IRAS OBSERVATIONS OF SYMBIOTIC STARS

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ABSTRACT. Of the 129 symbiotic stars in Allen's (1984) catalogue, 42 were found to be IRAS sources. Of these 42 IRAS sources, 22 are D-type (symbiotic Miras), 5 are D'-type (yellow symbiotics) and 15 are S-type. The separation of S, D and D' types into three distinct groups is clearer in the $\log[f\lambda(25\mu m)/f\lambda(12\mu m)]$ versus (H-K) diagram. The IRAS fluxes of S-type symbiotics are consistent with that observed from normal M giants. This result suggests that mass-loss rate from most of the S-type symbiotics is similar to that from normal M giants. The IRAS data of D-type symbiotics shows evidence for the presence of dust envelopes. The masses of the dust envelopes (10^{-6} to 10^{-7} Mo) around Miras in D-type symbiotics are similar to that observed in field Mira variables. These results suggest that mass-loss rates in symbiotic Miras are similar to those from field Mira variables and also that the mass loss from symbiotic Miras is pulsationally driven similar to that found in field Mira variables by Whitelock, Pottasch and Feast (1987). Analysis of IRAS data of yellow symbiotics M1-2, AS201, Cn1-1, Wray 157, and HD149427 suggests that they are young planetary nebulae containing a binary nucleus. M1-2, AS201 and Cn1-1 show evidence for the presence of evolved hot companions. The evolutionary stage of the late type (F-G) companions is not clear.

1. INTRODUCTION

The spectra of symbiotic stars show features commonly observed in late-type giants and high-excitation planetary nebulae. The late-type star in a symbiotic binary is typically a M-type giant or an AGB star or a Mira. The hot component of a symbiotic system is a hot white dwarf or probably the central star of a planetary nebula or an accretion disk surrounding a low mass main sequence star (Kenyon and Webbink, 1984). From the near-infrared observations symbiotic stars have been classified into three types (Webster and Allen, 1975; Allen, 1982). The S-type (stellar) symbiotics have stellar IR continua (Tcolour = 3000 K) corresponding to the associated M giants. The D-type (dusty: Tcolour = 800 K) symbiotics show the presence of circumstellar dust, and the cool component is a Mira variable. In the D'-type systems (yellow symbiotics) the dust is cooler (T < 500 K), and the cool component is of spectral type F-G.

Broad-band JHKL photometry has been obtained for nearly all symbiotics (Allen 1982; Kenyon and Gallagher 1983). However, 10μm and 20μm observations are available for only some bright symbiotics. The IRAS point source catalogue (Beichman et al. 1985) now provides

Table 1: IRAS OBSERVATIONS OF SYMBIOTIC STARS

	IR type	Observed Fluxes (Jansky)			
		12μm	25μm	60μm	100μm
EG and	S	3.22	0.89	<1.05	
M1-2	D'	1.79	2.59	1.53	
UV Aur	S	52.6	15.1	2.51	
Wray 157	D'	1.15	1.33	0.58	
RX Pup	D	204	101	12.1	6.9
AS 201	D'	1.22	2.84	2.14	1.08
He2-38	D	8.32	3.4	<3.72	
SY Mus	S	0.84	0.35		
BI Cru	D	18.9	13.3	<11.6	
SS 38	D	6.73	2.89	1.61	
RW Hya	S	0.88	<0.45	<0.4	
He2-104	D	9.35	8.62	5.98	
He2-106	D	33.9	21.0	4.61	29.3
He2-127	D	0.55	0.33	<0.68	
Cn1-1	D'	23.1	35.6	15.2	9.23
T CrB	S	0.61	0.24		
AG Dra	S	0.3	<0.75	<0.4	
He2-147	D	4.07	2.39	<0.4	
He2-171	D	7.36	3.54	0.61	
HD 149427	D'	2.65	8.16	1.45	
HE2-176	D	2.97	2.07		
Hen 1242	S	0.36	<0.25		
AS 210	D?	3.05	0.9	<0.4	
H2-5	D?	1.19	0.61		
H1-36	D	<18.2	20.8	4.35	
AS 245	D?	1.53	0.65		
Ap1-8	S?	0.85	0.53	3.14	34.4
SS 122	D?	1.45	0.84		
H2-38	D	3.35	1.69		
AS 296	S	0.88	0.35	<0.4	
He2-390	D	5.08	3.94	1.76	6.61
V3804 Sgr	S	0.51	<0.51	<0.44	
V443 Her	S	0.39	<0.25	<0.4	
CH Cyg	S	448	140	13.7	3.76
Hen 1761	S	0.42	<0.27	<0.4	
HM Sge	D	119	63.1	7.08	
CI Cyg	S	0.76	0.25	<0.45	
V1016 Cyg	D	45.1	26.9	3.03	
RR Tel	D	21.1	12.9	1.98	
AG Peg	S	1.49	0.47	<0.42	
Z And	S	0.58	0.21	<0.37	
R Aqr	D	1262	401	50.5	14.8

far-infrared fluxes from 12μm to 100μm for several symbiotic stars. The LRS 8-21μm data (Olnon and Raimond 1986) is available for few bright symbiotic stars. In this paper we report an analysis of the IRAS observations of symbiotic stars.

2. IRAS OBSERVATIONS

Allen's (1984) catalogue lists 129 symbiotic stars and 15 possible symbiotics. In Table 1 we list the IRAS observations of the symbiotics stars detected in the IRAS point source catlogue. The observed IRAS positions are in good agreement with their optical positions. The IRAS fluxes given in Table 1 have been colour corrected as described in the IRAS explanatory supplement. Only 8 symbiotic stars have LRS 8-21μm spectra (Figure 1).

3. ANALYSIS

Of the 129 symbiotic stars in the Allen's (1984) catalogue, 42 were found to be IRAS sources (Table 1); 22 are D-type, 5 are D'-type and 15 are S-type. Except D'-type symbiotics, the D-type and S-type symbiotics show decreasing IR flux with increasing wavelength. Most of the S-types do not show significant flux at 60μm. Only 3 D-type and 5 D'-type show flux at 100μm. He 2-106, Ap1-8, He2-390 show flux at 100μm. These three are close to the galactic plane, and the increased emission at 100μm may be due to IR cirrus. The flux ratio $f\lambda(12\mu m)/f\lambda(25\mu m)$ of S and D-types range from 1 to 3. This flux ratio from the data of D'-type symbiotics is in the range of 0.3 to 0.9. In figure 2 we show the flux ratios $\log[f\lambda(12\mu m)/f\lambda(2.2\mu m)]$ versus $\log[f\lambda(25\mu m)/f\lambda(12\mu m)]$. In Figure 2 the S-type symbiotics are in the same region as that defined by M giants, and D-types are in the same region as that defined by Mira variables. The D'-types appear to be well separated from S and D-types. H2-5, SS122, Ap1-8 and AS245 are in the border region of D-type symbiotic stars (Figure 2).

Figure 3 shows the (H-K) colour versus $\log[f\lambda(25\mu m)/f\lambda(12\mu m)]$; there S,D,D'-types are better separated than in Figure 2. Figure 3 clearly shows the large spread in the (H-K) colours and relatively less spread in the flux ratio $\log[f\lambda(25\mu m)/f\lambda(12\mu m)]$ of D-type symbiotics. From Figure 3 we clearly distinguish the five D'-types as a distinct group. The (H-K) colour and the flux ratio $\log[f\lambda(25\mu m)/f\lambda(12\mu m)]$ of SS122 suggests that it is a D-type symbiotic. SS122 appears to be similar to He2-176 and He2-147. He 2-147 was listed as a S-type symbiotic by Allen (1984). However, the position of He2-147 in Figures 2 and 3 suggests that it is most likely a symbiotic Mira. Ap1-8 and H2-5 are S-types; however, they appear to show excess flux at 12μm and 25μm compared to other S-types. AS245 also appears to show 12μm excess. It is listed as S-type, but its position in Figures 2 and 3 indicates that it may be a symbiotic Mira. The flux ratios of AS210 are similar to those of UV Aur and R Aqr. It is likely that AS210 may contain a carbon star or a symbiotic Mira. The IR types (S,D,D') based on Figures 2 and 3 and the far-infrared energy distributions of S type symbiotics are consistent with that expected from normal field M giants.

From IRAS data of S-type symbiotic stars we can conclude that they do not have dust envelopes similar to that observed in symbiotic Miras. These results suggest that the mass-loss rate in S-type symbiotics is
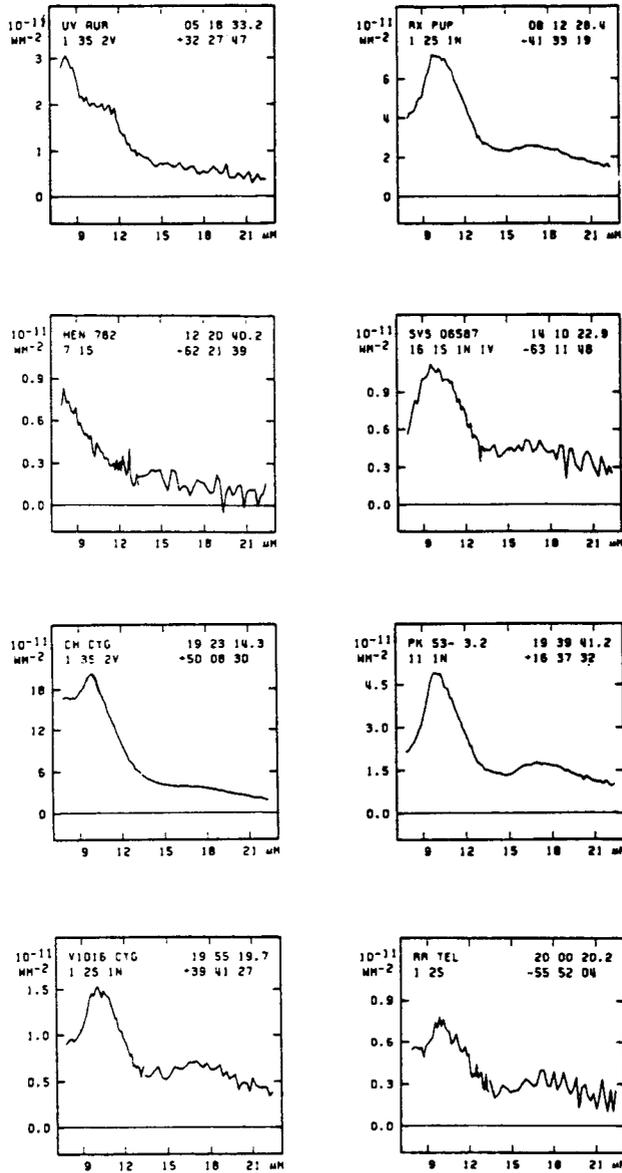
Figure 1. The low resolution 8 to 21 μm spectra of symbiotic stars.
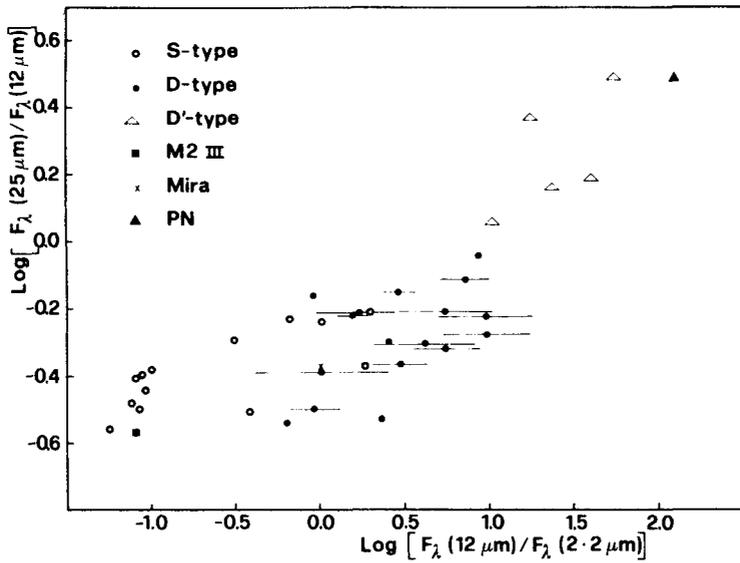
Figure 2. The colour-colour diagram for symbiotic stars. The solid lines indicate the amplitude of light variations of symbiotic Miras.
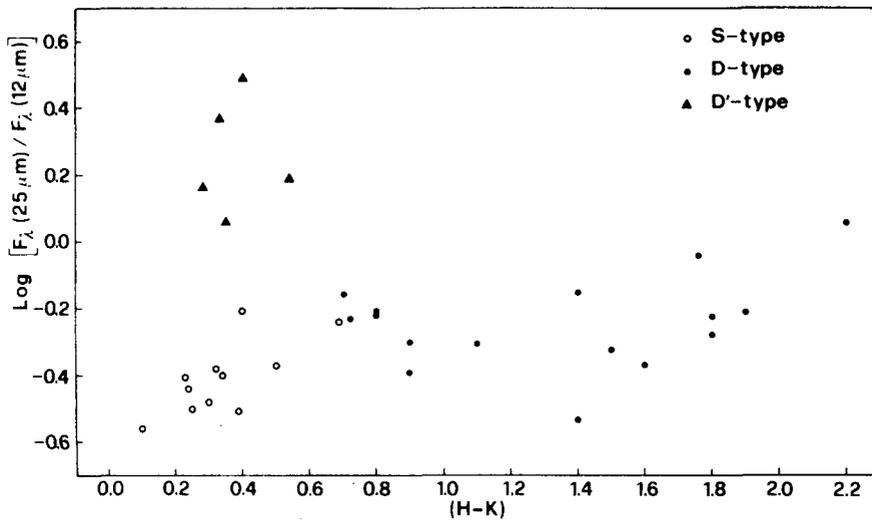
Figure 3. The colour-colour diagram for S, D and D'type symbiotics.

similar to that observed in normal M giants. However, a few S-type
symbiotic stars like CH Cyg have dust envelopes and show relatively
higher mass-loss rates. Kenyon, Fernandez-Castro and Stencel (1986)
analyzed the IRAS pointed observations of few a S-type symbiotics and
found similar results. The LRS spectra of the two S-type symbiotics
(Figure 1) CH Cyg and UV Aur show evidence for 10-μm silicate emission
feature. The IRAS fluxes of these two stars also indicate for the
presence of dust shells. From an analysis of the data we find that the
dust masses and dust temperatures to be of the order of 10^{-6} M☉ and 10^{-7}
M☉ and 500 K and 500 K for CH Cyg and UV Aur respectively. In order to
derive the characteristics of the dust shells around S-type symbiotics
we need good estimates of distances and effective temperatures of the
cool components.

3.1 SYMBIOTIC MIRAS

The IRAS data of all symbiotic Miras (D-type) (Table 1) show
evidence for the presence of dust envelopes. Pulsation periods are
known only for 10 symbiotic Miras (Whitelock, 1987). The
period-luminosity relation found from the Mira variables is also found
to be applicable to symbiotic Miras (Feast, 1984; Whitelock, 1987). The
pulsation periods, K magnitudes and distances for 10 symbiotic Miras
given in Table 2 are from Whitelock (1987). The M(bol) values are
obtained from the relation M(bol) = 1.06-2.242 log(P) (Feast, 1984).
The L values (pulsation amplitude in the L band) are estimated from the
light curves and are given in Table 2. The far-infrared luminosities
L(IR) given in Table 2 are derived from the IRAS fluxes (Table 1) and
distances (Table 2). The dust temperatures given in Table 2 are derived
from the IRAS fluxes. The average dust temperature in the dust
envelopes of symbiotic Miras is found to 320 K. The masses of the dust
envelopes M(d) are estimated from the equation (Hilderbrand, 1983)

$$M(d) = 4/3(a\rho d^2 f(\upsilon)/Q(\upsilon)B(\upsilon,T(d)), \qquad (1)$$

where d is the distance to the symbiotic Mira, $f(\upsilon)$ is the observed flux
density (IRAS), $B(\upsilon,T(d))$ is the Planck function with dust temperature
$T(d)$, a is the radius of the dust particle, and ρ is the dust grain
density. The quantity $a\rho/Q(\upsilon)$ is dependent on the dust properties and a
value of $a\rho/Q(\lambda)(25\mu m) = 1.5 \ 10^{-3}$ is adopted (Whitelock et al. 1987).
The temperatures and masses of the dust envelopes of these ten symbiotic
Miras (Table 2) are similar to that found for Mira variables by
Whitelock et al. (1987). The dust envelopes areound BI Cru, He2-104 and
H1-36 may have temperature gradients. We have not taken the temperature
gradients into account. Whitelock et al. (1987) found evidence for
pulsationally driven mass loss from Mira variables. They derived a
relation between dust shell mass, pulsation period and pulsation
amplitude (at L band).

$$\log M(d) \ (Mo) = 2.17 \log (P) +1.88\Delta L-13.38 \qquad (2)$$

We obtained the ΔL values for symbiotic Miras from their light curves
(Whitelock, 1987), and from the pulsation periods we estimated the
masses of the dust envelopes from the above equation. These values are
also listed in Table 2 for comparison. From both these estimates of
dust masses we conclude that the masses of the dust envelopes of
symbiotic Miras are of the order of 10^{-6} to 10^{-7} M☉. These values are

Table 2 :SYMBIOTIC MIRAS

Luminosities Temperatures and Masses of the Dust Envelopes

	Period days	K mag	d kpc	M_{bol} mag	L mag	L_{IR} $L_\odot$	T_d K	M_d $M_\odot$	M_d (P& L) $M_\odot$
RX Pup	580	2.4	1.5	-5.1	0.88	1761	350	1.2×10^{-6}	1.9×10^{-6}
He2-38	433	4.4	3.0	-4.9	0.67	330	400	1.3×10^{-7}	4.0×10^{-7}
BI Cru	280	4.8	2.3	-4.4	0.1	547	300	6.9×10^{-7}	1.3×10^{-8}
He2-104	400	6.7	4.7	-4.8		1277	220	5.6×10^{-6}	
He2-106	450	4.7	2.8	-4.9	0.73	1164	250	3.0×10^{-6}	5.6×10^{-7}
H1-36	500	7.4	7.6	-5.0		6476	200	4.2×10^{-5}	
HM Sge	540	4.2	2.3	-5.1	0.7	2501	375	1.3×10^{-6}	7.3×10^{-7}
V1016Cyg	450	5.1	3.4	-4.9	0.5	2185	300	2.8×10^{-6}	2.1×10^{-7}
RR Tel	387	4.1	2.5	-4.7	0.55	565	300	7.2×10^{-7}	1.9×10^{-7}
R Aqr	387	-1.0	0.25	-4.7	0.8	241	500	4.0×10^{-8}	5.5×10^{-7}

Table 3:YELLOW SYMBIOTIC STARS

Luminosities,Temperatures and Masses of the Dust Envelopes

	Sp	K(mag)	d(kpc)	L_{IR} ($L_\odot$)	T_d (K)	M_d ($M_\odot$)
M1-2	G2Ib	9.8	2.0	61	220	2.6×10^{-7}
Wray157	G	9.4	2.5	51	260	1.1×10^{-7}
AS201	G2III	9.9	2.2	77	165	1.1×10^{-6}
Cn1-1	F5III	7.6	0.45	40	235	1.3×10^{-7}
HD149427	A-F	10.3	2.	150	250	4.0×10^{-7}

similar to those found for field Mira variables by Whitelock et al.
(1987). These results suggest that the mass-loss rate from symbiotic
Miras is of the same order of magnitude as that found from Mira
variables.

The LRS 8-21μm spectra (Figure 1) of RX Pup, He2-106, HM Sge, V1016
Cyg and RR Tel show the 10μm silicate emission feature. However, the
LRS spectrum of BI Cru (Figure 1) shows no 10μm silicate emission
feature. The 8-21μm spectrum of BI Cru is in agreement with the hot
grey continuum from dust without any additional silicate component.
Roche et al. (1983) made a spectroscopic survey of 22 symbiotic stars in
the wavelength region 2μm to 13μm. They found that most of the D-types
(symbiotic Miras) show the 10μm silicate emission feature. Roche et al.
(1983) also found a featureless smooth dust emission component. They
found no silicate emission feature in BI Cru, AS210, He2-104, and
He2-390. IRAS observations (Figure 1, Table 1) of these four symbiotic
also shows that they do not have 10μm silicate emission feature. The
25μm and 60μm fluxes of He2-104 and He2-390 suggests temperature
gradients in their dust envelopes. Roche et al. suggested iron based
dust grains to explain the hot grey component in the 2 to 13μm spectra
of symbiotic Miras. Whitelock (1987) suggests the presence of large
dust grains in the dust envelopes of some symbiotic Miras, which may
explain the featureless component in the LRS spectra. But very large
particles are not required. According to Draine and Lee (1984) minimum
sizes of between 3×10^{-5} and 10^{-4} cm will suffice and can produce neutral
extinction.

3.2 YELLOW SYMBIOTIC STARS

M1-2, Wray 157, AS201, Cn1-1 and HD149427 show combination spectra
(nebular emission lines + underlying stellar absorption spectrum) like
the symbiotic stars. But the primary components of yellow symbiotics
(D'-type) are of spectral type F-G. The dust temperature is also lower
than that observed in symbiotic Miras. All these five objects show
near-infrared excess and are also classified as planetary nebulae. In
the flux-ratio diagrams (Figures 2 and 3) these five objects are well
separated from symbiotics and symbiotic Miras. The far-infrared colours
and flux distributions (Table 1) of these five yellow symbiotics are
similar to those observed in planetary nebulae. In Figure 2 He2-104 and
H1-36 are in the border region of yellow symbiotics. However, in Figure
3 they are clearly in the region of symbiotic Miras, and yellow
symbiotics are well separated from the rest. Cn1-1 shows a F5III
spectrum in the optical region with nebular emission lines superposed on
it, and the UV (IUE) spectrum suggests the presence of a hot (O-B)
companion (Lutz, 1984; Bhatt and Mallik, 1986). Cn1-1 shows strong
emission lines characteristic of a high-density planetary nebula (Glass
and Webster, 1973). The temperature of the hot (O-B) component is of
the order of 70,000 K (Lutz, 1984; Bhatt and Mallik, 1986). The optical
spectrum of AS201 shows characteristics of a G2III star (Kohoutek, 1977,
1987). Kohoutek (1977) considered AS201 as a possible photoplanetary
nebula. Feibelman (1988) obtained (IUE) ultraviolet spectrum of AS201
and found evidence for a hot companion in strong CIII, CIV and HeII
emissions and a fairly strong UV continuum. He argued that AS201 is a
planetary nebula and estimated the temperature of the hot companion to
be of the order of 60,000 K. Feibelman (1983) also studied the IUE
ultraviolet spectrum of M1-2. In the optical region M1-2 shows the

spectrum of a G2Ib star (O'Dell, 1966). Feibelman (1983) concludes that M1-2 is a young compact high-density planetary nebula of excitation class 5 or 6, and its nucleus is a binary consisting of a G2Ib star with a hot companion, probably a type O subdwarf. Recently Gutierrez-Moreno et al. (1987) studied the optical spectrum of HD149427 and concluded that it is a planetary nebula and not a symbiotic star.

The far infrared (IRAS) colours and flux distributions suggests that these five objects (Table 3) are most likely young compact high-density planetary nebulae. From IRAS data of these five objects we estimated the temperatures, luminosities and masses of the dust envelopes around them (Table 3). The masses of the dust envelopes are estimated from equation 1. Based on all the available observations we conclude that M1-2, Wray 157, AS201, Cn1-1, and HD149427 are young planetary nebulae containing a binary nucleus. The evolutionary stage of the late-type (F-G) components is not clear; they may be evolving leftward from the tip of the AGB in the H-R diagram, and the hot components may be subdwarfs or white dwarfs. Another possibility is that the late type (F-G) components are normal giants/supergiants and the dust envelopes are formed from the severe mass loss from the evolved companions which are now hot subdwarfs or white dwarfs. A CNO abundance study of the late-type (F-G) components of these five systems (Table 3) may enable us to understand their evolutionary stage. Kohoutek (1987) finds that the hot components of AS201, M1-2, and Cn1-1 are located on the Harman-Seaton sequence in the region of evolved central stars of planetary nebulae. Kohoutek estimates zanstra temperatures of 78000 K, 72000 K, and 85000 K for the hot components of AS201, Cn1-1 and M1-2 respectively.

4. CONCLUSIONS

Of the 129 symbiotic stars in the Allen's (1984) catalogue 42 were found to be IRAS sources. Only 13 D-type and 5 D'-type symbiotics show flux at 60μm. The separation of S,D and D'-types into three different groups is clearer in the $\log[f\lambda(25\mu m)/f\lambda(12\mu m)]$ versus (H-K) plot. The $f\lambda(25\mu m)/f\lambda(12\mu m)$ flux ratios and H-K colours of SS122, He2-147, AS245, and AS210 suggests that they may be symbiotic Miras. AS210 may contain a carbon star or a Mira. The IRAS fluxes and colours of S-type symbiotics stars are consistent with those observed from normal M giants. Excepting CH Cyg and UV Aur, most of the S-type symbiotic stars do not have dust envelopes. These results suggest that mass loss rate from the M giants in S-type symbiotics is similar to that from field normal M giants.

The IRAS data of D-type symbiotic stars (symbiotic Miras) show evidence for the presence of dust envelopes. The dust temperatures and masses of the dust envelopes are estimated for 10 symbiotic Miras with known pulsation periods. The dust temperatures are found to be in the range of 200 to 500 K. The masses of the dust envelopes are of the order of 10^{-6} to 10^{-7} Me. The dust envelopes in few symbiotic Miras may have temperature gradients.

Analysis of the IRAS data of yellow symmbiotic stars (D'-type) M1-2, Wray 147, AS201, Cn1-1 and HD149427 suggests that they are young high density planetary nebulae containing a binary nucleus. They show evidence for the presence of a hot evolved companion. The evolutionary

stage of the late type (F–G) companions in these systems is not clear; they may be evolving from the tip of AGB towards left in the H–R diagram.

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