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Electron EDM and soft leptogenesis in supersymmetric B–L extension of the Standard Model

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Abstract

We analyze the connection between electric dipole moment of the electron and the soft leptogenesis in supersymmetric B–L extension of the Standard Model. In this model, the B–L symmetry is radiatively broken at TeV scale. Therefore, it is a natural framework for low scale seesaw mechanism and also for implementing the soft leptogenesis. We show that the phases of trilinear soft SUSY breaking couplings A, which are relevant for the lepton asymmetry, are not constrained by the present experimental bounds on electric dipole moment. As in the MSSM extended with right-handed neutrinos, successful leptogenesis requires small bilinear coupling B, which is now given by A_N and B–L breaking VEVs. SUSY B–L model with non-universal A-terms such that $A_N = 0$ while $A_\nu \neq 0$ is a promising scenario for soft leptogenesis. The proposed EDM experiments will test this scenario in the future.

1. Introduction

The current measurement of the baryon-to-entropy ratio of the Universe is given by [1]

$$Y_B \equiv \frac{n_B}{s} = (0.87 \pm 0.02) \times 10^{-10}, \tag{1}$$

where $s = 2\pi^2 g_\star T^3/45$ is the entropy density and $g_\star$ is the effective number of relativistic degrees of freedom. CP violation is an essential requirement in order to obtain this asymmetry. It is

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well known that in the Standard Model (SM), it is not possible to generate sufficient baryon asymmetry through the phase of the Cabibbo–Kobayashi–Maskawa (CKM) mixing matrix, $\delta_{\rm CKM}$ [2].

Supersymmetric (SUSY) extensions of the SM contain new CP-violating sources beyond $\delta_{\rm CKM}$, namely the Higgs bilinear term, μ, and the soft breaking terms (gaugino and squark soft masses, bilinear and trilinear couplings). The most stringent constraints on the SUSY phases come from continued efforts to measure the electric dipole moments (EDM) of the neutron, electron, and mercury atom [3].

Leptogenesis [4], based on a high scale seesaw mechanism, provides an attractive scenario to explain the baryon asymmetry. However, in this scenario, supersymmetry should be introduced to stabilize the electroweak scale. Therefore, leptogenesis is more natural in SUSY models. Recently, a new leptogenesis scenario, soft leptogenesis, has been proposed [5–7], where sneutrino decays offer new possibilities for generating the asymmetry.

Assuming universal soft SUSY breaking terms, the relevant terms for the soft leptogenesis in the minimal supersymmetric Standard Model (MSSM) extended with three right-handed neutrino superfields are given by

$$\mathcal{L}_{\rm soft} = \frac{\tilde{m}_N^2}{2}\tilde{N}^{c\dagger}\tilde{N}^c + \frac{B_M^2}{2}\tilde{N}^c\tilde{N}^c + A_\nu Y_\nu \tilde{L}\tilde{N}^c H_2 + \text{h.c.}, \tag{2}$$

and in the case of mSUGRA, $B_M^2 = B_N M_N$. This sector has one physical CP violating phase

$$\phi_\nu = \arg\left(A_\nu B_N^*\right). \tag{3}$$

In this respect, a mixing between the sneutrino $\tilde{N}^c$ and the antisneutrino $\tilde{N}^{c\dagger}$ is an analogue to the B^0–$\bar{B}^0$ and K^0–$\bar{K}^0$ systems. The mass difference and the two sneutrino mass eigenstates are given by

$$\Delta M = |B_N|, \qquad \Delta\Gamma = \frac{2|A_\nu|\Gamma}{M_N}. \tag{4}$$

The CP violation in the $\tilde{N}^c$-mixing, induced by the phase ϕ_ν, generates lepton asymmetry in the final states of the $\tilde{N}^c$-decay. This lepton asymmetry is converted to baryon asymmetry through the sphaleron process [8]. The baryon to entropy ratio for $M_N \gg A_\nu$ case is given by [6]

$$\frac{n_B}{s} \simeq -10^{-3}\eta\left[\frac{4\Gamma|B_N|}{4|B_N|^2+\Gamma^2}\right]\frac{|A_\nu|}{M_N}\sin\phi_\nu, \tag{5}$$

where η is the efficiency parameter which is suppressed for small and large M_N because of the insufficient $\tilde{N}$ production and strong washout effect.

It has been noticed [6] that for 1 TeV $\ll M_N \leqslant 10^8$ GeV soft leptogenesis may give important contribution to the baryon asymmetry only if the parameter B_N is very small. It means that, in this case, deviation from resonant condition gives too small baryon asymmetry.

The TeV scale right-handed neutrino is naturally obtained in supersymmetric B–L extension of the Standard Model (SUSY B–L), which is based on the gauge group $G_{B-L} \equiv SU(3)_C \times SU(2)_L \times U(1)_Y \times U(1)_{B-L}$. In this type of model, the B–L Higgs potential receives large radiative corrections that induce spontaneous B–L symmetry breaking at TeV scale, in analogy to the electroweak symmetry breaking in MSSM [9]. This result provides further motivation for considering the phenomenological and cosmological implications of this model.

In this paper, we investigate the possibility of soft leptogenesis in minimal SUSY B–L model. This model has the B-term coming from a new A-term $A_N\tilde{N}\tilde{N}\chi_1$ and μ-term $\mu'\chi_1\chi_2$, where