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Analysing the effect of calibration errors and instrumental noise on HI 21-cm maps from the EoR using the LCS

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The early universe, within its first billion years, underwent two pivotal phases: the Cosmic Dawn (CD) and Epoch of Reionization (EoR). These periods are believed to have significantly shaped the large-scale structure of the universe. However, current observations have yet to definitively characterize the Intergalactic Medium (IGM) properties during these epochs, leaving a gap in our understanding. Studying this crucial epoch is essential to understanding cosmic history. The evolving 21-cm line from the neutral hydrogen in the IGM serves as a vital probe of this era. The highly sensitive next-generation telescopes such as the Square Kilometer Array (SKA1-Low) can make the tomographic map of the evolving 21-cm signal. However, the observation of a 21-cm signal is a very challenging experiment because of the astrophysical foreground, Earth's ionosphere, instrumental effect and other systematic effects.

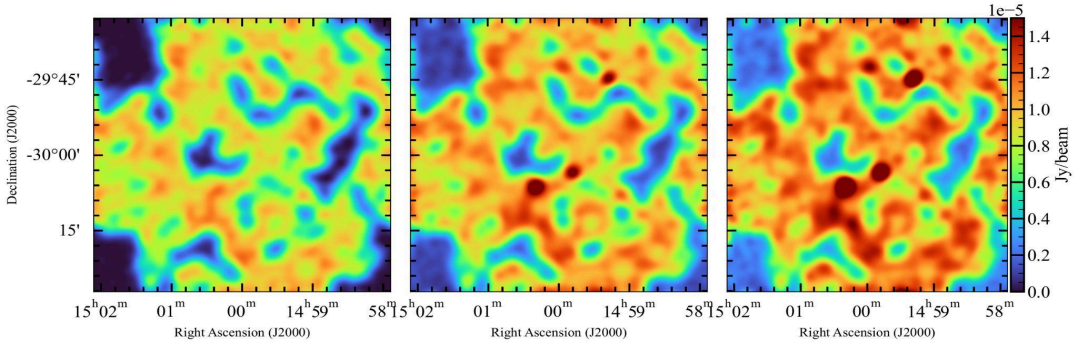

Figure 1: Comparison of the slices of the brightness temperature map without gain error (left) and with gain error (middle & right).

This work investigates the evolution of reionization using a novel statistic, the Largest Cluster Statistic (LCS). We focus on the morphological and topological changes of ionized regions during different stages of reionization, particularly at the percolation transition. We assess the effect of the array's synthesized beam on the development of LCS estimation, observing that the percolation transition shifts towards the later stages of reionization [1]. Furthermore, we investigate the effect of antenna-based gain calibration error and instrumental noise of SKA1-Low on the LCS analysis. We quantified the bias introduced by these effects in synthetic radio observation using the 21cmE2E pipeline [2] of ionized region morphology. This allows us to draw inferences about the history of reionization. Here, we present the initial results of the simulation on reionization history in the presence of antenna-based gain calibration errors and instrumental noise on LCS analysis.

1. S. Dasgupta, S. K. Pal, S. Bag, et al., “Interpreting the hi 21-cm cosmology maps through largest cluster statistics. part i. impact of the synthetic ska1-low observations,” JCAP, vol. 2023, no. 05, p. 014, May 2023. doi:10.1088/1475-7516/2023/05/014.

2. Mazumder, A., Datta, A., Chakraborty, A. and Majumdar, S., 2022. Observing the Reionization: Effect of calibration and position errors on realistic observation conditions. MNRAS. 515. doi:10.1093/mnras/stac1994.