Chiral tensor particles in the early Universe

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Using contemporary experimental constraints on the chiral tensor particles, we reconsider their interactions with the constituents of the early Universe plasma, their creation, decay, annihilation and scattering. We define the periods of efficiency of these processes and the increase of the Universe expansion rate due to the new particles.

1 Introduction

The chiral tensor particles (CTP) were introduced as an extension of Standard Model for completeness of the representation of the Lorentz group (see Chizhov, 1993, 1995, 2011) [1,2,3]. CTP are carriers of new interaction, but unlike the gauge bosons, they have only chiral interactions with the known fermions, through tensor anomalous coupling.

The cosmological influence of CTP has been considered (see for example refs.(Kirilova, Chizhov, Velchev, 1995) [4] and (Chizhov, Kirilova, 2009) [5]. CTP effect on universe dynamics was determined. Due to their contribution to the matter tensor in the right-hand side of the Einstein–Hilbert equation, CTP increase Universe density and change the dynamical evolution of the Universe. Besides, CTP direct interactions with the particles present at the early high energy stage of the Universe evolution were studied. A cosmological constraint on the CTP coupling constant was obtained. According to it CTP interactions are expected to be centiweak $G_T \leq 10^{-2} G_F$, where $G_T \sim (g_T/M_T)^2 q^2/M_T^2$, and CTP masses M_T are in the TeV region.

The role of CTP for solving the hierarchy problem was studied, as well, (Chizhov, Dvali, 2011) [6].

CTP have unique properties, which help to disentangle them from other discussed hypothetical Beyond Standard Model particles at hadron colliders (see Chizhov et al, 2008; Chizhov, 2009). [7,8] At present the search of CTP is conducted by ATLAS Collaboration at LHC. First experimental constraints on CTP masses were obtained, (Aad et al. (ATLAS Coll.) 2014, 2014a) [9,10]. Using contemporary experimental status of CTP we reconsidered the processes involving CTP in the early Universe, namely the dynamical effect of CTP and their interactions with the constituents of the early Universe plasma, their creation, decay, annihilation and scattering. We determined the periods of efficiency of these processes.

2 Cosmological Effects of the Chiral Tensor Particles

In this section we discuss CTP influence on Universe dynamics and CTP direct interactions with the constituents of the early Universe plasma. Present experimental constraints on the masses of the tensor particles interacting with down type fermions at 95% CL are: $M_{T^0} > 2.85$ TeV and $M_T^+ > 3.21$ TeV. [9,10]. We have recalculated the CTP interactions accounting for the new experimental findings concerning CTP couplings and masses. [11] The main results of our study are presented below.

2.1 CTP influence on the Universe expansion

In the extended model with CTP the total effective number of the degrees of freedom, while the additional particles are relativistic, is $g_* = g_{\rm SM} + g_{CTP} = 106.75 + 28 = 134.75$. Hence, the energy density of the Universe is increased in comparison with the Standard Cosmological Model case: $\rho = \rho_{SCM} + \rho_{CTP}$. The rate of the universe expansion $H = \sqrt{8\pi^3 G_N g_*/90}\, T^2$ is increased.

2.2 CTP interactions

Chiral tensor particle interactions are effective in the early Universe when their characteristic interaction rates are greater than the expansion rate $\Gamma_{int} \sim \sigma n > H(T)$. The temperature of unfreezing of an interaction $i \to f$ is defined from: $\sigma_{if}(T_{eff})n(T_{eff}) = H(T_{eff})$, the corresponding cosmic time in seconds is: $t_{eff} \approx 2.42/\sqrt{g_*}\, T_{eff}^2$, where T_{eff} is in MeV.

CTP creation from fermion-antifermion collisions: The cross-section for creation of pairs of longitudinal CTP from fermion-antifermion collisions is:

$$\sigma_c \approx \frac{g_T^4 \ln(T/v)}{4^5 \pi T^2} \tag{1}$$

where the Higgs vacuum expectation is $v \approx 246$ GeV. CTP creation is effective at temperatures $T < T_c$, where $T_c \approx 1.83 \times 10^{17}$ GeV, and cosmic times $t > t_c \approx 6 \times 10^{-42}$ s.

Fermions scattering on CTP: The cross-section of fermions scattering on CTP is:

$$\sigma_s \approx \frac{\pi g_T^2}{3 \times 4^5 \pi T^2} \tag{2}$$

The process is effective at temperatures $T < T_s \approx 1.89 \times 10^{15}$ GeV and cosmic time $t > t_s \approx 5.86 \times 10^{-38}$ s.

CTP annihilations: CTP annihilations proceed till

$$t_a \approx 2.42/(\sqrt{g_*}\, T_a^2[\text{MeV}])\ \text{s} \approx 5 \times 10^{-14}\ \text{s} \tag{3}$$

where $T_a = 2M_T$ and $M_T = 3$ TeV is assumed.

CTP decays: The decay width of the tensor particles is:

$$\Gamma \approx g_T^2 M_T/4\pi \approx 102\ \text{GeV}. \tag{4}$$

The lifetime and the corresponding cosmological temperature are, correspondingly, $t_d = 6.5 \times 10^{-27}$ s and $T_d = 5.7 \times 10^9$ GeV. Thus, the period of CTP effectiveness is : 6×10^{-42} s $< t <$ 6.5×10^{-27} s. The corresponding energy range is 1.8×10^{17} GeV$> E > 5.7 \times 10^9$ GeV. Thus, CTP are present at energies typical for inflation, Universe reheating, lepto- and baryogenesis.

3 Conclusions

The existence of CTP does not contradict the experimental data of precise low energy experiments. Besides, the presence of CTP solves the hierarchy problem. CTP may be produced and detected at powerful high energy colliders.

The provided analysis of the cosmological place of the chiral tensor particles shows, that their direct interactions are effective for a short period from 6×10^{-42} s till 6.5×10^{-27} s during the Universe evolution, which corresponds to the energy window 1.8×10^{17} GeV $< T < 5.7 \times 10^9$ GeV.

Cosmological observational data allows the presence of tensor particles, since CTP decay at very early epoch and their decay products do not disturb Big Bang Nucleosynthesis and Cosmic Microwave Background formation epoch. However, they slightly speed the expansion of the Universe and change its temperature-time dependence. CTP are present at energies typical for inflation, Universe reheating and lepto- and baryogenesis. Thus, it is interesting to explore further the role of CTP in the early Universe.

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