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Fast likelihood evaluation of eccentric–precessing binaries using relative binning

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As gravitational-wave detectors gain sensitivity at low frequencies, inferring source properties becomes challenging due to long-duration signals and high signal-to-noise ratios. With enhanced low-frequency sensitivity, we also expect to observe many more eccentric binaries, with potentially a large impact on our understanding of binaries. The presence of orbital eccentricity enhances the emission of GW radiation not only at twice the orbital frequency but also across a whole spectrum of integer multiples of the orbital frequency. Consequently, eccentric waveforms are complex and computationally expensive, with both effects increasing with eccentricity.

We present an efficient scheme for likelihood evaluation of eccentric–precessing signals using the relative binning method. Our approach constructs the relative binning approximation mode by mode, enabling accurate incorporation of higher harmonics enhanced in eccentric systems. We apply this method to low-mass binaries with lower cutoff frequencies of 20 Hz and 5 Hz, relevant to current and future detectors. For second-generation detectors, our method achieves speed-ups of a factor of 5–20 compared to standard frequency-domain calculations. For Einstein Telescope, the computational gain is more dramatic, with likelihood evaluations accelerated by a factor of 50–1000, while maintaining accuracy. Finally, we demonstrate that posterior distributions inferred with our method are statistically indistinguishable from those obtained with exact likelihood evaluations.

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