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PeV scale Left–Right symmetry and baryon asymmetry of the Universe

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Abstract

We study the cosmology of two versions of supersymmetric Left–Right symmetric model. The scale of the B–L symmetry breaking in these models is naturally low, 10^4–10^6 GeV. Spontaneous breakdown of parity is accompanied by a first order phase transition. We simulate the domain walls of the phase transition and show that they provide requisite conditions, specifically, CP violating phase needed for leptogenesis. Additionally soft resonant leptogenesis is conditionally viable in the two models considered. Some of the parameters in the soft supersymmetry breaking terms are shown to be constrained from these considerations. It is argued that the models may be testable in upcoming collider and cosmology experiments.

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1. Introduction

Left–right symmetric model [1–5] is a simple extension of the Standard Model (SM) [6–8]. From a theoretical point of view it provides an elegant explanation for the conservation of B–L which automatically becomes a gauge charge, and as a bonus provides a natural explanation for the meaning of the electroweak hypercharge. The new gauge symmetries required constitute the group $SU(2)_R \otimes U(1)_{B-L}$. The model has long been understood as a possible intermediate state in the $SO(10)$ [9,10] grand unified theory (GUT). However unification in $SO(10)$ generically also forces the possible intermediate scale of Left–Right symmetry to be high and therefore inaccessi-

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ble to accelerators. On the other hand, the less restrictive principle of exact Left–Right symmetry is still appealing though it leaves the $U(1)_{B-L}$ charge unrelated to the two identical charges of $SU(2)_L$ and $SU(2)_R$. As for the fermion sector the presence of right-handed neutrino states in the theory allows the possibility of explaining the smallness of the observed neutrino masses [11–14] from the see-saw mechanism [15–18]. While the scale of Majorana masses is no longer as high as in the conventional see-saw expectations, the PeV scale still permits [19] explaining the smallness of the light neutrino mass scale for at least certain textures of fermion mass parameters. It is therefore worth exploring the possibility that the scale of Left–Right symmetry be the PeV scale, potentially testable in colliders.

Whether we follow the GUT proposal or the PeV scale possibility, the large hierarchy between the mass scales $M_{\rm EW} \sim 250$ GeV of electroweak symmetry and $M_{\rm GUT} \sim 10^{15}$ GeV is difficult to understand within the Higgs paradigm. While the Higgs sector of the Standard Model is poorly understood, it is nevertheless very successful. We therefore speculate that the breaking of both the $SU(2)_L$ and $SU(2)_R$ being at a comparable scale will have a similar explanation, possibly a comprehensive one including both. There remains the need to understand the hierarchy with respect to a larger mass scale either the GUT scale or the Planck scale. In this paper we assume supersymmetry (SUSY) to be the mechanism to stabilize the hierarchy beyond the electroweak scale [20,21], in other words we assume TeV scale SUSY.[1] We study what has been called the minimal supersymmetric Left–Right symmetric model (MSLRM) [25] with the gauge group $SU(3)_c \otimes SU(2)_L \otimes SU(2)_R \otimes U(1)_{B-L}$ augmented by parity P exchanging L and R sectors. Lee et al. [26] have studied a similar model with the gauge group $SU(4)_c \otimes SU(2)_L \otimes SU(2)_R$ and connected it to cosmological phenomena, specifically inflation. Our discussion differs in being specifically PeV scale.

In the MSLRM class of Left–Right symmetric models, spontaneous gauge symmetry breaking required to recover SM phenomenology also leads to observed parity breaking. However, for cosmological reasons it is not sufficient to ensure local breakdown of parity. We have earlier proposed [27] that the occurrence of the SM like sector globally is connected to the SUSY breaking effects from the hidden sector. Another approach to implementing the global uniformity of parity breaking is to have terms induced by gauge symmetry breaking which signal explicit parity breaking [28,29]. This model has been dubbed MSLR$\not{P}$. In earlier papers we have explored the overall cosmological setting for these models and traced issues such as removal of unwanted relics and a successful completion of the first order phase transition. Here we show that sufficient conditions exist in the model to provide for the leptogenesis required to explain the baryon asymmetry of the Universe.

A possible implementation of this idea follows the thermal leptogenesis [30] route. This however has been shown to generically require the scale of Majorana neutrino mass, equivalently, in our model the scale of B–L breaking to be 10^{11}–10^{13} GeV [31,32], with a more optimistic constraint $M_{B-L} > 10^9$ GeV [33,34]. This situation is not improved [35–38] by assistance from cosmic string induced violation [39–41] of lepton number [42]. On the other hand, it has been shown [19,43] that the only real requirement imposed by leptogenesis is that the presence of heavy neutrinos should not erase lepton asymmetry generated by a given mechanism, possibly non-thermal. This places the modest bound $M_1 > 10^4$ GeV, on the mass of the lightest of the heavy Majorana neutrinos. A scenario which exploits this window and relies on supersymmetry

[1] See for instance [22–24] and references therein.