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ORIGINAL ARTICLE

Holographic dark energy interacting with two fluids and validity of generalized second law of thermodynamics

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Abstract We have considered a cosmological model of holographic dark energy interacting with dark matter and another unknown component of dark energy of the universe. We have assumed two interaction terms Q and Q' in order to include the scenario in which the mutual interaction between the two principal components (i.e., holographic dark energy and dark matter) of the universe leads to some loss in other forms of cosmic constituents. Our model is valid for any sign of Q and Q'. If $Q < Q'$, then part of the dark energy density decays into dark matter and the rest in the other unknown energy density component. But if $Q > Q'$, then dark matter energy receives from dark energy and from the unknown component of dark energy. Observation suggests that dark energy decays into dark matter. Here we have presented a general prescription of a cosmological model of dark energy which imposes mutual interaction between holographic dark energy, dark matter and another fluid. We have obtained the equation of state for the holographic dark energy density which is interacting with dark matter and other unknown component of dark energy. Using first law of thermodynamics, we have obtained the entropies for holographic dark energy, dark matter and other component of dark energy, when holographic dark energy interacting with two fluids (i.e., dark matter and other component of dark energy). Also we have found the entropy at the horizon when the radius (L) of the event horizon measured on the sphere of the horizon. We have investigated the GSL of thermodynamics at the present time for the universe enveloped by this horizon. Finally, it has been obtained validity of GSL which implies some bounds on deceleration parameter q.

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1 Introduction

Recent observation of the luminosity of type Ia supernovae indicate (Bachall et al. 1999; Perlmutter et al. 1999) an accelerated expansion of the universe and the surveys of clusters of galaxies show that the density of matter is very much less than the critical density. This observation leads to a new type of matter which violate the strong energy condition i.e., $\rho + 3p < 0$. The matter content responsible for such a condition to be satisfied at a certain stage of evaluation of the universe is referred to as dark energy (Sahni and Starobinsky 2000; Peebles and Ratra 2003; Padmanabhan 2003; Copeland et al. 2006). This mysterious fluid is believed to dominate over the matter content of the Universe by 70% and to have enough negative pressure as to drive present day acceleration. Most of the dark energy models involve one or more scalar fields with various actions and with or without a scalar field potential (Maor and Brustein 2003; Cardenas and Campo 2004; Ferreira and Joyce 1998). On the other hand when the universe was 380,000 years old neutrinos was 10% atoms i.e. usual baryonic matter was 12%, dark matter was 63%, photons 15% and dark energy was negligible. In the analysis of dark energy the main attraction should be on the state parameter $w = \frac{p}{\rho}$ where p and ρ are the pressure and energy density of the dark energy. In Cosmological constant model $w = -1$ around present epoch (Alam et al. 2004) from $w > -1$ in the near past (Feng et al. 2005). There are various kinds of models of dark energy and among all of them, the simplest case is the ΛCDM