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МАССИВНОЕ ГРАВИТАЦИОННОЕ ПОЛЕ В ПЛОСКОМ ПРОСТРАНСТВЕ-ВРЕМЕНИ. IV. ВЕКОВОЙ ДРЕЙФ АТОМНЫХ СПЕКТРОВ И ОПТИКА СВЕРХНОВЫХ ТИПА Ia

М.А. Сердюкова, А.Н. Сердюков

Гомельский государственный университет имени Франциска Скорины

A MASSIVE GRAVITATIONAL FIELD IN FLAT SPACETIME. IV. THE SECULAR DRIFT OF ATOMIC SPECTRA AND OPTICS OF TYPE Ia SUPERNOVAE

M.A. Serdyukova, A.N. Serdyukov

Francisk Skorina Gomel State University

Космологическое приложение предложенной ранее в рамках СТО калибровочно-инвариантной теории массивного гравитационного поля предсказывает существование во Вселенной динамически однородного фонового гравитационного поля с единственной ненулевой временной компонентой, которое доминирует во Вселенной, управляя ее циклической эволюцией посредством сбалансированного обмена энергией с гравитирующей материей. Предшествующее и продолжающееся увеличение энергии покоя атомов прекрасно объясняет космологическое красное смещение их спектров без гипотетического разбегания далеких галактик. Превосходное численное согласие теории с наблюдательными оптическими данными от сверхновых типа Ia достигнуто в результате фитирования только двух параметров: возраста текущего цикла (24 млрд лет) и текущего значения скалярной фоновой напряженности, выраженную через постоянную Хаббла (68 км/с/Мпс). Предсказанное космологическое ускорение распада нестабильных ядер и частиц подтверждается растяжением кривых блеска сверхновых Ia с коэффициентом $(1+z)$, наблюдаемое послесвечение которых происходит за счет высокоэнергетических фотонов гамма-излучения, испускаемых в цепочке бета-распадов $^{56}\mathrm{Ni} \to {}^{56}\mathrm{Co} \to {}^{56}\mathrm{Fe}$.

***Ключевые слова**: фоновое гравитационное поле, вековой дрейф атомных спектров, космологическое красное смещение, оптическое излучение сверхновых типа* Ia.

The cosmological application of the proposed early special-relativistic gauge-invariant theory of a massive gravitational field predicts the existence in the universe of a dynamical spatially uniform background gravitational field with a single non-zero time component, which dominates in Universe controlling its cyclic evolution through the balanced exchange of energy with gravitating matter. The previous and continuing increase in the rest energy of matter perfectly explains the cosmological redshift of atomic spectra without the hypothesis of a general recession of distant galaxies. The excellent numerical agreement of theory with the data from SNe Ia is achieved by fitting only two parameters: the age of the current cycle (24 Gyr) and the current value of the background scalar strength expressed through the Hubble constant (68 kms^{-1} Mpc^{-1}). The predicted cosmological acceleration of the decay of unstable nuclei and particles is confirmed by $(1+z)$-stretching of the light curves of SNe Ia, the observed afterglow of which occurs owing to the high-energy gamma-ray photons released in the chain of beta decays $^{56}\mathrm{Ni} \to {}^{56}\mathrm{Co} \to {}^{56}\mathrm{Fe}$.

Keywords: *background gravitational field*, *secular drift of atomic spectra*, *cosmological redshift*, *optical radiation of type* Ia *supernovae*.

Introduction

The cosmological redshift of the atomic spectra is one of the main directly observed global phenomena in the universe. Due to the finiteness and constancy of the speed of light, this phenomenon is a reliable source of unique information about the cosmological evolution of matter and the evolutionary history of the universe as a whole. Two circumstances allow us to look into the history of the evolution of matter itself, rejecting the hypothesis of an expanding universe: the obvious connection between the "age" of the observed cosmic event and the distance from it and the Hubble law – the redshift of the observed objects increases with their distance from the observer. In short, the greater the redshift of the galaxy's radiation, the further away it is located, but the further away the galaxy, the earlier the events observed in it took place. The astronomical mosaic of observed "redshifted" events happened at different epoches will, of course, add up to a realistic history of the universe if, moreover, we have an appropriate theory that correctly reflects the physical nature of the cosmological redshift. In the application here presented of the offered scalar theory of the gravitational field to the entire flat universe, the cosmological redshift of the atomic spectra finds a natural explanation, without requiring the Hubble's "radial velocities of «...» extra-galactic nebulae", increasing as they recede from the observer [1], and any other unavoidable *ad hoc* assumptions.

As we will see, in the model of the universe based on this theory, the redshifts of atomic spectra and their growth with increasing cosmological distances are alternatively explained as a manifestation of a part of the cyclic process of synchronous change in the inertial mass of atoms throughout infinite space in the visible past epoch up to the present time. The inertial masses and rest energies in various quantum states of atoms, as well as the distances between their energy levels and the frequencies of the emitted photons, were increasing at this epoch at the expense of the energy of the existing slowly varying background gravitational field. This field is significantly different from what we knew about gravity before. In a homogeneous universe, the four-vector strength of this field is represented by a single time component, which is a three-dimensional scalar.

By the way, it should be admitted that Edwin Hubble himself understood the possibility of an alternative to the Döppler redshift mechanism proposed by him. At that time he had serious reasons to suspect this, because, according to the then scale of cosmological distances, "The familiar interpretation of red-shifts seems to imply a strange and dubious universe, very young and very small" [2]. But starting with Hubble's first publication [1], due to the lack of a better alternative to the expansion of the universe, the far-reaching myth of the recession of distant galaxies became firmly "established in most astronomer's minds" and has "survived through the decades until the present" [3, p. 417–418].

We present in this peper the alternative scenario of the evolution of the dust-filled universe eternally dominated by the background gravitational field. The proposed model of the cyclically evolving universe is based on the canonical linear theory of the massive scalar field, which we use as a working model of the gravitational field. It is amazing how a completely new dynamics of a non-expanding universe, confidently explaining the results of astronomical observations accumulated over the past century, directly follows from the updated scalar model of gravity in combination with the cosmological principle, which postulates only a homogeneous and isotropic distribution of matter. It is especially important that the adopted simplest non-geometric approach to the problem of relativistic generalization of Newtonian gravity is sufficient for an unambiguous interpretation of astronomical observations without the previously mentioned speculative theoretical artifacts of presently existing cosmology.

1 The equations of the background gravitational field

In this section, we will try to reconstruct a dynamical model of the universe filled with gravitating dust-like matter, homogeneously and isotropically distributed in space, in the presence of the evolving background gravitational field. We would like to prevent the appearance in the new model of the universe of 'dark clouds', similar to the mysterious concepts of "dark energy" and "dark matter", which have long been entrenched in the existing cosmology. We now turn to a consideration of the customary model of a dust-filled homogeneous universe, treating it as a unified gravitating system. In the following, we will mainly be interested in the collective gravitational field created by all the dust particles forming such a system, whether it be whole galaxies, individual atoms in intergalactic clouds or simply massive elementary particles. To calculate the background field we use the Klein – Gordon equation

$$\left(\Box - \varkappa^2 - \frac{2\pi G_0}{c^2}\Theta\right)\phi = 0, \qquad (1.1)$$

where Θ is the spatially averaged source of the field:

$$\Theta = \frac{1}{\mathscr{V}}\int_{(\mathscr{V})}\sum_a m_a\sqrt{1-\frac{v_a^2}{c^2}}\,\delta^{(3)}(\mathbf{r}-\mathbf{r}_a)\,dV \qquad (1.2)$$

(see [4, Eqs. (3.2) and (3.3)). Here we assume that the averaging is performed in the rest frame of the universe over a cosmological volume $\mathscr{V}$ whose linear dimensions in all directions are much larger than the averaged distances between individual "dust particles", such as separate galaxies and their clusters, that is of about 10^8 to 10^9 light years. It is also assumed that upon averaging, the individual contributions $m_a\left(1-v_a^2/c^2\right)^{1/2}$ to the common source of the background field are taken at the same fixed instant of the standard (special-relativistic) cosmic time t counted by a photon clock.

In order to refine the gravitational field equation (1.1) by presenting the field-dependent source density Θ explicitly in terms of the desired field variable ϕ, we must express in (1.2) the square of the velocity of each individual particle in terms of the square of its conserved momentum. For this we use two (ordinary and Hamilton's) forms of particle energy,

$$\mathscr{E} = \frac{c^2 m\phi^2}{\sqrt{1-v^2/c^2}} = \sqrt{c^2p^2 + c^4m^2\phi^4}, \qquad (1.3)$$

relating v^2 to p^2 for solving our preliminary task. In this way, we represent the source (1.2) as a somewhat complicated but explicit function of the conserved momentum of particles and the variable Ψ of the field itself (we omit the index a):

$$\Theta(\phi) = \frac{1}{\mathscr{V}}\sum_{(\mathscr{V})}\frac{m}{\sqrt{1+\dfrac{p^2}{c^2m^2\phi^4}}}. \qquad (1.4)$$

The time-dependent strength $Q(t)$ of the background gravitational field initiates, as we know from [5] (see Section 2), the appearance of the radial (convergent or divergent, dependently of sign of Q) energy fluxes directed along a local field $\mathbf{g}$ created by individual gravitating bodies, such as stars, atoms, or, simply, elementary particles. This means that, contrary to the current opinion, the inertial mass of each particular gravitating body and, ultimately, of every individual elementary particle is their variable characteristic, which slowly changes together with the strength $Q(t)$ of the background field throughout the history of the modeled universe.

This process must be balanced as required by the law of energy conservation. To proof this, we start from the field equation (1.1), which we rewrite again, using the detailed expression (1.4) for the field source:

$$\left(\Box - \varkappa^2 - \frac{2\pi G_0}{c^2}\frac{1}{\mathscr{V}}\sum_{(\mathscr{V})}\frac{m}{\sqrt{1+\dfrac{p^2}{c^2m^2\Psi^4}}}\right)\phi = 0. \quad (1.5)$$

Note that the equation (1.1) in form (1.5) remains invariant with respect to the gauge transformation $\phi \to C\phi'$, since this transformation also generates a scale transformation $\mathbf{p} \to \mathbf{p}' = C^2\mathbf{p}$ of the particle momentum, which is proportional in this case to ϕ^2.

In our further analysis of global processes in the universe, we will refer to the frame of reference associated with all matter filling the space. In this fundamental frame, which is inertial by definition, the dustlike matter is distributed uniformly and isotropically and is at rest on the average. From symmetry considerations it follows that the instantaneous picture of the distribution in space of the background gravitational field coupled to this background matter should inherit its spatial homogeneity. This means that in the fundamental frame of reference, which will be adopted henceforth, this field should depend on time alone, that is $\phi(x) = \Psi(t)$. In this case, equation (1.5) can be rewritten as follows:

$$\frac{d^2\Psi}{dt^2} + c^2\varkappa^2\Psi + 2\pi G_0\frac{1}{\mathscr{V}}\sum_{(\mathscr{V})}\frac{m}{\sqrt{1+\dfrac{p^2}{c^2m^2\Psi^4}}}\Psi = 0, \quad (1.6)$$

where, as before, in the summation over all particles in a volume $\mathscr{V}$, the squares of their random momenta are assumed to be time-independent. Multiplying the equation (1.6) with the expression $\left(c^2/2\pi G_0\right)d\Psi/dt$ and using the connection (1.3), after some simple transformations we get the equality

$$\frac{d}{dt}\left(W_M + W_Q\right) = 0. \quad (1.7)$$

Here the quantity

$$W_M = \frac{1}{\mathscr{V}}\sum_{(\mathscr{V})}\frac{c^2m\Psi^2}{\sqrt{1-\dfrac{v^2}{c^2}}} \quad (1.8)$$

is the energy density of the dust matter, averaged over the space, whereas the density of the energy stored in the field itself is

$$W_Q = \frac{c^4}{2\pi G_0}\left[\frac{1}{c^2}\left(\frac{d\Psi}{dt}\right)^2 + \varkappa^2\Psi^2\right]. \quad (1.9)$$

In complete agreement with the results presented in [5] (see Section 1), this expression denote the density of the energy accumulated by this field in two forms, kinetic and potential. Thus, the equation (1.7) shows that the sum of the energy densities W_M and W_Q of these two main constituents of the *not expanding* as well as *not contracting* universe does not change with cosmological time.

2 Gravitational background in the quiet homogeneous universe

In order to remove the complexities in our discussion of dynamical cosmology, we must, as usual, accept a simplified idealized model of the universe endowing it with the minimum number of necessary averaged parameters.

The first simplified assumption that we have to accept is that the matter filling the space is nonrelativistic. This means that the velocities of the vast majority of randomly moving masses of "dust particles", that is of stars, galaxies, and their clusters in the visible universe are much lower than the speed of light. Therefore $p \ll cm$ for all of them, so that, in the range of values of $\Psi(x)$ different appreciably from zero, the ratio $\mathbf{p}^2/\left(cm\Psi^2\right)^2$ in equation (1.5) can be neglected in comparison with unity. In fact, in this way we can replace the precise source (1.4) of the background field by the expression $\Theta \approx \frac{1}{\mathscr{V}}\sum_{(\mathscr{V})} m = \bar{\mu}$ is constant. However in this case the illegality of the given limiting transition with disappearing value of $\Psi(x)$ becomes non-obvious. As can be seen from (1.4), the exact value of the averaged parameter $\Theta(\Psi)$ depends on time together with the field Ψ and tends to zero if this field variable vanishes. So this case requires a separate consideration.

In our consideration, we will also neglect the global mass defect accumulating over space time due to the stellar nucleosynthesis and structural changes in matter after its gravitational condensation. This will allow us to consider the averaged density $\bar{\mu}$ of the gravitational mass of matter unchanged for a long cosmological era. Of course, only in a universe without expansion or contraction, the spatial density of gravitational mass can be considered unchanged over very long (by cosmological standards) time intervals, and we assume that this is indeed the case.

Thus, under the above assumptions that our Universe during a long cosmological epoch is filled mainly with nonrelativistic dust-like matter, the complex nonlinear equation (1.5) [as well as (1.6)] for the background field in an acceptable approximation is reduced in an arbitrarily chosen inertial frame to the linear Klein – Gordon equation

$$\left(\Box - \frac{\Omega^2}{c^2}\right)\Psi(x) = 0. \quad (2.1)$$

Here, for brevity, we have introduced the notation for the new combined cosmological parameter

$$\Omega^2 = c^2\varkappa^2 + 2\pi G_0\bar{\mu} \quad (2.2)$$

with the dimension of the squared inverse time (squared frequency). Its more precise physical significance as a characteristic of the evolving universe will be explained below. But even a cursory glance at equation (2.1) is enough to understand that this parameter should play a huge role in our investigation of the dynamics of the universe. Primarily we see that the value of Ω determines the space and time changes of the logarithmic potential ϕ of the background field. But Ψ, in turn, governs the energy content of gravitating matter from elementary particles to macroscopic bodies and stars and, therefore, controls the cosmological evolution of their inertial mass.

Parameter (2.2) is certainly a fundamental characteristic of the universe, combining two main contributions to the total "effective source" of the background field Ψ in (2.1). One of them is the averaged density $\bar{\mu}$ of the gravitational mass of the background dust-like non-relativistic matter that fills the space, while the second is related to the parameter $\varkappa$ presented in theory and having a purely field origin inherent in a massive field. Thus, the hypothesis that the graviton as a quantum of the scalar gravitational field is an exotic elementary particle with a nonzero gravitational mass $m_G = \hbar\varkappa / c$, creates an additional degree of freedom. In cosmological applications of the theory, the nonzero graviton mass, as seen from (2.2), can alternatively parameterize the well-known lack in the observed Universe of hadronic matter, established when trying to interpret some key astronomical observations within the currently accepted theory of gravity.

Having discarded the commonly accepted hypothesis of accelerated expansion of the universe, as well as the cosmological expansion as such, as erroneous in order to explain the Hubble redshift as such and its observed nuances, we find no reason to believe that the average kinetic energy density of randomly moving galaxies and, therefore, the universe parameters Θ and Ω could be noticeably different their current values in directly observed past cosmic history. In this case, it can also be assumed that these parameters will not noticeably change over a long cosmological time in the future history of the universe.

Considering the model of the Universe uniformly filled with nonrelativistic matter, we choose a simple monochromatic solution of equation (2.1),

$$\Psi(x) = \mathscr{A}\sin\left(-k_\mu x^\mu + \alpha\right), \quad (2.3)$$

as a global gravitational field that permeates all infinite space along with matter. In this expression, parameters $\mathscr{A}$ and α are the usual integration constants. We emphasize that our choice of the simple particular solution (2.3) for the background gravitational field and not any other was not random. It was motivated by considerations of reasonable sufficiency and corresponds to the model of a homogeneous universe accepted here.

By virtue of the Klein – Gordon equation (2.1), the components of a constant four-dimensional wave vector

$$\left(k^\mu\right) = \left(\frac{\omega}{c}, \mathbf{k}\right) \quad (2.4)$$

in (2.3) satisfy the condition

$$k_\mu k^\mu = -\frac{\Omega^2}{c^2}.$$

The inequality $k_\mu k^\mu = \mathbf{k}^2 - \frac{\omega^2}{c^2} < 0,$ which results from this, means that for the four-vector k^μ there exists a preferred inertial reference frame in which the ordinary wave vector $\mathbf{k}$, formed by the spatial components of k^μ, vanishes. Hence the frequency of the wave

$$\omega = \left(\Omega^2 + c^2\mathbf{k}^2\right)^{1/2} \quad (2.5)$$

reaches in this frame its minimum value $\omega_{\min} = \Omega.$ Using, in addition, the fact that the phase constant α, without loss of generality, can also be made equal to zero by a suitable choice of the time origin, we can rewrite (2.3) in this preferred frame in the form

$$\Psi(t) = \mathscr{A}\sin\Omega t. \quad (2.6)$$

Thus, the wavelength $\lambda = 2\pi/|\mathbf{k}|$ of the flat harmonic gravitational wave (2.3) is stretched to infinity on going to the mentioned fundamental reference frame. As a result, for the observer catching up with this frame, the wave behavior of the background field is leveled and completely disappears. Hence, in the fundamental frame of reference the background gravitational field, being spatially homogeneous, exhibits only oscillatory behavior. We will call the frequency Ω of these oscillations the cardinal or fundamental frequency of the cyclically evolved universe.

If we choose the spatial homogeneity of the background gravitational field as an unconditional preliminary restriction, then the Klein – Gordon equation (2.1) can be reduced in the fundamental frame of reference to a simple equation of a pendulum oscillations without spatial derivatives:

$$\frac{d^2\Psi}{dt^2} + \Omega^2\Psi = 0. \quad (2.7)$$

The physical acceptability of the solutions of this equation, independent of spatial coordinates, is completely obvious from the point of view of an observer in the fundamental frame of reference. From symmetry arguments, it becomes obvious that in this reference frame a scalar source of whatever nature (such as, for example, the gravitational mass of gravitating matter), which is at rest and uniformly and isotropically distributed throughout the space, cannot create any global scalar field that would depend on the coordinates and thus distinguish a certain direction in space determined by a nonzero gradient.

Therefore, the spatial components of the strength four-vector $g^{\mu} = (Q, \mathbf{g})$ of the background gravitational field, expressed in terms of its variable Ψ as

$$g^{\mu} = -2c^2 \frac{1}{\Psi} \partial^{\mu} \Psi, \qquad (2.8)$$

are zero, that is, $g^{\mu} = (Q, 0, 0, 0)$. In contrast, the temporal component

$$Q = 2c \frac{1}{\Psi} \frac{d\Psi}{dt} \qquad (2.9)$$

of this four-vector, if we take into account (2.6), is a nonzero periodic function of time:

$$Q = 2c\Omega \cot \Omega t. \qquad (2.10)$$

Unlike $\Psi(t)$ given by (2.6), this field changes in time with frequency 2Ω, that is, with the fundamental period

$$T = \frac{\pi}{\Omega}. \qquad (2.11)$$

Of course, the equation (2.1) admits a wide set of other solutions besides the chosen above. However, our choice of a solution (2.6) harmonically oscillating in time is the most preferable of them. It is motivated by considerations of simplicity and reasonable sufficiency, and also by the fact of isotropy and homogeneity of the modeling dust-like universe, established by astronomical observations and fixed as a cosmological principle.

But besides the original symmetry arguments that simplify the model of the universe, the correspondence of the subsequent theoretical conclusions to real astronomical observations was crucial for our final choice of field variables (2.6) and (2.10) among other admissible solutions that determine the evolution of the universe. The adopted solution (2.6) describes a field possessing precisely these properties of spatial homogeneity and isotropy. Consequently, the strength (2.10) represents the large-scale background gravitational field in the already introduced fundamental frame of reference existing together with matter of the entire universe.

So, the state of the background gravitational field is given by its wave function $\Psi(t)$, the logarithmic time derivative of which determines the observable of this field – its scalar strength $Q(t)$.

3 Cyclic evolution of the inertial mass

In our previous search for a suitable "minimal" dynamical generalization of Newtonian static gravity, compatible with the special-relativistic conservation laws and satisfying Maxwell's principle of the positivity of energy density of the field, we did not seek to construct in advance a theory of variable inertial mass of matter. As we have discussed earlier in [5], the gravitational variability of the energy, stored by a massive body or classical point particle at rest, arises as a completely natural phenomenon from the point of view of the theory of a mass-coupled canonical scalar field. In a weak local (non background) field, this looks like a small mass defect accompanying the gravitational interaction.

But apart from this, the proposed theory of the gravitational field, which meets the stated requirements, unexpectedly reveals the physical essence of the concept of mass hidden in the phenomenology of two equivalences: mass-energy and also inertial and gravitational masses. We have to be convinced of the limitations of our current understanding of inertial mass as a passive form of accumulated energy "'dormant' in massive bodies, that is released in part during chemical and especially nuclear reactions" [8] as well as in the cosmic processes of gravitational clustering of matter. The rest energy also does not participate in the transformation into other forms of in separate stable elementary particles (with the exception of matter-antimatter annihilation).

Up to our time, the classical relativistic mechanics, having discovered the rest energy, did not give any keys to understanding its physical nature and the mechanism of its formation, hidden in the phenomenology of perhaps the most famous physical formula $\mathscr{E} = mc^2$. Remaining within the framework of generally accepted physical concepts, we can only talk about the binding energy and mass defect, that is, about a completely insignificant imbalance of the rest energy accumulated in the inertial mass, arising as a result of the formation, transformation, or decay of complex material structures, such as atomic nuclei, atoms, molecules, or cosmic bodies formed with the participation of various physical fields. For example, the mass defect in the splitting of a helium nucleus bound by strong interaction is only 0.75% of its total inertial mass.

As for the contributions to the inertial mass produced by the other three fundamental interactions, they are known to be even more negligible. A simple calculation leads to the conclusion that the gravitational binding energy of the earth contributes a fraction 8.4×10^{-10} of its total rest energy [3]. The fractional mass defect of a star such as the sun is $\sim10^{-6}$.

In the case of an individual atom, the contributions of the strong, electromagnetic, weak and gravitational interactions to its binding energy and, therefore, to the inertial mass are estimated respectively as $1 : 10^{-2} : 10^{-12} : 10^{-40}$ relative to each other [6]. (Meanwhile, Richard Feynman a year earlier gave a different relationship between fundamental forces, another in relation to weak interaction, namely: $1 : 10^{-2} : 10^{-5} : 10^{-40}$ in the same sequence [7] (see Table 2.3 on the page 2.10).) However, the comparison presented for individual atom is actually misleading. In the case of the gravitational condensation of large amounts of electrically neutral matter, the formation of compact supermassive objects is limited only by centrifugal forces, which are of a random nature. The gravitational binding energy of compact cosmic bodies, such as a white dwarf, neutron star or black hole, increases sequentially and reaches tens of percent in the case of a black hole. A calculation using simplified models of a homogeneous white dwarf and a neutron star with the mass of the Sun shows values of the fractional mass defect of about 10^{-4} and 10^{-1} respectively.

But the alternative special-relativistic approach to the gravity problem and its cosmological application that we develop here, breaks this restriction with respect to the gravitational interaction: we come to the conclusion that the rest energy and therefore the inertial mass itself are completely of gravitational nature. Of course, the existence of a small additive correction term $\Delta m = m\Phi / c^2$ in the nonrelativistic and weak-field approximation, keeping only first-order terms in small quantities v^2 / c^2 and Φ / c^2, against the background of the relativistic value mc^2 cannot be a sufficient reason for changing the traditional view, which is confirmed at every turn, that the entire rest energy of matter can be transformed into other forms of energy only in the processes of matter-antimatter annihilation. However, a remarkable feature of the scalar gravitational field is that in the general case it leads not only to small corrections in the rest energy, that is, in the inertial mass of a gravitationally coupled system. This is equally applicable both to the mass of black holes, neutron stars, white dwarfs, then to individual macroscopic bodies, atoms, nuclei and even to the *entire mass spectrum of elementary particles* due to their energy exchange with gravitational fields. And this applies not only to small but rapid (on a cosmological time scale) variations of inertial mass in local familiar vector fields **g**. Especially and above all this conclusion refers to the interaction of listed objects with the background gravitational field, what is particularly important – to its slow, very long, but deep evolution, from maximum value up to zero and vice versa, in the cyclic background scalar field *Q*.

We will see that a simple zero-spin gauge-invariant theory of a gravitational field is very effective and looks nontrivial even against monumental general relativity. Being applied to the universe, it forces us to raise the status of the inertial mass of elementary particles from a phenomenological constant to the level of a dynamical variable, and therefore pushes the physics of fundamental interactions beyond the existing Standard Model.

Now we will continue to discuss the phenomenon of gravitational variability of the rest energy and inertial mass of gravitating matter, focusing our attention on the participation of the background gravitational field in this process. As before, our subsequent reasoning will relate to the absolute frame of reference associated with the universe. As we have so far assumed, the matter in this frame is at rest on the average and uniformly and isotropically distributed throughout space, so that the varying in time background field must be also spatially uniform.

As was already shown in [5], in space where exists the vector field of strength **g**, the scalar strength *Q* involves in the formation of flows of the gravitational energy directed along or opposite vector **g**. Therefore converging or diverging energy fluxes around gravitating bodies are invariably present during successive long stages of positive and negative background field $Q(t)$ in the evolving universe. This means the existence of the replacing each other long half-cycles of slow synchronous increase and decrease in the inertial mass of all individual elementary particles, atoms, stars and other condensed bodies.

It follows from (1.3) and (2.6) that the cosmological evolution of the inertial mass $\tilde{m}$ associated with the rest energy of nonrelativistic matter, contained in each individual gravitating particle, atom, body, or star with the constant gravitational mass *m*, is given by the formula

$$\tilde{m}(t) = m\mathscr{A}^2 \sin^2 \Omega t, \qquad (3.1)$$

where Ω is the cardinal frequency (2.2) of the cyclically evolving universe.

So far we have used the previously determined solution (2.6) for the logarithmic potential $\Psi(t)$ of the background field without worrying about the fact that the integration constant $\mathscr{A}$ in it remained uncertain. Formula (3.1) shows that it would be reasonable to get rid of the ambiguity in this solution by choosing an initial condition for it, establishing that at the current time t_0,

$$\Psi(t_0) = \mathscr{A} \sin \Omega t_0 = 1. \qquad (3.2)$$

Now, using this convention, we can rewrite field (2.6) as

$$\Psi(t) = \frac{\sin \Omega t}{\sin \Omega t_0}. \qquad (3.3)$$

Such convention applied to the background field is extremely convenient, since in this case the present value $\tilde{m}(t_0)$ of time-dependent inertial mass of every particle or condensed body

$$\tilde{m}(t) = m\frac{\sin^2 \Omega t}{\sin^2 \Omega t_0} \qquad (3.4)$$

coincides with their gravitational mass *m*. Therefore the current value of the evolving rest energy

$$\mathscr{E}(t) = mc^2 \frac{\sin^2 \Omega t}{\sin^2 \Omega t_0} \qquad (3.5)$$

is given by the customary Einstein's formula

$$\mathscr{E}(t_0) = mc^2.$$

At the same time, the maximum value of the evolving inertial mass of a particle is reached in the middle of the cyclic epoch and takes a well-defined quantity

$$\tilde{m}_{\max} = \frac{m}{\sin^2 \Omega t_0}. \qquad (3.6)$$

Thus, any body at rest or just a massive elementary particle serves as a natural pantry for the energy of the background gravitational field. Each of them has a certain limiting energy capacity, predetermined by its gravitational mass *m*:

$$\mathscr{E}_{\max} = \frac{mc^2}{\sin^2 \Omega t_0}. \quad (3.7)$$

The current value of the phase Ωt_0 of the present evolutionary cycle was determined by fitting the measured relation between redshift and peak luminosity of SNe Ia with the correspondent theoretical formula (for details in Section 6). This significant cosmological parameter with a great degree of certainty is about $\Omega t_0 = 0.68$. This leads in turn from (3.6) and (3.7) to the numerical connections

$$\tilde{m}_{\max} = 2.5m \quad \text{and} \quad \mathscr{E}_{\max} = 2.5mc^2,$$

while the gravitational mass *m* remains unchanged.

Thus, according to (3.4), the inertial mass $\tilde{m}$ corresponding to the energy accumulated in a certain epoch in a resting particle has, in a true sense, a gravitational origin. In fact only "gravitationally charged" particles can have the rest energy and, therefore, can possess the inertia with a possibility of a movement with velocities smaller than speed of light and even to be at rest. In turn they become, due to this, successful in formation of atoms, their various groupings, and condensed macroscopic and cosmic bodies.

The varying energy content $\mathscr{E}(t) = c^2\tilde{m}(t)$ of resting elementary particles (and gravitating bodies in general) is formed at the expense of the energy of the background gravitational field *Q* and controlled by it forming the energy flows proportional to the product *Q***g**. Along with this, their inertial mass and rest energy also are slightly corrected by the intervention of local contribution to the background field *Q* produced during the change in time of the local potential Φ.

And finally, the rest energy accumulated in the form of the inertial mass can be completely pumped out of the particles under the influence of the background field, and this instantaneous massless state of matter regularly repeats in the Universe after the time interval *T* given by (2.11). Our estimates, based on observational data from Type Ia supernovae, show that the last such dramatic event in the universe occurred about 24 billion years ago.

4 Gravitational nature of the cosmological redshift of atomic spectra

It is well-known the Lev Landau's aphorism cited, for instance, by Michio Kaku in [9, p. 10]: "cosmologists are often in error but never in doubt". However, the lack of alternatives to the generally accepted explanation of the cosmological redshift by the expansion of the universe, which for ninety years seemed so obvious to everyone, made it possible in the book [10] of Landau and Lifshitz to make an exception to this rule. On page 383 we read the authors' categorical statement: "There is *no doubt* that this property ("the expanding universe") gives a correct explanation of the phenomenon of the red shift, which is fundamental for the cosmological problem" [italics added].

The search for an explanation of the cosmological redshift under the tacit assumption that the physical conditions that existed in the material world in the remote past, like matter itself with its elementary particles, atoms and atomic nuclei, did not differ from existing ones, inevitably led the discoverers of this phenomenon to its naive Döppler interpretation. Then, within the framework of general relativity, this explanation was transformed into the now commonly accepted, but from many points of view, vulnerable model of an expanding universe created from a big-bang singularity. This hypothetical expansion is interpreted by the general theory of relativity as the stretching of space itself, in which wavelengths of light waves also stretch during the long journey to observer, manifesting itself as a redshift of atomic spectra.

Repeating partially the arguments that we have already presented in [5, Section 3], we will show below that the theory of the canonical massive scalar field, adapted as a dynamical special -relativistic theory of gravity and applied to the model of the homogeneous dust-like universe, predicts cosmological redshift as a natural periodic phenomenon, which is inevitable at certain stages of its cyclic evolution. We will see immediately that the cosmological redshift of atomic spectra can be alternatively explained as a result of the grows of the inertial mass – rest energy of atoms, occurring presently and in the visible past on the scale of the entire *non-expanding* universe. This growth is initiated by the background gravitational field (2.10), which has transferred own energy to the elementary particles of gravitating matter for 24 billion years and continues to replenish their rest energy in the current era. Moreover, as we will see below, the proposed theory of gravitation applied to the homogeneous dust-like universe predicts (without any additions!) the phenomenon of cosmological redshift with surprising details in its relation versus the luminosity distance, which were discovered from observations of SNe Ia [11]–[13].

Thus, accepting the scalar theory of gravity, one must admit that the observed cosmological redshift of atomic spectra has nothing to do with the idea of an expanding universe. To show this, it is merely enough to assume that all available cosmic processes and events, both recent and sufficiently distant in the past, belong to the first half of the current evolutionary cycle of the universe, which is one of an infinite number of identical cyclic epochs. This means that observed events, we believe, have happened at the time *t* satisfying to the condition $0 < t \le t_0 < \pi / 2\Omega$. At this time in the past, the energy content factor $\Psi^2(t)$, and therefore the rest energy

$$\mathscr{E}(t) = c^2 m\, \Psi^2(t) \qquad (4.1)$$

of elementary particles, then of atoms, stars, and other cosmic bodies and their structures as they formed, appeared to grow monotonically and continue to increase at present.

Like the rest energy of an atom in the ground or excited state, the spacings between its energy levels also change with cosmic time t in accordance with the same cosmological generalization (4.1) of the fundamental law of proportionality of inertial mass and rest energy. Consequently, for the frequencies of photons emitted at a certain instant t of cosmic time by an atom at rest as a result of a quantum transition from an initially excited state with energy $\mathscr{E}_n(t)$ to a lower state with energy $\mathscr{E}_m(t)$ in the general case we can write

$$\nu_{nm}(t) = \nu_{nm}^{(0)} \Psi^2(t), \qquad (4.2)$$

where $\nu_{nm}^{(0)}$ is the frequency of the photon currently emitted by the similar atom:

$$\nu_{nm}^{(0)} = \frac{\mathscr{E}_n^{(0)} - \mathscr{E}_m^{(0)}}{2\pi\hbar}.$$

Each of the values $\mathscr{E}_n^{(0)}$ in this expression is evidently the present quantity of the rest energy of atom in the n-th excited (or in ground) energy state.

For the already found normalized harmonic background field (3.3), the formula (4.1) gives the already known cyclic time dependence (3.5) of the rest energy for all individual atoms (or nuclei) in any quantum state

$$\mathscr{E}_n(t) = \mathscr{E}_n^{(0)} \frac{\sin^2 \Omega t}{\sin^2 \Omega t_0}. \qquad (4.3)$$

Corresponding to this, the epoch-dependent spectral frequencies of every atom vary with cosmic time t as

$$\nu_{nm}(t) = \nu_{nm}^{(0)} \frac{\sin^2 \Omega t}{\sin^2 \Omega t_0}. \qquad (4.4)$$

The observed discrete frequency spectra of electromagnetic radiation from very distant galaxies, quasars, or other cosmic objects are clearly quantum in nature. The photons, emitted by ancient atoms at a much earlier instant of cosmic time, arrive to an observer on the earth at present time t_0 with a very large (up to ten billion years or more) retardation time $t_{\text{ret}} = t_0 - t$.

Being massless, a free photon do not create the proper vector gravitational field **g** which would participate in a pair with the scalar background field Q in the formation of energy fluxes of the gravitational field, which, in turn, could change its energy content. Consequently, the long travel of photons during time t_{ret} in a flat non-expanding universe filled with the energy of the evolving background field Q took place without any changes in their energy, and hence in frequency. For this reason, the spectra currently observed by astronomers are the spectra of atoms from the distant past of our universe. They are shifted to the red compared with the laboratory spectra of similar, but more massive, currently existing atoms: the rest energy of both young and aged atoms is determined by the evolving factor Ψ^2, which has undergone a corresponding gradual *increase* over time t_{ret}. We observe a cosmological shift in the frequency of arriving photons exactly to the red edge of the spectrum, because during the time t_{ret} of their propagation, the rest energy and inertial mass of today's atoms have become higher, so that the frequency and energy of the photons emitted by them, which we use as reference ones, have proportionally increased.

The parameter z of the cosmological redshift is determined in this case as usually by comparing of the wavelengthes λ_{emit} or frequencies ν_{emit} of electromagnetic radiation, emitted by the faraway atoms in the remote past and presently observed, with their laboratory analogues λ_0 or ν_0 received presently from similar atoms on the earth:

$$z = \frac{\lambda_{\text{emit}} - \lambda_0}{\lambda_0} = \frac{\nu_0 - \nu_{\text{emit}}}{\nu_{\text{emit}}}. \qquad (4.5)$$

For a certain energy transition of an atom, we should make in (4.5) the replacement

$$\nu_0 \to \nu_{nm}(t_0), \quad \nu_{\text{emit}} \to \nu_{nm}(t_0 - t_{\text{ret}}),$$

so that the definition of redshift (4.5) reads as follows:

$$z = \frac{\nu_{nm}(t_0) - \nu_{nm}(t_0 - t_{\text{ret}})}{\nu_{nm}(t_0 - t_{\text{ret}})} = \frac{\nu_{nm}(t_0)}{\nu_{nm}(t_0 - t_{\text{ret}})} - 1.$$

Keeping in mind (4.2), from this we obtain the general definition of the parameter of cosmological shift of spectral lines in the form

$$z = \frac{\Psi^2(t_0)}{\Psi^2(t_0 - t_{\text{ret}})} - 1. \qquad (4.6)$$

For the slowly oscillating logarithmic potential (3.3) of the background field this gives

$$z = \frac{\sin^2 \Omega t_0}{\sin^2 \Omega\left(t_0 - t_{\text{ret}}\right)} - 1. \qquad (4.7)$$

So once again, briefly. While free photons have traveled through the universe for billions of years having fixed frequencies, all atoms in the universe have been exposed to the background gravitational field all this time and have continuously experienced a secular increase in their rest energies. This increase happened with the universal factor $\Psi^2(t)$, regardless of whether atoms were in excited or ground states. Therefore, the spacing between energy levels of atoms gradually expanded in the same extent, determined by the factor $\Psi^2(t)$ too. This is an alternative to the model of the expanding universe and the "tired light" hypothesis, successfully explaining why the arriving cosmic photons, emitted long ago and far away as a result of atomic transitions, are softer than the photons emitted today by exactly the same but aged atoms in similar energy transitions.

Applying formula (4.7) to real astronomical observations, one should, of course, take into account the uncertainty in the cosmological redshift caused by the longitudinal Döppler shift of the spectral lines because of the peculiar nonrelativistic motion of the galaxies. In turn, the Döppler shift, caused by the participation of the Milky Way itself in this movement, should lead to a dipole anisotropy of the cosmological redshift, similar to the dipole anisotropy of the cosmic microwave background.

The question may arise: how should the magnitude – redshift (or blueshift) diagram look like for hypothetical observers at different epochs in the history of our Universe? We address this problem in the next section. Here we only note in passing, that for any previous or future time of hypothetical observation t_{obs}, the equation, connecting cosmological shift z of atomic spectra (red in the case of positive z or blue if z is negative) with the time of the journey of photons having the spectral frequencies $\nu_{nm}(t_{\text{obs}} - t_{\text{ret}})$ shifted with respect to the correspondent "laboratory" frequencies $\nu_{nm}(t_{\text{obs}})$, can be obtained from (4.7) by replacing the current time t_0 by t_{obs}. In this case the required connection reads as follows:

$$1 + z = \frac{\sin^2 \Omega t_{\text{obs}}}{\sin^2 \Omega\left(t_{\text{obs}} - t_{\text{ret}}\right)}. \tag{4.8}$$

When the present cycle was young, so that the condition $\Omega t_{\text{obs}} \ll 1$ for early hypothetical observations was satisfied, the formula (4.8) gives for $t_{\text{ret}} < t_{\text{obs}}$ the approximate equality

$$1 + z \approx \frac{t_{\text{obs}}^2}{\left(t_{\text{obs}} - t_{\text{ret}}\right)^2}. \tag{4.9}$$

We emphasize that under the conditions just specified the parameter z in this formula is positive. This corresponds to the redshift of photons that were emitted at time $t_{\text{obs}} - t_{ret}$ by "young" distant atoms compared to photons emitted later at a certain cosmological epoch t_{obs} of the supposed observation by similar but "aged" by the time t_{ret} atoms as a result of the similar radiative quantum transitions.

A formula very similar to our approximate formula (4.9), in which, however, the current observations of the cosmological redshift are assumed [i. e., in (4.9) one must put $t_{\text{obs}} = t_0$], was obtained by Hoyle and Narlikar [11], [12] as a strict consequence of their "Conformally invariant theory of gravity". This theory was announced later by Arp and Narlikar in [13] as "a unified framework for extragalactic redshifts".

The Hoyle-Narlikar consideration is based on the Mach's idea of the appearance of the inertia (must be read 'the inertial mass') in an individual particle from the rest of the particles in the universe. This idea was understood and interpreted in [11], [12] as a result of the interaction of a particle with a hypothetical "mass field", which, in turn, arose "predominantly from particles at great distance". In fact, the variability of the inertial mass appears in [13] as a result of a separate, not related to the gravitational interaction and poorly grounded *ad hoc* hypothesis of the instantaneous action of bodies at cosmological distances.

Let us suppose now that we observe the atomic spectra of light from a galaxy located at the distance $d = ct_{\text{ret}}$ not very large on a cosmological scale. This means that the light, which spectra we analyze, was emitted by atoms in past at time $t_0 - t_{\text{ret}}$ sufficiently close to the present epoch in the sense that $t_{\text{ret}} \ll t_0$. In this case, we can expand the function of two time variables, $z(t_0, t_{\text{ret}})$, in (4.7) [or in the general formula (4.6)] in a power series in the small ratio t_{ret} / t_0, limiting ourselves to the linear approximation. The result of this approximation, of course, is a linear relationship between the redshift z and the time t_{ret} of light propagation to the observer:

$$z = H_0 t_{\text{ret}}. \tag{4.10}$$

This linear in time t_{ret} approximation of (4.7), we can now rewrite in terms of the redshift z of the optical spectra of atoms in not very remote galaxies and the light travel distance $d = ct_{\text{ret}}$ from them:

$$z = \frac{1}{c} H_0 d. \tag{4.11}$$

In the formulas (4.10), (4.11), we denote by H_0 a coefficient that represents the current value of the logarithmic time derivative of the square of the background field $\Psi(t)$:

$$H(t) = \frac{1}{\Psi^2(t)} \frac{d\Psi^2(t)}{dt}. \tag{4.12}$$

Because of the general harmonic solution (2.6) for $\Psi(t)$ [or its normalized example (3.3)], from this we find

$$H_0 = 2\Omega \cot \Omega t_0. \tag{4.13}$$

The constant H_0 in (4.10), (4.11) is the same as in the well-known Hubble linear empirical connection

$$v = H_0 d. \tag{4.14}$$

Edwin Hubble is known to have explained the cosmological redshift as a result of the Döppler shift associated with the hypothetical general recession of galaxies [1], [17] (the last together with Milton Humason). At that time, ninety years ago, the idea of scalar gravity, with its gravitationally dependent Nordström's mass, experienced an "early demise", and the general recession of distant nebulae was perhaps the only reasonable explanation for the discovered astronomical phenomenon, which has since become firmly established in modern cosmology. Based on this interpretation, Hubble expressed the "Döppler redshift parameter" $z = v / c$ in terms of the "radial recession velocities" v of galaxies and related it by the empirical formula (4.14) with the distances d at which the currently registered photons were emitted by young atoms $t_{\text{ret}} = d / c$ time ago.

According to (4.12), the natural unit of the Hubble parameter should be the inverse unite of time, that is the inverse second or inverse year. Any of these two simple units of the Hubble constant H_0 should be accepted in the proposed alternative model of the universe without the mythical cosmological expansion. The use in this work of a non-standard artificial unit, $\text{kms}^{-1}\text{Mps}^{-1}$, for the current value of the Hubble constant, which is convenient in the Friedmann – Robertson – Walker cosmology, is forced for obvious reasons. But over time, its use in the model of a quiet universe without a big bang will look like a meaningless anachronism.

5 Redshifted spectra of distant atoms as dating tool of past cosmic events and processes

We call attention to the fact that if we adopt the scalar approach to the gravity problem and the presented model of the evolution of the universe as true, we could use the Hubble's redshift as an independent readily accessible precision indicator of cosmological distances. To demonstrate this specifically, we will have to return to (4.7), but now we must express the travel time t_{ret} of photons from a distant source as a function of the cosmological redshift z, bearing in mind that at the moment of emission the source was at rest in the observer's frame of reference. Of course, one should remember in this case some uncertainty in determining the distance d and time of light propagation $t_{\text{ret}} = d / c$, introduced by the Döppler frequency shift, arising from the uncontrolled peculiar motion of a distant source.

Thus, using (4.13), from (4.7), we can find the time t_{ret} of a long journey to the Earth of photons emitted by atoms whose optical spectra are shifted to the red side. Expressed through the redshift parameter z of the observed spectra, this time is

$$t_{\text{ret}} = \frac{2\cot\Omega t_0}{H_0}\left(\Omega t_0 - \arcsin\frac{\sin\Omega t_0}{\sqrt{1+z}}\right). \quad (5.1)$$

This formula involves only two freely specifiable parameters; these are the Hubble constant H_0 and the present phase Ωt_0 of the current cycle of the evolution of the universe.

Starting from (5.1) and using the numerical values (6.10), (6.11) of these parameters derived from astronomical observations, we can offer a working formula for the convenience of numerical calculations of the distance $d = ct_{\text{ret}}$ traveled by the light radiation with the observed redshift z:

$$d(z) = 35.27\left(0.68 - \arcsin\frac{\sin 0.68}{\sqrt{1+z}}\right)\times \quad (5.2)$$
$$\times 10^9 \text{ lightyears.}$$

Thus, we obtained this formula using the results of high-precision astronomical measurements of peak values of the brightness of supernovae type Ia, which were observed in a few random galaxies. Now formula (5.2) should ensure the same accuracy of determining the distance to any galaxy exclusively through its redshift.

Having thus installed in (5.1) the high-precision data of astronomical observations of SNe Ia, we obtained a formula that should provide the same accuracy in determining distances to galaxies only through redshifts, which was achieved for not numerous random galaxies by means of careful measurements of the peak apparent luminosities of their supernovae.

The travel times of radiation from distant cosmic objects with large z, calculated by formula (5.2), significantly exceed the corresponding estimates made in the conventional big bang cosmology with suitable cosmological parameters. (In contrast to the two parameters presented in formula (5.1), in the Λ CDM model, to calculate $d(z)$, at least three parameters must be specified. As a rule, these are: $\Omega_m = 0.3$, $\Omega_\Lambda = 0.7$ and current value of the Hubble parameter $H_0 = 70\ \text{kms}^{-1}\text{Mps}^{-1}$.)

As examples, we presented in Table 5.1 for comparison the corresponding estimates of the time of light propagation from several relatively recently discovered galaxies and quasars with large redshifts.

Table 5.1 – Revised light travel distance from known high-z sources in the nonexpanding universe

Object	z	Light travel distance, Gly	
		Big-bang cosmology	Variable-mass cosmology
Galaxy GN-z11 [18]	11.09	13.4	17.57
Galaxy Egsy8p7 [19]	8.68	13.2	16.81
Quasar J0313-1806 [20]	7.642	13.1	16.38
Quasar ULAS J1342+0928 [21]	7.54	13.1	16.33
Galaxy z8 GND 5296 [22]	7.51	13.0	16.32
Quasar ULAS J1120+0641 [23]	7.085	12.9	16.12
Quasar J043947.08+163415.7 [24]	6.51	12.8	15.82

6 Evolved Chandrasekhar's limit and luminosity of distant SNe Ia

As a result of Chandrasekhar's fundamental research of the stability conditions of ideal spherical nonrotating carbon-oxygen white dwarfs [25], [23, Chapter XI], [27], it is commonly accepted in today's astrophysics and cosmology that the mass of progenitors of all SNe Type Ia, as well as their peak absolute luminosity must be standard and do not depend on cosmic time [28]. However, the observational data from SNe Ia with identical redshifts showed that there is a noticeable spread in their peak brightness. Those individual deviations from standard are natural and can be caused primarily by unavoidable deviation in the critical amount of carbon-oxygen substance in pre-exploding white dwarfs because of their rapid rotation with different random angular velocities [29], [30]. But such a variety in the peak brightness of different supernovae with identical redshift can be corrected because of the presence of correlation between their absolute magnitude and duration of the bright phase: brighter stars have accumulated more substance and naturally radiate longer than dim ones [31], [32]. Thus, the distances to these standardizable candles can be compared with the unprecedented in observational cosmology precision by measuring and correcting their peak apparent magnitude.

However, according to the above analysis, these bright sources of light adopted in astronomy as standard indicators of distance appear to be more "difficult" than that is commonly believed today, first of all, because of the cosmological variability of the inertial mass. The point is that the Type Ia supernovae explosions, registered at different cosmological distances, occurred at various cosmological epochs. Hence the registered peak luminosity of the supernova of this type is influenced by a number of facts which are changed themselves in the conditions of cosmological evolution. Therefore there are several reasons why the luminosity distances, determined by using the SNe Ia, must be analyzed and defined anew, from the standpoint of the developed theory. Among them, three circumstances raise suspicions, as capable of causing a change in the peak absolute luminosity of SNe Ia over cosmic times:

(i) As we look further and further out into space, we register photons that were emitted by atoms or nuclei consisted of younger and younger elementary particles having smaller and smaller rest energies. This means that any two identical nuclei or atoms in two different supernovae, currently seen at very different distances, and therefore radiated at various epochs give different energy release $\Delta\varepsilon$ of a nuclear transmutations or chemical reactions (or other transformations), which decreases with distance. Hence, according to (4.3), we can write

$$\frac{\Delta\varepsilon_1}{\Delta\varepsilon_0} = \frac{\sin^2 \Omega(t_0 - t_{\text{ret}})}{\sin^2 \Omega t_0}.$$

Here and throughout this section, the indices 1 and 0 refer to the time $t_1 = t_0 - t_{\text{ret}}$ of sending the electromagnetic signal from supernova explosion in the past and to the present time t_0 of its detection on the earth, respectively. Finally, keeping in mind (4.7), we get from the previous formula

$$\Delta\varepsilon_1 = \frac{1}{1+z}\Delta\varepsilon_0. \tag{6.1}$$

(ii) As it follows from the quantum mechanical uncertainty relation between the width of energy levels and the lifetime of excited states, simultaneously with the decrease of the rest energy of unstable particle and nuclei in the local external gravitational field, their lifetimes increases [33]. Since the progenitors of distant Type Ia supernovae exploded at an earlier stage of the matter evolution, the evolved half lives of unstable nuclei of ^{56}Ni (synthesized from ^{12}C and ^{16}O during the explosion) and then of its daughter ^{56}Co isotope would be correlated, according to (6.1), with their redshifts and current half-life $T_0^{(1/2)}$ as

$$T_1^{(1/2)} = (1+z)T_0^{(1/2)}. \tag{6.2}$$

This means that the nuclear transformations of the explosion products of two faraway Type Ia supernovae, whose progenitors were two identical carbon-oxygen white dwarfs, occurred more slowly and continued for a longer time in that of them that was placed at a greater distance from the observer.

Therefore, the energy of more distant type Ia supernovae, which is released per unit time during spontaneous transformations of unstable nuclei, will be further reduced, according to (6.2), by a factor of $1/(1+z)$. From this, in turn, it follows that, because of the increase in the delay of the emission of secondary photons with distance, the peak absolute luminosity of more distant white dwarfs, exploded as SNe Ia, will additionally decrease with increasing z by the same factor $1/(1+z)$.

(iii) Finally, as was noted at the beginning of this section, due to the longer duration of the bright phase of SNe Ia having more massive progenitors, but with the same redshifts, their apparent peak brightness can be confidently standardized to eliminate the spread in the observed data brightness – redshift correlation due to the exceed of Chandrasekhar's limiting number of baryons calculated for a non-collapsing ideal non-rotating white dwarf. However, the loss of stability of non-rotating white dwarfs in binary systems accreting matter from a companion is achieved at different epochs with different limiting values of their inertial mass, which is modulated on cosmological time scales by the energy content factor $\Psi^2(t)$ determined by (3.3), so that

$$\mathfrak{M}^{\text{Ch}}(t) = \frac{\sin^2 \Omega t}{\sin^2 \Omega t_0}\mathfrak{M}_0^{\text{Ch}},$$

in accordance with formula (3.4). Parameterizing as before the age t_{ret} of photons emitted from the visible white dwarf at the past time $t = t_0 - t_{\text{ret}}$ by their redshift z in agreement with formula (4.8), we find that

$$\mathfrak{M}^{\mathrm{Ch}}(z) = \frac{1}{1+z}\mathfrak{M}_0^{\mathrm{Ch}}.$$

At the same time, since the mass of each individual elementary particle changes in proportion to the same factor $\Psi^2(t)$, explosions of white dwarfs – the progenitors of each of SN Ia have been and will happen with the same (on average) number of baryons, that is with

$$\mathfrak{N}^{\mathrm{Ch}} = 37.0 \cdot 10^{55}\,\text{baryons}. \qquad (6.3)$$

Therefore, the *invariant* characteristic of the stability of ideal non-rotating white dwarfs in the evolving Universe is their limiting *gravitational* mass or the limiting total number (6.3) of baryons calculated using the current limiting Chandrasekhar mass and mass of hydrogen atom, but by no means their total inertial mass, which changes with cosmological time.

The peak value $I(t_0 - t_{\mathrm{ret}})$ of the power of a distant supernova Ia with cosmological redshift z is decreased by the factor $(1+z)^2$, due to the first two circumstances (i) and (ii) compared to the peak power $I(t_0)$ of a local supernova with z close to zero. Thus from (6.1) and (6.2) it follows

$$I(t_0 - t_{\mathrm{ret}}) = \frac{I(t_0)}{(1+z)^2}. \qquad (6.4)$$

Because of this, the supernova will look dimmer and it will seem to us that it is located $(1+z)$ times farther than the real distance $d = ct_{\mathrm{ret}}$ traveled by the light.

Taking into account (6.4), we obtain that in perfectly transparent universe without expansion or contraction the luminosity distance defined from Type Ia supernova depends on its redshift factor $(1+z)$ and the light travel time t_{ret} as follows:

$$d_L = (1+z)ct_{\mathrm{ret}}. \qquad (6.5)$$

Using this formula and taking into account (5.1), we represent the luminosity distance d_L in terms of the red shift parameter z, as it is usually required for cosmological applications. We get thus finally the following redshift – luminosity distance relation for Type Ia supernovae:

$$d_L(z) = \frac{2c(1+z)\cot\Omega t_0}{H_0}\left(\Omega t_0 \arcsin\frac{\sin\Omega t_0}{\sqrt{1+z}}\right). \qquad (6.6)$$

The foregoing considerations show that the correlation between red shifts and luminosity distances from cosmic sources having other light emission mechanisms than SNe Ia during their afterglow *may be different* from that determined by formula (6.6). This will be the case, for example, when using standard stationary sources as distance indicators, such as a specific sample of bright stars, globular clusters or galaxies. Other types of supernovae, which, unlike SNe Ia, emit light simultaneously with the explosion without noticeable delay, can also be such sources.

Using the rich available data of redshifts and apparent magnitudes of Type Ia supernovae at the peak of their brightness, we can now quantitatively verify the validity of the proposed description of the evolutionary dynamics of the universe.

Substituting the expression (6.6) for the luminosity distance for Type Ia supernovae in the well-known formula that presents the definition of the bolometric distance modulus,

$$\mu_{\mathrm{bol}} = 5\lg\frac{d_L(z)}{10\mathrm{pk}},$$

we shall write it for the case of SNe Ia as standard candles in the form:

$$\mu_{\mathrm{bol}}(z) = \qquad (6.7)$$

$$= 5\lg\left[\frac{2c(1+z)\cot\Omega t_0}{10\mathrm{pk}\cdot H_0}\left(\Omega t_0 - \arcsin\frac{\sin\Omega t_0}{\sqrt{1+z}}\right)\right],$$

where the numerical values of the light velocity c and the Hubble's constant H_0 must be expressed in units of km sec^{-1} and km sec^{-1}Mpc^{-1}, respectively.

This formula would remain true also in the case when the observer would compare the brightness of the same, but differently red-shifted spectral lines from SNe Ia appeared at various distances. However, it is known that the photometry of supernovae with different z is performed by means of photodetectors with special filters (templates) that are transparent at fixed narrow spectral band. For this reason, the measured apparent magnitude of distant source of light will be additionally smaller by the factor $(1 + z)$ than that for a similar local source [33]. This fact requires to modify the formula (6.7) by adding a correction term – the so-called *K*-correction associated with this "non-selective" effect:

$$K = 2.5\lg(1+z). \qquad (6.8)$$

This correction was proposed and justified by John Oke and Alan Sandage in [33] (see "effect (*b*)" in formula (2)).

In order to compare the presented theory with the existing results of astronomical observations of SNe Ia in the blue band, we restrict ourselves to this basic correction. For the more scrupulous fitting of the universe parameters responsible for the correlation of SNe Ia peak brightness with their redshift, it is necessary, instead of (6.8), to use the empirically found progressively finer *K*-corrections [35] caused by the non-uniformity of the spectral distribution of the light energy in SNe Ia. But it seems that further refinement of the cosmological parameters would lead to additional calculations unreasonably cumbersome for the purposes of this article.

Finally, introducing the correction (6.8) into (6.7) we find the test formula for the peak apparent magnitudes of SNe Ia measured in any *X* band:

$$\mu_X(z) = 25 + \qquad (6.9)$$

$$+5\lg\left[\frac{2c(1+z)^{3/2}\cot\Omega t_0}{1\mathrm{Mpk}\cdot H_0}\left(\Omega t_0 - \arcsin\frac{\sin\Omega t_0}{\sqrt{1+z}}\right)\right].$$

Despite the unsightly form, this formula, as well as the initial redshift-distance relation (5.1), contains only two free adjustable parameters. These are the present values of the Hubble parameter H_0 and the phase Ωt_0 of the background field $\Psi(t)$, that make the formula very simple and convenient in fitting the observational data.

Next, we can use (6.9) to obtain the best suitable curve for an ensemble of measurement results for Type Ia supernovae characteristics by fitting these two parameters. According to our preliminary "manual" fitting to these data, the best values for the two adjustable parameters in (6.9) are

$$H_0 \simeq 68 \text{ kms}^{-1}\text{Mps}^{-1}, \qquad (6.10)$$

$$\Omega t_0 \simeq 0.68. \qquad (6.11)$$

From (4.13) it follows that the age t_0 of the current cycle can be calculated through parameters (6.10), (6.11) by the formula

$$t_0 = 2H_0^{-1}\Omega t_0 \cot \Omega t_0.$$

Thus, we find the value $t_0 = 24$ billion years, which we gave several times earlier.

Thus, the proposed gauge-invariant model of the massive scalar gravitational field, which underlies the presented cyclic scenario of the evolution of the universe without a hypothetical expansion, agrees well with the observational data from Type Ia supernovae accepted in extragalactic astronomy as standard candles.

We note straight away that our result (6.10) for the present value of Hubble parameter coincides with the recent (2020) result that was reached in [36] using the collaborative data from SNe Ia collected in [37]. And it is in excellent agreement with the value

$$H_0 = (67.4 \pm 0.5) \text{ kms}^{-1}\text{Mps}^{-1}$$

of the Hubble constant obtained in [38] by careful processing of precision data of 2018 from the *Planck* mission. [The previous two results, (67.3 ± 1.2) kms^{-1}Mps^{-1} and (67.8 ± 0.9) kms^{-1}Mps^{-1}, received early by *Planck* Collaboration in 2013 [39] and in 2015 [40] respectively, are also in perfect agreement with our estimate (6.10).]

REFERENCES

1. *Hubble*, *E.* A relation between distance and radial velocity among extra-galactic nebulae / E. Hubble // Proc. Nat. Acad. Sci. – 1929. – № 15. – P. 168 –173.

2. *Hubble*, *E.* The Observational Approach to Cosmology / E. Hubble. – Oxford: Oxford University Press. – 1937. – 54 p.

3. *Weinberg*, *S.* Gravitation and Cosmology: Principles and Applications of the General Theory of Relativity / S. Weinberg. – New York: Wiley, 1972. – 657 p.

4. *Serdyukova*, *M.A.* A Massive Gravitational Field in Flat Spacetime. I. Gauge Invariance and Field Equations / M.A. Serdyukova, A.N. Serdyukov // Problems of Physics, Mathematics and Technics. – 2019. – № 2 (39). – P. 45–53.

5. *Serdyukova*, M.A. A Massive Gravitational Field in Flat Spacetime. II. Conservation laws and gravitational variability of the inertial mass / M.A. Serdyukova, A.N. Serdyukov // Problems of Physics, Mathematics and Technics. – 2019. – № 3 (40). – P. 33–39.

6. *Chiu*, *H.-Y.* Introduction / H.-Y. Chiu, W.F. Hoffmann // Gravitation and Relativity (Eds. H.-Y. Chiu and W.F. Hoffmann). – New York: Benjamin. 1964. – 353 + xxxv p.

7. *Feynman*, *R.P.* The Feynman Lectures on Physics: Mainly Mechanics, Radiation, and Heat / R.P. Feynman, R.B. Leighton, M. Sands. – Reading, Massachusetts: Addison-Wesley, 1963. – 685 p.

8. *Okun*', *L.B.* Reply to the letter "What is mass?" by R.I Khrapko / L.B. Okun' // Physics – Uspekhi. – 2000. – № 43 (12). – P. 1270–1275.

9. *Kaku*, *M.* Parallel Worlds: The Science of Alternative Universes and Our Future in the Cosmos / M. Kaku. – London: Allen Lane. – 2004. – 448 p.

10. *Landau*, L.D. The Classical theory of fields. Vol. 2 of Course of Theoretical Physics / L.D. Landau, E.M. Lifshitz. – Oxford: Butterworth-Heinemann, 1987. – 428 p.

11. *Observational evidence from supernovae for an accelerating universe and a cosmological constant* / A.G. Riess [et al.] // Astron. J. – 1998. – № 116. – P. 1009–1038.

12. *Measurements of* Ω *and* Λ *from* 42 *high-redshift supernovae* / S. Perlmutter [et al.] // Astrophys. J. – 1999. – № 517. – P. 565–586.

13. *The high-z supernova search*: *Measuring cosmic deceleration and global curvature of the universe using Type* IA *supernovae* / B.P. Schmidt [et al.] // Astrophys. J. – 1998. – № 507. – P. 46–63.

14. *Hoyle*, *F.* Cosmological Models in a Conformally Invariant Gravitational Theory. I. The Friedmann Models / F. Hoyle, J.V. Narlikar // Mon. Not. R. astr. Soc. – 1972. – № 155. – P. 305–321.

15. *Hoyle*, *F.* Cosmological Models in a Conformally Invariant Gravitational Theory. II. A New Model / F. Hoyle, J.V. Narlikar // Mon. Not. R. astr. Soc. – 1972. – № 155. – P. 323–335.

16. *Narlikar*, *J.V.* Flat spacetime cosmology: A unified framework for extragalactic redshifts / J.V. Narlikar, H. Arp // Astrophys. J. – 1993. – № 405. – P. 51–56.

17. *Hubble*, *E.* The velocity-distance relation among extra-galactic nebulae / E. Hubble, M. Humason // Astrophys. J. – 1931. – № 74. – P. 43–80.

18. *A remarkably luminous galaxy at* $Z = 11.1$ *Measured with Hubble Space Telescope Grism Spectroscopy* / P.A. Oesch [et al.] // Astrophys. J. – 2016. – № 819 (2). – Article id. 129. – 11 p.

19. *Lyman-alpha emission from a luminous* $z = 8.68$ *galaxy*: *implications for galaxies as tracers of cosmic reionization* / A. Zitrin [et al.] // Astrophys. J. Lett. – 2015. – № 810 (1). – Article id. L12. – 6 p.

20. *Luminous Quasar at Redshift* 7.642 / F. Wang [et al.] // Astrophys. J. Lett. – 2021. – № 907 (L1). – 7 p.

21. *An* 800-*million-solar-mass black hole in a significantly neutral Universe at a redshift of* 7.5 / E. Bañados [et al.] // Nature. – 2018. – № 553. – P. 473–476.

22. *A galaxy rapidly forming stars* 700 *million ears after the Big Bang at redshift* 7.51 / S.L. Finkelstein [et al.] // Nature. – 2013. – № 502. – P. 524–527.

23. *A luminous quasar at a redshift of* $z = 7.085$ / D.J. Mortlock [et al.] // Nature. – 2011. – № 474. – P. 616–619.

24. *The Discovery of a Gravitationally Lensed Quasar at* $z = 6.51$ / X. Fan [et al.] // Astrophys. J. Lett. – 2019. – № 870 (2). – Article id. L11. – 6 p.

25. *Chandrasekhar*, *S*. The maximum mass of ideal white dwarfs / S. Chandrasekhar // Astrophys. J. – 1931. – № 74. – P. 81–82.

26. *Chandrasekhar*, *S*. An Introduction to the Study of Stellar Structure / S. Chandrasekhar. – Illinois: University of Chicago Press. – 1939. – 509 p.

27. *Chandrasekhar*, *S*. On Stars, Their Evolution and Their Stability (Nobel Lecture) / S. Chandrasekhar // Angew. Chem. Int. Ed. Engl. – 1984. – № 23. – P. 679–689.

28. *Branch*, *D*. Type Ia Supernovae as standard candles / D. Branch, G.A. Tammann // Annu. Rev. Astron. Astrophys. – 1992. – № 30. – P. 359–389.

29. *Anand*, *S.P.S*. On Chandrasekhar's limiting mass for rotating white dwarf stars / S.P.S. Anand // Proc. Natl. Acad. Sci. USA. – 1965. – № 54 (1). – P. 23–26.

30. *Yoon*, *S.-C*. Presupernova evolution of accreting white dwarfs with rotation / S.-C. Yoon, N. Langer // Astron. Astrophys. – 2004. – № 419. – P. 623–644.

31. *The Hubble Space Telescope Cluster Supernova Survey*. V. *Improving the dark-energy constraints above* $z > 1$ *and building an early-type-hosted supernova sample* / N. Suzuki [et al.] // Astrophys. J. – 2012. – № 746. – P. 85–108.

32. *Kasen*, *D*. On the origin of the Type Ia Supernova width-luminosity relation / D. Kasen, S.E. Woosley // Astrophys. J. – 2007. – № 656. – P. 661–665.

33. *Serdyukova*, *M.A*. A Massive Gravitational Field in Flat Spacetime. III. Gravitational variability of radioactive decay / M.A. Serdyukova // Problems of Physics, Mathematics and Technics. – 2019. – № 3 (40). – P. 40–42.

34. *Oke*, *J.B*. Energy distributions, K corrections, and the Stebbins – Whitford effect for giant elliptical galaxies / J.B. Oke, A. Sandage // Astrophys. J. – 1968. – № 154. – P. 21–32.

35. *K-Corrections and spectral templates of Type Ia Supernovae* / E.Y. Hsiao [et al.] // Astrophys. J. – 2007. – № 663. – P. 1187–1200.

36. *Rameez*, *M*. Is there really a Hubble tension? / M. Rameez and S. Sarkar // ArXiv E-Prints. – 2020. – 6 p. – [arXiv:1911.06456v2].

37. *Improved cosmological constraints from a joint analysis of the* SDSS-II *and* SNLS *supernova samples* / M. Betoule [et al.] // Astron. Astrophys. – 2014. – № 568 (A22). – 32 p.

38. *Planck* 2018 *results*. VI. *Cosmological parameters* / N. Aghanim [et al.] // ArXiv E-Prints. – 2018. – 71 p. – [arXiv:1807.06209].

39. *Planck* 2013 *results*. XVI. *Cosmological parameters* / P.A.R. Ade [et al.] // ArXiv E-Prints. – 2014. – 69 p. – [arXiv:1303.5076v3].

40. *Planck* 2015 *results*. XIII. *Cosmological parameters* / P.A.R. Ade [et al.] // Astron. Astrophys. – 2016. – № 594. – 63 p.

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