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Phenomenology: Orthogonality and transitions between black-hole quasibound states

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It is well known that the response of a black hole (BH) to an external perturbation consists in a series of damped sinusoids, dictated by complex frequencies called quasi-normal modes (QNMs). Massive fields also admit a different family of solutions called quasi-bound states (QBSs). Both families of modes dissipate energy at the BH horizon, and QNMs also radiate at infinity. This dissipation causes the non-Hermiticity of the system, and hence a normal-mode spectral analysis is not possible as the spectral theorem does not guarantee the orthogonality of these modes. In a recent work, we introduced a bilinear form under which scalar, massive QBSs (and massive QNMs) are orthogonal in a Kerr background. This product is obtained in a fully relativistic framework, and reduces to the hydrogenic inner product in the non-relativistic limit. Finally, as a practical application, we showed how this bilinear form allows to compute the excitation of modes due to a perturbation to the BH potential, due e.g. to an extreme-mass-ratio companion.

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