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ORIGINAL ARTICLE

Geometric and thermodynamic properties in Gauss-Bonnet gravity

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Abstract In this paper, the generalized second law (GSL) of thermodynamics and entropy is revisited in the context of cosmological models in Gauss-Bonnet gravity with the boundary of the universe is assumed to be enclosed by the dynamical apparent horizon. The model is best fitted with the observational data for distance modulus. The best fitted geometric and thermodynamic parameters such as equation of state parameter, deceleration parameter and entropy are derived. To link between thermodynamic and geometric parameters, the "entropy rate of change multiplied by the temperature" as a model independent thermodynamic state parameter is also derived. The results show that the model is in good agreement with the observational analysis.

Keywords Gauss-Bonnet · Apparent horizon · Generalized second law · Thermodynamic · Entropy · Best-fit · Equation of state · Deceleration

1 Introduction

Recent observations of high redshift type Ia supernovae, the surveys of clusters of galaxies, Sloan digital sky survey (SDSS) and Chandra X-ray observatory reveal the universe accelerating expansion and that the density of matter is very much less than the critical density (Riess et al. 1998, 2004; Perlmutter et al. 1999; Tonry et al. 2003; Bennet et al. 2003; Netterfield et al. 2002; Halverson et al. 2002; Pope et al. 2004; Knop et al. 2003; Abazajian et al. 2003, 2004a, 2004b; Tegmark et al. 2004; Allen et al. 2004). In addition, the observations of Cosmic Microwave Background (CMB) anisotropies indicate that the universe is flat and the total energy density is very close to the critical one (Bennett et al. 2003; Spergel et al. 2003).

The observations strongly indicates that the universe presently is dominated by a smoothly distributed and slowly varying dark energy (DE) component. A dynamical equation of state (EoS) parameter that is connected directly to the evolution of the energy density in the universe and indirectly to the expansion of the Universe can be regarded as a suitable parameter to explain the acceleration and the origin of DE (Tegmark 2005; Farajollahi et al. 2010; Farajollahi and Milani 2010; Farajollahi and Mohamadi 2010; Seljak et al. 2005; Setare 2007a, 2007b; 2009a, 2009b, 2009c, 2009d; Farajollahi et al. 2011). In scalar-tensor theories (Sahni and Starobinsky 2000; Nojiri and Odintsov 2004a, 2004b, 2004c; Cognola et al. 2005; Cognola et al. 2006; Henttunen et al. 2008; Mohseni Sadjadi 2007b), interaction of the scalar field with matter (for example in chameleon cosmology) can be used to interpret the late time acceleration and smoothly varying EoS parameter (Setare and Jamil 2010; Davis et al. 2009; Ito and Nojiri 2009; Tamaki and Tsujikawa 2008; Farajollahi and Salehi 2010a, 2010b; Dimopoulos and Axenides 2005).

Motivated by the black hole physics, it was realized that there is a profound connection between dynamic and thermodynamic of the universe (see for example Jacobson 1995; Cai and Kim 2005). In particular, the validity of the GSL (Setare and Shafei 2006; Davies 1987, 1988; Pollock and Singh 1989; Pavon 1990; Mukohyama 1997; Brustein 2000; Davis et al. 2003; Izquierdo and Pavon 2006; Setare 2006, 2007b; Mohseni Sadjadi 2007a; Gong et al. 2007; Horvat

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