Instituto de Física Teórica UAM-CSIC

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Soft SUSY breaking in Type IIA flux compactifications

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Work in progress with W. Staessens & F. Marchesano

Outline

Motivation

SUSY is nice framework for physics beyond the Standard Model (to be experimentally confirmed at LHC)

- Solve the hierarchy problem
- Unification of gauge couplings
- Provide some candidates to Dark Matter

If exist, SUSY must be broken on the accesible energy scale

- Spontaneous SUSY breaking $Q_\alpha|0>\neq 0 \qquad Q_\alpha^\dagger|0>\neq 0$
- Explicit SUSY breaking

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$$\mathcal{L}_{\rm soft} = M_a\lambda^a\lambda^a + m_{ij}^2\phi^i\bar{\phi}^{\bar{j}} + B_{ij}\phi^i\phi^j + A_{ijk}\phi^i\phi^j\phi^k$$

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This is called soft SUSY breaking

SUSY breaking basics

It is difficult to directly couple a dynamical SUSY breaking to the visible sector.

F-term SUSY breaking $\langle F^{C^\alpha} \rangle \neq 0$

- Require C^α to be a SM singlet
- Does not lead to a phenomenologically viable of pattern of supersymmetry-breaking parameters.
- Gauginos masses cannot arise in renormalizable SUSY theory at tree-level.

D-term SUSY breaking $\langle D_a \rangle \neq 0$

- Does not lead to a acceptable spectrum of sparticles.

Soft SUSY-breaking terms should arise indirectly or radiatively, not from tree-level couplings to the SUSY breaking sector.

Hidden sector framework

Particles with no direct (or tiny) coupling to visible sector (i.e moduli sector in String Theory).

SUSY is spontaneously broken in the hidden sector by $\langle F^{h^i} \rangle \neq 0$

$$\Lambda_{\mathrm{SUSY}} = \langle F \rangle^{1/2}$$

Both sectors share some mediating interactions that transmit supersymmetry breaking from the hidden sector to the visible sector (i.e gravity)

Fields in the visible sector feel SUSY breaking at the scale

$$m_{\mathrm{soft}} = \frac{\Lambda^2_{\mathrm{SUSY}}}{M_p}$$

If we expect $m_{\mathrm{soft}} \sim \mathcal{O}(\mathrm{TeV})$ $\Rightarrow$ $\Lambda_{\mathrm{SUSY}} \sim 10^{10-11}\,\mathrm{GeV}$

SUGRA effective field theory

Expanding K and W in powers of the matter fields Soni & Weldon '83 Brignole, Ibañez & Muñoz '93 , Kaplunovsky & Louis '93

$$W = \hat{W}(h^i) + a_\alpha(h^i)C^\alpha + \frac{1}{2}\mu_{\alpha\beta}(h^i)C^\alpha C^\beta + \frac{1}{6}Y_{\alpha\beta\gamma}(h^i)C^\alpha C^\beta C^\gamma + \ldots.$$

$$K = \hat{K}(h^i, \bar{h}^{\bar{i}}) + \tilde{K}_{\alpha\bar{\beta}}(h^i, \bar{h}^{\bar{i}})C^\alpha C^{\bar{\beta}} + \left(\frac{1}{2}Z_{\alpha\beta}(h^i, \bar{h}^{\bar{i}})C^\alpha C^\beta + h.c\right) + \ldots.$$

Expanding the SUGRA scalar potential

$$V_{\rm soft} = m_{\alpha\bar{\beta}}C^\alpha C^{\bar{\beta}} + \left(\frac{1}{6}A_{\alpha\beta\gamma}C^\alpha C^\beta C^\gamma + \frac{1}{2}B_{\alpha\beta}C^\alpha C^\beta + h.c\right)$$

The soft SUSY breaking terms are

$$m^2_{\overline{\alpha}\beta} = \left(m^2_{3/2} + V_0\right)\tilde{K}_{\overline{\alpha}\beta} - \overline{F}^{\overline{m}}\left(\partial_{\overline{m}}\partial_n\tilde{K}_{\overline{\alpha}\beta} - \partial_{\overline{m}}\tilde{K}_{\overline{\alpha}\gamma}\tilde{K}^{\gamma\overline{\delta}}\partial_n\tilde{K}_{\overline{\delta}\beta}\right)F^n$$

SUGRA effective field theory

$$A_{\alpha\beta\gamma} = \frac{\hat{W}^*}{|\hat{W}|}\, e^{\hat{K}/2} F^m \left\{ \hat{K}_m Y_{\alpha\beta\gamma} + \partial_m Y_{\alpha\beta\gamma} \right.$$
$$\left. - \left(\tilde{K}^{\delta\bar{\rho}} \partial_m \tilde{K}_{\bar{\rho}\alpha} Y_{\delta\beta\gamma} + (\alpha \leftrightarrow \beta) + (\alpha \leftrightarrow \gamma) \right) \right\}$$

$$B_{\alpha\beta} = \frac{\hat{W}^*}{|\hat{W}|}\, e^{\hat{K}/2} \left\{ F^m \left(\hat{K}_m \mu_{\alpha\beta} + \partial_m \mu_{\alpha\beta} - \left(\tilde{K}^{\delta\bar{\rho}} \partial_m \tilde{K}_{\bar{\rho}\alpha} \mu_{\delta\beta} + (\alpha \leftrightarrow \beta) \right) \right) \right.$$
$$\left. - m_{3/2} \mu_{\alpha\beta} \right\} + m_{3/2} F^m \left[\partial_m Z_{\alpha\beta} - \left(\tilde{K}^{\delta\bar{\rho}} \partial_m \tilde{K}_{\bar{\rho}\alpha} Z_{\delta\beta} + (\alpha \leftrightarrow \beta) \right) \right]$$
$$+ (2 m_{3/2}^2 + V_0) Z_{\alpha\beta} - m_{3/2} F^{\bar{m}} \partial_{\bar{m}} Z_{\alpha\beta}$$
$$- F^{\bar{m}} F^n \left[\partial_n \partial_{\bar{m}} Z_{\alpha\beta} - \left(\tilde{K}^{\delta\bar{\rho}} \partial_n \tilde{K}_{\bar{\rho}\alpha} \partial_{\bar{m}} Z_{\delta\beta} + (\alpha \leftrightarrow \beta) \right) \right]$$

The tree-level cosmological contant

$$V_0 = \kappa_4^2 e^{\kappa_4^2 \hat{K}} \left[\hat{K}_{n\bar{m}} F^n F^{\bar{m}} - 3 m_{3/2}^2 \right], \quad F^n = \kappa_4^2 e^{\kappa_4^2 \hat{K}/2} \hat{K}^{n\bar{m}} D_{\bar{m}} \hat{W}^*$$

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- Knowledge of the Kähler metric for matter fields (normalization of the matter fields).
- Determine the underlying source of SUSY breaking (related to moduli stabilisation).

Soft SUSY breaking terms from string compactifications

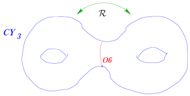
Heterotic compactifications Brignole, Ibañez & Muñoz '93 , Brignole, Ibañez, Muñoz & Scheich '96 , Kim & Muñoz '96
Lack of potential to stabilise moduli

Type IIB compactifications (KKLT,LVS), Camara, Ibañez & Uranga '04 ,Conlon, Cremades & Quevedo '05 , Conlon, Quevedo & Suruliz '06 , Aparicio et al. '14
SUSY is broken by background fluxes (non-perturbative effects to stabilise Kähler moduli)

Type IIA Orientifolds

Compactification of Type IIA String Theory on CY orientifolds.

Discrete symmetry $\mathcal{O} = (-1)^{F_L}\Omega_p\mathcal{R}$



$$\begin{aligned} \mathcal{R} : J &= -J \\ \mathcal{R} : \Omega &= e^{2i\theta}\bar{\Omega} \end{aligned}$$

$\mathcal{N} = 1$ SUGRA theory in 4d (closed string sector) Grimm & Louis '05

Massless spectrum: $h_-^{(1,1)}$ Kähler moduli, $h^{(2,1)}$ complex structure moduli, axion-dilaton multiplet and $h_+^{(1,1)}$ vector multiplets

The Kähler potential

$$\hat{K} = -\ln\left[\frac{1}{6}\mathcal{K}_{abc}(T^a + \bar{T}^a)(T^b + \bar{T}^b)(T^c + \bar{T}^c)\right] - 2\ln\left[\frac{\mathcal{F}_{KL}}{2}\left(N^K + \bar{N}^K\right)\left(N^L + \bar{N}^L\right)\right]$$

If background fluxes are turning on

$$\hat{W}_{\mathrm{IIA}} = e_0 + ie_aT^a - \frac{1}{2}\mathcal{K}_{abc}q^aT^bT^c - \frac{im_0}{6}\mathcal{K}_{abc}T^aT^bT^c - h_KN^K$$

Dp-branes

String Theory contains extended objects with p-spatial dimensions where the endpoints of open strings are attached   Polchinski '95

Space-time filling Dp-branes $\mathcal{W}_{p+1} = M_{(1,3)} \times \Pi_{p-3}$

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- $U(1)$ gauge theory for a single Dp-brane.

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- $U(1)$ gauge theory for a single Dp-brane.
- N concident Dp-branes support $U(N)$ gauge theory on their worldvolume.

Gauge coupling constant $g_a^{-2} \sim \mathrm{Vol}\left(\Pi_{p-3}\right)$

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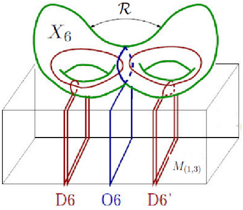
Type IIA String Theory contains Dp-branes with $p = 0, 2, 4, 6, 8$

D6-branes and Supersymmetry

We may include D6-branes preserving the $\mathcal{N} = 1$ supersymmetry of the bulk theory   Blumenhagen et al. '02,   Kachru & McGreevy '99



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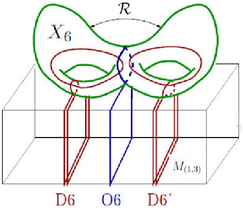

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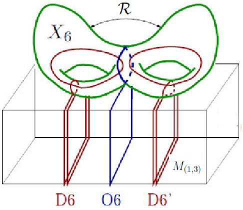

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Supersymmetry conditions

- $J|_{\Pi_3} = 0, \quad \mathrm{Im}\left(e^{-i\theta}\Omega\right)|_{\Pi_3} = 0$
- $B - \frac{l_s^2}{2\pi} F = 0$

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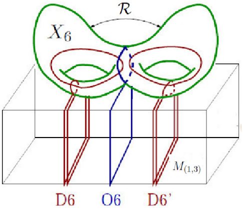

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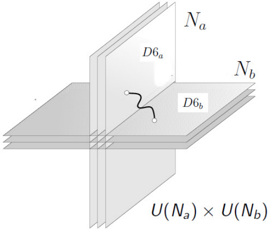
Tadpole cancellation condition

$$\sum_{a=1}^{K} N_a \, [\Pi_3^a] = 4 \left[\Pi^{06}\right]$$

Model building

Berkooz et al.'96



Intersecting D6-branes support chiral fermions at their intersection, charged in the bifundamental representation $(N_a, \bar{N}_b)$

Nice geometric interpretation of chirality

The chiral spectrum is computed from intersection numbers $I_{ab} = \Pi_a \circ \Pi_b$ of the 3-cycles

Sector	Representation
$ab + ba$	I_{ab} $(\square_a, \bar{\square}_b)$ fermions
$ab' + b'a$	$I_{ab'}$ $(\square_a, \square_b)$ fermions
$aa' + a'a$	$\frac{1}{2}(I_{aa'} - \frac{1}{2} I_{a,O})$ $\square\square$ fermions
	$\frac{1}{2}(I_{aa'} + \frac{1}{2} I_{a,O})$ $\begin{smallmatrix}\square\\\square\end{smallmatrix}$ fermions

Non-chiral spectrum is unknown in general.

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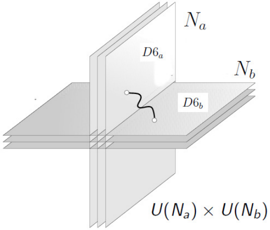

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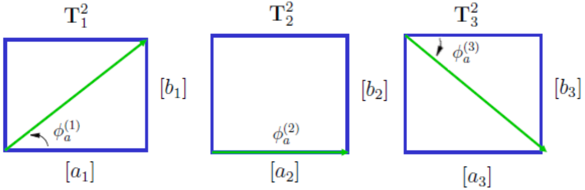
aa-Sector

- $U(N)$ gauge bosons
- $p-3$ chiral multiplets in the adjoint representation, parametrising continuous displacements and Wilson lines

Toroidal example

On factorizable tori $\mathbf{T}^6 = \mathbf{T}^2 \otimes \mathbf{T}^2 \otimes \mathbf{T}^2$



homology class of 1-cycles

$$\pi_a^i = n_a^i[a_i] + m_a^i[b_i]$$

homology class of 3-cycles $\Pi_a = \otimes_{i=1}^3 \pi_a^i$

SUSY condition $\phi_a^{(1)} + \phi_a^{(2)} + \phi_a^{(2)} = 0$

$$\arctan\left(\frac{m_a^1}{n_a^1}\tau_1\right) + \arctan\left(\frac{m_a^2}{n_a^2}\tau_2\right) + \arctan\left(\frac{m_a^3}{n_a^3}\tau_3\right) = 0, \qquad \tau_i = \frac{R_y^i}{R_x^i}$$

Intersection number

$$I_{ab} = \Pi_a \circ \Pi_b = \prod_{i=1}^{3} \left(n_a^i m_b^i - n_b^i m_a^i\right)$$

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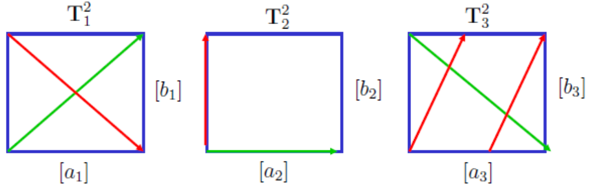

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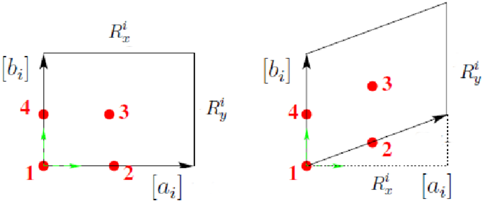
$\mathbf{T}^6/\mathbb{Z}_2 \times \mathbb{Z}_2$ orbifold

Orbifold action $\theta, \omega : z^i \to e^{2\pi i \nu_i} z^i$ (3 generation models) Cvetic, Shiu & Uranga '01

$$\vec{\nu}_\theta : (1/2, -1/2, 0) \quad \vec{\nu}_\omega : (0, 1/2, -1/2)$$

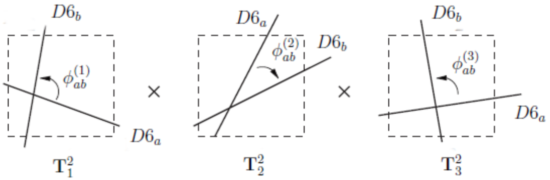


Under the $\mathbb{Z}_2 \times \mathbb{Z}_2$ symmetry

$$U(N_a) \to U(N_a/2)$$

Closed string sector (without discrete torsion)
$h^{(1,1)}$ Kähler moduli: 3 untwisted T^i (volume of $\mathbf{T}_i^2$), 16 at θ-fixed points, 16 at ω-fixed points and 16 at $\theta\omega$-fixed points.
$h^{(2,1)}$ Complex structure moduli: 3 untwisted U^i (shape of $\mathbf{T}_i^2$)

Kähler metric for chiral matter



Lüst et al. '04
Akerblom et al. '07
Honecker '11

- *ab*-sector Bifundamental chiral matter C^{α}_{ab}
- *aa′*-sector Chiral matter $C^{\alpha}_{(aa)}$ and $C^{\alpha}_{[aa]}$ transforming in the symmetric and antisymmetric representations of $U(N_a/2)$ respectively.

$$\tilde{K}_{C^{\alpha}_{ab}\bar{C}^{\beta}_{ab}} = \delta_{\alpha\bar{\beta}}\,\kappa_4^{-2}\,e^{D}\sqrt{\prod_{i=3}^{3}\frac{c^{i}_{ab}}{(T^{i}+\bar{T}^{i})}}, \qquad c^{i}_{ab} = \left(\frac{\Gamma(\phi^{(i)}_{ab})}{\Gamma(1-\phi^{(i)}_{ab})}\right)^{-\frac{\mathrm{sgn}(\phi^{(i)}_{ab})}{\mathrm{sgn}(I_{ab})}}$$

Supersymmetric configurations require $\sum_{i=1}^{3}\phi^{(i)}_{ab} = 0$

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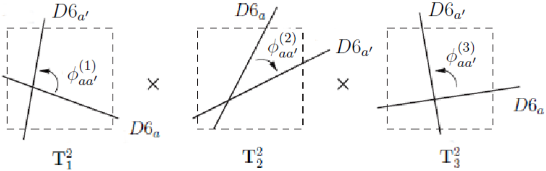

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Kähler metric

- Bifundamental non-chiral matter $(a \upuparrows b$ on $\mathbf{T}_i^2)$

$$\tilde{K}_{C^{\alpha}_{ab}\bar{C}^{\beta}_{ab}} = \delta_{\alpha\bar{\beta}}\,\kappa_4^{-2}\; e^D \sqrt{\frac{8\pi V^{(i)}_{ab}}{(T^j+\bar{T}^j)(T^k+\bar{T}^k)}}, \qquad i \neq j \neq k$$

with $V^{(i)}_{ab} = \tau_i^{-1} n^i_a n^i_b + \tau_i \tilde{m}^i_a \tilde{m}^i_b$

- *aa*-sector Adjoint matter C^{α}_{aa} (3 chiral multiplets)

$$\tilde{K}^{\mathbf{Adj}}_{C^{\alpha}_{aa}\bar{C}^{\beta}_{aa}} = \delta_{\alpha\bar{\beta}} \frac{\sqrt{2\pi}\,\kappa_4^{-2}\, e^D}{T^i+\bar{T}^i} \sqrt{\frac{V^{(j)}_{aa} V^{(k)}_{aa}}{V^{(i)}_{aa}}}$$

Additional dependence on the dilaton and complex structure moduli

$$\tau_i = \sqrt{\frac{(U^j+\bar{U}^j)\,(U^k+\bar{U}^k)}{(U^i+\bar{U}^i)\,(S+\bar{S})}}, \qquad e^D = \left[\frac{1}{16}(S+\bar{S})\prod_{i=1}^{3}(U^i+\bar{U}^i)\right]^{-1/4}$$

Soft SUSY breaking terms

Soft gaugino masses

$$M_a = \frac{1}{2} \left(\mathrm{Re}\, f_a\right)^{-1} F^n \partial_n f_a$$

Diagonal Kähler metric and vanishing Z-terms lead

$$\begin{aligned} m_\alpha^2 &= (m_{3/2}^2 + V_0) - F^{\bar{m}} F^n \partial_{\bar{m}} \partial_n \ln \tilde{K}_\alpha \\ \hat{A}_{\alpha\beta\gamma} &= \hat{Y}_{\alpha\beta\gamma} F^m \left(\hat{K}_m + \partial_m \mathrm{Log}\, Y_{\alpha\beta\gamma} - \partial_m \ln(\tilde{K}_\alpha\, \tilde{K}_\beta\, \tilde{K}_\gamma) \right) \\ \hat{B}_{\alpha\beta} &= \hat{\mu}_{\alpha\beta} \left[F^m \left(\hat{K}_m + \partial_m \ln \mu_{\alpha\beta} - \partial_m \ln \tilde{K}_\alpha \tilde{K}_\beta \right) - m_{3/2} \right] \end{aligned}$$

The VEV's of the F-terms can be parametrized Brignole, Ibañez & Muñoz '93

$$\begin{aligned} F^S &= \sqrt{3} C m_{3/2} \hat{K}_{S\bar{S}}^{-1/2} \sin\theta\, e^{-i\gamma_S}, \qquad C^2 = 1 + \frac{V_0}{3 m_{3/2}^2} \\ F^{U^i} &= \sqrt{3} C m_{3/2} \hat{K}_{U^i \bar{U}^i}^{-1/2} \cos\theta\, \Theta_i^U\, e^{-i\gamma_{U^i}} \\ F^{T^i} &= \sqrt{3} C m_{3/2} \hat{K}_{T^i \bar{T}^i}^{-1/2} \cos\theta\, \Theta_i^T\, e^{-i\gamma_{T^i}}, \qquad \sum_{i=1} |\Theta_i^U|^2 + |\Theta_i^T|^2 = 1 \end{aligned}$$

Gaugino masses

The gauge kinetic function f_a for the gauge fields living on the worldvolume of N coincident D6-branes is Cremades, Ibañez & Marchesano '02

$$f_a = \frac{1}{4}\left(n_a^1 n_a^2 n_a^3 S - \sum_{i=1}^{3} n_a^i m_a^j m_a^k U^i \right), \qquad i \neq j \neq k$$

Soft gaugino masses

$$M_a = \frac{\sqrt{3}}{8} C\, m_{3/2} \left(\mathrm{Re}\, f_a\right)^{-1} \Big\{ n_a^1 n_a^2 n_a^3 \left(S + \bar{S}\right) \sin\theta e^{-i\gamma_S} - \cos\theta \sum_{i=1}^{3} n_a^i m_a^j m_a^k \left(U^i + \bar{U}^i\right) \Theta_i^U\, e^{-i\gamma_{U^i}} \Big\}$$

Non-universal gaugino masses are possible

Soft-term for bifundamental chiral matter

Soft masses (independent of the D6-brane configuration and the phases on the parametrization)

$$m_{\alpha}^{(ab)2} = (m_{3/2}^2 + V_0) - \frac{3}{4} C^2 m_{3/2}^2 \left[\sin^2\theta + \cos^2\theta \sum_{i=1}^{3} \left(2|\Theta_i^T|^2 + |\Theta_i^U|^2 \right) \right]$$

$\hat{A}$-terms

$$\hat{A}_{\alpha\beta\gamma} = \sqrt{3} C\, m_{3/2} \hat{Y}_{\alpha\beta\gamma} \left\{ \left(-\frac{1}{4} + \left(S + \bar{S}\right)\, \partial_S \ln Y_{\alpha\beta\gamma} \right) \sin\theta\, e^{-i\gamma_S} \right.$$
$$+ \cos\theta \sum_{i=1}^{3} \left\{ \left(\frac{1}{2} + \left(T^i + \bar{T}^i\right)\, \partial_{T^i} \ln Y_{\alpha\beta\gamma} \right) \Theta_i^T\, e^{-i\gamma_{T^i}} \right.$$
$$\left. \left. + \left(-\frac{1}{4} + \left(U^i + \bar{U}^i\right)\, \partial_{U^i} \ln Y_{\alpha\beta\gamma} \right) \Theta_i^U\, e^{-i\gamma_{U^i}} \right\} \right\}$$

Soft-term for bifundamental chiral matter

$\hat{B}$-terms

$$\hat{B}_{\alpha\beta} = \sqrt{3}C\, m_{3/2}\hat{\mu}_{\alpha\beta} \left\{ \left(\left(S+\bar{S}\right)\, \partial_S \ln \mu_{\alpha\beta} - \frac{1}{2} \right) \sin\theta\, e^{-i\gamma_S} \right.$$

$$+ \cos\theta \sum_{i=1}^{3} \left\{ \left(T^i + \bar{T}^i\right)\, \Theta_i^T\, e^{-i\gamma_{T^i}} \partial_{T^i} \ln \mu_{\alpha\beta} \right.$$

$$\left. \left. + \left(\left(U^i + \bar{U}^i\right)\, \partial_{U^i} \ln \mu_{\alpha\beta} - \frac{1}{2} \right) \Theta_i^U\, e^{-i\gamma_{U^i}} \right\} - \frac{1}{\sqrt{3}C} \right\}$$

The normalized Yukawa couplings and μ-terms

$$\hat{Y}_{\alpha\beta\gamma} = \frac{\hat{W}^*}{|\hat{W}|} e^{\hat{K}/2} \left(\tilde{K}_\alpha \tilde{K}_\beta \tilde{K}_\gamma\right)^{-1/2} Y_{\alpha\beta\gamma}, \quad \hat{\mu}_{\alpha\beta} = \frac{\hat{W}^*}{|\hat{W}|} e^{\hat{K}/2} \left(\tilde{K}_\alpha \tilde{K}_\beta\right)^{-1/2} \mu_{\alpha\beta}$$

No-scale Minkowski vacuua

Camara, Font & Ibañez '05

$$\kappa_4^2 \hat{K} = -\ln(S+\bar{S}) - \sum_{i=1}^{3} \ln(U^i + \bar{U}^i) - \sum_{i=1}^{3} \ln(T^i + \bar{T}^i)$$

The superpotential (mirror to the Type IIB superpotential with ISD fluxes)

$$\hat{W}_{IIA} = e_0 + ih_0 S + i\sum_{i=1}^{3} e_i T^i - q_1 T^2 T^3 - q_2 T^1 T^3 - q_3 T^1 T^2 + im_0 T^1 T^2 T^3$$

The cosmological constant

$$V_0 = \kappa_4^2 e^{\kappa_4^2 \hat{K}} \left[\sum_{S,T^i} \hat{K}^{n\bar{m}} D_n \hat{W} D_{\bar{m}} \bar{\hat{W}} + \sum_{U^i} \hat{K}^{n\bar{m}} D_n \hat{W} D_{\bar{m}} \bar{\hat{W}} - 3|\hat{W}|^2 \right]$$

$$= \kappa_4^2 e^{\kappa_4^2 \hat{K}} \sum_{S,T^i} \hat{K}^{n\bar{m}} D_n \hat{W} D_{\bar{m}} \bar{\hat{W}}$$

F-term conditions $D_n \hat{W} = 0 \quad \Longrightarrow \quad V_0 = 0$

$$\mathrm{Im}\, T^i = -\frac{q_i}{m_0}, \quad \mathrm{Im}\, S = \frac{e_0 m_0^2 - q_1 q_2 q_3}{h_0 m_0}, \quad h_0 \mathrm{Re}\, S - m_0 \mathrm{Re}\, T^1 \mathrm{Re}\, T^2 \mathrm{Re}\, T^3 = 0$$

U-dominated SUSY breaking

SUSY is spontaneously broken by $\langle F^{U^i} \rangle = i m_{3/2}(U^i + \bar{U}^i)$

$$\Lambda_{\rm SUSY} = 2 m_{3/2}\sqrt{u_1^2 + u_2^2 + u_3^2} \qquad m_{3/2}^2 = \frac{h_0 m_0}{32 u_1 u_2 u_3}, \qquad W_0 = 2 i h_0 s$$

Isotropic case $U^1 = U^2 = U^3 = U$

The parametrization requires $\sin\theta = 0$, $\Theta_i^T = 0$, $\Theta^U = 1$,$\gamma_U = -\pi/2$

Gaugino masses

$$M_a = -i m_{3/2}\tau^2 \frac{\sum_{i=1}^3 n_a^i m_a^j m_a^k}{n_a^i n_a^j n_a^k + \tau^2 \sum_{i=1}^3 n_a^i m_a^j m_a^k}, \quad \tau^2 = \frac{(U+\bar{U})}{(S+\bar{S})}$$

Universal soft masses for bifundamental chiral matter

$$m_{C^\alpha}^{(ab)2} = m_{3/2}^2\left(1 - \frac{3}{4}|\Theta^U|^2\right) = \frac{1}{4} m_{3/2}^2$$

The $\hat{A}$ and $\hat{B}$ terms are

$$\hat{A}_{\alpha\beta\gamma} = -i m_{3/2}\,\hat{Y}_{\alpha\beta\gamma}\left[\frac{3}{4} - \left(U+\bar{U}\right)\partial_U \ln Y_{\alpha\beta\gamma}\right]$$

$$\hat{B}_{\alpha\beta} = -i m_{3/2}\,\hat{\mu}_{\alpha\beta}\left[\frac{3}{2} - i - \left(U+\bar{U}\right)\partial_U \ln \mu_{\alpha\beta}\right]$$

A toy model

Ibañez & Uranga '12

N_a	(n_a^1, m_a^1)	(n_a^2, m_a^2)	$(n_a^3, \tilde{m}_a^3)$
$N_a = 6$	$(1,0)$	$(3,1)$	$(3,-1/2)$
$N_b = 4$	$(1,1)$	$(1,0)$	$(1,-1/2)$
$N_c = 2$	$(0,1)$	$(0,-1)$	$(2,0)$
$N_d = 2$	$(1,0)$	$(3,1)$	$(3,-1/2)$

Sector	Fields	$U(3)_a \times U(2)_b$	Q_a	Q_b	Q_c	Q_d	Y
ab	Q_L	$(3,2)$	1	-1	0	0	1/6
ab'	q_L	$2(3,2)$	1	1	0	0	1/6
ac	U_R	$3(\bar{3},1)$	-1	0	1	0	$-2/3$
ac'	D_R	$3(\bar{3},1)$	-1	0	-1	0	1/3
bd	L	$(1,2)$	0	-1	0	1	$-1/2$
bd'	l	$2(1,2)$	0	1	0	1	$-1/2$
cd	ν_R	$3(1,1)$	0	0	1	-1	0
cd'	E_R	$3(1,1)$	0	0	-1	-1	$-1/2$
bc	H_d	$(1,2)$	0	-1	1	0	$-1/2$
bc'	H_u	$(1,2)$	0	-1	-1	0	1/2

SUSY condition $\tau_1 = \tau_3 = \frac{1}{2}\tau_3$

More D-branes to cancel RR tadpoles

The hypercharge $Y = \frac{1}{6}Q_a - \frac{1}{2}Q_c - \frac{1}{2}Q_d$

gauged $U_{B-L}(1)$ symmetry

The Kähler metric for the bifundamental chiral matter

$$\tilde{K}_{C_{ab}^{\alpha}\bar{C}_{ab}^{\alpha}} = c_{ab}\left(\frac{1}{64}\left(S+\bar{S}\right)\left(U+\bar{U}\right)^3\right)^{-1/4}\prod_{i=1}^{3}\left(T^i+\bar{T}^i\right)^{-1/2}$$

Soft-terms (U-dominated SUSY breaking)

Universal soft masses for squarks, sleptons $m_\alpha^2 \sim m_{3/2}^2$
The Yukawa coupling allowed are

$$W = Y_u\, q_L\, H_u\, U_R + Y_d\, q_L\, H_d\, D_R + Y_l\, l\, H_d\, E_R + Y_l\, H_u\, \nu_R$$

The Yukawa couplings $Y_{\alpha\beta\gamma} \sim e^{-\frac{A}{2\pi\alpha'}}$ Cremades, Ibañez & Marchesano '08
A-terms involving three bifundamentals (Universal trilinear terms)

$$\hat{A}_{\alpha\beta\gamma} = -i\frac{3}{4} m_{3/2} \hat{Y}_{\alpha\beta\gamma}$$

A μ-term $\mu H_u H_d$ is forbidden by $U_b(1)$ symmetry (but it may be generated instantons) No bilinear term

Conclusions

1. Type IIA compactifications provide a nice framework where we can set up all the necessary ingredients (Kähler metrics, moduli stabilisation,Yukawa couplings,...) to determine the structure of the soft SUSY breaking terms from string compactifications.
2. Here, we focus on structure of the soft SUSY breaking terms involving bifundamental chiral matter and soft gaugino masses.
   - Universal soft masses for the bifundamental chiral matter $m_{C^{\alpha}_{ab}} \sim m_{3/2}$.
   - Universal bilinear and trilinear terms for the bifundamental chiral matter.
   - Gaugino masses depend on the choice of the lattice (universal gaugino masses $M_a = -im_{3/2}$ only appear for D6-branes with some $n_a^i = 0$)

Thank you for your attention