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Simulation Based Inference from the CD-EoR 21-cm signal

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Cosmic Dawn (CD) and Epoch of Reionization (EoR) are epochs of the Universe which host invaluable information about the cosmology and astrophysics of X-ray heating and hydrogen reionization. Radio interferometric observations of the 21-cm line at high redshifts have the potential to revolutionize our understanding of the Universe during this time. However, modelling the evolution of these epochs is particularly challenging due to the complex interplay of many physical processes. This makes it difficult to perform the conventional statistical analysis using the likelihood-based Markov-Chain Monte Carlo (MCMC) methods, which scales poorly with the dimensionality of the parameter space. We show how the Simulation-Based Inference through Marginal Neural Ratio Estimation (MNRE) provides a step towards evading these issues. We use 21cmFAST to model the 21-cm power spectrum during CD–EoR with a six-dimensional parameter space. With the expected thermal noise from the Square Kilometre Array, we are able to accurately recover the posterior distribution for the parameters of our model at a significantly lower computational cost than the conventional likelihood-based methods. We further show how the same training data set can be utilized to investigate the sensitivity of the model parameters over different redshifts. Our results support that such efficient and scalable inference techniques enable us to significantly extend the modelling complexity beyond what is currently achievable with conventional MCMC methods.

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