Phenomenological aspects of coupling term within dark sector

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Abstract

In this short review we discuss the di erent possible form of coupling term within dark sector of the universe. Due to absence of the fundamental theory of dark sector physics the choice of di erent coupling term can be phenomenological. The form of coupling term can be either linear or non-linear function of Hubble parameter H, and energy densities of components of dark sector. We consider two components of dark sector namely dark energy and dark matter. The equation of state of dark matter consider as zero under pressureless dust approximation.

1 Introduction

The Supernova Ia observations[1, 2] in 1998 establish the fact of cosmic acceleration. This observed acceleration of universe also supported by other cosmic observations[3, 4, 5, 6, 7]. To encounter this observational e ect an exotic type of energy introduce with matter energy density. This exotic energy density consist negative pressure which provide it negative equation of state while normal matter having positive or zero equation of state. Apart from cosmological constant there are number of other possible candidates of this exotic energy. This exotic energy dubbed as dark energy. The real scalar led are categorized as the class of the dynamical dark energy model. The CDM model in which the dark energy consider as cosmological constant have persist serious issue namely

.The interacting dark energy model proposed by several numbers of researcher unsolved problems namely Cosmological constant and coincidence problems of CDM model. In the coupled dark energy model the components of the universe coupled to each other with coupling term to follow the transfer of their energy.

The interaction process in the coupled dark energy scenario the rate of expansion of the universe might be alter and which should a ects the structure formation in the universe. The second possibility of the interaction process in the coupled dark energy model may change the e ective mass of the dark matter under energy transfer from dark energy to dark matter. A number of interacting process proposed by several authors in their coupled dark energy model[8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21]

Coupled scalar eld (quintessence, phantom, tachyon etc.) Decaying cosmological constant

w = 1 crossing and interacting models

Coupled holographic dark energy

Coupled Holographic Ricci dark energy

Coupled agegraphic dark energy

2 Coupling Strength

Due to absence of any fundamental theory of dark sector at present, the choice of coupling term within dark sector is purely heuristic. In coupled dark energy model the conservation of energy of individual components is not hold good this violation of conservation of energy is local while the total (global) conservation of energy is hold good for all components of the universe. Thus, by consideration of this we have the following mathematical expression for the conservation law of energy

$$\_{a} + 3H(1 + w_{a})\ {}_{a} = 0; \qquad (1)$$

$$\_{b} + 3H(1 + w_{b})\ {}_{b} = 0 \qquad (2)$$

and

$$\_{c} + 3H(1 + w_{c})\ {}_{c} = 0; \qquad (3)$$

where w_a; w_b and w_c are stand for the equations of state parameters respectively. While the following mathematical statement is regards to conservation law of the total energy

$$\_{total} + 3H(1 + w_{total})\ {}_{total} = 0; \qquad (4)$$

where ${}_{total} = {}_{a} + {}_{b} + {}_{c}$ and w_{total} be the e ective equation of state parameter of combined system.

$$\_{a} + 3H(1 + w_{a})\ {}_{x} = +K \qquad (5)$$

$$\_{b} + 3H(1 + w_{b})\ {}_{b} = K \qquad (6)$$

There are large number of options to x the coupling strength K due to absence of fundamental theory of dark sector. It is natural to consider following two form of coupling strength K as linear or non-linear form.

2.1 Coupling term in the linear form

In the dark sector interaction theory the quantity K could not obtain through the rst principles. Follow the right hand side of conservation of energy expressions the coupling strength K should be a function of linear combination of quantities (H; ${}_{a}$; ${}_{b}$; t) and must be too small. Thus, under these approximations there exist a number of possible combi-nations and the following two are more speci c combinations that is K = f(H ${}_{a}$; H ${}_{b}$). Expanding this function under power law and consider the only rst term we have

$$K\ ' \ {}_{a}H\ {}_{a} + {}_{b}H\ {}_{b}: \qquad (7)$$

Due to incomplete information about the K, it appears reasonable to work with a single parameter rather than two. Thus, three di erent simple choices arise, namely,

$${}_{a} = 0;$$

$${}_{b} = 0;$$

and

$${}_{a} = {}_{b}:$$

The expressions of this type can be obtained from the scalar{tensor theory of gravity. Another logical linear form of coupling strength is

$$K = f(_a; _b)$$

and proceeding as before it can be written as

$$K = _a a + _b b \qquad (8)$$

where $_i$; (i = $_a$; $_b$) is a constant and represented as decay rates of energy density of dark matter ($_a$) and dark energy($_b$). The inspiration of this particular form of K appears in reheating models, curvaton decay and decay of dark matter into radiation etc.

3 Coupling term in the non-linear form

In the analysis of theory of linear form of coupling strength K appears in the conservation energy equations of the individual components in a form proportional either to dark matter density, to dark energy density, or to a particular form of linear combination of both densities. It is more reasonable that the coupling between the components should depend upon the product of the components as happens in nuclear reactions. A number of authors consider a non-linear form of coupling strength proportional to the product of individual energy densities of dark matter and dark energy.

Bolotin et al.[22] have been suggest the an ansatz on the coupling strength given as K = 3H where stands as

$$= ^{l} \, ^{m} (1 + q)^{d}; \qquad (9)$$

here is a positive constant, = $_a$ + $_b$ and q = $\frac{a}{b}$. The powers l; m and d specify the coupling strength K. Some particular combinations of the parameters (l; m; d) which provide us an analytically solvable models with non-linear coupling terms.

4 Conclusion

In this short review we discuss brie y the phenomenological choice of coupling strength in coupled dark energy scenario. Due to absence of the fundamental theory of dark sector the exact form of coupling strength is unknown. The choice of phenomenological form of coupling strength f is either linear or non-linear form. Apart from the linear and non-linear form of coupling strength there might be possibility of theory of decaying cosmological constant(as potensial candidate of dark energy in the dark sector of the universe).

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