Hastening Slowly from MSLRMs to NMSGUT : All ready to roll ?

Charanjit S. Aulakh

(Panjab Univ, Chandigarh & IISER, Mohali)

- Peroration
- SO(10) and MSGUT basics
- SO(10) Fitting Frenzy TO MSGUT Doom : Sumit Garg
- Saving the MSGUT : New Minimal Susy GUT Sumit Garg
- Threshold Corrections at M_S and M_X
- Rolling to be Ready : Searches for $m_f/\theta_f/\Gamma_B^{d=5}$-viable fits

R PARITY and B-L

- SM : Gauge Invariance, Renormalizability $\Rightarrow$
  $B, L(perturbative) \Rightarrow B - L$ (Exact ,Unique Global U(1)).

- MSSM:Sfermions & Shiggs $\Rightarrow$
  $\mathcal{L}_{\Delta_{B,L}\neq 0} = [W_{!R_p}]_F = [\mu' LH + \lambda LLe^c + \lambda' LQd^c + \lambda'' u^c d^c d^c]_F \Rightarrow$
  catastrophic B, L violation $\Rightarrow \tau_p^{d=4} \sim (\frac{gM_S}{\lambda_{!R} M_X})^4 \tau_p^{d=6} \Rightarrow$
  $\lambda_{!R} < 10^{-12}$

- $R_p : Z_2$: *Susy Particles odd* : forbids B,L violating terms
  Mohapatra : (1986) : $R_p = (-1)^{3(B-L)+2S} = (-)^{2S} M_p \Rightarrow$
  $M_p \subset U(1)_{B-L} \subset G_{LR} \subset G_{PS} \subset SO(10)$

- Even B-L vevs(M_ν Compatible) $\Rightarrow$ R$\surd\surd \Rightarrow : \Rightarrow$
  LSP Stable : good as Dark Matter!!
  MSLRMs : CSA,Benakli,Senjanovic, Melfo ....(1995-8)

VIRTUES OF SO(10) UNIFICATION

- $\{Q_L, L_L, u_L^c, d_L^c, l_L^c) \oplus \nu_{\mathbf{L}}^{\mathbf{c}}\} \equiv 16$: Tight and complete !
- Simple Tri-band FM Higgs Channel Spectrum

$$\begin{aligned} 16 \otimes 16 &= 10 \oplus 120 \oplus 126 \Rightarrow (10 + 120 + \overline{126}_H) \\ \overline{126} &= (15,2,2) + \Delta_R(10,1,3) + \Delta_L(\overline{10},3,1) + (6,1,1) \end{aligned}$$

- $M_p \subset U(1)_{B-L} \subset G_{LR} \subset G_{PS} \subset SO(10) \quad \bigoplus < \Delta_{L,R} > \Rightarrow R_p$, Stable LSP
- NATURAL HOME TO BOTH SEESAWS :
  $\vec{\Delta}_R(1,3,-2), \vec{\Delta}_L(3,1,2) \subset \overline{126}$ PRESERVE R_p !!:
  $M_{B-L} \sim < \vec{\Delta}_R >_{SM=0} \Rightarrow M_{\nu^c} \Rightarrow M_\nu^I$
  $\frac{v_W^2}{M_{B-L}} \sim < \vec{\Delta}_L >_{Y=2, T_{3L}=-1} \Rightarrow \Rightarrow M_\nu^{II}$

TWO SCHOOLS OF SO(10)

Renormalizable SO(10)	NON-REN GUTS
Renormalizable couplings	Non Renorm. couplings
No ad-hoc symmetries	Ad-hoc symmetries necessary
Large(126,210,..) few (AS!)	Small (10,16,45,54) irreps (AF)
# Parameter minimal	Unlimited # parameters
No Higgs duplication	Duplicates Higgs
$M_p \subset SO(10)$ gauged	R_p broken or ungauged
Only B-L even vevs	"string motivated" Z_2
Higgs-Matter distinct	Higgs-Matter mix
a) $210 \oplus 126 \oplus \overline{126}$	$16_H^n \oplus 10 \oplus 45^m$ plethora
b)$54 \oplus 45 \oplus 126 \oplus \overline{126}$	

Guts OF MSGUT

- **AM Higgs** : $< \mathbf{210}(\Phi_{ijkl}), \ \overline{\mathbf{126}}(\overline{\mathbf{\Sigma}}_{ijklm}) \ , \mathbf{126} > \Rightarrow$
  $Susy\ SO(10) \longrightarrow MSSM$
- **Superpotential**

$$\begin{aligned} W &= m\ 210^2 + \lambda\ 210^3 + M\ 126 \cdot \overline{126} + \eta\ 210 \cdot 126 \cdot \overline{126} \\ &+ 10 \cdot 210(\gamma\ 126 + \bar{\gamma}\ \overline{126}) \\ &+ M_H\ 10^2 + h_{AB}\ 16_A \cdot 16_B + f'_{AB}\ 16_A 16_B \end{aligned}$$

  Superpotential Parameters : (**25**) **Minimal** !! ABMSV(2003)

- **GUT scale VEVS** : $SO(10) \rightarrow MSSM$

$$\begin{aligned} \langle(15,1,1)\rangle_{210} &: \ a \qquad \langle(15,1,3)\rangle_{210} : \omega \\ \langle(1,1,1)\rangle_{210} &: \ p \\ \langle(10,1,3)\rangle_{\overline{126}} &: \ \bar{\sigma} \quad ; \quad \langle(\overline{10},1,3)\rangle_{126} \ : \sigma \end{aligned}$$

- D Terms, preserve SUSY : $|\sigma| = |\overline{\sigma}|$
- F Terms : SSB completely analyzable !! 4 eqns $\Rightarrow$ **Cubic in**

$x = -\lambda\omega/m : \xi = \frac{\lambda M}{\eta m}$. (ABMSV 2003)

$8x^3 - 15x^2 + 14x - 3 = -\xi(1-x)^2$

- Units : $\frac{m}{\lambda}$
  $\tilde{a} = \frac{(x^2+2x-1)}{(1-x)} \quad ; \quad \tilde{p} = \frac{x(5x^2-1)}{(1-x)^2} \quad ; \quad \tilde{\sigma}\tilde{\overline{\sigma}} = \frac{2}{\eta}\frac{\lambda x(1-3x)(1+x^2)}{(1-x)^2}$
- Chiral GUT scale spectra : 52 MSSM multiplet sets,
  26 MSSM types : 18 unmixed , 8 mixed : 504 Fields

  CSA, Girdhar(2003) ; Fukuyama, Ilakovac, Kikuchi, Mejanac, Okada (2004), BMSV (2004), CSA Girdhar(2004)

  Complete gauge, spinor couplings , Clebsches : CSA Girdhar (2002) (2004) Spectra⇒ RG including Threshold effects etc.CSA, Girdhar (2004)

PARAMETER COUNTING & MINIMALITY

- Minimality: All desire and most claim it ! : Grounds : a) Renorm/Non renorm. (b) Fewer Representations (c) Size of Irreps (AS/AF)(d) Parameter Counting (e) Number of ad-hoc symmetries (f) Higgs channel sparseness/completeness
- MSGUT: Renormalizable, has few irreps AND only one of each , no ad-hoc symmetries, but is AS (but $\Delta_X > 1.5$!!) and Higgs channel incomplete
- COUNTING : $m_{210}, M_{126}, M_H : 3 \times 2 = 6$; $\lambda, \eta, \gamma, \bar{\gamma} : 4 \times 2 = 8$; $y_{10} \oplus y_{\overline{126}} : 2 \times 2 \times 6 = 24$; $Sum = 38$ LESS (4 (Rephasing) + 9 (SO(10)-U(3) flavour) equals 25 superpotential parameters, two more (M_H) fixed by Doublet fine TUNING = 23 real parameters
- PARAMETER COUNTING MINIMAL !! : COMPETITORS (SU(5)NONREN ETC) : > 40 PARAMETERS

MSSM_{eff} : Light Doublets

- Doublet Mass matrix CSA, Girdhar (2003) : $\mathbf{10}, \overline{\mathbf{126}}, \mathbf{126}, \mathbf{210}$

$$\mathcal{H} = \begin{pmatrix} -M_H & +\overline{\gamma}\sqrt{3}(\omega - a) & -\gamma\sqrt{3}(\omega + a) & -\bar{\gamma}\bar{\sigma} \\ -\overline{\gamma}\sqrt{3}(\omega + a) & 0 & -(2M + 4\eta(a + \omega)) & 0 \\ \gamma\sqrt{3}(\omega - a) & -(2M + 4\eta(a - \omega)) & 0 & -2\eta\overline{\sigma}\sqrt{3} \\ -\sigma\gamma & -2\eta\sigma\sqrt{3} & 0 & -2m + 6\lambda(\omega - a) \end{pmatrix}$$

- $\overline{U}^T \mathcal{H} U = Dg(m_H^{(1)}, m_H^{(2)}, ..); \ h^{(i)} = U_{ij} H^{(j)} \ ; \ \bar{h}^{(i)} = \bar{U}_{ij} \bar{H}^{(j)}$
- Fine Tune $M_H (INEVITABLY COMPLEX!) \Leftarrow$

  $Det\mathcal{H} = 0 \Rightarrow$ Light Doublets $H^{(1)}, \overline{H}^{(1)} \Rightarrow E << M_X$

  $h^{(i)} \rightarrow \alpha_i H^{(1)} \ ; \ \alpha_i = U_{i1}; \ \bar{h}^{(i)} \rightarrow \bar{\alpha}_i \bar{H}^{(1)} \ ; \ \bar{\alpha}_i = \bar{U}_{i1}$

  $\mathcal{H}\alpha = 0 \ ; \ \bar{\alpha}^T \mathcal{H} = 0 \ \Rightarrow \alpha, \overline{\alpha}.$

  (ABMSV(2003), BMSV(2004), NMSGUT CSA,Garg(2006))

FERMION YUKAWAS IN SO(10)

- Data for GUT To Explain :
  Measured(17) : $m_{q,l}, \theta_i^{CKM}, \delta^{CKM}, \Delta m_\nu^2, \theta_{12,23}^{PMNS}$
  Bounded: $\theta_{13}^{PMNS} < .1$
- **Awaited (4) :** $M_\nu, \delta^{PMNS}, \alpha_{1,2}^{PMNS}$
- Yukawa couplings : $h = h^T, f = f^T, g = -g^T$
  $W = \mathbf{16}_A \times \mathbf{16}_B \cdot (h_{AB}\mathbf{10} + f_{AB}\overline{\mathbf{126}} + g_{AB}\mathbf{120})$
- MSGUT(AM+CKN 1983)/GENERIC : BABU MOHAPATRA(1992) : USE ONLY $\mathbf{10} + \overline{\mathbf{126}}$
- MSGUT SPECIFIC formulae need 16×16 clebsches CSA,Girdhar(2004,5), NULL EIGENVECTORS OF $\mathcal{H}$ CSA, Bajc, Melfo, Senjanovic,Vissani ; CSA, Girdhar(2005)

$$\begin{aligned} y^u &= (\hat{h} + \hat{f}) \\ y^\nu &= (\hat{h} - 3\hat{f}) \\ y^d &= (r_1\hat{h} + r_2\hat{f}) \end{aligned}$$

$$y^l = (r_1\hat{h} - 3r_2\hat{f})$$

- Weinberg Operator Coefficients :

$$\kappa_\nu^I = v r_4 \hat{n}$$
$$\kappa_\nu^{II} = 2 v r_3 \hat{f}$$
$$\hat{n} = (\hat{h} - 3\hat{f})\hat{f}^{-1}(\hat{h} - 3\hat{f})$$

- Babu and Mohapatra (1992): $\mathbf{10} \oplus \overline{\mathbf{126}} \Leftrightarrow \quad m_{q,l} \Rightarrow$ Predictive in the Neutrino Sector ?! : failure (1992,93,94..)

- Matsuda, Koide , Fukuyama, Nishiura (2002): Type I, large θ^{PMNS}, GENERICfit. CP violation!(complex couplings)

Type II: BM -BSV FITTING FRENZY

- Bajc, Senjanovic, Vissani (2003) Large PMNS mixing angle $b-\tau$ unification connection

  $$M_\nu^{II} \sim f < \Delta_L > \sim (M_d - M_l) \sim m_\tau \begin{pmatrix} & \epsilon^2 & \epsilon^2 \\ \epsilon^2 & & \frac{(m_b - m_\tau)}{m_\tau} \end{pmatrix} \Rightarrow$$

  MSSM : $m_b \simeq m_\tau(M_X)(all\ simple\ GUTs) \quad \Rightarrow \theta_{23}^{PMNS} \simeq 1$

- Goh Mohapatra Ng : Type II : 3 generations, Real/Complex : Good GENERICFits except $\delta^{CKM} > \frac{\pi}{2}$.

- Bertolini, Malinsky (2004)(Type II, $\oplus$120) ; Babu Macesanu (2005)(I+II) **Good Angle and Ratio GENERIC !!**

- Datta Mimura,Mohapatra(2004/5) **120**,$< CP >$,Type II: and GENERIC fits excellent. $d = 5, \Delta B \neq 0$ control by cancellations

MSGUT DOOM(2005)

- Type I ,Type II GENERIC fits : freedom to choose r_1, r_2, r_3, r_4 *assumed.* M_ν scale, Relative strength of Type I / Type II *assumed.* NOT JUSTIFIED IN MSGUT !
- IN MSGUT MAGNITUDE AND RELATIVE STRENGTH OF SEESAW MASSES FIXED !! FIT FULLY SPECIFIED : IS IT VIABLE ??
- Does it Work ? : NO !!CSA , CSA,Garg (2005). SCISSORS : $< \Delta_L(3,1,2) >\sim v_W^2/M_\Delta \Rightarrow$ too small : Type I ¿¿ Type II. BUT Type I itself too small because ; $f_{22}(126) \sim h_2 2(10) << h_{33}$ used for Georgi-Jarlskog 2-generation charged fermion improvement and thus M_{ν^c} is too large !

NMSGUT : FM-Higgs Completion

- $\mathbf{10} \oplus \overline{\mathbf{126}}$ FM Higgs irreps ⇒ Type I , Type II Seesaw failure : $\oplus$**120**-plet : THIRD FM CHANNEL ! ⇒VIABLE y_f, κ_ν???
- **120** Yukawa : $g_{AB} = -g_{BA}$: Novel Fitting Properties.
- NEW SCENARIO : $h \oplus g >> f \quad \Rightarrow (m_{q,l}, \theta_q^i, \delta_c)$.
- $\mathbf{120} \supset (\mathbf{15}, \mathbf{2}, \mathbf{2}) \oplus (\mathbf{1}, \mathbf{2}, \mathbf{2}) \Rightarrow 2$ new doublet pairs ($M_H 6 \times 6$, $M_T 7 \times 7$
- $f << h, g \Rightarrow$ Type I boosted !!($\hat{n} \sim \hat{f}^{-1}$) !
- $f < 10^{-4} \quad \Rightarrow M_X >> M_{\nu^c} \sim< 10^{12} GeV$: Characteristic feature !! Well adapted for Leptogenisis !

Guts of NMSGUT

- Decomposition **120**-plet w.r.t $SU(4) \times SU(2)_L \times SU(2)_R$

$$\begin{aligned} O_{ijk}(120) &= O^{(s)}_{\mu\nu}(10,1,1) + \overline{O}^{\mu\nu}_{(s)}(\overline{10},1,1) + O_{\nu\alpha\dot{\alpha}}{}^{\mu}(15,2,2) \\ &+ O^{(a)}_{\mu\nu\dot{\alpha}\dot{\beta}}(6,1,3) + O^{(a)}_{\mu\nu}{}_{\alpha\beta}(6,3,1) + O_{\alpha\dot{\alpha}}(1,2,2) \end{aligned}$$

- AM SSB unmodified, 26 MSSM multiplet types same.

$$\begin{aligned} W_{120} &= M_O\ 120 \cdot 120 + k\ 10 \cdot 120 \cdot 210 + \rho\ 120 \cdot 120 \cdot 210 \\ &+ \zeta\ 120 \cdot 126 \cdot 210 + \bar{\zeta}\ 120 \cdot \overline{126} \cdot 210 + g_{[AB]} 16_A \cdot 16_B \cdot 120 \end{aligned}$$

- Parameter Counting : Complex Case

$$M_O, k, \rho, \zeta, \bar{\zeta}, g_{AB} : (1+1+1+2+3) \times 2 - 1 = 15 \oplus 24\ \ (old) = 39$$

(Minimal No Longer ?)

- Pangloss approach : Spontaneous CP violation only ? $\Rightarrow$ All Superpot couplings Real (but M_H cannot be !!), CP violation phases phases from vevs ($\Rightarrow Complex\ \ x$!!)

$$\begin{aligned} OLD &: \quad m, M, M_H, \lambda, \eta, \gamma, \bar{\gamma}, h_{AB}, f_{AB} : 7+3+6=16 \\ NEW &: \quad M_O, k, \rho, \zeta, \bar{\zeta}, g_{AB} : 5+3=8 \\ TOTAL &: \quad 24 \ \ I.E \ \ one\ less \ \ than \ \ MSGUT! \end{aligned}$$

- Honest Renormalizable-SO(10) : No ad-hoc CP Z_2 , Keep all gauge allowed couplings. Fine tuning requires complex M_H anyway !! 15 extra phases $\Rightarrow$ 38 couplings in all. Still competitive. Moreover is Structurally minimal and FM-Higgs complete. Effect of phases on fitting flexibility is marginal(LKG)

- 6×6 DOUBLET MASS MATRIX CSA TIWANA; CSA,GARG(2005,6)

$$\begin{pmatrix} -M_H & \bar\gamma\sqrt{3}(\omega-a) & -\gamma\sqrt{3}(\omega+a) & -\bar\gamma\bar\sigma & kp & -\sqrt{3}ik\omega \\ -\bar\gamma\sqrt{3}(\omega+a) & 0 & -(2M+4\eta(a+\omega)) & 0 & -\sqrt{3}\bar\zeta\omega & i(p+2\omega)\bar\zeta \\ \gamma\sqrt{3}(\omega-a) & -(2M+4\eta(a-\omega)) & 0 & -2\eta\bar\sigma\sqrt{3} & \sqrt{3}\zeta\omega & -i(p-2\omega)\zeta \\ -\sigma\gamma & -2\eta\sigma\sqrt{3} & 0 & -2m+6\lambda(\omega-a) & \zeta\sigma & \sqrt{3}i\zeta\sigma \\ pk & \sqrt{3}\bar\zeta\omega & -\sqrt{3}\omega\zeta & \bar\zeta\bar\sigma & -m_o & \frac{\rho}{\sqrt{3}}i\omega \\ \sqrt{3}ik\omega & i(p-2\omega)\bar\zeta & -i(p+2\omega)\zeta & -\sqrt{3}i\bar\zeta\bar\sigma & -\frac{\rho}{\sqrt{3}}i\omega & -m_0-\frac{2\rho}{3}a \end{pmatrix}$$

- DIAGONALIZE $\mathcal{H}$ after $Det\mathcal{H}=0 \Rightarrow, H, \bar H \Rightarrow M_H FIXED$!!
  LIGHT. R-L Eigenvectors $\Rightarrow \alpha_i, \bar\alpha_i$

- Yukawa couplings (CSA,Girdhar(2004),CSA,Garg(2006))

$$\begin{aligned} \hat y^u &= (\check h + \check f + \check g) \quad ; \quad r_1 = \frac{\bar\alpha_1}{\alpha_1} \quad ; \quad r_2 = \frac{\bar\alpha_2}{\alpha_2} \\ \hat y^\nu &= (\check h - 3\check f + (r_5 - 3)\check g) \quad ; \quad r_5 = \frac{4i\sqrt{3}\alpha_5}{\alpha_6 + i\sqrt{3}\alpha_5} \\ \hat y^d &= (r_1\check h + r_2\check f + r_6\check g); \quad r_6 = \frac{\bar\alpha_6 + i\sqrt{3}\bar\alpha_5}{\alpha_6 + i\sqrt{3}\alpha_5} \\ \hat y^l &= (r_1\check h - 3r_2\check f + (\bar r_5 - 3r_6)\check g); \quad \bar r_5 = \frac{4i\sqrt{3}\bar\alpha_5}{\alpha_6 + i\sqrt{3}\alpha_5} \end{aligned}$$

$$\check{g} = 2ig\sqrt{\frac{2}{3}}(\alpha_6 + i\sqrt{3}\alpha_5) \quad ; \quad \check{h} = 2\sqrt{2}h\alpha_1 \quad ; \quad \check{f} = -4\sqrt{\frac{2}{3}}if\alpha_2$$

- New Baryon Decay Channels : $P[3, 3, \pm\frac{2}{3}]$, $K([3, 1, \pm\frac{8}{3}] \subset 120$
- Viable m_f , CKM , Δm_ν^2, PMNS ?? : No! : GJ FAILURE IMPLIES $y_{d,s}$ come out too small. Numerical analysis confirms otherwise excellent fits unable to raise $y_{d,s}$. BUT just for $T_3 = -1/2$ quarks there are significant

Threshold Corrections at M_S

- $\tan\beta \sim m_t/m_b \sim 40-60$ generic in SO(10) GUTs. Single **10** $t-b-\tau$ unification allows $\tan\beta \sim 50-60 \sim m_t/m_b$ only.
- $m_b \simeq m_\tau$ expected in simple single FM Higgs GUTs. Also in SO(10) with negligible $\overline{126}$ yukawas.
- LARGE SUSY THRESHOLD CORRECTIONS to $m^{quark}_{T_3=-.5}$ AT LARGE $\tan\beta$ (α_s(gluino) and ($A_t y_t^2$ loops for 3d gen)) !!! Carena, Olechowski, Pokorski and Wagner(1994); Hall Ratzzi and Sarid(1994)
- FITTING FRENZY IGNORED effect OF THRESHOLD CORRECTIONS IN B-TAU-TOP-ν_τ.... UNIFICATION !!

Large THRESHOLD CORRECTIONS to y_f at M_S

- Threshold corrections in unbroken limit Freitas et al ($\epsilon_i = \epsilon_i^G + \epsilon_i^B + \epsilon_i^W + \epsilon^y \delta_{ib}$):

$$\frac{y_i^{GUT}(M_S)\cos\beta}{y_i^{SM}(M_S)} = \frac{1}{1+\epsilon_i(m_{\tilde{f}}, M_i\mu, A_t)\ \tan\beta}$$

Dominant corrections for quarks:

$$\epsilon_i^G \quad = \quad -\frac{2\alpha_S}{3\pi}\frac{\mu}{M_3}H_2(u_{\tilde{Q}_i}, u_{\tilde{d}_i}) \qquad \epsilon^y = -\frac{y_t^2}{16\pi^2}\frac{A_t}{\mu}H_2(v_{\tilde{Q}_3}, v_{\tilde{u}_3})$$

- Loop function $H_2 < 0$ $\Rightarrow$ lowering $y_{d,s}^{SGUT}$ $\Rightarrow$ $\mu, -A_t >> M_{\tilde{f}}$ with cancellation for y_b FITTING GIVES THIRD GEN SFERMIONS HEAVIER THAN FIRST TWO GENERATIONS ! DISTINCT CLASS OF SPECTRA ! LHC

- Corrections available only in diagonal approximation. Numerical fit requires non degenerate sfermion families at M_X as well as splitting in A_0 values for families !

LARGE THRESHOLD CORRECTIONS to y_f at M_X !

- Negligible ?? BUT $120 \times .1^2 \sim 1 \Rightarrow$ large wavefunction renormalization !

  Threshold correction to a Yukawa coupling matrix then has the form (Wright 1994)

$$Y_f = Y_f + \Delta_f^T \cdot Y_f + \Delta_f \cdot Y_f + \Delta_{H^\pm} \cdot Y_f \qquad (1)$$

  $W = \frac{1}{6}\sum_{ijk} Y_{ijk}\Phi^i\Phi^j\Phi^k \Rightarrow$,

$$\Delta_i^j = \frac{1}{32\pi^2}(-2g_{10}^2 \sum_{k,A} F_1(m_A^2, m_k^2) T_{ik}^A T_{kj}^A + \frac{1}{2}\sum_{kl} Y_{ikl}Y_{jkl}^* F_1(m_k^2, m_l^2)) \qquad (2)$$

  F_1 : Passarino-Veltman function

$$F_{12}(M_A, M_B, \mu) = \frac{1}{(M_A^2 - M_B^2)}(M_A^2 ln\frac{M_A^2}{\mu^2} - ln\frac{M_B^2}{\mu^2}) - 1 \qquad (3)$$

- Large effect on Yukawa couplings! Make possible fits with $A_A^0 = A_0$ and $m_1^0 = m_2^0 \neq m_3^0$ is only non-universal soft breaking.

$d = 5$ NUCLEON DECAY

- FAMILIAR $\bar{t}[\bar{3}, 1, -\frac{2}{3}] \oplus t[3, 1, \frac{2}{3}] \oplus$ NOVEL $P[3, 3, \pm\frac{2}{3}], K[3, 1, \pm\frac{8}{3}]$ MULTIPLET TYPES CONTRIBUTE TO BARYON VIOLATION IN SO(10) BABU,PATI,WILCZEK(2000);CSA,GIRDHAR,GARG(2004,2006)

  $$W_{eff}^{\Delta B \neq 0} = -\hat{L}_{ABCD}(\frac{1}{2}\epsilon \hat{Q}_A \hat{Q}_B \hat{Q}_C \hat{L}_D) - \hat{R}_{ABCD}(\epsilon \bar{\hat{e}}_A \bar{\hat{u}}_B \bar{\hat{u}}_C \bar{\hat{d}}_D)$$

  where the coefficients are

  $$\begin{aligned} \hat{L}_{ABCD} &= \mathcal{S}_1{}^1 \tilde{h}_{AB} \tilde{h}_{CD} + \mathcal{S}_1{}^2 \tilde{h}_{AB} \tilde{f}_{CD} + \mathcal{S}_2{}^1 \tilde{f}_{AB} \tilde{h}_{CD} + \mathcal{S}_2{}^2 \tilde{f}_{AB} \tilde{f}_{CD} \\ &- \mathcal{S}_1{}^6 \tilde{h}_{AB} \tilde{g}_{CD} - \mathcal{S}_2{}^6 \tilde{f}_{AB} \tilde{g}_{CD} + \sqrt{2}(\mathcal{P}^{-1})_2{}^1 \tilde{g}_{AC} \tilde{f}_{BD} \\ &- (\mathcal{P}^{-1})_2{}^2 \tilde{g}_{AC} \tilde{g}_{BD} \end{aligned}$$

  $\mathcal{S} = \mathcal{T}^{-1}$; $\quad W = \bar{t}^i \mathcal{T}_i^j t_j + ...$ similarly R_{ABCD} (also involves K^{-1})

- $L_{ABCD}, R_{ABCD}(M_X)$ GOOD ESTIMATORS FOR

$L_{ABCD}, R_{ABCD}(M_S)$ WE USE WITH SFERMION FITS AND MIXING ASSUMPTIONS TO ESTIMATE DECAY RATE WITHIN SEARCH ALGORITHM

NUMERICAL SEARCH FOR COMPLETE GUT PARAMETERS

PRECISION SM m_f AT $Q = M_Z$

$\Rightarrow$ MSSM +threshold corrections $\Rightarrow$ y_f at fixed $v, \tan\beta$

$\Downarrow$

2 loop MSSM $\Downarrow$ FLOW

$M_X = 10^{16.3}$ GeV,DOWNHILL SIMPLEX,ANTUSCH ERRORS

Unification Constraints, Fit all but $y_{b,d,s}$ accurately

2 loop MSSM soft + hard $M_X \Downarrow M_Z$ RG FLOW

with achieved yukawas $\Downarrow$ and random soft Sugra

LARGE $\tan\beta$ Corrections $\Rightarrow$ FITS Across M_Z to SM Precision Data $\Rightarrow$ Optimal SUGRA SOFT SUSY

USE SPHENO FOR FULL $\Downarrow$ MSSM ONE LOOP EFFECTS

2 loop MSSM RG FLOW TO M_X

$\Downarrow$

ITERATE !

Fitting Features

- "Solutions" with $\chi^2 < .1$ for 18 fermion quadratic data fitted.
- $h_{AB} \sim 10^{-7} - 10^{-2} \quad ; \quad g_{AB} \sim 10^{-2} - 10^{-4} \quad ; \quad f_{AB} \sim 10^{-7} - 10^{-4}$
- $M_X \sim 10^{17.8} - 10^{19} GeV, \Delta\alpha_3(M_Z) \sim -.01, \alpha_G \sim .1, Max(L_{ABCD}, R_{ABCD}) < 10^{-21} GeV^2$
- Third sgeneration much heavier,μ, A0 large and of opposite signs (M_i positive) $M_{\frac{1}{2}}(M_X) = 200.000000000, A^0(MX) = -7061.56862128, (m^2_{\tilde{f}})_{1/2} = 1.169457E6, (m^2_{\tilde{f}})_3 = 5.40168346545E7, m_{H_1^2} = 9.52660735743E6, m_{H_2^2} = -5.45339726387E6$
- $|(y_b - y_\tau)/(y_s - y_\mu)| = 1.0 \pm .05$ Expected on Real Core view !!
- freedom of gaugino phases and mu signs unexploited.
- $d = 5$ Baryon decay rates calculated using complete fit data (Lucas Raby, Goto Nihei) $< 10^{32} yr^{-1}$.

Conclusions

- M_S, M_X threshold corrections to fermion yukawas calculated (M_X due to 120 novel).
- SM data fitted in NMSGUT BY DOWNHILL SIMPLEX SEARCHES in 38 dimensional Superpot parameter space plus 5 soft parameters at M_X
- SO(10) NMSGUT MAY WELL BE COMPATIBLE WITH ALL FM DATA and Baryon decay Constraints
- M_S THRESHOLD CORRECTIONS CONSTRAIN SUGRA SOFT PARAMETERS, THIRD GEN HEAVY, large trilinears A_0 !
- SMALL $\overline{\mathbf{126}}$ COUPLINGS VITAL TO SUCCESSFUL NEUTRINO MASS AND ANGLE FIT : DOOR OPEN TO PERTURBATIVE UNDERSTANDING OF HIERARCHY
- UNIFICATION SCALE GENERICALLY RAISED TO NEAR PLANCK SCALE : ASTRONG PROBLEM POSTOPONED:

so(10) GRAVITY CONNECTION ?

- D=5 NUCLEON DECAY CONSTRAINTS ON SFERMION SPECTRA MARGINALLY SATISFIED : AWAIT SUPERPARTNER DISCOVERY
- NMSGUT VULNERABLE TO FALSIFICATION AT LHC