Holographic aspects of four-dimensional asymptotically flat $N = 2$ BPS black holes

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with Pedro Aniceto and Suresh Nampuri, arXiv:2111.13190

with A. Kidambi, S. Nampuri, V. Reys, M. Rosselló, arXiv:2211.06873

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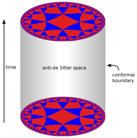
BPS black holes

AdS/CFT correspondence: quantum gravity in an asymptotically AdS space-time encoded in CFT on its conformal boundary.



BPS black hole solutions in four dimensions: asymptotically flat, near-horizon geometry $AdS_2 \times S^2$.

AdS_2/CFT_1 `Sen, arXiv: 0805.0095`

How is BPS black hole entropy encoded in CFT_1?

A conformal quantum mechanics model: DFF model.
`de Alfaro, Fubini, Furlan, 1976`

BPS black holes:

extremal, supersymmetric, charged (q_I, p^I)

$4D, N = 2$ supergravity theories reduced on S^2

Einstein-Maxwell-dilaton type actions with additional scalar fields Y^I.

Dimensional reduction on two-sphere S^2:

$$ds_4^2 = ds_2^2 + v_2(t,r)\left(d\theta^2 + \sin^2\theta\, d\varphi^2\right) \quad , \quad v_2 > 0$$

$$ds_2^2 = h_{ij} dx^i dx^j \quad , \quad x^i = t, r \, ,$$

$$F^I_{rt} = e^I(t,r) \to q^I \quad , \quad F^I_{\theta\varphi} = p^I \sin\theta \quad , \quad Y^I(t,r)$$

Rescaling $h_{ij} = \tilde{h}_{ij}/\sqrt{v_2}$, get $2D$ action in the form

$$L_2 = \frac{1}{2}\sqrt{-\tilde{h}}\left(-v_2\,\tilde{R}_2 + U(v_2, q, p, Y) + v_2\,(\partial Y)^2 + \dots\right)$$

Expanding $v_2(t,r) = \phi_0 + \epsilon\,\phi(t,r)$, $Y^I(t,r) = Y^I_0 + \epsilon\,\mathcal{Y}^I(t,r)$,

$$L_2 = -\frac{1}{2}\sqrt{-\tilde{h}}\,\phi_0\,\tilde{R}_2 + \frac{1}{2}\sqrt{-\tilde{h}}\,\phi\left(-\tilde{R}_2 + \frac{2}{v_1^{3/2}(q,p)}\right) + \mathcal{O}(\phi^2, (\mathcal{Y})^2, (\partial\mathcal{Y})^2$$

JT gravity type action.

Constant curvature solution supported by constant scalar fields v_2 and Y^I: in Fefferman-Graham gauge

$$\begin{aligned} ds_2^2 &= h_{ij} dx^i dx^j = dr^2 + h_{tt}(t,r)\, dt^2 \\ \sqrt{-h_{tt}} &= \alpha(t)\, e^{r/\sqrt{v_1}} + \beta(t)\, e^{-r/\sqrt{v_1}} = \sqrt{-h_0} \\ v_2 &= v_1(q,p) \quad , \quad Y_0^I(q,p) \end{aligned}$$

$R_2 = 2/v_1(q,p)$.

Near-horizon geometry of a BPS black hole in $4D$:

Sen, arXiv: 0809.3304

black hole in AdS_2 ($\times S^2$)

$$ds_2^2 = v_1 \left[-(\rho^2 - 1) dt^2 + d\rho^2/(\rho^2 - 1) \right] \quad , \quad \rho > 1 \qquad \alpha = 1, \beta = -1$$

First-order perturbations:

$$\sqrt{-h} = \sqrt{-h_0} + \epsilon\, \sqrt{-h_1}\ , \ v_2 = v_1(q,p) + \epsilon\, \phi\ , \ Y^I = Y_0^I + \epsilon\, \mathcal{Y}^I$$

First-order deformation

$$\sqrt{-h_1} = -\frac{\sqrt{-h_0}}{v_1}\,\phi - 2\,\partial_t\left(\frac{\partial_t \nu}{\alpha}\right)$$

$$\phi = \nu(t)\,e^{r/\sqrt{v_1}} + \vartheta(t)\,e^{-r/\sqrt{v_1}}$$

$$\left(\Box - \frac{2}{v_1}\right)\bar{\mathcal{Y}}^I = 0$$

with

$$\vartheta = \frac{1}{\nu}\left(c_0 - \frac{v_1}{4}\left(\frac{\nu'}{\alpha}\right)^2\right)\,,\ \beta = -\frac{\alpha}{\nu^2}\left(c_0 - \frac{v_1}{4}\left(\frac{\nu'}{\alpha}\right)^2\right) - \frac{v_1}{2\,\nu}\left(\frac{\nu'}{\alpha}\right)'$$

Example: take a black hole in AdS_2, deform by a constant $\nu = \nu_0$

$$\alpha = \frac{1}{\sqrt{v_1}}\,,\ \beta = -\frac{\mu^2}{4\sqrt{v_1}} \implies c_0 = \frac{\mu^2}{4}\,\nu_0^2 > 0$$

Now $\nu(t) = \nu_0 + f(t)$, $\mathcal{Y}^I = 0$:

Dynamics of $\nu(t)$ described by the renormalized on-shell action:

$$S_{ren} = \int_{\partial M} dt \left(\frac{c_0}{\nu} + \frac{(\nu')^2}{4\,\nu} \right) \quad , \quad \nu(t) = x^2(t)$$

$$S_{\rm DFF} = \int_{\partial M} dt \left(\frac{c_0}{x^2(t)} + (x')^2 \right)$$

Conformal mechanics Lagrangian of DFF. $c_0 > 0$, 'wrong' sign.

Converting to global time, C, Kidambi, Nampuri, Reys, Rosselló, arXiv:2211.06873

$$\begin{aligned} S_{\rm DFF} &= \int dt \left[\frac{(\nu')^2}{4\,\nu} + c_0 \left(\frac{1}{\nu} + \nu \right) \right] \\ S_{\rm Liouv} &= \int dt \left[\frac{1}{2} (l')^2 + 2 e^{-l} \right] \end{aligned}$$

Holographic model for BPS BHs in $D = 4$.

Lin, Maldacena, Rozenberg, Shan, 2207.00408