Stringy holography at finite charge density

Mikhail Goykhman

Lorentz Institute, Leiden University

Based on arXiv:1304.4496 [hep-th] in collaboration with Andrei Parnachev

Strings 2013, Seoul, Korea

Outline

- We study strongly-interacting d-dimensional QFT via holographic-dual classical theory in $d+1$-dimensional bulk
- Finite temperature and chemical potential of QFT correspond holographically to charged black hole in the bulk
- In such problems one usually solves classical equations of motion (Einstein, Yang-Mills,...) for the fields in the bulk
- In contrast with the usual holographic approach, we use $2d$ worldsheet action to describe classical dynamics of the graviton and gauge field
- It allows us to consider QFT with finite number of degrees of freedom (finite-N) and see purely stringy effects
- We study the same model in gravity approximation and find expected agreement with string results

Holographic dual of Little String Theory

- Our holographic correspondence can be seen as a generalization of holographic description of Little String Theory to the case of non-vanishing charge density
- Little String Theory can be viewed as theory on worldvolume of N coincident NS5-branes at vanishing string coupling (so that bulk d.o.f. decouple)
- Its holographic dual is the theory of closed strings in the 'cigar' background of NS5-branes (Aharony, Berkooz, Kutasov, Seiberg '98; Itzhaki, Maldacena, Sonnenschein, Yankielowicz '98; Boonstra, Skenderis, Townsend '98)
- When $N \simeq (R/\ell_s)^2$ is large supergravity approximation in the bulk is valid

Low-energy modes

- Consider strongly interacting QFT at finite temperature and charge density; with stress-energy tensor $T_{\mu\nu}$ and charge current j_μ
- We are looking for low-energy excitations. Their dispersion relations are read off as poles of two-point functions

$$\langle T_{\mu\nu}\, T_{\lambda\rho}\rangle\,, \quad \langle T_{\mu\nu}\, j_\lambda\rangle\,, \quad \langle j_\mu\, j_\lambda\rangle$$

which can't be computed perturbatively in strongly interacting QFT

Holographic prescription

- We compute these correlators using the string dual
- The holographic correspondence is

$$G_{\mu\nu}\ \text{(graviton)} \leftrightarrow T_{\mu\nu}\ \text{(stress – energy tensor)}$$
$$A_{\mu}\ \text{(gauge field)} \leftrightarrow j_{\mu}\ \text{(charge current)}$$

- The dynamics of $G_{\mu\nu}$ and A_μ is described by worldsheet action
- The holographic prescription for two-point functions is:

$$\langle T_{\mu\nu} T_{\lambda\rho}\rangle_{QFT} = \langle G_{\mu\nu} G_{\lambda\rho}\rangle_{worldsheet} \quad \langle j_\mu j_\nu\rangle_{QFT} = \langle A_\mu A_\nu\rangle_{worldsheet}$$

$$\langle T_{\mu\nu} j_\lambda\rangle_{QFT} = \langle G_{\mu\nu} A_\lambda\rangle_{worldsheet}$$

String dual

- Our holographic dual theory is string theory defined by gauged WZW model on the coset (Johnson '94, Giveon, Rabinovici, Sever '03)

$$\frac{SL(2,R) \times U(1)_x}{U(1)}$$

where asymmetric gauging of $U(1)$ subgroup is defined by

$$(g, x_L, x_R) \sim \left(e^{\tau \cos \psi \sigma_3 / \sqrt{N}} g e^{\tau \sigma_3 / \sqrt{N}}, x_L + \tau \sin \psi, x_R \right)$$

- The corresponding classical solution is the two-dimensional charged black hole (McGuigan, Nappi, Yost '91), CBH_2
- We apply BRST quantization of a string on a coset
- We consider black-brane background $CBH_2 \times R^{d-1}$

String dual

- The temperature, chemical potential and pressure of the QFT are given by (Giveon, Kutasov '05)

$$T = \frac{1}{2\pi\sqrt{N}} \frac{\cos\psi}{\cos^2(\psi/2)}\,, \quad \mu = \tan(\psi/2)\,, \quad P = 0$$

- The vertex operator of the graviton is

$$G^{\mu\nu} = (j^{\mu}_{-1}\tilde{j}^{\nu}_{-1} + j^{\nu}_{-1}\tilde{j}^{\mu}_{-1})V_g$$

- Taking one polarization along $U(1)_x$ and performing KK reduction we obtain the gauge field

$$a^{\mu} = (j^{\mu}_{-1}\tilde{j}^{x}_{-1} + j^{x}_{-1}\tilde{j}^{\mu}_{-1})V_g$$

Low-energy modes

- Choose X to be direction of propagation of excitations, and Y to be some transverse to it direction. Denote p - momentum and ω - frequency of excitations
- We have computed $\langle T_{XY} T_{XY} \rangle$ via string holographic dual and found the poles at

$$\omega = -i \frac{\sqrt{N}}{2} p^2$$

$$\omega = -i \cos\psi \frac{\sqrt{N}}{2} p^2$$

- From QFT point of view we therefore have two different non-interacting fluids, each supporting one of these modes
- Similar is true for $\langle T_{XX} T_{XX} \rangle$,... correlators

Supergravity approximation

- We have verified these results in type-II gravity, solving linearized equations of motion for fluctuations on top of the charged black brane background
- The fluctuation equations split into two decoupled systems. Therefore we again have two non-interacting fluids. Each fluid supports a low-energy excitation mode, with the same dispersion relation as the one derived by worldsheet consideration

Thank you!