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Ethylene in the circumstellar envelope of IRC+10216

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Abstract. Ethylene (C_2H_4) is a symmetric molecule that is best detected using mid-infrared transitions. We report on observations of the 10.5 μm ν_7 band using the cryogenic grating spectrograph TEXES. These confirm the previous ethylene detection in the IRC+10216 circumstellar shell. We detect 18 ethylene lines. The lines are both narrow and weak with depths of no more than ∼2%. The ethylene lines suggest an excitation temperature of ∼80 K.

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Due to symmetry ethylene does not have a permanent dipole moment and there are no strong microwave rotational transitions. Astronomically ethylene is best detected through the ν_7 out-of-plane bending mode at 10.5 μm. Ethylene (C_2H_4) was first detected in space by observing the ν_7 lines in the circumstellar shell of the dust-obscured carbon-rich AGB star IRC+10216. Infrared heterodyne spectroscopy and a 1.5 m telescope were employed (Betz 1981, Goldhaber *et al.* 1987).

Heterodyne spectroscopy is a novel mid-infrared technique useful for molecules with line frequencies in near coincidence with available reference lines. The detected ethylene lines were shallow, at most a few percent deep. The observations consisted of individual ethylene line profiles that were spectrally highly resolved but rather noisy. We felt that inspection of the entire spectral region might lead to (1) insight into possible blends and (2) detection of additional ethylene features. This in turn would lead to much improved information on the creation and destruction of ethylene in the circumstellar environment.

The observations were again of IRC+10216, a carbon star obscured in a dust shell of material shed from the star in mass loss. IRC+10216 is relatively close by and very bright in the thermal infrared, allowing highly sensitive infrared and microwave searches for molecular lines. The carbon-rich mass outflow from IRC+10216 results in a rich selection of organic circumstellar molecules. A recent review by Olofsson (2005) lists more than 30 species known in the IRC+10216 circumstellar envelope.

We observed the 10.4 μm (958 cm^{-1}) to 10.8 μm (924 cm^{-1}) spectral region to conduct a full search for the ν_7 ethylene lines. The new observations were carried out using the cryogenic grating spectrograph TEXES on the NASA IRTF. TEXES is a sensitive high-resolution cryogenic grating spectrograph of innovative design which works in the mid-IR (Lacy *et al.* 2002). The observed spectral resolution ($\lambda/\Delta\lambda$) was ∼10^5. A single exposure covered ∼5 cm^{-1} in segments of ∼0.7 cm^{-1}. Multiple grating settings were used to span

the observed spectral range. Exposures were taken so the spectra overlapped eliminating gaps and systematics.

The observed spectrum confirms the previous work of Betz (1981) and Goldhaber *et al.* (1987); ethylene lines previously reported in these papers were detected as were considerably stronger circumstellar lines of ammonia and silane. A total of 18 C_2H_4 lines were identified. The ethylene lines are indeed weak with central depths of at most a few percent (Figure 1). The lines are also narrow, with full widths dominated by the TEXES instrumental resolution of $\sim$3 km s^{-1}. The line profiles observed with the heterodyne equipment, at $>$ 10 times the TEXES resolution, have FWHM $\sim$2 km s^{-1}. Ethylene has an outflow velocity of $\sim$14 km s^{-1}.

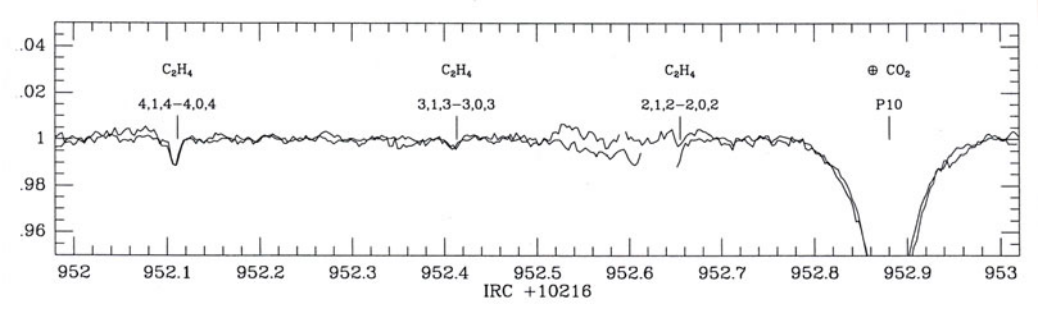

Figure 1. A section of the spectrum of IRC+10216 as observed by TEXES. The spectrum has been continuum normalized with only the 5% of intensity next to the continuum displayed. Three ethylene lines are identified and one telluric line of CO_2. This spectral region was observed twice. The overlap and offset of the spectral sections is visible (see text).

The current observations show that the ethylene lines are not blended by any other molecular bands. The signal-to-noise of the new measurements exceeds that of the measurements done in the 1980s. However, the ethylene lines are very weak with typical equivalent width $\sim 1 \times 10^{-4}$ cm^{-1}. As a result considerable uncertainty remains in the equivalent widths. A preliminary Boltzmann plot gives a rotational excitation temperature of $\sim$80 K.

The excitation temperature and velocity of the lines are indications of where the lines are formed in the circumstellar shell. In the near- and mid-infrared line profiles from molecules existing throughout the circumstellar shell, such as CO, HCN, and C_2H_2, have complex profiles. Semi-empirical circumstellar models can be derived from this information (e.g., Keady *et al.* 1988, Fonfría *et al.* 2008) and can be applied to modeling the ethylene spectrum. Detailed modeling of the ethylene lines is underway. With an excitation temperature of $\sim$80 K ethylene lines could arise from the external shell of IRC+10216 where many radicals have been found.

References

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