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Modeling mode amplitudes in precessing binary black-hole ringdown

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Amplitudes of quasi-normal modes in the gravitational-wave signal emitted during the ringdown phase of a binary black-hole merger provide valuable insights into the strong-field non-linear dynamics of the pre-merger phase. While several studies have modeled mode amplitudes for spin-aligned sources, the more complex scenario of precessing sources has received less attention. In this work, we analyze approximately 2000 waveforms from the SXS catalog of numerical relativity simulations to investigate the phenomenology of mode amplitudes in precessing systems. Similar to the spin-aligned case, we find that the (2,±2) modes are generally dominant. However, the hierarchy of subdominant modes for precessing sources is more complex, with modes such as (2,±1) and (2,0) sometimes becoming as prominent as the (2,±2) modes in some rare edge cases. Additionally, we introduce initial models for (2,m) and (3,±3) modes using Gaussian Process Regression, a Bayesian supervised regression algorithm which can address the high dimensionality of the parameter space and data sparsity.

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