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Assessing and Benchmarking the Fidelity of Posterior Inference Methods for Astrophysics Data Analysis

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In this era of large and complex astronomical survey data, interpreting, validating, and comparing inference techniques becomes increasingly difficult. This is particularly critical for emerging inference methods like Simulation-Based Inference (SBI), which offer significant speedup potential and posterior modeling flexibility, especially when deep learning is incorporated. We present a study to assess and compare the performance and uncertainty prediction capability of Bayesian inference algorithms –from traditional MCMC sampling of analytic functions to deep learning-enabled SBI. We focus on testing the capacity of hierarchical inference modeling in those scenarios. Before we extend this study to cosmology, we first use astrophysical simulation data to ensure interpretability. We demonstrate a probabilistic programming implementation of hierarchical and non-hierarchical Bayesian inference using simulations derived from the DeepBench software library, a benchmarking tool developed by our group that generates simple and controllable astrophysical objects from first principles. This study will enable astronomers and physicists to harness the inference potential of these methods with confidence.

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