon_{min}$ is a minimal energy of one graviton of an initial interacting pair. If gravitons with energies $\epsilon^{''},\ \epsilon^{'''}$ 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 $\sim 93$ 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 [41]). 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 [42, 43], 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.

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

I would like to show here (see [44]) 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 [16] to verify the conjecture about the described local quantum character of redshifts turned out to be very rigid: a laser with instability of $\sim 10^{-17}$ hasn't appeared after 9 years. But if $T = 2.7K$, the satellite of main laser line of frequency $\nu$ after passing the delay line will be red-shifted at $\sim 10^{-3}$ eV/h and its position will be fixed (see Fig. 8). It will be caused by the fact that on a very small way in the delay line only a 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

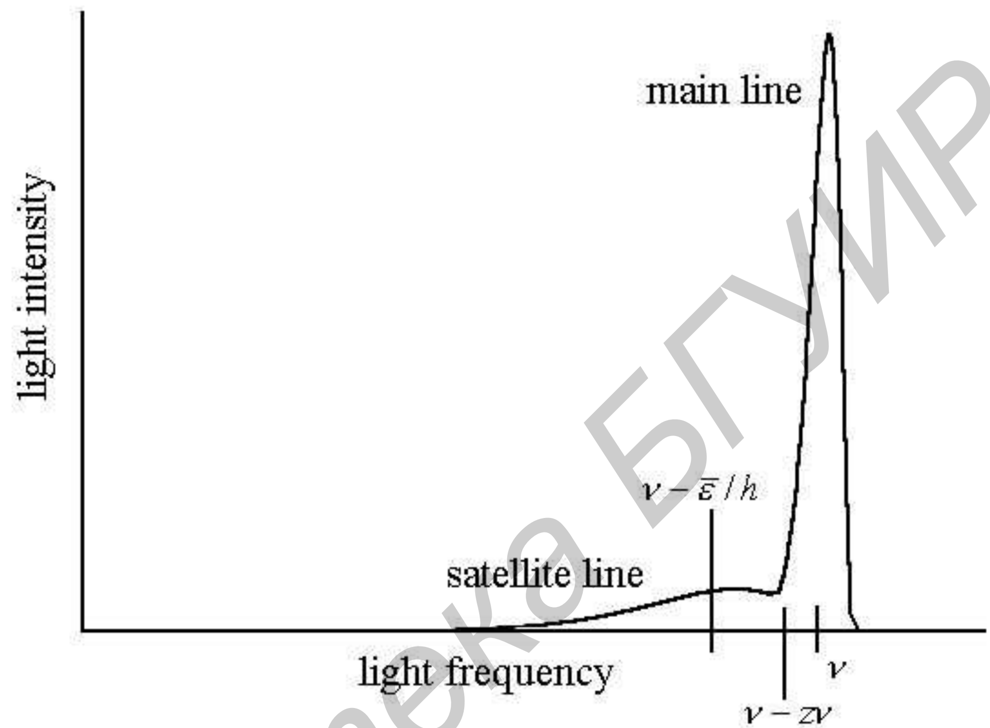


Figure 8: The main line and the expected red-shifted satellite line of a stable laser radiation spectrum after a delay line. Satellite's position should be fixed near $\nu - \bar{\epsilon}/h$, and its intensity should linear rise with a path of photons in a delay line, $l$. A center-of-mass of both lines is expected to be approximately near $\nu - z\nu$.

of this approach with 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 $\sim 1\ eV$. 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:

$$t = \frac{\bar{\epsilon}^2 c^2}{H^2} \frac{n^2 N_n}{q^2 P^2 l^2}. \tag{47}$$

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.

# 7 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. [45, 46] (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 particles (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. 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. 9). 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 here)* that

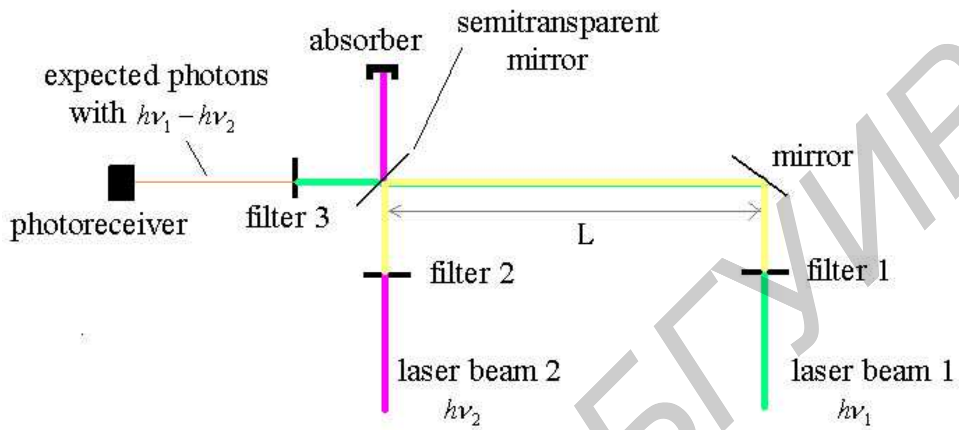


Figure 9: The scheme of laser beam passes. Two laser beams 1 and 2 collide into the area with a length $L$. An expected beam of photons with energies $h\nu_1 - h\nu_2$ falls to a photoreceiver.

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 (8) should be replaced with $1/\varphi$, where $\varphi$ is a divergence of laser beam 2, and one must use a quantity $P/S$ instead of $\sigma T^4$ in (8), 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, $H_{laser}$:

$$H \to H_{laser} = \frac{1}{\varphi} \cdot D \cdot h\nu_2 \cdot \frac{P}{S}. \tag{48}$$

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 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.

I think there is not any sense to try to analyze theoretically consequences of this conjecture - it will be easier to verify it experimentally. The Nature may answer the question if we ask correctly. All that was said in the above sections doesn't depend on the answer, but it would be very important for our understanding of known interactions. 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 electron-positron pair creation) and an essential impact of such a non-locally born object as the graviton background.

# 8 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. Non-local models were considered by G.V. Efimov in his book [47]. 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 [48], but the Pioneer 10 anomaly [2], 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. Cosmological models with the inversion of the time arrow were considered by Sakharov [49]. Penrose has noted that a hidden physical law may determine the time arrow direction [50]; 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 much bigger than the Planck length, needs to be described only in some unified manner.

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