Nuclear Activity in Galaxies Across Cosmic Time
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Accelerating universe in modified teleparallel gravity theory

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Abstract. This paper studies the cosmology of accelerating expansion of the universe in modified teleparallel gravity theory. We discuss the cosmology of $f(T,B)$ gravity theory and its implication to the new general form of the equation of state parameter w_{TB} for explaining the late-time accelerating expansion of the universe without the need for the cosmological constant scenario. We examine the numerical value of w_{TB} in different paradigmatic $f(T,B)$ gravity models. In those models, the numerical result of w_{TB} is favored with observations in the presence of the torsion scalar T associated with a boundary term B and shows the accelerating expansion of the universe.

Keywords. $f(T,B)$ gravity theory; accelerating universe; equation of state parameter.

1. Introduction

To explain the cause behind the current cosmic accelerating expansion, different suggestions have been put forward. For instance, one suggestion is that the cosmological constant is the one responsible for this cosmic acceleration, as presented in Saul *et al.* (2003) and the second approach is the modification of General Relativity (GR) as Timothy *et al.* (2012). In the second approach, several extra degrees of freedom are presented through the modification of GR to account for the present cosmic accelerating expansion and to study if the cosmic history from the early universe can produce this cosmic acceleration. This paper discusses how the modified teleparallel gravity so-called, $f(T,B)$ gravity scenario, is taken as an alternative approach for the ΛCDM model to describe the late-time accelerating expansion of the universe. We obtain the new expression of the equation of state parameter w_{TB} in the effective torsion fluid.

2. The cosmology of $f(T,B)$ gravity

We consider different paradigmatic $f(T,B)$ gravity models, and in each model, we describe the accelerating universe in the late time by plotting the w_{TB} versus redshift z. It is close to the well-known equation of state parameter $w = -1$. We start by providing the action that contains the $f(T,B)$ Lagrangian:

$$I_{f(T,B)} = \frac{1}{2\kappa^2}\int d^4xe\Big[T + f(T,B) + L_m\Big]\ , \tag{2.1}$$

where e is the determinate of the tetrad field e^{μ}_{A}, L_m is the matter Lagrangian and $\kappa^2 = 8\pi G/c^4$ is the coupling constant†. We assume that the total cosmic medium is composed of matter ρ_m, radiation ρ_r and effective torsion fluid ρ_{TB}, and that one can directly derive the corresponding thermodynamic quantities in $f(T,B)$ gravity from eq. (2.1), such as the energy density ρ_{TB} and

† We assume that $\kappa^2 = 8\pi G/c^4 = 1$.

pressure p_{TB} of the torsion-like fluid as presented in Bahamonde *et al.* (2017):

$$\kappa^2\rho_m = -3H^2(3f_B + 2f_B) + 3H\dot{f}_B - 3\dot{H}f_B + \frac{f(T,B)}{2}\ , \tag{2.2}$$

$$\kappa^2 p_m = 3H^2 + \dot{H})(3f_B + 2f_T)2H\dot{f}_T - \ddot{f}_B - \frac{f(T,B)}{2}\ . \tag{2.3}$$

Therefore, the new general form of w_{TB} can be constructed from the above equations for the effective torsion fluid defined as $w_{TB} = p_{TB}/\rho_{TB}$ and is given by:

$$w_{TB} = -1 + \frac{\ddot{f}_B - 3H\dot{f}_B - 2\dot{H}f_T - 2H\dot{f}_T}{3H^2(3f_B + 2f_T) - 3H\dot{f}_B + 3\dot{H}f_B - f(T,B)/2}\ . \tag{2.4}$$

In the following we consider the well known two models namely: exponential and power-law $f(T)$ gravity models associated with the boundary term as $f(T,B) = B + f(T)$, for $B = 0$ it reads $f(T,B) = f(T)$ as presented in Nayem (2017).

3. Conclusions

Generally, in all models that are treated above, we numerically computed the effective equation of state parameter form of $w(z)$ through the use of eq. (2.4) and the value of $w(z)$ is favored with the observed value of the effective equation of state parameter of cosmological constant $w \approx -1$ in the present universe. So, we clearly show that all two $f(T,B)$ gravity models can be regarded as an alternative way of cosmological constant model to describe the late-time accelerating expansion of the universe. Surprisingly, in all models the value of $w(z)$ in the present and near past universe asymptotically approaches to the equation of state parameter of the cosmological constant $w = -1$. For instance in Fig. 1, we clearly observe the history of the universe phase with the phantom-like $w(z) < -1$ and quintessence-like $w(z) > -1$ phases, while the other two models in Fig. 2 show only the quintessence-like phase. GR can be recovered for $B = b = 0$ for all models.

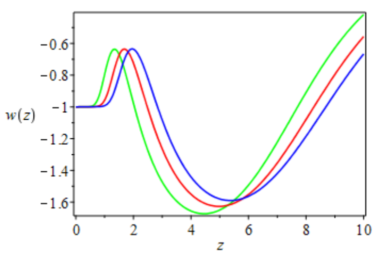

Figure 1. $w(z)$ versus redshift z for $f(T,B) = B - T + \alpha T_0\left(1 - e^{b\frac{T}{T_0}}\right)$ gravity model with different value of b. We use $b = 0.002$, $b = 0.004$ and $b = 0.006$ for green, red and blue lines, respectively.

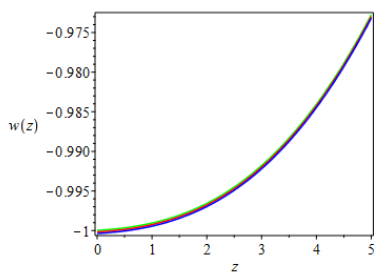

Figure 2. $w(z)$ versus redshift z for power-law $f(T,B) = B - T + \alpha(-T)^b$ gravity model with different value of b. We use $b = 0.1$ for green line, $b = 0.4$ for red line and $b = 0.7$ for blue line.

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