Quantum corrections to the general relativistic description of the near-horizon region of a Schwarzschild black hole

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Abstract

We examine how a Schwarzschild black hole back-reacts to constantly fluctuating inhomogeneous vacuum density. More precisely, by embracing the microscopically singular expectation value of the local energy density of the inhomogeneous vacuum fluctuations (as predicted by quantum field theory), we study how a black hole metric back-reacts in two distinct regions: the vicinity of the black hole, and onto the horizon. As a result, we demonstrate that fluctuations of the inhomogeneous vacuum above a given threshold, considered onto the horizon, cause deviations from the traditional general relativistic description. Meanwhile, fluctuations below that threshold, considered in the vicinity of the horizon, lead to metric fluctuations of order the Schwarzschild radius. Physically, the conjectured modifications to general relativity, induced by the strong vacuum fluctuations onto the horizon, were argued to lead to nonlocal release of information-carrying Hawking particles. On the other hand, we argue that the weak fluctuations in the near-horizon region yield potentially observable macroscopic quantum gravity effects in the form of metric fluctuations of order the Schwarzschild radius. That is, constant oscillations of the horizon between $r = 2M$ and $r = 2M + \delta$. As far as a distant observer is concerned, she may interpret the conjectured metric fluctuations as a physical membrane just outside the horizon. Thus the proposed metric fluctuations may serve as the microscopic origin of the stretched horizon in observer complementarity. Also, we assume the proposed metric fluctuations play a significant role in binary black hole mergers.

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