On the Nature of the Redshift in the Standard Model of Cosmology

V.S. Troitsky
Radiophysical Research Institute
B. Pecherskaya 25
603600 Nizhny Novgorod, Russia
email: sneg@nirfi.sci-nnov.ru

It is known that the redshift in the standard model of cosmology, defined by the expression $(z+1) = a(t_o)/a(t)$*, is usually explained as a kinematic Doppler effect induced by the recession of galaxies. It is shown in this work that this treatment is physically wrong. According to the mathematical formalism of the standard model, the redshift is formed in the process of light propagation—being defined by the expansion of space—and is, therefore, the parametric Doppler effect. It is shown, that the redshift in the standard model must be defined by the sum of both Doppler effects, i.e. the parametric effect due to space expansion and the kinematic effect due to recession of galaxies equal to* $(z+1) = \sqrt{(1+v/c)/(1-v/c)}$*, which is not taken into account. The existence of the variable scale factor in metrics (the scale of the unit length) inevitably leads to time variation of physical constants, including light velocity, which is shown to define the parametric Doppler effect. The use of a variable scale of length and, as a consequence, variable light velocity, contradicts modern physical concepts. Methods are considered for eliminating the contradictions from the theory.*

Introduction

It is shown in the present paper, that the standard model of cosmology, owing to its mathematical structure, is actually based on the concept of a variation of light velocity with time, due to which the redshift is observed. First, we recall the fundamental statements of the standard cosmology.

The generally accepted Big Bang cosmology is based on the space-time metric:

$$ds^2 = c_o^2 dt^2 - a^2(t)\left[dr^2 + f^2(r)\left(d\theta^2 + \sin^2\theta\, d\varphi^2\right)\right] \quad (1)$$

Here $a(t)$ is the radius of the Universe or, otherwise, the scale dimension of space defined by the solution of the Einstein gravity equation; φ, θ are the angular coordinates of galaxies, and r is the relative constant radial coordinate. To simplify the expression we shall consider the case of plane space, for which $f(r) = r$. In this case, the metric distance up to galaxies detected by the stationary length standard will be, according to (1), $R(t) = a(t)r$. This signifies that the Universe is a sphere of radius $a(t)$, filled with galaxies the location of which inside the sphere is unchanged with time, *i.e.*, $r = R(t)/a(t) = \text{const}$ and $0 \le r \le 1$.

Misconception of the Nature of Redshift in the Standard Model

To define the redshift we consider the radial propagation of a light pulse from a galaxy with coordinates r, φ, θ, to the observer at the origin of the coordinates ($r = 0$). The propagation process is defined by the metric (1) with the condition $ds = 0$ and $d\varphi = d\theta = 0$, then $dr = C dt/a(t)$. This expression is a trivial form of the expression for light propagation in the frame of axis r, where the observer is also located. The expression determines the distance dr the light travels in time dt, with the velocity at the instant t being proportional to $C/a(t)$. The total relative distance which light propagates from the instant of emission t_1 to the instant of reception t_o by any galaxy will be:

$$r = \int_{t_1}^{t_o} \frac{c_o dt}{a(t)}, \qquad (2)$$

The metric distance between these galaxies according to the condition $R(t)/a(t) = r$ will be equal to:

$$R(t_1, t_o) = a(t_o) r = a(t_o) \int_{t_1}^{t_o} \frac{c_o dt}{a(t)} \qquad (3)$$

at the time of observation $t = t_o$.

Now note that the metric distance traveled by light $a(t_o)r$ is essentially larger than that at the instant of emission $a(t_1)r$. This means that space is expanding and increases while the light propagates to the observer. This can be reduced to an equivalent decrease of light propagation velocity. Further, as was mentioned above, in standard cosmology from expression (2) we find an equation for the redshift by using the light pulse propagation in space between the emitting and receiving galaxies. If the pulse begins propagation at instant t_1 and arrives at the instant $t_1 + \Delta t_1$, then the beginning and the end of the pulse at the observer's location will be at instants t_o and $t_o + \Delta t_o$. By virtue of the constancy of the relative distances of the galaxies, r, the front and rear of the wave of the pulse cover one and the same relative distance, *i.e.*

$$r = \int_{t_1}^{t_o} \frac{c_o dt}{a(t)} = \int_{t_1+\Delta t_1}^{t_o+\Delta t_o} \frac{c_o dt}{a(t)}. \qquad (4)$$

Writing the second integral in the form of the sum of integrals $\int_{t_1}^{t_o} - \int_{t_1}^{t_1+\Delta t_1} + \int_{t_o}^{t_o+\Delta t_o}$ and taking into account that at small intervals of time Δt_1 and Δt_o the radius $a(t)$ is constant, we obtain $\Delta t_1/a(t_1) = \Delta t_o/a(t_o)$. We assume Δt_1 to be equal to the oscillation period at the radiator and, hence, Δt_o to be equal to the oscillation period at the observer. Then, indicating the periods by the frequency $\Delta t_1 - 2p/w_1$, $\Delta t_o = 2p/w_o$, we obtain $w_1/w_o = (z+1)$, the generally known relation for the redshift:

$$(z+1) = \frac{a(t_o)}{a(t_1)} \qquad (5)$$

From this calculation it can be seen that the redshift occurs as light propagates through the space between galaxies. It is independent of the relative velocity of the galaxy to the observer, and hence is not the well-known kinematic Doppler effect. From (5) it can be seen that the redshift is proportional to a variation in a certain parameter of the medium for the time of the signal propagation through it. This parameter is the length scale, which varies with time; it characterizes the expansion of space. Here, the frequency shift arises during propagation of an electromagnetic wave. This phenomenon is well known in physics and is called the parametric Doppler effect (*cf. Physical Encyclopaedic Dictionary*, 1984).

To explain the nature of the effect, we consider the material medium as the light velocity changes with time according to the relation $C(t) = C/n(t)$, where $n(t)$ is the refraction index. Such media are found in nature and technology. Let there be a radiator in this medium at the constant distance R from the observer, which sends a light pulse of Δt_1. The corresponding instants of reception will be t_o and $t_o + \Delta t_o$. Equating the expressions for the distance traveled by the front $R = \int_{t_1}^{t_o} C(t) dt$ and by the rear $R = \int_{t_1+\Delta t_1}^{t_o+\Delta t_o} C(t) dt$, using the above calculation we find that for $C(t) > C(t_o)$ the redshift has the form:

$$(z+1) = \frac{C(t_1)}{C(t_o)} = \frac{n(t_o)}{n(t_1)} \qquad (6)$$

This expression is similar to (5) in physical content. But neither expression has anything to do with the formula for the kinematic Doppler effect $(z+1) = \sqrt{(1 + v(t_1)/c_o)/(1 - v(t_1)/c_o)}$.

Returning to the redshift formula in the standard cosmology (4), it is not difficult to see that it is not correct. In fact, to define the redshift, one should consider the events in real, observed space, which is determined by the real metrical distance between galaxies. So, to define the redshift, one must use the expression for the metrical distance between galaxies $R(t_1, t_o)$ (3), not just the r part.

We consider the motion of a light pulse between galaxies. Due to recession of the galaxies the distance traveled by the front and rear of the wave will be different. The difference is $\Delta R = R(t_1 + \Delta t_1, t_o + \Delta t_o) - R(t_1, t_o)$ and depends on the current time t_o and t_1. With a small interval Δt_1 and Δt_o, the value ΔR is close to the total differential $\Delta R = \Delta t_1 \partial R/\partial t_1 + \Delta t_o \partial R/\partial t_o$. From here, according to (3) we obtain:

$$\Delta R = \dot{a}(t_o) \Delta t_o r + a(t_o) \left[\frac{c_o \Delta t_o}{a(t_o)} - \frac{c_o \Delta t_1}{a(t_1)} \right] \qquad (7)$$

Here, the first term is the difference of path of the front and rear of the waves due to variation of $a(t_o)$, and the second one, due to variation of r. But under the conditions of the problem solution for galaxy motion we have $r =$ constant, and so the total differential $\mathrm{d}r = 0$. Now, we have two conditions:

$$\frac{\mathrm{d}R}{\mathrm{d}t_o} = \dot{a}(t_o)r \text{ and } \frac{\Delta t_o}{a(t_o)} - \frac{\Delta t_1}{a(t_1)} = c_o^{-1}\mathrm{d}r = 0 \qquad (8)$$

These expressions produce the kinematic and parametric Doppler effects, respectively. Now, according to the mathematical formalism of the standard cosmology, the observed redshift of galaxies is formed due to both the light velocity evolution and recession of galaxies. Misunderstanding of this fact leads to a situation where the redshift in the form (5) in the standard cosmology, corresponding in reality to the parametric Doppler effect, is explained as a kinematic Doppler effect, whereas in fact expression (5) has nothing to do with the expressions for the kinematic Doppler effect. Recently, Harrison (1993) came to same the conclusion on the confusion of concepts of regarding the nature of the redshift which one finds in the scientific literature on the standard cosmology.

Evidently, it is correct to consider both effects, but this problem is not simple. The shift in frequency of light emitted from a moving galaxy is defined, according to the special relativistic theory, by the relative velocity of the galaxy at the moment of radiation, but it is only measured by the observer millions or even billions of years afterward. The question then arises, by what mechanism can the radiated signal transmit the value of the recession velocity to the galaxy, when this velocity does not exist at the instant of emission? We must to assume that light emitted a very long ago carries primarily information on the kinematic Doppler effect, and on its way it experiences the parametric Doppler effect as well. Then the sum of the redshifts must be defined by the product of the effects:

$$(z+1) = (z_v+1)(z_a+1) = \sqrt{\frac{1+b_1}{1-b_1}}\,\frac{a(t_o)}{a(t_1)}. \qquad (9)$$

Here (z_v+1) and (z_a+1) are the shifts in the frequency due to the kinematic and parametric Doppler effects, respectively, $b_1 = V(t_1)/C_o$ where $V(t_1) = \dot{a}(t_1)r$ is the relative velocity of the observed galaxy at the instant of emission t_1.

We can calculate the total redshift in the model with plane space ($q_o = \tfrac{1}{2}$, $k = 0$, $p = 0$) for which $a(t) = (t/t_o)^{2/3} a_o$. The parametric Doppler shift according to (5) is equal to $(z_a+1) = (t_1/t_o)^{-2/3}$, and according to (3) we have $(t_1/t_o)^{1/3} = (1 - H_oR/2C)$. With the exception of t_1/t_o we find the known relation $(z_a+1) = (1 - H_oR/2C)^{-2}$. The kinematic Doppler effect can conveniently be represented by the relative velocity $V(t_o)$ at the instant of observation. Evidently, $V(t_1)/V(t_o) = a(t_1)/a(t_o) = (t_1/t_o)^{-1/3}$, where we use the previous calculation $V(t_1)/V(t_o) = (1 - H_oR/2C)^{-1}$; thus $(z_v+1) = (1 + H_oR/2C)^{1/2}(1 - 3H_oR/2C)^{-1/2}$, and according to (9) the general frequency shift will be:

$$(z+1) = (z_v+1)(z_a+1) = \left(\frac{1+H_oR/2c_o}{1-3H_oR/2c_o}\right)^{1/2}\frac{1}{(1-H_oR/2c)^2}. \quad (10)$$

It is not difficult to see that at $H_oR/C << 1$ the shift is $Z = 2H_oR/C$. Therefore, if the shift is defined by two Doppler effects, then the measured value of the Hubble constant is $2H_o$, *i.e.*, in reality $25 \le H_o \le 50$. This leads to an essential difference in the theoretical expressions for the apparent luminosity $m(z)$ and the angular dimensions $q(z)$ of galaxies.

Physical Nature of the Parametric Doppler Effect in the Standard Cosmology

The existence of a factor that varies with time scale in the interval d*s* inevitably leads to an admission that all physical values and some constants containing the length scale and, in particular, the light velocity, must vary. As a result, we find that the redshift (5) relating to space expansion is also defined by the change in light velocity. It also defines the distance between galaxies. In fact, according to (3), at the fixed instant of observation $a(t_o) =$ constant, we obtain the following expression for the distance to galaxies that emit observed light at the instant *t* in the past:

$$R(t) = a(t_o)\int_t \frac{c_o\,\mathrm{d}t}{a(t)} = \int_t \frac{c_o\,\mathrm{d}t}{n(t)} = \int_t c(t)\,\mathrm{d}t. \qquad (11)$$

Here $n(t) = a(t)/a(t_o)$ has the meaning of a dimensionless refraction coefficient of the medium in which waves propagate which defines the variable light velocity $C(t) = C_o/n(t)$, where $C_o = C(t_o)$. At the instant of observation $a(t_o) =$ constant, R is the metric distance constant and the redshift will be:

$$(z+1) = \frac{c(t)}{c(t_o)} = \frac{a(t_o)}{a(t)}. \qquad (12)$$

From this it can be seen that both methods for the description of the redshift, *i.e.*, by space expansion or light velocity variation defined by the scale factor, are completely equivalent. But here the recession of galaxies is absent, *i.e.*, the Universe is stationary. Thus, the standard cosmology is, in reality, based on the introduction of a space where light velocity varies with time due to variation of the length scale; not taking the kinematic Doppler effect into account signifies that the Universe is static. It is interesting to note that in his book the astrophysicist McVittie (1961) pointed out the occurrence of a varying light velocity in the formulae of cosmology.

The existence in nature two kinds of Doppler effects was discovered as early as 1899 by the Russian physicist Mikhelson and published in an article titled "On the problem of the correct application of the Doppler principle" (1899). He started from the formulae for the Doppler effect for $V << C_o$, which in the customary form is given by $(z+1) = 1 + V/C_o$, where $V = \mathrm{d}l/\mathrm{d}t$. He considered the case of matter along the light path with a refraction coefficient n and dimension Δ. Then the equivalent path length of light is $l = l_C + \Delta \cdot (n-1)$, where l_C is the geometrical distance between the radiator and the observer. Here at any instant a frequency shift will be observed:

$$z = \frac{dl_C}{dtC_o} + (n-1)\frac{d\Delta}{dtC_o} + \Delta \cdot \frac{dn}{dtC_o}.$$

If $\Delta =$ constant, $n =$ constant and $V = dl_C/dt \neq 0$, then we have a kinematic Doppler effect due to variation of the geometrical distance. When $l_C =$ constant a frequency shift takes place if Δ or n depend on time, which was confirmed by Perot's tests (Frankfurt & Frenk 1972). At present, this type of frequency shift is called the parametric Doppler effect. It explains the well known fact of stellar colour scintillation near the horizon, where both $d\Delta/dt$ and dn/dt are sufficiently large. Kinematic and parametric Doppler effects occur simultaneously in observations of radio emission from the Earth's satellites as they set or rise on the horizon. Thus, it is not surprising that in observations of the redshift of radiation from galaxies we measure the summed Doppler effect induced by both variation of the geometrical distance (recession of galaxies) and by variation of conditions of the propagation of light due to variation of the length scale. The peculiarity of this process, which has caused such confusion, is the fact that variations of distance and variations of the parameter of the medium are defined by the same function $a(t)$.

Results and Conclusions

We conclude that:

1. The adequate physical interpretation of the mathematical formalism of the standard cosmology is the idea of space expanding by itself, where galaxies, as if attached to it, are receding with the velocity of expansion. Both processes are expressed by the time function $a(t)$, which is a solution of the Einstein gravitation equation, *i.e.* they are directed by gravitation.
2. The redshift in the standard cosmology is formed in two different ways: by the influence of the medium of light propagation, where light velocity decreases with time, as well as by the recession of galaxies. In the first case the parametric Doppler effect occurs; in the second, the kinematic Doppler effect. The observed redshift is defined by the sum of both effects.
3. The standard cosmology corrected for errors of physical interpretation is not completely free from either internal contradictions or confrontation with fundamental physical laws. Contradictions with accepted physical laws arise when length scale evolution is introduced, and hence change in light velocity, which in turn requires an evolution of interaction constants, for example e^2/hc, as well as many other physical values in which the length unit is used. The internal contradictions include the initial statement in the definition of ds^2 for the same passage of time throughout space, which, according to the SRT cannot take place as galaxies recede. The standard model of cosmology is also not correlated with SRT, since it admits the existence of an infinitely large relative velocity of recession for galaxies $dR/dt = \dot{a}(t)r \to \infty$ for $t \to 0$.

How can the relativistic cosmology rid itself of these contradictions with fundamental physics? Evidently, we cannot completely eliminate the serious contradictions demonstrated here without completely renouncing the theory of relativistic cosmology. The most radical way is to give up treating $a(t)$ as space expansion, and thereby exclude the parametric Doppler effect. Then there remains only the recession of galaxies with the Hubble velocity and the kinematic Doppler effect. However, one can easily see that this reduces to a well-developed nonrelativistic Newtonian cosmology. We can evidently reduce the number of contradictions if we stay in the framework of relativistic cosmology. In fact, if we refuse to use the variable length scale by inserting the change in light velocity into the metrics, only one problem remains: that of correlating the changing light velocity with physical laws. A cosmology on this basis will obviously have the metric:

$$ds^2 = C^2(t)dt^2 - a_o^2\left[dr^2 + f^2(r)\left(d\theta^2 + \sin^2\theta d\varphi\right)\right] \quad (11)$$

where the scale parameter $a_o =$ constant. The Universe model that follows from this metric has been investigated in detail (Troitsky 1986, 1987, 1995). The model in question is static, *i.e.* the recession of galaxies is absent, since the distance between them $R = a_o r =$ constant. The motion of light is described at $ds = 0$ by the relation $R = \int_{t_1}^{t_o} c(t)dt$, from which the parametric Doppler effect follows (5). The evolution of the static Universe is defined by the function $C(t)$, which can be found from the Einstein equations.

In the initial state $t = 0$, the light velocity and temperature of matter are infinitely large. To explain the observed redshift, the light velocity must decrease at a rate of near 2cm/s per year. This model preserves the idea of the initial hot state of matter, formation of three-degree relict background of the micro-wave radio emission and estimation of helium abundance. Yet one debatable claim remains in this model, namely, the change of the light velocity, which must lead to an evolution of dimensionless interaction constants, for example, e^2/hc, and others. This difficulty is overcome by assuming variation of a number of constants synchronous with $C(t)$, which preserves all four interaction constants invariable. This ensures observance of the fundamental laws of microphysics including, for example, radiation by atoms and molecules, radioactive decay, *etc*. It is not correlated with a number of conservation laws, though, the same is true for the standard cosmology. However, it is not yet proven that the conservation laws are valid for cosmological scales of time. Actually, the model described here does not solve the problem, and it is necessary to develop a new cosmology which would be free from internal contradictions and be correlated with modern physics. This is all the more imperative given that recent astrophysical tests of the standard cosmology theory do not confirm the hypothesis of recession of galaxies and expansion of universal space (Troitsky 1993).

References

Frankfurt, U.I. and Frenk, A.M., 1972. *Optics of Moving Bodies*, Moscow, Nauka.

Harrison, E., 1993. *Astrophys. Journ.* 403:28.

McVittie, G.K., 1965. *General Relativity and Cosmology*, 2nd ed., Urbana, Univ. of Illinois.

Physical Encyclopaedic Dictionary, 1984, Moscow, Nauka.

Troitsky, V.S., 1986. *DAN SSSR* 290:1.

Troitsky, V.S., 1987. *Astrophysics and Space Science* 139:389.

Troitsky, V.S., 1993. *Astrophysics and Space Science* 201:203.

Troitsky, V.S., 1995. *Astrophysics and Space Science*, in press.