Nernst Branes in Gauged Supergravity

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Motivation

- Extremal black holes in string theory:

  asymptotically flat: detailed microscopic understanding available.

  Systems at $T = 0$ with $\mathcal{S} \neq 0$.

- What about black objects satisfying Nernst law?

  Systems at $T = 0$ with $\mathcal{S} = 0$.

  Appear to exist in AdS space-times.

  Examples in Einstein + Maxwell + $\Lambda < 0$:

  - $D = 4$, with a dilaton field: `Goldstein et al, 0911.3586`
  - $D = 5$, with a magnetic field: `D'Hoker and Kraus, 0911.4518`

Of interest in AdS/CFT applications to condensed matter systems.

Extremal black branes in $D = 4$

When embedding Einstein + Maxwell + $\Lambda < 0$ into string theory, obtain gauged supergravity. Study Nernst brane configurations in

$$N = 2 \; U(1) \text{ gauged supergravity in } D = 4, 5.$$

$D = 4$: Einstein+Maxwell type theories with complex scalar fields and fluxes. Electric-magnetic duality.

Model encoded in:

- prepotential $F(Y)$, complex scalar fields Y^I , $F_I = \partial F / \partial Y^I$
- superpotential $W(Y) = h_I \, Y^I - h^I \, F_I$, dyonic fluxes (h_I, h^I)
- dyonic charges (Q_I, P^I) $\quad I = 0, \ldots, n \quad , \quad U(1)^{n+1}$.

Static brane configurations

Interested in static black branes, i.e. translationally invariant horizons.

Ansatz:

$$ds^2 = -e^{2U}\, dt^2 + e^{-2U}\left(dr^2 + e^{2\psi}(dx^2 + dy^2)\right)$$

$$U = U(r) \quad , \quad \psi = \psi(r) \quad , \quad Y^I = Y^I(r)$$

Need to determine these profiles.

Extremal black branes: $T = 0$

- Reduced Lagrangian = Lagrangian$|_{\text{ansatz}}$
- Reduced Lagrangian = $\sum$ squares of first-order flow equations
- Solutions to these first-order flow equations = extremal
- Supplement with Hamiltonian constraint: $Q_I\, h^I - P^I\, h_I = 0$

Dall'Agata + Gnecchi, arXiv:1012.375

Flow equations

First-order flow equations for the scalars $Y^I(r)$: $\quad F_I = \partial F(Y)/\partial Y^I$

$$\begin{pmatrix} (Y^I - \bar{Y}^I)' \\ (F_I - \bar{F}_I)' \end{pmatrix} = -2i\, \mathrm{e}^{-\psi}\, \mathrm{Im} \begin{pmatrix} \mathrm{e}^{i\gamma}\, N^{IJ}\, \hat{Q}_J \\ \mathrm{e}^{i\gamma}\, \bar{F}_{IJ}\, N^{JK}\, \hat{Q}_K \end{pmatrix} + 2i\, \mathrm{e}^{\psi - 2U}\, \mathrm{Re} \begin{pmatrix} \mathrm{e}^{i\gamma}\, N^{IJ}\, \hat{h}_J \\ \mathrm{e}^{i\gamma}\, \bar{F}_{IJ}\, N^{JK}\, \hat{h}_K \end{pmatrix}$$

where

$$\hat{Q}_I = Q_I - F_{IJ}\, P^J \quad , \quad \hat{h}_I = h_I - F_{IJ}\, h^J \quad , \quad N_{IJ} = -i(F_{IJ} - c.c.)$$

- Reminiscent of attractor equations of ungauged supergravity ($h_I = h^I = 0$), but much more complicated to solve.
- Consistent with analysis for supersymmetric backgrounds

  Dall'Agata + Gnecchi, arXiv:1012.375

Supersymmetric solutions

Find:

- can construct $AdS_2 \times R^2$ backgrounds $\quad ((Y^I)' = 0)$;
- exact solutions in model $F = -iY^0 Y^1$ (dilaton-gravity model)

  C. Charmousis, B. Gouteraux, B. S. Kim, E. Kiritsis, R. Meyer, arXiv:1005.4690

- model $F = -(Y^1)^3/Y^0$:

  interpolating solution between AdS_4 and $AdS_2 \times R^2$,

- STU-model $F = -Y^1 Y^2 Y^3 / Y^0$:

  Nernst brane solutions $(T = 0, \mathcal{S} = 0)$. Not a small black hole.

  Electric $(Q_0; h_1, h_2, h_3) \longrightarrow \quad Q_I h^I - P^I h_I = 0 \quad$ satisfied.

  Attractor.

Nernst brane solutions

Killing horizon at $r = 0$. Near horizon solution:

- infinitely long throat of unusual type (not $AdS_2 \times R^2$):

$$ds^2 = -r^{5/2}\, dt^2 + r^{-5/2}\, dr^2 + r^{1/2}\,(dx^2 + dy^2)$$

  conformal to Lifshitz metric with $z = 3$

$$ds^2 = \tilde{r}^{-1}\left(-\tilde{r}^{2z}\, dt^2 + \tilde{r}^2\,(dx^2 + dy^2) + \tilde{r}^{-2}\, d\tilde{r}^2\right)$$

  Vanishing area density.

- Infinitely long throat + attractor mechanism: black.

  Vanishing entropy density.

Solution interpolates between conformally flat metric at $r = \infty$ and unusual throat ($r = 0$). Curvature invariants well-behaved.

Nernst brane solutions

Behaviour of the physical scalar fields S, T, U:

$$S = Y^1/Y^0 \qquad T = Y^2/Y^0 \quad , \quad U = Y^3/Y^0$$

They blow up both at the horizon and asymptotically.

Embedding into type IIA string theory: S, T, U are Kähler moduli of internal space.

Blow up $\longrightarrow$ solution decompactifies

$\longrightarrow$ good solution in $D = 10$ dimensions.

Work in progress

- Explore the space of Nernst solutions in $D = 4$.
- Static black branes in $D = 5$:
  - electric charges Q_A only: no Nernst solutions
  - constant magnetic field in z-direction, say: $F = B\, dx \wedge dy$
  - electric charges + constant magnetic field

Thanks!