Cosmological evolution in exponential gravity

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Abstract

We explore the cosmological evolution in the exponential gravity $f(R)=R-\beta R_E(1-\exp(-R/R_E))$ ($c_{1,2}$ = constant) [1,2,3]. We summarize various viability conditions and explicitly demonstrate that the late-time cosmic acceleration following the matter-dominated stage can be realized. We also study the equation of state for dark energy and confirm that the crossing of the phantom divide from the phantom phase to the non-phantom (quintessence) one can occur. Furthermore, we illustrate that the cosmological horizon entropy globally increases with time. We also explore the future evolution of the cosmological horizon entropy and illustrate that the cosmological horizon entropy oscillates with time due to the oscillatory behavior of the Hubble parameter.

Motivation

The cosmological observations such as supernovae Ia, cosmic microwave background radiation, large scale structure, and weak lensing have revealed that the universe has been undergoing an accelerating expansion since the recent "past". There are two representative approaches to explain the late time acceleration of the universe. One is modified the matter side of Einstein equation called "dark energy". The another is the consideration of a modified gravitational theory, such as f(R) gravity. In this poster, we will concentrate on the second approach.

Theory & Calculation

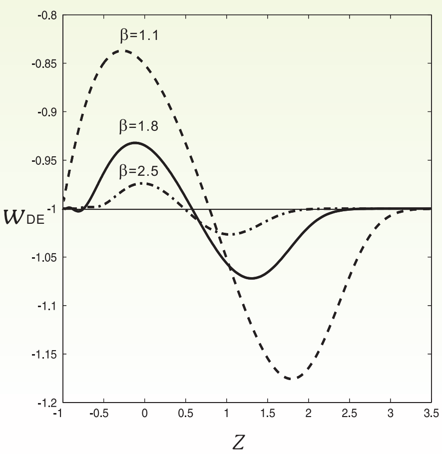
- The modified gravitation equation in $f(R)$ gravity is given by $H^2-(f_R-1)(HH'+H^2)+(f-R)/6+H^2 f_{RR} R' = \kappa^2\rho_M/3$
- Introducing the following variables $y_H = H^2/m^2 - a^{-3}$, $y_R = R/m^2 - 3a^{-3}$ with $m^2 = \kappa^2\rho_m(z=0)/3$ [4], we have

$$\Rightarrow\; y_H'' + \left(4 + \frac{1}{y_H + a^{-3}}\frac{1-f_R}{6m^2 f_{RR}}\right) y_H' + \left(\frac{1}{y_H + a^{-3}}\frac{2-f_R}{3m^2 f_{RR}}\right) y_H = 3a^{-3} + \frac{1}{6m^2 f_{RR}}\frac{(1-f_R)a^{-3} + (R-f)/3m^2}{y_H + a^{-3}}$$

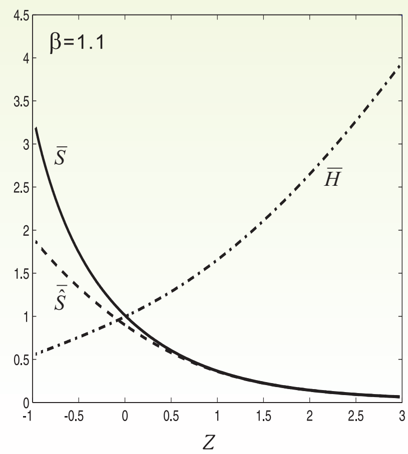
- The equation of state for dark energy is $w_{DE} = P_{DE}/\rho_{DE} = -1 - y'_H/3y_H$
- The second order differential equation tells the evolution of y_H, i.e. Hubble parameter, and the future oscillaion.
- In Ref. [5], it is shown that it is possible to obtain a picture of equilibrium thermodynamics on the apparent horizon in the FLRW background for f(R) gravity as well as that of non-equilibrium thermodynamics due to a suitable redefinition of an energy momentum tensor of the "dark" component that respects a local energy conservation. In general relativity, the Bekenstein-Hawking entropy "S=A/4G" is a global geometric quantity which is proportional to the horizon area A.

  Note: (i) $' = d/d\ln a$ and (ii) $f_R = df/dR$

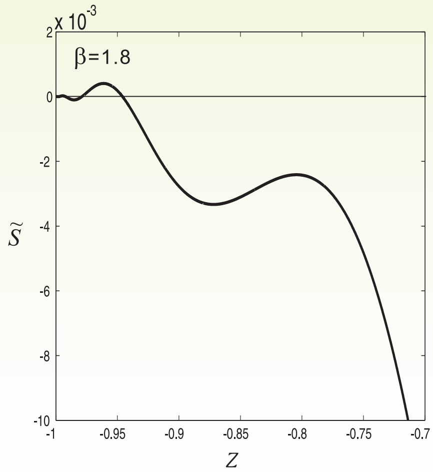
Result



Cosmological evolution of w_{DE} as a function of the redshift z



Cosmological evolutions of horizon entropy and Hubble constant as a function of the redshift z



Future oscillation of horizon entropy as a function of the redshift z

Reference

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