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Nuclear Physics B 929 (2018) 21–57

NUCLEAR PHYSICS B

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Texture zero neutrino models and their connection with resonant leptogenesis

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Received 16 November 2017; received in revised form 10 January 2018; accepted 4 February 2018
Available online 8 February 2018
Editor: Tommy Ohlsson

Abstract

Within the low scale resonant leptogenesis scenario, the cosmological CP asymmetry may arise by radiative corrections through the charged lepton Yukawa couplings. While in some cases, as one expects, decisive role is played by the λ_τ coupling, we show that in specific neutrino textures only by inclusion of the λ_μ the cosmological CP violation is generated at 1-loop level.

With the purpose to relate the cosmological CP violation to the leptonic CP phase δ, we consider an extension of MSSM with two right handed neutrinos (RHN), which are degenerate in mass at high scales. Together with this, we first consider two texture zero 3×2 Dirac Yukawa matrices of neutrinos. These via see-saw generated neutrino mass matrices augmented by single $\Delta L = 2$ dimension five (d = 5) operator give predictive neutrino sectors with calculable CP asymmetries. The latter is generated through $\lambda_{\mu,\tau}$ coupling(s) at 1-loop level. Detailed analysis of the leptogenesis is performed. We also revise some one texture zero Dirac Yukawa matrices, considered earlier, and show that addition of a single $\Delta L = 2$, d = 5 entry in the neutrino mass matrices, together with newly computed 1-loop corrections to the CP asymmetries, give nice accommodation of the neutrino sector and desirable amount of the baryon asymmetry via the resonant leptogenesis even for rather low RHN masses ($\sim$few TeV–10^7 GeV).

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https://doi.org/10.1016/j.nuclphysb.2018.02.001

1. Introduction

Problem of neutrino masses and generation of the baryon asymmetry of the Universe, together with the dark matter problem and naturalness issues, call for some reasonable extension(s) of the Standard Model (SM). Perhaps simplest and most elegant simultaneous resolution of the first two puzzles is by the SM extension with the right handed neutrinos (RHN). This, by the $\Delta L = 2$ lepton number violating interactions generates the neutrino masses via celebrated see-saw mechanism [1,2], accommodating the atmospheric and solar neutrino data [3], and gives an elegant possibility for the baryogenesis through the thermal leptogenesis [4] (for reviews see Refs. [5–7]).

Motivated by these, we consider the minimal supersymmetric standard model (MSSM)[1] augmented by two degenerate RHNs. Note that the degeneracy in the RHN mass spectrum offers an elegant possibility of resonant leptogenesis [8–10] (see [11–15] for recent discussions on resonant leptogenesis). This framework, as it was shown in [15–17], with specific forms of the Yukawa couplings, allows to have highly predictive model. In particular, in [18] all possible two texture zero 3×2 Dirac type neutrino Yukawa couplings have been considered. Those, via see-saw generated neutrino mass matrices augmented by a single $\mathrm{d} = 5$, $\Delta L = 2$ operator, gave consistent neutrino scenarios. As it was shown, all experimentally viable cases allowed to calculate the cosmological CP violation in terms of a single known (from the model) leptonic phase δ.[2] In the subsequent work [15], the quantum corrections, primarily due to the λ_τ Yukawa coupling, have been investigated and, confirming earlier claim of Refs. [46], it was shown that the cosmological CP asymmetry arises at 1-loop order.[3] Demonstrated on a specific fully consistent neutrino model [15], this was shown to work well and opened wide prospect for the model building for the low scale resonant leptogenesis.

The goals of this work are following. First we give detailed and conscious derivation of the loop induced leptonic cosmological CP violation showing the necessity of inclusion of the charged lepton Yukawa couplings. Proof includes analytical expressions and is extended by inclusion of the λ_μ coupling which as it turns out in specific neutrino scenarios is the only relevant source of the cosmological CP violation within considered scenarios with the RHN masses $\lesssim 10^7$ GeV. We apply obtained result to specific neutrino textures. While in Refs. [16,17,19–25] the textures relating the cosmological CP violation to the leptonic δ phase (being still undetermined from the construction) have been discussed, in [18] we have proposed models, which not only give such relations, but also predict the values of the δ (the leptonic Dirac phase) and $\rho_{1,2}$ (two leptonic Majorana phases) and consequently the cosmological CP violation. From the constructions of [18] we consider viable neutrino models built by two texture zero 3×2 Yukawa coupling generated see-saw neutrino mass matrices augmented by the single $\Delta L = 2$, $\mathrm{d} = 5$ operator. For all these neutrino models, applying obtained all relevant corrections, we investigate the resonant leptogenesis process, which has not been performed before. Along with the cases where crucial is λ_τ coupling, we have ones for which the leptonic asymmetry originates due to the λ_μ Yukawa coupling. Such possibility has not been presented before in the literature. We also revise textures of [17] and consider their improved versions by addition of single $\mathrm{d} = 5$ entry

[1] This setup with the SUSY scale $M_S \sim$ few TeV guarantees the natural stability of the EW scale.

[2] The approach with texture zeros has been put forward in [19], which successfully relates the phase δ with the cosmological CP asymmetry [15–25].

[3] Studies of [17] included only λ_τ's 2-loop effects in the RG of the RHN mass matrix, which give parametrically more suppressed cosmological CP violation in comparison with those evaluated in [15].