THE ASTROPHYSICAL JOURNAL, 169:L35–L37, 1971 October 1

MILLIMETER OBSERVATIONS OF CO, CN, AND CS EMISSION FROM IRC+10216

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Received 1971 July 28

ABSTRACT

We report the discovery of three additional molecular lines from an object in which we have previously detected carbon monoxide. The data presented tend to support our model of a small expanding shell with high brightness temperature.

I. INTRODUCTION

In an earlier paper (Solomon *et al.* 1971; hereinafter SJPW) we reported the detection of a broad spectral line near 2.6 mm attributed to the $J = 1$ to $J = 0$ transition in $^{12}C^{16}O$ in the infrared object IRC+10216. As we pointed out in that paper, the large infrared diameter of the object "makes it a good candidate for the detection of thermal radiation in microwave molecular lines, particularly in the millimeter range where the beam dilution will be minimized." Accordingly, we have continued our study of this object and have now found line emission from the CN $N = 1$–0, CS $J = 3$–2, and $^{13}C^{16}O$ $J = 1$–0 transitions.

II. OBSERVATIONS

Observations were made in February with the 36-foot antenna of the National Radio Astronomy Observatory[1] using the 40-MHz-wide line-receiving system with 2-MHz resolution, as before. The observations were made by switching 40 MHz with 5-minute integrations alternately on and 30′ away from the source. The resulting spectra, with a velocity resolution of $\sim$5 km s^{-1}, are presented in Figure 1 and summarized in Table 1. The position of the source was taken to be R.A. $9^h46^m25^s.6$ and decl. 13°24′39″.9 (1950) (Becklin *et al.* 1969), which agreed within our pointing accuracy ($\sim$10″) with the observed position of peak CO line intensity.

As can be seen from Figure 1 all four spectra show very broad, rather flat emission lines centered at the same LSR velocity and with approximately the same linewidth. The $^{12}C^{16}O$ line profile has the highest signal-to-noise ratio, and the central velocity is $V_{LSR} = -21.4 \pm 3$ km s^{-1} with a width of 29 km s^{-1}. This corresponds to a heliocentric velocity of -14.3 km s^{-1}, in excellent agreement with the value of -16 km s^{-1} found

[1] The National Radio Astronomy Observatory is operated by Associated Universities, Inc., under contract with the National Science Foundation.

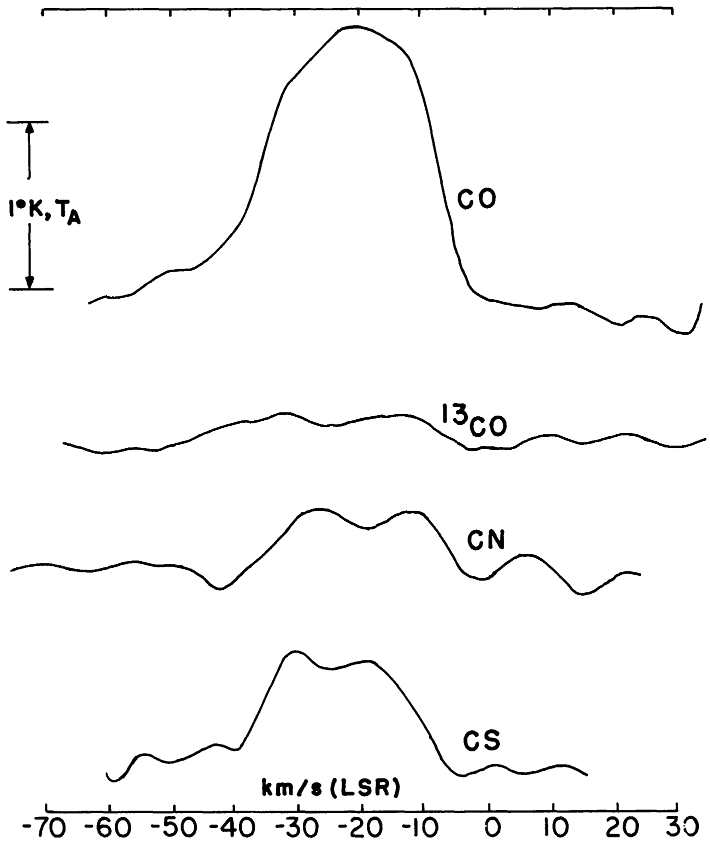

FIG 1.—The $^{13}C^{16}O$ line is probably distorted by baseline error at its negative-velocity edge, causing the line to appear wider than it actually is. CN has another line 9 MHz (24 km) lower in frequency at one-third the intensity of the main line. Given our signal-to-noise ratio, it is not surprising that we have not detected it.

TABLE 1

SUMMARY OF SPECTRA

Molecule	Laboratory Frequency (MHz)	T_A, max (° K)	v (km s^{-1})	Δv (km s^{-1})
$^{12}C^{16}O$........	115,271.2	1.7	-21.3 ± 3	29
$^{13}C^{16}O$........	110,201.4	0.2	$-25\ \ \pm6$	37
CN..........	113,491*	0.4	-19.7 ± 5	28
CS...........	146,969.2	0.6	-22.9 ± 4	26

* The CN frequency is based on an unpublished refinement to the work of Jefferts, Penzias, and Wilson (1970).

for the underlying carbon-star lines by Herbig and Zappala (1970). Although the closeness of the agreement may be partly fortuitous, the fact that the microwave and optical lines have the same central velocity provides strong evidence for a physical connection between the microwave molecular line emitting region and the carbon star.

The angular size and position of the source were also investigated by means of its 115-GHz $^{12}C^{16}O$ line radiation. The pointing and beam size of the antenna were first measured at this frequency using Jupiter, which had an angular diameter of 40″ during the period of observation. From these measurements, the half-power beam width of the antenna was found to be 55″ (el) × 72″ (az). A series of five spectral observations spaced 30″ apart in declination and centered on IRC+10216 were then made, followed by three more in right ascension. From these data we infer upper limits to the angular size of the source of 30″ and 90″ in declination and right ascension, respectively, consistent with our small-source interpretation (SJPW) of the line emission. These observations were limited by poor observing conditions, and a better size determination will no doubt be obtained from further observations.

The antenna efficiency of the 36-foot telescope at 2.6 mm is approximately 40 percent. Thus, the brightness temperature T_B of the lines, for a small source centered with respect to the beam response, is given by $T_B = 2500\, T_A/\theta^2$, where θ is the angular radius of the source in seconds of arc. For the CO line, $T_A = 1.7°$ K, giving

$$\theta = \left(\frac{R_1}{D}\right) = \left(\frac{4250}{T_B}\right)^{1/2},$$

where R_1 is the size of the source in astronomical units and D is the distance in parsecs; this is in good agreement with our previous estimate (SJPW). The smaller observed antenna temperatures for the CN and CS lines may be due either to optical thinness in these lines or to a subthermal excitation. This question can be answered by future observations of the isotope lines in CS and CN. The absence of detectable satellite lines in the CN spectrum indicates that it is at least not heavily saturated.

The observed intensity ratio of the ^{13}CO to ^{12}CO lines is 1/8. Although the ^{13}CO line has a poor signal-to-noise ratio, we can definitely say that the intensity ratio and therefore the ^{13}C/^{12}C isotope ratio is less than 1/4, which is the value expected from matter processed through the C-N-O cycle. The true isotope ratio could actually be much smaller than this if the ^{12}CO line were optically thick.

In SJPW we suggested that the broad, nearly flat CO line profile could be interpreted as an expanding envelope from a small shell with high brightness temperature surrounding the late-type carbon star. The estimates for the mass and size of the envelope were similar to those expected for a planetary nebula in the process of formation. This current series of observations containing three additional lines having profiles similar to CO, and more importantly with evidence for a small source, tends to support this model. However, a more substantial effort to determine the size of the source is needed before definite conclusions can be reached about the nature of this unique object.

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