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The future of cosmological likelihood and simulation-based inference

Monday, 27 January 2025 14:00 (20 minutes)

I will discuss a new paradigm for cosmological likelihood-based inference, leveraging recent developments in machine learning and its underlying technology, to accelerate Bayesian inference in high-dimensional settings. This paradigm combines (i) emulation, where a machine learning model is trained to mimic cosmological observables, e.g. CosmoPower-JAX; (ii) differentiable and probabilistic programming, e.g. JAX and NumPyro, respectively; (iii) scalable Markov chain Monte Carlo (MCMC) sampling techniques that exploit gradients, e.g. Hamiltonian Monte Carlo; and (iv) decoupled and scalable Bayesian model selection techniques that compute the Bayesian evidence purely from posterior samples, e.g. the learned harmonic mean implemented in harmonic. This paradigm allows to carry out a complete Bayesian analysis, including both parameter estimation and model selection, in a fraction of the time of traditional approaches. For instance, if we consider a joint analysis between three simulated next-generation surveys, each performing a 3x2pt analysis resulting in more than 150 parameters, standard nested sampling techniques are simply unlikely to be feasible, requiring a projected 12 years of compute time on 48 CPU cores; on the other hand, the proposed approach only requires 8 days of compute time on 24 GPUs. I will also discuss recent developments in simulation-based inference which promise to overcome the limitations of likelihood-based approaches, especially in light of the SKAO and its precursors like MWA, and which will be crucial for the SKA Science Data Challenge 3b.

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