Publ. Astron. Soc. Japan **36**, 387–390 (1984)

A Negative Search for CO Absorption Lines (J=0–1) toward High-Redshift Quasars

Fumio TAKAHARA, Yoshiaki SOFUE, Makoto INOUE, and Naomasa NAKAI

Nobeyama Radio Observatory, Minamimaki-mura, Minamisaku-gun, Nagano 384–13*

and

Hiroto TABARA and Tatsuji KATO

Faculty of Education, Utsunomiya University, Mine 350, Utsunomiya 321

(Received 1983 December 24; accepted 1984 March 1)

Abstract

A search has been made for absorption lines of CO molecules in the direction of six high-redshift quasars with strong continuum emission in the millimeter-wave range. The 45-m telescope at the Nobeyama Radio Observatory (NRO) combined with wide-band spectrometers was used to investigate redshifted CO (J=0–1) absorption lines in the 40-GHz band with a 0.5–3.75-GHz band width. No significant features are found in the obtained spectra and upper limits for the optical thickness of the CO gas against the J=0–1 transition are determined for six quasars, OS+356, OX+057, OD+148, OJ+248, OI−061, and MC3 1331+170.

Key words: CO absorption lines; Quasars; Radio astronomy.

1. Introduction

Quasar absorption lines give important information about underlying galaxies and intergalactic material in the remote past. As a result of extensive investigation in optical and ultraviolet bands, there are now a wealth of evidence for the existence of a hot gas ($T>10^4$K) in the intervening galaxies and intergalactic clouds (Weymann et al. 1981). There have also been searches for redshifted H I 21-cm absorption lines, which have been found for five quasars (Wolfe 1980). Identification of H_2 and CO molecular lines in the optical spectra of high-redshift quasars is still in controversy (Weymann et al. 1981; Varshalovich and Levshakov 1982; Val'tts 1982). Khersonskij et al. (1981) proposed that H_2CO and CO molecules may be found as absorption lines in the radio band.

Here we report the results of a search for CO (J=0–1) redshifted absorption lines toward high-redshift quasars which have strong continuum emission in millimeter wave-

* Nobeyama Radio Observatory, a branch of the Tokyo Astronomical Observatory, University of Tokyo, is a facility open for general use by researchers in the field of astronomy and astrophysics.

Table 1. Summary of observations.

Source name	Redshift	Expected frequency (GHz)	Continuum flux (Jy)	T_A (K)	Frequency range (GHz)	Integration time (min)	T_{rms} (K)	τ_{ul}
OS+356	1.814	40.96	1.7	0.39	40.885–42.885	45	0.05	0.5
OX+057	1.936	39.26	4.0	0.92	39.135–42.885	45	0.05	0.2
OD+148	2.065	37.61	1.3	0.28	37.485–39.485	45	0.06	1.0
OJ+248	2.046	37.84	1.4	0.32	37.485–39.485	60	0.055	0.7
OI−061	1.901	39.735	1.0	0.23	39.300–39.800	90	0.035	0.6
	1.9299*	39.343			39.323–39.363†		0.08††	—
	1.9123*	39.580			39.560–39.600†		0.08††	—
MC3 1331+170	2.081	37.413	0.5	0.12	41.350–41.850	90	0.035	2.1
	1.7852*	41.387			41.367–41.407†		0.07††	—
	1.7764**	41.518			41.511–41.551†		0.08††	—
	1.7755*	41.531			41.511–41.551†		0.08††	—

* Optical absorption.
** H I absorption.
† High-resolution spectrometers.
†† Values for a bandwidth of 80 kHz.

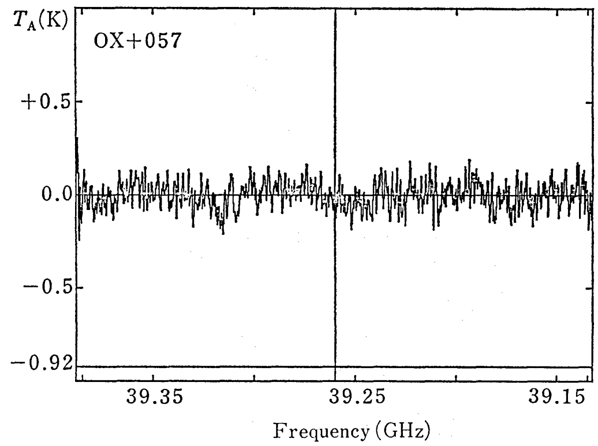

Fig. 1. The obtained spectrum of OX+057 for a frequency range of 39.135–39.385 GHz. The vertical line indicates the expected location of a redshifted CO (J=0–1) line (z= 1.936). Horizontal lines show the expected continuum level.

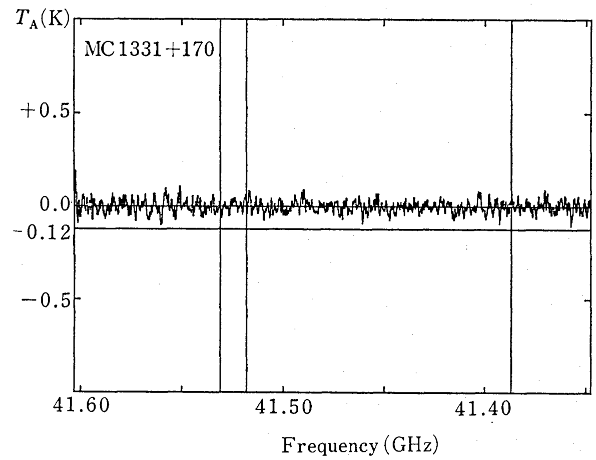

Fig. 2. The obtained spectrum of MC3 1331+170 for a frequency range of 41.35–41.60 GHz The vertical lines indicate the expected locations of redshifted CO (J=0–1) lines (z= 1.7755, 1.7764, and 1.7852). Horizontal lines show the expected continuum level.

lengths. Two of them are known to have H I and/or optical absorption lines. We used the recently constructed 45-m telescope at NRO which is appropriate for such a purpose because of its high surface accuracy and wide-band acousto-optical spectrometers available.

2. Observations

We have selected six objects which have redshifts such that the CO J=0–1 line with the rest frequency of 115.27 GHz is redshifted to the 40-GHz band and have strong millimeter continuum fluxes. Among the six sources thus selected, two objects (MC3 1331+170 and OI−061) are known to have H I and/or optical absorption lines.

Observations were conducted on April 22, 1983 with the 45-m telescope at NRO. The frequency range was set around the redshifted CO line frequencies expected from their redshifts of optical emission and absorption lines with a 0.5–3.75-GHz band width. Four objects which are selected primarily because of strong millimeter fluxes were observed using 8 wide-band spectrometers to attain the widest band coverage. Each spectrometer has a resolution of 250 kHz with a total band width of 250 MHz. For two objects which have optical and H I absorption lines we used high-resolution spectrometers with a resolution of 40 kHz and a total band width of 40 MHz in addition to the wide-band spectrometers in order to examine the frequency range corresponding to the H I and optical absorption redshifts in detail. Those resolutions correspond to velocity resolutions of about 2 km s^{-1} and 0.3 km s^{-1}, respectively. The system temperature was about 600 K and the integration time was 45–90 min for each object with the position switching method with a blank sky. The pointing accuracy was about 10″.

Their continuum fluxes were estimated from reported fluxes at nearby frequencies in the literature; no continuum measurement was made. We then estimate expected antenna temperature, T_A, of the contiunum level by assuming the reported flux densities and the aperture efficiency of 40% at 40 GHz. The obtained rms temperature for a band width of 500 kHz, T_{rms}, is about 0.05 K.

3. Results

In table 1 we summarize the obtained results for the six quasars. Examples of the obtained spectra are shown in figures 1 and 2. In figure 1 is shown a part of the spectrum of OX+057, which has the strongest continuum emission among the six sources observed. In figure 2 is shown the case of MC3 1331+170, which is known to have an H I absorption feature. As is seen in these figures no significant absorption features were detected. We may calculate an upper limit to the optical thickness, τ, due to intervening CO molecules at the 3σ level by the equation

$$T_A(1-e^{-\tau})<3T_{rms}\,. \tag{1}$$

For example, in the case of OX+057, the 3σ upper limit τ_{ul}, is shown to be 0.2 for a 4 km s^{-1} width. For the other quasars studied, τ_{ul} is shown to be of the order of 0.5–1.

This work was performed under a collaborating research program at NRO. The authors express their thanks to the staff of NRO for their assistance in the observations.

References

Khersonskij, V. K., Varshalovich, D. A., and Levshakov, S. A. 1981, *Soviet Astron.*, **25**, 16.
Val'tts, I. E. 1982, *Soviet Astron.*, **26**, 511.
Varshalovich, D. A., and Levshakov, S. A. 1982, *Comm. Astrophys.*, **9**, 199.
Weymann, R. J., Carswell, R. F., and Smith, M. G. 1981, *Ann. Rev. Astron. Astrophys.*, **19**, 41.
Wolfe, A. M. 1980, *Phys. Scr.*, **21**, 744.