Measurement of sub-dominant harmonic modes for gravitational wave emission from a population of binary black holes

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Dated: March 15, 2019

Abstract

Measurements of multiple harmonic modes in the gravitational wave signals from binary black hole events could provide an accurate test of general relativity, however they have never been observed. The sub-dominant modes, other than the main (l = 2, m = 2) mode, are weak in amplitude and thus difficult to detect in a single event at the current sensitivity of the gravitational-wave detectors. To recover sub-dominant modes, we use an unmodeled method for summation of signals from a population of binary black holes. The method coherently stacks all signal modes, so the amplified signal can be extracted from the noisy data. To test the method, we consider a population of binary black holes and use the coherent WaveBurst algorithm for signal detection and reconstruction. With no a priori information about the signal model, we determine the transformation to coherently synchronize the merger and post-merger of one signal to another. We demonstrate the synchronization of multiple signals and show the efficient stacking of the (2, 2) mode and the sub-dominant modes. We apply this method to the ten binary black hole events which have been detected by Advanced LIGO.