HI absorption towards nearby compact radio sources

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ABSTRACT
We present the results of HI absorption measurements towards a sample of nearby Compact Steep-Spectrum (CSS) and Giga-Hertz Peaked Spectrum (GPS) radio sources, the CORALZ sample, using the Giant Metrewave Radio Telescope (GMRT). We observed a sample of 18 sources and find 7 new detections. These sources are of lower luminosity than earlier studies of CSS and GPS objects and we investigate any dependence of HI absorption features on radio luminosity. Within the uncertainties, the detection rates and column densities are similar to the more luminous objects, with the GPS objects exhibiting a higher detection rate than for the CSS objects. The relative velocity of the blueshifted absorption features, which may be due to jet-cloud interactions, are within $\sim-250$ km s$^{-1}$ and do not appear to extend to values over 1000 km s$^{-1}$ seen for the more luminous objects. This could be due to the weaker jets in these objects, but requires confirmation from observations of a larger sample of sources. There appears to be no evidence of any dependence of HI column density on either luminosity or redshift, but these new detections are consistent with the inverse relation between HI column density and projected linear size.

Key words: galaxies: active – galaxies: evolution – galaxies: nuclei – galaxies: jets – radio lines: galaxies

1 INTRODUCTION
Radio observations of various classes of active galactic nuclei (AGN) have revealed a wide scale of structures. For the luminous radio galaxies and quasars these range from the subgalactic-sized Giga-Hertz Peaked Spectrum (GPS) and Compact Steep-Spectrum (CSS) objects (O'Dea 1998) to the giant radio sources which extend over a Mpc in size (e.g. Ishwara-Chandra & Saikia 1999). The GPS sources have convex spectra which peak at frequencies much higher than 1 GHz, while the CSS objects may exhibit a flattening or turnover at significantly lower frequencies (e.g. O'Dea 1998). The GPS sources have projected linear sizes $\lesssim1$ kpc, while CSS sources are usually defined to have a projected linear size $\lesssim15$ kpc (H$_{\odot}$ = 71 km s$^{-1}$ Mpc$^{-1}$, $\Omega_m=0.27$, $\Omega_{\Lambda}=0.73$; Spergel et al. 2003). In addition, the high-frequency peakers, where the radio spectra peak at frequencies much $>1$ GHz, are likely to be the youngest with dynamical ages of $\sim10^{2}$ to $10^{3}$ yr (e.g. Phillips & Mutel 1982; O’Dea 1998; Polatidis & Conway 2003), which evolve into the CSS objects with ages of $\sim10^{5}$ yr (e.g. Murgia et al. 1999), and which in turn evolve into the larger sources which could be over $10^{8}$ yr old (e.g. Jamrozy et al. 2008; Konar et al. 2008).

These young, radio-loud AGN are ideal objects for studying the triggering of radio activity, the early evolution of classical double-lobed radio sources, interactions of the radio jets with the interstellar medium, and AGN feedback which could affect the evolution and formation of galaxies. These sources could also be used as probes of the environments of the central regions and the interstellar medium of the host galaxies via HI 21-cm absorption observations (e.g. van Gorkom et al. 1989; Vermeulen et al. 2003; Pihlström, Conway & Vermeulen 2003; Gupta et al. 2006, and references therein), as well as radio polarisation measurements (e.g. Mantovani et al. 1994; Saikia & Gupta 2003). The absorbing neutral hydrogen could be associated with either the circumnuclear disk and the putative torus or the halo of the host galaxy. Detection of this gas is also important for studying the anisotropy of the radiation field and thereby testing the unified scheme for active galaxies. An understanding of the distribution and kinematics of this gas over a large range of redshifts and/or luminosities can provide valuable infor-
mation on the evolution of its properties with source size (age), radio luminosity and cosmic epoch.

Several recent studies of CSS and GPS objects have demonstrated that HI absorption is seen in ∼35 per cent of the objects, with the HI column density being anti-correlated with the source size (Vermeulen et al. 2003; Pihlström, Conway & Vermeulen 2003; Gupta et al. 2006). To a first order, the HI gas may be distributed in the form of a disk, but exhibits a variety of line profiles, suggesting significant and sometimes complex motions. van Gorkom et al. (1989) had reported that HI absorption tends to be redshifted relative to the systemic velocity, suggesting infall of gas. However, recent observations show the situation to be more complex. These observations find many sources with substantial blue shifts, suggesting that the atomic gas may also be flowing out, interacting with the jets or rotating around the nucleus (Vermeulen et al. 2003; Gupta et al. 2006). Morganti et al. (2005) report the detection of low optical depth HI gas which may be blue shifted by over ∼1000 km s⁻¹, possibly due to jet-cloud interactions.

Gupta et al. (2006) examined and found no evidence of any correlation between HI column density and luminosity or redshift for a sample of CSS and GPS objects with a radio luminosity largely ≥10³⁵ W Hz⁻¹ at 5 GHz. Their sample was compiled by combining the results of their observations with existing observations in the literature. Since most of these sources were compiled from strong flux-density limited samples, luminosity and redshift were strongly correlated. To study the properties of HI absorbers in lower-luminosity GPS and CSS sources, and also to examine any dependence independently on luminosity and redshift, one needs different samples to fill in the redshift-luminosity plane. With these objectives we observed the Compact Radio sources at Low Redshift (CORALZ) sample, which was compiled by Snellen et al. (2004), with the sources having flux densities larger than 100 mJy at 1400 MHz and angular sizes less than 2 arcsec. Snellen et al. (2004) used the Faint Images of the Radio Sky at Twenty-Centimeters (FIRST) survey (White et al. 1997), the Automated Plate Measuring (APM) machine catalogue (McMahon & Irwin 1992) of the Palomar Observatory Sky Survey (POSS) and their own observations to select radio sources identified with bright galaxies. Further observations led to a sample of 18 sources with redshifts in the range 0.005<z<0.16 which they estimate to be ∼95 per cent complete (Snellen et al. 2004; de Vries et al. 2009). Almost all the sources are CSS or GPS objects, suitable for studying young radio sources in the nearby Universe. These sources are also significantly weaker than the CSS or GPS objects studied so far (e.g. Gupta et al. 2006 and references therein) making it possible to determine gas properties in sources of low radio luminosity. The median 5 GHz radio luminosity of these sources is ∼120 times weaker than those studied by Gupta et al. (2006).

In this paper, we present the results of our observations with the Giant Metrewave Radio Telescope (GMRT) of the CORALZ sample. The observations and data analyses are described in Section 2, while the observational results are described in Section 3. The results are discussed in Section 4, and summarized in Section 5.

2 OBSERVATIONS AND DATA ANALYSIS

These observations were made with the GMRT during 2009 December to 2010 February, using a base-band bandwidth of 4 MHz (~900 km s⁻¹) in the hardware correlator and an integration time of 16s. Each source was observed for ∼4 to 5 hr including calibration overheads. The 4 MHz bandwidth consisted of 128 spectral channels, giving a spectral resolution of ∼7 km s⁻¹. Simultaneously data were also recorded using the software correlator with a wider bandwidth of 16 MHz over 256 channels and integration times of 16s as well as 2s. The data were acquired with a small visibility integration time from the correlator to help in the identification of radio frequency interference (RFI). The frequencies were tuned such that the expected HI absorption line for each source, corresponding to the optical redshifts listed by Snellen et al. (2004) and the NASA Extragalactic Database (NED), were within the observing bands. The flux density and bandpass calibrators were either 3C48, 3C147 or 3C286, and phase calibrators were observed before and after each scan of a source. Observational details are listed in Table 1. The data reduction was mainly done using AIPS++. The data were reduced using an automated pipeline developed by one of us (SS). After applying bandpass corrections on the phase calibrators, gain and phase variations were estimated. The flux density, bandpass, gain and phase calibration from calibrators were applied to the target sources.

While calibrating the data, bad data were flagged at various stages. The data for antennas with high errors (7σ) in antenna-based solutions were examined and flagged over certain time ranges. Some baselines were flagged based on closure errors on the bandpass calibrator. Channel and time-based flagging of data points corrupted by RFI were done using a median filter with a 6σ threshold. Residual errors above 5σ were also flagged after a few rounds of target field calibrators (using point source model). Both polarizations (RR and LL) were processed independently for consistency checks. The linear fits (of line free channels) at an interval of 5 minutes were subtracted from the calibrated data. The spectra for the targets were made after averaging the resulting data and correcting for the velocities for the Earth’s motion using dopset. Data from both the software and hardware correlator were analysed for consistency checks. The spectra were similar and the ones presented here are from the hardware correlator because it has twice the spectral resolution than those obtained from the software correlator data. The typical channel r.m.s. for the spectra presented here are ∼1.3 mJy.

3 OBSERVATIONAL RESULTS

3.1 HI observations

Some of the basic properties of the sample of sources and the observational results are summarized in Table 2, which is largely self explanatory. The classification of GPS and CSS sources are based on the spectra presented by Snellen et al. (2004) and any additional information from Labiano et al. (2007). Sources with a reasonably well-defined spectral peak at frequencies ≥500 MHz have been classified as GPS, while the others have been termed as CSS objects. J102618+454618 has been classified as CFS (Compact Flat
Spectrum) because it appears to have a high-frequency spectral index of \(\sim 0.41\) (Snellen et al. 2004; de Vries et al. 2009). From observations of the sources in the CORALZ sample with the GMRT, we report the detection of H\(_i\) absorption in 7 sources, of which 3 are GPS sources and 4 are CSS objects (Table 2). The detected absorption lines were fitted with multiple Gaussian components to determine the peak optical depth \(\tau_v\) and FWHM \((\Delta v; \text{km s}^{-1})\) of the spectral components. H\(_i\) column densities were determined using the relation

\[
N(\text{HI}) = \frac{1.835 \times 10^{18} T_s \int_0^{\tau_v} d\nu}{f_c} \text{cm}^{-2} = 1.93 \times 10^{18} \frac{T_s \tau_v \Delta v}{f_c} \text{cm}^{-2}
\]

(1)

where \(T_s\) and \(f_c\) are the spin temperature (in K) and the fraction of the background source covered by an absorbing cloud. We have assumed \(T_s=100\) K and \(f_c=1.0\). The column densities range from \(\sim 1.78 \times 10^{20}\) to \(\sim 10^{22}\) cm\(^{-2}\), with a median value of \(\sim 7.5 \times 10^{20}\) cm\(^{-2}\). These values are similar to those of the more luminous GPS and CSS sources where the median value is \(\sim 5 \times 10^{20}\) cm\(^{-2}\) (Gupta et al. 2006).

For the non-detections, we have determined the upper limits on H\(_i\) column densities using 3\(\times\)r.m.s. of the optical depths as \(\tau_v\) and \(\Delta v=100\) km s\(^{-1}\). These upper limits range from \(\sim 0.9\) to \(\sim 4.2 \times 10^{20}\) cm\(^{-2}\). The spectra for the non-detections are shown in Fig. 1, while the spectra for the detections are presented in Fig. 2 along with the Gaussian fits to the optical depths. All the spectra have been plotted relative to the systemic velocity inferred from the redshifts listed in Table 2, which are from NED, but taken mainly from the Sloan Digital Sky Survey (SDSS; Adelman-McCarthy et al. 2008, and references therein), except for J083139+460800 and J103719+433515 which have been plotted relative to the redshifts listed by Snellen et al. (2004). For all the non-detections, the absence of H\(_i\) absorption has also been confirmed from the wider bandwidth software correlator data, except for J103719+433515, where there was an error in the settings. We describe below each source briefly including J083139+460800 and J103719+433515, which is then followed by the discussion Section.

### 3.2 Notes on individual sources

**J073328+560541:** Very Long Baseline Interferometric (VLBI) images at \(\sim 1.6\) and 5 GHz show the source to have an extent of \(\sim 80\) mas (Bondi et al. 2001; de Vries et al. 2009), while Very Large Array A-array observations at 8.4 GHz show an unresolved source with an angular extent \(<0.2\) arcsec (Patnaik et al. 1992). The location of the core is unclear and the source is unpolarized (Bondi et al. 2004). Goncalves & Serote Roos (2004) suggest the presence of Low Ionization Nuclear Emission-line Region (LINER), while Dennett-Thorpe & Marchâ (2000) suggest that the source might be variable at 1.4 GHz. The radio spectrum peaks at \(\sim 460\) MHz (Snellen et al. 2004). We do not find evidence of H\(_i\) absorption.

**J073934+495438:** VLBI images of the source at \(\sim 5\) GHz show it to be unresolved (de Vries et al. 2009). The radio spectrum peaks at \(\sim 950\) MHz (Snellen et al. 2004). We do not find evidence of H\(_i\) absorption.

**J083139+460800:** VLBI observations show the source to be double lobed with an overall separation of 4.4 mas in the image of epoch 2000, while a weak component visible towards the north in the image of epoch 2004 gives an overall size of \(\sim 9\) mas (de Vries et al. 2009). The redshift of the host galaxy from SDSS is 0.1311, while Snellen et al. (2004) list it as 0.127. It is a GPS source with a turnover at \(\sim 2200\) MHz (Snellen et al. 2004). We do not find evidence of H\(_i\) absorption. In the spectrum shown in Fig. 1, zero velocity corresponds to optical redshift of 0.127 listed by Snellen et al. (2004) and de Vries et al. (2009). While

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**Table 1. Observational details of the GMRT search for H\(_i\) absorption in the CORALZ sample.**

| Source Name | Date       | COB\(^1\) Freq | Total Observation time | Flux density and Bandpass | Phase Calibrator |
|-------------|------------|-----------------|------------------------|---------------------------|-----------------|
| J073328+560541 | 2009 Dec 31 | 1286.5          | 5                      | 3C147                     | J0713+438       |
| J073934+495438 | 2010 Jan 05 | 1347.5          | 5                      | 3C286                     | J0713+438       |
| J083139+460800 | 2010 Jan 05 | 1260.0          | 5                      | 3C286                     | J0713+438       |
| J083637+440109 | 2010 Jan 04 | 1346.0          | 5                      | 3C286                     | J0713+438       |
| J090615+463618 | 2010 Feb 03 | 1309.0          | 5                      | 3C286                     | J0713+438       |
| J102618+45229  | 2010 Jan 02 | 1232.0          | 5                      | 3C147                     | J1219+484       |
| J103719+433515 | 2009 Dec 29 | 1388.5          | 5                      | 3C286                     | J1219+484       |
| J115000+552821 | 2010 Jan 03 | 1247.3          | 5                      | 3C286                     | 3C286           |
| J120902+411559 | 2010 Jan 01 | 1297.0          | 5                      | 3C147                     | J1227+365       |
| J131739+411545 | 2009 Dec 29 | 1332.5          | 5                      | 3C286                     | J1227+365       |
| J140051+521606 | 2010 Jan 27 | 1270.5          | 5                      | 3C286                     | 3C286           |
| J140942+360416 | 2010 Jan 03 | 1237.9          | 5                      | 3C286                     | 3C286           |
| J143521+505122 | 2010 Jan 02 | 1292.5          | 5                      | 3C286                     | 3C286           |
| J150805+342323 | 2010 Jan 01 | 1359.0          | 5                      | 3C286                     | 3C286           |
| J160246+524358 | 2010 Jan 04 | 1284.5          | 5                      | 3C286                     | J1634+627       |
| J161148+404020 | 2010 Feb 09 | 1233.0          | 5                      | 3C286                     | J1613+342       |
| J170330+454047 | 2009 Dec 11 | 1340.0          | 5                      | 3C286                     | J1613+342       |
| J171854+544148 | 2010 Feb 02 | 1238.5          | 5                      | 3C48                      | J1634+627       |

\(^1\) COB Freq: Centre of Band Frequency before any correction for velocity using doppler shift.
Table 2. Characteristics of sources in the CORALZ sample. The redshifts, \( z \), are from NED with the original references being listed in Column 4, while the flux densities are from the FIRST survey. The luminosities from Snellen et al. (2004) have been re-estimated in the cosmology used here. The largest angular sizes (\( \theta \)) are from de Vries et al. (2009) except for J073328+560541 (Bondi et al. 2001) and J170330+454047 (Gu & Chen 2010). LS denotes the corresponding linear sizes.

| Source Name         | Opt Id. | \( z \) | Refs. | \( S_{1.4 \text{GHz}} \) (mJy) | \( L_{5.0 \text{GHz}} \) (\( 10^{25} \text{W Hz}^{-1} \)) | \( \theta \) (mas) | LS (pc) | Spectral Class | \( N(\text{H}I) \) cm\(^{-2} \) |
|---------------------|---------|--------|-------|-----------------------------|----------------------|------------------|--------|----------------|-----------------------------|
| J073328+560541 G    | 0.1040  | 1      | 348   | 0.467                       | 80                   | 151              | GPS    | <1.076         |
| J073934+495438 G    | 0.0540  | 1,2    | 107   | 0.042                       | <2                   | <2.1             | GPS    | <2.097         |
| J083139+460800 G    | 0.1311  | 3      | 131   | 0.408                       | 9                    | 20.7             | GPS    | <1.256         |
| J083637+440109 G    | 0.0554  | 3      | 139   | 0.045                       | 1600                 | 1699             | CSS    | <1.945         |
| J090615+463618 G    | 0.0848  | 1,3    | 314   | 0.302                       | 31                   | 48.9             | GPS    | 7.482          |
| J102618+454618 G    | 0.1517  | 3      | 105   | 0.347                       | 17                   | 44.7             | CFS    | <3.617         |
| J103719+433515 G    | 0.0247  | 3,4    | 129   | 0.009                       | 19                   | 8.7              | CSS    | <1.932         |
| J115000+552821 G    | 0.1385  | 3      | 143   | 0.363                       | 41                   | 93.9             | CSS    | 6.31           |
| J120902+411559 G    | 0.0950  | 2      | 147   | 0.178                       | 20                   | 34.8             | CSS    | <1.854         |
| J131739+411545 G    | 0.0662  | 1,3    | 249   | 0.229                       | 4                    | 5                | GPS    | 3.785          |
| J140051+521606 G    | 0.1180  | 3      | 174   | 0.224                       | <150                 | <316             | CSS    | <1.139         |
| J140942+360416 G    | 0.1484  | 3      | 143   | 0.276                       | 27                   | 69.2             | CSS    | 7.667          |
| J143521+505122 G    | 0.0997  | 3      | 141   | 0.155                       | <150                 | <271             | CSS    | <2.339         |
| J150805+342323 G    | 0.0456  | 5      | 130   | 0.022                       | 170                  | 148              | CSS    | 125.183        |
| J150805+342323 G    | 0.0456  | 5      | 130   | 0.022                       | 170                  | 148              | CSS    | 125.183        |
| J150805+342323 G    | 0.0456  | 5      | 130   | 0.022                       | 170                  | 148              | CSS    | 125.183        |
| J160246+524358 G    | 0.1057  | 3      | 576   | 0.549                       | 180                  | 345              | CSS    | <0.929         |
| J161145+404020 G    | 0.1520  | 3      | 143   | 0.276                       | 27                   | 69.2             | CSS    | 7.667          |
| J170330+454047 G    | 0.0604  | 6      | 119   | 0.034                       | <7.3                 | <8.4             | CSS    | <4.165         |
| J171854+544148 G    | 0.1470  | 1,7    | 329   | 0.617                       | 68                   | 172.9            | GPS    | 9.541          |

References for redshifts: 1 Labiano et al. (2007); 2 Snellen et al. (2004); 3 SDSS (Adelman-McCarthy et al. 2008 and references therein); 4 Falco et al. (1999); 5 Mazzarella et al. (1993); 6 de Grijp et al. (1992); 7 Kim & Sanders (1998)

Figure 1. GMRT spectra for the non-detections. The y-axis shows the normalised intensity while the x-axis shows the velocity in \( \text{km s}^{-1} \).
Figure 2. The optical depth of the H\textsubscript{i} absorbers vs velocity in km s\textsuperscript{-1} relative to the systemic velocity.
the redshift of 0.1311 is not within the range covered by the hardware correlator, it is within the range covered by the software correlator and no HI absorption is seen.

J083637+440109: The MERLIN image at 1.6 GHz (de Vries et al. 2009) shows most of the emission to form a C-shaped structure with an angular size of \( \sim 1600 \) mas. We do not find evidence of HI absorption.

J090615+463618: The radio structure revealed by the VLBI maps (de Vries et al. 2009; Helmboldt et al. 2007) has been suggested to be due to emission on opposite sides of the core by Bondi et al. (2004). The source exhibits no significant polarization at both radio (\(<0.99\%\)) and optical (\(<1.2\%)\) wavelengths (Marchâ et al. 1996; Dennett-Thorpe & Marchâ 2000). Caccianiga et al. (2002) classify it as a Narrow Emission Line Galaxy, while Goncalves & Serote Roos (2004) suggest it to be a LINER. We detect HI absorption in this source with one main component blueshifted by \( \sim 8 \) km s\(^{-1}\) (Fig. 2) for which the Gaussian fit parameters are given in Table 3.

J102618+454618: The VLBI map at 5 GHz (de Vries et al. 2009), has multiple components with an overall separation of 17 mas, with the central feature being the most prominent one. From the VLBI maps at 1665 and 4993 MHz (de Vries et al. 2009), the central feature has a flat spectra. We do not find evidence of HI absorption.

J103719+433515: This source too has an elongated structure with multiple components and an overall size of 19 mas. The brightest component in the central region of the source appears to have a flat spectrum (de Vries et al. 2009). There is no evidence of HI absorption. The zero velocity in the spectrum corresponds to the optical redshift of 0.023 as given by Snellen et al. (2004), while the one given by NED is 0.0247 (Falco et al. 1999), which was not covered by the hardware correlator. There was also an error in the settings of the software correlator. For the present, we have classified it as a non-detection.

J115000+552821: The VLBI map at 1.6 GHz shows a dominant compact component with weak emission towards the east separated from it by \( \sim 41 \) mas (de Vries et al. 2009). We detect HI absorption, with three components (Fig. 2), one of which is redshifted and one blueshifted relative to the systemic velocity. The third one, which is weaker and would be useful to confirm, is consistent with the systemic velocity, consistent with rotation of the absorbing gas (Fig. 2; Table 3).

J115050+553221: The VLBI map at 1.6 GHz shows a compact flat-spectrum core with jet-like structure (de Vries et al. 2009). We detect HI absorption towards this source. The HI line profile shows two components, one blueshifted while the second one is redshifted relative to the systemic velocity, consistent with rotation of the absorbing gas (Fig. 2; Table 3).

J120902+411559: The source exhibits multiple components with a prominent central feature and is elongated along the east-west direction with angular size \( \sim 20 \) mas (de Vries et al. 2009). The radio spectrum of this source peaks at 370 MHz (Snellen et al. 2004). There is no evidence of HI absorption.

J131739+411545: VLBI maps show a complex structure with size of \( \sim 4 \) mas (Helmboldt et al. 2007; de Vries et al. 2009). The radio spectrum of this source peaks at 2.3 GHz (Snellen et al. 2004). We detect HI absorption, where the line profile is redshifted with respect to the optical redshift by 77 km s\(^{-1}\) indicating infall of gas towards the central source (Fig. 2). The Gaussian fit parameters are listed in Table 3.

J140051+521606: The MERLIN map at 1.4 GHz shows a resolved component with a deconvolved angular size of

![Figure 3](image-url)
**Table 3.** Multiple Gaussian fit parameters to the H\textsubscript{i} absorption spectra for the detections.

| Object               | Component Number | Vel km s\(^{-1}\) | FWHM km s\(^{-1}\) | \(\tau_p\)  | \(N(\text{H}\textsubscript{i})\) 10\(^{20}\) cm\(^{-2}\) |
|----------------------|------------------|------------------|-------------------|--------------|----------------|
| J090615+463618       | 1                | −8.2(4.2)        | 151.5(10.1)       | 0.0256(0.0015) | 7.48(0.93)   |
| J115000+552821       | 1                | −83.1(2.6)       | 42.1(6.1)         | 0.0343(0.0043) | 2.79(0.76)   |
|                      | 2                | −0.9(4.0)        | 36.0(9.6)         | 0.0206(0.0047) | 1.43(0.71)   |
|                      | 3                | 57.9(1.3)        | 21.5(3.0)         | 0.0504(0.0060) | 2.09(0.54)   |
| J131739+411545       | 1                | 77.0(2.4)        | 66.8(5.8)         | 0.0294(0.0022) | 3.79(0.61)   |
| J140942+360416       | 1                | −52.2(3.4)       | 49.2(7.9)         | 0.0316(0.0033) | 3.00(0.80)   |
|                      | 2                | 25.7(3.3)        | 65.6(8.4)         | 0.0369(0.0029) | 4.67(0.97)   |
| J150805+342323       | 1                | −256.1(1.4)      | 28.8(3.6)         | 0.0822(0.0083) | 4.56(1.04)   |
|                      | 2                | −178.4(1.1)      | 91.1(1.7)         | 0.6100(0.0084) | 107.20(3.46) |
|                      | 3                | −137.5(0.9)      | 37.4(3.1)         | 0.1862(0.0178) | 13.42(2.39)  |
| J160246+524358       | 1                | −58.4(4.2)       | 94.9(9.8)         | 0.0097(0.0009) | 1.78(0.34)   |
| J171854+544148       | 1                | 90.1(1.4)        | 50.6(4.2)         | 0.0317(0.0024) | 3.10(0.49)   |
|                      | 2                | 137.2(5.7)       | 149.9(10.9)       | 0.0223(0.0019) | 6.44(1.01)   |

**Figure 4.** The distribution of the velocity of the different H\textsubscript{i} absorbing components relative to the systemic velocities of the host galaxies. The GPS sources are shown shaded.

1 (Moran et al. 1996; Wisotzki & Bade 1997). There is no evidence of H\textsubscript{i} absorption.

**J171854+544148:** This source shows two prominent components with a separation of \(\sim 68\) mas at \(\sim 1.6\) GHz, reminiscent of a CSO, but shows two weaker components in a higher-resolution image at \(\sim 5\) GHz (de Vries et al. 2009). This source has been classified as a Seyfert type 2 (Veilleux et al. 1999). It was earlier classified by Leech et al. (1994) as an interacting system, but the second object appears to be a foreground star (Bruston, Ward & Davies 2001; Davies, Burston & Ward 2002). The object is also associated with an ultraluminous infrared galaxy (ULIRG) F17179+5444 (Leech et al. 2004). The radio spectrum of the source peaks at \(\sim 480\) MHz. We detect H\textsubscript{i} absorption towards this source (Fig. 2; Table 3), with two main components, both of which are redshifted relative to the systemic velocity.

### 4 DISCUSSION

The radio luminosity of the sources in the core CORALZ sample which have a flux density at 1400 MHz > 100 mJy, redshift in the range 0.005 to 0.16 and angular size < 2 arcsec (Snellen et al. 2004; de Vries et al. 2009) are almost always less than \(\sim 10^{25}\) W Hz\(^{-1}\) at 5 GHz. Since the radio luminosities of 95 per cent of the sources in the sample compiled by Gupta et al. (2006) are greater than \(\sim 10^{25}\) W Hz\(^{-1}\) at 5 GHz, we have compared our results with those of Gupta et al. (2006) to examine any broad dependence on radio luminosity. In this section, we leave out J102618+454618 which has a flat high-frequency spectrum (Snellen et al. 2004). In the remaining sample of 17 compact low redshift sources, we were able to detect 7 new sources in H\textsubscript{i} absorption. Of these seven, three are GPS and four are CSS objects, the fraction of detection for the GPS sources being \(\sim 50\) per cent (3/6) compared with \(\sim 36\) per cent (4/11) for CSS objects. Although the numbers are small and statistical uncertainties are large, these are consistent with the detection rates for the more luminous sources, and the tendency for GPS objects to have a higher detection rate compared with CSS objects (e.g. Vermeulen et al. 2003; Palmstrøm et al. 2003; Gupta et al. 2006). As mentioned earlier in Section 3.1, the column densities are similar to those for the more luminous CSS and GPS objects.

#### 4.1 H\textsubscript{i} column density vs linear size

Earlier studies have shown an inverse correlation between the H\textsubscript{i} column density and the projected linear size. This was first noticed by Palmstrøm et al. (2003) and was later shown to be also true for a significantly larger sample of sources by Gupta et al. (2006). In Fig. 3 we have plotted the results of our observations for these 17 sources in the H\textsubscript{i} column density vs linear size diagram, along with the list of higher-luminosity sources compiled by Gupta et al. (2006). These
4.2 Relative velocity of H\textsubscript{i} absorption features

The distribution of the relative velocity for the H\textsubscript{i} absorbing components listed in Table 3 is shown in Fig. 4. These range from \(\sim-250\) to \(140\) km s\(^{-1}\), with a median value of \(\sim-50\) km s\(^{-1}\). Although the number of absorption features is small, and there are uncertainties in the systemic velocities (e.g. Morganti et al. 2001) there appears to be a marginal trend for a higher number of blueshifted features.

Although blueshifted H\textsubscript{i} absorption features could also arise from either halo or circumnuclear gas affected by winds and/or radiation pressure from the nuclear region, jet-cloud interactions are likely to significantly affect the gas properties in compact steep-spectrum radio sources. The tendency for CSS and GPS objects to be more asymmetric in location, brightness and polarization of the lobes compared with the larger objects suggest strong interaction of the jets with the circumnuclear region (e.g. Saikia et al. 1995, 2001; Arshakian & Longair 2000; Saikia & Gupta 2003). Rotation measure (RM) studies also indicate high values in many compact sources (e.g Mantovani et al. 1994, 2010; O’Dea et al. 1998), often with large asymmetries in the RM values for the oppositely-directed lobes due to interaction with asymmetrically located clouds of gas (e.g. Junor et al. 1999).

Evidence of interaction is also seen in optical emission and absorption line studies (e.g. Gelderman & Whittle 1994; Chatzichristou et al. 1999; Labiano et al. 2005; Gupta et al. 2005).

Excess of blueshifted absorption features has been reported earlier. For example, for a sample of quasars Baker et al. (2002) found a small excess of blueshifted C\textsc{iv} absorption features in CSS objects compared with the larger sources which they attribute to absorbing material being away from the jet axis, whereas van Ojik et al. (1997) found an excess of blueshifted Ly\alpha absorption features in their sample of small-sized high-redshift radio galaxies which they attribute to absorbing clouds uniformly covering the whole source signifying a halo origin. The sample of CSS and GPS objects compiled by Gupta et al. (2006) also shows a tendency for the H\textsubscript{i} absorption features to be blueshifted with velocities extending to over 1000 km s\(^{-1}\). Although the number of low-luminosity sources needs to be increased, the present observations suggest that the blueshifted velocities in these low-luminosity sources could be smaller possibly due to the weaker radio jets in these objects.

4.3 H\textsubscript{i} column density vs luminosity and redshift

It is generally believed that AGN activity is triggered by the accretion of matter onto a supermassive blackhole at the centre of the galaxy. Mergers and interactions of galax-
ies could facilitate the supply and inflow of gas into the central regions of these active galaxies leading to both circumnuclear starbursts and fuelling the supermassive blackholes (e.g. Sanders et al. 1988; Hopkins et al. 2005). It may therefore be relevant to investigate whether the H\textsc{i} column density may depend on either radio luminosity or redshift. Gupta et al. (2006) did not find any evidence of such relationships in their sample of luminous CSS and GPS objects. However, since most of the sources in their sample were selected from strong-source surveys, luminosity and redshift are strongly correlated. Constraining the sources from the Gupta et al. (2006) sample to those with redshifts <0.2, we have examined any dependence of column density on luminosity over a similar redshift range but find no evidence of any significant relationship (Fig. 5). The CORALZ sources are of lower luminosity than the Gupta et al. (2006) sample making it difficult to examine variation with redshift for similar luminosity objects. We have plotted the H\textsc{i} column density vs redshift for the CORALZ sources along with all the sources from the Gupta et al. (2006) sample (Fig. 6) and find no evidence of any correlation.

5 SUMMARY

The results of H\textsc{i} absorption measurements towards a sample of nearby CSS and GPS radio sources, the CORALZ sample, using the GMRT are summarized briefly here. These sources are of lower luminosity than earlier studies of CSS and GPS objects.

(i) We observed a sample of 18 sources and find 7 new detections. Within the uncertainties caused by the small sample size, the detection rates are similar to the more luminous objects, with the GPS objects again exhibiting a higher detection rate (3/6) than for CSS objects (4/11).

(ii) The relative velocity of the blueshifted absorption features, which may be due to jet-cloud interactions, extend to only $\sim$250 km s$^{-1}$ for these CORALZ sources compared with values of over $\sim$1000 km s$^{-1}$ for the more luminous CSS and GPS objects. This could be due to the weaker jets in these low-luminosity objects, although this needs confirmation from a larger sample of objects.

(iii) There appears to be no evidence of any dependence of H\textsc{i} column density on either luminosity or redshift. Examining sources over a similar redshift range (<0.2) also shows no evidence of any correlation with luminosity.

(iv) The weaker CSS and GPS objects are also consistent with the known inverse relation of H\textsc{i} column density with projected linear size.

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