THE UNUSUAL CARBON-RICH DUST AROUND THE R CRB VARIABLES

H.J. Walker[1], **I. Heinrichsen**[2], **G.C. Clayton**[3], **A.E. Rosenbush**[4]

[1]CLRC Rutherford Appleton Laboratory, Chilton, Didcot, Oxon, UK
[2]IPAC, California Institute of Technology, Pasadena, California, USA
[3]Louisiana State University, Baton Rouge, Louisiana, USA
[4]Main Astronomical Observatory, National Academy of Sciences of the Ukraine, Kiev, Ukraine

ABSTRACT

The dust shell around R CrB was observed with the low resolution spectrometer on ISO (ISOPHOT-S), and an unusual broad plateau of emission between $5\,\mu$m and $8\,\mu$m was found. Three further observations of R CrB were taken during the ISO mission, showing that the broad emission plateau varies in strength and shape. A second member of the R CrB class of stars, RY Sgr, was observed three times, and these spectra showed that RY Sgr has the same type of broad, variable plateau. A third member of the class, V854 Cen, has detectable hydrogen in its stellar atmosphere (R CrB and RY Sgr have very little hydrogen), and the ISOPHOT-S spectrum of the dust around this star showed PAH emission features as well as the plateau emission.

Key words: ISO; infrared astronomy; circumstellar dust; variable stars.

1. INTRODUCTION

R CrB is a peculiar type of variable star, in that the variability is caused by the formation of a cloud of carbon dust in the line of sight. The cloud is formed near the stellar photosphere, condenses (dimming the star's visual brightness by several magnitudes, if it is in the line of sight) and then dissipates as it moves away from the star. The star is very overabundant in carbon, and underabundant in hydrogen and oxygen. An observation of R CrB was made early in the ISO mission, using the low resolution spectrometer in the photometer on ISO (ISOPHOT-S), see Kessler et al. (1996), Lemke et al. (1996) and Klaas et al. (1997) for details of ISO, ISOPHOT, and ISOPHOT-S respectively. The spectrum revealed a very unusual carbon dust feature, a plateau of emission between around $5\,\mu$m and $8\,\mu$m (Walker et al. 1996). A further three observations of R CrB have been made during the ISO mission.

Another member of the small group of R CrB stars, RY Sgr, has been observed three times during the ISO mission and a third member of the group, V854 Cen, has been observed once. Whereas R CrB and RY Sgr have very little hydrogen in their stellar atmospheres, V854 Cen has a measurable amount of hydrogen. V854 Cen is also much more active than the other members of the class (Lawson et al. 1992). All the stars have warm dust shells, with temperatures around 400 K to 800 K, and IRAS data showed that there were extended cool dust shells around some of the R CrB stars (Walker 1986).

The data were reduced from the raw data stage (ERD) using PIA v7, to ensure the most recent calibration files were accessed. Data from ISOPHOT-S are reduced using the default calibration files, which are orbit-dependent. Calibration observations have shown the long-term reproducibility of the ISOPHOT-S response function is better than 30% (Klaas et al. 1997). Heinrichsen et al. (1998) compared the spectrum of RY Sgr with a calibration star, HR6688, showing that much (if not all) of the 'structure' in the plateau is caused by uncorrected instrumental effects.

2. COMPARISON OF ISOPHOT-S DATA

In Figure 1, the spectrum of R CrB, taken on 14 August 1997, is compared to the spectrum of RY Sgr, taken on 23 March 1997. The dust in RY Sgr has the same broad plateau emission feature, but it is not as strong as in R CrB. Both spectra show evidence of a rise from $10\,\mu$m to $12\,\mu$m, which is very different to the behaviour noted with the IRAS LRS (Low Resolution Spectrometer) data, taken in 1983 (Walker 1986). The IRAS data had a very steady decline of flux with wavelength from $8\,\mu$m to $23\,\mu$m, with no slope change. The IRAS LRS spectrum for R CrB fitted well with the earliest ISOPHOT-S spectrum of R CrB (which had no rise). The IRAS LRS spectrum of RY Sgr is very different from the ISOPHOT-S spectrum in flux density level. Photometry with ISOPHOT at $60\,\mu$m, $80\,\mu$m, and $100\,\mu$m emphasises that the energy distributions for R CrB and RY Sgr change with time, even at the far-infrared wavelengths. V854 Cen (data taken on 19 August 1997) is fainter, but the plateau is present and the spectrum of this object shows the PAH emission features at $6.2\,\mu$m, around $8\,\mu$m, and $11.3\,\mu$m. The $6.2\,\mu$m and $7.7\,\mu$m features are CC mode features, those at

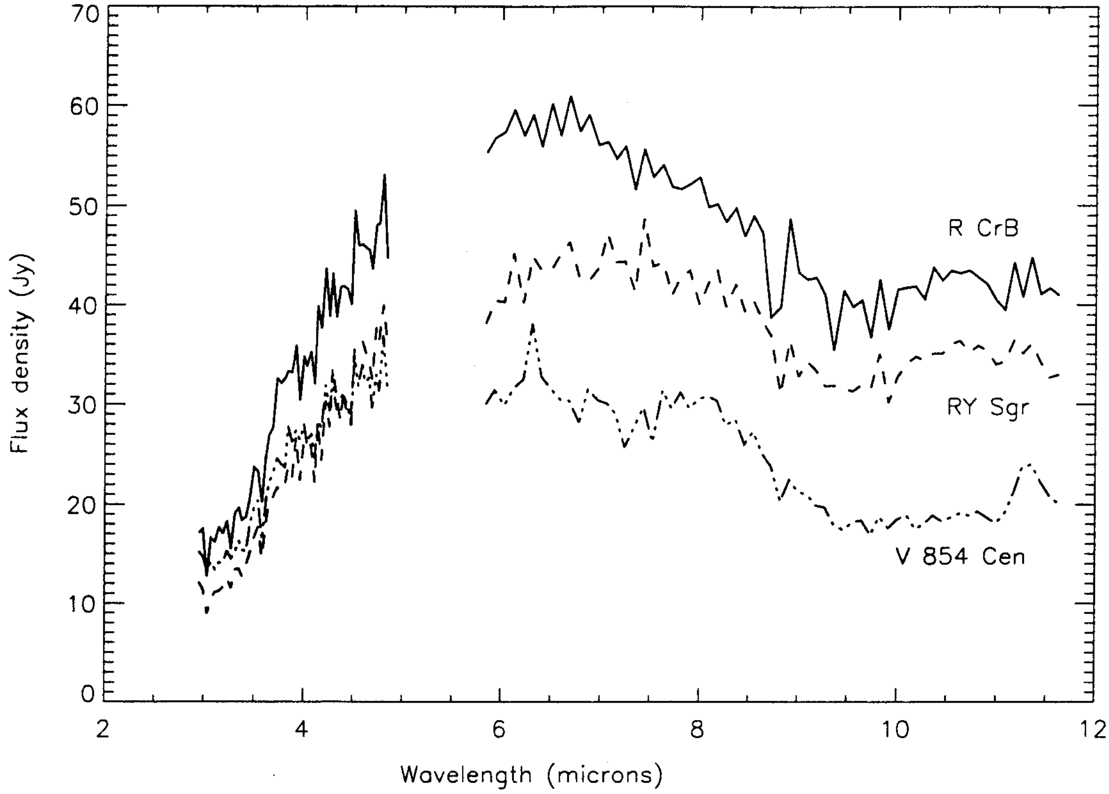


Figure 1. ISOPHOT-S spectra of R CrB (top), RY Sgr (middle) and V854 Cen (bottom).

8.6 μm and 11.3 μm are CH mode features. The three stars appear to show a feature around 8.8 μm, this could be an instrumental effect.

3. VARIABILITY OF SPECTRA

3.1. R CrB

The four spectra shown in Figure 2 (upper panel) are spread over a two year time period. Buss et al. (1993) reported the 6.2 μm CC mode feature in R CrB, we do not see this feature in any of our four spectra. The first spectrum has the highest plateau, the other three have a broadly similar plateau, but in the last two, the emission at the longest ISOPHOT-S wavelengths is higher. When the long wavelength photometry is included, the change in shape is more obvious, and may reflect a change in dust temperature. The underlying thermal continuum must be removed a more detailed comparison of the dust plateau proceeds.

3.2. RY Sgr

The three spectra of RY Sgr, shown in Figure 2 (lower panel), are spread out over one year. As with R CrB, the first spectrum of RY Sgr is the brightest. The plateau from 5 μm to 8 μm is visible in all three spectra, as is the rise in emission beyond 10 μm. The energy distribution is much more complex, and a cool excess at 100 μm is seen in the ISOPHOT photometry and was also seen in the IRAS data (Walker 1986).

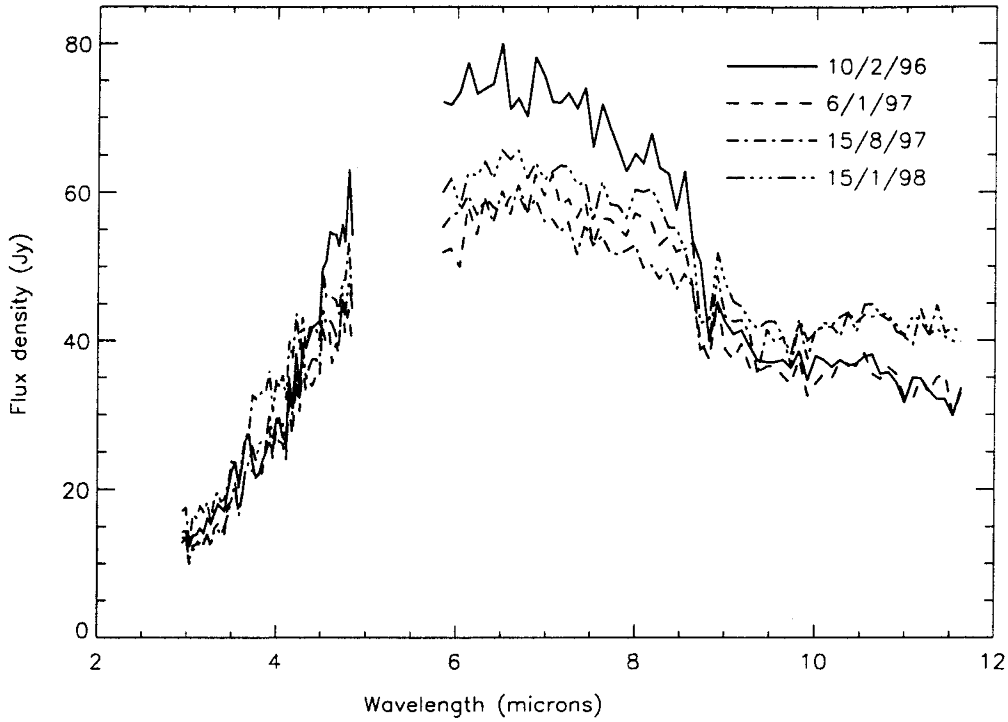
4. DISCUSSION

As can be seen clearly from V854 Cen (see Figure 1), the spectra of R CrB and RY Sgr show no sign of PAH or related CC mode emission features. The PAH features are present in V854 Cen, which is known to have hydrogen in its stellar atmosphere (although it is significantly underabundant compared to normal stars). The PAH molecules containing hydrogen are important chains in the dust condensation process.

The rise in emission from 10 μm could be due to silicon carbide, but this was not seen in the 1983 IRAS LRS data.

The thermal continuum from the warm dust could be variable. This variability could be caused by the expulsion of clouds of carbon from the star, but not expelled in the line of sight (so no fading takes place).

The warm dust shells have observed with ISOPHOT to determine the dust temperature, which is typically several hundred degrees. In addition to the warm dust shell, several R CrB stars were found to have



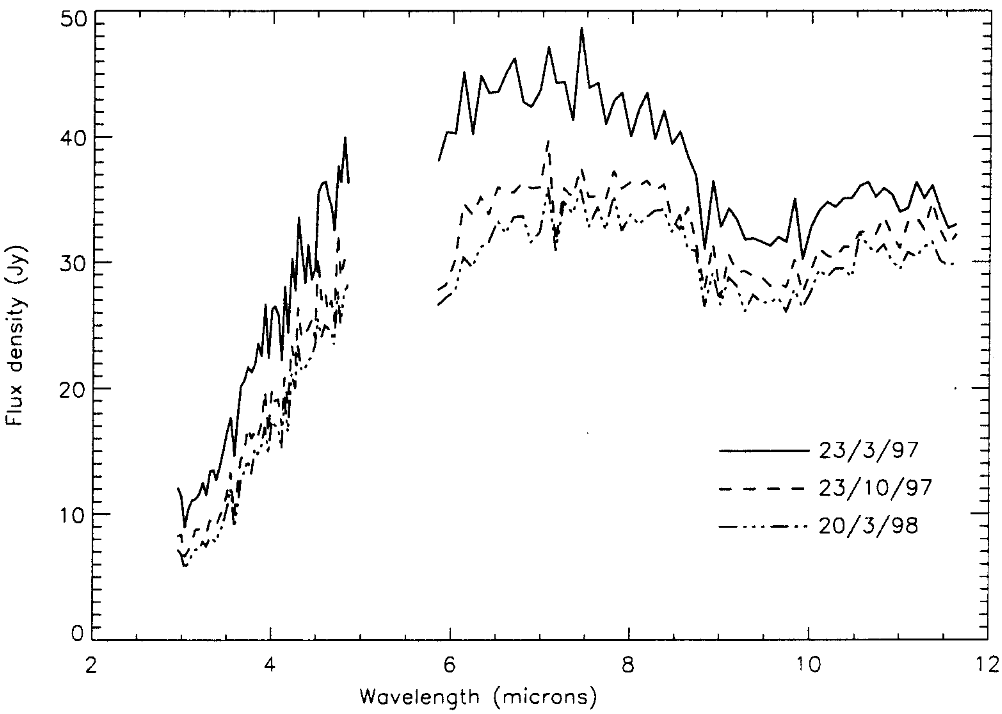


Figure 2. Four ISOPHOT-S spectra of R CrB, taken over a two year period (upper panel). Three ISOPHOT-S spectra of RY Sgr, taken over a one year period (lower panel).

very large, cool 'fossil' dust shells, from IRAS data (Walker 1986).

ACKNOWLEDGMENTS

ISO is an ESA project with instruments funded by ESA Member States (especially the PI countries:

France, Germany, the Netherlands and the United Kingdom) and with the participation of ISAS and NASA. PIA is a joint development by the ESA Astrophysics Division and the ISOPHOT Consortium led by the Max Planck Institute of Astronomy (MPIA), with contributing institutes DIAS, RAL, AIP, MPIK, and MPIA.

REFERENCES

Buss, R.H., Tielens, A.G.G.M., Cohen, M., Werner, M.W., Bregman, J.D., Witteborn, F.C., 1993, Astrophys. J. 415, 250.

Heinrichsen. I., Walker, H.J., In 'ISO to the Peaks workshop'

Kessler, M.F., Steinz, J.A., Anderegg, M.E., et al., 1996, A&A 315, L27.

Klaas, U., Acosta-Pulido, J.A., Ábrahám, P., et al., 1997, In 'Proc. First ISO Workshop on Analytical Spectroscopy', (ESA SP-419), 113.

Lawson, W.A., Cotterell, P.L., Gilmore, A.C., Kilmartin, P.M., 1992, Mon. Not. R. Astron. Soc. 256, 339.

Lemke, D., Klaas, U., Abolins, J.A., et al., 1996, A&A 315, L64.

Walker, H.J., 1986, In 'Hydrogen Deficient Stars and Related Objects', eds. K. Hunger, D. Schönberner, N.K. Rao, Astrophys. Space Sci. Library 128, 407.

Walker, H.J., Heinrichsen, I., Richards, P.J., Klaas, U., Rasmussen, I.L., 1996, A&A 315, L249.