Mass Ratios and Mixing Angles from a SU(3) Gauge Family Symmetry

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Flavor Physics is a Window on High Energy Physics

Is it true?

To what extent?

Orthogonal Idea (TEST):
What about Gauge Low-Energy Effective Theory
Of Flavor (and CP) Symmetry Breaking?

The Perfect Theory of Flavor

- Microscopic Details (Susy? GUT?)
- Complete Field Content (Messengers…)
- Symmetry Breaking Dynamics (Scalars?)

- Explicit Symmetry Breaking

- Symmetries (Global, Gauge, Approximate)
- Symmetry Breaking Pattern (Spontaneous)
- Low Energy: Masses, Mixing, CPV

The Perfect Theory of Flavor

UV

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IR

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UV

FLAVOR EFT

IR

Program

- Gauge and Global Family Symmetries
- Effective Field Theory Treatment below Symmetry-Breaking Scale of FLAVOR.
- Explicit Symmetry Breaking: UV-Dependent Quantities
- Spontaneous Symmetry Breaking: Low-Energy Description.
- What CANNOT be explained by the EFT is

a Window on High Energy Physics

Results

- Hadronic Sector:

  IR) PREDICTIONS: Mixing Angles, CP violation, Mass Ratios,

  UV) INPUT: Top Mass, Bottom Mass.

- Leptonic Sector:

  IR) Small Mixing Angles (deviations from maximal or zero)

  UV) Tau Mass, Neutrino Scale, Neutrino Nature (Majorana vs. Dirac).

  ??) Large Mixing Angles, CPV: Flavor Changing and Flavor Conserving.

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WORK
IN PROGRESS
PRELIMINARY!!!!!

A Model for Quarks Gauged Family SU(3)

- Global SU(3)xSU(3)xZ3 (Broken)
- Gauged SU(3) Subgroup: Explicit Symmetry Breaking.

		$SU(3)_1$	$SU(3)_2$	Z_3	$SU(3)_c$	$SU(2)_L$	$U(1)_Y$
SM Fermions	q	3	1	$1''$	3	2	$\frac{1}{6}$
	u^c	3	1	$1'$	$\bar{3}$	1	$-\frac{2}{3}$
	d^c	3	1	1	$\bar{3}$	1	$\frac{1}{3}$
New Up-type Fermions	χ	3	1	$1'$	3	1	$\frac{2}{3}$
	χ^c	3	1	1	$\bar{3}$	1	$-\frac{2}{3}$
Visible Scalars	h	1	1	1	1	2	$-\frac{1}{2}$
	S	$\bar{6}$	1	$1'$	1	1	0
	Σ	$\bar{6}$	1	$1''$	1	1	0
Hidden Scalars	H	1	$\bar{6}$	1	1	1	0

Spontaneous Symmetry Breaking

- Gauge Coupling Off: H decoupled !
- Dynamics of Scalars Unknown
- Assumed VEVS:

$$\langle S \rangle = F \begin{pmatrix} 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & s \end{pmatrix} \qquad \langle \Sigma \rangle = F \begin{pmatrix} 0 & 0 & 0 \\ 0 & \sigma & 0 \\ 0 & 0 & 0 \end{pmatrix}$$

$$\langle H \rangle = F \begin{pmatrix} b_1^2 & b_2 & b_3 \\ b_2 & a_1 & a_3 \\ b_3 & a_3 & a_2 \end{pmatrix}$$

Tree-Level Mass Matrices

- UV-controlled Effective Operators:

$$\mathcal{L}_Y = y_d \frac{qhSd^c}{F} + y_1 \frac{q\tilde{h}S\chi^c}{F} + y_2 \chi S u^c + y_3 \chi \Sigma \chi^c + \text{h.c.}$$

- Mass Matrices:

$$M_d = y_d v \frac{\langle S \rangle}{F} = y_d\, v \begin{pmatrix} 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & s \end{pmatrix}$$

$$(u\ \chi) \tilde{M}_u \begin{pmatrix} u^c \\ \chi^c \end{pmatrix} = (u\ \chi) \begin{pmatrix} 0 & y_1\, v \frac{\langle S \rangle}{F} \\ y_2 \langle S \rangle & y_3 \langle \Sigma \rangle \end{pmatrix} \begin{pmatrix} u^c \\ \chi^c \end{pmatrix}$$

Radiative Corrections

- Gauge Coupling On: H Coupled !

$$\delta\langle S\rangle_{ij} = -\frac{\alpha}{\pi} sF\log(\frac{M_c^2}{M_F^2})(t_a)_i^3(t_b)_j^3 O_{ac}O_{bc}.$$

- New Mass Matrices:

$$\langle S\rangle' = \langle S\rangle + \delta\langle S\rangle = F\begin{pmatrix} \mathcal{O}(\frac{\alpha}{\pi}b^2) & \mathcal{O}(\frac{\alpha}{\pi}b) & \mathcal{O}(\frac{\alpha}{\pi}b) \\ \mathcal{O}(\frac{\alpha}{\pi}b) & \mathcal{O}(\frac{\alpha}{\pi}) & \mathcal{O}(\frac{\alpha}{\pi}) \\ \mathcal{O}(\frac{\alpha}{\pi}b) & \mathcal{O}(\frac{\alpha}{\pi}) & s \end{pmatrix} \quad \text{(down)}$$

$$\langle \Sigma\rangle' = \langle \Sigma\rangle + \delta\langle \Sigma\rangle = F\begin{pmatrix} \mathcal{O}(\frac{\alpha}{\pi}b^2) & \mathcal{O}(\frac{\alpha}{\pi}b) & \mathcal{O}(\frac{\alpha}{\pi}b) \\ \mathcal{O}(\frac{\alpha}{\pi}b) & \sigma & \mathcal{O}(\frac{\alpha}{\pi}) \\ \mathcal{O}(\frac{\alpha}{\pi}b) & \mathcal{O}(\frac{\alpha}{\pi}) & \mathcal{O}(\frac{\alpha}{\pi}) \end{pmatrix}$$

$$\tilde{M}_u\tilde{M}_u^\dagger = \begin{pmatrix} y_1^2 v^2 \frac{\langle S\rangle'\langle S\rangle'^\dagger}{F^2} & y_1 y_3 v \frac{\langle S\rangle'\langle \Sigma\rangle'^\dagger}{F} \\ y_1 y_3 v \frac{\langle \Sigma\rangle'\langle S\rangle'^\dagger}{F} & y_2^2\langle S\rangle'\langle S\rangle'^\dagger + y_3^2\langle \Sigma\rangle'\langle \Sigma\rangle'^\dagger \end{pmatrix}$$

Fitting the data

- Perturbative Expansion:

$$(\alpha^2/\pi^2)b^2 \ll z^2 \ll b^2 \ll 1 \qquad z \equiv y_2/y_3$$

- Approximate Results (Numerical Exact!)

$$\frac{m_c}{m_t} \approx \frac{\alpha}{\pi}\frac{z}{b} \qquad \frac{m_s}{m_b} \approx \frac{\alpha}{\pi} \qquad \frac{m_u}{m_t} \approx \frac{\alpha^2}{\pi^2}bz \qquad \frac{m_d}{m_b} \approx \frac{\alpha}{\pi}b^2$$

$$\theta_{12} \approx b. \qquad \theta_{23} \approx \frac{\alpha}{\pi} \qquad \theta_{13} \approx \frac{\alpha^2}{\pi^2}b$$

- Fit: 3 parameters, 7 observables
  (6 ok, 1 to be improved)

$$\frac{\alpha}{\pi} \approx 0.04 \qquad z \approx 0.04 \qquad b \approx 0.2$$

What about Neutrinos?

What about Neutrinos?

- Idea: Neutrinos=Hidden Sector (direct communication suppressed by small masses!)
- H is (prop to) Neutrino Mass Matrix

$$\langle H \rangle = F \begin{pmatrix} b_1^2 & b_2 & b_3 \\ b_2 & a_1 & a_3 \\ b_3 & a_3 & a_2 \end{pmatrix}$$

- Fit Free Parameters in H to Exact Bimaximal
- Use the Fitted H in the Loops, and Predict Quark (and Charged Leptons) Physics.

Agenda…

- Leptons and Neutrinos (in Progress)
- CPV (Incomplete)

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- FCNC (No Surprises Expected)
- Stabilization Mechanism (Susy? Little Flavons?)

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hep-ph/0309182 - PRD69

Conclusions

- EFT of Family Gauge Symmetry CAN Explain a lot: Mass Ratios, Mixing Angles (and some CP Violation).

- But NOT Everything: Overall Fermion Mass Scales, Neutrino Nature, Large Mixing Angles, some CP Violation… are direct Windows on Microscopic Structure of Nature.