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Overlapping signals in next-generation gravitational wave observatories: A recipe for selecting the best parameter estimation technique

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Third-generation gravitational wave detectors such as Einstein Telescope and Cosmic Explorer will have significantly better sensitivities than current detectors, as well as a wider frequency bandwidth. This will increase the number and duration of the observed signals, leading to many signals overlapping in time. If not adequately accounted for, this can lead to biases in parameter estimation. Our recent work combines the joint parameter estimation method with relative binning to handle full parameter inference on overlapping signals from binary black holes, including precession effects and higher-order mode content [1]. As the joint parameter estimation is computationally more expensive than traditional single-signal parameter estimation, it is crucial to devise a method to determine which method suits the problem at hand, i.e., when joint parameter estimation is necessary and when traditional single-signal parameter estimation is sufficient when analysing two overlapping signals. In an initial step, we test a time-frequency overlap method and a prior-informed Fisher matrix to help us decide when joint parameter estimation is necessary. We find the former method to be accurate in 86% of close binary black hole mergers. We improve upon previous Fisher matrix implementations by including the prior information and performing an optimization routine to better locate the maximum likelihood point point, but we still find the method unreliable. We end by developing our own method of estimating bias due overlaps, where we reweight the single signal parameter estimation posterior to quantify how much the overlapping signals affect it. We show it has 99% accuracy for zero noise injections (98% in Gaussian noise), at the cost of one additional standard sampling run when joint parameter estimation proves to be necessary.

1. T. Baka et al., “Overlapping signals in next-generation gravitational wave observatories: A recipe for selecting the best parameter estimation technique,” Phys. Rev. D. (2025), arXiv:2507.10304 [gr-qc].

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