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21cmEMU3: an emulator of 21cmFAST summary observables

The cosmic dawn (CD) of the first luminous objects and eventual reionisation (EoR) of the intergalactic medium (IGM) remain among the greatest mysteries in modern cosmology. The 21-cm line is one of the most powerful probes of these crucial moments in the history of the Universe, providing a clean window into both cosmology and astrophysics. Current 21-cm observations are upper limits on the power spectrum (PS) from instruments such as LOFAR, HERA, and MWA. Upcoming instruments, such as the SKA, will provide a detection of the 21-cm PS as well as a 3D map of the neutral hydrogen content of the Universe. A great deal of computational resources are required to improve our understanding of the CD/EoR via Bayesian inference. Past works have found that artificial neural networks significantly reduce the computational costs while accurately reproducing posteriors obtained with the simulator. While most past works focus on emulating a single summary statistic, we focus on emulating several as it is the synergy between different probes that allows us to produce the best constrains. Previously, we presented 21cmEMU1, an emulator that allows us to perform state-of-the-art inferences in over 10^5 times faster than traditional inferences. In this work, we present 21cmEMU3, an emulator of six summary statistics, including, among others, the cylindrical (2D) 21-cm power spectrum, and the ultra violet luminosity functions. This emulator is trained on more realistic simulations from 21cmFAST than 21cmEMU1. In this new database, we have a total of about 50k samples where we vary 10 astrophysical parameters and σ_8. 21cmEMU3 is the first emulator of cylindrical 21-cm PS, as well as the first score-based generative emulator of the 2D PS. 21cmEMU3 is also the first LSTM emulator of four of the remaining five summary statistics. We apply 21cmEMU3 on previous and upcoming 21-cm PS upper limits from the HERA instrument.

AI keywords

score-based diffusion; LSTM; Bayesian inference;

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Track Classification: Simulations & Generative Models