NONSINGULAR, ACCELERATING, ALWAYS EXPANDING UNIVERSE WITH ENTROPY PRODUCTION

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Abstract: In several previous papers a theory of gravitation in flat space-time was applied to study nonsingular cosmological models. The results permitted two interpretations, namely expanding and nonexpanding universes. Nonexpanding universes with positive cosmological constant and no entropy production are in agreement with the second law of Thermodynamics. The redshift of spectral lines is explained by energy loss of the photons on there way. In this paper expanding nonsingular cosmological models with positive cosmological constant and entropy production are studied. The second law of Thermodynamics requires that in addition to radiation matter consists not only of dust but also of a density satisfying a stiff equation of state. This energy can also be explained by a scalar field fulfilling field equations without potential. Proper time and absolute time are different from one another. The age measured with proper time of this universe yields that the density parameter of the additional matter is small compared to the density parameter of dust to be in agreement with the presently assumed age of our universe. The additional matter is only important in the beginning of the universe. It can be identified with the neutrinos in our universe. The local velocity of light is always the vacuum light-velocity but the velocity of light at distant objects appears greater than the vacuum light-velocity because clocks at earlier times go faster than the clocks at present. This gives a new explanation of the observed superluminal velocities at distant objects. All cosmological models of the flat space-time theory of gravitation are spatially flat as recent astrophysical measurements have yielded.

1. INTRODUCTION

A covariant theory of gravitation in flat space-time [1-3] yields nonsingular homogeneous isotropic cosmological models [4-8]. The results permit two interpretations: (1) Space is expanding in analogy to the results of Einstein's theory. The second law of Thermodynamics with standard definition of internal energy yields a vanishing cosmological constant [5, 6].
(2) Space is nonexpanding. Then, the redshift of spectral lines from distant galaxies results by energy loss of the emitted photons on there way to the observer [7, 8]. In particular, a cosmological model with a positive cosmological constant yields a non-expanding space with no entropy production by virtue of the second law of Thermodynamics [7, 8]. Nonsingular cosmological models with anisotropic black body radiation are studied in paper [9]. It is worth mentioning that all homogeneous isotropic cosmological models of flat space-time theory of gravitation give spatially flat universes whereas Einstein's theory permits cosmological models with curved spaces. A summary of the theory of gravitation in flat space-time with several applications can be found in [10].
Recent observations of supernova light curves [11, 12] suggest by the use of the interpretation of an expanding space that the expansion of the universe is accelerating rather than decelerating. Combined with evidence from the cosmic microwave background [13-17] and other observations [18], this suggests that the universe is spatially flat and dominated by a cosmological density parameter $\Omega_\Lambda \approx 0.7$.
In this paper nonsingular homogeneous isotropic cosmological models with positive cosmological constant, radiation and matter are studied by the use of the interpretation of an expanding space. The second law of Thermodynamics with the total energy as internal energy requires matter satisfying a stiff equation of state in addition to the usually assumed dust. This matter can also be explained by a scalar field fulfilling field equations with vanishing potential. Entropy is always produced by virtue of the expanding space. Proper time and absolute time are different from one another. The age of the universe measured with proper time yields that the density parameter of this additional matter is small compared to the density parameter of dust to be in agreement with the presently assumed age of our universe. This additional matter is only important in the beginning of the universe. It can be identified with the neutrinos in our universe. In the beginning of the universe all the energy is in form of gravitation and the scaling factor has a small positive value. The universe begins to expand, the additional matter, radiation, dust and vacuum energy (given by the cosmological constant) arise and entropy is produced. The total energy is always conserved. The additional matter dominates radiation and dust in the beginning of the universe. The age of the universe is infinite measured with absolute time but finite measured with proper time. The velocity of light is locally always the vacuum light-velocity. At distant objects the velocity of light appears greater than vacuum light-velocity because clocks at earlier times go faster than clocks at present. This gives a new explanation for the observed superluminal velocities at distant objects. This result can not be received by Einstein's theory. The model is non-singular, i. e., all arising energy terms and the temperature are finite for all times.

After the time when the additional matter becomes unimportant, this cosmological model agrees formally with previously studied nonsingular models [7, 8] but with the interpretation of an expanding space.

2. COSMOLOGICAL MODEL

The cosmological model is described by the use of the theory of gravitation in flat space-time [1-3]. The metric is the pseudo-Euclidean geometry

$$(ds)^2 = -\eta_{\nu\mu} dx^\nu dx^\mu \tag{2.1}$$

with

$$\eta_{ij} = diag(1,1,1,-1) \tag{2.2}$$

where $x^i (i = 1,2,3)$ are the Cartesian coordinates and $x^4 = ct$ (t absolute time).
The proper time τ, measured by atomic clocks, is

$$c^2 (d\tau)^2 = -g_{\nu\mu} dx^\nu dx^\mu . \tag{2.3}$$

The gravitational potentials g_{ij} satisfy covariant differential equations of order two in divergence form where the source for the gravitational field is the total energy-momentum tensor including the covariant energy-momentum tensor of the gravitational field.
Additional to the field equations there are covariant equations for the motion of matter and a covariant conservation law of the total energy-momentum [1-3].
The application of this gravitational theory to homogeneous isotopic cosmological models implies (see [4-8])

$$g_{ij} = \begin{cases} a^2(t) & , i = j = 1,2,3 \\ 1/h(t) & , i = j = 4 \\ 0 & , i \neq j \end{cases} . \tag{2.4}$$

The four-velocity is assumed in the form

$$(u^i) = (0,0,0,u^4) \tag{2.5a}$$

where it follows by (2.3)

$$u^4 = c / h^{1/2}(t) . \tag{2.5b}$$

The energy-momentum tensor of matter (dust), additional matter and radiation has the form

$$\overset{M}{T}{}^i{}_j = \begin{cases} (p_m + p_a + p_r)c^2 & , i = j = 1,2,3 \\ -(\rho_m + \rho_a + \rho_r)c^2 & , i = j = 4 \\ 0 & , i \neq j \end{cases} \tag{2.6}$$

with the equations of state

$$p_m = 0,\ p_a = \rho_a,\ p_r = \frac{1}{3}\rho_r . \tag{2.7a}$$

The equations of motion imply

$$\rho_m = \rho_{m0} / h^{1/2},\ \rho_a = \rho_{a0} / \left(a^3 h^{1/2}\right),\ \rho_r = \rho_{r0} / \left(a h^{1/2}\right) \tag{2.7b}$$

where, ρ_{m0} , ρ_{a0} and ρ_{r0} denote the present densities of dust, additional matter and radiation.
It is proven in the paper [19] that a scalar field satisfying field equations with vanishing potential gives the same energy-momentum tensor as the additional matter field in (2.6) and (2.7).
Put

$$\chi = 4\pi k / c^4 \tag{2.8}$$

where k is the gravitational constant then the energy-momentum tensor of vacuum with cosmological constant Λ is given by

$$\overset{\Lambda}{T}{}^{i}{}_{j}=\begin{cases}-\dfrac{\Lambda}{2\chi}a^{3}/h^{1/2} & ,i=j=1,2,3,4\\ 0 & ,i\neq j\end{cases}\tag{2.9}$$

The energy-momentum tensor of the gravitational field has the form

$$\overset{G}{T}{}^{i}{}_{j}=\begin{cases}\dfrac{1}{16\chi}L_G & ,i=j=1,2,3\\ -\dfrac{1}{16\chi}L_G & ,i=j=4\\ 0 & ,i\neq j\end{cases}\tag{2.10}$$

where

$$L_G=\frac{1}{c^2}a^3h^{1/2}\left(-6\left(\frac{\dot{a}}{a}\right)^2+6\frac{\dot{a}}{a}\frac{\dot{h}}{h}+\frac{1}{2}\left(\frac{\dot{h}}{h}\right)^2\right)\ .\tag{2.11}$$

Here, the dot denotes the t-derivative.
Let

$$a(0)=1,\ h(0)=1,\ \dot{a}(0)=H_0,\ \dot{h}(0)=\dot{h}_0\tag{2.12}$$

be the conditions on the field functions at the present time $t_0=0$ where H_0 is the Hubble constant and $\dot{h}_0$ is an arbitrary constant not appearing in Einstein's theory.
Put for abbreviation

$$\frac{1}{2}\frac{\varphi_0}{H_0}=\frac{3}{2}\left(1+\frac{1}{6}\frac{\dot{h}_0}{H_0}\right).\tag{2.13}$$

The conservation law of energy implies by the use of (2.6), (2.7b), (2.9) and (2.10)

$$\rho_{m0}c^2/h^{1/2}+\rho_{a0}c^2/\left(a^3h^{1/2}\right)+\rho_{r0}c^2/\left(ah^{1/2}\right)+\frac{\Lambda}{2\chi}a^3/h^{1/2}+\frac{1}{16\chi}L_G=\lambda c^2\tag{2.14}$$

where λ is a positive constant of integration and λc^2 denotes the total energy inclusive the gravitational energy.
The first law of Thermodynamics has the form

$$dU=-PdV+TdS\tag{2.15}$$

where U, P, V, T and S denote internal energy, pressure, volume, absolute temperature and entropy.
Let us assume that the internal energy U corresponds to the total energy λc^2, then we get

$$dU=d\left(\lambda c^2\right)=0\ .\tag{2.16}$$

Hence we have from (2.15)

$$PdV=TdS\ .\tag{2.17}$$

This relation is especially fulfilled for

$$dV=dS=0\tag{2.18}$$

that is, the universe does not expand and no entropy is produced. These cosmological models have been studied in the papers [7, 8].

Another possibility to interpret (2.17) in agreement with the second law of Thermodynamics

$$dS \geq 0 \qquad (2.19)$$

is the increase of the volume

$$V \sim a^3 \qquad (2.20)$$

where without loss of generality a positive pressure is assumed.

The field equations yield by the use of (2.14)

$$a^3 h^{1/2} = 2\chi c^4 \lambda t^2 + \varphi_0 t + 1 . \qquad (2.21)$$

Introducing the density parameters

$$\Omega_m = \frac{8\pi k \rho_{m0}}{3{H_0}^2}, \Omega_a = \frac{8\pi k \rho_{a0}}{3{H_0}^2}, \Omega_r = \frac{8\pi k \rho_{r0}}{3{H_0}^2}, \Omega_\Lambda = \frac{\Lambda c^2}{3{H_0}^2} \qquad (2.22)$$

then the equations (2.14) can be rewritten by elimination of h with the aid of (2.21)

$$\left(\frac{\dot{a}}{a}\right)^2 = \frac{{H_0}^2}{\left(2\chi c^4 \lambda t^2 + \varphi_0 t + 1\right)^2}\left\{-\frac{1}{3}\left(\frac{2\chi c^4 \lambda}{{H_0}^2} - \left(\frac{1}{2}\frac{\varphi_0}{H_0}\right)^2\right) + \Omega_a + \Omega_r a^2 + \Omega_m a^3 + \Omega_\Lambda a^6\right\}. \qquad (2.23)$$

This relation implies at the present time $t_0 = 0$ with the aid of (2.12)

$$\frac{1}{3}\left(\frac{2\chi c^4 \lambda}{{H_0}^2} - \left(\frac{1}{2}\frac{\varphi_0}{H_0}\right)^2\right) = \Omega_a + \Omega_m + \Omega_r + \Omega_\Lambda - 1 . \qquad (2.24)$$

Define

$$\Omega_m K_0 = \Omega_a + \Omega_m + \Omega_r + \Omega_\Lambda - 1 \qquad (2.25)$$

and

$$\Omega_m K_1 = 1 - \Omega_m - \Omega_r - \Omega_\Lambda \qquad (2.26)$$

then

$$\frac{2\chi c^4 \lambda}{{H_0}^2} - \left(\frac{1}{2}\frac{\varphi_0}{H_0}\right)^2 = 3\Omega_m K_0 \qquad (2.27a)$$

$$\Omega_m K_0 + \Omega_m K_1 = \Omega_a \ . \qquad (2.27b)$$

A necessary condition to avoid a singularity in (2.23) is the condition

$$2\chi c^4 \lambda t^2 + \varphi_0 t + 1 > 0$$

for all $t \in \Re$ which is by the use of (2.27a) equivalent to

$$K_0 > 0 . \qquad (2.28)$$

For $\Omega_a = 0$ the solution of (2.23) has a minimum at a finite time, that is, the universe is contracting at least shortly before that time in contradiction to the second law of Thermodynamics (2.19) and (2.20). It follows from (2.23) by the use of (2.27) that the condition

$$K_1 \geq 0 . \qquad (2.29)$$

implies an expanding universe for all times where entropy is produced by virtue of relations (2.17) and (2.20). Subsequently we assume the less stronger condition

$$K_1 > 0 . \qquad (2.30)$$

Hence, the differential equation (2.23) has for an expanding universe the form

$$\frac{\dot{a}}{a} = \frac{H_0}{2\chi c^4 \lambda t^2 + \varphi_0 t + 1}\left[\Omega_m K_1 + \Omega_r a^2 + \Omega_m a^3 + \Omega_\Lambda a^6\right]^{1/2} . \qquad (2.31)$$

The detailed calculations of the results of this section can be found in the papers [4-6]. A solution $a(t)$ of (2.31) with the condition

$$a(0)=1 \tag{2.32}$$

gives by the use of (2.21) the function $h(t)$. Then, the total solution of the homogeneous isotropic expanding universe with entropy production is known.

The space-coordinates $\left(\tilde{x}^i\right)$ of the expanding universe are as for the general theory of relativity

$$\tilde{x}^i = a(t)x^i \qquad (i=1,2,3) \tag{2.33}$$

and the proper time τ_r of a clock is by virtue of (2.3) and (2.4)

$$d\tau_r = dt / h^{1/2}(t). \tag{2.34}$$

Hence, the periods of proper time and absolute time are different from one another whereas they agree at present time t=0 by virtue of (2.12). Einstein's theory gives the same periods for proper time and absolute time for all times.

With the new coordinates (2.33) and (2.34) the proper time (2.3) with (2.4) and the line-element (2.1) with (2.2) have the form

$$c^2(d\tau)^2 = -\sum_{i=1}^{3}\left(d\,\tilde{x}^i\right)^2 + \frac{2}{c}\frac{\dot{a}}{a}h^{1/2}\sum_{i=1}^{3}\tilde{x}^i d\,\tilde{x}^i dc\tau_r + \left(1-\frac{1}{c^2}\left(\frac{\dot{a}}{a}\right)^2 h\sum_{i=1}^{3}\left(\tilde{x}^i\right)^2\right)(dc\tau_r)^2 \tag{2.35}$$

and

$$\begin{aligned}(ds)^2 = &-\frac{1}{a^2}\sum_{i=1}^{3}\left(d\,\tilde{x}^i\right)^2 + \frac{2}{c}\frac{1}{a^2}\frac{\dot{a}}{a}h^{1/2}\sum_{i=1}^{3}\tilde{x}^i d\,\tilde{x}^i dc\tau_r + \\ &+h\left(1-\frac{1}{c^2}\frac{1}{a^2}\left(\frac{\dot{a}}{a}\right)^2\sum_{i=1}^{3}\left(\tilde{x}^i\right)^2\right)(dc\tau_r)^2 .\end{aligned} \tag{2.36}$$

The transformation formula for an object at distance $\left(x_0^1, x_0^2, x_0^3\right)$ in the expanding universe is

$$\tilde{x}^i = a(t)\left(x^i - x_0^i\right) \qquad (i=1,2,3) \tag{2.37}$$

giving the proper time

$$c^2(d\tau)^2 = \sum_{i=1}^{3}\left(d\,\tilde{x}^i\right)^2 + \frac{2}{c}\frac{\dot{a}}{a}\sum_{i=1}^{3}\tilde{x}^i d\,\tilde{x}^i dct + \frac{1}{h}\left(1-\frac{1}{c^2}\left(\frac{\dot{a}}{a}\right)^2 h\sum_{i=1}^{3}\left(\tilde{x}^i\right)^2\right)(dct)^2 . \tag{2.38}$$

3. SOLUTION

Subsequently let us assume

$$\Omega_r a^2 << \Omega_m K_1 + \Omega_m a^3 + \Omega_\Lambda a^6$$

for all $a \ge 0$ then relation (2.31) can be rewritten in the form

$$\frac{\dot{a}}{a} = \frac{H_0}{2\chi c^4 \lambda t^2 + \varphi_0 t + 1}\left[\Omega_m K_1 + \Omega_m a^3 + \Omega_\Lambda a^6\right]^{1/2} . \tag{3.1}$$

The equation (3.1) with the condition (2.32) can be rewritten in the form

$$H_0 \int_0^t \frac{dt}{2\chi c^4 \lambda t^2 + \varphi_0 t + 1} = \int_1^a \frac{da}{a\left[\Omega_m K_1 + \Omega_m a^3 + \Omega_\Lambda a^6\right]^{1/2}} . \tag{3.2}$$

Longer elementary calculations give the solution

$$a^3(t) = 2\Omega_m K_1 B F(t) \Big/ \left[\left(B - \frac{1}{2}\Omega_m F(t)\right)^2 - \Omega_m K_1 \Omega_\Lambda F^2(t)\right] \tag{3.3a}$$

where we have put

$$B = \Omega_m K_1 + \frac{1}{2}\Omega_m + \left(\Omega_m K_1\right)^{1/2} \tag{3.3b}$$

$$F(t) = \exp\left(\left(\frac{3K_1}{K_0}\right)^{1/2} arctg\left(\frac{\left(3\Omega_m K_0\right)^{1/2} H_0 t}{1 + \frac{1}{2}\frac{\varphi_0}{H_0} H_0 t}\right)\right). \tag{3.3c}$$

The condition that $a(t)$ exists for all finite t is equivalent to the condition that the denominator of (3.3a) is positive for all finite t. There are two possibilities:

(1) The denominator converges to zero as $t \to \infty$.
This implies

$$\frac{1}{2}\frac{\varphi_0}{H_0} = \left(3\Omega_m K_0\right)^{1/2} \Big/ tg\left[\left(\frac{K_0}{3K_1}\right)^{1/2} \log\left(B \Big/ \left(\frac{1}{2}\Omega_m + \left(\Omega_m K_1 \Omega_\Lambda\right)^{1/2}\right)\right)\right] \tag{3.4}$$

and $a(t)$ converges to infinity as $t \to \infty$.

(2) The denominator goes to a finite value as $t \to \infty$.
This yields

$$\frac{1}{2}\frac{\varphi_0}{H_0} > \left(3\Omega_m K_0\right)^{1/2} \Big/ tg\left[\left(\frac{K_0}{3K_1}\right)^{1/2} \log\left(B \Big/ \left(\frac{1}{2}\Omega_m + \left(\Omega_m K_1 \Omega_\Lambda\right)^{1/2}\right)\right)\right] \tag{3.5}$$

and $a(t)$ goes to a finite value $a(\infty)$ as $t \to \infty$.

To get small values of $a(t)$ as $t \to -\infty$ we assume

$$K_0 << K_1 << 1. \tag{3.6}$$

Then, (3.3) yields by elementary calculations as $t \to -\infty$

$$a(t) \approx a(-\infty) \exp\left(\frac{\left(\Omega_m K_1\right)^{1/2}}{\left(\frac{1}{2}\frac{\varphi_0}{H_0}\right)^2} \Big/ \left(-H_0 t\right)\right) \tag{3.7a}$$

with

$$a(-\infty) = \left(2\Omega_m K_1 / B\right)^{1/3} \exp\left(-\pi\left(\frac{K_1}{K_0}\right)^{1/2} + \left(\Omega_m K_1\right)^{1/2} \Big/ \left(\frac{1}{2}\frac{\varphi_0}{H_0}\right)\right). \tag{3.7b}$$

Hence, relation (3.7b) gives by virtue of (3.6)

$$0 < a(-\infty) << 1 \tag{3.8}$$

i. e., the universe starts with a small but positive scaling factor. The function $h(t)$ as $t \to -\infty$ follows by (2.21). Hence, in the beginning the universe consists of gravitational energy. Matter, radiation and vacuum energy arise from this energy in the course of time.

The proper time of the universe from the beginning until the time t under the assumption $a(-\infty) << a(t)$ is given by (compare e. g. [7])

$$\tau(t) = \int_{-\infty}^{t} \frac{dt}{h^{1/2}(t)} = \frac{1}{3H_0} \int_{a^3(-\infty)}^{a^3(t)} \frac{dx}{\left(\Omega_m K_1 + \Omega_m x + \Omega_\Lambda x^2\right)^{1/2}} =$$

$$= \frac{1}{3\Omega_\Lambda^{\ 1/2} H_0} \log\Big[\Big(\Omega_\Lambda a^3 + \Omega_m/2 + \tag{3.9}$$

$$+ \Omega_\Lambda^{\ 1/2}\left(\Omega_m K_1 + \Omega_m a^3 + \Omega_\Lambda a^6\right)^{1/2}\Big) \Big/ \left(\Omega_m/2 + \left(\Omega_m K_1 \Omega_\Lambda\right)^{1/2}\right)\Big].$$

Hence, the age of the universe at present is

$$\tau(0) = \frac{1}{3\Omega_\Lambda^{\ 1/2} H_0} \log\left[\left(\Omega_\Lambda + \Omega_m/2 + \Omega_\Lambda^{\ 1/2}\right) \Big/ \left(\Omega_m/2 + \left(\Omega_m K_1 \Omega_\Lambda\right)^{1/2}\right)\right]. \tag{3.10}$$

The presently assumed best cosmological parameters are

$$\Omega_m \approx 0.3, \Omega_\Lambda \approx 0.7, H_0 \approx 65 \frac{km}{\sec Mpc}, \tau(0) \approx 14 \cdot 10^9 y \tag{3.11}$$

Substituting these values in relation (3.10) we must assume

$$\left(\Omega_m K_1 \Omega_\Lambda\right)^{1/2} << \Omega_m/2 \tag{3.12}$$

implying

$$\tau(0) \approx \frac{1}{3\Omega_\Lambda^{\ 1/2} H_0} \log\left[\left(\Omega_\Lambda + \Omega_m/2 + \Omega_\Lambda^{\ 1/2}\right) \Big/ \left(\Omega_m/2\right)\right]. \tag{3.13}$$

This relation gives with the values of (3.11)

$$\tau(0) \approx 0.964 \frac{1}{H_0} \approx 14.5 \cdot 10^9 y \tag{3.14}$$

in good agreement with the presently accepted age (3.11) of the universe.
The condition (3.10) is rewritten by the use of (2.27b) and (3.6) in the form

$$\Omega_a << \frac{1}{4} \Omega_m^{\ 2} / \Omega_\Lambda \tag{3.15}$$

giving with the aid of the parameters (3.11)

$$\Omega_a << 0.03\ . \tag{3.16}$$

Hence, the density parameter of the additional matter must be small compared to the density parameter of dust. This additional matter is only important in the beginning of the universe and it is negligible at later times, in particular at present. The theory of gravitation in flat space-time together with the second law of Thermodynamics requires in addition to dust matter the density of that satisfies a stiff equation of state.
This matter can be identified with the neutrinos in our universe.

Let us now study the solutions $a(t)$ and $h(t)$ for sufficiently large t, i. e. as $t \to \infty$ under the assumptions (3.6). Then, it follows from (3.4) and (3.5) by the use of (2.27b) and Taylor expansion

$$\frac{1}{2} \frac{\varphi_0}{H_0} \approx \frac{3}{2} \Omega_m \Big/ \left(1 - \Omega_\Lambda^{\ 1/2}\right) \approx \frac{3}{2}\left(1 + \Omega_\Lambda^{\ 1/2}\right) \tag{3.17a}$$

for case (1) and

$$\frac{1}{2} \frac{\varphi_0}{H_0} > \frac{3}{2}\left(1 + \Omega_\Lambda^{\ 1/2}\right) \tag{3.17b}$$

for case 2. These formulas are identical with the corresponding ones for nonexpanding cosmological models with cosmological constant studied in the papers [7,8]. We can rewrite (3.2) for sufficiently large $t - t_1$ and $a(t)$ not too small by the use of (2.27) and (3.6) in the form

$$\frac{H_0}{\left(\frac{1}{2}\frac{\varphi_0}{H_0}\right)^2}\int_0^t \frac{dt}{(H_0 t - H_0 t_1)^2} \approx \int_1^a \frac{da}{a\left[\Omega_m a^3 + \Omega_\Lambda a^6\right]^{1/2}} \tag{3.18}$$

where we have put

$$H_0 t_1 \approx -\frac{1}{\frac{1}{2}\frac{\varphi_0}{H_0}} \ . \tag{3.19}$$

Elementary calculations give by the use of (2.26) and (3.6) the solution

$$a^3(t) = \left(\frac{1}{2}\frac{\varphi_0}{H_0}\right)^2 (H_0 t - H_0 t_1)^2 \Bigg/ \left[\left(\left(\frac{1}{2}\frac{\varphi_0}{H_0}\right)^2 - 3\frac{1}{2}\frac{\varphi_0}{H_0} + \frac{9}{4}\Omega_m\right)(H_0 t)^2 + \right.$$
$$\left. + \left(2\frac{1}{2}\frac{\varphi_0}{H_0} - 3\right)H_0 t + 1\right]. \tag{3.20a}$$

Relation (2.21) yields by the use of (2.27a) and (3.6)

$$h^{1/2}(t) = \left(\left(\frac{1}{2}\frac{\varphi_0}{H_0}\right)^2 - 3\frac{1}{2}\frac{\varphi_0}{H_0} + \frac{9}{4}\Omega_m\right)(H_0 t)^2 + \left(2\frac{1}{2}\frac{\varphi_0}{H_0} - 3\right)H_0 t + 1 \ . \tag{3.20b}$$

The solutions (3.20) are valid for both cases (1) and (2). For case (1) the solutions can be rewritten in the form

$$a^3(t) = \left(\frac{1}{2}\frac{\varphi_0}{H_0}\right)^2 (H_0 t - H_0 t_1)^2 \Bigg/ \left[\left(2\frac{1}{2}\frac{\varphi_0}{H_0} - 3\right)H_0 t + 1\right] \tag{3.21a}$$

$$h^{1/2}(t) = \left(2\frac{1}{2}\frac{\varphi_0}{H_0} - 3\right)H_0 t + 1 \tag{3.21b}$$

where (3.17a), (2.26) and (3.6) are used. The formulae (3.21) give a linear growth for the functions $a^3(t)$ and $h^{1/2}(t)$ for sufficiently large t whereas for case (2) the relations (3.20) yield that $a^3(t)$ converges to a finite value and $h^{1/2}(t)$ increases quadratically as $t \to \infty$. The solutions (3.20) and (3.21) are indentical with those of a nonexpanding nonstationary universe with a cosmological constant studied in [7, 8]. For both cases the function $a(t)$ starts from a small positive value at $t = -\infty$ and it increases for all t whereas $h(t)$ is infinite at $t = -\infty$, it decreases to a minimum value and then it increases to infinity as $t \to \infty$. The relations (2.13) and (3.17) yield that $h(t)$ is increasing at present time t=0.

The redshift z of the spectral lines emitted at time t from an atom at a distant galaxy is given by (see [7, 8])

$$a(t) = 1/(1+z). \tag{3.22}$$

This galaxy has at present the distance

$$r = -\int_0^t \frac{dt}{ah^{1/2}} = \frac{c}{H_0}\int_0^z \frac{dx}{\left(\Omega_\Lambda + \Omega_m (1+x)^3\right)^{1/2}} \ . \tag{3.23}$$

These formulae follow along the lines of the papers [7, 8] and they are identical with the ones of a nonstationary nonexpanding universe of flat space-time theory of gravitation and also with the ones of Einstein's general theory of relativity.

The temperature of the black body radiation in the expanding universe is given by (compare [5, 19])

$$T(t) = T_0 / \left(a(t) h^{1/8}(t) \right). \tag{3.24}$$

The velocity of light in the center of any reference frame (observer) is by virtue of relation (2.35) always the vacuum light-velocity. The periods of proper time and absolute time are equal at present time t=0. Therefore, the light-velocity at distant objects follows from (2.38) giving

$$\left| \frac{1}{c} \frac{d\,\tilde{x}_L}{dt} \right| = \left| \left(\frac{1}{h} - \frac{1}{c^2} \left(\frac{\dot{a}}{a} \right)^2 \left| \tilde{x} \right|^2 \sin^2 \alpha \right)^{1/2} + \frac{\dot{a}}{a} \left| \tilde{x} \right| \cos \alpha \right|. \tag{3.25}$$

Here, $|\cdot|$ denotes the Euclidean norm and α is the angle between the direction of the vector $\left(\tilde{x}_1, \tilde{x}_2, \tilde{x}_3 \right)$ and the light-velocity. In the special case that these two directions are identical relation (3.25) yields

$$\frac{1}{c} \left| \frac{d\,\tilde{x}_L}{dt} \right| = 1/h^{1/2}(t) + \frac{\dot{a}}{a} \left| \tilde{x} \right|. \tag{3.26}$$

The last term represents the expansion of the universe and it is small in the neighbourhood of the center. Therefore, the light-velocity has the form

$$\frac{1}{c} \left| \frac{d\,\tilde{x}_L}{dt} \right| \approx 1/h^{1/2}(t). \tag{3.27}$$

The relations (3.20a) and (3.22) give by the use of (3.19)

$$H_0 t - H_0 t_1 = \left(\frac{3}{2} \frac{1}{2} \frac{\varphi_0}{H_0} + \frac{3}{2} \frac{1}{2} \frac{\varphi_0}{H_0} \left(1 + \Omega_m \left((1+z)^3 - 1 \right) \right)^{1/2} - \frac{9}{4} \Omega_m \right) \Bigg/ \left[\frac{1}{2} \frac{\varphi_0}{H_0} \times \right.$$

$$\left. \times \left(\left(\frac{1}{2} \frac{\varphi_0}{H_0} \right)^2 \left((1+z)^3 - 1 \right) + 3 \frac{1}{2} \frac{\varphi_0}{H_0} - \frac{9}{4} \Omega_m \right) \right].$$

Then, equation (3.27) yields with the aid of the formulae (2.21), (2.27a) and (3.6) the velocity of light

$$\frac{1}{c} \left| \frac{d\,\tilde{x}_L}{dt} \right| = \frac{1}{(1+z)^3} \left[\left(\left(\frac{1}{2} \frac{\varphi_0}{H_0} \right)^2 \left((1+z)^3 - 1 \right) + 3 \frac{1}{2} \frac{\varphi_0}{H_0} - \frac{9}{4} \Omega_m \right) \Bigg/ \left(\frac{3}{2} \frac{1}{2} \frac{\varphi_0}{H_0} + \right. \right.$$

$$\left. \left. + \frac{3}{2} \frac{1}{2} \frac{\varphi_0}{H_0} \left(1 + \Omega_m \left((1+z)^3 - 1 \right) \right)^{1/2} - \frac{9}{4} \Omega_m \right) \right]^2 \tag{3.28}$$

as function of the redshift z. This relation gives for any fixed $z > 0$ that the light-velocity is increasing with increasing $\frac{1}{2} \frac{\varphi_0}{H_0}$ in case (1) and (2) and it can be several times the vacuum light-velocity. This can be explained by the fact that atomic clocks go faster at earlier times, i. e., at distant objects with redshift $z > 0$ than the atomic clocks a present.

Hence, the observed extragalactic radio sources with expansion of small radio components at velocities apparently a few times greater then that of the vacuum light-velocity (see e. g. [20-22]) can be explained.

As example let us consider the quasar 1928 + 738 (compare [22]) with the redshift $z = 0.36$ where several subcomponents have a motion relative to the core with velocities of about 13.85c when the Hubble constant (3.11) is used. By virtue of (3.28) and the above remarks it follows the inequality

$$\frac{1}{2}\frac{\varphi_0}{H_0} \geq 10.7 \tag{3.29}$$

where the equality holds for $\frac{1}{c}\left|\frac{d\tilde{x}}{dt}\right| = 13.85$.

Hence, we have

$$\frac{1}{2}\frac{\varphi_0}{H_0} > 10.7 \tag{3.30}$$

then, the subcomponents of this quasar appear to have superluminal velocities and the light-velocity at this quasar is greater than these superluminal velocities for an observer at present. Inequality (3.30) gives a lower limit for $\frac{1}{2}\frac{\varphi_0}{H_0}$. It is very likely that there exist distant objects with some redshift z implying a greater value for $\frac{1}{2}\frac{\varphi_0}{H_0}$ than that by inequality (3.30). Then the greatest one is a lower limit for $\frac{1}{2}\frac{\varphi_0}{H_0}$. Inequality (3.30) yields by the use of (3.17b) that our universe is described by case (2), i. e., the equations (3.20a, b) hold with inequality (3.17b). Hence, the function $a(t)$ converges to a finite value as $t \to \infty$ whereas $h^{1/2}(t)$ increases quadratically for sufficiently great values of t.

We have received a new explanation of the observed apparent superluminal velocities at distant objects which can not be given by Einstein's general theory of relativity because for that theory proper time and absolute time are equal. It is worth mentioning that there exist several theoretical models to explain the apparent superluminal velocities (compare e. g. [23-26] where also criticism can be found).

The entropy production is by virtue of (2.17) and (2.20)

$$\begin{aligned} dS &= \frac{1}{T_r + T_a}(p_r + p_a)dV \sim \frac{1}{T_r + T_a}\left(\frac{p_{r0}}{a^4 h^{1/2}} + \frac{p_{a0}}{a^6 h^{1/2}}\right)da^3 \sim \\ &\sim \frac{3}{T_r + T_a}\left(p_{r0} + \frac{p_{a0}}{a^2}\right)\frac{1}{a\,h^{1/2}}\frac{\dot{a}}{a}dt . \end{aligned} \tag{3.31}$$

Here, T_r and T_a denote the absolute temperature of radiation and of neutrinos, respectively. It follows that the entropy production by neutrinos dominates that of radiation in the beginning of the universe.

4. CONCLUSION

All homogeneous isotropic cosmological models of flat space-time theory of gravitation are spatially flat in agreement with recent astrophysical measurements whereas Einstein's theory permits curved spaces. Furthermore, nonsingular cosmological models exist in contrast to the general theory of relativity. The periods of absolute and proper time are different from one another but they agree at present, whereas Einstein's theory yields equal periods for all times. Recent astrophysical observations suggest an accelerating universe which can be explained by a positive cosmological constant. Homogeneous isotropic cosmological models with cosmological constant of flat space-time theory of gravitation permit two interpretations:

(1) The universe does not expand and no entropy is produced. Then, the redshift of spectral lines of atoms from distant galaxies is explained by energy loss of the emitted photons on their way to the observer (see [7, 8]).
(2) The universe always expands. Then, the second law of Thermodynamics yields the production of entropy. This result requires a two component fluid of matter consisting as usually of dust and an additional matter component satisfying a stiff equation of state. This additional component also can be explained by a scalar field with vanishing potential in the field equations. The presently assumed best astrophysical parameters of our universe give a small density parameter for the additional matter compared to the one of dust. This additional matter is only important in the beginning of the universe and it can be identified with the neutrinos in our universe.

At later times most of the formulae of the two interpretations agree. The velocity of light in the expanding universe is locally the vacuum light-velocity for any observer and for all times. But the velocity of light at distant objects can appear several times the vacuum light-velocity. This follows from the fact that clocks at earlier times, i. e. at distant objects go faster than clocks at present. This result gives a new interpretation of the observed superluminal velocities at extragalactic objects which can not be stated with the aid of Einstein's theory. The application of this interpretation to a special quasar which has superluminal motions of several subcomponents yields for our universe that the scaling factor $a(t)$ increases to a finite value as time goes to infinity and the period of proper time converges to zero. The formulae for the black body temperature and for the entropy production are different from those of Einstein's theory. But the formula for the distance of an extragalactic source as function of the redshift agrees with the one of the general theory of relativity.

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