First multi-redshift limits on HI 21 cm signal from z = 1.96 - 3.58 using uGMRT

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Target Field : ELAIS N1



- 1. We have calibrated (direction-independent) the whole 200 MHz bandwidth data and made an image. There are 3728 components (compact sources) present in the model and have been subtracted this point-source model from the calibrated visibility data, using UVSUB in CASA.
- 2. This residual data is being used for power spectrum analysis. We do not attempt to model and subtract the diffuse foreground emissions in this analysis to avoid any suppression or loss of the diffuse 21 cm signal.

Power spectrum at 310 MHz (z = 3.58)

Cylindrically averaged 2D power spectrum

Spherically averaged 3D power spectrum



We use visibility correlation in delay space to estimate the power spectrum using 8 MHz sub-bands around redshifts z = 1.96, 2.19, 2.62, 3.58. We use one-dimensional CLEAN' algorithm to reduce the foreground spillover during FFT along frequency for a non-uniformly sampled data set due to RFI flagging. To avoid the positive noise bias, we cross correlate all the visibilities among each other within a uv-cell, whose dimension is inverse of the half-power beam width of the primary beam. The off-diagonal terms of the correlation matrix for each uv-cell are expected to be free of noise bias and the average of those terms is being quoted as the estimated power corresponding to that cell.





$$\begin{split} \Delta_{\rm HI}^2(k,z) &= \overline{T}(z)^2 [b_{\rm HI}(k,z)]^2 \frac{k^3 P_{\rm DM}(k,z)}{2\pi^2} \\ \overline{T}(z) &\simeq 0.39 \frac{\Omega_{\rm HI}(z)}{10^{-3}} \Big[\frac{\Omega_{\rm m} + \Omega_{\Lambda}(1+z)^{-3}}{0.29} \Big]^{-1/2} \\ & \left[\frac{(1+z)}{2.5} \right]^{1/2} {\rm mK}, \end{split}$$
$$[\Omega_{\rm HI} b_{\rm HI}] &< 0.09, 0.11, 0.12, 0.24 \\ z &= 1.96, 2.19, 2.62, 3.58 \end{split}$$

The best upper-limit at k=1 Mpc-1 for 4 redshifts. Also the theoretical HI (black) and dark matter power spectrum (magenta) are shown.

We use the best-limits at 4 redshifts to put constraint on product of neutral HI mass density and HI bias the underlying dark matter density field $\left[\Omega_{\text{HT}}b_{\text{HT}}\right]$

For the first time we pu upper limit on post-EoR HI power spectrum using 13 hours on-source time of ELAIS N1 field with uGMRT. We put stringent limit at z=1.96,2.19, 2.62, 3.58. We are still 3-4 orders of magnitude higher than the theoretical expected HI power spectrum at these redshifts. We will try to put more deep limits on post-EoR signal using uGMRT in future.