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I.C.T.P., P.O. BOX 586, 34100 TRIESTE, ITALY, CABLE: CENTRATOM TRIESTE

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SOLVING SUSY GUT PROBLEMS: GAUGE HIERARCHY, FERMION MASSES AND PROTON DECAY

Z. BEREZHIANI
Dept. of Physics
University of Ferrara, Italy
and
IP, Tbilisi

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MAIN BUILDING STRADA COSTIERA, 11 TEL. 22401 TELEFAX 224163 TELEX 460392 ADRIATICO GUEST HOUSE VIA GRIGNANO, 9 TEL. 224241 TELEFAX 224531 TELEX 460449
MICROPROCESSOR LAB. VIA BEIRUT, 31 TEL. 224471 TELEFAX 224600 TELEX 460392 GALILEO GUEST HOUSE VIA BEIRUT, 7 TEL. 22401 TELEFAX 2240310 TELEX 460392

Solving SUSY GUT problems: gauge hierarchy, Fermion masses, and proton decay (GIFT)

Z. Berezhiani
INFN Ferrara & I.P. Tbilisi

Based on

1. With G. Dvali, 1989
2. With R. Barbieri, G. Dvali, A. Strumia and L. Hall, 199[illegible]
3. Some Next Steps.

Fermion mass Pattern

$\boxed{m_t \sim v = 174 \text{ GeV} ?}$ $\qquad g_t \simeq 1$

$b, \tau, c \sim \varepsilon^2 t \qquad (\varepsilon \sim 0.1)$

$(b = \tau)$

$s, \mu \sim \varepsilon' b \sim \sqrt{ut}$

$\left(s = \frac{\mu}{2}, \frac{\mu}{3}\right)$

. . . .

Fermion mixing pattern

$s_{23} \sim \varepsilon' \sim \frac{s}{b}\ (0.04) \qquad s_{12} \sim 1 \quad (0.22)$

SUSY SU(5) GUT

Fermions: $\bar{5}_i^{\alpha} = (d^c, \ell)_i$, ($\alpha,\beta = 1 \ldots 5$ - SU(5))

$10_{i[\alpha\beta]} = (u^c, q, e^c)_i \qquad i = 1,2,3$

Higgs: $24 = \Phi^{\alpha}_{\beta} \qquad \bar{5}+5 = \bar{H}^{\alpha} + H_{\alpha}$

$$\langle \Phi \rangle = V_G \,\mathrm{diag}\left(\tfrac{2}{3}, \tfrac{2}{3}, \tfrac{2}{3}, -1, -1\right)$$

$$SU(5) \xrightarrow{\langle \Phi \rangle} \underbrace{SU(3) \times SU(2) \times U(1)}_{MSSM}$$

$$5_H = T(3,1) + h(1,2)$$
$$\bar{5}_H = \bar{T}(\bar{3},1) + \bar{h}(1,2)$$

MSSM Higgs
(light)

"GUT" Higgs Triplets (heavy)

$h + \bar{h}$ – light $\Leftarrow$ EW symmetry breaking,
Fermion masses
Coupling crossing.

$T + \bar{T}$ – heavy $\Leftarrow$ Proton stability, Coupling crossing

"Higgs" Superpotential

$$W = \frac{1}{2} M \, Sp\, \Phi^2 + \frac{\lambda}{3} Sp\, \Phi^3 + f(\bar{H} \Phi H) + m \bar{H} H$$

$$\langle \Phi \rangle = \frac{M}{\lambda} \operatorname{diag}(2, 2, 2, -3, -3), \quad \langle \bar{H} \rangle, \langle H \rangle = 0$$

light $h + \bar{h} \Longrightarrow \boxed{m = \frac{3f}{\lambda} M}$ **Fine Tuning**

Then $T + \bar{T} \Longrightarrow$ heavy

GIFT Mechanism

(Goldstones Instead of Fine Tuning)

$\boxed{SU(5)}$ — Inoue, Kakuto, Takano 1986
Anselm, Johansen, 1988

$$\underbrace{24+5+\bar{5}+1}_{SU(5)} \Longrightarrow \underbrace{35}_{SU(6)}$$

$$\Phi + H + \bar{H} + S = \Sigma = \left(\begin{array}{c|c} -\frac{5}{\sqrt{30}} S & H \\ \hline \bar{H} & \Phi + \frac{1}{\sqrt{30}} S \end{array}\right)$$

$$\underbrace{W(\Phi, H, \bar{H}, S)}_{\substack{SU(5)_{loc} \\ SU(5)_{glob}}} = \underbrace{W(\Sigma)}_{\substack{SU(5)_{loc} \\ SU(6)_{glob}}}$$

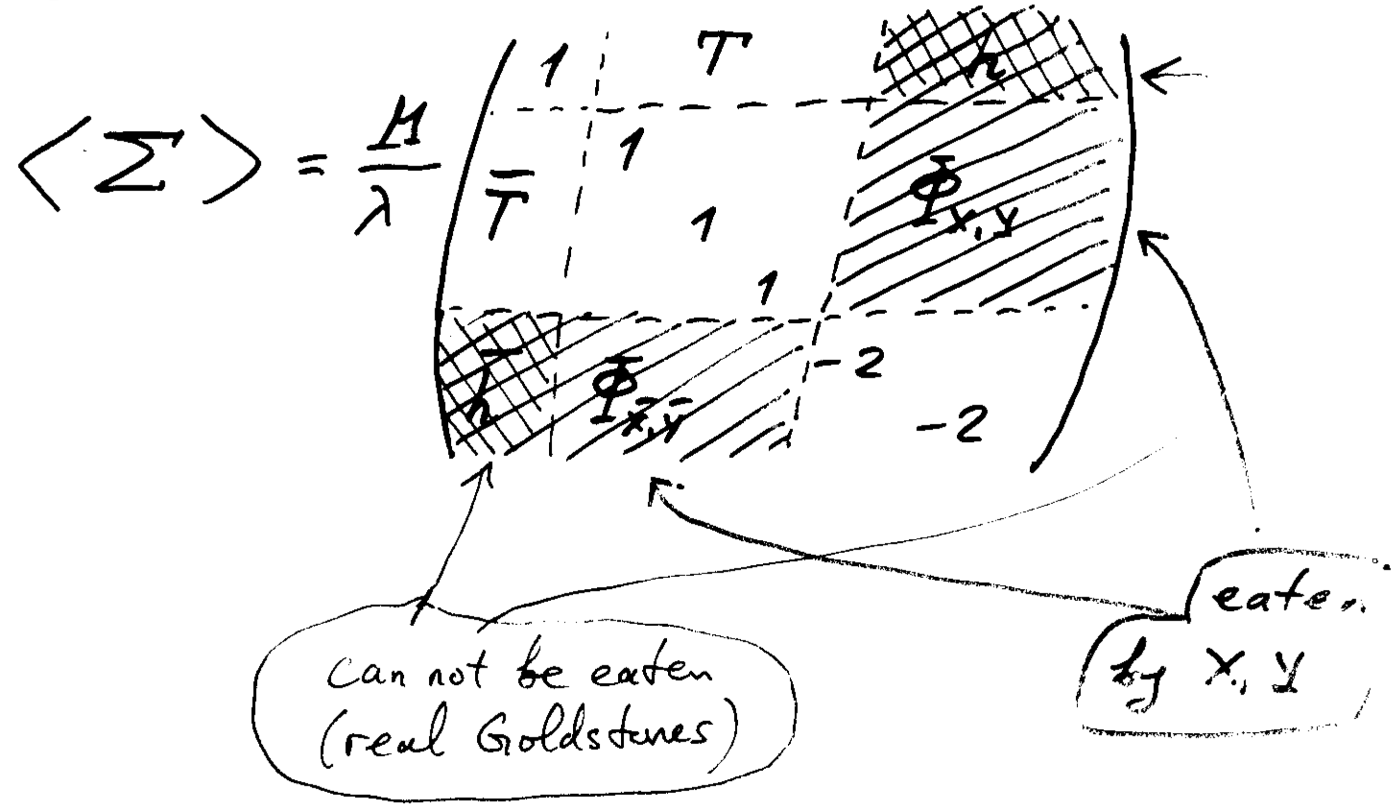
in fact, many fine tunings instead of one

$$W(\Sigma) = \frac{1}{2} M\, Sp\, \Sigma^2 + \frac{1}{3}\lambda\, Sp\, \Sigma^3 =$$

$$= \frac{1}{2}\underline{M}\Phi^2 + \underline{M}\bar{H}H + \frac{1}{2}\underline{M} S^2 + \frac{\lambda}{3}\Phi^3 + \underline{\lambda}\bar{H}\Phi H + \underline{\frac{\lambda}{\sqrt{30}}}\Phi^2 S$$

$$+ \underline{\frac{2}{3}\sqrt{\frac{2}{15}}}\lambda S^3 - \underline{2\sqrt{\frac{2}{15}}}\bar{H}HS$$

However, once being assumed, the extra global symmetry ($SU(6)$) of the Superpotential is stable, until SUSY is unbroken



$$SU(6)_{loc} \to SU(3) \times SU(2) \times U(1)$$

$$SU(6)_{glob} \Rightarrow SU(4) \times SU(2) \times U(1)$$

pseudo — after SUSY is broken

$h + \bar{h}$ are light, since they are Goldstone bosons of extra global pseudosymmetry of Higgs Superpotential

! $SU(6)_{glob}$ is not symmetry of whole superpotential — only of "Higgs" Part

Yukawa Couplings

$$\bar{5} \cdot 10 \cdot \bar{H} + 10 \cdot 10 \cdot H$$

do not respect $SU(6)_{glob}$.

???

If we stay
At $SU(5)$ level

GIFT (Goldstones Instead of Fine Tuning) = LOST (Lot of Strange Tunings)

Thus, we have to go to the Next Floor — $SU(6)$

SU(6) GIFT

Z.B and G. Dvali, 1989

$\boxed{SU(6)_{loc} \text{ Theory}}$

Fermions: $\left[\bar{6}_1^{\alpha} + \bar{6}_2^{\alpha} + 15_{[\alpha\beta]}\right]_i$ $\quad i = 1,2,3$ - family

$\alpha, \beta = 1, \dots 6$ - SU(6)

Higgs: $\Sigma^{\alpha}_{\beta} = 35$, $\bar{H}^{\alpha} + H_{\alpha} = \bar{6}^{\alpha} + 6$

$$SU(6)_{loc} \xrightarrow{\Sigma} SU(4)\otimes SU(2)\otimes U(1)$$
$$SU(6)_{loc} \xrightarrow{H+\bar{H}} SU(5)$$
$$\Rightarrow SU(3)\otimes SU(2)\otimes U(1)$$

$\bar{6}_1 = \underline{\bar{5}_1} + 1$, $\bar{6}_2 = \bar{5}_2 + 1$ $\quad$ $5+\bar{5}$ becomes heavy

$15 = 5 + \underline{10}$ $\quad$ $\bar{5}_1 + 10$ remains light (Standard SU(5) family)

"Higgs" Superpotential:

$$\underbrace{W(\Sigma, H, \bar{H})}_{\substack{SU(6)_{loc} \\ SU(6)_{glob}}} = \underbrace{W(\Sigma)}_{\substack{SU(6)_{loc} \\ SU(6)_{\Sigma\, glob}}} + \underbrace{W(H, \bar{H})}_{\substack{SU(6)_{loc} \\ SU(6)_{H\, glob}}}$$

$$W(\Sigma) = \frac{1}{2} M \Sigma^2 + \frac{1}{3} \lambda \Sigma^3$$

$$W(H, \bar{H}) = S(H\bar{H} - \mu^2)$$

$f \bar{H} \Sigma H$ — is suppressed $\boxed{f=0}$

One "Fine Tuning"

$(\bar{H}H)(\Sigma^2)$

local symmetry — $SU(6)$

Global symmetry of $\underline{W(\Sigma, H, \bar{H})}$ — $SU(6)_\Sigma \times SU(6)_H$

(Not of all Superpotential)

$$\langle \Sigma \rangle = V \left(\begin{array}{cccc|cc} 1 & & & & & \\ & 1 & & & & \\ & & 1 & & & \\ & & & 1 & & \\ \hline & & & & -2 & \\ & & & & & -2 \end{array} \right) \qquad \langle H, \bar{H} \rangle = \begin{pmatrix} V_6 \\ \hline 0 \\ 0 \\ 0 \\ 0 \\ 0 \end{pmatrix}$$

$$SU(6)_\Sigma \xrightarrow{\langle\Sigma\rangle} SU(4)\times SU(2)\times U(1)$$

Goldstones $(4,2)+\underbrace{(\bar 4,\bar 2)}=$

$=(3,2)+(1,2)+\underbrace{(\bar 3,\bar 2)+(1,\bar 2)}$

$$SU(6)_H \xrightarrow{\langle H,\bar H\rangle} SU(5)$$

Goldstones $5+\bar 5 = (3,1)+(1,2)+\underbrace{(\bar 3,1)+(1,\bar 2)}$

$$SU(6)_{loc} \xrightarrow{\Sigma,H,\bar H} SU(3)\times SU(2)\times U(1)$$

$(3,2)_\Sigma$, $(3,1)_H$, and $\underline{\underline{1}}$ combination of
$(1,2)_\Sigma+(1,2)_H$ (+ conjugates)

$\boxed{\text{are eaten up by gauge } SU(6) \text{ bosons}}$

Another combination of $(1,2)_\Sigma+(1,2)_H$
stays <u>massless</u>

$h=\frac{1}{N}\left(3\langle\Sigma\rangle h_H-\langle H\rangle h_\Sigma\right)$ → (Pseudo)Goldst.

$\bar h=\frac{1}{N}\left(3\langle\Sigma\rangle \bar h_H-\langle\bar H\rangle \bar h_\Sigma\right)$ → before SUSY breaking.

In Supergravity

$$V = \sum_{K} \left| \frac{\partial W}{\partial \varphi_K} \right|^2 + \frac{1}{2} g^2 \sum_{\alpha} D_\alpha^2 + V_{SB}$$

$$V_{SB} = A m\, W_3 + B m\, W_2 + m^2 |\varphi_K|^2$$

$$\Downarrow$$

$$V(H_1, H_2) = (m^2 + \mu^2) |H_1 + H_2|^2 + \frac{1}{8}(g_1^2 + g_2^2)(H_1^2 - H_2^2)^2$$

μ - is $\mu H_1 H_2$ mass for Higgsino terms.

$$\boxed{\mu = m \text{ if } A = B - 1}$$

$$V_m = m_1^2 H_1^2 + m_2^2 H_2^2 + m_3^2 (H_1 H_2 + h.c.)$$

boundary — $m_1^2 = m_2^2 = m_3^2$

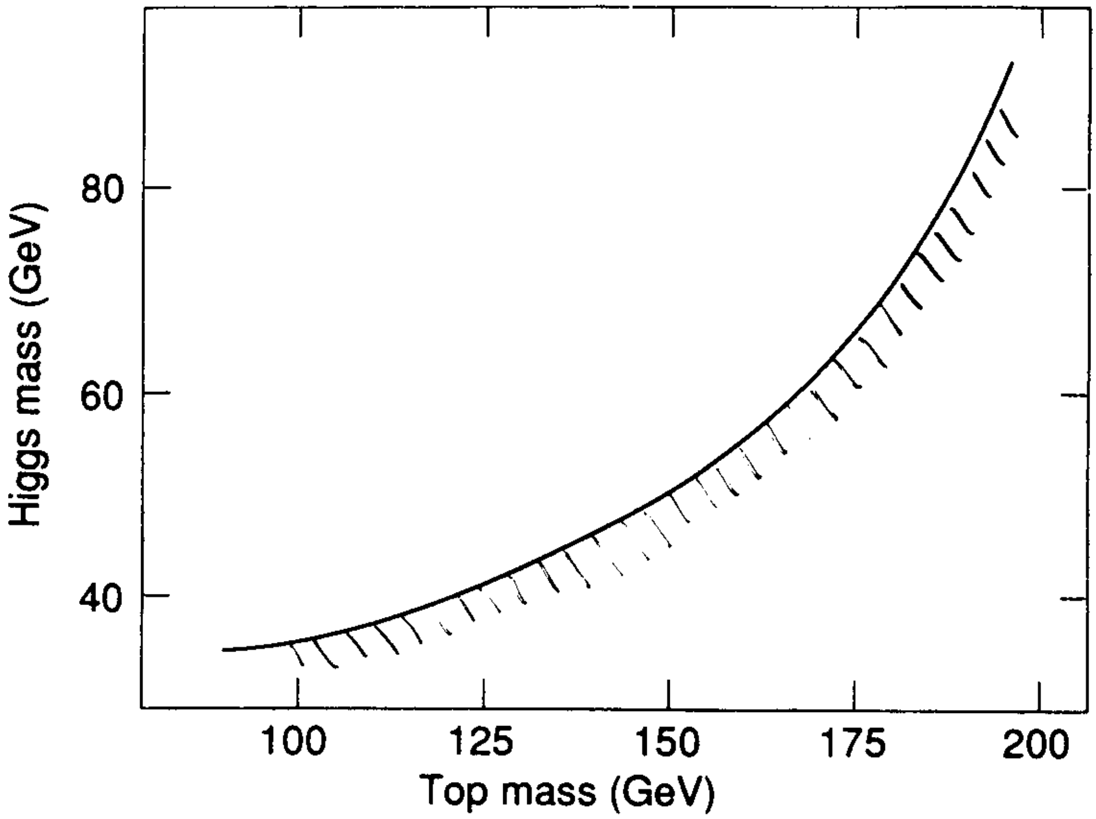
SUSY breaking (without rad. correction) <u>does not</u> break extra global symmetry, and <u>1</u> state stays to be <u>truly</u> Goldstone boson $\underline{\tan\beta = 1}$ at M_{GUT}!

Rad. corrections:

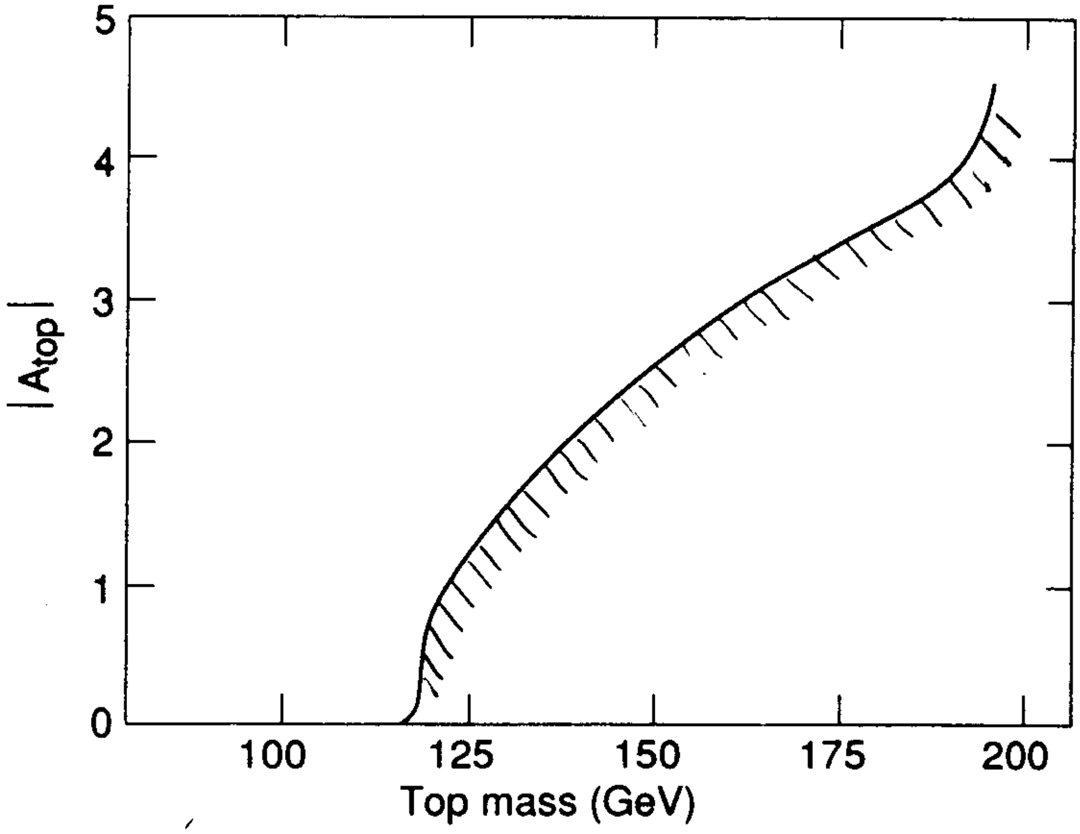
$$V = A\, m\, g_t\, \tilde{t}_L \tilde{t}_R^* H_2 + h.c.$$

etc.

$$v \frac{d}{dv} m_S^2(v) = \frac{3 g_t}{16\pi^2} \left(2m^2 + \mu^2 + A_t^2 m^2 + 2 A_t \mu m\right)$$



- Fig. 1 -



- Fig. 2 -

Ba[illegible], M[illegible]tti, [illegible]993

What for fermion Masses?

$g\,\bar{6}'\cdot 15\cdot \bar{H}$ — the only <u>one</u> renorm coupling allowed by $SU(6)_{loc}$.

$\Big\Downarrow\ SU(5)$

$$\underbrace{g\,\bar{5}'\cdot 5\cdot\langle \bar{H}\rangle}_{\text{becomes superheavy}} + g\,\underbrace{\bar{5}'\cdot 10\cdot h_{\bar{H}}}_{\text{mixes 10 with superheavy state}}$$

$\Downarrow$

No mass term for light down quarks (stays in $\bar{6}$)

Effective operators at which level quarks can get masses:

Down quarks (+leptons) $\frac{1}{M}\,\bar{6}(\Sigma\,\bar{H})15$

Up quarks $\frac{1}{M^2}\,15\cdot(H\Sigma H)\cdot 15$

$$\boxed{m_t \ll m_b \quad ???}$$

SU(6) GIFT and Fermion Masses:

with R. Barbieri, G. Dvali, A. Strumia
L. Hall, 1994

Fermion family structure

$$\bar{6} + \bar{6}' + 15 \xrightarrow[SU(5)]{\langle H\rangle, \langle \bar{H}\rangle} \bar{5} + 10$$

($\bar{5}' + 5$ become heavy)

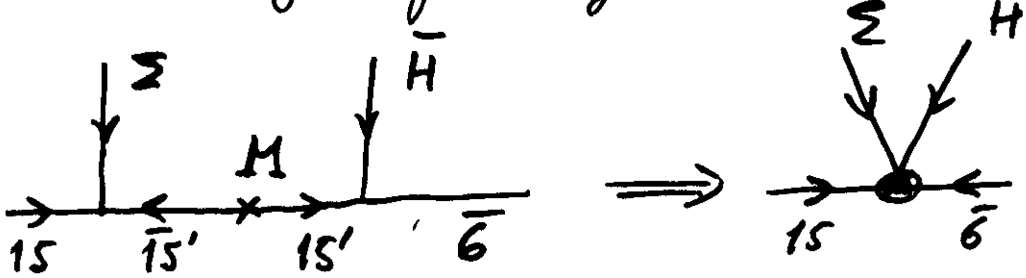
But <u>No</u> mass term for quarks & leptons at renormalizable level

How to make fermion masses?

Theory can (must) contain superheavy vector-like states $\Psi + \bar{\Psi}$ in any representations of SU(6)

$M \bar{\Psi} \Psi$, $M \gg M_{GUT}$ — Survival Hypothesis

exchange of heavy states:



$$\boxed{\frac{1}{M} 15 (\bar{H} \Sigma) \bar{6}}$$

But: Is Survival Hypothesis absolute?
i.e. are all real representations superheavy?

Answer: Not necessarilly:

E.g. $20_{\alpha\beta\gamma}$ — 3-index antisymmet. rep.

$$\underbrace{20}_{u(6)} = \underbrace{10 + \overline{10}}_{su(5)}$$

$$\boxed{\begin{matrix} M \cdot 10 \cdot \overline{10} \; ? \\ \text{No} \end{matrix}}$$

$$M\, 20_{\alpha\beta\gamma} \cdot 20_{\rho\sigma\delta}\, \varepsilon^{\alpha\beta\gamma\rho\sigma\delta} = 0$$

$$M \cdot 20^{A}_{\alpha\beta\gamma} \cdot 20^{B}_{\rho\sigma\delta}\, \varepsilon^{\alpha\beta\gamma\rho\sigma\delta}\, \underline{\underline{\varepsilon_{AB}}}$$

— is antisymmetric

So, if <u>even</u> number of 20's, <u>all</u> are massive.

if <u>add</u> number — <u>1 20-plet</u> stays <u>massles</u>

— <u>survives</u>

What then? New couplings

$20 \cdot 15 \cdot H$ $\qquad (20_{\alpha\beta\gamma} \cdot 15_{\rho\sigma} \cdot H_\delta \, \varepsilon^{\alpha\beta\gamma\rho\sigma\delta})$

$20 \cdot 20 \cdot \Sigma$ $\qquad (20_{\alpha\beta\gamma} \cdot 20_{\rho\sigma\mu} \cdot \Sigma^\mu_\delta \, \varepsilon^{\alpha\beta\gamma\rho\sigma\delta})$

$20 = 10 + \overline{10}$, $\qquad 15 = 5 + 10$ $\qquad \bar{6}' = \bar{5}' + 1$

$\bar{6} = \bar{5} + 1$

$\bar{6}' \cdot 15 \cdot \bar{H}$

$\langle \bar{H} \rangle \, 5 \cdot \bar{5}'$

$\langle H \rangle \, \overline{10} \cdot 10$ – massive

$(20 \cdot 15 \cdot H)$

$10 \cdot 10 \cdot h_\Sigma$

$(20 \times 20 \cdot \Sigma)$

$\langle H \rangle \gg \langle \Sigma \rangle$

$(SU(6) \to SU(5) \to SU(3) \times SU(2) \times U(1))$

$h \simeq h_\Sigma, \quad \bar{h} \simeq \bar{h}_\Sigma$

Only one fermion, which can get mass at the leading order (renormalizable term) – is **one** of the <u>up-quarks</u>

$\Longrightarrow$ top-quark.

But how with other masses?

Next order operators:

$$\frac{1}{M} 15 (\bar{H}\Sigma)\bar{6} + \frac{1}{M^2} 20 \bar{H}\Sigma\bar{H}\bar{6}$$

$$\langle H \rangle \gg \langle \Sigma \rangle \qquad \boxed{\frac{\langle H \rangle}{M} = \varepsilon}$$

$$s, \mu \sim \varepsilon \quad \gg \quad b \sim \varepsilon^2$$

bad !!!

To remind!!! The D-T splitting was also not perfect — $\bar{H}\Sigma H$ coupling was suppressed by hands.

So let's try to introduce some symmetry reasons to solve all problems together!

$SU(6) \times Z_3$ symmetry.

Fermion sector: $[\bar{6} + \bar{6}' + 15]_i + 20 \quad i = 1,2,3$

Higgs sector: $\Sigma_1 + \Sigma_2 \quad (35)$

$H + \bar{H} \quad (6 + \bar{6})$

Z_3:

$\bar{6}_i, \bar{6}'_i$	15_i	20	Σ_1	Σ_2	$H, \bar{H}$
ω	ω^*	ω	ω	ω^*	1

$\omega = e^{i\frac{2\pi}{3}} \qquad \boxed{\omega^* = e^{-i\frac{2\pi}{3}}}$

$\langle H \rangle = \langle \bar{H} \rangle \gg \langle \Sigma_1 \rangle \sim \langle \Sigma_2 \rangle$,

$SU(6) \rightarrow SU(5) \rightarrow SU(3) \times SU(2) \times U(1)$

$\varepsilon_H = \frac{\langle H \rangle}{M}, \qquad \varepsilon_\Sigma = \frac{\langle \Sigma \rangle}{M}$

Z_3 implies automatic matter parity

$\Rightarrow$ R-parity.

"Higgs" Superpotential $\boxed{Z_3 !}$

$$W(H,\bar{H},\Sigma_1,\Sigma_2) = W(H,\bar{H}) + W(\Sigma_1,\Sigma_2)$$

(at renorm. level)

$$W(H,\bar{H}) = \lambda S(\bar{H}H - \mu^2)$$

$$W(\Sigma_1,\Sigma_2) = M\,\Sigma_1\Sigma_2 + \lambda_1\Sigma_1^3 + \lambda_2\Sigma_2^3$$

No $\bar{H}\Sigma H$ due to Z_3

Warning! But $\frac{1}{M}\bar{H}\Sigma_1\Sigma_2 H$ is allowed.

$\downarrow$

$SU(6)_\Sigma \times SU(6)_H$ global symmetry of the Higgs superpotential is automatic

Alternative "Specific" Higgs Superpotential

$$W = S(\bar{H}H - \mu^2) + h\Sigma_1^3 + h'\Sigma_2^3 + \frac{1}{M_{(pl)}}(\bar{H}H)(\mathrm{Tr}\,\Sigma_1\Sigma_2)$$

$$\Uparrow$$

$$Z\bar{H}H + M_{(pl)}Z\bar{Z} + \bar{Z}\,\mathrm{Tr}(\Sigma_1\Sigma_2)$$

$$\langle H\rangle = \langle\bar{H}\rangle = M_6$$

$$\langle\Sigma_1\rangle \sim \langle\Sigma_2\rangle \sim M_5 \sim \frac{M_6^2}{M_{(pl)}} \sim 10^{16}\,\mathrm{GeV}$$

$$\boxed{M_{(pl)} \sim 10^{18}\,\mathrm{GeV}} \Longrightarrow \text{String scale}$$

$$\Downarrow$$

$$M_6 \sim 10^{17}\,\mathrm{GeV}$$

1) $\dfrac{M_5}{M_6} = \dfrac{M_6}{M_{(pl)}} \sim \dfrac{1}{10} \div \dfrac{1}{30}$ $\quad M_{(pl)} \sim 10^{18} \div 10^{19}\,\mathrm{GeV}$

$M_5 = 10^{16}\,\mathrm{GeV}$, $M_6 \simeq 3 \cdot 10^{17}\,\mathrm{GeV}$, $M_{pl} = 10^{19}\,\mathrm{GeV}$

Fermion Masses.

Tree level Yukawa Couplings:

$$\lambda_2 \cdot \overset{(\omega)}{20} \cdot \overset{(1)}{H} \cdot \overset{(-\omega)}{15_3} \Rightarrow \lambda_2 \langle H \rangle \underset{(20)}{\underline{\overline{10}}} \cdot \underset{(15_3)}{10_3} \qquad \text{Mass} \sim M_6$$

$$\lambda_3^{ij}\, \overset{(\omega)}{\bar{6}_i'}\, \overset{(1)}{\bar{H}}\, \overset{(-\omega)}{15_j} \Rightarrow \lambda_3^{ij} \langle \bar{H} \rangle\, \underset{(\bar{6}')}{\bar{5}_i'} \cdot \underset{(15_j)}{\underline{5_j}} \qquad \text{Mass} \sim M_6$$

$$\lambda_1 \cdot \overset{(\omega)}{20} \cdot \overset{(\omega)}{\Sigma_1}\, \overset{(\omega)}{20} \Rightarrow \lambda_1 \cdot 10 \cdot 10 \cdot h_\Sigma \Rightarrow \text{top gets mass}$$

$$h_\Sigma = \Sigma_5^6$$

$$\boxed{t \simeq \lambda_1 v \sin\beta} \qquad \boxed{\lambda_t \equiv \lambda_1}$$

No operators at $\frac{1}{M}$ level!

$$20 = 10 + \underline{\overline{10}}$$

$$15 = \underline{5} + 10_{(3)}$$

$$\bar{6} = \bar{5} + 1$$

$$\bar{6}' = \underset{\sim}{\bar{5}}' + 1$$

Operators at $\frac{1}{M^2}$ order

1) $\frac{\gamma_2}{M^2} \, 20 \cdot \overset{(\omega)}{\bar{H}} \, \overset{(1)}{\Sigma_1} \, \overset{(\omega)}{\bar{H}} \, \overset{(1)}{\bar{6}_3} \overset{(\omega)}{} \Rightarrow \gamma_2 \frac{\langle \bar{H} \rangle^2}{M^2} \, \underset{\subset 10}{10} \cdot \underset{\bar{6}_3}{\bar{5}_3} \cdot \underset{(\Sigma_1)^5_6}{\bar{h}_3}$

b, τ get masses

Since $\frac{\langle \Sigma \rangle}{\langle H \rangle} \ll 1$, $b = \tau \left(1 + O\left(\frac{\varepsilon_\Sigma}{\varepsilon_H}\right)\right)$

$$\boxed{b \cong \tau \simeq \varepsilon_H^2 \gamma_2 \, v \cos\beta}$$

!! – b–τ – Unification !!

$$\boxed{\lambda_b = \lambda_\tau \simeq \varepsilon_H^2 \gamma_2} \Rightarrow m_b \simeq 4.5 \text{ GeV}$$

2) $\frac{\gamma_1^{(ij)}}{M^2} \, 15_i \, \overset{(\omega^*)}{H} \, \overset{(1)}{\Sigma_2} \, \overset{(\omega^*)}{H} \, \overset{(1)}{15_j} \overset{(\omega^*)}{} \Rightarrow$ factorization,

$\gamma_1^{(ij)} = (a, b)^T \otimes (c, d)$

$\Downarrow$

$\gamma_1^{(ij)} = \begin{pmatrix} 0 & 0 \\ 0 & \underline{\underline{\gamma_1^{(2)}}} \end{pmatrix}$

$\frac{\gamma_1^{(2)}}{M^2} \cdot \underbrace{15_2 \cdot H \Sigma_2 \cdot H \cdot 15_2}_{10_2 \langle H \rangle h_2 \langle H \rangle 10_2}$

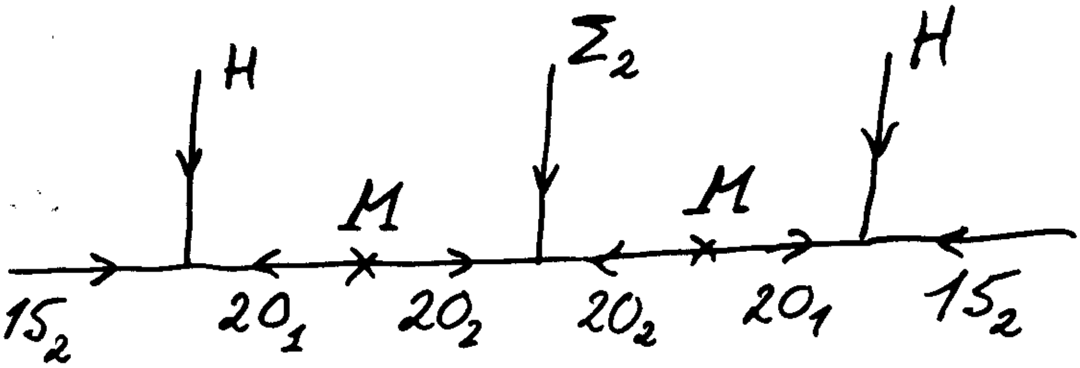
c-quark gets mass

$$\boxed{c = \gamma_1^{(2)} \varepsilon_H^2 \, v \sin\beta} \qquad \lambda_c = \gamma_1^{(2)} \varepsilon_H^2$$

$c \sim b \cong \tau \qquad m_c \sim m_b, m_\tau$

How to achieve "factorization"

– The higher order operators are obtained by heavy fermion state exchange.



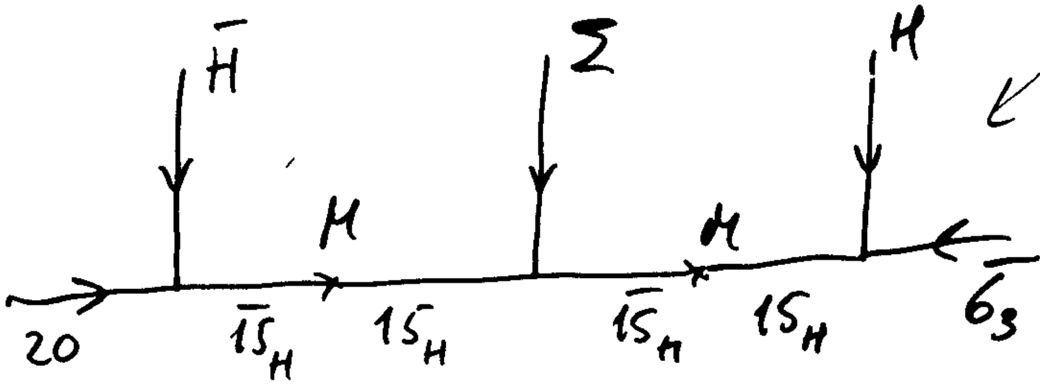
$$\overset{(\omega^*)}{(g_1 15_1' + g_2 15_2')}\ \overset{(\omega)}{20_1} \cdot \overset{(1)}{H} \Rightarrow g\, 15_2\, 20_1 \cdot H$$

the orthogonal state 15_1 is decoupled.

$$M\ \overset{(\omega)}{20_1} \cdot \overset{(\omega^*)}{20_2} \Rightarrow \quad 20_1 + 20_2 \text{ is superheavy,}$$

$$\overset{(\omega^*)}{20_2} \cdot \overset{(\omega^*)}{\Sigma_2} \cdot \overset{(\omega^*)}{20_2} \Rightarrow \quad h_\Sigma = \Sigma_5^6$$

for b-τ



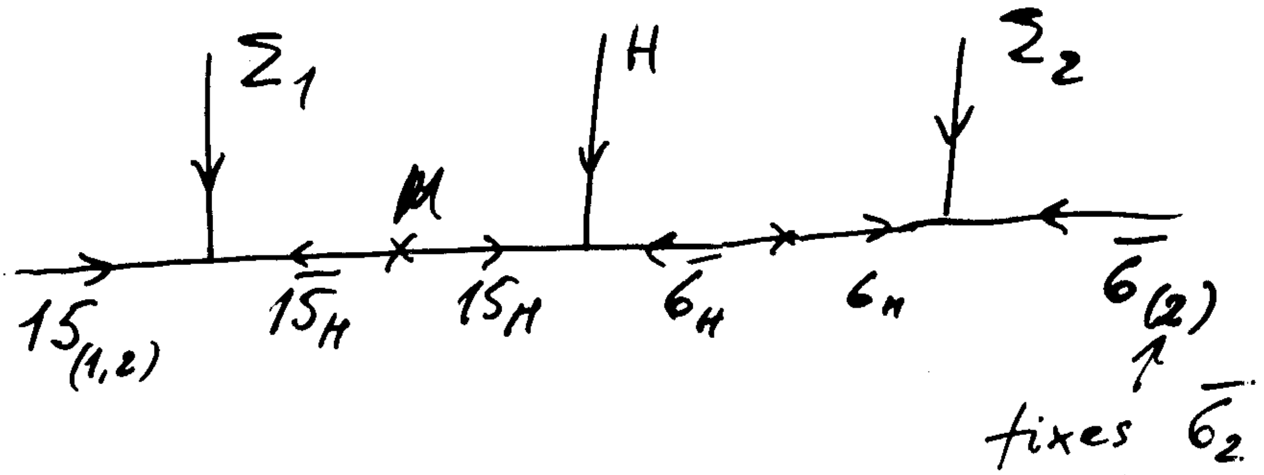
$\frac{1}{M^3}$ order operators:

$$A_1 = \frac{\sigma_2^{(ij)}}{M^3}\, \overset{\omega^*}{15_i}\, (\overset{1}{\bar H}\, \overset{\omega}{\Sigma_1})(\overset{\omega^*}{\Sigma_2}\, \overset{\omega}{\bar 6_j}) \qquad \Delta_e = -2\Delta_d$$

$$A_2 = \frac{\sigma_2^{(ij)}}{M^3}\, 15_i\, (\bar H\, \Sigma_1 \Sigma_2)\, \bar 6_j \qquad \Delta_e = \Delta_d$$

$$A_3 = \frac{\sigma_3^{(ij)}}{M^3}\, (15\, \bar H)(\Sigma_1 \Sigma_2\, \bar 6_j) \qquad \boxed{\Delta_e, \cancel{\Delta_d} = 0}$$

Let's choose A_1; and assume factorisation.



gives s- and μ-masses:

$$\boxed{\lambda_s = -\frac{1}{2}\lambda_\mu \simeq \varepsilon_H \varepsilon_\Sigma \sigma_1^{(2)}}$$

$$\boxed{m_s \simeq 180 \div 200 \text{ MeV}}$$

$$
\begin{array}{c}
 \\ q_1 \\ q_2 \\ q_{20}
\end{array}
\begin{array}{c}
\begin{array}{ccc} u_1^c & u_2^c & u^c_{(20)} \end{array} \\
\left(\begin{array}{ccc}
\varepsilon_\Sigma^2 \varepsilon_H^2 & \sim \varepsilon_\Sigma \varepsilon_H^2 & \sim \varepsilon_\Sigma \varepsilon_H \\
'' - '' & \varepsilon_H^2 \gamma_1 & \sim \varepsilon_\Sigma \varepsilon_H \\
'' - '' & '' - '' & \lambda_1
\end{array}\right)
\end{array}
$$

$$
\begin{array}{c}
 \\ q_1 \\ q_2 \\ q
\end{array}
\begin{array}{c}
\begin{array}{ccc} d_1^c & d_2^c & d_3^c \end{array} \\
\left(\begin{array}{c|cc}
\sim \varepsilon_\Sigma^2 \varepsilon_H & \sigma_{12} \varepsilon_\Sigma \varepsilon_H & \sigma_{13} \varepsilon_\Sigma \varepsilon_H \\
\sim \varepsilon_\Sigma^2 \varepsilon_H & \sigma_{22} \varepsilon_\Sigma \varepsilon_H & \sigma_{23} \varepsilon_\Sigma \varepsilon_H \\
\hline
0 & 0 & \varepsilon_H^2 \gamma_2
\end{array}\right)
\end{array}
\quad
\begin{array}{l}
\updownarrow S_{12} \\
\updownarrow S_{23}
\end{array}
$$

$\frac{\varepsilon_\Sigma}{\varepsilon_H}$

$\sim \varepsilon_H$

$\sim \frac{3}{6}$

$$
\begin{array}{c}
 \\ e_1^c \\ e_2^c \\ e_3^c
\end{array}
\begin{array}{c}
\begin{array}{ccc} l_1 & l_2 & l_3 \end{array} \\
\left(\begin{array}{ccc}
\varkappa\, \varepsilon_\Sigma^2 \varepsilon_H & \multicolumn{2}{c}{\boxed{-\underline{\underline{2}}\, \sigma_{ij}\, \varepsilon_\Sigma \varepsilon_H}} \\
\varkappa\, \varepsilon_\Sigma^2 \varepsilon_H & & \\
0 & 0 & \varepsilon_H^2 \gamma_2
\end{array}\right)
\end{array}
$$

$\boxed{\varkappa = ?}$ to find proper exchange $\frac{1}{12}$ operator.

$$O_1 = \frac{1}{M^3}\, 15 (H \Sigma^3)\, 6 \qquad -\Delta_e = \Delta_d$$

$$O_2 = \frac{1}{M^3}\, 15 (H \Sigma^2)(\Sigma \bar{6}) \qquad \Delta_e = -2\Delta_d$$

$$O_3 = \frac{1}{M^3}\, 15 (H \Sigma)(\Sigma^2 \bar{6}) \qquad \Delta_e = 4\Delta_d$$

$$O_4 = \frac{1}{M^3}\, 15\, H (\Sigma^3 \bar{6}) \qquad \boxed{\Delta_e, \Delta_d = 0}$$

$O_1 + O_2$ works:

$$\frac{m_d}{m_s} = \frac{1}{8}\,\frac{m_e}{m_\mu}$$

$$\Downarrow$$

$$\frac{m_s}{m_d} \simeq 25$$

Results:

1. Only t-quark can be heavy

$$\sim V_{EW} \simeq 174 \text{ GeV}$$

2. $b, \tau, c \sim \varepsilon_H^2\, t$

$b \cong \tau$, $\tan\beta \simeq 1 \div 2$ (moderate)

top is near infrared fix point

$$M_t = \sin\beta\,(190 \div 205)\,\text{GeV} \simeq 140 \div 200 \text{ GeV}$$

$m_A - m_t$ correlation

3. $s, \mu, \sqrt{ut} \sim \varepsilon_\Sigma \varepsilon_H\, t$

$$\boxed{s = -\frac{\mu}{2}} \qquad m_s(1\text{ GeV}) \simeq 150 \div 170 \text{ GeV}$$

$\sqrt{uc} \sim \varepsilon_\Sigma \varepsilon_H^2$

$d, e \sim \varepsilon_\Sigma \varepsilon_H^3$

$u \sim \varepsilon_\Sigma^2 \varepsilon_H^2$

$s_{12} \sim \varepsilon_\Sigma / \varepsilon_H \sim \frac{s}{b}$

$s_{12} \sim 1$

$s_{13} \sim s_{12} \cdot s_{23}$

Summary.

GIFT solves gauge hierarchy + doublet-triplet splitting problem

$h + \bar{h}$ are understood as goldstone bosons of automatic extra global symmetry of Higgs superpotential

After SUSY breaking they pick up $\sim m_{3/2}$ mass —

μ-problem is also solved

$\mu \sim m$

Can be extended further (E_6, ...)

Proposal: to find model in which GIFT mechanism will be stable against $\frac{1}{M_{pl}}$ corrections.

9. $d=5$ operators can be suppressed for proton decay.

No family symmetry, no mass matrix ansatz, no zero texture was used!!!

The family structure came as gift from GIFT mechanism.