On observed consequences of influence of the dragging effect in the Universe scale

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Abstract. The analysis of metrology procedures, underlying methods of defining a distance up to astrophysical object, indicates the necessity to account special effects of moving media electrodynamics when experimental data are processed.

As an example the calculation of delay of a light signal from an astrophysical object owing to an interaction of an electromagnetic wave with atoms of an interstellar medium of fast expanding fields of the Universe is offered.

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1. Introduction. By considering a process of electromagnetic radiation propagation in the expanding Universe we can use the relativistic law permitting to calculate a motion velocity of an astrophysical object from the magnitude of the red shift of the radiation, emitted by the object.

To determine a distance up to remote astrophysical object we can use the law of Habbl. As the obtained in such way results based on the data of radiation, adopted in the current instant, distance up to an object is determined at the moment of radiation emission.

Analyzing the data of distances up to some astrophysical objects, it is possible to conclude that the objects were outside the Universe at the moment of radiation. For example, the source 3C427.1 has the red shift $z = 1{,}175$, from what follows, that it was apart $R_2 = 13$ of billions light years at the moment of radiation of light [2]. On the other hand, the age of the Universe in different cosmological models comprises from 10 to 20 billions light years. Then, by suggesting that the expansion of the Universe happens not faster than speed of light, and accepting a size of the Universe about $R_0 = 20$ billions light years, it is possible to receive a size of the Universe at the moment of an emission of light - $R_1 = 7$ of billions light years. But then the source at the moment of radiation was outside the Universe.

The reduced deduction has received a title of a cosmological paradox.

One of possible paths of a paradox solution is linked with the idea of the space expansion [1]. According to this hypothesis the Doppler shift of a radiation frequency of the remote object is not bound to a motion of the object, but to a motion of a space field, in which the object is located. The velocity of an object relative to the expanding space can be insignificant. From this approach the possibility of a remote astrophysical objects motion relative to the Earth with velocities exceeding speed of light in the vacuum follows that explains the cosmological paradox.

Also it may be shown, that effects of moving media electrodynamics should be taken into account at the analysis of metrology procedures, underlying the determination of a distance up to astrophysical objects.

As an example we can show, that the time of electromagnetic radiation propagation from the source to the observer is influenced by the effect of a time delay of propagation owing to interaction of an electromagnetic wave with atoms of an interstellar medium of expanding fields of the Universe.

The equations of electrodynamics are noted concerning vacuum in some selected inertial reference system (IRS). Relating the current IRS with the observer located on the Earth, we shall come to an inference, that the red shift of a spectrum of radiation is stipulated by a motion of astrophysical object relative to the current IRS independently on the velocities which the space is dilated the object in this space goes with.

It follows from the fact that only velocity of a remote astrophysical object concerning the selected IRS will enter the solution of the equations of moving media electrodynamics besides the velocity of a medium.

In a general case we should know the distribution of coordinates and the velocities of particles of an interstellar medium along the trajectory of a wave vector, the resulting velocity vector of the source formed with the velocity of an object in the expanding space and the velocity of a space expansion as well as the rotation variables, when a transformation of an electromagnetic radiation is described in the expanding Universe [3, 4].

By neglecting the effects stipulated with a rotation, the radiation propagation through moving substance will be accompanied with the longitudinal effect of Fizeau, which can render influence on the red shift of a radiation spectrum. But this influence is essential only in the field of a space, where a density of an interstellar medium and its velocity of a motion are considerable, as after the radiation is emitted from this field the electromagnetic wave gets a phase shift, but its frequency remains constant.

These parameters can be high in frontier fields of the Universe, which are sufficient removed from the ground observer; therefore influence of the Fizeau's effect on a wave length of radiation in the field of the ground observer can be neglected.

The much greater influence the motion of an interstellar medium can render on the propagation time of an electromagnetic radiation in the field of a space, where the motion velocity of atoms in an interstellar medium is rather high. In the case the velocity of a medium motion relative to the selected IRS will include in the dispersion equation, in which there is an observer.

2. Calculations. Let us consider a solution of a dispersion equation at the lack of a medium demarcation, neglecting by dispersion, at the lack of a tangential component velocity of a medium motion, when the motion of a medium is guided against a wave vector of an electromagnetic wave.

For the module of a wave vector for the $i-$th layer of a medium we shall receive the expression

$$k_{in} = \frac{\omega_0}{c}\frac{-\kappa_i \gamma^2{}_i \beta_{in} + \sqrt{1+\kappa_i}}{1-\kappa_i \gamma_i^2 \beta_{in}^2}. \tag{1}$$

Here $\kappa_i = \varepsilon_i \mu_i - 1, \beta_{in} = \dfrac{u_{in}}{c}, \gamma_i^{-2} = 1-\beta_{in}^2$, the magnitudes $u_{in}, \varepsilon_i, \mu_i$ characterize normal components of a velocity, dielectric and magnetic conductivities of the i-th layer of a medium in a IRS of an observer, c - the velocity of light in the vacuum, ω_0 - the frequency of an electromagnetic wave emitted by a remote astrophysical object, in a IRS of an observer.

This expression characterizes propagation of an electromagnetic radiation without a space-time curvature and without the effect of a trajectory deformation of a wave vector, bound with rotation [3,4].

The frequency of electromagnetic radiation will not change since there is a normal velocity of a motion of a demarcation of media. In the result a velocity of radiation propagation in the $i-$th moving layer of a medium will pay off under the formula

$$c_i' = \frac{\omega_0}{k_{in}} = c\frac{1-\kappa_i \gamma_i^2 \beta_{in}^2}{-\kappa_i \gamma^2{}_i \beta_{in} + \sqrt{1+\kappa_i}} \tag{2}$$

The time of radiation propagation in the $i-$ th layer of a medium can be calculated as follows

$$\Delta t_i = \frac{\Delta z_i}{c_i'} = \frac{\Delta z_i}{c} \frac{n_i\left(1-\beta_{in}^2\right)-\left(n_i^2-1\right)\beta_{in}}{1-n_i^2\beta_{in}^2}. \tag{3}$$

Here Δz_i is a width of the i-th layer of a medium possessing a velocity u_{in}, $n_i = \sqrt{\varepsilon_i \mu_i}$ is an index of refraction of the i-th layer of a medium.

Generally the velocity of a medium is a function of coordinates and time. For simplicity it is possible to assume, that the law $\beta_n(z)$ is known for us, i.e. the association of a medium velocity in the world points, which sequentially is transited by an electromagnetic wave.

As an example it is possible to consider the linear relation of a velocity from a coordinate

$$\beta_n(z) = -\left(R_0 - z\right)\hat{\beta} \quad , \tag{4}$$

where $\hat{\beta}$ is the normalizing factor with the dimensionality m^{-1}. The velocity of a motion of atoms of the medium linearly decreases from the maximum value at $z=0$ up to zero at $z=R_0$, i.e. on the Earth.

Let us assume that the index of refraction of an interstellar medium is the stationary value.

Then summing (3) on i and passing to a limit at $\Delta z_i \to 0$ we shall receive expression for propagation time of electromagnetic radiation on the terminal distances from z_1 up to z_2:

$$t = \frac{n}{c}\int_{z_1}^{z_2} \frac{1-\beta_n^2(z) - \dfrac{n^2-1}{n}\beta_n(z)}{1-n^2\beta_n^2(z)}\,dz\,. \tag{5}$$

It is necessary to pay attention, that the integrand can reduce to infinity at the values of the radicals of a denominator $\beta_{n1,2} = \pm 1/n$.

However numerator vanishes at $\beta_{n3} = 1/n$, $\beta_{n4} = -n$, so the equivalence $\beta_{n1} = \beta_{n3}$ is fulfilled. Therefore for the determination of a function value in this point we discover a limit

$$\lim_{\beta_n \to 1/n} \frac{1-\beta_n^2(z) - \dfrac{n^2-1}{n}\beta_n(z)}{1-n^2\beta_n^2(z)} = \frac{1}{c}\frac{n^2+1}{2n} \tag{6}$$

Hence, the function has discontinuities only in one point $\beta_{n2} = -1/n$.

The integration (5) gives

$$t = \frac{n}{c\hat{\beta}}\left[\frac{1}{2n}\left(1-\frac{1}{n^2}\right)\ln\left|\frac{1+n\beta_n}{1-n\beta_n}\right| + \frac{\beta_n}{n^2} + \frac{n^2-1}{2n^3}\ln\left|1-n^2\beta_n^2\right|\right]\Bigg|_{\beta_{n1}}^{\beta_{n2}} \tag{7}$$

After transformations and substitution of limits of the integration we shall receive

$$t = \frac{z_2 - z_1}{cn} + \frac{n^2-1}{cn^2\hat{\beta}}\ln\left|\frac{1-n\hat{\beta}\left(R_0-z_2\right)}{1-n\hat{\beta}\left(R_0-z_1\right)}\right| \tag{8}$$

The first item gives time of radiation propagation in a fixed medium, and second - additional contribution owing to a time delay of radiation propagation in a moving medium.

As it is easy to note, in the limiting case, when $z_1 = z_2$, the time is equal to zero. Similarly at $n = 1$ we shall receive the equality to zero for the second term, that is compounded with required physical restrictions.

The found radical $\beta_{n2} = -1/n$ indicates that the function will convert in this point aims at infinity, and consequently the integral, one of which limits aims to β_{n2}, will aim also at infinity. Really, substituting $\hat{\beta} = 1/nR_0$, $z_1 = 0$, we shall receive, that $t \to \infty$.

The physical idea of this deduction is that the radiation propagates in a medium in the direction of an observer on the Earth with a velocity tended to zero in the fields of the Universe, which moves off with a velocity about $v_n \approx -c/n$.

Therefore, the astrophysical objects are further from the observer at the moment of radiation emitting, than it follows from culculations, which do not take into account interactions of an electromagnetic wave with atoms of an interstellar medium.

In order to our estimates have an actual basis, it is necessary to take into account, that the magnitude $|\beta_n|$ in a case, when the radiation reaches the ground observer, should be less 1/n, therefore for our calculations we shall involve small parameter α , such, that

$$\hat{\beta} = \frac{1}{nR_0(1+\alpha)}, \qquad \alpha << 1 \tag{9}$$

Then (8) is reduced in an aspect

$$t = \frac{z_2 - z_1}{cn} + (1+\alpha)nR_0\left(1 - \frac{1}{n^2}\right)\ln\left|\frac{\alpha R_0 + z_2}{\alpha R_0 + z_1}\right| \tag{10}$$

By allowing $z_1 = 0$, $z_2 = R_0$, we shall receive

$$t = \frac{R_0}{cn}\left[1 + (n^2 - 1)(1+\alpha)\ln\left|\frac{1+\alpha}{\alpha}\right|\right] \tag{11}$$

As we see, the result of calculations of propagation time of a light signal depends on an index of refraction of a medium, but in the greater degree it depends on the parameter α , which characterizes a motion velocity of a radiation source.

To estimate α we shall assume, that the time delay owing to a medium motion has an order of a magnitude of propagation time of electromagnetic radiation in a fixed medium, i.e. light extends twice more slowly, than in a fixed medium.

Then the equality will be fulfilled

$$(n^2 - 1)(1+\alpha)\ln\left|\frac{1+\alpha}{\alpha}\right| = 1 \tag{12}$$

Taking into account, that $\alpha << 1$ is possible to receive a relation between α, n:

$$\alpha = \exp\left(-\frac{1}{n^2 - 1}\right) \tag{13}$$

The substitution $n = 1{,}05$ gives $\alpha = 5{,}8 \cdot 10^{-5}$, and, as will be shown below, the magnitude n can be less.

3. Conclusion. The parameters $n = 1{,}05$ and $\alpha = 5{,}8 \cdot 10^{-5}$ ensure the double time of transiting of a distance R_0 with a light signal, that is equivalent to a determination of an object in 2 times further from the Ground observer than it follows from the law of Habble (in an approximation of the velocity constancy of the Universe expansion).

Actually the velocity of an expansion should decrease and reduce in a drop of influence of a propagation time delay effect of an electromagnetic radiation in a direction to the observer with the age of the Universe. Therefore the radiation will come with smaller delays from more remote fields of the Universe that should reduce in the nonlinear shape of the law of Habble.

Generally, the obtained result indicates that the effect of a light signal propagation time delay in a moving medium leads to the magnification of the computed speed of remote astrophysical objects, and consequently the velocity of space expansion increases, that should be taken into account in cosmological models.

Here it is necessary to point out the used assumptions. The law (4) and constancy of an index of refraction along an axis z concerns to them. As follows from the general relativity theory, the velocity of expansion of the Universe should decrease in due course, since influence of a gravitational attraction between bodies gradually should be incremented.

Therefore law (4) should have the nonlinear form. The dependence of an refraction index on the coordinate z also should have the nonlinear form, and, obviously, that in remote younger fields the density of an interstellar medium should be higher.

The reduced notes indicate that the more detail solution of the current problem should reduce in an amplification of an influence of the considered effect.

It should be pointed out that the discussed effect must be differently observed for different electromagnetic regions of the spectrum.

If the experiment doesn't confirm these suppositions, it can be a new argument in favor of the cosmological principle, as velocity of a medium relative to local field of expended space should be accounted in calculations.

It costs to notice that dragging effect of light must be observed in rotating stellar atmospheres and similar cases.

References

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