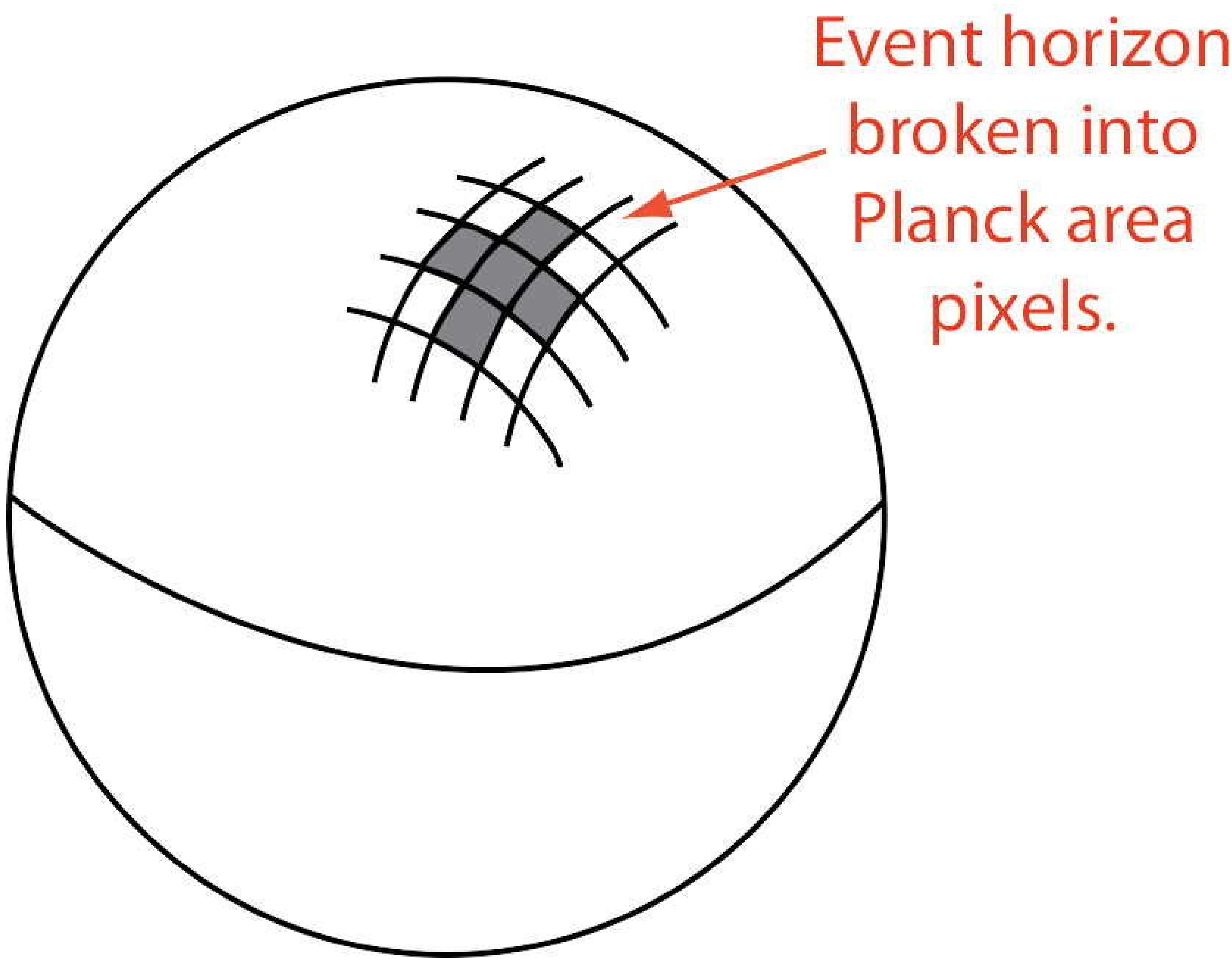
Exploring the microscopic structure of black holes from the viewpoint of thermodynamics

September 28 2018



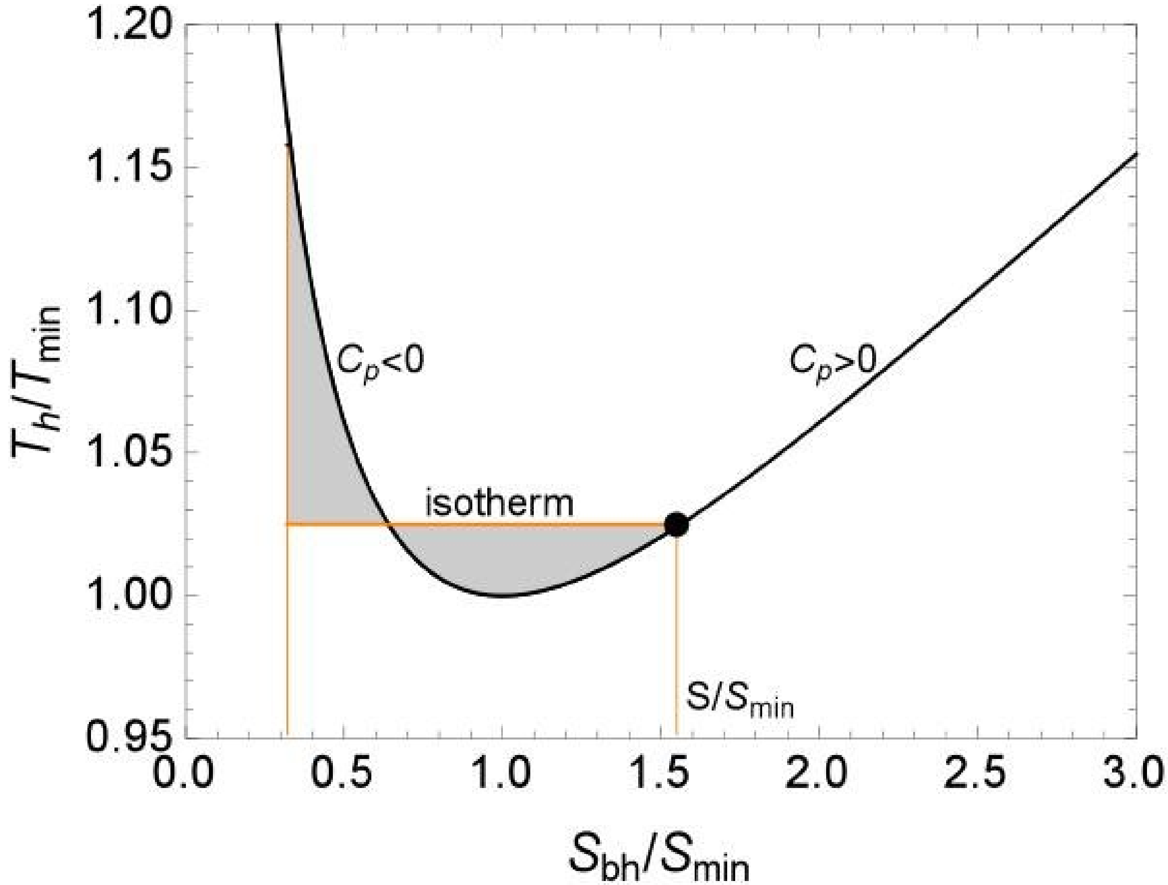
The event horizon broken up into Planck area pixels. These Planck area pixels correspond to the black-hole molecules. (This picture is taken from the article arXiv:1309.0901[gr-qc].) Credit: ©Science China Press

Since the first detection of gravitational waves by LIGO and VIRGO, black holes have aroused widespread discussion and interest. For scientists, black holes play a unique role in connecting quantum mechanics and general relativity. The microscopic structure of black holes has always been a huge problem for scientists. A recent study reveals the microscopic mystery of black holes from the viewpoint of thermodynamics.

The paper, titled "Interaction potential and thermo-correction to the equation of state for thermally stable Schwarzschild anti-de Sitter black holes," was published in *Science China Physics, Mechanics & Astronomy*. The research was completed by Professor Yan-Gang Miao and his Ph.D. student Zhen-Ming Xu, School of Physics, Nankai University.

Researchers are highly interested in studying black holes from the perspective of thermodynamics. A large number of studies have shown that black holes have temperature and entropy, and can also undergo phase transitions in certain conditions. Therefore, it has become an urgent research problem to explore the microstructure of black holes.

In the early stage, string theory and fuzzball theory were the most favorable candidates for the exploration of the microscopic structure of black holes, wherein the relevant calculations depend either on supersymmetric and extreme configurations or on other speculation. More recently, the microscopic mechanism of black holes has been explored from the viewpoint of thermodynamics. The spacetime atom approach gives a possible microscopic description of gravity through a holographic equipartition law. Moreover, Ruppeiner thermodynamic geometry deals with the macroscopic properties of black holes as thermodynamic systems by extrapolation from the concepts of black-hole molecules hypothesis (Fig.1) and the relevant number densities.



The SAdS black hole in the (Th, Sbh) plane. The black point corresponds to the thermal stable SAdS black hole with positive heat capacity at constant pressure CP>0. Credit: ©Science China Press

In this research, Ruppeiner's thermodynamic geometry method is used to study the microscopic behavior of a thermally stable SAdS black hole (Fig.2). A natural explanation for the microscopic behavior of the black hole is given. "We see that for the thermodynamically stable SAdS black hole, an attractive interaction dominates among black-hole molecules," the researchers write in the article.

At the same time, the molecular potential of a thermal stable SAdS black hole is proposed for the first time. In addition, based on the proposed molecular potential description, the thermo-correction to the equation of state for thermally stable SAdS black holes is calculated, and the rationality of the correction term is analyzed.

"We propose a new attempt to explore constituents of black holes according to the type of interaction," the researchers explained, "and this method can also be regarded as a new attempt to expand black hole thermodynamics."

The proposal of "molecular potential" in this research is of novelty and significance. On the one hand, it enriches the research content and depth of black hole thermodynamics, and on the other hand, it provides a new perspective and method for exploring the microstructure of black holes.

More information: Yan-Gang Miao et al, Interaction potential and thermo-correction to the equation of state for thermally stable Schwarzschild anti-de Sitter black holes, *Science China Physics, Mechanics & Astronomy* (2018). DOI: 10.1007/s11433-018-9254-9

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