LARGE ν MIXING IN GUTs

AND MORE...

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based on work with G. Altarelli and I. Masina
[hep-ph/0007254]

Minimal versions of GUTs (here minimal SU(5)) are plagued by severe fine-tuning problems:

1. DOUBLET-TRIPLET SPLITTING ↔ 10^{-14} adjustm.

splitting upset by $\begin{cases}\text{radiative corrections when } \underline{\cancel{\text{SUSY}}} \\ \text{non-renormalizable operators}\end{cases}$

2. PROTON DECAY minimal SU(5) ruled out by SK: $\tau_p / BR(p \to K^+ \bar{\nu}) > 1.9 \; 10^{33}$ ys 90% CL

In the absence of flavour symmetries:

$$\frac{QQQL}{M_{Pl}} \longrightarrow \tau_p \approx 10^{20}\ \text{ys} \leftrightarrow 10^{-7}\ \text{adjustement}$$

3. WRONG MASS RELATIONS for 1st and 2nd gen.

$$SU(5) \begin{cases} m_e = m_d \\ m_\mu = m_s \end{cases} \longmapsto \begin{matrix} m_e \approx m_d/3 \\ m_\mu \approx 3\, m_s \end{matrix} \quad \text{at the GUT scale}$$

correct order of magnitude

ν masses and mixings

4. $\alpha_s(M_Z)\big|_{\substack{min \\ SU(5)}} = 0.130 \pm 0.01$ within exp. error but somewhat large

5. Additional issues specific to SUSY realization e.g. SUSY flavour problem, ...

We attempted to construct a <u>semi-realistic</u> model, addressing 1 to 4, based on:

$$SU(5) \times \boxed{U(1)_Q} \quad \text{FLAVOUR SYMMETRY}$$

$$SU(5) \longrightarrow SU(3)\times SU(2)\times U(1) \text{ by } \underbrace{\langle Y\rangle \neq 0}_{(75,\,0)}$$

① DT SPLITTING

→ Masiero, Tamvakis, Nanopoulos, Yanagida '82

missing partner mechanism $(5, \bar{5}, 50, \overline{50}, Y, X)$

$X \sim \begin{cases} SU(5) \text{ singlet} \\ Q = -1 \end{cases}$ the only Q-charged field acquiring a large VEV.

- EXACT SUSY :
  - doublets are massless
  - $m_T = \frac{c_2 c_3}{c_4} \frac{\langle Y\rangle^2}{\langle X\rangle}$ effective mass in dim 5, $\Delta B = \pm 1$ operators
  - $\langle X\rangle$ undetermined
  - $5\bar{5}X^m Y^n$ $(m, n \geq 0)$ forbidden by $U(1)_Q$ | stable doublets

- SUS$\not{Y}$:
  - $\langle X\rangle \lesssim \Lambda \leftarrow$ cut-off
  - μ-term from $K = \frac{S^\dagger X^\dagger 5\bar{5}}{\Lambda^2} + \text{h.c.}$

    when $\langle S\rangle = \theta^2 F_S$

2 CONSEQUENCES :

(i) $\alpha_3(M_Z)$ receiveces large threshold corrections from the splitted Y supermultiplet :

$$\underbrace{\alpha_3(M_Z)\Big|_{\substack{\text{missing}\\ \text{partner}}}}_{\text{too small now!}} < \alpha_3(M_Z)\Big|_{\substack{\text{minimal}\\ SU(5)}}$$

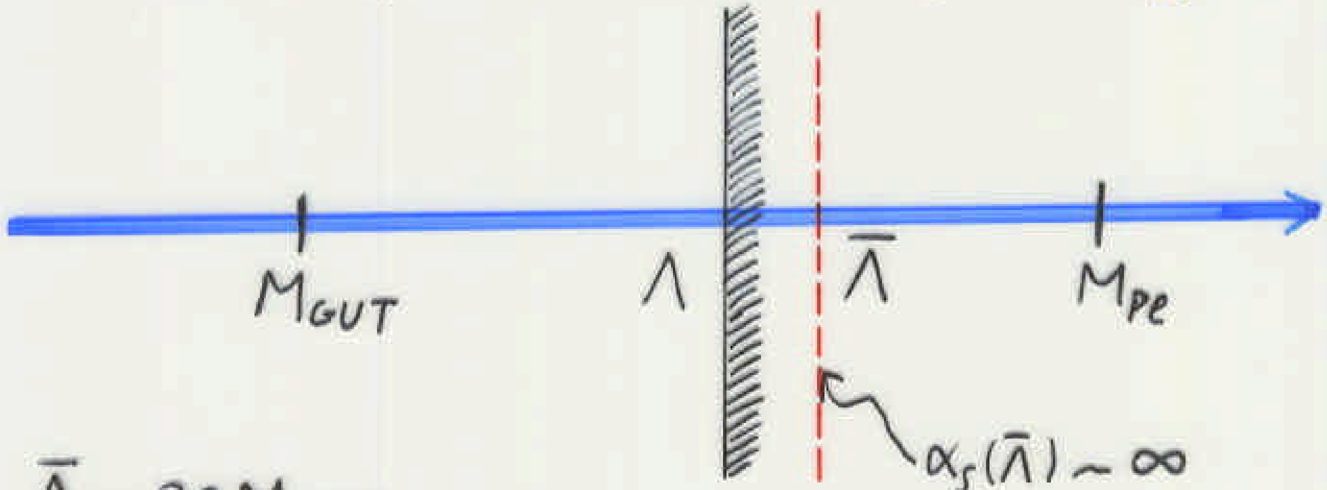
- Yamada '93
- Hagiwara, Yamada '93
- Bagger, Matchev, Pierce '95

larger values of m_T are required

Typically $(m_T)_{\substack{\text{missing}\\ \text{partner}}} \approx 20-30\,(m_T)_{\substack{\text{minimal}\\ SU(5)}}$

good for p-decay.

(ii) SU(5) no longer asymptotically free due to $50+\overline{50}$. $\alpha_5(Q)$ blows up at $\bar{\Lambda} < M_{Pl}$



$$\underbrace{\bar{\Lambda} \approx 20\, M_{GUT}}_{\text{It will be useful}}$$

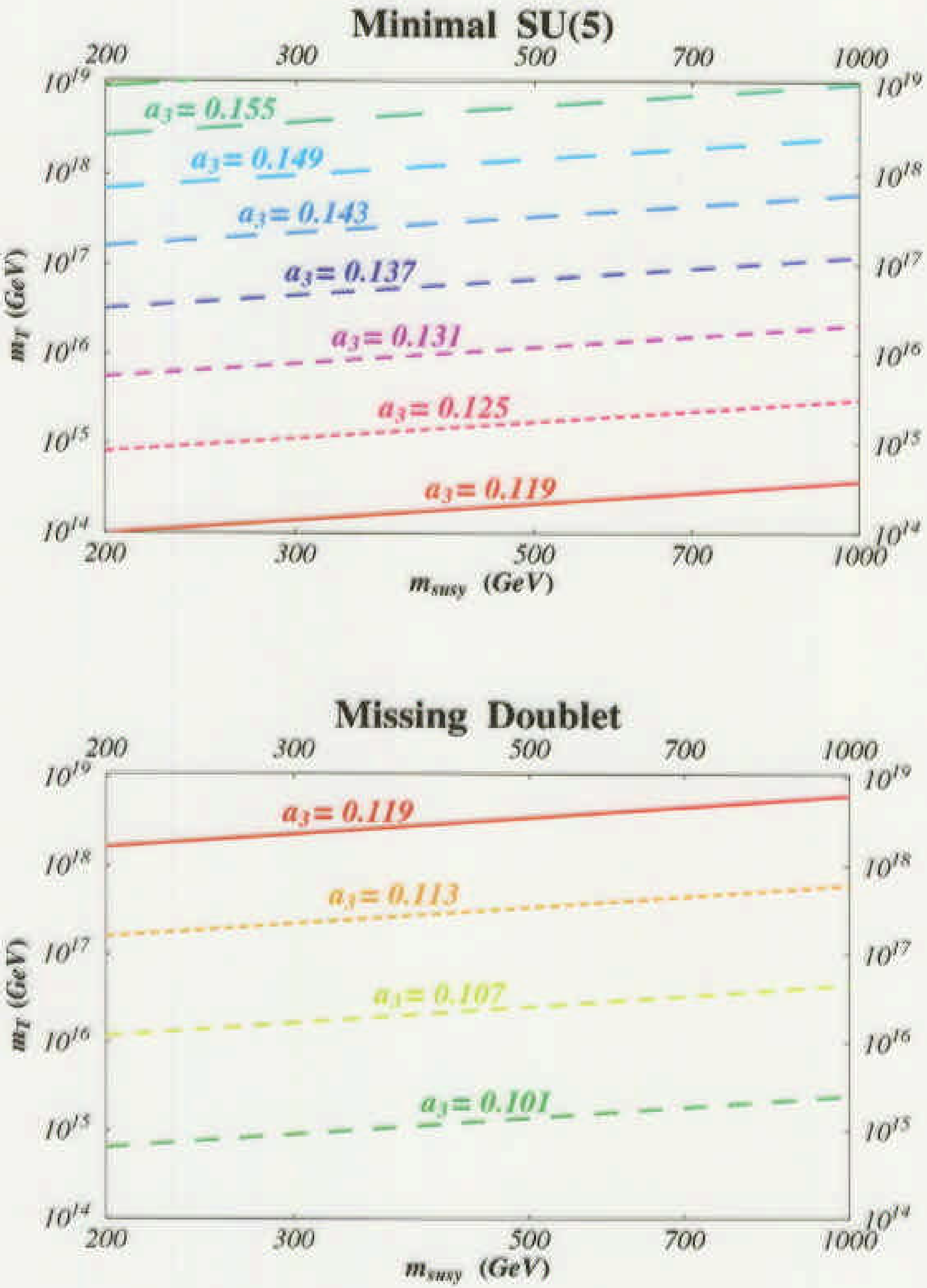


Figure 1: Contours of $a_3 \equiv \alpha_s(m_Z)$ in the plane (m_{SUSY}, m_T), for the minimal $SU(5)$ and the missing doublet model. The SUSY spectrum is parametrized as in Table 1.

③ FERMION MASSES

They come from the $U(1)_Q$ charge assignements

$Q(\Psi_{10}) = (4,3,1)$
$Q(\Psi_{\bar 5}) = (4,2,2)$
$Q(\Psi_1) = (1,-1,0)$
$Q(5) = -2 \quad Q(\bar 5) = +1$

$Q(X) = -1$
no other Q-charged field with large VEV

RESULTS :

- **QUARKS** m_u, m_d, V_{CKM} O.K.
  $tg\,\beta \sim O(1)$ nice for p-decay

- **NEUTRINOS** U(1) assignement + see-saw :

$$m_\nu^{eff} = m_\nu^T M_{maj}^{-1} m_\nu$$

→ large atm mixing ↔ large (μ,τ) mixing
large (s^c, b^c) mixing
from $m_e^T = m_d$

→ large solar mixing
LOW or VO solutions to solar ν problem

→ $\vartheta_{13} \simeq 0{,}05$

- **CHARGED LEPTONS**

$$\underbrace{m_e = m_d^T} \longleftrightarrow \Psi_{10} G_d \Psi_{\bar 5} \bar 5$$

broken by $\frac{1}{\Lambda} \Psi_{10} F_d \Psi_{\bar 5} \bar 5 Y$

$$m_d \approx \left[G_d + \frac{\langle Y \rangle}{\Lambda} F_d \right]$$

$$m_e^T \approx \left[G_d - 3 \frac{\langle Y \rangle}{\Lambda} F_d \right]$$

- G_d, F_d dictated by U(1)
- we can obtain
  $m_e \approx m_d/3$ & $m_\mu \approx 3 m_s$
  with $\frac{\langle Y \rangle}{\Lambda} \approx 10\%$

② PROTON DECAY mainly from dim 5 op.

$$w(\Delta B = \pm 1) = \frac{1}{m_T}\left[Q\hat{A}QQ\hat{C}L + U^c\hat{B}E^cU^c\hat{D}D^c\right]$$

4 differences w.r.to minimal SU(5):

- Hisano
Murayama
Yanagida '93
- Arnowitt
Chamseddine
Nath '85

1. larger m_T by a factor 20-30

→ suppression factor 400-900 in rates

2. Beyond $[\Psi_{10}\, G_u\, \Psi_{10}\, 5]$ also $[\Psi_{10}\, \underbrace{G_{\overline{50}}}\, \Psi_{10}\, \overline{50}]$ is allowed.

unconstrained by data $\langle\overline{50}\rangle = \emptyset$.

$$\hat{B} = -2\hat{A} = \left[G_u - \frac{c_2\langle Y\rangle}{c_4\langle X\rangle} G_{\overline{50}}\right]$$

large region in parameter space where a sizeable destructive interference can occur.

3. $\hat{C} = -G_d \boxed{-\frac{\langle Y\rangle}{\Lambda}F_d}$ $\hat{D} = G_d \boxed{-\frac{\langle Y\rangle}{\Lambda}F_d}$ a not-too-large effect on p-decay rates

absent in minimal SU(5)

4. $A\big|_{\text{non renorm}} \simeq A\big|_{\text{triplet exchange}}$ ← no fine-tuning needed

RESULTS: