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Dynamical system analysis of agegraphic dark energy in brane-induced gravity

Arvin Ravanpak* **and Golnaz Farpour Fadakar**
Vali-e-Asr university, Rafsanjan, Iran
E-mail: a.ravanpak@vru.ac.ir, *E-mail:* g.fadakar@vru.ac.ir

One of the main aspects of physics beyond the standard model is the concept of extra dimensions. Among many extra dimensional cosmological models the so called DGP model (also called brane-induced gravity) with two branches (normal and self accelerating) is of particular interest. In this manuscript we consider the normal branch of the DGP model by assuming agegraphic dark energy (ADE) which is necessary to explain the late time acceleration of the universe. We study this model in a dynamical system approach where is a useful tool in investigating cosmological models. By defining a set of suitable new dimensionless variables, critical points of the system that show two important cosmological epochs and the related eigenvalues will be obtained. Also, we find the effect of extra dimensions in eigenvalues.

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1. The Model and the Stability Analysis

In the DGP braneworld cosmology, the universe is taken as a flat, homogeneous and isotropic 3-dimensional brane embedded in 5-dimensional Minkowski bulk. The Friedmann equation on the brane for the normal branch is[1]

$$H^2 + \frac{H}{r_c} = \frac{\rho_m + \rho_{DE}}{3M_p^2} \tag{1.1}$$

Where ADE energy density defined as $\rho_D = 3n^2M_p^2/T^2$[2]. The structure of the dynamical system can be studied via phase plane analysis. In order to perform the phase-space and stability analysis, one have to introduce some auxiliary variables to transform the cosmological equations of motion into a self-autonomous dynamical system. Here, we introduce the following phase variables:

$$x = \sqrt{\frac{\rho_m}{3M_p^2(H^2 + \frac{H}{r_c})}}, \quad y = \sqrt{\frac{\rho_{DE}}{3M_p^2(H^2 + \frac{H}{r_c})}} \tag{1.2}$$

With these definitions we can rewrite the Friedmann constraint as $x^2 + y^2 = 1$ Also, the total EoS parameter of the universe [3] can be written in terms of new variables as

$$w_{tot} = -1 - \frac{2\dot{H}}{3H^2} = -1 + \frac{2z^2(x^2 + \frac{2}{3n}y^3 z)}{z^2 + 1} \tag{1.3}$$

where $z = 1 + 1/Hr_c$. Then, the following autonomous system of ordinary differential equations can be obtained

$$x' = -\frac{3}{2}x + \frac{3}{2}x\left(x^2 + \frac{2}{3n}y^3 z\right), \quad y' = -\frac{zy^2}{n} + \frac{3}{2}y\left(x^2 + \frac{2}{3n}y^3 z\right) \tag{1.4}$$

To determine the critical points we must impose the conditions $x' = 0$ and $y' = 0$, simultaneously. The critical points and their eigenvalues and also the related total EoS parameter have been shown in table below Point A, which is an unstable point relates to the matter dominated era. On the other

point	(x,y)	eigenvalues	w_{tot}	stability
A	(1 , 0)	$(3, 3/2)$	0	unstable
B	(0 , 1)	$(-3/2 + 1/n, 2/n)$	> -1	saddle

Table 1: The Fixed points for the normal DGP model with ADE

hand, point B, can be related to the DE dominated era. Since $y^2 = \Omega_{DE}/z$ it means the value of Ω_{DE} is at least one for 4D and more than one for extra dimensional effects. This point is a saddle point. Also, there is another critical point $x = 0$, $y = 0$ that shows a stable point but this point do not satisfy Friedmann constraint, so it cannot be one of the solutions.

References

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[2] R. G. Cai, *A Dark Energy Model Characterized by the Age of the Universe*, *Phys. Lett. B* **657** (2007) 228 [arxiv:0707.4049].