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IS THERE A COSMOLOGICAL EVIDENCE FOR ADDITIONAL PARTICLES

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Abstract

An extended cosmological model of the early Universe with additional antisymmetric tensor particles is described. The cosmological effects of the additional particles, namely additional interactions of the early Universe plasma with the tensor particles, a shift of the early Universe temperature-time dependence and the total energy density increase are discussed. The efficiency of the tensor particles interactions with the early Universe plasma components and their corresponding cosmological time and temperature are determined.

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1 Introduction

Recently an extended model of electroweak interactions with additional antisymmetric tensor particles was proposed (Chizhov 1993). These particles manifest interesting and unusual properties (Avdeev & Chizov 1994 a,b; Chizhov 1995). Their presence may also lead to concrete experimental effects in different processes in particle physics (Chizhov 1994 a; Chizhov 1996), and it can influence the early Universe processes, as well. Applying the new model for analysis of some of the low energy anomalies of the standard electroweak model SU(2)xU(1) showed that it can successfully solve them. Therefore, we consider interesting to study the cosmological role of the additional tensor interactions. Such an investigation may be useful for particle physics also, as far as the analysis of standard cosmological model modification with additional antisymmetric particles may provide cosmological restrictions on the investigated new physics.

In this work we discuss first the indications for tensor particles from low energy physics experiments and the successful simultaneous explanation of the anomalies of the experimental data through the introduction of tensor particles. Then we discuss the qualitatively different effects due to the presence of the tensor particles in the early Universe.

As it will be shown below, the presence of the additional tensor particles in the cosmological plasma leads to several qualitatively different effects: shifting of the temperature-time dependence in the early Universe, introduction of additional interactions for the components of the cosmological plasma and increasing of the total energy density of the Universe. The provided analysis shows that the characteristic efficiency period of the tensor particles processes in the early Universe is very early and extremely short. Therefore, the pointed three effects are very weak and they do not lead to a considerable changes of the observable characteristics of the Universe, i.e. the presence of the considered antisymmetric tensor particles is allowed from the cosmological viewpoint.

2 Tensor Particles And The Anomalies of Particle Physics

There exists a standard model of electroweak interactions (SM), which until recently was considered to be in absolute agreement with the experimental data (the experiments at LEP provide better than 1% accuracy of the most precise data on SM tests at high energies). However, recently *problems in low energy physics* were revealed, namely:

- Three particles semileptonic decays of the mesons (Bolotov 1990), namely:

  -semileptonic K_{e3} decay: $K^+ \rightarrow \pi^0 e^+ \nu_e$

  -radiative $\pi_{e2\gamma}$ decay: $\pi^- \rightarrow e^- \tilde{\nu}_e \gamma$

  cannot be interpreted in the framework of the standard $V-A$ interactions. The measured decay parameter values differ from the predicted in SM by more than 3 standard deviations. There exist indications for additional tensor terms, not natural for SM.

- K_L-K_S mass difference $\delta = (m_{K_L} - m_{K_S})/m_{K_L}$ value, predicted theoretically (see Shifman 1988), differs from the experimentally measured one: $\delta^{th} \sim 0.6\delta^{exp}$

- The unitarity of the measured first row elements of the CKM matrix is not accurately fulfilled (Particle Data Group 1996):

$$|V_{ud}|^2 + |V_{us}|^2 + |V_{ub}|^2 = 0.9965 \pm 0.0021$$

The *extended electroweak model*, proposed in (Chizhov 1993, 1994a) provides a successful explanation of these experimental data and predicts new tensor interactions. The detailed analysis provided in a series of works showed that this model is in a good accordance with all the experimental data, namely:

- It solves the π-decay problem (Poblaguev 1992).
- It simultaneously solves the K-and π-decay anomalies (Chizhov 1993).
- The antisymmetric tensor field, incorporated into SM provides the rest of the K_L-K_S mass difference, so that $\delta^{th}=\delta^{exp}$ (Chizhov 1994a).
- The experimental data from pure leptonic decays is in accordance with tensor interactions (Chizhov 1994b).
- The analysis accounting for tensor interactions in semileptonic τ decays (Gordina Nava & Lopez Castro 1995) and pure leptonic τ decays (Chizhov 1995) shows that the available experimental data allows the presence of tensor particles (Saeger, Boyko and Chizhov 1998).
- Both the data from semileptonic decays $n \rightarrow pe^-\tilde{\nu}_e$ (Poblaguev 1990) and
- two particle π decays (Chizhov 1993) allow tensor terms.

  The last experiment in high energy physics in DIS at HERA shows event excess in comparison with the standard one. This could also be explained by additional tensor interactions (Chizhov 1997).

3 Antisymmetric Tensor Particles In The Early Universe

The tensor particles parameters: The mass M_T of the antisymmetric tensor particles $T_{\mu\nu} = -T_{\nu\mu}$ is introduced through the mechanism of the spontaneous symmetry breaking (Englert & Brout 1964) and is estimated to be about 300 GeV. The ratio of the coupling constant of the antisymmetric tensor particles with quarks and leptons f to the mass M can be estimated from the meson decays experiments (Chizhov 1993). In our calculations we have used the value $f_T^2 = 6.3 \times 10^{-3}$. The considered particles are unstable and they have the following decay channels $T^- \rightarrow e^-\tilde{\nu}_e$, $T^+ \rightarrow e^+\nu_e$, $T^- \rightarrow d\tilde{u}$ and $T^+ \rightarrow u\tilde{d}$.

Cosmological effects: The tensor particles are present at the early stage of the Universe evolution - the stage of radiation domination RD-stage. At this stage, according to the standard cosmological model, the expansion rate has the following dependence on temperature

$$H = (8\pi^3 G/90)^{1/2}\sqrt{g_*}\,T^2, \tag{1}$$

where $G^{-1/2} = 1.22 \times 10^{19}$ GeV, and g_* is the effective number of the degrees of freedom $g_* = \sum_b g_b + \frac{7}{8}\sum_f g_f$. In the standard cosmological model at energies $E \geq 300$ GeV, the following particles are relativistic: quarks q, antiquarks $\tilde{q}$, leptons l, antileptons $\tilde{l}$, gauge bosons γ, Z^0, $W^\pm$, gluons g and Higgs particle H^0, $\tilde{H}^0$, $H^\pm$. Then the effective number of the degrees of freedom is $g_* = 106.75$.

- Shifting $T(t)$ dependence due to the presence of tensor particles:

The theory of the antisymmetric tensor particles requires the introduction of two additional tensor doublets and one more Higgs doublet. This leads to an increase of the total effective number of the degrees of freedom at $T > 300$ GeV in the extended cosmological model with additional tensor particles: $g_*^T = 118.75$. This change leads to an increase of the expansion rate $H(t) = \left(\frac{8\pi^3 G}{90}\right)^{1/2}\sqrt{g_*^T}\,T^2$ and correspondingly to a decrease of the cosmological time at a given temperature. In other words the introduction of additional tensor particles into the cosmological plasma changes the time-temperature dependence in the early Universe due to the increase of the effective number of the degrees of freedom.

- Direct interactions:

Except their influence on the expansion rate, the tensor particles have direct interactions with the cosmological plasma components. Here we present the calculated total cross section values for the characteristic interactions of the tensor particles in the early Universe plasma, namely:

-tensor particle creation and annihilation processes: $e^+ + e^- \to T^+ + T^-$, $\sigma_{PC} \sim 2f_T^4/(\pi T^2)$

-electron scattering on tensor particles: $T + e^\pm \to T + e^\pm$, $\sigma_s \sim f_T^4/(\pi T^2)$

-tensor particle decay: $T \to e\nu$, $\Gamma_d \sim f_T^2\ M_T \sim 1.9\ GeV$

Tensor particle interactions are effective when the characteristic rates of interaction are greater than the expansion rate $\Gamma_{int} \geq H$. Otherwise, these particles drop out from the thermodynamical contact with the cosmological plasma because of the unefficiency of their interactions in comparison with the rate of change of the cosmological plasma parameters. The reaction rates are usually estimated as $\Gamma_{int} \simeq \sigma_{int} n$, where σ_{int} is the process total cross section, and n is the concentration of the particles. At energies greater than the tensor particles mass, the cross sections have the following behavior $\sigma \sim E^{-2}$. Due to this dependence, at high energies the tensor particles do not interact with the cosmological plasma, their reactions are frozen, and with the decrease of the temperature in the process of Universe expansion and the decrease of the characteristic energies, there occurs unfreezing (effective switch on) of the tensor particles reactions with the plasma components at $\Gamma_{int} \leq H$. The temperature of the unfreezing of a given interaction $i \to f$ is defined from

$$T^2 = (90/8\pi^3 G)^{1/2} g_*^{-1/2} n\sigma_{if}, \tag{2}$$

and the corresponding cosmological time is

$$t = 2.42/(\sqrt{g_*}\,T^2[MeV])\ s. \tag{3}$$

This way, on the basis of the analysis of the main interactions of the antisymmetric tensor particles with the rest components of the cosmological plasma, there have been calculated the characteristic temperatures and cosmological moments of the interactions of these particles in the early Universe.

Particle creation: In the expanding Universe the creation of pairs of tensor particles is effective at temperatures higher than the rest mass of the particles and lower than the temperature of particle creation T_c, at which the processes of tensor particles creation become greater than the expansion rate: $2m \leq T \leq T_c$. The temperature below which the tensor particles creation becomes effective and its corresponding cosmological time are: $T_c = 1.6 \times 10^{14}\ GeV$, $t_c = 8.1 \times 10^{-36}\ s$.

Electron scattering on a tensor particle: A typical example of electron scattering on tensor particles is their interaction with the electrons and the positrons of the cosmological plasma. The tensor particles interaction with the fermions becomes effective at $T \leq T_s$ and times greater than t_s, where $T_s = 8.8 \times 10^{13}\ GeV$, $t_s = 2.9 \times 10^{-35}\ s$.

Annihilation of tensor particles: The annihilation of tensor particles becomes possible at temperatures $T \leq T_a$ and times $t \geq t_a$, where $T_a = 1.1 \times 10^{14}\ GeV$, $t_a = 1.9 \times 10^{-35}\ s$. The annihilation of the particles ends at the moment $t_{ta} = 2.42/(\sqrt{g_*}\ T_{ta}^2[MeV])\ s = 6.2 \times 10^{-13}\ s$, defined from (3), where T_{ta} is put equal to $2M$.

Tensor particles decay: The decay width of the tensor particles is $\Gamma \sim f^2 M = 1.89\ GeV$. The corresponding cosmological time and the decay temperature are $\tau_d = 3.5 \times 10^{-25}\ s$, $T_d =$

8.0×10^9 GeV. It is interesting to compare the characteristic moment of decay of the particles t_d and the time of their full annihilation. As far as $t_d \ll t_{ta}$ the tensor particles mainly decay. The corresponding to the temperature interval $T_d \leq T \leq T_c$ time interval of effectiveness is very narrow $\Delta t \sim 3.5 \times 10^{-25}$ s.

- Total energy density increase:

The analysis of the possibility of tensor particles domination in the total energy density of the Universe $\rho_{tot} = \frac{\pi^2}{30} g_*^T T^4$, at some period of its evolution, shows that in case when the tensor particles drop from equilibrium with the cosmological plasma being relativistic; their domination is principally possible, at temperatures lower than T_m and time later than t_m, where $T_m = 1.0$ GeV, $t_m = 2.1 \times 10^{-7}$ s. However, having in mind that the annihilation and the decay time values of these particles are much smaller $t_d \ll t_{ta} \ll t_m$, it is obvious that the tensor particle domination stage cannot be realized. Therefore, from the requirement that their density should not be greater than the critical Universe density for a given epoch, $\rho_T(t) \leq \rho_{crit}(t)$, it is not possible to put cosmological constraints on the tensor particles characteristics.

4 Conclusions

The provided analysis of the cosmological place of antisymmetric tensor particles shows, that their direct interactions with the components of the high temperature plasma of the early Universe are effective in the interval 8.1×10^{-36} $s \leq t \leq 3.5 \times 10^{-25}$ s. The beginning of this time interval is defined from the moment of unfreezing of the characteristic reactions of the tensor particles with the rest components of the cosmological plasma, while the end of this time interval is the moment of their decay. Thus, the interval of efficiency of tensor particles interactions with the components of early Universe plasma is very early and extremely short! Therefore, obviously their influence on processes proceeding in later epochs, like the cosmological nucleosynthesis and the recombination, is hardly noticeable. The tensor particles cannot dominate in the total energy density of the Universe. Their influence is reduced mainly to a slight increase of the expansion rate, due to the change of the effective number of the degrees of freedom in comparison with the standard cosmological model.

The provided analysis of the cosmological role of the tensor particles does not establish essential cosmological restrictions to the parameters of the tensor particles on the basis of the observed characteristics of our Universe. A subject of further investigation on antisymmetric tensor particles from the cosmological standpoint could be the more detail analysis of the question of interactions of tensor particles with all the early Universe plasma components , as well as the study of the possible role the antisymmetric tensor particles may play in the inflationary cosmological theories and in the cosmological models with a cosmological constant.

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