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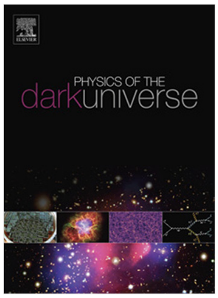

New limits on coupled dark energy model after Planck 2015

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New limits on coupled dark energy model after Planck 2015

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We used the Planck 2015 cosmic microwave background anisotropy, baryon acoustic oscillation, type-Ia supernovae, redshift-space distortions, and weak gravitational lensing to test the model parameter space of coupled dark energy. We assumed the constant and time-varying equation of state parameter for dark energy, and treated dark matter and dark energy as the fluids whose energy transfer was proportional to the combined term of the energy densities and equation of state, such as $Q = 3H\xi(1 + w_x)\rho_x$ and $Q = 3H\xi[1 + w_0 + w_1(1 - a)]\rho_x$, the full space of equation of state could be measured when we considered the term $(1+w_x)$ in the energy exchange. According to the joint observational constraint, the results showed that $w_x = -1.006^{+0.047}_{-0.027}$ and $\xi = 0.098^{+0.026}_{-0.098}$ for coupled dark energy with a constant equation of state, $w_0 = -1.076^{+0.085}_{-0.076}$, $w_1 = -0.069^{+0.361}_{-0.319}$, and $\xi = 0.210^{+0.048}_{-0.210}$ for a variable equation of state. We did not get any clear evidence for the coupling in the dark fluids at 1σ region.

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I. INTRODUCTION

The dark energy theory could be used to explain the late-time cosmic acceleration, a cosmological constant Λ with equation of state $w_\Lambda = -1$ is the simplest candidate of dark energy, which is favored by the cosmic microwave background observations from Planck 2015[1–3], however it is plagued with the fine-tuning problem and coincidence problem [4–6].

In the cosmological standard model, dark matter and dark energy are assumed to be free each other. However, from a particle physics point of view, it would be natural to assume that these fields interact with each other [7–36]. Thus in this paper, we allow for coupling between dark matter and dark energy, that is, a phenomenological energy transfer term exists in the dark fluids. The coupled dark energy could be adopted to avoid the coincidence problem of the cosmological constant model. In the literature, there are two main categories for the choice of the phenomenological energy exchange term: (1) A choice for a phenomenological interaction is only related to either the energy densities or some combination of them (without including the Hubble parameter and hence an implicit time dependence), as done for example in Refs. [37–57]; (2) In another class of coupled dark energy models, Q is composed by the times of Hubble rate H and energy densities [58–147]. For example, the energy exchange is $Q = 3H\xi\rho_c$, $Q = 3H\xi\rho_x$ (the parameter ξ is the constant interaction rate), or their sum of the energy densities $Q = 3H\xi(\rho_c + \rho_x)$, the majority of the literature have considered this kind of couplings. The times of energy densities is also a phenomenological coupling $Q = 3H\xi\rho_c\rho_x/(\rho_c + \rho_x)$ [103, 105]. $Q \propto \xi\rho_c^\alpha\rho_x^\beta$ or $Q \propto \xi\rho_c^\alpha\rho_x^\beta(\rho_c + \rho_x)^\gamma$ is the power law form of energy densites [99, 100]. $Q \propto a^\alpha$ is the power law form of scale factor [114, 121, 135]. $Q = \rho_i'$ and $Q = \rho_i''$ ($i = c, x, c + x$, the prime represents the derivative about the conformal time) is the derivative of energy densities [107–109]. The combination of equation of state and energy densities $Q = H(\xi + 3w_x)\rho_c\Omega_x$ (w_x is dark energy equation of state) is also a different type of coupled dark energy model [102, 104].

To test the gravity on large scales, the only possible tool is the cosmic observations which include the geometrical and dynamical measurements. Through the geometrical measurements, for example the cosmic microwave background (CMB), baryon acoustic oscillation (BAO), type Ia supernovae (SNIa), the background evolution history can be fixed. When the information of the large scale structures is included, the dynamical evolution, such as the growth of the matter perturbation, can be determined. Combining the two sides measurements, the degeneracies between model parameters would be broken; and a tight constraint can be obtained. Redshift-space distortions (RSD) [150–153] arising from peculiar velocities of galaxies on an observed galaxy map provide a direct measurement of the linear growth rate $f(z)$ of the large-scale structure formation, this opinion has been proved in Refs. [154–162]. The constraint results of energy exchange $Q = 3H\xi\rho_x$ from CMB, BAO, SNIa, RSD have shown that the interaction rate

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