Left–right symmetric model of neutrino dark energy

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A B S T R A C T

We implemented the neutrino dark energy (νDE) proposal in a left–right symmetric model. Unlike earlier models of mass varying neutrinos, in the present model the mass parameter that depends on the scalar field (acceleron) remains very light naturally. The required neutrino masses then predicts the $U(1)_R$ breaking scale to be in the TeV range, providing new signals for LHC. Compared to all other νDE proposals, this model has the added advantage that it can also be embedded into a grand unified theory. In this scenario leptogenesis occurs through decays of scalars at very high energy.

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Present observations reveal that the dark energy $\sim (3 \times 10^{-5} \text{ eV})^4$ [1] contributes about 70% to the total density of our universe. Since the only known physics around this scale is the neutrino mass, there are now attempts to relate the origin of the dark energy with the neutrino masses [2–4]. This connection is based on the idea of quintessence [5], and have several interesting consequences [6,7].

In the original model of neutrino dark energy (νDE) or the mass varying neutrinos (mavans) [2–4], the standard model is extended by including singlet right-handed neutrinos $N_i$, $i = 1, 2, 3$, and giving a Majorana mass to the neutrinos which varies with a scalar field, the acceleron. This model was not complete and several problems were pointed out [3,8]. Some of the problems have been solved in subsequent works [9,10], but more studies are required to make this model fully consistent. The main motivation of the present article is to justify the very low scale entering in the model naturally, embed this idea into a left–right symmetric model and also in grand unified theories. Since the right-handed neutrinos are not very heavy, leptogenesis occurs through scalar decays.

In the νDE models, the Majorana masses of the right-handed neutrinos varies with the acceleron field and that relates the scale of dark energy with the light neutrino masses. Naturalness requires the Majorana masses of the right-handed neutrinos also to be in the range of eV, so the main motivation of the seesaw mechanism is lost. The smallness of the light neutrino masses cannot be attributed to a large lepton number violating mass scale in the theory. In this νDE model, the neutrino Dirac masses cannot be made to vary with the acceleron field, since that will then allow coupling of the acceleron field with the charged leptons and a natural scale for the dark energy will then be the mass of the heaviest charged lepton. For the same reason, this mechanism cannot be embedded into a left–right symmetric model, in which the $SU(2)_R$ group relates the right-handed neutrinos to the right-handed charged leptons.

The problem with the smallness of the mass parameter that depends on the acceleron field can be softened in the νDE models with triplet Higgs scalars [10]. In these models the standard model is extended to include triplet Higgs scalars. In any phenomenologically consistent triplet Higgs scalar model, lepton number is violated explicitly by a trilinear scalar couplings of the triplet Higgs scalar with the standard model Higgs doublet. In the νDE model with the triplet Higgs scalars, the coefficient of this trilinear scalar coupling with mass dimension varies with the acceleron field, and naturalness allows this parameter to be as large as a few hundred GeV. Although the scale of this mass parameter predicts new signals in the TeV range, there is no symmetry that makes this scale natural.

We propose a left–right symmetric model, in which the mass parameter that varies with the acceleron field remains small naturally and the scale of dark energy is related to the neutrino masses. This is the only νDE model that can be embedded into a grand unified theory, without relating the scale of dark energy to the charged fermion masses. We then discuss the question of leptogenesis in this model.

We start with the left–right symmetric extension of the standard model [11] with the gauge group $G_{LR} \equiv SU(3)_c \times SU(2)_L \times SU(2)_R \times U(1)_{B-L}$, and the electric charge is related to the generators of the group as:

$$Q = T_{3L} + T_{3R} + \frac{B - L}{2} = T_{3L} + Y. \quad (1)$$