Lopsided texture compatible with thermal leptogenesis in partially composite Pati-Salam unification

M.J.S.Yang, Arxiv:1904.02881

Saitama Univ. (PD)
Masaki Yang（梁　正樹）

Abstract

・ We research realistic FN charges compatible with leptogenesis and Pati-Salam unification.

・ Partial compositeness can generate lopsided texture and can decrease FN charges from its GUT relation.

Lopsided texture compatible with thermal leptogenesis in partially composite Pati-Salam unification

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it will be substantially modified…

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Abstract

・ We research realistic FN charges compatible with leptogenesis and Pati-Salam unification.

・ Partial compositeness can generate lopsided texture and can decrease FN charges from its GUT relation.

Flavor puzzle : overview

- **Flavor symmetry** $U(1)_{FN}$ Froggatt & Nielsen, **79**, **1600cited**
  - SU(2), SU(3), …
  - S_3 , Harari, Haut, Weyers, **78**, A_4, S_4, …
  - **Family unification** Ramond **79**, Wilczek & Zee, 82 , **280cited**

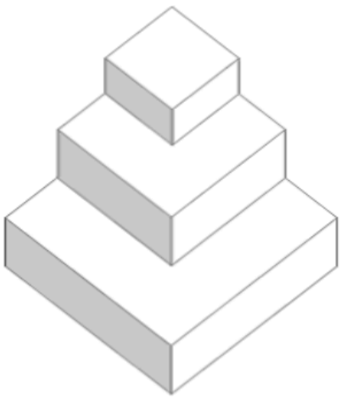
    SO(16), SO(18), E_7, E_8, etc, $\supset$ SO(10)×SU(3)
- **6 zero texture** Weinberg **77**, Fritzsch **77**, **820cited**
  - n(=2,3,4..) zero,
  - Democratic texture Harari, Haut, Weyers, **78**,
  - Lopsided texture Sato, Yanagida, 98
- Ex. dim., Little (or composite) Higgs,

  Theory dep. approach

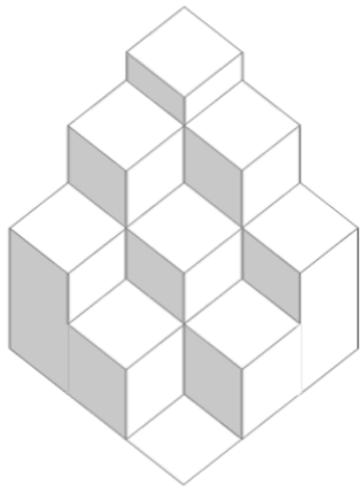
Texture ⇒ hint to what Higgs is ?

Cascade vs Waterfall

Haba, Takahashi, Tanimoto, Yoshioka, ‘08



[Cascade]



[Waterfall]

$\begin{pmatrix} \epsilon & \epsilon & \epsilon \\ \epsilon & \delta & \delta \\ \epsilon & \delta & 1 \end{pmatrix}$	$\begin{pmatrix} \epsilon^2 & \epsilon\delta & \epsilon \\ \epsilon\delta & \delta^2 & \delta \\ \epsilon & \delta & 1 \end{pmatrix}$
Cascade	Waterfall

Cascade vs Waterfall

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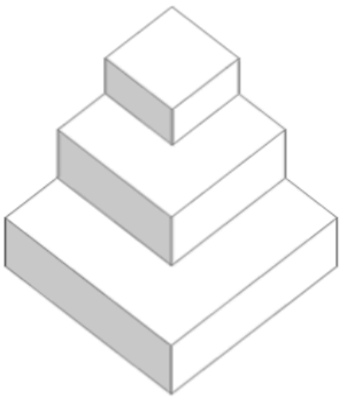

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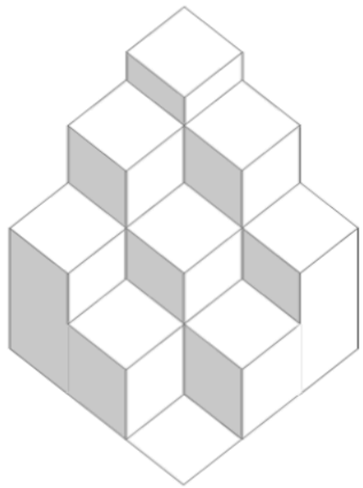

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Cascade	Waterfall

type I seesaw $$M_R \propto Y_\nu^T m_\nu^{-1} Y_\nu$$

m_ν is not hierarchical ⇒ M_R is Waterfall whether Yν is cascade or not

M. Yang, '16 (Democratic M_R is difficult if Yν ∼ Yu)

Universal origin of flavor ⇒ Waterfall is natural

Which waterfall is realistic for Yukawa?

If Yukawas are symmetric $\Rightarrow$ Aproximate 0 texture is necessary for CKM matrix

Hall, Rasin, 93

c.f., $$\mathbf{U} = \begin{pmatrix} (U_{11} << u_1) & \sqrt{u_1 u_2} & (U_{13} << \sqrt{u_1 u_3}) \\ \sqrt{u_1 u_2} & (U_{22} << u_2) & \sqrt{u_2 u_3} \\ (U_{13} << \sqrt{u_1 u_3}) & \sqrt{u_2 u_3} & u_3 \end{pmatrix},$$

But, zero textures require complicate symmetry and fields…

$\Rightarrow$ Asymmetric **lopsided texture** is natural?

- Coset space unif. — Sato, Yanagida, 98 ← Talk at 1st day
- U(1) Froggatt-Nielsen
- E6 twist mech. — Bando, Kugo, Yoshioka '99
- partial compositeness — Kaplan '99, Contino et al '06

Lopsided texture

Sato, Yanagida, 98
$E_7/SU(5)$, coset space unif.

$$y_u \propto \begin{pmatrix} \lambda^6 & \lambda^5 & \lambda^3 \\ \lambda^5 & \lambda^4 & \lambda^2 \\ \lambda^3 & \lambda^2 & \lambda^0 \end{pmatrix}, \quad y_d \propto y_e^T \propto \begin{pmatrix} \lambda^4 & \lambda^3 & \lambda^3 \\ \lambda^3 & \lambda^2 & \lambda^2 \\ \lambda^1 & \lambda^0 & \lambda^0 \end{pmatrix}, \quad m_\nu \propto \begin{pmatrix} \lambda^2 & \lambda^1 & \lambda^1 \\ \lambda^1 & \lambda^0 & \lambda^0 \\ \lambda^1 & \lambda^0 & \lambda^0 \end{pmatrix}.$$

$$\Rightarrow \quad V_{\rm CKM} \simeq \begin{pmatrix} 1 & \lambda & \lambda^3 \\ \lambda & 1 & \lambda^2 \\ \lambda^3 & \lambda^2 & 1 \end{pmatrix}, \quad U_{\rm MNS} \simeq \begin{pmatrix} 1 & \lambda & \lambda \\ \lambda & 1 & 1 \\ \lambda & 1 & 1 \end{pmatrix},$$

Lopsided texture

Sato, Yanagida, 98
$E_7/SU(5)$, coset space unif.

$$y_u \propto \begin{matrix} & 3 & 2 & 0 \\ 3 & \lambda^6 & \lambda^5 & \lambda^3 \\ 2 & \lambda^5 & \lambda^4 & \lambda^2 \\ 0 & \lambda^3 & \lambda^2 & \lambda^0 \end{matrix}, \quad y_d \propto y_e^T \propto \begin{matrix} & 1 & 0 & 0 \\ 3 & \lambda^4 & \lambda^3 & \lambda^3 \\ 2 & \lambda^3 & \lambda^2 & \lambda^2 \\ 0 & \lambda^1 & \lambda^0 & \lambda^0 \end{matrix}, \quad m_\nu \propto \begin{matrix} & 1 & 0 & 0 \\ 1 & \lambda^2 & \lambda^1 & \lambda^1 \\ 0 & \lambda^1 & \lambda^0 & \lambda^0 \\ 0 & \lambda^1 & \lambda^0 & \lambda^0 \end{matrix}.$$

$$\Rightarrow \quad V_{\rm CKM} \simeq \begin{pmatrix} 1 & \lambda & \lambda^3 \\ \lambda & 1 & \lambda^2 \\ \lambda^3 & \lambda^2 & 1 \end{pmatrix}, \quad U_{\rm MNS} \simeq \begin{pmatrix} 1 & \lambda & \lambda \\ \lambda & 1 & 1 \\ \lambda & 1 & 1 \end{pmatrix},$$

Lopsided texture

Sato, Yanagida, 98
$E_7/SU(5)$, coset space unif.

$$
y_u \propto \begin{array}{c} \\ 3 \\ 2 \\ 0 \end{array}\!\!\begin{array}{c} \begin{array}{ccc} 3 & 2 & 0 \end{array} \\ \begin{pmatrix} \lambda^6 & \lambda^5 & \lambda^3 \\ \lambda^5 & \lambda^4 & \lambda^2 \\ \lambda^3 & \lambda^2 & \lambda^0 \end{pmatrix} \end{array}, \quad y_d \propto y_e^T \propto \begin{array}{c} \\ 3 \\ 2 \\ 0 \end{array}\!\!\begin{array}{c} \begin{array}{ccc} 1 & 0 & 0 \end{array} \\ \begin{pmatrix} \lambda^4 & \lambda^3 & \lambda^3 \\ \lambda^3 & \lambda^2 & \lambda^2 \\ \lambda^1 & \lambda^0 & \lambda^0 \end{pmatrix} \end{array}, \quad m_\nu \propto \begin{array}{c} \\ 1 \\ 0 \\ 0 \end{array}\!\!\begin{array}{c} \begin{array}{ccc} 1 & 0 & 0 \end{array} \\ \begin{pmatrix} \lambda^2 & \lambda^1 & \lambda^1 \\ \lambda^1 & \lambda^0 & \lambda^0 \\ \lambda^1 & \lambda^0 & \lambda^0 \end{pmatrix} \end{array}.
$$

$$
\Rightarrow \quad V_{\text{CKM}} \simeq \begin{pmatrix} 1 & \lambda & \lambda^3 \\ \lambda & 1 & \lambda^2 \\ \lambda^3 & \lambda^2 & 1 \end{pmatrix}, \quad U_{\text{MNS}} \simeq \begin{pmatrix} 1 & \lambda & \lambda \\ \lambda & 1 & 1 \\ \lambda & 1 & 1 \end{pmatrix},
$$

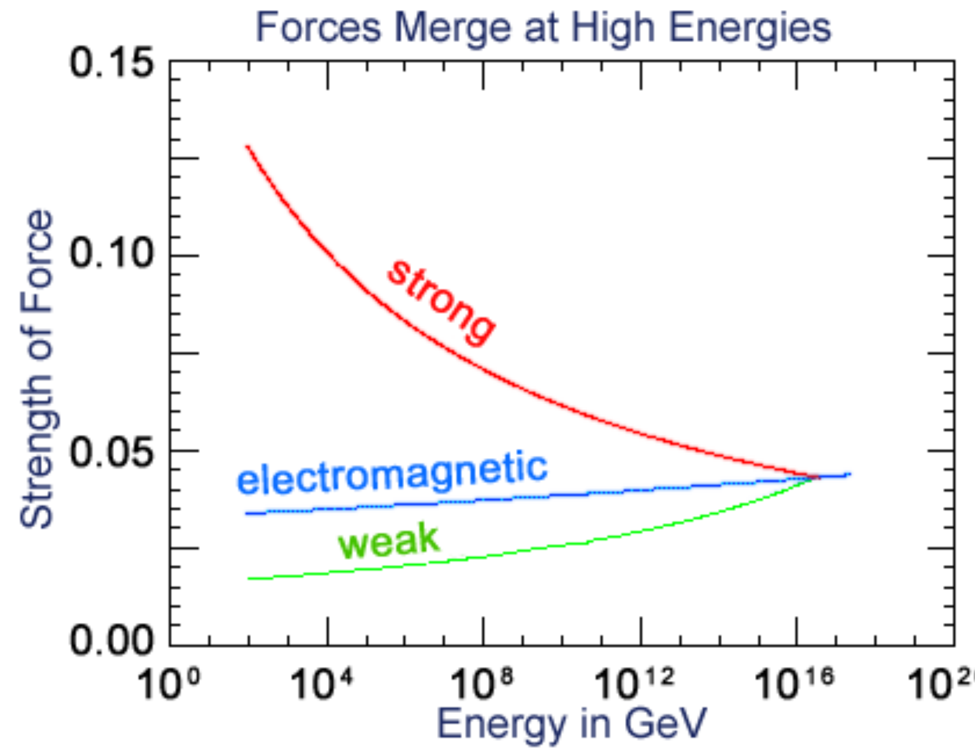
U(1) FN mechanism is compatible with SU(5) GUT

$$
\mathcal{L} = \sum_f c_{ij}^f \left(\frac{\langle \theta \rangle}{M} \right)^{n_{Li}+n_{Rj}} \bar{f}_{Li} f_{Rj} H + \text{h.c.}, \qquad \frac{\langle \theta \rangle}{M} = \lambda,
$$

Field	$\mathbf{10}_1$	$\mathbf{10}_2$	$\mathbf{10}_3$	$\bar{\mathbf{5}}_1$	$\bar{\mathbf{5}}_2$	$\bar{\mathbf{5}}_3$	$\mathbf{1}_1$	$\mathbf{1}_2$	$\mathbf{1}_3$
$U(1)$	3	2	0	$n+1$	n	n	$n_{\nu 1}$	$n_{\nu 2}$	$n_{\nu 3}$

$10=(q_L, u_R, e_R)$,
$5=(d_R, l_L)$, $1=\nu_R$

Grand Unified Theories (大統一理論)



- unification of gauge bosons, quarks and leptons ⇒ **proton decay**

⇒ verify by Kamiokande

Kamioka Observatories

Higgstan.comより

$\tau/B(p \to e^+\pi^0) > 2.6 \times 10^{32}$ [year]

⇒ Simplest SU(5) was rejected

$> 1.6 \times 10^{34}$ [year]

Current bound

$> 6.3 \times 10^{34}$ [year]

@2036（建設6年、実験10年）

$> 1.0 \times 10^{35}$ [year]

@2046（建設6年、実験20年）

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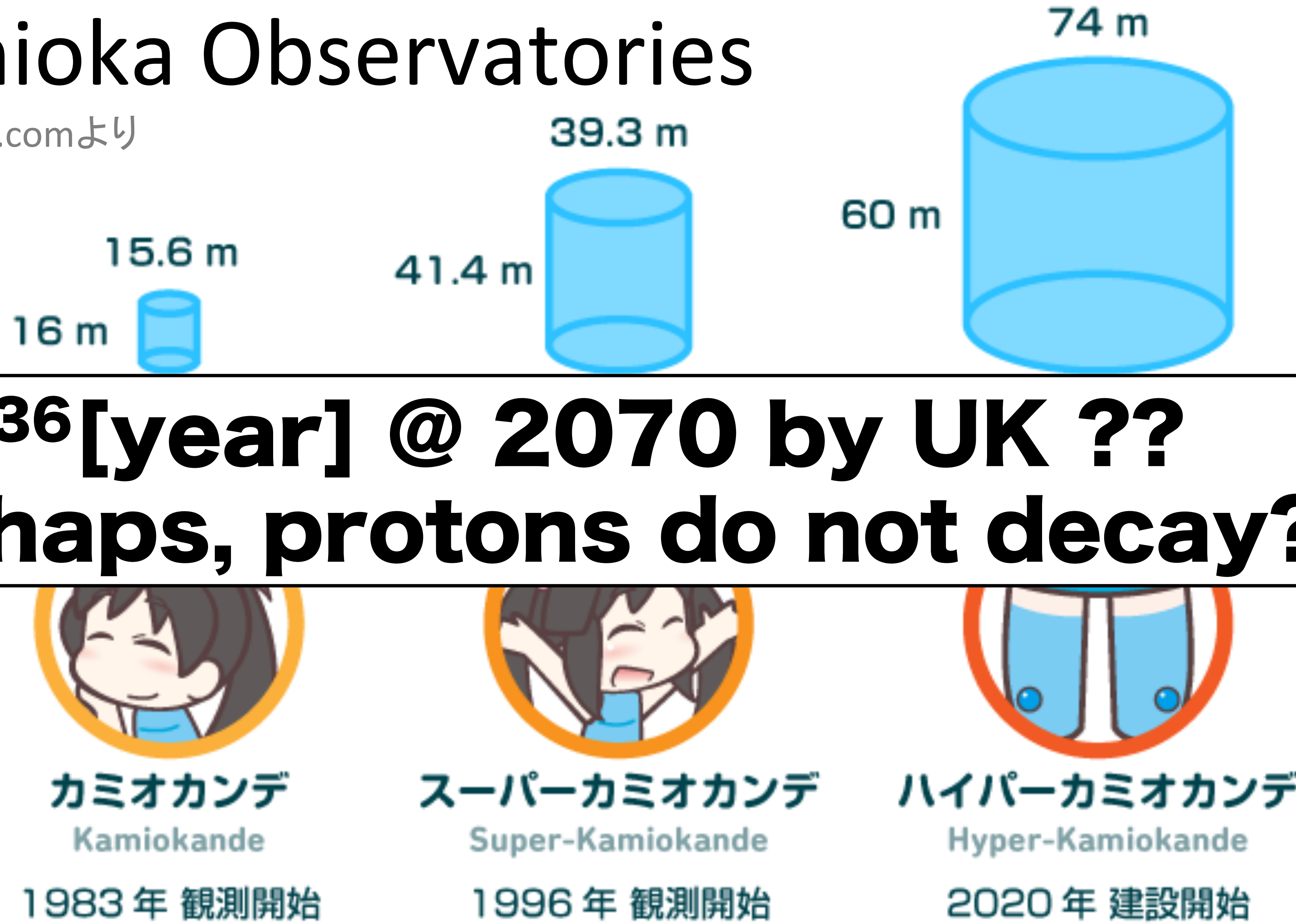

>10^{36}[year] @ 2070 by UK ??
Perhaps, protons do not decay?

$\tau/B(p \to e^+\pi^0) > 2.6 \times 10^{32}$ [year]

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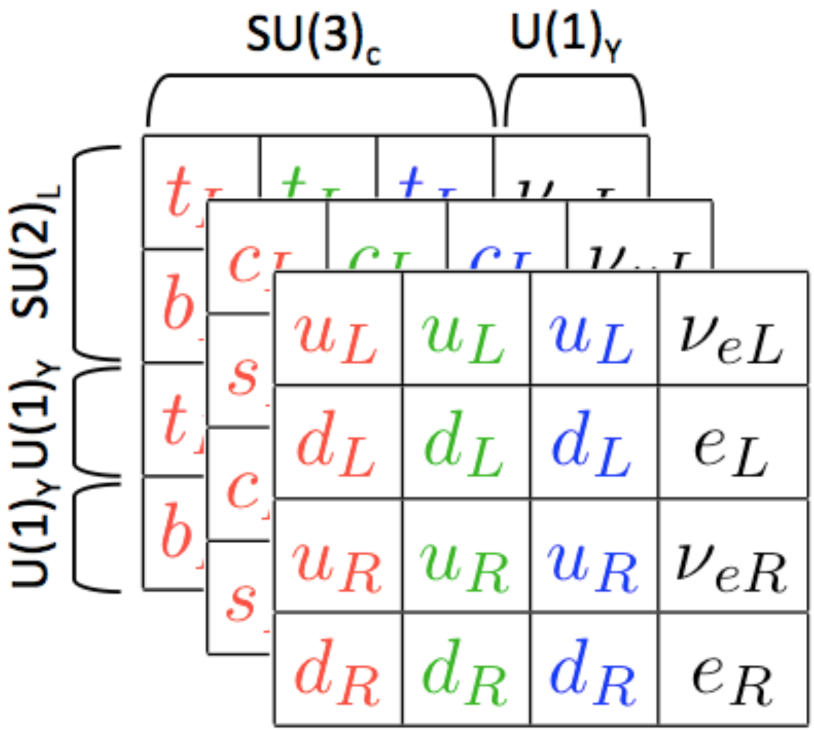
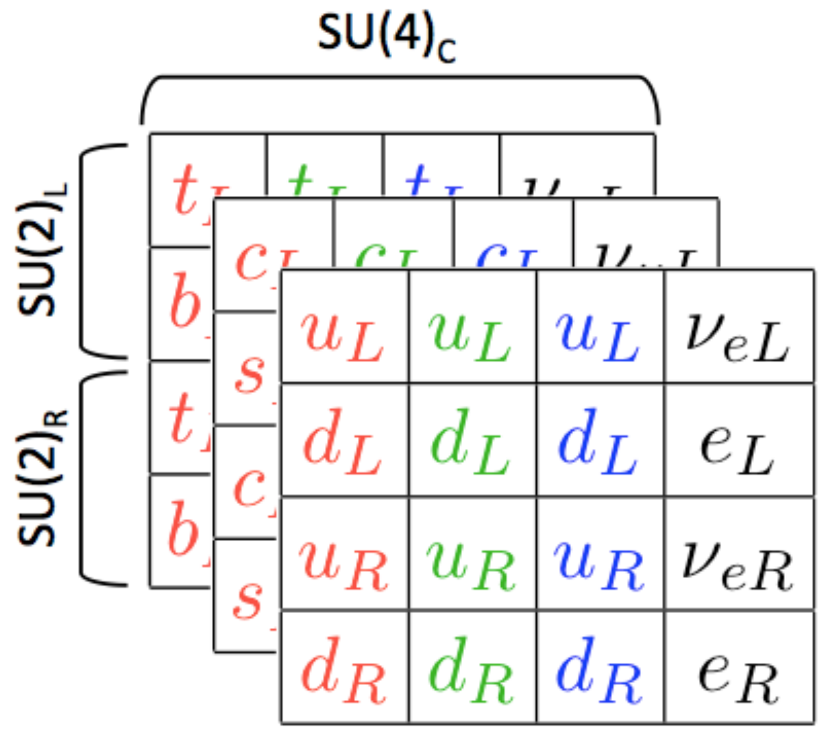
SU(4)×SU(2)$_L$×SU(2)$_R$ Pati-Salam model

GUT without proton decay (only L is broken)



SM



PS model

SSB and GUT breaking Higgs

GUT breaking effect should mediate flavor texture

We choose a bi-fundamental rep. Higgs

Antoniadis, Leontaris, 89

$$H_R^{\alpha a}(\mathbf{4},\mathbf{1},\mathbf{2}) = \begin{pmatrix} u_H^1 & u_H^2 & u_H^3 & \nu_H \\ d_H^1 & d_H^2 & d_H^3 & e_H^- \end{pmatrix}, \quad \langle H_R \rangle = \langle \nu_H \rangle \sim M_{\rm GUT},$$

$$SU(4)_c \times SU(2)_L \times SU(2)_R \to SU(3)_c \times SU(2)_L \times U(1)_Y$$

(It corresponds 16 rep. Higgs in SO(10).)

It can couples only to d_{Ri} and l_{Li} (and ν_{Ri}).

⇒GUT inv. FN charge is determined as $n_{qi} = (3,2,0)$

FN charges in GUT

$$y_\nu \propto \begin{pmatrix} \lambda^{n_{\nu 1}+1} & \lambda^{n_{\nu 2}+1} & \lambda^{n_{\nu 3}+1} \\ \lambda^{n_{\nu 1}} & \lambda^{n_{\nu 2}} & \lambda^{n_{\nu 3}} \\ \lambda^{n_{\nu 1}} & \lambda^{n_{\nu 2}} & \lambda^{n_{\nu 3}} \end{pmatrix}, \quad M_{\nu R} \propto \begin{pmatrix} \lambda^{2n_{\nu 1}} & \lambda^{n_{\nu 1}+n_{\nu 2}} & \lambda^{n_{\nu 1}+n_{\nu 3}} \\ \lambda^{n_{\nu 1}+n_{\nu 2}} & \lambda^{2n_{\nu 2}} & \lambda^{n_{\nu 2}+n_{\nu 3}} \\ \lambda^{n_{\nu 1}+n_{\nu 3}} & \lambda^{n_{\nu 2}+n_{\nu 3}} & \lambda^{2n_{\nu 3}} \end{pmatrix},$$

FN charges of ν_{Ri} are not determined: we consider two case

$n_{\nu i} \simeq n_{qi} = (3, 2, 0)$ quark type

$n_{\nu i} \simeq n_{li} = (n+1, n, n)$ lepton type

(n depend on tan β through the mass : $m_{ei} = y\, v \cos\beta/\sqrt{2}$.)

Observation:FN charges in PS GUT

1. GUT Higgs H : (4,1,2)

   ⇒ it determines GUT inv. FN charge as $n_{qi} = (3,2,0)$

2. Thermal leptogenesis (by ν_{R1})

Davidson − Ibarra bound $M_{\nu R1} \gtrsim 10^9\mathrm{GeV}$ ⇒ $5.5 \gtrsim (n_{\nu 1} + n_{l1})$.

However, if ν_{Ri} are not hierarchical, it does not holds

3. Manitude of M_{GUT} and M_F

Davidson, Kitano, 04

n = 0	$(3,2,0) \to (1,0,0)$	Large mixing	$M_{\mathrm{GUT}} \gtrsim M_F$
n = 2	$(3,2,0) \to (3,2,2)$	Small mixing	$M_{\mathrm{GUT}} \ll M_F$

Back up (for insurance)

$$m_\nu^{\rm diag} \sim m \begin{pmatrix} \lambda^{2n_{l1}} & 0 & 0 \\ 0 & \lambda^{2n_{l2}} & 0 \\ 0 & 0 & \lambda^{2n_{l3}} \end{pmatrix} \sim \begin{pmatrix} 0.002 & 0 & 0 \\ 0 & 0.01 & 0 \\ 0 & 0 & 0.05 \end{pmatrix} [\rm eV].$$

$$M_{\nu R} = \frac{v^2 s_\beta^2}{2} y_\nu^T m_\nu^{-1} y_\nu, \tag{17}$$

$$= \frac{v^2 s_\beta^2}{2m} \begin{pmatrix} \lambda^{2n_{\nu1}} & \lambda^{n_{\nu1}+n_{\nu2}} & \lambda^{n_{\nu1}+n_{\nu3}} \\ \lambda^{n_{\nu1}+n_{\nu2}} & \lambda^{2n_{\nu2}} & \lambda^{n_{\nu2}+n_{\nu3}} \\ \lambda^{n_{\nu1}+n_{\nu3}} & \lambda^{n_{\nu2}+n_{\nu3}} & \lambda^{2n_{\nu3}} \end{pmatrix} \sim \frac{246^2\,[{\rm GeV}^2] s_\beta^2 \lambda^{2n_{\nu1}}}{2m} \begin{pmatrix} 1 & 0 & 0 \\ 0 & \lambda^{2(n_{\nu2}-n_{\nu1})} & 0 \\ 0 & 0 & \lambda^{2(n_{\nu3}-n_{\nu1})} \end{pmatrix}$$

$$M_{\nu R1} \sim \frac{6\times 10^4\,[{\rm GeV}^2] s_\beta^2 \lambda^{2n_{\nu1}}}{2\lambda^{-2n_{l1}} 0.002\,[{\rm eV}]} \gtrsim 10^9\,[{\rm GeV}],$$

$$6\times 10^{14}\,[{\rm GeV}] s_\beta^2 \lambda^{2(n_{\nu1}+n_{l1}-1)} \gtrsim 10^9\,[{\rm GeV}],$$

$$1.5\times 10^7 \lambda^{2(n_{\nu1}+n_{l1})} \gtrsim 1, \quad \Rightarrow \quad 5.5 \gtrsim (n_{\nu1}+n_{l1}).$$

Table of summary

	quark type	lepton type
$n=0$ $\tan\beta \simeq 40$ $M_{\rm GUT} \gtrsim M_F$	$n_{\nu i} = (3,2,0)$ $n_{li} = (1,0,0)$ it would be simplest realization	$n_{\nu i} = (1,0,0)$ $n_{li} = (1,0,0)$ it requires another change of $n_{\nu i}$
$n=2$ $\tan\beta \simeq 1$ $M_{\rm GUT} \ll M_F$	$n_{\nu i} = (3,2,0)$ $n_{li} = (3,2,2)$ incompatible with thermal leptogenesis	$n_{\nu i} = (3,2,2)$ $n_{li} = (3,2,2)$ it requires another change of $n_{\nu i}$

Here, the case n=1 (or (3,2,0) → (2,1,1)) is not considered, because it requires both increase and decrease of FN charges.

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It contains E6 twist model

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In next paper

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Here, the case n=1 (or (3,2,0) → (2,1,1)) is not considered, because it requires both increase and decrease of FN charges.

FN charge should be <u>decrease</u>! ⇒ Partial compositeness

The partial compositeness

D. Kaplan '91, R. Contino, T. Kramer, M. Son, and R. Sundrum, '07

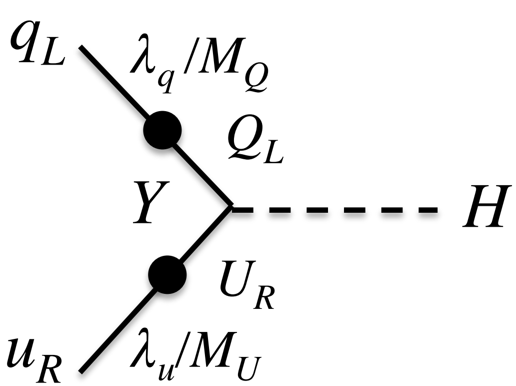
- Elemental and composite fields are mixed as γ-ρ mixing
- Higgs (NGB of a global sym.) only couples to composites
- Theory has massless chiral and massive vectorlike fermions

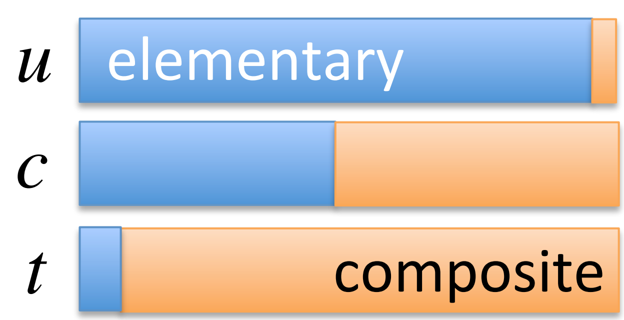
$$\mathcal{L} = \mathcal{L}_{\text{composite}} + \mathcal{L}_{\text{mixing}} + \mathcal{L}_{\text{elementary}} \qquad \mathcal{L}_{\text{mix}} = \lambda^q_{ij}\bar{q}_{Li}Q_{Rj} + \lambda^u_{ij}\bar{U}_{Li}u_{Rj} + h.c.$$

$$(\bar{q}_{Li} \quad \bar{Q}_{Li}) \begin{pmatrix} \lambda^q_{ij} \\ M_{Qi}\delta_{ij} \end{pmatrix} Q_{Rj} + \text{h.c.}\,.$$

$$\boxed{y^u_{\text{SM}} = \lambda^q M_Q^{-1} Y^U M_U^{-1} \lambda^u\,,}$$

"double seesaw like formula"





$$\begin{pmatrix} \epsilon^2 & \epsilon\delta & \epsilon \\ \epsilon\delta & \delta^2 & \delta \\ \epsilon & \delta & 1 \end{pmatrix}$$

Waterfall

model

(We just assume vectorlike massive fermions
And UV completion (and global sym.) is not considered.)

		$SU(4)_c$	$SU(2)_L$	$SU(2)_R$
elementals (massless chiral)	f_{Li}	$\mathbf{4}$	$\mathbf{2}$	$\mathbf{1}$
	f_{Ri}	$\mathbf{4}$	$\mathbf{1}$	$\mathbf{2}$
composites (massive vectorlike)	$F_{(L,R)i}$	$\mathbf{4}$	$\mathbf{2}$	$\mathbf{1}$
	$F'_{(L,R)i}$	$\mathbf{4}$	$\mathbf{1}$	$\mathbf{2}$
Higgs fields	Φ	$\mathbf{1}$	$\mathbf{2}$	$\mathbf{2}$
	H_R	$\mathbf{4}$	$\mathbf{1}$	$\mathbf{2}$

$$\mathcal{L}_{\text{composite}} = \bar{F}_i(i\not{D} - M_{F_i})F_i + \bar{F}'_i(i\not{D} - M_{F'_i})F'_i + Y^F_{ij}\bar{F}_{Li}\Phi F'_{Rj} + \text{h.c.}\,,$$

$$\mathcal{L}_{\text{mixing}} = \lambda^{f_L}_{ij}\bar{f}_{Li}F_{Rj} + \lambda^{f_R}_{ij}\bar{F}'_{Li}f_{Rj} + \text{h.c.}\,,$$

⇒ GUT inv. Yukawa matrices $y^f_{\text{SM}} = \lambda^{f_L} M_F^{-1} Y^F M_{F'}^{-1} \lambda^{f_R}.$

decrese FN charges of d_{Ri}, l_{Li} (3,2,0) → (1,0,0) ⇒ Increase of λ^f or Decrease of M_F by $\langle H_{GUT} \rangle$

Exotics $\psi_L^{\alpha\beta}(6,1,1) \sim (\tilde{D}_R^c, \tilde{D}_L)$ $\chi_R^{ab}(1,2,2) \sim (\tilde{L}_L^c, \tilde{L}_R)$

Mediate GUT breaking vev to d_{Ri} and l_{Li}.

ψ + χ form 10 rep fermion
In SO(10)
σ is for majorana mass

	$SU(4)_c$	$SU(2)_L$	$SU(2)_R$
ψ_L	**6**	**1**	**1**
χ_R	**1**	**2**	**2**
σ	**1**	**1**	**1**

The general Yukawa interactions (between only composites)

$$\mathcal{L} = Y^6 \bar{\psi}_L^{\alpha\beta} H_R^{\alpha a} F_R'^{\beta a} + Y^{22} \bar{F}_L^{\alpha a} H_R^{\alpha b} \chi_R^{ab} + \tilde{Y}^6 \bar{F}_L'^{\alpha a} H_R^{\dagger\beta a} \epsilon^{\alpha\beta\gamma\delta} (\psi_L^c)^{\gamma\delta} + \tilde{Y}^{22} \epsilon^{ad} (\bar{\chi}_R^c)^{de} \epsilon^{eb} H_R^{\dagger\alpha a} F_R^{\alpha b} + h.c.,$$

(∼16_F 10_F 16_H in SO(10))

SSB induces additional linear mixing terms

$$\mathcal{L} \to Y_{ij}^6 V \bar{\tilde{D}}_{Li}^{\alpha} D_{Rj}^{\alpha} + Y_{ij}^{22} V \bar{L}_{Li}^{a} \tilde{L}_{Rj}^{a} + \tilde{Y}_{ij}^6 V \bar{D}_{Li}^{\alpha} \tilde{D}_{Rj}^{\alpha} + \tilde{Y}_{ij}^{22} V \bar{\tilde{L}}_{Li}^{a} L_{Rj}^{a} + h.c.,$$

Analysis

Higgs should couple only with composites (by some global sym.)

⇒ ~~Increase of λ^f~~ or Decrease of M_F by $\langle H_{GUT} \rangle$

Mass matrices

$$\bar{D}_L \begin{pmatrix} M_F & \lambda^f \end{pmatrix} \begin{pmatrix} D_R \\ d_R \end{pmatrix} \to \begin{pmatrix} \bar{D}_L & \bar{\tilde{D}}_L \end{pmatrix} \begin{pmatrix} M_F & \tilde{Y}^6 V & \lambda^f \\ Y^6 V & M_\psi & 0 \end{pmatrix} \begin{pmatrix} D_R \\ \tilde{D}_R \\ d_R \end{pmatrix}$$

decrese FN charges of d_{Ri}, l_{Li} (3,2,0) → (1,0,0)

⇒ 1st, 2nd generation of $D_{L,R}$, $L_{L,R}$ should be lighter $M_{F1,2} \to \lambda^2 M_{F1,2}$

it requires $\lambda^2 \sim$ 5% fine–tuning between $M_{F,\psi}$ and Y^6V.

(This shall not apply when Higgs couples to elemental fields directly.
This case do not have fine tunings, but the "double seesaw formula" can not be justified.)

Majorana neutrino mass

Type I seesaw

⇒ hierarchy of Y_ν and M_R should cancel

⇒ composite neutrino majorana mass is required

$$\mathcal{L} = Y^{1R} \bar{F}_L^{\alpha a} H_R^{\alpha a} \sigma_R + \frac{M_{\sigma R}}{2} \bar{\sigma}_R^c \sigma_R + h.c.,$$

Mediate GUT breaking

$$\mathcal{L} \ni \zeta_{ij}^{f_R} \bar{N}_{Li} \nu_{Rj} - \bar{N}_{Li} M_{Ni} N_{Ri} - \frac{1}{2} m_{Rij} \bar{N}_{Ri}^c N_{Rj} + \mathrm{h.c.}\,,$$

Mediate flavor structure

$$\mathcal{L} \ni -\frac{1}{2} M_{\nu Rij} \bar{\nu}_{Ri}^c \nu_{Rj} + \mathrm{h.c.}\,, \quad M_{\nu Rij} = (\zeta^{f_R T} M_N^{-1} m_R M_N^{-1} \zeta^{f_R})_{ij}.$$

Same flavor structure to Yv

⇒ heavy composites should have trivial flavor structure.

Conclusions

- We considered lopsided texture compatible with thermal leptogenesis in Pati-Salam unification.
- Partial compositeness can generate lopsided texture and decrease FN charges.
- since the GUT Higgs cannot couple with the massless fermions, $\lambda^2 \sim 5\%$ fine-tunings is required for Yukawa matrix.
- In composite sector, trivial flavor structure is desirable for large mixing of MNS matrix.

That’s all. Thank you!

That’s all. Thank you!

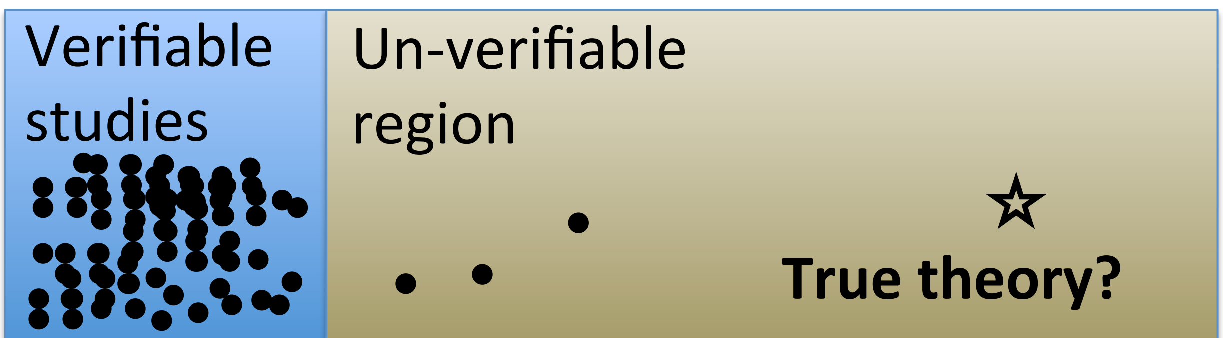
I appreciate if you ask slowly ^^;

Back up

Verifiability（検証可能性）

I don’t care much, because

1. Verifiable models are studied all over the world
2. The true theory might be un−verifiable by exp. in recent years.



Indirect constraint can be done by
RGEs, leptogenesis, consistency, and simpleness.

Flavor texture vs proton decay

Natural texture	**GUT w/o proton decay**
Asymmetric losided texture	PS GUT w/o B breaking
⇒ SU(5) is natural	⇒ LR model
⇒ protons should decay	⇒ texture is symmetric

左右対称な模型から非対称な世代構造を出すには？