Alignment in multi-Higgs doublet models through family symmetries

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Outline

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Higgs

Multi-Higgs

Yukawa

Hideki Yukawa
("maiden" name, Hideki Ogawa)
We might be saying "Ogawa couplings" today...

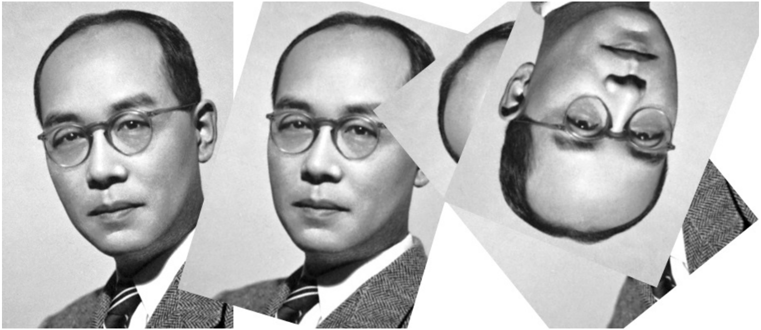
Multi-Higgs models and Yukawa

In MHDM, for each family (u, d, l, ν) there is a Yukawa for each Higgs.

$$\mathcal{L}_u = \sum_{A=1}^{N} (Y_A^u)^{ij} H_A^\dagger Q_i u_j^c + h.c. \qquad (1)$$

The $Y_A^{u,d,l,\nu}$ are in principle unrelated... Not simultaneously diagonal:
would lead to FCNC which have not been observed.

Multi-Ogawa



Yukawa alignment

Solution: Yukawa alignment, no FCNC:
A. Pich and P. Tuzon, Phys.Rev. D80 (2009)

Alignment can not be preserved by renormalisation (unless additional symmetries are applied):
P. Ferreira, L. Lavoura, and J. P. Silva, Phys.Lett. B688 (2010)

But deviations from running may be sufficiently small (for current bounds):
C. B. Braeuninger, A. Ibarra, and C. Simonetto, Phys.Lett. B692 (2010)

Exact alignment from family symmetries

IdMV, Phys.Lett. B701 (2011)

- Single FS invariant combination (for each family)
- All H_A trivial singlets under the FS

See also different approach:
H. Serôdio, Phys.Lett. B700 (2011)

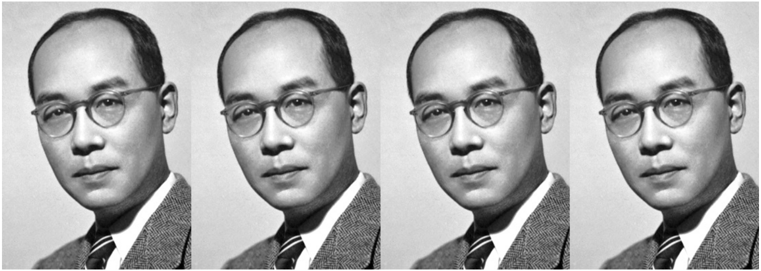
Exact alignment example

FS: $SU(3)_{[]} \otimes SU(3)_{()}$

$$\mathcal{L}_u = \sum_{A=1}^{N} c^u_A H^\dagger_A [\phi^i_Q Q_i](\phi^j_u u^c_j) + h.c. \tag{2}$$

All $\left(Y^u_A\right)^{ij} \propto \langle \phi^i_Q \phi^j_u \rangle$: exact alignment
Note: single $SU(3)$ has also $\sum_{A=1}^{N} c'^u_A H^\dagger_A (\phi^i_u Q_i)(\phi^j_Q u^c_j)$...

Alignment



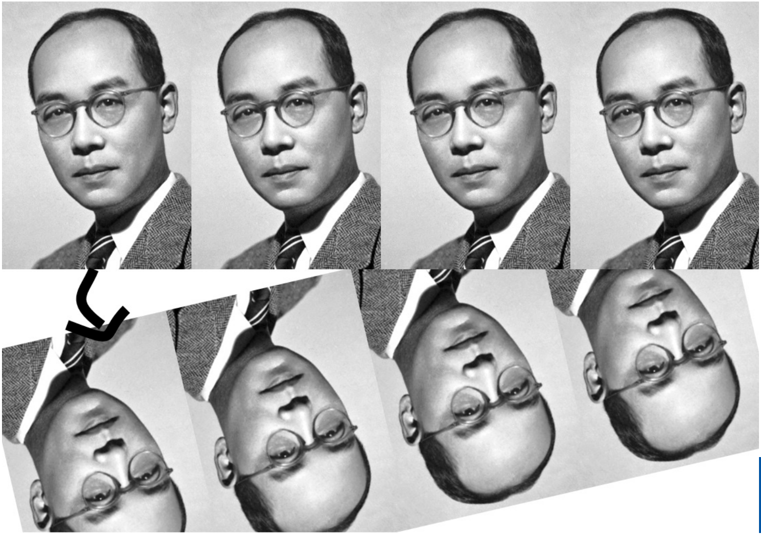
Up, Down

$SU(3)_{[]} \otimes SU(3)_{()} \otimes C_2$

$$\mathcal{L}_Q = \sum_{A=1}^{N} [\phi_Q^i Q_i] \left(c_A^d H_A (\phi_d^j d_j^c) + c_A^u H_A^\dagger (\phi_u^j u_j^c) \right) + h.c.$$

With e.g. ϕ_d, d^c as -1 under the C_2 (prevents ϕ_u, ϕ_d swapping places)

Up and down alignment



Up and down alignment

No νs

	Q	u^c	d^c	L	e^c	ϕ_Q	ϕ_u	ϕ_d	ϕ_L	ϕ_e
$SU(3)_{[]}$	**3**	**1**	**1**	**3**	**1**	$\bar{\mathbf{3}}$	**1**	**1**	$\bar{\mathbf{3}}$	**1**
$SU(3)_{()}$	**1**	**3**	**3**	**1**	**3**	**1**	$\bar{\mathbf{3}}$	$\bar{\mathbf{3}}$	**1**	$\bar{\mathbf{3}}$
C_7	1	1	α^3	α	α^4	α	α^6	α^3	α^2	1

Table : $SU(3)_{[]} \otimes SU(3)_{()} \otimes C_7$ assignments. $\alpha^7 = 1$.

All families

	Q	u^c	d^c	L	e^c	ν^c	ϕ_Q	ϕ_u	ϕ_d	ϕ_L	ϕ_e	ϕ_ν
$SU(3)_{[]}$	$\mathbf{3}$	$\mathbf{1}$	$\mathbf{1}$	$\mathbf{3}$	$\mathbf{1}$	$\mathbf{1}$	$\bar{\mathbf{3}}$	$\mathbf{1}$	$\mathbf{1}$	$\bar{\mathbf{3}}$	$\mathbf{1}$	$\mathbf{1}$
$SU(3)_{()}$	$\mathbf{1}$	$\mathbf{3}$	$\mathbf{3}$	$\mathbf{1}$	$\mathbf{3}$	$\mathbf{3}$	$\mathbf{1}$	$\bar{\mathbf{3}}$	$\bar{\mathbf{3}}$	$\mathbf{1}$	$\bar{\mathbf{3}}$	$\bar{\mathbf{3}}$
C_{10}	1	1	α^3	α	α^4	α^7	α	α^9	α^6	α^2	α^3	1

Table : $SU(3)_{[]} \otimes SU(3)_{()} \otimes C_{10}$ assignments. $\alpha^{10} = 1$.

Rank 1

All the mass matrices in the above example are rank 1 (this is a feature of using $SU(3)_{[]} \otimes SU(3)_{()}$).

Can use discrete subgroups (example in paper).
IdMV, Phys.Lett. B701 (2011)

Approximate alignment

Abandon single FS invariant combination
Keep leading order rank 1 Yukawa (as observed): approximate alignment!

Conclusion

Conclusions

- Exact alignment from single FSIC + Family singlet H
- Single FSIC: too restrictive for realistic Yukawas
- FS + LO rank 1 provides approximate alignment