Quantum gravity without quantization*

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Abstract

An alternative way to construct a quantum model of gravity is described, not by quantizing the classical model, but by introducing a graviton background, which has a low temperature but strongly interacts with any particle. Gravity in this case is the effect of screening the background of gravitons by bodies; several additional effects appear when photons or bodies move through the background. These small additional effects can be important for cosmology, since they allow us to describe the results of cosmological observations without dark energy.

Key words: low-energy quantum gravity, superstrongly interacting graviton background, photon-graviton interaction, quantum mechanism of redshifts, diffuse cosmic optical background, cosmology without dark energy

1 Introduction

Heroic efforts were made over the course of a century to construct a quantum theory of gravity by quantizing general relativity [1]. Currently, there are no known effects that would require such a theory to explain, but based on the analogy with other interactions, it seemed logical to look for a quantum description of gravity by quantizing the classical model. The considered most promising model of loop quantum gravity leads to the quantization of space, rather than metrics or connectivity, as one might expect. My model of low-energy quantum gravity uses a different approach: gravity arises as a screening effect in a sea of gravitons, i.e. the quantum side of the phenomenon is primary [2, 3, 4]. To provide the observed intensity of interaction, background gravitons must be super-strongly interacting particles. In this model, Newton's constant can be calculated using the new fundamental constant and the graviton background temperature. The universality of the interaction of gravitons with any particles

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leads to a number of small effects not predicted by general relativity, which can be important for cosmology. In particular, dark energy is not required to describe the observations, since the additional darkening of distant objects is associated here with the scattering of some photons. The main features of this model and its cosmological implications are described here.

2 Gravity as a screening effect

The model accepts the hypothesis of the existence of an isotropic background of super-strongly interacting gravitons having the same temperature T as the cosmic microwave background radiation. A new dimensional constant D is introduced, so that for forehead collisions of any particle with the energy E and a graviton with the energy ϵ we define a cross-section of interaction $\sigma(E,\epsilon)$ as:

$$\sigma(E,\epsilon) = D \cdot E \cdot \epsilon. \tag{1}$$

The constant D should have the value: $D = 0.795 \cdot 10^{-27} m^2/eV^2$. Screening of the graviton background creates both attractive and repulsive forces for any pair of bodies due to the pressure of gravitons. For single gravitons these forces are approximately balanced, but each of them is much greater than the force of Newtonian attraction. If single gravitons are paired, then the attractive force due to the pressure of such graviton pairs is twice as large as the corresponding repulsive force if the graviton pairs are destroyed upon collision with a body. Using the Plank formula for the graviton spectrum and taking into account the pairing effect for a part of gravitons, we get for Newton's constant G:

$$G = \frac{4}{3} \cdot \frac{D^2 c (kT)^6}{\pi^3 \hbar^3} \cdot I_2, \tag{2}$$

where the computed integral I_2 is equal to: $I_2 = 2.3184 \cdot 10^{-6}$. Interestingly, this model requires the existence of some atomic structure of bodies in order for the inverse square law to be satisfied.

3 Vacuum effects

Due to to forehead and backhead collisions with gravitons, any massive body or particle, which moves through the background with a non-zero velocity v, should have the anomalous deceleration w:

$$w = -w_0 \cdot 4\eta^2 \cdot (1-\eta^2)^{0.5}, \tag{3}$$

where $w_0 \equiv H_0 c = 6.419 \cdot 10^{-10}\ m/s^2$, if we use the theoretical value of H_0 in this model, $\eta \equiv v/c$, where $H_0 = 66.875\ km \cdot s^{-1} \cdot Mpc^{-1}$ is Hubble's constant, c is the speed of light. Its maximum value is equal to: $|w|_{max} = 1.54 \cdot w_0$. This anomalous deceleration leads to the absence of exactly closed orbits and to the non-planar motion of massive bodies in the central field by some conditions [4].

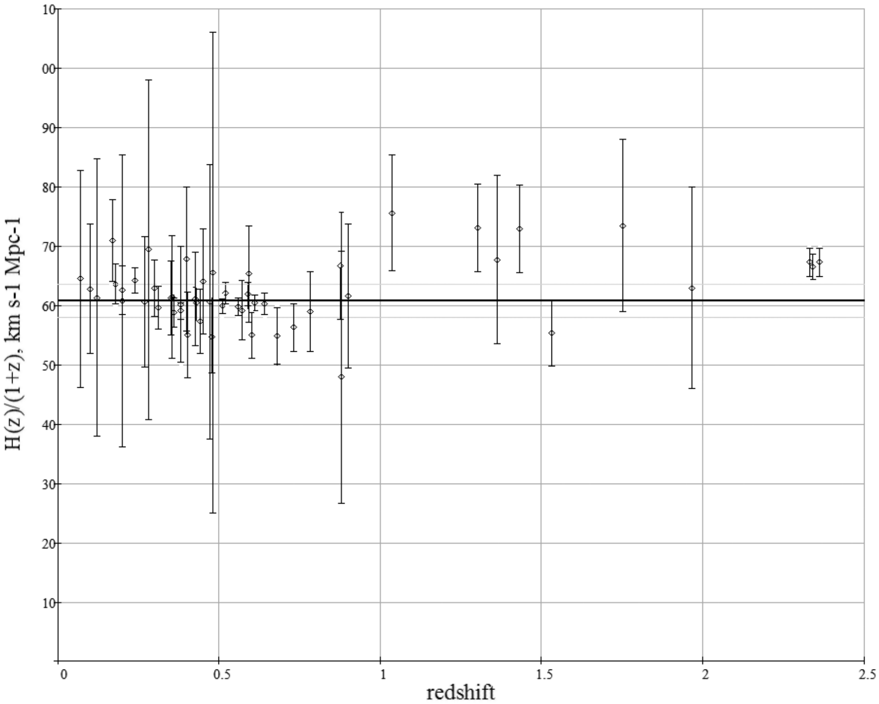

Figure 1: The ratio $H(z_i)/(1+z_i) \pm \sigma_{0i}$ and the weighted value of the Hubble constant $< H_0 > \pm\sigma_0$ (horizontal lines). Observed values of the Hubble parameter $H(z_i)$ (51 points) are taken from Table 1 of [5].

Energy losses of photons only due to forehead collisions with gravitons of the background give the following geometrical distance/redshift relation:

$$r(z) = ln(1 + z) \cdot c/H_0. \tag{4}$$

Then the Hubble parameter $H(z)$ in this model without the cosmological expansion can be defined as:

$$H(z) \equiv \frac{dz}{dr} \cdot c = H_0 \cdot (1 + z). \tag{5}$$

This formula gives us a possibility to evaluate the Hubble constant using observed values of the Hubble parameter $H(z)$. As an example, let us consider the compilation of data points of $H(z)$ (51 points in the redshift range $0.07 < z < 2.36$) from Table 1 of [5]. The ratio $H(z_i)/(1+z_i) \pm \sigma_{0i}$ and the weighted value of the Hubble constant $< H_0 > \pm\sigma_0$ (horizontal lines) are shown in Fig. 1. We have for this data set: $< H_0 > \pm\sigma_0 = (61.24 \pm 3.156)\ km \cdot s^{-1} \cdot Mpc^{-1}$. The value of χ^2 is now equal to 50.053. By 51 degrees of freedom of this data set, it means that the hypothesis described by Eq. (5) cannot be rejected with 51.12%

C.L. The last three points with $z = 2.33, 2.34, 2.36$ are taken in this set from the papers [6, 7, 8] and are not independent, since they were obtained after statistical analysis of overlapping samples of a large number of quasars. If we leave only one of them from [6] with $z = 2.33$, the quality of fitting increases significantly, to 91% C.L., with $\chi^2 = 36.332$ and $< H_0 > \pm\sigma_0 = (60.75 \pm 2.80)\ km \cdot s^{-1} \cdot Mpc^{-1}$.

Recently, the DESI collaboration reported results of measurements of the ratio $D_{H(z)}/r_d$ of the distance variable $D_{H(z)} \equiv c/H(z)$ to the sound horizon r_d for five z bins [9]. This gives the possibility to find Hubble's parameter $H(z)$ by the formula:

$$H(z) = c/D_H/r_d \cdot r_d, \tag{6}$$

using the value $r_d = 147.09 \pm 0.26$ Mpc obtained from using all CMB and CMB lensing information [10]. Calculated $H(z)$ values and their corresponding mean-square deviations are given in Table 1. We can repeat our calculations for this

z	H(z)	σ_H
0.51	97.215	1.27
0.706	101.572	1.379
0.93	114.07	1.681
1.317	147.581	2.808
2.33	239.386	7.31

Table 1: Calculated $H(z)$ values for five z bins based on the DESI BAO statistics for D_H/r_d and the r_d value [9].

very small set of the DESI BAO Hubble parameters. The ratio $H(z_i)/(1+z_i) \pm \sigma_{0i}$ and the weighted value of the Hubble constant $< H_0 > \pm\sigma_0$ (horizontal lines) are shown in Fig. 2. We have for this data set: $< H_0 > \pm\sigma_0 = (61.80 \pm 3.13)\ km \cdot s^{-1} \cdot Mpc^{-1}$, i.e. almost the same as in the previous case of 51 points. But now the value of χ^2 is equal to 50.392 by only five degrees of freedom; it means that the hypothesis described by Eq. (5) can be accepted only with $1.15 \cdot 10^{-7}$% C.L. For the combined set of 49 points from the first set and of 5 points of DESI BAO, it were obtained $< H_0 > \pm\sigma_0 = (61.306 \pm 3.025)\ km \cdot s^{-1} \cdot Mpc^{-1}$ and $\chi^2 = 89.419$; by 54 degrees of freedom it means that the hypothesis described by Eq. (5) can be accepted only with 0.17% C.L.

It must be borne in mind that all cosmological measurements are now carried out with full confidence in the validity of the hypothesis about the cosmological expansion of the universe after the big bang. BAO analyses need to assume a fiducial cosmology: 1) which is adopted to convert tracer angular positions and redshifts to comoving coordinates, and 2) the theoretical calibration of the BAO scale is encoded by a full early-universe matter power spectrum generated assuming a fiducial cosmological model [9]. In the model under consideration, the expansion of the universe does not take place, and the dependence of the redshift on the distance to a remote object, as well as the luminosity distance, differ significantly from the ones in the standard model. To carry out a correct

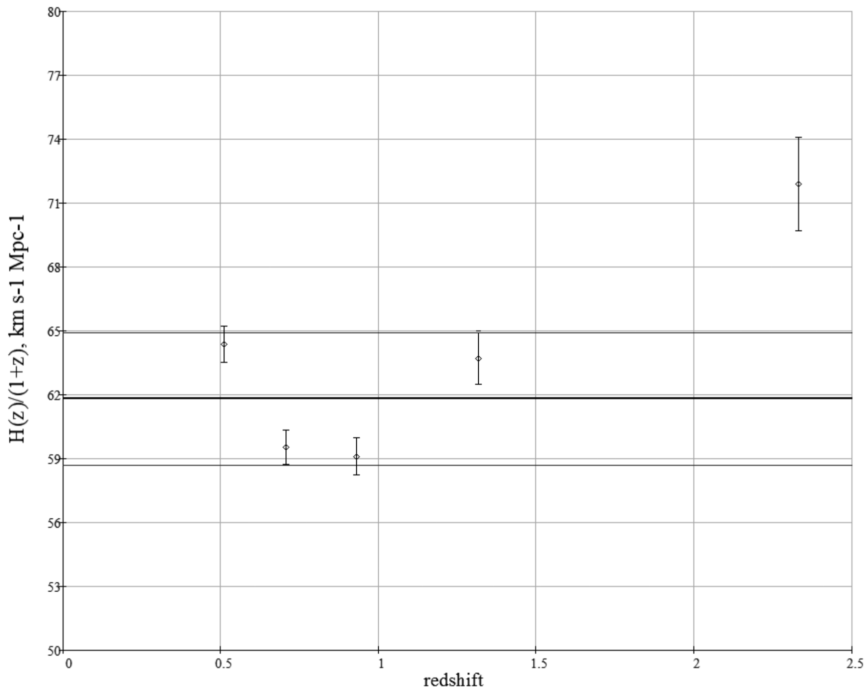

Figure 2: The ratio $H(z_i)/(1 + z_i) \pm \sigma_{0i}$ and the weighted value of the Hubble constant $< H_0 > \pm\sigma_0$ (horizontal lines) for the DESI BAO Hubble parameters $H(z_i)$ from Table 1.

comparison of this model with measurement results, it is necessary to understand how to correct the measurement results (if possible) when rejecting the expansion hypothesis, or to carry out measurements using a technique that takes into account the absence of expansion. An example of such a correction can be found below: the observed values of the distance modulus must be corrected for there to be no time dilation effect in this model.

Non-frontal collisions of photons with gravitons lead to the deviation of some photons from the initial direction of propagation, which weakens the light flux. Both forehead and non-forehead collisions of photons with gravitons give the luminosity distance/redshift relation:

$$D_L(z) = c/H_0 \cdot \ln(1 + z) \cdot (1 + z)^{(1+b)/2}, \tag{7}$$

where the parameter b belongs to the range 0 - 2.137. It has been shown in [2], that for very soft radiation:

$$b = \frac{4}{\pi}(\int_0^{\pi/4} 2\cos^2\theta d\theta + \int_{\pi/4}^{\pi/2} \sin^2 2\theta d\theta) = \frac{3}{2} + \frac{2}{\pi} \simeq 2.137, \tag{8}$$

and $b \to 0$ for very hard one. To fit this model, observations should be corrected for no time dilation as: $\mu(z) \to \mu(z) + 2.5 \cdot \lg(1+z)$, where $\lg x \equiv \log_{10} x$, and the distance modulus: $\mu(z) \equiv 5lgD_L(z)(Mpc) + 25$. The theoretical Hubble diagrams $\mu_0(z)$ of this model with $b = 2.365$ (solid) and with $b = 1.11$ (dashed) are shown in Fig. 3, SN Ia observational data (31 binned points of the JLA compilation (black)) are taken from Tables F.1 and F.2 of [11] and GRB observational data with the Yonetoku calibration (44 points (empty)) are taken from Table 3 of [12], all points are corrected for no time dilation. We have for the JLA compilation $\chi^2 = 30.71$ and the confidence level of 43.03%, for GRB's with the Yonetoku calibration there are $\chi^2 = 32.58$ with 87.62% C.L. It is interesting that in the Yonetoku calibration for the GRB the value of factor b is noticeably smaller than for the visible emission of supernovae Ia in the JLA compilation.

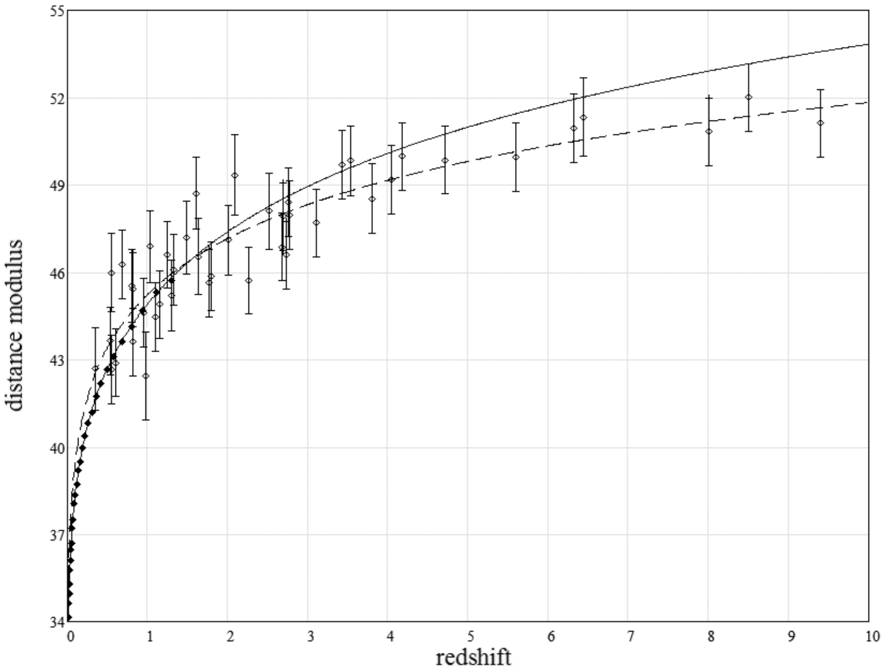

Figure 3: The theoretical Hubble diagrams $\mu_0(z)$ of this model with $b = 2.365$ (solid) and with $b = 1.11$ (dashed), Supernovae Ia observational data (31 binned points of the JLA compilation (black)) [11] and GRB observational data with the Yonetoku calibration (44 points (empty)) [12].

The existence of photons scattered as a result of non-frontal collisions with gravitons should lead to an additional effect of light from nowhere: after repeated scattering, such photons should form an isotropic background. If we define the ratio $\delta(z)$ of the scattered flux to the the remainder reaching the observer, then in this model it is equal to [13]:

$$\delta(z) = (1 + z)^b - 1. \tag{9}$$

For $b = 2.137$ we have, for example: $\delta(0.4) = 1.05$, i.e. this effect is large enough to explain the preliminary detection of the diffuse cosmic optical background [14].

4 Conclusion

This model of quantum gravity, due to its simplicity, does not contain any divergences usually expected in such models. Since Newton's constant is calculated in it as a statistical characteristic of the effect of screening the background of gravitons by bodies, this model is in some sense deeper than general relativity. The considered small additional effects of the model allow us to take a different look at the results of cosmological observations, abandoning the paradigm of the expansion of the universe and receiving as a bonus a model that does not require dark energy. An important fact is the impossibility of smooth movement of microparticles in this model due to the continuous influence of background gravitons, which gives us a chance to approach quantum mechanics in a new way.

References

[1] Rovelli, C.. Notes for a brief history of quantum gravity. [arXiv:gr-qc/0006061v3].

[2] Ivanov, M.A. Gravitons as super-strong interacting particles, and low-energy quantum gravity. In the book "Focus on Quantum Gravity Research", Ed. D.C. Moore, Nova Science, NY, 2006, 89−120.

[3] Ivanov, M.A. Selected papers on low-energy quantum gravity. [http://ivanovma.narod.ru/selected-papers-Ivanov2018.pdf].

[4] Ivanov, M.A. Low-energy quantum gravity and cosmology without dark energy. *Advances in Astrophysics*, *4* (2019) 1−6.

[5] Magana, J., Amante, M.H., Garcia-Aspeitia, M.A. and Motta, V. The Cardassian expansion revisited: constraints from updated Hubble parameter measurements and Type Ia Supernovae data. *Monthly Notices of the Royal Astronomical Society*, *476* (2018) 1036−1049.

[6] Bautista J. E., et al. Measurement of baryon acoustic oscillation correlations at $z = 2.3$ with SDSS DR12 Lyα-Forests. *Astron. Astrophys.*, *603* (2017) A12.

[7] Delubac, T., et al. Baryon acoustic oscillations in the Lyα forest of BOSS DR11 quasars. *Astron. Astrophys.*, *574* (2015) A59.

[8] Font-Ribera, A. et al. Quasar-Lyman-α forest cross-correlation from BOSS DR11: Baryon Acoustic Oscillations. *JCAP 05* (2014) 027.

[9] DESI Collaboration: Adame, A.G., Aguilar, J., Ahlen ,S., S. Alam, S., Alexander, D. M. et al. DESI 2024 VI: Cosmological Constraints from the Measurements of Baryon Acoustic Oscillations. [arXiv:2404.03002v2 [astro-ph.CO]].

[10] Planck Collaboration, N. Aghanim, Y. Akrami, M. Ashdown, J. Aumont, C. Baccigalupi et al. Planck 2018 results. VI. Cosmological parameters, *Astron. Astrophys.*, *641* (2020) A6.

[11] Betoule, M. et al. Improved cosmological constraints from a joint analysis of the SDSS-II and SNLS supernova samples. *Astronomy & Astrophysics*, *568* (2014) A22.

[12] Lin, H.-N., Li, X., and Chang, Z. Effect of GRB spectra on the empirical luminosity correlations and the GRB Hubble diagram. *MNRAS*, *459* (2016) 2501−2512.

[13] Ivanov, M.A. Three Different Effects of the Same Quantum Nature. PoS(EPS-HEP2021)114.

[14] Lauer,T.R., et al. New Horizons Observations of the Cosmic Optical Background. *The Astrophysical Journal*, *906* (2021) 77.