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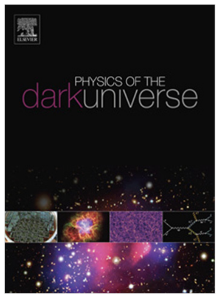

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Cosmological models with running cosmological term and decaying dark matter

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Abstract

We investigate the dynamics of the generalized ΛCDM model, which the Λ term is running with the cosmological time. On the example of the model $\Lambda(t) = \Lambda_{\text{bare}} + \frac{\alpha^2}{t^2}$ we show the existence of a mechanism of the modification of the scaling law for energy density of dark matter: $\rho_{\text{dm}} \propto a^{-3+\lambda(t)}$. We use an approach developed by Urbanowski in which properties of unstable vacuum states are analyzed from the point of view of the quantum theory of unstable states. We discuss the evolution of $\Lambda(t)$ term and pointed out that during the cosmic evolution there is a long phase in which this term is approximately constant. We also present the statistical analysis of both the $\Lambda(t)$CDM model with dark energy and decaying dark matter and the ΛCDM standard cosmological model. We use data such as Planck, SNIa, BAO, $H(z)$ and AP test. While for the former we find the best fit value of the parameter $\Omega_{\alpha^2,0}$ is negative (energy transfer is from the dark matter to dark energy sector) and the parameter $\Omega_{\alpha^2,0}$ belongs to the interval $(-0.000040, -0.000383)$ at 2-σ level. The decaying dark matter causes to lowering a mass of dark matter particles which are lighter than CDM particles and remain relativistic. The rate of the process of decaying matter is estimated. Our model is consistent with the decaying mechanism producing unstable particles (e.g. sterile neutrinos) for which α^2 is negative.

Keywords: dark energy, dark matter, running cosmological constant, observational constraints.

1. Introduction

In cosmology, the standard cosmological model (ΛCDM model) is an effective theory which well describes the current Universe in the accelerating phase of the expansion. All the astronomical observations of supernovae SNIa and measurements of CMB favor this model over the alternatives but we are still looking for theoretical models to dethrone the ΛCDM model.

On the other hand the ΛCDM model has serious problems like the cosmological constant problem or the coincidence problem which are open and waiting for a solution. Among different propositions, it is an idea of introducing the running cosmological term [1]. The most popular way of introducing a dynamical form of the cosmological term is a parametrization by the scalar field, i.e. $\Lambda \equiv \Lambda(\phi)$ or the Ricci scalar, i.e. $\Lambda \equiv \Lambda(R)$, where R is the Ricci scalar. Recently an interesting approach toward a unified description of both dark matter and dark energy was developed by consideration non-canonical Lagrangian for the scalar field $L = X^\alpha - \Lambda$, where $X = \dot{\phi}^2/2$ is a kinetic part of the scalar field energy [2] (see also [3]). In the both mentioned cases, the covariance of field equation is not violated and $\Lambda \equiv \Lambda(t)$ relation emerges from covariant theories.

Two elements appear in the ΛCDM model, namely dark matter and dark energy. The main aim of observational cosmology is to constrain the density parameters for dark energy as well as dark matter. In the testing of the ΛCDM model, the idea of dark energy is usually separated from the dark matter problem. The latter is considered as the explanation of flat galactic curves. Of course the conception of dark matter is also needed for the consistency of the model of cosmological structures but the hypothesis of dark energy and dark matter should be tested not as a isolated hypothesis.

In this paper, we explore the $\Lambda(t)$CDM model with $\Lambda(t) = \Lambda_{\text{bare}} + \frac{\alpha^2}{t^2}$, where t is the cosmological time for which we know an exact solution [1]. It is interesting that this type of a $\Lambda(t)$ relation is supported by the non-critical string theory consideration [4]. This enables us to show the nontrivial interactions between the sectors of dark matter and dark energy. It would be demonstrated that the model, which is under consideration, constitutes the special case of models with the interaction [1] term $Q = -\frac{d\Lambda(t)}{dt}$. We will be demonstrated that the time dependence of the Λ term is responsible for the modification of the standard scaling law of dark matter $\rho_{\text{dm}} = \rho_{\text{dm},0}a^{-3}$, where a is the scale factor [1]. Wang and Meng [5] developed a phenomenological approach which is based on the modified matter scaling relation $\rho_{\text{m}} = \rho_{\text{m},0}a^{-3+\delta}$, where δ is the parameter which measures a deviation from the standard case of cold dark matter (CDM).

The both effect of the decaying Λ term and the mod-

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