LETTERS TO PROGRESS IN PHYSICS

Cosmological Redshift in the De Sitter Stationary Universe

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Here we focus on our previous studies, wherein we deduced the redshift formula in the de Sitter metric space. The non-Newtonian gravitational forces of repulsion, acting in the de Sitter universe, increase with distance. Thus these forces produce the redshift effect on photons coming from distant objects. The redshift in the de Sitter universe increases with distance from the observed objects, and is hyperbolic that matches with the non-linear redshift recently registered by astronomers. As a result, we no longer need the expanding model of the Friedmann metric to correctly explain the redshift in the spectra of galaxies and quasars. The observed "cosmological" redshift is as well good explained in the de Sitter universe which is stationary as is well known.

Earlier, we studied the metric of the inner space of a liquid sphere — the sperical space filled with an ideal incompressible liquid (the so-called Schwarzschild 2nd metric). The obtained results were published in all necessary detail in [1–3]. In particular, in our book *Inside Stars* [2] we considered stars as liquid spheres. Our computations made by the mathematical methods of the General Theory of Relativity showed a good coincidence with the observational data known in astronomy. We also showed, in the journal papers [1, 2] and in §1.2 of the book *Inside Stars* [2], that the liquid sphere metric transforms into the de Sitter metric (the metric of a spherical space fulled with physical vacuum) under the following two common conditions. First, under the gravitational collapse condition, when the radius of the liquid sphere becomes equal to its gravitational radius (i.e. when the liquid sphere becomes gravitational collapsar). And second, when the space-time breaking matches with the radius of the liquid sphere. We also showed that the observed Universe is equivalent to a sphere in the state, which is very close to gravitational collapse (See Chapter 6 in [2] for detail). Thus the space of our Universe can be described by the metric of the de Sitter vacuum sphere. This means, in particular, that the non-Newtonian gravitational forces acting in the de Sitter metric space must manifest themselves in some astronomical phenomena observed in our Universe (read about the non-Newtonian forces of gravitational attraction and repulsion in §5.5 of our book *Fields, Vacuum and the Mirror Universe* [4]). For example, the non-Newtonian gravitational forces may also be the source of the observed redshift in the spectra of galaxies and quazars.

Now, this observed phenomenon is known as the "cosmological redshift" due to Lemaître who in 1927 showed [5] that such redshift may be originated due the Doppler effect on photons in an expanding universe (the universe of the Friedmann metric). On the other hand, proceeding from the aforementioned theoretical results [1–3] we can now state that the observed redshift in the spectra of galaxies and quazars has no relation to cosmology but is the "effect of distance" in the stationary universe of the de Sitter metric. Such a redshift formula was derived in our publications [1–3]. But because those publications were focused on the internal constitution of stars, the redshift effect in the de Sitter space was not emphasized and analysed properly.

We now aim to emphasize it for better understanding of the obtained result.

The redshift formula is derived by integration of the scalar geodesic equation for photons. There are the scalar geodesic equation and the vectorial geodesic equation. They are the respective projections of the four-dimensional geodesic equation (the equation of motion along the shortest/geodesic lines) onto the time line and the three-dimensional spatial section of the observer. The scalar geodesic equation, the projection onto the time line, is the equation of energy. The vectorial geodesic equation is the equation of three-dimensional motion. So, integrating the scalar geodesic equation of a photon along its path, we obtain how its energy and, hence, its frequency changes during its travel. As a result, we obtain the redshift formula. As a matter of fact that the geodesic equations and, hence, their integration, depends on the metric of the particular space wherein the photons travel.

The three-dimensional sub-space of the de Sitter space (space-time) does not rotate and deform. But there is the gravitational inertial force. This force acting inside a sphere filled with physical vacuum, i.e. in the de Sitter space, in the radial coordinates takes the form (5.74) [4, §5.5]

$$F = \frac{\lambda c^2}{3}\, r = \frac{c^2}{a^2}\, r\,,$$

where $\lambda = \varkappa\rho_0$ is the Einstein cosmological constant, $\varkappa$ is the Einstein gravitational constant, while ρ_0 is the density of the physical vacuum that fills the de Sitter space (see §5.3 [4]).

The Hubble constant $H = (2.3 \pm 0.3) \times 10^{-18}$ sec^{-1} is expressed through the radius of the Universe $a = 1.3 \times 10^{28}$ cm as $H = c/a$. Thus, we obtain (6.11) [1]

$$F = H^2 r\,,$$

where the Hubble constant plays the rôle of a fundamental frequency

$$H = \frac{2\pi}{T}$$

expessed through the time T of the existence of the Universe. So, the gravitational inertial force F acting in the de Sitter space depends the Hubble constant H.

Because $F > 0$ in the de Sitter space, this is a force of repulsion. This force is proportional to the radial distance r to the observer: each system of reference is connected with its own observer and his reference body, which is the "centre" of his own universe.

Consider the scalar and vectorial geodesic equations for a photon. This is the system of equations (6.22) [2]. Because the de Sitter space does not rotate and deform, the equations take the simplified form (6.23), where the photon is affected by only the gravitational inertial force and the space non-uniformity (expressed with the Christoffel symbols). Integrating the scalar geodesic equation (the equation of energy) for the photon travelling along the radial coordinate r in the de Sitter space, with taking the vectorial geodesic equation, we obtain the formula of the photon's frequency ω (6.27) [2]

$$\omega = \frac{\omega_0}{\sqrt{1 - r^2/a^2}}\,,$$

where ω_0 is the photon's frequency in the beginning of its travel (at its source wherefrom it was emitted). We see that the photon's frequency is asymptotically increasing when the photon's source approaches to the event horizon (radius) of the Universe.

At distances much shorter than the Universe's radius i.e. much shorter than the event horizon of the Universe ($r \ll a$), the formula for the photon's frequency becomes (6.28)

$$\omega \simeq \omega_0 \left(1 + \frac{r^2}{2a^2}\right).$$

That is we get the quadratic additive to the initially frequency of the photon or, in another word, the redshift effect z of parabolic type (6.29–6.31)

$$z = \frac{\omega - \omega_0}{\omega_0} = \frac{1}{\sqrt{1 - r^2/a^2}} - 1 \simeq \frac{r^2}{2a^2} > 0\,,$$

which, in terms of the Hubble constant $H = c/a$, is

$$z \simeq \frac{H^2 r^2}{2c^2}\,.$$

As is seen, the photon frequency shift is positive in this case: $z > 0$ (otherwise it would be blueshift). This means that the redshift effect takes place in the de Sitter universe. The space of the de Sitter metric is stationary: it neither expands nor compresses. The redshift effect in the de Sitter universe is due to the non-Newtonian gravitational force of repulsion.

In the last decades, astronomical observations of the most distant galaxies showed an increase of the redshift effect in the spectra of the most distant galaxies, which are located close to the event horizon. The astronomers supposed therefore, on the basis of the Friedmann metric of an expanding universe, that the space of our Universe expands with acceleration. On the other hand, the non-linear redshift at large distances is easily explained in the framework of the de Sitter static universe: see formula for z that above. This non-linear effect is due to only the non-linearity of the non-Newtonian gravitational force of repulsion acting on the photon. From the viewpoint of an earthy observer this effect looks as the increasing redshift with the increasing distance from the Earth to the observed object (the source of the photon).*

The observed high redshift in the spectra of quazars is as well explained due to the powerful inner non-Newtonian forces of repulsion (not the far intergalactic distances in the Friedmann expanding universe). As we conclude on the basis of our book *Inside Stars* [2], the ratio of the gravitational radius and the space breaking radius to the physical radius a (i.e. the ratio r_g/a and r_{br}/a) is close to 1 for neutron stars and quazars. If a star is in the state of gravitational collapse, the space breaking matches with both the gravitational radius of the star r_g and the star's surface a, i.e. $a = r_g = r_{br}$. If the space breaking matches with only the star's surface ($r_{br} = a$), gravitational collapse occurs at the radius

$$r_c = \sqrt{9a^2 - 8a^3/r_g}$$

(2.7) in [1]. The physical radius a of such a star is

$$r_g < a < 1.125\, r_g$$

see (2.8 – 2.9) in [1]. In other words, neutron stars and quazars are objects in the state, which is very close to collapse. The latter means that the inner non-Newtonian gravitational force of repulsion is so strong near the surface of a neutron star or a quazar that photons emitted from its surface into the cosmos bear a high redshift independent on the distance from the observer. For this reason, quazars may be located not somewhere near the event horizon of our Universe, but somewhere much much closer to us.

In the end, a few words about our Universe as a whole. According to the contemporary astronomical data, its average density is $\sim 10^{-29}$ g/cm^3, while the ultimate large observed distance (the radius of the Universe, or the event horizon) is $\sim 1.3 \times 10^{28}$ cm. With such characteristics, the collapse radius is $\sim 1.2 \times 10^{28}$ cm (a little lesser than the event horizon,

*This conclusion on the unnecessity of the Friedmann metric meets another study [6–8] showing that the observed redshift, including its non-linearity, may be caused by the light-speed rotation of the isotropic space (the partially degenerate space, wherein light-like particles e.g. photons travel). The found basic redshift effect in a flat space has the form of exponent, while the paticular space metrics make only an additional goal to it.

while the space breaking radius is the same as he event horizon $\sim 1.3 \times 10^{28}$ cm. These observed facts mean that we live in the inner space of an object which is either collapsar or is in the state which is very close to the state of collapse. The description of such an object anyhow excludes the expanding model. That is the Friedmann metric of an expanding universe is non-applicable to the observed Universe.

Finally, the observed non-linear redshift in the soectra of galaxies and quazars is well explained in the de Sitter stationary space, wherein it is merely a "distant effect" due to the non-Newtonian forces of repulasion which increase with distance from the observer. The de Sitter universe is stationary — it is a bubble that has closed space and time on itself, and is floating in the surrounding outer space (because we have no reason to assert that our Universe exists in isolation as an exceptional object).

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