Galaxy number counts in a presence of the graviton background

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Abstract

In the model of low-energy quantum gravity by the author, cosmological redshifts are caused by interactions of photons with gravitons. Non-forehead collisions with gravitons will lead to an additional relaxation of any photonic flux. Using only the luminosity distance and a geometrical one as functions of a redshift in this model, theoretical predictions for galaxy number counts are considered here. The Schechter luminosity function with $\alpha = -2.43$ is used. The considered model provides a good fit to galaxy observations by Yasuda et al. (AJ, 122 (2001) 1104) if the same K-corrections are added. It is shown that observations of $N(z)$ for different magnitudes m are a lot more informative than the ones of $N(m)$.

1 Introduction

The standard cosmological model explains observations only under the circumstance that almost all matter and energy of the Universe are hidden in some unknown *dark* forms. In my model of low-energy quantum gravity based on the idea of an existence of the background of super-strong interacting gravitons (for more details, see [1]), a cosmological redshift is caused by interactions of photons with gravitons. Non-forehead collisions with gravitons lead to a very specific additional relaxation of any photonic flux that gives a possibility of another interpretation of supernovae 1a data - without any kinematics or dark energy [1]. I would like to summarize here the main cosmologically essential consequences of this model. Average energy losses of a photon with an energy E on a way dr through the graviton background will be equal to: $dE = -aEdr$, where $a = H/c$, H is the Hubble constant. If we introduce a new dimensional constant D, so that: $\sigma(E, \epsilon) = D \cdot E \cdot \epsilon$, $\sigma(E, \epsilon)$ is a cross-section of interaction by forehead collisions of a photon with an energy E and a graviton with an energy ϵ, then we can compute the Hubble constant in this approach: $H = (1/2\pi)D \cdot \bar{\epsilon} \cdot (\sigma T^4)$, where $\bar{\epsilon}$ is an average graviton energy, and T is a temperature of the background. The constant D should have the value: $D = 0.795 \cdot 10^{-27} m^2/eV^2$; the one may be found from the Newtonian limit of gravity. If r is a geometrical distance from a source, then we have for $r(z)$, z is a redshift: $r(z) = ln(1+z)/a$. None-forehead collisions of photons with gravitons of the background will lead to a scatter of photons and to an additional relaxation of a photonic flux, so that the luminosity distance D_L is equal in this approach to: $D_L = a^{-1} \ln(1+z) \cdot (1+z)^{(1+b)/2} \equiv a^{-1} f_1(z)$, where $f_1(z) \equiv \ln(1+z) \cdot (1+z)^{(1+b)/2}$ is the luminosity distance in units of c/H. This luminosity distance function fits supernova observations very well for roughly $z < 0.5$. It excludes a need of any dark energy to explain supernovae dimming.

In this paper, I consider galaxy number counts/redshift and counts/magnitude relations on a basis of this model. I assume here that a space is flat and the Universe is not expanding.

2 The galaxy number counts-redshift relation

Total galaxy number counts $dN(r)$ for a volume element $dV = d\Omega r^2 dr$ is equal to: $dN(r) = n_g dV = n_g d\Omega r^2 dr$, where n_g is a galaxy number density (it is constant in the no-evolution scenario), $d\Omega$ is a solid angle element. Using the function $r(z)$ of this model, we can re-write galaxy number counts as a function of a redshift z:

$$dN(z) = n_g d\Omega (H/c)^{-3} \frac{ln^2(1+z)}{1+z} dz. \qquad (1)$$

Let us introduce a function (see [2])

$$f_2(z) \equiv \frac{(H/c)^3 dN(z)}{n_g d\Omega z^2 dz};$$

then we have for it in this model:

$$f_2(z) = \frac{ln^2(1+z)}{z^2(1+z)}. \tag{2}$$

A graph of this function is shown in Fig. 1; the typical error bar and data point are added here from paper [3] by Loh and Spillar. There is not a visible contradiction with observations. *There is not any free parameter in the model to fit this curve;* it is a very rigid case.

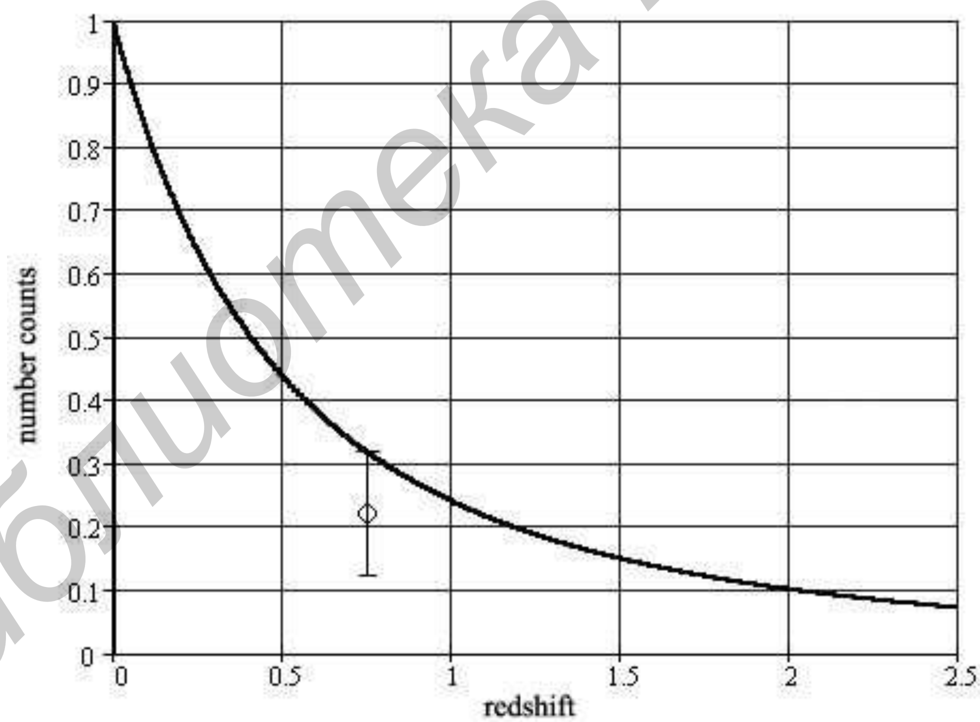

Figure 1: Number counts f_2 as a function of the redshift in this model. The typical error bar and data point are taken from paper [3] by Loh and Spillar.

It is impossible to count a *total* galaxy number for big redshifts so as very faint galaxies are not observable. For objects with a fixed luminosity, it is easy to find how their magnitude m changes with a redshift. So as $dm(z)$ under a constant luminosity is equal to: $dm(z) = 5d(lgD_L(z))$, we have for $\Delta m(z_1, z_2) \equiv \int_{z_1}^{z_2} dm(z)$:

$$\Delta m(z_1, z_2) = 5lg(f_1(z_2)/f_1(z_1)). \tag{3}$$

This function is shown in Fig.2 for $z_1 = 0.001; 0.01; 0.1$.

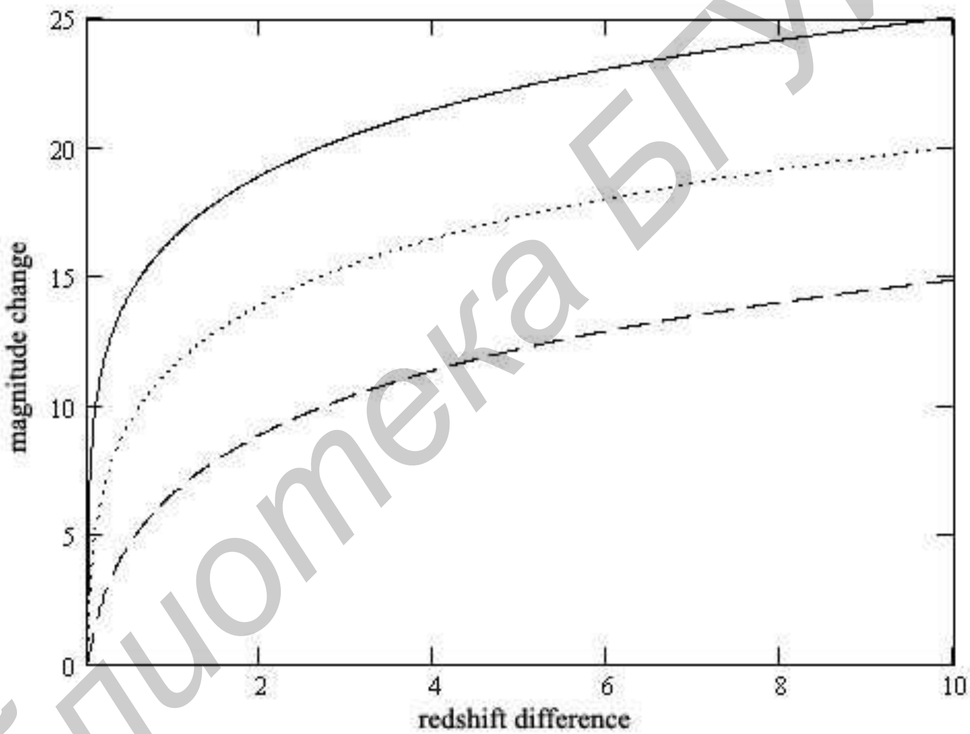

Figure 2: Magnitude changes Δm as a function of the redshift difference $z_2 - z_1$ in this model for $z_1 = 0.001$ (solid); 0.01 (dot); 0.1 (dash).

I would like to note that a very fast *initial* growth of the luminosity distance with a redshift z in this model might explain the observed excess of faint blue galaxy number counts above an expected one in the standard model (for example, see [4]). A galaxy color depends on a redshift, and a galaxy dimming depends on the luminosity distance, because by big values of the ratio $\Delta m(z_1, z_2)/(z_2 - z_1)$ in a region of small redshifts and by a further much slower change of it (see Fig.3) an observer will see many faint but blue enough galaxies in this region (in the no-evolution scenario).

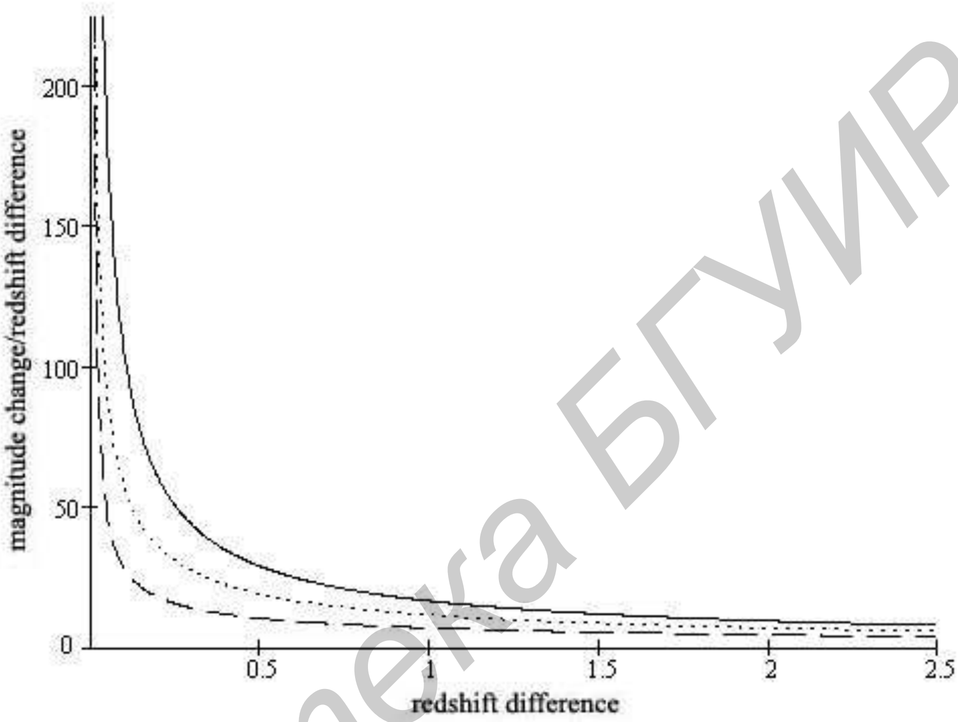

Figure 3: To a possible explanation of the excess of faint blue galaxy number counts: $\Delta m(z_1, z_2)/(z_2 - z_1)$ vs. the redshift difference $z_2 - z_1$ in this model for $z_1 = 0.001$ (solid); 0.01 (dot); 0.1 (dash).

3 Taking into account the galaxy luminosity function

Galaxies have different luminosities L, and we can write n_g as an integral: $n_g = \int dn_g(L)$, where $dn_g(L) = \eta(L)dL$, $\eta(L)$ is the galaxy luminosity function. I shall use here the Schechter luminosity function [5]:

$$\eta(L)dL = \phi_*(\frac{L}{L_*})^\alpha exp(-\frac{L}{L_*})d(\frac{L}{L_*}) \tag{4}$$

with the parameters ϕ_*, L_*, α.[1] So as we have by a definition of the luminosity distance $D_L(z)$ that a light flux I is equal to: $I = \frac{L}{4\pi D_L^2(z)}$, and a visible

[1]To turn aside the problem with divergencies of this function by small L for negative values of α, all computations are performed here for $z > 0.001$.

magnitude m of an object is $m = -2.5 \lg I + C$, where C is a constant, then m is equal to:

$$m = -2.5 \lg I + 5 \lg D_L(z) + (C - 4\pi). \tag{5}$$

We can write for L :

$$L = A \cdot \frac{D_L^2(z)}{\kappa^m}, \tag{6}$$

where $\kappa = 10^{0.4}$, $A = const$. For a thin layer with $z = const$ we have:

$$dL = \frac{\partial L}{\partial m} \cdot dm,$$

where

$$\frac{\partial L}{\partial m} = -m\kappa \cdot A \frac{D_L^2(z)}{\kappa^m} = -m\kappa L. \tag{7}$$

Then

$$dn_g(m, z) = -(\phi_* \kappa) \cdot l^\alpha(m, z) \exp(-l(m, z)) \cdot (m \cdot l(m, z)) dm, \tag{8}$$

where $(-dm)$ corresponds to decreasing m by growing L when $z = const$, and

$$l(m, z) \equiv \frac{L(m, z)}{L_*}.$$

Let us introduce a function $f_3(m, z)$ with a differential

$$df_3(m, z) \equiv \frac{dN(m, z)}{d\Omega(-dm).} \tag{9}$$

We have for this differential in the model:

$$df_3(m, z) = (\frac{\phi_* \kappa}{a^3}) \cdot m \cdot l^{\alpha+1}(m, z) \cdot \exp(-l(m, z)) \cdot \frac{ln^2(1 + z)}{(1 + z)} dz, \tag{10}$$

where $a = H/c$, H is the Hubble constant. An integral on z gives the galaxy number counts/magnitude relation:

$$f_3(m) = (\frac{\phi_* \kappa}{a^3}) \cdot m \cdot \int_0^{z_{max}} l^{\alpha+1}(m, z) \cdot \exp(-l(m, z)) \cdot \frac{ln^2(1 + z)}{(1 + z)} dz; \tag{11}$$

I use here an upper limit $z_{max} = 10$. To compare this function with observations by Yasuda et al. [6], let us choose the normalizing factor from the condition: $f_3(16) = a(16)$, where

$$a(m) \equiv A_\lambda \cdot 10^{0.6(m-16)} \tag{12}$$

is the function assuming "Euclidean" geometry and giving the best fit to observations [6], $A_\lambda = const$ depends on the spectral band. In this case, we have two free parameters - α and L_* - to fit observations, and the latter one is connected with a constant $A_1 \equiv \frac{A}{a^2 L_*}$ if

$$l(m, z) = A_1 \frac{f_1^2(z)}{\kappa^m}.$$

If we use the magnitude scale in which $m = 0$ for Vega then $C = 2.5 \lg I_{Vega}$, and we get for A_1 by $H = 2.14 \cdot 10^{-18}\ s^{-1}$ (it is a theoretical estimate of H in this model [1]):

$$A_1 \simeq 5 \cdot 10^{17} \cdot \frac{L_\odot}{L_*}, \tag{13}$$

where $L_\odot$ is the Sun luminosity; the following values are used: $L_{Vega} = 50 L_\odot$, the distance to Vega $r_{Vega} = 26\ LY$.

Without the factor m, the function $f_3(m)$ by $\exp(-l(m, z) \rightarrow 1$ would be close to $a(m)$ by $\alpha = -2.5$. Matching values of α shows that $f_3(m)$ is the closest to $a(m)$ in the range $10 < m < 20$ by $\alpha = -2.43$. The ratio $\frac{f_3(m) - a(m)}{a(m)}$ is shown in Fig.4 for different values of A_1 by this value of α. All such the curves conflow by $A_1 \leq 10^2$ (or $5 \cdot 10^{15} < L_*$), i.e. observations of the galaxy number counts/magnitude relation are *non-sensitive* to A_1 in this range. For fainter magnitudes $20 < m < 30$, the behavior of all curves is identical: they go below of the ratio value 1 with the same slope. If we compare this figure with Figs. 6,10,12 from [6], we see that the considered model provides a no-worse fit to observations than the function $a(m)$ if the same K-corrections are added (I think that even a better one if one takes into account positions of observational points in Figs. 6,10,12 from [6] by $m < 16$ and $m > 16$) for the range $10^2 < A_1 < 10^7$ that corresponds to $5 \cdot 10^{15} > L_* > 5 \cdot 10^{10}$.

Observations of $N(z)$ for different magnitudes are a lot more informative. If we define a function $f_4(m, z)$ as

$$f_4(m, z) \equiv (\frac{a^3}{\phi_* \kappa}) \cdot \frac{df_3(m, z)}{dz}, \tag{14}$$

this function is equal in the model to:

$$f_4(m, z) = m \cdot l^{\alpha+1}(m, z) \cdot \exp(-l(m, z)) \cdot \frac{ln^2(1+z)}{(1+z)}. \tag{15}$$

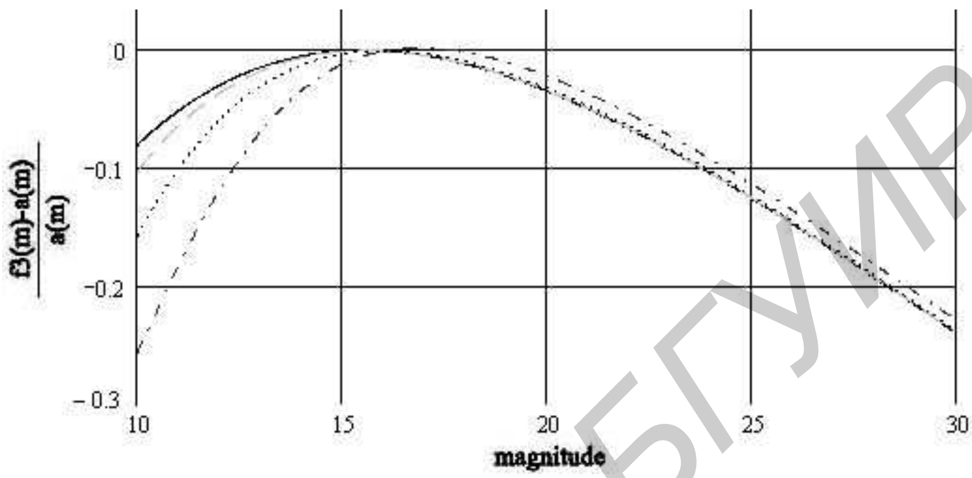

Figure 4: The relative difference $(f_3(m) - a(m))/a(m)$ as a function of the magnitude m for $\alpha = -2.43$ by $10^{-2} < A_1 < 10^2$ (solid), $A_1 = 10^4$ (dash), $A_1 = 10^5$ (dot), $A_1 = 10^6$ (dadot).

Galaxy number counts in the range $m_1 < m < m_2$ are proportional to the function:

$$f_5(m_1, m_2) \equiv \int_{m_1}^{m_2} f_4(m, z) dm = \tag{16}$$

$$= \int_{m_1}^{m_2} m \cdot l^{\alpha+1}(m, z) \cdot \exp(-l(m, z)) \cdot \frac{ln^2(1+z)}{(1+z)} dm.$$

Graphs of both $f_4(m, z)$ and $f_5(m_1, m_2)$ are shown in Fig. 5 by $\alpha = -2.43$, $A_1 = 10^5$; they are very similar between themselves. We see that even the observational fact that a number of visible galaxies by $z \sim 10$ is very small allows us to restrict a value of the parameter A_1 much stronger than observations of $N(m)$.

4 Quasar number counts

For quasars, we can attempt to compute the galaxy number counts/redshift relation using Eq. 16 with another luminosity function $\eta'(l(m, z))$:

$$f_5(m_1, m_2) \equiv \int_{m_1}^{m_2} f_4'(m, z) dm = \int_{m_1}^{m_2} m \cdot l(m, z) \cdot \eta'(l(m, z)) \cdot \frac{ln^2(1+z)}{(1+z)} dz. \tag{17}$$

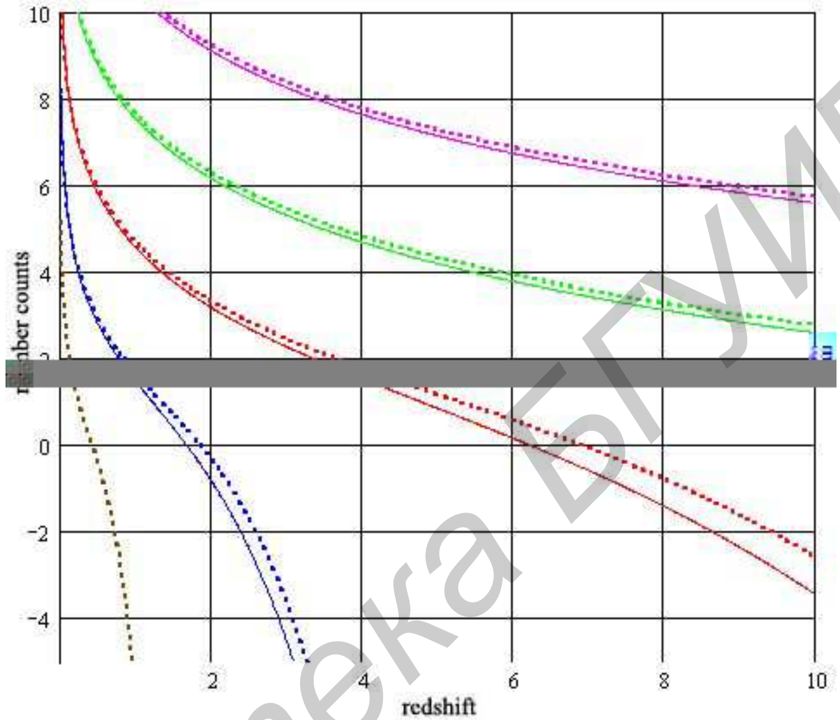

Figure 5: Number counts $f_4(m,z)$ (dot) and $f_5(m_1,m_2)$ (solid) (logarithmic scale) as a function of the redshift by $A_1 = 10^5$ for $\alpha = -2.43,\ m_1 = 10$ and different values of $m = m_2$: 15 (blue), 20 (red), 25 (green), and 30 (mag); $m = 10$ (brown, only $f_4(m,z)$),.

The following luminosity functions were probed here (see Fig. 6): the Schechter one with $\alpha = 0$, $A_1 = 10^{6.55}$ (blue); the double power law [7, 8]:

$$\eta'(l(m,z)) \propto \frac{1}{l^{-\alpha}(m,z) + l^{-\beta}(m,z)} \tag{18}$$

with $\alpha = -3.9,\ \beta = 1.6,\ A_1 = 4.5 \cdot 10^6$ (green); the Gaussian one:

$$\eta'(l(m,z)) \propto \exp(\frac{-(l(m,z)-1)^2}{2\sigma^2}) \tag{19}$$

with $\sigma = 0.5,\ A_1 = 4.5 \cdot 10^6$ (brown, dot); the combined one:

$$\eta'(l(m,z)) \propto l^{\alpha}(m,z) \cdot \exp(\frac{-(l(m,z)-1)^2}{2\sigma^2}) \tag{20}$$

with two sets of parameters: $\alpha = -1.45,\ \sigma = 0.6,\ A_1 = 1.3 \cdot 10^6$ (red, solid) and $\alpha = -1.4,\ \sigma = 0.7,\ A_1 = 3 \cdot 10^6$ (red, dot). There is a couple of curves

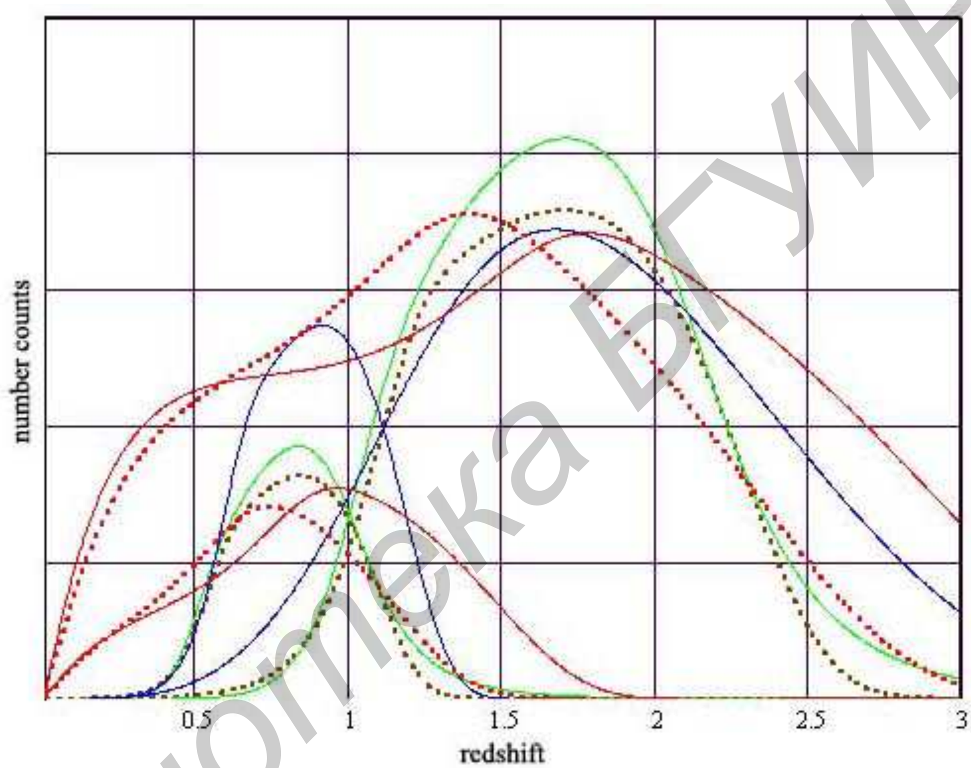

Figure 6: QSO number counts $f_5(m, z)$ (arbitrary units) as a function of the redshift for different luminosity functions: Gaussian (brown, dot), the double power law (green), Schechter's (blue), combined (red, solid and dot) with parameters given in the text. The left-shifted curve of each couple corresponds to the range $16 < m < 18.25$, another one corresponds to $18.25 < m < 20.85$.

for each case: the left-shifted curve of any couple corresponds to the range $16 < m < 18.25$, another one corresponds to $18.25 < m < 20.85$. These ranges are chosen the same as in the paper by Croom et al. [7], and you may compare this figure with Fig. 3 in [7]. We can see that the theoretical distributions reflect only some features of the observed ones but not an entire picture. In all these cases, a slope of an analog of $\log(f_3(m))$ near $m = 18$ is in the range 0.29 - 0.325, when quasar observations give a larger slope (see

Fig. 4, 21 in [7] and Fig. 13 in [9]; in the latter paper, this slope has been evaluated to be equal to about 1). We can summarize that, as well as in the standard cosmological model, it is impossible to fit quasar observations using some simple luminosity function with fixed parameters.

In the standard model, an easy way exists to turn aside this difficulty: one ascribes it to a quasar "evolution", then a luminosity function (for example, the double power law [7, 8]) is modified for different redshifts to take into account this "evolution". There exist two manner to do it: one may consider L_* as a function of a redshift (pure luminosity evolution) [7] or one may assume that indices α and β of the distribution (double power law) vary with z [8] - in both variants, it is possible to fit observations in some range of redshifts; of course, there are many other descriptions of the "evolution" [9]. It is strange only that "evolutions" are not concerted: we can see exponential, quadratic and other kinds of them - and it means that there is not any real evolution: we deal with a pure fine art of fitting, nothing more. In the considered model, this way is forbidden.

I think that it is necessary to consider some theoretical model of a quasar activity to get a distribution of "instantaneous" luminosities. It is known that the typical lifetime of individual quasars is uncertain by several orders of magnitude; a lifetime of $4 \cdot 10^7$ years may be considered as an average value [10]. If one considers a quasar light curve $L(t)$ (in a manner which is similar to the one by Hopkins et al. [11]) in a parametric form, it is possible to get the luminosity function which takes into account a probability to observe a quasar with a given luminosity. Let us consider the two simple examples. The simplest case is a constant luminosity L of any quasar during its lifetime τ. If initial moments of quasar activity are distributed uniformly in time and may be described by a frequency ν, then a probability P_{obs} to observe a quasar will be equal to:

$$P_{obs} = \int_0^\tau \exp(-\nu t') d(\nu t') = 1 - \exp(-\nu\tau). \qquad (21)$$

For $\nu\tau \ll 1$ we have $P_{obs} \simeq \nu\tau$. If we further assume that $\tau \propto 1/L$, i.e. that a full emitted quasar energy is constant, then a distribution of observable luminosities is

$$\eta'(L) \propto \eta(L) \cdot 1/L, \qquad (22)$$

where $\eta(L)$ is an initial distribution of values of L.

The second example is the quasar exponential light curve:

$$L(t) = L_0 \exp(-t/\tau), \qquad (23)$$

where τ is a lifetime, L_0 is an initial luminosity. If L_0 has a distribution $\eta(L_0)$, then we get:

$$\eta'(L) \propto \int \eta(L_0) \cdot [\exp(t_{max}/\tau(L_0)) - 1]^{-1} \cdot (L_0/L)^{2-\nu\tau(L_0)} \cdot dL_0, \tag{24}$$

where t_{max} is a maximum time during which one can distinguish a quasar from a host galaxy, and τ depends on L_0 in some manner. We see that even in this simple toy example the dependence on τ is not trivial.

In a general case, it is necessary to describe both - front and back - slopes of a quasar light curve. Together with a total emitted energy (or a peak luminosity), we need at least three independent parameters; if we take into account their random distributions, this number should be at least doubled.

5 Conclusion

Starting from a micro level and considering interactions of photons with single gravitons, we can find the luminosity distance and a geometrical distance in this approach. Using only these quantities, I compute here galaxy number counts-redshift and galaxy number counts-magnitude relations for a case of a flat non-expanding universe. It has been shown here that they are in a good accordance with observations. It may be important as for cosmology as for a theory of gravity.

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