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Costs of Bayesian Parameter Estimation in Third-Generation Gravitational Wave Detectors

Bayesian inference with stochastic sampling has been widely used to obtain the properties of gravitational wave (GW) sources. Although computationally intensive, its cost remains manageable for current second-generation GW detectors because of the relatively low event rate and signal-to-noise ratio (SNR). The third-generation (3G) GW detectors are expected to detect hundreds of thousands of compact binary coalescence (CBC) events every year with substantially higher SNR and longer signal duration, presenting significant computational challenges. In this study, we systematically evaluate the computational costs of {CBC} source parameter estimation (PE) in the 3G era by modeling the PE time cost as a function of SNR and signal duration. We examine the standard PE method alongside acceleration methods including relative binning, multibanding, and reduced order quadrature. We predict that PE for a one-month-observation catalog with 3G detectors could require {at least billions} of CPU core hours with the standard PE method, whereas acceleration techniques can reduce this demand to {less than millions} of core hours, {which is as high as the cost of analyzing GW events in the past 10 years}. These findings highlight the necessity for more efficient PE methods to enable cost-effective and environmentally sustainable data analysis for 3G detectors. In addition, we assess the accuracy of accelerated PE methods, emphasizing the need for careful treatment in high-SNR scenarios.

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