A self-consistent description of time evolution of black holes including collapsing matter and Hawking radiation

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Abstract

What happens to objects falling into an evaporating black hole? We examine this problem in a self-consistent manner. First, we consider a 4D spherically symmetric collapsing matter consisting of s-wave excitations of massless scalar fields, and we analyze the time evolution by eikonal approximation. Particle creation occurs due to the time dependence of the spacetime, and its back reaction also needs to be considered. As a result, a compact high-density star with no horizon or singularity is formed and eventually evaporates. This is a quantum black hole. We can construct a self-consistent solution of the semi-classical Einstein equation showing this structure. In fact, we solve the massless scalar fields on this spacetime metric, evaluate the energy momentum tensor and prove the self-consistency. Large pressure appears in the angular direction to support this black hole, and it is generated by the vacuum fluctuations of the components of the fields having large angular momenta. Furthermore, we will investigate the time evolution of the wave function of the collapsing matter on this space-time. As a result, the information finally returns with almost no energy, and most of the energy flux is created from the initial vacuum state. Finally, if we count the number of possible microscopic states of a reversibly formed stationary black hole, the area law of entropy is reproduced.

Ref:
H. Kawai, Y. Matsuo, and Y. Yokokura, Int. J. Mod. Phys. A **28**, 1350050 (2013), H. Kawai and Y. Yokokura, Int. J. Mod. Phys. A **30**, 1550091 (2015); Phys. Rev. D **93**, no. 4, 044011 (2016); Universe **3**, no. 2, 51 (2017); to be appeared.

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