Structure of Anomalies in 4d SCFTs from M5-branes

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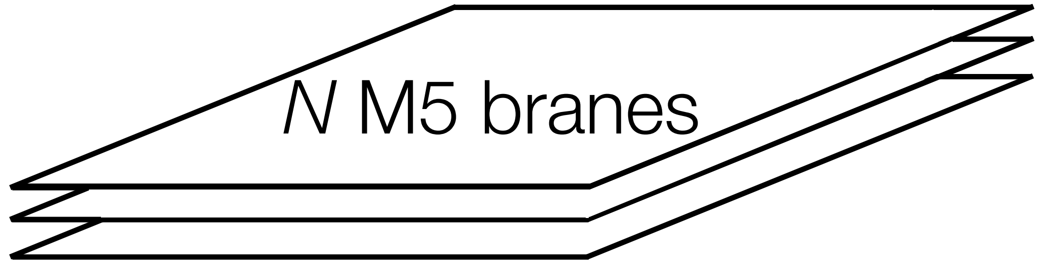
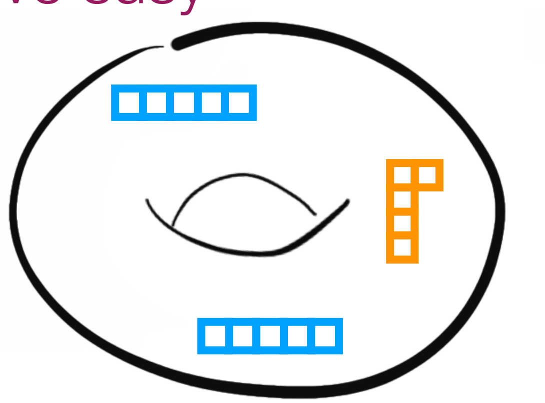
Arena:



Effective worldvolume theory is

6d (2,0) SCFTs of type A_{N-1}

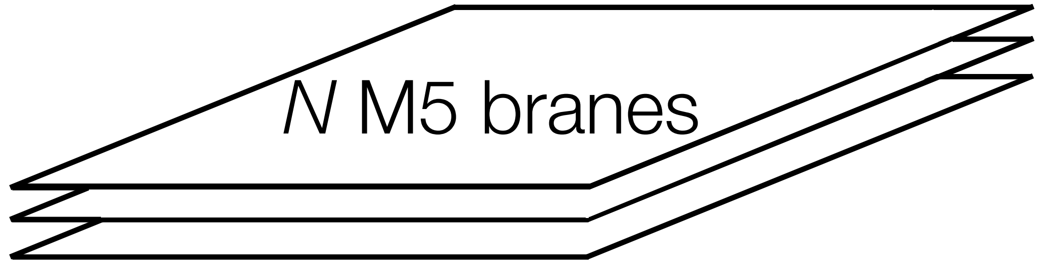
Partial **topological twist** over
$\Sigma_{g,n}$ (genus g, n punctures)
to preserve susy



4d theory of “**Class *S***”

[Witten] - early constructions
[Gaiotto; Gaiotto, Moore, Neitzke] - $\mathcal{N}$=2
[Bah, Beem Bobev, Wecht] - $\mathcal{N}$=1

Arena:



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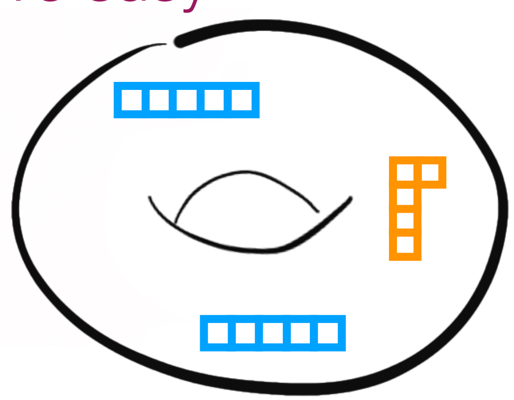


4d theory of "**Class *S***"

The 4d SCFTs are labeled by:

- Euler characteristic $\chi(\Sigma_{g,n}) = -(2g-2+n)$
- Local data at the punctures.

punctures

→ boundary conditions for the branes

→ flavor symmetries in 4d,

1-1 with Young tableaux

[Chacaltana, Distler, Tachikawa]

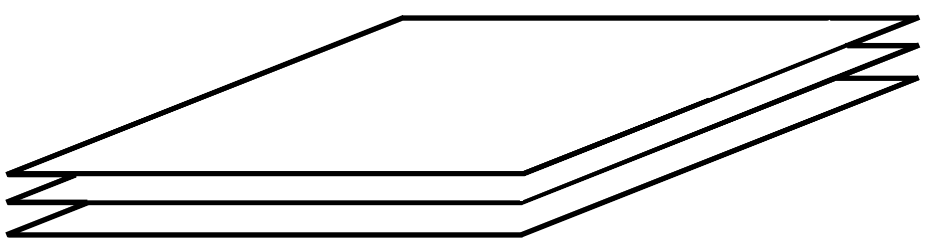
- This setup allows us to organize a large space of (generically strongly coupled!) QFTs geometrically.
- Much of the richness of Class *S* comes from the punctures!

Goal: First principles way of computing 't Hooft anomalies when compactifying M5-branes on a Riemann surface, for both $\mathcal{N}=1$ and $\mathcal{N}=2$ in 4d.

For simplicity, here I'll restrict to $\mathcal{N}=2$.

4d anomalies from 6d

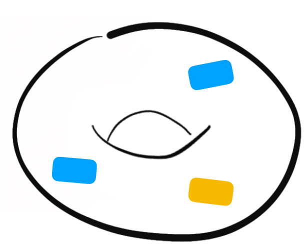
- In general, one can **reduce** anomalies to lower dimensions. This will capture the contribution due to the compactification (although might fail with accidental symmetries!).
- For class *S*, when *n*=0 this method has been powerful in computing the anomalies of the 4d theories. [Bah, Beem Bobev, Wecht]



✴ With punctures, there are additional contributions. These are known indirectly from QFT dualities + Higgsing. [Chacaltana, Distler, Tachikawa]

6d (2,0) SCFTs of type A_{N-1}

$I_8[A_{N-1}]$



our work: compute these **directly**

4d theory of Class *S*

$$I_6^{\mathcal{S}} = \underbrace{I_6(\Sigma_{g,n})}_{\text{depends on } \chi(\Sigma_{g,n})} \left[+ \sum_{i=1}^{n} \underbrace{I_6(P_i)}_{\text{depends on Young Tableaux data}} \right]$$

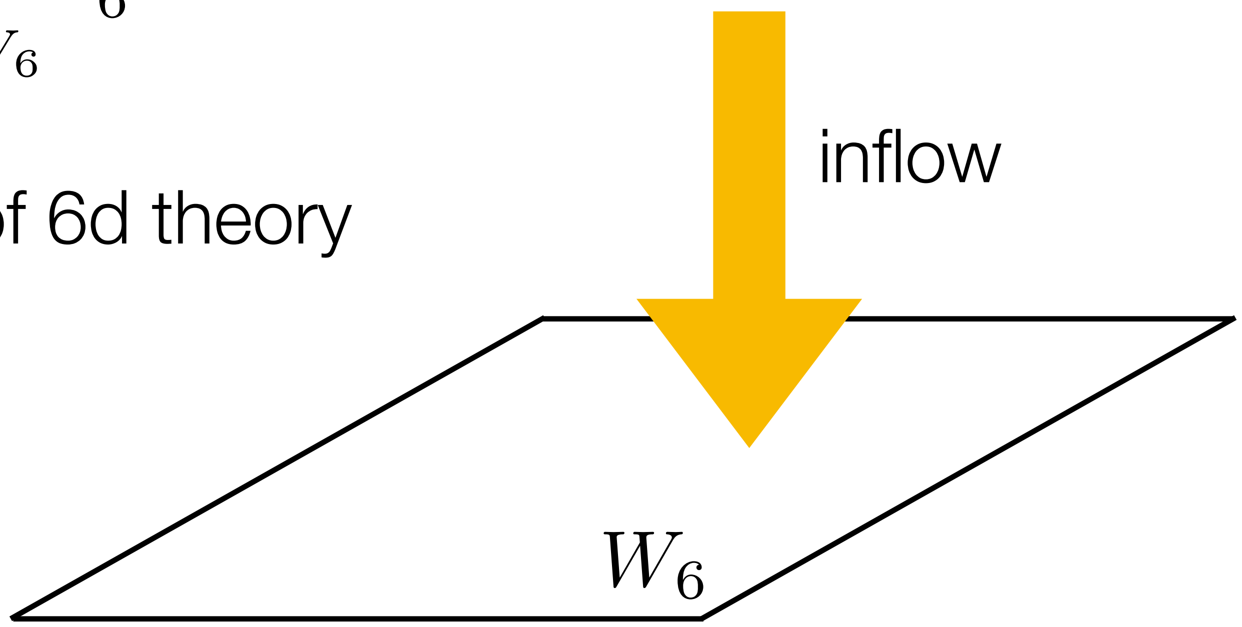
Method: Anomaly Inflow

- In the presence of M5-branes, bulk diffeomorphisms localized on the brane are **anomalous**. The anomalies are canceled by terms in the bulk 11d sugra effective action:

$$\delta S_{\text{eff}} = 2\pi \int_{W_6} I_6^{(1)}$$

$I_6^{(1)}$ related to anomaly polynomial I_8 of 6d theory via the **descent** procedure,

$$I_8 = dI_7^{(0)}, \qquad \delta I_7^{(0)} = dI_6^{(1)}$$



[Witten; Freed, Harvey, Minasian, Moore; Harvey, Minasian, Moore]

Roadmap: Inflow for M5-branes on $M^{1,3}$ x $\Sigma_{g,n}$

[Bah, EN]

1. M5-branes magnetically source G_4:

$$dG_4 = N\delta^{(5)}(r)dr \wedge \underbrace{d\Omega_4}_{\text{angular form on the 5 transverse directions} = SO(5)\text{-bundle}} \xrightarrow{(*)} N\underbrace{d\rho(r)}_{\text{bump form}} \wedge \underbrace{e_4}_{\text{gauge-invariant, closed, globally defined angular form}}$$

(*) subtle! see [Freed, Harvey, Minasian, Moore]

(**) our work

(**)

2. Generalizing to the Class *S* geometries, the normal bundle **reduces** *SO*(5) → *SO*(3) x *SO*(2): $Nd\rho(r) \wedge e_2^{\Omega} \wedge e_2^{\phi}(F_\Sigma)$

3. The RHS is a function of connection forms for background field strengths. F_Σ over $\Sigma_{g,n}$ has **sources** at the punctures.

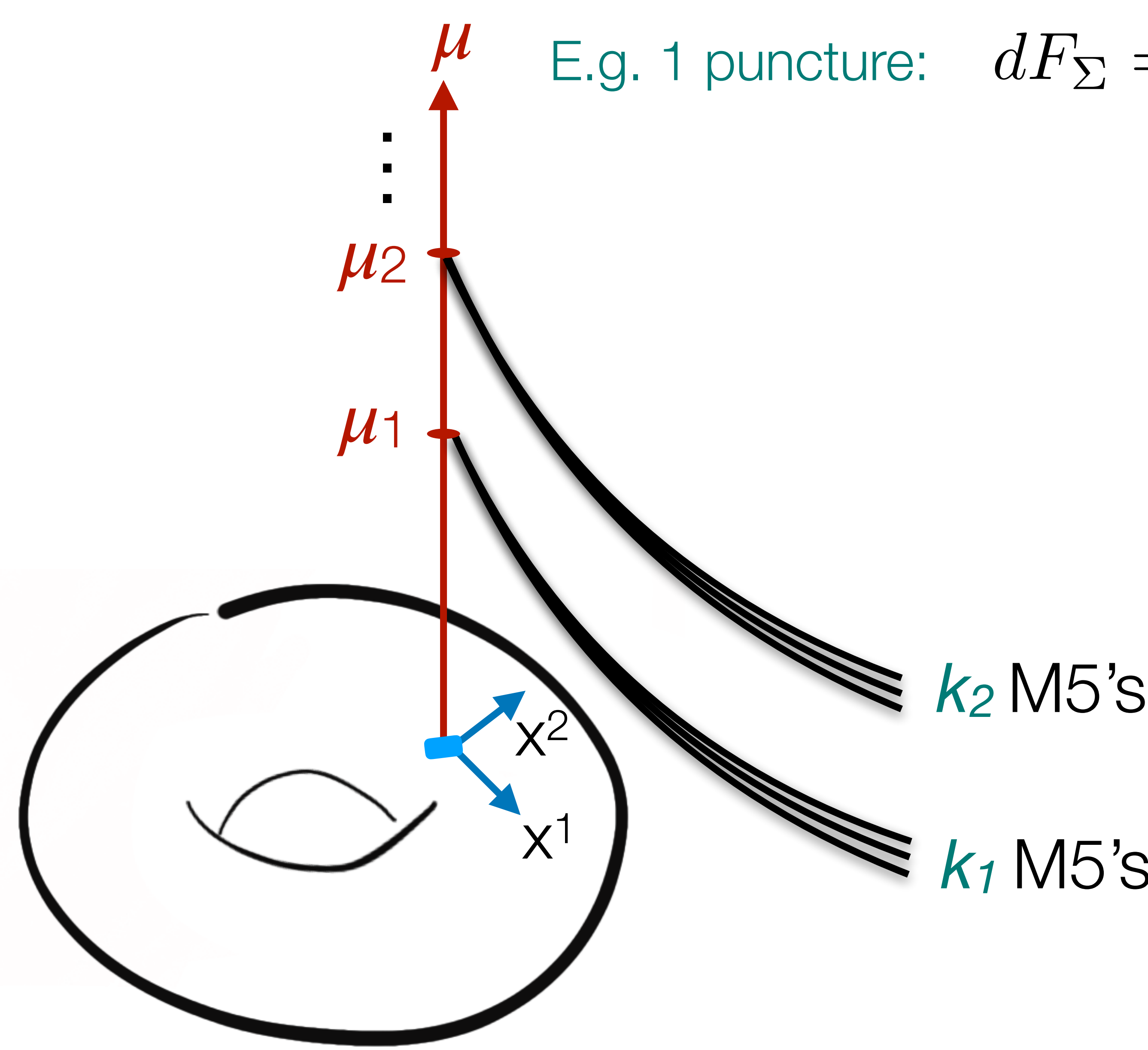
4. δS_{eff} has new contributions from **boundary** terms in the integration by parts.

Punctures imply sources

[Bah, EN; Bah, Bonetti, Minasian, EN]

- Motivated by the holographic description, [Gaiotto, Maldacena; Bah] the curvature form F_Σ gets explicit sources localized at the punctures as well as along a transverse direction μ to the branes:

E.g. 1 puncture: $$dF_\Sigma = \sum_a 2\pi\delta(\vec{x})dx^1 \wedge dx^2 \wedge \delta(\mu - \mu_a)d\mu$$



✳ Each source is a KK **monopole** in M-theory that some of the N M5-branes can end on.

✳ Monopole charge k_a = # of M5's ending on the monopole.

✳ $U(k_a)$ induced on each set of branes, → 4d global **symmetry**.

✳ Sources for F_Σ imply sources for G_4, which must be smoothed.

New components for inflow with punctures:

[Bah, EN; Bah, Bonetti, Minasian, EN]

- There are now two types of terms in the variation:

$$\frac{\delta S_{\rm eff}}{2\pi} = \boxed{\int_{S^2_\Omega \times S^1_\phi \times [\mu] \times \Sigma_{g,n} \times M^{1,3}} \widetilde{e}_4 \wedge \left(N \widetilde{I}_6^{\rm inf(1)} - \frac{N^3}{6} \widetilde{e}_4 \wedge \widetilde{e}_2^{(1)} \right)}$$

gives 6d (2,0) I_8

localizes on the brane

$$+ \int_{S^2_\Omega \times S^1_\phi \times \partial([\mu] \times \Sigma_{g,n}) \times M^{1,3}} \widetilde{e}_3^{(0)} \wedge \left(N \widetilde{I}_6^{\rm inf(1)} - \frac{N^3}{9} \widetilde{e}_4 \wedge \widetilde{e}_2^{(1)} \right)$$

$$I_8^{\rm inf} = -\frac{1}{48} \left(p_2(TW_6) + p_2(NW_6) - \frac{1}{4} \left[p_1(TW_6) - p_1(NW_6) \right]^2 \right)$$

p_k = Pontryagin classes

$$\widetilde{e}_4 = d\widetilde{e}_3^{(0)}, \quad \delta \widetilde{e}_3^{(0)} = d\widetilde{e}_2^{(1)}$$

$$I_6^{\mathcal{S}} = \underline{I_6(\Sigma_{g,n})} + \sum_{i=1}^{n} I_6(P_i)$$

✳ This has the structure of the usual bulk integrand, but now $e_4 \to \widetilde{e}_4$ depends on the improved connection forms. Reducing over $\Sigma_{g,n}$ gives the known answer.

New components for inflow with punctures:

[Bah, EN; Bah, Bonetti, Minasian, EN]

- There are now two types of terms in the variation:

$$\frac{\delta S_{\text{eff}}}{2\pi} = \int_{S^2_\Omega \times S^1_\phi \times [\mu] \times \Sigma_{g,n} \times M^{1,3}} \widetilde{e}_4 \wedge \left(N \widetilde{I}_6^{\text{inf}(1)} - \frac{N^3}{6} \widetilde{e}_4 \wedge \widetilde{e}_2^{(1)} \right)$$

$$+ \boxed{\int_{S^2_\Omega \times S^1_\phi \times \partial([\mu] \times \Sigma_{g,n}) \times M^{1,3}} \widetilde{e}_3^{(0)} \wedge \left(N \widetilde{I}_6^{\text{inf}(1)} - \frac{N^3}{9} \widetilde{e}_4 \wedge \widetilde{e}_2^{(1)} \right)}$$

localizes on the boundaries

$$I_6^{\mathcal{S}} = I_6(\Sigma_{g,n}) + \sum_{i=1}^{n} \underline{I_6(P_i)}$$

✴ Reducing over the boundaries gives the additional puncture anomalies.

⇒ **The topological structure of the 4d anomalies follows directly from inflow arguments.**

Thanks!

ありがとうございます