Higgs Mediators, θ_{13} and light familons
based on 1203.6636 with Graham Ross

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Outline

Motivation

The data

Fermion masses (heavy top, hierarchies, neutrino masses)
Fermion mixing (Cabibbo angle, near TBM, θ_{13})

GUT models

The challenge

ALL fermion masses and mixing (unified framework)
Improve upon existing models
(with $SU(3)$, $\Delta(27)$, recent ones with $PSL_2(7)$ [King, Luhn])

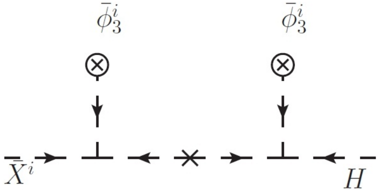
Higgs mediators

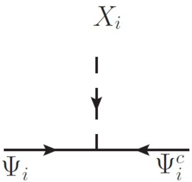
$$P_S = M\bar{X}^i X_i + \bar{\phi}_3^i \bar{\phi}_3^i H \bar{X}^i / M_X^a$$

$$H_l \approx X_3 + H \frac{M\, M_X^a}{\langle \bar{\phi}_3 \rangle^2}$$

$$P_Y = X_i \Psi_i \Psi_i^c$$

Higgs mediators diagrams





Fermion masses

$$\langle\bar{\phi}_{23}\rangle/M_d = (0,\epsilon,-\epsilon)\,, \quad \langle\bar{\phi}_{123}\rangle/\langle\bar{\phi}_{23}\rangle \sim \epsilon$$

$$M_f \sim \begin{pmatrix} 0 & -\epsilon_f^3 & \epsilon_f^3 \\ \epsilon_f^3 & a^f\epsilon_f^2 & -2ba^f\epsilon_f^2+2\epsilon_f^3 \\ -\epsilon_f^3 & -2ba^f\epsilon_f^2-2\epsilon_f^3 & 1 \end{pmatrix}$$

Majorana terms

$$P_M \propto \frac{\bar{\phi}_3^i \bar{\phi}_3^j}{M_X^2} + \frac{\bar{\phi}_{23}^i \bar{\phi}_{23}^j \left[\bar{\phi}_{23}\bar{\phi}_{23}\bar{\phi}_{23}\bar{\phi}_3\bar{\phi}_3\right]}{M_X^7}$$

$$+ \frac{\bar{\phi}_{123}^i \bar{\phi}_{123}^j \left[\bar{\phi}_{23}\bar{\phi}_{23}\bar{\phi}_3\bar{\phi}_3\bar{\phi}_3\right]}{M_X^7} + \frac{\bar{\phi}_{123}^i \bar{\phi}_{23}^j \left[\bar{\phi}_{123}\bar{\phi}_{23}\bar{\phi}_3\bar{\phi}_3\bar{\phi}_3\right]}{M_X^7}$$

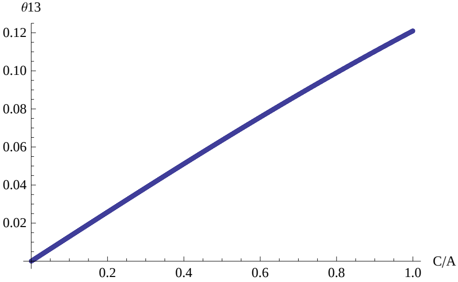
Majorana terms matrix

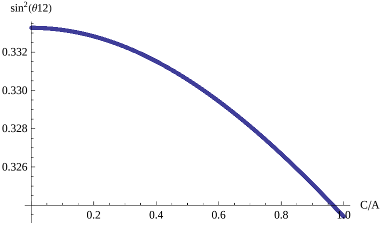
$$M_R \propto \begin{pmatrix} B\epsilon^6 & (B+C)\epsilon^6 & . \\ (B+C)\epsilon^6 & A\epsilon^5 & . \\ . & . & (M_X/M_d)^5 \end{pmatrix}$$

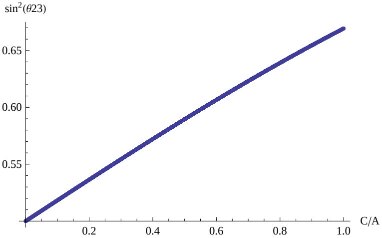
$$\frac{m_\odot}{m_@} = \sqrt{\frac{\Delta m^2_\odot}{\Delta m^2_@}} \sim \frac{\langle\bar\phi_{123}\rangle^2\langle\bar\phi_3\rangle}{\langle\bar\phi_{23}\rangle^3} \simeq O(\epsilon)\,,$$

$$\theta_{13} \simeq O(\epsilon)\,, \quad \epsilon = \langle\bar\phi_{23}\rangle/M_d = 0.15\,, \quad \langle\bar\phi_{123}\rangle/\langle\bar\phi_{23}\rangle \sim \epsilon$$

Mixing angles







Alignment term

Model has discrete Z_4^R symmetry
no μ problem, no 5-dim nucleon decay
(see [Lee, Raby, Ratz, Ross, Schieren])

Superpotential term $P(\bar{\phi}_{123})^2\bar{\phi}_{23}/M_X^3 \rightarrow m(\bar{\phi}_{123})^2\bar{\phi}_{23}/M_X$
$\langle\bar{\phi}_{123}\rangle \rightarrow (1,1,1)$ independent of VEV hierarchies

Light familons

Fermion components get mass from $m(\bar{\phi}_{123})^2\bar{\phi}_{23}/M_X$:

Mixed bi-linears $\bar{\phi}_{123}\bar{\phi}_{23}$, mass $m\langle\bar{\phi}_{123}\rangle$
Non-mixed bi-linears of $\bar{\phi}_{123}$, mass $m\langle\bar{\phi}_{23}\rangle$
Seesaws into bi-linears of $\bar{\phi}_{23}$ with mass $m\epsilon^3$

Summary

Family invariants & ν phenomenology

- Innovative method with Higgs mediators enables new possibilities.
- Majorana terms lead to GUT results including $\frac{m_\odot}{m_@}, \theta_{13} \sim \epsilon$.
- VEV alignment improved, leads to light familons with potentially interesting phenomenological consequences.

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Content

Field	$SU(4)$	$SU(2)_L$	$SU(2)_R$	$\Delta(6n^2)$	Z_5	Z_4^R
ψ	4	2	1	3_{1_l}	0	1
ψ^c	$\bar{4}$	1	2	3_{1_l}	0	1
θ	8	1	2	1	1	0
H	1	2	2	1	1	0
X	1	2	2	$3_{1_{-2l}}$	0	0
$\bar{X}$	1	2	2	$3_{1_{2l}}$	0	2
Y	1	2	2	$3_{1_{-2l}} + 3_{1_l}$	2	0
$\bar{Y}$	1	2	2	$3_{1_{2l}} + 3_{1_{-l}}$	3	2
Z	1	2	2	3_{2_l}	0	0
$\bar{Z}$	1	2	2	$3_{1_{-l}}$	0	2
Σ	15	1	3	1	3	0

Content familons

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Ψ	4	2	1	3_{1_l}	0	1
Ψ^c	$\bar{4}$	1	2	3_{1_l}	0	1
θ	8	1	2	1	1	0
ϕ	1	1	1	$1'$	0	0
ϕ_1	1	1	1	3_{1_l}	1	0
$\bar{\phi}_3$	1	1	1	$3_{1_{-l}}$	2	0
$\bar{\phi}_{23}$	1	1	1	$3_{1_{-l}}$	3	0
$\bar{\phi}_{123}$	1	1	1	$3_{2_{-l}}$	1	0

Scalar terms

$$P_S = M\bar{X}X + M\bar{Y}Y + \phi\bar{Z}Z + \bar{\phi}_3^i\bar{\phi}_3^i H\bar{X}^i/M_X^a$$
$$+ a\bar{\phi}_{23}^i\bar{\phi}_{23}^i H\bar{Y}^{(a),i}/M_X^b + b[\bar{\phi}_{23}\bar{\phi}_{23}H\bar{Y}^{(b)}]_+/M_X^b$$
$$+ [\bar{\phi}_{23}\bar{\phi}_{123}H\bar{Z}]_-/M_X^c$$

Light combination

$$H_l \approx X_3 + \left(\frac{\bar{\phi}^3_{23}}{\bar{\phi}^3_3}\right)^2 \frac{M^a_X}{M^b_X}\left(a(Y^{(a)}_2 + Y^{(a)}_3) - 2bY^{(b)}_1\right)$$
$$+ \left(\frac{\bar{\phi}^3_{23}\bar{\phi}^3_{123}}{(\bar{\phi}^3_3)^2}\right)\frac{M^a_X}{M^c_X}(2Z_1 - Z_2 - Z_3) + H\frac{M\,M^a_X}{(\bar{\phi}^3_3)^2}$$

Yukawa couplings

$$P_Y = X_i \Psi_i \Psi_i^c + \left(a' Y_i^{(a)} \Psi_i \Psi_i^c + b' [Y^{(b)} \Psi \Psi^c]_+ \right) \Sigma / M_X + [Z \Psi \Psi^c]_-$$