Rigid Holography and surprises with the (2,0) field theory on S^1

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Weakly coupled grav. ←→ Strongly coupled FT

Strongly coupled bulk

- Isolated singularities - sometimes
- Throughout – rarely

Before gravity, there could be strongly coupled field theories on AdS

- (2,0) of $AdS_5 * S^1$
- Confinement in the bulk

Can we learn something new about them if embedded in AdS/CFT?

SUSY field theories on AdS

1. New handles – boundary conditions.
2. Related by conformal transformations to boundaries or defects in flat space.
3. New IR regulator, New representation theory.
4. $M_p \rightarrow$ infinity = new decoupled sectors in known SUSY field theories (on the boundary). **RIGID HOLOGRAPHY**
5. Bulk dynamics <-> Boundary dynamics, Boundary algebraic (?).
6. Surprising effects in the bulk

Bits and pieces on the 6D (2,0)

The $(2,0)_k$ SCFT on $R^{1,5}$

- Low energy of k M5 branes. No lagrangian.
- Moduli space R^{5k}/Z_k
- BPS objects: strings which are M2's ending on the M5s. Become tensionless at the origin of moduli space.
- Dualities: dual to M-theory on AdS_7*S^4; SUSY indices; S scales like $V_5N^3T^5$

- Another stringy realization: IIB string on C^2/Z_k – A_{k-1} singularity - when tuning B,C at the singularity to zero (3 metric blow up modes, $\int B, \int C$).

The $(2,0)_k$ SCFT on $R^{1,4}*S^1$

- SYM on $R^{1,4}$. $g^2_{ym}=R_5$ ➔ small (large) radius is weak (strong) coupling.
- BPS objects along the flat directions
- W bosons which are the 6D BPS strings winding on the 5^{th} circle.
- Instantons on R^4 are particles = KK modes on the 5^{th} circle.

$AdS_5 * S^5/Z_k$ vs. Quiver gauge theories

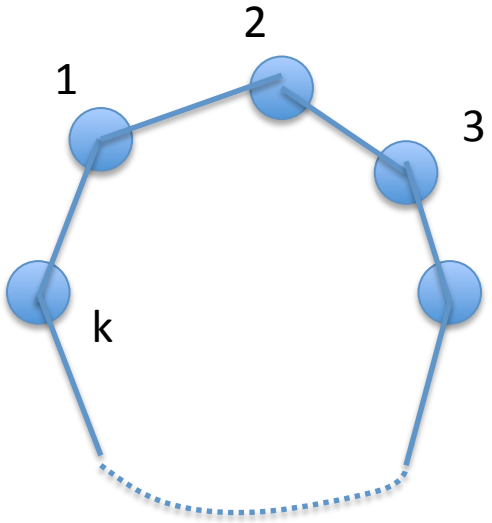
Simplest point: Orbifold. Embed S^5 inside C^3 and act with

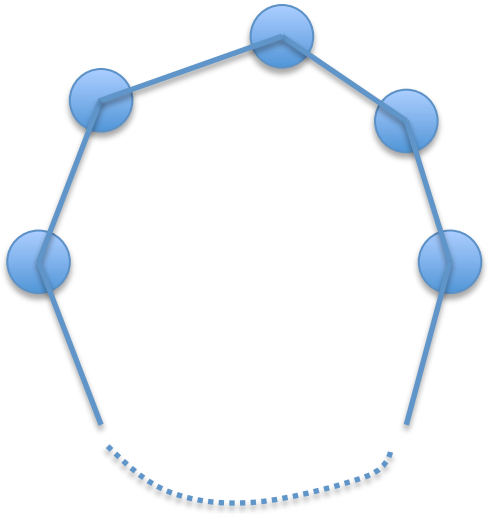
$(z_1,z_2,z_3) \rightarrow (w\, z_1, w^{-1} z_2, z_3)$ == Near horizon of D3 branes probing A_{k-1} orbifold

$w=\exp(2\pi i/k)$

There is an $AdS_5 * S^1$ worth of A_{k-1} singularities ($z_1=z_2=0$).

The field theory dual is the 4D N=2 quiver (Kachru-Silverstein) .
Each node has an SU(N) gauge theory.
Each link has a bi-fundamental hyper.





The theory has k complex exactly marginal deformations which are the k complex couplings of the gauge group.

$$\tau_a = \frac{\theta_a}{2\pi} + i\frac{4\pi}{g^2_{YM,a}}$$

One of them is invariant under Z_k and the rest are charged.

Gravity side:

-IIB Dilaton-Axion

- k-1 2-cycles at the singularity.

From each, 3 metric blow up modes are massive (BF bound) $\int B, \int C$ remain massless on AdS_5 – map to the couplings above. The orbifold corresponds to $\int B \neq 0$,

$\tau_1 = \tau_2 = .. = \tau_k$

Naïve expectation and a FT no-go

At the orbifold point we have the (2,0) theory, along a flat direction, on a (large) S^1. The 4+1 dynamics is 4+1 SYM along the flat diretcions → The bulk gauge symmetry is $U(1)^{k-1}$, which agrees with the quiver. It is a global symmetry from the point of view of the 4D N=2 theory – it is the relative rotation of the hypers.

The singular limit: $\int B \to 0 \ / \tau_1 = \tau_2 = .. = \tau_{k-1} \to 0, \sum_1^k \tau_i \quad fixed$

We expect to get an **enhanced SU(k) global symmetry**. But such enhancements of symmetry are **forbidden** in N=2 SYM without additional higher spin symmetries (← dictated by the structure of long N=2 SUCONF multiplets splitting into short ones). The U(1)'s do not have these higher spin currents

What actually happens is:

- The theory posses a strongly coupled SU(k) symmetry in the bulk, **everywhere along the moduli space**. Unlike the flat usual flat space picture it is never higgsed.

- It is not directly related to the $U(1)^{k-1}$ along the flat directions. The latter is not related to higgsing the former.

- There are more degrees of freedom living at the boundary of AdS. Degrees of freedom migrate freely from the bulk to the boundary as we move on the moduli space.

Note: we are at $R_s=R_{AdS,}$ so g^2_{ym}/R is of order 1.

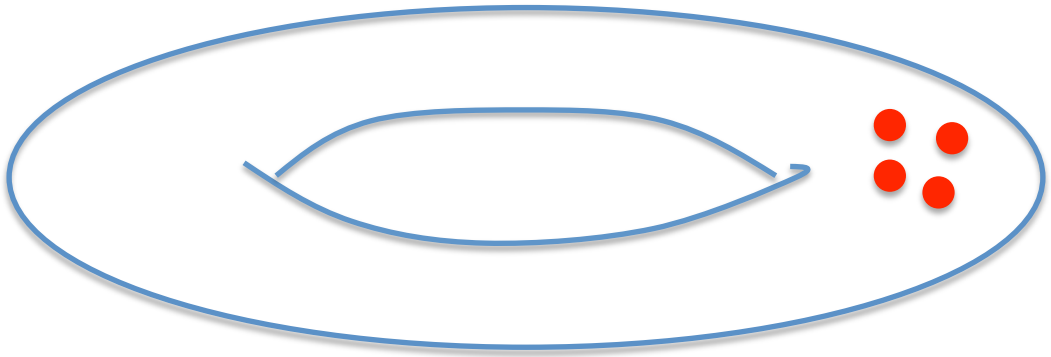
4D N=2 SUSY gauge theories

Gaiotto,….

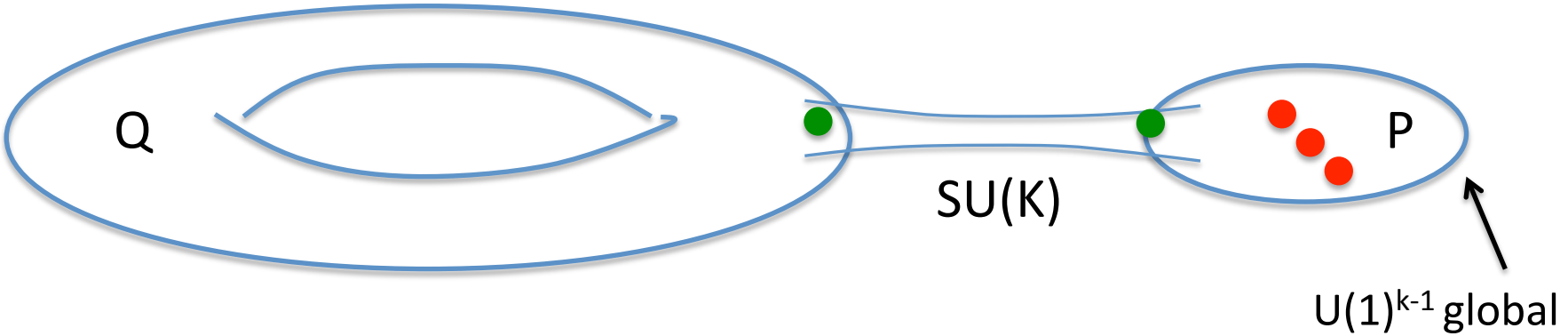
The moduli space of field theories is given by k couplings.

The exact moduli space is the k-punctured 2-torus. If the locations of the punctures is w_a, then $\tau_a = w_{a+1} - w_a$

The orbifold translates into the k punctures being equidistant. The singular limit translates into the k-punctures coming together on a fixed size torus.



In this limit the theory becomes a product:
Q(N,K) – 4D N=2 SCFT given by the (2,0) A_{N-1} on a torus with SU(K) puncture
P(K) - 4D N=2 SCFT with K minimal puncture and one SU(K) puncture
SUSY gauging of the SU(K) symmetry.



For example, if one bring the points together one obtains the theory, we get that P(K)=SU(2)*SU(3)*….*SU(k-1) with bi-fundamental hyper for adjacent gauge groups, a hyper doublet of SU(2) and K fund. Hypers for SU(K-1).

Bulk Perspective

Higher spin perspective: The "bridge" SU(K) is weakly coupled (but gauged) => at the origin of moduli space there are an infinite number of of conserved higher spin charges, including the "graviton" of the component P.

A simpler perspective: P(K) lives on the boundary and the bulk theory is Q(N,K).

The degrees of freedom in the bulk theory correspond to the Q(N,K) theory. The SU(K) gauge symmetry of the (2,0) field theory on a circle, corresponds to the global SU(K) symmetry of Q, if we impose the standard AdS boundary conditions that gauge fields are quantized as global currents (Q is conformal by itself).

P(K) are degrees of freedom which explicitly live on the boundary of AdS.

SU(K) is taken with non-standard boundary conditions such that it is a gauge symmetry which couples the bulk Q and the boundary P (these boundary conditions are assumed to be forbidden in AdS_5, but they are allowed for strongly coupled gauge fields + boundary d.f.).

SU(K) symmetry of the (2,0) on a circle = SU(K) of the Riemann surface long throat.

But the latter is never broken (an exact statement from the field theory dual and from the gauge field boundary conditions).

Turning on a B field and a C field at the singularity does not higgs the SU(K). A very different picture than in flat space times a circle.

The $U(1)^k$ which exists along the flat directions is not the Cartan of the SU(K) at the origin. They are part of P that lives at the boundary close to the singular point.

Rigid Holography

By taking M_p to infinity at fixed R_{AdS}, we decouple the interacting (2,0) CFT on S^1. On the field theory side, we focused on a subsector of Q(N,K) which

1. Closed under OPE
2. Has good local correlators
3. Does not have a local energy momentum tensor.

More generally look at cases in which we remain with a sector with finite interactions in the bulk in the limit of M_p taken to infinity. We call this **Rigid Holography.**

It teaches us about universal subsector of theories. In the case above such a (2,0)/S^1 sector appears for **any N=2 theory in which there is a limit of K regular punctures coming together.**

Other examples:

- NS 5-branes wrapping for example $AdS_4 * S^2$ in $AdS_5 * S^5$ = NS 5-branes intersection D3 branes in a 2+1 space.
  The gauge coupling on the NS 5-branes satisfies

$$\frac{R_{AdS}^2}{g_{ym}^2} = \sqrt{g_{st} N}$$

We take N to infinity, keeping this ratio fixed, and also the string scale. Decouples a (1,1) LST.

- LST limit of the singularity in $AdS_5 * S^5/Z_k$, by specifying how $\int B$ scales.

Summary

- We can learn new things on strongly (fixed) coupling theories by placing them AdS spaces and using exact results from the dual theory – Rigid Holography.
- A very different picture for the (2,0) on S^1 for large radius S^1.
- A new approach to LST?
- New universal components of field theories – correlation functions satisfy some local FT axioms, but no local energy momentum tensor. A non-local theory with reasonable local observables? Restricted bootstrap?

Implications:

- The dual of Q(N,K) is just the theory on the singular $AdS_5 * S^{5,\ wi}$ the standa. Unlike the theory before, it has no moduli which resolve the singularity.

- Unlike the case of the (2,0) on S^1, the metric at the origin of moduli space diverges. The origin of the moduli space is blown to an entire manifold, which are the parameters of P.

- Rigid Holography