

DETECTION OF HC¹⁸O⁺ IN SAGITTARIUS B2

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ABSTRACT

Line emission at 85.1 GHz attributed to the $J = 1 \rightarrow 0$ rotational transition of the formyl ion HC¹⁸O⁺ has been detected in Sgr B2 (OH). The double isotopic ratio (¹⁸O/¹⁶O)/(¹²C/¹³C) in the formyl ion in Sgr B2 is estimated to be in the range 5–10, hence within a factor 2 of the terrestrial value 5.5. This determination implies that the ¹³C/¹²C ratio near the galactic center does not differ greatly from that in local molecular clouds.

Subject headings: interstellar: abundances — interstellar: molecules

Klemperer's (1970) identification of the strong interstellar line at 89,188 MHz as the lowest rotational transition of the formyl ion HCO⁺ has been conclusively confirmed in the laboratory by Woods and co-workers. In addition to the normal molecular ion, they have measured the frequency of this transition for the deuterium, ¹³C, and ¹⁸O isotopic species (Woods *et al.* 1975, 1978), and as a result, the first two of these rare species have now been identified in space (Hollis *et al.* 1976; Snyder *et al.* 1976). Astronomical detection of the ¹⁸O species is the subject of the present *Letter*. Relative to ¹⁶O the terrestrial abundance of ¹⁸O is 1/490; in astronomical sources it has been detected previously in OH (Whiteoak and Gardner 1975), CO (Penzias, Jefferts, and Wilson 1971), and H₂CO (Gardner, Ribes, and Cooper 1971).

Figure 1a is a spectrum of Sgr B2 (OH) which we have obtained with the NRAO¹ 36 foot (11 m) telescope in the vicinity of the $J = 1 \rightarrow 0$ transition of HC¹⁸O⁺ (the 1950 coordinates are $\alpha = 17^{\text{h}}44^{\text{m}}11^{\text{s}}$, $\delta = -28^{\circ}22'30''$, and the exact rest frequency according to Woods *et al.* 1978 is 85,162.157 MHz); Figures 1b and 1c are spectra of this transition in H¹³CO⁺ and HCO⁺ taken by Snyder *et al.* (1976) in the same direction with the same instrument. At an HC¹⁸CO⁺ velocity of 54 km s⁻¹ there is a weak but definite emission line A which matches almost exactly in velocity and width a similarly sharp component B in the spectrum of H¹³CO⁺. This velocity agrees well with that of other sharp molecular lines in Sgr B2 (OH), which nearly all lie between 50 and 55 km s⁻¹ (Table 1).

Snyder *et al.* (1976), impressed by the intensity and sharpness of B relative to the diffuse H¹³CO⁺ emission at higher velocity, and by the marked difference between the spectra of H¹³CO⁺ and HCO⁺, suggested that B might in fact be a new line of unknown origin. Knowing the density of unidentified lines in Sgr B2 (OH) (probably less than 5 per GHz for lines 0.2 K and stronger), one can readily calculate that the match of A with B is highly unlikely to be the result of chance,

and hence this interpretation is almost certainly incorrect. There can be little doubt instead that in A we have detected the ¹⁸O species of the formyl ion.

Sgr B2 is a complex molecular source which, in spite of many observations, remains poorly understood. To explain the broad, apparently self-reversed lines of CO, CS, and SiO toward the OH maser source at the center of the complex, Scoville, Solomon, and Penzias (1975) have proposed a model with two components. They suppose that cool, low density foreground gas at a radial velocity of 62 km s⁻¹ absorbs the wider emission from a dense and turbulent background cloud centered at about the same velocity. The foreground gas is opaque in the lines of CO, CS, etc., explaining why these lines are self-reversed, but it is transparent to less abundant molecules like OCS, for which only a single line at 62 km s⁻¹ from the background is observed.

Such a two-component model explains the self-reversed HCO⁺ spectrum in Figure 1c, and can account in a general way for the marked difference between HCO⁺ and H¹³CO⁺ which puzzled Snyder *et al.* (1976),

TABLE 1
SINGLE-PEAKED LINES IN THE DIRECTION OF
SAGITTARIUS B2 (OH)

Molecule	Line	Peak Velocity (km s ⁻¹)	Full Width at Half-Intensity	Reference
HC ¹⁸ CO ⁺ . . .	1-0	54	13	1
H ¹³ CO ⁺	1-0	51.7	11.3	2
²⁹ SiO	2-1	51.5	15	5
H ₂ S	1 ₀ -1 ₀₁	50	14	3
C ³⁴ S	2-1	54	13.4	1
HC ¹⁵ N	1-0	53	12	1
HN ¹³ C	1-0	53.7	15	1
SO	3 ₂ -2 ₁	61	21	1
C ¹⁸ O	1-0	64.3	28	7
CCH	1-0	53.4	24	4
OCS	7-6	62	24	1
HC ₂ N	10-9	62	26	6
HC ₃ N	31-30	61	25	3

REFERENCES.—¹ Present *Letter*. ² Snyder *et al.* 1976. ³ Guélin and Thaddeus, unpublished. ⁴ Tucker *et al.* 1974. ⁵ Morris 1978, private communication. ⁶ Morris *et al.* 1976. ⁷ Wannier *et al.* 1976.

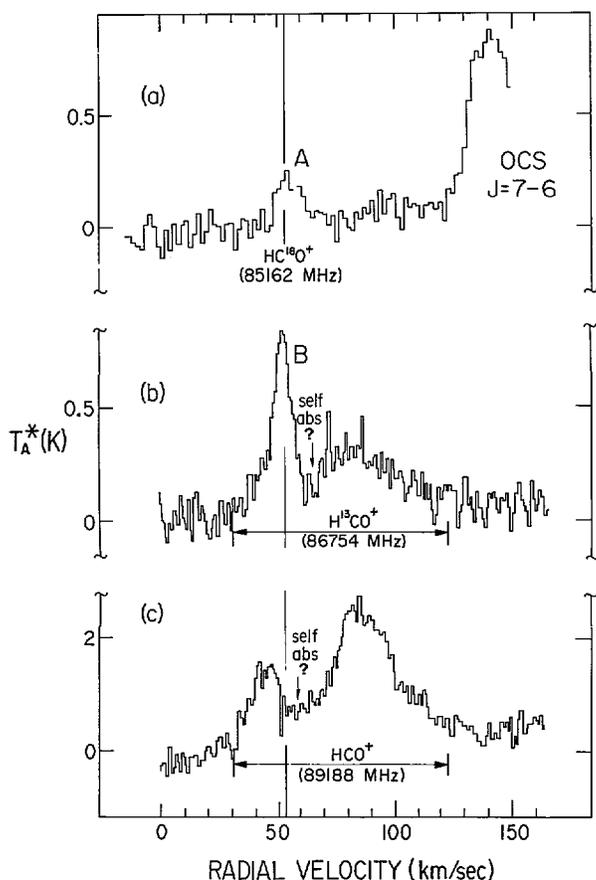


FIG. 1.—Upper spectrum (a), the $J = 1 \rightarrow 0$ rotational transition of HC^{18}O^+ observed in the direction of Sgr B2 (OH) with a spectral resolution of 1.76 km s^{-1} . The broad line on the right is the $J = 7 \rightarrow 6$ transition of OCS at $85,139 \text{ MHz}$. Lower spectra (b) and (c), the $J = 1 \rightarrow 0$ transitions of H^{13}CO^+ and HCO^+ observed by Snyder *et al.* (1976) in Sgr B2 (OH) with a spectral resolution of 0.88 km s^{-1} . Differences in the profiles of the three isotopic species are interpreted as effects of self-absorption.

but it does not give a very satisfactory interpretation of A and B. If these are the residues of much wider self-absorbed emission lines, why are they so sharp and symmetrical, and (since the frequency-dependent foreground absorption presumably differs by a large factor) why do they agree so well in velocity and width with each other, and with other rare isotopic species (Table 1)? We suspect that the most reasonable answer to these questions is that A is not appreciably self-absorbed at all, and B is only slightly so, and that both originate in a condensation of the background cloud at 53 km s^{-1} , or even a distinct source at this velocity. Morris *et al.* (1976) have postulated just such a low-velocity source to account for observations of HC_3N . The relation of this object to the more turbulent background cloud is unclear, but, since it is most conspicuous in lines of low optical depth, it is presumably one of the most massive objects in the Sgr B2 molecular complex.

The double isotopic ratio $c/a = (^{16}\text{O}/^{18}\text{O})/(^{12}\text{C}/^{13}\text{C})$ in interstellar molecules is a valuable probe for studying the variation of the oxygen and carbon isotopes throughout the Galaxy, since it is less affected by saturation than the ratio c or a separately. By comparing C^{18}O and ^{13}CO line emission in Sgr B2 at high velocity (where he thought both lines were optically thin), Wannier (1977) has derived a value for c/a of 25 ± 10 —significantly higher than the terrestrial value 5.5. Since there is reason to think that the oxygen ratio c is fairly constant throughout the Galaxy, Wannier has suggested that ^{13}C may be 5 times as abundant in Sgr B2 as on Earth.

A hazard in attempting to deduce bulk isotopic ratios from observations of a particular interstellar molecule is the possibility of fractionation. In several nearby sources, deuterium is now known to be concentrated by an enormous factor (10^2 – 10^5) in HCO^+ , HCN , and perhaps other molecules, and in a distant, complex object like Sgr B2 there is hence no *a priori* assurance that a small but significant fractionation of the rare carbon and oxygen isotopes does not occur. The best way to check Wannier's reasoning is to determine c/a for other molecules, and our detection of HC^{18}O^+ provides such a check.

The ratio of integrated line intensities B/A for the data in Figure 1 is 5 ± 2 , and, since foreground absorption tends to reduce B relative to A, this is probably for the formyl ion a firm lower limit for c/a in the Sgr B2 53 km s^{-1} source. What is the upper limit? While we cannot give a definite answer to this question, we think it unlikely that c/a is as high as 25, since this would require a fivefold attenuation of B relative to A by the frequency-dependent foreground absorption. To maintain the observed agreement in velocity and width of B and A, a reasonable limit on such foreground absorption is probably a factor 2. If this is so, c/a is no more than twice the terrestrial value, and is in agreement with that of most molecular clouds away from the region of the galactic center.

It is perhaps significant that in formaldehyde, the third molecule whose ^{13}C and ^{18}O species have been observed in Sgr B2, a similarly low value of c/a is found. Gardner *et al.* at Parkes deduced $c \approx 10$ from the 6 cm formaldehyde lines, and on repeating these observations with the NRAO 43 m telescope, Tucker, Kutner, and Massano (1979) recently determined an even lower value, $c/a = 6$ –7.

This apparent discrepancy between c/a in carbon monoxide, on the one hand, and formaldehyde and the formyl ion, on the other, is not so acute that an explanation in terms of line formation or instrumental calibration (or both) can be definitely ruled out, since $c/a \approx 10$ nearly reconciles the conflicting data. It is a discrepancy, however, which we believe calls into question Wannier's contention that the $^{13}\text{C}/^{12}\text{C}$ ratio near the galactic center may differ appreciably from that in the solar neighborhood, and it underscores the caution required in deducing bulk isotopic ratios from molecular observations.

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