COSMOLOGICAL CONSTANT, QUINTESENCE AND EXPANSIVE NONDECELERATIVE UNIVERSE

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Abstract
Recent observations of the Universe have led to a conclusion suppressing an up-to-now supposed deceleration of the Universe caused by attractive gravitational forces. Contrary, there is a renaissance of the cosmological member $\Lambda$ and introduction of enigmatic repulsive dark energy in attempts to rationalize a would-be acceleration of the Universe expansion. It is documented that the model of Expansive Nondecelerative Universe is capable to offer acceptable answers to the questions on the Universe expansion, state equations of the Universe, the parameter $\omega$, the cosmological member $\Lambda$ without any necessity to introduce new strange kinds of matter or energy being in accord with the fundamental conservation laws and generally accepted parameters of the Universe.

1 Background of the ENU model
Solving Einstein equations of field by means of Robertson-Walker metric, Friedmann obtained equations of universe dynamics. In the Expansive Nondecelerative Universe (ENU) model it has been rationalized [1, 2] that the
Universe, throughout the whole expansive evolutionary phase, expands by
the velocity of light $c$, and the gauge factor $a$ can be thus expressed as

$$a = c.t_c$$ (1)

where $t_c$ is the cosmological time (the present values provided by calculations
based on ENU are $a \cong 1.3x10^{26}\text{m}; t_c \cong 4.3x10^{17}\text{s}$). In this approach, the
curvature index $k$ and cosmologic member $\Lambda$ are of zero value

$$k = 0$$ (2)

$$\Lambda = 0$$ (3)

Solving Friedmann equations in the ENU leads to

$$c^2 = \frac{8\pi G \rho a^2}{3} = -\frac{8\pi G p a^2}{c^2}$$ (4)

where $\rho$ is the mean (critical) mass density of the Universe (at present, $\rho \approx 10^{-26}\text{ kg m}^{-3}$) and $p$ is the pressure. Since the energy density $\varepsilon$ is

$$\varepsilon = \rho c^2$$ (5)

in accordance with the General Theory of Relativity and (4), the Universe
with total zero and local non-zero energy meets the state equation [3]

$$p = -\frac{\varepsilon}{3}$$ (6)

Providing that the velocity of the Universe expansion is equal to $c$, the
total gravitational force must be equal to zero (compare 1 and 6). Equation
(4) leads then to the expression for $\rho$

$$\rho = \frac{3c^2}{8\pi Ga^2}$$ (7)

and, due to (2), for $\rho$ representing the density of the Universe with the mass
$m_u$, it must be valid for a flat Universe at the same time

$$\rho = \frac{3m_u}{4\pi a^2}$$ (8)

Taking into account the expressions (7) and (8), for the gravitational
radius it then holds

$$a = \frac{2G m_u}{c^2}$$ (9)
Since $a$ is increasing in time, $m_u$ must increase as well (its present value approaches $8.6 \times 10^{52}$ kg), i.e. in the ENU, the creation of matter occurs [3]. The total energy of the Universe must, however, be exactly zero. It is achieved by a simultaneous gravitational field creation, the energy of which is $E < 0$. The fundamental mass-energy conservation law is thus observed. Due to the matter creation, in ENU Schwarzschild metrics must be replaced by Vaidya metrics [4, 5].

The ENU model has been up to now able to offer answers to several current questions of both micro-world and micro-world [6]. In connection to the matter discussed in this contribution, we would like to remind the zero value of $\Lambda$ and the state equation (3) leading directly to $\omega$ value

$$\omega = -\frac{1}{3}$$

where the parameter $\omega$ is defined as the ratio

$$\omega = \frac{p}{\varepsilon}$$

From the viewpoint of ENU, gravitation is a local phenomenon which can manifests itself only in cases when the total energy density exceeds the critical energy density. The total average energy density of the Universe is identical to the critical density and thus, from the global point of view, gravitational forces cannot exhibit themselves.

A typical nature of the ENU model is its simplicity, no “additional parameters” or strange “dark energy” needed, and the usage of only one state equation in describing the Universe. Calculated gauge factor $a$, cosmological time $t_c$, and energy density $\rho$ match well the generally accepted values.

2 Cosmological member $\Lambda$

One of the corner stones of many modern cosmological theories has for long time been a postulate stating that after its inflation period, the Universe has undergone a classic Friedman expansion which would gradually decelerate due to the gravitational force influence. The measure of this deceleration would depend on the energy density of the Universe.

Relation between the pressure $p$ and the energy density $\varepsilon$ of the Universe can be expressed via three equations, namely:

$$p = \varepsilon$$
Relation (12) describes the relativistic particles, equation (13) which is used for the radiation era, (14) is the state equation of dust particles and can be applied in the matter era.

Measurements of radiation intensity (brightness) of distant supernovas performed in the last years have shown that this intensity is significantly lower than that predicted. Consequently, these objects should be more distant than expected and, in turn, there should be no deceleration in the Universe expansion caused by gravitation. It seems that these observations justify the introduction of the cosmological member \( \Lambda \). This member represents the negative pressure or repulsive forces of the vacuum counteracting to the attractive forces of gravitation. The cosmological member was introduced by Einstein as a mode of the preservation of static character of the Universe.

Stemming from the Hubble discovery and characterization of the Universe expansion, there is no need to take the cosmological member into account any longer.

The second introduction of \( \Lambda \) was connected to an inaccuracy in the Hubble constant \( H \) determination. Too high value having been estimated would led, however, directly to a too short age of the Universe. The problem was overcome introducing \( \Lambda \) which allowed to prolong the age. After performing a more precise determination of \( H \), the cosmological member become irrelevant.

The third instance of the cosmological member \( \Lambda \) introduction into theory appeared in relation to the inflation model of the Universe, where this member describes certain quantum effects of the physical vacuum.

### 3 Parameter \( \omega \)

For cases of a nonzero value of the cosmological member \( \Lambda \) it must hold

\[
\omega = -1
\]  

(15)

Owing to some generally accepted present parameters of the Universe (such as gauge factor, cosmological time, critical energy density) many problems appear in the models of the Universe incorporating the cosmological member.
In the inflation model with a nonzero cosmological member, the above parameters values can be approached in such a way that following the inflation period the Universe decelerated due to gravitation and matter emerged beyond the causal horison first, and then due to an influence of the cosmological member, the Universe expansion accelerated. To describe such a Universe, two state equations are required as a minimum. One can, however, hardly believe that just at the time being the critical energy density of the Universe is reached. Moreover, it is not clear how this critical energy density would be kept during a gradual acceleration of the Universe expansion in the future. The most recent measurements of $\omega$ suggest that the value

$$\omega = -2/3$$

is more probable than the value in (15).

4 The fifth force

A newly established model of the Universe – quintessential model [7] – is based on the supposed existence of the fifth force, i.e. a special dark energy, which generates negative pressure and thus contributes to the acceleration of the Universe expansion. This quintessential energy is not so “rigid” as the cosmological member is, contrary, it is “soft” and its properties and effects can vary during the Universe expansion.

Quintessential model works with a value of $\omega$ in the range

$$\omega = (-1, -1/3)$$

the most probable being the value given by equation (16). The inherent problems of this model lie in the inability to characterize the matter responsible for the creation of the quintessential energy. In this model several state equations are used and it is highly improbable that a combination of such state equations could lead just to the present critical energy density.

5 Conclusions

The corner stones of the model of Expansive Nondecelerative Universe (ENU) were laid in the nineties of the last century [2]. It was shown [3] that in the
ENU model $\omega = -1/3$ ($[^{10}]$), which is a value falling into a range predicted based on the latest experimental observations and calculations.

To determine an exact value of $\omega$, several new experimental observations have been proposed, e.g. utilization of a satellite SAP (Supernova Acceleration Probe) to investigate distant supernovas, and an Earth-located telescope ELASST able to measure the differences in angle dimensions of hot and cold spots in microwave radiation of the cosmic background. It should be pointed out, however, that in evaluation of $\omega$ value, its interrelation with Hubble constant must be taken into account. In the case of SAP project, the value of Hubble constant must be determined as precisely as possible. A lower value of $H$ could prefer the ENU model with $\omega$ value given in ($[^{10}]$), a higher value would lead to quintessential model with ($[^{16}]$) or, vice versa, the measured results can be rationalized using ($[^{10}]$) for a lower $H$ or ($[^{16}]$) for a higher value of $H$.

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