A flipped $SU(3)_C \otimes SU(4)_L \otimes U(1)_X$ model

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Abstract. An anomaly free flipped 341 model where leptons and quarks generations are arranged in new different $SU(4)_L$ representations is proposed.

1. Introduction

The neutrinos oscillation phenomenon reveals that the Standard Model is an effective field theory, therefore, theories Beyond the SM (BSM) are needed to explain and answer all the remaining unsolved questions.

Among the many BSM models, we are interested in the 341 models based on the gauge group $SU(3)_C \otimes SU(4)_L \otimes U(1)_X$ for which one can distinguish different versions according to:

(i) The values of the parameters β and γ which the electric charge $\widetilde{Q}$ is written in function of them.

$$\widetilde{Q} = \frac{1}{2}\left(\lambda_3 - \frac{1}{\sqrt{3}}\lambda_8 - \frac{4}{\sqrt{6}}\lambda_{15}\right) + X, \tag{1}$$

where λ_3, λ_8 and λ_{15} are the diagonal Gell-Mann matrices of the group SU(4). Each value of β and γ lead to a model with different fermions field content.

(ii) The presence or absence of the exotic fermions (quarks and leptons) electric charge.

(iii) Moreover, we classify the 341 models according to the scalar sector content [1, 2].

The construction of any model beyond the SM must be free from the gauge anomalies [3], to ensure the cancellation of the $[SU(4)_L]^3$ anomaly (which requires that the number of multiplets lying in the fundamental representation 4 be the same as the number of anti quadruplets arranged in $\overline{4}$) in the 341 models, the three quarks generations have to be arranged in different representations: two of the three families with the three lepton generations lie in the fundamental representation 4, while, the third one have to arrange in the conjugate representation $\overline{4}$ (or vice versa). Table 1 represents the fermion content of the 341 models for generic β and γ.

2. The model

All the 341 model versions require that the quarks generations must be arranged in different representations in order to cancel the triangle gauge anomalies. It turns out that this scheme is not unique. The quarks families are arranged in the same representation while leptons are not, leading to a new version called the flipped 341 model. Table 2 shows the particle content in this model where we have used $\beta = \frac{1}{\sqrt{3}}$, $\gamma = \frac{-2}{\sqrt{6}}$ [1].

Table 1. The content of the 341 model for generic β and γ parameters.

Name	341 model representation	flavors
ψ_l	$(1,4,\frac{-1}{2} - \frac{\beta}{2\sqrt{3}} - \frac{\gamma}{2\sqrt{6}})$	3
$Q_{1,2}$	$(3,\overline{4},\frac{1}{6} + \frac{\beta}{2\sqrt{3}} + \frac{\gamma}{2\sqrt{6}})$	3
Q_3	$(3,4,\frac{1}{6} - \frac{\beta}{2\sqrt{3}} - \frac{\gamma}{2\sqrt{6}})$	1
u^c	$(\overline{3},1,\frac{-2}{3})$	3
d^c	$(\overline{3},1,\frac{1}{3})$	3
$U^c_{1,2}$	$(\overline{3},1,\frac{-1}{6} - \frac{\sqrt{3}\beta}{2})$	3
U^c_3	$(\overline{3},1,\frac{-1}{6} + \frac{\sqrt{3}\beta}{2})$	3
$D^c_{1,2}$	$(\overline{3},1,\frac{-1}{6} - \frac{\beta}{2\sqrt{3}} - \frac{2\gamma}{\sqrt{6}})$	3
D^c_3	$(\overline{3},1,\frac{-1}{6} + \frac{\beta}{2\sqrt{3}} + \frac{2\gamma}{\sqrt{6}})$	3
ϕ_1	$(1,\overline{4},\frac{-\beta}{2\sqrt{3}} + \frac{\gamma}{2\sqrt{6}})$	1
ϕ_2	$(1,\overline{4},\frac{-1}{2} + \frac{\beta}{2\sqrt{3}} + \frac{\gamma}{2\sqrt{6}})$	1
ϕ_3	$(1,\overline{4},\frac{1}{2} + \frac{\beta}{2\sqrt{3}} + \frac{\gamma}{2\sqrt{6}})$	1
ϕ_4	$(1,\overline{4},\frac{-3\gamma}{2\sqrt{6}})$	1

This model contains:

(i) An extra lepton field $\widetilde{L}$ which contains new exotic leptons arranged in $\overline{4}$ with $X = \frac{-1}{2}$.

(ii) A new lepton 10-plet L_e transforming as the fundamental representation of the group SU(4) with $X = 0$, and which contributes as much as eight quadruplets in the anomaly $[SU(4)_L]^3$ [4].

The lepton sextet L_e which decomposes into sub-representations according to:

$$(1, 10, 0) \supset (1, 6, \frac{-1}{3}) + (1, 3, \frac{1}{3}) + (1, 1), \tag{2}$$

where we have used the following product tensor [4]:

$$4 \otimes 4 = 10 \oplus 6 \tag{3}$$

where $(1,6,\frac{-1}{3})$ is a sextet with $X=\frac{-1}{3}$ [3], a triplet $(1,3,\frac{1}{3})$ with $X=\frac{1}{3}$ and a singlet lepton $(1,1,1)$. The L_e contains new leptons and stands as triplet sub-representations, (ν_e, e) from $SU(2)_L$ doublets, other leptons composed the triplet which we reported it as $(3,\frac{1}{3})$ while the remaining leptons are singlets.

As for ϕ_1, ϕ_2, ϕ_3 and ϕ_4, they are the scalars fields which will generate masses for the particles in our model except for the 10-plet lepton, to acquire masses for its entries, a new scalar matrix S is introduced.

The flipped 341 model is free from the following gauge anomalies $[SU(4)_L]^3$, $[SU(3)_C]^2[SU(4)_L]$, $[SU(4)_L]^2[U(1)_X]$, $[SU(3)_C]^3$, $[U(1)_X]^3$ and from $[U(1)_X]^2[Grav]^2$ which result from the triangle anomalies only if its particle content satisfies the following non trivial conditions:

Table 2. The content of the flipped 341 model.

Name	341 model representation	flavors
L_e	$(1,10,0)$	1
$L_\alpha(\alpha \equiv \mu, \tau)$	$(1,4,\frac{-1}{2})$	2
$\widetilde{L}$	$(1,\overline{4},\frac{-1}{2})$	1
l_α^c	$(1,1,1)$	8
$l_\alpha^{'c}$	$(1,1,-1)$	2
Q_α	$(3,\overline{4},\frac{1}{6})$	3
u^c	$(\overline{3},1,\frac{-2}{3})$	6
d^c	$(\overline{3},1,\frac{1}{3})$	6
ϕ_1	$(1,\overline{4},\frac{-1}{2})$	1
ϕ_2	$(1,\overline{4},\frac{1}{2})$	1
ϕ_3	$(1,\overline{4},\frac{-1}{2})$	1
ϕ_4	$(1,\overline{4},\frac{1}{2})$	1
S	$(1,15,0)$	1

$$
\begin{aligned}
\sum X_l^L \;+\; & 3\sum X_q^L = 0 \\
3\sum X_l^L \;-\; & 3\sum_{Sing} X_q^R = 0 \\
4\sum X_l^L \;+\; & 12\sum X_q^L - 3\sum X_q^R - \sum X_l^R = 0 \\
4\sum (X_l^L)^3 \;+\; & 12\sum (X_q^L)^3 - 3\sum_{Sing} (X_q^R)^3 - \sum_{Sing} (X_l^R)^3 = 0
\end{aligned}
\tag{4}
$$

Where X_l^L, X_q^L are the quantum numbers associated from the group $U(1)_X$ of the left handed leptons and quarks respectively whereas X_q^R are those for the right handed quarks.

3. Conclusion

In this work, we have introduced a new model based on the gauge group $SU(3)_C \otimes SU(4)_L \otimes U(1)_X$ called the flipped 341 model where all the three quarks generations are arranged in the same representation, whereas leptons are not.

Acknowledgments

References

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