

# Tails and tails of tails: Probing event horizon via gravitational waves

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Solutions of perturbations of black hole consists of both ingoing and outgoing waves. When we approach the horizon the outgoing one vanishes. This is consistent with what we expect from the black hole horizon that absorbs all the waves. However, considering the finiteness of the derivatives of solution with respect to a suitable regular coordinate, it appears that it diverge for slowly damping modes. Therefore, depending on the order of derivatives of fundamental equations of motion, the solution is restricted for certain types of waves that only allows finite number of dominant quasi-normal modes to be produced in black hole perturbation. For the rest of the modes we would have continuum spectrum. The finiteness condition also allows outgoing damping waves  $\omega = \omega_R - i\omega_I$  to be excited from ingoing natural modes of ringdown near the horizon with damping frequency of  $\omega_I \geq 1/2M$  through the backreaction process in GR. This observation that rely on order of fundamental equations of motion gives rise to possible existence of postmerger outgoing gravitational wave (tails of tails ringdown), provides mechanism to test order of fundamental equations of motion, and introduces a soft boundary condition for quasi-normal modes.

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