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COSMOLOGY

Observables in a spatially flat Planckian universe

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Abstract. An evolutionary scenario of processes, especially of the thermodynamic processes, in a perpetually mass-generating Planckian model universe has been studied. This is a Milne-type flat-space, $R = ct$, model with steady radial mass flow as recently described by us. In this 'Broadcasting TV' model universe the rest-mass particles are moving practically with light speed and the neutrinos and photons, both in thermal equilibrium and decoupled states, are moving in (almost) perpendicular directions along the light cones as the frozen-in particles. Therewith the density of radiation has the same dilutional dependence as for the radially squared lowering density of rest-mass particles. In such model universe the horizon problem is avoided automatically, whereas the light-cone photons are moving relative to atomic matter along the logarithmic Archimedes spiral around the mass-generating Planckian source, covering during evolution about 22 cycles. Crucially, the cosmic 'dark ages' start at 33.2 times younger age and about 10^3 times greater densities of matter, leading to much earlier formation of stars and galaxies than in the traditional ΛCDM cosmology. In the Planckian universe the cosmological principle holds for every epoch, thus removing the anthropocentric principle. The modified critical density in the model is $\rho = 8.6 \cdot 10^{-31} g \cdot \text{cm}^{-3}$. The needed dark matter contribution $\rho_\nu = 3 \cdot 10^{-31} g \cdot \text{cm}^{-3}$ can be provided by neutrinos if their rest energy is 0.16 eV. These correspond to degenerated cooled neutrinos at velocities of the order $v_F = 10^4$ km/s.

Key words: cosmology, model universes, Mach's principle, dark matter, dark energy.

1. INTRODUCTORY REMARKS

The problem to specify the nature of dark matter in cosmology has been on agenda of cosmologists for some decades, but has remained unsolved. Numerous attempts to specify it by any known or hypothetical physical particles have so far failed.

In our studies we got a lot of inspiration from Mach's principle in which local physical laws must incorporate gravitational interaction with matter in the whole universe (Einstein 1916a, 1916b). This helped us to remove necessity of dark energy (Sapar, 2019).

We have been sceptical about the presence of any specifically cosmological particles. Our concept can rather be classified as the Occam's razor principle – instead of searching radically new tools we apply the well known ones to unique cosmological conditions.

In the paper (Sapar, 2019) we proposed the perpetually mass-generating Planckian model universe as a candidate, fitting well to our real universe. We proved that in the Milne-type, $R = ct$, model universe the necessity for dark energy is removed automatically if correction due to modification of Friedmann–Einstein equations by Mach's principle is applied. But it is necessary to elucidate that the main observables are also in concordance with this model universe in the evolutionary stages when first the neutrinos and thereafter the photons are decoupled from the atomic matter. For photons this corresponds to the dawn of the cosmic dark ages at temperature 3000 K, but for neutrinos much earlier, when the temperature corresponded to the rest energy of electrons, at the epoch of annihilation of electron-positron pairs, when temperature was about $T = 10^{10}$ K.

Traditionally the equations of general relativity have been used in cosmology, assuming that the expanding universe has been created momentarily or almost momentarily by the 'Big Bang'. Such assumptions enable one to introduce the co-moving coordinates in the expanding universe. First such coordinates were introduced by Friedmann (1922, 1924) and thereafter theoretically more strictly adjusted to Einstein equations of general relativity by Robertson (1929) and Walker (1936). By the use of these coordinates primarily it was concluded, that initially the density and temperature of the universe were infinite. F. Hoyle (1948, 1949) named such theory pejoratively as the 'Big Bang cosmology' and tried to save the theory from this paradoxical situation, elaborating with colleagues the concept of a steady-state universe, where at any space point and time moment the matter was spontaneously created by the additional creation matrix.

The situation changed radically when the 3 K cosmic microwave background (CMB) was discovered by Penzias and Wilson (Penzias and Wilson, 1965a, 1965b). This discovery for the first time gave an observational link to formulate the thermodynamic evolutionary scenario of the universe, which radically disfavoured the steady-state concept. However, on the thermodynamics of the universe there were some former published papers, and in some of them the current cosmological temperature was predicted quite accurately, especially by Gamow with colleagues. The infinite initial temperature was removed first by Lemaître (1931) when he in a short note suggested that primordial universe has been initiated from the Planckian units, corresponding to the gravitational quantum processes.

Success in modelling universe has been the slow one, because the extrapolations needed to apply are tremendous. This demanded high-precision observations with large telescopes.

Some years before the radio-astronomical snapshot of CMB was recorded, I started to elaborate cosmological model universes, specially studying the temporal run of observables in them. I used a new aspect (Sapar, 1964) – summing contributions by different equations-of-state, characterized by integral values n, being for atomic matter $n = 3$, for radiation, $n = 4$, and for the negative pressure of unknown origin, $n = 2$.

At the early stages of modelling of the universe different suggestions were proposed how the fundamental coefficients of physics could be coupled with the structure of universe. I also studied different possibilities of this kind (Sapar, 1961). In the 1970s I considered that the initial state of the universe had a Planckian nature (Sapar, 1976, 1977), demonstrating that our universe evolves simply as power functions relative to the age of universe, expressed as straight lines on logarithmic scales. In the traditional Big Bang theory the radial dimension of the expanding universe expands too slowly to match with the initial Planckian seed-universe. To overcome this apparent horizon problem the concept of the very early exponential expansion of the universe, named the inflationary expansion, was proposed by quantum-field theorists (Guth, 1980; Starobinsky, 1980; Linde, 1982). This very complicated hypothetical concept remained for almost thirty years as the mainstream paradigm and all other concepts were ignored as the heretic ones.

The next essential step for cosmology was discrepancies between theory and observations. To overcome those, first the concept of dark matter and thereafter of the expelling dark energy (Perlmutter et al., 1998; Riess et al., 1998) were postulated.

We made different attempts to get rid of the dark energy and understand the role of neutrinos in cosmology and galaxies (Sapar, 2011, 2013, 2014, 2017). When in the current decade as a result of observations by large ground-based and satellite-based telescopes, it was established that the expanding universe is spatially flat and thus remarkably close to the critical density, several cosmologists started to propose different modified concepts, including presence of special cosmic particles, say WIMPs, and different modifications of the equations of general relativity. Unfortunately these investigations could not solve new problems, which had appeared meantime.

The situation changed when it was realized that the concept of the flat but populated Milne-type universe explains the light curve of remote SN Ia supernovae much simpler and by smaller number of parameters than the Bayesian credibility fitting in the mainstream ΛCDM concept. In our recent paper (Sapar, 2019) we demonstrated that the necessity for dark energy is eliminated if Mach's principle is taken into account by using the non-local gravitational potential. In addition, it was obligatory to use the Milne-type universe and to take into use the concept of eternal and steady creation of kinetic energy (or mass) and the numerically equal, but negative, gravitational potential, to demonstrate that in the model universe the total energy is conserved and is identically zero.

The energy generation proceeds steadily in the domain of the Heisenberg uncertainty principle. Creation of matter removes the possibility to introduce, started from an initial moment, the co-moving Robertson-Walker coordinates for the very early universe, as done in different versions of Big Bang theory.

In the Planckian model universe, following $R = ct$, is simultaneously formed with mass-creation the constant gravitational potential, c^2, and consequently the necessity for any accelerative or decelerative expansion of the universe has been automatically eliminated. This model universe can be described as 'dilutional' due to the radial mass flow at speed, which with high precision corresponds to the light speed at the cosmic horizon.

The equations of the model universe are very simple. Namely, we obtain the information by photons on the light-cone. It turns out that the light-cone photons, and neutrinos on the light-cone, must be frozen-in, similarly to the magnetic fields in plasmas.

Let us now study the situation by formulae.

2. FORMULAE FOR OBSERVABLES IN PLANCKIAN UNIVERSE

In the local coordinates of observers the space coordinates relative to any point on the celestial sphere are given by the formulae for geometry of a spherical model universe in flat space. These can be written as photon emission coordinates, which correspond to polar angle ω_i relative to observers, in the form

$$X_i = R_i\omega_i \sin\delta \cos\alpha, \;\; Y_i = R_i\omega_i \sin\delta \sin\alpha,$$

$$Z_i = R_i\omega_i \cos\delta, \qquad (1)$$

where δ is the latitude and α is the longitude, named the right ascension, of the mapped celestial sphere relative to observer. Observers use celestial coordinates to specify the directions in 3-space. From these formulae it is evident that the value of $R\omega_i$ and the location of the source in the space are directly unperceptive for us. The polar angle ω_i on the light cone corresponds to time $t_o - t_i$.

In the paper (Sapar, 2019) we showed that in the Milne-type populated universe, following $R = ct$, the polar angle ω_i is given by

$$\omega_i = \ln(1+z_i) = \ln(R_o/R_i). \qquad (2)$$

This formula demonstrates that the trajectory of any photon on the light-cone corresponds to a logarithmic Archimedes spiral or involute. From here it follows that the light-cone photons make a full circle around the widening universe during $R_o/R_i = e^{2\pi} = 535.5$. Thus, for the flat universe, the horizon problem has been automatically eliminated, whereas all these points in the past have been twice in the interaction with the present moment universe. The problem of removing a horizon for causal interaction of different parts of the universe has been an important feature in formulating the inflationary expansion of the primordial universe.

Decoupling of photons from baryonic matter, which corresponds to the observed CMB, occurs approximately at $z_d = 1100$, which corresponds to $1100 \cdot 2.725 = 2997.5$ K. The polar angle, corresponding to it is $\omega_d = \ln 1100 = 7.00$. In angular units this means a full circle and 42.64 degrees.

The contribution of different generic particles in both, the traditional Friedmann–Einstein cosmology and in the Planckian universe is described for density by the formula (Sapar, 2019)

$$4\pi G\rho_n t^2 = \frac{2}{n^2}. \qquad (3)$$

This equation must hold for both – for the equation of dilutional transfer of matter and radiation in the universe. This means that radiation in these coordinates is radically frozen-in and transfers almost perpendicularly relative to matter. This follows quite figuratively from the differential form of the light-cone for photons $cdt/R = d\omega$. Thus, the decoupled photons arriving to us, including the CMB radiation, are moving perpendicularly relative to the radius of diluting matter in the flat universe. In the Milne-type model universes the radial expansion is lacking, or as it often has been expressed, it is frozen-in (similarly to the magnetic field in plasma). Thus, the traditional space expansion is replaced in the Milne-type model universe by spherical dilution in the gravitational field around the mass-source, say, like in the case of planetary nebulae.

For the Milne-type model universes also the general formula for the apparent surface brightness B, holds

$$B(z) = \frac{B_i}{(1+z)^4}. \qquad (4)$$

This means that the red-shifted, diluted and curved trajectories of light-cone photons must be applied also to the CMB. The observed CMB decoupled at temperature $T_d = 3000$ K, while free electrons recombined with protons, and formed the CMB, which conserved its black-body distribution redshifted by $z_o = 1100$. As $T_d/(z_o+1) = 2.725K = T_o$, we assume thata such contraint must hold for each model universe. Thus, generally

$$1+z = \frac{T}{T_o} \qquad (5)$$

and thus for our 'dilutional' or 'Broadcast' model universe

$$1+z_i = \left(\frac{R_o}{R_i}\right)^{1/2} = \left(\frac{t_o}{t_i}\right)^{1/2}. \qquad (6)$$

This equation differs radically from the traditional one of pure atomic matter in the Big Bang cosmology, assumed to be dominating in the model universe, for which $1+\delta_j = R_o/R_j = (t_o/t_j)^{2/3}$. If $z_i = \delta_j = 1100$, i.e. the redshifts of Big Bang and Broadcast model universes are equal at decoupling of CMB, then

$$\frac{R_o^2}{R_j^2} = \frac{R_o}{R_i}, \qquad \left(\frac{t_o}{t_j}\right)^{4/3} = \frac{t_o}{t_i}. \qquad (7)$$

According to these formulae for the Broadcast model universe the dawn of dark ages began at $R_o/R_i = 1.21 \cdot 10^6$, thus while the Broadcast model universe was $\sqrt{1100} = 33.2$ times younger than in the conventional Big Bang theory. This means that the age of our universe is about million times larger than at the decoupling time of observable CMB at $t_i = 11\ 000$ years, instead of traditional age $t_j = 377\ 000$ years. Thus, at the dawn of dark ages the matter density of universe, according to Eq. (3), was about one thousand times greater than traditionally accepted. This circumstance has favoured essentially earlier formation of stars and stellar systems.

Now we study how the Broadcast model redshifts are correlated with respect to the Big Bang redshifts of the light curve of the SN Ia supernovae as the cosmological standard candles. If $R_j = R_i$ then, denoting the redshift in Big Bang model universes by δ_j, we obtain $1+\delta_j = (1+z_i)^2$ or

$$\delta_j = 2z_i(1+z_i/2). \tag{8}$$

This means that the redshift of the Big Bang universe is in the Broadcast model universe equal to the doubled Milne distance, expressed via redshifts. For small redshifts $\delta_j = 2z_i$. This explains why the Milne reduced distance is well concordant with the reduced distance of ΛCDM model universe, which has been emphasized and illustrated figuratively by Chodorowski (2005). The concordance of the ΛCDM cosmology with the Milne-type cosmology has been analysed in detail by Wei et al. (2015) and by Nielsen et al. (2016). Several aspects in favour of the $R = ct$ Milne-type model universe compared with ΛCDM cosmology have during recent years been emphasized by Tatum with colleagues in numerous papers, starting with paper (Tatum et al., 2015) and summarizing the results in paper (Tatum, 2018). Also, similar analysis has been carried out by Melia (2012, 2013, 2015, 2017), who has been criticized by Mitra (2014).

From Eq. (2) it follows that starting from the Planckian seed-universe up to now the maximal value of ω is $\Omega_o = \ln(R_o/R_P) = 139.32$. Thus, the number of overlapping full circles is 22.17. From the presented formulae it follows how in the universe, which is expanding and generating new matter, the events of the younger universe can be seen via its redshifted light cones.

Due to spherical symmetry, the older and therewith outer layers do not give any accelerative contribution to the inner region, where the flat Minkowski space corresponds to them. This means that we cannot see any older regions (corollary of Birkhoff theorem). At any fixed value of R_j the situation is time-independent, i.e. the stationary one.

As mentioned above, at small redshifts the Big Bang theory gives redshift values, enlarged by multiplier 2 compared with the Broadcast model universe. Thus, the required total density of matter is more tenuous by factor 4, i.e. $\rho = 8.6\ \mathrm{g\cdot cm^{-31}}$. The observed atomic mass density in the model universe is about $\rho_a = 5.6\cdot 10^{-31}\mathrm{g\cdot cm^{-3}}$. Thus, the needed additional contribution of neutrinos is only half of that value, namely about $\rho_\nu = 3\cdot 10^{-31}\ \mathrm{g\cdot cm^{-3}}$. The contribution by photons is in the Broadcast universe the same as in the Big Bang modifications, being small and we can ignore it.

Now we need to estimate the contribution by neutrinos, having the rest masses. In the accepted approximation the total density of matter consists only of two components:

$$\rho = \rho_\nu + \rho_a, \tag{9}$$

i.e. the contributions by neutrinos and atomic matter. Here, due to frozen-in radial expansion, the equation-of-state indices both, that the matter and neutrinos are reduced to $n = 2$.

To simplify the study of neutrino contribution, we assume that for cosmology the neutrino oscillations can be ignored, assuming that cosmological neutrinos correspond to mass eigenvalues, thus having definite gravitational properties. Further we assume that each of the three neutrino flavours, n_ν^f, gives the matter density an equal contribution.

The relative dilution of both, electrons and protons is about 10^{-9} due to small asymmetry of primordial matter–antimatter. Consequently $N_\nu/N_a = 10^9$. The number density of protons in universe is about $N_a = \rho_a/M_p = 5.6\cdot 10^{-31}/1.673\cdot 10^{-24} = 3.35\cdot 10^{-7}\ \mathrm{cm^{-3}}$. For each of three flavours n_ν^f of neutrinos we get consequently $N_\nu = 335\ \mathrm{cm^{-3}}$. If the whole dark mass would consist of cooled neutrinos, their mean rest-mass would be

$$m_\nu = \frac{\rho_\nu}{n_\nu^f N_\nu} = \frac{10^{-31}}{335} \approx \frac{1}{3}10^{-33}\mathrm{g} = \frac{0.16}{c^2}\mathrm{eV}. \tag{10}$$

Now we check whether the massive neutrino background is the classical, named also the cooled one, degenerated Fermi condensation. Thus, we need to use corresponding limiting kinetic energy, $E_F = \frac{m_\nu c^2}{\sqrt{1-\beta_F^2}} - m_\nu c^2 = m_\nu c^2\beta_F^2/2$, given by

$$E_F = \frac{\pi^2\hbar^2}{2m_\nu}\left(\frac{3N_\nu}{\pi}\right)^{2/3}, \tag{11}$$

from where it follows that for the reduced cooled Fermi velocity, $\beta_F = v_F/c < 1$, holds

$$\beta_F = \frac{1.09\cdot 10^{-36}}{m_\nu r_F}, \qquad \frac{1}{r_F} = (N_\nu)^{1/3}. \tag{12}$$

Thus, we find that $\beta_F = 0.03$ which corresponds to $v_F = 10^4$ km/s. Numerically we have $E_F = 1.21\cdot 10^{-15}$ ergs and $E_T = 1.5kT = 5.64\cdot 10^{-16}$ ergs. Whereas $E_F > E_T$ the neutrinos must be in the classical degenerated state. The neutrinos can be the main component of the dark matter in galaxies (Sapar, 2014).

This study demonstrates that probably there is no need for enigmatic dark matter. Some contribution to dark matter can also be provided by primordial black holes. The results are to be further elaborated in more detail.

3. DISCUSSION

In the introduction we briefly reviewed the history of our non-conventional standpoint of the physics of our universe. Primarily we tried to take Mach's principle more adequately into account, discussing how the microphysics and the large-scale physics of the universe are coupled between themselves. About a decade later we concluded that the primordial universe and its evolutionary scenario are determined by the Planckian units.

Thereafter for almost three decades I did not participate in studies of cosmology, watching aside the successes of the new mainstream paradigm that hypothetical repulsive 'inflaton' field generated exponential expansion of initial Planckian universe and created almost momentarily tremendous amount of matter in it. However, the observations of remote type Ia supernovae as standard candles for cosmology required modifying the theory by dark energy and dark matter.

An important discovery that the space of the universe is probably flat, stimulated us once more to modify the equations, determining the evolutionary scenario of the universe. Finally we arrived at the concept of an eternal mass-generating Planckian universe, naming it, for similarities with broadcasting TV, the Broadcast universe. It could also be baptized as the diluting universe.

In this model universe a perpetual mass generation proceeds corresponding to Heisenberg's uncertainty principle. For any complicated system, including the Schrödinger cat in the dark box, the uncertainty is growing additively. Somewhat mysteriously, this chaotic process seems to result in free volution of living beings, which probably cannot be analysed more precisely by traditional scientific methods.

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Vaadeldavad suurused tasaruumilises Plancki universumis

Arved Sapar

Traditsiooniliselt lähtutakse kosmoloogias Friedmanni-Einsteini mudeluniversumi võrrandeist. Sellise mudeluniversumi võrdlus vaatlusandmetega on aga tõstatanud probleemid, mille ületamiseks on kasutusele võetud tumeenergia ja tumeaine mõisted, mille füüsikaline olemus on aga senini lahtine.

Meie universum on modelleeritav (Sapar 2018) massi genereeriva tasaruumilise Plancki universumina, mille algseis ja evolutsioon baseeruvad neljal füüsika universaalkonstandil, milleks on Newtoni gravitatsioonikonstant G, valguse kiirus c, Plancki mõjukvant $\hbar = h/2\pi$ ning Boltzmanni konstant k termodünaamikas. Seejuures on universumi geomeetria kirjeldatav Milne'i mudeluniversumi valemiga $R = ct$, kus R on laieneva universumi hetkeraadius ja t on vanus sellel ajahetkel. Seejuures massiteke ajaühikus (massi allikfunktsioon) osutub avaldatavaks kujul $\dot{M} = c^3/6G$ ehk veidi üle 30 000 Päikese massi sekundis.

Valguse kiirusega laieneva universumi koguenergia koosneb elementaarosakeste kineetilisest energiast ja sellega võrdsest, kuid negatiivsest gravitatsioonilisest potentsiaalsest energiast c^2. Sellise mudeluniversumi nulline koguenergia säilib automaatselt ja sealjuures pole vaja ei ülivarajast suurt pauku ega tumeenergiat. Kosmoloogiline printsiip kõikide ajahetkede samaväärsusena valemites kõrvaldab ka nüüdishetke eristaatusesse tõstva antropotsentrilisuse.

Plancki universumis osutub punanihe lineaarselt sõltuvaks temperatuurist (valem (5)), olles radiaalmõõtme ruutjuurega pöördvõrdelises sõltuvuses (valem (6)). Neist valemeist järeldub, et tasaruumilise Plancki universumi evolutsioon toimub tunduvalt teisiti kui tavakosmoloogias. Tasaruumilisele universumile vastav aine kriitiline tihedus väheneb 12-kordselt (väärtusele $\rho = 8{,}6$ g/cm^3) ja elektronide rekombinatsioon, mis määrab tumeajastu alghetke, nihkub 33,2 korda nooremasse ja umbes tuhat korda suuremate ainetihedustega evolutsioonieteppi, soodustades tunduvalt varasemat tähtede ning tähesüsteemide teket.

Neutriinode vabalevi algas, kui universumi temperatuur oli langenud väärtusele umbes 10^{10} K ja toimus elektronpositronpaaride annihilatsioon, kusjuures alles jäi vaid aine ning antiaine asümmeetriamäärale 10^{-9} vastav hulk ainet.

Footonite vabalevi algas tunduvalt hiljem, temperatuuril 3000 K, kui toimus elektronide rekombinatsioon aatomituumadega ja moodustus vaadeldav musta keha mikrolainefoon (CMB) punanihkega $z = 1100$. Universumi vanuseks tollal oli kõigest 11 000 aastat, seega tunduvalt vähem kui tavakosmoloogia kohaselt. Nii vabalevi neutriinod kui ka footonid liiguvad valguskiirusega peaaegu valguskiiruselise atomaaraine suhtes. Relatiivsusteoreetiliste kiiruste liitmise tulemusena käituvad need radiaalselt kinnikülmunutena, levides aine suhtes nurksuundades.

Vajaliku neutriinofooni massitihedus tumeainena kahaneb Plancki universumis väärtusele $3 \cdot 10^{-31}$ g/cm^3. Sellele vastava neutriino keskmine seisuenergia on umbes 0,16 eV. Selline neutriinofoon osutub klassikaliste kiirusteni jahenenuks. See neutriinofoon on mandunud Fermi gaas piirkiirusega umbes $v_F = 10\ 000$ km/s.