Conductivity using 'no-wall' holographic QCD model

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Introduction

AdS/CFT[1] (anti-de Sitter/conformal field theory) correspondence is an effective tool to study the dynamics of a strongly coupled system. Famously called as holography this conjecture states that using a weakly coupled gravitational system in one higher dimension we can study a strongly correlated system at the boundary of that system.

Many models have been introduce to capture the dynamics of QCD using classical supergravity framework[2, 3]. In this work we have study numerical ac conductivity in a 'no-wall' model[4]. We use Einstein-Maxwell system with the dilaton field, known as soft wall model. The soft wall model is a modified form of hard wall model with the dilaton field included to introduce the confinement in the system. Further, we have use the model as a 'no-wall' by scaling the gauge field and metric perturbations to study ac conductivity for the quark-gluon plasma at a finite charge density.

Holographic Model

The soft wall model in the Einstein-Maxwell system is given as

$$S = \int d^5x\sqrt{-g}e^{-2\phi}\left(\frac{1}{2\kappa^2}(R-2\Lambda)+\frac{1}{4g^2}F^2\right) \quad (1)$$

where F^2 is field strength with U(1) gauge field A_μ, ϕ=cu is dilaton field, $\kappa^2 = 8\pi G_5 = 1$ and $\Lambda = -6/l^2$ (l is AdS radius, set as 1) . The equations of motion are given as,

$$R_{\mu\nu} - \frac{1}{2}g_{\mu\nu}R - \Lambda g_{\mu\nu} = 8\pi G_5 T_{\mu\nu} \quad (2)$$

$$\nabla_\mu e^{-2\phi}F^{\mu\nu} = 0 \quad (3)$$

$T_{\mu\nu}$ is the energy-momentum tensor. The metric ansatz for charged black hole with negative cosmological constant is given as,

$$ds^2 = \frac{r_+^2}{l^2u}\left(-f(u)dt^2+\sum_{i=1}^{3}(dx_i)^2\right)+\frac{l^2du^2}{4u^2f(u)} \quad (4)$$

where $A_t = \mu(1-u)$ (μ is the chemical potential), $f(u) = (1-u)(1+u-au^2)$, the dilaton factor is calculated as $c = 0.388\text{GeV}^2$[5] with $a = \frac{l^2\kappa^2Q^2}{6g^2}$ and $Q = \frac{2\mu}{r_+}$.

Conductivity Flow

To study the ac conductivity numerically we have to use linearised perturbative equation for the gauge field A_x coupled with the metric perturbations for a finite charge density. Taking the fourier decomposition as given below the linearised equations of motion can be obtained.

$$g_{mn} = g^0_{mn} + \int \frac{d^4k}{(2\pi)^4}e^{-i\omega t+ikz}\tilde{h}_{mn}(k,u)$$

$$A_m = A^0_m + \int \frac{d^4k}{(2\pi)^4}e^{-i\omega t+ikz}\tilde{A}_m(k,u)$$

where g^0_{mn} and A^0_m are the background field. For 'no-wall' model we have scaled the gauge field as $\tilde{A}_x = e^{\phi}A_x$ and $\tilde{h}_{tx} = e^{2\phi}h_{tx}$ to eliminate the dilaton background(taking gauge, $A_r = 0$). Also only h^x_t metric perturbation is used for further study. Thus the equations of motion are given as:

$$A''_x + A'_x\frac{f'}{f} + A_x\left(\frac{cf'}{f} - c^2 + \frac{1}{4uf^2}(\omega^2-k^2f)\right) - \frac{A'_t h'^x_t e^{\phi}}{f} = 0 \quad (5)$$

$$\omega h'^x_t - 3a\omega u A_x = 0 \quad (6)$$

Using the equations we have shown the low frequency and momentum behavior of the AC conductivity in Fig.1. Then taking the limit

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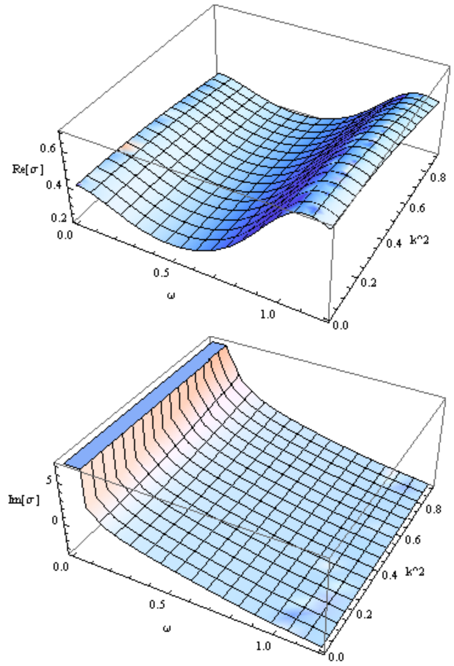

FIG. 1: 3D plot for ac conductivity for low frequency and momentum at $\mu = 0.05$

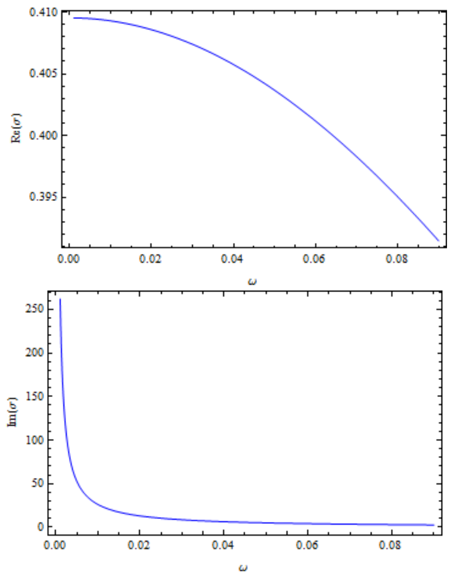

FIG. 2: AC conductivity for low frequency at $\mu = 0.05$ and $k = 0$

$k = 0$ the flow is shown in Fig.2 at $\mu = 0.05$.

Next for the probe limit the frequency dependence of AC conductivity at $\mu = 0.1$ is shown in the Fig.3 which shows the Drude peak for the real part of the conductiivty.

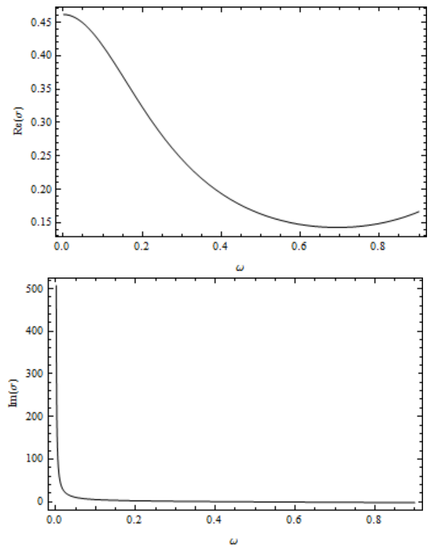

FIG. 3: AC conductivity in the probe limit at $\mu = 0.1$ and $k = 0$

Conclusions

We have shown the frequency dependence of ac conductivity in the 'no-wall' model at a fixed chemical potential. We can conclude that this model is a simple holographic model to study the transport properties of a strongly correlated system. And we can explore more novel experimentally observed features of condensed matter system using 'no-wall' model.

References

[1] J. M. Maldacena, Adv. Theor. Math. Phys. **2**, 231 (1998)
[2] T. Sakai and S. Sugimoto, Prog. Theor. Phys. **113**, 843 (2005)
[3] J. Erlich, et.al., Phys. Rev. Lett. **95**, 261602 (2005)
[4] S. S. Afonin, Int. J. Mod. Phys. A **26**, 3615 (2011)
[5] A. Karch, et.al., Phys. Rev. D **74**, 015005 (2006)