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THE PRIMARY NUCLEOSYNTHESIS IN CYCLIC NON-EXPANDING UNIVERSE INVOLVING LONG-LIVED RAPIDLY MOVING PRIMORDIAL NEUTRONS

In a relativistic generalization of the theory of gravitation, we preserve the Newtonian concept of gravity as a force field and develop it on the basis of the canonical linear theory of a massive spinless field $\phi(x)$ satisfying the equation

$$\left(\Box - \varkappa^2 - \frac{2\pi G_N}{c^2}\vartheta\right)\phi = 0,$$

where, in the presence of the source of the field consisting of massive gravitating particles,

$$\vartheta = \sum_a m_a\sqrt{1 - \frac{v_a^2}{c^2}}\,\delta^{(3)}(\mathbf{r} - \mathbf{r}_a).$$

We motivate this task with the unresolved challenges of the "dark energy" and "dark matter" in modern observational cosmology based on the general theory of relativity that is devoid of special-relativistic laws of conservation for the energy, momentum, and angular momentum.

As a result, in the case of a universe completely filled with uniform dustlike matter, when the background field $\phi(\mathbf{r}, t) = \psi(t)$, the alternative cyclic scenario with the period of about 110 Gyr of the evolution of eternal universe without expansion or contraction is aroused. The first half of each cyclic epoch is characterized by the increase in the inertial masses, from zero to the maximum, equal to 250% of their present values, of the primordial ultrarelativistic elementary particles, and then of atoms, stars, and other cosmic bodies as they form.

Simultaneously with the stretching of the energy spectra of quantum systems, their energy levels are also broadened with a factor

$$\psi^2(t) = \frac{\sin^2 \Omega t}{\sin^2 \Omega t_0}. \tag{1}$$

On the contrary, in accord with this coefficient, as the rest energy of these systems decreases in the course of the second half-cycle, their energy levels become narrower. Therefore from the law of energy evolution

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

and the quantum mechanical uncertainty relation between the width of energy levels $\Delta\mathscr{E}$ and the lifetime of excited states $\Delta\tau$,

$$\Delta\tau \cdot \Delta\mathscr{E} \sim \hbar,$$

it follows that the lifetime of a system in bounded state depends on the age t of cycle in such a way that

$$\Delta\tau(t) \sin^2 \Omega t = \text{const}. \tag{3}$$

In this case we find from (3) that the half-life of unstable particles or nuclei varies with cosmic time as follows:

$$T^{1/2}(t) = T_0^{1/2} \frac{\sin^2 \Omega t_0}{\sin^2 \Omega t}.$$

Putting the look-back time t_{ret} by setting $t = t_0 - t_{ret}$, one can write from this for distant decaying particles observed at present time t_0:

$$T^{1/2}(t_{ret}) = T_0^{1/2} \frac{\sin^2 \Omega t_0}{\sin^2 \Omega (t_0 - t_{ret})}. \tag{4}$$

In agreement with the probabilistic nature of a radioactive decay of individual nucleus, the number dN of nuclei decayed at a given epoch t during small time interval dt is proportional to the number $N(t)$ of presented undecayed nuclei with the time-dependent factor (1), so that

$$dN = -\frac{\ln 2}{T_0^{1/2} \sin^2 \Omega t_0} \sin^2 \Omega t \, N(t) \, dt. \tag{5}$$

Expressed in terms of the fractional quantity of undecayed nuclei, the modified law of a radioactive decay obtained by integrating the equation (5) has the form

$$\frac{N(t)}{N_{\text{ref}}} = \exp\left[\frac{-\ln 2}{2\, T_0^{1/2} \sin^2 \Omega t_0}\left(t - t_{\text{ref}} - \frac{\sin 2\Omega t - \sin 2\Omega t_{\text{ref}}}{2\Omega}\right)\right]. \tag{6}$$

Here t_{ref} denotes the reference time, that is, some fixed instant of standard cosmic time given at a certain epoch, with respect to which the registration of undecayed nuclei in the previous time and thereafter is carried out; the number of undecayed nuclei $N_{\text{ref}} = N(t_{\text{ref}})$ at this instant is assumed to be given.

For further discussion of this law, it is convenient to choose in place of t the time coordinate $t' = t - t_{\text{ref}}$ with origin at a given reference instant t_{ref}. Dropping the prime on the introduced new time coordinate, we rewrite the cosmological law of radioactive decay (6) in the form

$$\frac{N(t)}{N_{\text{ref}}} = \exp\left\{\frac{-\ln 2}{2\,T_0^{1/2}\sin^2 \Omega t_0}\left[t - \frac{\sin 2\Omega(t_{\text{ref}} + t) - \sin 2\Omega t_{\text{ref}}}{2\Omega}\right]\right\}. \quad (7)$$

The idea of the special role of free neutrons in the primary nucleosynthesis belongs, as is known, to George Gamow and his collaborators [1], [2], [3]. Among many exotic assumptions about the state of primordial matter in the model of the expanding universe, Gamow's hypothesis adds the necessary condition that the baryonic matter in the earliest universe should have consisted primarily of free neutrons. The second exotic feature of the theory of a primary nucleosynthesis developed on Gamow's idea is the presentation of too rigid requirements to physical conditions in the very early universe, in which "the production of elements must have been essentially complete in a time of the order of magnitude of the neutron decay lifetime" [3], that is, during the period just over 12,8 minutes.

Refusing the big-bang scenario of the universe evolution, we will nevertheless try to reconsider Gamow's idea of the special role of primordial neutrons in primary nucleosynthesis with reference to the alternative model of the cyclic universe proposed here. For obvious reasons, here we cannot consider this problem numerically in details. We will focus our attention only on the possibility of having a sufficient number of free neutrons in the early epoch of the evolutionary cycle for rather a long period of time, and then try to determine the physical mechanisms that could contribute to the efficiency of primary nucleosynthesis involving neutrons to provide a cosmic abundance of light elements, which is now observed.

Let us first consider the decay of unstable particles in a short period of time at the very end of one of the evolutionary cycles and at the very beginning of the next. At a junction of two cycles, it is convenient to count down the number of undecayed particles directly from the instant of zeroing of their mass. So, setting in general formula (7) $t_{\text{ref}} = 0$, we write

$$\frac{N(t)}{N(0)} = \exp\left[\frac{-\ln 2}{2\,T_0^{1/2}\sin^2 \Omega t_0}\left(t - \frac{\sin 2\Omega t}{2\Omega}\right)\right]. \quad (8)$$

The general picture of the decay of unstable particles at the junction of two cyclic epochs, calculated by using the equation (8), is shown in Figure

1 on the example of the decay of neutrons, whose current half-life is 613,9 secods [4].

The slowing decay of these unstable particles at the very end of previous cycle is shown in a small section of the curve in this figure to the left of $t = 0$. The continuation of this curve shows the slowly accelerating decay of the primordial neutrons left over from the previous cycle after the complete disintegration of the nuclei and survived the times of the radiation-like state of the matter.

In accordance with figure 1, half of the primordial neutrons decays in the course of 300 thousand years after the beginning of the cycle (instead of present scanty 613,9 seconds!). As can be seen from the same figure, neutrons remain almost stable in the course of the first 100 thousand years.

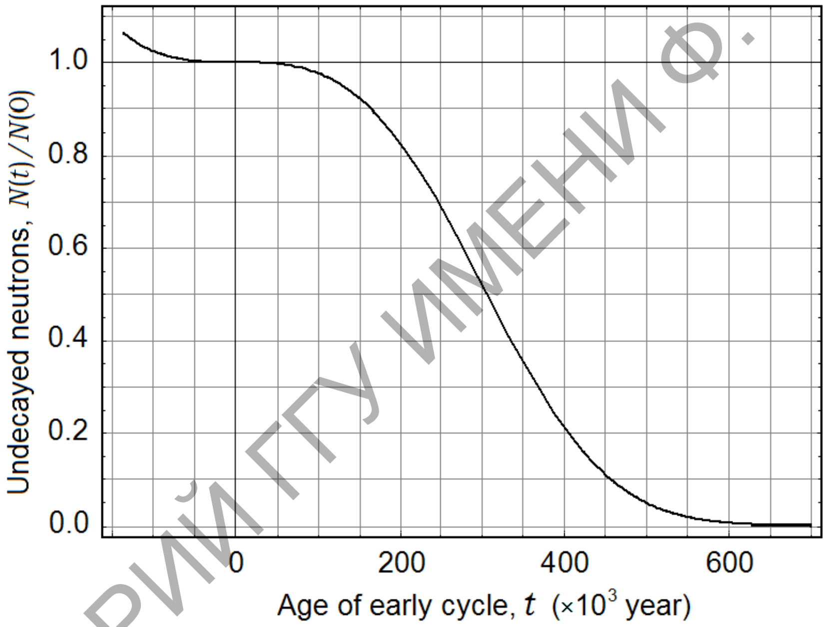

Figure 1 – The decay of primordial neutrons at the junction of two cyclic epochs

It should also be remembered that all particles at the very beginning of the cycle are extreme relativistic. Therefore, along with a large lifetime of neutrons and other unstable particles including intermediate unstable radionuclides, more frequent collisions occur between them. These two circumstances should obviously provide an effective mechanism for involving neutrons in the primary nucleosynthesis. As a result, the whole idea acquires a more solid theoretical basis instead of Gamow's special hypothesis [1] about the neutron dominance in early baryonic matter.

Therefore, because of the long lifetime and frequent collisions of rapidly moving free neutrons and intermediate unstable nuclides in early cyclic epoch, light primordial nuclei, such as ^{2}H, ^{3}H, ^{3}He, ^{4}He, and heavier, during the first 450 thousand years could have been synthesized, quite effectively to reach the abundances that are now observed.

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THE LAW OF ENERGY-MOMENTUM CONSERVATION OF MASSIVE SPIN-ZERO GRAVITATIONAL FIELD

Turning to the 20-year history of the theoretical study of the cosmological problem of dark energy and analyzing its current state, we will not find the gravitational field among discussed its probable carriers. The first thing that comes to mind about the possible reasons for the lack of progress in understanding the nature of this mysterious energy is the absence in general relativity of the law of conservation of energy, as well as the questionable status of energy itself as a significant physical concept. This theory underlying the big-bang cosmology objectively does not allow us to investigate the local as well as the large-scale and global energy problems in the universe (a brief remark on this subject is contained also in [1], pp. 83–84). Since gravity is the dominant interaction on the scale of the Universe, this circumstance, unfortunately, significantly paralyzed the evidence base of modern cosmology and predetermined the failure of two decades of brainstorming the problem of the physical nature of "dark energy".

The principal impossibility of a mathematically rigorous formulation of the law of energy conservation for the gravitational field in general relativity was first noted by David Hilbert as a characteristic feature of this theory