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Extraction of Global 21-cm Signals from Cosmic Dawn and Epoch of Reionization with Chromatic Ionospheric Effects using ANN

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The Epoch of Reionization (EoR) and Cosmic Dawn (CD) are pivotal phases in the early Universe, shaping its structure during its first billion years. The properties of the Intergalactic Medium (IGM) during these periods remain poorly understood through observations [2]. Current and upcoming radio telescopes, such as EDGES, SARAS, MWA, and SKA, aim to detect the redshifted HI 21-cm signal but face significant challenges due to systematic errors and the need for precise foreground removal. Additionally, the Earth's ionosphere introduces distortions at lower frequencies, including direction-dependent and chromatic effects of the primary beam, complicating the detection of the global 21-cm signal [4, 1, 3]. Therefore, understanding each source of corruption is crucial when using non-parametric techniques for accurately detecting the 21cm signal. To address these challenges, we utilize Artificial Neural Networks (ANNs) to extract the global 21-cm signal parameters from the combined all-sky averaged signal, which includes foreground, ionospheric, and beam chromatic effects. Our approach models ionospheric phenomena such as refraction, absorption, and thermal emission. To examine the impact of beam chromaticity on the detection of the global 21cm signal. We employ advanced modelling techniques to simulate the chromatic effects and develop strategies to mitigate their influence. By incorporating detailed simulations of the beam's frequency-dependent behaviour, we assess the extent to which chromaticity affects the accuracy of signal recovery. Our trained model shows promise for improving ground-based observations, demonstrating significant accuracy in recovering signal parameters from both the Cosmic Dawn (CD) and the Epoch of Reionization (EoR) using synthetic observations of global signal experiments. Our methodology provides a robust framework for overcoming observational challenges and enhancing our understanding of these critical cosmic epochs.

References

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