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Gaugino masses

from

string loops

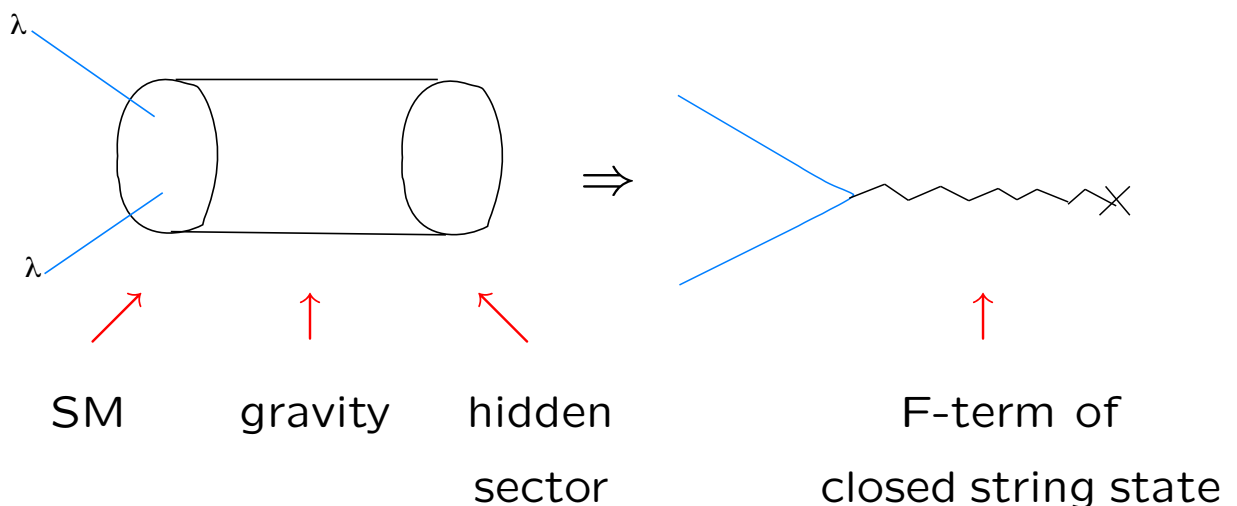**problem:**

$m_{1/2} = 0$ to lowest order

$\Rightarrow$ generated by string loop corrections

Framework: type I string theory

- effective field theory: may be still tree-level

  closed string gravity exchange $\Rightarrow$

  SUGRA tree-level

| SM | gravity | hidden sector | | F-term of closed string state |

Gaugino masses: protected by R-symmetry

but broken in 4d SUGRA by the gravitino mass

Two possible ways for generating $m_{1/2}$:

(1) via gravity (brane susy) $\Rightarrow$

generate $m_{1/2}$ from $m_{3/2}$

one gravitational loop: 1 handle + 1 boundary

$$\Rightarrow m_{1/2} \sim g_s^2 \frac{m_{3/2}^3}{M_s^2} \qquad \text{I.A.-Taylor '04}$$

(2) keep gravity subdominant $\Rightarrow$

generate $m_{1/2}$ from brane α'-corrections

two gauge loops: 3 boundaries

$$\Rightarrow m_{1/2} \sim g_s^2 \frac{m_0^4}{M_s^3} \qquad \text{I.A.-Narain-Taylor '05}$$

gauginos: open strings

$\Rightarrow$ at least one boundary (brane) $h \geq 1$

$N = 2$ superconformal charge:

3/2 units for each (chiral) gaugino

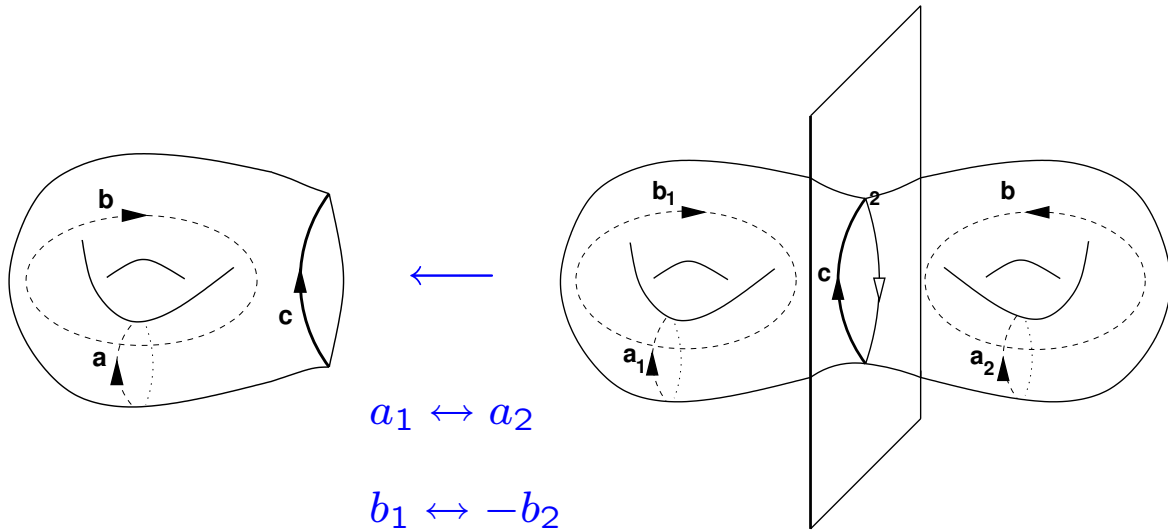± 1 unit for each 2d supercurrent insertion T_F

$\Rightarrow$ at least 3 T_F insertions
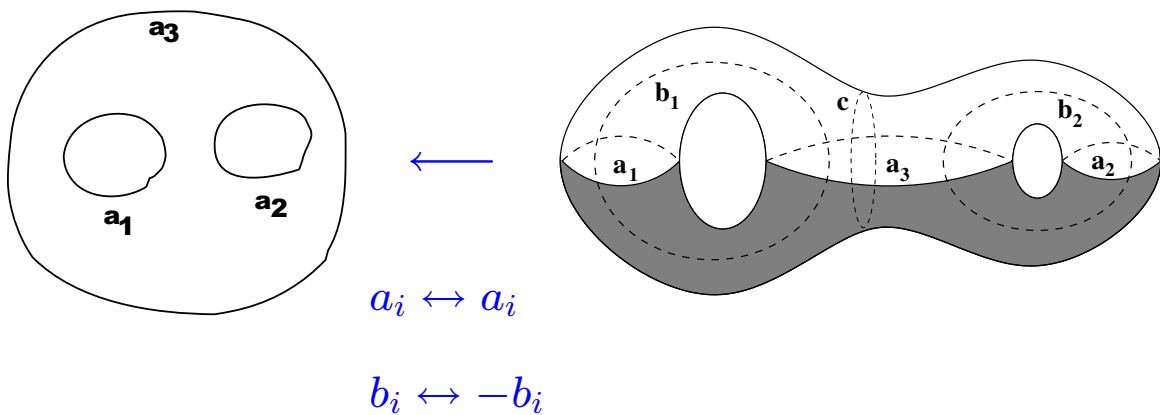
lowest order (effective genus): $g + h/2 = 3/2$

independently of the source of SUSY breaking!

Oriented case

(1) $g = 1$ $h = 1$ from mirror involution of $g = 2$

$a_1 \leftrightarrow a_2$

$b_1 \leftrightarrow -b_2$

(1) $g = 0$ $h = 3$ from mirror involution of $g = 2$

$a_i \leftrightarrow a_i$

$b_i \leftrightarrow -b_i$

Topological partition function F_g ← genus g

computes $N = 2$ SUSY F-terms

AGNT, BCOV '93

$$F_g \int d^4\theta \, W_{N=2}^{2g} \quad \rightarrow \quad F_g \, R^2 \, T^{2g-2}$$
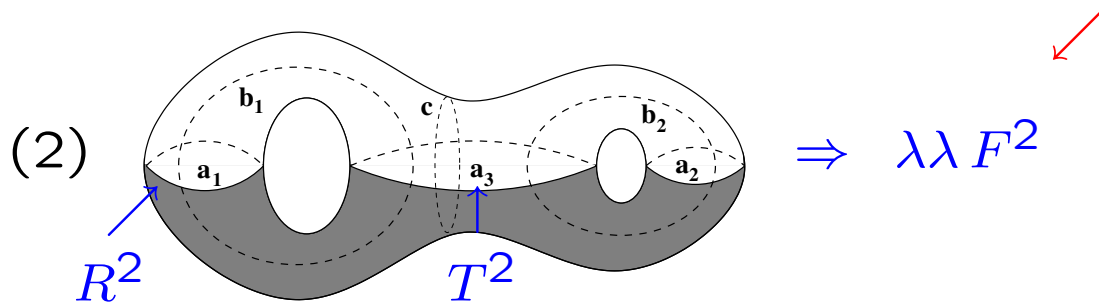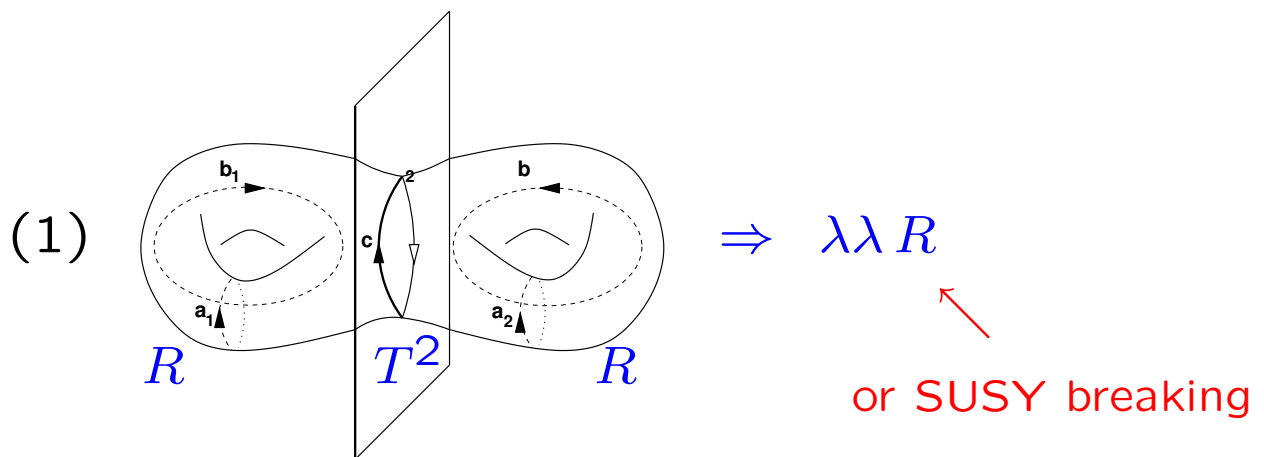
F_g: moduli dependent function

Weyl superfield: $W_{N=2} = T + \theta^2 R + \cdots$
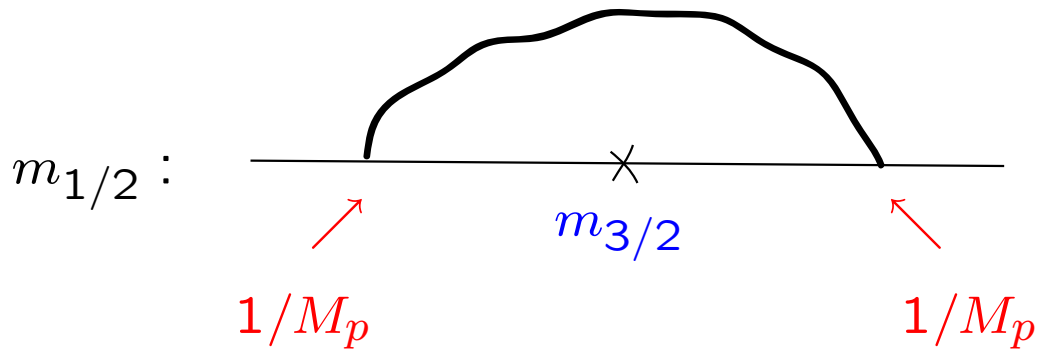
T: graviphoton field strength

R: Riemann tensor

$$F_2 \int d^4\theta \, W^4_{N=2} \quad \rightarrow \quad F_2 \, R^2 \, T^2$$

- graviphoton vertex $T = (\text{gaugino})^2$

- graviton vertex $= (\text{gauge field})^2$

(1) $\Rightarrow \lambda\lambda R$

or SUSY breaking

(2) $\Rightarrow \lambda\lambda F^2$

SUSY breaking: $R \rightarrow \langle \text{gravity auxiliary field} \rangle$

$$F \rightarrow \langle \mathsf{D} \rangle$$

$m_{1/2}:$

$1/M_p$ $m_{3/2}$ $1/M_p$

$$\sim \frac{m_{3/2}}{M_p^2} \times \begin{cases} \Lambda_{UV}^2 & \text{if quadr. divergent} \\ \\ m_{3/2}^2 & \text{if convergent} \end{cases}$$
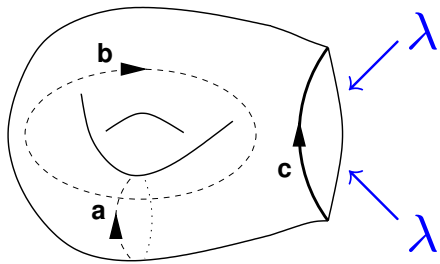
$$\sim g_s^2\, \frac{m_{3/2}^3}{M_s^2} \qquad g_s \sim g^2$$

but it vanishes for orbifolds

I.A.-Taylor '04

- anomaly mediation:

$$m_{1/2} \sim g^2 m_{3/2} \qquad g^2 \sim g_s$$

• power of g_s does not match

one loop correction always vanishes

by $N = 2$ superconformal charge

• two loops behave $\sim m_{3/2}^3$

- hierarchy between gaugino and scalar masses

however numerics not very good

unless every loop factor $\sim 10^{-2}$

Sherk-Schwarz along an interval $\perp$ branes

$\Rightarrow m_{3/2} \sim 1/R$

gravity strength $\Rightarrow R^{-1} = \frac{2}{\alpha_G^2} \frac{M_s^3}{M_p^2} \sim 10^{13}$ GeV

for $M_s \sim M_{\mathsf{GUT}} \sim 10^{16}$ GeV

- $m_{1/2} \sim g_s^2 \frac{m_{3/2}^3}{M_s^2} \sim 1$ TeV

if every loop-factor $\sim 10^{-2}$

- $m_0 \gtrsim g_s \frac{m_{3/2}^2}{M_s} \sim 10^8$ GeV

scalar masses induced at one loop
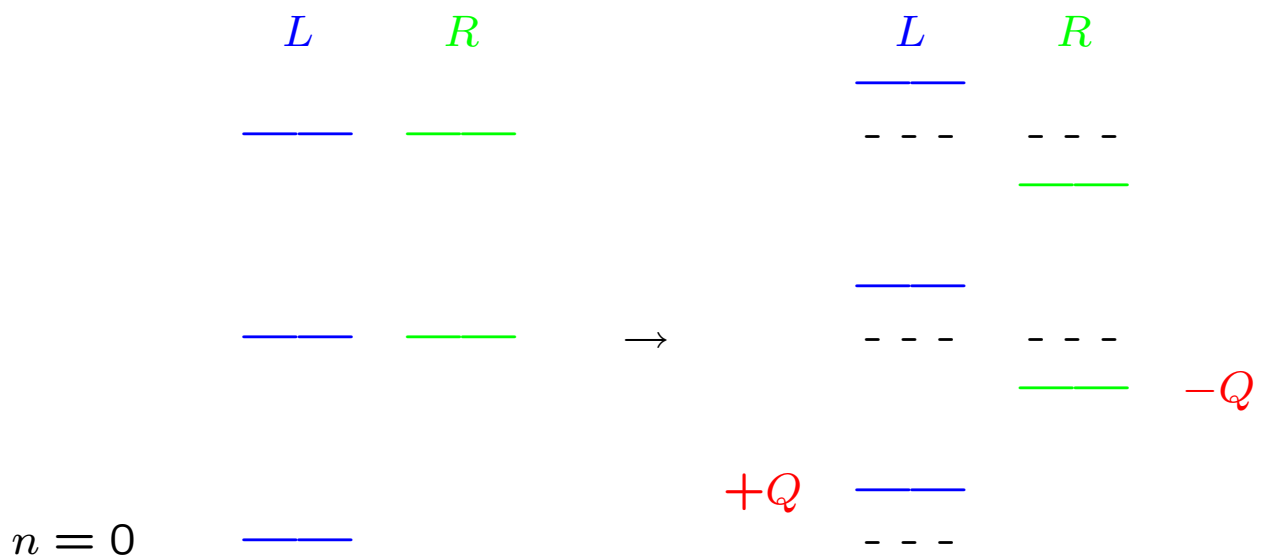
$\Rightarrow$ split supersymmetry framework

heavy scalars, light fermions

Arkani Hamed-Dimopoulos, Giudice-Romanino '04

Break SUGRA keeping R-symmetry

I.A.-Dimopoulos '04

SS breaking on $S^1/\mathbb{Z}_2 \perp$ brane $\Rightarrow$ 3/2-KK states

- generic shift $Q \Rightarrow$ Majorana masses, $\not{R}$

  $Q/R < E < 1/R \Rightarrow$ 4d SUGRA

  $E >> 1/R \Rightarrow$ 5d SUGRA

- $Q = 1/2 \Rightarrow$ pairing $|n+Q\rangle_L$ with $|n+1-Q\rangle_R$

  $\Rightarrow$ Dirac masses, unbroken R-symmetry

  no intermediate regime $\Rightarrow$ no 4d SUGRA description

SUSY breaking by internal magnetic fields

or equivalently branes at angles

Effective QFT description: D-breaking

magnetic field $H \sim \langle D \rangle$-term of $U(1)$

$\langle D \rangle \sim m_0^2$ $\qquad\qquad\qquad$ $U(N)$ brane stack

R-symmetry broken by string corrections

$\Rightarrow$ higher-dim effective operators:

$\qquad\qquad\qquad\qquad\qquad$ I.A.-Narain-Taylor '05
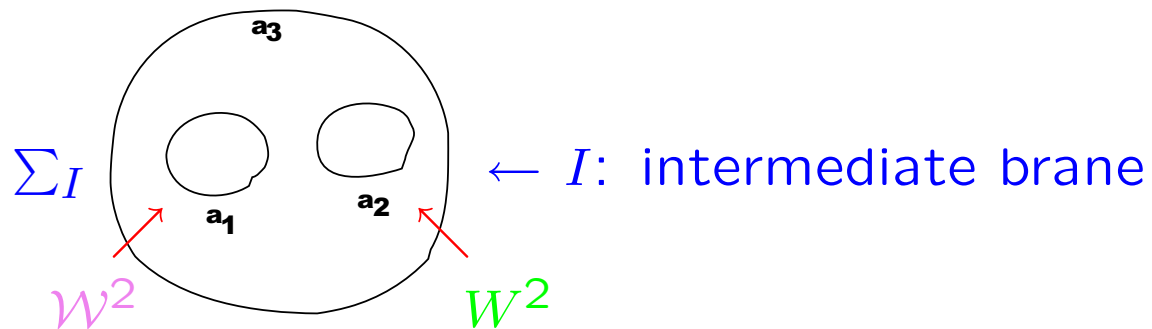
$F_{(0,3)} \int d^2\theta \, \mathcal{W}^2 \mathrm{Tr} W^2$ $\qquad\qquad$ $\langle \mathcal{W} \rangle = \theta \langle D \rangle$

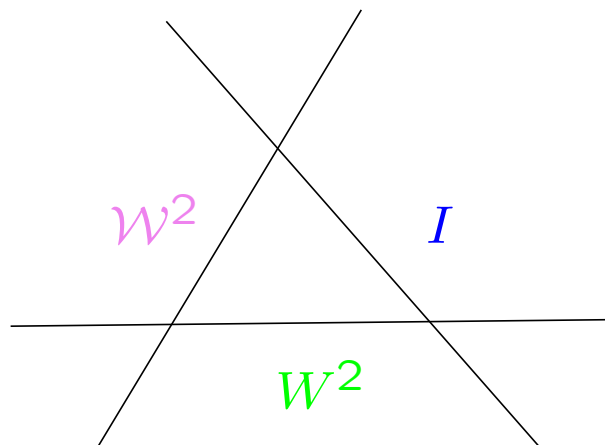$\Rightarrow \; m_{1/2} \sim \epsilon^2 \dfrac{m_0^4}{M_s^3}$ $\qquad\qquad$ ϵ^2: 2-loop factor

$\qquad\qquad\qquad \sim$ TeV for $m_0 \sim 10^{13} - 10^{14}$ GeV

World-sheet with 3 boundaries (2 loops)

Σ_I $\leftarrow I$: intermediate brane

$\mathcal{W}^2$ W^2

T-duality $\Rightarrow$

$\mathcal{W}^2$ I

W^2

$\neq 0$: I-brane away from the intersection

of the other two

● as gauge mediation with string scale gaugino masses

- Higgsino mass

$$\int d^2\theta \mathcal{W}^2 \bar{D}^2 \bar{H}_1 \bar{H}_2 \Rightarrow \mu \sim \epsilon \frac{m_0^4}{M_s^3} \lesssim m_{1/2}$$

$$\nearrow$$

$$\psi_1 \psi_2$$

- Simple toroidal models

gauge multiplets: $N = 4$ (or $N = 2$) SUSY

$\Rightarrow$ Dirac gaugino masses without R̸

$$\int d^2\theta \mathcal{W} \mathrm{Tr} W A \Rightarrow m_D \sim \epsilon \frac{m_0^2}{M_s} \qquad \text{1-loop factor}$$

$N = 2$ vector $= N = 1$ vector W + chiral A

they can still be consistent with unification

in inermediate energy scales $\sim 10^7 - 10^{13}$ GeV

I.A.-Benakli-Delgado-Quirós-Tuckmantel '05