Unified Model of k-Inflation, Dark Matter & Dark Energy

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We present a k-essence model where a single scalar field is responsible for the early expansion of the universe through the process of k-inflation and at appropriate subsequent stages acts both as dark matter and dark energy. The Lagrangian contains a potential for the scalar field as well as a non-canonical kinetic term, and is of the form $F(X)V(\phi)$ which has been widely used as a k-essence Lagrangian. After the period of inflation is over the model can be approximated as purely kinetic k-essence, generating dark matter and dark energy at late times. We show how observational results are used to put constraints on the parameters of this model.

I. INTRODUCTION

Till date the nature of both dark matter and dark energy is largely unknown and they constitute one of the biggest puzzles of modern cosmology. The dynamics of the process driving the current acceleration of the universe is still unclear but there exist a wide variety of approaches that could theoretically account for this acceleration. The combination of observations of high redshift supernovae, CMBR and large scale structure have categorized the current energy density of the universe to consist of approximately 73% dark energy, which drives the late time acceleration of the universe, and approximately 23% dark matter which clusters and is responsible for the formation of large-scale structure in the universe (see [1] and references therein). These observations, including those of the nearly scale-independent density perturbations, are also in conformity with the widely held view that the early universe underwent a brief period of accelerated expansion, dubbed as inflation.

Since accelerated expansion is a common feature for both the very early and the very late universe, it is plausible that some common mechanism could be responsible for both. Several models have been constructed to explain inflation and dark energy using a single scalar field (see, for example, quintessential inflation [2]). It is also possible for the two dark components of the universe to be the manifestations of a single entity, and a considerable number of models can be found in the literature that try to unify dark matter and dark energy (for instance [ ], [ ]). Apart from the above schemes there are models that try to unify inflation and dark matter (for instance [ ]) and also those that attempt to unify all three, *viz.* inflation, dark matter and dark energy (for instance [ ]).

In many of these unification models the dynamics of one or more scalar fields plays the central role. In fact, the idea of k-essence driven by scalar field with a non-canonical kinetic term motivated from the Born-Infeld action of string theory [ ], was first introduced as a possible model for inflation [ ]. Later, it was noted that k-essence could also yield interesting models for the dark energy [ ], [ ]. An interesting attempt was made to unify dark matter and dark energy using kinetic k-essence in [ ]. Though this model had its share of problems (it is worth noting that a purely kinetic k-essence leads to a static universe when the late time energy density of the universe is expressed simply as a sum of a cosmological constant and a dark matter term [ ]), extensions of the formalism to extract out dark matter and dark energy components within a unified framework have been used also in subsequent works [ ].

Recently, we [ ] have proposed a k-essence model that reproduces the essential features of inflation, dark matter and dark energy within a unified framework. We found that a couple of parameters of this model had to be tuned in order to conform with various observational features pertaining to both the early and the late time eras of the universe. The Lagrangian chosen in this model was of the form where the kinetic and potential terms were decoupled in the standard way. However, it may be recalled that in most k-essence models [ ], [ ] including the original k-inflation idea [ ], the distinguishing feature was the use of non-canonical kinetic terms in the Lagrangian of the form $F(X)V(\phi)$. In the present paper we return to such a Lagrangian with the motivation of reproducing the features of inflation in the early universe, and also generating dark matter and dark energy at late times. We find that after the early expansion is over, our present model can be approximated as kinetic k-essence, i.e., the dynamics becomes dominated by only the kinetic component of the scalar field. We show that the late time energy density reproduces a cosmological constant and a matter like term which we call dark matter. We then consider observational results from the both the early and late eras, which are used to put constraints on the parameters of this model.

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