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ORIGINAL ARTICLE

The generalized second law of thermodynamics for the interacting in $f(T)$ gravity

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Abstract We study the validity of the generalized second law (GSL) of gravitational thermodynamics in a non-flat FRW universe containing the interacting in $f(T)$ gravity. We consider that the boundary of the universe to be confined by the dynamical apparent horizon in FRW universe. In general, we discuss the effective equation of state, deceleration parameter and GLS in this framewok. Also, we find that the interacting-term Q modifies these quantities and in particular, the evolution of the total entropy, results in an increases on the GLS of thermodynamic, by a factor $4\pi R_A^3 Q/3$. By using a viable $f(T)$ gravity with an exponential dependence on the torsion, we develop a model where the interaction term is related to the total energy density of matter. Here, we find that a crossing of phantom divide line is possible for the interacting-$f(T)$ model.

Keywords Universe · The generalized second law (GSL) of gravitational thermodynamics

1 Introduction

Observational data of the luminosity-redshift of type Ia supernovae (SNeIa), large scale structure (LSS) and the cosmic microwave background (CMB) anisotropy spectrum, have provided confirmation that our universe has recently entered a phase of accelerated expansion (Riess et al. 1998). A possible responsible of this acceleration of the universe is the dark energy (DE) and the nature of this energy is an important problem today in the modern physics. For a review of DE candidates and models, see Caldwell et al. (1998).

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In the last years, a $f(T)$ theory was introduced to explain the current expansion of the universe without considering the DE (Ferraro and Fiorini 2007; Bengochea and Ferraro 2009; Myrzakulov 2011). The $f(T)$ theory is a generalization of the teleparallel gravity (TG) and becomes equivalent of General Relativity (Einstein 1928). The idea original of the $f(T)$ theory results from the generalization of the TG from the torsion scalar T (Ferraro and Fiorini 2007; Linder 2010a), similarly to the motivation of the Ricci scalar R in the Einstein-Hilbert action by replacing the function $f(R)$. However, in $f(T)$ theory the field equations are second order as opposed to the fourth order equations of $f(R)$ theory. In the formalism of the TG, the tetrad fields are the basic variable of TG together with the Weitzenbock connection, see Ferraro and Fiorini (2007), Einstein (1928), Clifton et al. (2012) for a review.

In the recent years, the thermodynamics aspects of the accelerating universe has considered much attention and different results has been obtained (Bekenstein 1972). In particular, the verification of the first and second law of the thermodynamic, studying the dynamic together with the thermodynamics aspect of the accelerated expansion of the universe.

In the context of the validity the generalized second law (GSL) of thermodynamics, is necessary that the evolution with respect to the cosmic time of the total entropy $\dot{S}_{Total} = d(S_A + S_m)/dt \geq 0$. Here, S_A is the Bekenstein-Hawking entropy on the apparent horizon and S_m denotes the entropy of the universe filled matter (pressureless baryonic matter (BM) and dark matter (DM)) inside the dynamical apparent horizon (Cai and Kim 2005). Therefore, in conformity with the GLS of thermodynamic, the evolution of the total entropy, S_{Total}, cannot decrease in time (Bekenstein 1973; Pavón 1990).

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