published a lot of data related to microvariability, δ Scuti, β Cephei and RR Lyr variables. Similar holds true for the Leiden group, using the famous Walraven photometer. Very probably, this list of photometric and spectroscopic projects carried out at La Silla is incomplete, but yet suited to illustrate the significance of the excellent ESO site for asteroseismology, as well as for the importance and effectivity of small and medium sized telescopes. "Big Science" not always demands "Big Telescopes".

Finally, we would like to briefely touch on our future projects at La Silla related to asteroseismology, in addition to continuing our survey and participating in world-wide observing campaigns.

As has been clearly demonstrated by a recent ESA Assessment Study for project PRISMA (*ESA SCI* (**91**) 5, asteroseismology will enter a new era, if observations can be done from space. The elimination of atmospheric noise and the possibilities of very long, continuous data strings with a large duty cycle are the main reasons. One such asteroseismological space experiment is already approved for the Sovjet MARS-94 probe and has the acronym EVRIS. The other space project, more versatile, elaborate and powerful, is presently in Phase A study at ESA and is called PRISMA (Probing Rotation and Interior of Stars: Microvariability and Activity).

As already shown earlier in this article, supplementing ground-based observations are mandatory for a full exploitation of the scientific potential of asteroseismology. In the case of EVRIS, basic stellar data of sufficient accuracy, like effective temperature, log g and luminosity are missing for many EVRIS target stars. Furthermore, a careful investigation of the immediate vicinity of the very bright target stars is necessary in order to avoid a poor target choice. Photometric problems may arise from even very faint background sources which drift in and out of the photometer aperture due to satellite jitter. To our surprise, there are presently no data archives available which would allow to extract the required astrometric and photometric information for EVRIS. As a consequence, all the candidate target fields have to be carefully observed in various colours with CCD techniques.

This synergy between space- and ground-based observations is another example for the necessity to develop both and not to ignore one at the expenses of the other.

Words of thanks: Many colleagues, impossible to list all here, have contributed to this article through discussions, cooperations and contributions. WWW is particularly grateful to the teams of EVRIS and PRISMA.

Multi-Wavelength Observations of Infrared-Bright Carbon Stars

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1. Introduction

The carbon star phase is one of the last phases of evolution of intermediate mass stars (1-8 solar masses). Carbon stars reside on the Asymptotic Giant Branch (AGB) in the Hertzsprung-Russell diagram. The carbon is produced in thermal pulses, short periods of explosive He-shell burning, and transported to the surface by convective mixing. Many of the physical processes that play a role in the formation and evolution of carbon stars are still poorly understood, e.g. the production and dredge-up of carbon, the origin and evolution of the mass loss. Here we briefly report on an observational study of infrared-bright carbon stars.

In a recent paper Groenewegen et al. (1991) have studied an infrared-complete sample of bright carbon stars containing all 109 carbon stars with $S_{12}>100$ Jy in the IRAS PSC. This sample is more complete than others previously studied in that both optical and infrared carbon stars are included.

Using near-infrared photometry from the literature they derived near-infrared colour temperatures and from the energy distribution they calculated infrared bolometric corrections. Distances were derived assuming $M_{bol}=-4.9$, corresponding to $L=7050\ L_\odot$. From available CO data mass-loss rates were calculated for about 80 stars in their sample.

The sample was divided into five groups depending on their infrared properties, extending the classification of carbon stars of Willems and de Jong (1988). Group I stars show the silicate feature in their LRS spectra, possibly because they are very recently formed carbon stars. Since none of the known Group I stars is bright enough to have made it into the sample they will not be dicussed further. Group II stars have a pronounced 60-μm excess, high near-infrared temperatures, small bolometric correction and low mass-loss rates. They probably turned into a carbon star quite recently and their excess at 60-μm is due to a cool circumstellar shell, probably the oxygen-rich remnant of the preceding high mass loss phase. From group III to V the mass-loss rate of carbon stars steadily increases, and as a consequence the near-infrared temperatures decrease and the bolometric corrections increase.

Using average bolometric corrections for each group the infrared-complete sample was transformed into a volume-complete one. The scale height of carbon stars is found to be 190 pc and their local space density equals 185 kpc^{-3}.

From the calculated space densities of carbon stars in each group relative timescales are derived. Adopting a lifetime of 20,000 years for group II stars from model calculations, Groenewegen et al. find a total lifetime of the carbon star phase of about 26,000 years, uncertain to a factor 2. The total mass lost during the carbon star phase equals about 0.04 $M_\odot$. This number is uncertain to a factor 5, a factor 2 arising from the uncertainty in the lifetime of group II stars and a factor 2.5 arising from the uncertainty in the mass-loss rates. For an adopted average white dwarf mass of 0.65 $M_\odot$ this implies that most stars are already of low mass when they turn into carbon stars, probably around $0.69_\odot$ and certainly less than 0.85 $M_\odot$.

The location of the 109 stars in the IRAS colour-colour diagram is shown in Figure 1. The colours $C_{21}=2.5\ \log(S_{25}/S_{12})$ and $C_{32}=2.5\ \log(S_{60}/S_{25})$ are indicated along the axes. As discussed

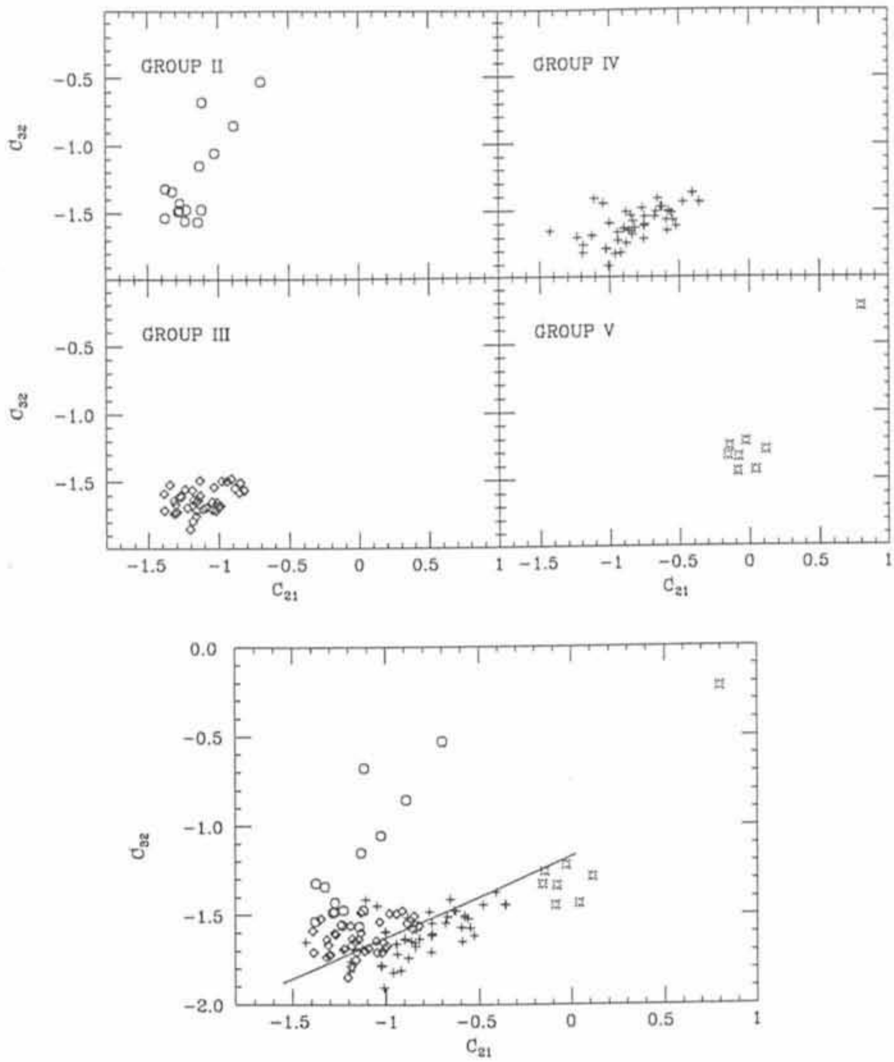

Figure 1: *The location of the 109 carbon stars in the IRAS colour-colour diagram. In the top four figures the sample is divided into the different evolutionary groups. In the bottom figure the total sample is plotted. The solid line indicates the location of the blackbody line.*

above, available near-infrared (NIR) data were used to calculate bolometric corrections and CO data to calculate mass-loss rates. Searching in the literature we noticed that existing observations are biased against infrared carbon stars (groups IV and V). For example, NIR data existed in the literature for 14 out of the 15 group II stars, but 10 out of 48 group IV stars (~20 %) did not have NIR photometry. Likewise for the CO data. For group II stars, 13 out of 15 have been measured in either CO(1–0) or CO(2–1), for group IV this is only 29 out of 48. With regard to optical photometry the situation is even worse. Except for the well-known carbon star CW Leo none of the group IV and V stars seems to have been measured at optical wavelengths. There seems to be a misconception that infrared carbon stars (or in general infrared AGB stars) have no optical counterpart. However, several of these 'obscured' stars (usually AFGL sources) have been identified (e.g. Lebofsky and Kleinmann, 1976, Allen et al., 1977, Cohen and Kuhi, 1977).

To study the group IV and V stars in more detail we had several observing runs at La Silla in the beginning of 1991. Optical (V, R, I) photometry was obtained at the 1.5-m Danish telescope, NIR photometry at the 1.0-m and 2.2-m telescopes and CO data at the SEST.

One of the purposes of the observing runs was to confirm that some of our stars were indeed carbon stars. Many of the infrared carbon stars display the silicon carbide (SiC) feature in their LRS spectra, but some have an almost featureless LRS spectra (the group V objects) or are misclassified in the LRS atlas. Therefore, we obtained CVF spectra around 3 μm for a number of stars at the 2.2-m telescope as well as HCN (1–0) data from the SEST.

In section 2 we present the data obtained for three stars in our sample for which we obtained NIR photometry and CVF spectra as well as CO and HCN data. They are 08074–3615 (a group IV star), 11318–7256 (group III) and 13477–6532 (group IV). Several observed parameters like galactic longitude and latitude, colour-corrected IRAS fluxes, C_{21} and C_{32}, LRS classification and VAR index are listed in Table 1. In sections 3 and 4 we derive mass-loss rates from the CO line profiles and fit the energy distribution using a radiative transfer model. The results are briefly discussed in section 5.

2. The Data

Near-infrared photometry was obtained on February 17–18, 1991 at the ESO 1.0-m telescope and on February 25–28 at the ESO/MPI 2.2-m telescope. We used the standard INSB photometer with apertures of 15″ and 8″ and a throw of 20″ and 15″ at the 1.0-m and 2.2-m, respectively. Standard stars were observed from the list of Bouchet et al. (1991). The reduction was done at La Silla using the reduction programme written by P. Bouchet. The results are given in Table 2.

The 3-μm spectra were obtained at the 2.2-m telescope with a Circular Variable Filter wheel. After observing a programme star, a nearby standard star was observed. We used the standard reduction technique of dividing the source spectrum by the standard star spectrum and then multiply either by the assumed blackbody temperature of the standard or the known continuum flux in case of G-dwarfs (Koornneef, 1983). Absolute calibration was achieved by adopting a K magnitude for the standard. The standard stars used with their adopted magnitudes are listed in Table 2. The calibrated spectra are shown in Figure 2.

All three stars show the characteristic carbon star feature at 3.1 μm attributed to photospheric HCN and C_2H_2 (Ridgway et al., 1978). For 11318–7256 this is not surprising since it is a known optical carbon star (C3062 in Stephenson's 1989 catalogue of carbon stars) with an IRAS LRS classification of 44. For 08074–3615 and 13477–6532 these ob-

Table 1: *General parameters*

Name	l	b	S_{12}	S_{25}	S_{60}	S_{100}	C_{21}	C_{32}	LRS	VAR
08074–3615	253.5	– 1.8	156	100	26.6	6.1	–0.48	–1.44	22	9
11318–7256	297.3	–11.2	265	85.7	18.1	9.7	–1.22	–1.69	44	4
13477–6532	309.0	– 3.6	134	78.5	19.7	<10.8	–0.58	–1.50	04	0

Table 2: *NIR photometry and spectrophotometry*

Name	J	H	K	L	M	Standard star	K-mag.
08074−3615	–	–	9.79 ± 0.02	4.51 ± 0.04	2.78 ± 0.05	HR 3842	3.39
	15.6:	13.7 ± 0.7	9.78 ± 0.05	4.57 ± 0.02	2.92 ± 0.04		
11318−7256	5.11 ± 0.04	3.12 ± 0.06	1.52 ± 0.06	−0.47 ± 0.05	−0.73 ± 0.05	HR 4523	3.32
	4.92 ± 0.02	3.00 ± 0.02	1.48 ± 0.01	−0.47 ± 0.02	−0.89 ± 0.03		
13477−6532	16.2:	10.39 ± 0.07	7.28 ± 0.03	2.91 ± 0.03	1.64 ± 0.03	HR 5459	−1.51

Note. If two entries are given, the top row refers to data from the 2.2-m telescope and the bottom row to the 1.0-m telescope. A colon indicates an uncertain value.

servations establish their carbon star nature. They have not been classified as optical carbon stars before. Their LRS classifications are 22 and 04, although visual inspection of the LRS spectrum revealed weak emission around 11 μm.

The SEST data were taken on March 24–26, 1991. We used two Schottky receivers with the wide-band AOS backend. The main beam efficiencies and HPBW (half power beam width) at 88.6 (HCN(1–0)), 115.3 (CO(1–0)) and 230.5 (CO(2–1)) GHz were 0.76 (56″), 0.71 (44″), 0.50 (23″), respectively. The velocity resolution at 115 GHz was 1.81 km/s. The CO(2–1) data were smoothened to give the same resolution. The pointing was found to be accurate within 10″. Calibration was done by a standard chopping wheel technique, switching between the sky and an ambient load. Linear baselines were subtracted. The spectra were obtained using dual beam switch mode with a throw of 11.5′. The spectra are displayed in Figure 3. The derived parameters are given in Table 3 where we list the rms noise temperature, the velocity with respect to the local standard of rest, the expansion velocity as measured as half the full width at zero intensity, the peak temperature and the integrated intensity under the line. The velocities are in km/s and the temperatures are in K expressed as main beam temperatures.

IRAS 08074–3615 was detected at CO(1–0) by Zuckerman and Dyck (1986). Their peak temperature of 0.20 K compares well to our value. They quote an expansion velocity of 17.3 km/s which is smaller than ours. They did not publish the spectrum so we cannot comment on the difference. The HCN (1–0) transition was detected by Lucas et al. (1988) with an intensity of 9.2 K km/s. Again, no spectrum was published. IRAS 11318–7256 was independently detected recently by Nyman et al. (1991) in CO(1–0) with a peak temperature (0.17 K) and intensity (7 K km/s) which are very similar to our values. Our measurements of CO(2–1) and HCN(1–0) in 11318–7256 and CO(1–0), CO(2–1) and HCN(1–0) in 13477–6532 are all new detections.

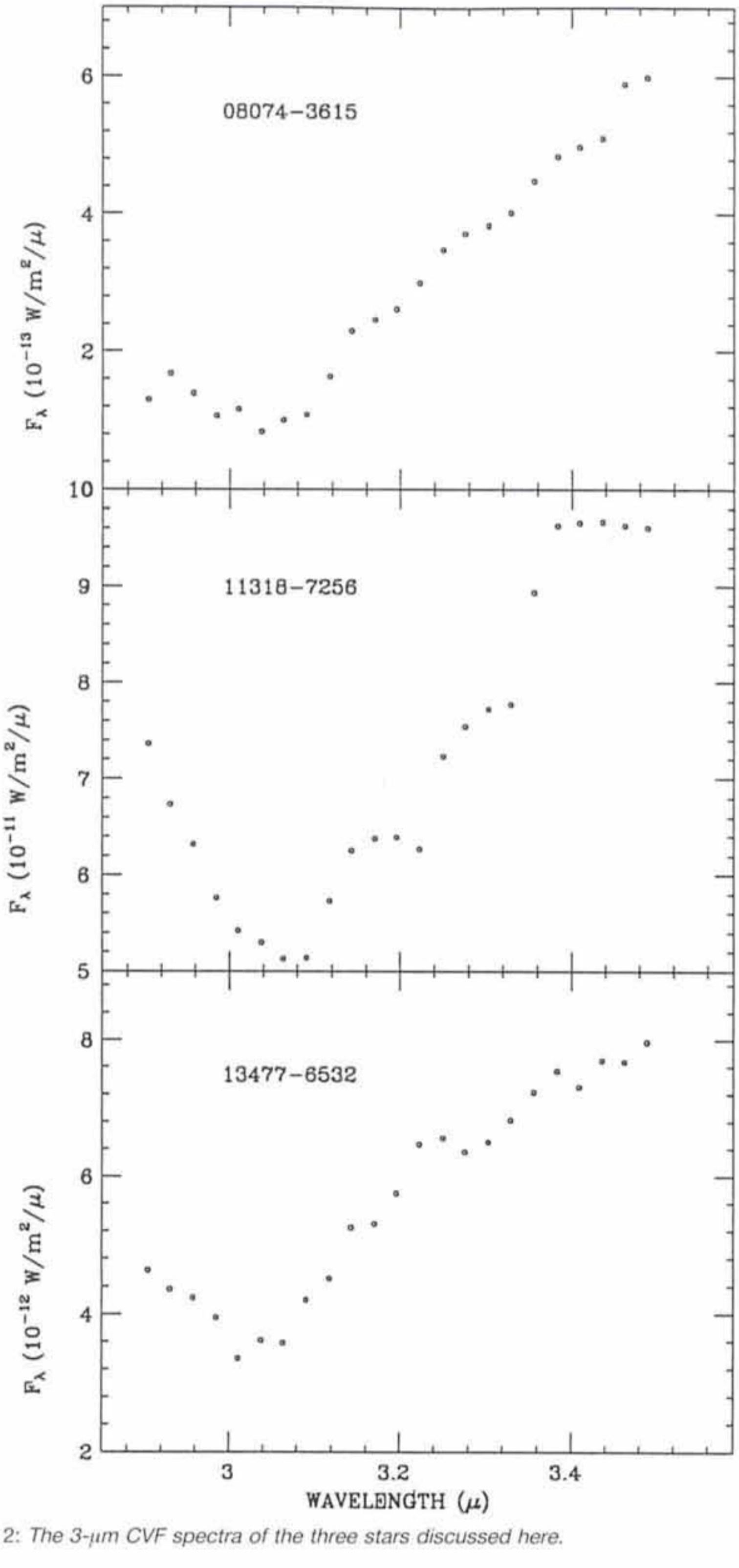

Figure 2: *The 3-μm CVF spectra of the three stars discussed here.*

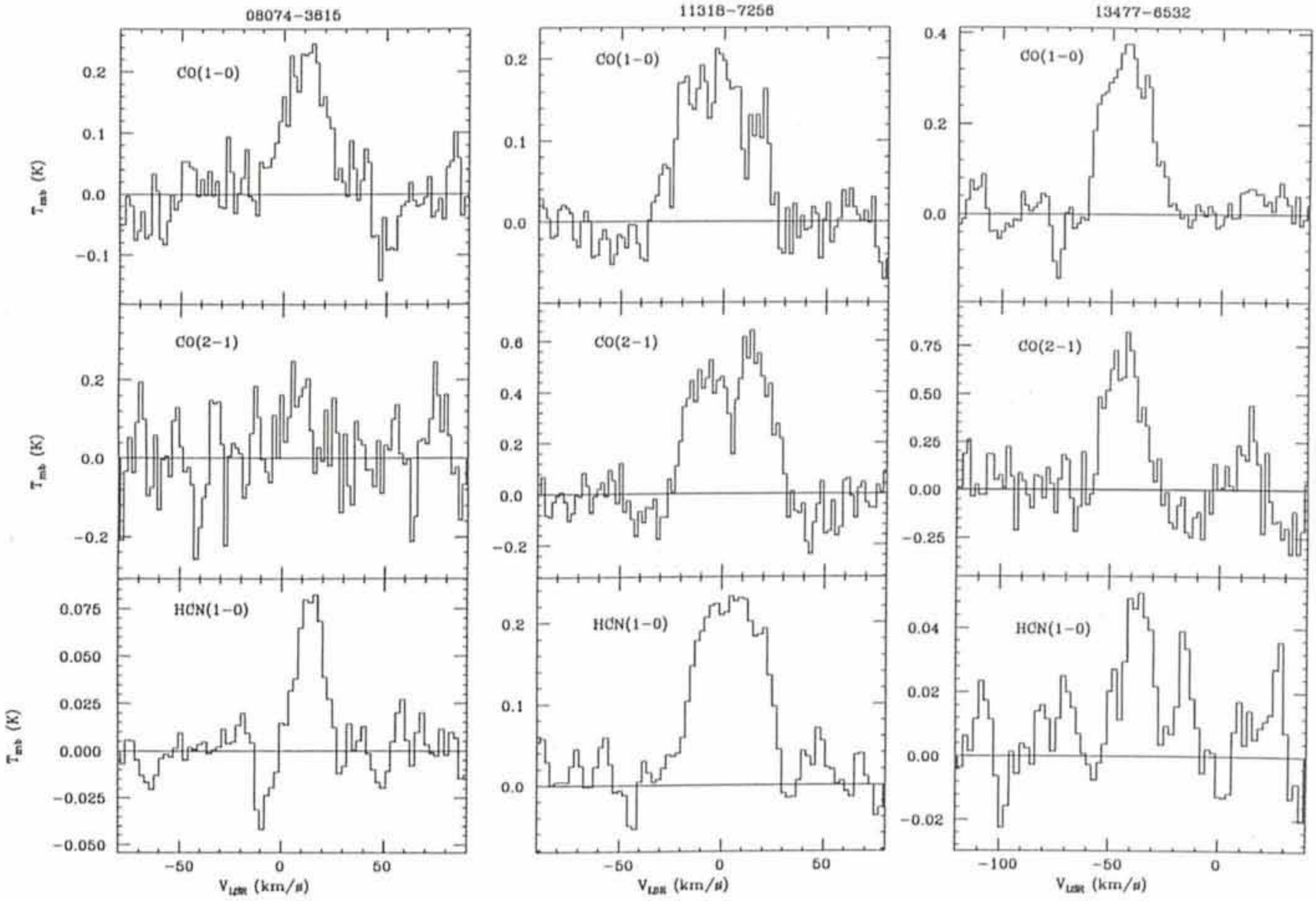

Figure 3: *The CO(1–0), CO(2–1) and HCN(1–0) data.*

3. The Analysis

The NIR and CO data are used to determine bolometric corrections and mass-loss rates in a way identical to Groenewegen et al. (1991) to which we refer for details.

Distances were determined from the observed bolometric flux using $M_{bol} = -4.9$ ($L = 7050\ L_\odot$), the mean value observed for carbon stars in the LMC (Frogel et al., 1980).

Near-infrared colour temperatures were derived by fitting a blackbody to the J, H, K, L, M magnitudes. Mass-loss rates were determined from the CO line profiles as discussed by Groenewegen et al. The results are displayed in Table 4 where we list near-infrared colour temperature, total observed flux at earth, bolometric corrections with respect to the colour-corrected IRAS 12 μm magnitude (BC_{12}), the distance in kpc and the mass-loss rate. These values supercede the data listed for these stars in Tables 2 and 5 of Groenewegen et al. Note however that due to the radiative transfer modelling discussed below and the numerical uncertainty in calculating the observed flux at earth, the final values for these quantities are different.

4. A Radiative Transfer Model

Combining the NIR data with the IRAS data, we have observations of the most important part of the spectral energy distribution (SED). Since these stars are fairly red, their energy output in the optical is insignificant. In this section we present the results of radiative transfer calculations attempted to fit the observed SED as well as the LRS spectrum.

We used the model of Groenewegen and de Jong (1992). This model allows for time-dependent mass-loss rates and radius-dependent velocity laws. In the calculations presented below we restrict ourselves to simple r^{-2} density laws unless otherwise mentioned. The programme simultaneously solves the radiative transfer equation and the thermal balance equation for the dust. The inner radius is determined by the model to equal the adopted dust temperature at the inner radius, which is an input parameter. The outer radius is determined from the condition that the dust temperature at the outer radius is 20 K. Other input parameters are the expansion velocity of the circumstellar shell and the mass-loss rate, both assumed for the moment to be constant, the absorption coefficient Q which is assumed to be a mix of AC amorphous carbon

Table 3: *CO and HCN data*

Name	Transition	T_{rms}	V_{LSR}	V_{exp}	T_{peak} (K)	I (K km/s)
08074−3615	CO(1-0)	0.042	10	21	0.24	5.6 ±0.2
	CO(2-1)	0.11	–	–	–	<4.8[a]
	HCN(1-0)	0.012	14	~18	0.080	1.26±0.03
11318−7256	CO(1-0)	0.028	− 6	32	0.18	7.2 ±0.7
	CO(2-1)	0.082	2	28	0.52	21 ±1.0
	HCN(1-0)	0.025	5	28	0.22	8.9 ±0.8
13477−6532	CO(1-0)	0.042	−43	19	0.36	9.9 ±0.3
	CO(2-1)	0.14	−44	15	0.70	14.6 ±1.0
	HCN(1-0)	0.012	~−40	–	0.048	0.9 ±0.1

Note. Derived from V_{exp} T_{rms}.

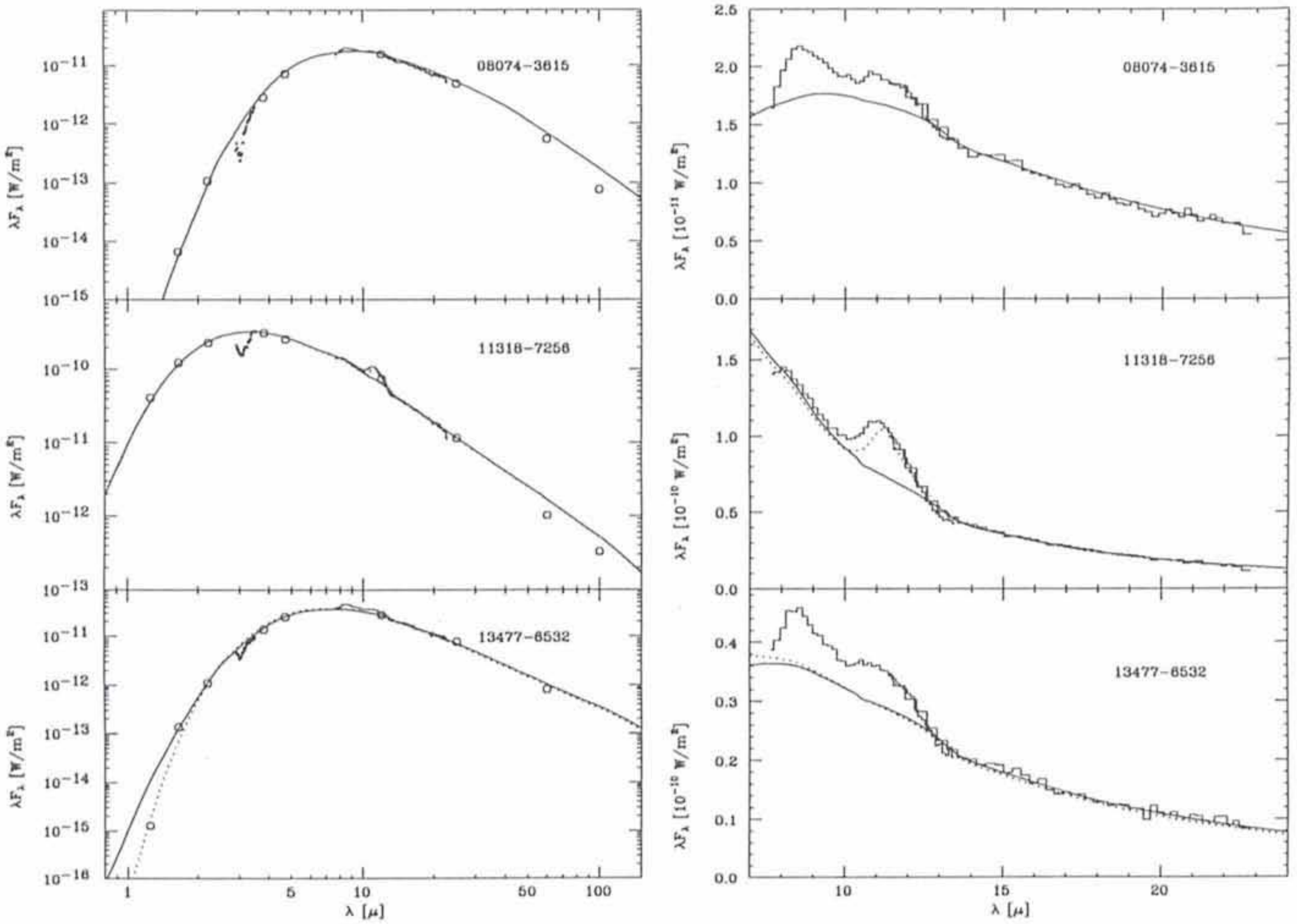

Figure 4: *Observed and predicted spectral energy distributions and LRS spectra. For details of the model parameters see text.*

(Bussoletti et al., 1987[1]) and SiC (Pegourie 1988) and the dust-to-gas ratio ψ which will be the main independent variable. Minor input parameters are the grain size a, assumed to be 0.03 μ and the grain density ρ, assumed to be 3.3 g/cm^3. The shape of the spectrum, for a fixed temperature at the inner radius, is solely determined by the optical depth at some reference wavelength.

$$\tau \sim \frac{\dot{M}\ \Psi\ Q/a}{R_*\ r_{in}\ v_\infty\ \rho}$$

The temperature of the central star was assumed to be 2500 K. This choice is not critical as long as most of the radiation is reemitted in the infrared. The stellar radius was fixed at 447 $R_\odot$.

Because the IRAS sources are variable with unknown periods, the NIR and IRAS data cannot be expected to have been taken at the same phase. Therefore we proceeded in the following way. The optical depth τ was changed in such a way as to fit the NIR data. Then the 25-μm flux was scaled to fit the model prediction. The same scale factor was applied to the other IRAS fluxes. This is justified because the predicted C_{21}, C_{32} and C_{43} colours hardly depend on the optical depth and their variation is much less than the error in the observed colours due to the uncertainty in the IRAS fluxes. The LRS spectrum was scaled in such a way that the long wavelength part (λ>18 μ) fitted the model. It proved necessary to correct the observed IRAS fluxes of 08074–3615, 11318–7256, 13477–6532 by −55 %, +13 % and −17 %, respectively. The largest correction is necessary for the IRAS source with the highest variability flag. Because a change in the IRAS fluxes changes the integrated flux at earth and therefore the distance (for a fixed luminosity) and mass-loss rate we recalculated both quantities. The final values are d=3.04 kpc, $\dot{M}$ = 5.6 10^{-5} $M_\odot$/yr (08074–3615); d = 0.70, $\dot{M}$ = 4.90 10^{-6} (11318–7256) and d = 2.07, $\dot{M}$ = 3.3 10^{-5} (13477–6532).

The results of some radiative calculations are gathered in Figure 4 where in the left panel the observed NIR magnitudes, the 3 μm spectrum, the IRAS data and the LRS spectrum is plotted together with the model fits and in the right panel the observed LRS spectrum and the fits (the full lines). It should be noted that we did not attempt to fit the 3-μm spectrum.

The parameters of the models are collected in Table 5, where the assumed mass percentage of SiC and the assumed temperature at the inner radius are listed. Derived parameters are the inner and outer radius (in stellar radii), the optical depth at 0.5 μm and the dust-to-gas ratio.

In the case of 11318–7256 we also calculated models with lower values of

Table 4: *Some derived parameters*

Name	T_{nir} (K)	F (10^{-10} W/m^2)	BC_{12}	D (kpc)	$\dot{M}$ ($M_\odot$/year)
08074−3615	490	0.54	8.53	2.0	2.5 (-5)
11318−7256	1294	5.63	6.54	0.63	3.9 (-6)
13477−6532	566	0.66	8.14	1.85	1.6 (-5)

[1] Actually we multiplied the Q-values of Bussoletti et al. by a factor of 5 to let their results agree with those of Koike et al. 1980.

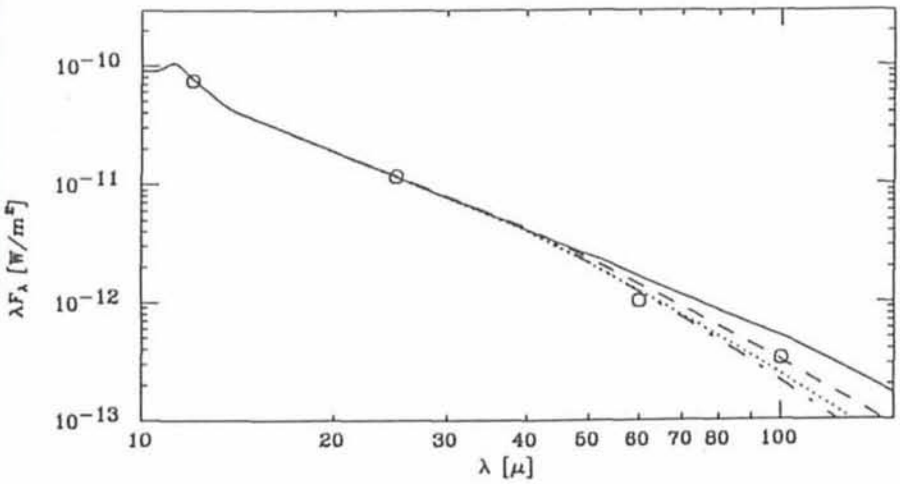

Figure 5: *The long-wavelength part of the spectrum of 11318–7256 for the standard model (solid line) and for models with reduced absorptivity (dashed line), variable mass loss (dotted line) and smaller outer radius (dot-dashed line).*

T_{inner}. Only values >1300 K give good fits. A mixture of 40 % SiC and 60 % amorphous carbon can explain the feature at 11.3 μm fairly well.

For 08074–3615 and 13477–6532 only pure amorphous carbon models are shown because we could not get a satisfactory fit of the broad feature between 10 and 12.5 μm with the SiC of Pegourie. Furthermore, there is evidence in both stars for emission between 7.5 and 10 μm.

5. Discussion

We presented NIR photometry, spectrophotometry and CO/HCN data for three carbon stars from the infrared-complete carbon star sample of Groenewegen et al. (1991). Assuming a mean luminosity of 7050 $L_\odot$ we derive distances and mass-loss rates. Using a radiative transfer model we derive dust-to-gas ratios of $\Psi \approx 0.0007$ ($\approx$1/1600). The main uncertainty in this value is the absolute value of the absorptivity. When the mass-loss rates are calculated from CO data (i.e. $\dot{M} \sim D^2$) and for fixed effective temperatures, Ψ scales with $\sim D^{-1}$ or $\sim L^{0.5}$, so the assumed luminosity is not a major source of uncertainty. The dust-to-gas ratio we derive is a factor of 2 lower than usually quoted (0.0013 for our value of $\varkappa(60\ \mu) = 520$ cm^2 g^{-1}, Jura 1986) but recently Sahai (1990), using a self-consistent CO model for U Cam finds $\Psi \leq 0.00015$. Analysis of other carbon stars also indicate low dust-to-gas ratios (Sahai, 1991).

With regard to the broad-band features in the LRS spectrum we showed that in the case of the optically visible group III star 11318–7256 a satisfactory fit could be obtained with a mixture of 40 % SiC and 60 % amorphous carbon. In the case of the two infrared carbon stars of group IV there seem to be two broad features: one between 7.5 and 10 μm and the other between 10 and 12.5 μm. The latter feature seems to be too broad to be explained in terms of SiC.

The feature between 7.5 and 10 μm, peaking at 8.6 μm is most puzzling. Willems (1988) discovered an unidentified feature at 8.6 μm in the spectra of group II stars. He did not find it in group III stars (consistent with 11318–7256), which have thicker circumstellar shells. Now we find a feature at 8.6 μm in group IV stars, with even thicker shells. Is this feature (see also Baron et al., 1987) related to the feature in group II stars?

In all three cases our model predicts too much flux at 60 and 100 μm. We consider four possibilities: (1) the envelope is resolved by the IRAS beam, (2) the outer radius is smaller, (3) a steeper emissivity law and (4) a lower mass-loss rate in the past.

The 100-μm emission comes mainly from the region with dust temperatures ~30 K which is at about 21,000 stellar radii corresponding to 60" diameter at a distance of 0.7 kpc. The IRAS beam at 100 μm was roughly 100" so the shell is probably not resolved.

To investigate the other possibilities we calculated three additional models for 11318–7256 with (a) a smaller outer radius (r_{outer} = 5000 R_*; the dot-dashed line in Fig. 5), (b) an emissivity law $Q\lambda \sim \lambda^{-1.5}$ for λ >40 μm (dashed line) and (c) a mass-loss rate which increased by a factor 2 over the past 3300 years (dotted line). One cannot distinguish between these three possibilities on the basis of the fits in Figure 5. It has been advocated that the detection of HCN emission is a sufficient criterium to identify optically invisible carbon stars. However, oxygen-rich stars have also been detected in HCN. From Lindqvist et al. (1988) we derive that the mean of the ratio I(HCN)/I(CO(1–0)) in their 10 oxygen-rich stars with detected HCN is 0.12 and the maximum value observed is 0.26. The same ratio in our stars is 0.23, 1.24 and 0.09 respectively. This means that solely on the basis of HCN emission, in 2 out of 3 cases the confirmation as carbon stars could not have been made. We suggest that the presence of the 3.1 μm feature is a more suitable carbon star identification mark than the HCN/CO ratio.

Table 5: *Radiative transfer model parameters*

Name	In Figure 4	Percentage SiC	T_{inner} (K)	r_{inner} (R_*)	r_{outer} (R_*)	$\tau_{0.5}$	Ψ
08074–3615	solid line	0	900	9.67	53200	28.8	0.00086
11318–7256	solid line	0	1800	1.68	50400	7.62	0.00065
	dotted line	40	1800	1.68	55400	8.01	0.00104
13477–7256	solid line	0	1000	7.20	36000	20.7	0.00072
	dotted line	0	1300	4.42	35400	28.0	0.00060

Acknowledgements

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Astronomy from Large Databases II

Strasbourg Observatory – 14–16 September 1992

A follow-up event to the 1987 conference on "Astronomy from Large Databases" (Eds. F. Murtagh and A. Heck, ESO Conf. and Workshop Proc. 28) is timely. The area has seen much progress. "Astronomy from large Databases II" will allow archival research results from various experiments to be reviewed.

Much has happened in the area of astronomical databases in recent years. HST is in full operation; some such as EXOSAT have stopped growing and now function for retrieval purposes only; NED has come into being; etc. Hundreds, or even thousands, of papers have been based on data retrieved from archives. Archived material from various sources is increasingly combined with data obtained through joint observational campaigns involving ground-based and space-borne experiments working in different wavelength ranges.

Technically databases have evolved. SIMBAD 3.0 is fully operational. User interfaces now include windows and point-and-click access mechanisms, hypertext and hypermedia. Commercial products have considerably improved. Distributed databases are now highly relevant, pointing to the important role of networks. CD-ROMs and other storage media are more and more widely used. The 1987 conference predates the births of ESIS and ADS, among many other developments.

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Open House at ESO

On Saturday, October 12, 1991, ESO Headquarters in Garching again opened its doors to the public. More than 2000 persons took the opportunity to visit the organization and learn about science and technology at our organization; this corresponded to 1 person every 10 seconds. There was a lot of interest and curiosity, especially about the VLT and the Hubble Space Telescope, the latter being presented by the ESA/ESO Space Telescope European Coordinating Facility, installed at ESO HQ. Visitors of all ages could choose among various attractions; they saw some of the ESO video films, were introduced to the virtues of large CCDs, admired the rear-lighted Milky Way panorama and finally filled out the "Star-Quiz" to participate in the lottery with ESO books and posters as main prizes.

About 20 ESO staff members took part in the preparations for this event and were present during seven hectic hours to guide the many visitors. There was a continuous, very lively interaction and by the end of this long day, the good result lit quite a few smiles on otherwise worn-out faces.