Measuring higher order black hole ringdown modes with Advanced LIGO

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The remnant black hole formed by a binary black hole merger is expected to eventually settle down to a Kerr black hole. The final observable part of the signal, the ringdown, is predicted to consist of a superposition of damped sinusoids, known as quasi-normal modes, characteristic of the final Kerr black hole. Measurement of the quasi-normal modes can enable us to test the predictions of general relativity about the Kerr nature of the final object, such as the no-hair theorem[1], and also allows us to analyse the ringdown signature to constrain proposed alternative theories [2, 3]. Many of these tests require the measurement of higher order modes, which have not yet been detected [4], in addition to the dominant one. Indeed, some previous studies argue that detection of these subdominant modes will require third-generation or space-based detectors [5].

We present a new method employing Bayesian inference to detect the presence of subdominant quasi-normal modes and to estimate their parameters. Our analysis utilises waveform models based on perturbations of the Kerr metric as well as an agnostic approach allowing for deviation from the Kerr assumption. We perform a study of the population of black hole mergers and find the expected rate of events with higher modes detectable through our method for Advanced LIGO at design sensitivity.

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