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Benchmarking field-level inference from galaxy surveys and its application to primordial non-Gaussianity analysis

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Field-level inference has emerged as a powerful framework to fully exploit cosmological information from next-generation galaxy surveys. It involves performing Bayesian inference to jointly estimate the cosmological parameters and initial conditions of the cosmic field directly from the observed galaxy density field. However, the computational feasibility of MCMC (Markov Chain Monte Carlo) sampling methods for large-scale field-level inference remains an open question. To address this, we introduce a standardized benchmark using a fast, differentiable galaxy density simulator based on JaxPM. We evaluate various sampling techniques, including Hamiltonian Monte Carlo (HMC), the No-U-Turn Sampler (NUTS), and Microcanonical Langevin Monte Carlo (MCLMC), comparing their efficiency in generating independent samples per model evaluation. Our results demonstrate that careful preconditioning of latent variables is crucial, and that MCLMC outperforms other methods by an order of magnitude in efficiency while maintaining minimal bias in the marginal posterior.
These methodological advances pave the way for applying field-level cosmological inference to galaxy surveys. Specifically, we explore its application to the analysis of primordial non-Gaussianity (PNG) using DESI data, with a particular focus on a rigorous field-level treatment of imaging systematics.

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