New results in $\mathrm{AdS}_3/\mathrm{CFT}_2$

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1. Introduction

2d CFTs play a prominent role in string theory, and provide the best arena to test the AdS/CFT correspondence

The conformal group in 2d is infinite dimensional and this makes 2d CFTs much more tractable than their higher dim counterparts

In turn, certain AdS_3 solutions involve only NS-NS fields, and are tractable using standard worldsheet methods

Canonical example: Near horizon of D1-D5 $AdS_3 \times S^3 \times CY_2$ geometry realising (4,4) superconformal symmetry. CFT dual believed to be the free symmetric product orbifold (Gaberdiel, Gopakumar, Eberhardt'18-19)

Much less is known for (0,4) superconformal symmetry:
Orbifolds of (4,4), realised in D1-D5-KK or D1-D5-D9 branes

However, (0,4) CFTs have been proposed for the microscopical description of black holes (Haghighat, Lockhart, Vafa and collab'13-15) with most of them lacking a holographic description

In this talk we will fill this gap and provide a complete classification of AdS_3 solutions to massive IIA supergravity with (0,4) (small) susy (and SU(2) structure) and a concrete proposal for their 2d dual CFTs

Our solutions contain the AdS_3 solutions constructed in Couzens, Lawrie, Martelli, Schafer-Nameki, Wong'17 from F-theory on Y_3 as a particular example

- New AdS/CFT pair
- Relevant for the microscopical description of black holes
- New set-up in which 2d (0,4) CFTs appear in String Theory
- Defect interpretation in an ambient 6d (1,0) CFT

Outline:

1. Introduction and motivation
2. AdS_3 solutions to massive IIA with (0,4) SUSY
3. The 2d CFT
4. Interpretation as defects in 6d (1,0) CFTs
5. Conclusions

Based on 1908.09851, 1909.09636, 1909.10510 and 1909.11669, in collaboration with N. Macpherson, C. Nunez and A. Ramirez

2. AdS_3 solutions to massive IIA with (0,4) susy

Classification in [1]: $AdS_3 \times S^2 \times M_4 \times I$ solutions, with

- $M_4 = CY_2$: Generalisation of D4-D8 (Youm'99)

- $M_4 =$ Kähler: Generalisation of the (T-duals of the) sols obtained from F-theory on Y_3 (Couzens, Lawrie, Martelli, Schafer-Nameki, Wong'17)

Concentrate in first class:

$$ds^2 = \frac{u}{\sqrt{h_4 h_8}}\Big(ds^2_{AdS_3} + \frac{h_8 h_4}{4h_8 h_4 + u'^2} ds^2_{S^2}\Big) + \sqrt{\frac{h_4}{h_8}} ds^2_{CY_2} + \frac{\sqrt{h_4 h_8}}{u} d\rho^2$$

u, h_4, h_8 : Linear functions in ρ

B_2 -field:

$$B_2 = \frac{1}{2}\Big(-\rho + \frac{uu'}{4h_4h_8 + u'^2} + 2n\pi\Big)\text{vol}(S^2)$$

for $\rho \in [\rho_n, \rho_{n+1}]$, such that $\frac{1}{4\pi^2}\int_{S^2} B_2 \in [0,1]$ and

one NS5-brane is created at each interval

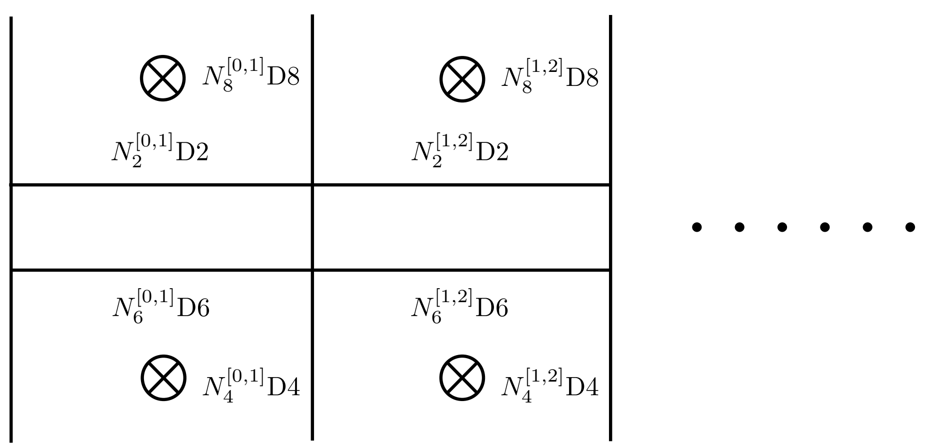
Page fluxes	Branes
$F_0 = h_8'$	D8
$\hat{F}_2 = \Big(h_8 - (\rho - 2n\pi)h_8'\Big)\text{vol}_{S^2}$	D6
$\hat{F}_4 = h_4'\text{vol}_{CY_2}$	D4
$\hat{F}_6 = \Big(h_4 - (\rho - 2n\pi)h_4'\Big)\text{vol}_{CY_2} \wedge \text{vol}_{S^2}$	D2

D2 and D6 branes are stretched among NS5-branes. They play the role of colour branes

D4 and D8 are perpendicular, and play the role of flavour branes

Supported by the analysis of Bianchi identities

Brane set-up:



We will concentrate on solutions for which $u \sim \rho$ and h_4, h_8 are piecewise linear, with the change of slope due to the presence of D4 and D8 branes, respectively

We will also impose that $h_4(P+1) = h_8(P+1) = 0$, such that the space terminates at $\rho = P+1$ and we can have a well defined dual CFT

Our proposal: The brane set-up describes a (0,4) QFT that flows to a strongly coupled CFT in the IR, dual to our solutions

3. The 2d CFT

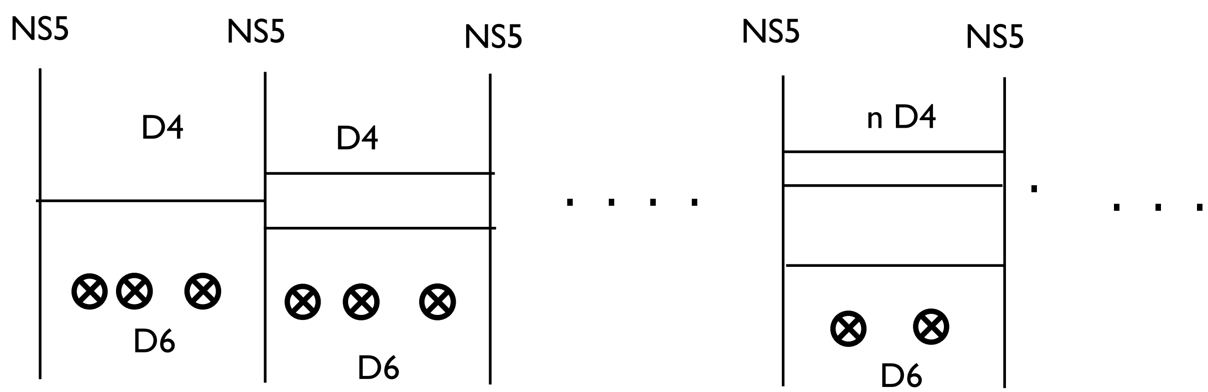
Main features of the brane set-up:

D2 and (wrapped) D6 colour branes

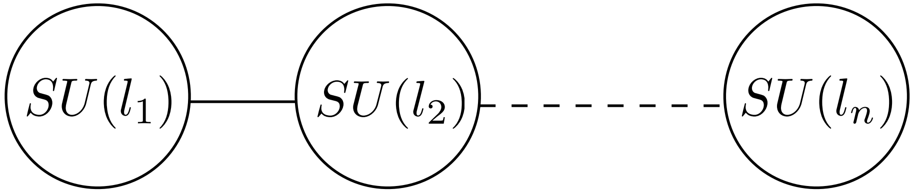
D4 and (wrapped) D8 flavour branes

Consistency conditions:

Usual Hanany-Witten brane set-ups



have associated linear quivers which must satisfy certain consistency conditions

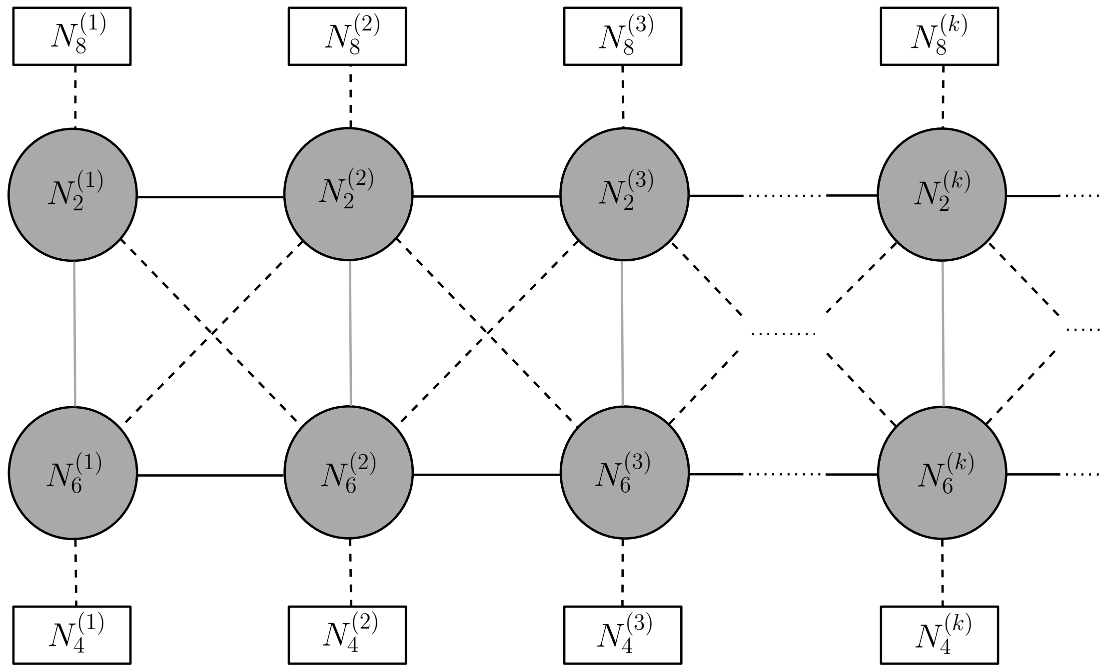


which, in order to satisfy conformal invariance:

$$2l_n = l_{n+1} + l_{n-1}$$

These D4/NS5 brane set-ups realize 4d $\mathcal{N} = 2$ CFTs with gauge groups connected by bifundamentals (Witten'97)

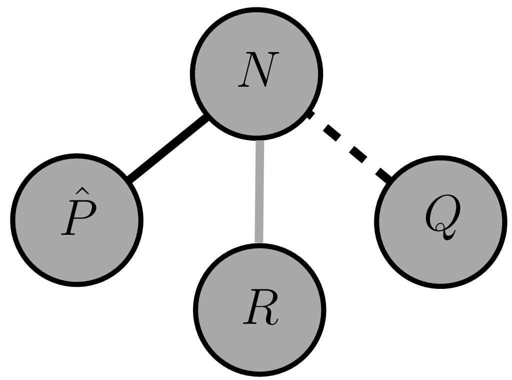
In our case we have two types of *colour* and *flavour* branes, and the quiver becomes *planar*



The resulting *planar* quiver consists on two (4,4) linear quivers coupled by (0,4) and (0,2) matter fields

The field theory is described in terms of (0,2) multiplets, that combine into (0,4) and (4,4) multiplets

It is obtained by assembling the building block:



Where:

Circles represent (4,4) vector multiplets, the black line a (4,4) hypermultiplet, the grey line a (0,4) hypermultiplet and the dashed line a (0,2) Fermi multiplet

This building block is non-anomalous if $2R = Q$

This must be satisfied at each node of our quiver

We can then compute the central charge of the CFT in the IR, using that the (0,4) superconformal algebra relates the central charge with the R-symmetry anomaly:

$$c = 6k = 6(n_{hyp} - n_{vec})$$

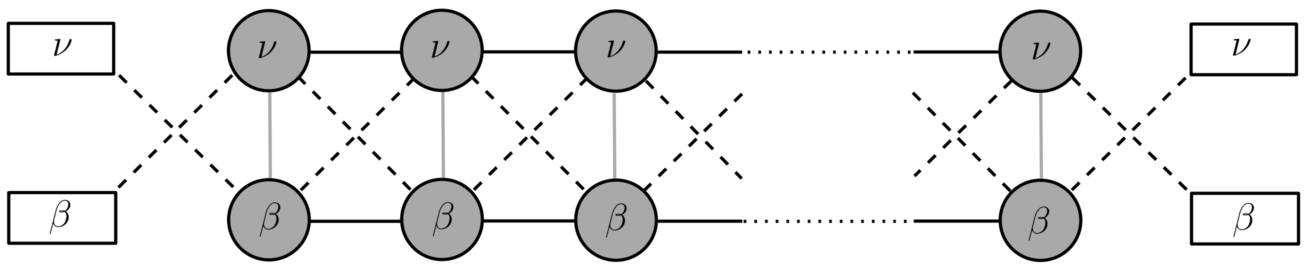
(Putrov, Song, Yan'15)

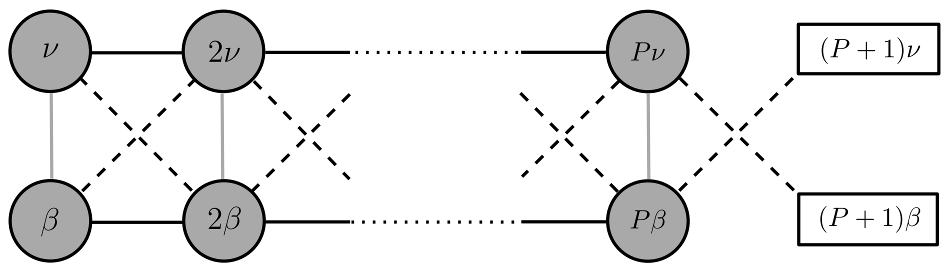
The holographic central charge, in turn, is computed from

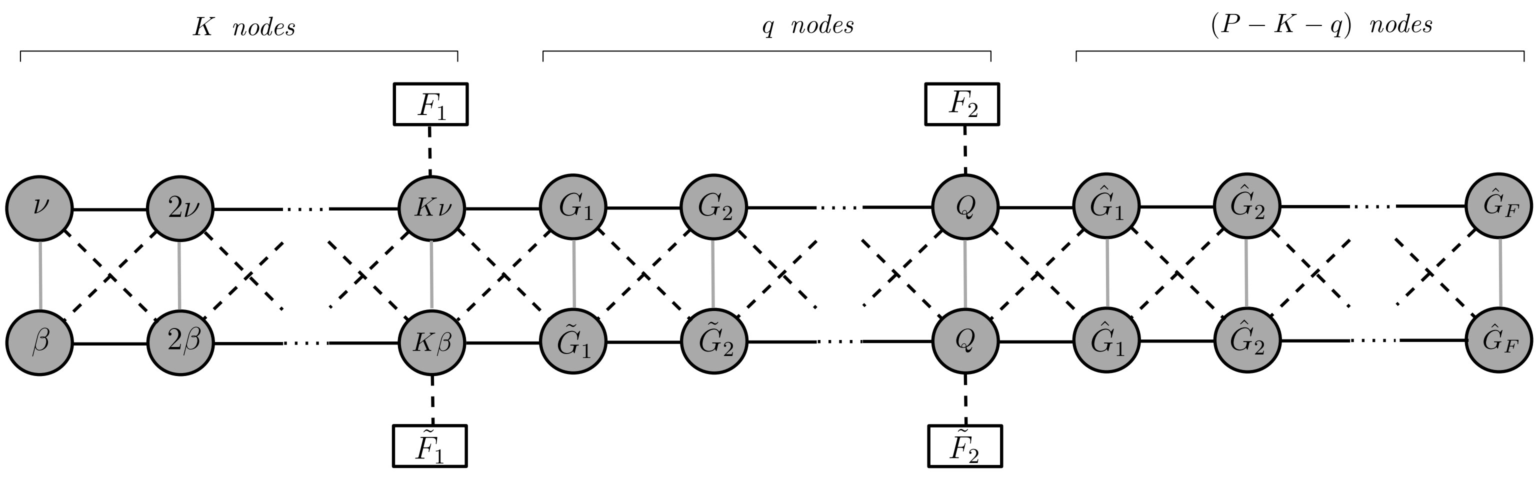
$$c \sim V_{int} = \frac{3\pi}{2G_N} \int d\rho \, h_8 h_4$$

We have checked in various examples that these two expressions agree in the holographic limit

For example,


ν
β


ν
2ν
$P\nu$
$(P+1)\nu$
β
2β
$P\beta$
$(P+1)\beta$


K $nodes$
q $nodes$
$(P-K-q)$ $nodes$
F_1
F_2
ν
2ν
$K\nu$
G_1
G_2
Q
$\hat{G}_1$
$\hat{G}_2$
$\hat{G}_F$
β
2β
$K\beta$
$\tilde{G}_1$
$\tilde{G}_2$
Q
$\hat{G}_1$
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$\hat{G}_F$
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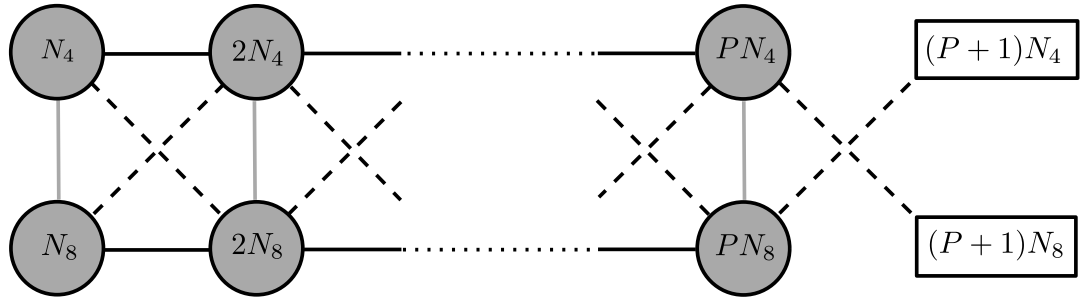
$\tilde{F}_2$

Example II:



Gauge anomaly vanishes: $R = N_8;\ Q = 2N_8 \quad \Rightarrow 2R = Q$

$$n_{hyp} = \sum_{j=1}^{P-1} j(j+1)(N_4^2 + N_8^2) + \sum_{j=1}^{P} j^2 N_4 N_8$$

$$n_{vec} = \sum_{j=1}^{P} (j^2 N_4^2 - 1 + j^2 N_8^2 - 1)$$

$\Rightarrow \quad c \sim 2N_4 N_8 P^3$ to leading order in P

AdS dual:

$$u = N_4 N_8\, \rho$$

$$h_8(\rho) = N_8. \begin{cases} \rho & 0 \le \rho \le P \\ P((P+1)-\rho) & P \le \rho \le (P+1). \end{cases}$$

$$h_4(\rho) = N_4. \begin{cases} \rho & 0 \le \rho \le P \\ P((P+1)-\rho) & P \le \rho \le (P+1). \end{cases}$$

For large P, $c_{hol} = 2N_4 N_8 P^3$, exactly as in field theory!

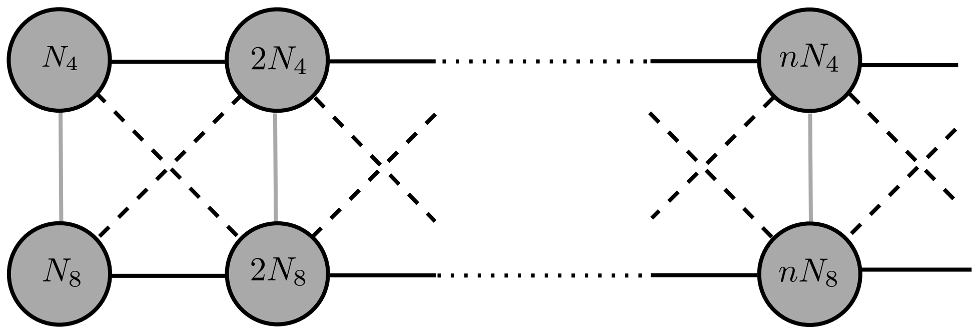
This solution is the *completion* of the non-Abelian T-dual of $AdS_3 \times S^3 \times CY_2$, defined by $u, h_8, h_4 \sim \rho$

This solution was actually the inspiration, as in other cases, for searching a classification of (0,4) solutions.

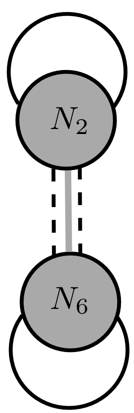
Both the non-Abelian and the Abelian T-dual of $AdS_3 \times S^3 \times CY_2$ are simple solutions in our class

They have associated 2d dual CFTs that belong to our class of CFTs

NATD:



ATD:

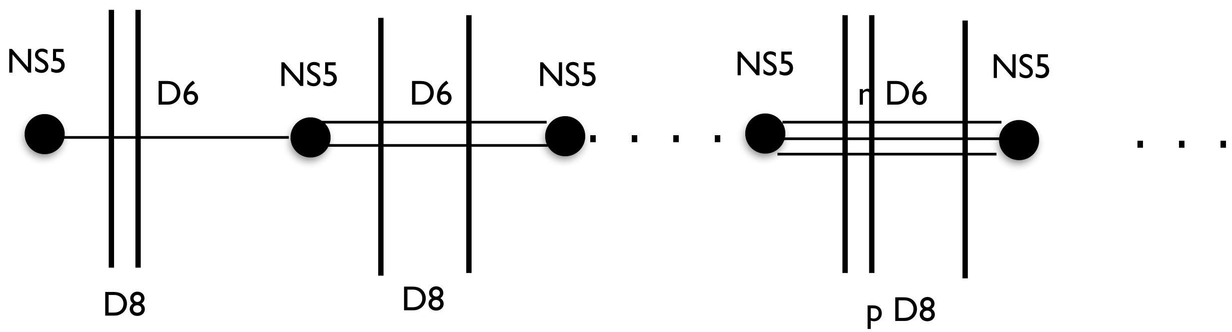


Enhancement to (4,4) susy

4. Defects in 6d (1,0) CFTs

Apruzzi, Fazzi, Rosa, Tomasiello'14: Complete classification of AdS_7 solutions in massive IIA.

Gaiotto, Tomasiello'15; Cremonesi, Tomasiello'15: Dual to 6d (1,0) CFTs living in D6-NS5-D8 brane systems (Hanany, Zaffaroni'97; Brunner, Karch'97)



In 6d: Gauge anomaly cancelation requires $N_f = 2N_c$

Apruzzi, Fazzi, Passias, Rota, Tomasiello'15: AdS_5 and AdS_4 solutions to massive IIA arise as compactifications on 2d or 3d manifolds:

$$ds^2_{AdS_{5(4)}} + ds^2_{\Sigma_{2(3)}} \leftrightarrow ds^2_{AdS_7}$$

D6-NS5-D8 wrapped on $\Sigma_{2(3)}$

In the AdS_3 case: D6-NS5-D8 wrapped on CY_2

+

D2-D4 branes (defect brane *sector*)

The D2-D4 *defect* breaks susy by a half

Way to see why there are no 2d CFTs with 8 supercharges living in D2-NS5-D4 Hanany-Witten brane set-ups!

5. Conclusions

- AdS_3 solutions to massive IIA with (0,4) susy classified:

  They are of the form $AdS_3 \times S^2 \times M_4 \times I$ with M_4 either CY_2 or Kähler

- 2d CFTs dual to the first class identified as IR fixed points of 2d QFTs built out of (0,2) multiplets

- Duality checked with the computation of the central charge

- Defect interpretation in 6d (1,0) CFTs

Open problems:

- Dual CFTs of the solutions in class II, related with the F-theory solutions studied in Couzens, Lawrie, Martelli, Schafer-Nameki, Wong'17

- Flow between AdS3 and AdS7?

Dibitetto, Petri'17: AdS_3 solutions interpolating between AdS_7 and (asymptotically locally) $AdS_3 \times T^4$, interpreted as defects

However, different asymptotics than our solutions

$\mathbb{R}_{1,1} \times CY_2$ flows?

- More checks of the duality

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THANKS!