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Entropy of the Hawking radiation

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Hawking showed that the von Neumann or fine-grained entropy of the radiation emanating from an evaporating black hole monotonically increases throughout the black hole's lifetime. This suggests that black hole formation and evaporation can evolve a pure quantum state of a collapsing star into a mixed quantum state of the Hawking radiation. This is in direct conflict with the unitarily of time evolution in quantum mechanics, which requires that the radiation entropy vanishes once the black hole has completely evaporated. I will review some recent progress on this issue and discuss a new formula for computing the von Neumann entropy of the radiation that more carefully accounts for the gravitational nature of the theory. It predicts that the entropy of the radiation far away from the black hole can receive contributions from the black hole interior, including a term coming from the area of a surface near the event horizon. I will show how this formula produces an entropy that is consistent with unitary black hole evaporation and gives the so-called "Page curve" of an entropy that initially rises but then ultimately diminishes down to zero.

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