Holographic duals for 5d SCFTs

Christoph Uhlemann
UCLA

Strings 2017, Tel Aviv

arXiv:1606.01254, arXiv:1611.09411, arXiv:1703.08186, arXiv:1705.01561, arXiv:1706.00433

with Eric D'Hoker, Michael Gutperle, Andreas Karch, Chrysostomos Marasinou, Andrea Trivella

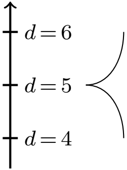
Introduction

5d SCFTs

Classification of superconformal algebras allows for $d > 4$ [Nahm '78]
$\operatorname{tr} F^2$ relevant, gauge theories non-renormalizable $\quad (\sim \sqrt{g}R$ in $4d)$

5d SCFTs

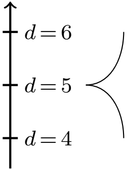
Classification of superconformal algebras allows for $d > 4$ [Nahm '78]
$\operatorname{tr} F^2$ relevant, gauge theories non-renormalizable ($\sim \sqrt{g}R$ in $4d$)



- strongly-coupled UV fixed points for large classes of gauge theories [Seiberg '95;...]
- no standard Lagrangian, existence from Coulomb branch analysis and string theory
- unique superconf. algebra $F(4)$, 16 supercharges

5d SCFTs

Classification of superconformal algebras allows for $d > 4$ [Nahm '78]
$\operatorname{tr} F^2$ relevant, gauge theories non-renormalizable (~ $\sqrt{g}R$ in $4d$)



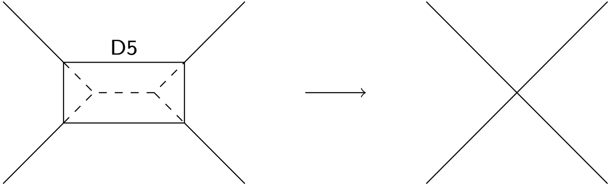
- strongly-coupled UV fixed points for large classes of gauge theories [Seiberg '95;...]
- no standard Lagrangian, existence from Coulomb branch analysis and string theory
- unique superconf. algebra $F(4)$, 16 supercharges

Asymptotically safe gauge theories, parents to isolated $4d$ theories, relations to $6d$, exceptional global symmetries, dualities, ...

5d SCFTs from 5-brane webs

[Aharony,Hanany,Kol '97]

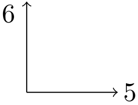
5-brane web: arrangement of (p, q) 5-branes, junctions with fixed angles and conserved charges



Coulomb branch
finite gauge coupling

UV fixed point CFT

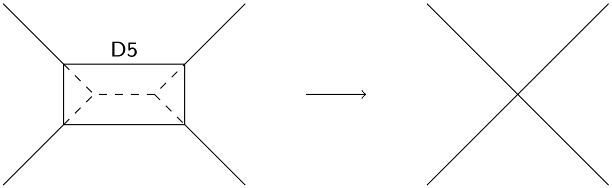
	0	1	2	3	4	5	6	7	8	9
D5	×	×	×	×	×	×				
NS5	×	×	×	×	×		×			



5d SCFTs from 5-brane webs

[Aharony,Hanany,Kol '97]

5-brane web: arrangement of (p,q) 5-branes, junctions with fixed angles and conserved charges



Coulomb branch
finite gauge coupling

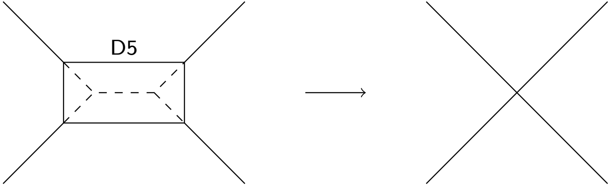
UV fixed point CFT

Large classes of 5d SCFTs, with and without gauge theory deformations, beyond initial classification

5d SCFTs from 5-brane webs

[Aharony,Hanany,Kol '97]

5-brane web: arrangement of (p,q) 5-branes, junctions with fixed angles and conserved charges



Coulomb branch
finite gauge coupling

UV fixed point CFT

Large classes of 5d SCFTs, with and without gauge theory deformations, beyond initial classification

Coulomb branches, relevant deformations and RG flows,...

5d SCFTs from 5-brane webs: supergravity duals?

AdS/CFT for EE, correlators, ... needs corresponding AdS_6 solutions in IIB supergravity: not a standard near-horizon limit

5d SCFTs from 5-brane webs: supergravity duals?

AdS/CFT for EE, correlators, ... needs corresponding AdS_6 solutions in IIB supergravity: not a standard near-horizon limit

BPS eq. with corresponding ansatz in type IIB studied in [Apruzzi,Fazzi,Passias,Rosa,Tomasiello '14, Kim,Kim,Suh '15, Kim,Kim '16]

5d SCFTs from 5-brane webs: supergravity duals?

AdS/CFT for EE, correlators, ... needs corresponding AdS_6 solutions in IIB supergravity: not a standard near-horizon limit

BPS eq. with corresponding ansatz in type IIB studied in [Apruzzi,Fazzi,Passias,Rosa,Tomasiello '14, Kim,Kim,Suh '15, Kim,Kim '16]

IIA solutions from D4/D8/O8, singular due to O8, T-duals in IIB w/ further singularities [Brandhuber,Oz '99; Bergman,Rodríguez-Gómez '12 Cvetic,Lu,Pope,Vazguez-Poritz '00;Lozano,Ó Colgáin,Rodríguez-Gómez,Sfetsos '12]

5d SCFTs from 5-brane webs: supergravity duals?

AdS/CFT for EE, correlators, ... needs corresponding AdS_6 solutions in IIB supergravity: not a standard near-horizon limit

BPS eq. with corresponding ansatz in type IIB studied in [Apruzzi,Fazzi,Passias,Rosa,Tomasiello '14, Kim,Kim,Suh '15, Kim,Kim '16]

IIA solutions from D4/D8/O8, singular due to O8, T-duals in IIB w/ further singularities [Brandhuber,Oz '99; Bergman,Rodríguez-Gómez '12 Cvetic,Lu,Pope,Vazguez-Poritz '00;Lozano,Ó Colgáin,Rodríguez-Gómez,Sfetsos '12]

This talk: AdS_6 solutions in IIB and connection to 5-brane webs

AdS_6 solutions in type IIB supergravity

Outline:

- Ansatz and general local solution
- Global solutions on the disc
- Connection to 5-brane webs
- Entanglement entropy vs. free energy

AdS_6 solutions in type IIB supergravity
– ansatz and local solution –

Symmetries and ansatz

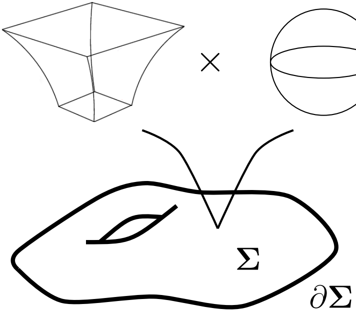
$$\mathrm{AdS}_6 + 16 \text{ susies} \;\rightarrow\; \mathrm{F}(4) \;\supset\; \text{bosonic } \mathrm{SO}(2{,}5) \oplus \mathrm{SO}(3)$$

Symmetries and ansatz

$$\mathsf{AdS}_6 + 16 \text{ susies} \;\rightarrow\; \mathsf{F(4)} \;\supset\; \text{bosonic } \underset{\nearrow \atop \mathsf{AdS}_6}{\mathsf{SO(2,5)}} \oplus \underset{\nwarrow \atop \mathsf{S}^2}{\mathsf{SO(3)}}$$

Symmetries and ansatz

$$\text{AdS}_6 + 16 \text{ susies} \;\to\; \text{F}(4) \;\supset\; \text{bosonic } \underset{\nearrow \atop \text{AdS}_6}{\text{SO}(2,5)} \oplus \underset{\nwarrow \atop \text{S}^2}{\text{SO}(3)}$$



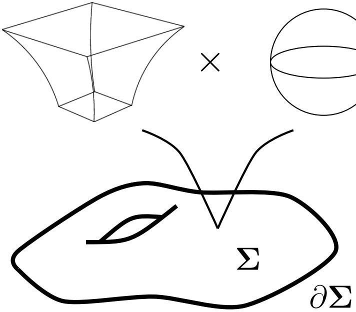
General ansatz: AdS_6 and S^2 warped over Riemann surface Σ

$$\mathcal{M} = (\text{AdS}_6 \times \text{S}^2) \times_{\text{w}} \Sigma$$

Symmetries and ansatz

AdS_6 + 16 susies $\rightarrow$ F(4) $\supset$ bosonic SO(2,5) $\oplus$ SO(3)

AdS_6 $\qquad$ S^2



General ansatz: AdS_6 and S^2 warped over Riemann surface Σ

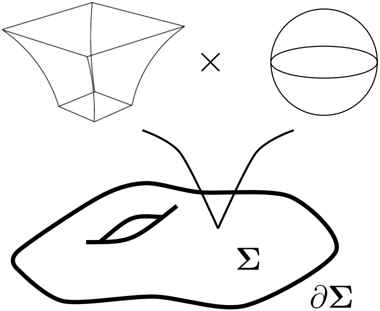
$$\mathcal{M} = (\mathrm{AdS}_6 \times \mathrm{S}^2) \times_{\mathrm{w}} \Sigma$$

$$\psi_M = \lambda = 0$$

Symmetries and ansatz

AdS_6 + 16 susies $\;\rightarrow\;$ F(4) $\;\supset\;$ bosonic SO(2,5) $\oplus$ SO(3)

AdS_6 $\qquad\qquad$ S^2



General ansatz: AdS_6 and S^2 warped over Riemann surface Σ

$$\mathcal{M} = (\mathrm{AdS}_6 \times \mathrm{S}^2) \times_{\mathrm{w}} \Sigma$$

$$\psi_M = \lambda = 0$$

Remaining bosonic fields: $\quad C_{(4)} = 0 \qquad C_{(2)} \propto \mathrm{vol}_{\mathrm{S}^2} \qquad \tau = \chi + ie^{-2\phi}$

General local solution

With complex coordinate w on Σ

$$ds^2 = f_6(w)^2 ds^2_{\mathrm{AdS}_6} + f_2(w)^2 ds^2_{\mathrm{S}^2} + 4\rho(w)^2 |dw|^2$$

$$C_{(2)} = \mathcal{C}(w)\,\mathrm{vol}_{\mathrm{S}^2} \qquad B(w) = \frac{1 + i\tau(w)}{1 - i\tau(w)}$$

General local solution

With complex coordinate w on Σ

$$ds^2 = f_6(w)^2 ds^2_{\mathrm{AdS}_6} + f_2(w)^2 ds^2_{\mathrm{S}^2} + 4\rho(w)^2 |dw|^2$$

$$C_{(2)} = \mathcal{C}(w)\,\mathrm{vol}_{\mathrm{S}^2} \qquad B(w) = \frac{1 + i\tau(w)}{1 - i\tau(w)}$$

Decomposing Killing spinors, reducing BPS eq. on AdS_6 and S^2
$\rightarrow$ coupled PDEs on Σ for supergravity fields & Killing spinors

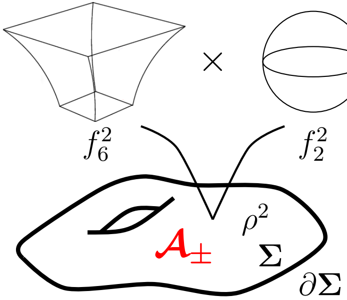
FF

General local solution

$\ldots \to$ general local solution to BPS eq., parametrized by two locally holomorphic functions on Σ.

General local solution

$\ldots \to$ general local solution to BPS eq., parametrized by two locally holomorphic functions on Σ.



Arbitrary locally holomorphic

$$\mathcal{A}_\pm : \Sigma \to \mathbb{C}$$

yield metric functions f_6^2, f_2^2, ρ^2, axion-dilaton B, two-form field $\mathcal{C}$ and Killing spinors solving BPS eq.

SU$(1,1) \otimes \mathbb{C}$ transf. of $\mathcal{A}_\pm$ induce SL(2,$\mathbb{R}$) on supergravity fields

General local solution

Explicit solution for supergravity fields:

$$f_6^2 = c_6^2 \sqrt{6\mathcal{G}} \left[\frac{1+R}{1-R}\right]^{1/2} \qquad f_2^2 = \frac{c_6^2}{9} \sqrt{6\mathcal{G}} \left[\frac{1-R}{1+R}\right]^{3/2}$$

$$\rho^2 = \frac{\kappa^2}{\sqrt{6\mathcal{G}}} \left[\frac{1+R}{1-R}\right]^{1/2} \qquad B = \frac{\partial_w \mathcal{A}_+ \, \partial_{\bar{w}} \mathcal{G} - R \, \partial_{\bar{w}} \bar{\mathcal{A}}_- \partial_w \mathcal{G}}{R \, \partial_{\bar{w}} \bar{\mathcal{A}}_+ \partial_w \mathcal{G} - \partial_w \mathcal{A}_- \partial_{\bar{w}} \mathcal{G}}$$

$$\mathcal{C} = \frac{4ic_6^2}{9} \left[\frac{\partial_{\bar{w}} \bar{\mathcal{A}}_- \, \partial_w \mathcal{G}}{\kappa^2} - 2R \, \frac{\partial_w \mathcal{G} \, \partial_{\bar{w}} \bar{\mathcal{A}}_- + \partial_{\bar{w}} \mathcal{G} \, \partial_w \mathcal{A}_+}{(R+1)^2 \, \kappa^2} - \bar{\mathcal{A}}_- - 2\mathcal{A}_+\right]$$

with composite quantities

$$\kappa^2 = -|\partial_w \mathcal{A}_+|^2 + |\partial_w \mathcal{A}_-|^2 \qquad \partial_w \mathcal{B} = \mathcal{A}_+ \partial_w \mathcal{A}_- - \mathcal{A}_- \partial_w \mathcal{A}_+$$

$$\mathcal{G} = |\mathcal{A}_+|^2 - |\mathcal{A}_-|^2 + \mathcal{B} + \bar{\mathcal{B}} \qquad R + \frac{1}{R} = 2 + 6 \, \frac{\kappa^2 \, \mathcal{G}}{|\partial_w \mathcal{G}|^2}$$

General local solution

Explicit solution for supergravity fields:

$$f_6^2 = c_6^2 \sqrt{6\mathcal{G}} \left[\frac{1+R}{1-R}\right]^{1/2} \qquad f_2^2 = \frac{c_6^2}{9} \sqrt{6\mathcal{G}} \left[\frac{1-R}{1+R}\right]^{3/2}$$

$$\rho^2 = \frac{\kappa^2}{\sqrt{6\mathcal{G}}} \left[\frac{1+R}{1-R}\right]^{1/2} \qquad B = \frac{\partial_w \mathcal{A}_+ \, \partial_{\bar{w}} \mathcal{G} - R \, \partial_{\bar{w}} \bar{\mathcal{A}}_- \partial_w \mathcal{G}}{R \, \partial_{\bar{w}} \bar{\mathcal{A}}_+ \partial_w \mathcal{G} - \partial_w \mathcal{A}_- \partial_{\bar{w}} \mathcal{G}}$$

$$\mathcal{C} = \frac{4ic_6^2}{9} \left[\frac{\partial_{\bar{w}} \bar{\mathcal{A}}_- \, \partial_w \mathcal{G}}{\kappa^2} - 2R \, \frac{\partial_w \mathcal{G} \, \partial_{\bar{w}} \bar{\mathcal{A}}_- + \partial_{\bar{w}} \mathcal{G} \, \partial_w \mathcal{A}_+}{(R+1)^2 \, \kappa^2} - \bar{\mathcal{A}}_- - 2\mathcal{A}_+\right]$$

with composite quantities

$$\kappa^2 = -|\partial_w \mathcal{A}_+|^2 + |\partial_w \mathcal{A}_-|^2 \qquad \partial_w \mathcal{B} = \mathcal{A}_+ \partial_w \mathcal{A}_- - \mathcal{A}_- \partial_w \mathcal{A}_+$$

$$\mathcal{G} = |\mathcal{A}_+|^2 - |\mathcal{A}_-|^2 + \mathcal{B} + \bar{\mathcal{B}} \qquad R + \frac{1}{R} = 2 + 6 \, \frac{\kappa^2 \, \mathcal{G}}{|\partial_w \mathcal{G}|^2}$$

General local solution

General type IIB supergravity solution with 16 supersymmetries on $\mathsf{AdS}_6 \times \mathsf{S}^2$ warped over Σ, in terms of locally holomorphic $\mathcal{A}_\pm$ on Σ.

General local solution

General type IIB supergravity solution with 16 supersymmetries on $\mathrm{AdS}_6\times\mathrm{S}^2$ warped over Σ, in terms of locally holomorphic $\mathcal{A}_\pm$ on Σ.

(Singular) T-dual of type IIA solution included as special case. ✓

Generic $\mathcal{A}_\pm$ do not lead to physically regular solutions. ✗

General local solution

General type IIB supergravity solution with 16 supersymmetries on $\mathrm{AdS}_6 \times \mathrm{S}^2$ warped over Σ, in terms of locally holomorphic $\mathcal{A}_\pm$ on Σ.

(Singular) T-dual of type IIA solution included as special case. ✓

Generic $\mathcal{A}_\pm$ do not lead to physically regular solutions. ✗

$\rightarrow$ global solutions

AdS_6 solutions in type IIB supergravity
– global solutions on the disc –

Regularity conditions

Demanding real, geodesically complete geometry with consistent spacetime signature and $\mathrm{Im}(\tau) > 0$ imposes constraints:

$$\kappa^2\big|_{\mathsf{int}(\Sigma)} > 0 \qquad\qquad \mathcal{G}\big|_{\mathsf{int}(\Sigma)} > 0$$

$\rightarrow \Sigma$ must have a boundary ($\partial_w \partial_{\bar{w}} \mathcal{G} = -\kappa^2$ by construction)

Regularity conditions

Demanding real, geodesically complete geometry with consistent spacetime signature and $\mathrm{Im}(\tau) > 0$ imposes constraints:

$$\kappa^2\big|_{\mathsf{int}(\Sigma)} > 0 \qquad\qquad \mathcal{G}\big|_{\mathsf{int}(\Sigma)} > 0$$

$\rightarrow \Sigma$ must have a boundary ($\partial_w \partial_{\bar{w}} \mathcal{G} = -\kappa^2$ by construction)

For 10d geometry w/o boundary, collapse S^2 on $\partial\Sigma$ (AdS_6 finite):

$$\kappa^2\big|_{\partial\Sigma} = 0 \qquad\qquad \mathcal{G}\big|_{\partial\Sigma} = 0$$

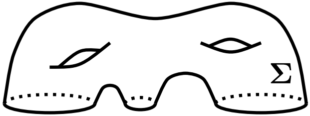
Not all independent, $\mathcal{G}|_{\mathrm{int}(\Sigma)} > 0$ implied by the other conditions.

Solving the regularity conditions

Fix topology of Σ, 1) construct locally holomorphic $\mathcal{A}_\pm$ producing regular κ^2, 2) implement additional constraints for regular $\mathcal{G}$.

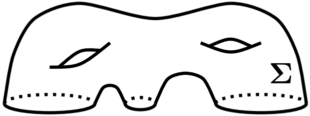
Solving the regularity conditions

Fix topology of Σ, 1) construct locally holomorphic $\mathcal{A}_\pm$ producing regular κ^2, 2) implement additional constraints for regular $\mathcal{G}$.



Solving the regularity conditions

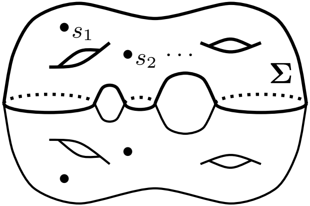
Fix topology of Σ, 1) construct locally holomorphic $\mathcal{A}_\pm$ producing regular κ^2, 2) implement additional constraints for regular $\mathcal{G}$.



1a) $\Phi \equiv -\ln|\partial_w \mathcal{A}_+/\partial_w \mathcal{A}_-|$ from 2d electrostatics analogy:

Solving the regularity conditions

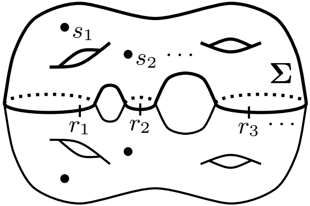
Fix topology of Σ, 1) construct locally holomorphic $\mathcal{A}_\pm$ producing regular κ^2, 2) implement additional constraints for regular $\mathcal{G}$.



1a) $\Phi \equiv -\ln |\partial_w \mathcal{A}_+ / \partial_w \mathcal{A}_-|$ from 2d electrostatics analogy:
N positive charges s_n inside Σ + negative mirror charges

Solving the regularity conditions

Fix topology of Σ, 1) construct locally holomorphic $\mathcal{A}_\pm$ producing regular κ^2, 2) implement additional constraints for regular $\mathcal{G}$.

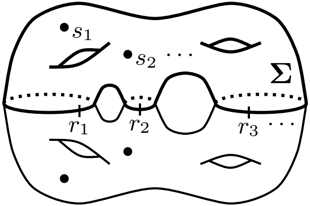


1a) $\Phi \equiv -\ln|\partial_w \mathcal{A}_+ / \partial_w \mathcal{A}_-|$ from 2d electrostatics analogy:
N positive charges s_n inside Σ + negative mirror charges

1b) constructing $\partial_w \mathcal{A}_\pm$, $\mathcal{A}_\pm$ adds L poles r_ℓ on $\partial\Sigma$ + constants

Solving the regularity conditions

Fix topology of Σ, 1) construct locally holomorphic $\mathcal{A}_\pm$ producing regular κ^2, 2) implement additional constraints for regular $\mathcal{G}$.



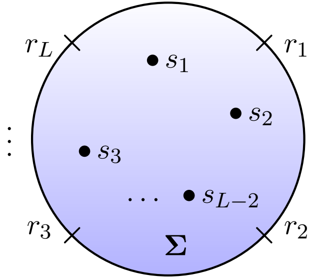
1a) $\Phi \equiv -\ln|\partial_w \mathcal{A}_+ / \partial_w \mathcal{A}_-|$ from 2d electrostatics analogy:
N positive charges s_n inside Σ + negative mirror charges

1b) constructing $\partial_w \mathcal{A}_\pm$, $\mathcal{A}_\pm$ adds L poles r_ℓ on $\partial\Sigma$ + constants

2) further integration for $\mathcal{G}$, $\mathcal{G}|_{\partial\Sigma} = 0$ constrains parameters

Regular solutions on the disc

$\Sigma =$disc/upper half plane, $L \geq 3$ poles, $N = L - 2$ "charges"



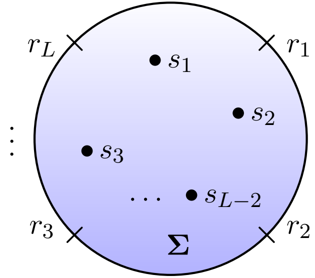
$$\mathcal{A}_+ = \mathcal{A}_+^0 + \sum_{\ell=1}^{L} Z_+^\ell \ln(w - r_\ell)$$

$$Z_+^\ell = \sigma \prod_{n=1}^{L-2} (r_\ell - s_n) \prod_{k\neq\ell}^{L} \frac{1}{r_\ell - r_k}$$

$$\mathcal{A}_-(w) = -\overline{\mathcal{A}_+(\bar{w})} \quad \sum_{\ell} Z_+^\ell = 0$$

Regular solutions on the disc

$\Sigma =$disc/upper half plane, $L \geq 3$ poles, $N = L-2$ "charges"



$$\mathcal{A}_+ = \mathcal{A}_+^0 + \sum_{\ell=1}^{L} Z_+^\ell \ln(w - r_\ell)$$

$$Z_+^\ell = \sigma \prod_{n=1}^{L-2} (r_\ell - s_n) \prod_{k\neq\ell}^{L} \frac{1}{r_\ell - r_k}$$

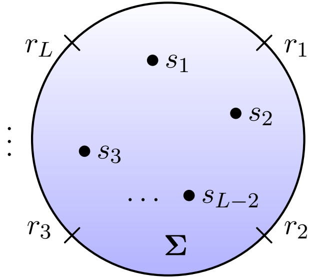
$$\mathcal{A}_-(w) = -\overline{\mathcal{A}_+(\bar{w})} \quad \sum_\ell Z_+^\ell = 0$$

$\mathcal{G}|_{\partial\Sigma} = 0 \sim$ one local condition per pole $\to 2L-2$ free parameters

$$\mathcal{A}_+^0 Z_-^k - \mathcal{A}_-^0 Z_+^k + \sum_{\ell\neq k} Z^{[\ell,k]} \ln|p_\ell - p_k| = 0$$

Regular solutions on the disc

Σ =disc/upper half plane, $L \geq 3$ poles, $N = L - 2$ "charges"



$$\mathcal{A}_+ = \mathcal{A}_+^0 + \sum_{\ell=1}^{L} Z_+^\ell \ln(w - r_\ell)$$

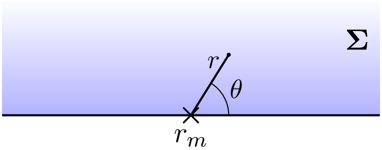
$$Z_+^\ell = \sigma \prod_{n=1}^{L-2} (r_\ell - s_n) \prod_{k \neq \ell}^{L} \frac{1}{r_\ell - r_k}$$

$$\mathcal{A}_-(w) = -\overline{\mathcal{A}_+(\bar{w})} \qquad \sum_{\ell} Z_+^\ell = 0$$

$\mathcal{G}|_{\partial\Sigma} = 0 \sim$ one local condition per pole $\rightarrow 2L - 2$ free parameters

Solutions regular everywhere, except for possibly the poles. . .

Regular solutions on the disc – behavior near poles



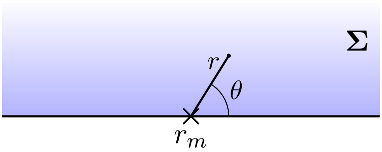
Supergravity fields in terms of κ^2, $\mathcal{G}$, R

$$\mathcal{G} = \sum_{\ell \neq \ell'}^{L} Z^{[\ell,\ell']} \left[\frac{1}{2} \ln \left\{ \frac{w - r_{\ell'}}{(r_\ell - r_{\ell'})^2} \right\} \overline{\ln \left\{ \frac{w - r_\ell}{(r_\ell - r_{\ell'})^2} \right\}} + \int_\infty^w dz \, \frac{\ln(z - r_\ell)}{z - r_{\ell'}} - \text{c.c} \right]$$

$$\kappa^2 = -|\partial_w \mathcal{A}_+|^2 + |\partial_w \mathcal{A}_-|^2 \qquad\qquad R + \frac{1}{R} = 2 + 6\, \frac{\kappa^2\, \mathcal{G}}{|\partial_w \mathcal{G}|^2}$$

simplify drastically in $r \ll 1$ expansion...

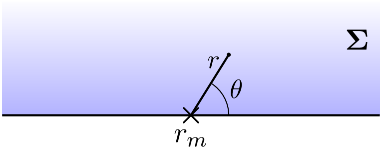
Regular solutions on the disc – behavior near poles



string frame:

$$\widetilde{ds}^2 \approx \frac{2}{3}\left|Z_+^m - Z_-^m\right| \left[3\,c_6^2\,|\ln r| ds^2_{\mathrm{AdS}_6} + \overbrace{\frac{dr^2}{r^2} + d\theta^2}^{\Sigma} + c_6^2 \sin^2\theta\, ds^2_{\mathrm{S}^2}\right]$$

Regular solutions on the disc – behavior near poles

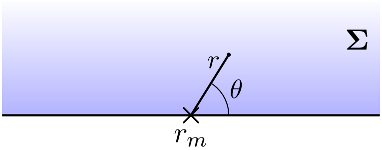


string frame:

$$\widetilde{ds}^2 \approx \frac{2}{3}\left|Z_+^m - Z_-^m\right| \Bigg[\underbrace{3\,c_6^2\,|\ln r|ds^2_{\mathrm{AdS}_6}}_{\to\,\mathbb{R}^{1,5}} + \overbrace{\frac{dr^2}{r^2} + d\theta^2}^{\Sigma} + c_6^2 \sin^2\theta\, ds^2_{\mathrm{S}^2}\Bigg]$$

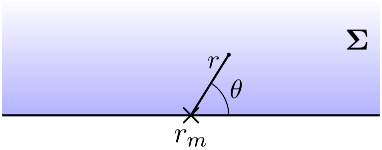
$$\underbrace{d\theta^2 + c_6^2 \sin^2\theta\, ds^2_{\mathrm{S}^2}}_{\mathsf{S}^3}$$

Regular solutions on the disc – behavior near poles



string frame: $$\widetilde{ds}^2 \approx \frac{2}{3}\left|Z_+^m - Z_-^m\right|\left[ds^2_{\mathbb{R}^{1,5}} + \frac{dr^2}{r^2} + ds^2_{\mathrm{S}^3}\right]$$

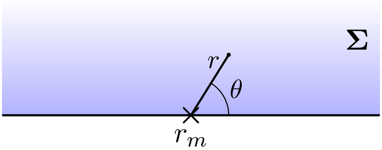
Regular solutions on the disc – behavior near poles



string frame: $$\widetilde{ds}^2 \approx \frac{2}{3}\left|Z_+^m - Z_-^m\right|\left[ds^2_{\mathbb{R}^{1,5}} + \frac{dr^2}{r^2} + ds^2_{\mathrm{S}^3}\right]$$

$$dC_{(2)} \approx \frac{8}{3} Z_+^m \mathrm{vol}_{\mathrm{S}^3} \qquad e^{-2\phi} \approx \frac{\sqrt{3}\,\kappa_m^2}{4\,\mathrm{Re}(Z_+^m)^2}\,\frac{r}{\sqrt{|\ln r|}} \qquad \chi \approx \frac{\mathrm{Im}(Z_+^m)}{\mathrm{Re}(Z_+^m)}$$

Regular solutions on the disc – behavior near poles



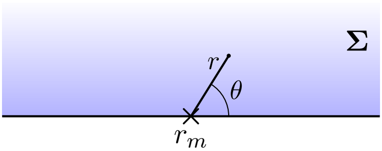
string frame: $$\widetilde{ds}^2 \approx \frac{2}{3}\left|Z_+^m - Z_-^m\right| \left[ds^2_{\mathbb{R}^{1,5}} + \frac{dr^2}{r^2} + ds^2_{\mathrm{S}^3}\right]$$

$$dC_{(2)} \approx \frac{8}{3} Z_+^m \mathrm{vol}_{\mathrm{S}^3} \qquad e^{-2\phi} \approx \frac{\sqrt{3}\,\kappa_m^2}{4\,\mathrm{Re}(Z_+^m)^2} \frac{r}{\sqrt{|\ln r|}} \qquad \chi \approx \frac{\mathrm{Im}(Z_+^m)}{\mathrm{Re}(Z_+^m)}$$

Entire near-pole solution matches (p,q) 5-branes of [Lu,Roy '98]

$$p - iq \quad \longleftrightarrow \quad Z_+^m$$

Regular solutions on the disc – behavior near poles



string frame: $\quad \widetilde{ds}^2 \approx \frac{2}{3}\left|Z_+^m - Z_-^m\right|\left[ds^2_{\mathbb{R}^{1,5}} + \frac{dr^2}{r^2} + ds^2_{\mathrm{S}^3}\right]$

$$dC_{(2)} \approx \frac{8}{3} Z_+^m \mathrm{vol}_{\mathrm{S}^3} \qquad e^{-2\phi} \approx \frac{\sqrt{3}\,\kappa_m^2}{4\,\mathrm{Re}(Z_+^m)^2}\,\frac{r}{\sqrt{|\ln r|}} \qquad \chi \approx \frac{\mathrm{Im}(Z_+^m)}{\mathrm{Re}(Z_+^m)}$$

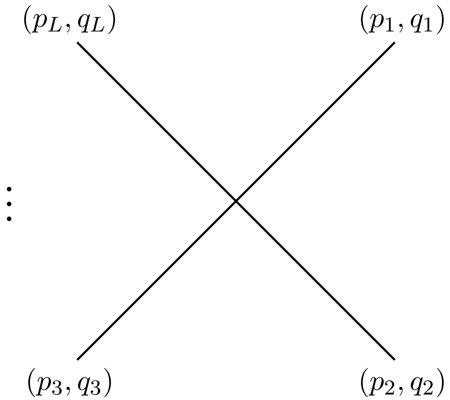
Entire near-pole solution matches (p,q) 5-branes of [Lu,Roy '98]

$$p - iq \quad \longleftrightarrow \quad Z_+^m$$

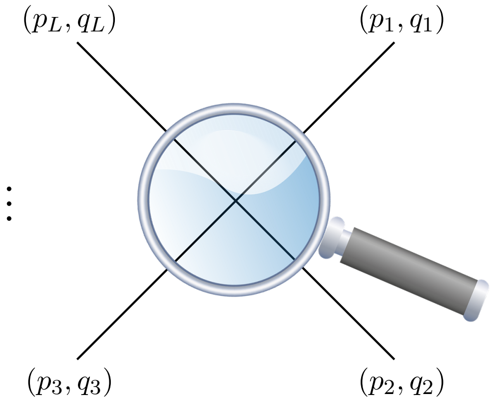
Solutions regular with isolated poles corresponding to 5-branes ✓

AdS_6 solutions in type IIB supergravity
– connection to 5-brane webs –

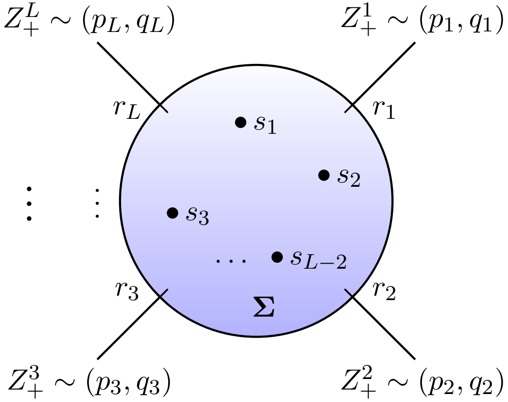
5-brane web picture



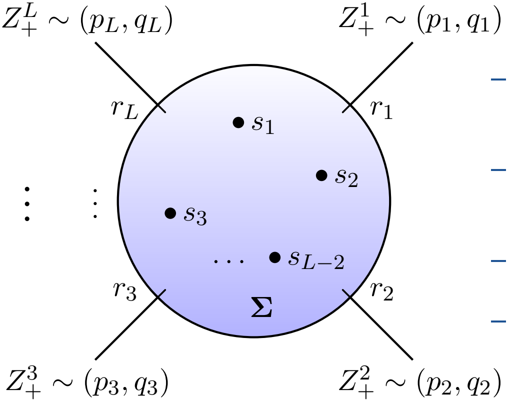
5-brane web picture



5-brane web picture

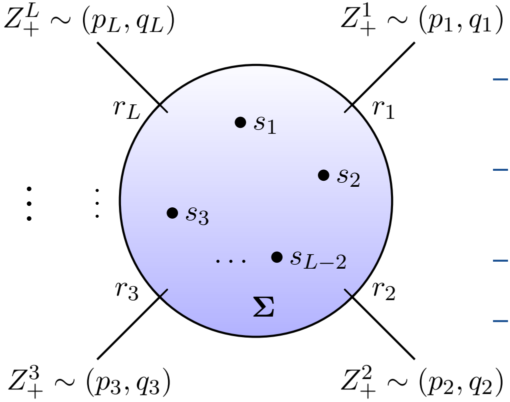


5-brane web picture



- external 5-branes explicitly (p, q) charge conserved
- parametrized by choice of residues mod charge cons.
- $\mathrm{AdS}_6 + 16$ susies $= F(4)$
- need $L \geq 3$, p and q charge

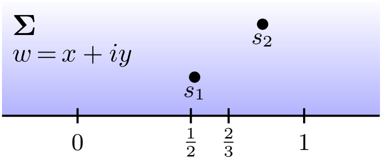
5-brane web picture

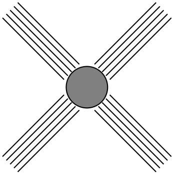


- external 5-branes explicitly (p, q) charge conserved
- parametrized by choice of residues mod charge cons.
- $\mathrm{AdS}_6 + 16$ susies $= F(4)$
- need $L \geq 3$, p and q charge

Supergravity solutions for fully localized 5-brane intersections. ✓

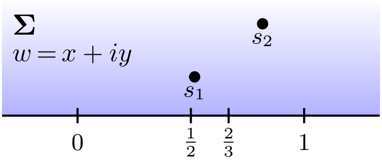
4-pole example

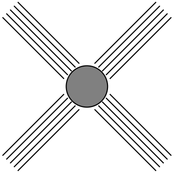




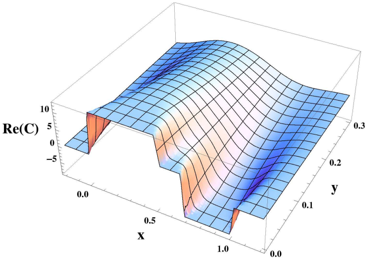
$$-Z_+^1 = Z_+^3 = 2 + 2i$$
$$-Z_+^4 = Z_+^2 = 3 - 3i$$

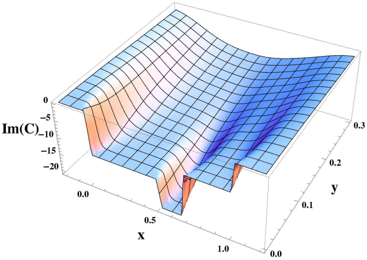
4-pole example





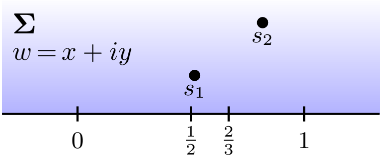
$$-Z_+^1 = Z_+^3 = 2 + 2i$$
$$-Z_+^4 = Z_+^2 = 3 - 3i$$

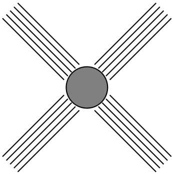




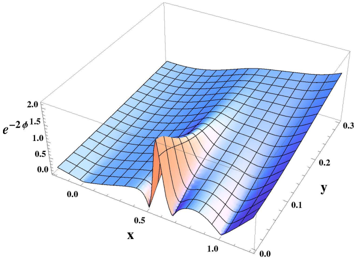
$\Delta\mathcal{C} \sim p - iq$, charge conservation $\sim \sum \Delta\mathcal{C} = 0$

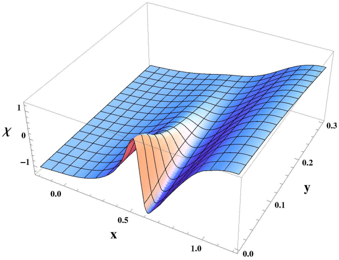
4-pole example





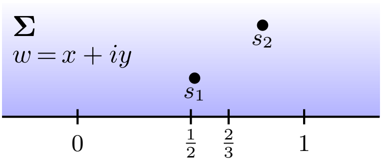
$$-Z_+^1 = Z_+^3 = 2 + 2i$$
$$-Z_+^4 = Z_+^2 = 3 - 3i$$

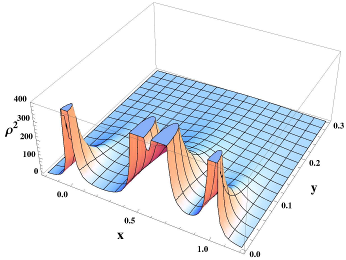


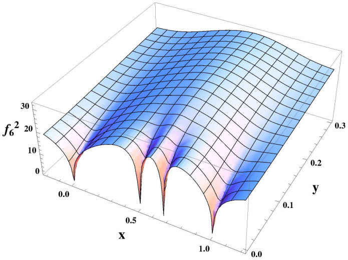


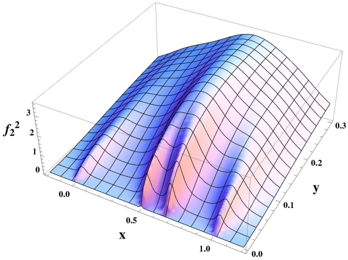
$\exp(-2\phi) \to 0$ at poles, χ finite

4-pole example









Einstein-frame metric as needed for string-frame 5-brane metric ✓

AdS$_6$ solutions in type IIB supergravity
– entanglement entropy vs. free energy –

Entanglement entropy vs. free energy

First steps in AdS/CFT: Holographic interpretation consistent?
Quantitative indications on dual SCFTs?

Entanglement entropy vs. free energy

First steps in AdS/CFT: Holographic interpretation consistent?
Quantitative indications on dual SCFTs?

$$S_{\mathrm{EE}}(\mathrm{disc})\big|_{\mathrm{finite}} \stackrel{?}{=} -\mathcal{F}(S^5)$$

Entanglement entropy vs. free energy

First steps in AdS/CFT: Holographic interpretation consistent?
Quantitative indications on dual SCFTs?

$$S_{\mathrm{EE}}(\mathrm{disc})\big|_{\mathrm{finite}} \overset{?}{=} -\mathcal{F}(S^5)$$

8d min. surface
wrapping S^2 and Σ

on-shell action, $C_{(4)} = 0$
total derivative [Okuda,Trancanelli '08]

Entanglement entropy vs. free energy

First steps in AdS/CFT: Holographic interpretation consistent?
Quantitative indications on dual SCFTs?

$$S_{\mathrm{EE}}(\mathrm{disc})\big|_{\mathrm{finite}} \overset{?}{=} -\mathcal{F}(S^5)$$

8d min. surface
wrapping S^2 and Σ

on-shell action, $C_{(4)} = 0$
total derivative [Okuda,Trancanelli '08]

- relation expected on general grounds, but translates to non-trivial identities on Σ for our solutions
- sensitive to internal geometry and poles – singularities?

Entanglement entropy vs. free energy

First steps in AdS/CFT: Holographic interpretation consistent?
Quantitative indications on dual SCFTs?

$$S_{\mathrm{EE}}(\mathrm{disc})\big|_{\mathrm{finite}} \stackrel{?}{=} -\mathcal{F}(S^5)$$

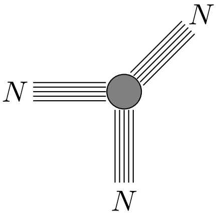
8d min. surface wrapping S^2 and Σ

on-shell action, $C_{(4)} = 0$
total derivative [Okuda,Trancanelli '08]

- relation expected on general grounds, but translates to non-trivial identities on Σ for our solutions
- sensitive to internal geometry and poles – singularities?

Computation straightforward for both – no divergences from poles, no finite contributions. Related as expected. ✓

Entanglement entropy vs. free energy – examples

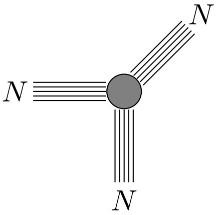


'N-junction' $=$ 5d uplifts for 4d $T[A_{N-1}]$ theories, gauge theory deformation:

$$N - SU(N-1) \times \cdots \times SU(2) - 2$$

[Benini,Benvenuti,Tachikawa '09;Bergman,Zafrir '14]

Entanglement entropy vs. free energy – examples



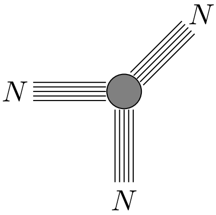
'N-junction' = 5d uplifts for 4d $T[A_{N-1}]$ theories, gauge theory deformation:

$$N - SU(N-1) \times \cdots \times SU(2) - 2$$

[Benini,Benvenuti,Tachikawa '09;Bergman,Zafrir '14]

$\mathcal{F}(Z_+^1 = -iZ_+^2 = N) \sim \zeta(3) N^4$

Entanglement entropy vs. free energy – examples



'N-junction' = 5d uplifts for 4d $T[A_{N-1}]$ theories, gauge theory deformation:

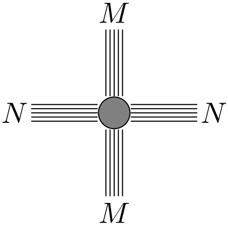
$$N - SU(N-1) \times \cdots \times SU(2) - 2$$

[Benini,Benvenuti,Tachikawa '09;Bergman,Zafrir '14]

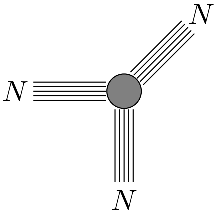
$$\mathcal{F}(Z_+^1 = -iZ_+^2 = N) \sim \zeta(3) N^4$$

NS5/D5 intersection: [Aharony,Hanany,Kol '97]

$$N - \underbrace{SU(N) \times \cdots \times SU(N)}_{SU(N)^{M-1}} - N$$



Entanglement entropy vs. free energy – examples



'N-junction' = 5d uplifts for 4d $T[A_{N-1}]$ theories, gauge theory deformation:

$$N - SU(N-1) \times \cdots \times SU(2) - 2$$

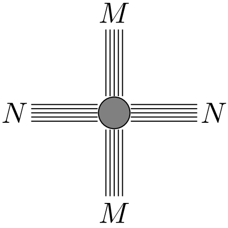
[Benini,Benvenuti,Tachikawa '09;Bergman,Zafrir '14]

$$\mathcal{F}(Z_+^1 = -iZ_+^2 = N) \sim \zeta(3) N^4$$

NS5/D5 intersection: [Aharony,Hanany,Kol '97]

$$N - \underbrace{SU(N) \times \cdots \times SU(N)}_{SU(N)^{M-1}} - N$$

$$\mathcal{F}(Z_+^1 = -Z_+^3 = M, Z_+^2 = iN) \sim \zeta(3) M^2 N^2$$



Summary & Outlook

Summary

Supergravity solutions for fully localized 5-brane intersections in type IIB. Holographic duals for the corresponding 5d SCFTs.

Solutions regular everywhere except for isolated physically meaningful singularities, tame enough for AdS/CFT.

Free energy and entanglement entropy satsify expected relation, first quantitative indications on dual SCFTs.

[Extension to disc with punctures and SL$(2,\mathbb{R})$ monodromy, for 5-brane intersections with (mutually local) 7-branes.]

$\rightarrow$ arXiv:1706.00433

Outlook

Establish relation to dual SCFTs: compare free energy to field theory computation using supersymmetric localization.

AdS/CFT with warped products: spectra, correlation functions, defects, Wilson lines, truncation to 6d $F(4)$ gauged sugra...

More general Riemann surfaces Σ: Annulus worked out explicitly, no solutions (so far). Single boundary and higher genus?

Solutions with non-commuting SL(2,$\mathbb{R}$) monodromies for mutually non-local 7-branes.

Outlook

Establish relation to dual SCFTs: compare free energy to field theory computation using supersymmetric localization.

AdS/CFT with warped products: spectra, correlation functions, defects, Wilson lines, truncation to 6d $F(4)$ gauged sugra...

More general Riemann surfaces Σ: Annulus worked out explicitly, no solutions (so far). Single boundary and higher genus?

Solutions with non-commuting SL(2,$\mathbb{R}$) monodromies for mutually non-local 7-branes.

Thank you!