LETTER TO THE EDITOR

Neutrino masses and the gluino axion model

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Abstract. We extend the recently proposed gluino axion model to include neutrino masses. We discuss how the canonical seesaw model and the Higgs triplet model may be realized within this framework. In the former case, the heavy singlet neutrinos are contained in superfields which do not have any vacuum expectation value, whereas the gluino axion is contained in one which does. We also construct a specific renormalizable model which realizes the mass scale relationship $M_{SU} \sim f_a^2 / M_U$, where $f_a$ is the axion decay constant and $M_U$ is a large effective mass parameter.

A new axionic solution [1] to the strong CP problem was recently proposed [2]. Instead of coupling to ordinary matter as in the DFSZ model [3] or to unknown matter as in the KSVZ model [4], this new axion couples to the gluino as well as all other supersymmetric particles. The instanton-induced CP violating phase [5] of quantum chromodynamics is then cancelled by the dynamical phase of the gluino mass, as opposed to that of the quarks in the DFSZ model and that of the unknown coloured fermions in the KSVZ model. This means that CP violation is absent in the strong-interaction sector and experimental observables, such as the neutron electric dipole moment [6], are subject only to weak-interaction contributions.

What sets the gluino axion model [2] apart from all other previous models is its identification of the Peccei–Quinn global symmetry $U(1)_{PQ}$ with the $U(1)_R$ symmetry of superfield transformations. Under $U(1)_R$, the scalar components of a chiral superfield transform as $\phi \to e^{i\theta R} \phi$, whereas the fermionic components transform as $\psi \to e^{i\theta (R-1)} \psi$. In the minimal supersymmetric standard model (MSSM), the quark and lepton superfields $\hat{Q}, \hat{u}, \hat{d}, \hat{L}, \hat{e}$ have $R = +1$, whereas the Higgs superfields $\hat{H}_u, \hat{H}_d$ have $R = 0$. The superpotential

$$\hat{W} = \mu \hat{H}_u \hat{H}_d + h_u \hat{H}_u \hat{Q} \hat{u} + h_d \hat{H}_d \hat{Q} \hat{d} + h_e \hat{H}_d \hat{L} \hat{e}$$

(1)

has $R = +2$ except for the $\mu$ term (which has $R = 0$). Hence the resulting Lagrangian breaks $U(1)_R$ explicitly, leaving only a discrete remnant, i.e. the usual $R$ parity: $R = (-1)^{3B+L+2J}$. The gluino axion model replaces $\mu$ with a singlet composite superfield $\hat{S}^2 / M_{P}^{1/2}$ where $\hat{S}$ has $R = +1$ so that the resulting supersymmetric Lagrangian is invariant under $U(1)_R$. It also requires all supersymmetry breaking terms to be invariant under $U(1)_R$, the spontaneous breaking of which then produces the axion and solves the strong CP problem.

In the MSSM, neutrinos are massless. However, in view of the recent experimental evidence for neutrino oscillations, it is desirable to incorporate into any realistic model naturally small Majorana neutrino masses [7, 8]. In the following we will discuss how the canonical seesaw model [9] and the Higgs triplet model [10] may be realized within the framework of