Impact of Texture Zeros on Leptogenesis within Minimal Inverse Seesaw Framework

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***Abstract*—We study the prediction of one zero textures of the light neutrino mass matrix on neutrino phenomenology and baryon asymmetry of Universe (BAU) within the framework of an inverse seesaw ISS (2,3). In ISS (2,3) two right handed neutrinos instead of three are added along with three gauge singlet fermions to the standard model. The model leads to two pairs of quasi-Dirac particles and one sterile state in keV scale along with three active neutrinos. Implementing texture zeros in the framework of minimal inverse seesaw reduces the free parameters. The decay of the quasi-Dirac pairs create lepton asymmetry that can be converted to baryon asymmetry of the Universe by sphaleron process. We carry out a detailed numerical analysis to obtain neutrino masses and BAU through leptogenesis. The viability of different two zero textures within the framework has been verified with the latest cosmology data on BAU.**

Keywords—Neutrino Phenomenology; Baryon Asymmetry; Leptogenesis

I. INTRODUCTION

Baryon asymmetry of the universe (BAU) is an appealing mystery in particle physics as well as cosmology. There must be some mechanism through which the universe develops such asymmetry during its evolution. The mechanism is referred to as baryogenesis [1,2,3]. In 1967, Andrew Sakharov put forward three key ingredients for successful baryogenesis [4]. Several mechanisms have been proposed to realize BAU. Among these, a very popular mechanism to explain the baryon asymmetry of the universe is leptogenesis. In this work, we have chosen inverse seesaw ISS (2,3) to study leptogenesis [5,6]. In this framework, lepton asymmetry can be produced through out of equilibrium decay of the quasi-Dirac pairs present in the model. The Yukawa couplings of the heavy neutrinos are the sole source of CP violation in this mechanism. The leptonic asymmetry has been resonantly enhanced in this model. Again, implementing texture zeros to the mass matrices can reduce the free parameters in the model. In this paper, we try to find the possible one zero textures of the light neutrino mass matrix in this model. After constructing the zero textures, we perform a detailed analysis of Baryon asymmetry created in all the textures. The viability of the different textures is identified by implementing astrophysical and cosmological bounds on baryon asymmetry of universe.

The paper is structured as follows. In section II, we briefly describe the framework of ISS (2, 3) and discuss about leptogenesis in ISS (2, 3). Section III contains the results and discussion. In section IV, we present our conclusion.

II. ISS(2,3) FRAMEWORK AND LEPTOGENESIS

A. The framework

In inverse seesaw ISS (2,3), the Standard Model is extended by the sequential addition of RH neutrinos and SM singlet fermions s [5,6].

The interaction Lagrangian can be written as,

$$\mathrm{L} = -\frac{1}{2} n^{T}\, \mathrm{C\,M\,n} + \mathrm{h.c.}$$

Where, $\mathrm{C} = \mathrm{i}\gamma^2\gamma^0$ is the charge conjugation matrix and the basis $\mathrm{n} = (L_{i\alpha}, N_{iR}, s)^T$. Here $L_{i\alpha}$ with $(\alpha = \mathrm{e}, \mu, \tau)$ are left handed neutrinos $N_{iR}(i = 1, N_{iR})$ are right handed (RH) neutrinos, while s_j $(\mathrm{j} = 1, s)$ are sterile fermions.

From the above equation, one can write M as,

$$\mathrm{M} = \begin{pmatrix} 0 & \mathrm{M_D} & 0 \\ \mathrm{M_D^T} & 0 & \mathrm{M_N} \\ 0 & \mathrm{M_N} & \mu \end{pmatrix}$$

Dimension of the mass matrices are,

$$\mathrm{M_D} = \#\mathrm{v_L} \times \#M_N = 3 \times 2$$

$$\mathrm{M_N} = \#M_N \times \#\mathrm{s} = 2 \times 3$$

$$\mu = \#\mathrm{s} \times \#\mathrm{s} = 3 \times 3$$

Here, # represents number of flavor of neutrinos.

As already mentioned, ISS(2,3) contains two quasi-Dirac pairs in TeV scale. The decay of these pairs can produce lepton asymmetry which can be converted into baryon asymmetry through sphaleron process [7]. Thus the mechanism leptogenesis can be studied within the model. However, the decay of the heavier pair is washed out by the scattering processes. Therefore, in this work, we have focused on the lepton asymmetry created by the lightest quasi-Dirac pairs only. The governing equations can be found in [6]. In [6], the study involves the leptogenesis in flavor symmetric model. In this paper, we have studied the impact of different texture zeros in leptogenesis. Below we discuss the possible one zero textures of neutrino mass matrix.

B. One zero textures in ISS(2,3):

In ISS(2,3), there are three mass matrices $\mathrm{M_d}$, $\mathrm{M_N}$ and μ. The textures of these three matrices yield the light neutrino mass matrix. One can obtain three one zero textures of light neutrino mass matrix in this framework [8].

$$A1 = \begin{pmatrix} \times & 0 & \times \\ 0 & \times & \times \\ \times & \times & \times \end{pmatrix}, A2 = \begin{pmatrix} \times & \times & \times \\ \times & \times & 0 \\ \times & 0 & \times \end{pmatrix}, A3 = \begin{pmatrix} \times & \times & 0 \\ \times & \times & \times \\ 0 & \times & \times \end{pmatrix}$$

Here, × represents the non zero elements in the matrix.

The above textures can be obtained from the following structures of the three mass matrices [8].

For Class A1: $M_d = \begin{pmatrix} 0 & b \\ c & 0 \\ e & h \end{pmatrix}, M_N = \begin{pmatrix} f & 0 & 0 \\ 0 & g & 0 \end{pmatrix}, \mu = \begin{pmatrix} p & 0 & 0 \\ 0 & p & 0 \\ 0 & 0 & p \end{pmatrix}$

For Class A2: $M_d = \begin{pmatrix} a & b \\ c & 0 \\ 0 & h \end{pmatrix}, M_N = \begin{pmatrix} f & 0 & 0 \\ 0 & g & 0 \end{pmatrix}, \mu = \begin{pmatrix} p & 0 & 0 \\ 0 & p & 0 \\ 0 & 0 & p \end{pmatrix}$

For class A3: $M_d = \begin{pmatrix} 0 & b \\ c & d \\ e & 0 \end{pmatrix}, M_N = \begin{pmatrix} f & 0 & 0 \\ 0 & g & 0 \end{pmatrix}, \mu = \begin{pmatrix} p & 0 & 0 \\ 0 & p & 0 \\ 0 & 0 & p \end{pmatrix}$

With these textures, the obtained form of the light neutrino mass matrix:

$$A1 = -p \begin{pmatrix} k_1^2 & 0 & k_1 k_2 \\ 0 & k_2^2 & k_2 k_3 \\ k_1 k_2 & k_2 k_3 & k_1^2 + k_4^2 \end{pmatrix}$$

$$A2 = -p \begin{pmatrix} k_1^2 + k_2^2 & k_2 k_3 & k_1 k_4 \\ k_2 k_3 & k_3^2 & 0 \\ k_1 k_4 & 0 & k_4^2 \end{pmatrix}$$

$$A3 = -p \begin{pmatrix} k_1^2 & k_1 k_3 & 0 \\ k_1 k_3 & k_1^2 + k_3^2 & k_2 k_4 \\ 0 & k_2 k_4 & k_4^2 \end{pmatrix}$$

Where, k1, k2,k3 and k4 are functions of the parameters present in the matrices M_d, and M_N

Thus in ISS(2,3), there exists three allowed one zero textures of the light neutrino mass matrix.

III. RESULTS AND DISCUSSION:

We first evaluate the model parameters in all the textures using the following equation [9],

$$M_\nu = U_{PMNS}\, M_\nu^{diag}\, U_{PMNS}^T$$

Here, U_{PMNS} is the PMNS matrix that diagonalizes the light active neutrino matrix that can be seen in [10]. After evaluating parameters, we then feed these model parameters in the calculation of the lepton asymmetry created in all the textures. The results obtained in all the textures are shown from fig1 to fig3. In these figures, we have shown baryon asymmetry as a function of the model parameter (k_1).

From fig 1, it has been observed that the texture A1 leads to the observed baryon asymmetry. The texture A2 is very weak in the prediction of the observed baryon asymmetry as can be seen from fig2. Again, fig 3 shows that a very small parameter space is allowed from the latest cosmology data on BAU. One can obtain similar results considering the other parameters for the three textures.

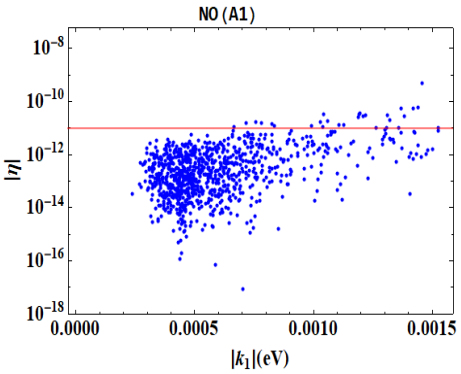

Fig1 BAU as a function of model parameter k1 for A1. Red horizontal line represents the Planck limit on observed BAU.

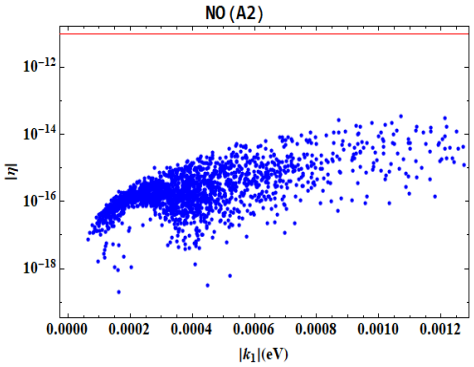

Fig2 BAU as a function of model parameter k1 for A2. Red horizontal line represents the Planck limit on observed BAU.

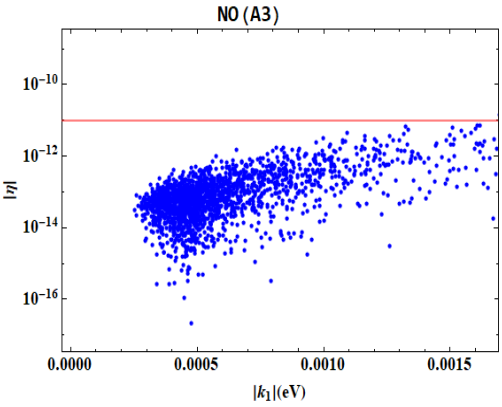

Fig3 BAU as a function of model parameter k1 for A3. Red horizontal line represents the Planck limit on observed BAU.

IV. CONCLUSION

In this work, we have studied a popular mechanism of generating baryon asymmetry of the Universe known as leptogenesis, within the framework of inverse seesaw ISS(2,3). This framework is successful in explaining neutrino phenomenology as well. Different one zero textures of the light neutrino mass matrix have been formed within ISS(2,3). One important conclusion is that the allowed number of one zero textures in this model is three. After studying leptogenesis, we can conclude that among the three textures, two are allowed from the latest cosmology data.

V. REFERENCES

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VI. ACKNOWLEDGEMENT

NG acknowledges Department of Science and Technology (DST),India(grant DST/INSPIRE Fellowship/2016/IF160994) for the financial assistantship.