Quantum Effects in String theoretic SUSY Breaking

StringPheno 09

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1. Spontaneous SUSY breaking in Global SUSY leads to a CC at the SUSY breaking scale - cannot be fine-tuned to zero.

2. Adding a set of explicit soft SUSY breaking terms to a global theory (like the MSSM) has far too much arbitrariness - does not give us a theory.

3. A theory of SUSY breaking is therefore necessarily a SUGRA with a scalar potential which has a minimum that breaks SUSY spontaneously.

4. As is well known such a theory allows the fine-tuning of the CC to zero (i.e.$10^{-120}M_P^4$).

5. A SUGRA needs to be embedded in string theory.

Experimental inputs:

- CC is tiny $\sim O((10^{-3}eV)^4)$
- No light scalars with gravitational strength coupling
- SUSY partner masses $\gtrsim O(100GeV)$
- Lightest Higgs $> 114GeV$
- Flavor changing neutral currents (FCNC) suppressed
- No large CP violating phases

Theory of SUSY breaking must satisfy these.

Better still these should emerge naturally from the theory!

Work within general framework of SUGRA

Set

$\kappa^2 \equiv 8\pi G_N = M_P^{-2} = 1$

$d^8z \equiv d^4xd^4\theta$, $d^6z \equiv d^4xd^2\theta$

Action depends on

$K(\Phi^A, \bar{\Phi}^{\bar{A}})$, $W(\Phi^A)$, $f(\Phi^A)$.$A = 1, \ldots N$

At two derivative level this structure is fixed by SUGRA.

Quantum corrections only have effect of changing the classical form of the functions K, W, f with following caveats.

1. W (holomorphic) - no perturbative corrections
2. f (holomorphic) - No higher than one loop perturbative corrections
3. K (real analytic) - Has both perturbative and NP corrections.

Starting point of String Phenomenology.

Classical K given by String theory.

W, f obtained from string theory with NP effects in W as suggested by field theory and/or string instanton calculations.

Chiral (super) Fields Φ^A:

Φ^i: 'Moduli' (gauge singlets)

C^α: MSSM Fields $H_{1,2}$ Higgs.

$$
\begin{aligned}
W &= \hat{W}(\Phi) + \tilde{\mu}_{\alpha\beta}(\Phi) C^\alpha C^\beta + \\
&\quad \frac{1}{6} Y_{\alpha\beta\gamma}(\Phi) C^\alpha C^\beta C^\gamma + \ldots, \\
K &= \hat{K}((\Phi, \bar{\Phi}) + \tilde{K}_{\alpha\bar{\beta}}(\Phi, \bar{\Phi}) C^\alpha \bar{C}^{\bar{\beta}} \\
&\quad + [Z_{\alpha\beta}(\Phi, \bar{\Phi}) C^\alpha C^\beta + h.c.] + \ldots \\
f_a &= f_a(\Phi).
\end{aligned}
$$

a labels gauge groups. $\tilde{\mu}_{\alpha\beta} = \mu \delta_\alpha^{H_1} \delta_\beta^{H_2}$, $Z_{\alpha\beta} = Z \delta_\alpha^{H_1} \delta_\beta^{H_2}$

Potential:

$$V(\Phi) = F^A F^{\bar{B}} K_{A\bar{B}} - 3|m_{3/2}(\Phi)|^2 + \sum_a f_{ab} D^a D^b$$

$$F^A = e^{K/2} K^{A\bar{B}} D_{\bar{B}} W, \; D_A W \equiv \partial_A W + K_A W$$

$$|m_{3/2}|^2 \equiv e^K |W|^2, \; K_A = \partial_A K, \; K_{A\bar{B}} = \partial_A \partial_{\bar{B}} K$$

$$D^a = f^{ab} k_b^A D_A W / W$$

$$f_{ab} = f_a \delta_{ab}, \; k_a = \text{Killing vector}$$

Any theory of SUSY breaking must start from finding a minimum for V which breaks supersymmetry with zero CC:

$$F^i \neq 0, \; |F|^2 = 3m_{3/2}^2,$$

Note: Required for consistency of GMSB also! Without a theory of modulus stabilization it is impossible to claim the dominance of one or other mechanism of SUSY breaking and transmission. Even with such a theory it becomes a matter of landscape statistics!

Predictions for LHC physics from a general SUGRA:

KL formulae for soft terms Kaplunovsky+Louis, Brignole+Ibanez+Munoz

$$\begin{aligned}
\mu_{\alpha\beta} &= e^{\hat{K}/2}\tilde{\mu}_{\alpha\beta} + m_{3/2}Z_{\alpha\beta} - \bar{F}^{\bar{A}}\partial_{\bar{A}}Z_{\alpha\beta}, \\
B\mu_{\alpha\beta} &= F^A D_A \mu_{\alpha\beta} - m_{3/2}\mu_{\alpha\beta}, \\
M_a &= \frac{F^A \partial_A f_a}{2 f_a}, \\
m^2_{\alpha\bar{\beta}} &= V|_0 \tilde{K}_{\alpha\bar{\beta}} + (m^2_{3/2}\tilde{K}_{\alpha\bar{\beta}} - F^A F^{\bar{B}} R_{A\bar{B}\alpha\bar{\beta}}), \\
A_{\alpha\beta\gamma} &= F^A D_A e^{\hat{K}/2} Y_{\alpha\beta\gamma}.
\end{aligned}$$

Here $D_A = K_A/2 + \nabla_A$. PQ symmetry $\tilde{\mu} = 0$.

The fact that these formulae are valid even after including quantum effects can hardly be over emphasized.

This means that for instance that AMSB formulae are also contained here! All one needs to do for that is to use the expression for f_a given in another KL paper! SdA hep-th/0801.0578

Effective physical gauge coupling:

C: Weyl compensator, $c_a = T(G_a) - \sum_r T_a(r)$ sum over all light matter reps of gauge group G_a.

$$\begin{aligned} H_a(\Phi) &= f_a(\Phi) - \frac{3c_a}{8\pi} \ln C - \\ &\quad \frac{T_a(r)}{4\pi^2} \ln \tau_{matter} - \frac{T_a(G_a)}{4\pi^2} \tau_{gauge}. \end{aligned}$$

C Weyl compensator - Second term cancels Weyl anomaly. To get Kaehler-Einstein gauge set:

$$\ln C + \ln \bar{C} = \frac{1}{3} K|_{harmonic}$$

τ chiral rotation on matter fields. From normalizing matter Kinetic terms:

$$\tau_{matter} + \bar{\tau}_{matter} = \ln \det \tilde{K}_r|_{harmonic}$$

$\tilde{K}_r$ matter metric in rep r

From normalizing gauge Kinetic terms:

$$\tau_{gauge} + \bar{\tau}_{gauge} = -\ln \Re H_a|_{harmonic}$$

Lowest component gives NSVZ formula for gauge coupling.

F-term of H gives:

$$\begin{aligned} \frac{m_a}{g_a^2} &= [\Re F^i \partial_i f_a(\Phi)| - \frac{c_a}{8\pi^2} F^i K_i - \\ &\quad \frac{T_a(r)}{4\pi^2} F^i \partial_i (\ln \det \tilde{K}_r)] \times \\ &\quad [1 - \frac{T(G_a)}{8\pi^2} g_a^2]^{-1} \end{aligned}$$

NSVZ type formula for gaugino mass. Valid at any scale to all orders in P.T.! SdA to appear

All forumulae at a given scale - i.e. m_a/g_a^2 at scale μ given by RHS with f_a, K etc evaluated at that scale. Contains entire contribution of AMSB.

Identify classical theory at scale Λ (chosen fixed independent of moduli) needs to be below string thresholds. To one loop can take $K, \tilde{K}_r$ at classical values.

Identify original classical coupling f at Λ. If no thresholds

$$f_a(\Phi;\mu) = f_a(\Phi;\Lambda) - \frac{b'_a}{8\pi^2}\ln\frac{\Lambda}{\mu}.$$

Note second term gives no contribution to m_a/g_a^2 contrary to usual AMSB arguments where factor of C inserted in log!

Suppose intermediate threshold at X (with $F^X \neq 0$) (as in GMSB)

$$f_a(\Phi,X;\mu) = f_a(\Phi;\Lambda) - \frac{b_a}{8\pi^2}\ln\frac{X}{\mu} - \frac{b'_a}{8\pi^2}\ln\frac{\Lambda}{X}$$

Then contribution to m_a/g_a^2

$$\Re f_a(\Phi,\mu)|_F \sim \Re f_a(\Phi;\Lambda)|_F - \frac{b_a - b'_a}{8\pi^2}\frac{F^X}{X_0}$$

If $F^X/X \sim m_{3/2}$ can lead to additional term $\propto m_{3/2}$ as in the usual argument but coefficient is different!

Generic possibilities after moduli stabilization - $m_{soft} \sim 1TeV$

- mSUGRA: $m_{soft} \sim m_{3/2}$. Quantum effects suppressed. Cosmological problems

- Sequestered mSUGRA: No scale and extended no-scale type $m_{soft} \ll m_{3/2}$. Quantum effects comparable to classsical. AMSB special case usually additional contribution of same order.

- GMSB: Need to have $m_{3/2} \ll m_{soft}$. Additional sector for SUSY breaking. Need to stabilize with moduli and additional sector X and find a minimum such that F_X/X dominates over $F_{Modulus}/M_P$. Highly fine-tuned from Landscape point of view. Also need a messenger sector.

String Theory IIB input:

Moduli Kaehler potential (classical): α' correction included. $\xi > 0$ for $h_{12} > h_{11}$.

$$\begin{aligned}\hat{K} &= -2\ln\left(\mathcal{V} + \frac{\xi}{2}\left(\frac{(S+\bar{S})}{2}\right)\right) \\ &\quad - \ln\left(i\int \Omega \wedge \bar{\Omega}(U,\bar{U})\right) - \ln(S+\bar{S}),\end{aligned}$$

S - dilaton, $U = \{U^a\}$ - $a = 1, \ldots, h_{12}$ - complex structures

Even with only one T, (with race track)

$$F^T \sim m_{3/2},\ F^S, F^U \ll m_{3/2},\ |V_0| \sim \frac{m_{3/2}^2}{\mathcal{V}}$$

minimum possible for fine tuned $W_{flux} \ll 1$.

Much nicer to have (with at least two T^i)

"Swiss Cheese" type- h homogeneous function - degree 3/2. Conlon, Quevedo+...

$$\mathcal{V} = \tau^{3/2} - h(\tau^l),$$

$\tau^l = \frac{1}{2}(T^l + \bar{T}^{\bar{l}})$, $l = 1, \ldots, h_{11}$ - Kaehler structures. $\tau \equiv \tau^1$

LVS minimum

$$|V_0| \sim \frac{W_0^2}{\mathcal{V}^3} \sim \frac{m_{3/2}^2}{\mathcal{V}}$$

$$\sum A_i e^{-a_i T^i} \sim \frac{W_{flux}}{\mathcal{V}}$$

$$M_{string} \sim \frac{1}{\sqrt{\mathcal{V}}},\; M_{KK} \sim \frac{1}{\mathcal{V}^{2/3}} \sim \frac{1}{\tau}$$

Estimate of F-terms:

$$
\begin{aligned}
F^T \bar{F}^{\bar{T}} K_{T\bar{T}} &\sim 3m_{3/2}^2 \\
F^i \bar{F}^{\bar{j}} K_{i\bar{j}} &\lesssim \frac{m_{3/2}^2}{\mathcal{V}} \\
F^S \bar{F}^{\bar{S}} K_{S\bar{S}} &\lesssim \frac{m_{3/2}^2}{\mathcal{V}} \\
F^a \bar{F}^{\bar{b}} K_{a\bar{b}} &\lesssim \frac{m_{3/2}^2}{\mathcal{V}}
\end{aligned}
$$

Last two can potentially give classical uplift!

Matter:

On D3 brane at a singularity or D7 brane wrapping a four-cycle. Dynamics of potential minimization drives this below string scale to a collapsed cycle: Maharanna, Conlon, Quevedo+

Matter metric Large volume behavior:

$$\tilde{K}_{\alpha\bar{\beta}} \sim \frac{k_{\alpha\bar{\beta}}(\tau^i, U, \bar{U}, S, \bar{S})}{\mathcal{V}^{2/3}} \sim \frac{k_{\alpha\bar{\beta}}(U, \bar{U}, S, \bar{S})}{\tau}$$

$$Z_{\alpha\beta} \sim \frac{z_{\alpha\beta}(\tau^i, U, \bar{U}, S, \bar{S})}{\tau}$$

Last formula from requiring finite non-zero physical Yukawas as $\mathcal{V} \to \infty$.

To leading order in large volume (large T) expansion

$$R_{T\bar{T}\alpha\bar{\beta}} = \frac{1}{3}\hat{K}_{T\bar{T}}\tilde{K}_{\alpha\bar{\beta}}$$

so to leading order

$$m^2_{I\bar{J}} = m^2_{3/2} Z_{I\bar{J}} - F^T F^{\bar{T}} R_{T\bar{T}I\bar{J}} = 0$$

Similarly $B\mu$ A-terms are also zero. As in no-scale!

Sub-leading effects, FCNC?

$$
\begin{aligned}
M_a &= \frac{F^i \partial_i f_a}{2 f_a} = \frac{F^S}{2S} \lesssim O\left(\frac{m_{3/2}}{\sqrt{\mathcal{V}}}\right), \\
m^2_{\alpha\bar{\beta}} &= V_{class}|_0 \tilde{K}_{\alpha\bar{\beta}} + \\
& \quad (m^2_{3/2} \tilde{K}_{\alpha\bar{\beta}} - F^A F^{\bar{B}} R_{A\bar{B}\alpha\bar{\beta}}) \\
&\lesssim (O\left(\frac{m^2_{3/2}}{\mathcal{V}}\right)) \tilde{K}_{\alpha\bar{\beta}} + \ldots, \\
A_{\alpha\beta\gamma} &= \frac{W_m^*}{|W_m|} F^A D_A Y_{\alpha\beta\gamma} \lesssim O\left(\frac{m_{3/2}}{\sqrt{\mathcal{V}}}\right) Y_{\alpha\beta\gamma}, \\
\mu_{\alpha\beta} &\lesssim O\left(\frac{m_{3/2}}{\sqrt{\mathcal{V}}}\right) Z_{\alpha\beta} \\
B\mu/\mu &\lesssim O\left(\frac{m_{3/2}}{\sqrt{\mathcal{V}}}\right),
\end{aligned}
$$

Effective Field theory quantum effects:

Need cutoff.

$$\Lambda \gtrsim M_{GUT} \sim 10^{16} GeV \sim 10^{-2} M_P$$
$$\frac{\Lambda^2}{16\pi^2} \gtrsim 10^{-6} M_P^2.$$

Coupling constant unification - only piece of experimental evidence for SUSY!

Should be taken seriously even at cost of additional fine tuning.

Quadratic divergence issues and mSUGRA

Coeff of divergence:

$$\mathrm{Str}M^2(\Phi) \equiv \sum_J (-1)^{2J}(2J+1)\mathrm{tr}M^2(\Phi) \neq 0$$

$$\begin{aligned} V|_0 &= (F^m \bar{F}^{\bar{n}} K_{m\bar{n}} - 3m_{3/2}^2)(1 + \frac{(N-5)\Lambda^2}{16\pi^2}) \\ &+ \frac{\Lambda^2}{16\pi^2}(m_{3/2}^2(N-1) - F^T \bar{F}^{\bar{T}} R_{T\bar{T}}), \\ m_{\alpha\bar{\beta}}^2 &= V|_0 Z_{\alpha\bar{\beta}} + (m_{3/2}^2 Z_{I\bar{J}\alpha\bar{\beta}} - F^T F^{\bar{T}} R_{T\bar{T}\alpha\bar{\beta}}) \times \\ & (1 + \frac{(N-5)\Lambda^2}{16\pi^2}) \\ & - \frac{\Lambda^2}{16\pi^2}('' R^{2''}) O(m_{3/2}^2) \end{aligned}$$

Gaillard and Jain, Ferrara Kounnas Zwirner, Choi, Lee, Munoz hep-ph/9709250.

Classical+1 loop CC:

$$V_{classical}|_0 + \frac{\Lambda^2}{16\pi^2} m_{3/2}^2 M_P^2 (h_{21} - 1) = 0$$

Need to finetune Classical CC to cancel this.

Estimate of F-terms and soft terms: SdA-08

$$\begin{aligned} |F^T| &= \sqrt{3} m_{3/2} + O(h_{21} \frac{\Lambda^2}{16\pi^2} m_{3/2}) \\ |F^i| \sim F^S| \sim |F^u| &\sim O(\frac{\Lambda}{4\pi} m_{3/2}) \end{aligned}$$

$$\begin{aligned} m_{\alpha\bar{\beta}}^2 &\sim \frac{\Lambda^2}{16\pi^2} m_{3/2}^2 [(h_{21} - 2N_v) \tilde{K}_{\alpha\bar{\beta}} + O(?) \tilde{K}'_{\alpha\bar{\beta}}] \\ &\sim 10^{-6} m_{3/2}^2 [(h_{21} - 2N_v) \tilde{K}_{\alpha\bar{\beta}} + O(?) \tilde{K}'_{\alpha\bar{\beta}}] \end{aligned}$$

Need $h_{21} > 2N_v \sim 10^2$.

For A, μ and $B\mu$ terms also classical contribution from F^T is zero - as in no-scale.

Subleading classical plus leading quantum effect:

A terms:

$$A_{\alpha\beta\gamma} = \{F^i D_i e^{\widehat{K}/2} Y_{\alpha\beta\gamma}(1 + \frac{N-5}{16\pi^2}\Lambda^2) - \frac{\Lambda^2}{16\pi^2} O(F^T)\}$$

Generically terms not proportional to $Y_{\alpha\beta\gamma}$ as well!

μ and $B\mu$ terms:

$$\mu_{\alpha\beta} = -\bar{F}^{\bar{a}}\partial_{\bar{a}} Z_{\alpha\beta} = O(\sqrt{h_{21}}\frac{\Lambda}{4\pi} m_{3/2}) Z_{\alpha\beta}$$

$$B\mu_{\alpha\beta} = V_{classical}|_0 Z_{\alpha\beta} \sim O(h_{21}\frac{\Lambda^2}{16\pi^2} m_{3/2}^2).$$

Gaugino masses:

$$\frac{m_a}{g_a^2} = F^m \partial_m f_a \sim F^S \partial_S f_a \sim O(1)\frac{\Lambda}{4\pi} m_{3/2}$$

Summary (physical):

$$
\begin{aligned}
m_s &\sim \sqrt{h_{21}}\frac{\Lambda}{4\pi}m_{3/2} \\
\widehat{A}_{\alpha\beta\gamma} &\sim \frac{\Lambda}{4\pi}Y_{\alpha\beta\gamma} \\
\widehat{\mu} &\sim \sqrt{h_{21}}\frac{\Lambda}{4\pi}m_{3/2} \\
\widehat{B\mu} &\sim h_{21}\frac{\Lambda^2}{16\pi^2}m_{3/2}^2 \\
m_a &\sim g_a^2\frac{\Lambda}{4\pi}m_{3/2}
\end{aligned}
$$

Comparison with String loop calculations*: Berg,Haac
et al, Cicolli,CQ

$$K_q = \frac{\alpha(S,\bar{S},U,\bar{U})}{T+\bar{T}} + O\left(\frac{1}{(T+\bar{T})^2}\right)$$

In simple models α independent of τ^i

$$V_q \sim O(\frac{m_{3/2}^2}{(T+\bar{T})^2})$$

$O(m_{3/2}^2/(T+\bar{T})$ leading term cancels - extended no-scale structure.

Compare with effective field theory:

$$\Lambda \sim \frac{1}{T+\bar{T}}$$

*In collaboration with F. Quevedo+?

MSSM part expected to acquire similar correction (CMQ)

(no calculation so far!)

$$K = -3\ln(T+\bar{T}) + \frac{\alpha}{T+\bar{T}} + \frac{C^{\alpha}\bar{C}^{\bar{\beta}}}{T+\bar{T}}(1+\frac{\beta}{T+\bar{T}})k_{\alpha\bar{\beta}}.$$

This generates a soft mass contribution

$$m^2_{\alpha\bar{\beta}} = \frac{2(\alpha/3-\beta)}{T+\bar{T}} m^2_{3/2}\tilde{K}_{\alpha\bar{\beta}}.$$

Implies

$$m_s \sim \frac{m_{3/2}}{\sqrt{(T+\bar{T}}} \sim \sqrt{\Lambda} m_{3/2}$$

- Larger than classical $m_s^{cl} \sim m_{3/2}/(T+\bar{T})^{3/4}$.
- Contradicts effective field theory calculation $m_s \sim \Lambda m_{3/2}$ unless $(\alpha/3-\beta) = 0$!

Suppose this is the case.

$$m_s^{(q)} \sim \frac{m_{3/2}}{(T+\bar{T})} \sim \frac{W}{(T+\bar{T})^{5/2}}$$

Note this is smaller than classical contribution

$$m_s^{(cl)} \sim \frac{m_{3/2}}{(T+\bar{T})^{3/4}} \sim \frac{W}{(T+\bar{T})^{9/4}}$$

LVS phenomenology - No fine-tuning of W to be small!

To have $m_s \sim 1TeV$ need

$$\mathcal{V} \sim 10^{10} \Longrightarrow M_{string} \sim \frac{M_P}{\sqrt{\mathcal{V}}} \sim 10^{13}GeV$$

This is well below GUT scale! Also:

$$\Lambda \sim M_{KK} \sim \frac{1}{T+\bar{T}} \sim 10^{11} - 10^{12}GeV$$

In general this scenario will not be valid.

Eg: in $K_q \sim \alpha/(T+\bar{T})$ α dependent on (τ^i/τ^j).

$$V_q \sim \frac{m_{3/2}^2}{(T+\bar{T})} O(1) \sim \frac{m_{3/2}^2}{\mathcal{V}^{2/3}}$$

Compare with cut-off Field theory:

$$\Lambda \sim \frac{1}{\sqrt{T+\bar{T}}}$$

$$m_s \sim \frac{m_{3/2}(\alpha/3-\beta)^{1/2}}{\sqrt{(T+\bar{T}}} \sim \Lambda m_{3/2}$$

In agreement with effective field theory - no need to demand $\alpha/3-\beta=0$!

Also here

$$\Lambda \sim \mathcal{V}^{1/6} M_{string} > M_{string}$$

Actually here LVS classical vacuum destabilized!

$$|V_{cl}| \sim \frac{m_{3/2}^2}{\mathcal{V}} < |V_q| \sim \frac{m_{3/2}^2}{\mathcal{V}^{2/3}}$$

Assuming a new min exists get,

$$m_s \sim m_s^q \sim \frac{|W|}{\mathcal{V}^{4/3}}$$

So $m_s \sim 1 TeV$, $W \sim O(1) \Rightarrow \mathcal{V} \sim 10^{11}$

$$M_{string} \sim 10^{13} GeV,\ \Lambda \sim 10^{15} GeV$$

To get GUT scale M_{string} and TeV soft masses need $|W| \sim 10^{-10}$!

FCNC Problems with ≥ 2 Kaehler moduli?

$$K = -2\ln Y - \ldots,\ Y \equiv \mathcal{V} + \frac{\hat{\xi}}{2}.$$

Simple "Swiss Cheese" $\mathcal{V} = \tau_b^{3/2} - \tau_s^{3/2}$

$$T^i + \bar{T}^i = 2\tau^i + 2\mu i \omega^i_{\alpha\bar{\beta}} \phi^\alpha \bar{\phi}^{\bar{\beta}} + \ldots$$

For D3 (or D7 on collapsed cycle) GGJL

$$K_{\alpha\bar{\beta}} = c(\omega^b_{\alpha\bar{\beta}} \frac{1}{\tau_b} - \omega^s_{\alpha\bar{\beta}} \frac{1}{\tau_b} \sqrt{\frac{\tau_s}{\tau_b}})$$

$$R_{T\bar{T}\alpha\bar{\beta}} = \frac{1}{3} K_{T\bar{T}} c[\frac{\omega_b}{\tau_b} - \frac{7}{4}\frac{\omega_s}{\tau_b}\sqrt{\frac{\tau_s}{\tau_b}}]_{\alpha\bar{\beta}}$$

Using $F^T F^{\bar{T}} K_{T\bar{T}} = 3m_{3/2}^2$

$$
\begin{aligned}
m_{\alpha\bar{\beta}}^2 &= m_{3/2}^2 K_{\alpha\bar{\beta}} - F^T F^{\bar{T}} R_{T\bar{T}\alpha\bar{\beta}} \\
&= m_{3/2}^2 \frac{3}{4}\sqrt{\frac{\tau_s}{\tau_b}} K'_{\alpha\bar{\beta}}.
\end{aligned}
$$

$K'_{\alpha\bar{\beta}} = c\omega^s_{\alpha\bar{\beta}}/\tau_b$ not proportional to $K_{\alpha\bar{\beta}}$. FCNC!

Cannot be fine-tuned away but still under discussion!

IIB Phenomenology only with one T?

How generic is this?

Can we have IIB (F-theory) MSSM on 7-branes on a finite 4-cycle?

If so get classical soft terms $O(m_{3/2})$ would need to have a gravitino as LSP to avoid cosmological problems - GMSB?

Note: Not a prediction - just a phenomenological requirement!

Without a theory of moduli stabilization it is unclear whether it can in fact be achieved.

Tuning issues:

Compare to one Kaehler modulus case

Tuning (in addition to CC and $m_{3/2}$) 1 part in 10^3?

But high $m_{3/2}$ compared to EW scale!

To get low value additional tuning

by a factor $\left(\frac{m_{3/2}(high)}{m_{3/2}(low)}\right)^6$ needed Douglas.

So even if classical mSUGRA solution existed

Need additional tuning by $\left(\frac{10^4}{10^2}\right)^6 = 10^{12}$

In GMSB no FCNC tuning needed. So factor is 10^9.

Also additional sector (X) needed to break SUSY with $F^X \sim F^{moduli} \sim m_{3/2}M_P$ but $< X > \ll M_P$.

Hard to achieve. SdA hep-th/0703247

Basically problem comes from lightness of moduli stabilized by NP effects

Also generically a component of SUSY breaking lies in modulus direction.

Eg in IIB models with extended no-scale cannot meaningfully integrate out

the T modulus to get a theory of GMSB SUSY breaking.

In the coupled T, X theory it is very difficult to ensure a small $< X > \ll < T > \sim M_P$ to get $F^X/X \gg F^T/(T+\bar{T}) \sim m_{3/2}$.

Not a no-go theorem!

But shows that getting GMSB is highly unnatural in string theory.

Generic property:

Kaehler potential for Kaehler T^i (and complex structure z^α) moduli satisfies.

$$K_A K^A = 3$$

Broken by α' and quantum corrections.

Classical shift symmetries imply W independent of T^i giving no-scale property. Classical soft masses suppressed relative to gravitino.

Broken by NP quantum corrections.

If perturbative string theory is to make sense corrections must be small.

Results may be generic consequences of these properties.

Predictive models?

Anything beyond the above - flux dependent.

Eg: sparticle couplings

$$A_{IJK}(z^{\alpha}) = a(U)Y_{IJK}(U) + \epsilon Y'_{IJK}(U)$$

Models must be such that FCNC violating second term suppressed.

a, Y' predictions - but flux dependent!

Can have very large number of solutions satisfying std model constraints.