Oscillatory behaviors near a black hole triple point

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Studying the thermodynamics and phase transition of black holes is of great help in revealing the nature of black holes and gravity. Since the establishment of the four laws of black hole thermodynamics and discovery of the Hawking-Page phase transition, the black hole phase transition has attracted great attention, and important progress has been made in viewing the cosmological constant as the thermodynamic pressure [1, 2], which enables various interesting observations on the black hole phase transition in the so-called extended phase space. Of note, a characteristic phenomenon, the existence of the triple point, has been extensively investigated.

Recently, the authors of ref. [3] systemically studied the thermodynamics and phase dynamics for a charged black hole in the six-dimensional Gauss-Bonnet gravity [4]. It is known that three black hole phases, i.e., the small, intermediate, and large black hole phases, can coexist at the triple point. The authors first showed the phase structure in a temperature-horizon radius diagram, where a double-peak pattern presented is significantly different from that of the small-large black hole phase transition with only one peak located at the critical point.

By assuming that the phase transition can be described by a stochastic process via the thermal fluctuations [5], the dynamic process of the black hole phase transition near the triple point was investigated by numerically solving the Smoluchowski equation [3]. The evolution of the black hole

state is characterized by the probability distribution. It was revealed that no matter which phase the initial black hole is in, the system will transit to the other two phases dynamically. This confirms that the thermodynamic phase transition of a black hole can indeed occur. Of particular interest is that, during this dynamic process, strong, weak, and tiny oscillatory behaviors were observed, disclosing the non-trivial details in the dynamic process of the black hole phase transition.

The observation made in ref. [3] near the triple point shall trigger further exploration. (1) The implications of the oscillatory behavior are worthy to be further investigated. (2) More interesting dynamic properties of the phase transition are expected to be observed. Here the dynamic process of the phase transition was only examined in the anti-de Sitter space. The result may be extended to more general cases of asymptotically de Sitter and flat spaces. (3) Disclosing the imprint of black hole thermodynamics and phase dynamics among strong gravitational phenomena of black holes is also an attractive topic.

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