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The Impact of Sky Model Defects on SKA EoR Experiments: A Source Blending Case Study

Twenty-one-centimetre signals from the Epoch of Reionization (EoR) are expected to be detected in the low-frequency radio window by the next-generation interferometers, particularly the Square Kilometre Array (SKA). However, precision data analysis pipelines are required to minimize the systematics within an infinitesimal error budget. Consequently, there is a growing need to characterize the sources of errors in EoR analysis. In this study, we identify one such error origin, namely source blending, which is introduced by the overlap of objects in the densely populated observing sky under SKA1-Low's unprecedented sensitivity and resolution, and evaluate its two-fold impact in both the spatial and frequency domains using a novel hybrid evaluation (HEVAL) pipeline combining end-to-end simulation with an analytic method to mimic EoR analysis pipelines. Sky models corrupted by source blending induce small but severe frequency-dependent calibration errors when coupled with astronomical foregrounds, impeding EoR parameter inference with strong additive residuals in the two-dimensional power spectrum space. We report that additive residuals from poor calibration against sky models with blending ratios of 5 and 0.5 per cent significantly contaminate the EoR window. In contrast, the sky model with a 0.05 per cent blending ratio leaves little residual imprint within the EoR window, therefore identifying a blending tolerance at approximately 0.05 per cent. Given that the SKA observing sky is estimated to suffer from an extended level of blending, strategies involving de-blending, frequency-dependent error mitigation, or a combination of both, are required to effectively attenuate the calibration impact of source-blending defects.

Reference:

* Shan,+ 2024: An evaluation of source-blending impact on the calibration of SKA EoR experiments

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