The Universe at Low Radio Frequencies
IAU Symposium, Vol. 199, 2002
A. Pramesh Rao, G. Swarup and Gopal-Krishna, eds.

Using Gravitational Lenses to Probe HI at High z

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Abstract. We investigate the possibility of detecting damped Lyman-α systems at high redshifts using GMRT if these clouds are magnified by intervening cluster lenses. We show that if the HI mass of the damped clouds $\geq 2 \times 10^{10}\,\mathrm{M}_\odot$ then they can be detected with a probability ≥ 0.2 using GMRT.

The number distribution of damped Lyman-α clouds along a line of sight is known from the absorption studies for $3 < z < 3.5$ (Lanzetta, Wolfe, & Turnshek 1995), the redshift range of interest to us here (corresponding to the redshifted 21-cm HI line observed at $\nu \simeq 327\,\mathrm{MHz}$). Assuming a transverse size, r_t, of the cloud and the background FRW model, the observed number distribution along a line of sight can be converted to the number density of clouds at a given redshift. In this poster we consider a FRW model with $\Omega_m = 1$, $h = 0.5$, and $\Omega_\Lambda = 0$.

1. Flux from the Clouds

Given the column density of the cloud, its angular size, and the velocity width of the observed line, the flux of redshifted 21-cm line radiation is:

$$F = 3.97\mu\mathrm{Jy\,arcsec}^{-2}(1+z)^{-3}\left(\frac{N_{\mathrm{HI}}}{10^{21}\,\mathrm{cm}^{-2}}\right)\left(\frac{200\,\mathrm{km\,sec}^{-1}}{\Delta V}\right)\Delta A. \qquad (16)$$

Here N_{HI} is the HI column density, ΔA is the angular size of the cloud in arcsec^2, and ΔV is the velocity width of the redshifted 21-cm line along a line of sight. Observations suggest that $\Delta A \simeq 4$–$10\,\mathrm{arcsec}^2$ and $\Delta V \simeq 200\,\mathrm{km\,sec}^{-1}$.

https://doi.org/10.1017/S0074180900168664 Published online by Cambridge University Press

2. Parameters of GMRT

Using GMRT, the minimum detectable temperature at $\nu \simeq 327\,\mathrm{MHz}$ is expected to be:

$$\Delta T_{\rm min} = 50\,\mu\,\mathrm{K}\left(\frac{30}{N}\right)\left[\left(\frac{10\,\mathrm{hr}}{t}\right)\left(\frac{1.25\times10^5\,\mathrm{Hz}}{\Delta\nu}\right)\right]^{1/2} \quad (17)$$

Here t is the integration time, $\Delta\nu$ is the observation band-width, and N is the number of antennas. For GMRT $N_{\rm max} = 30$ and the total frequency width is 116x1.25 $\times\ 10^5$ Hz. The system gain for GMRT is $0.32\mathrm{KJy}^{-1}$. Using the typical parameters given in Eq. (2) and the system gain, a source of flux $\simeq 150\mu$Jy can be detected.

3. Results

We model clusters as elliptical lenses (for details see Schneider, Ehlers, & Falco 1992). These are characterized by a core radius R_c, velocity dispersion σ, and ellipticity parameter ϵ. We consider the following range of parameters: $1400\,\mathrm{km\,sec^{-1}} \leq \sigma \leq 1800\,\mathrm{km\,sec^{-1}}$, $40\,\mathrm{kpc} \leq R_c \leq 60\,\mathrm{kpc}$, $0 \leq \epsilon \leq 0.3$, and $0.1 \leq z_l \leq 0.3$.

For our study we take an angular area $\Delta\Omega = 1'\mathrm{x}1'$ centered at the cluster center as significant magnification can only occur in this region. In a volume bounded by this angular area and the depth corresponding to the frequency width of GMRT at $\nu \simeq 327\,\mathrm{MHz}$, we calculate the total number of clouds in this region as a Poisson deviate with the mean determined from the observed distribution of damped Lyman-α clouds. For determining the distribution of received flux from clouds (Eq. (1)) we fix $\Delta V = 200\,\mathrm{km\,sec^{-1}}$ and the angular size of the cloud. The received flux is then a function of column density only. We assign column densities, and thereby the flux, randomly according the observed probability distribution of column densities.

The probability of getting a magnification exceeding a value μ given by:

$$C(\mu) = \frac{A(\mu)}{A_t}, \quad (18)$$

where $A(\mu)$ is the area on the source plane within which the amplification exceeds μ and A_t is the total area. We calculate the probability by simulating the caustic structure of a given lens. The source is then placed in the area of $1'\mathrm{x}1'$ centered at the cluster center, and the magnification is calculated for all the positions in the source plane.

Our analysis shows that *if the damped Lyman-α clouds have $M_{\rm HI} \geq 2 \times 10^{10}\,M_\odot$ they could be detected with probability ≥ 0.2 using GMRT, if observed through a massive cluster of galaxies.*

References

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