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TACHYONIC DARK ENERGY MODEL: DYNAMICS AND EVOLUTION

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Abstract

Dynamics of dark energy are widely studied in order to understand the present acceleration of the universe. *Dirac-Born-Infeld* (DBI) tachyon scalar field arose from string theory is one candidate of the dark energy models. A previous study Calcagni and Liddle (2006) has shown that a class of scalar field potentials is viable for the dark energy candidate. Here, we re-investigate the dynamics using alternative definition of dynamics variables as of Copeland, Liddle and Wands, 1998. We explicitly use two forms of tachyon potential which yields observationally acceptable rage of equation of state parameter, $V(\phi) = V_C\exp(-\mu\phi)$ and $V(\phi) = V_C/\cosh(\mu\phi)$. The dynamics can be extended for a qualitative and numerical approach.

Introduction

Today our universe is expanding with an acceleration. There are many dark energy models trying to describing this situation of our universe. The tachyon scalar field with *Dirac-Born-Infeld* (DBI) action is one candidate of those dark energy models. The dynamics of tachyon dark energy has been widely studied in order to understanding the present acceleration of the universe. As a previous study of Calcagni and Liddle (2006), they have shown that a class of scalar field potentials is viable for the dark energy candidate.

In this work, we are re-investigateing the dynamics of tachonic field by using an alternative definition of dynamical variables as of Copeland, Liddle and Wands (1998).

Tachyon Dark Energy

Tachyon in FLRW cosmological model is described by an effective fluid with the energy density ρ and pressure density p as follow:

$$\rho=\frac{V(\phi)}{\sqrt{1-\dot{\phi}^2}} \quad \text{and} \quad p=-V(\phi)\sqrt{1-\dot{\phi}^2} \tag{1}$$

with the equation of state $w_\phi = p/\rho = \dot{\phi}^2-1$. We consider the universe filled with the tachyonic field and the barotropic fluid with the equation of state is $w_m=\gamma-1$ and the background equations of motion are in the form,

$$H^2=\frac{\kappa^2}{3}\left[\frac{V(\phi)}{\sqrt{1-\dot{\phi}^2}}+\rho_m\right] \tag{2}$$

$$\frac{\ddot{\phi}}{1-\dot{\phi}^2}+3H\dot{\phi}+\frac{V_{,\phi}}{V}=0 \tag{3}$$

$$\dot{\rho}_m+3\gamma H\rho_m=0 \tag{4}$$

where $V_{,\phi}=\frac{dV}{d\phi}$, and

$$\dot{H}=-\frac{\kappa^2}{2}\left[\frac{\dot{\phi}^2V(\phi)}{\sqrt{1-\dot{\phi}^2}}+\gamma\rho_m\right] \tag{5}$$

Then we will define the dynamical variables as

$$x=\dot{\phi} \quad \text{and} \quad y=\frac{\kappa\sqrt{V(\phi)}}{\sqrt{3}H} \tag{6}$$

The autonomous equations are in the form

$$x'=-(1-x)(3x-\sqrt{3}\lambda y), \tag{7}$$

$$y'=\frac{y}{2}\left[-\sqrt{3}\lambda xy-\frac{3(\gamma-x^2)y^2}{\sqrt{1-x^2}}+3\gamma\right], \tag{8}$$

$$\lambda'=-\sqrt{3}\lambda^2xy(\Gamma-3/2). \tag{9}$$

Together with a constraint equation

$$\frac{y^2}{\sqrt{1-x^2}}+\frac{\kappa^2\rho_m}{3H^2}=1 \tag{10}$$

where λ and Γ are the dimensionless parameters and defined by

$$\lambda\equiv-\frac{V_{,\phi}}{\kappa V^{3/2}}, \quad \Gamma\equiv\frac{VV_{,\phi\phi}}{V_{,\phi}^2} \tag{11}$$

Tachyon Potentials

In this work, we are considering two forms of tachyon potential

$$V(\phi)=V_c\exp(-\mu\phi) \tag{12}$$

and

$$V(\phi)=\frac{V_c}{\cosh(\mu\phi)} \tag{13}$$

for positive values of μ. The exponential potential Eq.(12) gives the case where λ approaches to infinity while the field increases to infinity without oscillations.

Discussions

For the exponential potential Eq.(12) gives us $\Gamma=1$ and Eq.(9) becomes

$$\lambda'=\frac{\sqrt{3}}{2}\lambda^2xy \tag{14}$$

which leads to the growth of λ for $x>0$. In the limit of $\lambda\to\infty$, we find the dynamical critical point $x_c\to\infty, y_c\to\infty$ as in Fig.1. For q is a standard deceleration parameter defined as

$$q\equiv-\frac{\ddot{a}a}{\dot{a}^2} \tag{15}$$

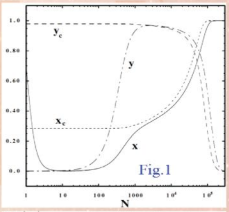

Fig.1

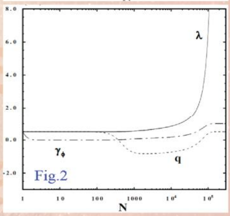

Fig.2

In Fig.2, we find that the universe begins to accelerate for $N\geq 400$ and stop after $N\geq 6.5\times10^4$ by considering the evolution of q. Copeland et al. (2005) suggested that we are possibility living in a transient regime where the acceleration occurs for λ less than an order of unity. For the second potential, Eq.(13), gives the same result with the exponential potential in the limit of large field, $\phi\to\infty$.

Conclusions

The exponential potential gives the acceleration universe in the transient period for $\lambda\leq1$. This leads to an absence of accelerating expansion and reaching the dust attractor in the future. It is possible that we are living in this transient regime of accelerating phase. The result of the inverse hyperbolic cosine potential gives the same result as the exponential potential in the large field limit.

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