Critical phenomena of holographic superconductors in Einstein-Gauss-Bonnet gravity

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Abstract: We investigate the critical behaviors for the holographic superconductors in a Gauss-Bonnet black hole Background by the perturbation method. We find that the critical temperature, thermodynamic susceptibility, correlation length, static susceptibility and relaxation time depend on the Gauss-Bonnet parameter and the dimension of the AdS space. However, we demonstrate that the critical exponents, which take the standard mean-field values, are independent of the Gauss-Bonnet factor and the dimension.

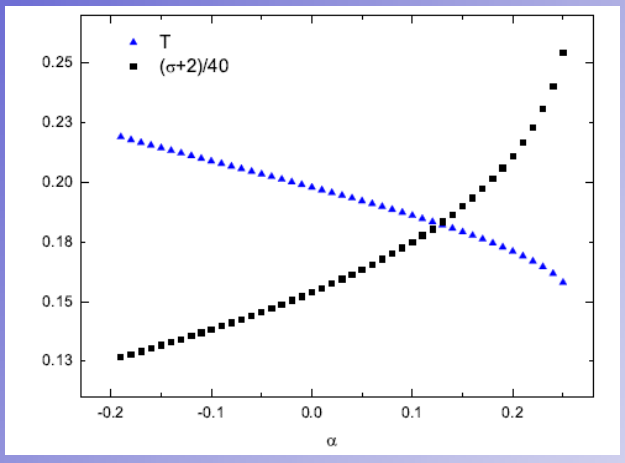
Perturbation at high-temperature phase: Considering a scalar perturbation $\psi_{\varpi,\,q}(u)e^{-i(\omega t+kx)}$ in the RN-AdS spacetime described by the metric:

$$ds^2_{p+2}=\frac{l^2}{u^2}\left[-\frac{r_H^2(1+c)^{\frac{2}{1-p}}f(u)}{J^2(u)}dt^2+\frac{J^{\frac{2}{p-1}}(u)}{f(u)}du^2+r_H^2(1+c)^{\frac{2}{1-p}}J^{\frac{2}{p-1}}(u)dx_p^2\right]$$

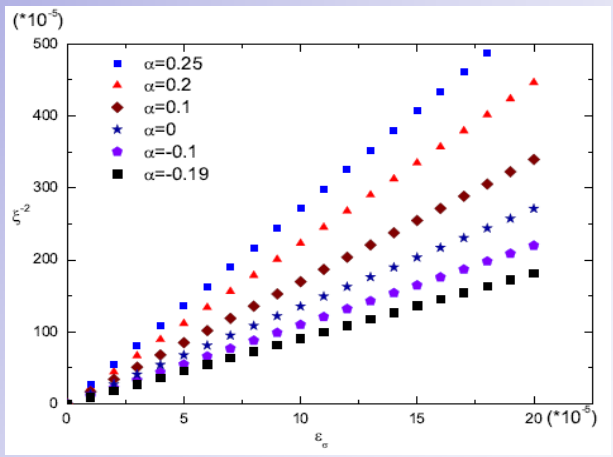
We can obtain the equation of motion of the scalar field:

$$\left[u^p\frac{d}{du}\frac{f}{u^p}\frac{d}{du}+\frac{J^{2p/(p-1)}(\varpi+\aleph)^2}{f(1+c)^{2/(1-p)}}-\frac{q^2}{(1+c)^{2/(1-p)}}-\frac{l^2m^2J^{2/(p-1)}}{u^2}\right]\psi_{\varpi,\,q}(u)=0$$

Numerically solving the equation under the boundary conditions at the horizon and AdS boundary and studying the critical behaviors of physical quantities, we can obtain the critical exponents. Furthermore, we can study the effect imposed by the Gauss-Bonnet factor and the dimensions of spacetimes on these exponents.



The values of (δ + 2)/40 (black line) and the critical temperature (blue line) as a function of Gauss-Bonnet factor α .



The correlation length ξ as a function of ξ^{-2} for different α . Plotted are for the deviation ε_σ = 10^-5*n.

Conclusions: We have made a thorough investigation on the critical behaviors for the holographic superconductors with the second-order phase transition in a charged Gauss-Bonnet black hole background by the perturbation method. The result shows that the larger Gauss-Bonnet parameters in general make the condensation harder to form while the increase of the dimension of the AdS space makes it easier for the scalar operator to condense. We discuss the thermodynamic susceptibility, correlation length, static susceptibility and relaxation time, and find that they all depend on the Gauss-Bonnet parameter and the dimension of the AdS space. In particular, it should be noted that the imaginary parts of the QNMs decrease with the increase of the Gauss-Bonnet parameter or the decrease of the dimension suggesting that it is harder for the scalar hair to form, which is consist with the behavior of the critical temperature. However, we demonstrate that the critical exponents are independent of the Gauss-Bonnet parameter and the dimension. Thus, we conclude that a holographic superconductor in Einstein-Gauss-Bonnet gravity still has the conventional mean-field behavior.

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