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Impact of Massive Black Hole Binaries Source Confusion on Uncertainties of Parameters Estimation in Space-based Gravitational Wave Detection for the TaiJi Mission

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We systematically investigate the impact of source confusion on parameter estimation for massive black hole binaries (MBHBs) in the context of the Taiji space-based gravitational wave mission. Source confusion, arises from simultaneous overlap of signals in both time and frequency domains, can degrade the accuracy of parameter recovery. To assess this effect, we simulate MBHB populations using three representative models and estimate the prevalence of overlapping events. Assuming a detection rate of 50 events per half-year, we find that genuine source confusion is relatively rare, with only 0.16 to 2.1 overlapping events expected per half-year, depending on the model. We quantify parameter uncertainties using both the Fisher information matrix and Markov chain Monte Carlo (MCMC) techniques. Employing the IMRPhenomD waveform model, as conventionally used in the literature, we show that parameter uncertainties can increase significantly, while the inclusion of higher-order modes (HMs) in the waveform model effectively mitigates this degradation. The uncertainty ratio $\gamma - 1$ can exceed $\mathcal{O}(10^1)$ even when higher-order modes (HMs) are included, provided that the relative chirp mass difference $\Delta\mathcal{M}_z/\mathcal{M}_z$ is below 0.2\%, while such strong degeneracies occur in fewer than 0.14\% in all three population models. MCMC results not only confirm Fisher's forecasts but also reveal that HMs help break key parameter degeneracies, with or without signal overlap. These findings underscore the importance of incorporating HMs in waveform modeling for robust and accurate inference in future space-based gravitational wave observations.

Collaboration you are representing

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