Polarized Black Holes in AdS

Lauren Greenspan

[hep-th/1511.08505 Costa, LG, Oliveira, Penedones, Santos]

Motivation

- Find interesting new geometries in AdS.
- Study Black Hole Polarization
- What can we learn about the dual field theories?

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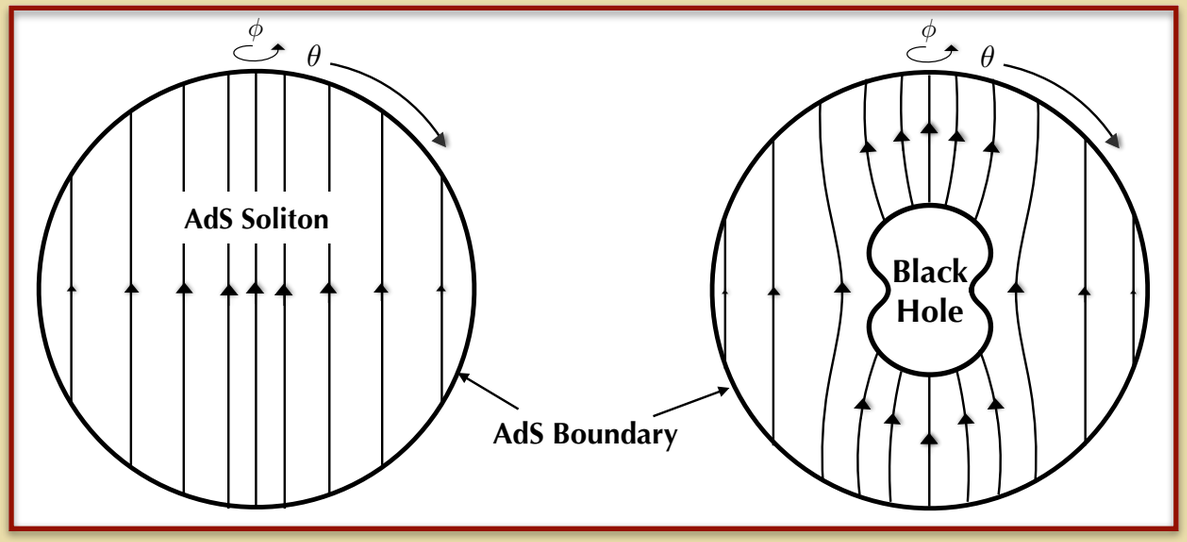
Idea

- Study the thermodynamics of deformed 4-dimensional black holes subject to a dipolar potential $A_\tau = i\mathcal{E}\cos\theta$ that are dual to a 3-dimensional field theory.

Gravity Set-up

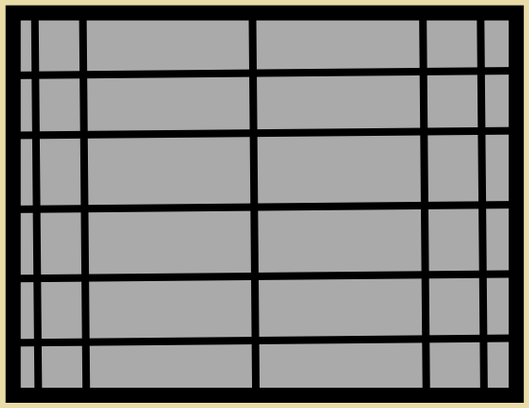
$$S = \frac{1}{16\pi G_N}\int d^4x\sqrt{-g}\left(R + \frac{6}{l^2} - F_{\alpha\beta}F^{\alpha\beta}\right) + \frac{1}{8\pi G_N}\int d^3x\sqrt{h}K$$

- gauge field $\tilde{A}_\mu$
- metric $g_{\mu\nu}$



Study numerical solutions Einstein-Maxwell gravity with a dipolar potential source.

$$R_{\mu\nu} + \frac{3}{l^2}\,g_{\mu\nu} = 2F_{\mu\alpha}F_{\nu}{}^{\alpha} - \frac{1}{2}g_{\mu\nu}F_{\alpha\beta}F^{\alpha\beta}\,, \qquad d\star F = 0\,.$$



✤ Descretize PDEs chebyshev x fourier

✤ Solve with Spectral Methods (exponential convergence)

Ansatze

$$ds^2_{sol} = \frac{1}{(1-r^2)^2}\left\{ A(r,x)\,d\tau^2 + \frac{4\,G(r,x)dr^2}{2-r^2} + r^2(2-r^2)\left[\frac{4\,C(r,x)}{2-x^2}\left(dx + \frac{H(r,x)dr}{r}\right)^2 + B(r,x)\,(1-x^2)^2 d\phi^2\right]\right\}$$

$$\tilde{A}^{sol}_{\tau} = -\,i\,r\,D(r,x)\,d\tau$$

$$ds^2_{BH} = \frac{1}{(1-r^2)^2}\left(d\tau^2 r^2 A(r,\theta) f_{BH}(r) + R^2\left(\frac{4dr^2 G(r,\theta)}{f_{BH}(r)} + C(r,\theta)(d\theta + 2rdrH(r,\theta))^2 + d\phi^2 B(r,\theta)\sin^2\theta\right)\right)$$

$$f_{BH}(r) = (1-r^2)^2 - Q^2(1-r^2)^3 + R^2(3-3r^2+r^4)$$

$$\tilde{A}^{BH}_{\tau} = -ir^2 D(r,\theta)d\tau$$

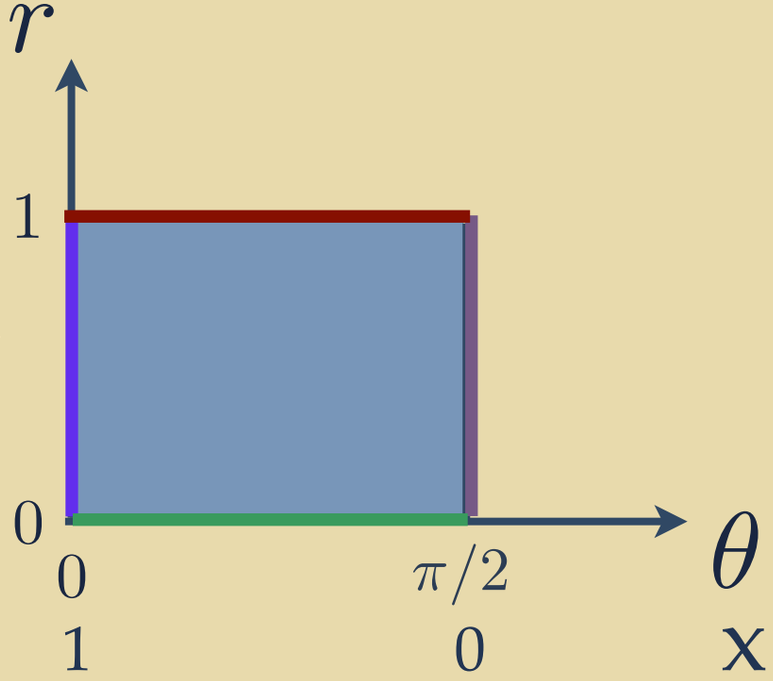
Boundary Conditions:

- Regularity at Axes of Symmetry { hor / origin; equator; pole

- At infinity $A = G = C = B = 1$

$H = 0$

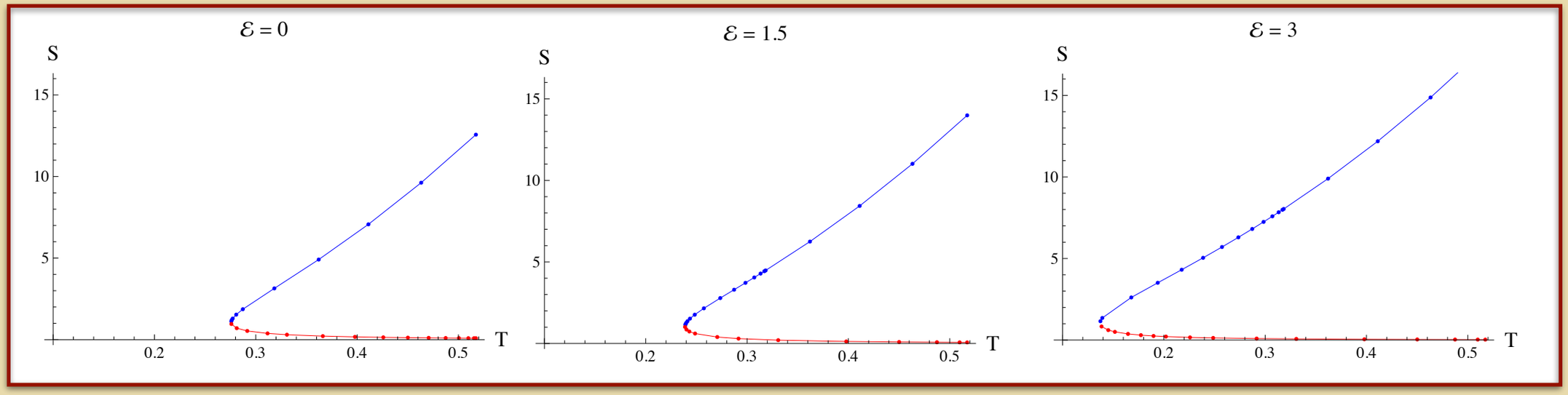
$D = \mathcal{E}\cos\theta$

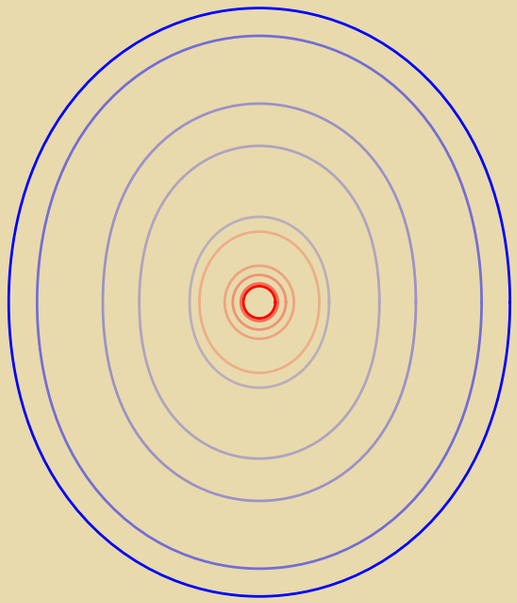


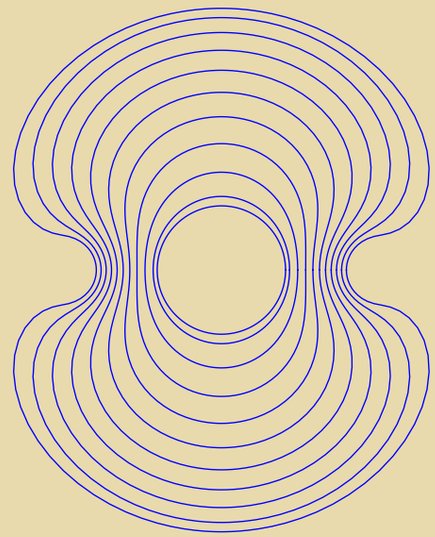
Black Hole Polarization

What happens to the shape of the horizon when we change $\mathcal{E}$ and T?

$$S = \frac{\mathcal{A}}{4G_N} = \frac{\pi R^2}{G_N} \int_0^{\frac{\pi}{2}} d\theta \, \sin\theta \sqrt{C(0,\theta)B(0,\theta)}$$







Free Energy

$$T_{\mu\nu} = \frac{2}{\sqrt{h}} \frac{\delta S}{\delta h^{\mu\nu}} = \frac{1}{8\pi G_N} \left(K_{\mu\nu} - K\, h_{\mu\nu} + G_{\mu\nu} - 2 h_{\mu\nu} \right)$$

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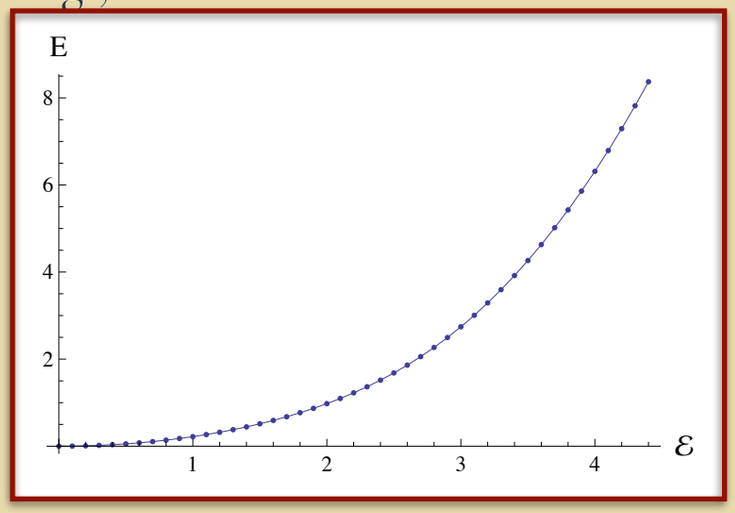
e.g., for the soliton…



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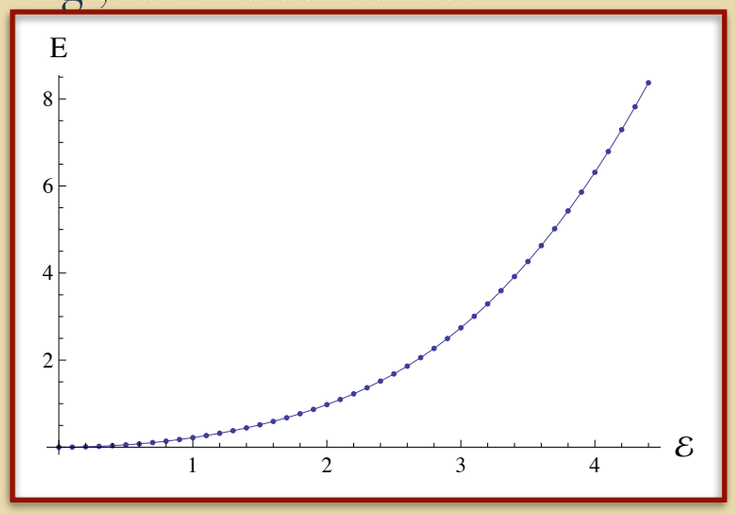

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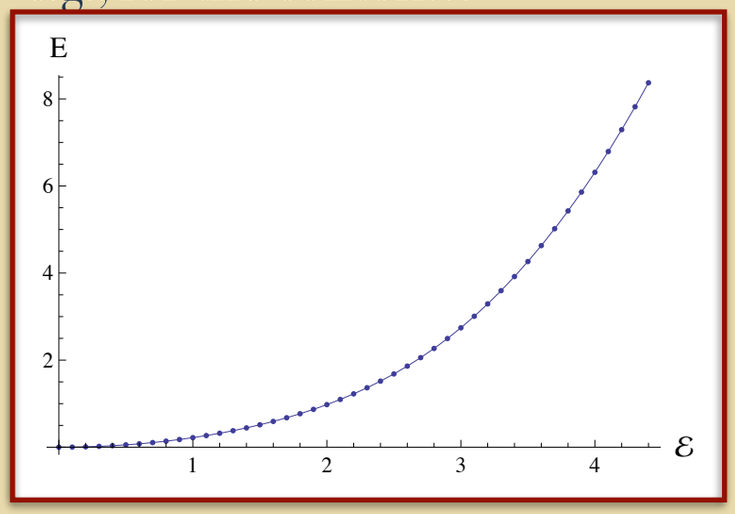

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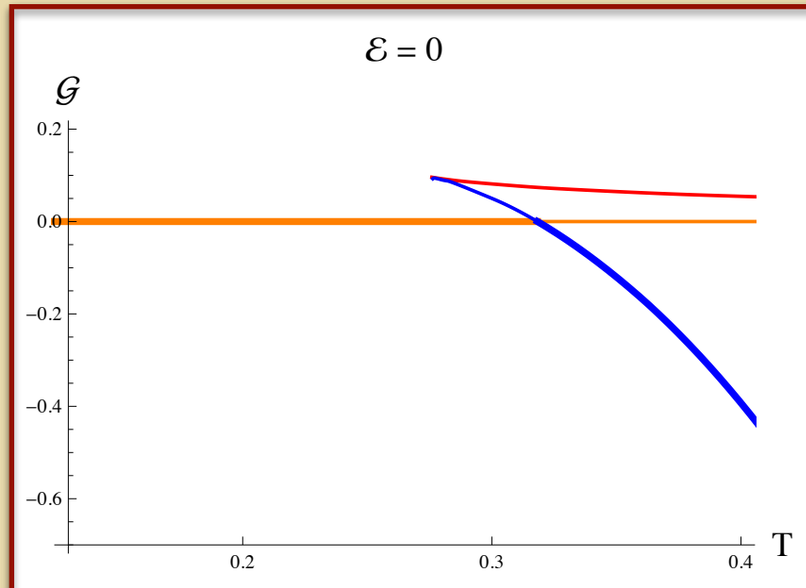
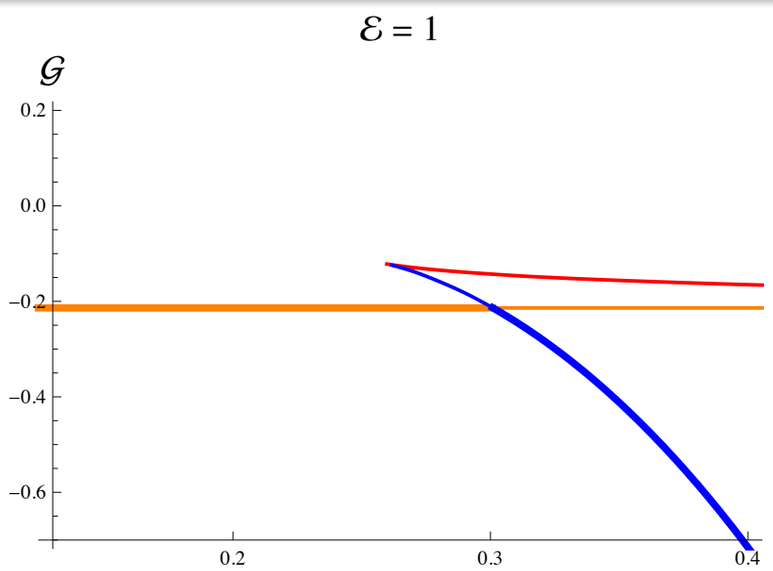
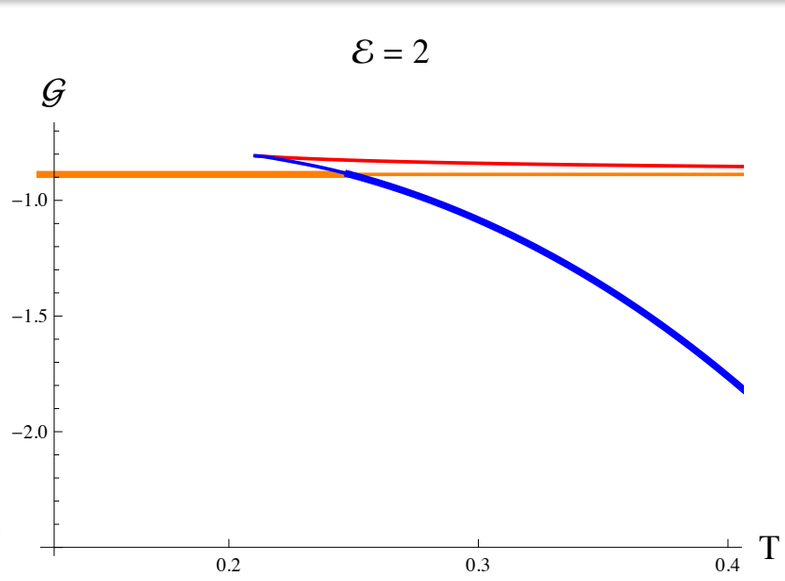
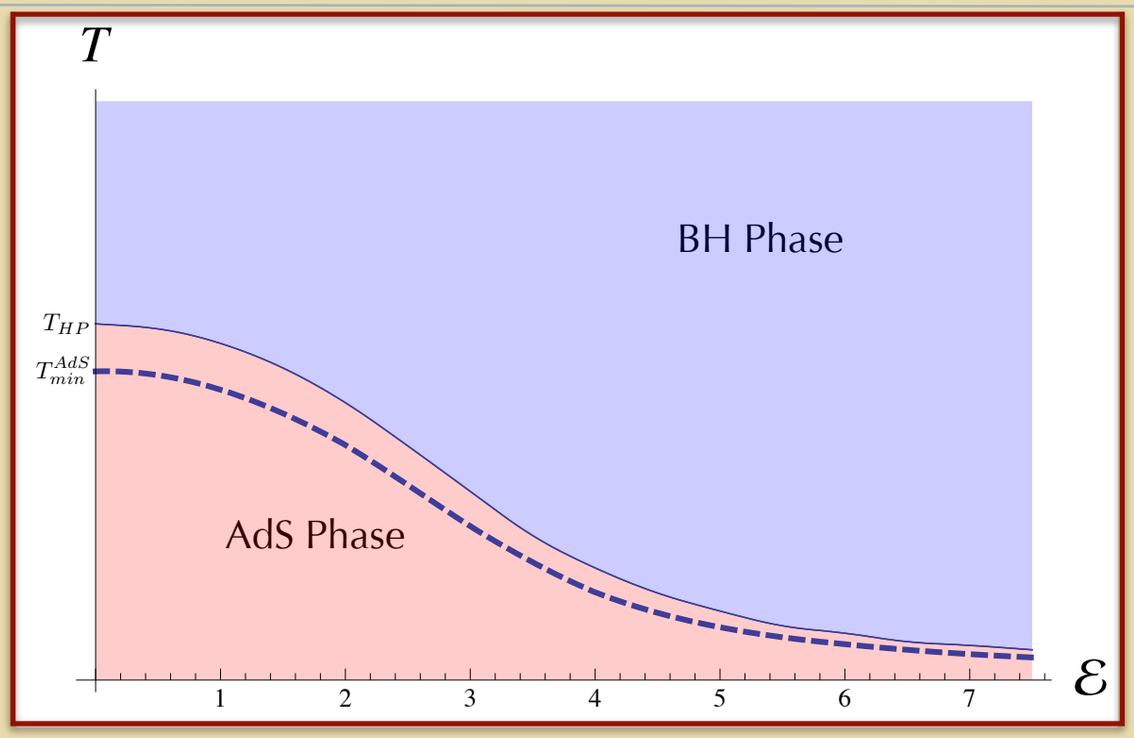
$$\mathcal{G} = E - TS - 4\pi\int_0^{\pi/2} d\theta \sin\theta\,\rho(\theta)\,\mathcal{E}\cos\theta$$







Phase diagram



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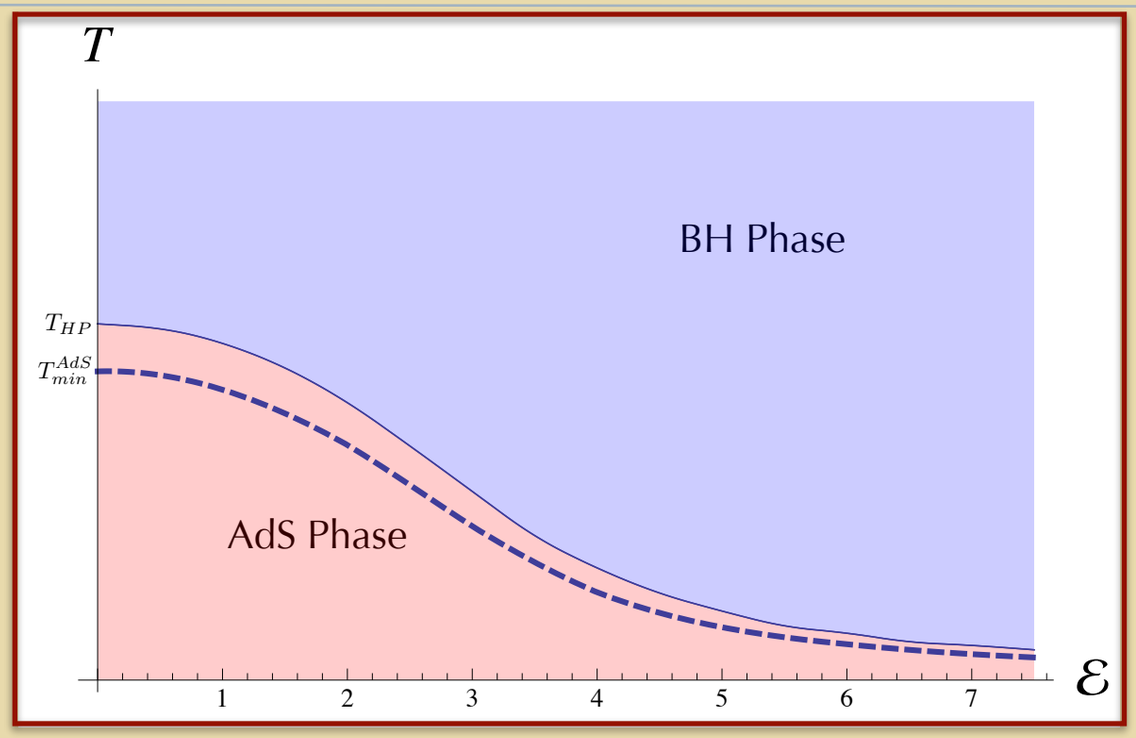

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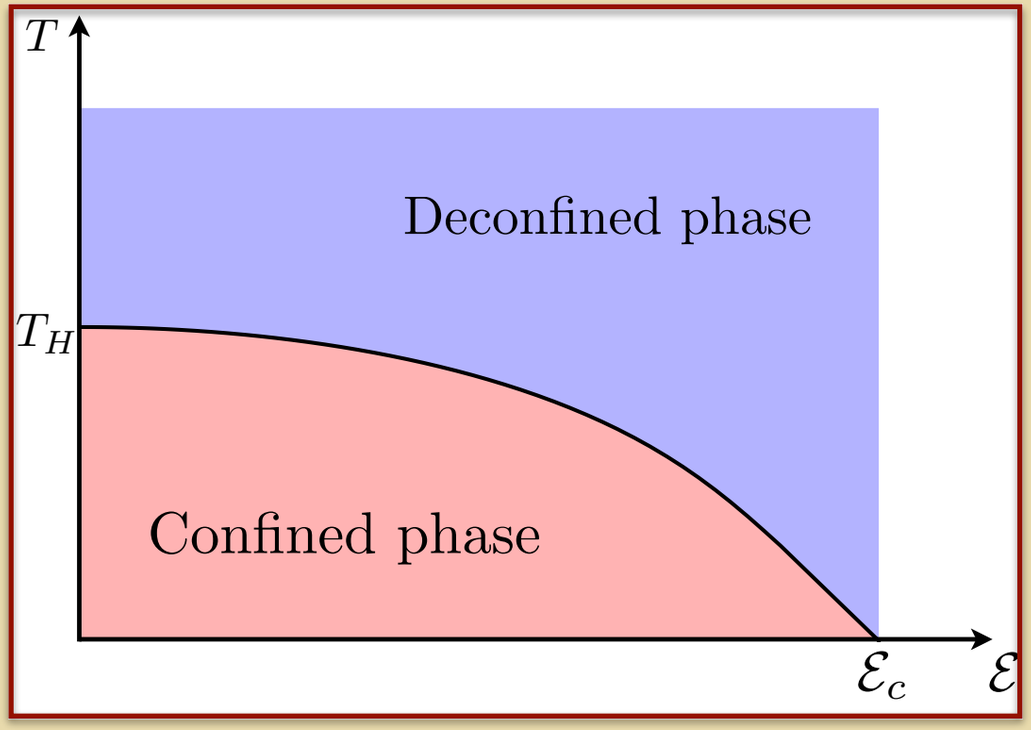

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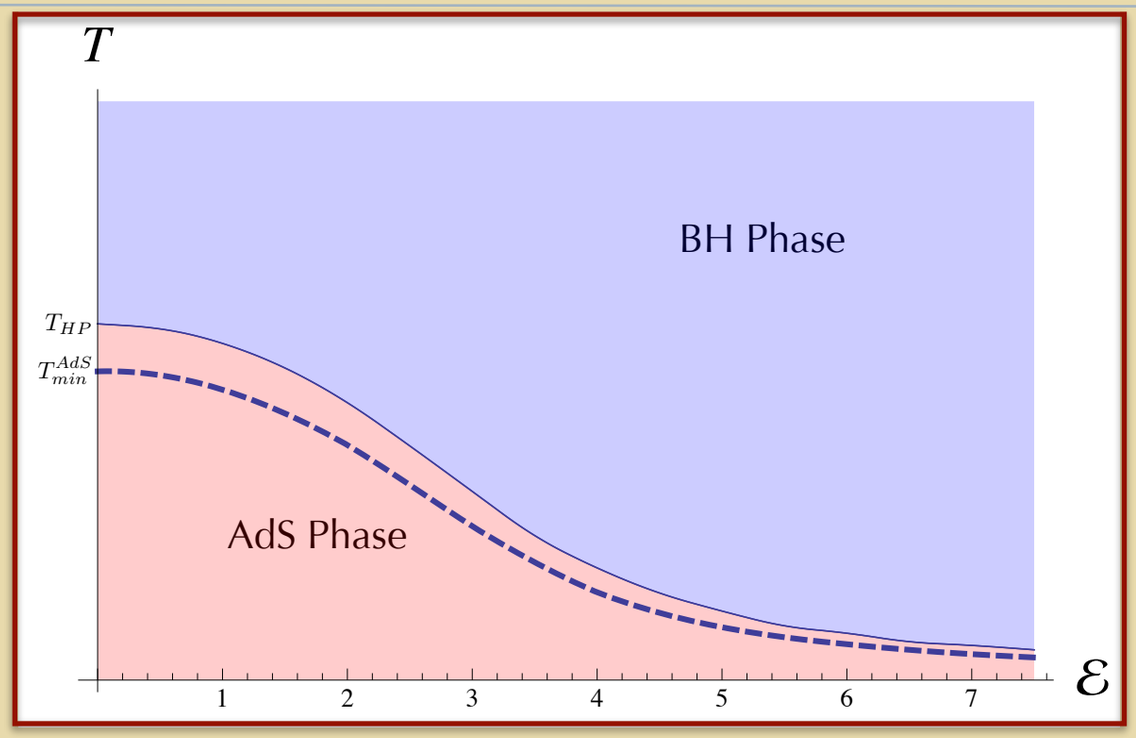

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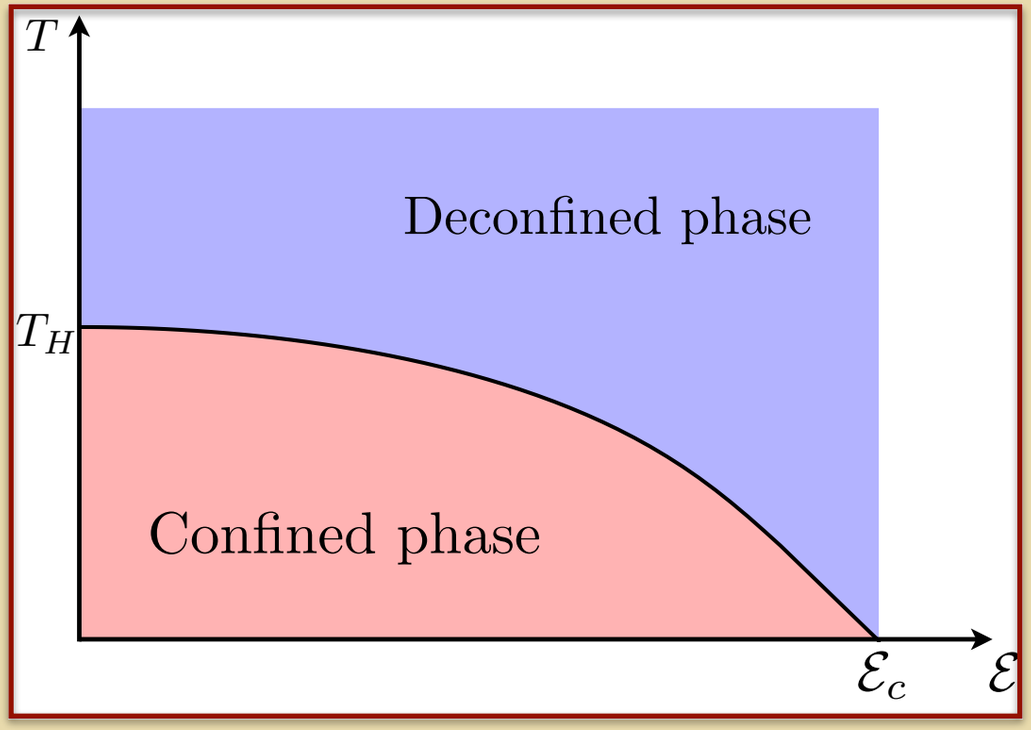
  no maximum electric field



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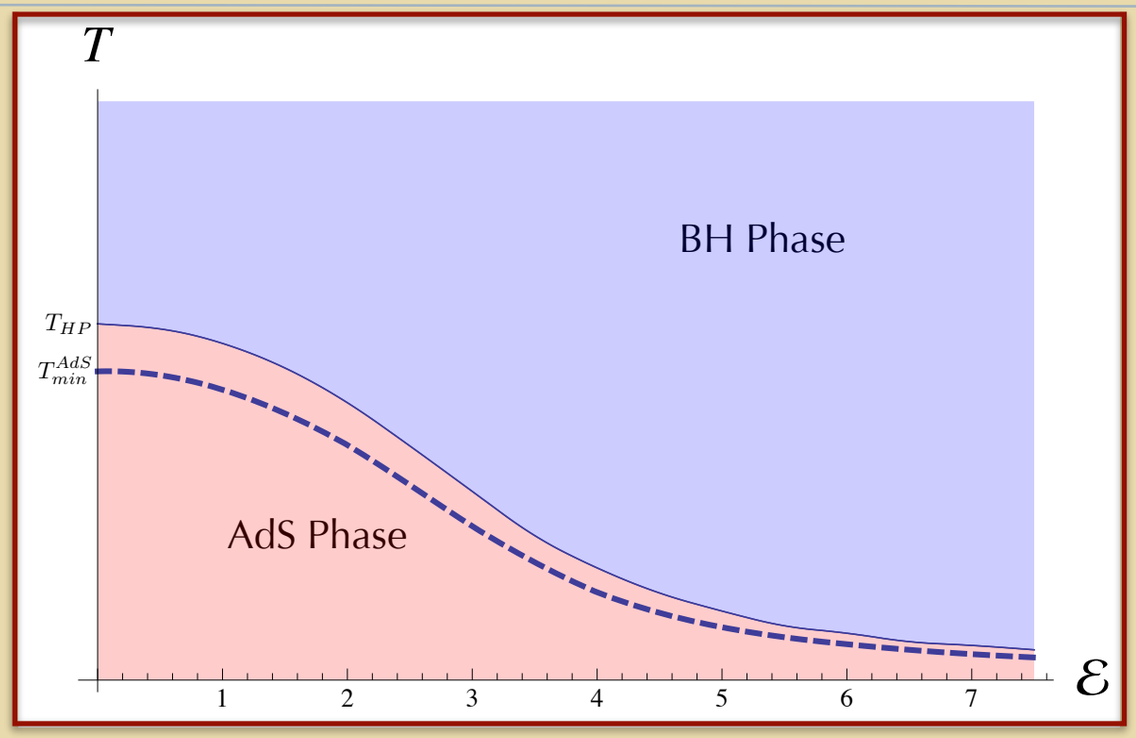

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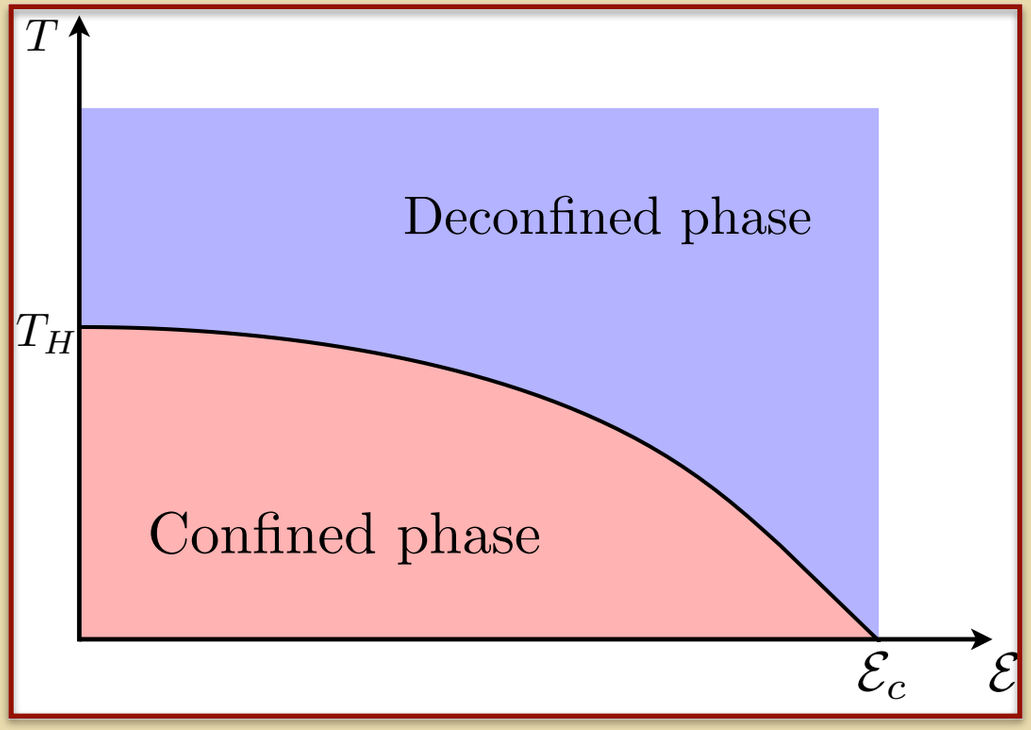

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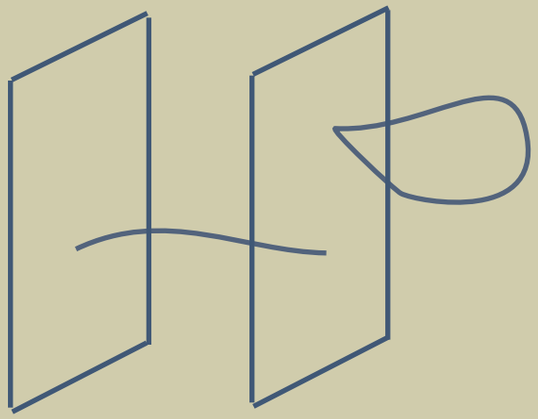
What is the correct gauge/gravity description for polarized black holes?

Current Work: ABJM [Aharony, Berenstein, Jafferis, Maldacena 2008]

A precise dual of BH polarization is deformed 3 d ABJM theory



ABJM

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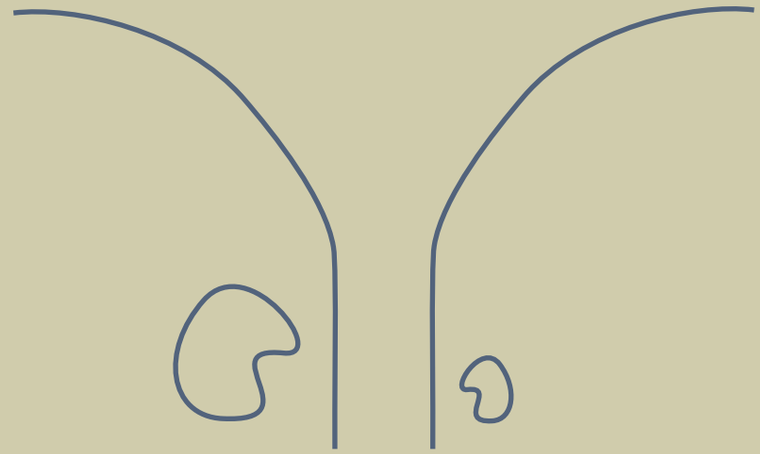

M-theory on $AdS_4 \times S^7$

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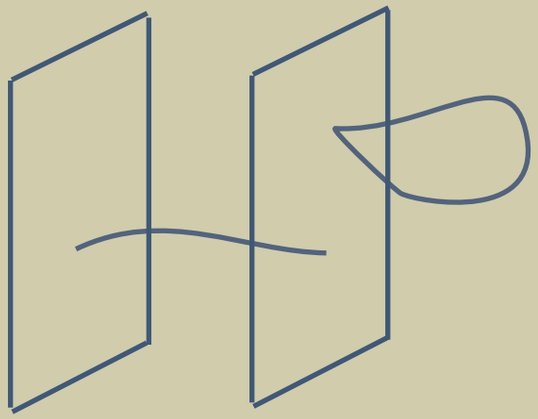

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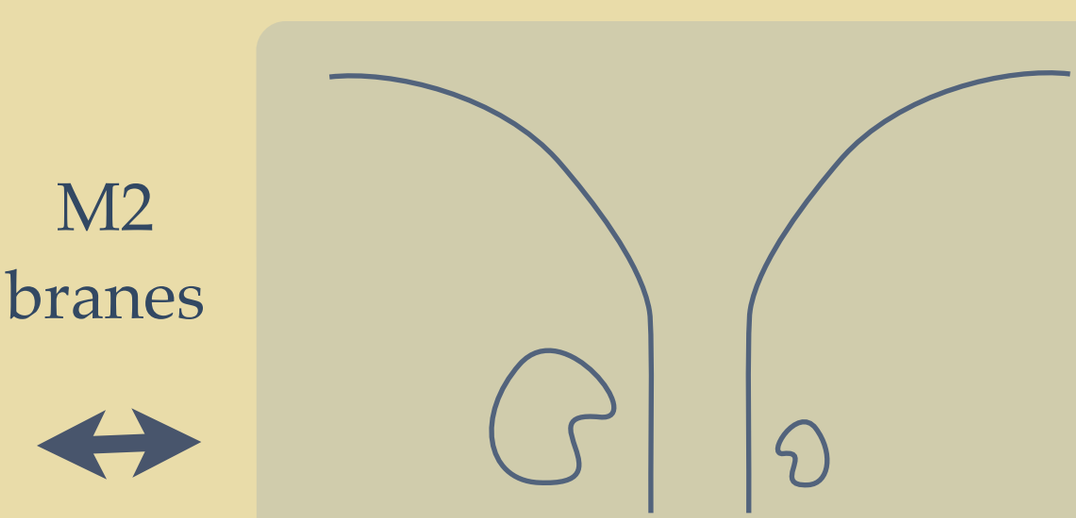

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$AdS_4 \times S^7$ → 4 d gauged SUGRA that can be truncated to include

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- scalar field Φ
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[Cvetic, Duff, Hoxha et. al. 1999]

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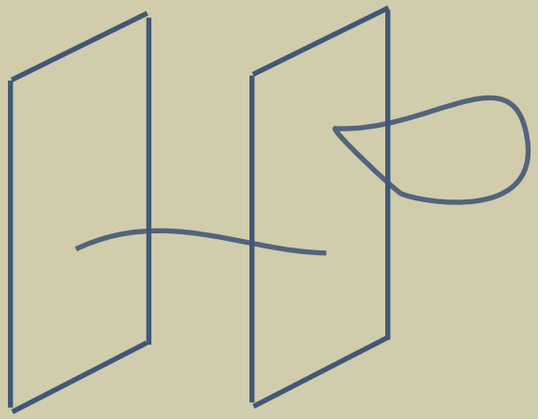

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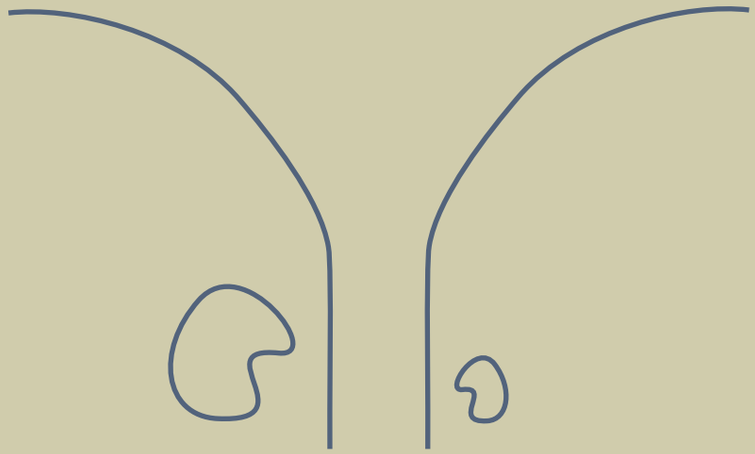

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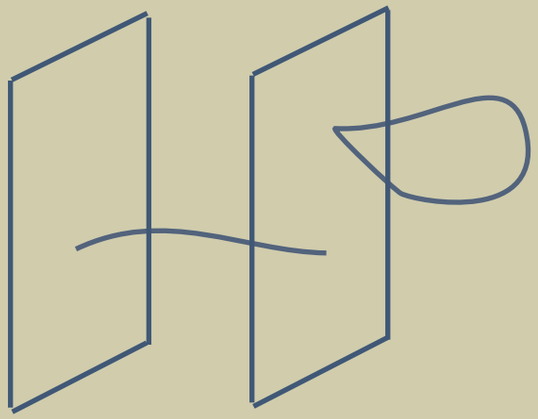

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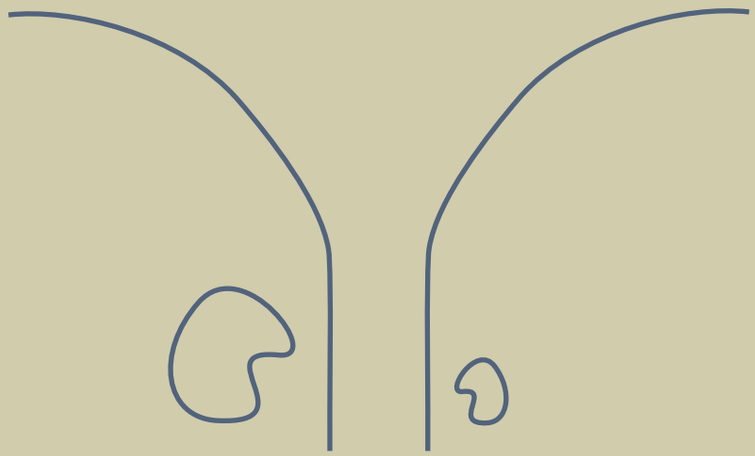

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Concrete Realization of the gauge/gravity duality!

[Itzhaki, Maldacena, Sonnenschein, Yankielowicz '98]

Current / Future Work

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- Can deformation of ABJM be simulated on a computer?
- Condensed Matter…

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Thank You