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Foreground Mitigation and Calibration with HERA

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1 Abstract

The Hydrogen Epoch of Reionization Array (HERA) has been optimized to measure 21 cm emission from the primordial intergalactic medium (IGM) throughout cosmic reionization ($z = 6$–12), with support for exploring earlier stages of our Cosmic Dawn ($z \sim 30$). During these epochs, early stars and black holes heat and ionize the IGM, introducing fluctuations in 21 cm emission. HERA characterizes the evolution of the 21 cm power spectrum in detail to constrain the timing and morphology of reionization, the properties of the first galaxies, the evolution of large-scale structure, and the early sources of heating in the IGM.

HERA is working to develop a hybrid approach to calibration that incorporates both sky-based and redundancy-based features, modeling instrument and sky systematic uncertainties to minimize their impact on analysis. Several features of the HERA instrument may be leveraged to support this. The compact, staggered core of HERA's antenna configuration furnishes redundant measurements sampled on a sub-aperture scale. This allows one to use partial coherence to instantaneously solve for degrees of freedom in the HERA beam within a redundant calibration framework and provides the dense multiply sampled *uv*-coverage needed to develop precise foreground models. HERA's dense grid also provides numerous interferometric baselines that sample identical angular modes at different frequencies. Using redundancy along the frequency axis provides a natural framework for determining the spectral evolution of an instrument and for constraining the amount of spectral structure that can be absorbed into a calibration model. However, to be effective, these calibration models must be informed by sky-based calibration results in order to parametrize them effectively.

In this talk, we assess the current state of calibration and foreground mitigation in HERA data and examine how these are impacted by the design of the HERA instrument. We offer some lessons garnered from HERA and one of its predecessors, the Precision Array for Probing the Epoch of Reionization (PAPER), and discuss near-term and more speculative analysis techniques that might help control how smooth-spectrum foregrounds interact with an inherently chromatic instrumental response.