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Spectral instability in fundamental mode and high overtones

We propose a criterion for the emergence of instability in the quasinormal modes, particularly the fundamental mode, as recently observed by Cheung et al., identifying it as a universal feature in black hole perturbations. The instability manifests as an exponentially growing spiral that deviates from quasinormal frequencies due to a slight perturbation moving away from the compact object. We begin by examining a specific case involving a truncated Pöschl-Teller potential, where we derive the conditions for the onset of instability. Our analysis reveals that while the fundamental mode remains stable in this scenario, instability arises for high overtones (n » 1). This result is then generalized to a broader class of potentials through two mathematical frameworks: one based on poles in the black hole's reflection amplitude and the other on zeros in the transmission amplitude. We also revisit and extend a toy model with disjointed perturbations to the effective potential, showing that such configurations invariably induce instability in the fundamental mode, with the resulting outward spiral always occurring counterclockwise. Our numerical results, which align well with analytical predictions, support our findings by accurately capturing the spiral's period and the relative frequency deviation.

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