Proceedings of the Estonian Academy of Sciences,
2017, **66**, 2, 159–173
https://doi.org/10.3176/proc.2017.2.06
Available online at www.eap.ee/proceedings

COSMOLOGY

A physical model universe without dark energy and dark matter

Arved Sapar

Estonian Academy of Sciences, Kohtu 6, 10130 Tallinn, Estonia; sapar@to.ee

Received 16 November 2016, accepted 2 January 2017, available online 6 April 2017

Abstract. Postulating kinetic energy dominance (KED) in the flat or observationally quasi-flat elliptical model universe with neither dark matter nor dark energy, it has been demonstrated that the curves of apparent luminosity versus redshift as the distance measure in the KED model universe and in the standard ΛCDM universe for Ia type supernovae as the standard candles are well-matching ones. This circumstance demonstrates that in cosmology there is probably no need for additional gravitationally attractive dark matter and repulsive dark energy. The KED model universe incorporates an additive, $p_2 = -\rho_2 c^2/3$, to the equation of state that describes the total energy integral, often treated as a special case of 'quintessence'. The Einstein equations of general relativity have been tentatively modified in the spirit of Mach's principle, multiplying a new cosmological coefficient by the ratio of total retarding gravitational potential of matter in the universe to c^2. The KED model universe can originate from a collapsing huge-mass black hole in its internal region, describable by isotropic coordinates, as a new expanding universe. The mass of such a collapsing black hole passes, for a long time and with a constant rate, $\dot{M} = c^3/2G$, through the past horizon (Schwarzschild trap surface), generating a modified Milne-type expanding Big-Bang universe.

Key words: flat-space model universes, dark matter, dark energy, kinetic energy dominance.

1. SCENARIOS OF COSMOLOGY GUIDING TO ACCEPTING THE KINETIC ENERGY DOMINATED MODEL UNIVERSE

During some last decades the unexpected observational results in cosmology have generated hypothetical concepts or paradigms of dark matter and thereafter of dark energy, both used to match the physical parameters in the Friedmann–Einstein equations to different observational data of cosmology.

It deserves emphasizing that even the recent Nobel Prize winners of the acceleratively expanding universe paradigm have encouraged theoreticians to explain the physical nature of these hitherto largely hypothetical subjects. Thus, in the present study we try to demonstrate that an evolutionary scenario of the universe can be formulated without them.

Modern cosmology is based on the principles and equations of general relativity. In the derivation of the equations of general relativity a hundred years ago, one of Einstein's leading ideas was Mach's principle (Einstein, 1916a,1916b), stating that the equations for the gravitation field must be connected with the universe as the whole. However, Einstein equations of general relativity, similarly to original Maxwell equations of electromagnetic field (without non-local potentials) are usually treated as the local ones. Paradoxically, for a long time the idea of Mach's principle was implicitly discarded, and persons who nevertheless tried to discuss it were often rebuked for such a heretical line of reasoning.

Einstein estimated highly the deep physical nature and the mathematical majesty of Riemann geometry for the description of curved space-time in general relativity. However, he simultaneously emphasized the imperfectness of the energy-momentum tensor in the accepted form.

Several years later Friedmann (1922, 1924) derived his fundamental equations of expanding or contracting universe from general relativity applied to the isotropic and homogeneous, i.e. the uniform (Giordano Bruno's cosmological principle) universe filled with matter. Einstein, in order to obtain static universe, had earlier introduced the term with the cosmological constant. The name, given by Einstein, emphasizes that it can be essential for the solution of problems in cosmology and can therewith be somehow connected with Mach's principle.

Thereafter Lemaître (1927) showed that the universe, having the positive cosmological constant Λ, turns out to be exponentially expanding in time. He also estimated preliminarily the presence of the corresponding redshift in spectra of galaxies. As accepted nowadays, Λ can be treated as the hypothetical vacuum energy density.

Soon Hubble (1929), processing observational data, discovered that spectral lines of standard type galaxies have redshifts proportional to their distances. This demonstrated that the universe is uniformly expanding. The problem why the universe is expanding remained unexplained, being partly a puzzle hitherto.

A special-relativistic flat kinematical model universe was proposed by Milne (1935). It corresponds to an extreme Einstein–Friedmann universe model of zero energy density (an empty universe), which extrapolates the linear Hubble expansion law from Planck unit length to infinity in the flat Minkowski 4-space.

Thus, there appeared two different extreme evolutionary scenarios of model universes: the exponentially expanding Lemaître concept, based on the cosmological coefficient Λ, and the Milne scenario of the linearly in time expanding (almost) empty universe, which suits well for late evolutionary stages of the universe.

The Hubble expansion rate of the universe was three times recalibrated in the direction of twice larger distances, slower expansion, and longer age of the universe (Baade, 1952; Sandage, 1954, 1958). At the present time the expansion rate of the universe, named the Hubble constant, is estimated to be approximately 73 km/s per megaparsec. The inverse value of this quantity gives for the corresponding age of the universe 13.7 gigayears.

For some astrophysicists the result of the non-perpetual universe seemed unacceptable. So, Hoyle (1948, 1949) and later he with a co-author (Hoyle and Narlikar, 1964) proposed a concept of the steady-state universe that is expanding, but the density of matter in it is constant due to its steady creation. This property of the universe is the same as due to the cosmological constant. Pejoratively Hoyle named the concept of the initial or creation moment for the universe 'the Big Bang'. Contrary to his hopes, the term 'Big Bang cosmology' has survived in the modern cosmology.

Astronomers succeeded in determining distances to remote stellar systems with the needed high precision due to the presence of astronomical bodies that could be used as standard candles. The nearest distances have been determined by annual solar parallaxes of stars. These distances overlap with distances of the Cepheids, used as the standard candles, which have definite luminosity–period relations. For very large distances the Ia type supernovae (SNIa) have been used as extremely high-luminosity standard candles with a weak but definite time-dependence rate versus absolute luminosity. From the detailed analysis of the apparent luminosity versus redshift for SNIa, the concept of an acceleratively expanding universe was concluded (Perlmutter et al., 1998; Riess et al., 1998). In the 21st century the small effects have been extrapolated to the paradigm of an exponentially in time expanding universe.

Let us again go half a century back when radioastronomers Penzias and Wilson (1965a, 1965b) discovered the 3 K cosmic microwave background (CMB), which specified the thermodynamical state of the expanding universe. This was an unpleasant obstacle to Hoyle, who was convinced that the universe had been existing forever in the same state.

Somewhat earlier than the CMB was detected, we had started to study problems of relativistic cosmology (Sapar, 1964, 1965), trying to generalize the set of acceptable model universes. The emphasis in these papers was on the study of different principally observable relationships in the universe with cold matter and radiation, treated as predominantly the cosmic neutrino background. As an original feature, a class of model constituents with free parameters satisfying the general equation of state $3p_n = (n-3)\rho_n c^2$ was studied, which for $n = 3$ describes pressureless standing massive particles and for $n = 4$ the radiation assumed to be photons and neutrinos. In this pioneering paper also as possible model universes with contribution corresponding to $n = 2$ were studied and treated as a negative pressure component, i.e. additional pull instead of normal pushing pressure. Now we treat it as due to kinetic energy dominance in a model universe studied. Presently the equation of states is usually written in the form $p = w\rho c^2$, where $w = (n-3)/3$. A quantum-mechanical generation of different constants C_n, called Friedmann integrals, in the early universe at temperatures about 1 TeV, due to the interplay of the gravitational and electro-weak interactions, was proposed by Chernin (2001).

In the paper (Sapar, 1964) a number of analytical formulae, including for the universe with matter, radiation, and the kinetic energy integral in the flat space, were derived. These formulae are useful also nowadays and are partly used in the present paper. Differently from papers of most other cosmologists of that time, our analytical formulae, avoiding Taylor expansion relative to redshift, z, are valid also at large redshifts. Reaching such redshifts observationally seemed to us then unrealistic for centuries.

One trend in studies on cosmology has been to demonstrate that the initial Big-Bang universe was generated due to quantum fluctuations in vacuum, specified by the Planck units, which are composed of the fundamental constants of physics. The possibility of the creation of the universe from 'a primeval atom' was first discussed by Lemaître (1931).

We also studied the problem from some aspects (Sapar, 1977), but the problem how to connect the past horizon on a light cone causally with the Planck units remained unsolved. This problem found a solution at the beginning of the 1980s, when Guth (1980), Linde (1982), and Starobinsky (1980) proposed the concept that the very early universe passed through an inflationary (exponential in time) expansion, which increased no less than 2^{80} decimal orders its characteristic lengths due to repulsive forces, generated, say, by a hypothetical inflaton field. Thus, according to this concept, our presently causally connected world is only a tiny part of the inflated universe. According to the scenario, during the inflationary epoch also the bulk of matter was created from the excited vacuum state at (almost) constant density of matter, similarly to the Hoyle steady-state cosmology. This solution explained well the previous flatness and horizon paradoxes in model universes. The modelling has been essentially generalized by several mainstream cosmologists elaborating the scenario of the steady-state creation of universes similarly to Hoyle's concept of matter generation.

Presently a somewhat similar evolutionary scenario of transition to a dark energy dominated universe is ruling in the mainstream cosmology. In this concept the cosmological constant corresponds in the equation of state to $n = 0$, denoting that the energy density of vacuum is constant. This scenario is dynamically similar to the Lemaître model universe, but conceptually it is similar to the Hoyle steady-state universe.

A recent important pioneering observational result is undoubtedly the detection of the gravitational waves in the coalescence of two stellar-origin black holes (Abbot et al., 2016). This observation proved that, as expected, the velocity of gravitation waves is the same as the velocity of light. Up to now one could hesitate in the acceptability of light velocity to the gravitation phenomena, because no detectable gravitational retardation effects had been detected in the limits of the solar system where high-accuracy measurements have been conducted.

The detailed studies of stellar orbital velocity curves during about four last decades generated the observational concept of an essential contribution of enigmatic dark matter (about 25% of critical density) in the universe, which is about 5 times larger than the 5% contribution of the usual atomic matter in the universe. However, this can be true for galaxies in the vicinity of our galaxy due to the high concentration of the strongly down-cooled non-relativistic massive neutrino background, concentrated to stars and galaxies, but their total contribution can be rather marginal and can be ignored for the evolutionary scenario of the universe.

The concept of dark energy is strongly based on the concept of the paradigm of dark matter, and its repulsive force predominantly must compensate for the effects of gravitational attraction of dark matter. In the present paper, we shall study how well removable this cosmological push–pull phenomenon is.

The striving in the modelling of the universe in the direction of the lower mass component in it is interestingly realized by Benoit-Lévy and Chardin (2012). However, the most impressive and inspiring is the recent paper by Nielsen et al. (2016) about the almost marginal evidence for fundamental physics (about 3σ level) of the cosmic acceleration from extended analysis of the SNIa visible luminosity curve versus redshift parameter z. Their paper also demonstrated a good coincidence of luminosity curves of the standard ΛCDM cosmology and of the Milne universe models. This circumstance inspired us to study the kinetic energy dominated (KED) model universe in more detail, ignoring thereby fully both dark matter and dark energy and replacing them with kinetic energy dominance in the universe. A different likelihood maximization of the ΛCDM and the Milne-type, $R_h = ct$, model universe was also carried out in the recent papers by Melia (2012, 2013), Melia and Maier (2013), and Wei et al. (2015).

We accept a flat or observationally a quasi-flat elliptic model universe, where about 5% of the energy belongs to atomic matter and 95% is contributed by the KED. The age of such a KED universe corresponds well to the value of the Hubble age, fitting thus with the result that follows from the evolutionary scenarios of stars, stellar systems, and galaxies. Therefore the concept probably will not generate new contradictions or paradoxes, which have been always characteristic features of model universes. Only the short-time radiation-dominated epoch will become somewhat longer and the long mass-dominated epoch will shorten somewhat.

Both the KED model universe and the Milne kinematic model universes, if extrapolated to the Planck epoch, tend approximately to the Planck unit length. This circumstance enabled Tatum et al. (2015) to replace the scenario of inflationary expansion of the universe by an interesting alternative flat-space scenario. The time-proportional Schwarzschild radius and Hawking temperature of black holes have been successfully ascribed to this model universe. We demonstrate further that the expanding universe can also originate from a huge collapsing black hole.

Summing up, in our model universe dark matter and dark energy have been replaced by a single and well understood physical parameter – the total energy integral in the space. This model universe also enables better fitting of the contribution by massive very low-temperature neutrinos concentrating around stars and stellar systems, giving a small total contribution to the density of matter in the universe, and can modify the velocity curves of stars in galaxies (Sapar, 2011, 2014).

The Friedmann equations of cosmology divide the model universes by space geometry into three classes, specified by different values of the scaled curvature parameter k, namely:

(1) the forever expanding hyperbolic universes, if their kinetic energy exceeds the potential energy, $k = -1$;
(2) the flat universes, if the kinetic and potential energy are strictly equal, $k = 0$;
(3) the elliptic universes, if the potential energy exceeds the kinetic energy, $k = 1$.

Caldwell and Kamionkowski (2004) avoided such scaling and showed what the difference between the model classes in the luminosity versus distance formula is. The difference appears starting from the third degree term of the Taylor expansion relative to the redshift parameter z and incorporates explicitly the radius of the curvature of the universe, avoided in the traditional studies. The result means that high-precision measurements are needed to discriminate finally of which class the universe is.

We hope to demonstrate that applying in addition a concept of retarded gravitational potential of the universe in the spirit of Mach's principle can somewhat help to explain the properties of the locally empty space. An evident property of the matter in the whole universe is that bodies located at very large distances, for example quasars, galaxies, and the highest luminosity γ-ray bursters, specify the non-rotating reference frame far from them. In the reference systems, rotating relative to such a co-moving reference frame, the Coriolis and centrifugal forces appear.

2. AN ATTEMPT TO FORMULATE PHYSICALLY MACH'S PRINCIPLE

Now we try to modify the equations of general relativity in the spirit of Mach's principle. Thus we specify also the favoured reference frames for cosmology.

Einstein's system of 4-dimensional general relativity tensor equations has the form

$$R_{\mu\nu} - \frac{1}{2} g_{\mu\nu} R = \gamma T_{\mu\nu} - \Lambda g_{\mu\nu}, \quad \gamma = \frac{8\pi G}{c^4}. \tag{1}$$

In this form, where the Λ-term is placed on the right-hand side, we emphasize that it does not belong to the geometry but to the energy-momentum tensor, which for continuous matter accepted for cosmology has the form

$$T^{\mu\nu} = \big(\rho + \frac{p}{c^2}\big) v^\mu v^\nu + p g^{\mu\nu}, \quad v^\mu v_\mu = -c^2. \tag{2}$$

The scalar energy density of gravitation sources is determined as the trace of the energy-momentum tensor in the form

$$c^2 \rho_e = g_{\mu\nu} T^{\mu\nu}. \tag{3}$$

If the local matter density is ρ_e, then the gravitational potential of the universe can be expressed by

$$U = G \int \frac{\rho_e}{d_L} dV, \tag{4}$$

where d_L is the bolometric distance between an observer and the current source point, and dV is the volume element at the current past light cone point. The expression gives observers the retarded gravitational potential values. The corresponding Mach's principle modified Einstein's equations can be reduced to the form

$$\begin{gathered} R_{\mu\nu} - \frac{1}{2} g_{\mu\nu} R = \gamma T_{\mu\nu} - \frac{U}{c^2} \lambda g_{\mu\nu}, \\ ds^2 = c^2 d\tau^2 = g_{\mu\nu} dx^\mu dx^\nu = c^2 dt^2 - R^2 \left[d\omega^2 + \frac{\sin^2(\sqrt{k}\omega)}{k} (d\vartheta^2 + \sin^2 \vartheta d\varphi^2) \right]. \end{gathered} \tag{5}$$

Starting from here R is the curvature radius of the model universe and ω is the angular variable in the used isotropic coordinates. Thus, we have tentatively modified Einstein's equations of general relativity, multiplying a new cosmological coefficient λ of the type Λ by U/c^2, which gives a non-local contribution due to retarded and redshifted gravitational potential U of the matter inside the past light cone, as a physical realization of 'quintessence'.

3. GENERAL FORMULAE OF RELATIVISTIC COSMOLOGY

Further we will try to demonstrate that the observation data of SNIa luminosity curves can be well explained by replacing the contributions of the dark energy and the dark matter in model universes by the KED model universe, studied by us earlier (Sapar, 1964, 2013). Besides Einstein's equations, for cosmology the equations of light cones and of space geometry are essential.

The equation of light cone in the direction of ω is obtained from (5) taking into account that for photons the proper time $d\tau = 0$ and scaling to the space curvature, R, then it follows that

$$d\omega = c\frac{dt}{R} = c\frac{dR}{R\dot{R}}, \tag{6}$$

where the variable ω is named the angular variable.

The radial volume layer connecting the observer with the past by the light cone in the universe is

$$dV = 4\pi R^3 S_k^2(\omega) d\omega, \tag{7}$$

where, for brevity, dependence on the space curvature type of the model universes geometry

$$S_k(\omega) = \frac{1}{\sqrt{k}} \sin(\sqrt{k}\omega). \tag{8}$$

Here the generalized sine function for the hyperbolic model universes is $S_{-1}(\omega) = \sinh\omega$, for the flat universes it is $S_0(\omega) = \omega$, and for the elliptical model universes $S_1(\omega) = \sin\omega$. Thus, traditionally the hyperbolic model universes are kinetic energy dominated, the elliptic ones are potential energy dominated, and the flat universes are with strictly zero total energy.

From Einstein's equations for the conservation law $T^{\mu\nu};_\nu = 0$ follows a constraint on the equation of state

$$\dot{\rho}c^2 = -3\frac{\dot{R}}{R}(\rho c^2 + p), \tag{9}$$

which enables generation of matter if $p < 0$. Further, the physically simplest special cases are

$$\rho_n = \frac{C_n}{R^n}, \quad p_n = \frac{n-3}{3}\rho_n c^2. \tag{10}$$

If $\rho_n c^2 + p_n = 0$, i.e. if $n = 0$, then $\dot{\rho}_0 = 0$, and for the vacuum mass density, ρ_0, holds $\gamma\rho_0 = \Lambda$. The general expression of the energy-momentum tensor to the Friedmann equation contains the sum of all contributions ρ_n and p_n.

For the atomic matter $p_3 = 0$ and for radiation $p_4 = \rho_4 c^2/3$. By the present observed atomic mass density, ρ_o, and the present 4-dimensional redshifted radiation density constant, p_o, we can formulate the evolutionary constant contributions, defined correspondingly by

$$M = \frac{4\pi}{3}\rho_o R_o^3, \qquad W = \frac{4\pi}{3c^2} p_o R_o^4. \tag{11}$$

Here the indices o denote their present (observational) moment values and R_o is the current characteristic cosmological length. By using the characteristic length (the black hole Schwarzschild radius) α and a similar characteristic area β for radiation as in (Sapar, 1964, 2013), defined by

$$\alpha = \frac{2GM}{c^2}, \ \beta = \frac{2GW}{c^2}, \tag{12}$$

the most general Friedmann equation of model universes takes, expressed by dimensionless additives, the form

$$\frac{\dot{R}^2}{c^2} = \frac{\alpha}{R} + \frac{\beta}{R^2} + \kappa - k + \frac{1}{3}\Lambda R^2, \tag{13}$$

where k is the integration constant treated as the space curvature index, and κ is the KED integral contribution corresponding to $n = 2$ in the model universes (Sapar, 1964). From the temporal derivative of (13) it follows that κ and k do not participate in dynamics, and thus these can be treated as energy integrals.

Further we study mainly the flat universe without the cosmological constant and introduce the constant κ, scaling it to unity in the flat universe similarly to hyperbolic model universes. Thus we obtain a modified equation in the flat universe, which in form coincides with the hyperbolic universe but has different scaling and space geometry:

$$\frac{\dot{R}^2}{c^2} = \frac{\alpha}{R} + \frac{\beta}{R^2} + 1. \tag{14}$$

For the light cone the angular variable corresponding to the initial moment t_i is

$$\omega_i = c\int_{t_i}^{t_o} \frac{dt}{R} = c\int_{R_i}^{R_o} \frac{dR}{R\dot{R}}. \tag{15}$$

The bolometric distance d_i, used both for matter and radiation, is defined by

$$d_i = \frac{R_o^2}{R_i} S_k(\omega_i). \tag{16}$$

Now the retarding potential energy can be written in the form

$$U_o = \frac{GM}{R_o} C_o, \tag{17}$$

where the correction coefficient due to retardation and KED, obtained integrating over volume (7), is expressed by

$$C_o = \frac{3}{R_o} \int_0^{\Omega_o} R_i S_k(\omega_i) d\omega_i. \tag{18}$$

Here Ω_o is the past (particle) horizon value of ω_i, corresponding to the observation in the model universe at t_o if $t_i = 0$.

Similarly we obtain for the gravitational potential of radiation, taking into account also the redshift,

$$\Phi_o = \frac{GW}{R_o^2} C_o. \tag{19}$$

Now the problem has been reduced to finding the formulae for the correction term C_o and its numerical value for the flat KED model universes.

4. MAIN FORMULAE FOR FLAT-SPACE KED COSMOLOGY

As shown in our papers (Sapar, 2013, 1964), from Eq. (14) it follows that the needed indefinite integral

$$y \equiv y(R) = 2Q + 2R + \alpha, \quad Q = \frac{cR}{\dot{R}} = \sqrt{R^2 + \alpha R + \beta} \tag{20}$$

and by it the angular variable for the definite integral is

$$\omega_i = \ln\big(y(R_o)/y(R_i)\big). \tag{21}$$

Consequently

$$y(R_i) = y(R_o) e^{-\omega_i}. \tag{22}$$

From (20), squaring Q, we find that inversely

$$R(y) = \frac{1}{4}\big(y - 2\alpha + (\alpha^2 - 4\beta) y^{-1}\big). \tag{23}$$

Now the needed dependence for $R(\omega_i)$ is

$$R_i = R(\omega_i) = \frac{1}{4}\left(y(R_o) e^{-\omega_i} - 2\alpha + (\alpha^2 - 4\beta) \frac{e^{\omega_i}}{y(R_o)} \right). \tag{24}$$

The numerical values of parameters α, β, and R_0 are to be found by taking initially $R_o = R_H = c/H_o = 1.267 \cdot 10^{29}$ cm and solving thereafter iteratively the formulae

$$\alpha = \frac{8\pi G \rho_m R_o^3}{3c^2}, \tag{25}$$

$$\beta = \frac{8\pi G\rho_r R_o^4}{3c^2}, \tag{26}$$

and the corrected value of R_o from the KED equation for distance scale

$$H_o R_o = c\left(\frac{\alpha}{R_o} + \frac{\beta}{R_o^2} + 1\right)^{1/2}. \tag{27}$$

Now we start to compute the reduced bolometric distance curves versus redshift z. We study two different model universes, one being KED and the other ΛCDM model universe, which both have three sure parameters. These parameters are the observed Hubble constant H_o =73 km·sec^{-1}·Mpc^{-1}, the critical mass density $\rho = 1.00\cdot 10^{-29}$ g· cm^{-3} corresponding to flat model universe, with given H_o and the weak cosmic background radiation density $\rho_r = 4.3\cdot 10^{-34}$ g· cm^{-3}, corresponding to 2.7 K.

Their different parameters are the following:

(1) For the KED model universe the density of atomic matter $\rho_m = 0.5\cdot 10^{-30}$ g· cm^{-3}.
From these parameters we obtained $\alpha = 1.178\cdot 10^{27}$ cm, $\beta = 7.643\cdot 10^{51}$ cm^2, and $R_o = 1.300\cdot 10^{28}$ cm.

(2) For the ΛCDM model universe the density of matter, including dark mass, $\rho_m = 2.9\cdot 10^{-30}$ g· cm^{-3}.
From these parameters we obtained $\alpha = 6.133\cdot 10^{27}$ cm, $\beta = 1.367\cdot 10^{52}$ cm^2, and $R_o = 1.504\cdot 10^{28}$ cm.

Having fixed the parameters for our proposed flat KED model universe we can find its retarded gravitation potential correction coefficient (18).

First, the past horizon value of angular variable ω_i is

$$\Omega_o = \ln Y_o, \quad Y_o = y(R_o)/y(0). \tag{28}$$

Using this quantity and integrating (18), taking into account also (24), we obtain the correction coefficient to the local gravitational potential of the universe at the present epoch in the form

$$C_o = \frac{3}{4R_o}\left(y(R_o)E_m - \alpha\Omega_o^2 + (\alpha^2 - 4\beta)\frac{E_p}{y(R_o)}\right), \tag{29}$$

where integrating gives

$$E_p = Y_o(\Omega_o - 1) + 1 \tag{30}$$

and

$$E_m = -\frac{1}{Y_o}(\Omega_o + 1) + 1. \tag{31}$$

Numerically we obtained $C_o = 2.713$.

The time interval is obtained by

$$c(t_o - t_i) = \int_{R_i}^{R_o} \frac{RdR}{Q} = Q_i - \frac{\alpha}{2}\omega_i, \quad Q_i = Q(R_o) - Q(R_i). \tag{32}$$

The age of the KED universe T_0 is thus

$$cT_K = \int_0^{R_o} \frac{RdR}{Q} = Q_o - \frac{\alpha}{2}\Omega_o, \quad Q_o = Q(R_o) - Q(0). \tag{33}$$

For the standard Λ and massive matter cosmology the age T_Λ of the universe, making re-scaling $R = R_o a$, ignoring β-term, and taking into account that $\int dx/\sqrt{\gamma^2 + x^2} = \ln(x + \sqrt{\gamma^2 + x^2})$, has the form

$$cT_\Lambda = \int_0^{R_o} \frac{\sqrt{R}dR}{\sqrt{\alpha + \Lambda R^3/3}} = \sqrt{\frac{3}{\Lambda}}\int_0^1 \frac{a^{1/2}da}{\sqrt{\gamma^2 + a^3}} = \frac{2}{\sqrt{3\Lambda}}\ln\left(\frac{1+\sqrt{1+\gamma^2}}{\gamma}\right); \;\; \gamma = \frac{3^{1/2}\alpha^{1/2}}{R_o^{3/2}\Lambda^{1/2}}. \tag{34}$$

For observations, in units of critical density and ignoring the β term, we can write

$$\frac{\dot{a}^2}{a^2} = H_o^2(\Omega_m a^{-3} + \Omega_\Lambda), \quad \Omega_\Lambda + \Omega_m = 1, \tag{35}$$

from where by integrating we obtain

$$T_\Lambda = \frac{2}{3H_o\sqrt{\Omega_\Lambda}} \ln\left(\frac{1+\sqrt{\Omega_\Lambda}}{\sqrt{\Omega_m}}\right). \tag{36}$$

From here it follows that for the given model universe $T_\Lambda = 13.04$ Gyr.

For the KED model universe, in units of any density, we can write in similar but now conventional scaling

$$\frac{\dot{a}^2}{a^2} = H_o^2(\Omega_m a^{-3} + \Omega_K a^{-2}), \quad \Omega_K + \Omega_m = 1, \tag{37}$$

from where, taking into account that integrating, $\int x^2 dx/\sqrt{\gamma^2+x^2} = \frac{x}{2}\sqrt{\gamma^2+x^2} - \frac{\gamma^2}{2}\ln(x+\sqrt{\gamma^2+x^2})$, we obtain

$$T_K = \frac{1}{H_o\sqrt{\Omega_K}}\left[\sqrt{\gamma^2+1} - \gamma^2 \ln\left(\frac{1+\sqrt{1+\gamma^2}}{\gamma}\right)\right], \quad \gamma = \sqrt{\Omega_m/\Omega_K}, \quad \Omega_K + \Omega_m = 1. \tag{38}$$

From here it follows that for the flat KED model universe $T_K = 12.52$ Gyr.

Summing up, by the KED concept the dark energy and dark mass can be replaced by the kinetic energy integral of the universe. However, iterative fine tuning of the age of the universe is necessary. This incorporates modifications due to relativistic and particle generation effects at primordial high temperatures, but also the effect of variable Mach multiplier, C_o, for the evolutionary scenario of the model universes.

5. DISTANCE VERSUS REDSHIFT FOR FRIEDMANN–EINSTEIN COSMOLOGY

Next we give also the formulae for ω model universes studied. For the ΛCDM model

$$\omega_\Lambda = \frac{c}{H_o R_o}\int_{a_i}^{1} \frac{da}{a(\Omega_m/a + \Omega_\Lambda a^2)^{1/2}} \tag{39}$$

and for the KED model universe

$$\omega_K = \frac{c}{H_o R_o}\int_{a_i}^{1} \frac{da}{a(\Omega_m/a + \Omega_K)^{1/2}}. \tag{40}$$

Denoting $a = x^2$, we obtain

$$\omega_K = \frac{c}{H_o R_o\sqrt{\Omega_K}}\int_{\sqrt{a_i}}^{1} \frac{2dx}{(\gamma^2+x^2)^{1/2}} = \frac{2c}{H_o R_o\sqrt{\Omega_K}} \ln\left(\frac{1+\sqrt{\gamma^2+1}}{\sqrt{a_i}+\sqrt{\gamma^2+a_i)}}\right), \quad \gamma = \sqrt{\Omega_m/\Omega_K}. \tag{41}$$

By using these formulae we study whether the SNIa visible light curve versus distance measured from spectral line redshifts is in accordance with the proposed KED model universe. The redshift variable on the past light cone, z, is given by

$$a = (1+z)^{-1}. \tag{42}$$

Thus we obtain for the ΛCDM model universe the scaled bolometric distance d_Λ, expressed via redshift, a simple expression

$$d_\Lambda = (1+z)\omega_\Lambda. \tag{43}$$

For the KED model universe the similarly scaled bolometric distance is

$$d_K = (1+z)\omega_K. \tag{44}$$

Our next task is to compare the reduced bolometric distances d_Λ and d_K. Therefore we present in Fig. 1 $\log d_K$ and $\log d_\Lambda$ versus z and, in addition, in Fig. 2 $\log(1+d_K)$ and $\log(1+d_\Lambda)$ versus z in order to see better the run of d at small redshifts. As we can see, these curves differ only slightly.

A figure similar to our Fig. 1 was published by Choudhury and Padmanabhan (2005), who based on the best observation data available at that time for the determination of cosmological parameters from SNIa data,

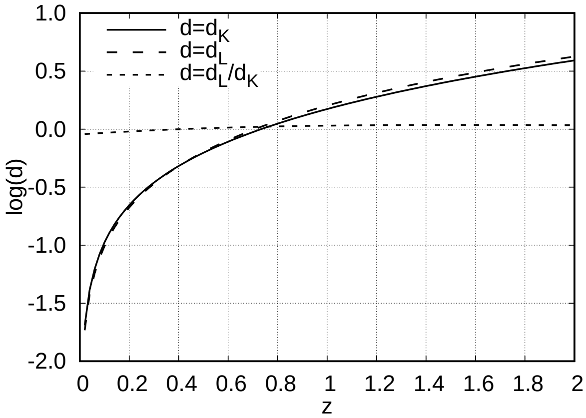

Fig. 1. The run of scaled distance $\log d_\Lambda$ for a flat model universe with matter and cosmological constant and for the KED model universe $\log d_K$, both versus the redshift, z. The illustrative difference of curves $d = d_\Lambda/d_K$ is small at any redshift.

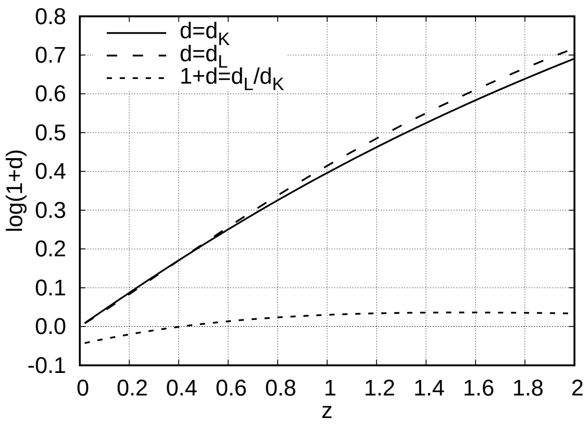

Fig. 2. The run of $\log(1+d_\Lambda)$ for a flat model universe with matter and cosmological constant and for the KED model universe $\log(1+d_K)$ versus the redshift. The difference of the curves where $1+d = d_\Lambda/d_K$ at redshifts $z>1$ is approximately 1.08 or $\Delta M = 0.17$, which lies well inside the error band of SNIa reduced data.

critically analysed and compared three most confident observation data sets. The analysis based dominantly on the published data of Nobel Prize winners Perlmutter, Riess, and their colleagues. One of the sets included also observation data by the Planck satellite telescope, where the largest redshift is about $z = 1.8$. They analysed a wide range of possible variants of model universes, particularly the model universes where the Λ-term is a redshift dependent quintessence. Their main conclusion was that it is impossible to single out the uniquely correct model universe from the present observation data. In these and more recent observations the half-widths of the error bars for remote distances in stellar magnitudes are typically about 0.3.

In Figs 1 and 2 the differences of our curves at any value of z remain inside the band of error bars. Thus, we conclude that hitherto there is no urgent need to introduce any dark energy or quintessence. We can hardly find any decisive argument in favour of Λ without using data of essentially higher precision.

It deserves emphasizing that in addition to the apparent luminosity curves, an important role has been played by small inhomogeneities in the angular diameters of the CMB generated by acoustic waves.

The distance by the apparent angular diameter is defined by

$$d_\theta = \frac{R_i^2}{R_o^2} d_L = \frac{d_L}{(1+z)^2}, \tag{45}$$

which is essentially smaller than the luminosity distances. This means that the angular distances of objects at large z values depend as $d_\theta \propto z^{-1}$. Therefore the angular details of CMB extend to several degrees.

Cosmologists studying fine structure details of the CMB based on data by the WMAP satellite telescope mission (Bennett et al., 2003a, 2003b; Spergel et al., 2003) and by the BICEP operation telescope on the South Pole (Ade et al., 2014), concluded that our universe is close to being flat. This was a decisive motive why we concentrated here on studying observationally flat model universes.

From Planck satellite observations it was found that there exist inhomogeneities of small amplitude but large area (many solid angle square degrees) in the CMB. This can be explained by the primordial small inhomogeneities of the KED model universe.

6. EQUATIONS FOR MODIFIED COSMOLOGICAL CONCEPTS

We discuss here the Milne-type model universes and their interconnection with the KED-type universes. The final analytical formulae derived below give a possibility of explaining the interconnection between these model universes. From formulae (12) and (13) for late evolutionary stages with only α-term matter, it follows that the following holds

$$H^2R^2 = \dot{R}^2 = \frac{2GM}{R}. \tag{46}$$

This is the classical condition of equality of the kinetic and the potential energy of the expanding universe. If $\dot{R} = c$, then our model universe reduces to a version of the Milne kinematic expanding universe with matter creation, described by $2GM/R = c^2$, corresponding to the Schwarzschild radius of the black hole, due to which the universe is steadily on the critical density level, and thus the present moment in this aspect does not differ from any moment. Such model universe is investigated in a paper by Tatum et al. (2015) and in their former papers. This means that according to this concept, the universe expands steadily with light velocity c from Big-Bang Planck units up to the present, at which approximately $R = ct$ and $\dot{R} = c$.

This is also a most important feature of the Milne kinematic model universe in the flat space. Thus, this model universe replaces a very short inflationary period of the universe expansion with a continuous steady-state expansion and matter creation in the spirit of Hoyle. More physically it can be treated as a continuous fall of black hole matter into the white hole generated universe with its generation rate given by

$$\dot{M} = c^3/2G. \tag{47}$$

This equation demonstrates that for the white hole as the world-generating source the mass generation rate has a constant value and the lack of the Planck constant in it testifies that it is specialized without any need of quantum mechanics.

The Milne-type model universes were extensively studied by Melia (2012, 2013), Melia and Maier (2013), and Wei et al. (2015). These model universes deserve to be studied due to their almost excellent fit with the ΛCDM luminosity curve for SNIa standard star candles (Nielsen et al., 2016).

At the Planck epoch the classical Schwarzschild black hole radius and the de Broglie–Compton quantum wavelength $\lambda = \hbar/mc$ for Planck mass particles (maximons) turned out to be equal ones (Sapar, 1977). The maximons have final mass of Hawking's decaying classical black holes and to them can be ascribed the maximum mass and shortest (Planck) wavelength of quantum particles.

Next we need to emphasize the role of slow velocities or classic mechanical evolutionary cooling of particles in the expanding universe after the photons are released during the CMB formation epoch.

It is clear that during the evolution of the universe both the potential energy and the kinetic energy of atomic particles must pass transition from the relativistic stage to the non-relativistic (classical mechanics) stage. Taking into account the de Broglie wave-pilot principle of matter waves in the form $p = h/\lambda$ it follows that its equation of state is characterized by $n = 5$ or $\varepsilon = (n-3)/3 = 2/3$. Thus we can write

$$\rho_5 = \frac{C_5}{R^5}, \tag{48}$$

which gives an additional contribution into the Friedmann–Einstein equations, namely

$$\frac{\dot{R}^2}{c^2} = \frac{\alpha}{R} + \frac{\beta}{R^2} + \frac{\gamma}{R^3} + \kappa - k, \quad U = \frac{4\pi U_0 R_0^5}{3}, \quad \gamma = \frac{2GU}{c^2}, \quad k = \frac{2GM_c}{c^2 R_c}. \tag{49}$$

The quantity k here is due to Mach's principle incorporating a term of the potential of the universe. This equation demonstrates that non-relativistic particles are cooling with temperature $T \propto R^{-2}$, i.e. by the law acquiring much lower temperatures than the photon background. Due do this circumstance the neutral atomic particles in the post-neutralization 'dark ages' are cooling rapidly, which favours the formation of stars and galaxies. The same holds for the last evolutionary stage of massive neutrinos, which have cooled to slow velocities and thus can concentrate to galaxies, forming in them an almost central-symmetrical dark mass halo (Sapar, 2014). The rest energy of neutrinos is probably of the order 0.1 eV, giving about 0.7% of the present critical Hubble density.

As demonstrated by Eddington (1924), the Schwarzschild internal metric can be transformed into the isotropic coordinates, which can be given in the form

$$ds^2 = \left(\frac{1 - \frac{R_S}{4R_c}}{1 + \frac{R_S}{4R_c}}\right)^2 c^2 dt^2 - \left(1 + \frac{R_S}{4R_c}\right)^4 (dR_c^2 + R_c^2 d\Omega^2), \quad R_S = \frac{2GM_c}{c^2}. \tag{50}$$

Here R_c is the curvature radius of the universe, M_c is the current mass in the white-hole universe, and Ω is the solid angle. For the flat-space isochronic lightcones $ds = 0$ and $d\Omega = 0$, from where we obtain

$$\dot{R}_c = c\left(1 - \frac{R_S}{4R_c}\right)\left(1 + \frac{R_S}{4R_c}\right)^{-2}. \tag{51}$$

An essential feature of this metric is that in the isotropic form for the curvature radius R_c appears $\dot{R}_c$, which determines the evolutionary scenario of the universe. During the initial scenario the formalism coincides with the Milne cosmology concept by

$$M_c = \dot{M}_c t, \quad R_S = \frac{2GM_c}{c^2}, \quad \frac{4\pi}{3}\rho_c = \dot{M}_c R_c^{-2}, \tag{52}$$

and thus the equation for the white-hole model universe evolution scenario is

$$\dot{R}_c = \frac{R_c}{t} = c\left(1 - \frac{G\dot{M}_c t}{2R_c}\right)\left(1 + \frac{G\dot{M}_c t}{2R_c}\right)^{-2}. \tag{53}$$

Thus it follows from here that if all black-hole mass is transferred to the white-hole generated world, i.e. if $t > t_m$, then $\dot{M} = 0$, $M = M_S$, and $R \gg R_S$, and for late evolutionary stages of the universe we obtain

$$\dot{R}_c = c\left(1 - \frac{R_S}{R_c}\right) \Rightarrow c, \quad R_c \Rightarrow ct \tag{54}$$

as a feature of the Milne universes.

The result can be interpreted as the generation of a new expanding isotropic white hole in 3-space. If the collapsed black hole had a definite time-dependent mass source rate, $\dot{M}$, then inside the white hole universe it could be treated as the creation of matter, having a definite ratio $M_c/R_c = \dot{M}_c/\dot{R}_c$.

Thus, if similarly applied to the picture for the 4-dimensional Euclidean space, then instead of a white hole it would be necessary to use the inner metric of the expanding universe with a constant rate $\dot{M}$, describing the Milne expanding flat-space universe and fitting well with the SNIa luminosity curve. The discussion demonstrates that the Big Bang from quantum theoretical Planck units followed by inflation can be replaced topologically by a concept of creation of matter, corresponding to $n = 2$ in (9) for the Milne universe model of Tatum et al. (2015).

7. GENERAL DISCUSSION

For dozens of centuries human generations have tried to give a contribution to understanding the origin and nature of our surrounding environment and of the universe. Present cosmologists are not exceptional in this aspect. However, the revolutionary progress in the astronomical instrumentation, fundamental physics, theoretical astrophysics, and computing facilities during the last century have promoted cosmology to enable detailed studies of the birth and different evolutionary stages up to the present epoch, but also prognostication of the future of our universe for gigayears.

The main equations of cosmology are simple; nevertheless, there have continuously been different paradoxes and paradigms, which have been overcome step-by-step but, as a rule, new challenges of deeper nature have been generated. Such is also the situation in the current cosmology. The main mysteries for the last decades have here been the nature of dark matter and of dark energy, which have been introduced to match the theoretical results with observational data. This has also generated a boom in observational and theoretical search of astroparticles, including quite new and puzzling ones. Unfortunately these researches have hitherto remained without essential success.

Our studies in cosmology started slightly more than half a century ago. Even at that time it was clear that the main constituents in the evolving universe have been and are matter, which consists of atomic particles, and radiation – photons and neutrinos. We derived new, mostly analytical formulae, describing the evolution of the universe filled with atomic particles, radiation, and negative, i.e. sucking or pulling, additive pressure terms, describing only the gravitational interaction between them.

The thermodynamical state of the universe was then unknown, although some theoreticians, including Gamow and Dicke, had made pioneering forecasts in this field. With the discovery of the 2.7 K cosmic radiation background this deficiency was overcome. Thereafter several cosmologists, among them also I, when extrapolating Friedmann equations back to the past reached the Planck epoch of the Big Bang, characterized by fundamental constants of physics. All seemed to be nice, except that the characteristic scale of the evolving universe for primordial evolutionary stages for the Planck epoch was in the evolutionary scenario about 30 decimal orders larger than the Planck length. This contradiction has been removed from observational paradox status by prominent theorists, who proposed and elaborated the theory of inflationary expansion of the universe. This can serve as a testimony that success in cosmology often relies on bold hypotheses. A similar situation has now been assumed by accepting the dark energy paradigm.

In the mainstream cosmology the efforts to give a physically reasonable meaning to dark mass and dark energy have been on the agenda for more than two decades. Time flies but, figuratively speaking, the big fish have remained in the deep and wild seas. This is a motive why we have chosen the conservative way, which is based on the traditional physical quantities and laws in the spirit of Occam's razor concept.

We analysed in the present paper also an alternative possible scenario of the formation of our Big-Bang universe from Eddington isotropic coordinates in the internal region of huge black holes (probably having a mass more than 10^{56} g), starting from Eddington isotropic coordinates. It turns out that such mass passes for a long time and with a constant transfer rate through the past horizon or Schwarzschild trap surface, generating a modified Milne-type expanding Big-Bang universe with the creation of matter.

The KED universe concept proposed here by us can help to remove the necessity of both dark energy and dark mass. The model corresponds to the Newtonian expanding KED model universe. As another essential feature, the contribution of massive neutrinos, cooled to non-relativistic velocities and concentrated as dark matter in galaxies, can be of importance (Sapar, 2014). The most problematic but luring result seems to be the origin of our Big-Bang universe in the internal part of a huge collapsing black hole.

And last but not least, an attempt has been made to formulate Mach's principle by multiplying the cosmological constant of the model universe with the retarded and redshifted gravitational potential. This can help also to understand the generation of Coriolis and centrifugal forces.

ACKNOWLEDGEMENTS

I am grateful to the Estonian Academy of Sciences for partial financial support of the present paper and for appreciating the established fruitful scientific community of cosmologists. The publication costs of this article were covered by the Estonian Academy of Sciences.

REFERENCES

Abbot, B. P., Abbot, R., Abbot, T. D., et al. 2016. GW151226: Observation of gravitational waves from a 22-solar-mass binary black holes coalescence. *Phys. Rev. Lett.*, **116**, 241103, 1–14.

Ade, P. A. R., Aikin, R. W., Barkats, D., et al. 2014. Detection of *B*-mode polarization at degree angular scales by BICEP2. *Phys. Rev. Lett.*,**112**, 241101.

Baade, W. 1952. A revision of extra-galactic distance scale. *Trans. IAU*, **8**, 397–398.

Bennett, C. L., Bay, M., Halperk, G., et al. 2003a. The *Microwave Anisotropy Probe* mission. *Ap.J.*, **583**, 1–23.

Bennett, C. L., Hill, R. S., Hinshaw, G., et al. 2003b. First-year *Wilkinson Microwave Anisotropy Probe (WMAP)* observations: foreground emission. *Ap.J. Suppl.*, **148**, 97–117.

Benoit-Lévy, A. and Chardin, G. 2012. Introducing the Dirac–Milne universe. *A&A*, **537.** Manuscript No. BLC11, 1–12.

Caldwell, R. R. and Kamionkowski, M. 2004. Expansion, geometry and gravity. *J. Cosm. Astropart. Phys.*, **9**, 1–6.

Chernin, A. D. 2001. Discovering internal symmetry in cosmology. astro-ph/10003C.

Choudhury, T. R. and Padmanabhan, T. 2005. Cosmological parameters from supernova observations: a critical comparison of three data sets. *A&A*, **429**, 807–818.

Eddington, A. S. 1924. *The Mathematical Theory of Relativity*. Cambridge University Press.

Einstein, A. 1916a. Grundlage der allgemeinen Relativitätstheorie. *Annalen der Physik (Ser. 4)*, **49**, 769–822.

Einstein, A. 1916b. Ernst Mach. *Physikalische Zeitschrift*, **17**, 101–104.

Friedmann, A. 1922. Über die Krümmung des Raumes. *Z. Phys.*, **10**, 377–386.

Friedmann, A. 1924. Über die Möglichkeit einer Welt mit konstanter negativer Krümmung des Raumes. *Z. Phys.*, **21**, 326–332.

Guth, A. H. 1980. Inflationary universe: a possible solution to the horizon and flatness problem. *Phys. Rev.*, D**23**, 347–356.

Hoyle, F. 1948. A new model of expanding universe. *MNRAS*, **108**, 372–382.

Hoyle, F. 1949. On the cosmological problem. *MNRAS*, **109**, 363–371.

Hoyle, F. and Narlikar, J. V. 1964. A new theory of gravitation. *Roc. Roy. Soc. A*, **282**, 191–207.

Hubble, E. 1929. A relation between distance and radial velocity among extra-galactic nebulae. *P. Natl. Acad. Sci.* USA, **15**(3), 168–173.

Lemaître, G. 1927. Un univers homogène de masse constante et de rayon croissant, rendant compte de la vitesse radiale des nébuleuses extragalactiques. *Ann. Sci. Soc. Brux.*, **47A**, 41–49.

Lemaître, G. 1931. The beginning of the world from the point of view of quantum theory. *Nature*, **127**, 706.

Linde, A. D. 1982. A new inflationary universe scenario: a possible solution of the horizon, flatness, homogeneity, isotropy, and primordial monopole problems. *Phys. Lett. B*, **108**, 389–393.

Melia, F. 2012. Fitting the Union2.1 SN sample with the $R_h = ct$ universe. *Astron. J.*, **144**, A110.
Melia, F. 2013. The $R_h = ct$ universe without inflation. *A&A*, **553**, A76.
Melia, F. and Maier, R. S. 2013. Cosmic chronometers in the $R_h = ct$ universe. *MNRAS*, **432**, 2669–2675.
Milne, A. 1935. *Relativity, Gravitation and the World Structure*. Oxford University. Press.
Nielsen, J. T., Guffanti, A., and Sarkar, S. 2016. Marginal evidence for cosmic acceleration from Type Ia supernovae. *Sci. Rep.*, **6**, Article No 35596.
Penzias, A. A. and Wilson, R. W. 1965a. A measurement of excess antenna temperature at 4080 Mc/s. *Ap.J. Lett.*, **142**, 419–421.
Penzias, A. A. and Wilson, R. W. 1965b. A measurement of the flux density of Cas A at 4080 Mc/s. *Ap.J. Lett.*, **142**, 1149–1154.
Perlmutter, S., Aldering, G., Goldhaber, G., et al. 1998. Measurements of Ω and Λ from 42 high-redshift supernovae. *Ap.J.*, **517**, 565–586.
Riess, A. G., Filippenko, A. V., Challis, P., et al. 1998. Observational evidence from supernovae for an accelerating universe and a cosmological constant. *Ap.J.*, **116**, 1009–1038.
Sandage, A. 1954. The first four years of extragalactic research with the Hale 200-inch telescope. *Astron. J.*, **59**, 180–
Sandage, A. 1958. Current problems in the extragalactic distance scale. *Ap.J.*, **127**, 513–526.
Sapar, A. 1964. Theory of some observable quantities in the cosmology of uniform universe. *Publ. Tartu Astrophys. Obs.*, **34**, 223–318.
Sapar, A. 1965. Theory of some observable quantities in the cosmology of uniform universe. II. *Tartu Astr. Obs. Teated*, **13**, 1–105.
Sapar, A. 1977. Evidence for the fundamental role of Planck units in cosmology. *Publ. Tartu Astrophys. Obs.*, **45**, 204–210.
Sapar, A. 2011. Cosmological neutrino background and connected problems. *Baltic Astronomy*, **20**, 267–274.
Sapar, A. 2013. Physical alternative to the dark energy paradigm. *Baltic Astronomy*, **22**, 315–328.
Sapar, A. 2014. Dynamics of cosmic neutrinos in galaxies. *Baltic Astronomy*, **23**, 71–91.
Spergel, D. N., Verde, L., Peiris, H. V., et al. 2003. First-year *Wilkinson Microwave Anisotropy Probe (WMAP)* observations: determination of cosmological parameters. *Ap.J. Suppl.*, **148**, 175–194.
Starobinsky, A. A. 1980. A new type of isotropic cosmological models without singularity. *Phys. Lett. B.*, **91**, 99–102.
Tatum, E. T., Seshavatharam, U. V. S., and Lakshminarayana, S. 2015. Flat space cosmology as an alternative to LCDM cosmology. *Frontiers Astron. Astrophys. Cosmology*, **1**, 98–104.
Wei, J.-J., Wu, X.-E, Melia, F., and Maier, R. S. 2015. A comparative analysis of the supernova legacy survey sample with ΛCDM and the $R_h = ct$ universe. *Astron. J.*, **149**, 102–112.

Füüsikaline tumeenergiast ja tumeainest vaba mudeluniversum

Arved Sapar

Modifitseerides Friedmanni-Einsteini universumi evolutsiooni võrrandeid vaadeldavas üsna tasaruumilises universumis kineetilise energia dominantseteks (KED) võrranditeks, on näidatud, et vaatlustulemuste tänapäevast täpsust arvestades saab vaatlusandmetega kooskõlaliselt pidada hüpoteetilise tumeenergia ja tumeaine sisalduvust universumis nulliseks, kui võtta kasutusele KED tasaruumilise või nõrgalt elliptilise universumi mudel. Nõrgalt elliptilise universumi mudelil on see eelis, et see võimaldab meie universumi teket kirjeldada kollabeeruva musta augu siseruumis kujunevana. KED-universumi evolutsiooni kirjeldamiseks on esitatud analüütilised valemid.

On näidatud, et mitterelativistlike osakeste – aatomite ja seisumassiga neutriinode – temperatuur universumis kahaneb mitte võrdeliselt universumi paisumisteguriga, vaid selle ruuduga, soodustades seega oluliselt tähtede ja galaktikate teket ning seisumassi omavate neutriinode koondumist neisse. Modifitseerides Friedmanni võrrandit Machi printsiibile toetudes, on Einsteini üldrelatiivsuse võrrandsüsteemis asendatud kosmoloogilist konstanti sisaldav liige avaldisega, mis seostab lokaalse gravitatsioonivälja ka paisuva universumi gravitatsioonipotentsiaaliga. On näidatud, et meie universumi kujunemine ja areng on käsitletav Milne'i kinemaatilise universumi, s.o valguse kiirusega paisuva tasaruumilise universumi mudeli üldistusena, mis on üldrelatiivsusteooriast tuletatav ülisuure massiga kollabeeruva 'musta aukuniversumi' baasil kujuneva suure paugu universumina. Seejuures saabub läbi valguskoonuse horisondi kui lõkspinna meie universumisse pidevalt ainet konstantse ajatuletisega määratult. See muudab kõik ajahetked samaväärseteks, vältides praeguse, homotsentrilise ajastu eristaatust.