Threshold Corrections in Intersecting Brane Models

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0806.3039 + work in progress

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OUTLINE

I Motivation

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III Threshold corrections

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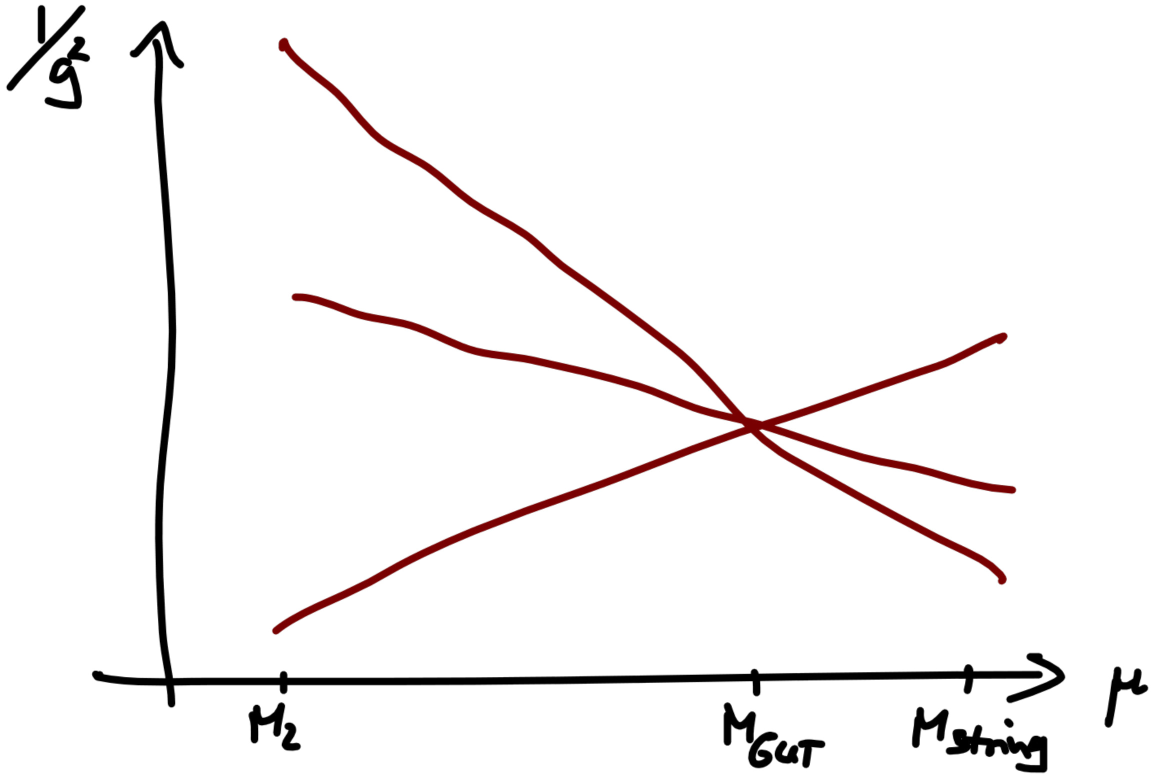
MOTIVATION



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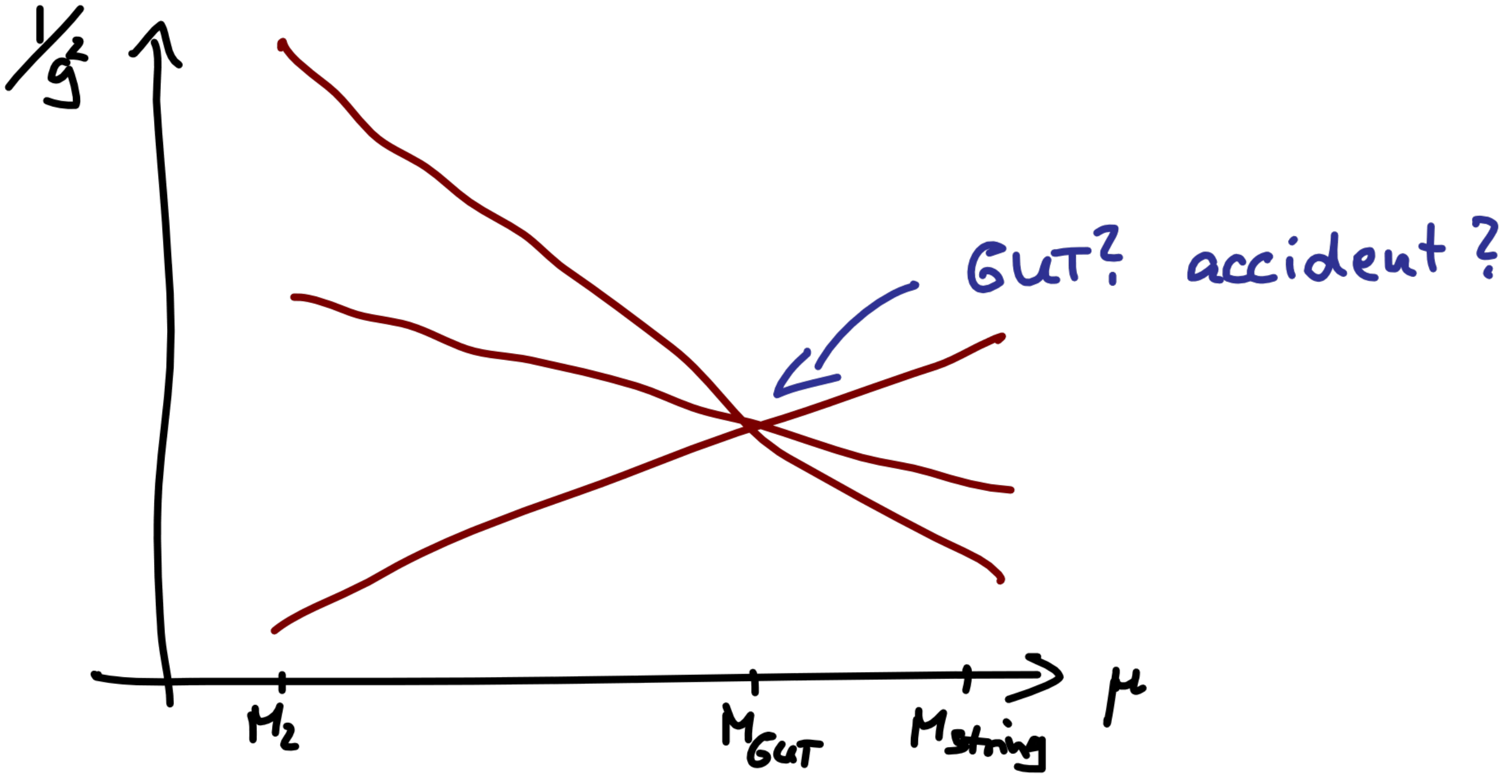

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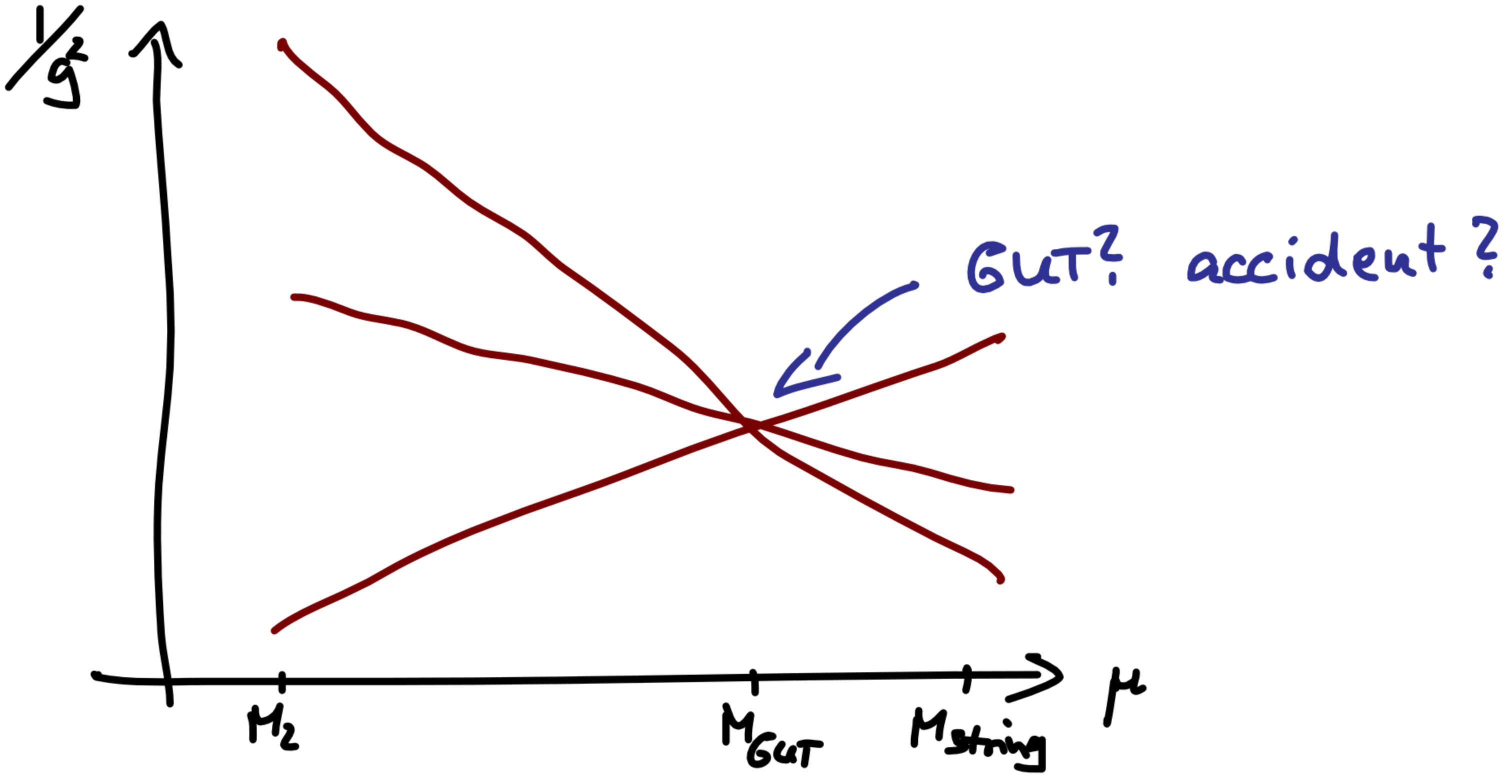

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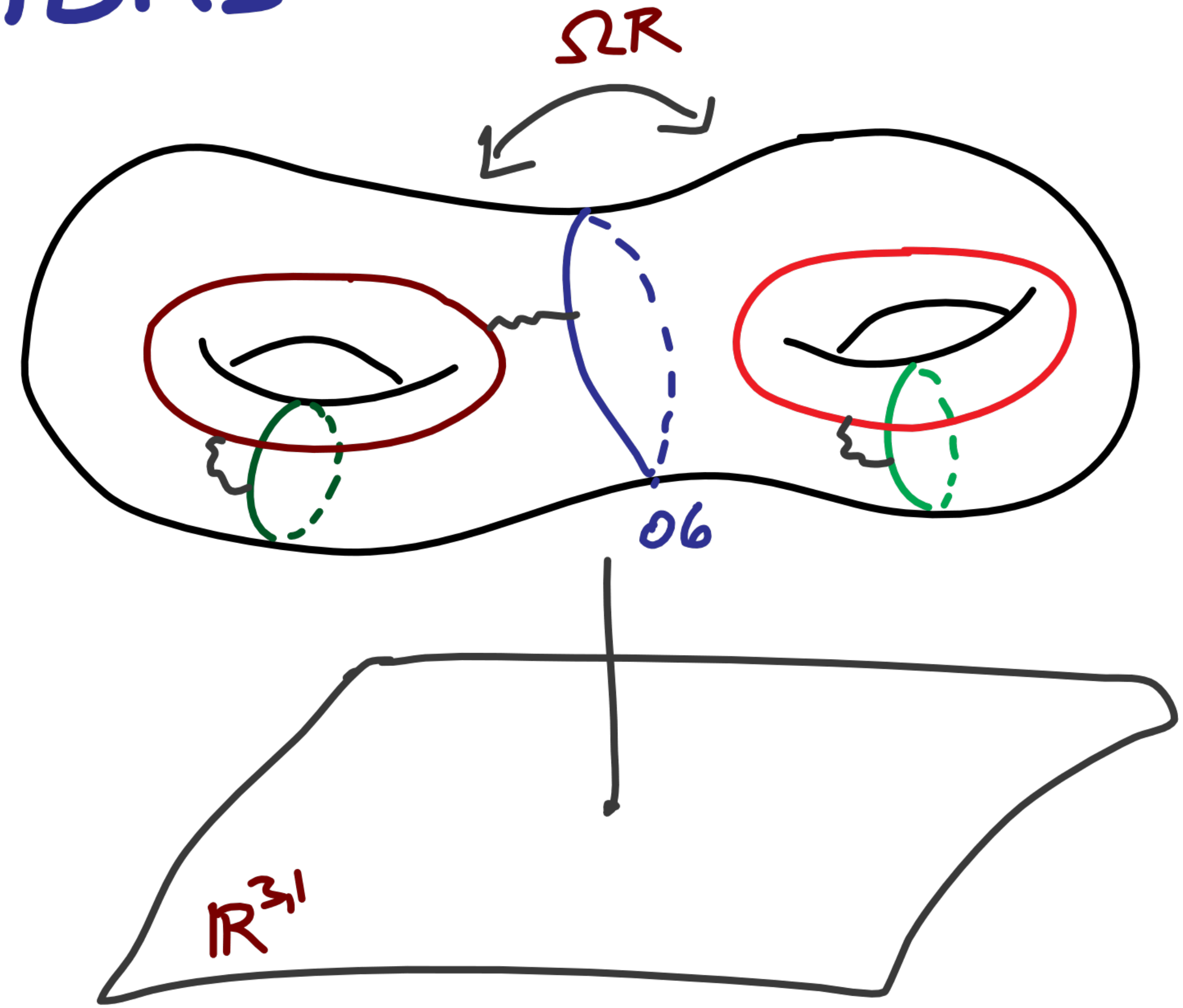
- Can we reproduce the running from an MSSM (+X) @ the string scale ?
- What about the Landscape ?
  - → how are gauge couplings distributed ?
  - → are there common patterns ?
- Use simple + well understood playground
  - → intersecting brane models

IBMs



- D6 branes + O6 planes wrapping 3-cycles
- matter @ intersections
- nice + simple, but
  - → no moduli stabilisation
  - → no fully realistic models

$$\mathbb{R}^{3,1} \times T^6 / _{\Omega R \times G} \qquad G \in \{\mathbb{Z}_N, \mathbb{Z}_N \times \mathbb{Z}_M\}$$

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tadpoles: $\sum_i N_i \left(\Pi_i + \Pi_i' \right) = 4\, \Pi_{O6}$

\# branes on stack i

orientifold image

O6 charge

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branes on stack i

orientifold image

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K-theory: $\sum_i N_i \, \Pi_i \circ \Pi_{Sp(2)} \equiv 0 \mod 2$

probe brane

IBMs

spectrum :

- closed string : $N=1$ SUGRA
- open string : $U(N)$, $SO(2N)/Sp(2N)$ gauge groups + charged matter
  - $\longrightarrow$ bifundamental
  - $\longrightarrow$ Sym, Anti, Adj.

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chiral open string spectrum: (on $\mathbb{Z}_{2N}$ orbifold)

$$\chi^{ab} = -\frac{1}{2} \sum_{k=0}^{N-1} \left(I^{a(\theta^k b)} + I_{\mathbb{Z}_2}^{a(\theta^k b)} \right)$$

orbifold group generator

exceptional part of fractional cycle

IBMs

full open string spectrum:

$$\varphi^{ab} = \frac{1}{2}\sum_{k=1}^{N-1} \left| I^{a(\theta^k b)} + I^{a(\theta^k b)}_{\gamma_2} \right|$$

Sym, Anti, Adj. can be computed analogously.

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$\rightsquigarrow$ everything given as (simple) algebraic equations

THRESHOLDS

couplings. (1 loop)

$$\frac{1}{\alpha_a} = \frac{1}{\alpha_a^{string}} + \frac{b_a}{4\pi} \ln\left(\frac{M_{string}}{\mu}\right) + \frac{\Delta_a}{4\pi}$$

running

threshold corrections

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$$\circ \quad \frac{1}{\alpha_a^{string}} = \frac{M_{pl}}{G\, M_{string}} \prod_{i=1}^{3} \sqrt{V_a^{(i)}}$$

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- $$\frac{1}{\alpha_a^{\text{string}}} = \frac{M_{pl}}{g\, M_{\text{string}}} \prod_{i=1}^{3} \sqrt{V_a^{(i)}}$$ ← volume of cycle a on torus (i)

- running generated by massless string states,

e.g.

$$b_a^{SU(N)} = -N_a\left(3 - \varphi^{Adj}\right) + \sum_{b\neq a} \frac{N_b}{2}\left(\varphi^{ab} + \varphi^{ab'}\right) + \frac{N_a - 2}{2}\varphi^{Anti} + \frac{N_a + 2}{2}\varphi^{Sym}$$

THRESHOLDS

- running of $U(1)$s (e.g. hypercharge) given as $U(1)_X = \sum_i x_i \, U(1)_i$

$$\leadsto \quad b_{U(1)_X} = \sum_i x_i^2 b_i + 2 \sum_{i \neq j} N_i N_j x_i x_j \left(-\varphi^{ij} + \varphi^{ij'} \right)$$

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- full massless spectrum needed to compute b's for all brane stacks / gauge groups

THRESHOLDS

- thresholds Δ receive contributions from massive states

  $\longrightarrow$ compute 1-loop amplitudes to obtain coefficients in front of $\int \frac{1}{g^2} F \wedge * F$

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- background field method.

  quantize string in magnetic bg B and expand 1-loop vacuum energy in B

  $\rightsquigarrow$ thresholds $b_a + \Delta_a$ can be read off B^2-term.

THRESHOLDS

$$\Lambda_{1\text{-loop}} = 0 + B^2 (1/g^2) + B^4 \ldots$$

SUSY!

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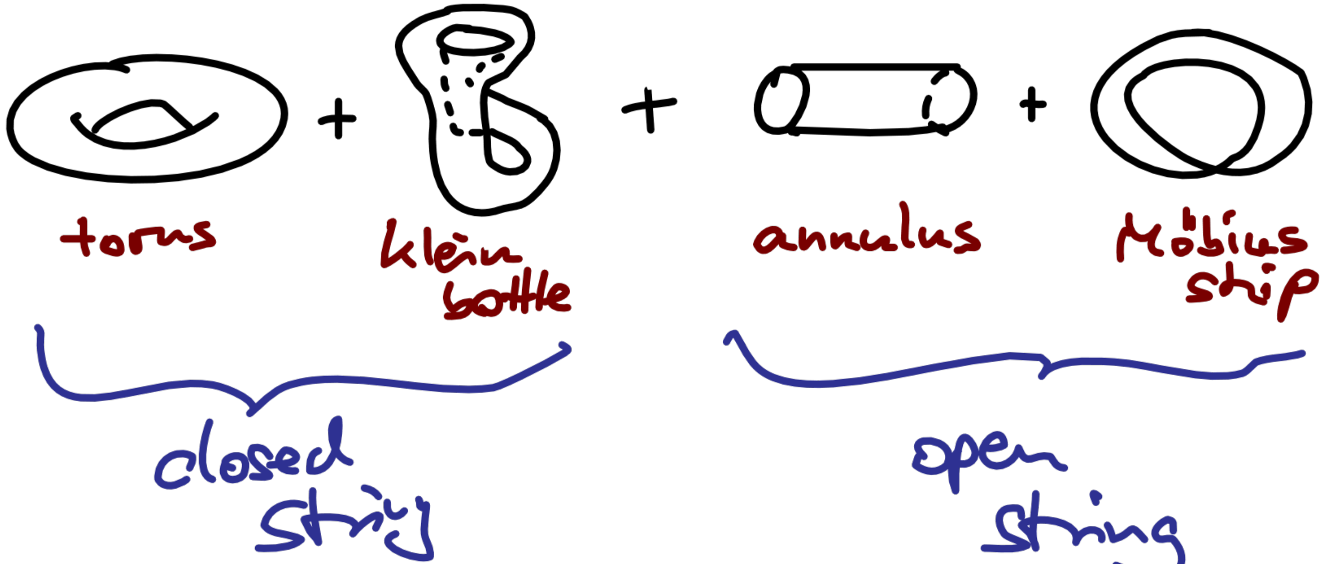
susy!

$=$



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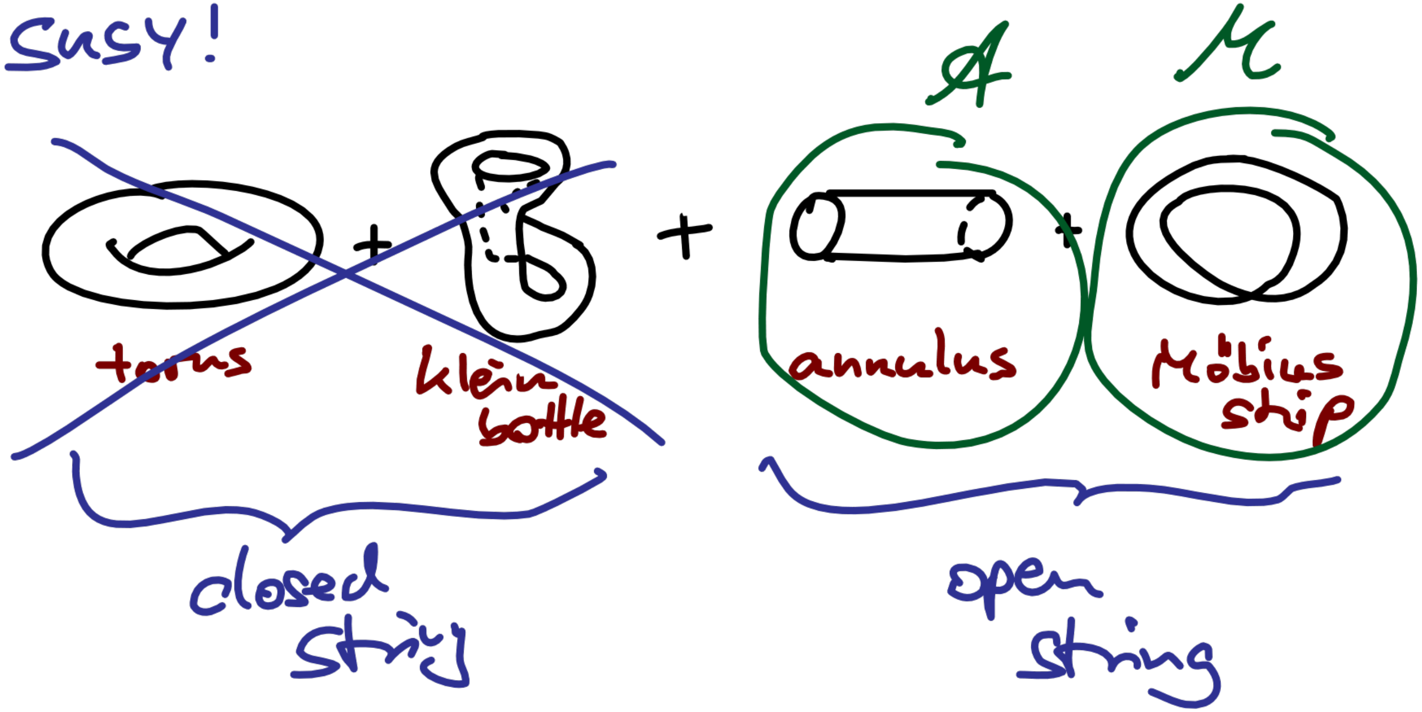

THRESHOLDS

$$\longrightarrow \quad b_a + \Delta_a = \sum_b \left(\mathcal{A}(a,b) + \mathcal{A}(a,b') + \mathcal{M}(a,O6) \right)$$

Example:

$$\mathcal{A} \sim \int d\tau \sum_{(\alpha,\beta)} (-1)^{2(\alpha+\beta)} \frac{\vartheta\left[\substack{\alpha \\ \beta}\right](0,\tau)}{\eta^3(\tau)} \mathcal{A}_{compact}$$

use open string 1-loop $\longleftrightarrow$ closed string tree level correspondence

- contributions to $A_{compact}$ depend on the brane configuration, oscillator + lattice modes

THRESHOLDS

e.g. branes parallel,

$$\mathcal{A}_{\text{comp.}} \sim V_{ab}\,\mathcal{L}$$

lattice

brane intersections

$$V_{ab} = \frac{R_1}{R_2} n^a n^b + \frac{R_2}{R_1}(m^a + b n^a)(m^b + b n^b)$$

torus geometry

wrapping numbers

tilted torus?

$$\mathcal{L} \sim \sum_{m,n} e^{-2\pi t M^2}$$

$$M^2 \sim \frac{1}{V_{ab}}\left[\frac{1}{v}\left(m + \frac{\tau_{ab}}{2}\right)^2 + v\left(n + \frac{\sigma_{ab}}{2}\right)^2\right]$$

Wilson lines

brane displ.

THRESHOLDS

$\rightarrow$ integration gives a contribution to Δ_a.

depending on the values for τ + σ we might also get a divergent contribution that (after regularization) contributes to b_a.

EXAMPLE

$T^6/\mathbb{Z}_6'$:

$$\theta : z^k \longrightarrow e^{2\pi i v_k} z^k \,, \qquad v_k = \frac{1}{6}(1,2,-3)$$

$$R : z^k \longrightarrow \overline{z^k}$$

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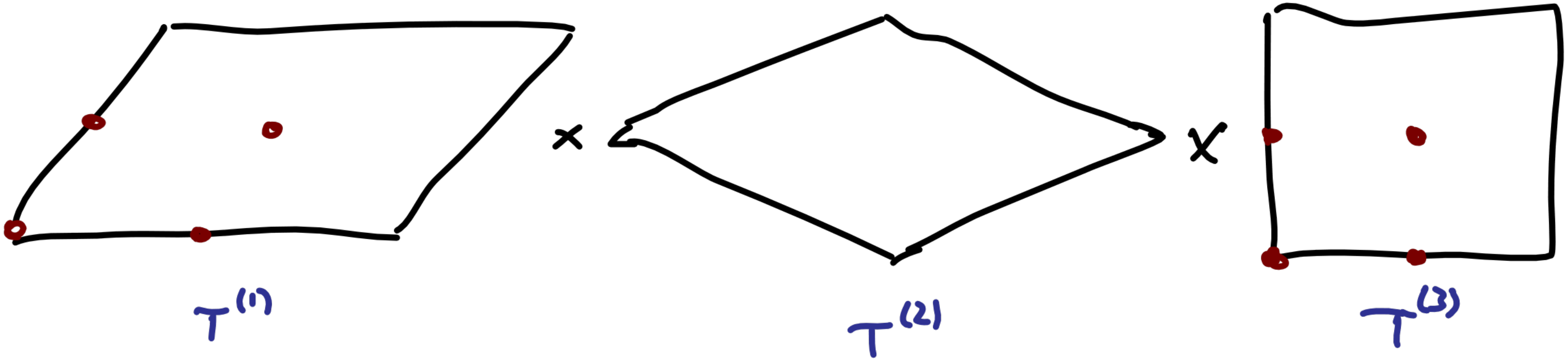

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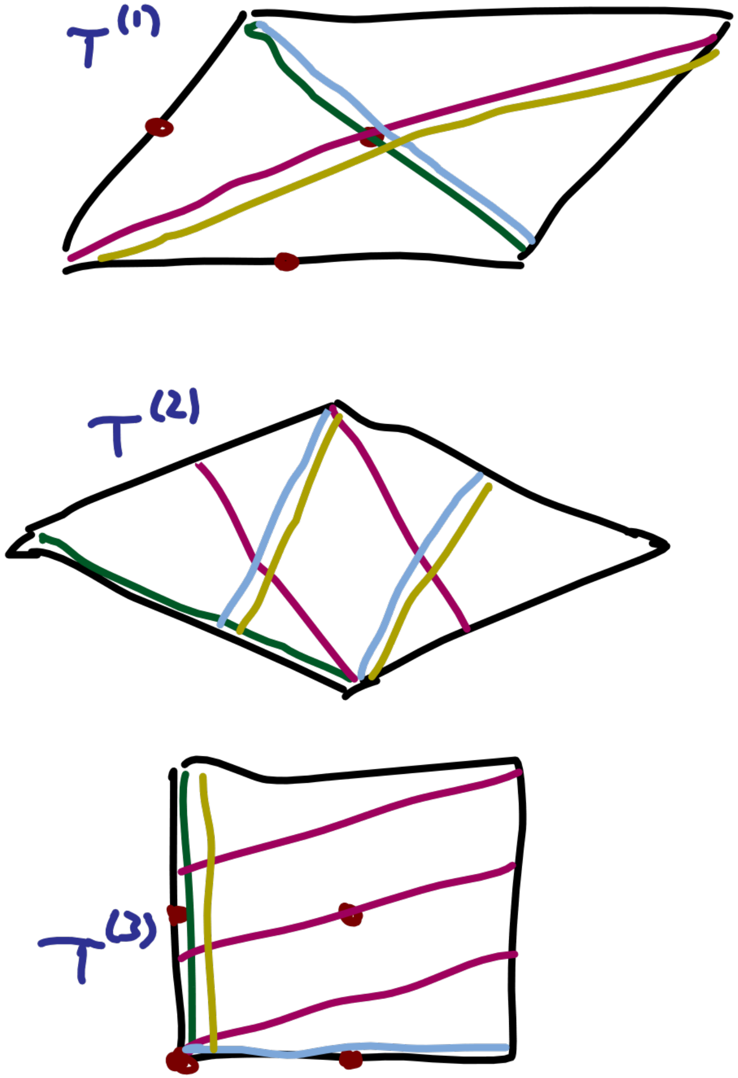

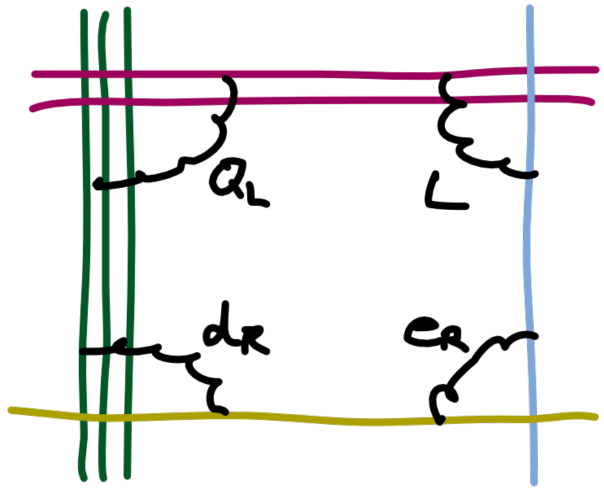

$$U(1)_Y = \frac{1}{6} U(1)_a + \frac{1}{2}\left(U(1)_b + U(1)_d\right)$$

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- values @ string scale.

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- running:

$$b_a = 14 \qquad b_b = 91 \qquad b_Y = \frac{181}{3}$$

problem!

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- thresholds:

$$\Delta_a \sim 149 \qquad \Delta_b \sim 406 \qquad \Delta_c \sim 235$$

(for medium volume)

OUTLOOK

- Statistics ! → generic pattern?
- $b_a < 0$?
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Thanks!