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Measuring eccentricity in binary black hole mergers

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Measuring eccentricity from gravitational wave signals is of fundamental importance in order to address questions about the origin and formation of stellar-mass binary black holes. In this work we present a new, systematic set of spinning but non-precessing numerical relativity (NR) simulations of eccentric binary black hole coalescences, with initial eccentricities up to 0.3 and mass ratios between 1 and 4. We develop a robust pipeline for measuring the eccentricity evolution from numerical relativity waveforms that is applicable even to short-duration signals. We investigate the reliability of this procedure by quantifying its accuracy and assess how the length of the NR waveform impacts the measurement of eccentricity, especially when extrapolating to low frequencies. Using the measured values of eccentricity as initial conditions, we generate effective-one-body waveforms and quantify how the precision in the eccentricity measurement, and therefore the choice of the initial conditions, impacts the agreement with the NR data. We find that even small deviations in the initial eccentricity can lead to non-negligible differences in the phase and amplitude of the waveforms. However, we find that we can reliably match the eccentricities between NR data and analytic models, which is crucial for robustly building eccentric hybrid waveforms, and can subsequently be used to improve the accuracy of models in the strong-field regime.

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