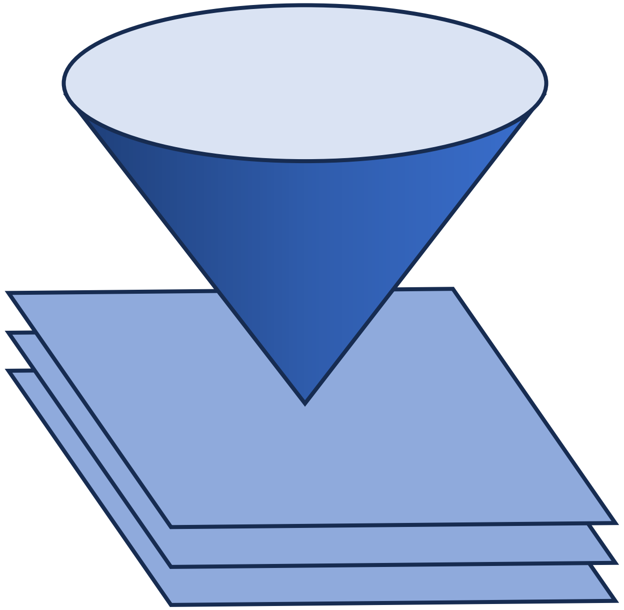
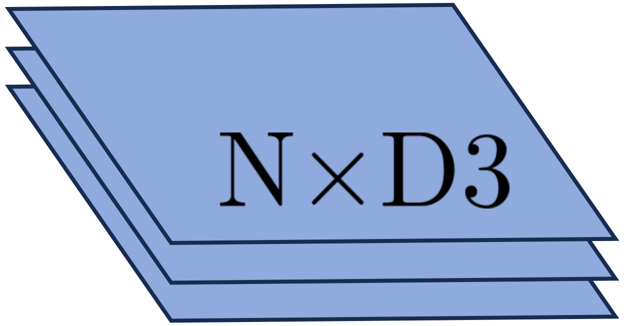
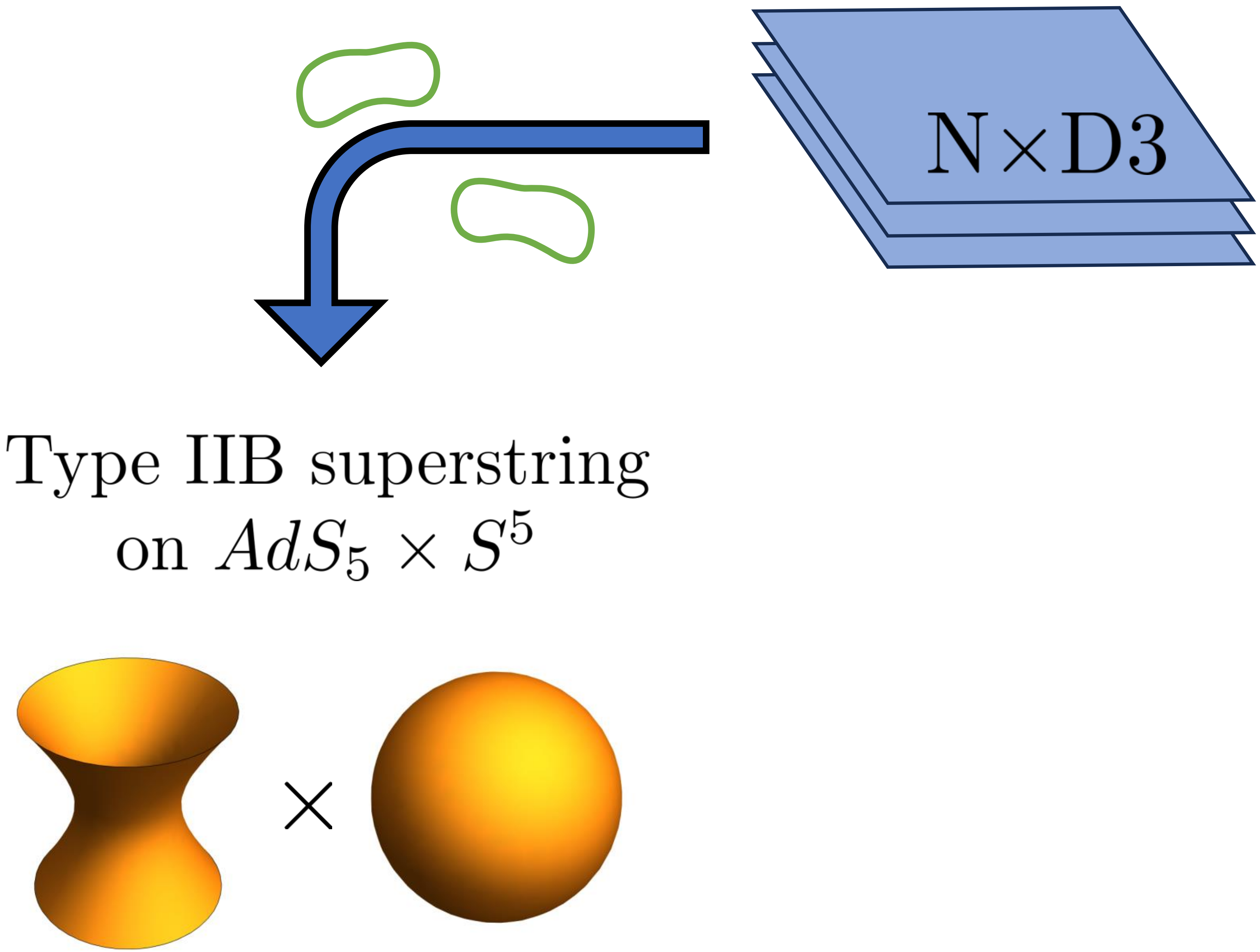
$\mathcal{N} = 2$ orbifolds and their deformations

Torben Skrzypek (DESY)

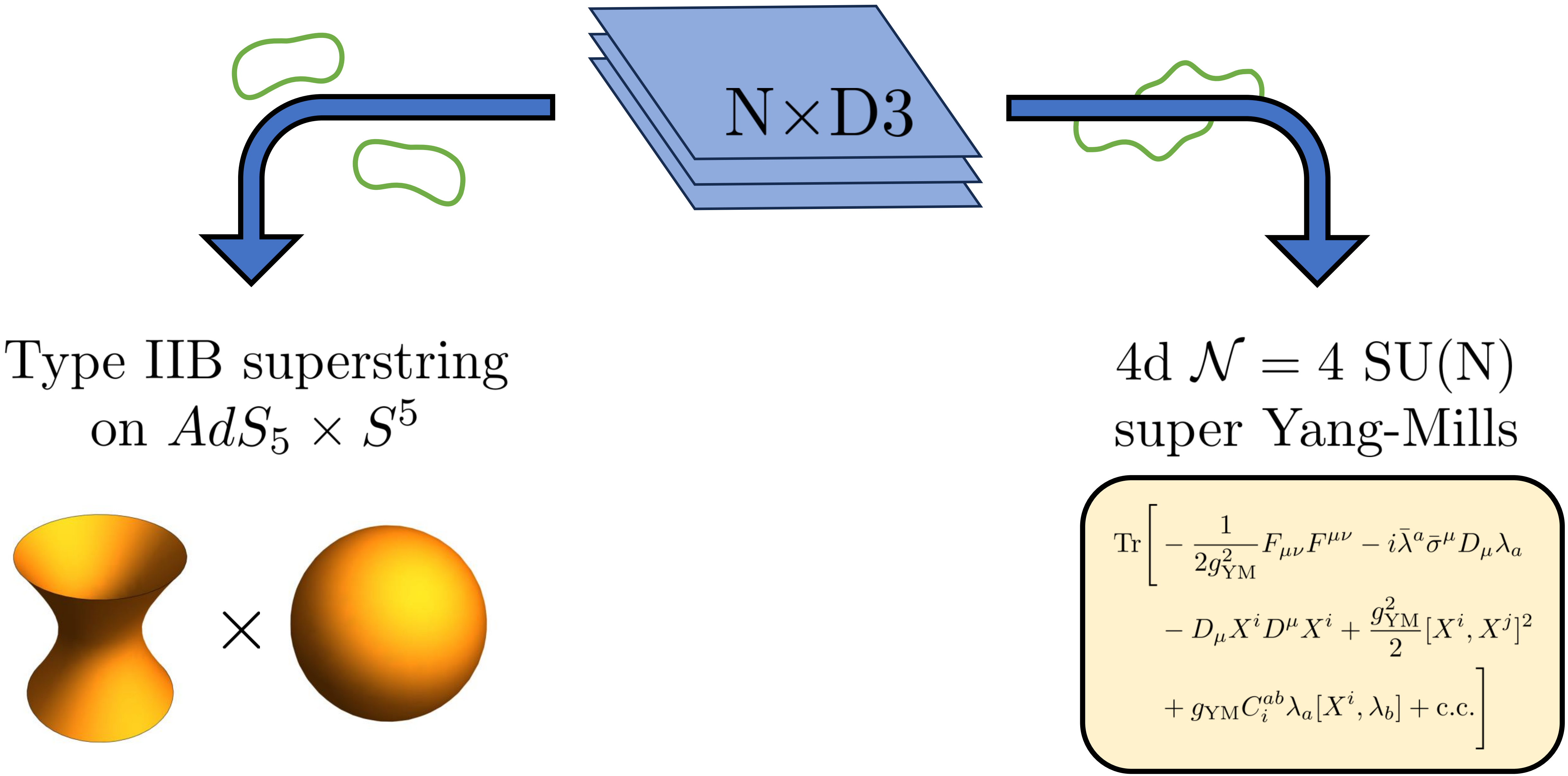


Friday Seminar, Wigner RCP, Budapest, 13.03.2026


N×D3



N×D3
Type IIB superstring
on $AdS_5 \times S^5$
×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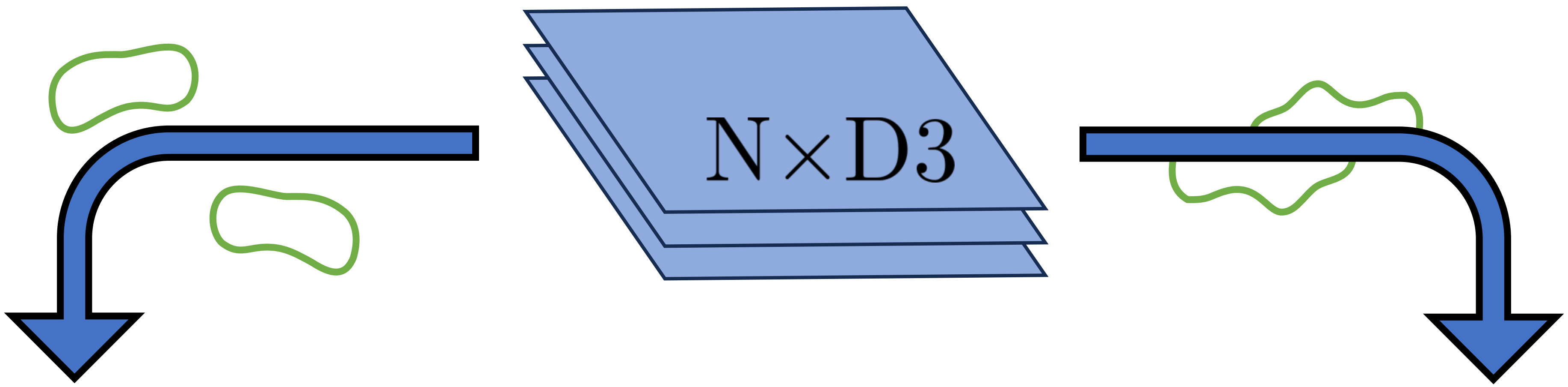
4d $\mathcal{N} = 4$ SU(N)
super Yang-Mills
$\mathrm{Tr}\Big[-\frac{1}{2g_{\mathrm{YM}}^2}F_{\mu\nu}F^{\mu\nu} - i\bar{\lambda}^a\bar{\sigma}^\mu D_\mu\lambda_a - D_\mu X^i D^\mu X^i + \frac{g_{\mathrm{YM}}^2}{2}[X^i, X^j]^2 + g_{\mathrm{YM}}C_i^{ab}\lambda_a[X^i, \lambda_b] + \mathrm{c.c.}\Big]$

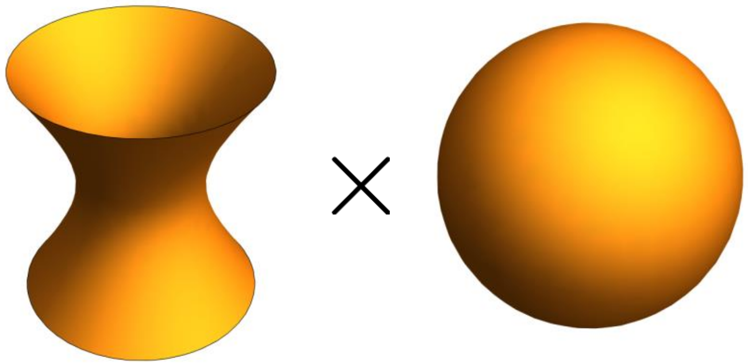
[Maldacena '97]
[Witten '98]



Type IIB superstring on $AdS_5 \times S^5$

AdS/CFT

4d $\mathcal{N} = 4$ SU(N) super Yang-Mills



$$g_s = 4\pi g_{\rm YM}^2 \to 0$$

$$\frac{R^4}{\alpha'^2} = \lambda = g_{\rm YM}^2 N$$

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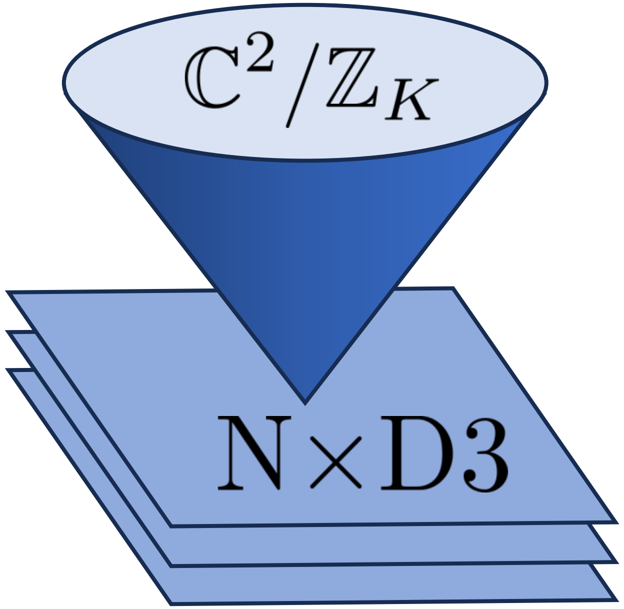
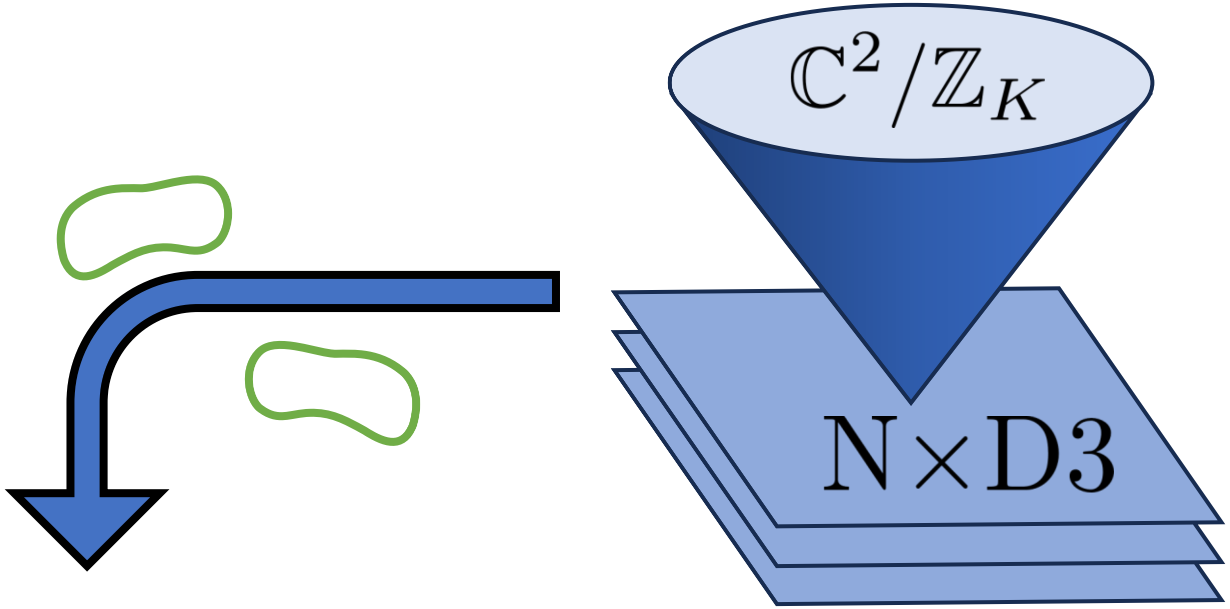
[Kachru, Silverstein '98]
[Lawrence, Nekrasov, Vafa '98]



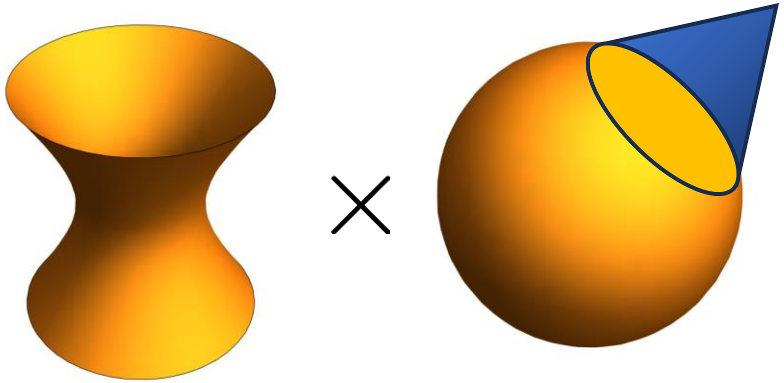
The orbifold

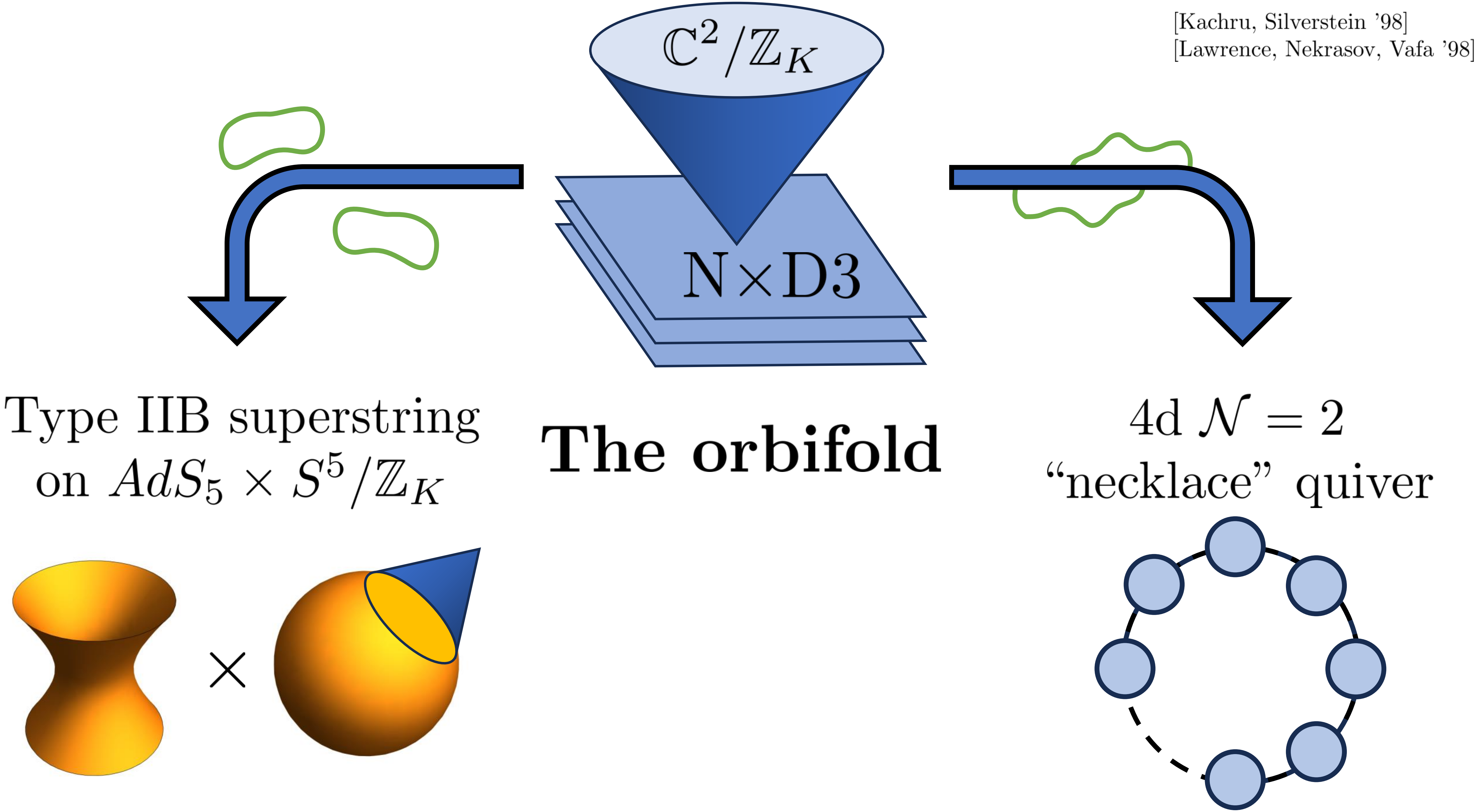
[Kachru, Silverstein '98]
[Lawrence, Nekrasov, Vafa '98]

The orbifold



Type IIB superstring on $AdS_5 \times S^5/\mathbb{Z}_K$





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N×D3
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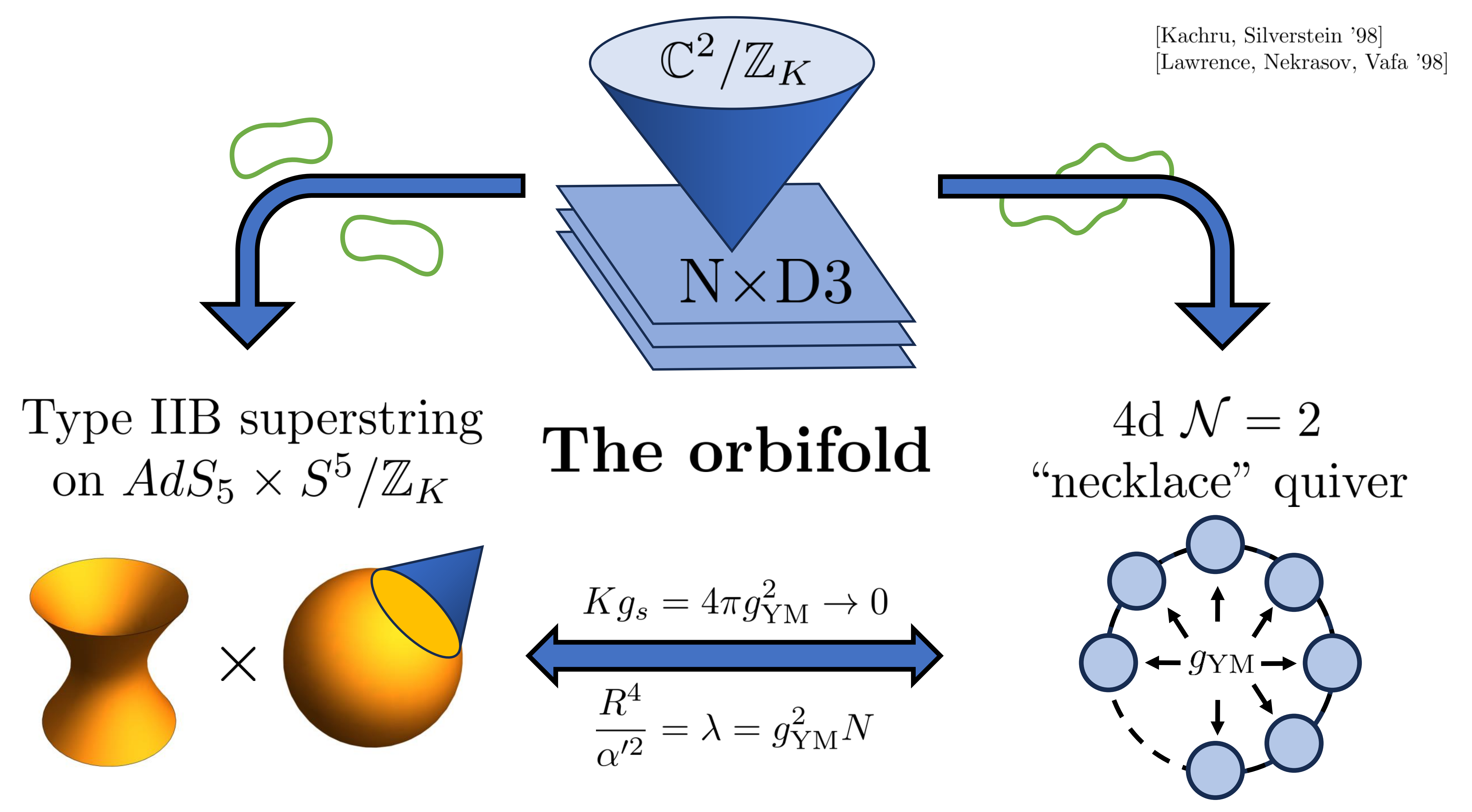
The orbifold
4d $\mathcal{N}=2$
"necklace" quiver



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g_{YM}

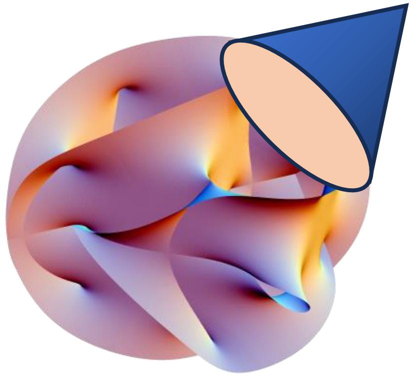
Motivation

Motivation

- **Simple way of breaking SUSY**

used in pheno: $\mathbb{R}^{1,3} \times \mathrm{CY3}$ + fluxes + **O-planes**

also good local approximation of CY3 manifolds



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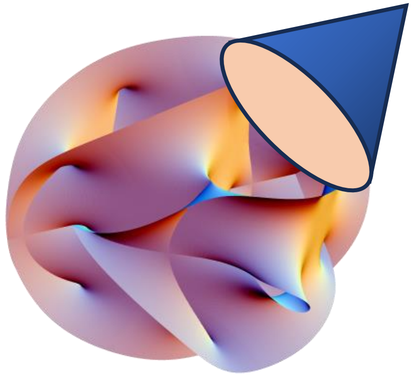
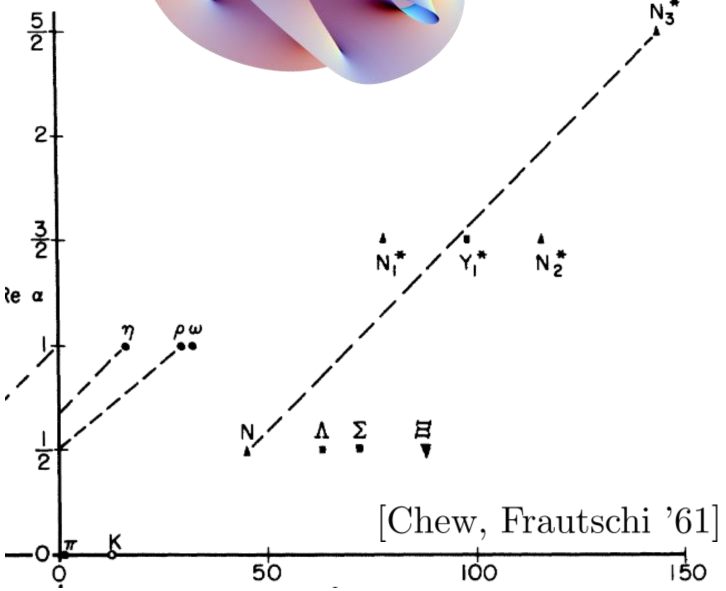


- **Approaching QCD via AdS/CFT**

  $\mathcal{N} = 4 \text{ SYM} \rightarrow \mathcal{N} = 2 \text{ SCQCD} \rightarrow \mathcal{N} = 1 \ldots$



[Chew, Frautschi '61]

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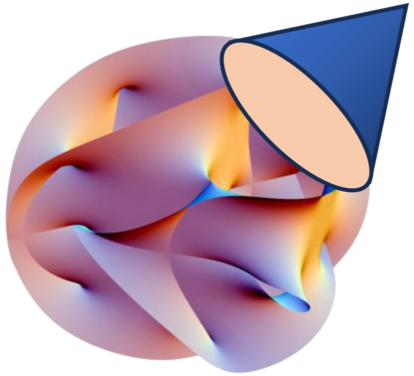

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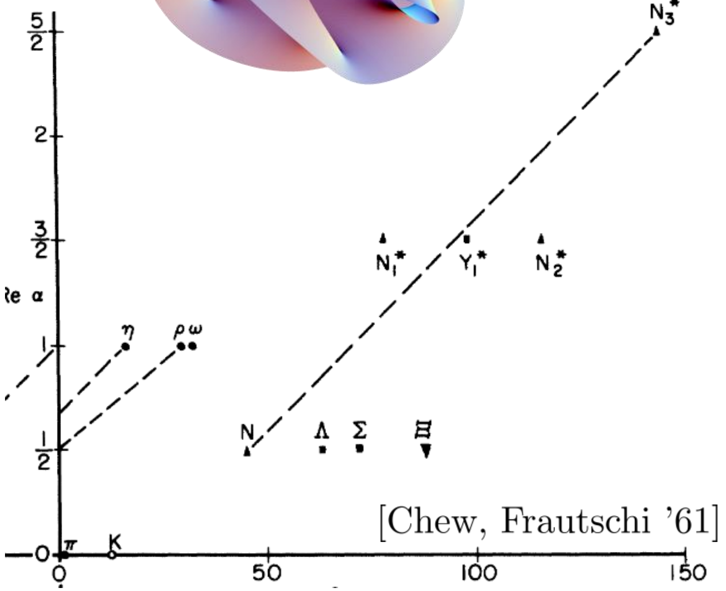


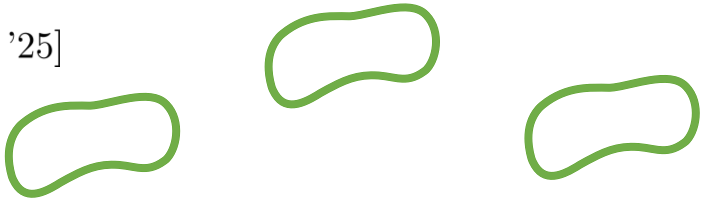
[Chew, Frautschi '61]

- **Honestly: Learn about string theory**

  less SUSY $\rightarrow$ corrections hit "earlier"

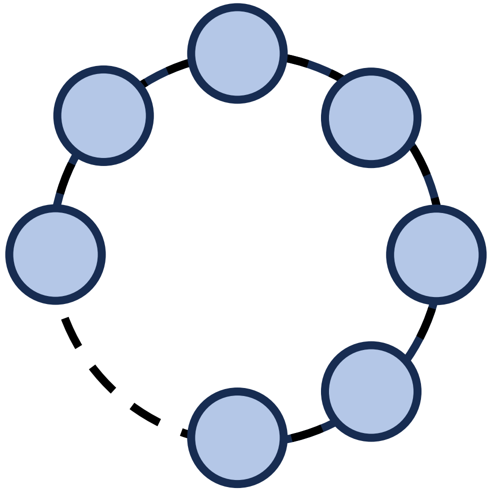
  e.g. α'-corrections from localisation [TS, Tseytlin '23] [Barredo Martínez, TS '25]

  instanton corrections become important



Outline

- Gauge theory perspective
- String theory perspective
- Integrability
- Marginal deformations
- Open problems



e.g. [Ideguchi '04]

The gauge theory

$\mathcal{N} = 4$ SYM: PSU$(2,2|4)$ and SU(KN) gauge group

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$$\Gamma : \quad \left(\begin{array}{c|c} 1 & 0 \\ \hline 0 & R \end{array}\right) \quad \otimes \quad \mathrm{diag}(1, \omega, \omega^2, \ldots, \omega^{K-1})$$

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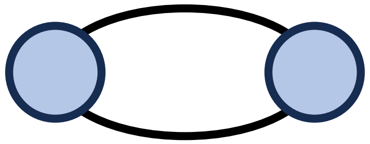
$\mathcal{N}=2$ orbifold: $\mathrm{PSU}(2,2|2)$ and $K\times\mathrm{SU}(N)$ gauge group

Simplest example: $\mathbb{Z}_2$ orbifold 

$$X \to (X_{12}, X_{21})\,,\; Y \to (Y_{12}, Y_{21})\,,\; Z \to (Z_{11}, Z_{22})$$

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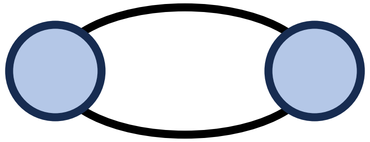
Simplest example: $\mathbb{Z}_2$ orbifold 

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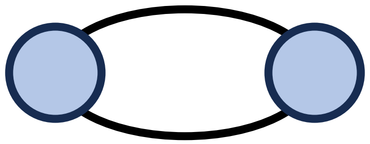
Simplest example: $\mathbb{Z}_2$ orbifold 

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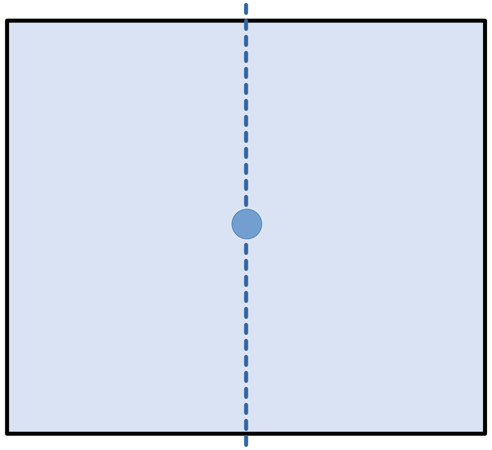
- Standard tools: CFT, planar limit, perturbation theory, ...
- SUSY allows for localisation at any λ

large # of papers after [Pestun '07]

[Dixon, Harvey, Vafa '85]

String theory on orbifolds



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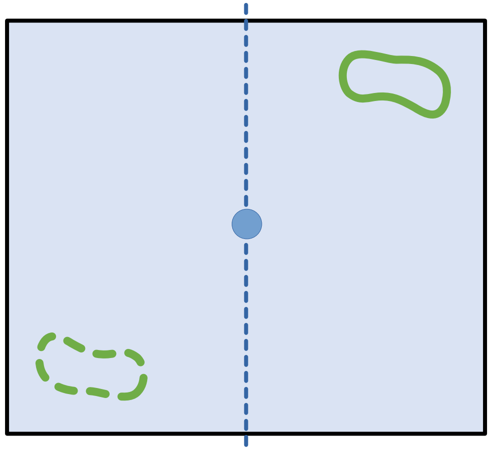

- Already Γ-invariant states $\rightarrow$ untwisted sector

[Dixon, Harvey, Vafa '85]

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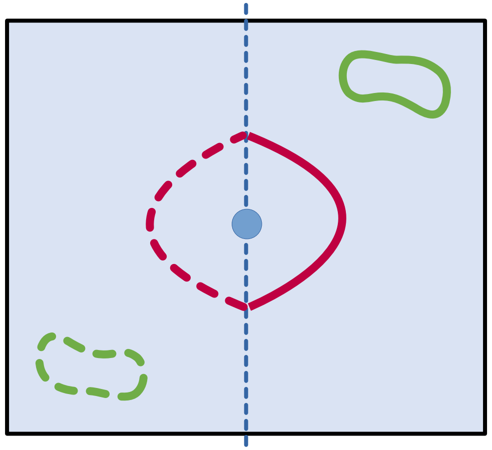

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[Dixon, Harvey, Vafa '85]

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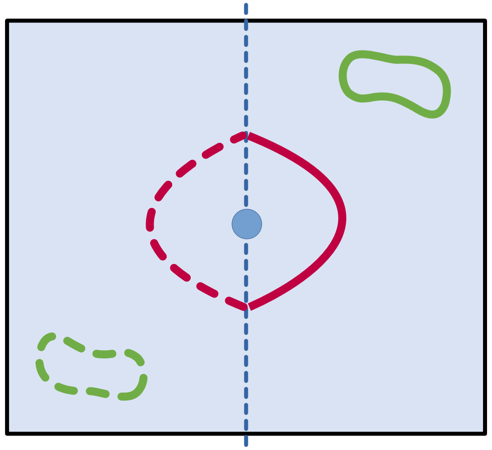

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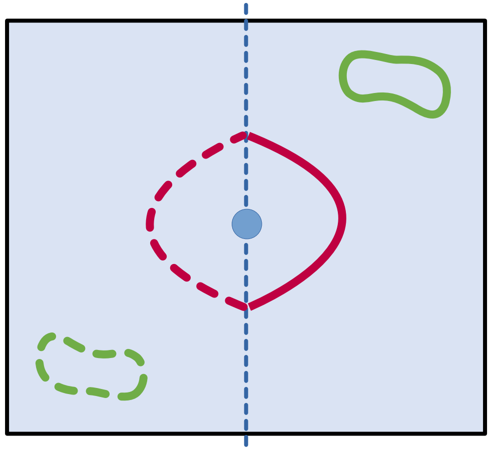

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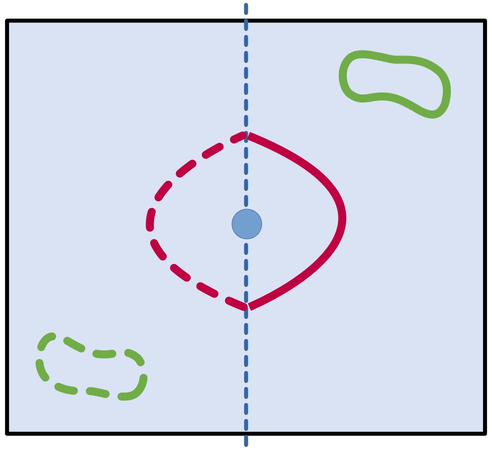

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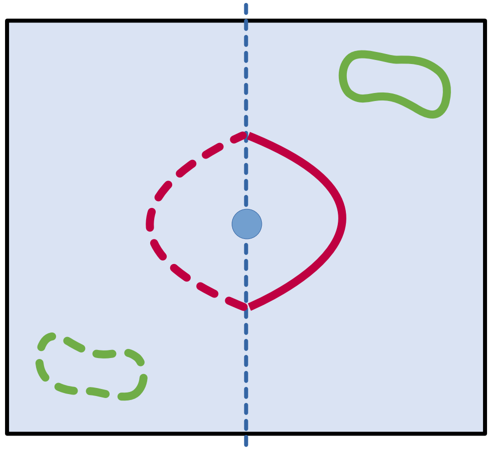

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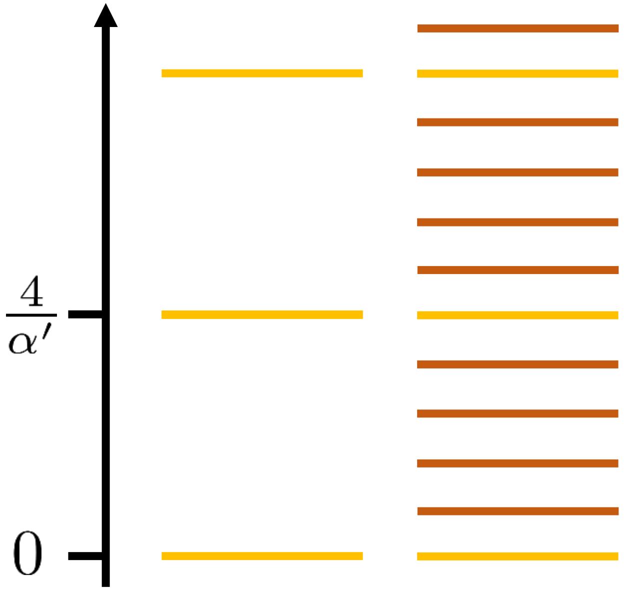

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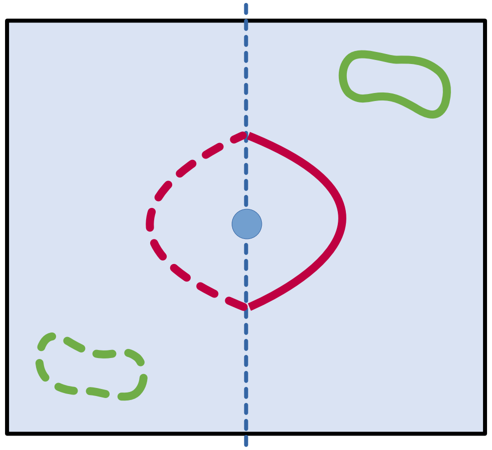

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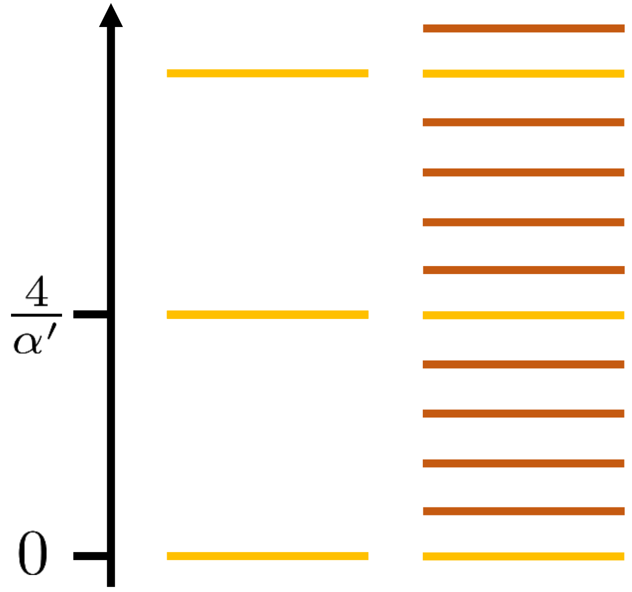

⇒ **Twisted string amplitudes** [Hamidi, Vafa '86] [Barredo Martínez, TS '25]

[Eguchi, Hanson '79]
[Gibbons, Hawking '78]

The background geometry

[Eguchi, Hanson '79]
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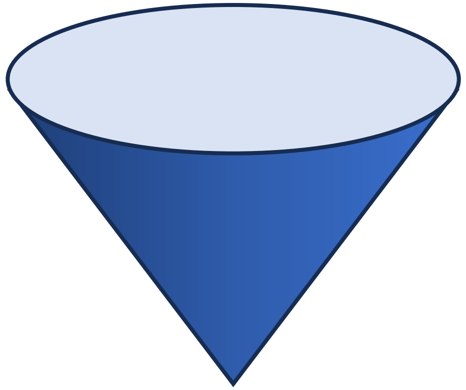
The background geometry



Orbifold space: $\mathrm{d}s^2 = \mathrm{d}r^2 + \frac{r^2}{4}(\mathrm{d}\Omega_2^2 + f^2)$

$$S^3 = S^1 \hookrightarrow S^2\,, \quad f = \mathrm{d}\psi + \cos\theta\,\mathrm{d}\phi\,, \quad \psi \in [0, \tfrac{4\pi}{K})$$

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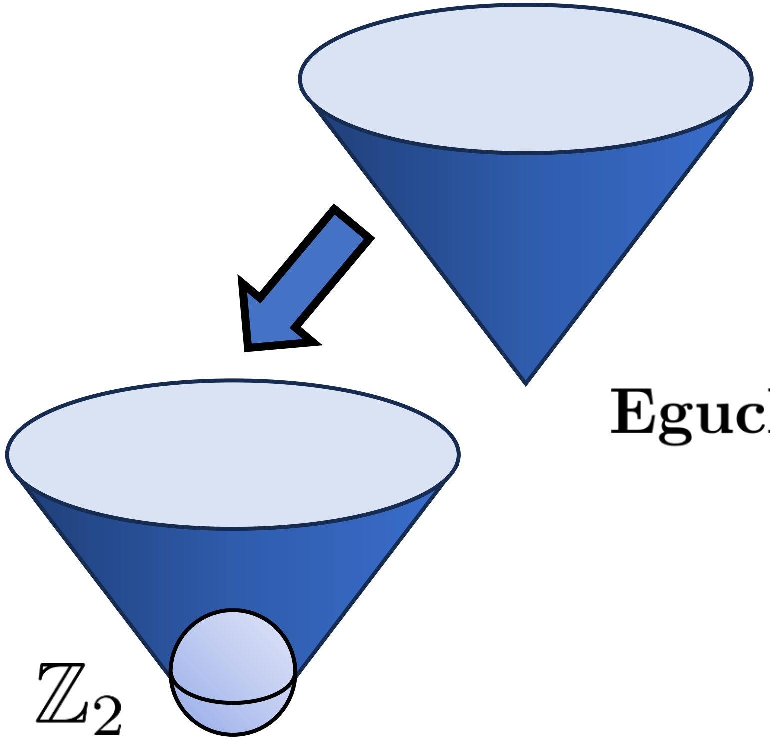

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Eguchi-Hanson space: $\mathrm{d}s^2 = V(r)^{-1}\mathrm{d}r^2 + \frac{r^2}{4}(\mathrm{d}\Omega_2^2 + V(r)f^2)$

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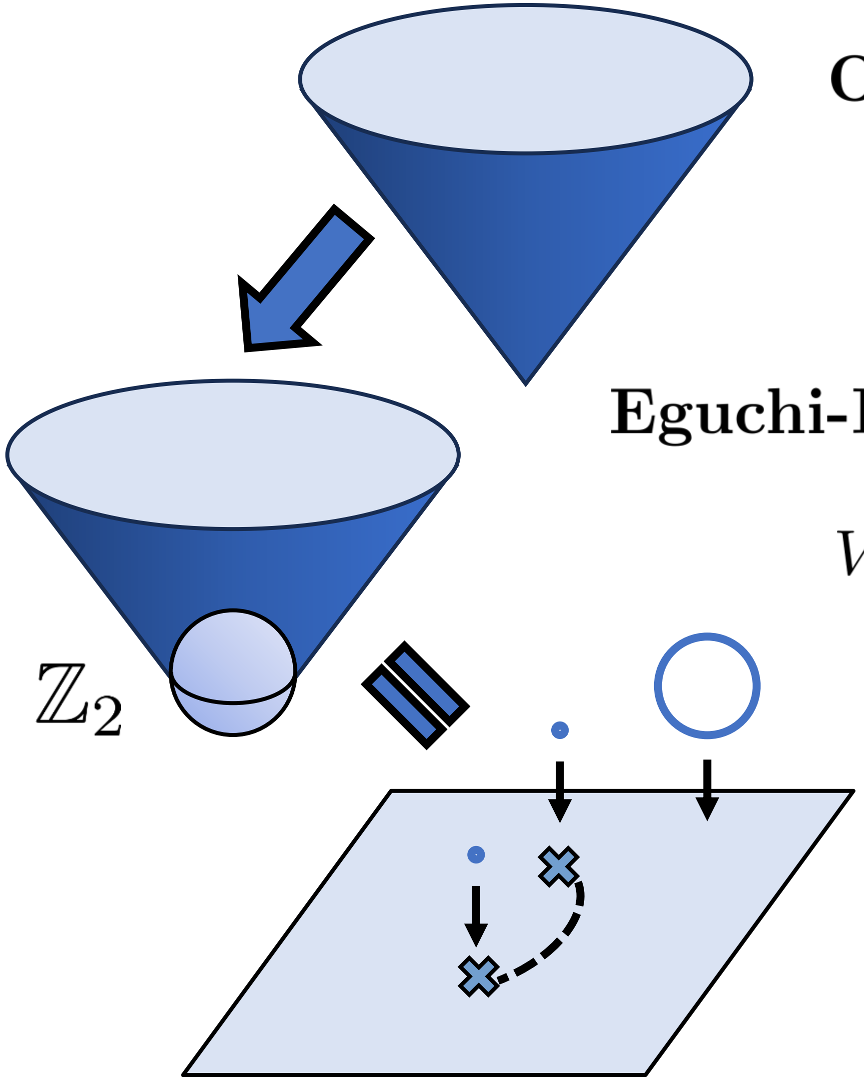

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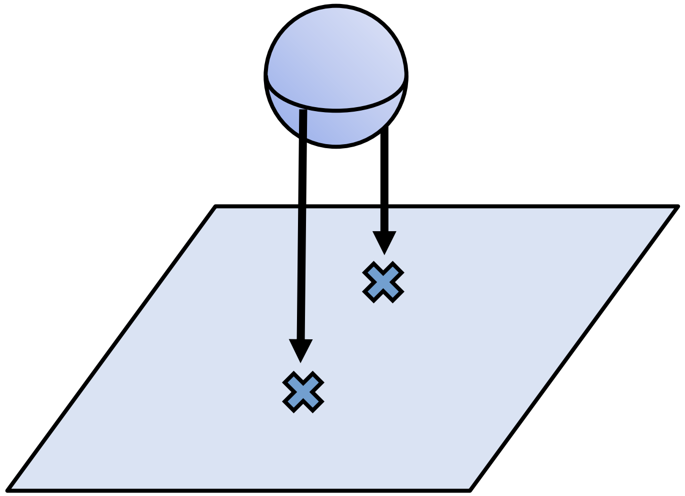
Gibbons-Hawking space:

$$\mathrm{d}s^2 = U(x)\mathrm{d}x_i\mathrm{d}x^i + U(x)^{-1}(\mathrm{d}\tau + \omega_i(x)\mathrm{d}x^i)^2$$

$$U(x) = \sum_{n=1}^{K} \frac{1}{|x - \vec{x}_n|}\,, \qquad \nabla_i U(x) = \pm\varepsilon_i^{\ jk}\nabla_j\omega_k(x)$$

[Douglas, Moore '96]

Twisted sector in supergravity



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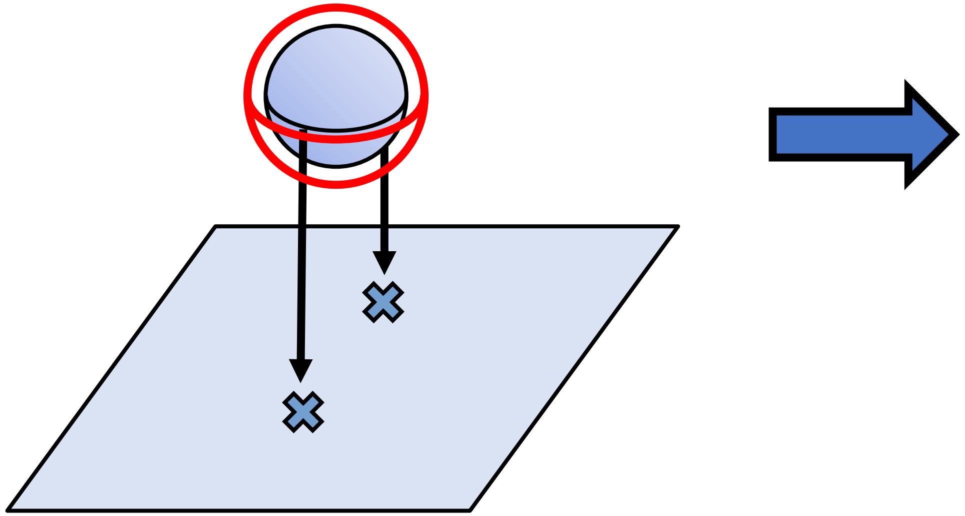
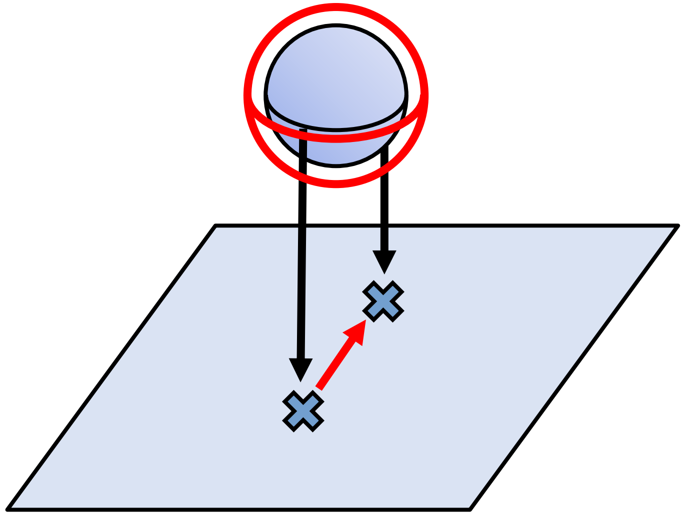


2 scalars from wrapped B_2 and C_2
1 ASD 2-form from wrapped C_4

[Douglas, Moore '96]

Twisted sector in supergravity



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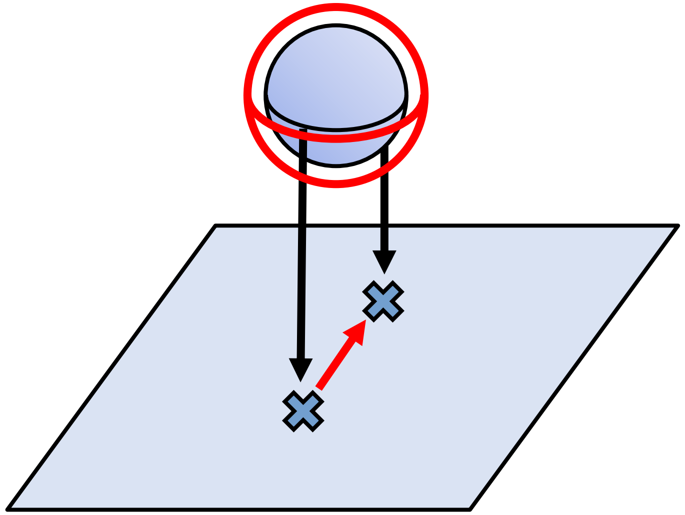
3 scalars from geometric moduli

[Douglas, Moore '96]

Twisted sector in supergravity



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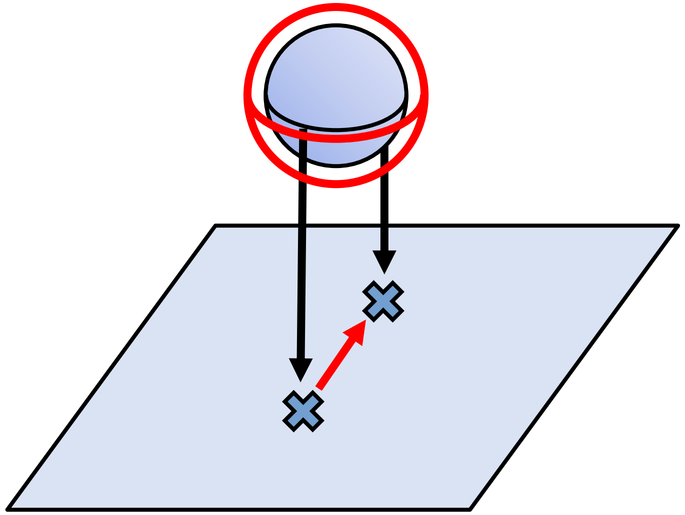
6d $\mathcal{N} = (2,0)$ tensor multiplet

[Douglas, Moore '96]

Twisted sector in supergravity



2 scalars from wrapped B_2 and C_2
1 ASD 2-form from wrapped C_4

3 scalars from geometric moduli

6d $\mathcal{N} = (2,0)$ tensor multiplet

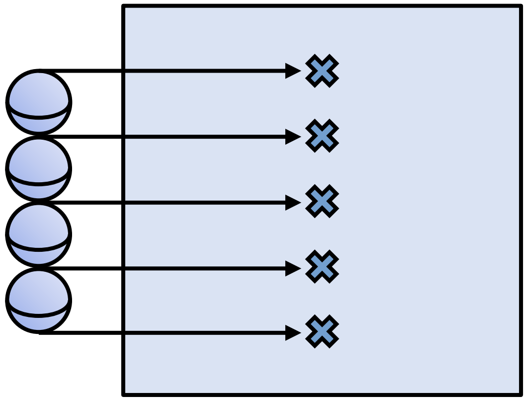
- 10d supergravity on resolved background
  $\rightarrow$ effective 6d $\mathcal{N} = (2,0)$ supergravity

- For α'-corrections: Need twisted string amplitudes

[Barredo Martínez, TS '25]

[Korchemsky, Testa '25]
[Barredo Martínez, TS '25]

Long quiver limit



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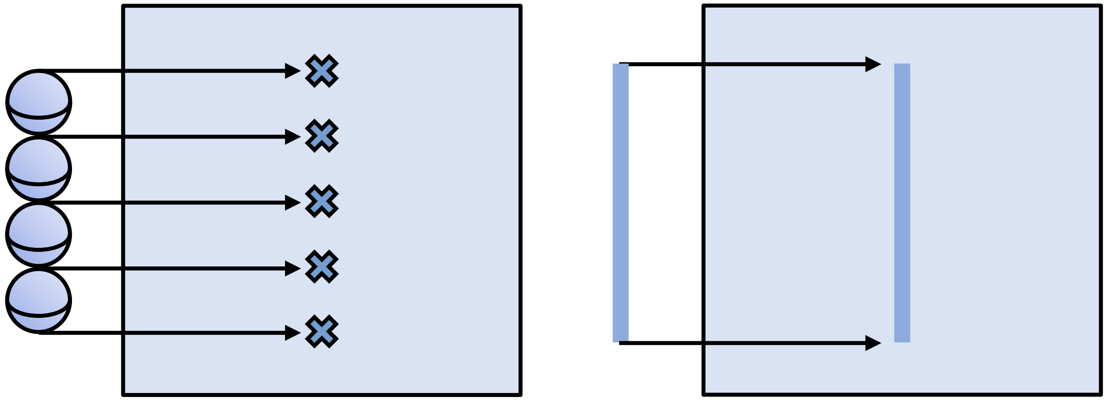

- Large-K limit was analysed with localisation
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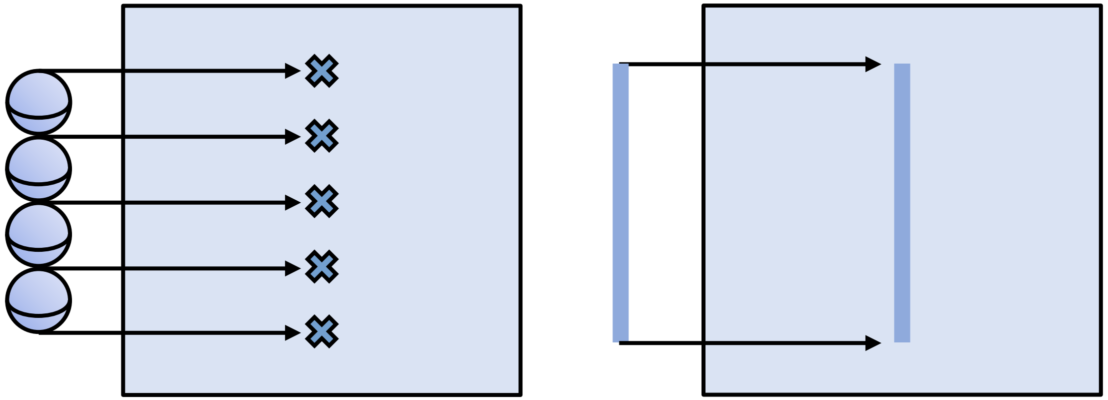

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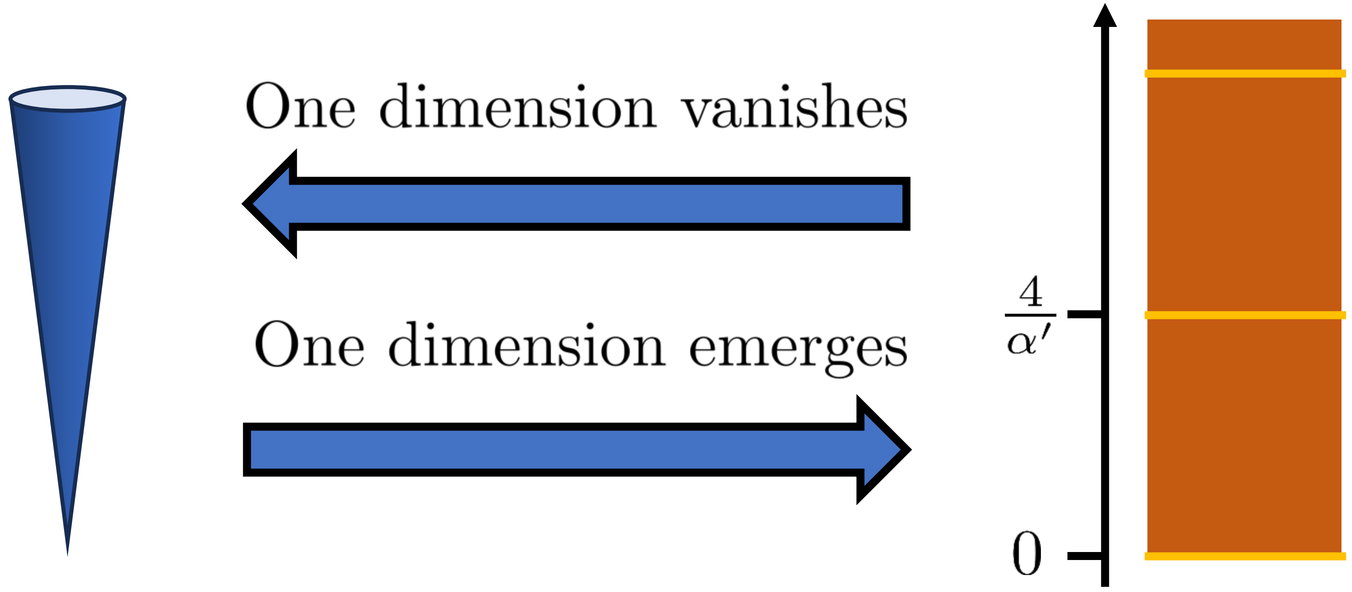

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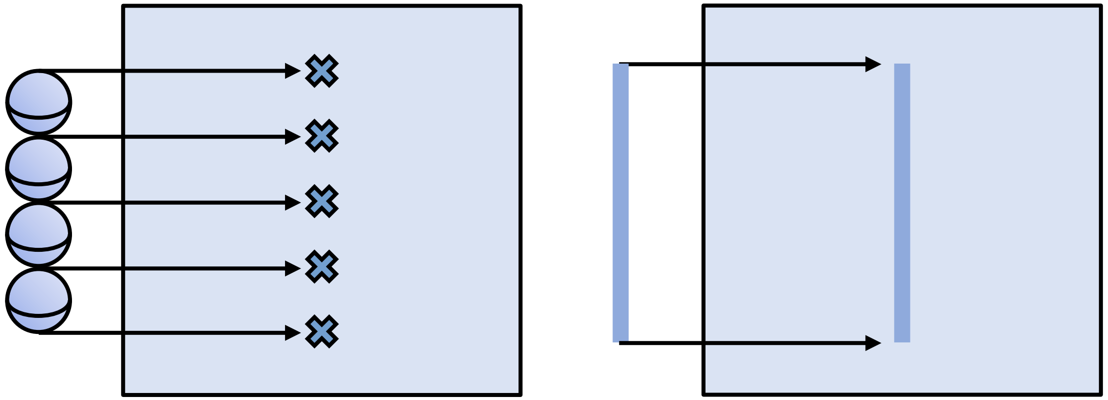

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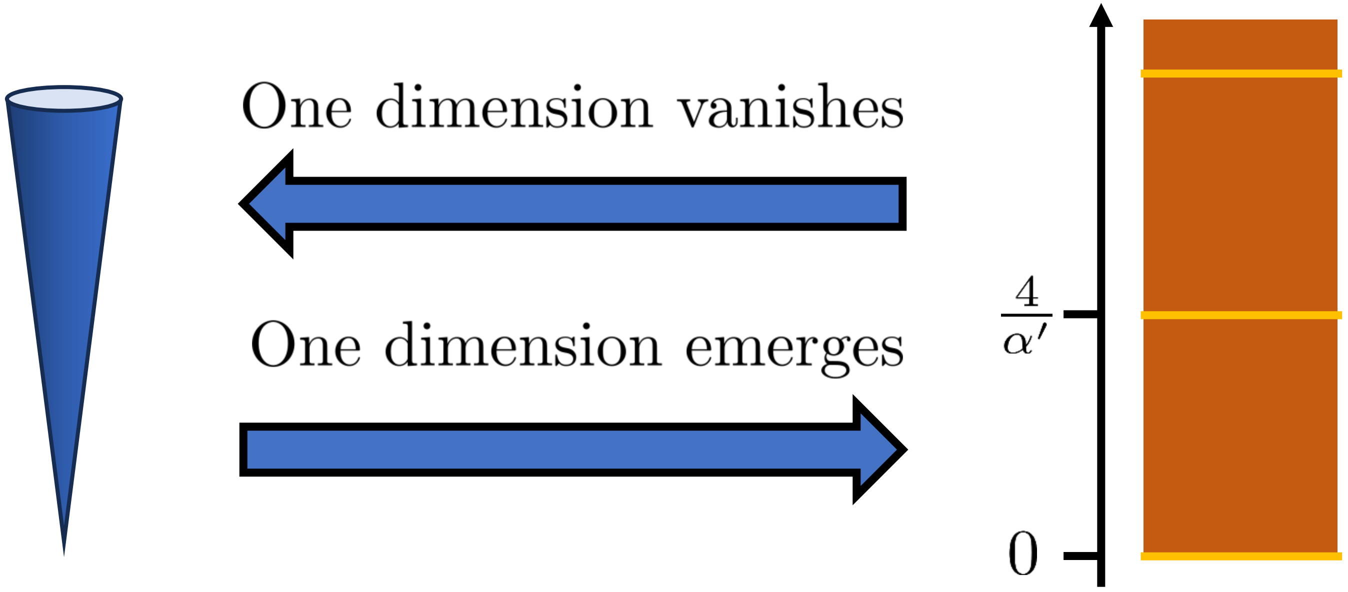
Open questions

- How to embed this orbifold into $AdS_5 \times S^5$?
- What is the "T-dual" geometry when supergravity fails?



Integrability

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- **Classical integrability**: E.o.M.s equivalent to flat Lax connection $L(z)$

$$\mathrm{d}L(z) + [L(z), L(z)] = 0 \quad \Rightarrow \quad \infty\text{-ly many conserved charges}$$

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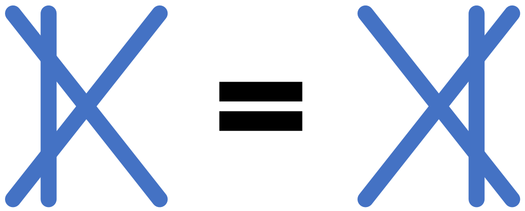

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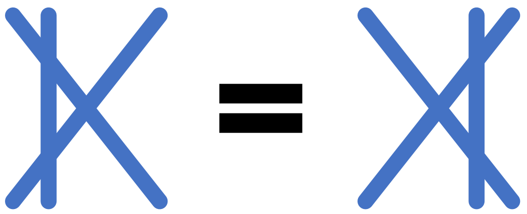

- Light-cone gauged GS string on $AdS_5 \times S^5$ is **integrable** with

$$L(z) = j^{(0)} + \frac{z^2+1}{z^2-1} j^{(2)} - \frac{2z}{z^2-1} \star j^{(2)} + \sqrt{\frac{z+1}{z-1}} j^{(1)} + \sqrt{\frac{z-1}{z+1}} j^{(3)} \, .$$

[Bena, Polchinski, Roiban '98]

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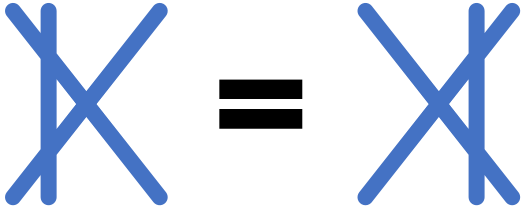

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[Bena, Polchinski, Roiban '98]

- Importantly: **Orbifolds preserve this integrability**

[Beisert '05]

Spectral problem

[Berenstein, Maldacena, Nastase '02]
[Minahan, Zarembo '03]
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Spectral problem

closed string states ⟺ single-trace operators

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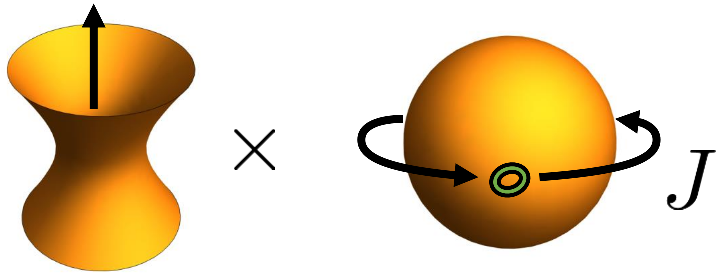
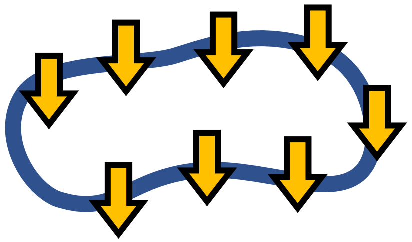


$$\mathrm{Tr}(\underbrace{ZZZ\ldots Z}_{J})$$



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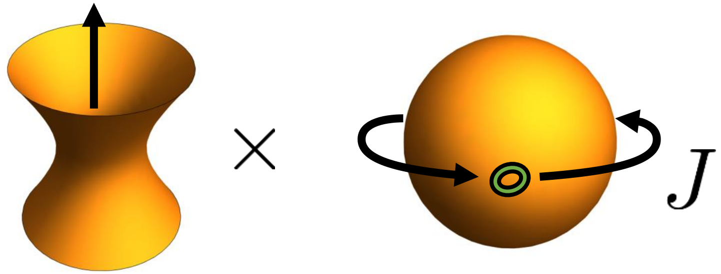

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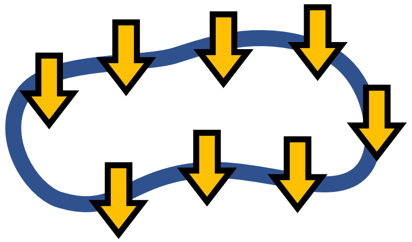
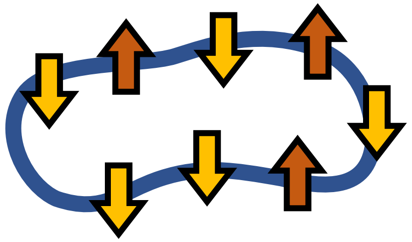


+ WS perturbations ⟺ $\mathrm{Tr}(ZYYZ\ldots Z)$



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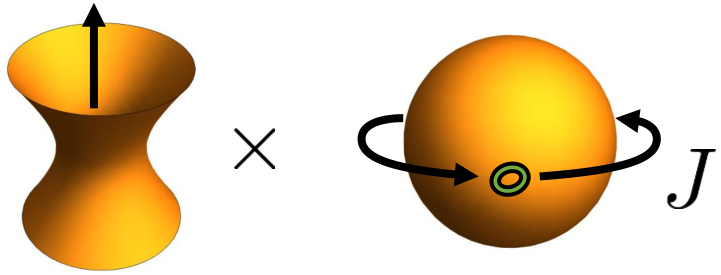

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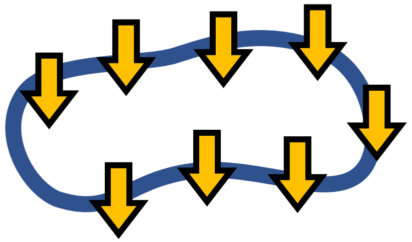

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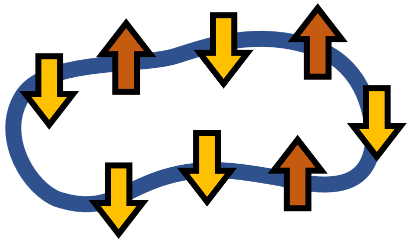

ABA

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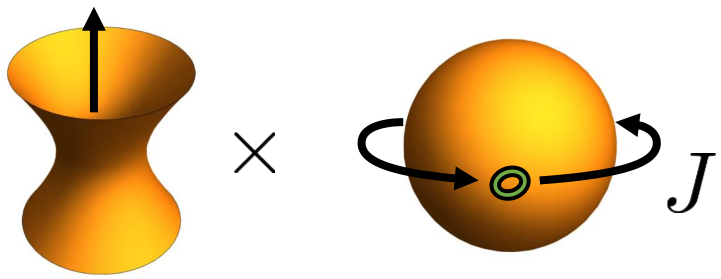

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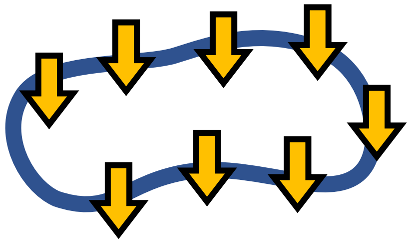

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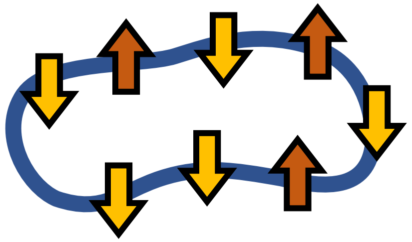

ABA

TBA

Spectral problem

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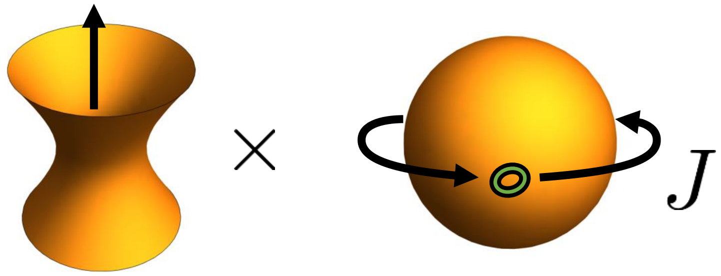

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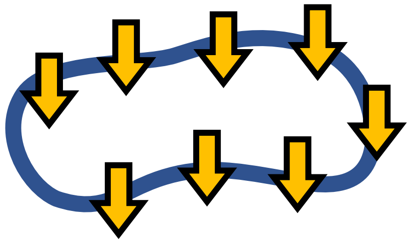

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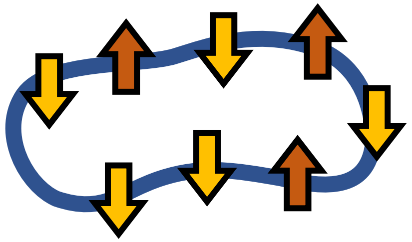

ABA **TBA** **QSC**

Spectral problem

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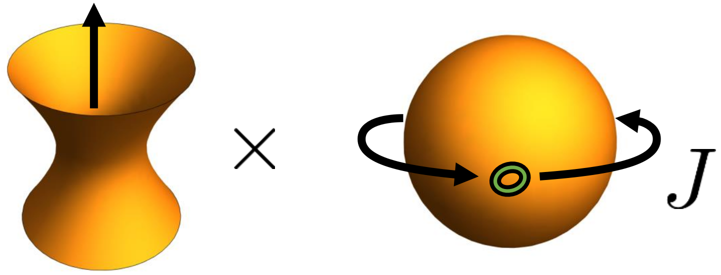

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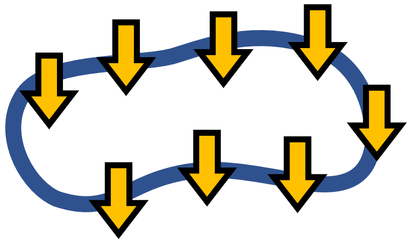

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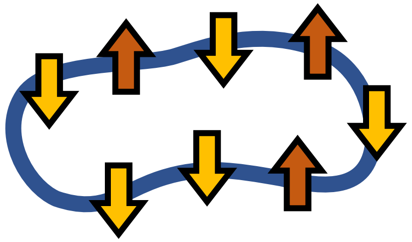


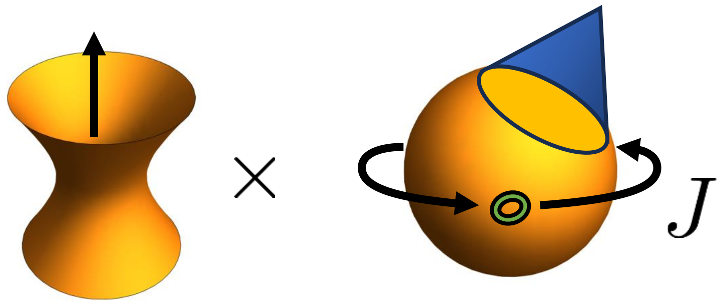
ABA **TBA** **QSC** ⟹ Full spectrum at arbitrary λ

large # of papers

[TS '22]

Spectral problem

closed string states ⟺ single-trace operators



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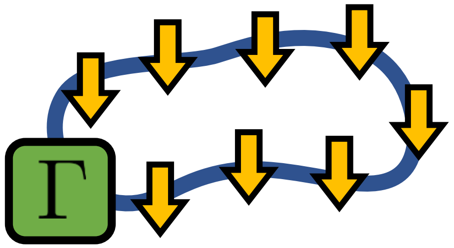

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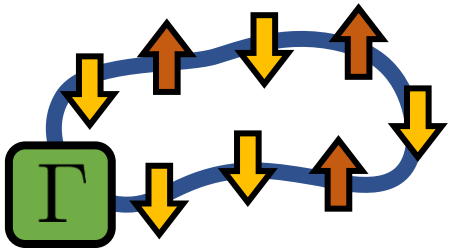

ABA Γ   **TBA** Γ   **QSC** Γ → Full spectrum at arbitrary λ

[Basso, Komatsu, Vieira '15]

Structure constants

$$\langle \mathcal{O}_k(x_1)\mathcal{O}_l(x_2)\mathcal{O}_m(x_3)\rangle = \frac{\mathcal{C}_{\mathcal{O}^k\mathcal{O}^l\mathcal{O}^m}}{|x_1-x_2|^{\Delta_1+\Delta_2-\Delta_3}|x_1-x_3|^{\Delta_1+\Delta_3-\Delta_2}|x_2-x_3|^{\Delta_2+\Delta_3-\Delta_1}}$$

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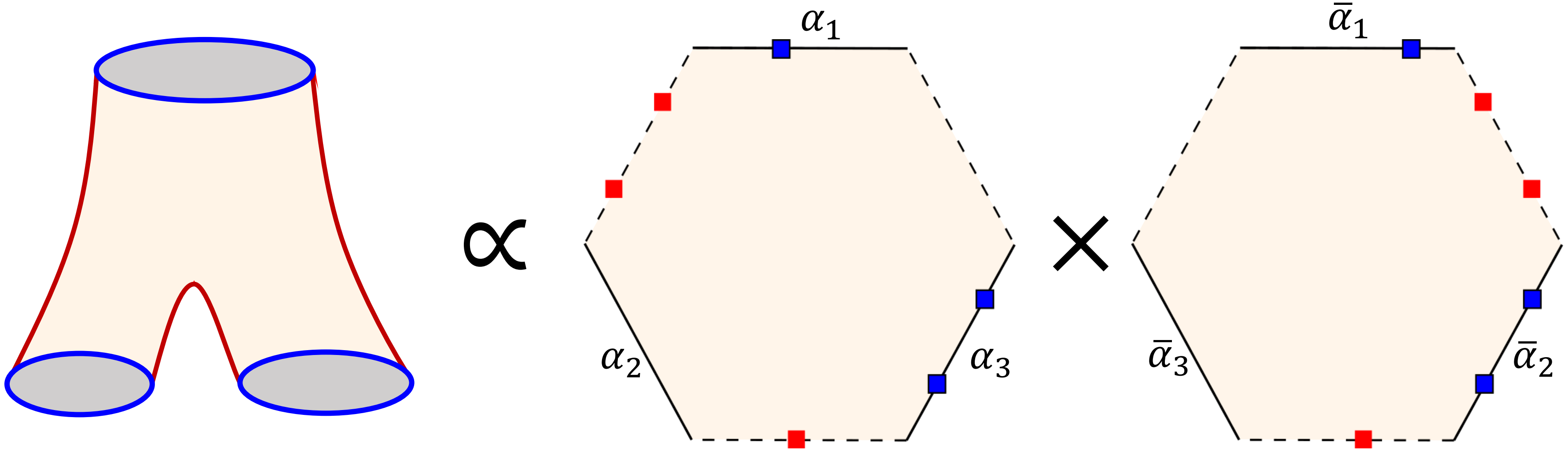

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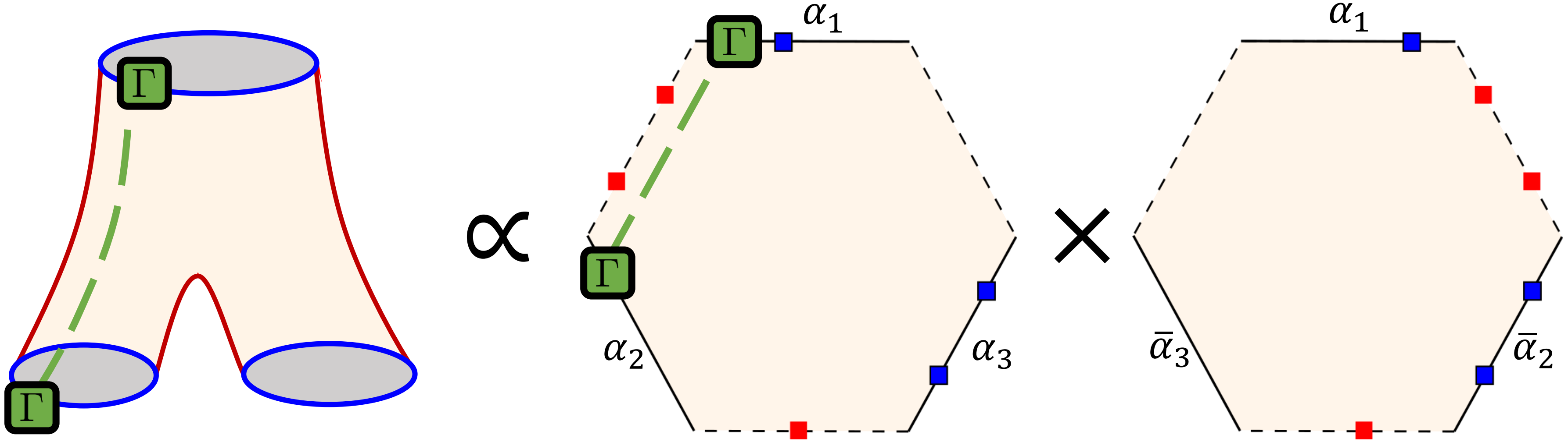

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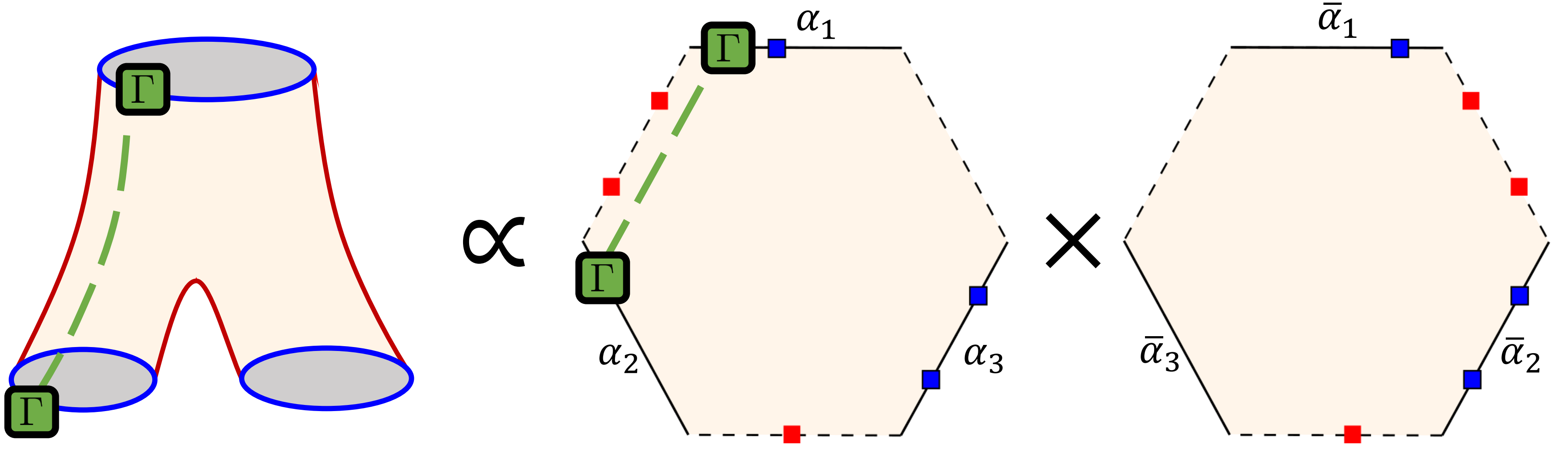

- Structural match with localisation results for BPS operators

[Ferrando, Komatsu, Lefundes, Serban '25]

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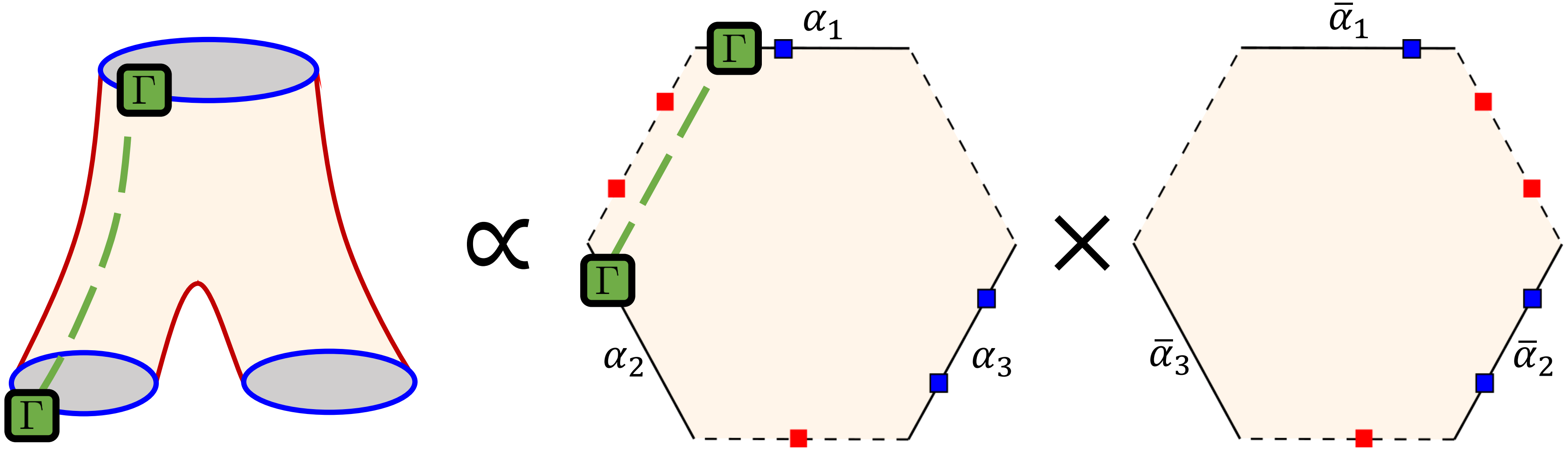

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[le Plat, TS '25]

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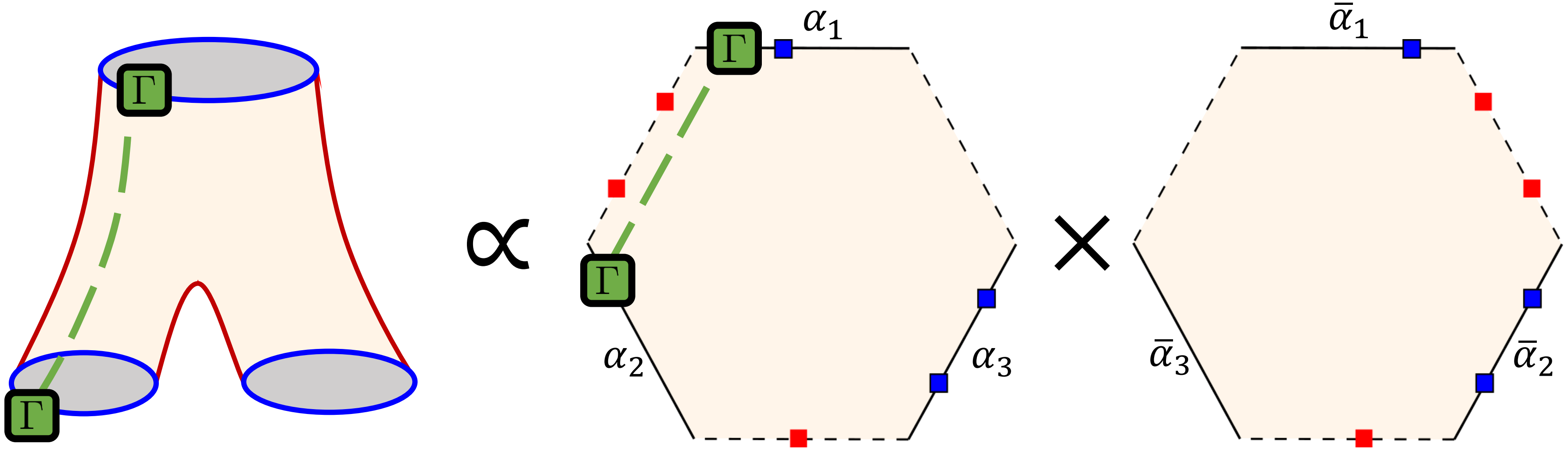

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- **To do**: 1-loop, higher loop, glueing and wrapping, strong coupling, …

[WIP w/ le Plat]

Marginal deformations

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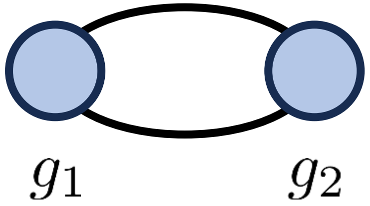

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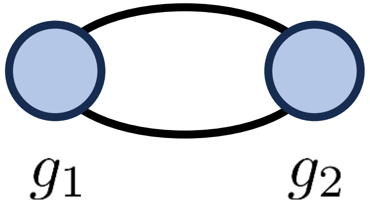

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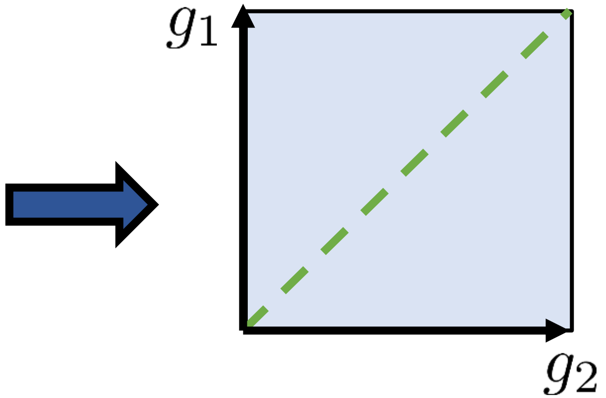

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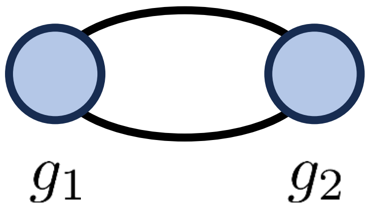

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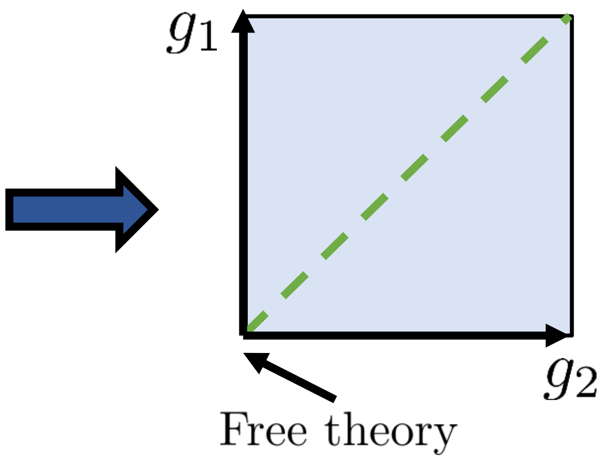

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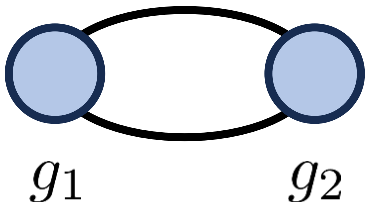

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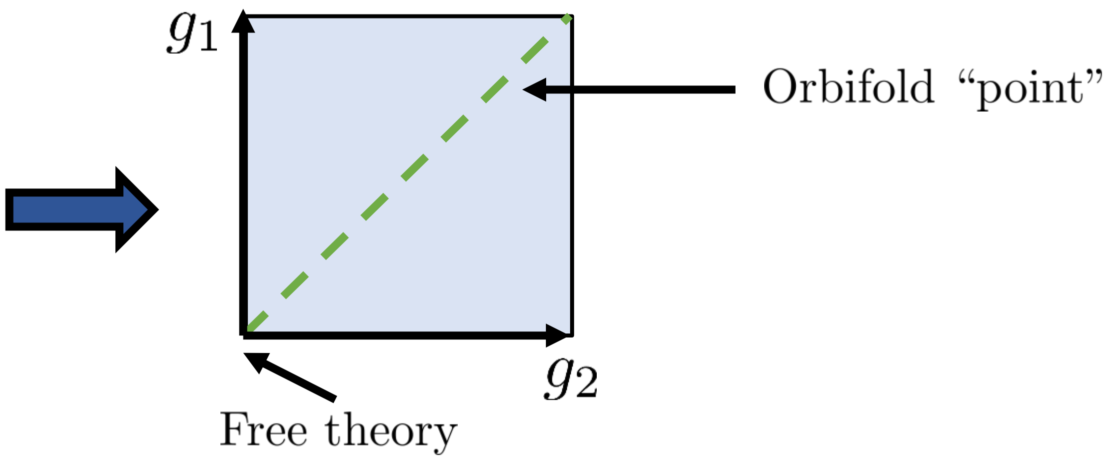

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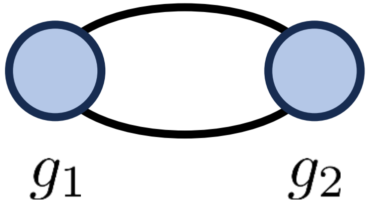

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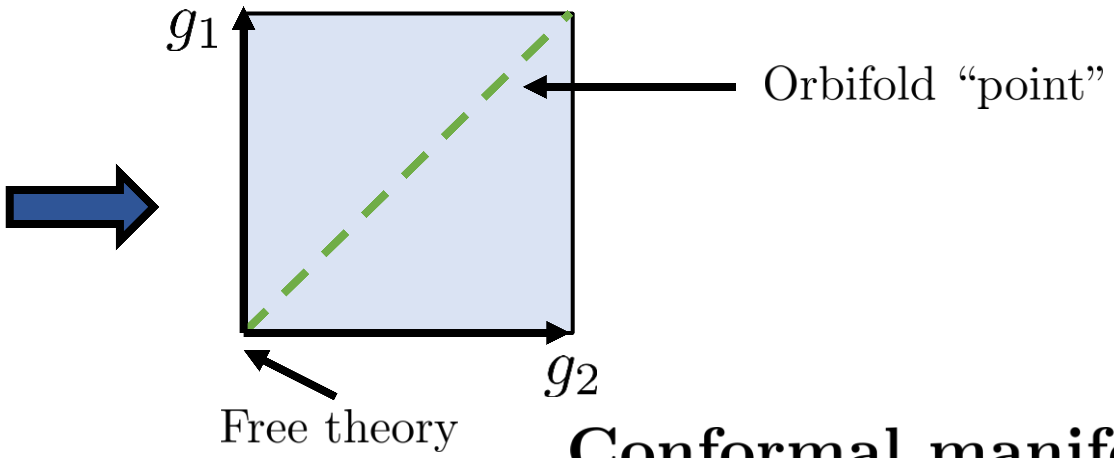
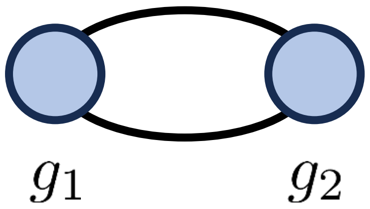


Conformal manifold

Marginal deformations



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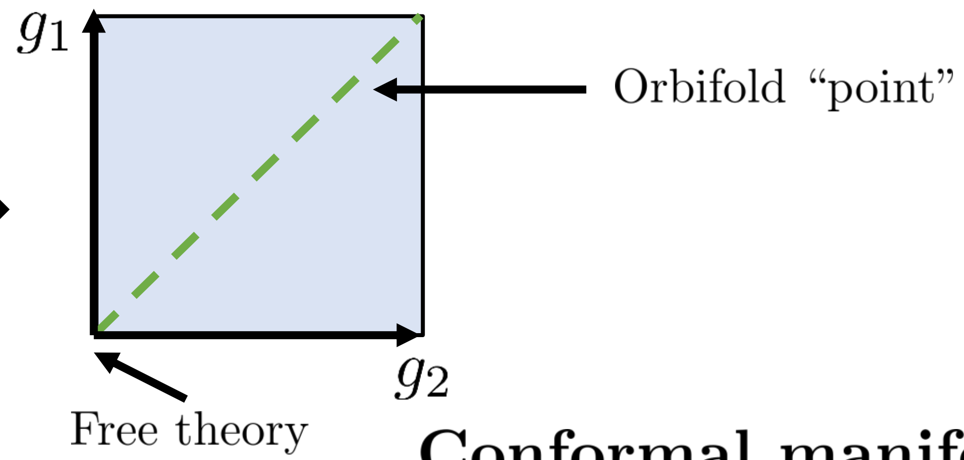

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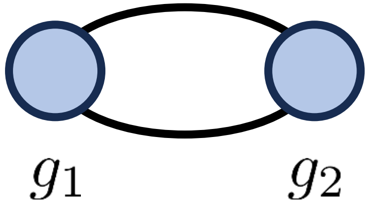

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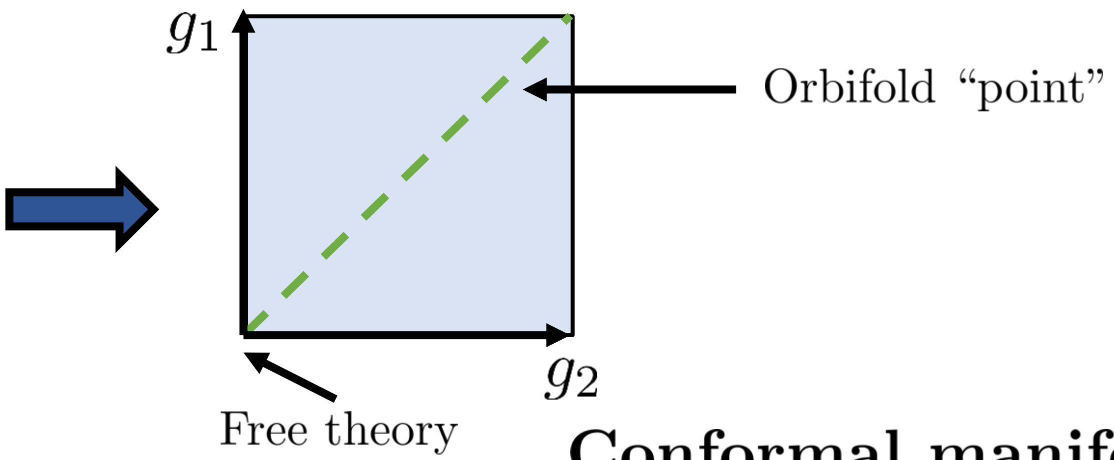

Conformal manifold

AdS/CFT

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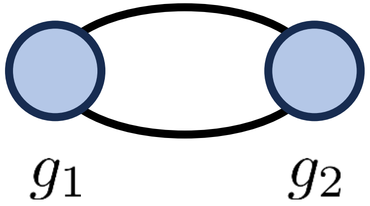

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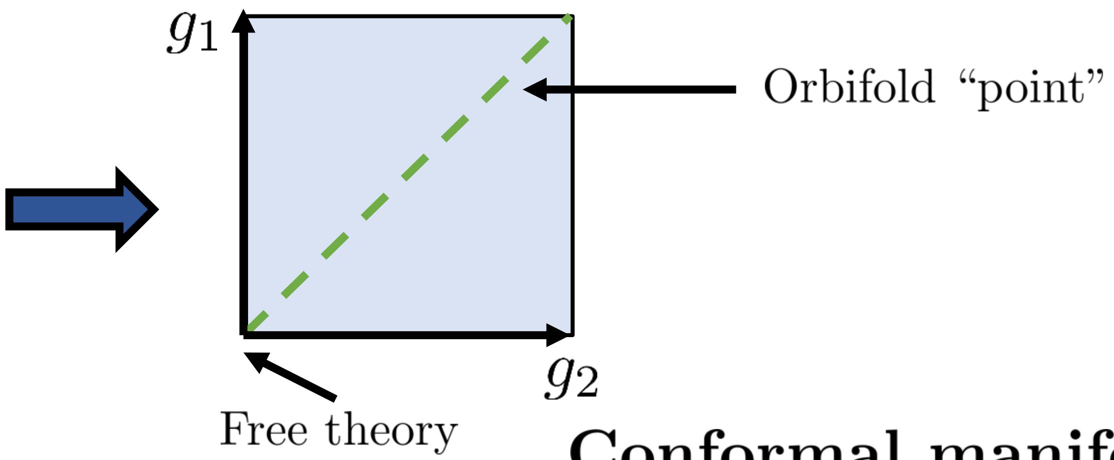

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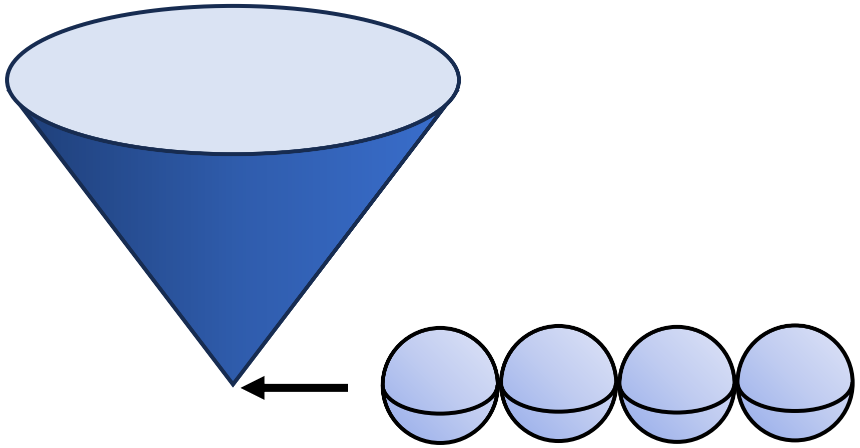

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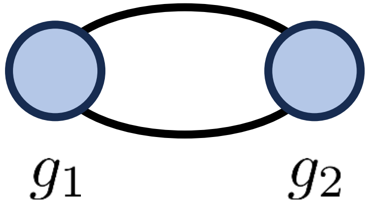

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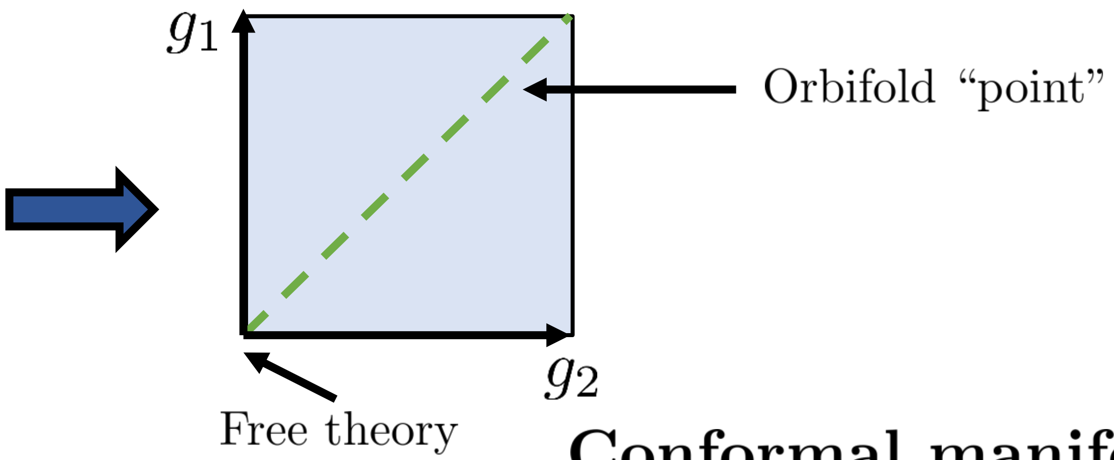

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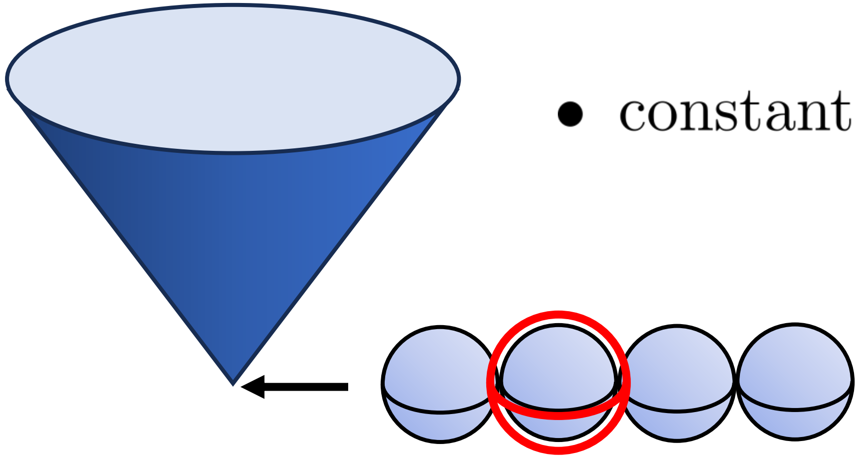

- constant B_2-field can wrap the resolution cycles

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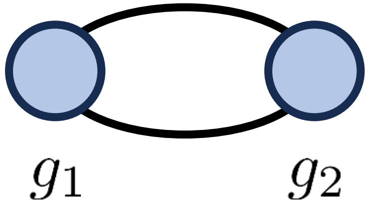

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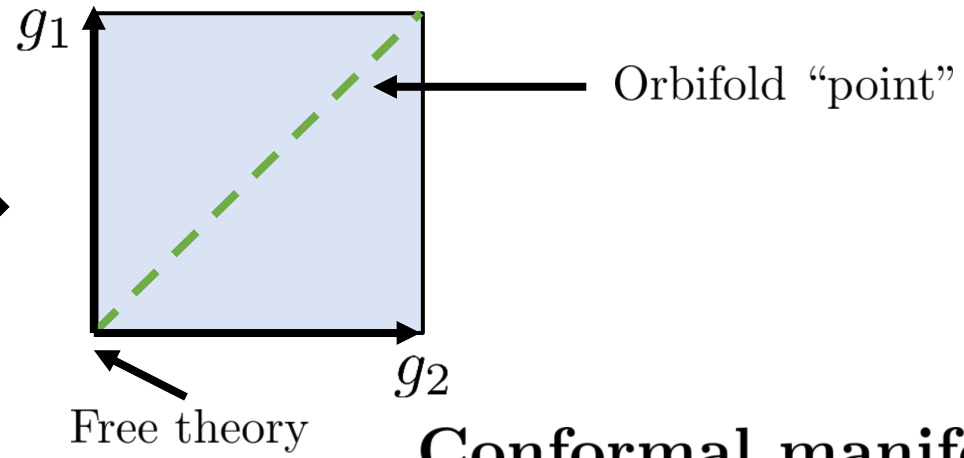

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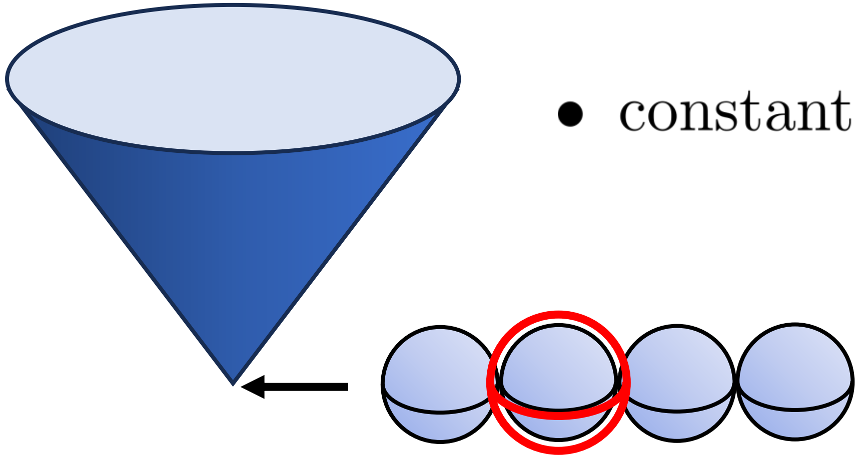

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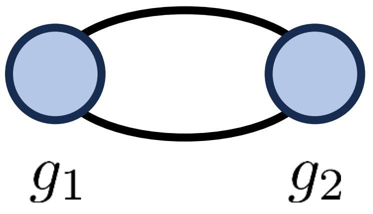

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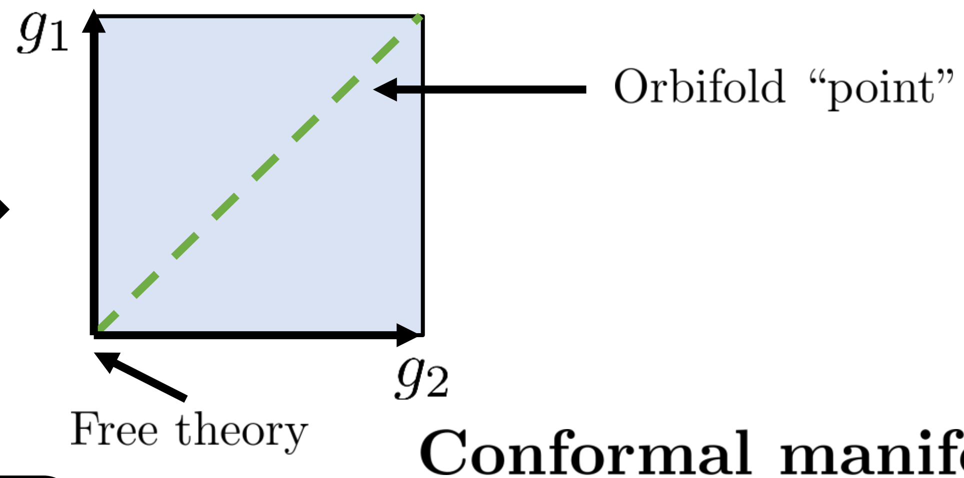

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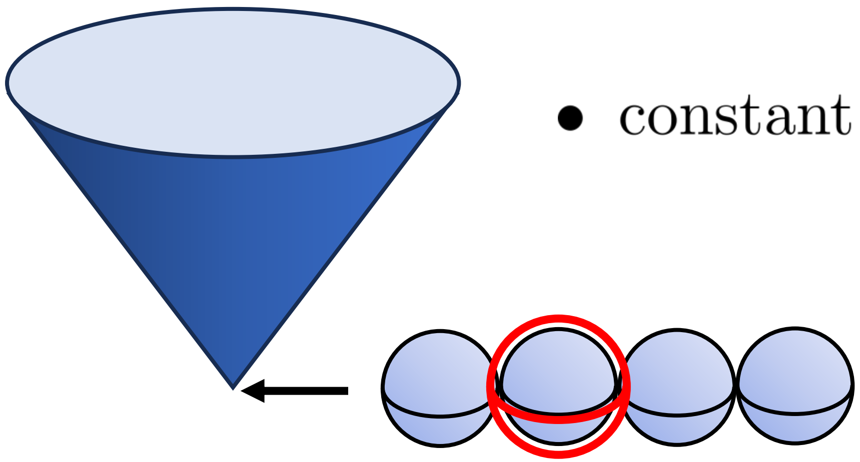

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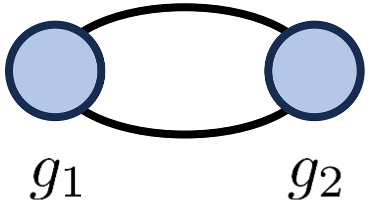

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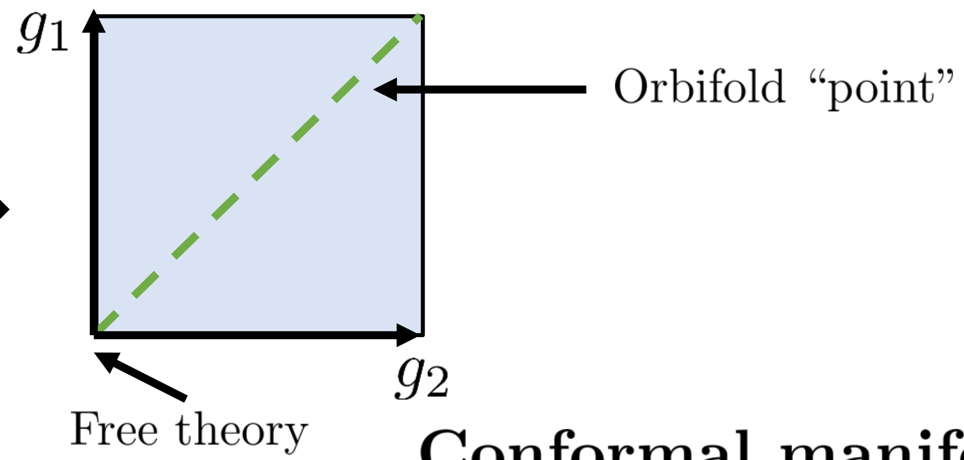

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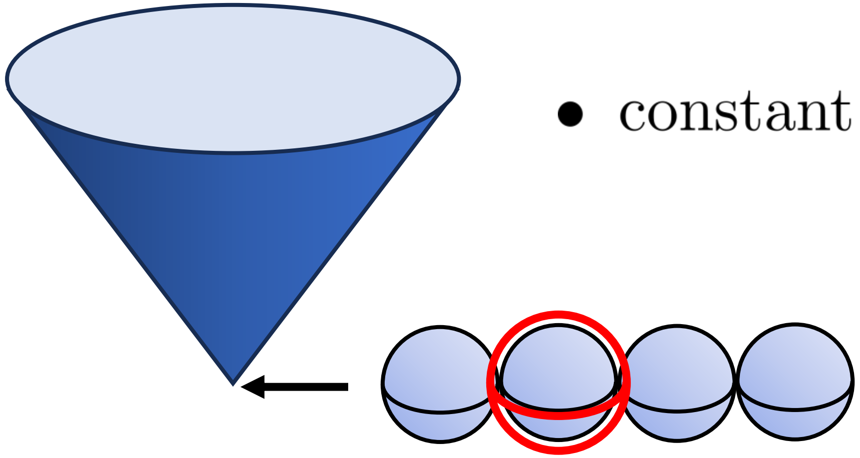

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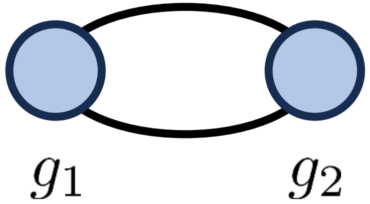
⇒ Related to ratios of couplings ($\frac{g_2^2}{g_1^2} = \frac{b}{1-b}$ for $\mathbb{Z}_2$)

[Gadde, Pomoni, Rastelli '09]

The decoupling limit



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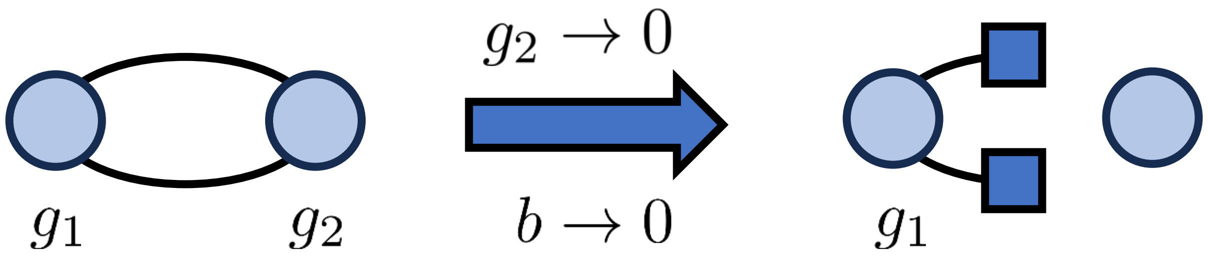

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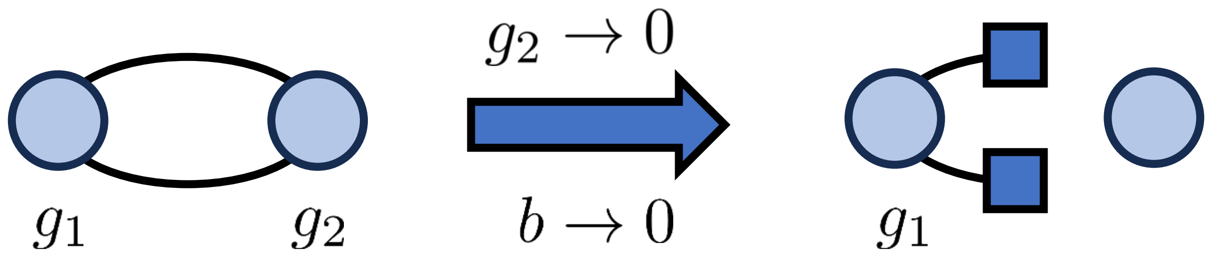

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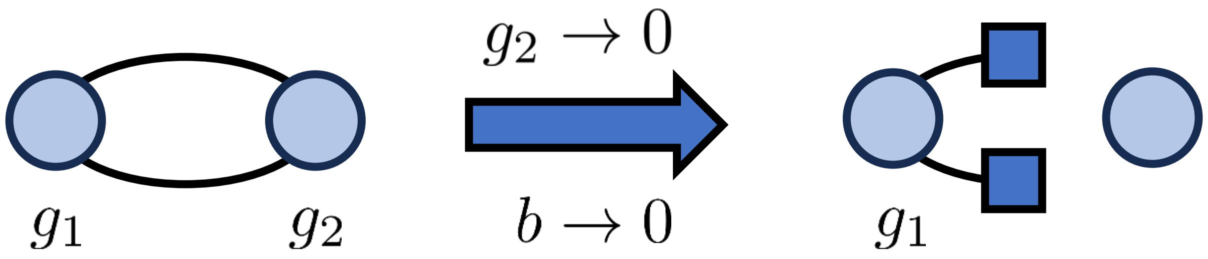

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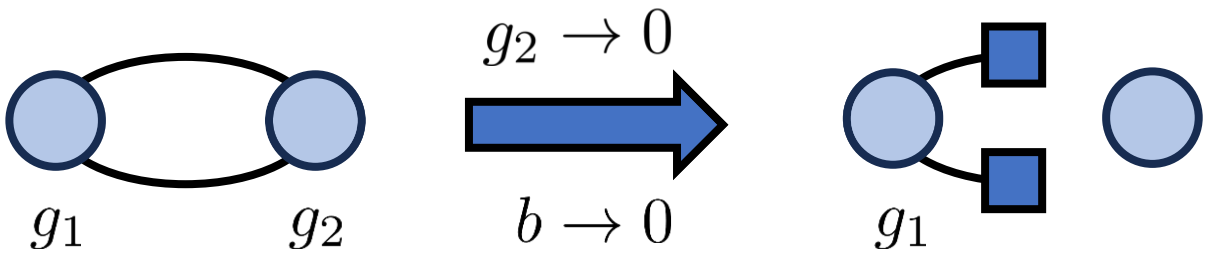

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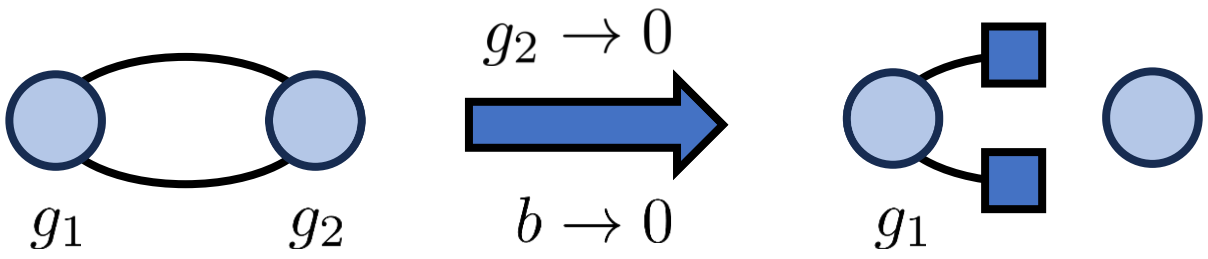

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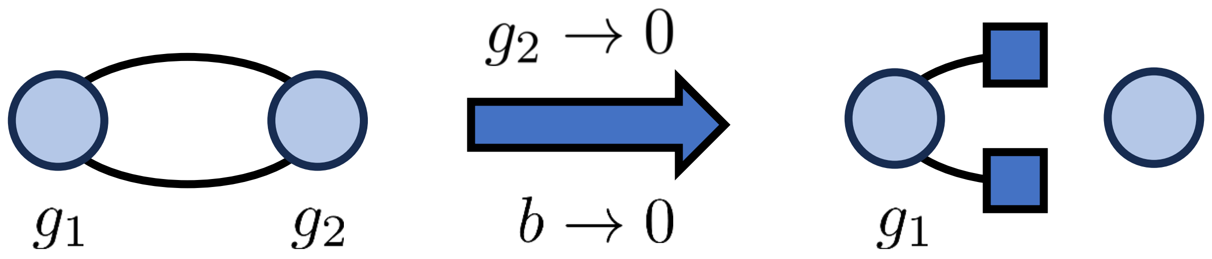

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- Should first check BPS quantities and compare to localisation

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[WIP w/ Barredo Martínez]

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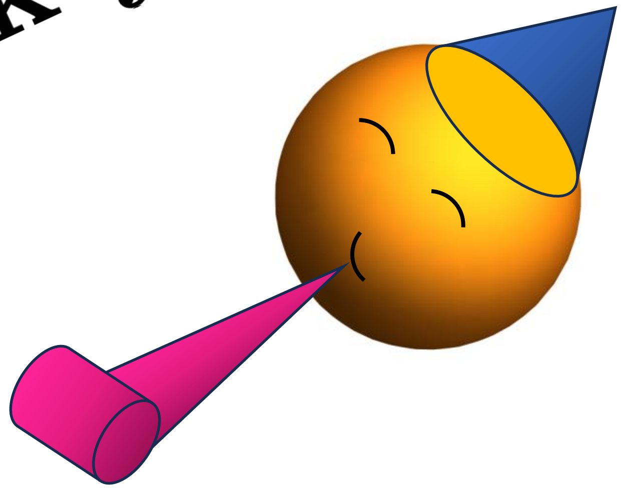
- Consider $\mathcal{N} = 1$ orbifolds

  [WIP w/ Mantegazza, Pomoni]

Thank you !



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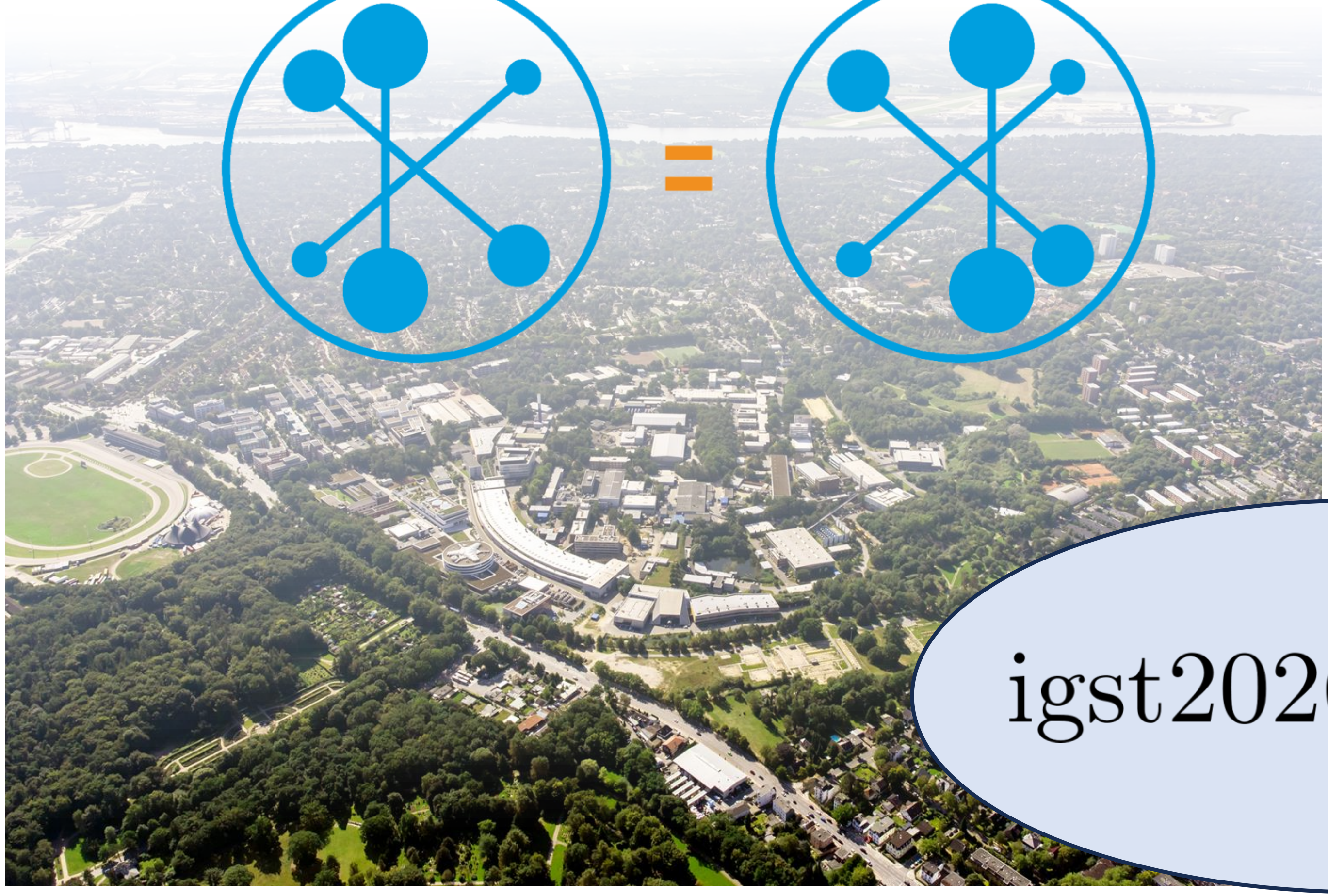

igst2026.desy.de

Type IIA reasoning

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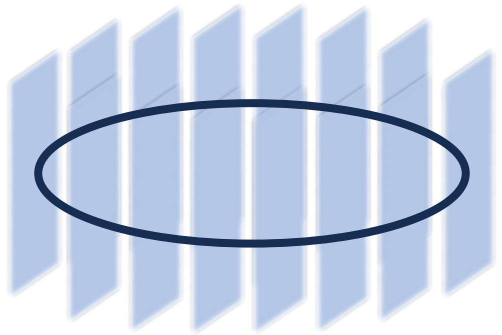
$$\mathrm{d}s^2_{10} = \mathrm{d}s^2(\mathbb{R}^{1,5}) + H(r)\left(\mathrm{d}r^2 + r^2\mathrm{d}\Omega_2^2 + \mathrm{d}\tilde{\phi}^2\right)$$



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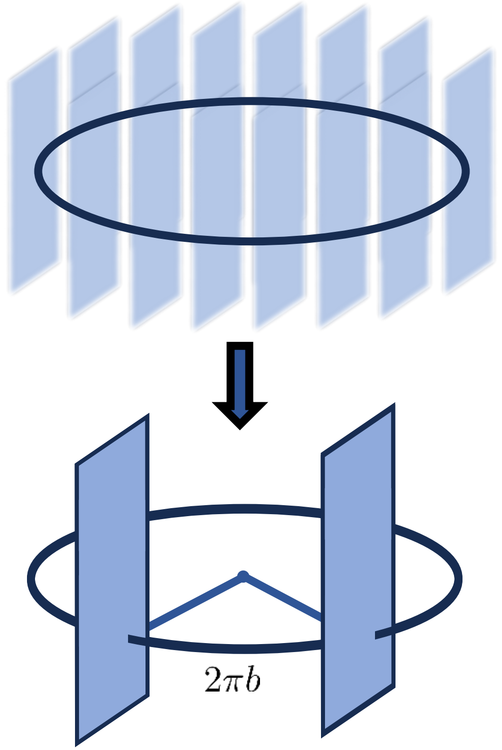

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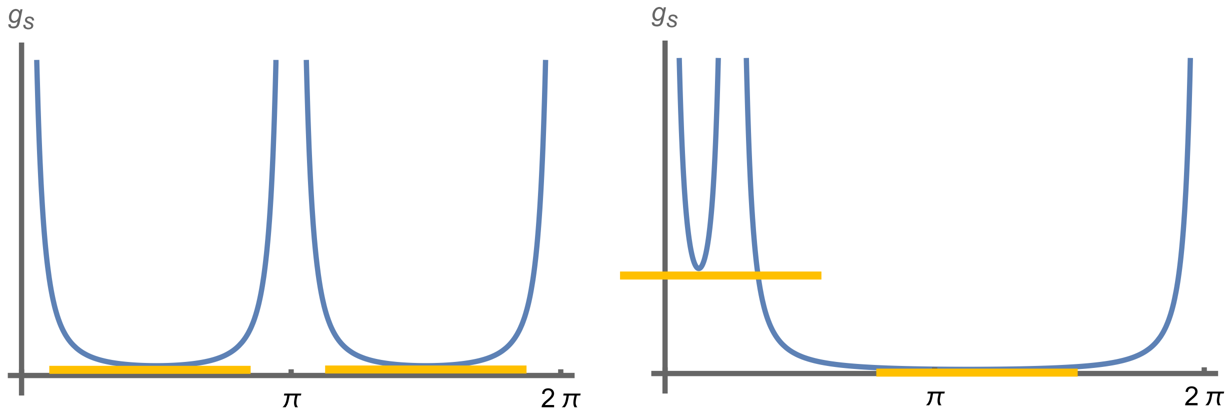

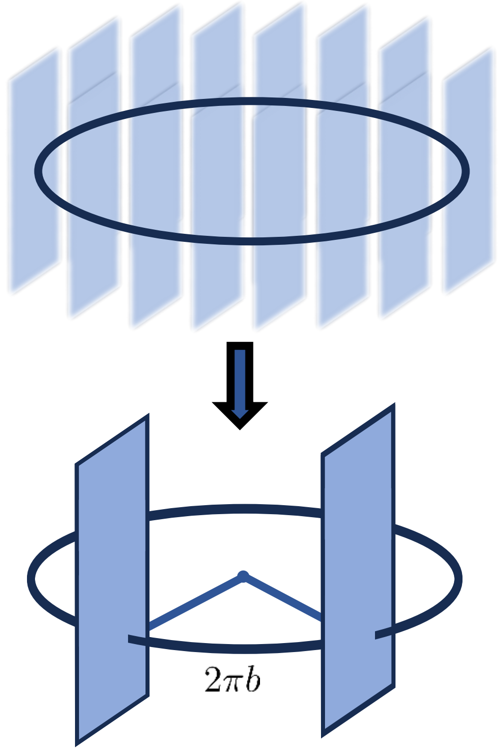

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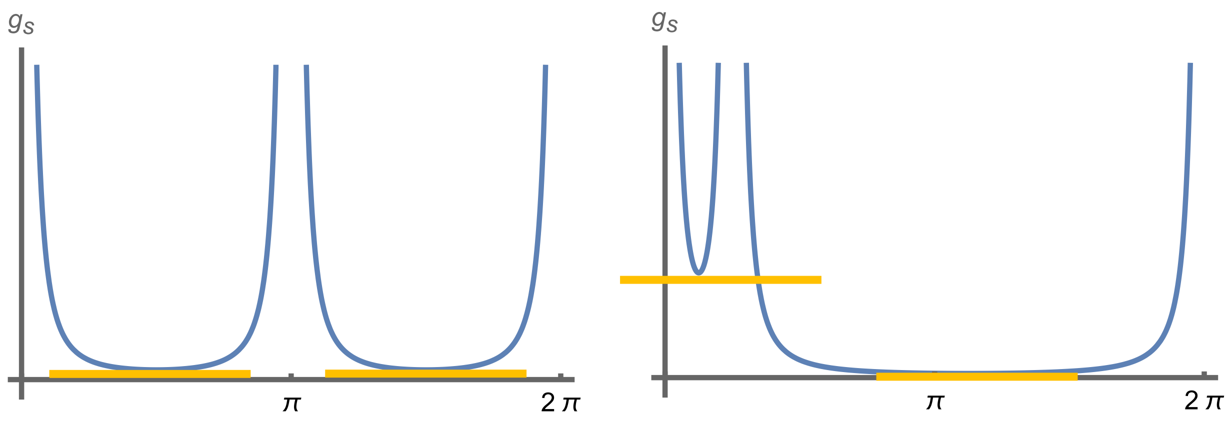

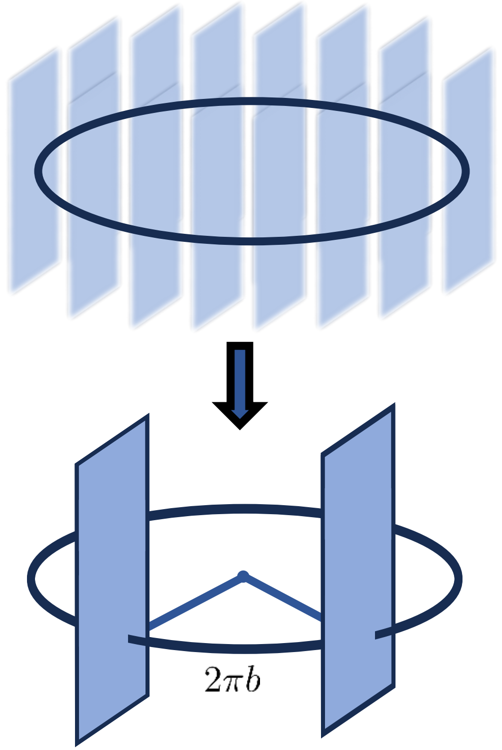

- Locally around the NS5-brane stack → CHS → "non-critical string"

[Callan, Harvey, Strominger '91] [Kazama, Suzuki '89]