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IRAS PHOTOMETRY OF DUST SHELLS AROUND RCB STARS AND OTHER COOL CARBON STARS

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1. *Introduction*

Between launch on 26th January, 1983, and the end of mission on 22nd November, 1983, the IRAS satellite surveyed almost the whole sky at 12 μm, 25 μm, 60 μm and 100 μm (see Beichman *et al.* 1984, for details). It proved a useful tool for examining the dust shells around stars. Most RCB stars have no significant contribution from the central star towards the fluxes observed by IRAS. Kilkenny and Whittet (1984) showed that by the M band (5 μm) there was very little flux from the star contributing to the flux measured. Goebel and Johnson (1984) recently suggested that galactic N and late R irregular variables may be deficient in hydrogen, as a result of modelling the emergent flux between 1 μm and 5 μm in these cool Carbon stars.

Walker (1985) showed the energy distributions for several RCB stars observed in the IRAS survey, and also showed LRS spectra for two RCB stars, R CrB and RY Sgr, which had the characteristically smooth spectrum between 8 μm and 23 μm due to carbon-rich dust. Stephenson's catalogue of cool Carbon stars (1973) was examined for stars either reported by Stephenson (or Bidelman 1956) as deficient in hydrogen, or having LRS spectra similar to R CrB or RY Sgr, or being noted as N-type Carbon stars.

2. *Results*

About 100 sources were found in the IRAS Point Source Catalogue fulfilling the criteria that they should be either with known or suspected deficiency in hydrogen, or noted in Stephenson's (1973) catalogue as type N, and bright enough to have an LRS spectrum available (i.e. 12 μm flux larger than approximately 50 Jy). Several of

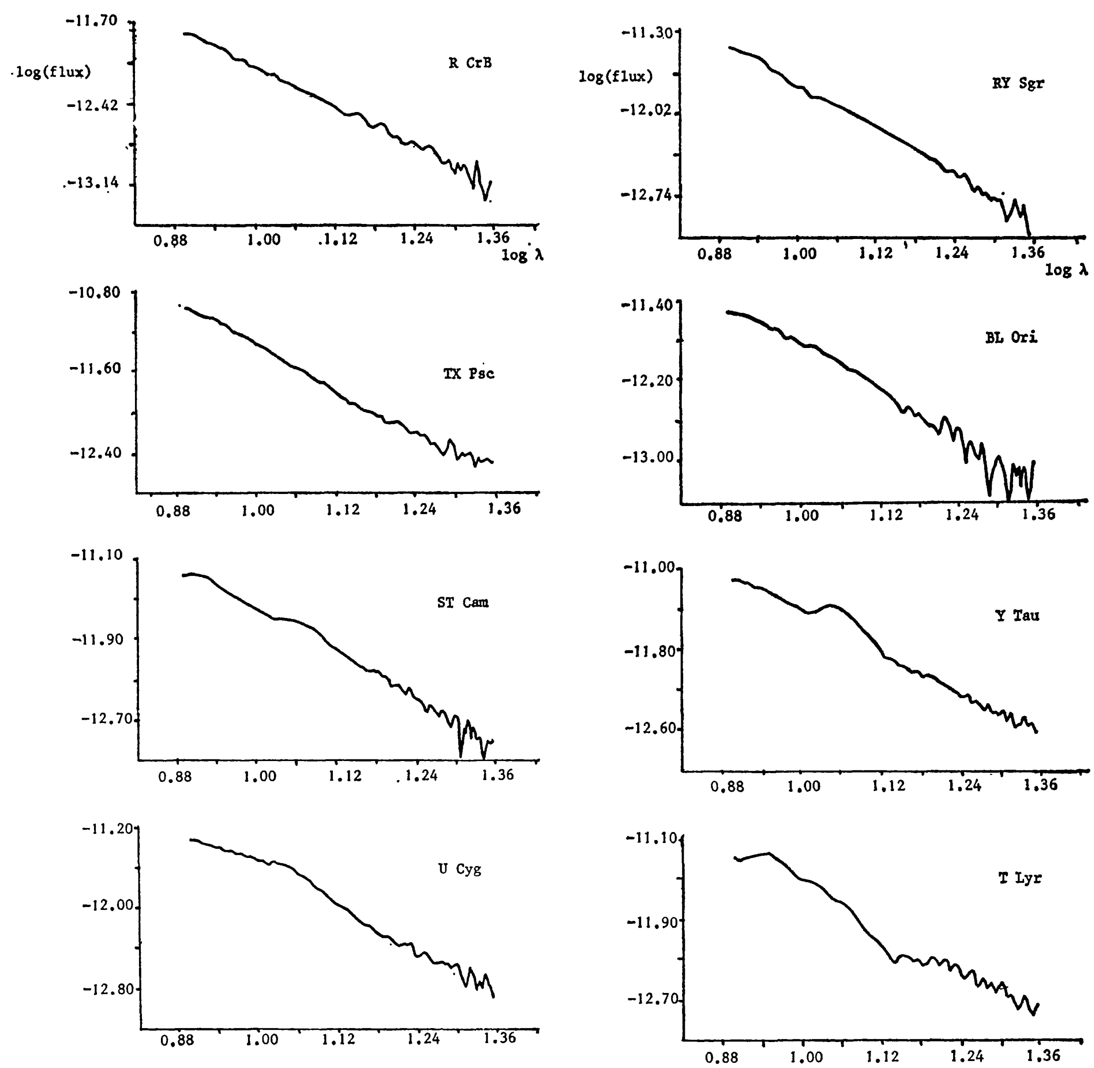

Figure 1. LRS spectra of R CrB, RY Sgr and several cool Carbon stars. λ is measured in μm, flux in W m^{-2} μm^{-1}.

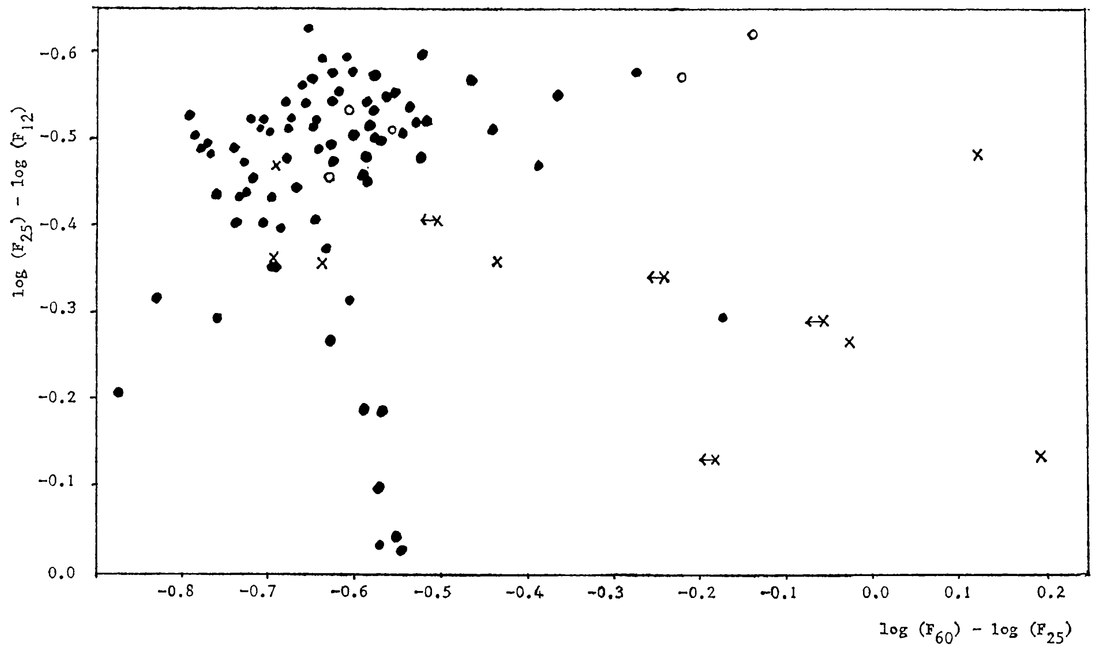

Figure 2. IRAS colour-colour diagram.
x–RCB stars : ●–cool Carbon stars : o–smooth spectrum Carbon stars.

the N spectral type stars were found to have 'smooth' LRS spectra, similar to R CrB and RY Sgr (see Figure 1). More usually the spectra were found to show an emission feature around 11 μm (SiC has a feature at 11.5 μm, silicates around 9.5 μm). The wavelength of the feature will change when the spectrum is normalised. There were several stars noted by Stephenson (1973) as having SiC_2 in their spectrum and none of this group were found to have a smooth spectrum. The smooth spectrum objects included TX Psc, which is noted by Goebel and Johnson (1984) as a candidate for hydrogen deficiency, due to its weak H^- emission feature. U Cyg is noted as having a fairly smooth decline, with a weak feature at 11 μm, and this is noted by Stephenson as having SiC_2 and Hα emission. For comparison LRS spectra from two of the more normal N-type stars are shown in Figure 1, including ST Cam, which is noted by Stephenson (1973) as being a typical Nb star. T Lyr has an anomalous spectrum, with an emission feature at 9 μm, and a very shallow, broad feature at 11 μm; the star is identified by Stephenson (1973) as Np.

In an attempt to classify the stars in the IRAS domain, a colour-colour diagram was constructed, plotting $\log(F_{60}) - \log(F_{25})$ against $\log(F_{25}) - \log(F_{12})$, the fluxes being in Janskys, and using the conventions of the $(U\text{-}B)/(B\text{-}V)$ diagram. There is, of course, no reddening in the IRAS version. The RCB stars form an almost horizontal line across the diagram, and the smooth spectrum cool Carbon stars show a tendency to lie above this line. The objects to the lower left of the main concentration of stars in Figure 2 are objects in Marie de Muizon's infrared selected list (25 μm flux larger than 100 Jy), and one or two of the objects on the far left of the diagram are noted as emission line sources. The rest of the stars cluster together, which is surprising since they range from objects for which only the very cool dust shell is observed by IRAS, to the naked star with no sign of a dust shell. The IRAS flux ratio (12 μm/25 μm) is used to determine the black-body temperature, and this varied from 350 K to 2700 K.

Table 1

Full-Width-Half-Maximum values for the calibration point source and RCB stars from IRAS additional observations

	FWHM (arcmin)			
	12 μm	25 μm	60 μm	100 μm
NGC 6543	0.80 ± 0.03	0.84 ± 0.03	1.54 ± 0.04	3.09 ± 0.05
RY Sgr	0.76 ± 0.03	0.80 ± 0.03	1.60 ± 0.04	3.02 ± 0.10
R CrB	0.80 ± 0.03	0.80 ± 0.03	1.53 ± 0.04	5.01 ± 0.06
SU Tau	0.77 ± 0.03	0.87 ± 0.05	1.74 ± 0.10	4.58 ± 0.10
XX Cam	0.84 ± 0.04	0.88 ± 0.05	——	——

There is, however, more information available from IRAS for a few of the RCB stars. Three groups led by Evans (Keele), Hill (St. Andrews) and Nandy (Edinburgh) successfully applied to make additional observations with IRAS. As a member of the consortium I have started to reduce the observations, so that the rest of my colleagues can then proceed with the analysis. Observations of NGC 6543 (a planetary nebula) were retrieved, taken with exactly the same techniques as the observations of the RCB stars, and taken only a little time before the RCB observations. This source is a calibration source for IRAS and is regarded as a point source. The first results from my reductions are shown in Table 1. The Full-Width-Half-Maximum (FWHM) for R CrB and SU Tau are significantly different from NGC 6543 and RY Sgr in the 100 μm band. The noise for SU Tau in the longer wavelength bands is high, since the point source itself is weak. XX Cam was too weak to be included in the IRAS Point Source Catalogue, so the data in the 12 μm and 25 μm bands is new. The uncorrected ratio of these fluxes gives a black-body temperature for the dust shell of 500 K.

3. *Conclusions*

The RCB stars have dust shells, and from IUE data (Holm *et al.* 1982, Hecht *et al.* 1984) the graphite feature at 2400 A can be modelled using small glassy/graphite spheres and amorphous carbon smoke. From the additional observations made by IRAS of some of the dust shells, they can be sufficiently intense to be observed as extended by IRAS. Making a rough allowance for the instrumental profile, using NGC 6543, R CrB may have a dust shell 1 pc across at 100 μm (using the distance of 2 kpc from Schoenberner, 1975). It may be possible to examine the raw data from IRAS to find other examples. There are, certainly, some spectral type N stars with dust shells similar in nature to those of the RCB stars, with a smooth decline in flux with wavelength, over the region 8 μm to 23 μm, and no evidence of a feature around 11 μm, but these are a minority. There is no evidence to suggest that this subgroup is hydrogen deficient in the same manner as the RCB stars. The RCB stars do tend to separate from the group of cool Carbon stars from Stephenson's (1973) catalogue, in the IRAS colour-colour diagram, as do some of the strong infrared Carbon stars.

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THE ROLE OF DUST IN MASS LOSS FROM LATE-TYPE STARS

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1. *Introduction*

Mass loss from red giants is very important, both for replenishing the interstellar medium and for altering the evolution of the star itself. For example, the mass loss may be so efficient that an intermediate-mass star initially of, say, 5 $M_\odot$ may ultimately become a white dwarf with $\sim$1 $M_\odot$. The goal of this review (see also Zuckerman 1980, Glassgold and Huggins 1985, Olofsson 1985) is to describe the key role which grains appear to have in driving the very extensive mass loss that occurs.

At least by stellar standards, the atmospheres of red giants are low temperature ($T \sim 3000$ K), and therefore only a moderate amount of cooling is required for refractory material to condense into grains. This naturally occurs as the matter expands and flows away from the star. Consequently, cool stars losing large amounts of material