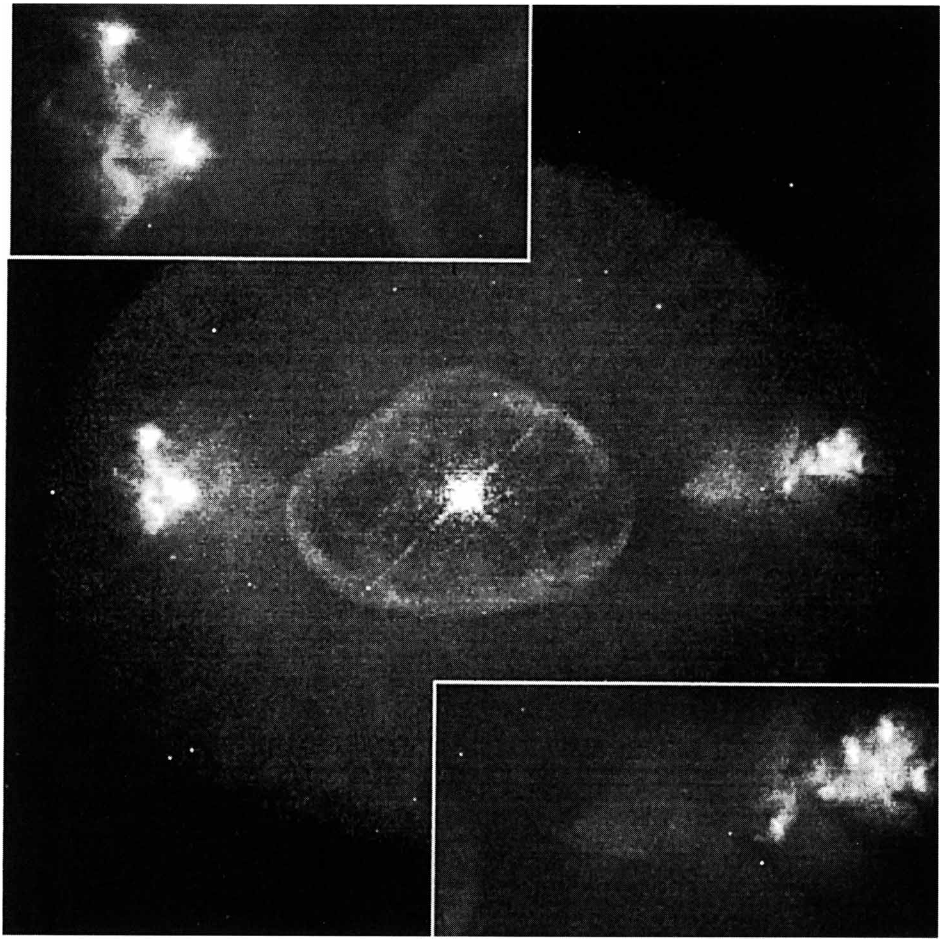
IV. ENVELOPES

https://doi.org/10.1017/S0074180900130190 Published online by Cambridge University Press



NGC 6826 observed with the Planetary Camera of the Hubble Space Telescope in the light of [N II]658.3nm. In order of distance from the *stellar nucleus*, the main features are the sharp-edged elliptical *bright rim*, the smooth surrounding *shell*, and the pair of low-ionization *FLIER clusters* seen near the major axis (magnified x2 in the insets).
Credit: *Narrowband HST Images of Microstructures in Planetary Nebulae*,
Bruce Balick, J. Alexander, A. Hajian, Yervant Terzian, M. Perinotto, and P. Patriarchi.

https://doi.org/10.1017/S0074180900130190 Published online by Cambridge University Press

ISO RESULTS ON AGB AND POST-AGB OBJECTS

P. COX

Institut d'Astrophysique Spatiale, Bât. 121,
Université de Paris XI, 91405 Orsay Cedex, France

Abstract. We present results obtained on well-known AGB and post-AGB sources with the Long Wavelength Spectrometer (LWS) and ISOCAM on board the Infrared Space Observatory (ISO). The main findings of these studies are briefly summarized.

1. Introduction

The infrared wavelength range (2-196 μm) covered by ISO provides a unique opportunity to probe the inner hottest regions of the circumstellar envelopes (CSE) of AGB stars and study the photodissociation regions (PDR) associated with the neutral envelopes of planetary nebulae (PNe). The major molecular and atomic cooling lines are found at infrared wavelengths enabling a detailed study of the physical conditions in these sources. In addition, the dust can be traced via the continuum emission and the spectral features. We present ISO LWS grating spectra of the AGB stars IRC+10216 and W Hya, the proto-planetary nebula AFGL 2688, and the young PN NGC 7027. Finally, ISOCAM results are presented on the Helix nebula, the prototype of a fully evolved PN. In an accompanying paper, Beintema et al. (this volume) discuss the results obtained on PNe with the Short Wavelength Spectrometer (SWS). The LWS instrument and the calibration procedures are described by Clegg et al. (1996) and Swinyard et al. (1996), respectively. The ISOCAM instrument is presented by Cesarsky et al. (1996).

H. J. Habing and H. J. G. L. M. Lamers (eds.), Planetary Nebulae, 139–144.

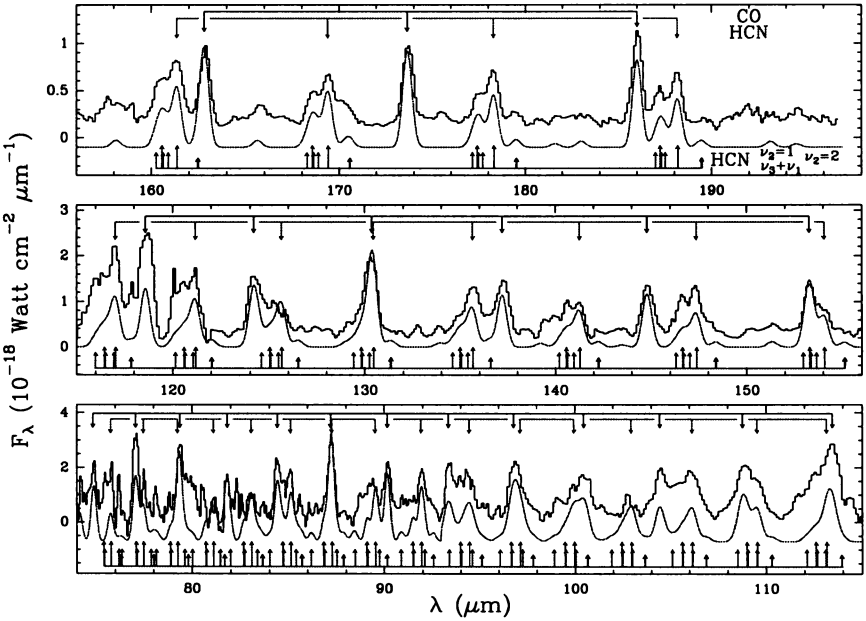


Figure 1. Continuum subtracted LWS grating spectrum of the carbon-rich AGB star IRC+10216. The major features are labelled. The results of model calculations are shown as thin lines with a slight offset for clarity (from Cernicharo et al. 1996)

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 (Cernicharo et al. 1996 - see Fig 1). 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 the main coolant of this C-rich CSE where it plays a similar rôle to that of water in O-rich CSEs as in W Hya discussed in the next section.

https://doi.org/10.1017/S0074180900130190 Published online by Cambridge University Press

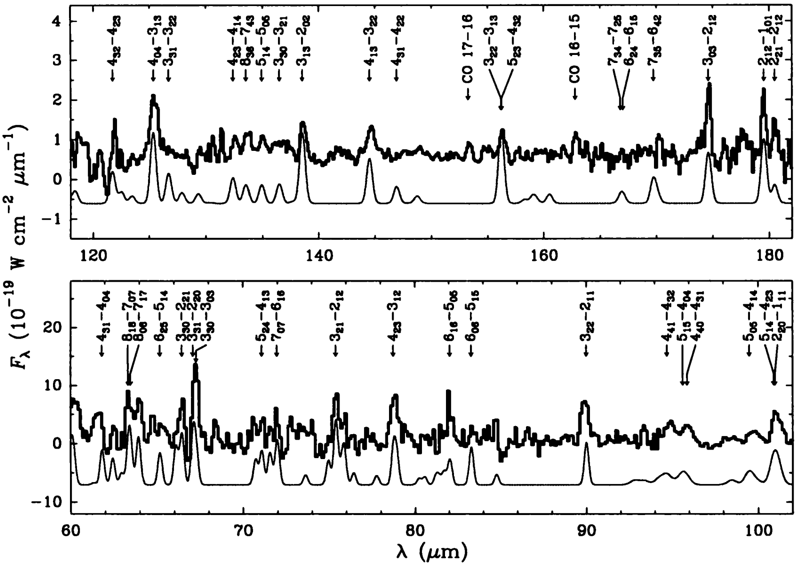


Figure 2. Continuum subtracted LWS grating spectrum of the oxygen-rich AGB star W Hya. The dominant water vapour lines are labelled. The results of the best-fit model for the H_2O emission spectrum is shown as thin lines with a slight offset for clarity (from Barlow et al. 1996)

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. This mass-loss rate is significantly smaller than the estimates made by Neufeld et al. (1996) on the basis of higher lying levels detected with the SWS at mid-infrared wavelengths. 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.

https://doi.org/10.1017/S0074180900130190 Published online by Cambridge University Press

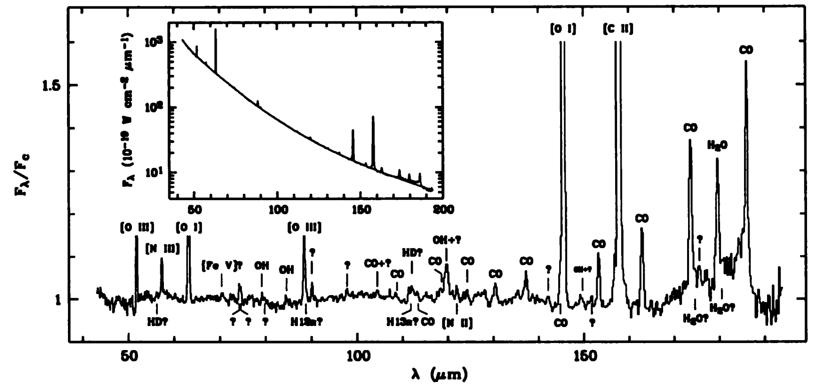


Figure 3. The ISO LWS spectrum of NGC 7027 between 156 and 194 μm after dividing by the continuum (the original spectrum is shown in the insert). The main species are identified in the figure with in particular the far-infrared CO emission lines together with the OH and H_2O lines (after Liu et al. 1996)

4. AFGL 2688

AFGL 2688 is one of the few sources known to be in the rapidly evolving transition from the AGB to the PN phase. The far-infrared spectrum of AFGL 2688 shows, on top of a strong continuum due to the dust emission, the lines of the rotational spectrum of CO from J=14-13 to J=23-22 as well as some weak HCN lines (Cox et al. 1996). No other lines are detected including the atomic fine structure lines [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) - see Fig. 3. From the ionized region, fine-structure lines from [N II], [N III] and [O III] are observed whereas the photodissociation region (PDR) is seen via the strong [O I] 63 and 146μm 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 (500 - 1000 K) and dense (a few 10^6 cm^{-3})

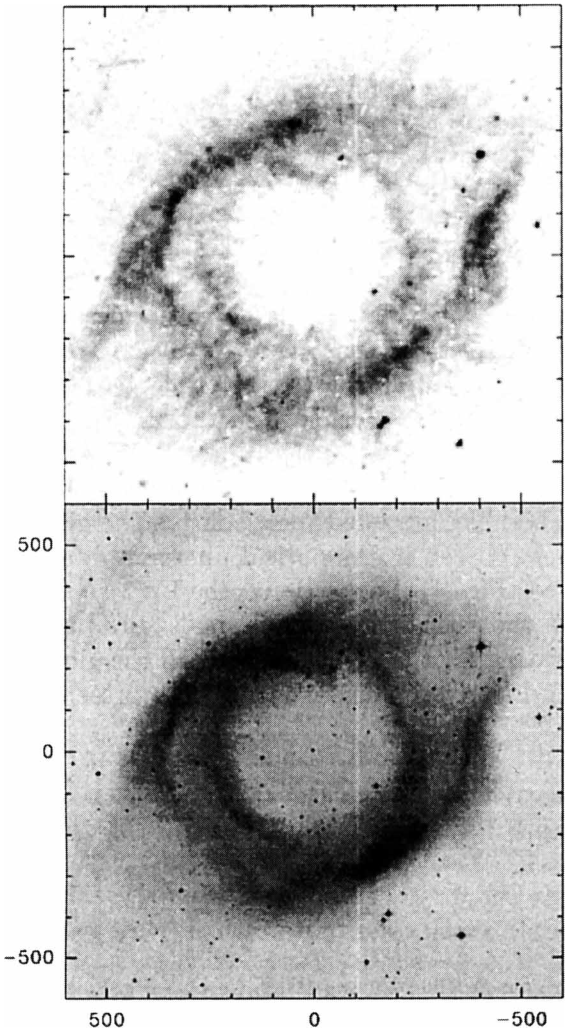


Figure 4. The ISOCAM LW2 image of the Helix nebula (upper panel) compared with a R-band image (lower panel). The offsets are given in arcsec relative to the position of the central star. The pixel size of the ISOCAM image is 6″ and the peak intensity is about 8 mJy/pixel. The centre of the figure is at $\alpha 22^{h}26^{m}54.7^{S}$, $\delta - 21o05'37''$ (1950.0).

molecular gas. A striking result 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 the presence 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 1997). Recently, Cernicharo et al. (1997) have identified in the LWS spectrum of

https://doi.org/10.1017/S0074180900130190 Published online by Cambridge University Press

NGC 7027 five transitions of the pure rotational spectrum of CH^+ further illustrating the rich chemistry taking place in the dense PDR of this young PN.

6. The Helix nebula

The Helix nebula (NGC 7293) is one of the nearest PN with an estimated distance of $\sim$ 160 pc. Its large angular size (1000 arcsec) and the presence of a massive neutral envelope makes this nebula a unique target to study the relative spatial distribution of various ions, atoms, molecules, and solid particles. The Helix nebula has been measured extensively using ISO as part of an open time program. As an illustration of the major advance achieved in the infrared mapping of low surface brightness nebulae, we present in Fig. 4 a mosaic image of the Helix taken in the LW2 ISOCAM filter. The emission in the LW2 filter which extends from 5 to 9 μm (comprising the 6.2, 7.7 and 8.6 μm dust emission bands and some atomic lines) shows a highly contrasted morphology. The globules, filaments, and wisps of the nebula seen in the optical photograph are clearly detected in the mid-infrared (Fig. 4). In the Helix, the LW2 emission is dominated by the emission in the dust bands with a small (10%) contribution of atomic lines demonstrating for the first time that all the globules in the Helix are dusty. A detailed analysis of these data will be presented elsewhere (Cox et al. 1997).

We are greatly indebted to the LWS and ISOCAM Instrument Dedicated Teams at VILSPA for their support in the calibration and analysis of LWS and ISOCAM data.

References

Barlow, M.J., Nguyen-Q-Rieu, Truong-Bach, Cernicharo, J. et al 1996, AA 315, L241
Bachiller, R., Huggins, P.J., Forveille, T., & Cox, P. 1997, AA in press
Cernicharo, J., Barlow, M.J., Cox, P.González-Alfonso, E., et al. 1996, AA 315, L201
Cernicharo, J., Liu, X.-W., Gonzalez-Alfonso, E., Cox, P., Barlow, M.J., Lim, T., & Swinyard, B.M. 1997, AA submitted
Cesarsky, C. et al. 1996, AA 315,L32
Clegg, P.E. et al. 1996, AA 315, L38
Cox, P., González-Alfonso, E., Barlow, M.J., Liu, X.-W. et al. 1996, AA 315, L265
Cox, P. 1997, in *Molecules in Astrophysics:Probes and Processes* IAU Symposium 178, E. van Dishoeck (ed.), in press
Liu, X.-W., Barlow, M.J., Nguyen-Q-Rieu, Truong-Bach et al. 1996, AA 315, L257
Neufeld, D.A., Chen, W. Melnick, G.J., de Graauw, T., Feuchtgruber, H., Haser, L., Lutz, D., & Harwit, M. 1996, AA 315, L237
Swinyard, B.M. et al. 1996, AA 315, L43