Abstract

The Ooty Radio Telescope (ORT) is being upgraded to function as a linear radio-interferometric array the Ooty Wide Field Array (OWFA). This is expected to operate at central frequency of $\nu_c = 326.5\,\mathrm{MHz}$ that directly corresponds to the HI radiation from a redshift $z_c = 3.35$. OWFA can operate simultaneously in two independent radio-interferometric modes - PI and PII. Observation of the HI 21-cm signal holds the possibility of being a valuable cosmological probe over large redshift range in the cosmic history. Such observations are however dominated by the different astrophysical foregrounds that pose a challenge towards measuring the redshifted HI 21-cm signal. In this thesis we have made quantitative predictions for measuring the HI 21-cm power spectrum using OWFA. In the post-reionization era ($z \leq 6$) the HI 21-cm power spectrum is believed to be a biased tracer of the underlying matter power spectrum, and thereby of the underlying matter distribution at that epoch.

First, we have used the Fisher matrix analysis to predict the prospects of measuring the redshifted HI 21-cm power spectrum with OWFA. We have particularly aimed at making predictions of the Signal-to-Noise Ratio (SNR) for measuring A_{HI} where A_{HI}^2 sets the amplitude of the HI 21-cm power spectrum. We found that it is possible to have a $5-\sigma$ measurement of A_{HI} with 150 hrs of observation using OWFA PII. We have next made SNR predictions of for measuring the amplitude of the HI power spectrum in a number of k-bins using OWFA PII. This can be used to place constraints on the shape of the HI 21-cm power spectrum. We found that a $5-\sigma$ measurement of the binned HI 21-cm power spectrum is possible with 1000 hrs of observation in the k-range $0.05 \leq k \leq 0.3\,\mathrm{Mpc}^{-1}$. It should be noted that both the studies have ignored the effect of foregrounds and any possible radio-interference in these analyses.

We have further considered the possibility of measuring the cross-correlation of the OWFA redshifted HI 21-cm signal and the Lyman-α forest from a spectroscopic survey like SDSS-IV.In addition to being an independent probe of cosmology, the cross-correlation signal has the advantage that the effect of foregrounds are less severe as compared to the HI 21-cm autocorrelation signal. Our results show that it is possible to have a $6-\sigma$ detection of the cross-correlation power spectrum with OWFA PII using an observing time of 200 hrs each in 25 independent fields-of-view. It is possible to have measurements of the binned cross-correlation power spectrum at a confidence level of $5-\sigma$ or more for a number of k-bins at $k \leq 0.3\,\mathrm{Mpc}^{-1}$.

Simulations play a crucial role in testing and validating HI 21-cm power spectrum estimation techniques. The computational requirements may be large if we wish to simulate large number of statistically independent realizations of the HI 21-cm signal over a large cosmological volume incorporating both the chromatic response of the telescope parameters and the Light-Cone (LC) effect. This motivates us to consider an analytical method for simulating the HI 21-cm visibility signal expected at OWFA. This requires less computation as compared to numerical simulation techniques, and also accounts for the both the chromatic response of the telescope and the LC effect. We demonstrate and validate our method by applying it to simulate HI 21-cm visibility signal expected for OWFA PI.

Keywords: Cosmology, large scale structure of the Universe, intergalactic medium, diffuse radiation, neutral hydrogen, statistics, cross-correlation, power spectrum.