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ORIGINAL ARTICLE

A new type of interaction between generalized Chaplygin gas and dark matter

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Abstract In this paper, we investigate the model with a new type of interaction between generalized Chaplygin gas (GCG) and dark matter. It is shown that there exists a stable scaling attractor, which provides the possibility to alleviate the coincidence problem. The equation of state (EoS) of GCG approaches the attractor phase from either $w_g > -1$ or $w_g < -1$ depending on the choice of its initial cosmic density parameter and the ratio of pressure to critical energy density. For initial choice of $w_g < -1$, our new model allows the universe to cross the phantom divide (the transition from $w_g < -1$ to $w_g > -1$), and next cross again the phantom divide (the transition from $w_g > -1$ to $w_g < -1$), finally reach the attractor phase. We also find the new interacting term Q can change its sign from $Q < 0$ to $Q > 0$ as the universe expands, which is different from the usual interaction. Moreover, we investigate the model from statefinder viewpoint. The statefinder diagnostic can not only discriminate the model with different coupling constant but also distinguish the model from other dark energy models.

Keywords Interaction · Dark energy · Generalized Chaplygin gas · Attractor · Statefinder

1 Introduction

Strong evidences from the current cosmological observations such as SNe Ia (Riess et al. 1998, 2004; Perlmutter et al. 1999; Bahcall et al. 1999), SDSS (Tegmark et al. 2004), WMAP (Bennett et al. 2003) converge upon the fact that the universe is spatially flat and there exists an exotic component called dark energy, which drives the speed-up expansion of the universe. Such a component makes up about two thirds of the total energy density of the universe. In the recent years, various candidates of dark energy have been proposed. The simplest candidate is considered to be in the form of vacuum energy density or cosmological constant Λ, with EoS $w_\Lambda = -1$. However, the cosmological constant model suffers from two serious issues: Why the value of cosmological constant Λ is so tiny and not zero which is called "fine-tuning problem". Why the energy density of Λ is just comparable with the matter energy density in recent time which is called "coincidence problem". Other candidates include quintessence (Bagla et al. 2003; Nojiri and Odintsov 2006a; Wetterich 1998), Phantom (Caldwell 2002; Amendola et al. 2006), K-essence (Armendáriz-Picón et al. 2000), quintom (Guo et al. 2005; Gupta and Pradhan 2010), holographic dark energy (Nojiri and Odintsov 2006b; Huang and Li 2005) and GCG (Bento et al. 2003; Makler et al. 2003a; Hao and Li 2005; Liu and Li 2005) which is stemmed from the Chaplygin gas (CG) (Kamenshchik et al. 2001; Bilic et al. 2002). In particular, Hao and Li (2005) have extended the EoS of GCG to $w < -1$ regime.

On the other hand, the interaction between dark energy and dark matter is widely studied to alleviate the coincidence problem (Jamil and Farooq 2010; Jamil 2010; Wei and Cai 2005, 2006; Cai and Wang 2005; Chen et al. 2009; He et al. 2009; Zimdahl and Pavon 2001). Dark energy and dark matter interact through a coupling term Q, according to

$$\dot{\rho}_m + 3H\rho_m = Q, \tag{1}$$

$$\dot{\rho}_X + 3H(\rho_X + p_X) = -Q \tag{2}$$

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