107

Branch $\langle M \rangle \neq 0$, $B, b = 0$

D-flat: $\langle \check{L} \rangle \neq 0$ $\quad Sp(2N) \to SU(2)$

	$SU(2)$	$SU(2N-1)$
Q'	$\square$	$\square$
L'	$\square$	1
$\bar{u}^{\prime}$	1	$\bar{\square}$
$\bar{D}$	1	$\bar{\square}$

+ singlets

$W = \lambda Q' L' \bar{u}$

generalization of 3-2 model

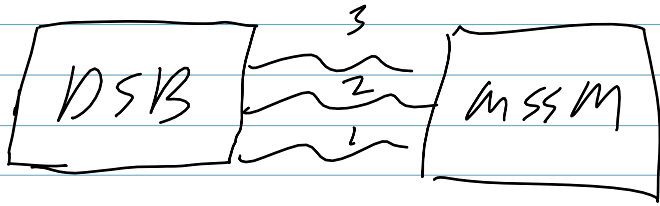
$\langle L \rangle \gg \Lambda_{su}$

$V \sim \Lambda^4_{su,eff} \propto \langle L \rangle^{\#p}$ drives $\langle L \rangle$ smaller

$\langle L \rangle \ll \Lambda_{su}$ use s-confined descr.

$\langle L \rangle \approx \Lambda_{su}$ $\quad V_L \sim \Lambda^4_{su} > V_B(\Lambda_{sp}, \Lambda_{su})$ $\xrightarrow{} 0$ as $\Lambda_{sp} \to 0$

Direct Mediation



	$SU(5)_1$	$SU(5)_2$	$SU(5) \supset SU(3)_1 \times SU(2)_2 \times U(1)$
Y	1	$\overline{\square}$	$\overline{\square}$
ϕ	$\overline{\square}$	1	$\square$
$\overline{\phi}$	1	$\overline{\square}$	1

$$W = \lambda Y \phi \overline{\phi}$$

$Y \gg \Lambda_1 \gg \Lambda_2$ $\qquad \Lambda_{eff}^{3\cdot 5} = \Lambda_1^{3\cdot 5-5} (\lambda X)^5$

$$X = (\det Y)^{1/5}$$

$$W_{eff} = \Lambda_{eff}^3 = \lambda X \Lambda_1^2$$

$$V \approx |\lambda \Lambda_1^2|^2 / Z_X$$

adjust λ local min $\gamma = 0$

$$\langle X \rangle > 10^{14} \text{ GeV}$$

$\Rightarrow$ Landau pole $> M_{pl}$

SUSY min $B\overline{B} = -\Lambda_1^{10}$, $M = 0$

metastability

heavy gauge messengers give
give negative contributions
to squark and slepton masses

$$G \times H \to SU(3) \times SU(2) \times U(1)$$

$$\langle X \rangle = M + \theta^2 F$$

$$\frac{1}{\alpha(\mu)} = \frac{1}{\alpha_G(\mu)} + \frac{1}{\alpha_H(\mu)}$$

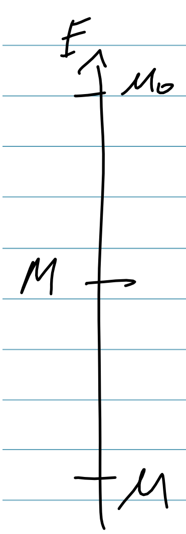
$$\tau = \frac{\theta_{YM}}{2\pi} + \frac{4\pi i}{g^2}$$

$$\tau(X,\mu) = \tau(\mu_0) + i\frac{(b_H + b_G)}{2\pi}\ln\frac{X}{\mu_0} + \frac{ib}{2\pi}\ln\left(\frac{\mu}{X}\right)$$

$$M_\lambda = \frac{1}{2}\frac{\partial \ln \tau}{\partial \ln X}\bigg|_{X=M} \frac{F}{M}$$ sec chap 6.

$$= \frac{-i}{2\tau(M,\mu)} \frac{b_H + b_G - b}{2\pi} \frac{F}{M}$$

$$= \frac{\alpha(\mu)}{4\pi}(b - b_H - b_G)\frac{F}{M}$$



$$Z = Z_0 \left(\frac{\alpha_H(\mu)_0}{\alpha_H(X)}\right)^{\frac{2C_2(r_H)}{b_H}} \left(\frac{\alpha(X)}{\alpha(\mu)}\right)^{\frac{2C_2(r)}{b}}$$

$$\alpha_H^{-1}(X) = \alpha_H^{-1}(\mu_0) + \frac{b_H}{4\pi}\ln\left(\frac{XX^\dagger}{\mu_0^2}\right)$$

$$\alpha^{-1}(X) = \alpha_G^{-1}(\mu_0) + \alpha_H^{-1}(\mu_0) + \frac{(b_H + b_G)}{2\pi}\ln\left(\frac{XX^\dagger}{\mu_0^2}\right)$$

$$\alpha^{-1}(\mu) = \alpha^{-1}(X) + \frac{b}{4\pi}\ln\left(\frac{\mu^2}{XX^\dagger}\right)$$

$$m_Q^2(\mu) = 2C_2(r)\left(\frac{\alpha(\mu)}{4\pi}\right)^2\left(\frac{F}{M}\right)^2$$
$$\times\left(\left(b+(R^2-2)b_H-2b_G\right)\xi^2+\frac{(b-b_H-b_G)(1-\xi^2)}{b}\right)$$

$$\xi=\frac{\alpha(M)}{\alpha(\mu)} \qquad R=\frac{\alpha_H(M)}{\alpha(M)}$$

$b_Y < 1$ Not A.F.

RH sleptons only have hypercharge
typically negative m^2

two-loop R.G.

$$\frac{d\,m_Q^2}{d\ln\mu} \propto g^2\left(c\,g^2\,\mathrm{Tr}\left((-1)^{2F}m_{ij}^2\right)-M_\lambda^2\right)$$

light messenger

drive + in IR

111

$\boxed{\text{DSB MSSM}}$ $\subset SU(5) \subset SU(3) \times SU(2) \times U(1)$

Single Sector

	$SU(k)$	$SO(10)$	$SU(10)$	$SU(2)$
Q	$\square$	$\square$	1	1
L	$\bar{\square}$	1	$\square$	1
$\bar{u}$	1	$\square$	$\bar{\square}$	1
S	1	16	1	$\square$

$$W = \lambda Q L \bar{u}$$

$\det \bar{u} \gg \Lambda_{10}$ $\quad W_{eff} \sim \bar{u}^{10/k}$

$\det \bar{u} \ll \Lambda_{10}$ $\quad W_{eff} \sim \bar{u}^{\frac{10(1-\gamma)}{k}}$

$$10 \geq k > 10(1-\gamma)$$

2 composite generations $\sim S$

degen. comp. squarks sleptons $m^2 \sim \frac{F^2}{\langle \bar{u} \rangle^2} = m_{comp}^2$

comp fermion masses suppressed $\sim$ higher dim op.

messengers $Q, \bar{u}, L$

fund. $\quad m_\lambda \sim \frac{\alpha}{4\pi} m_{comp}$

fund $\quad m_\phi^2 \sim \left(\frac{\alpha}{4\pi} m_{comp}\right)^2$

fund $\quad m_t \sim \lambda_t \langle H \rangle$

more minimal spectrum

The Coulomb Phase

$SO(N)$ $F = N-2$ generically $SO(N) \to SO(2) \sim U(1)$

dual is also $SO(2) \sim U(1)$

EM duality $E \leftrightarrow B$

S: $\tau \to \frac{-1}{\tau}$ exchanges two equiv. descr.

T: $\theta_{YM} \to \theta_{YM} + 2\pi$, $\tau \to \tau + 1$

$\Big\}\ SL(2, \mathbb{Z})$

holomorphic $\tau = \frac{\theta_{YM}}{2\pi} + \frac{4\pi i}{g^2}$

cannot be single valued

for large $z = \det(M)$ complex #

$\tau \approx \frac{i}{\pi} \ln\left(\frac{z}{\Lambda^b}\right)$ singularity at $z = \infty$

$\phi_j \to e^{2\pi i} \phi_j$, $z \to e^{2F\pi i} z$

$\tau \to \tau - 2F$ $\Big\}$ Monodromy $\mathcal{M}_\infty = T^{-2F}$

not single valued even at weak coupling

$\mathrm{Im}\,\tau = \frac{4\pi}{g^2}$ is invariant under $\mathcal{M}_\infty$
single valued at weak coupling

If $\mathrm{Im}\,\tau$ was single valued everywhere then $\frac{d^2}{dz^2}\mathrm{Im}\,\tau$ is well defined

since τ is holomorphic

$z = x + iy$ $\left(\frac{d}{dx^2} + \frac{d}{y^2}\right)\mathrm{Im}\,\tau = 0$

then its a harmonic function

cannot be positive definite

$\Rightarrow g^2_{eff}$ is imaginary

$\therefore$ $\mathrm{Im}\,\tau$ is not single valued

complicated topology of moduli space

$\downarrow$

?

or

singular points z_i

$\downarrow$

some particles become massless

these points have monodromies M_i

if $[M_i, M_\infty]$ commute then $\mathrm{Im}\,\tau$ is single valued