Abstract

Foreground removal is a major challenge for 21-cm tomography of the high-redshift Universe. In this thesis we have analyzed GMRT observations to characterize the foregrounds at 610 MHz and 150 MHz which corresponds to the HI signal from redshift of $z = 1.32$ and 8.5 respectively. We use the multi-frequency angular power spectrum $C_\ell(\Delta\nu)$ to characterize the statistical properties of the foregrounds at arcminute angular scales. Our measurement of $C_\ell(\Delta\nu)$ have revealed presence of oscillatory patterns along $\Delta\nu$, which turned out to be a severe impediment for foreground removal. We have shown that it is possible to considerably reduce these oscillations by tapering the Field of View of the primary antenna elements. We have developed a foreground removal technique where the chances of removing a part of HI signal along with the foreground is relatively low compared to other proposed techniques. Using our 610 MHz observations, we have shown that for the first three angular multipoles the tapering along with a low order polynomial fitting results in residuals of $\leq 0.02\,\mathrm{mK}^2$, which is consistent with the system noise at the 3σ level. Since the polynomial fitting is done after estimation of the power spectrum it can be ensured that the estimation of the HI signal is not biased. The corresponding 99% upper limit on the HI signal is $\bar{x}_{\mathrm{HI}} b \leq 2.75$, where $\bar{x}_{\mathrm{HI}}$ is the mean neutral fraction and b is the bias.

We have carried out 150 MHz GMRT observations to characterize the statistical properties of the foregrounds in four different fields of view. The measured multi-frequency angular power spectrum $C_\ell(\Delta\nu)$ is found to have values in the range 10^4 mK^2 to 2×10^4 mK^2 across $700 \leq \ell \leq 2 \times 10^4$ and $\Delta\nu \leq 2.5$ MHz, which is consistent with model predictions of point sources.

The observational data was used to assess how well we can subtract out the brightest and subsequently all the sources from our observed fields. We have used our most sensitive field (FIELD I), which has a rms noise of 1.3 mJy/Beam, to study the properties of the radio source population to a limiting flux of 9 mJy. We find there is no evidence for flattening of the source count which suggests that the source population is dominated by the classical radio-loud Active Galactic Nucleus (AGN).

The diffuse Galactic emission is revealed after the point sources are subtracted out from FIELD I . The angular power spectrum shows a power-law behavior $C_\ell \propto \ell^{-2.34}$ for $253 \leq \ell \leq 800$ which is characteristic of the Galactic synchrotron radiation measured at higher frequencies and larger angular scales. We estimate the fluctuations in the Galactic synchrotron emission to be $\sqrt{\ell(\ell+1)C_\ell/2\pi} \simeq 10\,\mathrm{K}$ at $\ell = 800$ ($\theta > 10'$). The measured C_ℓ is dominated by the residual point sources and artifacts at smaller angular scales where $C_\ell \sim 10^3$ mK^2 for $\ell > 800$.

Keywords: Cosmology: observations, diffuse radiation, large-scale structure of Universe, method: data analysis