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ORIGINAL ARTICLE

Dark energy and key physical parameters of clusters of galaxies

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Abstract We study physics of clusters of galaxies embedded in the cosmic dark energy background. Under the assumption that dark energy is described by the cosmological constant, we show that the dynamical effects of dark energy are strong in clusters like the Virgo cluster. Specifically, the key physical parameters of the dark mater halos in clusters are determined by dark energy: (1) the halo cut-off radius is practically, if not exactly, equal to the zero-gravity radius at which the dark matter gravity is balanced by the dark energy antigravity; (2) the halo averaged density is equal to two densities of dark energy; (3) the halo edge (cut-off) density is the dark energy density with a numerical factor of the unity order slightly depending on the halo profile. The cluster gravitational potential well in which the particles of the dark halo (as well as galaxies and intracluster plasma) move is strongly affected by dark energy: the maximum of the potential is located at the zero-gravity radius of the cluster.

Keywords Dark energy · Galaxy cluster

1 Introduction

It has recently been recognized that galaxies and clusters of galaxies (as well as all the other bodies of nature) are imbedded in the universal dark energy background discovered first by Riess et al. (1998) and Perlmutter et al. (1999) in observations of SNe type Ia at the global horizon-size distances $\sim$1000 Mpc. These and other observations and in particular the studies of the cosmic microwave background (CMB) anisotropy Spergel et al. (2007) indicate that the global dark energy density $\rho_\Lambda = 0.7 \times 10^{-29}$ g/cm^3, and dark energy contributes nearly $3/4$ to the total energy content of the universe. Close value of the cosmological constant was anticipated by Kofman and Starobinskii (1985), basing on the analysis of the existing upper limits for the microwave background anisotropy. According to the simplest, straightforward and quite likely interpretation adopted in the standard ΛCDM cosmology, dark energy is represented by the Einstein cosmological constant Λ and its density $\rho_\Lambda = \frac{c^2}{8\pi G}\Lambda$, where G is the gravitational constant. If this is so, dark energy is the energy of the cosmic vacuum Gliner (1966) and it may be described macroscopically as a perfectly uniform fluid with the equation of state $p_\Lambda = -\rho_\Lambda$ (here p_Λ is the dark energy pressure; the speed of light $c = 1$ hereafter). It is this standard interpretation that implies that although dark energy betrayed it existence through its effect on the universe as a whole, it exists everywhere in space with the same density and pressure.

Dark energy treated as Λ-vacuum produces antigravity, and at the present cosmic epoch, the antigravity is stronger than the gravity of matter for the global universe considered as a whole. May the dynamical effects of dark energy be strong on smaller scales as well? Local dynamical effects of dark energy were first recognized by Chernin et al. (2003); the studies of the Local Group of galaxies and the expansion outflow of dwarf galaxies around it revealed that the antigravity may dominate over the gravity at distance of $\simeq$1–3 Mpc from the barycenter of the group (Chernin 2001, 2008; Baryshev et al. 2001; Karachentsev et al. 2009; Byrd et al. 2007; Teerikorpi et al. 2008; Teerikorpi and

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