Strings and AdS/CFT at finite density

Goykhman, M.

Summary

The AdS/CFT correspondence is a powerful approach to problems of strongly coupled low-energy phases of matter. It has been proving to be efficient at giving a qualitative description of the phenomena such as confinement and chiral symmetry breaking in QCD-like models, and superconductivity and Fermi surfaces in strongly-coupled condensed matter systems. In this thesis we apply the methods of holography to find out properties of low-energy physics.

We begin in chapter 2 by considering a finite-density system of quarks, realized holographically by a probe brane in Anti-de Sitter (AdS) space, with a non-trivial gauge field background on its world-volume. We reproduce the holographic zero-sound in the longitudinal channel of the current-current correlation function. We generalize this result to the case of a non-vanishing background magnetic field. This field leads to a gap in the zero-sound mode, which scales proportionally to the magnitude of the field when it is small. At vanishing magnetic field the two-point correlation function of the transverse current component exhibits a non-trivial momentum-independent structure, signaling the presence of collective excitations in the system.

In chapter 3 we study the classical dynamics of the tachyon field in an AdS background described by the tachyon-Dirac-Born-Infeld (DBI) action. By considering a black hole in AdS space and switching on a non-vanishing background gauge field we obtained a holographic model of conformal symmetry breaking in a strongly coupled system at finite temperature and charge density. The resulting phase diagram in the temperature-chemical potential plane is reminiscent of the phase diagram of QCD. Most of the models in chapter 3 are phenomenological since we do not know the precise string-theoretic form of the tachyon potential. The tachyon in AdS space also models dynamical chiral and electro-weak symmetry breaking of walking technicolor models. The corresponding S-

parameter of techni-quarks derived holographically from the tachyon-DBI action is positive-valued and does not vanish for the tachyon potentials considered in chapter 3. Another observation made in chapter 3 is that the tachyon-DBI model can be used to describe conformal phase transitions to a walking region in theories conformal in their single-trace sector.

In chapter 4 we provide the exact string theoretic description of a quantum field theory at finite temperature and charge density. The advantage of such a description is that it allows to consider QFT with a finite number of degrees of freedom, therefore avoiding the large-N factorization that is almost always used in systems that are studied holographically. The bulk background is a black brane with a non-trivial gauge field flux. It is obtained as a direct product of the two-dimensional charged black hole and a flat space. The advantage of the two-dimensional charged black hole is that there is a known coset $SL(2,R)$-based realization of it, and the corresponding gauged Wess-Zumino-Witten model is exactly solvable. We construct vertex operators of the massless Neveu-Schwarz-Neveu-Schwarz states, which comprise the bosonic gravity multiplet, and find two-point functions of these vertex operators. From the poles of these two-point functions we infer dispersion relations of the low-energy modes. It turns out that supergravity gives exactly the same result for these dispersion relations as string theory. We conclude that the system behaves as a sum of two non-interacting fluids. In chapter 4 we study heterotic gravity in the black brane background with a gauge field flux. The resulting low-energy spectrum is described by hydrodynamics.

Finally, in chapter 5 we summarize our results and consider them in the general context of the AdS/CFT correspondence.