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ORIGINAL ARTICLE

Study of Non-spinning black holes with reference to the change in energy and entropy

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Abstract In this research paper, we have derived the formula for both the changes in energy (δE) and entropy (δS) and thereafter calculated the change in entropy (δS) with corresponding change in energy (δE) taking account the first law of the black hole mechanics relating the change in mass M, angular momentum J, horizon area A and charge Q, of a stationary black hole, when it is perturbed, given by formula satisfying in the vacuum as $\delta M = \frac{k}{8\pi}\delta A + \Omega\delta J - \upsilon\delta Q$, specially for Non-spinning black holes.

Keywords Horizon area · Surface gravity · Entropy · Hawking temperature

1 Introduction

A stationary black hole is parameterized by just a few number (Ruffini and Wheeler 1971): its mass, electric charge and angular momentum (and magnetic monopole charge, except its actual existence in nature has not been demonstrated yet), but in order to describe a physical system, we need other information, especially entropy, which is a measurement of its disorder. The mass of a body is related to energy by Einstein's mass-energy equivalence relation $E = Mc^2$. The energy of any system is associated with entropy and a thermodynamic system at temperature T changes its state, the consequent increments of its energy E and entropy S are related by the first law of thermodynamics ($T\delta S = \delta E - \delta W$). The total entropy of a system can never decrease, i.e. $\delta S \geq 0$, leading to the second law of thermodynamics. One of the intriguing properties of a black hole is that it carries entropy much like an ordinary hot body. Work by James Bardeen, Jacob Bekenstein, Carter, and Hawking in the early 1970s led to the formulation of the laws of black hole mechanics (Bardeen et al. 1973). These laws describe the behaviour of a black hole in close analogy to the laws of thermodynamics by relating mass to energy, area to entropy, and surface gravity to temperature. The analogy was completed when Stephen Hawking showed that quantum field theory predicts that black holes should radiate like a black body with a temperature proportional to the surface gravity of the black hole (Hawking 1974). The general formula for the entropy due to Bekenstein and Hawking provides a deep connection between quantum mechanics, general relativity and thermodynamics. Gibbons and Hawking gave the first direct quantum calculation of the black hole entropy in the context of Euclidean quantum gravity. They started with a formal functional integral expression for the canonical ensemble partition function in Euclidean quantum gravity and evaluated it for a black hole in the "zero loop" approximation. They also showed that in the case of a stationary system such as a star with no event horizon, the gravitational field has no entropy (Gibbons and Hawking 1977). Brown J.D. and York, J.W. had given a derivation of a black hole entropy using micro canonical ensemble (Brown and York 1993). Another approach to the calculation of black hole entropy has been to attribute it to the "entanglement entropy" resulting from quantum field correlations between the exterior and interior of the black hole (Holzhey et al. 1994; Callen and Wilzcek 1994). Strominger and Vafa showed that counting the microstates (entropy in statistical mechanics)

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