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*Corresponding author.

gayatrighsh@gmail.com

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Non-Unitarity in Neutrino mixing matrix and two and three flavored non resonant Leptogenesis from CP violation

Gayatri Ghosh[1]*

1 Physics Department Gauhati University, Pandit Deendayal Upadhyaya Adarsha Mahavidyalaya, Karimganj, Assam, India

Abstract

Background/Objectives: We will study the effects of non-unitarity parameters from existing experimental constraints, on cLFV decays such as, $\mu \rightarrow e\gamma$, $\mu \rightarrow \tau\gamma$, $\tau \rightarrow e\gamma$, on generation of baryon asymmetry through leptogenesis and neutrino oscillation probabilities. Considering flavor effects in leptogenesis, we do a parameter scan of a minimal seesaw model in a type I Seesaw framework satisfying Planck data on baryon to photon ratio of the Universe, which lies in the interval, $5.8\times10^{-10} < Y_B < 6.6\times10^{-10}$(BBN). We predict values of lightest neutrino mass, and Dirac and Majorana CP violating phase δ_{CP}, α and β, for normal hierarchy and inverted hierarchy for one, two and three flavor leptogenesis regimes. It is worth mentioning that all these four quantities are unknown yet, and future experiments will be measuring them. **Methods/Statistical analysis:** In spite of several experimental verifications of neutrino oscillations and precise measurements of two mass squared differences and the three mixing angles, the unitarity of the leptonic mixing matrix is not yet established, leaving room for the presence of small non unitarily effects. We study their effects on generation of baryon asymmetry through leptogenesis. Considering flavor effects in leptogenesis, we do a parameter scan of a minimal seesaw model in a type I Seesaw framework satisfying Planck data on baryon to photon ratio of the Universe, which lies in the interval, $5.8 \times 10^{-10} < Y_B < 6.6 \times 10^{-10}$(BBN). Findings: We predict values of lightest neutrino mass, for normal hierarchy and inverted hierarchy for two and three flavor leptogenesis regimes. It is worth mentioning that all these four quantities, lightest neutrino mass, and Dirac and Majorana CP violating phase δ_{CP}, α and β, are unknown yet, and future experiments will be measuring them. **Novelty/Applications:** Unitarity in U_{PMNS} matrix is not yet established, and hence it has left scope for testing non unitarity in the leptonic sector which will result in various implications of New Physics theories in predicting the values of leptonic CPV phase, δ_{CP}, Majorana phases, α, β and the absolute value of the neutrino masses. The interesting feature of our work is that we will evaluate the absolute value of lightest neutrino mass which is found to be consistent with the cosmological constraints on the sum of the neutrino mass bound, $\Sigma_i m_{(\nu\, i)}$ <

0.23 eV from CMB, Planck 2015 data (CMB_{15}+ LRG+ lensing + H_0). We note that absolute value of lightest neutrino mass is also not known so far, and hence our prediction made here may be tested in future when experiments (including neutrinoless double beta decay experiments) will determine its value in future.

Keywords: Non unitarity; CP violation phase; Majorana phases; leptogenesis; Baryogenesis.

1 Introduction

We have considered the possibility that the neutrino mixing matrix (considering charged lepton mass matrix to be diagonal), U_{PMNS} could be non unitary, and analysed how the non unitarity of U_{PMNS} can affect flavored and unflavored leptogenesis and the generation of baryon asymmetry of the universe in this regard. In this context we also calculated the values of lightest ν mass, dirac CPV phase δ_{CP} and majorana phases α and β, such that Y_B lies in the present day constraints ($5.8\times10^{-10} < Y_B < 6.6\times10^{-10}$) using type I see saw mechanisms for producing light ν masses. It is worth mentioning that all these four quantities are unknown yet, and future experiments will be measuring them, and thus our analysis could shed new light in this area.

Neutrinos have masses and mixings. There are 3 known flavors of neutrinos, ν_e, ν_μ, and ν_τ , each of which couples only to the charged lepton of the same flavor, ν_e, ν_μ, and ν_τ are superpositions of three mass eigenstates, $|\nu_\alpha>= U^*_{\alpha i}|\nu_i>$, where α = e, μ, τ and ν_i is the neutrino of definite mass mi . The cosmological constraints of the sum of the ν masses bound is $\Sigma_i\, m(\nu_i) < 0.23$ eV from CMB, Planck 2015 data (CMB15+ LRG+ lensing + H0)[1]. We note that the lepton mixing matrix U has a big mixing and we know almost nothing about the phases. The discoveries of neutrino mass and leptonic mixing have come from the observation of neutrino flavor change, $\nu_\alpha \rightarrow \nu_\beta$. In the conventional type I see-saw framework there are Dirac and Majorana mass matrices m_D and M_R in the Lagrangian,

$$L = \frac{1}{2} N_R M_R N_R^c + N_R m_D \nu_L + h.c \tag{1}$$

The low energy mass matrix is given by,

$$m_\nu = -m_D^T\, M_R^{-1}\, m_D \tag{2}$$

In the usual unitarity scenario, the three active neutrinos, the flavor eigen states ν_e, ν_μ, ν_τ are connected to the mass eigen states ν_1, ν_2, ν_3 via $\nu_\alpha = N_{\alpha\, i}\nu_i$, where $N^\dagger N$ = 1. Here N is the the generalised ν mixing matrix which could be both unitary and nonunitary.

In the diagonal charged lepton basis, m_ν is diagonalised by a unitary matrix as,

$$U^* P^* m_\nu P^\dagger U^\dagger = m_\nu^D \tag{3}$$

The Pontecorvo-Maki-Nakagawa-Sakata (PMNS) matrix is UP, where U is,

$$U = \begin{bmatrix} c_{12}c_{13} & s_{12}c_{13} & s_{13}e^{-i\delta} \\ -s_{12}c_{23} - c_{12}s_{23}s_{13}e^{i\delta} & c_{12}c_{23} - s_{12}s_{23}s_{13}e^{i\delta} & s_{23}c_{13} \\ s_{12}s_{23} - c_{12}c_{23}s_{13}e^{i\delta} & -c_{12}s_{23} - s_{12}c_{23}s_{13}e^{i\delta} & c_{23}c_{13} \end{bmatrix} \tag{4}$$

where, $\theta_{12} = 33.56^0$; $\theta_{23} = 41.6^0(50^0)$; $\theta_{13} = 8.46^0(8.49^0)$[2] (see ref.[2] for recent global fit values) are the solar, atmospheric and reactor angles for Normal Ordering (Inverted Ordering) respectively. The Majorana phases reside in P, where

$$P = \begin{bmatrix} diag 1 & e^{i\alpha} & e^{i(\beta+\delta)} \end{bmatrix} \tag{5}$$

In the See-Saw picture, we assume that, just as there are 3 light neutrinos M_1; M_2; M_3, there are 3 heavy right handed neutrinos M_1; M_2; M_3, where M_R~10^{9-14} GeV, M_R ~ M_1; M_2; M_3 which were there in the Hot Big Bang. The M_R decays modes are:

$$M \to l^- + H^+, M \to l^+ + H^-, M \to \nu + H^0, M \to \bar{\nu} + H^0 \tag{6}$$

where, l^- are e^-; μ^-; τ^-; and H^+; H^-; H^0 are SM Higgs. CP violation effects in the M_R decays, may result from phases in the decay coupling constants. This leads to unequal numbers of leptons (l^- and ν) and antileptons (l^+ and ν) in the Universe

$$\Gamma(M \to l^- + H^+) \neq \Gamma(M \to l^+ + H^-) \tag{7}$$

In leptogenesis, CP violating decays of heavy Majorana neutrinos creates a lepton- antilepton symmetry[3] and then B+L violating sphaleron processes[4] at and above the electroweak symmetry breaking scale converts part of this asymmetry into the observed baryon-antibaryon asymmetry. The heavy neutrinos are seesaw partners of the observed light ones. Depending on mass of the lightest heavy RH majorana neutrinos (whose decay causes leptogenesis) the leptogenesis can be of three types: unflavored (or one flavored), two flavored and three flavored leptogenesis. It can be shown that for lower values of M1 it depends on the avor of the _nal state leptons, and hence is called avored leptogenesis[5]. Here we consider flavored leptogenesis. For the ν mixing matrix N to be non unitary, we have

$$\nu_\alpha = N_{\alpha i} \nu_i \tag{8}$$

fusing the avor and mass states. The non-unitary matrix N is now assigned as

$$N = (1 + \eta)U \tag{9}$$

where U_0 = U*P. If m_ν , which is diagonalized by a non-unitary mixing matrix, originates from the see-saw mechanism, we have

$$m_D = i\sqrt{M_R} R \sqrt{m_\nu^{diag}} N^\dagger \tag{10}$$

And thereupon, we have

$$m_D\, m_D^\dagger = \sqrt{M_R} R \sqrt{m_\nu^{diag}} N^\dagger\, N \sqrt{m_\nu^{diag}}\, R^\dagger \sqrt{M_R} \;=\; \sqrt{M_R} R \sqrt{m_\nu^{diag}} \sqrt{m_\nu^{diag}}\, R^\dagger \sqrt{M_R} \tag{11}$$

since, 1 + $2U_0$⊠ηU_0 not equal to 1. Leptogenesis is no longer independent of the low-energy phases. It depends on the phases in U_0 as well as to the phases in η. Leptogenesis[6–8] is one of the exceedingly well inspired framework which produces baryon asymmetry of the Universe through B + L violating electroweak sphaleron process[4]. In a hierarchical case, of three right handed heavy Majorana neutrinos $M_{2,3} > M_1$, the lepton asymmetry created by the decay of M_1, the lightest of three heavy right handed neutrinos is[9] (for both flavored and unflavored leptogenesis)

$$\varepsilon_\alpha = \frac{7}{8 * 22 * v^2} \frac{1}{\left(m_D^\dagger m_D\right)_{11}} \left[\sum_{2,3} Im \left[(m_D^*)_{\alpha 1} \left(m_D^\dagger m_D\right)_{1j} (m_D^*)_{\alpha j} \right] g(x_j) + \sum_{2,3} Im \left[(m_D^*)_{\alpha 1} \left(m_D^\dagger m_D\right)_{j1} (m_D^*)_{\alpha j} \right] \frac{1}{1 - x_j} \right] \tag{12}$$

v = 174 GeV, the Higgs bidoublets vev which breaks the electroweak symmetry,

$$g(x) = \sqrt{x} \left(1 + \frac{1}{1-x} - (1+x) \ln \frac{1+x}{x} \right), x_j = \frac{M_j^2}{M_1^2} \tag{13}$$

At temperatures, T > 10^{12} GeV all charged lepton avors come out of equilibrium and thus all of them behave in the same way which results in the one avor regime. At moderate temperatures T < 10^{12} GeV (T < 10^9 GeV), tau (muon) yukawa coupling interactions come into equilibrium and hence flavor effects play an important role in the calculation of lepton asymmetry[10–15]. The region of temperatures belonging to 10^9 < T/GeV < 10^{12} and T/GeV < 10^9 are respectively denoted as two and three avor regimes of leptogenesis. Y_B in the two and three flavor regimes are designated as[16]

$$\begin{aligned} Y_B^{2\text{flavor}} &= \frac{-12}{37g^*} \left[\varepsilon_2 \rho \left(\frac{417}{589} \bar{\eta}_\tau \right) + \varepsilon_1^\tau \rho \left(\frac{390}{589} \bar{\eta}_\tau \right) \right] \\ Y_B^{3\text{flavor}} &= \frac{-12}{37g^*} \left[\varepsilon_1^e \rho \left(\frac{417}{589} \bar{\eta}_e \right) + \varepsilon_1^\mu \rho \left(\frac{344}{537} \bar{\eta}_\mu \right) + \varepsilon_1^\tau \rho \left(\frac{344}{537} \bar{\eta}_\tau \right) \right] \end{aligned} \tag{14}$$

g^{*} ~110 is the effective number of relativistic degrees of freedom at T = M_1,

$$\rho\left(\overline{\eta}_\alpha\right)=\left[\left(\frac{\eta_\alpha}{8.25\times10^{-3}}eV\right)^{-1}+\left(\frac{0.2\times10^{-3}eV}{\eta_\alpha}\right)^{-1.16}\right]^{-1}$$

$$\begin{aligned} &\varepsilon_2=\varepsilon_1^e+\varepsilon_1^\mu\\ &\overline{\eta}_2=\overline{\eta}_e+\overline{\eta}_\mu \\ &\overline{\eta}_\alpha=\frac{m_{D_{\alpha1}} * m_{D_{\alpha1}}}{M_1}\end{aligned} \tag{15}$$

, where ϵ^e, ϵ^μ, ϵ^τ, are the electron type, muon type and tao type lepton asymmetry in the unflavored leptogenesis regime. Neutrino oscillation has proved that neutrinos have non zero masses. These masses may have a quite different origin than the quark and charged lepton masses. We, and all matter, may be descended from heavy neutrinos. We list the values of mlightest for two avor and three avor regime for different hierachies and unitarity, non-unitarity of U_{PMNS} in table I, II respectively and check whether our values of mlightest are in consistent with the constraints on the absolute scale of neutrino masses. The paper is organized as follows. In Sect. 2, we present the values of various parameters used in our analysis for the generation of baryon asymmetry of the Universe through the mechanism of leptogenesis. Section 3 contains our calculations and results. Section 4 contains analysis and discussions. Section 5 summarizes the work.

We calculated new values of non−unitarity parameters of U_{PMNS} matrix from the bounds on rare cLFV decays and hence predicted the absolute value of lightest ν mass in this regard. We consider here a model where see-saw is extended by an additional singlet S which is very light, but can give rise to non-unitarity effects without affecting the form of see-saw formula. The values of lightest ν mass lies in the range of 0.0018 eV to 0.0023 eV, 0.048 eV to 0.056 eV, 0.05 eV to 0.054 eV, 0.053 eV to 0.062 eV in one flavored leptogenesis regime [17], 0.023 eV to 0.03 eV, 0.058 eV to 0.06 eV, 0.023 eV to 0.037 eV, 0.062 eV to 0.07 eV, 0.063 eV in two flavored leptogenesis regime and 0.065 eV to 0.07 eV, 0.08 eV to 0.085 eV in three flavored leptogenesis regime. All these values satisfy the constraint, $\Sigma_i m(\nu_i) < 0.23$ eV. The lightest ν mass range from 0.08 eV to 0.085 eV is consistent with the absolute ν mass bounds from tritium beta decay $\Sigma_i m(\nu_i) < 2$eV. We found that in case of three flavored leptogenesis no value of $m_{lightest}$ satisfy the constraint on Y_B in NH, U_{PMNS} unitary case. we calculated new limits on non-unitarity parameters from cLFV decays and predicted masses of lightest neutrino mass, by considering the possibility that U_{PMNS} could be non-unitary. Some studies on CP violation in the leptonic sector (neutrino oscillations) is also extensively studied [18,19] by assuming non-unitary U_{PMNS} matrix.

2 Low energy phenomonology of non-unitarity on leptogenesis

The baryon asymmetry should lie in the interval, 5.8 $*10^{-10} < Y_B < 6.6 *10^{-10}$ [20]. In general, we have taken complex and orthogonal matrix R = U_{PMNS}, as an adhoc assumption.

For the Normally ordered light ν masses, we have

$$M_R^{di\ ag}=\mathrm{diag}\left(M_1,M_2,M_3\right)=M_1\,\mathrm{diag}\left(1,\frac{M_2}{M_1},\frac{M_3}{M_1}\right)=M_1\,\mathrm{diag}\left(1,\frac{m_1}{m_2},\frac{m_1}{m_3}\right) \tag{16}$$

With m_1 ε [10^{-6}eV, 10^{-1}eV] and $m_2^2 - m_1^2 = 7.60 *10^{-5}eV^2$, $m_3^2 - m_1^2 = 2.48 * 10^{-3}eV^2$ as is evident from the ν oscillation data [2], m_1 being the lightest of three ν masses. For the inverted ordered light ν masses, we have

$$M_R^{\mathrm{diag}}=\mathrm{diag}\left(M_1,M_2,M_3\right)=M_1\,\mathrm{diag}\left(1,\frac{M_2}{M_1},\frac{M_3}{M_1}\right)=M_1\,\mathrm{diag}\left(1,\frac{m_1^{*}m_3}{m_2^2},\frac{m_1}{m_2}\right) \tag{17}$$

with m_3 being the lightest of three masses. For flavored leptogenesis regime, we take M_1 ~10^{10} GeV. Next we do the parameter scan for flavored leptogenesis of a minimal seesaw model satisfying the Planck data on baryon to photon ratio of the universe for four cases :

1. Normal Hierachical structure neutrino masses, Non unitarity of PMNS matrix.

2. Normal Hierachical structure neutrino masses, unitarity of PMNS matrix.
3. Inverted Hierachical structure of neutrino masses, Non unitarity of PMNS matrix.
4. Inverted Hierachical structure neutrino masses, unitarity of PMNS matrix.

We perform random scan of the parameter space for NH, IH in the light of recent ratio of the baryon to photon density bounds $5.8 *10^{-10} < Y_B < 6.6 *10^{-10}$ [(18)] in the following ranges:

$$\begin{aligned} m_1\,(m_3) &\in \left[10^{-6}eV, 0.1eV\right] \left(\left[10^{-6}eV, 0.1eV\right]\right) \\ \delta CP &\in [0, 2\pi] \\ \alpha &\in [0, 2\pi] \\ \beta &\in [0, 2\pi] \end{aligned} \tag{18}$$

While doing parameter scan, we find values of lightest ν mass, majorana phases α , β and dirac CPV phase δ_{CP} , for which baryon to photon ratio Y_B lies in the given range, for above four cases. This is done for two flavor and three flavor leptogenesis regimes.

3 Results and Discussion

Results of our analysis have been presented in [Figures 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13 and 14]. From [Figure 1] we find that in the two flavor regime of leptogenesis, normal hierarchical structure of neutrino masses, non-unitarity texture of PMNS matrix gives rise to correct baryon asymmetry of the Universe, $5.8 *10^{-10} < Y_B < 6.6 *10^{-10}$ [(18)], if the lightest ν mass lies around 0.023 eV to 0.03 eV, 0.034 eV to 0.038 eV and also around 0.058 eV to 0.06 eV. If $M_1 \sim 10^{10}$ GeV, then 2 flavored leptogenesis.

is favored in the light of baryon asymmetry. We show in [Figure 3], the scatter plot of the lightest neutrino mass m1 against the baryon asymmetry of the Universe with normal hierarchy, unitarity of UPMNS in two avor regime. For Y_B to be in the region, $5.8 *10^{-10} < Y_B < 6.6 *10^{-10}$ [(18)], m_1 lies between 0.023 eV to 0.037 eV and 0.06 eV. For Y_B to be in the order 10^{-10}, m_1 is mostly concentrated in the region 0.01eV to 0.065eV. In [Figure 5] , for Y_B in the said range, m_3, lies between 0.062 eV to 0.07 eV. For Y_B in the order 10^{-10}, the lightest neutrino mass m_3 is mostly concentrated in the region 0.01eV to 0.07eV. From [Figure 7] we find that in the 2-flavor regime, IH structure of neutrino masses, unitarity textures of PMNS matrix gives rise to correct BAU (baryon asymmetry of the Universe), if the lightest mass m_3 lies around 0.063 eV. Here $M_1 = 10^{10}$ GeV, then IH unitarity texture of PMNS matrix, in 2 flavor regime is favored in the light of baryon asymmetry. In the three-flavor regime, from [Figure 9] we find that NH structure of neutrino masses, non-unitarity textures of PMNS matrix can give rise to correct baryon asymmetry of the Universe, $5.8 *10^{-10} < Y_B < 6.6 *10^{-10}$, if the lightest neutrino mass m_1 lies around 0.065 eV to 0.07 eV, 0.08 eV to 0.0 85 eV, Here $M_1 = 10^8$ GeV. It can be noted from that in the three-flavor regime, NH structure of neutrino masses, unitarity Textures of PMNS matrix one cannot give rise to correct BAU, for $M_1 = 10^8$ GeV. Here, the calculated value of Y_B is found to be of the order of 10^{-20} which is very small compared to the allowed range as set by the Planck data [(18)], In the three-flavor regime, from [Figure 12] we find that IH structure of neutrino masses, unitarity textures of PMNS matrix can give rise to correct baryon asymmetry of the Universe, $5.8 *10^{-10} < Y_B < 6.6 *10^{-10}$, if the lightest neutrino mass m_3 lies around 0.032 eV to 0.043 eV, 0.06 eV to 0.065 eV. Few points of lightest neutrino mass m_3 are found to lie in the region, 0.065 eV to 0.1 eV for Y_B to lie in the region, $5.8 *10^{-10} < Y_B < 6.6 *10^{-10}$. Here $M_1 = 10^8$ GeV. It can be noted from [Figure 14] that in the three-flavor regime, IH structure of neutrino masses, non-unitarity texture of PMNS matrix one cannot give rise to correct BAU, for $M_1 = 10^8$ GeV. Here, the calculated value of Y_B is found to be of the order of 10^{-13} which is small compared to the allowed range as set by the Planck data [(18)]

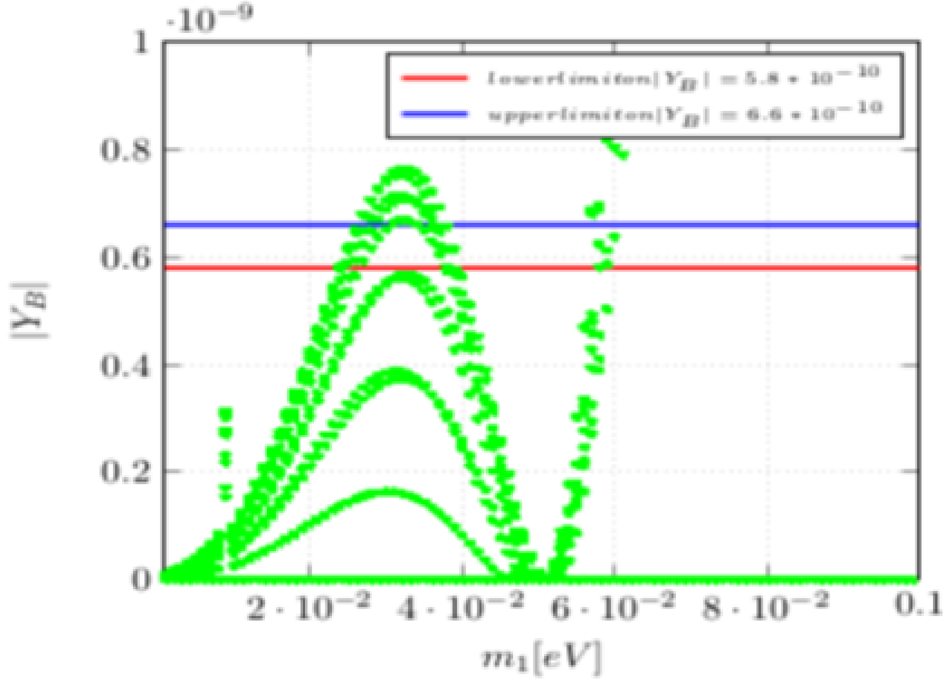

Fig 1. Scatter plot of the lightest neutrino mass m1 against the baryon asymmetry of the Universe with normal hierarchy, non-unitarity case in two avored leptogenesis regime.

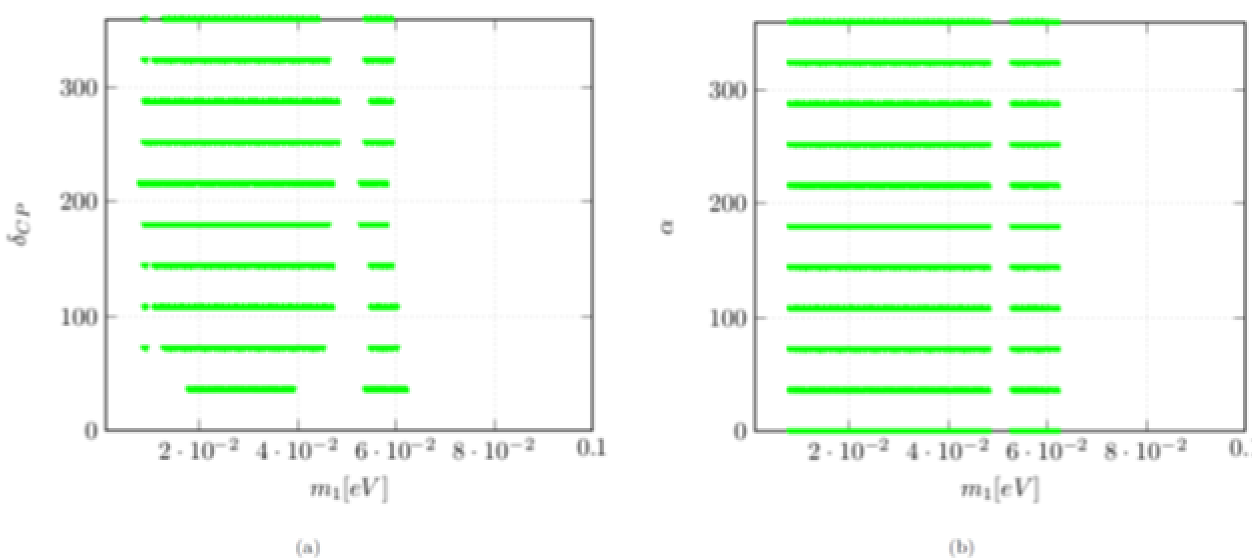

Fig 2. Variation of lightest neutrino mass m1against Dirac CP phase δCP and Majorana phase α for normal hierarchy, non-unitarity texture of UPMNS in the two flavored leptogenesis regime.

3.1 Analysis and Discussion

Two Flavor Leptogenesis: For this case also some lower values of $m_{lightest}$ are allowed in NH than IH (similar to one flavor regime), and non unitarity does not seem to affect values of $m_{lightest..}$

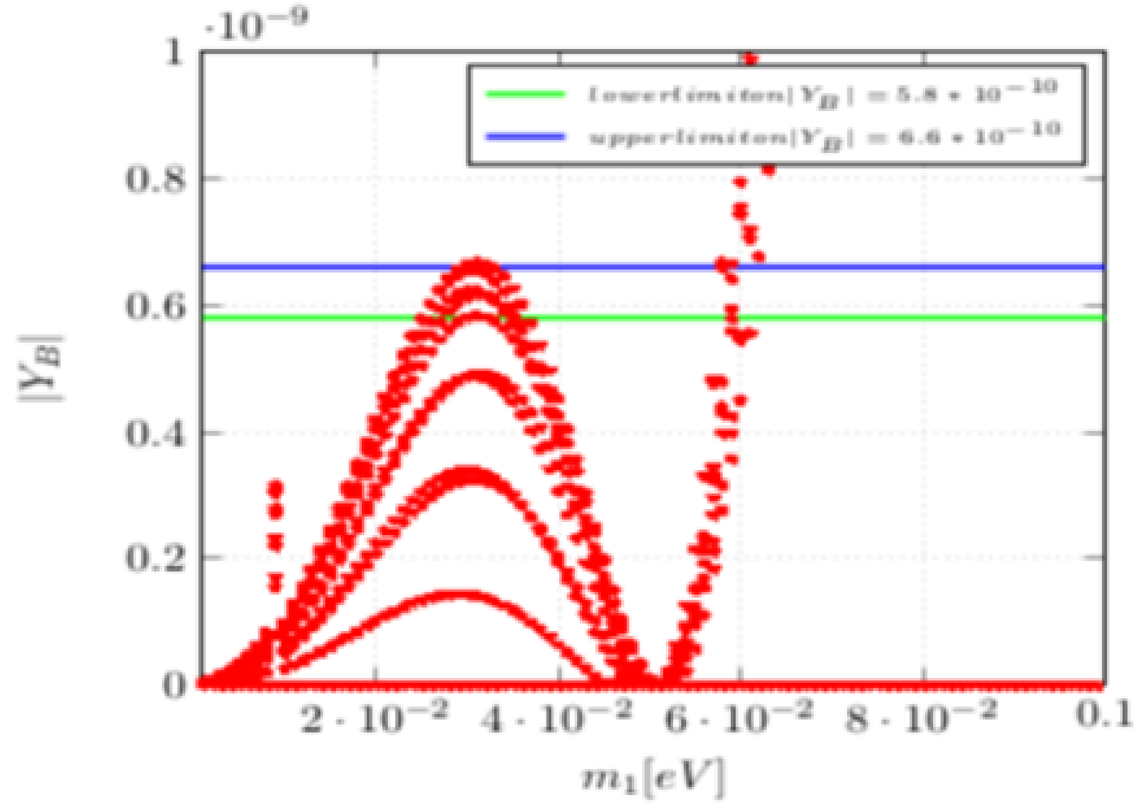

Fig 3. Variation of the lightest neutrino mass m1 against the baryon asymmetry of the Universe with normalhierarchy, unitarity in two avor regime of leptogenesis.

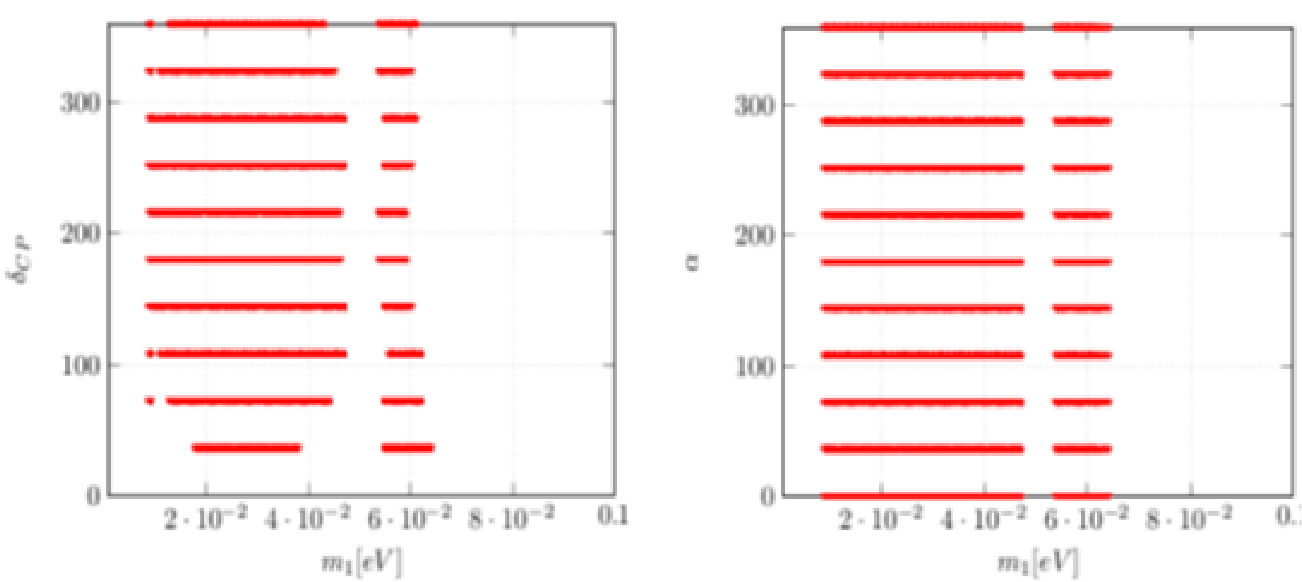

Fig 4. Variation of the lightest neutrino mass m1 against Dirac CPphase δ_{CP} and Majorana phase α for normal hierarchy, unitarity case, in the two flavored leptogenesis regime.

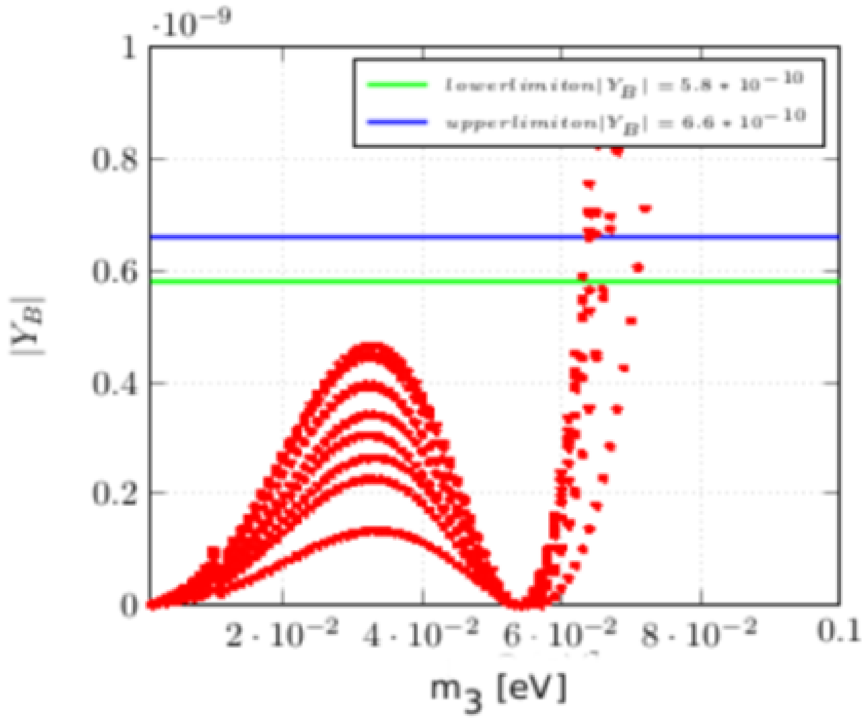

Fig 5. Variation of the lightest neutrino mass m3 against the the baryon asymmetry of the Universe with inverted hierarchy, non-unitarity case in two flavor regime of leptogenesis.

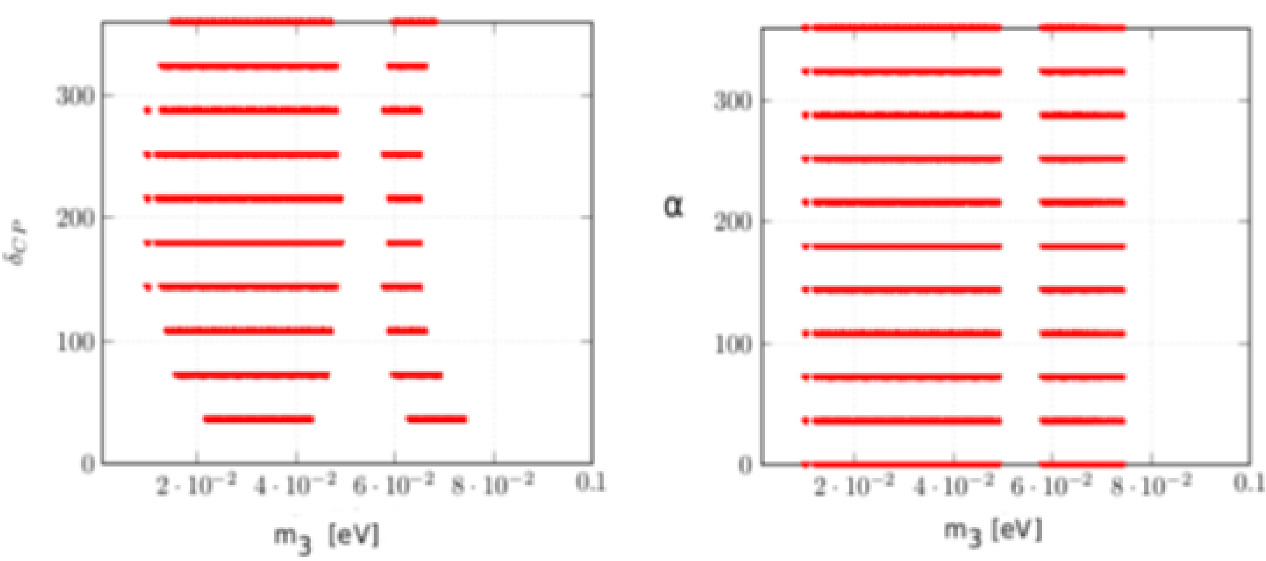

Fig 6. Variation of the lightest neutrino mass m3 against Dirac CPphase _CP and Majorana phase _ for inverted hierarchy, non-unitarity case, in the two flavored leptogenesis regime.

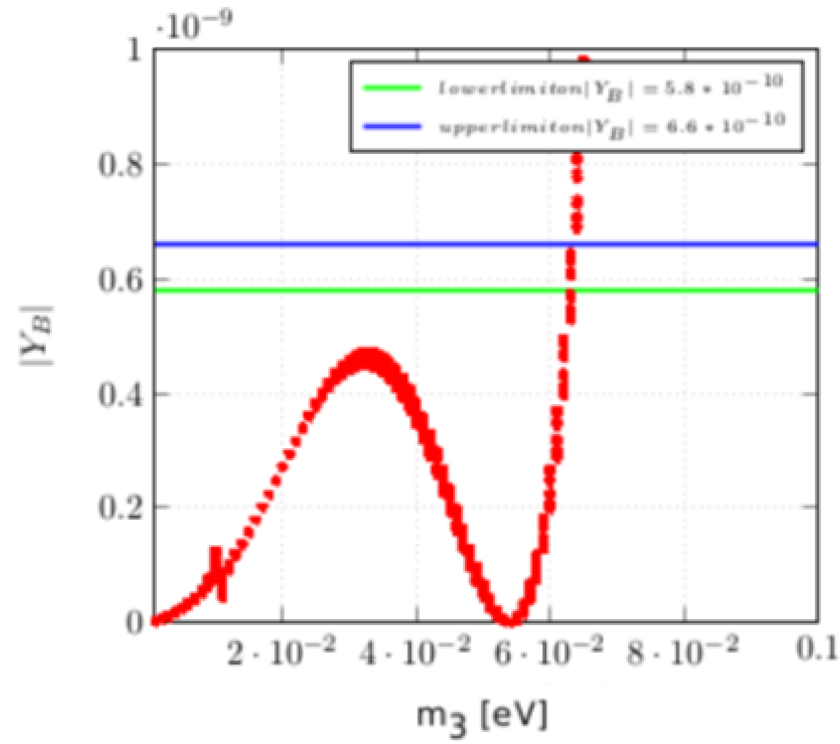

Fig 7. Variation of the lightest neutrino mass m_3 against the baryon asymmetry of the Universe with inverted hierarchy, unitarity case in two avor regime of leptogenesis.

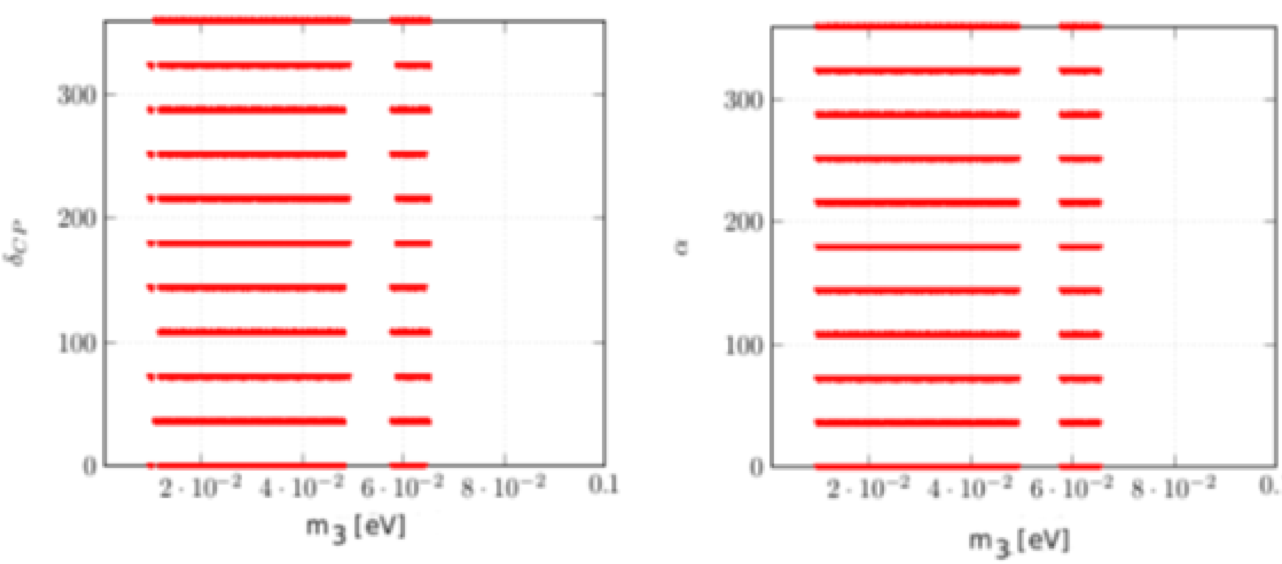

Fig 8. Variation of lightest neutrino mass m_3 against Dirac CP phase δ_{CP} and Majorana phase α for inverted hierarchy, non-unitarity case, in the two flavored leptogenesis regime.

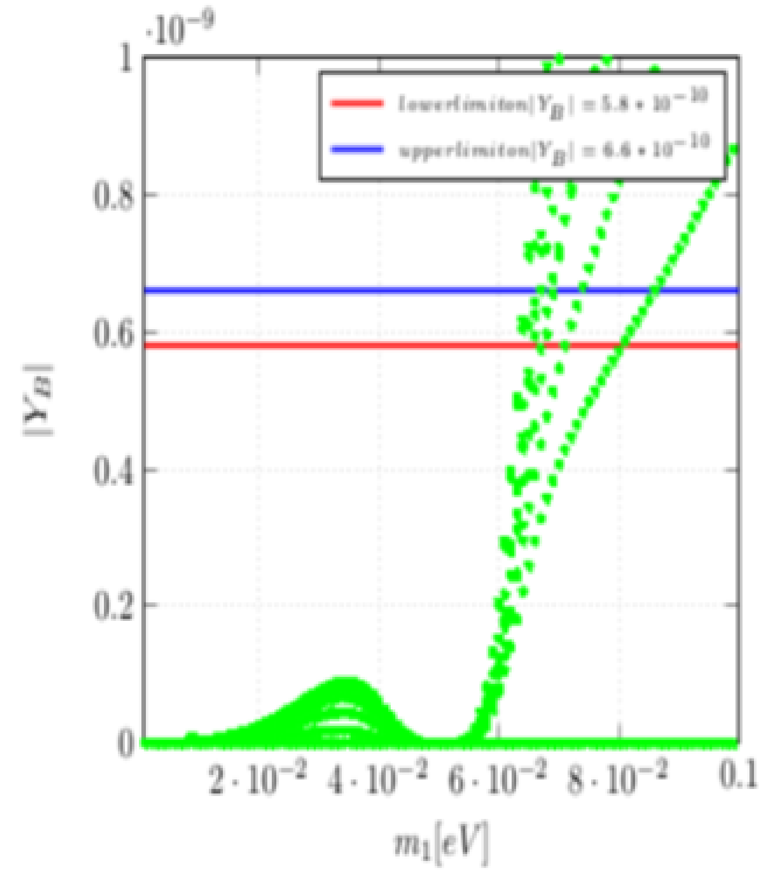

Fig 9. Variation of the lightest neutrino mass m_1 against the the baryon asymmetry of the Universe with normal hierarchy, non-unitarity case in three flavor regime of leptogenesis.

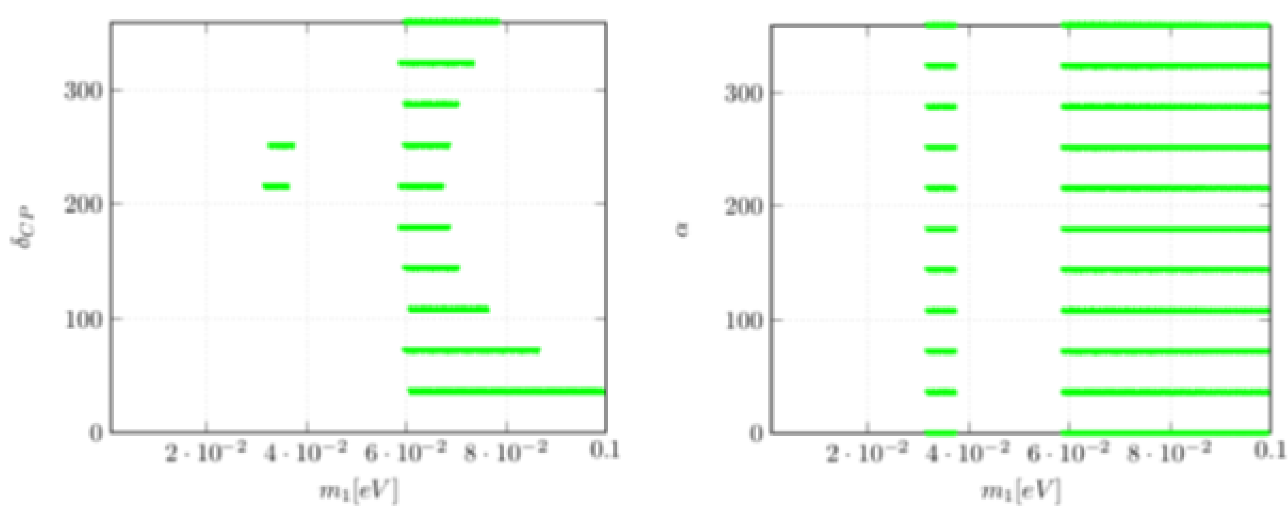

Fig 10. Variation of lightest neutrino mass m_1 against Dirac CPphase δ_{CP} and Majorana phase α for normal hierarchy, non-unitarity texture, in the three flavored regime, in the light of recent baryon to photon ratio of the Universe.

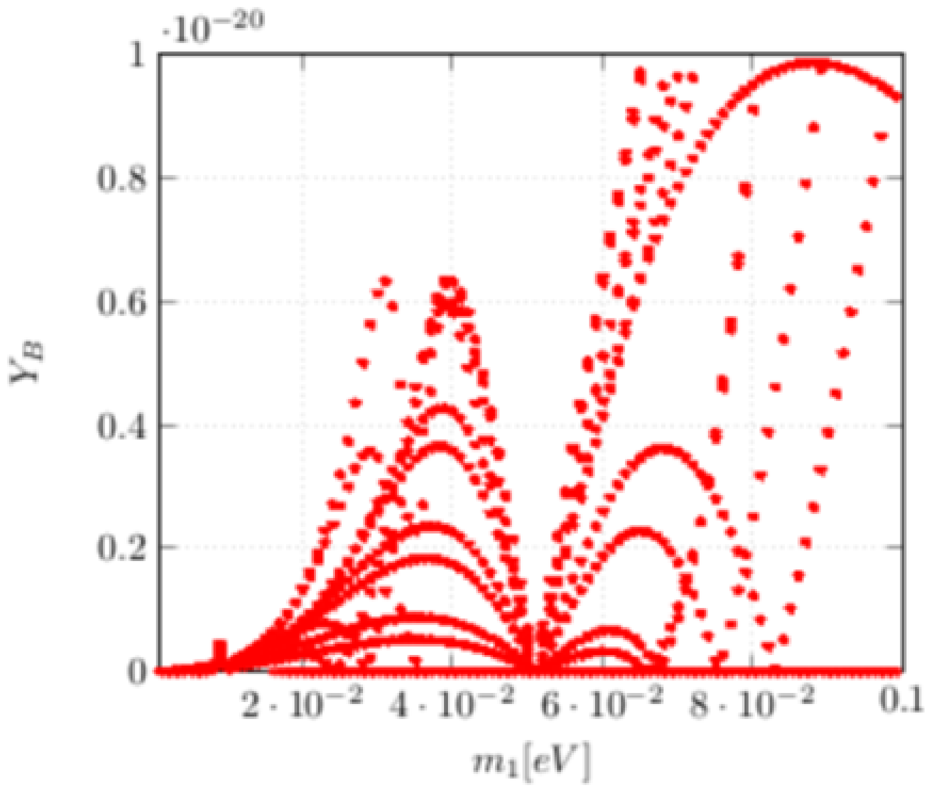

Fig 11. Scatter plot of the lightest neutrino mass m_1 against the the baryon asymmetry of the Universe with normal hierarchy, unitarity case in three avor regime of leptogenesis.

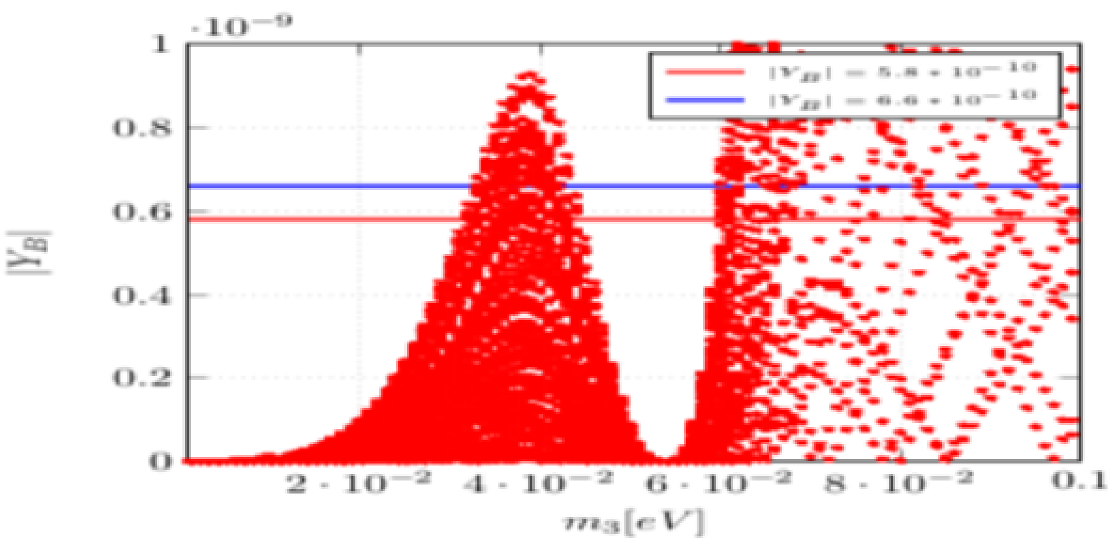

Fig 12. Scatter plot of the lightest neutrino mass m_3 against the baryon asymmetry of the Universe with inverted hierarchy, unitarity case inthree avor regime of leptogenesis.

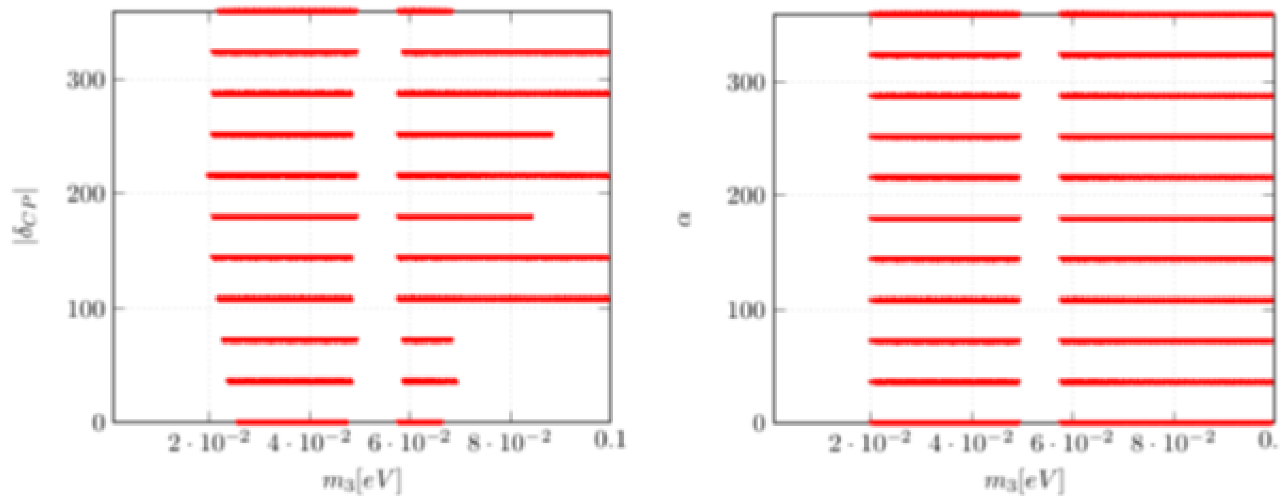

Fig 13. Variation of lightest neutrino mass m3against Dirac CPphase δ_{CP} and Majorana phase α for inverted hierarchy, unitarity texture,in the three avored regime, in the light of recent baryon to photon ratio ofthe Universe.

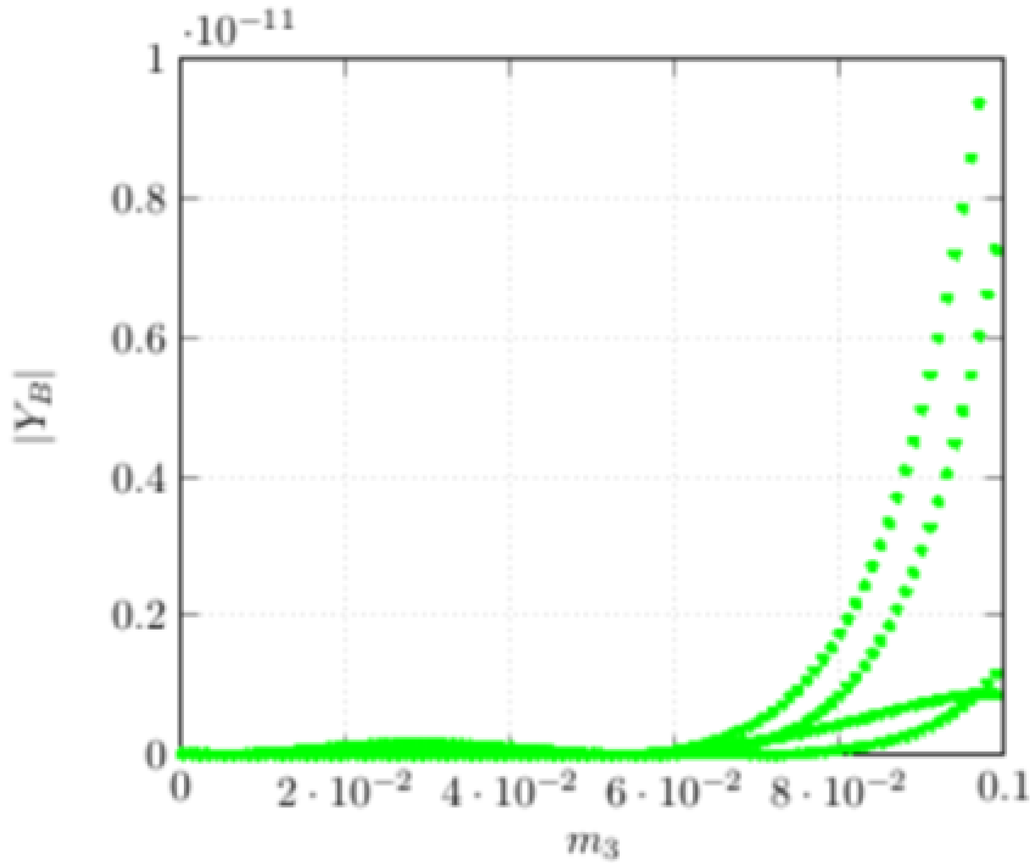

Fig 14. Scatter plot of the lightest neutrino mass m3 against the baryon asymmetry of the Universe with inverted hierarchy, nonunitarity case in three avor regime of leptogenesis. $m_3$is in eV.

Three Flavor Leptogenesis: No values of $m_{lightest}$ satisfy the constraint on Y_B in NH, UPMNS unitary case. Also for IH, U_{PMNS}, non-unitarity case, $m_{lightest}$ fails to satisfy the current bound on Y_B.

4 Conclusion

Baryogenesis through leptogenesis is believed to be responsible for producing the matter - antimatter asymmetry present in the present day universe, which can be expressed through parameter Y_B (baryon to photon ratio). We then analysed how the non unitarity of UPMNS can affect leptogenesis, and hence calculate the values of lightest neutrino mass, dirac CPV phase δ_{CP} and majorana phases α and β, such that Y_B lies in the present day constraints, $5.8 *10^{-10} < Y_B < 6.6 *10^{-10}$. This was done using type I see-saw mechanisms for producing light ν masses.

Above analysis was done for different cases : NH ν masses, unitary UPMNS; NH ν masses, non-unitary UPMNS; IH ν masses, unitary UPMNS; IH ν masses, non unitary UPMNS. We discussed these issues for two avor and three flavor leptogenesis regimes, for which $M_1 < 10^{12}$ GeV and $M_1 < 10^9$ GeV respectively where M1 is the lightest of the three heavy right handed majorana neutrinos, whose out of equilibrium decays produces lepton asymmetry (which in turn can be converted to BAU).

We found that except the NH masses, unitary U_{PMNS} in three flavored leptogenesis case and the IH masses, non-unitary U_{PMNS} in three flavored leptogenesis, in all other cases, we get values of lightest ν mass satisfying $\Sigma_i m(\nu_i) < 0.23$ eV, such that BAU also lies in presently allowed values, $5.8 *10^{-10} < Y_B < 6.6 *10^{-10}$. In the pattern normal ν hierarchy masses, non-unitarity case in three flavored leptogenesis regime, we find that $m_{lightest}$ in the region 0.08 eV to 0.085 eV is however disfavoured by the constraints on the absolute scale of ν masses, which is $\Sigma_i m(\nu_i) < 0.23$ eV [1] from cosmology, WMAP, Planck data. Nevertheless this region is favoured when one considers bounds on sum of the absolute ν mass from tritium beta decay is $\Sigma_i m(\nu_i) < 2$ eV [1].

Thus we have predicted values of lightest ν mass, for both the hierarchies, which is still unknown experimentally. We also have predicted values of CPV phase δ_{CP} (Dirac phase) and α and β (majorana phases), which are also unknown so far. Though majorana phases do not affect ν oscillation probability, they may affect ν mass measurements in $0\nu\beta\beta$ experiments. Hence the results in this work are important, keeping in view that in future, experiments will be endeavoring to measure the values of absolute value of neutrino mass, and CP violating phase δ_{CP} and α ; β (majorana phases) .

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