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Quasi-Rip universe induced by the fluid with inhomogeneous equation of state.**I. Brevik¹, V. V. Obukhov², A. V. Timoshkin²**¹ Department of Energy and Process Engineering,
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We investigate a specific model for a dark energy which lead to the Quasi-Rip cosmology. In the Quasi-Rip model the equation of state parameter w is less than -1 in the first stage, but then in the second stage is larger than -1 . The conditions for the appearance the Quasi-Rip in the terms of the parameters equation of state are received.

Keywords: dark energy, cosmological constant, equation of state, bound structures.

1 Introduction

The discovery accelerated expansion of the universe led to the appearance the new theoretical models in the cosmology (for recent review see [1,2]) and significantly changed our view of the fate of the universe. Recent observations suggest that the universe is dominated by a negative-pressure component named dark energy (dark fluid). Such quintessence/phantom dark energy proposed to explain the cosmic acceleration should have the strong negative pressure. It can be characterized by an equation of state parameter w , which is the ratio of the pressure to the density: $w = \frac{p}{\rho}$. Its equation of state parameter w is smaller than -1 .

The condition $w < -1$ corresponds to a dark energy density that monotonically increases with time t and scale factor a . There are the some interesting possible scenarios concerning the fate of the universe, including Big Rip [3-4], Little Rip [5-12], Pseudo-Rip [13] models. These models are based on the assumption, that the dark energy density ρ is a monotonically increasing function.

In this paper we are interested to study the cosmological model in which the dark energy density ρ monotonically increases ($w < -1$) in the first stage and then monotonically decreases ($w > -1$). At first stage it takes the place the disintegration of bound structures, but then at the second stage the disintegration process will stop, and the already disintegrated structures have the possibility to be recombined. This scenario in the cosmology was called the Quasi-Rip [14]. Note, that models for which ρ is not monotonic are physically less plausible, and it is more difficult to make any sort of general statement about such models.

The aim of this article is to examine the influence of dark fluid equation of state explicitly dependent on scale factor w and Λ to the occurrence of the Quasi-Rip.

2 Dark fluid with inhomogeneous equation of state in the Quasi-Rip model

Let us consider an explicit model of the Quasi-Rip. We choose to the energy density ρ as a function of the scale factor a . The simplest function ρ can be given [14]:

$$\rho = \rho_0 a^{\alpha - \beta \ln a}, \quad (1)$$

where $\rho = \rho_0$ at fixed time t_0 , α and β are both constants. The derivative of the energy density with respect to cosmic time t is equal:

$$\rho' = \rho H (\alpha - 2\beta \ln a) \quad (2)$$

where $H = \frac{a'}{a}$ is the Hubble rate. We assume, that our universe is filled with an ideal fluid (dark energy) obeying an inhomogeneous equation of state [15]:

$$p = w(a)\rho + \Lambda(a) \quad (3)$$

where $w(a)$ and $\Lambda(a)$ depend on the scale factor a , p is the pressure. Let us write down the energy conservation law:

$$\rho' + 3H(p + \rho) = 0 \quad (4)$$

Taking into account (2-4) we obtain:

$$\rho(\alpha - 2\beta \ln a) + \rho(1 + w(a)) + \Lambda(a) = 0 \quad (5)$$

Let us express from the equation (5) $w(a)$ and suppose, that the cosmological constant Λ is proportional to the square of the energy density, that is:

$$\Lambda(a) = \gamma \rho_0^2 a^{2(\alpha - \beta \ln a)}, \quad (6)$$

where γ is a some constant. Using (6), one obtains:

$$w(a) = -1 - \gamma \rho_0 a^{\alpha - \beta \ln a} + 2\beta \ln a - \alpha \quad (7)$$

If we require $\beta > 0$, then the extremum of ρ is a maximum. It is at $a = \exp \frac{\alpha}{2\beta}$, then the parameter is equal:

$$w(a) = -1 - \gamma \rho_0^{\frac{\alpha}{2}} \quad (8)$$

Consequently, if we take an ideal fluid, obeying an equation of state (3) and (5), then obtain the solution, which realize the Quasi-Rip (1). Note, that such Quasi-Rip is caused exceptionally with cosmological constant Λ . Let us solve the equation (5) about Λ and choose the parameter $w(a)$ in the view:

$$w(a) = -1 - \frac{\delta}{3\rho_0} a^{\beta \ln a - \alpha}, \quad (9)$$

where δ is a constant. We obtain the expression:

$$\Lambda(a) = -\rho_0 a^{\alpha - \beta \ln a} (\alpha - 2\beta \ln a) - \frac{\delta}{3} \quad (10)$$

In this case the Quasi-Rip is caused in the part w . The future behaviour of our universe depends on the particular model parameters α and β . Thus, we explored the equation of state (3), which gives the Quasi-Rip.

3 Conclusion

The Quasi-Rip model has an unique feature different from Big Rip, Little Rip and Pseudo-Rip. All these models arise from the assumption, that dark energy density is monotonically increasing. They lead to the dissolution of all bound structures. As distinct from these models in Quasi-Rip model this assumption is broken. Our universe has a possibility to be rebuilt after the rip. In present work we have built the Quasi-Rip universe induced by the dark fluid with inhomogeneous equation of state. It is shown, that the Quasi-Rip cosmology can be caused exceptionally with the cosmological constant or the parameter γ . It would be interesting to understand if Quasi-Rip cosmology may be mapped with dark energy fluid cosmology mimicking string-landscape features [16]. From another side, the role of viscosity in Rip cosmology may be also relevant in Quasi-Rip picture [17].

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Вселенная Quasi-Rip, индуцированная жидкостью с неоднородным уравнением состояния

Исследована специфическая модель темной энергии, которая приводит к Quasi-Rip космологии. В модели Quasi-Rip параметр w на первой стадии эволюции меньше -1 , а затем, на второй стадии эволюции, больше -1 . Получены условия для возникновения Quasi-Rip в терминах параметров уравнения состояния.

Ключевые слова: *темная энергия, космологическая постоянная, уравнение состояния, граничные структуры.*

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