ISO LWS SPECTRA OF AGB AND POST-AGB OBJECTS

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Abstract. We present ISO Long Wavelength Spectrometer (LWS) grating spectra of AGB and post-AGB stars. The LWS instrument and the calibration procedures are described by Clegg et al. (1996) and Swinyard et al. (1996).

1. Introduction

The far-infrared wavelength range provides a unique opportunity to probe the inner hottest regions of the circumstellar envelopes (CSE) of AGB stars and study the photodissociation regions around the planetary nebula (PN) phase via the major molecular and atomic cooling lines. In the following, several examples will be discussed.

2. IRC+10216

IRC+10216 is by far the brightest carbon-rich evolved object in the infrared sky. It has an extended CSE which is known to have a very rich carbon chemistry — more than 30 molecular species have been detected. Between 43 and 194 μm, the spectrum of IRC+10216 consists of strong dust continuum emission plus a forest of emission lines from CO, HCN, and vibrationally excited HCN (Fig. 1) — see Cernicharo et al. (1996). All the CO lines between $J = 14-13$ and $J = 39-38$ have been detected while lines of HCN with J_u as high as 48 have also been observed. The molecular emission arises from the warm and dense innermost zones of the CSE and the emission can easily be explained if the vibrational and rotational temperatures are around 700–1500 K. In the far-infrared, the power emitted in the HCN lines is 0.44 $L_\odot$ while that of CO is 0.28 $L_\odot$. Hence HCN is

E. F. van Dishoeck (ed.), Molecules in Astrophysics: Probes and Processes, 389–392.

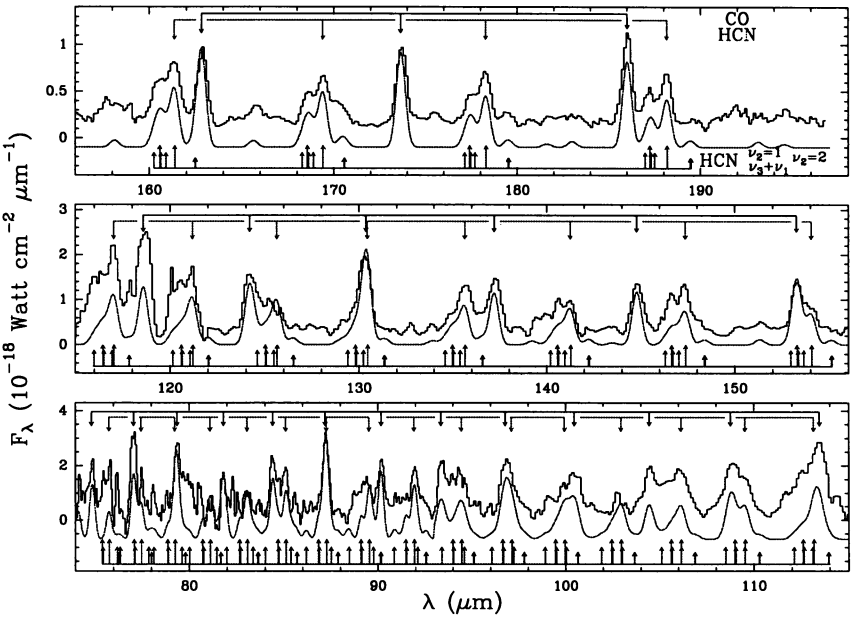

Figure 1. Continuum subtracted LWS grating spectra of the carbon-rich AGB star IRC+10216. The detected features are labelled. The results of model calculations are shown as thin lines with a slight offset for clarity (from Cernicharo et al. 1996).

the main coolant of this C-rich CSE where it plays a similar rôle to that of water in O-rich CSEs.

3. W Hya

W Hya is a semi-regular variable with a spectral type of M8e–M9e. It is a strong OH and H_2O maser source at a distance of 130 pc. The ISO LWS grating spectrum of W Hya (Fig. 2) is dominated by emission lines of water vapour, confirming that H_2O is the dominant coolant of the winds of these stars (Barlow et al. 1996). No OH lines are detected. An outflow model for the H_2O spectrum of W Hya has been presented in Barlow et al. (1996) which successfully matches most of the observed water vapour lines. The best fit (shown in Fig. 2) is obtained for a mass loss rate of 6×10^{-7} $M_\odot$ yr^{-1} and a H_2O/H_2 abundance of 8×10^{-4} for $R \leq 4.5 \times 10^{14}$ cm and 3×10^{-4} at larger radii. The availability for the first time of observations of the H_2O emission lines in oxygen-rich AGB stars should enable to improve the models of the wind temperature distribution.

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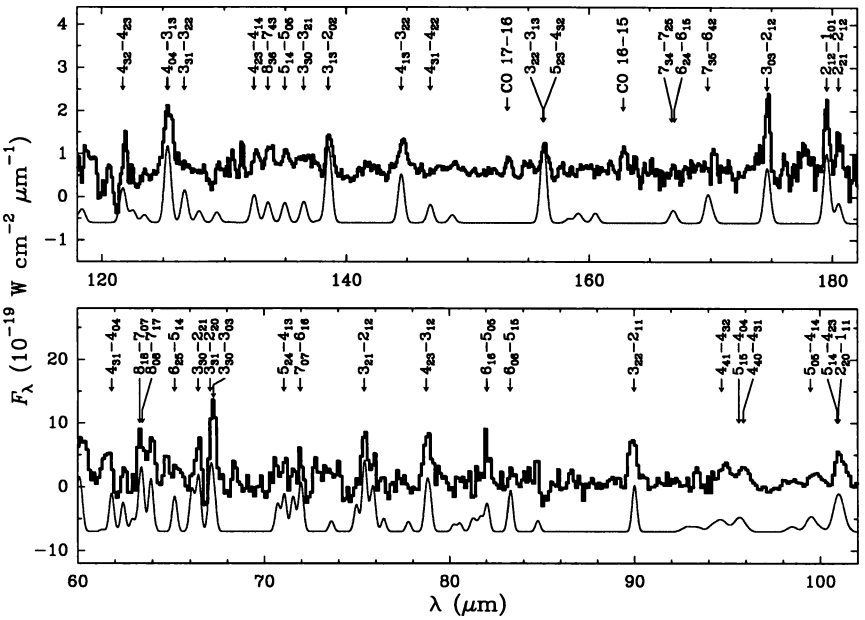

Figure 2. Continuum subtracted LWS grating spectra of the oxygen-rich AGB star W Hya. The dominant water vapour lines are labelled. The results of the best-fit model for the H_2O emission spectrum are shown as thin lines with a slight offset for clarity (from Barlow et al. 1996).

4. AFGL 2688

AFGL 2688 is one of the rare sources known to be in the rapidly evolving transition from the AGB to the planetary nebula phase. The far-infrared spectrum of AFGL 2688 shows strong rotational transitions of CO which are detected from $J = 14 - 13$ up to $J = 23 - 22$ (Cox et al. 1996). No other lines are detected including the atomic fine structure lines of [OI] and [CII]. This is consistent with the cool central star of AFGL 2688 not having yet photodissociated the molecular gas ejected during the AGB phase. The far-infrared CO emission in AFGL 2688 appears to originate in shocked dense gas at a temperature of $\sim$ 400 K.

5. NGC 7027

NGC 7027 is a young, dense PN with a hot central star. The ionized inner cavity is partly obscured by a massive molecular envelope. The complete LWS spectrum of NGC 7027 is very rich and displays at least 40 far-infrared emission lines, with 30 identified (Liu et al. 1996). From the ionized region, fine-structure lines from [N II], [N III] and [O III] are observed whereas the

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photodissociation region (PDR) is seen via the strong [O I] 63 and 146 μm and [C II] 158 μm fine-structure lines. Amongst the molecular lines, 11 rotational CO lines from $J = 14 - 13$ to $J = 24 - 23$ have been detected indicating the presence of warm (1000 K) and dense (10^5 cm^{-3} or higher) molecular gas. The most striking result, however, is the detection in this carbon-rich nebula of the o-H_2O 179.53 μm and OH 119.3 μm fundamental lines. The chemistry leading to substantial amounts of H_2O and OH in a carbon-rich environment is uncertain. However, the most plausible origin of these molecules is the warm and dense inner PDR which is known to be chemically active (Cox, this volume). The observed lines are consistent with emission from a 10^6 cm^{-3} medium at 1000 K with a size compatible with the PDR.

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