

Physical and Chemical Conditions in the Dust Formation Zone of IRC+10216

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Abstract. A mid-infrared high-resolution spectral survey of the source IRC+10216 (CWLeo) has been carried out in the range 11 to 14 μm . A large number of lines of C_2H_2 and HCN, among their most abundant isotopologues, have been identified. Many lines belong to hot bands involving high-energy ro-vibrational levels which allows the accurate determination of the physical and chemical conditions in the inner envelope. For this purpose, we have developed a radiative transfer model which can deal with almost all the detected lines, fitting them satisfactorily. We have fitted the continuum with the aid of the ISO available data, and more than 200 different rovibrational lines to get the kinetic, vibrational and rotational temperatures and the abundances of the C_2H_2 and HCN between 1 and 250 R_* .

Keywords. line: identification, line: profiles, surveys, stars: AGB and post-AGB, stars: carbon

1. Introduction

IRC+10216 is a C-rich AGB star with an large circumstellar envelope (CSE) at $\simeq 180$ pc from the Earth. The stellar temperature is $\simeq 2300$ K. The derived mass-loss rate is set to be $2 \times 10^{-5} M_\odot \text{ yr}^{-1}$ approximately (Keady et al. 1988, Cernicharo et al. 1999). By now, 60 different molecular species have been detected besides a large number of their isotopologues. The dust grains, which are assumed to be formed by amorphous graphite and refractory species such as SiC, condense in two different shells: the first one over $5 R_*$ and the second over $15 R_*$ (Keady et al. 1988). The acceleration produced by the interaction between the dust and the photons emitted by the star and other phenomena, establish a complex velocity profile with velocities of $1 - 3 \text{ km s}^{-1}$ ($1 \lesssim r/R_* \lesssim 5$), 11 km s^{-1} ($5 \lesssim r/R_* \lesssim 15$) and 14 km s^{-1} ($15 \lesssim r/R_*$) (Keady et al. 1988, Ridgway et al. 1988). The most abundant species is CO with 8×10^{-4} , followed by C_2H_2 with 8×10^{-5} and HCN with 4×10^{-5} (Keady et al. 1993, Cernicharo et al. 1996).

2. Observations, detections and results

The observations were obtained in December of 2002 with the TEXES spectrometer (Lacy et al. 2001), working between 5 and 25 μm , and the 3 m optimized infrared telescope IRTF in Hawaii. The data were corrected for atmospheric effects using the difference of a black body and the atmospheric emission. In addition, the baseline have been removed using a four degree polynomial.

In the forest of lines detected in the observed spectrum we have identified corresponding to the R and Q branches of rovibrational transitions ν_5 , $\nu_4 + \nu_5 - \nu_4$, $2\nu_5 - \nu_5$, $2\nu_4 + \nu_5 - 2\nu_4$,

$\nu_4 + 2\nu_5 - \nu_4 + \nu_5$ and $3\nu_5 - 2\nu_5$ for C_2H_2 , some of them for $H^{13}CCH$ and ν_2 and $2\nu_2 - \nu_2$ for HCN. Several lines of SiS have been identified and many lines remain still unidentified. The Figure 1 shows part of the whole spectrum.

The main results derived through the fittings of the lines show that the abundances of C_2H_2 and HCN have their maximums in the middle region (between the two dust formation shells) as the LTE models predict, being compatible with the values obtained from observations for the outer envelope. The vibrational temperature behavior depends on the energy of the level and seems to support the existence of radiative pumping mechanisms that deviates the populations of the vibrational levels from LTE (Cernicharo et al. 1999). These deviations depend on the molecule, being very different for C_2H_2 than HCN because of their radiative selection rules (e.g., $\nu_4(\pi_g)$ of C_2H_2 is not connected with the G.S.). While most of the vibrational levels of C_2H_2 are in LTE in the innermost envelope, deviating from it in the rest of the CSE, the vibrational levels of HCN present an important radiative pumping even near the star. The rotational levels seem to be in LTE until $J = 15$ for all the studied vibrational levels.

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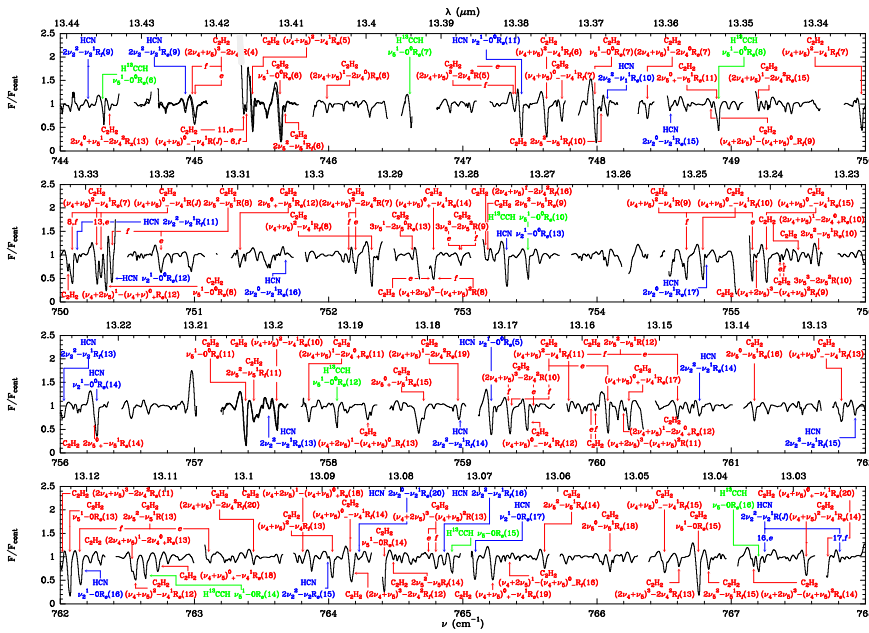


Figure 1. The Figure shows the 744 to 768 cm^{-1} spectrum observed toward IRC+10216.