Report

Shadow matter with 4 generations of fermions

Nepochataia Olga

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1. Introduction.

Modern physics deals with three basic types of spatial symmetry: reflection, translation and rotation. For elementary particles only translation and rotation are performed, reflection (P - symmetry) is violated in a weak interaction. This fact was assumed theoretically by Lee and Yang [1], and then it was confirmed experimentally.

For example, in beta-decay only left-polarized neutrino are born, and reflection gives (P - transformation) neutrino, which can't take part in weak interaction.

P-violation means that left and right coordinate systems are not equivalent, and the Universe has prefered orientation of coordinate axes. Lee and Yang assumed that there is a mirror partner for every elementary particle. In this case P-symmetry is broken, but equivalence of left and right systems is restored.

For a long time antiparticles were considered as candidates for the role of mirror particles. But the discovery of CP-violation showed that antiparticles are not mirror particles. I.Pomeranchuk, L.Kobzarev and L.Okun'[2] demonstrated that mirror particles, if they exist, take part only in gravitational interaction.

2. Model.

2.1. Physical model

In this paper, the possibility of existence mirror world is considered. The model suggests that this world exists parallely with the world of ordinary particles and consists of 4 generations of fermions (in the usual world there are 3 generations). We suggest that three generations of mirror particles are copies of three generations of ordinary particles, and the 4th generation consists of particles with masses less than mass of the “mirror Z-boson”, 4th generation mirror charged lepton is lighter than corresponding neutrino. Also 4th generation is stable.

We suggest that mirror world and usual word have different cosmology evolution. For example they had never been in the equilibrium. Shadow world interacts with the usual one only by gravity, but gravity is too weak for establish the thermodynamic equilibrium. We also neglect kinetic mixings of ordinary and mirror photons, Higgs bosons etc. We assume that mirror particles can form ~⅓ part of hot dark matter.

2.2. Cosmological scenario

2.2.1 Abundance of primordial helium.

The most important restriction for all models is connected with the data of abundance of primordial helium (contribution of primordial nuclei in baryon density in the end of the primordial nucleosynthesis period (fig.1)). This data restrict the quantity of any relativistic matter (including shadow matter) at the moment t~1 s, T~1 MeV. The modern researches based on the cosmological nucleosynthesis and the cosmic microwave background give the value 23,1% <Y <26,7%.

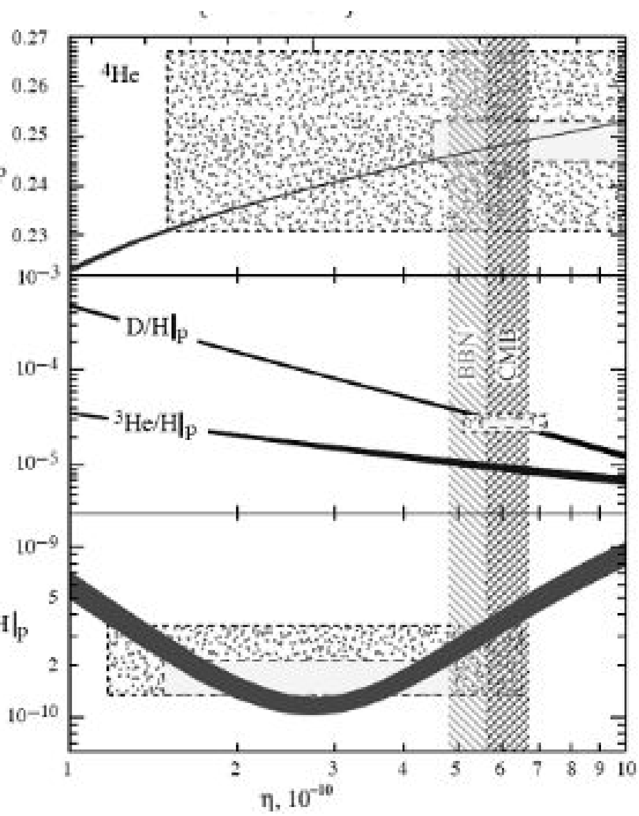

fig. 1. Contribution of primordial nuclei in baryon density. The thickness of lines corresponds to accuracy. Rectangles show the regions of values within the limits of errors from the experiments. Vertical stripes show regions of η_b values which are not forbidden by data of BBN and CMB. Index "p" means "primordial".

With good accuracy the part of mirror primordial helium formed in the early Universe is twice as many nucleons, which were neutrons at the moment of sufficient propagation of deuterium and the beginning of the process of formation of nuclei.

If there were 4th types of neutrino, the effective number of particle types would become 3.817 instead of 3.363, and the temperature drops faster in $\sqrt{3.817/3.363} \approx 1.135$ times.

It increases the fraction of neutrons and helium.

Adding each new generation increases Y on the value ≈ 0.013. It gives a restriction on the number of light neutrino generations. It can't be more than 6. Another restriction for the number of generations in usual world is connected with decay width of Z_0-boson. The mass of the 4-th generation mirror particles must be more than ½ mass of mirror Z_0-boson, but this case is not considered in this paper.

Calculation of the abundance of primordial helium:

The ratio between amount of protons and neutrons:

$$\frac{n}{p} = \exp\left(-\frac{\Delta m}{T}\right)$$

$$\Delta m = M_n - M_p = 1.29 \text{ MeV}$$

Where M_p and M_n - masses of protons and neutrons, T - freezing temperature.

$$T \approx \frac{(kG)^{\frac{1}{6}}}{G_F^{\frac{2}{3}}} \quad (3)$$

$$k = \sum g_s \left(\frac{T_i}{T}\right)^4 + \frac{7}{8} \sum \frac{g_s}{2}\left(\frac{T_i}{T}\right)^4,$$

k - statistical factor characterizing the density of the Universe. In our model we take into account ordinary and mirror photons, ordinary and mirror electrons and positrons, three generations of ordinary light neutrino, three generations of mirror one and one generation with mirror heavy neutrino. This factor for the Universe of our model is 6,88.

Temperature depends only on k. It means that the ratio between amount of protons and neutrons can be rewritten:

$$(n/p)' = (n/p)^{(k0/k)^{1/6}}$$

k is the value we calculate for the ordinary world with three generations of fermions.

$$k_0 = 5{,}375$$

$$(n/p)' = 0{,}154$$

Then by chain of nuclear reactions most of neutrons became to the helium nuclei. The formation of heavier nuclei does not occur because of the Coulomb's barrier. Also there are no stable nuclei with masses 5 and 8.

Then the concentration of mirror ^{4}He is

$$Y_p = \frac{He}{Barion} = \frac{2 \cdot (n/p)}{1 + n/p} \approx 0.267$$

This concentration falls within the constraints from the experimental data. It means that mirror world with 4 generations of fermions is possible.

2.2.2. Baryosynthesis and leptosynthesis.

We assume that baryosynthesis and leptosynthesis in mirror world followed the same scenario as in ordinary world. The only conserved quantities in the SU(3)xSU(2)xU(1) Standard Model correspond to gauge symmetries: electroweak generator T_3, electroweak hypercharge Y, two generators of SU(3) and B-L - the difference between baryonic and lepton charges (not this charges). In the period of thermodynamic equilibrium establishment, baryosynthesis and leptosynthesis, the ratio between baryonic quantity and B-L is calculated as follows:

$$N_b = N_{b-l} \cdot \frac{8 \cdot Ng + 4 \cdot Nd}{22 \cdot Ng + 13 \cdot Nd},$$

where N_g is a number of generations and N_d is the number of scalar doublets.

For three generations of usual matter this ratio is 28/79, for three usual generations and four mirror generations - 16/45. Adding new mirror generation doesn't change much this ratio. It means that mirror world with 4 generations of fermions is possible.

3. Conclusion.

In this paper the possibility of existing of mirror matter with 4 generations of fermions is described. It is shown that in the processes of baryosynthesis, leptosynthesis and nucleosynthesis there were no factors forbidding mirror matter with 4 generations of fermions.

The big part of warm dark matter can consist of mirror particles, because mirror particles take part only in gravitational interaction with usual matter. Shadow and ordinary matter have similar cosmological evolution and they can have similar total masses in the Universe, but in this paper there are no calculations confirming this fact.

There are other theories about 4th generation of fermions and mirror matter, for example:

- Sterile neutrino can be mirror particle. This neutrino haven't been observed by the present moment.
- All particles from the 4th generation of fermions are mirror.

etc. But in this paper these theories are not considered.

4. Literature.

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