Abelian gauge extensions with Higgs mixing

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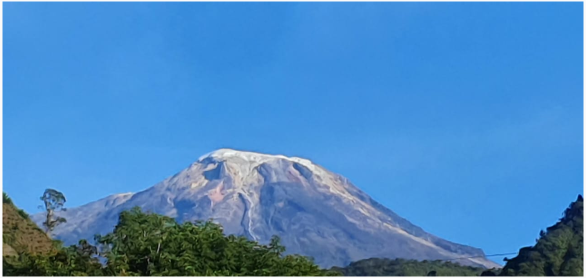

Local Abelian extensions of the SM

Anomaly cancellation of a gauge $U(1)_X$ extension

It is known that if we extend the SM by a local $U(1)_X$ and a set of α singlet chiral fields, N_α, the cubic and mixed gauge anomalies can be written in terms of two $U(1)_X$ charge, e.g, u and d, where u and d represent the charges of the right-handed up and down quarks, respectively

$$\begin{aligned} \sum_\alpha n_\alpha^3 &= -3(2d+u)^3 \\ \sum_\alpha n_\alpha &= -3(2d+u)\,. \end{aligned} \tag{1}$$

where n_α is the $U(1)_X$-charge of N_α.

$\alpha = 3$

If the set of N_α is just the set of heavy singlet chiral fields of the type-I seesaw

$$\sum_\alpha n_\alpha^3 = -3$$
$$\sum_\alpha n_\alpha = -3\,,$$

such that

$$2d + u = 1, \to u = 1 - 2d\,. \tag{2}$$

In this way, we can write the solution in terms of just one parameter: d

Examples of d with vector-like Dirac fermionic dark matter and mass mixing

For a vector-like fermionic dark matter candidate χ, $U(1)_X$ can guarantee the stability

Fields	$SU(2)_L$	$U(1)_Y$	$U(1)_X$	$U(1)_{B-L}$	$U(1)_R$	$U(1)_{\not{D}}$	$U(1)_{\not{U}}$
d_R	$\mathbf{1}$	$-1/3$	d	$1/3$	1	0	$1/2$
u_R	$\mathbf{1}$	$+2/3$	$1-2d$	$1/3$	-1	1	0
Q	$\mathbf{2}$	$1/6$	$1/2-d/2$	$1/3$	0	$1/2$	$1/6$
L	$\mathbf{2}$	$-1/2$	$-3/2+3d/2$	-1	0	$-3/2$	$-3/4$
e_R	$\mathbf{1}$	-1	$-2+3d$	-1	1	-2	$-1/2$
N_R	$\mathbf{1}$	0	-1	-1	-1	-1	-1
H	$\mathbf{2}$	$1/2$	$1/2-3d/2$	0	-1	$1/2$	$-1/4$
Φ_s	$\mathbf{1}$	0	2	2	2	2	2
χ_L	$\mathbf{1}$	0	$1/5$	$1/5$	$1/5$	$1/5$	$1/5$
χ_R	$\mathbf{1}$	0	$1/5$	$1/5$	$1/5$	$1/5$	$1/5$

Table 1: d will be a continuos variable reconverted to rational whenever necessary $\rightarrow$ mass mixing!

Gauged Type-I seesaw with χ and mass mixing

$$\begin{aligned}\mathcal{L} \supset & y_2^d \bar{Q} H d_R + y_2^u \bar{Q} \widetilde{H} u_R + y_2^e \bar{L} H e_R + y^D \bar{L} \widetilde{H} N_R + Y^M \overline{(N_R)^c} \Phi_s N_R + \text{h.c.} \\ & + i\bar{\chi}\gamma_\mu \left(\partial_\mu - i g_X \chi Z'_\mu\right) \chi - m_{\text{DM}} \bar{\chi}\chi + (\mathcal{D}_\mu H)^\dagger \mathcal{D}^\mu H + (\mathcal{D}_\mu \Phi_s)^* \mathcal{D}_\mu \Phi_s - V\,,\end{aligned} \tag{3}$$

and the scalar potential is,

$$V = \mu^2 H^\dagger H + \frac{\lambda}{2}\left(H^\dagger H\right)^2 + m_s^2 \Phi_s^\dagger \Phi_s + \frac{\lambda_s}{2}\left(\Phi_s^\dagger \Phi_s\right)^2 + \lambda_{sH} H^\dagger H \Phi_s^\dagger \Phi_s \tag{4}$$

where

$$H = \begin{pmatrix} G^+ \\ (v + H^0 + i\,G^0)/\sqrt{2} \end{pmatrix} \tag{5}$$

and,

$$\Phi_s = \left(S + v_s + iG'^0\right)/\sqrt{2}. \tag{6}$$

for any ψ

$$\mathcal{L} \supset -\frac{g_X}{4}\left[(X_R + X_L)\psi\gamma_\mu\psi + (X_R - X_L)\psi\gamma_\mu\gamma_5\psi\right] Z'^\mu, \tag{7}$$

Neutrino Masses

Neutrino masses are generated via the last two terms of Eq.(3). They induce the presence of Dirac and Majorana mass terms, which consequently lead to the mass matrix,

$$\begin{pmatrix} \nu & N_R \end{pmatrix} \begin{pmatrix} 0 & m_D \\ m_D^T & M_R \end{pmatrix} \begin{pmatrix} \nu \\ N_R \end{pmatrix} \tag{8}$$

where $m_D = y^D v_2/(2\sqrt{2})$ and $M_R = y^M v_s/(s\sqrt{2})$. From the diagonalization procedure, we conclude that,

$$m_\nu = m_D^T m_D/M_R,\ m_N = M_R, \tag{9}$$

for $M_R \gg m_D$.

Therefore, it is clear that our model naturally account for neutrino masses via the type-I seesaw mechanism, and usual can reproduce neutrino oscillation data