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DIPOLE COUPLING EFFECT OF HOLOGRAPHIC FERMION IN CHARGED DILATONIC GRAVITY

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In this note, we study the dipole coupling effect of holographic fermion in a charged dilatonic black hole proposed by Gubser and Rocha.[1] It is found that the property of Fermi liquid is rigid under perturbation of dipole coupling, and the Fermi momentum is linearly shifted. A gap is dynamically generated as the coupling becomes large enough and the Fermi surface ceases to exist as the bulk dipole coupling further increases.

Keywords: AdS-CFT correspondence.

1. Introduction and Summary

A boundary theory dual to the AdS Reissner-Nordström black hole in the presence of a dipole interaction term is proposed[2] and studied in several following works: Refs. 3–8. Upon tuning the dipole coupling strength, the boundary theory is found in a phase of either Fermi liquid, non-Fermi liquid or Mott insulator. We remark that while the extremal AdS RN background, without dipole coupling, was first claimed to be dual to a boundary theory of non-Fermi liquid at quantum critical point,[10] it is not clear which role does the dipole coupling play in a boundary theory of Fermi liquid. It is the goal of this paper to explicitly investigate the dipole coupling effect on a particular boundary theory of Fermi liquid,[a] which is dual to the charged dilatonic black hole proposed by Gubser and Rocha.[1]

Here, we summarize our finding as follows:

- We have found the structure of Fermi surface constructed by Gubser and Rocha is *rigid* regardless of the presence of dipole coupling. There is no sign about the Fermi/non-Fermi liquid transition by varying bulk dipole coupling.

[a]A linear dispersion relation was verified in Ref. 9.

- Fermi momentum can be linearly shifted by the dipole coupling strength.
- A gap appears for large dipole coupling strength, as a generic feature of dipole interaction. However, the gap might not be the Mott one, since we could not observe any clear sign of spectral weight transfer from the spectral function.
- The gap persists at finite temperature for large enough dipole coupling.

2. Rigidity of Fermi Surface

Now we would like to introduce the dipole coupling in the charged dilatonic black hole proposed by Gubser and Rocha.[1] Let us consider the bulk spinor action,

$$\mathcal{S}_D = i \int d^4x \sqrt{-g}\bar{\psi}(\not{D} - m - ip\not{F})\psi, \tag{1}$$

We found that the dipole coupling does not change the structure of Fermi surface but just shift the location of Fermi momentum. The *gradually* disappearance of Fermi surface with increasing p at the metal-insulator transition agrees with the ARPES measurement in some strongly-correlated oxides such as $La_{1-x}Sr_xMnO_3$.[11]

We do not observe any sign of non-Fermi liquid numerically by tuning the dipole coupling strength p. The linear relation between $k - k_F$ and ω implies the Fermi surface constructed in Ref. 1 is rigid and the property of Fermi liquid remains regardless of the bulk dipole coupling. The group velocity $v_g = \partial\omega/\partial k$ can also be read off as $v_g \simeq 0.79c$ for $p \leq 1$ and slows down for larger p, say $v_g \simeq 0.5c$ for $p = 5$. We can see the pole of Green function is shifted linearly up to some value of p, before the whole system enters the insulator phase where the pole disappears. The numerical result shows the best fit for relation: $k - k_0 \propto 0.66103\, p^{1.00161}$, where $k_0 = 2.19213747$ is the numerically-found Fermi momentum at $p = 0$.

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References

1. S. S. Gubser and F. D. Rocha, "Peculiar properties of a charged dilatonic black hole in AdS_5," Phys. Rev. D **81**, 046001 (2010) [arXiv:0911.2898 [hep-th]].
2. M. Edalati, R. G. Leigh and P. W. Phillips, Phys. Rev. Lett. **106**, 091602 (2011).
3. M. Edalati, R. G. Leigh, K. W. Lo and P. W. Phillips, Phys. Rev. D **83**, 046012 (2011).
4. D. Guarrera and J. McGreevy, arXiv:1102.3908 [hep-th].
5. J. P. Gauntlett, J. Sonner and D. Waldram, Phys. Rev. Lett. **107**, 241601 (2011).
6. J. Gauntlett, J. Sonner and D. Waldram, JHEP **1111**, 153 (2011).
7. W.-J. Li and H. Zhang, JHEP **1111**, 018 (2011).
8. J. P. Wu and H. B. Zeng, arXiv:1201.2485 [hep-th].
9. J. P. Wu, Phys. Rev. D **84**, 064008 (2011).
10. H. Liu, J. McGreevy and D. Vegh, Phys. Rev. D **83**, 065029 (2011).
11. A. Chikamatsu, H. Wadati, H. Kumigashira, M. Oshima, A. Fujimori, M. Lippmaa, K. Ono, M. Kawasaki and H. Koinuma, Physical Review B **76**, 201103 (2007).