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Gauge Coupling Unification in Radiative Neutrino Mass Models

We investigate the renormalization group running of gauge couplings in various radiative neutrino mass models, which generate neutrino masses at one- and two-loop order. We discuss the possibility for these couplings to unify in such models at an energy scale close to the GUT scale. The studies are performed both analytically, at one-loop level, and numerically, at two-loop level, using the software PyR@TE. We study five different classes of models, which are (i) minimal dimension-7 models which generate neutrino masses at one-loop level (15 models), (ii) the same models with additional dark matter candidates (15 models), (iii) models with minimal dark matter which generate neutrino masses at one-loop level (35 models), (iv) the same models with all particles colored, and finally, (v) models with scalar colored octets (three models). The dark matter candidates, which are added in class (ii), are not excluded by direct detection constraints. In addition, each of the dark matter representations should not have a contribution to the running so that there is a Landau pole below a presumed unification scale. We find that unification is achieved in several models. The particles in class (i) are added in up to six generations and we find unification in four versions of the models in this class. Out of the models in class (ii), we find that 15 models that unify. In classes (iii) and (iv), we find unification in eight and two models, respectively. Finally, none of the models in class (v) unify. In general, we find that unification can occur and the scale is normally in the range $(10^{10} - 10^{14})$ GeV. The model with the highest scale is a model in class (i), which has the scale $1.8 \cdot 10^{16}$ GeV.

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