Family Symmetries: phenomenology, UV completions & multi-Higgs alignment

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FLASY 2011, 2011/07/11

Outline

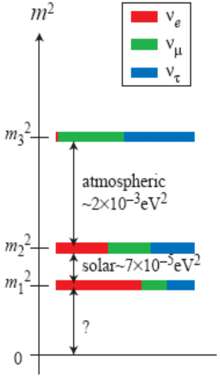
Family Symmetries and...

ν phenomenology (based on 1101.0602 with G.F. and S.)
UV completions (based on 1011.06662 with M.)
Multi-Higgs alignment (based on 1104.2601)

Summary of data: lepton mixing

Tribimaximal (TBM)

$$V_{PMNS} = \begin{pmatrix} -\sqrt{\frac{2}{3}} & \sqrt{\frac{1}{3}} & 0 \\ \sqrt{\frac{1}{6}} & \sqrt{\frac{1}{3}} & \sqrt{\frac{1}{2}} \\ \sqrt{\frac{1}{6}} & \sqrt{\frac{1}{3}} & -\sqrt{\frac{1}{2}} \end{pmatrix}$$



TBM decomposed

Decomposition

$$m_{TB} = U_{TB} d_\nu U_{TB}^T = x' C + y' P + z' D$$

$$C = \frac{1}{3}\begin{pmatrix} 2 & -1 & -1 \\ -1 & 2 & -1 \\ -1 & -1 & 2 \end{pmatrix}$$

$$P = \begin{pmatrix} 1 & 0 & 0 \\ 0 & 0 & 1 \\ 0 & 1 & 0 \end{pmatrix} \quad D = \frac{1}{3}\begin{pmatrix} 1 & 1 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & 1 \end{pmatrix}$$

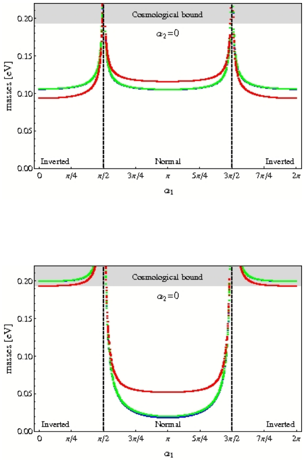
Masses: expresions

$$m_1 = \left| x e^{i\alpha_1} + y \right|$$

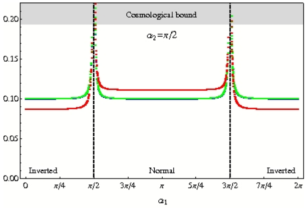
$$m_2 = \left| y + z e^{i\alpha_2} \right|$$

$$m_3 = \left| x e^{i\alpha_1} - y \right|$$

Top: $z = 0.1$ eV
Bottom: $z = 3.3 \times 10^{-3}$ eV



More plots


Cosmological bound
$\alpha_2 = \pi/2$
Inverted
Normal
Inverted
0.20
0.15
0.10
0.05
0.00
0
$\pi/4$
$\pi/2$
$3\pi/4$
π
$5\pi/4$
$3\pi/2$
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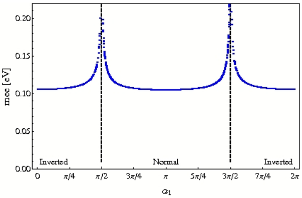
2π
α_1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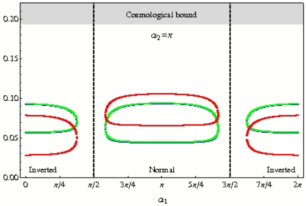
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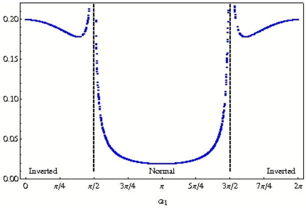
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Mixing scheme X

Other mass independent mixing schemes

$$m_\nu = U_X d_\nu U_X^T$$

$$U_X = K_X U_{TB}$$

$$m_\nu = K_X m_{TB} K_X^T$$

$\Delta(12)$ (A_4)

Relevant invariants

- At the effective level $LHLH\phi$, with $\langle\phi\rangle = (1,1,1)$ can get C, P (and tribimaximal), but without D.
- Can get D at higher order (e.g. $LH\phi LH\phi$).

$\Delta(12)$, D at different order (if present): expect z small.

$\Delta(3n^2)$

Relevant invariants

- At effective level mixing comes from LL: repeated irreps.
- In type II mixing scheme comes directly from LL: repeated irreps.
- In type I (III) mixing involves NN, but indirectly.

$\Delta(48)$ ($n = 4$) with C, P and D: expect z not small.
(Incompatible with P from LL, as often done in $\Delta(12)$).

Renormalisable couplings

Add messengers

$$w_\ell = h_d(\ell \chi_\tau^c) + M_{\chi_A}(\chi_A^c \chi_A) + \tau^c(\varphi_T \chi_\tau)$$

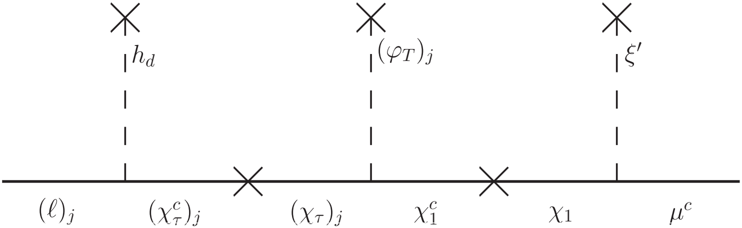
$$+\mu^c \xi' \chi_1 + e^c \xi' \chi_3 + (\varphi_T \chi_\tau)'' \chi_1^c + (\varphi_T \chi_\tau)' \chi_2^c + \chi_3^c \xi' \chi_2 \,.$$

Arguably more elegant and certainly more predictive!

Drawing the Muon: AM

One μ diagram (not two)

$$h_d(\ell\chi_\tau^c) + M_{\chi_A}(\chi_A^c\chi_A) + (\chi_\tau\varphi_T)''\chi_1^c + \chi_1\xi'\mu^c$$



MHDM alignment with family symmetries

Exact alignment from two ingredients

- A single symmetry invariant for each family
- All H_A are singlets of the symmetry

$$\mathcal{L}_u = \sum_{A=1}^{N} c_A H_A^\dagger [\chi^{ij} Q_i u_j^c] + h.c. \tag{1}$$

Summary

Family invariants & ν phenomenology

- Democratic component of tribimaximal mixing controls interesting phenomenological consequences.
- Model details affect naturalness of significant democratic contribution.
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