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Complete quasinormal modes of Type-D black holes

We developed a revolutionary new method to precisely calculate the full spectrum of vibrations (quasinormal modes, QNMs) emitted by black holes after collisions. This solves two major, decades-old theoretical puzzles: 1. The Spin Discrepancy Solved: The apparent discontinuity between spinning (Kerr) and non-spinning (Schwarzschild) black hole vibrations as the spin vanishes ($a \longrightarrow 0$) is an artifact of old methods. They couldn't calculate specific vibration modes crossing a key mathematical boundary (the negative imaginary axis). Our new method reveals the smooth transition. 2. The Special Frequency Puzzle Solved: When a QNM vibration frequency exactly coincides with a mathematically "special" (Algebraically Special, AS) frequency, an extra "unconventional" vibration mode appears nearby. This explains their spectral proximity. Crucially, for spinning black holes ($\ell=2$), the overtone sequences form exactly 5 distinct branches ($2\ell+1$), resolving the anomalous splitting without supersymmetry breaking. Our method is faster and more powerful than the best existing techniques (like Cook's continued fraction), calculating overtones with incredible precision (errors $< 10^{-10}$). It provides a definitive mathematical framework for these dissipative systems and confirms key theoretical predictions. This breakthrough gives a complete and accurate picture of how black holes ring.

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