Possible manifestations of the graviton background

By Michael A. Ivanov
Chair of Physics,
Belarus State University of Informatics and Radioelectronics,
6 P. Brovka Street, BY 220027, Minsk, Belarus.
E-mail: ivanovma@gw.bsuir.unibel.by

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Abstract

Possible effects are considered which would be caused by a hypothetical superstrong interaction of photons or massive bodies with single gravitons of the graviton background. If full cosmological redshift magnitudes are caused by the interaction, then the luminosity distance in a flat non-expanding universe as a function of redshift is very similar to the specific function which fits supernova cosmology data by Riess et al. From another side, in this case every massive body, slowly moving relatively to the background, would experience a constant acceleration, proportional to the Hubble constant, of the same order as a small additional acceleration of Pioneer 10, 11.

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1 Introduction

In the standard cosmological model [1], as well as in inflationary cosmological models [2], redshifts of remote objects are explained by expansion of the universe. A model of expansion gives an exact dependence of a distance r from an observer to a source on a redshift z. There is a known uncertainty of estimates of the Hubble constant H because of difficulties to establish a scale of cosmological distances which is independent on redshifts [3, 4]. Today, as one could think, there are not obvious observant facts which would demand some alternative model to interpret an origin of redshifts. But one cannot exclude that the effect may have some non-dopplerian nature.

In alternative cosmological models, which are known as "tired-light" ones, the cosmological redshift is considered namely as a non-dopplerian effect. Several mechanisms for photon energy loss have been supposed [5, 6]. There exist different opinions, what a cosmological model makes the better fit to the existing astrophysical data on some kinds of cosmological tests (compare, for example, [7, 8] with [6]).

In this paper, possible manifestations of the graviton background in a case of hypothetical superstrong gravitational quantum interaction are considered. From one side, the author brings the reasons that a quantum interaction of photons with the graviton background would lead to redshifts of remote objects too. The author considers a hypothesis about an existence of the graviton background to be independent from the standard cosmological model. One cannot affirm that such an interaction is the only cause of redshifts. It is possible, that the one gives a small contribution to an effect magnitude only. But we cannot exclude that such an interaction with the graviton background would be enough to explain the effect without an attraction of the big bang hypothesis. Comparing the own model predictions with supernova cosmology data by Riess et al [9], the author finds here good accordance between the redshift model and observations.

From another side, it is shown here, that every massive body, with a nonzero velocity v relatively to the isotropic graviton background, should experience a constant acceleration. If one assumes that a full observable redshift magnitude is caused by such a quantum interaction with single gravitons, then this acceleration will have the same order of magnitude as a small additional acceleration of NASA deep-space probes (Pioneer 10/11, Galileo, and Ulysses), about which it was reported by Anderson's team [10].

It is known, that a gravitational interaction between two particles is very weak on big distances. One may expect, that its non-dimensional coupling "constant", which could be an analogue of QED's coupling constant $\alpha \simeq 1/137$, would be proportional to $E_1 E_2 / E_{Pl}^2$, where E_1 and E_2 are energies of particles, $E_{Pl} \simeq 10^{19} GeV$ is the Planck energy (i.e. the mentioned "constant" is a bilinear function of energies of particles). May such an interaction with gravitons decelerate a big cosmic probe or, at the worst, give observable redshifts? We must take into account, that we know little of quantum gravity (see, for example, [11]). Today, there does not exist a complete theory of it. The weak field limit is successfully investigated in the context of linearized gravity [12]. In this approach, one considers gravitons without self-interaction, comparing their energies to the Planck scale. Unified theories, including gravity, contain, as a rule, big spectra of non-observed particles [13, 14].

The Newton gravitational constant G characterizes an interaction on a macro level. But on this level, from a quantum point of view, the interaction may be superstrong. For example, if we consider two stars, having the Sun masses, as "particles", then, for this case, the non-dimensional "constant" will be equal to 10^{72}. Of course, it means only, that one cannot consider an interaction between such "particles" as a result of exchange by single gravitons. Because of self-interaction of gravitons, possible Feynman's diagrams should be complex and should contain a lot of crossing chains of vertexes. Because of it, the Newton constant G may be, perhaps, much smaller than an unknown constant which characterizes a single act of interaction.

All considered effects depend on the equivalent temperature T of the graviton background, which are unknown out of standard cosmological models, based on the big bang hypothesis. But we must take into account, that known estimates of a classical gravitational wave background intensity are consistent with values of this equivalent temperature, which may be not more than few Kelvin degrees [15, 16, 17]. Probably, future gravitational wave detectors (for the low frequencies $\sim 10^{-3} Hz$) will give more exact estimates [18] - [21].

2 Photon energy losses due to an interaction with the graviton background

Let us introduce the hypothesis, which is considered here to be independent from the standard cosmological model: there exists the isotropic graviton background. Then photon scattering is possible on gravitons $\gamma + h \rightarrow \gamma + h$, where γ is a photon and h is a graviton, if one of the gravitons is virtual. The energy-momentum conservation law prohibits energy transfer to free gravitons.

Average energy losses of a photon with an energy E on a way dr will be equal to

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

where a is a constant. Here we 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 that a photon average energy loss $\bar{\omega}$ in one act of interaction is relatively small to a photon energy E. We must identify $a = H/c$, where c is the light velocity, to have the Hubble law for small distances [22].

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 $\bar{\omega} << E(r)$ takes place. Photons with a very small energy may loss or acquire an energy changing their direction of propagation after scattering. Early or late such photons should turn out in thermodynamic equilibrium with the graviton background, flowing into their own background. Decay of virtual gravitons should give photon pairs for this background too. Possibly, we know the last one as the cosmic microwave background [23, 24].

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. We see that this redshift do 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 [6]). In our case, they 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.

3 An additional relaxation of a photon flux due to non-forehead collisions with gravitons

An interaction of photons with the graviton background will lead to an additional relaxation of a photon flux, caused by transmission of a momentum transversal component to some photons. Photon flux's average energy losses on a way dr should be proportional to $badr$, where b is a 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 narrow beam of rays). Then we get the following estimate for the factor b :

$$b = 3/2 + 2/\pi = 2,137. \tag{4}$$

It is assumed here that a cross-section of interaction is modified by the factor $|\cos\alpha|$ where α is an angle between wave vectors of a photon and of a graviton raiding on it from front or back hemispheres. To average on the angle α, one must take into account a dependence of a graviton flux, which falls on a picked out area (cross-section), on the angle α. Thus in the 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 whole redshifts would caused by such an interaction with the background (instead of $(1+z)^2$ for the expanding uniform universe). Of course, this quantity may be modified with evolutionary effects. For near sources, the estimate of the factor b will be an increased one.

4 Comparison of the redshift model with supernova cosmology data

In a case of flat no-expanding universe, a photon flux relaxation can be characterized by the factor b, so that the luminosity distance D_L [9] is equal in our model to:

$$D_L = a^{-1} \ln(1+z) \cdot (1+z)^{(1+b)/2} \equiv a^{-1} f_1(z; b), \quad (5)$$

where z is a redshift. The theoretical estimate for b is: $b = 3/2 + 2/\pi = 2.137$. Thus, the redshift

$$z = \exp(ar) - 1 \quad (6)$$

and the luminosity distance D_L are characterized in the model by two parameters: H and b (r is a geometrical distance). One can introduce an effective Hubble constant

$$H_{eff} \equiv cdz/dr. \quad (7)$$

In our model

$$H_{eff} = H \cdot (z+1); \quad (8)$$

in a language of expansion it can be interpreted as "a current deceleration of the expansion".

High-z Supernova Search Team data [9] give us a possibility to evaluate H in our model. Instead of prompt fitting to data, we can use one of the best fits of the function $D_L(z; H_0, \Omega_M, \Omega_\Lambda)$ to supernovae data from [9] (see Eq.2 in [9]) with $\Omega_M = -0.5$ and $\Omega_\Lambda = 0$, which is unphysical in the original work. For $1 - \Omega_M > 0$ and $1 + \Omega_M z > 0$, the function $D_L(z; H_0, \Omega_M, \Omega_\Lambda)$ is equal to (see the integral in [25]):

$$D_L = a^{-1}(1+z)m^{-1} \sinh(\ln|(k-m)/(k+m)| - \ln|(1-m)/(1+m)|) \equiv$$

$$\equiv a^{-1} f_2(z; \Omega_M, \Omega_\Lambda), \quad (9)$$

where $m \equiv (1-\Omega_M)^{1/2}, k \equiv (1+\Omega_M z)^{1/2}$. Assuming $b = 2.137$, we can find H from the connection:

$$HD_L/H_0 D_L = f_1(z; b)/f_2(z; \Omega_M, \Omega_\Lambda), \quad (10)$$

where H_0 is an estimate of the Hubble constant from [9] (see Table 1). We see that $H/H_0 \simeq const$, a deviation $(H - <H>)/<H>$ from an average value $<H> \simeq 1.09 H_0$ is less than $\pm 5\%$.

Table 1: Comparison with supernovae data

z	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
f_1	0	0.110	0.242	0.396	0.570	0.765	0.983	1.222	1.480	1.759	2.058
f_2	0	0.103	0.219	0,359	0.511	0.677	0.863	1.074	1.301	1.565	1.854
H/H_0	-	1.068	1.105	1.103	1.115	1.130	1.139	1.138	1.138	1.124	1.110

It means, that the model is in good accordance with supernovae data. This accordance cannot become worse, if one evaluates both of the parameters fitting our two-parametric function $D_L(z; H, b)$ to supernovae data.

If one would suggest that $f_1(z; b)$ describes results of observations in an expanding universe, one could conclude that it is "an accelerating one". But a true conclusion may be strange: our universe is not expanding, and redshifts have the non-dopplerian nature.

5 Other possibilities to verify the conjecture about redshift's local nature

If redshifts of remote objects would be provided by such the local cause as an interaction of photons with the graviton background, then a spectrum of ultrastable laser radiation after a delay line should have a small redshift too. It gives us a hope to carry out a straight verification of the conjecture about redshift's local nature on the Earth after creation of ultrastable lasers with an instability $\sim 10^{-17}$ [26] and of optical delay lines for a delay ~ 10 s [27].

A discrete character of photon energy losses by interaction with gravitons may produce a specific deformation of a spectrum of ultrastable laser radiation in a delay line: a step would appear beside a spectral line, from the side of low frequencies [28]. Such steps would appear beside single narrow spectral lines of remote objects too. A width of the step should linear raise with z. For remote objects, this additional effect would be caused by multifold interactions of a small part of photons with the graviton background. This effect would be observable, if $\bar{\omega}$ will be comparable with a spectral line width, a redshift of which one will measure.

An establishment of a cosmological distance scale, which will be independent of redshifts, would allow to verify the expression (3) or its consequence:

$$r_1/r_2 = \ln(1+z_1)/\ln(1+z_2), \tag{11}$$

where r_1 and r_2 are the distances to the sources 1 and 2, z_1 and z_2 are their redshifts.

It follows from (6) for small ar that

$$z = ar + (ar)^2/2 + (ar)^3/6 + \ldots, \tag{12}$$

where $a = H/c$. Estimates of coefficients by $r^2, r^3, \ldots$, which would be received from an analysis of astrophysical data for small z, could be compared with their values from (12) (see [29]). The Canada-France redshift survey [30] may serve as an example of big statistics which could make possible such a comparison.

We can verify a proportionality of the ratio of an object visible angular diameter to a square root of visible luminosity to the quantity $(1+z)^{1,57}$, which takes place in the assumption that the uniform no-expanding universe with the quasi-Euclidean space are realized. We must keep in the mind, that evolutionary effects would change a value of the ratio.

Perspective programs of big statistics accumulation for quasar redshifts on a base of the microlensing effect [31] would be useful to verify the local nature of redshifts, too.

6 Deceleration of massive bodies by the graviton background

It was reported by Anderson's team [10] , that NASA deep-space probes (Pioneer 10/11, Galileo, and Ulysses) experience a small additional constant acceleration, directed towards the Sun. 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. 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 an universality of gravitational interaction, that not only photons, but all other objects, moving relatively to the background, should loss 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 relatively 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 $E = mc^2/\sqrt{1 - v^2/c^2}$, we get for the body acceleration $w \equiv dv/dt$ by a non-zero velocity:

$$w = -ac^2(1 - v^2/c^2). \tag{13}$$

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:

$$w \simeq -Hc. \tag{14}$$

If the Hubble constant H is equal to $1.6 \cdot 10^{-18} s^{-1}$, the acceleration will be equal to

$$w \simeq -4.8 \cdot 10^{-10} m/s^2, \tag{15}$$

that corresponds approximately to one half of the observed additional acceleration for NASA probes.

We must emphasize here that the acceleration w is directed against a body velocity only in a special system of reference (in which the graviton background is isotropic). In other systems of reference, we will find its direction, using transformation formulae for an acceleration (see [29]). We can assume that the graviton background and the microwave one are isotropic in one system of reference (the Earth velocity relatively to the microwave background was determined in [32]).

To verify our conjecture about an origin of probes' additional acceleration, one could re-analyze radio Doppler data for probes. One should find a velocity of the special system of reference and a constant probe acceleration w in this system which must be negative, as it is described above. These two parameters must provide the best fit for all probes, if our 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: $H =\mid w \mid /c$.

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. As a result, an orbit should be deformed. Possibly, the general relativity effect of a perihelion revolution [33] would lead to a partial compensation of an average influence of the considered acceleration within a big time. This question needs a further consideration.

7 Estimates of a cross-section and of new constants which would characterize an interaction with single gravitons

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

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

where $d\Omega$ is a space angle element, and the function $const(x)$ has a constant value for any x. If $f(\omega,T)d\Omega/2\pi$ is a spectral density of graviton flux in the limits of $d\Omega$ in some direction, i.e. an intensity of a graviton flux is equal to an 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):

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

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

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

where σ is the Stephan- Boltzmann constant [34]. As carriers of a gravitational "charge" (without consideration of spin properties), gravitons should be described in the same manner as photons (compare with [12]), i.e. one can write for them:

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

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

$$\sigma(E,\omega) = D \cdot E \cdot \omega.$$

Then

$$H = \frac{1}{2\pi} D \cdot \bar{\omega} \cdot (\sigma T^4), \qquad (16)$$

where $\bar{\omega}$ is an average graviton energy. [1]

Assuming $T \sim 3K, \bar{\omega} \sim 10^{-4} eV$, and $H = 1.6 \cdot 10^{-18} s^{-1}$, we get the following estimate for D :

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

that gives us the phenomenological estimate of cross-section by the same E and $\bar{\omega}$:

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

One can compare this value with the cross-section of quasi-elastic neutrino-electron scattering [35], having, for example, the order $\sim 10^{-44} m^2$ by a neutrino energy about 6 GeV.

[1] In this version, the remainder of this section is replaced with a corrected fragment

Let us introduce new constants: 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

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

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 $\sim 2 \cdot 10^{13}$ times smaller than a gravitational one by the same distance.

Using E_0 instead of E_{Pl}, we can evaluate the new non-dimensional "constant" (a bilinear function of E and ω) k, which would characterize one act of interaction: $k \equiv E \cdot \omega / E_0^2$. We must remember here, that an 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 $\omega \sim 10^{-4} eV$, we have $k \sim 4 \cdot 10^{-9}$. But for $E \sim 25MeV$ and $\omega \sim 10^{-3} eV$, we shall have $k \sim 10^{-2}$, i.e. k will be comparable with QED's constant α. Already by $E \sim \omega \sim 5KeV$, such an interaction would have the same intensity as a strong interaction ($k \sim 10$).

8 Conclusion

Independently from the described conjecture, we would wait that a straight verification of redshift's nature on the Earth should be one of main works for coming ultrastable lasers. In a case of the dopplerian nature of redshifts, one will get a negative result for a laser beam frequency shift after a delay line. Such a negative result would be an important indirect experimental confirmation of the big bang hypothesis. Today for most people, a positive result seems to be impossible. But in a case of such an unexpected positive result, the redshift laser experiment would be a key one for cosmology.

One can wait that unification of gravity with physics of particles will need non-ordinary solutions, for example, introduction of many-dimensional spaces, in which a model of gravity has the basic symmetries of the Standard

Model [36]. From another side, the author feels a necessity to include gravity in the model of composite fermions to describe a set of generations and to solve a problem of particle masses [37].

If further investigations display that an anomalous NASA probes' acceleration cannot be explained by some technical causes, left out of account today, it will give a big push to a further development of physics of particles. Both supernova cosmology data and the Anderson's team discovery may change a gravity position in a hierarchy of known interactions, and, possibly, give us a new chance to unify their description.

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