Late Time Cosmic Acceleration Model In $f(T, B)$ Gravity

Siddheshwar Atmaram Kadam

Department of Mathematics
BITS-Pilani, Hyderabad Campus, India

Under Supervision of :
Prof. Bivudutta Mishra

Cosmology From Home 2021

Outlines of the Presentation

- Introduction and field equation in f(T,B) gravity.
- Power law cosmology and analysis of the model
- Results and discussion

$f(T, B)$ Gravity Formalism

The flat FLRW space time is given by

$$ds^2 = -dt^2 + a^2(t)(dx^2 + dy^2 + dz^2) \tag{1}$$

Also, the tetrad choice for the $f(T, B)$ gravity with the scale factor a(t) can be considered as

$$e_i^{\mu} = (1, a(t), a(t), a(t))$$

The tetrad e_i^{μ} where i, μ running over 0,1,2,3 index and relates with the metric through the equation

$$g_{\mu\nu} = \eta_{ij} e_{\mu}^{i} e_{\nu}^{j} \tag{2}$$

$f(T, B)$ Gravity Formalism

The Weitzenböck connection is defined as

$$\hat{\Gamma}^{\lambda}_{\mu\nu} = e_i^{\lambda} \partial_{\nu} e^i_{\mu} = -e^i_{\mu} \partial_{\nu} e_i^{\lambda} \tag{3}$$

The nonzero torsion tensor is given by

$$T^{\lambda}_{\mu\nu} = \hat{\Gamma}^{\lambda}_{\nu\mu} - \hat{\Gamma}^{\lambda}_{\mu\nu} \tag{4}$$

The torsion scalar T in teleparallel gravity is given by

$$T = S_{\sigma}{}^{\mu\nu} T^{\sigma}{}_{\mu\nu} \tag{5}$$

Where

$$\frac{1}{2}(K^{\mu\nu}{}_{\sigma} + \delta^{\mu}_{\sigma} T^{\alpha\nu}{}_{\alpha} - \delta^{\nu}_{\sigma} T^{\alpha\mu}{}_{\alpha}) = S_{\sigma}{}^{\mu\nu} \tag{6}$$

$f(T, B)$ Gravity Formalism

$K^{\mu\nu}{}_{\sigma}$ is the contorsion tensor

$$(T^{\mu\nu}{}_{\sigma} + T^{\nu\mu}{}_{\sigma} + T_{\sigma}{}^{\mu\nu}) = -2K^{\mu\nu}{}_{\sigma} \tag{7}$$

We can derive torsion scalar from equation (9) as

$$6H^2 = T \tag{8}$$

over dot represents derivative with respect to coordinate time t, here boundary term is $(18H^2 + 6\dot{H}) = B$.
Which reproduce Ricci scalar $R = B - T = 6(2H^2 + \dot{H})$.
Field equations under these conditions as fallow

$$\kappa^2\rho = 9H^2 f_B + 6f + 6H^2 f_T - 3\dot{f}_B H + 3\dot{H} f_B - \frac{1}{2} f \tag{9}$$

$$\kappa^2 p = -(3H^2 - \dot{H})(3f_B + 2f_T) - 2H\dot{f}_T + \ddot{f}_B \tag{10}$$

Power Law Cosmology

Here we used the power law scale factor,

$$a(t) = \left(\frac{t}{t_0}\right)^h$$

.

The model used in the study $f(T, B) = \alpha T + \beta B^n$ then we will find the expression for pressure, energy density and equation of state.

Equation of state can be written as

$$\omega = -\frac{3\alpha h^2 - 2\alpha h + \beta 6^{n-1}(n-1)(3h+2n-1)(3h-2n)\left(\frac{h(3h-1)}{t^2}\right)^{n-1}}{3\alpha h^2 + \beta h 2^{n-1} 3^n (n-1)(3h+2n-1)\left(\frac{h(3h-1)}{t^2}\right)^{n-1}} \tag{11}$$

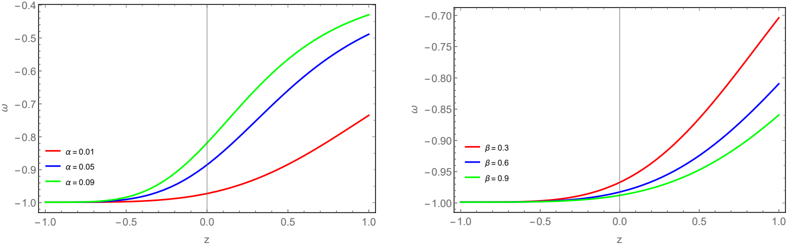

Figure 1: Variation of EoS parameter for power law scale factor display with respect to redshift (ω vs z) in the $f(T, B)$ gravity theory with variation in parameter h.

Energy conditions:

The energy conditions are emerged from the Raychaudhuri equation.

Energy conditions are mathematically framed boundary conditions to keep the energy density positive.

The energy conditions are given as

(i) Null Energy Condition(NEC): $\rho + p \geq 0$.
(ii) Weak Energy Condition(WEC): $\rho + p \geq 0$, $\rho \geq 0$.
(iii) Strong Energy Condition(SEC): $\rho + 3p \geq 0$.
(iv) Dominant Energy Condition(DEC): $\rho \pm p \geq 0$, $\rho \geq 0$.

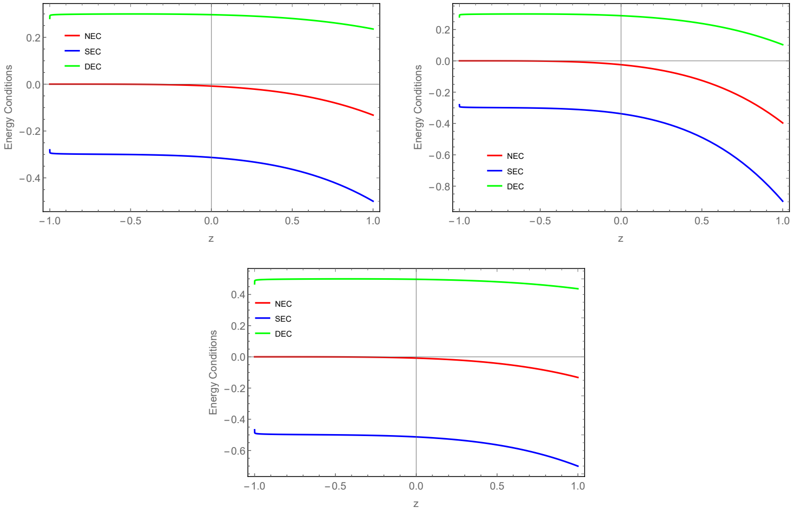

Figure 2: Plotting of energy conditions with respect to redshift z with varying parameters $\alpha = 0.01$, $\alpha = 0.03$, $\beta = 0.03$

Stability Analysis of the Model

The adiabatic speed of sound through the cosmic fluid is defined as

$$C_s^2 = dp/d\rho = \frac{dp/dt}{d\rho/dt} \tag{12}$$

The equation for $dp/d\rho$ can be calculated as [1] , [2]

$$\frac{dp}{d\rho} = \frac{\beta 6^n (n-1) n t^2 (2n-3h)(3h+2n-1)\left(\frac{h(3h-1)}{t^2}\right)^n - 6\alpha h^2 (9(h-1)h+2)}{3t^3\left(\frac{6\alpha h^3(3h-1)}{t^3} + \frac{\beta h 6^n (n-1) n (3h+2n-1)\left(\frac{h(3h-1)}{t^2}\right)^n}{t}\right)} \tag{13}$$

[1] B Mishra, FM Esmaeili, PP Ray, SK Tripathy, 2021 *Phys. Scr.*

[2] A. Balbi, M. Bruni, C. Quercellini, 2007 *Phys. Rev.D.*

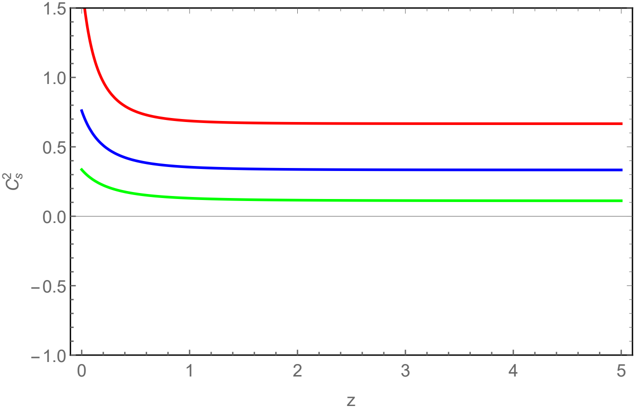

Figure 3: Plotting of stability as a function of redshift for the parametric value, $\alpha = 0.01$, $\beta = 0.3$, n $= 0.001$, $t_0 = 1.1$

Results and conclusion

- The model shows the accelerating behaviour. The EoS parameter has been presented in a combination of representative values of the model and scale factor parameters. Though the evolution in each of the combination starts from different, but at late time all supports the ΛCDM behaviour.
- The energy conditions are investigated, the plots have shown the violation of strong energy conditions, which has been a prescription for the geometrical modified theories of gravity.
- The stability analysis enabled us to assess the generality of the assumptions made to frame the model and we have obtained that our model is showing stable behaviour.

In collaboration with

Prof.Bivudutta Mishra.

Birla Institute of Science and Technology, Hyderabad Campus, Hyderabad, **India**.