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# 21cm absorbers at low and intermediate redshifts

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Results from the systematic GMRT survey to search for 21cm absorption in a representative and unbiased sample of 35 DLA candidates at $1.10 \leq z \leq 1.45$ are presented here. The survey has resulted in discovery of 9 new 21cm absorbers and has allowed us to constrain the number per unit redshift of 21cm absorbers ($n_{21}$) at z<1.5. We show that $n_{21}$ has fallen by a factor 4 from $< z >$=0.5 to $< z >$=1.3. Prior to our survey only one 21cm absorber was known in the redshift range: $0.7 \leq z \leq 1.5$. Blind searches of 21cm absorbers will be possible with the next generation radio telescopes such as APERTIF, ASKAP, EVLA and MEERKAT. These surveys will allow us to measure the $n_{21}$ without resorting to any preselection based on the UV absorption lines and will provide large number of 21cm absorbers that can be used for various follow-up studies.

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## 1. Introduction

The global comoving star-formation rate density peaks at $1 \leq z \leq 2$ and then sharply decreases towards $z \sim 0$ [1]. The physical conditions in the diffuse gas in galaxies are usually influenced by in-situ star-formation, cosmic ray energy density, photoelectric heating by dust as well as mechanical energy input from both impulsive disturbances like supernova explosions and steady injection of energy in the form of stellar winds. Therefore, determination of the gas mass density and its components (especially the molecules, dust and cold H I gas) over the same redshift range provides an independent and complementary understanding of the redshift evolution of star-formation at similar epochs. In the nearby Universe, the H I content of the galaxies is best probed by the surveys of 21cm emission. However the limited sensitivity of the current radio telescopes does not allow them to reach beyond the local Universe [2]. Blind surveys of damped Lyman-$\alpha$ absorption lines detected in the spectra of high-$z$ QSOs provide a luminosity unbiased way of probing the evolution of the bulk of neutral hydrogen in the Universe [3]. At $z > 2$, where the Lyman-$\alpha$ absorption is redshifted into the optical band, it has been possible to detect the large ($\sim$1000) number of damped Lyman-$\alpha$ absorbers from the Sloan Digital Sky Survey (SDSS; [4]). On the other hand very few ($\sim$50) DLAs are known at $z < 2$ with most of these detected from the searches based on the samples of Mg II absorbers [5]. It has been shown by [5] that DLAs essentially have Mg II rest equivalent width, $W_r$(Mg II$\lambda$2796)$\geq$0.6Å. Therefore, the search of 21cm absorption in a sample of strong Mg II absorbers is a unique way to probe the redshift evolution of physical conditions in DLA like absorption systems at intermediate and low-z. Motivated by this we have done a large systematic survey of 21cm absorbers using GMRT based on a sample of strong Mg II absorbers drawn from SDSS DR5.

## 2. Our GMRT sample

Our sample is drawn from the identification of strong Mg II systems, $W_r$(Mg II $\lambda$2796)$\geq$1.0Å, by [6] in SDSS DR3 and by us using our automatic procedure for additional systems in DR5. We select the absorbers that are in the redshift range: 1.10$\leq z_{abs} \leq$1.45 such that the redshifted 21cm frequency lies in the GMRT 610-MHz band. GMRT is the only radio telescope available at present in the *relatively* RFI-clean environment (say compared to Green Bank Telescope or Westerbork Synthesis Radio Telescope) for covering this redshift range. These absorbers are then cross-correlated with NVSS and FIRST surveys to select the Mg II absorbers in front of compact radio sources brighter than 50 mJy and hence suitable for the 21cm absorption search. We plot in Fig. 1 the redshift distribution of the 35 Mg II absorption systems observed as part of our GMRT survey along with the sample of [7]. Latter is the only large survey at low-$z$ for which both detections and non-detections are systematically reported. It includes 62 systems observed with the WSRT and 10 other systems from the literature satisfying their selection criterion [7]. In the same figure, the filled histogram shows the distribution of Mg II systems in our GMRT sample. For equivalent width cutoff of $\sim$ 1Å, our GMRT sample has more than twice the number of systems investigated by [7]. We observed our sample of 35 Mg II systems with GMRT 610-MHz band using in total $\sim$400 hrs of telescope time mostly spread over the years 2006-2008.



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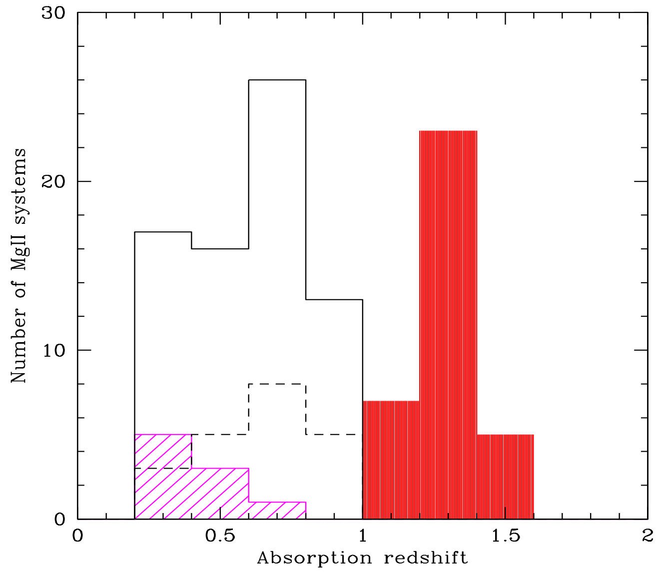


**Figure 1:** Redshift distribution of Mg II systems that were searched for 21cm absorption. The filled histogram is the GMRT sample of 35 Mg II systems presented in this paper (33 of these absorption systems have $W_r$(Mg II$\lambda$2796)$\geq$ 1Å). The solid line histogram is for the sample of [7]. The hatched histogram corresponds to 21cm detections in this sample. The distribution for the $W_r$(Mg II$\lambda$2796)$\geq$ 1Å sub-set of these systems is given by the dashed line histogram.

## 3. Results and Discussion

We present the results of a systematic Giant Metrewave Radio Telescope (GMRT) survey of 21cm absorption in a representative and unbiased sample of 35 strong Mg II systems in the redshift range: $z_{abs}$ ~1.10−1.45, 33 of which have $W_r$ ≥1 Å. The survey using ~400 hrs of telescope time has resulted in 9 new 21cm detections and good upper limits for the remaining 26 systems (Fig. 2). This is by far the largest number of systems detected in a single systematic survey in a narrow redshift range. Two of these systems also show 2175 Å dust feature at the redshift of the absorbers [8]. Results from the first phase of our survey are presented in [9]. Detailed description of the entire sample and results from the survey are presented in [10]. In the following we summarise the main results.

We estimate the number of 21cm absorption systems per unit redshift interval for a given limiting value of the integrated 21cm optical depth and $W_r$(Mg II$\lambda$2796). We show that the fraction of Mg II systems with 21cm absorption and the number per unit redshift decrease from $z \sim 0.5$ to $z \sim 1.3$ (Fig. 3). The decrease is larger when we use higher equivalent width cutoff. Using a sub-sample of compact sources, with high frequency VLBA observations available, we show that this can not be accounted for by simple covering factor effects. As mentioned above and based on the available data, it appears that most likely the main reason behind this cosmological evolution is the decrease of the CNM covering factor (and volume filling factor) in the strong Mg II absorbers. Indeed, it is known that the number of Mg II systems per unit redshift increases with increasing redshift. The evolution is steeper for stronger systems [6, 11]. Using the data of

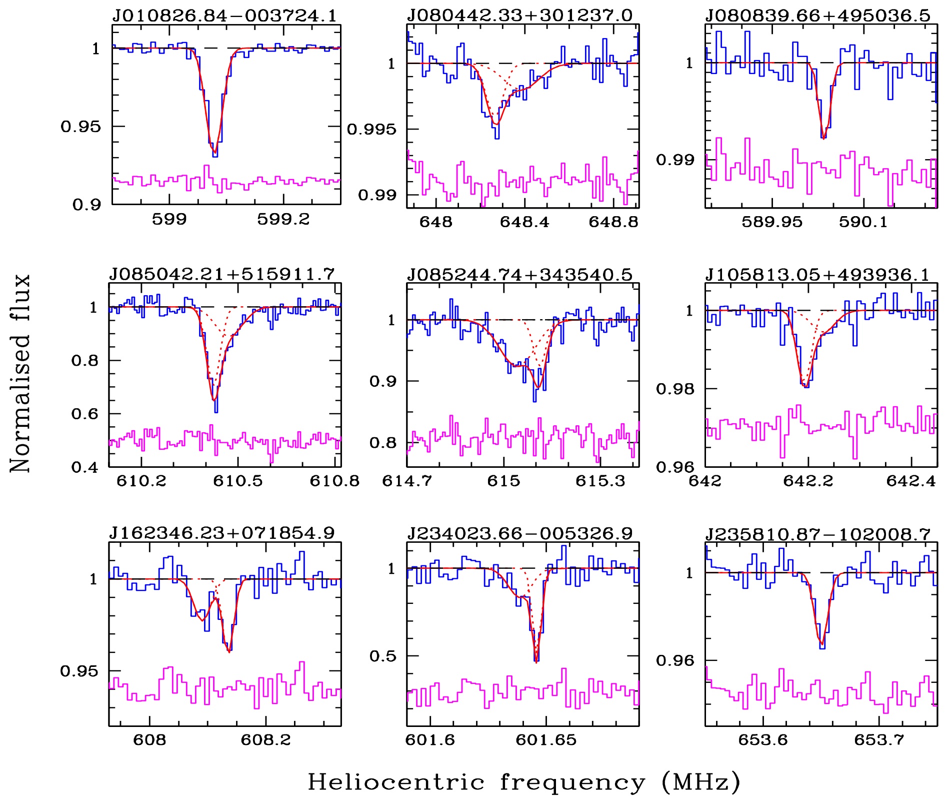


**Figure 2:** GMRT spectra of detected 21cm absorption lines. Individual Gaussian components and resultant fits to the absorption profiles are overplotted as dotted and continuous lines respectively. Residuals, on an offset arbitrarily shifted for clarity, are also shown.

[11], [12] found that the strongest redshift evolution was seen among the Mg II absorbers with $W_r$(Fe II)$\lambda$2383/$W_r$(Mg II)$\lambda$2796<0.5. This clearly means the physical conditions in strong Mg II absorbers are different at high and low-$z$.

Ideally one would like to estimate the number density of 21cm absorbers and measure the cosmological evolution without preselection from the UV absorption lines. This can be achieved only by a blind survey of 21cm absorption in front of radio loud QSOs. It will be possible to embark upon such surveys with the upcoming radio telescopes such as APERTIF, ASKAP, EVLA, MEERKAT, etc. These surveys made possible by the large instantaneous bandwidths and/or large field-of-view of these telescopes are expected to result in the discovery of large number of 21cm absorbers at $z < 1$ that can be used for (1) studying the morphology of the absorbing gas and their connection with galaxies, (2) the searches of molecules, (3) probing the time evolution of various fundamental constants and (4) probing the strength of magnetic fields in the galaxies.

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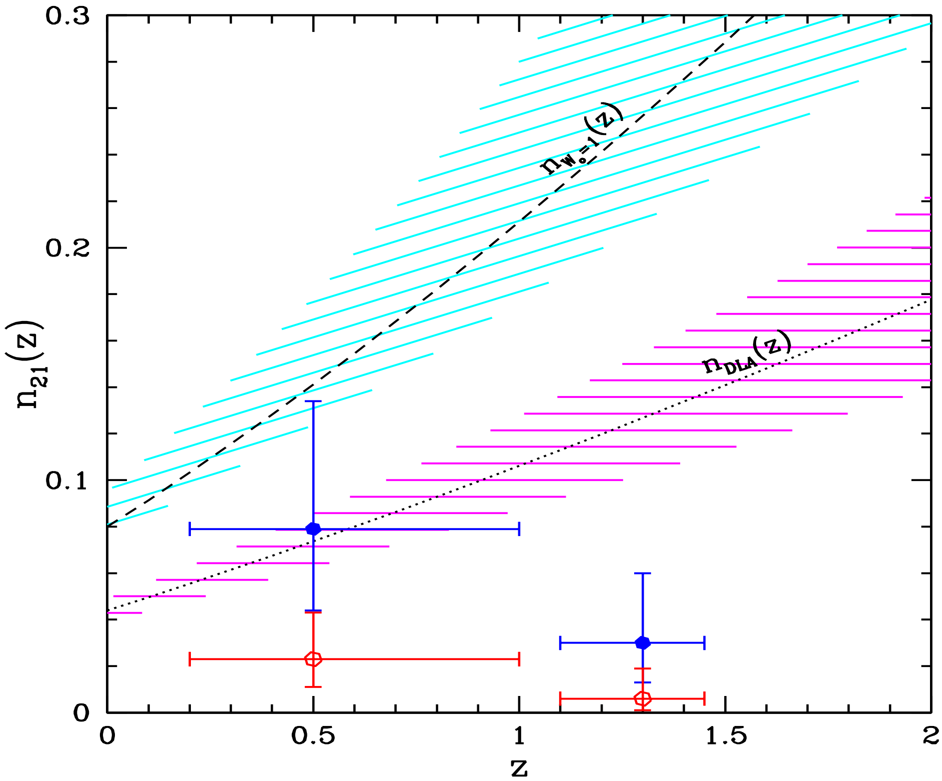


**Figure 3:** Number of 21cm absorbers per unit redshift, $n_{21}(z)$, for integrated 21cm optical depth, $\tau_o > 0.3$ and $W_o$(Mg II) $>$ 1.0Å (solid symbols) and $W_o$(Mg II) $>$ 1.8 Å (open symbols). Lines and hashed areas show the number of absorbers per unit redshift for DLAs (Rao et. al. 2006, dotted line) and Mg II absorbers with $W_o \geq$1Å ([6], dashed line).

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