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On black hole spectroscopy using overtones

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Validating the no-hair theorem with a gravitational wave observation from a compact binary coalescence presents a compelling argument that the remnant object is indeed a black hole described by the classical general theory of relativity. Validating this theorem relies on performing a spectroscopic analysis of the post-merger signal and recovering the frequencies of either different angular modes or overtones (of the same angular mode). For an equal mass binary black hole systems, the angular modes apart from $l = m = 2$ are not adequately excited but the overtones provide a prospect to perform this test. We discuss some challenges associated with performing as well as interpreting the results of the tests performed using black hole overtones. We investigate the robustness of modelling the post-merger signal of binary black hole coalescence as a superposition of overtones as well as study the bias expected in recovered frequencies as a function of the start time of the analysis. We provide a computationally cheap procedure to pick an optimal time to start the spectroscopic analysis of post-merger signal. Further, we find that resolving the frequencies of the overtones can be particularly challenging and requires high ringdown SNRs; for instance, the Rayleigh resolvability criterion suggests that for an event like GW150914, an SNR ~ 200 is necessary to resolve the overtone frequencies.

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