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Growth of Perturbations near a Rapidly Spinning Black Hole

SAMUEL GRALLA, University of Arizona

Aretakis discovered a horizon instability of extremal black holes, wherein transverse derivatives of axisymmetric perturbations grow polynomially in advanced time on the horizon. Since no physical black hole can be precisely extremal, nor any physical perturbation precisely axisymmetric, the physical implications rest on generalization to nonaxisymmetric perturbations of near-extreme black holes. We analytically study the response of a near-extremal Kerr black hole to generic external scalar, electromagnetic, and gravitational field perturbations. We show that the energy density, electromagnetic field strength, and tidal force experienced by infalling observers exhibit transient growth near the horizon. As the black hole spin is increased, the growth lasts arbitrarily long and occurs arbitrarily near the horizon, reproducing the Aretakis instability in a smooth way. We explain these results in terms of near-horizon geometry and discuss potential astrophysical implications.