A soliton menagerie in AdS

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Based on [1112.3979] with M. Rangamani and B. Withers

Motivation

- Hairy black holes are commonplace in Anti-de Sitter space.
- Charged, asymptotically AdS black branes develop charged scalar hair below a critical temperature.

  Gubser; Hartnoll, Herzog & Horowitz
- AdS/CFT motivation: charged hairy black brane $\leftrightarrow$ superfluid on the plane.
- What happens at low temperature?

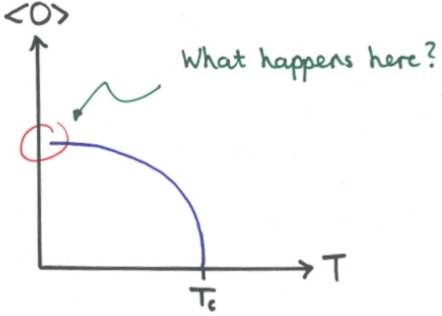
  Fernandez-Gracia & Fiol; Gubser & Nellore; Horowitz & Roberts

Main point

The planar limit of charged scalar solitons in global AdS_4

coincides generically with

the zero-temperature limit of charged hairy black branes.



Theory

- Einstein-Maxwell-scalar theory with $\Lambda < 0$:

$$S = \int d^4x\sqrt{-g}\left[R + \frac{6}{\ell^2} - \frac{1}{4}F^2 - (\partial\phi)^2 - \frac{q^2}{\ell^2}\phi^2 A^2 - m_\phi^2\phi^2\right]$$

- Choose $m_\phi^2\ell^2 = -2$ and set $\ell = 1$ from now on.

Planar limit

- Global Schwarzschild-AdS$_4$ (one-parameter family):

$$ds^2 = -r^2 \left(1 + \frac{1}{r^2} - \frac{m}{r^3}\right) dt^2 + \frac{dr^2}{r^2 \left(1 + \frac{1}{r^2} - \frac{m}{r^3}\right)} + r^2 d\Omega_2^2$$

- Consider the scaling limit

$$r \to \lambda r, \quad t \to t/\lambda, \quad \lambda \to \infty, \quad \lambda^2 d\Omega_2^2 \to d\vec{x}_2^2$$

- Leaves us with vacuum planar AdS$_4$ unless we scale $m \to \lambda^3 m$ too.
- When does a solution in global AdS have an interesting planar limit?
  1. Branch of solutions with unbounded asymptotic coefficient.
  2. Other coefficients must grow fast enough to survive.

Solitons vs. Branes

Global solitons:

- Regular core, horizon-free and asymptotic to global AdS_4.
- Non-topological
- Examples in this type of theory in 5D:
  Dias, Figueras, Minwalla, Mitra, Monteiro & Santos

Charged hairy black branes:

- Regular horizon and asymptotic to planar AdS_4.

Construction of solitons

- Ansatz:

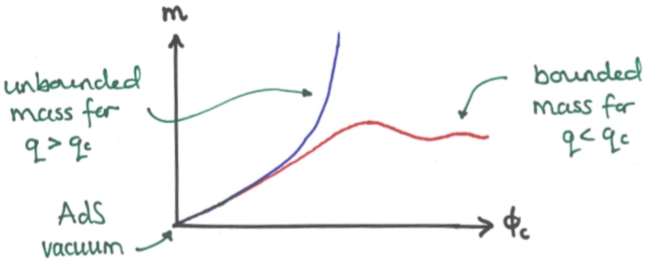
$$ds^2 = -g(r)e^{-\chi(r)}dt^2 + \frac{dr^2}{g(r)} + r^2 d\Omega_2^2$$
$$A = A_t(r)dt, \quad \phi = \phi(r)$$

- Asymptotic expansions:

$$g = r^2 + 1 + \frac{\phi_1^2}{2} - \frac{m}{r} + \ldots, \quad \chi = \chi_\infty + \ldots$$
$$A_t = \mu - \frac{\rho}{r} + \ldots, \quad \phi = \frac{\phi_1}{r} + \frac{\phi_2}{r^2} + \ldots$$

- Integrate numerically with remaining boundary conditions using a shooting method.
- One-parameter family at a given q.

Initial soliton results



- Critical q_c
- Physical intuition: force balance

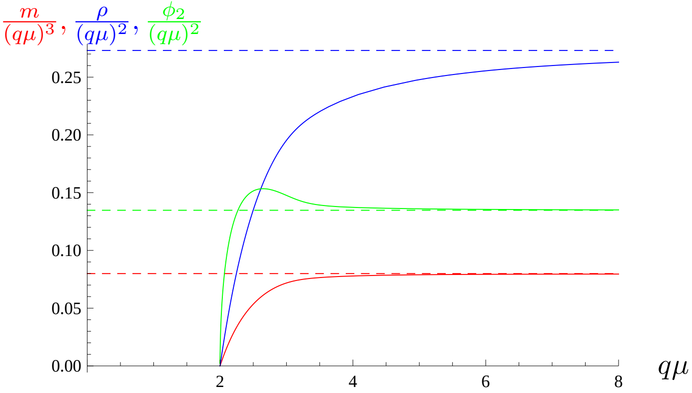
$\Rightarrow$ Planar limit exists

- Similar plots for charged boson stars in flat space:

  Kleihaus, Kunz, Lämmerzahl & List

Coincidence of limits

- Plot scaling-invariant quantities. Here is an example at $q^2 = 1.3 > q_c^2$. The dashed lines indicate these quantities for charged hairy black branes at low temperature.



- Regularity?

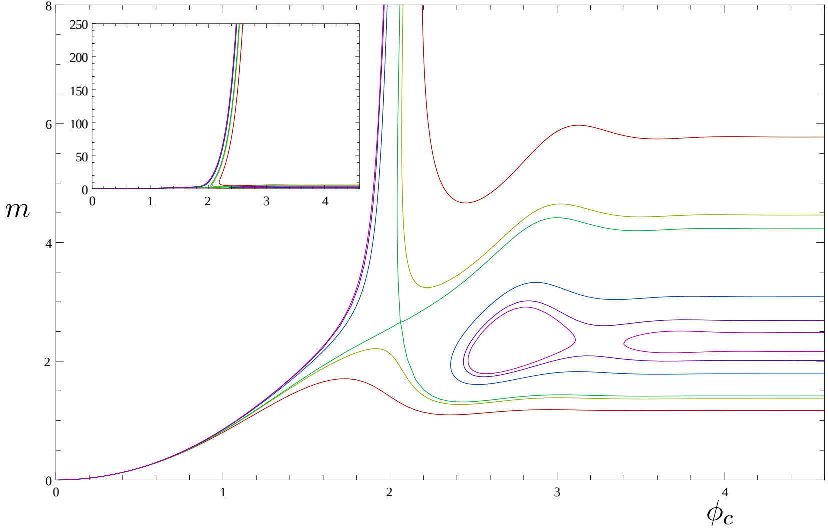
New soliton branches

- Low temperature charged hairy black branes exist for $q < q_c$.

$\Rightarrow$ Find new global soliton branches:
  - disconnected from AdS vacuum
  - planar limit exists $\forall\ q$
  - closed bubbles in space of solutions

- Coincidence of limits is generic.

New soliton branches



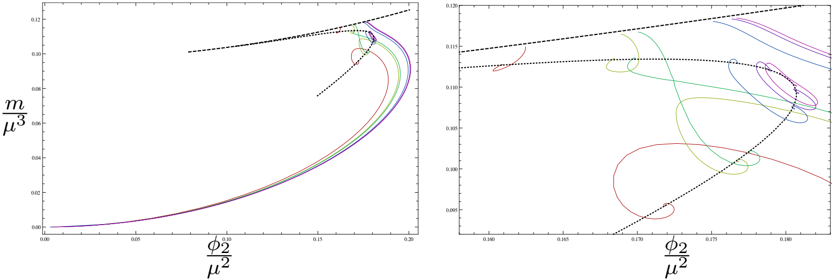
- Contours of the function $q(m, \phi_c)$: colour represents the value of q. Inset: behaviour over a larger range of m.

Summary

- Charged hairy black brane at zero T $\leftrightarrow$ planar soliton
- Coincidence of limits is generic.
- Useful technique for finding new connections between solutions.
- Starting point for understanding superfluid phases at low temperatures.

Generic coincidence of limits

- Scaling-invariant quantities. The right panel zooms in to the interesting bits.



– – – Low temperature charged hairy black brane

- - - - Large-ϕ_c global soliton