Thermal coordinates and black hole thermodynamics

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In black hole thermodynamics, two fundamental questions arise: the black hole explosion problem and the violation of the third law of thermodynamics.

The black hole explosion problem, as discussed in [3], arises from the expression for Hawking temperature, $T = \frac{1}{8\pi M}$, which diverges as the mass $M \to 0$. A proposed solution for Schwarzschild black holes was introduced in [1], involving a modification of Kruskal coordinates by introducing thermal coordinates, represented as:

$$T = \frac{1}{\mathcal{B}(M)} = \frac{1}{2\pi(4M + b)} \tag{1}$$

As M approaches a small value, this formulation prevents the temperature from diverging, instead allowing it to settle at a constant value.

However, this method does not address the violation of the third law of thermodynamics [2], which states that entropy should approach zero as temperature approaches zero. Indeed, the entropy of a black hole depends on temperature as:

$$S = \frac{1}{16\pi T^2} \tag{2}$$

Thus, as $T \to 0$, a violation of the third law of thermodynamics occurs, as formulated by Planck. In this talk, we propose a generalization of thermal coordinates [4] that addresses both the violation of the third law and the black hole explosion problem.

References

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