“FLAVOURED LEPTOGENESIS AND TYPE-II SEESAW MECHANISM WITH TWO HIGGS TRIPLET SCALARS”

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Introduction

- Neutrino mass generation through type-II seesaw mechanism
- Baryon asymmetry estimation through flavoured triplet leptogenesis

Model description

- Two triplet Higgs scalars with hypercharge, $\mathcal{Y} = 2$

$$T_1 = \begin{pmatrix} \frac{\delta_1^+}{\sqrt{2}} & \delta_1^{++} \\ \delta_1^0 & -\frac{\delta_1^+}{\sqrt{2}} \end{pmatrix}, \quad T_2 = \begin{pmatrix} \frac{\delta_2^+}{\sqrt{2}} & \delta_2^{++} \\ \delta_2^0 & -\frac{\delta_2^+}{\sqrt{2}} \end{pmatrix}$$

- Triplet vacuum expectation values:

$$< \delta_1^0 >= \omega_1 = |\omega_1| e^{i\alpha}, \quad < \delta_2^0 >= \omega_2$$

- $\omega_1, \omega_2 \ll v, \quad \omega_1 \sim [10^{-8} - 10^{-6}]\text{GeV}$
- $M_{T_1} \gg M_{T_2}, \quad M_{T_2} \sim 10^9 \text{ GeV}$

[Avinanda Chaudhuri, Biswarup Mukhopadhyaya (2016)]

Model description

- Extended Lagrangian

$$\mathcal{L} = Tr[(D_\mu T_k)^\dagger (D^\mu T_k)] - \frac{Y_{ij} L_i^T C_i \sigma T_k Lj}{\sqrt{2}},$$

- Lepton number breaking trilinear term $\mu_k \phi^\dagger T_k i\sigma_2 \phi^*$ in the potential $V(\phi, T_1, T_2)$, $\mu_1 = |\mu_1| e^{i\beta}$
- Neutrino mass generation

$$M_\nu = M_\nu^{(1)} + M_\nu^{(2)} = Y_1 \omega_1 cos\alpha + Y_2 \omega_2$$

[Avinanda Chaudhuri, Biswarup Mukhopadhyaya (2016)]

Neutrino mass matrix

- Two-zero texture B_2: [Madan Singh (2020)]

$$B_2 = \begin{pmatrix} \times & 0 & \times \\ 0 & \times & \times \\ \times & \times & 0 \end{pmatrix}$$

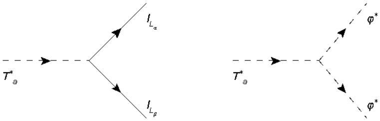
- The chosen neutrino mass matrix:

$$M_\nu = \begin{bmatrix} 0.04135 & 0 & 0.03411 \\ 0 & 0.05465 & 0.05085 \\ 0.03411 & 0.05085 & 0 \end{bmatrix}.$$

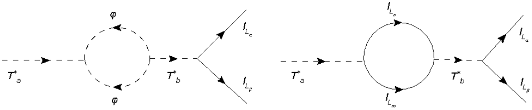
- $\Sigma = m_1 + m_2 + m_3 \approx 0.1459 eV < 0.16 eV$

Triplet decay modes

- Tree level decay diagram:



- One-loop decay diagram:



[R. Gonzalez Felipe, F.R. Joaquim, and H. Serodio (2013)]

Purely Flavoured Leptogenesis

- Fully flavoured CP asymmetry parameter: [Branco et al (2012)]

$$\epsilon^{\alpha\beta} = \frac{M_{T_2}(B_l B_\phi)^{\frac{1}{2}}}{4\pi v^2} \frac{c Im[(M_\nu^{(2)})_{\alpha\beta}(M_\nu^{(1)*})_{\alpha\beta}]}{[Tr(M_\nu^{(2)\dagger} M_\nu^{(2)})]^{\frac{1}{2}}}$$

$$\sum_{\alpha,\beta} \epsilon_{\alpha\beta} = 0$$

- $B_l \gg B_\phi$

Fully flavoured Boltzmann equations

[R. Gonzalez Felipe, F.R. Joaquim, and H. Serodio (2013)]

$$szH(z)\frac{d\Sigma_T}{dz} = -(\frac{\Sigma_T}{\Sigma_T^{eq}} - 1)\gamma_D - 2(\frac{\Sigma_T^2}{\Sigma_T^{eq^2}} - 1)\gamma_A, \quad (1)$$

$$szH(z)\frac{d\Delta_T}{dz} = -\gamma_D(\frac{\Delta_T}{\Sigma_T^{eq}} + \sum_{\alpha,\beta} B_1^{\alpha\beta}\frac{\Delta_{L_\alpha}}{Y_L^{eq}} - B_1^{\phi}\frac{\Delta_\phi}{Y_\phi^{eq}}), \quad (2)$$

$$szH(z)\frac{d\Delta_\phi}{dz} = \sum_{\alpha,\beta} X_{\alpha\beta} - 2B_1^{\phi}\gamma_D(\frac{\Delta_\phi}{Y_\phi^{eq}} - \frac{\Delta_T}{Y_T^{eq}}), \quad (3)$$

$$szH(z)\frac{d\Delta_{L_\alpha}}{dz} = \sum_{\alpha}[X_{\alpha\beta} - 2B_1^{\alpha\beta}\gamma_D(\frac{\Delta_T}{Y_T^{eq}} + \frac{\Delta_{L_\alpha} + \Delta_{L_\beta}}{2Y_l^{eq}})], \quad (4)$$

$$[z = \frac{M_T}{T}]$$

Lepton asymmetry plots: for different branching ratios

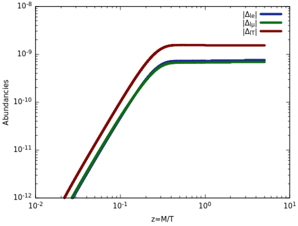


Figure: $B_l = 0.99999$

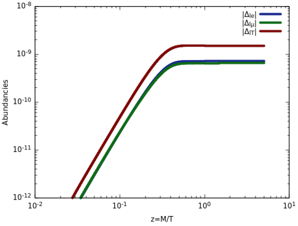


Figure: $B_l = 0.9999$

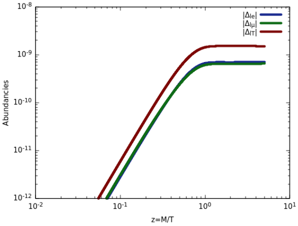


Figure: $B_l = 0.99$

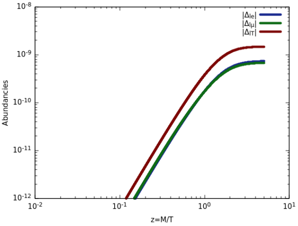


Figure: $B_l = 0.50$

Result

- Baryon asymmetry:

$$\eta_B = 3c_{sph} \sum_{\alpha,\beta} A^{-1}_{\alpha\beta} \Delta_{l_\beta}$$

- Result table:

B_l	η_B
0.99999	-5.24×10^{-10}
0.9999	-5.30×10^{-10}
0.99	5.85×10^{-10}
0.50	5.34×10^{-10}

Conclusion

- Type-II seesaw mechanism and baryon asymmetry
- Future work

The End

Back-up slides

Neutrino mass matrix with two zero texture-B_2

$$M_\nu = \begin{pmatrix} Ae^{i\phi_A} & 0 & Be^{i\phi_B} \\ 0 & Ce^{i\phi_C} & De^{i\phi_D} \\ Be^{i\phi_B} & De^{i\phi_D} & 0 \end{pmatrix}$$

Fully flavoured CP asymmetry parameters

$$\epsilon^{ee} = \frac{M_{T_2}(B_l B_\phi)^{\frac{1}{2}} c_{ee}\omega_1 cos\alpha sin\theta_a}{4\pi v^2} \times \frac{A^2}{\sqrt{A^2 + 2(B^2 + D^2) + C^2}},$$

$$\epsilon^{e\tau} = \frac{M_{T_2}(B_l B_\phi)^{\frac{1}{2}} c_{e\tau}\omega_1 cos\alpha sin\theta_b}{4\pi v^2} \times \frac{B^2}{\sqrt{A^2 + 2(B^2 + D^2) + C^2}},$$

$$\epsilon^{\mu\mu} = \frac{M_{T_2}(B_l B_\phi)^{\frac{1}{2}} c_{\mu\mu}\omega_1 cos\alpha sin\theta_c}{4\pi v^2} \times \frac{C^2}{\sqrt{A^2 + 2(B^2 + D^2) + C^2}},$$

$$\epsilon^{\mu\tau} = \frac{M_{T_2}(B_l B_\phi)^{\frac{1}{2}} c_{\mu\tau}\omega_1 cos\alpha sin\theta_d}{4\pi v^2} \times \frac{D^2}{\sqrt{A^2 + 2(B^2 + D^2) + C^2}},$$

Boltzmann equations

- $$X_{\alpha\beta} = (\frac{\Sigma_T}{\Sigma_T^{eq}} - 1)\gamma_D \epsilon_1^{\alpha\beta} + 2\gamma_D(B_1^L \epsilon^{\alpha\beta} - B_1^{\alpha\beta}\epsilon_1) - (2\frac{\Delta_T}{Y_T^{eq}} + \frac{\Delta_{L_\alpha} + \Delta_{L_\beta}}{2Y_l^{eq}})(2\gamma_{l_\alpha l_\beta}^{\overline{\phi\phi}} + \gamma_{l_\alpha \phi}^{\bar{l}_\beta \bar{\phi}}),$$

- $z = \frac{M_T}{T}$,
- $H(z) = \frac{H_0(M_T)}{z^2}$, $H_0(T) = \sqrt{\frac{4\pi^3}{45} g_*} \frac{T^2}{m_P}$
- $m_P = 1.22 \times 10^{19}$ GeV, $s = (\frac{2\pi^2}{45}) g_* T^3$, $g_* = 106.75$
- $\Delta_x = \frac{n_x - n_{\overline{x}}}{s}$, $\Sigma_T = \frac{n_T + n_{\overline{T}}}{s}$, $Y = \frac{n_x}{s}$

Boltzmann equations

- $$Y_T^{eq} = \frac{45 g_T}{4\pi^4 g_*} z^2 K_2(z), \quad Y_l^{eq} = \frac{3}{4}\frac{45\varsigma(3)}{2\pi^4 g_*} g_l, \quad Y_\phi^{eq} = \frac{45\varsigma(3)}{2\pi^4 g_*} g_\phi,$$
- $g_T = 1$ for each triplet component, $g_l = 2$ and $g_\phi = 2$
- $\varsigma(3) \simeq 1.202$, $K_i(z) =$ modified Bessel function.
- $$\gamma_D = s\Gamma_T \Sigma_T^{eq} \frac{K_1(z)}{K_2(z)},$$
- $$\gamma_A = \frac{M_T T^3 e^{-2\frac{M_T}{T}}}{64\pi^4}(9g^4 + 12 g^2 g_Y^2 + 3 g_Y^4)(1 + \frac{3T}{4M_T}).$$
- $$B_l = \frac{M_T}{8\pi\Gamma_T} Tr(Y^{T\dagger} Y^T), \quad B_\phi = \frac{M_T}{8\pi\Gamma_T}|\lambda|^2, \quad B_l + B_\phi = 1,$$

Initial values taken for numerical analysis

- $$\Sigma_T(z \ll 1) = \Sigma_T^{eq}(z \ll 1)$$
- $$\Delta_T(z \ll 1) = 0, \quad \Delta_{l_\alpha}(z \ll 1) = 0, \quad \Delta_\phi(z \ll 1) = 0.$$

Baryon asymmetry calculation

$$c_{sph} = \frac{28}{79}, \quad A = \begin{pmatrix} -\frac{151}{179} & \frac{20}{179} & \frac{20}{179} \\ \frac{25}{358} & -\frac{344}{537} & \frac{14}{537} \\ \frac{25}{358} & \frac{14}{537} & -\frac{344}{537} \end{pmatrix}$$