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Slowing time cosmology solving the double redshift paradox

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Abstract

In static space, the redshift of photons from the receding sources is related by the Doppler effect. In the expanding space, the sources in our rest frame emit without the Doppler redshift, but along the path wavelengths of photons will experience a redshift due to stretching. Photons from the comoving the expansion sources are emitted with Doppler redshifts in our rest frame, and along the path they acquire stretching redshift also, and thus their redshift turns out to be doubled. This is clear for nearby sources, where there is both stretching and the Doppler redshifts, and only the quadratic Doppler effect will be added for distant sources. A similar doubling occurred with the deflection angle of the rays w.r.t. the Newtonian one due to the curvature of space. This double redshift paradox in expanding space is unsolvable in Friedmann's models with a constant rate of proper times. It is shown that the models of slowing time cosmology (STC) solve this paradox. The observed redshifts contain the contribution of only one of the two effects, and this indicates the presence of a third effect with a violetshift, which compensates the contribution of one of the redshifts. In STC, proper times rate in the past were faster and photons were emitted with an initial violetshift, compensated along the path by the stretching redshift. The observed redshift is then associated only with the Doppler effect, in addition the visible luminosities become dimmer due to relativistic aberration. Observations already in the linear part of the distance dependence of redshifts reject the models with Friedmann's metric, leading to double redshift, and agree only with the STC. The basic relations of STC are presented, including the "distance modulus-redshift" relation describing observational data without dark energy. A modified picture of evolution in early epochs and the CMB properties are discussed. In particular, in STC the light speed in the past was faster and this solves the cosmological problems of the previous models (homogeneity, horizon, flatness, etc.).

Keywords: cosmological models, expansion of the universe, cosmological redshift, Doppler effect, CMB, dark matter, dark energy

Content

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Introduction

Cosmology studies the structure of space-time and the evolution of matter in the universe as a whole. The last hundred years, the only theory of gravity, the predictions of which were confirmed by experiments, remained general relativity (GR), thus the models of the universe were built on the basis of GR and the cosmological principle with some model approximations.

The simplest of such models, proposed by Einstein [1] in 1917, was the model of a closed static universe as a 3-sphere, where both the radius $a_0 = const.$ and the time rate are constant. But the equations of GR did not have static solutions, and antigravity (cosmological constant λ) was introduced for stabilization. In 1922 A. Friedman [2] found non-static solutions in the comoving coordinates with a variable scale factor and the need for antigravity with λ has disappeared. The line element, also with a constant rate of proper times, has been taken as:

$$ds^2 = c^2 d\tau^2 - a^2(\tau) \cdot (d\chi^2 + S_{k,\chi}^2 d\Omega_{(2)}^2), \quad d\Omega_{(2)}^2 = d\theta^2 + \sin^2\theta\, d\varphi^2, \qquad (1)$$

with $S_{k,\chi} = (\sin\chi, 1, \sinh\chi)$ at $k = (1, 0, -1)$. The solutions allowed both expansion and contraction, but when J. Lemaitre in 1927 [3] and E. Hubble in 1929 [4] found that redshifts increase with distance, it became clear that we deal with the expanding universe.

In static models, receding sources emit photons with Doppler redshift. In expanding space, the same photons, which have an initial Doppler redshift in our rest frame, will arrive at with an additional redshift due to stretching of their wavelength along the path. This is obvious for nearby sources, where there is both the Doppler effect and stretching. Therefore, the photons from the comoving the expansion sources will be with a doubled redshift (for the distant ones, also with the quadratic Doppler effect). Thus, in the expanding space *the double redshift paradox* takes place [5]. A similar doubling was in GR in the deflection angle of the rays with respect to the Newtonian one due to the additional contribution of the curvature of space.

However, in the standard formulation of relativistic cosmology, only one of two effects was indicated as the cause of the redshift. Some authors indicated the Doppler effect as the cause, while others - the stretching of the wavelength during expansion. Such duality in explaining the redshift was a problem, but instead of solving it, a myth was created that these two interpretations are equivalent ways of describing the same physical phenomenon, and on this mythical basis, when one of the effects was taken into account, the other was completely ignored. This was justified by the fact that if both contributions were taken into account, the predictions would double, in contradiction with observations, i.e. in fact, the theory was fitted to observations contrary to its internal logic.

In the previous paper [5], it was shown that agreement between theory and observations is achieved not by ignoring one of the two independent physical phenomena, which is erroneous and, as the result, led the development of theory to a standstill, but by the search for a third mechanism admissible in GR that compensates the contribution of one of the two redshifts. It was shown that in the Friedmann models with metric (1), the double redshift paradox is unsolvable due to the constancy of the proper times rate during expansion, i.e. due to a hypothesis inherited from Einstein's static model.

In [5] a more general model was considered, where not only the spatial components of the metric are variable, but also the temporal component too, which means that the time rate also changes with expansion. It was shown that the double redshift paradox is solved in models of *slowing time cosmology* (STC), where the line element (1) is written in terms of the time of present epoch t [$a = a(t)$, $a_0 = a(t_0)$]:

$$ds^2 = \frac{a_0^2}{a^2} c^2 dt^2 - a^2 \cdot (d\chi^2 + S_k^2(\chi) d\Omega_{(2)}^2). \quad (2)$$

But in [5], the STC was studied as a consequence of the diffusion treatment of gravity. In this paper, however, the STC will be formulated within the framework of GR without reference to a specific physical model of gravity, and the fact of slowing of time rate will be deduced from the observational data. If until now the influence on the cosmological evolution of the change in the spatial component of the metric and the related increase in the distances between objects has been studied, then the STC also studies the influence of the change in the time component of the metric and shows that GR is consistent with observations only at a faster rate of time in the past and its slowdown during expansion.

As the result of this fact, in addition to the two mechanisms of frequency shifting in cosmology, the Doppler effect and stretching, a third mechanism appears - the violetshift of photons emitted in earlier epochs, which is then compensated by the redshift due to the stretching of wavelengths along the path. As a result, the observed shift will be Doppler redshift only. Then, for the visible luminosity, one must also take into account the relativistic aberration.

In the paper the main relations of the STC, including the "distance modulus – redshift" relation, are presented. It is shown that STC is consistent with observations without hypotheses about antigravity (dark energy) and a large fraction of dark matter. In STC there are no cosmological problems of previous models, such as the problems of horizon, homogeneity, flatness and cosmological constant. Problems with horizon and homogeneity are absent since in early epochs the light speed was higher and the radius of the horizon increased faster than at the current speed of light. More details of the STC will be presented in the book [6].]

Some of the elements of the STC have been previously studied by many authors. There have been numerous attempts to explain redshifts only by the Doppler effect [7], but the treatment based on stretching has become standard, from which the well-known Mattig's formula follows [8]. Hypothetical models were widely developed in which redshifts were explained only by a varying speed of light [9]. In contrast to these particular treatments, STC takes into account all these effects simultaneously - in it, the slowing down of the time rate leads to the slowing down and the speed of light, and both the Doppler effect and the stretching contribute to the redshifts, but the latter effect is compensated by the initial violetshift.

In Section 1 three mechanisms of the cosmological frequency shift are discussed and it is shown that one must take into account the aberration in cosmology. In Section 2 the main relations of the STC are presented and its observable consequences, including a description of the redshifts, are considered. In Section 3 the description of the early Universe and the CMB in the STC, as well as the solution of cosmological problems, are discussed.

1. Three mechanisms of the cosmological frequency shift and aberration

1.1. Two redshift mechanisms: Doppler effect and stretching

In static space, objects receding in our rest frame (regardless of the reason of such motion) emit photons with the Doppler redshift, and then these photons arrive at us without changing their wavelength.

In the universe with expanding space, objects recede with speeds increasing with distance. Therefore, in our rest frame, photons from the comoving the expansion sources are also emitted with the Doppler redshift, but then at the propagation acquire an additional redshift due to the stretching of their wavelength during the expansion of space. These are two independent mechanisms of the cosmological redshift - the first effect takes place already at the beginning, and the second arises along the path, and both of these mechanisms contribute to the observed redshift. Therefore, first we will consider them separately, and then together.

In flat static space, photons from a source with the receding velocity $v(r) = H_0 r$, where H_0 is a constant, will arrive at the observer at $r = 0$ with the Doppler redshift z_D. At low velocities the observed wavelength λ_D is related with the initial wavelength λ_0 as:

$$\frac{\lambda_D}{\lambda_0} = 1 + z_D \simeq 1 + \frac{v}{c} \simeq 1 + \frac{H_0 r}{c}, \quad r \simeq \frac{c}{H_0} z_D. \tag{3}$$

In the first approximation, therefore, there is a linear growth of z_D with distance. Here, redshifts are already present *at the beginning*, and then photons propagate with this constant wavelength. For distant sources, when the speeds are not small, the Doppler effect must be taken into account in the relativistic form:

$$\frac{\lambda_D}{\lambda_0} = 1 + z_D = \sqrt{\frac{1 + v/c}{1 - v/c}} = \sqrt{\frac{1 + H_0 r/c}{1 - H_0 r/c}}. \tag{4}$$

The distance up to the source is then expressed in terms of z_D as:

$$r = \frac{c}{H_0} \cdot \frac{z_D + z_D^2/2}{1 + z_D + z_D^2/2}. \tag{5}$$

Let the space is expanding, the distance up to the object is $r = a(t)\chi$ and the source of photons is resting w.r.t. us at $r = const.$, i.e. non-comoving the expansion. Velocity of such static source in our rest frame is equal to zero $\dot{r} = \dot{a}\chi + a\dot{\chi} = 0$, and therefore its peculiar velocity $v_{pec} = a\dot{\chi}$ is equal and opposite to the receding velocity of objects comoving the expansion: $v_{pec} = -v$, where $v = \dot{a}\chi = Hr$, $H = \dot{a}/a$, $\dot{a} = da/dt$. The periods of photons from such source at the beginning (τ), at the end of the path (τ_E) and their ratio, inverse to the ratio of frequencies ω and ω_E, are given by the expressions:

$$c\tau = a \cdot \Delta\chi, \quad c\tau_E = a_0 \cdot \Delta\chi, \quad \frac{\tau_E}{\tau} = \frac{\omega}{\omega_E} = \frac{\lambda_E}{\lambda} = \frac{a_0}{a}. \tag{6}$$

During the propagation of the photon, the initial wavelength $\lambda = c/\tau$ increases with the scale factor a_0/a and becomes equal to $\lambda_E > \lambda$, i.e. the photon will arrive at with stretched redshift z_E due to the expansion of space:

$$\frac{\lambda_E}{\lambda_0} = \frac{a_0}{a} = 1 + z_E. \tag{7}$$

In the first approximation:

$$a \approx a_0 \cdot (1 + H_0 \Delta t) = a_0 \cdot \left(1 + \frac{H_0 r}{c}\right), \quad z_E \simeq \frac{H_0}{c} r \simeq \frac{v}{c}, \tag{8}$$

i.e. the linear growth occurs with a distance of both speed and z_E, which is similar to the linear Doppler effect case considered above.

Thus, the source in our rest frame (with a peculiar velocity $-H_0 r$ w.r.t. the comoving expansion bodies around it) emits photons without Doppler redshift, but during propagation, there appears the stretching redshift.

Above, we considered *two mechanisms* for the appearance of redshift in GR, when each of them revealed in its pure form, and the second was absent:

a. If *space is static* and the *source is receding*, the photons have the Doppler redshift at emission and arrive at with this redshift.
b. If, on the contrary, *space is expand*ing, and the *source is resting* w.r.t. us (with the peculiar velocity $v_{pec} = a\dot{\chi} = -H_0 r$), then photons will not have a Doppler shift, but their wavelengths are stretched during propagation.

At low velocities, in both cases, the redshift is the same $c\, z_E \simeq v \simeq H_0 r$, which was the reason for the confusion in its treatment.

Let us consider the *third case*, which is a combination of the two previous ones, and where, therefore, both redshift mechanisms will be present. This is the case when

c. *space is expanding*, but there is also a *receding source*, *comoving* the expansion, with velocities $v_{pec} = a\dot{\chi} = 0$ and $v = \dot{a}\chi = H_0 r$.

If the comoving source is behind the static source, then, for the observer at the static source, the photons from the comoving source, receding from it with the speed $H_0 r$, will have the Doppler redshift z_D from (4), i.e. with wavelength λ_D. Thus, the Doppler redshift of photons from the comoving source can be registered near the static source, at the beginning of their path.

Further, the photon from the static source with the wavelength λ_0 and the photon from the comoving source with the wavelength λ_D, propagating practically along the same path, will experience the same wavelength extension, proportional a. At arriving to us, the wavelength of the first photon λ_0 will become equal to λ_E from (7), while the second photon with the initial wavelength λ_D in the static frame arrives at with the wavelength λ_{DE}, which also follows from the analog of the formula (7):

$$\frac{\lambda_{DE}}{\lambda_D} = \frac{a}{a_0} = 1 + z_E. \tag{9}$$

Taking into account that, according (4), it was $\lambda_D = \lambda_0(1+z_D)$ at the beginning, we find the observed redshift z as a combined redshift, expressed through z_D and z_E as:

$$\frac{\lambda_{DE}}{\lambda_0} = \frac{\lambda_{DE}}{\lambda_D}\frac{\lambda_D}{\lambda_0} = (1+z_E)(1+z_D) = 1+z. \tag{10}$$

In the first approximation, this gives:

$$z \simeq z_E + z_D \simeq 2r \cdot H_0 / c \simeq 2v / c, \tag{11}$$

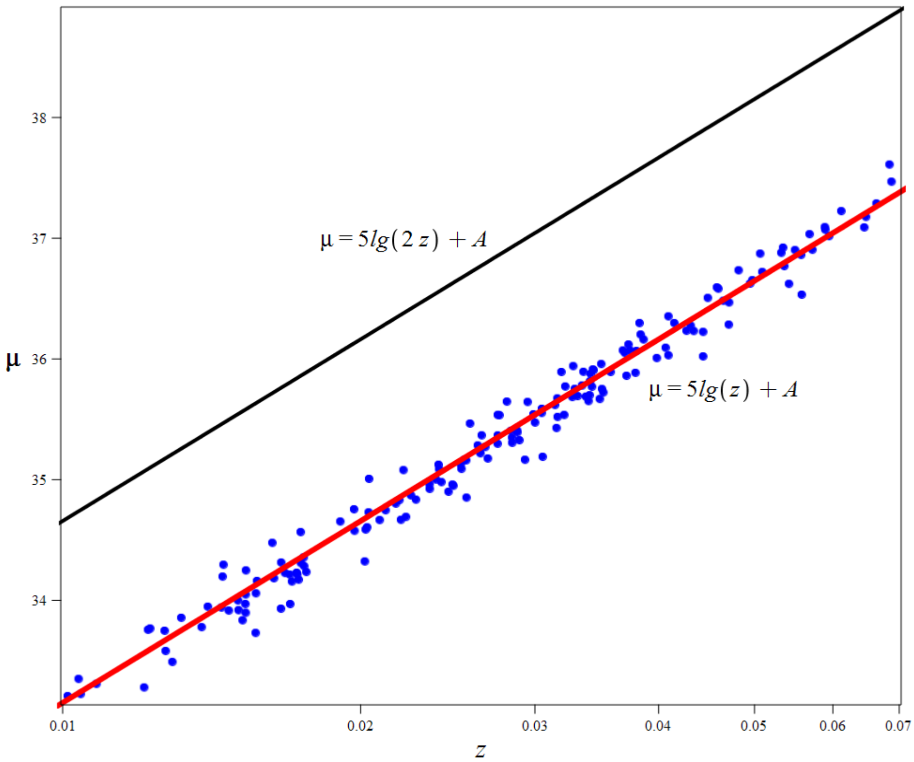


Fig. 1. Graph "distance modulus - redshift" for SN 1a in the linear part (in the logarithmic scale of z), $A = 5\lg(c/H_0) + 25$, $H_0 = 70\, km/\sec\cdot Mpc$, the data from [10a]. Black line – the double redshift with shift $\delta\mu = 5\lg(2) = 1.5$.

i.e. the contributions of the pure Doppler effect $z_D \simeq r \cdot H_0 / c$ and the pure stretching $z_E \simeq r \cdot H_0 / c$ are summed and lead to *a doubled redshift* than with one of the effects.

Fig. 1 shows that, in fact, a single effect is observed with $z \simeq H_0 r / c$ and $H_0 = 70\, km/\sec\cdot Mpc$ (red line). This shows that in the former formulation of relativistic cosmology there was a catastrophic discrepancy between theory and observations (black line). This is *the double redshift paradox*.

1.2. Third mechanism: violetshift at emission and observed Doppler shift

In GR, therefore, two types of cosmological redshift, due to the Doppler effect and due to stretching, had to be taken into account jointly. But when both mechanisms contribute to the total shift, the predicted redshifts for nearby objects become doubled and, since observations show a single shift, the double redshift paradox arises.

It follows from this fact that one of the initial assumptions of the standard formulation of relativistic cosmology is incorrect. As noted in [5], this is the initial choice of the time component of the metric as unchanged during the cosmological expansion. This means the hypothesis about the constancy of the proper time rate during the expansion. For agreement with observations, it turned out to be sufficient to abandon this limitation, natural for the static models only, and return to the general case of a non-static metric for the time component too.

In the general case, during expansion, both the spatial components of the metric and the temporal component can be variable. Moreover, if the latter is chosen such that the rate of proper times in earlier epochs is faster than the current one, then the frequencies of the emitted photons will then be higher than the current ones, i.e. they will be violet-shifted already when emitted. As a result, a third mechanism is added to the two previous ones, the Doppler effect and stretching, - the violetshift at emission in earlier epochs. If it is compensated by the redshift due to stretching along the path, then the observed displacement will appear as a single redshift, which is what the observations show. Thus, we come to the consideration of cosmological frequency shifts in the framework of the STC.

Returning to the above-mentioned hypothesis of the previous standard formulation, we see that it consisted in the fact that when a photon was emitted in early epochs at a large distance, its wavelength was considered *the same as here now*, at the moment of reception, although there is no reason for this and there is nothing has been proven. In reality, however, in GR, together with the cosmological principle, the wavelength of a photon, when it is emitted at an earlier epoch $\tau(\chi)=\tau_1$, should coincide with the wavelength of the same photon at the registration point $\chi_0=0$ only at the same early epoch, i.e. in their proper time $\tau(0)=\tau_1$. For example, the wavelength of a photon emitted far from us in the epoch of 10 billion years after the Big Bang in local time there should coincide with the wavelength of a photon here also in the epoch of 10 billion years after the Big Bang.

After the comparison of the wavelength of the photon at the place of its emission and at the place of observation is carried out correctly, i.e. in terms of the wavelength of the photons near the observer in the same early epoch, another problem arises - how is the wavelength of the photon here in that epoch associated with the wavelength of the same photon in our epoch.

Since the proper times in STC are variable, it is necessary to choose the time of one of the epochs as a standard one and the times of other epochs to express in its terms as a time coordinate. For us, the natural choice is our time, since signals from all previous epochs are compared with signals in our time. Then it is convenient to express the proper times τ in terms of our local proper time t:

$$d\tau^2 = g_{00}[a(t)]dt^2. \tag{12}$$

In GR, there remains arbitrariness in the choice of the metric's time component g_{00}, since it can be either less than unity $g_{00}[a(t)]<1$ or more than it $g_{00}[a(t)]>1$.

For this reason, turning to the observational facts, we see that the double redshift paradox can be solved only if, at the cosmological expansion, the rate of proper time everywhere slows down. The character of this dependence is naturally the same as for energies, i.e. the slowdown is proportional to the scale factor. For the proper times, therefore, we have:

$$d\tau = \frac{a_0}{a}dt. \tag{13}$$

For the metric in (12) this means that $g_{00}(t)=a_0^2/a^2$, i.e. for earlier epochs with $a<a_0$ we have $g_{00}(t)>1$, but for future epochs with $a>a_0$ it will be $g_{00}(t)<1$.

Since in earlier epochs the rate of proper time was faster, then at each point the photon frequencies were larger, and the wavelengths were shorter than those of the same photons now. This leads to a violetshift in earlier epochs by a factor opposite to the stretching factor in (9).

Therefore, if the wavelength of the photon at emission was equal λ_D only when the Doppler effect was taken into account, then in fact the wavelength was shorter due to the initial violetshift. Denoting this wavelength as λ_{CD}, we can find it from the relation:

$$\frac{\lambda_{CD}}{\lambda_D}=\frac{a}{a_0}=\frac{1}{1+z_E}. \tag{14}$$

Then, the initial violetshift due to the going faster of time in (14) and the further redshift due to stretching from (9) should mutually cancel each other and, as a result, the observed redshift should be reduced to the Doppler effect from (4). The observed wavelength λ_{CDE}, including the contribution of these three effects, is then calculated as the result of a chain of relations:

$$1+z=\frac{\lambda_{CDE}}{\lambda_0}=\frac{\lambda_{CDE}}{\lambda_{DE}}\frac{\lambda_{DE}}{\lambda_0}=\frac{\lambda_{CDE}}{\lambda_{DE}}\frac{\lambda_{DE}}{\lambda_D}\frac{\lambda_D}{\lambda_0}=\frac{a}{a_0}\frac{a_0}{a}\frac{\lambda_D}{\lambda_0}=\frac{\lambda_D}{\lambda_0}=1+z_D. \tag{15}$$

Thus, we really get the exact relations:

$$1+z=\frac{\lambda_{CDE}}{\lambda_0}=\frac{\lambda_D}{\lambda_0}=1+z_D,\quad \lambda_{CDE}=\lambda_D,\quad z=z_D. \tag{16}$$

In the first approximation, this gives a linear Doppler effect, which from the very beginning was considered as explanation of the observed linear dependence of z on r and v:

$$z=z_D\simeq r\cdot H_0/c\simeq v/c. \tag{17}$$

So, the paradox of double cosmological redshift, caused by the combined action of the Doppler effect and stretching during expansion, is naturally solved in the STC. Note that the previous formulation contradicted the observations already in the linear section, where the conclusions are model-independent, i.e. do not depend on the curvature of space and only one parameter of the universe H_0 plays a role.

1.3. Relativistic aberration

In relativistic kinematics, the Doppler effect and the aberration are associated with the same factors, and their difference is only that the first effect expresses changes in the frequency and wavelength of the photon, and the second - in the intensity and direction of the photon flux. Therefore, if the Doppler effect takes place in the STC, then there will be the aberration too.

The solid angle element $d\varphi d(\cos\theta')$ in the rest frame of the source differs from the same angle in the rest frame of the observer $d\varphi d(\cos\theta)$ due to the Lorentz transformation for $\cos\theta'$:

$$d(\cos\theta)=\frac{1-v^2}{(1+v\cos\theta')^2}d(\cos\theta'). \tag{18}$$

For the flow from a receding source in the rest frame of the observer, $v\cos\theta'\simeq -v$ and the observed element of the solid angle θ is found from:

$$d(\cos\theta)=\frac{1+v}{1-v}d(\cos\theta')=(1+z_D)^2 d(\cos\theta'), \tag{19}$$

where $(1+z_D)$ is the redshift factor due to the longitudinal Doppler effect.

As we see, the change in the solid angle depends on the same factor $(1+z_D)$, determining the Doppler effect and these two effects will contribute together - the first reduces the frequency of photons, and the second - the number of photons in a given solid angle. With an increase in the solid angle of the cone, the number of photons in the initial cone decreases, which means the dimming of the apparent luminosity. This decrease in the density of the light flux coming from receding objects must necessarily be taken into account in cosmology describing the expanding universe.

The neglect of aberration in the previous models of relativistic cosmology was associated with the above-considered misconception that the cosmological redshift was allegedly caused only by the stretching along the path. In this point of view, the Doppler effect was considered only as a visual analogy to illustrate a purely geometric effect. If there is essentially no Doppler effect, then there should be no aberration either.

This was explained in geometric language by the fact that in the expanding space the solid angles in the light fluxes do not change. However, in our rest frame, the Doppler effect takes place already at the emission of a flux of photons, and therefore in our rest frame there will initially be an aberration, i.e. distortion of the solid angle of the flow. Further, this flow spreads in expanding space without changing the solid angle.

The apparent luminosity is inversely proportional to the solid angle of the initial flow and is defined as $l = L/4\pi d_p^2$, where d_p is the photometric distance, L - the absolute luminosity. Therefore, at taking into account of the aberration, the apparent luminosities of distant objects $\tilde{l}$ will be less than l. This leads to the effective increasing of the photometric distance $\tilde{d}_p$ with respect to d_p in which aberration is not taken into account:

$$\tilde{l} = \frac{l}{(1+z_D)^2} = \frac{L}{4\pi \tilde{d}_p^2}, \qquad \tilde{d}_p = (1+z_D)d_p. \tag{20}$$

After inserting the definition of d_p, we obtain:

$$\tilde{d}_p = (1+z_D)^2 r_{k,\chi}, \tag{21}$$

where $r_{k,\chi}$ is the areal radius of the sphere onto which the radiation spreads.

2. Slowing time cosmology

2.1. Basics of the model

The double redshift paradox, considered above in standard cosmological models, and its solution in STC show that other news in the description of cosmological phenomena can be expected. In [5], the minimum necessary revisions in the models of relativistic cosmology in expanding 3-space were considered, but here this discussion will be continued with the improvement of some of the observational consequences.

In Friedmann's models the line element (1) was written in terms of proper time τ. In STC, this line element in terms of our time t with $d\tau = dt \cdot a_0 / a$ takes the form:

$$ds^2 = \frac{a_0^2}{a^2} c^2 dt^2 - a^2 \cdot (d\chi^2 + S_{k,\chi}^2 \cdot d\Omega_{(2)}^2). \tag{22}$$

The time component of the metric and the determinant are, therefore, equal to

$$g_{00}(t)=\frac{a_0^2}{a^2(t)},\quad \sqrt{-g}=a_0a^2\left|\sin\theta\right|S_{k,\chi}^2. \tag{23}$$

The energy-momentum tensor of homogeneous dust with a local energy density ρ is:

$$T^{ik}=\rho\frac{dx^i}{ds}\frac{dx^k}{ds},\quad T^{00}=\rho\frac{a^2}{a_0^2},\quad T_0^0=T^{00}g_{00}=\rho,\quad T_{00}=\rho g_{00}=\rho\frac{a_0^2}{a^2} \tag{24}$$

The energy-momentum conservation condition gives the relations ($\dot{a}=da/dt$):

$$\frac{1}{\sqrt{-g}}\frac{\partial}{\partial x^k}(T_i^k\sqrt{-g})-\frac{1}{2}\frac{\partial g_{kl}}{\partial x^i}T^{kl}=0,\quad \frac{1}{\sqrt{-g}}\frac{\partial}{\partial t}(T_0^0\sqrt{-g})-\frac{1}{2}\frac{\partial g_{00}}{\partial t}T^{00}=0, \tag{25}$$

$$\frac{1}{a^2}\frac{\partial}{\partial t}(\rho a^2)+\rho\frac{\dot{a}}{a}=0,\quad \frac{\partial}{\partial t}(\rho a^3)=0,\quad \rho a^3=\rho_0a_0^3. \tag{26}$$

The Einstein's equations

$$G_{ik}=\frac{8\pi G}{c^4}T_{ik}, \tag{27}$$

with the Einstein tensor $G_{ik}=R_{ik}-Rg_{ik}/2$, where R_{ik} is the Ricci tensor, $R=g^{ik}R_{ik}$, give:

$$\frac{3}{a^4}\left(a^2\frac{\dot{a}^2}{c^2}+ka_0^2\right)=\frac{8\pi G}{c^4}\rho\frac{a_0^2}{a^2},\quad k=0,\pm1. \tag{28}$$

After simplifying by using (26):

$$\frac{a^2}{a_0^2}\frac{\dot{a}^2}{c^2}+k=\frac{8\pi G\rho a^3}{3c^4}\frac{1}{a}=\frac{a_m}{a},\quad a_m\equiv\frac{8\pi G\rho_0a_0^3}{3c^4}, \tag{29}$$

we get the evolution equation:

$$\dot{a}^2=c^2\frac{a_0^2}{a^2}\left(\frac{a_m}{a}-k\right),\quad \dot{a}=\pm c\frac{a_0}{a}\sqrt{\frac{a_m}{a}-k}. \tag{30}$$

The comparison with the Friedman equation:

$$\left(\frac{da}{d\tau}\right)^2=c^2\left(\frac{a_m}{a}-k\right),\quad \frac{da}{d\tau}=\pm c\sqrt{\frac{a_m}{a}-k}, \tag{31}$$

shows that the expansion speed in (30) contains an additional factor a_0/a which means a faster expansion speed in earlier epochs in terms t. The light speed $\tilde{c}$ was also faster:

$$\tilde{c}^2dt^2-a^2d\chi^2=0,\quad \tilde{c}=\frac{a_0}{a}c. \tag{32}$$

For our epoch with a_0 and the constant H_0 the Eq. (30) gives the usual expressions:

$$\dot{a}_0=\pm c\frac{\sqrt{1-ka_0/a_m}}{\sqrt{a_0/a_m}}=\pm c\frac{\sqrt{1-kb}}{\sqrt{b}},\quad H_0=\frac{\dot{a}_0}{a_0}=\pm\frac{c}{a_0}\frac{\sqrt{1-kb}}{\sqrt{b}},\quad b\equiv\frac{a_0}{a_m}. \tag{33}$$

For proper time τ, we obtain from (31):

$$c\tau = \int_0^{a(t)} \frac{a^{1/2} da}{\sqrt{a_m - ka}} \tag{34}$$

with solutions:

$$c\tau = \begin{cases} \sqrt{a(a_m - a)} + a_m \arcsin\sqrt{\dfrac{a}{a_m}}, & k = 1 \\ \dfrac{2a^{3/2}}{3a_m^{1/2}}, & k = 0 \; . \\ \sqrt{a(a_m + a)} - a_m \operatorname{arcsh}\sqrt{\dfrac{a}{a_m}}, & k = -1 \end{cases} \tag{35}$$

For the time t corresponding $a(t)$, the evolution equation (30) gives:

$$ct = \frac{1}{a_0} \int_0^{a(t)} \frac{a^{3/2} da}{\sqrt{a_m - ka}} \tag{36}$$

with solutions:

$$ct = \begin{cases} \dfrac{3a_m}{4a_0}\left[a_m \arcsin\sqrt{\dfrac{a}{a_m}} - \left(1 + \dfrac{2a}{3a_m}\right)\sqrt{a(a_m - a)} \right], & k = 1 \\ \dfrac{2}{3}\dfrac{a^{3/2}}{a_m^{1/2}}\dfrac{3a}{5a_0} = \dfrac{3a}{5a_0}\tau, & k = 0 \\ \dfrac{3a_m}{4a_0}\left[a_m \operatorname{arcsh}\sqrt{\dfrac{a}{a_m}} - \left(1 - \dfrac{2a}{3a_m}\right)\sqrt{a(a_m + a)} \right], & k = -1 \end{cases} \tag{37}$$

2.2. The “distance modulus - redshift” relation

The world line of photons from distant sources is described by the relations:

$$\frac{a_0^2}{a^2} c^2 dt^2 - a^2 d\chi^2 = 0, \quad cdt = \pm \frac{a^2}{a_0} d\chi. \tag{38}$$

Together with (30), this allows one to find the magnitude of the angle χ passed by the photon:

$$\chi = \pm c \int_t^{t_0} \frac{a_0}{a^2} dt = \int_a^{a_0} \frac{da}{\sqrt{a(a_m - ka)}}. \tag{39}$$

Integration gives:

$$a_0 S_{k,\chi} = \frac{c}{H_0} \frac{a}{a_0} \cdot 2(1 - kb) \left[\frac{a_0}{a} - 1 + (2kb - 1)\left(\sqrt{1 + \frac{a_0 / a - 1}{1 - kb}} - 1 \right) \right]. \tag{40}$$

The ratio a_0 / a gives the magnitude of the stretching of the wavelengths:

$$\frac{a_0}{a} = 1 + z_E \tag{41}$$

and in the previous treatments explaining the cosmological redshift z by extension $z \to z_E$, it follows from (40)

$$a_0 \sin\chi = \frac{c}{H_0(1+z_E)}\frac{1}{q_0}\left[z_E + (q_0^{-1}-1)\left(\sqrt{1+2q_0 z_E}-1\right)\right]. \tag{42}$$

where $2q_0 = 1/(1-kb)$. This was the basis for Mattig's formula [8], which was obtained taking into account only stretching and therefore did not take into account both the Doppler effect and the aberration.

But in STC the observed redshift z is caused by the Doppler effect as in (4) $z = z_D$, and below we calculate its contribution. At first, consider the relativistic effects in static space, when a set of sources recede by speeds proportional to the distance $v = H_0 r$. It is necessary to clarify which of the definitions of the distance is used here.

The fact is that even in this simple case, there are different types of distances, each of which has its own specific physical meaning. The first of them is the curvature radius r of the sphere onto which the radiation of the source spreads. The second is the physical distance r, a number of standard scales on the hypersurface of simultaneity $t = const.$ from the observer up to the source:

$$\mathrm{r} = \int_0^r \frac{dr}{\sqrt{1-H_0^2 r^2/c^2}} = \frac{c}{H_0}\arcsin\left(\frac{H_0 r}{c}\right), \qquad H_0 r = c\sin\left(\frac{H_0 \mathrm{r}}{c}\right). \tag{43}$$

In the expanding space, where the physical distance is equal to $\mathrm{r}(t,\chi) = a(t)\chi$, the situation is more complicated. The local recession speed $\mathrm{v}(t,\chi)$ of objects depends on both distance and time and, instead of H_0, there appears $\mathrm{H}(\tau) = a^{-1}da/d\tau$. There is only a local law for the difference of speeds $\delta\mathrm{v}$ of nearby objects, the physical distance between which at the moment t is equal to $\delta\mathrm{r}$. From the definition of this distance

$$\delta\mathrm{r}(t,\chi) = \mathrm{r}(t,\chi+\delta\chi) - \mathrm{r}(t,\chi) = a(t)\delta\chi \tag{44}$$

we find the expansion speed of this spatial section in the form:

$$\delta\mathrm{v}(t,\chi) = \frac{\partial}{\partial\tau}\delta\mathrm{r}(t,\chi) = \mathrm{H}\cdot a\,\delta\chi, \tag{45}$$

which gives the desired local recession law:

$$\delta\mathrm{v}(t,\chi) = \mathrm{H}\cdot\delta\mathrm{r}(t,\chi). \tag{46}$$

In relativistic cosmology, the receding speeds of nearby objects on the hypersurface $t = const.$ are related by the relativistic relation:

$$\mathrm{v}(\chi+\delta\chi) = \frac{\mathrm{v}(\chi) + \mathrm{H}\,\delta\mathrm{r}}{1+\mathrm{v}(\chi)\cdot\mathrm{H}\,\delta\mathrm{r}/c^2}, \tag{47}$$

which, due to smallness of $\delta\mathrm{v}/c$, can be written as

$$\mathrm{v}(\chi+\delta\chi) - \mathrm{v}(\chi) \simeq [1-\mathrm{v}^2(\chi)/c^2]\mathrm{H}a\cdot\delta\chi. \tag{48}$$

From this we obtain the equation for determining the velocities:

$$\frac{d\mathrm{v}}{1-\mathrm{v}^2/c^2}=\mathrm{H}d\mathrm{r}=\mathrm{H}\frac{dr}{\sqrt{1-\mathrm{v}^2/c^2}},\tag{49}$$

which gives the dependence of the local velocities on the physical distance:

$$r(t)\simeq\frac{c}{\mathrm{H}}\int_0^{\mathrm{v}(t,\chi)}\frac{d(\mathrm{v}/c)}{\sqrt{1-\mathrm{v}^2/c^2}}=\frac{c}{\mathrm{H}}\arcsin\left(\frac{\mathrm{v}}{c}\right),\quad \mathrm{v}=c\sin\left(\frac{\mathrm{H}r}{c}\right).\tag{50}$$

The photons from the comoving the expansion sources arrive at us with the same Doppler redshift $(1+z_D)$ that was already at the beginning of their path. Therefore, the Eq. (4) contains v, what allows us to find the dependence of r from z_D:

$$r=\frac{c}{H_0}\frac{H_0}{\mathrm{H}}\arcsin\left(\frac{z_D+z_D^2/2}{1+z_D+z_D^2/2}\right).\tag{51}$$

Since H is proportional to H_0 and depends on the factor $a_0/a=(1+z_E)$, then:

$$\frac{H_0}{\mathrm{H}}=\frac{\dot{a}_0}{\dot{a}}\frac{a}{a_0}=\cdot\frac{f}{(1+z_E)}=\frac{1}{(1+z_E)\sqrt{1+2q_0z_E}},\tag{52}$$

where

$$f(z_E,b)=\sqrt{\frac{a_0/a-b}{1-b}}=\sqrt{1+\frac{z_E}{1-b}}.\tag{53}$$

At small distances $z_D,z_E\ll 1$, and the formula (50) passes into the linear law:

$$\mathrm{v}\simeq H_0r\simeq cz_D.\tag{54}$$

The apparent and absolute luminosities of sources l,L are related to the photometric distance d_p as $l=L/4\pi d_p^2$. They are expressed through apparent and absolute magnitudes, m, M, as $l=10^{-m/2.5}\cdot 2.52\cdot 10^{-5}erg/cm^2sec$, $L=10^{-M/2.5}\cdot 3.02\cdot 10^{35}erg/cm^2sec$. Expansion leads to a decrease in the energy and frequency of arrival of photons by a total value $(1+z_D)^2$, and relativistic aberration reduces the apparent luminosity by the same factor $(1+z_D)^2$. As a result, for apparent luminosity we obtain the expression:

$$l_F=\frac{L}{4\pi d_p^2}=\frac{L}{4\pi r^2}\cdot\frac{1}{(1+z_D)^4}.\tag{55}$$

The photometric distance d_p is thus equal to:

$$d_{p,0}=(1+z_D)^2r=10^{-5+(m-M)/5}Mpc,\tag{56}$$

from which for the distance modulus $\mu\equiv m-M=5\lg(d_p)+25$, using (51), follows the «distance modulus - redshift” relation ($A\equiv 5\cdot\lg(c/H_0)+25$):

$$\mu=5\lg\left(\frac{(1+z_D)^2}{(1+z_E)\sqrt{1+2q_0z_E}}\arcsin\left(\frac{z_D+z_D^2/2}{1+z_D+z_D^2/2}\right)\right)+A.\tag{57}$$

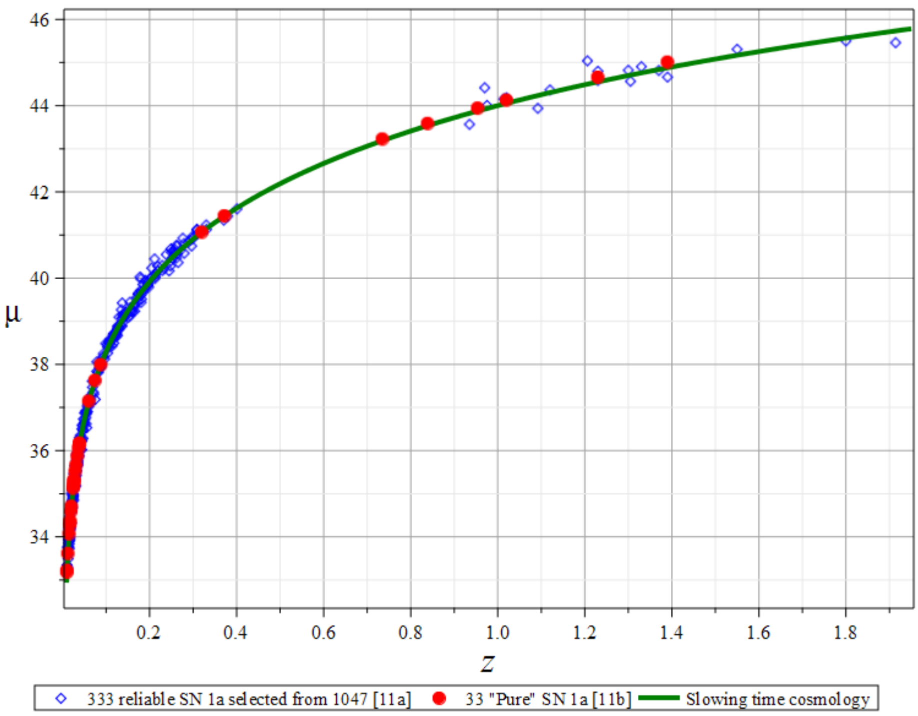
The value of $1+z_E$ is proportional to the distance, and hence the recession speed of the object, while $1+z_D$ at large distances contains a quadratic dependence on speed also and therefore $z_D > z_E$. Expression of z_E through z_D will sufficiently complicate the form of Eq. (57), while in order to estimate how STC can be in agreement with the observational data, we need to simplify this formula as much as possible. For this, the multiplier in front of arcsin we approximate by means of a small parameter α :

$$\frac{(1+z_D)^2}{(1+z_E)\sqrt{1+2q_0z_E}} \simeq (1+z_D)^{1+\alpha}. \tag{58}$$

Substituting this into (57), we obtain a simplified version of the relation "distance modulus - redshift" in STC:

$$\mu = 5\lg\left((1+z_D)^{1+\alpha}\arcsin\left(\frac{z_D + z_D^2/2}{1+z_D+z_D^2/2}\right)\right) + A \tag{59}$$

In Fig. 1 a comparison of (59) with the observational data on Type Ia supernovae (in the ordinary and logarithmic scales along z axis) is presented, where $H_0 = 0.70h$ is taken from the linear part and $\alpha = 0.2$. This value of α means $(1+z_E)\sqrt{1+2q_0z_E} \approx (1+z_D)^{0.8}$, which is quite realistic. At small distances, this means $z_E \approx z_D \cdot 0.8/(1+q_0)$. As we see, the STC relation (59), where there is only one free parameter α, is in good agreement with the observational data.



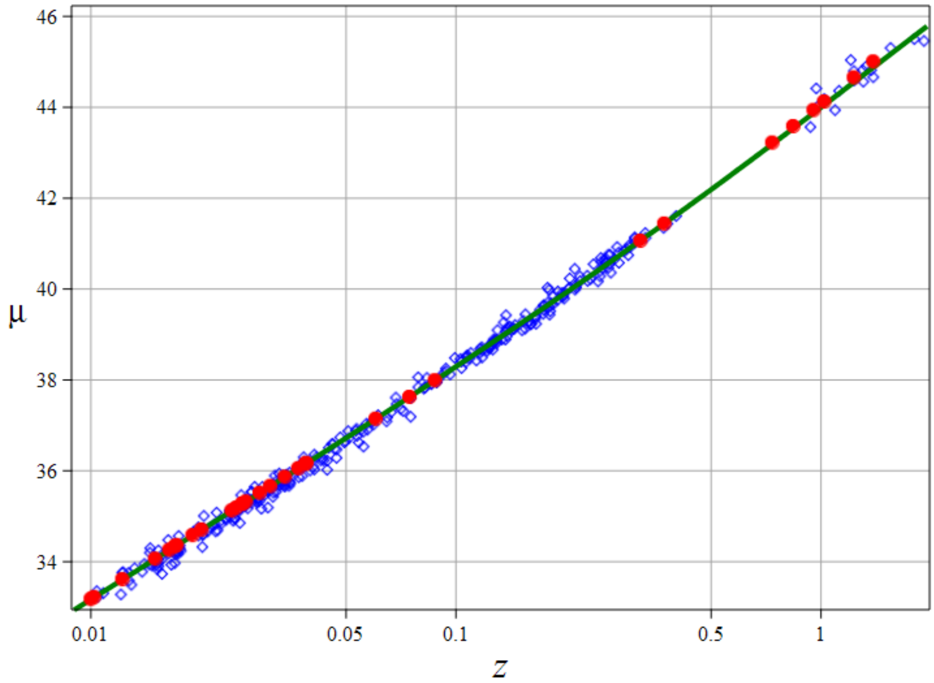


Fig. 1. The relation "distance modulus - redshift" for Type Ia supernovae in the usual (top graph) and logarithmic scales (bottom graph). Blue dots are 333 selected (with low distortion) data from a number of compilations [10a], and red dots are 33 "pure" supernovae outside or on the edge of galaxies [10b]. Green line - theoretical curve $\mu - z$ in STC according to (59) with $\alpha = 0.2$.

3. The early universe and cosmological problems

3.1. The early universe

Let's consider shortly the modifications in the cosmology of early epochs. The energy-momentum tensor of ultrarelativistic matter and radiation with the local energy density ρ and pressure $p = \rho / 3$, having the form:

$$T^{ik} = \frac{dx^i}{ds}\frac{dx^k}{ds}(\rho + p) - pg^{ik} = \frac{4}{3}\rho\frac{dx^i}{ds}\frac{dx^k}{ds} - \frac{1}{3}\rho g^{ik},$$
$$T^{00} = \rho\frac{a^2}{a_0^2}, \quad T_0^0 = T^{00}g_{00} = \rho, \quad T_{00} = \rho g_{00} = \rho\frac{a_0^2}{a^2} \tag{60}$$

we insert into the energy-momentum conservation condition:

$$\frac{1}{\sqrt{-g}}\frac{\partial}{\partial x^0}(T_0^0\sqrt{-g}) - \frac{1}{2}\frac{\partial g_{kl}}{\partial x^0}T^{kl} = 0, \tag{61}$$

and obtain the relations ($\dot{a} = da / dt$):

$$\frac{1}{a^2}\frac{\partial}{\partial t}(\rho a^2) + 2\rho\frac{\dot{a}}{a} = 0, \quad \frac{\partial}{\partial t}(\rho a^4) = 0, \quad \rho a^4 = \rho_0 a_0^4. \tag{62}$$

The evolution equation (28) then transforms into:

$$\frac{a^2}{a_0^2}\frac{\dot{a}^2}{c^2}+k=\frac{8\pi G\rho a^4}{3c^4}\frac{1}{a^2}=\frac{a_m a_0}{a^2}, \tag{63}$$

and:

$$\dot{a}^2=c^2\frac{a_0^2}{a^2}\left(\frac{a_m a_0}{a^2}-k\right),\quad \dot{a}=\pm c\frac{a_0}{a}\sqrt{\frac{a_m a_0}{a^2}-k}. \tag{64}$$

From a comparison with the Friedman equation:

$$\left(\frac{da}{d\tau}\right)^2=c^2\left(\frac{a_m a_0}{a^2}-k\right),\quad \frac{da}{d\tau}=\pm c\sqrt{\frac{a_m a_0}{a^2}-k}, \tag{65}$$

we see that the expansion speed contains an additional factor a_0/a again, which leads to a faster expansion speed in the early epochs in terms of the time of our epoch.

For proper time τ we get:

$$c\tau=\int_0^{a(\tau)}\frac{ada}{\sqrt{a_m a_0-ka^2}}=\begin{cases}\sqrt{a_m a_0}\left(1-\sqrt{1-a^2/a_m a_0}\right), & k=1\\ \dfrac{a^2}{2\sqrt{a_m a_0}}, & k=0\\ \sqrt{a_m a_0}\left(\sqrt{1+a^2/a_m a_0}-1\right), & k=-1\end{cases} \tag{66}$$

For the time t corresponding $a(t)$, the evolution equation (64) gives:

$$ct=\frac{1}{a_0}\int_0^{a(t)}\frac{a^2da}{\sqrt{a_m a_0-ka^2}}=\begin{cases}\dfrac{a_m}{2}\arcsin\left(\dfrac{a}{\sqrt{a_m a_0}}\right)-\dfrac{a}{2a_0}\sqrt{a_m a_0-a^2}, & k=1,\\ \dfrac{a^3}{3\sqrt{a_0^3 a_m}}, & k=0,\\ \dfrac{a}{2a_0}\sqrt{a_m a_0+a^2}-\dfrac{a_m}{2}\operatorname{arcsh}\left(\dfrac{a}{\sqrt{a_m a_0}}\right), & k=-1\end{cases} \tag{67}$$

3.2. Modifications in the properties of CMB

The observed CMB, emitted in a very early universe, allows one to study closer epochs, in particular, the recombination epoch, when the radiation disconnected from matter. Notice some revisions in the description of the CMB, which follow from the main distinctions of the STC from the former treatments.

The faster rate of proper times in early universe explains a number of facts for which radical hypotheses had to be advanced earlier. In particular, if the scale factor was 10^3 times smaller, then the speed of light was just as faster in terms of our time $\tilde{c}\sim 10^3 c$, which explains the homogeneity and isotropy of CMB by the much faster mixing of the photon flux, which practically removes the horizon problem.

Moreover, since in the very early universe the particles of matter were ultrarelativistic, then they then moved several orders of magnitude faster than photons in our era, which also explains the large-scale homogeneity and isotropy of all matter.

The ratio of the temperature of the CMB in an earlier epoch T_e to its observed temperature T_r is determined by the ratio of the observed wavelength λ_r to the wavelength in that epoch λ_e. In the Friedmann model, the redshift was attributed to stretching and therefore the ratio of wavelengths was given by the ratio of scale factors a_0 / a, and therefore depended on z_E, and also provided an equation for $T(a)$:

$$\frac{T_e}{T_r} = \frac{\lambda_r}{\lambda_e} = \frac{a_0}{a} = 1 + z_E, \quad \frac{dT}{T} = -\frac{da}{a}. \tag{68}$$

In STC all the redshifts of the radiation are determined by the Doppler effect and therefore the temperature ratio now depends on $v(a)$ and z_D:

$$\frac{T_e}{T_r} = \frac{\lambda_r}{\lambda_e} = \sqrt{\frac{1 + v/c}{1 - v/c}} = 1 + z_D. \tag{69}$$

As a result, the relation between redshifts z_D and a now turns out to be more complicated, since we must specified the dependence $v(a)$.

But the fact that there appears z_D instead of z_E already reveals some of the differences. Unlike linear stretching of wavelengths, the relativistic Doppler effect has a quadratic part (see (5)), dominating at large z_D, which means that the CMB is almost completely described by this part of the effect. At the same a, we have $z_D > z_E$, and therefore, re-treatment of the measured redshift as a Doppler shift $z_E \to z_D$ without changing its value means that it now refers to larger a than previously thought, i.e. to a later time t.

Larger values of a and later times t mean significantly lower densities of matter and radiation in that epoch when the CMB detached from matter. At $z_D \sim 1500$ and $v \simeq c - \delta v$, $\delta v \ll c$, the Eq. (69) takes the form:

$$\frac{T_e}{T_r} = \frac{\lambda_r}{\lambda_e} \simeq \sqrt{\frac{2c}{\delta v}} \simeq z_D, \quad \frac{\delta v}{c} \simeq \frac{2}{z_D^2} \simeq 9 \cdot 10^{-7} \tag{70}$$

and heterogeneities in the recombination epoch, through which the relict stream passed, would look flattened for us due to relativistic contraction.

Despite a later time and a larger scale factor than in the former models, processes in the recombination epoch went faster, and temperatures were higher by a factor $a_0 / a = 1 + z_E$.

And, finally, another important revision concerns measurements of the characteristics of the CMB in our epoch, from which the value of

$$\Omega_m h_0^3 \simeq 0.096 \tag{71}$$

is determined [11]. From this value, assuming $\Omega_m \simeq 0.315$, then a value $h \simeq 0.67$ was fixed, which was significantly different from $h \simeq 0.73$ determined from redshifts and apparent luminosities of Type 1a supernovae. In STC, on the contrary, the supernova redshifts fix the value $h \simeq 0.70$ (or $h \simeq 0.73$), and then Ω_m can be determined from the CMB data by using the empirical relation (71), which gives $\Omega_m \simeq 0.28$ (or $\Omega_m \simeq 0.25$). These lower values of Ω_m are confirmed by other independent observations of the distribution of galaxies giving $\Omega_m \simeq 0.26$. Thus, in STC there is no contradiction between the supernova data and the CMB observations, on the contrary, they only complement each other.

3.3. The lack of the former cosmological problems in the model

a. The lack of flatness problem

In the Friedmann model, in early epochs, space becomes flat with high accuracy. Indeed, the evolution equation (65) can be rewritten as:

$$\rho_c \frac{a^2}{a_0^2} = \rho - k\frac{A}{a^2}, \quad \rho_c = \frac{3c^2H^2}{8\pi G}, \quad A = \frac{3c^4}{8\pi G} \tag{72}$$

which through the curvature parameter $\Omega = \rho / \rho_c$ takes the form:

$$\Omega^{-1} - 1 = -\frac{kA}{\rho a^2}. \tag{73}$$

Then, at the dominance of matter or radiation, we have:

$$\frac{\Omega_0^{-1} - 1}{\Omega^{-1} - 1} = \frac{\rho a^3}{\rho_0 a_0^3}\frac{a_0}{a} = \frac{a_0}{a}, \quad \rho a^3 = const. \tag{74}$$

$$\frac{\Omega_0^{-1} - 1}{\Omega^{-1} - 1} = \frac{\rho a^4}{\rho_0 a_0^4}\frac{a_0^2}{a^2} = \frac{a_0^2}{a^2}, \quad \rho a^4 = const. \tag{75}$$

and in both cases Ω at $a \to 0$ tends to a flat value $\Omega \to 1$, i.e. to $k = 0$.

In STC, there is no flatness problem, since the curvature parameter Ω decreases in early epochs. The evolution equation (64), rewritten in the form:

$$\rho_c \frac{a^2}{a_0^2} = \rho - k\frac{A}{a^2}, \tag{76}$$

can be represented in the form similar to (73):

$$\frac{a^2}{\Omega a_0^2} - 1 = -\frac{kA}{\rho a^2}. \tag{77}$$

Then we obtain:

$$\frac{\Omega_0^{-1} - 1}{a^2/(\Omega a_0^2) - 1} = \frac{a_0}{a}\frac{\rho a^3}{\rho a_0^3} = \frac{a_0}{a}, \tag{78}$$

$$\frac{\Omega_0^{-1} - 1}{a^2/(\Omega a_0^2) - 1} = \frac{a_0^2}{a^2}\frac{\rho a^4}{\rho a_0^4} = \frac{a_0^2}{a^2}. \tag{79}$$

This shows that in both cases at $a \to 0$ the parameter Ω tends to zero as a^2:

$$\Omega = \frac{a^2}{a_0^2} \cdot \frac{1}{1 + (\Omega_0^{-1} - 1)a / a_0} \to \frac{a^2}{a_0^2}. \tag{80}$$

Thus, in terms of the time of our epoch, there is no flatness problem and there is no need for fine tuning.

b. Homogeneity and isotropy as a result of faster evolution

The large-scale homogeneity and isotropy of the distribution of matter in the model are consequences of a causal relationship between different regions under conditions of faster light speed and faster evolution.

During the radiation-dominated and recombination epochs, particles of matter diffuse as a small admixture in a high-temperature gas of photons, and such diffusion with large values of the light speed in those epochs smooth out any significant inhomogeneity in the distribution of matter and radiation in causally connected regions.

c. The lack of horizon problem

The horizon problem of the Friedmann model was that, on the one hand, at the expansion the size of a causally related region (horizon) grows as $r_{hor} \approx t$, while the scale factor grows more slowly – as $a \approx t^{1/2}$ in early epochs and as $a \approx t^{2/3}$ later. On the other hand, it was believed that the CMB flux ceased to interact with matter after the recombination epoch and the radiation density in causally unrelated regions could not be aligned in any way, but in fact, on average isotropic and homogeneous fluxes come to us from them.

In STC, the curvature radius of the universe and the size of the causally connected regions grew much faster in early epochs than was assumed in the Friedmann model, the light speed was also faster in terms of our time. Thus, in the STC there is no horizon problem.

d. The lack of a cosmological constant problem

The former standard cosmological paradigm was mainly based on the cosmological constant Λ or the dark energy. However, its value turned out to be so small that it could not be explained not only by the Standard Model of particle physics, but also by its hypothetical generalizations. This is the cosmological constant problem, which turned out to be practically insolvable in the former standard paradigms in both cosmology and particle physics.

In reality, particle physics provides neither theoretical nor observational grounds for introducing a zero-point vacuum energy [12]. This means that cosmology can be in agreement with particle physics only in the absence of the cosmological constant $\Lambda = 0$.

In STC the cosmological constant is absent, and Einstein's equations with matter energy-momentum density are sufficient to describe the observations. This means reaching agreement between cosmology and particle physics in the problem of vacuum energy.

e. The lack of the cosmological dark matter problem

Cosmological models set limits on the density of non-baryonic dark matter. In the STC there is no such need, although in principle a slight admixture of such matter is not excluded.

In any case, both the practical absence and the presence of some small admixture of dark matter is not a problem, and therefore there is no problem of dark matter in STC.

Conclusion

The standard model of relativistic cosmology, even with the inclusion of hypothetical dark matter and dark energy, leads to a doubling of redshifts due to the need to take into account in GR both the Doppler effect (due to the motion of the source in the observer's rest frame) and the stretching of the photon wavelengths during propagation (due to the expansion of space). Since only a single redshift is observed, the double redshift paradox takes place. This paradox means a catastrophic discrepancy between theory and observations and the failure of the previous models of relativistic cosmology.

The fact is that in models with the Friedmann metric, to which the standard model of cosmology belongs, the hypothesis of the static model about the constant rate of proper times during the expansion of space has been preserved. However, in relativistic theories, the geometry of space-time is variable and usually the variability of the geometry of space also leads to variability of the time rate, while the constancy of the time component of the metric is admissible only in short times.

The STC formulated in [5] with slowing down local proper times naturally solves the double redshift paradox. In STC in earlier epochs, photons were emitted with a violetshift, which was compensated by the redshift due to stretching during their propagation. As a result, the wavelengths at registration contain only the contribution of the relativistic Doppler effect

But if there is the Doppler effect, there is an aberration also, which leads to additional dimming of sources due to decreasing in the number of photons per unit solid angle. Therefore, STC differs from the Friedmann model also by taking into account the aberration.

The new "distance modulus – redshift" relation, following from STC, is consistent with the data on type 1a supernovae. The STC leads to a number of non-trivial consequences for the early universe and allows in a natural way to solve the cosmological problems of the previous models. The more complex dependence of the redshifts on the velocity and scale factor makes it possible to match the value of H_0 from the data on CMB and supernova.

A more details of STC and its consequences will be presented in the book [6].

References

1. Einstein A. (1917) *Sitz. Preuss. Akad. Wiss*., 142.
2. Friedmann A. (1922). *Z. Phys.*, **10**, 377.
3. Lemaître G. (1927) *Ann. Soc. Sci. Bruxel*., **A47**, 49.
4. Hubble E. (1929) *Proc. Nat. Acad. Sci*., **15**, 168.
5. Zakir, Z. (2020) *Quant. and Grav. Phys.* **1**:005-7130.
6. Zakir, Z. (2020) *Diffusion Quant. Mech. and Diffusion Gravity*. CTPA, T.
7. Milne E.A. (1934) *Q. J. Math. Oxf.* **5**, 64; Farley F.J.M. (2010) *P. R. Soc*. A., **466**:3089.
8. Mattig W. (1957) *Astron. Nachr*., **284**, 109.
9. Wold P.I. (1935) *Phys. Rev*., **47**, 217; Troitskii V.S. (1987) *Ap. & Sp. Sci*. **139**, 389.
10. Pruzhinskaya M.V. *et al*. (2020) arXiv:2006.09433 astro-ph; (2011) *Astron. Lett*., **37**, 663.
11. Planck 2018 results. VI. *Cosmological parameters*. arXiv:1807.06209.
12. Zakir, Z. (2020) *Quant. and Grav. Phys.* **1**:001-7128; **1**:002-7128.