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DETECTION OF ^{17}O IN IRC+10216*

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ABSTRACT

Lines of the fundamental vibration-rotation band of $^{12}C^{17}O$ have been observed near 4.7 μ in IRC+10216. Lines of $^{12}C^{18}O$ were not detected, indicating a lower limit of 5 for the abundance ratio $^{17}O/^{18}O$. A lower limit of 200 and a probable value of 400 is obtained for the ratio $^{16}O/^{17}O$. The presence of $^{12}C^{17}O$ is also indicated in α Her and α Sco.

Subject headings: abundances — infrared — spectra, molecular

In an earlier paper (Geballe, Wollman, and Rank 1973, hereafter denoted GWR), it was suggested that an absorption feature at 2142.0 cm^{-1} in the bright infrared source IRC+10216 could be identified with the 1–0 *R*6 transition of $^{12}C^{17}O$. Observations of this feature have since been repeated. In addition a second line of $^{12}C^{17}O$ has been observed in IRC+10216, confirming the identification of this isotopic species.

The spectra shown in figures 1 and 2 were obtained at the Lick Observatory's 120-inch (3-m) telescope with a tandem scanning Fabry-Perot interferometer operated at a resolution of 0.15 cm^{-1}. Figure 1 should be compared with figure 1 of GWR. The two spectra were taken approximately 6 months apart. All lines inherent to IRC+10216 have been shifted to lower frequency by about 0.4 cm^{-1} in the present spectrum due to the change in the radial velocity of IRC+10216 relative to the Earth. In particular, the absorption at the frequency of the 1–0 *R*6 line of $^{12}C^{17}O$ is now well isolated from the terrestrial H_2O absorption and, in view of its large signal-to-noise ratio, can no longer be regarded as tentative. Figure 2 shows a spectral region near that of figure 1. In it, the $^{13}C^{16}O$ line at $\sim$2134.65 cm^{-1} has a shoulder on its high-frequency side whose frequency agrees with that of the 1–0 *R*4 transition of $^{12}C^{17}O$ and whose strength is consistent with the previously mentioned *R*6 line of $^{12}C^{17}O$. A solar spectrum taken at the time showed no terrestrial absorptions other than the strong feature near 2135.5 cm^{-1}. Thus, figure 1 shows detection of an isolated line corresponding to $^{12}C^{17}O$ and figure 2 provides confirmatory evidence for $^{12}C^{17}O$ in IRC+10216.

The solid lines superposed on the data points are computer-generated synthetic spectra corresponding to absorption by an isothermal shell with a Gaussian line profile. The computed stellar spectrum was convolved with the instrumental profile, and the parameters of the absorbing layer were adjusted to produce a fit to the data. These parameters are listed in table 1. More complete discussions of the mathematics of the fit and the details of the structure of IRC+10216 can be found in Geballe, Wollman, and Rank (1972) and in GWR.[1]

The positions of the transitions of the fundamental vibration-rotation band of $^{12}C^{18}O$ are also shown in figures 1 and 2. The absence of absorption at these frequencies yields a lower limit of 5 for the abundance ratio $^{17}O/^{18}O$. Thus, $^{17}O/^{18}O$ in IRC+10216 is at least 25 times greater than the terrestrial value and the recently reported solar value (Hall 1973). The $^{16}O/^{17}O$ ratio of 400 is based on a theoretical best fit to the data which minimizes the $^{12}C^{16}O$ column density in the shell around IRC+10216. Since the $^{12}C^{16}O$ lines are saturated, an acceptable synthetic spectrum can be computed with nearly an order of magnitude more $^{12}C^{16}O$ and, consequently, an $^{16}O/^{17}O$ ratio which is essentially terrestrial. However, a standard C/H ratio in the shell would then imply a shell mass for IRC+10216 which is a few tenths of a solar mass. The large mass and associated optical extinction of the shell, coupled with the high ratio of $^{16}O/^{18}O$ ($>10^4$) required by such an interpretation of the data seem to us to be unrealistic. Consequently, it appears that the $^{16}O/^{17}O$ ratio is substantially lower than its terrestrial value.

A discussion of the production and surface enrichment of ^{17}O has been given by Wollman (1973). A low $^{16}O/^{17}O$ ratio in the material ejected by IRC+10216 requires post–main-sequence convection down to the region where partial NO processing has occurred. This is consistent with the post–main-sequence CN processing of the convective envelope required to produce the

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[1] Due to an error in calculation, the ages of the shells stated in GWR should be increased by approximately a factor of 4, and the column density of H_2 in the shell around the star reduced by the same factor. Accordingly, the total mass of the 2″ shell should be increased by the square of this factor.

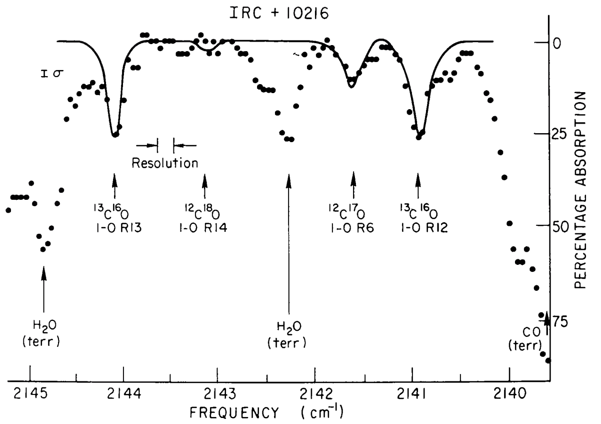

FIG. 1.—Infrared spectrum of IRC+10216 near 2142 cm^{-1}. *Dots*, observed spectra; σ is the probable error for a single data point. The solid line is a synthetic spectrum computed using the values for the parameters listed in table 1. The positions of terrestrial lines and possibly detectable lines in IRC+10216 are indicated by arrows.

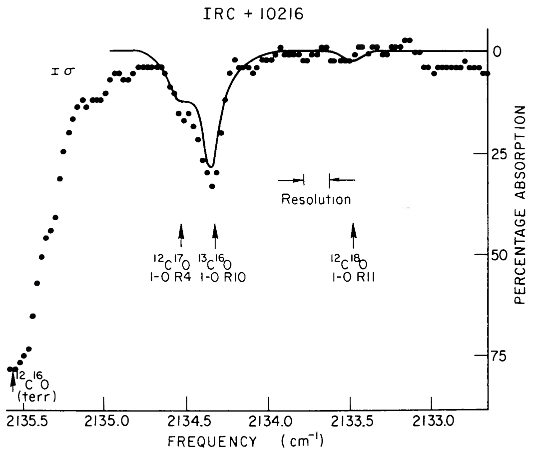

FIG. 2.—Infrared spectrum of IRC+10216 near 2134 cm^{-1}. Note that the $^{12}C^{17}O$ and $^{13}C^{16}O$ lines near 2134.5 cm^{-1} are on the edge of a broad terrestrial $^{12}C^{16}O$ absorption. Hence the stellar spectrum falls below the synthetic spectrum in this region.

TABLE 1

PARAMETERS FOR SIMULATION OF OBSERVED IRC+10216 SPECTRA

Assumed T_{eff}(° K)	T_R(° K)	T_V(° K)	$N(^{12}C^{16}O)$ (cm^{-2})	Line-Width Parameter σ(cm^{-1})	$^{12}C/^{13}C$	$^{17}O/^{18}O$	$^{16}O/^{17}O$
650	400	<300	$10^{19.7}$	0.009	8*	>5	400†

* Value obtained from measurements by Wilson *et al.* (1971).
† Value uncertain due to saturation effects.

low value of $^{12}C/^{13}C$ observed in IRC+10216 (see, e.g., Wilson *et al.* 1973, and GWR).

In addition to the spectra discussed above, we have recently observed the two late-type stars α Her and α Sco in spectral regions near 4.7 μ for the purpose of identifying lines of $^{12}C^{17}O$ and $^{12}C^{18}O$. Due to improvements in the Fabry-Perot spectrometer these spectra are of higher quality than those reported by Geballe *et al.* (1972) for these two stars. The profusion of lines of $^{12}C^{16}O$ and $^{13}C^{16}O$ from the first several vibrational levels makes identification of lines of rarer isotopic species very difficult. However, in both of these stars there is evidence for the presence of $^{12}C^{17}O$, indicating an $^{16}O/^{17}O$ abundance ratio of 200 with an estimated error of a factor of 3.[2] The presence of $^{12}C^{18}O$, which had been tentatively identified in α Her by Geballe *et al.* (1972), is uncertain, and its abundance is much less than was reported in that paper. The present data do not require a substantial deviation from the terrestrial $^{16}O/^{18}O$ ratio in α Her or α Sco.

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[2] Maillard (1973) has also recently reported the enrichment of ^{17}O in α Her from observations of the overtone bands of CO.