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# A story of De- and Re-coupling: SUSY breaking in string models

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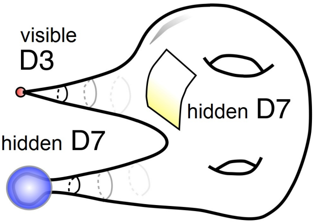
in collaboration with Marcus Berg, Joe Conlon and David Marsh

arxiv:1109.4153 and arxiv:1207.1103

# Motivation




- String theory allows for geometric interpretation of phenomenological features
- In type IIB can locate visible and hidden sectors in extra dimensions
- Many properties are determined locally (gauge group, massless spectrum), but global properties do not fully decouple.

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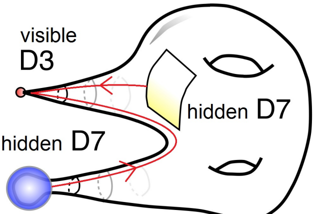


- String theory allows for geometric interpretation of phenomenological features
- In type IIB can locate visible and hidden sectors in extra dimensions
- Many properties are determined locally (gauge group, massless spectrum), but global properties do not fully decouple.
- For realistic models moduli stabilization is imperative
- **Here:** examine how moduli stabilization via non-perturbative effects alters the visible sector theory:
  1. new Yukawa couplings?
  2. structure of soft ~~SUSY~~ terms?

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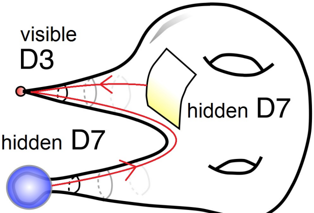


- Can stabilise moduli non-perturbatively (KKLT, LVS):
  E3-branes or gaugino condensation on D7-branes wrapping internal cycles.
- This creates a potential for (Kähler) moduli fields $T$
- Equally, non-perturbative effects induce new superpotential terms:

$$W^{np} \supset \mathcal{O} e^{-T}$$

- $\cancel{SUSY}$: Kähler modulus $T$ acquires $F$-terms $\Rightarrow W^{np}$ gives rise to important contribution to soft terms: de-sequestering.

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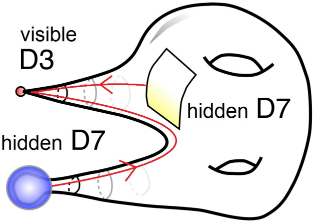


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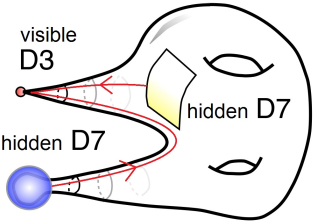


Analyze a setup with typical ingredients:

- Visible sector on D3s at a singularity
- Focus on non-perturbative effects from gaugino condensation on distant D7 branes

Two cases for the nonperturbative effect:

- KKLT-type: D7 wraps bulk 4-cycle
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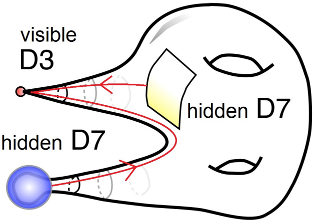


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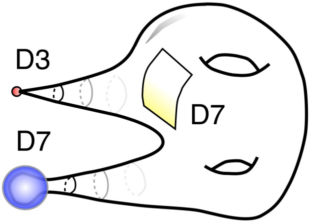
Tasks for this presentation: Answer ...

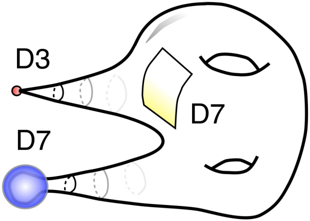
1. which models lead to non-perturbative corrections to Yukawas?
2. what is their flavor structure?
3. what is their parametric suppression w.r.t. the tree level Yukawas?

# Outline




1. SUSY breaking and sequestering
2. Orbifold CFT calculation
3. Superpotential de-sequestering due to moduli stabilization
   - KKLT
   - LVS
4. Phenomenological consequences
5. Summary and outlook

# Sequestering: the model




- Visible sector:
  D3 branes at orbifold singularity
- Complex structure moduli and dilaton flux-stabilized in a supersymmetric way:

$$D_U W = D_S W = 0$$

- Kähler moduli are stabilized by non-perturbative effects (gaugino condensation) at a $\cancel{\text{SUSY}}$ minimum.
- This breaking is mediated to visible sector by bulk fields

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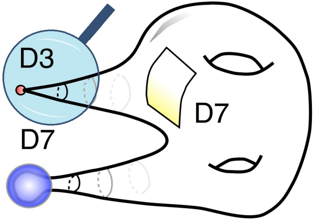


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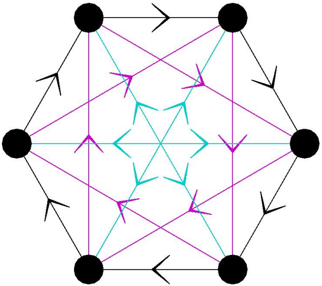

Example: D3s at $\mathbb{Z}_6'$: $\theta = \frac{1}{6}(1, -3, 2)$

- gauge group

$$\mathrm{SU}(M) \times \ldots \times \mathrm{SU}(N)$$

- Chiral superfields $C^1$, $C^2$, $C^3$ in bifundamental representations
- Yukawa operators = triangles in quiver
- Tree-level superpotential:

$$W^{\mathrm{tree}} = \epsilon_{rst} C^r C^s C^t$$

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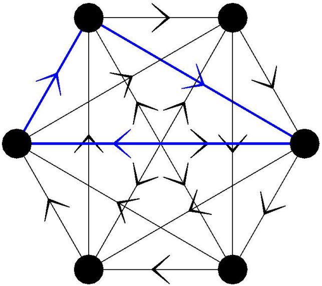

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- Tree-level Yukawa couplings have flavor structure

$$Y_{123}^{\mathrm{tree}} C^1 C^2 C^3$$

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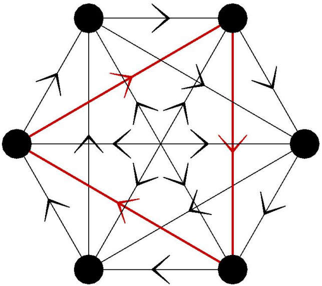

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- Chiral superfields $C^1$, $C^2$, $C^3$ in bifundamental representations
- Yukawa operators = triangles in quiver
- Other Yukawas allowed by gauge invariance:

$$Y_{333} C^3 C^3 C^3$$

but are not realized.

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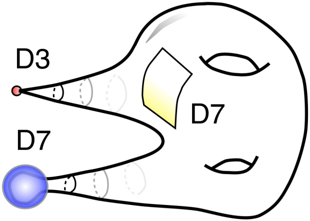


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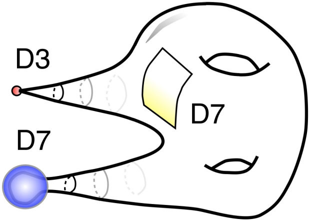


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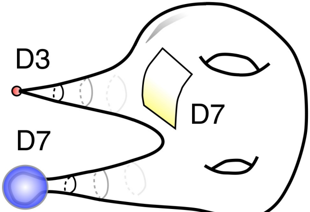


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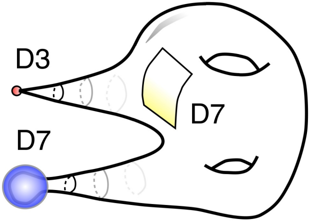


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- Presence of bulk fields in string theory allows for gravity- (moduli-) mediated SUSY breaking.
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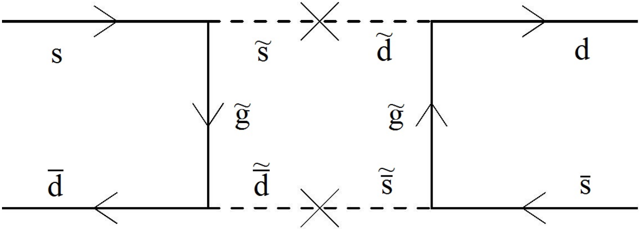

# Sequestering: SUGRA and soft terms

- Flavor problem ameliorated if gravity-mediated soft terms are suppressed.
- This occurs when $\cancel{\text{SUSY}}$ sector decouples from visible sector: $\rightarrow$ source of $\cancel{\text{SUSY}}$ is sequestered from the visible sector.

Need to study effective SUGRA Lagrangian

$$
\begin{aligned}
f &= -3M_{Pl}^2\, e^{-K/3M_{Pl}^2} \\
W &= W^{\text{tree}} + W^{\text{np}} \\
\tau &
\end{aligned}
$$

where $K$ is the Kähler potential.

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$$\begin{aligned} f &= f_{\text{hid}}(\Phi, \bar{\Phi}) + f_{\text{vis}}(C, \bar{C}) \\ W &= W_{\text{hid}}(\Phi) + W_{\text{vis}}(C) \\ \tau & \end{aligned}$$

where $\Phi_i$ are (SUSY breaking) moduli and $C_\alpha$ are visible fields.

# Sequestering: SUGRA and soft terms

- Extradimensional locality in 5d leads to the above structure
  [Randall, Sundrum]
- String theory allows for extradimensional locality:
  $\rightarrow$ Can sequestering occur in string theory?

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# Sequestering in string theory

Tree-level superpotential $W^{\mathrm{tree}}$:

- The ~~SUSY~~ moduli are Kähler moduli $T_i$.
- Kähler moduli exhibit axionic shift symmetries.
- This is in conflict with holomorphicity of $W^{\mathrm{tree}}(\Phi)$.

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$\Rightarrow$ $W^{\mathrm{tree}}$ is independent of $T_i$

$$W^{\mathrm{tree}} = W^{\mathrm{tree}}(\Phi) + W^{\mathrm{tree}}(C) = 0 + W^{\mathrm{tree}}(C)$$

The tree-level superpotential does not source soft terms.

# Sequestering in string theory

Examine $f$ function:

- Sequestering typically fails due to $f$. [Anisimov et.al. ] [Kachru, McGreevy, Svrcek]
- Bulk modes generate cross-couplings

$$f \supset \Phi\bar{\Phi}\frac{\lambda_{\alpha\beta}}{M_{Pl}^2}C^\alpha \bar{C}^\beta$$

$\Rightarrow$ $f$ does not take sequestered form in general

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Solutions:

- Warped sequestering/ conformal sequestering

  [Kachru, McAllister, Sundrum] [Luty, Sundrum]
- Sort-of sequestering in LVS [Conlon, Cremades, Quevedo] [Conlon, LW]

$\Rightarrow$ In many models $f$ does sequester.

# Sequestering: moduli stabilization

How is this modified by moduli stabilization (KKLT, LVS)?
Consider gaugino condensation on D7-branes wrapping internal cycles:
$\rightarrow$ also induce superpotential terms for visible fields.

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- Non-perturbative superpotential re-introduces cross-couplings into $W$:
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$$W = W^{\mathrm{tree}} + Y^{np}_{\alpha\beta\gamma} C^{\alpha} C^{\beta} C^{\gamma} e^{-aT} + \ldots$$

- Non-perturbative superpotential re-introduces cross-couplings into $W$:
  $\rightarrow$ de-sequestering [Berg, Marsh, McAllister, Pajer]
- The dependence on the SUSY breaking modulus $T$ leads to contributions to soft $A$-terms:

$$\delta A_{\alpha\beta\gamma} = -\frac{\mathcal{A}_0}{M_{pl}^3} Y^{np}_{\alpha\beta\gamma} a F^T e^{-aT}$$

- If $Y^{np}_{\alpha\beta\gamma} \neq c Y^{tree}_{\alpha\beta\gamma}$ the resulting contribution to soft scalar masses can lead to flavor violation.

# Worldsheet calculation

# Orbifold calculation

Non-perturbative superpotential due to gaugino condensation:

$$W_{np} = e^{-a\ \tau_{D7}}$$

The gauge kinetic function depends on moduli $\Phi^i$ and D3-matter fields $C^j$.
Expand in gauge-invariant combinations of matter fields:

$$\tau_{D7}(\Phi^i, C^j) = T + Y_{ijk}(\Phi^l)C^i C^j C^k + \ldots$$

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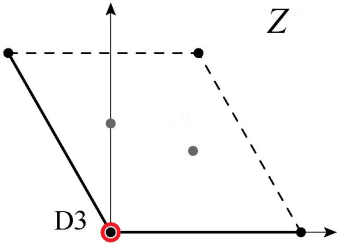
To determine $Y_{ijk}$ need to calculate a threshold correction to $\tau_{D7}$:

$$\langle\ \mathrm{Tr}(A_\mu A^\mu)\ \mathrm{Tr}(\phi^i \phi^j \phi^k)\ \rangle$$

# Why trust the orbifold?

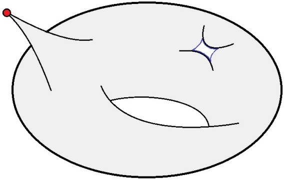
**Toroidal orbifold**

- flat
- bulk cycle
- singularities




**Swiss-Cheese Calabi-Yau**

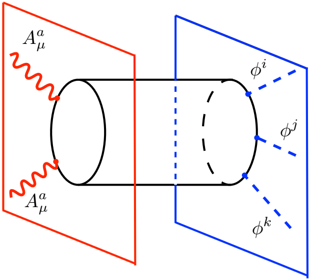
- almost flat
- large cycle
- small blow-up cycles (and singularities)



$\Rightarrow$ Swiss-Cheese Calabi-Yau is well-approximated by toroidal orbifold.

# Orbifold calculation

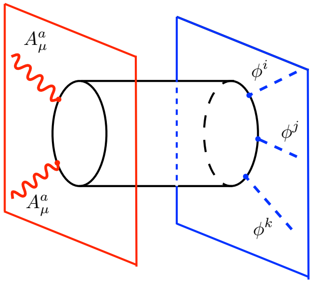
Need to calculate $\langle \, \mathrm{Tr}(A_\mu A^\mu) \; \mathrm{Tr}(\phi^i \phi^j \phi^k) \, \rangle$




- Double-trace operator: need worldsheet with two boundaries $\rightarrow$ cylinder worldsheet
- No other worldsheets contribute at this order.

# Orbifold calculation

Need to calculate $\langle\ \mathcal{V}^0_{A_1}(z_1)\mathcal{V}^0_{A_2}(z_2)\ \mathcal{V}^0_{\phi_i}(z_3)\mathcal{V}^0_{\phi_j}(z_4)\mathcal{V}^0_{\phi_k}(z_5)\ \rangle$

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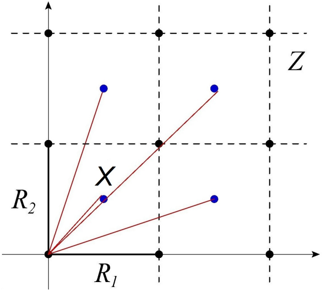
- $\langle\Psi\bar{\Psi}\rangle$ non-zero while $\langle\Psi\rangle = \langle\Psi\Psi\rangle = \langle\Psi\Psi\Psi\rangle = 0$
- Similarly, $\langle\partial Z\partial\bar{Z}\rangle$ non-zero and thus $\langle\partial Z\partial Z\partial Z\rangle_{QM} = 0$, but one can have a non-zero classical correlator.

# Orbifold calculation: classical solution




Have classical solutions in terms of winding states:

$$Z(\tau,\sigma) = Z_0 + \sqrt{\frac{\alpha'}{2}}\,[R_1 m + R_2 n + X]\sigma + \sum(\text{oscillators})$$

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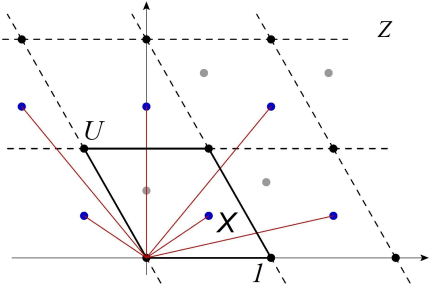


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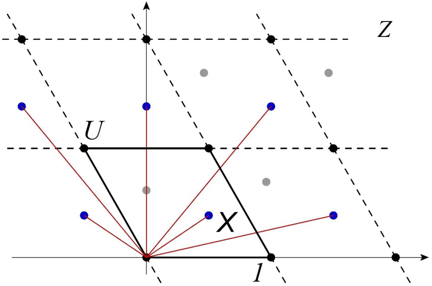
$$Z(z,\bar{z}) = Z_0 + \sqrt{\frac{\alpha' T_2}{2U_2}}\,[m + Un + X](z+\bar{z}) + \sum(\text{oscillators})$$

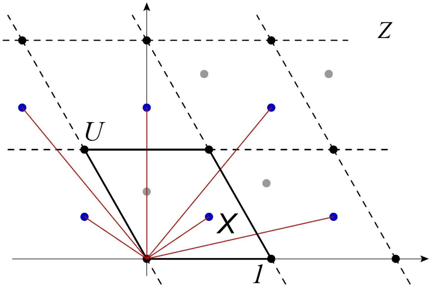
# Orbifold calculation: classical solution




Have classical solutions in terms of winding states:

$$\Rightarrow \partial Z_{\rm cl} = \sqrt{\frac{\alpha' T_2}{2U_2}}\,[m + Un + X] := r_{mn}$$

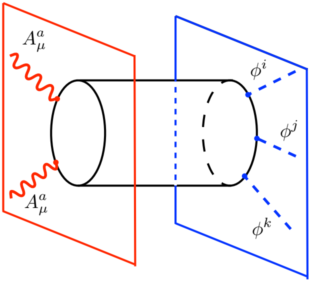
# Orbifold calculation: classical solution




The correlator becomes:

$$\langle \partial Z^i \partial Z^j \partial Z^k \rangle = \sum_{\substack{\text{classical} \\ \text{solutions}}} \partial Z^i_{\text{cl}} \partial Z^j_{\text{cl}} \partial Z^k_{\text{cl}} \, \langle \mathbb{1} \rangle_{QM} \, e^{-S_{\text{cl}}}$$

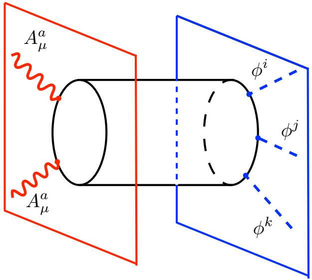
# Orbifold calculation: summary




**Necessary condition:** The above correlator and thus the whole cylinder amplitude can only be non-zero if the classical solutions $\partial Z^i_{\rm cl} \partial Z^j_{\rm cl} \partial Z^k_{\rm cl}$ exist:

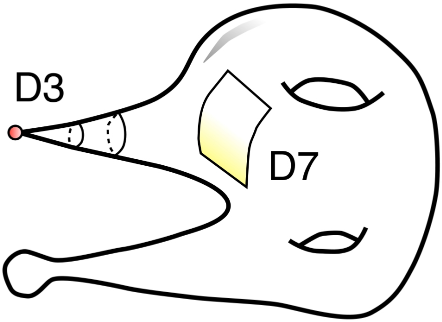
$$Y^{\rm np}_{ijk} \Leftrightarrow \partial Z^i_{\rm cl} \partial Z^j_{\rm cl} \partial Z^k_{\rm cl} \ .$$

# Orbifold calculation: summary

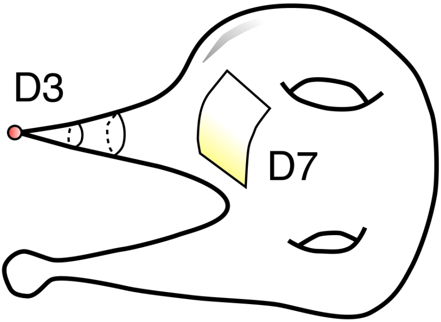



- Non-zero winding solutions can only exist with Dirichlet-Dirichlet boundary conditions and when there are are untwisted directions.

# Non-perturbative effects on Bulk D7s (KKLT)

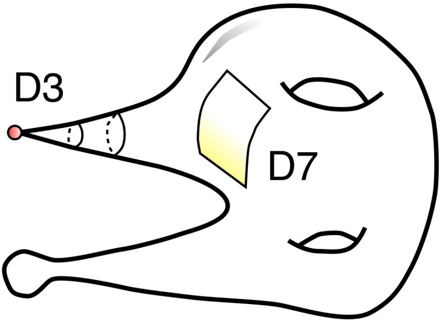


# Non-perturbative effects on Bulk D7s (KKLT)




- Visible sector localized at singularity
- D7s wrap a bulk 4-cycle

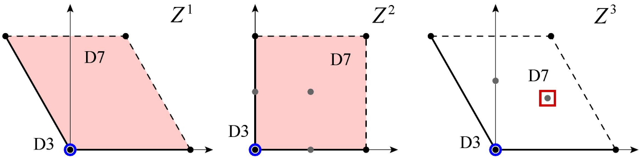
# Non-perturbative effects on Bulk D7s (KKLT)




- Take this picture to the orbifold limit
- To be specific work on $\mathbb{T}^6/\mathbb{Z}_6'$: $\theta = \frac{1}{6}(1, -3, 2)$

# Non-perturbative effects on Bulk D7s (KKLT)

Setup in $\mathbb{T}^6/\mathbb{Z}_6'$ orbifold: $\theta = \frac{1}{6}(1, -3, 2)$

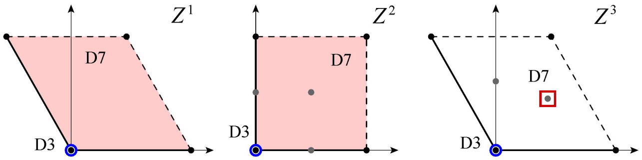



In the orbifold limit

- bulk D7s wrap two internal 2-tori
- bulk D7s are separated from visible D3 stack on one torus

# Non-perturbative effects on Bulk D7s (KKLT)

Setup in $\mathbb{T}^6/\mathbb{Z}_6'$ orbifold: $\theta = \frac{1}{6}(1, -3, 2)$

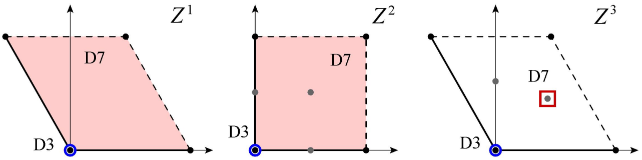



Check for classical solutions:

- First two tori: no winding due to Neumann-Dirichlet boundary condition
- Only allowed classical solution is trivial: $\partial Z^1_{\rm cl} = \partial Z^2_{\rm cl} = 0$

# Non-perturbative effects on Bulk D7s (KKLT)

Setup in $\mathbb{T}^6/\mathbb{Z}_6'$ orbifold: $\theta = \frac{1}{6}(1, -3, 2)$



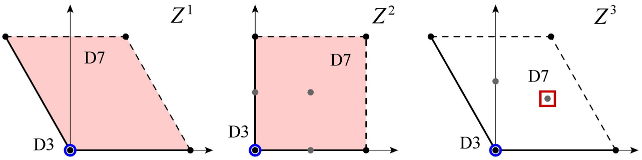

Check for classical solutions:

- Third torus: Dirichlet-Dirichlet boundary condition allows for non-trivial classical winding strings
- Set of classical solutions: $\partial Z^3_{\mathrm{cl}} = \sqrt{\frac{\alpha' T_2}{2U_2}}\left[m + Un + X\right]$

$$\Rightarrow \langle \partial Z^3 \partial Z^3 \partial Z^3 \rangle \neq 0$$

# Non-perturbative effects on Bulk D7s (KKLT)

Setup in $\mathbb{T}^6/\mathbb{Z}_6'$ orbifold: $\theta = \frac{1}{6}(1, -3, 2)$



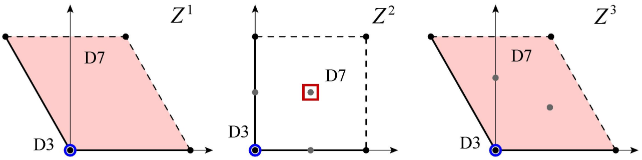

Check for classical solutions:

- Third torus: Dirichlet-Dirichlet boundary condition allows for non-trivial classical winding strings
- Set of classical solutions: $\partial Z^3_{\rm cl} = \sqrt{\frac{\alpha' T_2}{2U_2}}\,[m + Un + X]$

$\Rightarrow$ Generate Yukawa coupling $Y^{np}_{333} C^3 C^3 C^3 e^{-T}$

# Non-perturbative effects on Bulk D7s (KKLT)

Setup in $\mathbb{T}^6/\mathbb{Z}_6'$ orbifold: $\theta = \frac{1}{6}(1, -3, 2)$

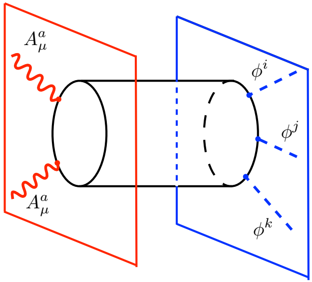



Does this configuration lead to new Yukawas?:

- Second torus: Dirichlet-Dirichlet boundary condition allows for non-trivial classical solution $\partial Z^2_{\mathrm{cl}} \partial Z^2_{\mathrm{cl}} \partial Z^2_{\mathrm{cl}}$
- However, $C^2 C^2 C^2$ is not gauge-invariant: no triangle in quiver.

$\Rightarrow$ No Yukawa coupling $Y^{np}_{222}$ induced.

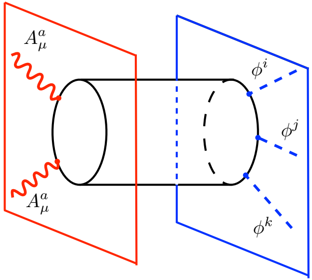
# Non-perturbative effects on Bulk D7s (KKLT)




Result of CFT calculation:

$$Y^{np}_{333} = \mathcal{C} \sum_{m,n} \int_0^\infty \frac{dt}{t} \, r^3_{mn} \, e^{-\frac{\pi t}{\alpha'}|r_{mn}|^2}$$

# Non-perturbative effects on Bulk D7s (KKLT)

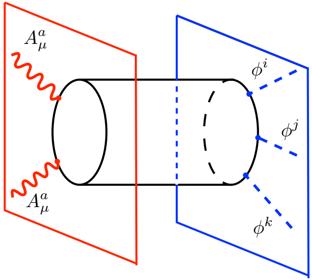



Result of CFT calculation:

$$Y_{333}^{np} = \mathcal{C} \frac{\partial^3}{\partial X^3} \ln |\vartheta_1 (X, U)|^2$$

where $U$ is the complex structure of the torus wrapped and $X$ is the separation between the brane stacks.

# Non-perturbative effects on Bulk D7s (KKLT)




Result of CFT calculation:

$$Y_{333}^{np} = \mathcal{C}\,\frac{\partial^3}{\partial X^3}\,\ln\left|\vartheta_1\left(X, U\right)\right|^2$$

Each KK modes contributes negligibly to the overall result.
The sum over all of them gives a non-zero result.

# Non-perturbative effects on Bulk D7s (KKLT)

- Result of orbifold calculation: generate $Y^{np}_{rrr} C^r C^r C^r e^{-T}$ with

$$\boxed{Y^{np}_{rrr} \;=\; \mathcal{C}\, \frac{\partial^3}{\partial X^3}\; \ln \left|\vartheta_1\left(X, U\right)\right|^2}$$

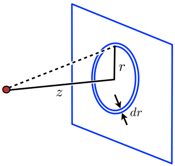
- Recall: tree-level Yukawa: $Y^{tree}_{123} C^1 C^2 C^3 \neq c Y^{np}_{rrr} C^r C^r C^r$

$\Rightarrow$ Phenomenological consequences:

- Non-zero $Y^{np}_{rrr}$ can lead to flavor violation.
  In KKLT this can be made subdominant. [Berg, Marsh, McAllister, Pajer]
- Incorporate $Y^{np}_{rrr} C^r C^r C^r$ into model to give desired squark masses (light 3rd, heavy 1st and 2nd generations)

# Non-perturbative effects on Bulk D7s (KKLT)

We found non-negligible interactions between branes at large separations. Why should this be expected?



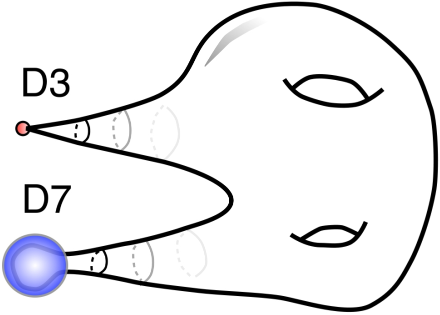

Estimate change of volume occupied by D7

- D3 pointlike in six int. dim.: sources metric perturbation $\frac{1}{\sqrt{r^2+z^2}^4}$
- D7 volume affected as

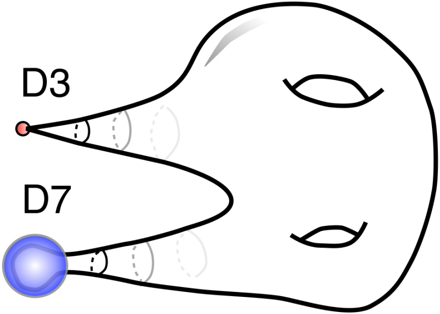
$$\sim \int_0^L r^3 \mathrm{d}r \frac{1}{(r^2+z^2)^2} \overset{L\to\infty}{\to} \log L$$

- The D7 is essentially infinite from point of view of D3

# D7s wrapping a small cycle (LVS)

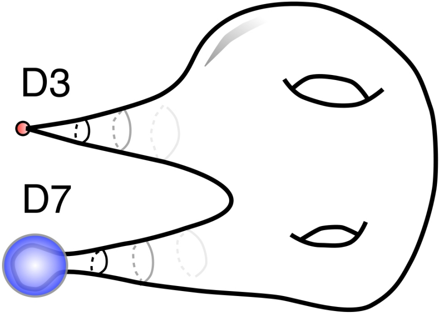


# D7s wrapping a small cycle (LVS)




- Here D7s wrap a small (blow-up) cycle
- D7s now do not wrap a large volume. Are they still affected by the presence of distant D3s?

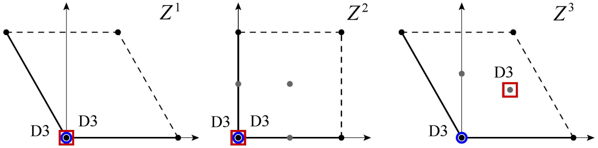
# D7s wrapping a small cycle (LVS)




- Again, take this picture to the orbifold limit
- To be specific work on $\mathbb{T}^6/\mathbb{Z}_6'$: $\theta = \frac{1}{6}(1, -3, 2)$

# D7s wrapping a small cycle (LVS)

$\mathbb{T}^6/\mathbb{Z}_6'$ orbifold: $\theta = \frac{1}{6}(1, -3, 2)$. D7-branes become fractional D3-branes.



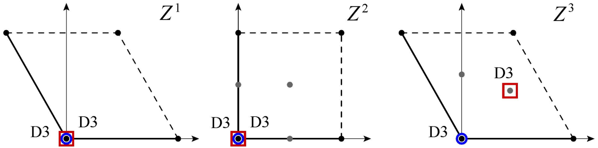

Again, study classical winding solutions.

- Examine sectors of the orbifold individually
- 6 sectors $\mathbb{T}^6/\theta^n$ with $n = 0, 1, \ldots 5$

$\Rightarrow$ Examine homology of $\mathbb{T}^6/\mathbb{Z}_6'$.

# D7s wrapping a small cycle (LVS)

Untwisted sector: $\mathbb{T}^6/\theta^0$



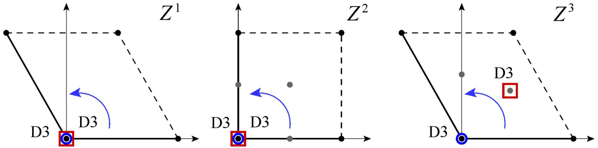

Winding solutions in principle allowed.

- This sector preserves $\mathcal{N} = 4$ SUSY
- The amplitude vanishes due to supersymmetry: $\langle \partial X^i \partial X^j \partial X^k \rangle = 0$

$\Rightarrow$ No corrections to Yukawa couplings from this sector.

## D7s wrapping a small cycle (LVS)

Fully twisted sector: $\mathbb{T}^6/\theta^1$ where $\theta = \frac{1}{6}(1, -3, 2)$




No contribution from winding states:

- Winding solutions not allowed in twisted direction: all $\langle \partial Z^i \partial Z^j \partial Z^k \rangle = 0$
- Twisted cycles are stuck to orbifold fixed points

$\Rightarrow$ No corrections to Yukawa couplings from this sector.

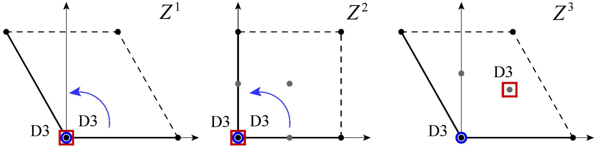
# D7s wrapping a small cycle (LVS)

Visualization of fully twisted cycle:

Photo: Michele Aquila

# D7s wrapping a small cycle (LVS)

Partially twisted sector: $\mathbb{T}^6/\theta^3$ where $\theta^3 = \frac{1}{6}(3,-3,0)$

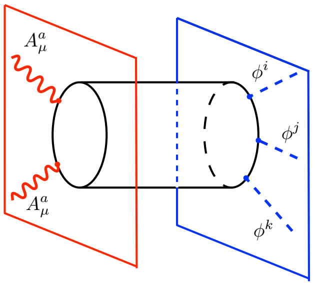



The third torus is left untwisted:

- Winding states only exist on third torus:
  only $\langle \partial Z^3 \partial Z^3 \partial Z^3 \rangle \neq 0$
- homology: 2-cycle shared by fixed points on third torus

$\Rightarrow$ Generate Yukawa coupling $Y^{np}_{333} C^3 C^3 C^3 e^{-T}$

# D7s wrapping a small cycle (LVS)

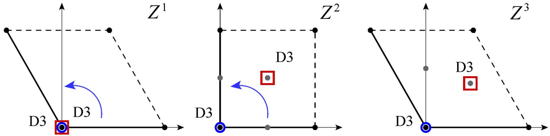



Find same numerical result as before:

$$Y^{np}_{333} \;=\; \mathcal{C}\,\frac{\partial^3}{\partial X^3}\,\ln\left|\vartheta_1\left(X,U\right)\right|^2$$

# D7s wrapping a small cycle (LVS)

Can this be avoided? Change the brane setup:



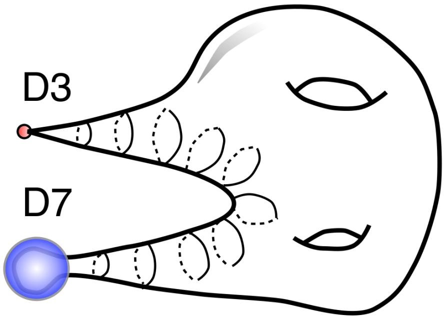

Branes also separated along second torus

- Branes are not connected by a 2-cycle: no winding solution possible

$\Rightarrow$ No corrections to Yukawa couplings for this setup.

# D7s wrapping a small cycle (LVS): Summary

**Necessary condition for non-perturbative Yukawa couplings:** visible and hidden sector connected by a homologous 2-cycle.



# D7s wrapping a small cycle (LVS): Summary

**Necessary condition for non-perturbative Yukawa couplings:**
visible and hidden sector connected by a 2-cycle.

$$\Downarrow$$

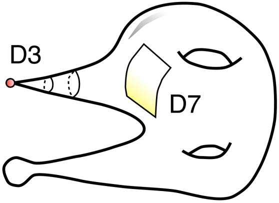
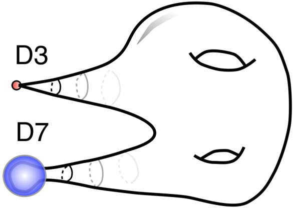
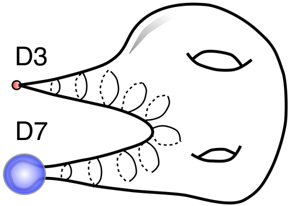
**Consequence for flavour structure:**
Strings wrapping 2-cycle along strings wrapping the $r$-th complex direction
$\rightarrow$ flavor structure: $Y^{np}_{rrr} C^r C^r C^r e^{-aT}$

$$\Downarrow$$

**Resulting soft terms:**
As $Y_{rrr} \neq c Y^{tree}_{123}$ the resulting soft terms can introduce flavor violation.
In LVS the corrections to soft A-terms severly constrain parameter space.

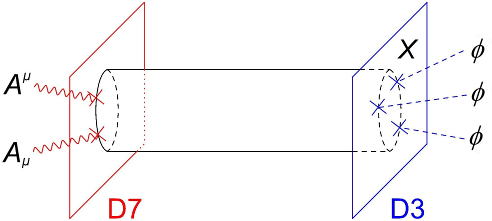
[Berg, Marsh, McAllister, Pajer]

# Summary

| Bulk D7 | D7 on small cycle | D7 on small cycle |
|---|---|---|
|  |  |  |
|  |  |  |
| $\mathbb{Z}_3$, $\mathbb{Z}_6$, $\mathbb{Z}_6'$ | $\mathbb{Z}_3$ | $\mathbb{Z}_6$, $\mathbb{Z}_6'$ |

# Summary: Connection to previous results

D7 threshold correction due to D3 at $X$ with matter fluctuation $\phi\phi\phi$

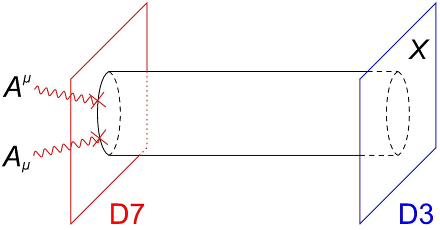



Our result:

$$\delta_{X,\phi\phi\phi}\left(\frac{8\pi^2}{g^2}\right) \sim \partial_X^3\left(-\ln|\vartheta_1(X,U)|^2 + 2\left[\mathrm{Im}(X)\right]^2\right)$$

# Summary: Connection to previous results

D7 threshold correction due to backreaction of D3 at $X$

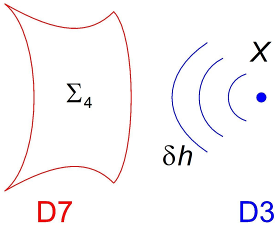



Worldsheet calculation [Berg, Haack, Körs]:

$$\delta_X \left( \frac{8\pi^2}{g^2} \right) \sim -\ln |\vartheta_1(X, U)|^2 + 2\,[\mathrm{Im}(X)]^2$$

# Summary: Connection to previous results

D7 threshold correction due to backreaction of D3 at $X$

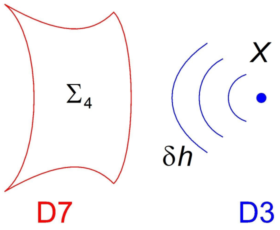



Geometrical closed string approach [Baumann et.al. ]:

$$\delta h \;\Rightarrow\; \delta V_{\Sigma_4} = \int_{\Sigma_4} d^4 Y \sqrt{g^{ind}} \delta h \;\Rightarrow\; \delta_\phi \left( \frac{8\pi^2}{g^2} \right) = T_3 \delta V_{\Sigma_4}$$

# Summary: Connection to previous results

D7 threshold correction due to backreaction of D3 at $X$




Geometrical closed string approach [Baumann et.al. ]:

$$\delta_X\left(\frac{8\pi^2}{g^2}\right) \sim -\ln|\vartheta_1(X,U)|^2 + 2\,[\mathrm{Im}(X)]^2$$

# Summary: Connection to previous results

D7 threshold correction due to D3 at $X$

- Calculate via open or closed string approach:

$$\delta_X \left( \frac{8\pi^2}{g^2} \right) \sim -\ln |\vartheta_1(X, U)|^2 + 2\,[\mathrm{Im}(X)]^2$$

D7 threshold correction due to D3 at $X$ with matter fluctuation $\phi\phi\phi$

- Calculated using worldsheet methods:

$$\delta_{X,\phi\phi\phi} \left( \frac{8\pi^2}{g^2} \right) \sim \partial_X^3 \left( -\ln |\vartheta_1(X, U)|^2 + 2\,[\mathrm{Im}(X)]^2 \right)$$

Our result appears as a coefficient in a Taylor expansion.

# Outlook:

1. Can our result be rederived using a geometrical closed string approach?
2. We worked in toy-models of KKLT and LVS scenarios, ignoring consistency conditions (tadpole cancellation etc. ). Our results still need to be embedded in more realistic constructions to properly assess the phenomenological consequences.
3. Need to consider more realistic string compactifications: analyze del Pezzo instead of orbifold singularities.
4. The study of sequestering is not complete by far: how does the matter metric $Z_{\alpha\bar{\beta}}$ depend on SUSY breaking moduli at 1-loop in string perturbation theory?

# Summary

1. Moduli stabilisation via gaugino condensation on D7-branes can lead to superpotential de-sequestering:
   new Yukawa couplings $Y^{np} C^r C^r C^r e^{-T}$ are generated

2. The flavor structure of $Y^{np}$ does not coincide with the tree-level flavour structure: $C^r C^r C^r \neq C^1 C^2 C^3$
   leading to possible flavor violation.

3. While generally present in KKLT constructions de-sequestering in the LVS occurs if visible and hidden sector share a homologous 2-cycle.

Many thanks!