Abstract

The redshifted 21-cm radiation from neutral hydrogen (H I) serves as a direct probe to observe the Epoch of Reionization (EoR). Several radio-interferometric experiments are continuously striving to measure power spectrum (PS) of the EoR 21-cm signal. The upcoming SKA-Low telescope is expected to measure the EoR 21-cm PS with a very high precision. The work presented in this thesis is focused on error predictions for the future SKA-Low observations.

The EoR 21-cm signal is predicted to be highly non-Gaussian with the impact of non-Gaussianity increasing as the reionization proceeds. The non-Gaussianity affects the PS error covariance $\mathbf{C}_{ij}$ through the bin averaged trispectrum $\bar{T}(k_i, k_j)$ which is zero for a purely Gaussian field. In this thesis, we have used simulations to predict the error covariance for observations with the upcoming SKA-Low. We present results considering different observing times and for different foreground scenarios. We find that the non-Gaussianity increases the error variance for the PS estimated in the different k bins. It also introduces a correlation among the errors in different k bins. These effects are pronounced particularly at small k ($\lesssim 0.4$ Mpc^{-1}) modes for moderately long observations ($t_{\rm obs} \gtrsim 1024$ hours). As expected these effects are more pronounced during the later stages of reionization.

The error covariance for the 21-cm PS $\mathbf{C}_{ij}$ also affects the parameter estimation for models of reionization. Here we consider an EoR model with three parameters namely (1) the minimum halo mass that can host ionizing sources, $M_{\rm min}$, (2) the number of ionizing photons escaping into the IGM per baryon within the halo, $N_{\rm ion}$, and (3) the mean free path of the ionizing photons within the IGM, $R_{\rm mfp}$. In this thesis, we make error predictions for these parameters considering the different observing times and for different foreground scenarios.

The light-cone (LC) effect breaks the ergodicity of the observed 21-cm signal along the line-of-sight. This makes the 3D PS $P(k)$ an inappropriate estimator of the signal. Later in this thesis, we consider the multifrequency angular power spectrum (MAPS) $C_\ell(\nu_1, \nu_2)$ to quantify the statistics of this non-ergodic signal. We use simulations to estimate the EoR 21-cm MAPS and also make corresponding error predictions considering different observing times for different foreground scenarios. We find that above 5σ measurements of $C_\ell(\nu, \nu)$ is possible with moderately long observations for a substantial range of multipoles ℓ and frequency bandwidth.

Keywords: cosmology: theory, dark ages, reionization, large-scale structures of universe, first stars, diffuse radiation– methods: statistical – techniques: interferometric.