VLA detection of OH absorption from the elliptical galaxy NGC 1052

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Abstract. VLA observations of OH absorption towards the elliptical galaxy NGC 1052 are presented. Both OH lines, at 1665 and 1667 MHz, were detected in absorption towards the center of NGC 1052. The hyperfine ratio of the two OH lines ($\tau_{1667}/\tau_{1665}$) is $2.6 \pm 0.8$ as compared to 1.8 expected for the excitation under LTE conditions for an optically thin cloud. The column density of OH is estimated to be $2.73(\pm 0.26) \times 10^{14}$ cm$^{-2}$ assuming $T_{\text{ex}} \sim 10$ K. The centers of both the OH lines are redshifted from the systemic velocity of the galaxy by $\sim 173$ km s$^{-1}$. The velocity of OH line coincides with the velocity corresponding to the strongest HI absorption. We suggest that OH absorption is arising from a molecular cloud falling towards the nucleus. The OH line, though narrower, is found to be within the much broader and smoother H$_2$O megamaser emission. The possible link between OH/HI and H$_2$O emission is discussed.

Key words. galaxies: active – galaxies:individual (NGC 1052) – galaxies: ISM – radio lines: galaxies

1. INTRODUCTION

The most extensive and conclusive confirmation for the presence of cold interstellar material in early-type galaxies came from observations of dust with the Infrared Astronomical Satellite (IRAS) (Neugebauer 1984, Knapp et al. 1985, Knapp et al. 1989). Sensitive observations of HI (van Gorkom et al. 1989, Huchtmeier et al. 1995) have also shown that elliptical galaxies contain a significant amount of cold interstellar matter. The molecular contents of elliptical galaxies has been studied mainly through CO observations of infrared bright elliptical galaxies (Wang et al. 1992, Wiklind et al. 1995, Knapp & Rupen 1996). These observations resulted in the detection of molecular gas in several galaxies in emission and four galaxies in absorption, indicating that the overall detection rate of CO in elliptical galaxies is about 10–15%. The OH radical in absorption is also a good tracer of molecular gas in interstellar clouds (Liszt & Lucas 1996). Single dish OH surveys (Schmelz et al. 1986, Baan et al. 1992, Staveley-Smith et al. 1993, Darling & Giovanelli 2000) of several hundred galaxies of various types resulted in the detection of about 3 dozen galaxies, of which none was an elliptical.

NGC 1052, a moderately luminous ($L_b = 1.6 \times 10^{10} L_\odot$) elliptical galaxy of type E4, is a member of a small group in the Cetus–I cloud. There are several estimates of the velocity for this system in the literature, which differ from each other by a few tens of km s$^{-1}$. We adopt $V_{\text{hel}} = 1474 \pm 10$ km s$^{-1}$, estimated from the optical emission lines (de Vaucouleurs 1991), which implies that NGC 1052 is at a distance of 21 Mpc (assuming $H_0 = 70$ km s$^{-1}$ Mpc$^{-1}$ and $q_0 = 0$). It is classified as a LINER (Fosbury et al. 1978, Ho et al. 1997), and is known for its several water megamasers (Braatz et al. 1996, Claussen et al. 1998). HI absorptions, redshifted from the systemic velocity, were detected at 1486, 1523 and 1646 km s$^{-1}$ against the nuclear continuum source (van Gorkom et al. 1986). NGC 1052 was reported to have CO emission as well as absorption by Wang et al. 1992, but later observations by Wiklind et al. 1995 failed to confirm those detections. More recently, Knapp & Rupen 1996 reported a possible CO absorption from NGC 1052 near 1622 km s$^{-1}$. Since the reported CO detections are quite noisy,
it remains uncertain whether NGC 1052 has a molecular component associated with the HI (21cm) absorption.

Here we report the first detection of 1665 and 1667 MHz OH absorption in NGC 1052. The next section describes the observational details and results. Subsequent sections compare these results with observations at optical, X-ray, and other wave bands, and discuss some of the implications.

2. OBSERVATIONS & RESULTS

NGC 1052 was observed in the B configuration of the VLA, which has interferometer baselines ranging from 100 m to 11 km. Data were recorded in the 4IF correlator mode, recording 1.5625 MHz in each of the two circular polarizations for two frequency bands, one centered at 1656.5 and other at 1658.3 MHz. The details of the observations are listed in Table 1. The data were reduced in AIPS using standard calibration and imaging methods. The amplitude, phase and frequency response of the antennas were calibrated separately for each IF. The phase and amplitude gains of the antennas were derived from observations of the standard VLA calibrator 0240–231 at intervals of 30 minutes. The flux scale was set using Baars et al. (1977) flux density of the standard VLA calibrator 3C48. A combined bandpass spectrum was generated using all the data taken on the amplitude and phase calibrators as well as on the strong radio source 0319+415 (3C84). A continuum data set was formed by averaging the calibrated visibility data of 50 line-free channels. The continuum data set was self-calibrated and the resulting antenna gain corrections were applied to every spectral channel separately. The continuum emission common to all channels was removed using the task 'UVLIN' inside AIPS. Continuum-free images for all channels were made at 1486, 1523 and 1646 km s$^{-1}$, which are redshifted with a FWHM of 173 km s$^{-1}$ with respect to the systemic velocity of the galaxy. The column density of OH can be estimated from

$$N_{OH} = 2.35 \times 10^{14} T_{ex} \int \tau_{1667} \, dV \, cm^{-2}$$

(1)

Table 1. Observation Parameters

| Parameter                  | Value               |
|----------------------------|---------------------|
| Date of Observation        | 1998 Sep03          |
| RA, Dec (J2000.0)          | 02 41 04.79, -08 15 20.75 |
| Observing duration (hrs)   | 5                   |
| Range of baselines (km)    | 0.1–11 (B config)   |
| Observing frequencies (MHz) | 1656.50, 1658.30     |
| Bandwidth per IF (MHz)     | 1.562               |
| Number of spectral channels| 64                  |
| Polarizations              | RCP & LCP           |
| Synthesised beam (Natural Weight) | 6.4′′$\times$4.3′′, PA= 9.7′′ |
| Velocity resolution (kHz/channel) | 4.4 km s$^{-1}$     |
| Frequency resolution (kHz/channel) | 24.4               |
| Amplitude calibrator       | 0137+331 (3C48)     |
| Phase calibrator           | 0240–231            |
| Bandpass calibrator        | 0319+415 (3C84)     |
| rms noise per channel (mJy beam$^{-1}$) | 0.7 |

The AIPS gaussian fitting routine ‘SLFIT’ was used to derive the line parameters. The peak optical depth of the 1667 MHz line is 5.8$(\pm0.2) \times 10^{-3}$ and that of the 1665 MHz line is 2.9$(\pm0.1) \times 10^{-3}$. The FWHM of 1667 and 1665 MHz lines are 18.8$\pm$1.3 and 14.5$\pm$2.6 km s$^{-1}$ respectively. Given the uncertainty in the overall shape of the 1665 MHz line due to low optical depth, profiles of the 1665 and 1667 MHz lines can be considered similar. The ratio of the integrated optical depth is 2.6$\pm$0.8 which is marginally higher than that expected (viz. 1–1.8) for excitation in thermal equilibrium. The mean value of 1667 to 1665 MHz line ratio is about 1.6 for galactic diffuse clouds (Dickey et al. 1981).

3. DISCUSSION

3.1. Link with HI and X-ray absorbing column

HI components in NGC 1052 have been seen in absorption at 1486, 1523 and 1646 km s$^{-1}$, which are redshifted from the systemic velocity (van Gorkom et al. 1986). The N(HI)/$T_{ex}$ values of three components are 0.6 $\times$ 10$^{18}$, 1.0 $\times$ 10$^{18}$ and 1.4 $\times$ 10$^{18}$ cm$^{-2}$ respectively. The strongest absorption ($\tau \approx 0.02$) is at 1646 km s$^{-1}$ with a FWHM of about 35 km s$^{-1}$. Due to the similarity in the velocity of OH absorption with the highest redshifted component of HI absorption, it is reasonable to associate this HI component with the OH detected in these observations. It is interesting that the velocity of OH absorption matches very well with the strongest HI absorption component at 1646
The peak flux density in the contour image is 1.4 Jy beam$^{-1}$. The peak flux densities of the E and W lobes are 22.3 and 19.4 mJy beam$^{-1}$ respectively. The grey scale represents the velocity-integrated optical depth of the 1667 MHz OH absorption. The synthesised beam depicted in the bottom left corner is 6.4$''$ x 4.3$''$, PA = 9.7$^\circ$. The radio continuum image of NGC 1052 drawn as contours with levels of 1.8 mJy beam$^{-1}$ x (1,1.5,2,3,4,6,8,12,16,24,32,48,64,96,128,192,256,384,512). The peak flux density in the contour image is 1.14 Jy beam$^{-1}$. The peak flux densities of the E and W lobes are 22.3 and 19.4 mJy beam$^{-1}$ respectively. The greyscale levels are 1.8 mJy beam$^{-1}$ x (1,1.5,2,3,4,6,8,12,16,24,32,48,64,96,128,192,256,384,512).

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arising towards the nucleus which is free-free absorbed at wavelengths corresponding to the HI and OH absorptions (Kameno et al. 2001), therefore, radio observations are sampling off nuclear gas which may be of different composition than the gas probed via X-ray observations.

3.2. Link with H$_2$O Megamasers?

It is very surprising that the OH absorption, though narrower than the water maser emission, is coincident with the velocity centroid of the 22 GHz H$_2$O masers. NGC 1052 is the only known elliptical galaxy having H$_2$O megamasers. The megamasers and their link with AGNs are generally understood in terms of obscuring torus models. The link is thought to be a consequence of irradiation of the inner face of the torus by hard X-rays from the nuclear continuum source, which enhances the abundance of OH by dissociation of H$_2$O masing gas. Efficient maser emission will arise towards the nucleus which is free-free absorbed at 84.3 GHz in H$_2$O, however it is not clear how HI/OH are quite stable density is well above than that predicted from our observations. Further simultaneous observations of HI, OH and H$_2$O masers are required to make a connection between molecular gas traced by OH absorption and H$_2$O masing gas.

4. SUMMARY

These VLA observations have resulted in the first detection of OH absorption in an elliptical galaxy. Both, 1665 and 1667 MHz OH absorption, were detected from the elliptical galaxy NGC 1052. The linewidths of both the OH lines are significantly large as compared to that expected for a cloud in thermal conditions at few tens of K. The gas is predicted to be close to the nucleus. A remarkable coincidence of velocity is found with the strongest and redshifted HI absorption and H$_2$O emission, however link to the megamasers is still not understood. Based on the abundance ratio of OH/H$_2$ in NGC 1052 is comparable to HI. Higher angular and spectral resolution observations of the OH absorption while simultaneous observations of H$_2$O and HI/OH absorptions would be necessary to understand the link between masing gas and molecular gas traced by OH absorption.

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