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Introduction to String Theory

Group Project: Holographic Superconductors

(Speakers at Strings 2012: Andreas Karch, Gary Horowitz, Nabil Iqbal)

Outline Recently, it has been found that black holes in Anti deSitter spacetime can coexist with a charged condensate outside their horizon [1]. This setup is dual to a superfluid (or possibly a superconductor) in the dual field theory [2, 3].

Task 1 Write up a one-page-summary explainig the main idea of and recent progress on higher spin holography.

Task 2 Construct a p-wave superconductor holographically. Consider the Einstein-Maxwell action

$$S = \frac{1}{2\kappa}\int d^4x[\mathcal{R} - \frac{1}{4}(F_{\mu\nu})^2 + \frac{6}{L^2}] \tag{1}$$

and use the Ansatz $A = \phi(r)\tau^3 dt + w(r)\tau^1 dx$. Let us see if we can have non-trivial static configurations of ϕ and w in the bulk. Note: This is a *background computation.*

The Euler-Lagrange equations are given by

$$0 = \phi'' + \frac{2}{r}\phi' - \frac{1}{r(r^3-1)}w^2\phi\,, \qquad 0 = w'' + \frac{1+2r^3}{r(r^3-1)}w' + \frac{r^2}{(r^3-1)^2}\phi^2 w\,. \tag{2}$$

with the near-horizon ($r_H = 1$)behavior

$$w = w_0 + w_2(r-1)^2 + \dots\,, \tag{3}$$
$$\phi = \phi_1(r-1) + \dots\,. \tag{4}$$

and the near-boundary ($r_B = \infty$) behavior

$$w = \frac{W_1}{r} + \dots\,, \tag{5}$$
$$\phi = p_0 + \frac{p_1}{r} + \dots\,. \tag{6}$$

a) Determine the solution to these two equations of motion numerically.

b) What is the meaning of the fields w and ϕ on the gauge side?

c) Find a numerical solution such that the non-normalizable mode of the field w vanishes, but its normalizable mode remains finite.

d) What do these boundary conditions imply for the gauge theory object corresponding to w?

Remark: Compare with [arXiv:0805.2960].

References

[1] S. S. Gubser, *Breaking an Abelian gauge symmetry near a black hole horizon*, *Phys.Rev.* **D78** (2008) 065034, [arXiv:0801.2977].

[2] S. A. Hartnoll, C. P. Herzog, and G. T. Horowitz, *Building a Holographic Superconductor*, *Phys.Rev.Lett.* **101** (2008) 031601, [arXiv:0803.3295].

[3] S. A. Hartnoll, C. P. Herzog, and G. T. Horowitz, *Holographic Superconductors*, *JHEP* **0812** (2008) 015, [arXiv:0810.1563].