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The far-infrared (IRAS) excess in BQ[ ] and related stars

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Summary. The far-infrared IRAS flux distributions and colours of 12 peculiar emission line objects HD 51585, Hen 401, Hen 591, Hen 1013, He 2–138, M 2–9, HD 326971, Hen 1357, Hen 1428, Tc 1, Hen 1475, and M 1–26 are found to be similar to that observed in young compact planetary nebulae. From the far infrared fluxes the temperatures, luminosities and masses of the dust envelopes are estimated. The results suggest that these 12 peculiar emission line stars suffered extensive mass loss in the past on their AGB stage of evolution. These objects appear to be evolving towards the early stages of planetary nebulae and may be described as transition objects or possible proto-planetary nebulae.

Key words: planetary nebulae: general – stars: early-type – stars: emission-line – infrared radiation

1. Introduction

AGB stars are understood to undergo thermal pulses, radial pulsations and severe mass loss through stellar wind. The AGB phase is terminated by the ejection of the most of the hydrogen-rich outer envelope. These processes are thought to be responsible for the formation of planetary nebulae. A detailed description of asymptotic giant branch stars is given by Iben and Renzini (1983) and Iben (1985). Theoretically and in particular observationally the transition stage between the AGB phase and the PN phase i.e. the proto-planetary nebula stage is least understood. Only recently it is becoming possible through IRAS data to recognize stars in the proto-planetary stage of evolution (Parthasarathy and Pottasch, 1986). In this paper we present a few peculiar Be stars having far infrared (IRAS) characteristics similar to those observed in planetary nebulae.

The emission line B stars showing abnormal spectra and strong forbidden emission lines were designated as BQ[ ] stars by Wackerling (1970). In addition to forbidden emission lines the spectrum of some of these stars shows P-Cygni type profiles and also shell components. Ciatti et al. (1974) made spectroscopic observations of a few of these stars. Andrillat and Houziaux (1973), Swings (1973b), Ciatti et al. (1974) suggested that the BQ[ ] star HD 51585 is in an evolutionary stage intermediate between a shell star and a planetary nebula. Allen and Swings (1972a) and Swings (1973a) found the low excitation forbidden emission line stars to show prominent infrared excesses. The similarity and possible evolutionary connection between B[e] stars and protoplanetary nebulae was stressed several times in the literature (Swings, 1973b, 1976; Allen and Swings, 1976; Swings and Andrillat, 1979; Swings, 1981). Allen (1973a, b, 1974) listed several objects with infrared excesses which are common to emission line star and planetary nebula catalogues. Allen and Swings (1976), Swings (1981), Allen et al. (1982), Allen and Glass (1974, 1975), Andrillat and Swings (1976), Henize (1976), Carlson and Henize (1980), Allen and Swings (1972), Swings (1973a) listed several peculiar early type stars with infrared excesses and forbidden emission lines. We have used the star lists from these papers and searched the IRAS point source catalogue (Beichman et al., 1985) for their far infrared counter parts. We found several emission line stars listed in the above mentioned papers that show significant far infrared (IRAS) fluxes. In this paper we present an analysis of 13 peculiar Be stars having far-infrared (IRAS) characteristics similar to those observed in planetary nebulae. The far infrared characteristics of several other peculiar emission line objects from the above mentioned lists will be discussed in the forthcoming papers.

2. IRAS observations

The IRAS observations of BQ and related stars at 12 μm, 25 μm, 60 μm, and 100 μm from the IRAS point source catalogue (Beichman et al., 1985) are given in Table 1. The observed IRAS positions are in excellent agreement with their optical positions. The percentage deviations of the fluxes given in Table 1, are of the order of 4% to 12%. Hen 591, Hen 1428, He 2–138, and HD 316248 were also observed from 8 μm to 22 μm with the low resolution spectrograph (LRS). We have also used the LRS (Olnon and Raimond, 1986 and unpublished) fluxes of these stars in the present analysis.

3. Analysis

From the IRAS fluxes given in Table 1 we estimate the temperatures, luminosities and masses of the dust envelopes around these stars. The method of analysis is described in our earlier paper (Parthasarathy and Pottasch, 1986). The far infrared fluxes integrated F_{IR}^{total} over 12 μm and 100 μm are listed in Table 2.

Table. 1. IRAS observations

	R.A. (1950) h m s	DEC ° ′ ″	Galactic longitude l_0	Galactic latitude b_0	V	Sp.	Observed IRAS fluxes (Jy) 12 μm	25 μm	60 μm	100 μm
HD 51585	06 55 37.6	+16 23 32	199	+ 9	11.5	BQ	1.4	7.17	4.27	1.72
Hen 401	10 17 48.6	−59 58 23	285	− 3	(12.5)	Be	4.15	38.27	75.85	41.08
Hen 591	11 06 33.5	−60 26 35	290	0	10.7	B[ ]	12.82	205.25	128.35	59.7
CPD-64° 2939 Hen 1013	14 33 07.4	−64 35 01	314	− 4	10.9	Be	4.08	108.68	70.62	20.11
HD 141969 He 2–138	15 51 19	−66 00 23	320	−10	11.93	BQ	2.18	48.11	43.2	19.05
M 2–9	17 02 51.8	−10 04 31	11	18	13.7	B[e]	50.58	110.18	123.13	74.81
Hen 1336 AS 218	17 04 06	−27 09 43	357	8	12.17	Be	0.3	0.66	1.0	
HD 326971 PK 345-1.1	17 06 54.4	−41 49 07	345	− 1	11.0	Be	3.29	25.82	58.43	32.81
−59° 6926 Hen 1357	17 11 56	−59 26 06	331	−12	10.95	Bo e	0.65	15.59	8.05	3.39
−49° 11554 Hen 1428	17 31 11.8	−49 24 33	341	− 9	10.68	Be	18.42	150.66	58.28	17.3
HD 161044 = Tc 1 He 2–274	17 41 52.4	−46 04 13	345	− 9	10.5	BQe	2.04	11.96	13.15	4.58
Hen 1475	17 42 18.8	−17 55 36	9	6	11.0	Be	7.09	28.24	63.28	32.9
HD 316248 M 1-26	17 42 45.1	−30 10 57	359	− 1	11.5	BQ[ ]	14.47	177.86	60.17	

Note: The percentage deviations of the fluxes are of the order of 4% to 12%. For details see IRAS point source catalogue (Beichman et al., 1985).

Table 2. Luminosities, temperatures and masses of dust envelopes

	d (kpc)	F_{IR} total (10^{-12} Wm^{-2})	L_{IR} ($L_\odot$)	T_d (K)	M_d ($M_\odot$)
HD 51585	5	1.08	$8.4\ 10^2$	125	$3.6\ 10^{-5}$
Hen 401	4	7.62	$3.8\ 10^3$	100	$3.9\ 10^{-4}$
Hen 591	3.6	29.6	$1.2\ 10^4$	125	$5.2\ 10^{-4}$
CPD −64°2939 Hen 1013	2.9	15.1	$4.0\ 10^3$	100	$4.1\ 10^{-4}$
HD 141969 He2-138	5.0	7.30	$5.7\ 10^3$	100	$5.7\ 10^{-4}$
M 2–9	3.0	22.77	$6.4\ 10^3$	140	$1.7\ 10^{-4}$
Hen 1336 AS218	2.1	0.14	20	200	$1.3\ 10^{-7}$
HD 326971 PK 345-1.1	2.0	6.56	$8.2\ 10^2$	100	$8.4\ 10^{-5}$
−59° 6926 Hen 1357	5.6	2.11	$2.1\ 10^3$	125	$8.8\ 10^{-3}$
−49° 11554 Hen 1428	2.6	19.8	$4.2\ 10^3$	125	$1.7\ 10^{-4}$
HD 161044 Tc 1	2.5	2.1	$4.1\ 10^2$	80	$1.0\ 10^{-4}$
Hen 1475	2.5	7.29	$1.4\ 10^3$	100	$1.5\ 10^{-4}$
HD 316248 M1-26	2.0	21.9	$5.4\ 10^3$	100	$2.8\ 10^{-4}$

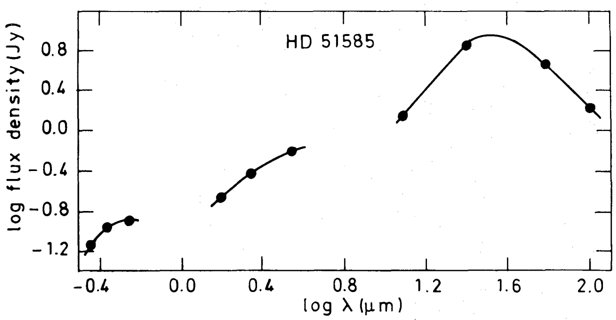

Fig. 1. Flux distribution of HD 51585

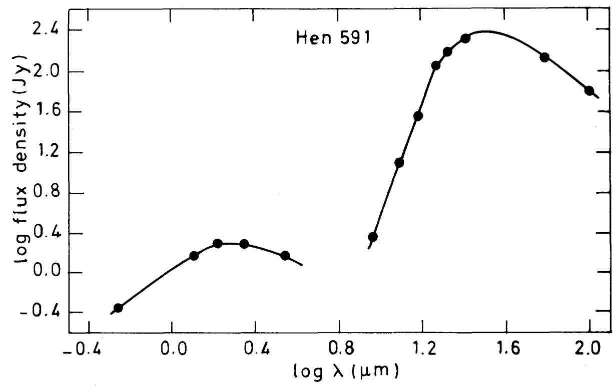

Fig. 2. Flux distribution of Hen 591

3.1. HD 51585

Beals (1951) classified it as a P-Cygni star. Andrillat and Houziaux (1973); Ciatti et al. (1974), Klutz and Swings (1977) made spectroscopic observations. The spectrum of HD 51585 shows strong emission lines of Fe II, [Fe II], [S II], [O III], [O II], [O I], and also He I, H I, Ca II, [Ca II] etc. Andrillat and Houziaux (1973) find that the line ratios for [O I], [O II], [O III] are not compatible with a unique set of N_e, T_e values. They suggest that the continuum is well represented by a B0.5 star. Allen (1973) made near IR photometric observations and derived $V-K=3^m0$. In addition to the cool dusty region there is a region of higher ionization ([O III], S III, O II and also a region of low ionization (O I, [Fe II], Ca II etc). The distance is uncertain. Andrillat and Houziaux (1973) estimate $E(B-V)=0.68$ and mentioned that $A_V/E(B-V)$ is somewhat higher than the usual value. Klutz and Swings (1977) made a detailed study of the visible and near infrared spectrum of HD 51585. They conclude that "HD 51585 is surrounded by an extended gaseous shell composed of regions of different temperatures, densities and velocities; such a shell is probably not stratified in inner hotter regions and cooler external layers, but seems to present rather complicated forms and motions". Arkhipova (1962) estimated the radius of the envelope to be about 30 $R_\odot$. Klutz and Swings (1977) found the Balmer lines to exhibit strong P-Cygni profiles. On the basis of two clearly separated [O III] emission components Klutz and Swings (1977) suggested the presence of an equatorial ring rotating around HD 51585. The infrared flux distribution is shown in Fig. 1. The IRAS flux distribution and colours are similar to that observed in planetary nebulae. From the IRAS flux distribution and colours we find the dust temperature T_d to be 125 K. Arkhipova (1963) estimated the visual absorption $A_V=2.16$ in the direction of HD 51585. From the photometric observations of stars in the region of HD 51585 we estimate $A_V=2.74$. The spectrum of HD 51585 suggests an absolute visual luminosity $M_V=-5$. The distance is estimated to be about 5 kpc.

3.2. Hen 401

Hen 401 is an early type emission line star (Henize, 1976; Sanduleak and Stephenson, 1973) and appears to be a bright bipolar planetary nebula. Allen (1978) obtained blue visual region spectrum of Hen 401. The spectrum shows emission lines due to H I, He I, [O I], [O II], Fe II, [Fe II], [Fe III], [S II], [N II], and Ca II (H and K lines). Hen 401 appears to be similar in morphology and spectrum to M 1–92. On ESO J films the bipolarity can be noticed. Additional faint nebulosity (25″ × 10″) appears to be present (Allen, 1978). The IRAS fluxes (Table 1) and colours are similar to those observed in planetary nebulae. Near infrared photometric observations (Allen and Glass, 1975) also suggest an infrared excess. The apparent faintness of the central star may be due to internal reddening similar to that observed in M 2–9. The spectrum published by Allen (1978) suggests a spectral type of B0 for the central star. The ratio of far-infrared luminosity to visual luminosity is very high which suggests that the central B star may be obscured by a dusty disk or a flattened torus. In this respect also Hen 401 appears to be similar to M 2–9 and M 1–92. Energy balance considerations also suggest an early B star at a distance of 4 kpc. The far-infrared (IRAS) flux distribution and colours yield the dust temperature to be about 100 K.

3.3. Hen 591

Hen 591 is a B type emission line star (Henize, 1976) showing a number of [Fe II] lines in its spectrum. Carlson and Henize (1980) suggest that it is a P-Cygni star. The great strength of [Fe II] lines relative to H lines renders this star unique. The Hγ and Hδ lines are not visible, may be filled in by emission, but several higher members of the series show weak broad absorption. The Balmer lines show significant violet shifts (Carlson and Henize, 1980). The Ca II H and K absorption lines are very strong with strength nearly equal to that of H9 and H10 lines. The Ca II H and K lines may be circumstellar in origin, however if they are photospheric then the spectral type suggested by these two lines is early F. The near IR observations show IR excess ($V-K=4.3$, see Fig. 2) with flux maximum near 1.6 μm, IRAS data (Fig. 2) shows flux maximum near 25 μm. The LRS 8 μm to 22 μm spectrum shows only continuum radiation by the dust. There are no emission lines, either they are extremely weak or absent. The far infrared (IRAS) flux distribution and colours of Hen 591 (Fig. 3) are similar to that observed in planetary nebulae. From the IRAS fluxes we find the dust temperature to be 125 K. Adopting $A_V=1^m0$, and $M_V=-4$ we find the distance to be 3.6 kpc.

3.4. Hen 1013 (−64° 2939)

Hen 1013 is an early type emission line star (Henize, 1976). Klare and Neckel (1977) made *UBV* and β photometric observations ($V=10.89$, $B-V=0.6$, $U-B=-0.36$, $\beta=2.42$). Recently Kozok (1985a) made *UBV* observations which are in good agreement with the observations of Klare and Neckel (1977).

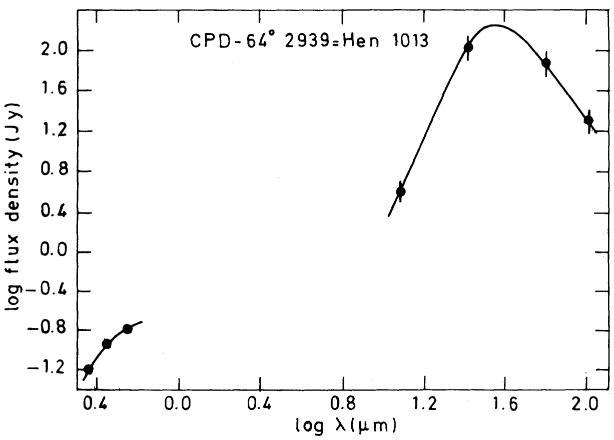

Fig. 3. Flux distribution of Hen 1013

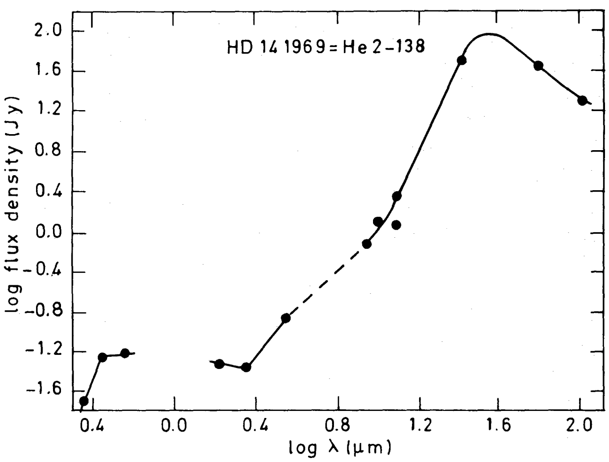

Fig. 4. Flux distribution of HD 141969

Kozok (1985b) estimates $V_0 = 8.31$, $(B-V)_0 = -0.21$, $(U-B)_0 = -0.95$, $M_V = -3.1$, $d = 1.9$ kpc. Klare and Neckel (1977) give percentage of polarization = 1.96. The IRAS flux maximum is around 25 μm (Fig. 3). The 12 μm to 25 μm flux ratio and far-infrared (IRAS) flux distribution is similar to that observed in planetary nebulae.

3.5. *HD 141969* (*He 2–138*)

Cohen and Barlow (1980) made near infrared photometric observations of HD 141969. Sanduleak and Stephenson (1972) listed it as a very low excitation (VLE) object. The spectrum appears to be continuous, Hβ, Hγ, Hδ, and Hε lines show P-Cyg emission. Near infrared photometric observations were made by Allen and Glass (1974) and Cohen and Barlow (1980). The 12 μm to 25 μm flux ratio (Fig. 4) is 0.045 and is similar to that observed in planetary nebulae. Kozok (1985a, b) made *UBV* photometric observations and derives $V = 11.925$, $E(B-V) = 0.4$, $V_0 = 10.6$, $(B-V)_0 = -0.07$, $(U-B)_0 = -0.16$. Kozok estimates $M_V = -0.67$ and $d = 1.8$ kpc. Webster (1969) estimated the distance to be $d = 3.8$ kpc. Mendez et al. (1987) have analysed the H and He line profiles of this star and find $T_{eff} = 27000$ K, $\log g = 2.7$. This leads to a distance $d = 5.0$ kpc. We use a distance of 5 kpc. Continuum radio emission is observed at 2 cm (82 mJy) and 6 cm (76 mJy) from a nebula with a radius of 3″.5 (Milne and Aller, 1982). The LRS spectrum shows a strong [Ne II] line at 12 μm and [Ne III] and [S III] emission lines as well. It is clearly a young planetary nebula.

3.6. *M 2–9*

Swings and Andrillat (1979) find great similarities between the spectrum of M 2–9 and that of B[e] stars or of proto-planetary nebulae. M 2–9 consists of 13^m.7 O – Be object and two symmetric lobes or wings extending in north-south direction (Allen and Swings, 1972b; Swings and Andrillat, 1979; Feibelman, 1984). Allen and Swings (1972b) find an electron density gradient ranging from 10^7 cm^{-3} for the core to 10^4 cm^{-3} for the outer portions of the wings. They suggested that it may be a young planetary nebula. Calvet and Cohen (1978) confirmed the stratification effects observed by Allen and Swings (1972) and derived an extinction $A_V = 5.35$ for the core. Schmidt and Cohen (1981) estimated the spectral type of the exciting star to be BIV and a distance of 1 kpc. Ciatti and Mammano (1975) compared M 2–9 to BQ[ ] radio stars on the basis of the strength of the O I λ 8446 line. Livio (1982) considers M 2–9 as a candidate for a suspected binary nucleus. The symmetric shape is responsible for the name Butterfly nebula, and Cohen (1983) considered it as a bipolar-planetary nebula. Brocka (1979) estimated the distance to be 7.9 kpc. Feibelman (1984) analysed the (IUE) ultraviolet spectra of M 2–9 and found *N* to be overabundant by a factor of 5. He suggests that M 2–9 is in the early stages of becoming a planetary nebula. The far-infrared IRAS fluxes (Table 1) and colours are similar to that observed in planetary nebulae. The temperature of the dust $T_d = 140$ K. The near infrared photometric observations also show infrared excess. The ratio of far infrared luminosity to visual luminosity is very high, which is most likely due to the obscuration of the central O – B star by a dusty disk. From the spectral type of the central star (Allen and Swings, 1972; Swings and Andrillat, 1979; Schmidt and Cohen, 1981) and from the energy balance considerations we estimate the distance to be 3 kpc. If we use the 8 kpc distance estimate of Brocka (1979) we find $L_{IR}/L_\odot$ and $M_d/M_\odot$ to be 4.6 10^4 and 1.22 10^{-3} respectively.

Schmidt and Cohen (1981) suggest that the nebulosities are polar lobes resulting from a flattened torus around the exciting star. Recently Aspin et al. (1988) obtained high spatial resolution infrared images of M 2–9. They find the colour images $(J-K)$ and $(H-K)$to show a highly reddened disk-like feature that is 20″ in size and extends across the central bright core region. Walsh (1981) determined radial velocities and electron densities at many positions over the bipolar nebula. He interpreted the velocity features over the core as an expanding shell driven by stellar wind. M 2–9 shows changes in brightness and structure (Allen and Swings, 1972b; van den Bergh, 1974) which are interpreted as due to modulation of the ultraviolet emission of the central object by dust clouds.

3.7. *Hen 1336* (*AS 218* = MHA 276-48)

Hen 1336 is an early type B emission line star. Kozok (1985a, b) made *UBV* observations and derives $V = 12.17$, $B-V = 1.13$, $U-B = 0.456$, $E(B-V) = 1.17$, $V_0 = 8.27$, $(B-V)_0 = -0.04$, $M_V = -3.3$, and $d = 2.1$ kpc.

3.8 *HD 326971* (*PK 345 1.1*)

HD 326971 is an emission line star (Merrill and Burwell, 1950). The far-infrared flux maximum is at 60 μm. The temperature of

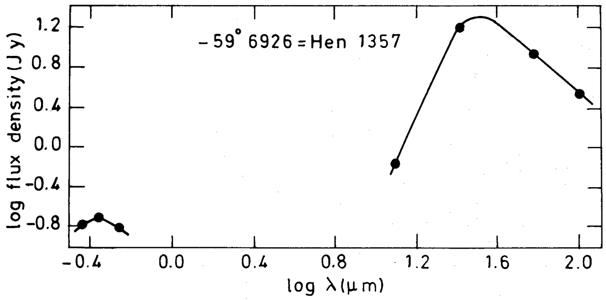

Fig. 5. Flux distribution of Hen 1357

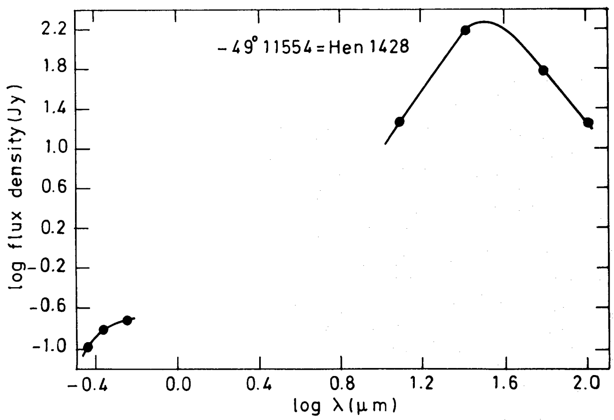

Fig. 6. Flux distribution of Hen 1428

the dust is found to be 100 K. The far-infrared flux distribution and colours are similar to that observed in planetary nebulae.

3.9 Hen 1357 (*−59°6926*)

Hen 1357 is an emission line B0 star (Henize, 1976), Kozok (1985a, b) made *UBV* photometry and derives $V=10.95$, $B-V=-0.043$, $U-B=-0.884$, $E(B-V)=0.18$, $V_0=10.37$, $(B-V)_0=-0.22$, $M_V=-3.4$, and $d=5.6$ kpc. The IRAS flux distribution is shown in Fig. 5.

3.10. Hen 1428 (*−49°* 11554)

Klare and Neckel (1977) made *UBV and β* polarization observations and derive $V=10.74$, $B-V=0.41$, $U-B=-0.58$, $\beta=2.436$ and percentage of polarization = 3.5. The *UBV* observations of Kozok (1985a, b) are in good agreement with the observations of Klare and Neckel. Kozok estimates $E(B-V)=0.63$, $V_0=8.63$, $(B-V)_0=-0.22$, $(U-B)_0=-1.02$, $M_V=-3.44$, and $d=2.6$ kpc. The IRAS flux distribution is shown in Fig. 6. The far-infrared flux distribution and colours are similar to that observed in planetary nebulae. From the IRAS data the dust temperature is found to be 125 K.

3.11. HD 161044 (*He 2–274* = Tc 1)

There is a shell around this star (Thackeray, 1956). [O III] λ 4959 and λ 5007 lines are much weaker than Hβ. This object is regarded as a planetary nebula of unusually low excitation. The nucleus is very bright compared with the nebula and consequently the continuous spectrum is very prominent and tends to mask the

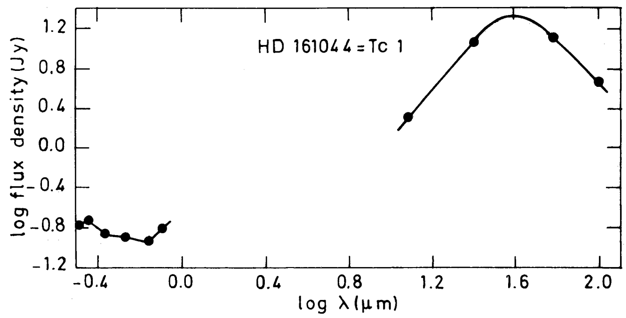

Fig. 7. Flux distribution of Tc 1

emission lines. But strong hydrogen lines can be seen extending well outside the continuous spectrum. Cohen and Barlow (1980) made near IR photometric observations. Kohoutek and Martin (1981) obtained the flux distribution from 3250 Å to 7900 Å. They estimate the temperature, luminosity and distance of the star: $\log T_z=4.51$, $\log L/L_\odot=3.01$, $d=1.6$ kpc. Mendez et al. (1987) find $\log T_{\rm eff}=4.53$ from a study of the stellar H and He line profiles. They find further that $\log g=3.4$ leading to a distance of 2.5 kpc, which we adopt. Milne and Aller (1982) find radio continuum both at 2 cm (130 mJy) and 6 cm (134 mJy). The shell has a redius of 4″.8. This is clearly a young planetary nebula. The IRAS flux distribution is shown in Fig. 7. From the IRAS data the dust temperature is found to be 80 K. Feibelman (1983) analysed the ultraviolet (IUE) spectra of Tc 1 and confirmed that the object is a low-excitation planetary nebula and that its central star is of spectral type O7. From 2200 Å absorption feature he estimated $E(B-V)=0.22$.

3.12. Hen 1475

It is a B type emission line star (Henize, 1976). The IRAS flux distribution and colours are similar to that observed in planetary nebulae. The far-infrared flux maximum is around 60 μm. The dust temperature is found to be 100 K.

3.13. HD 316248 (*M 1–26*)

M 1–26 is a Bep type emission line star. Minkowski (1946) reported that it is a planetary nebula having an angular diameter of 4″. The spectrum shows weak emission lines of [O II], [O III], H superimposed on a bright continuum. Hutsemekers and Surdej (1985), Allen and Swings (1976) have also reported the presence of emission lines [Fe III], [S III], [S II], and [Ar III] etc. From near IR photometry Allen (1973) and Cohen and Barlow (1980) found it to be a strong infrared source (Fig. 8). Aitken et al. (1979) found strong [Ne II] emission line at 12.8 μm, IRAS LRS spectrum also shows strong [Ne II] emission lines. Hutsemekers and Surdej confirm the non-stellar appearance of HD 316248. They find it to be diffuse and elongated having an angular size of 4″.4. They find a variation and net increase in the [O III] λ 4959, λ 5007 line intensities. The low excitation spectrum of HD 316248 is similar to that of a H II region suggesting a high luminosity for the central star. Hutsemekers and Surdej (1985) suggest M 1–26 is a proto-planetary nebula on the basis of its compact structure and the low excitation forbidden emission line spectrum. Kohoutek and Martin (1981) made blue visual region narrow band photometric observations. Martin (1981) estimates the temperature, luminosity and the distance of the central star: $\log T_z=4.48$,

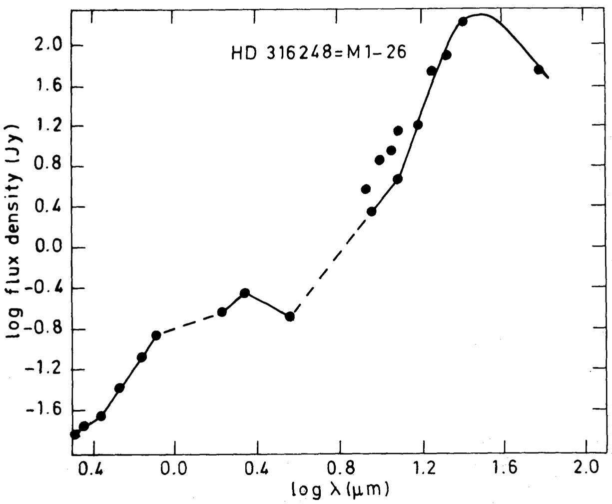

Fig. 8. Flux distribution of M 1–26

$\log L/L_{\odot} = 3.96$, $d = 2$ kpc. Mendez et al. (1987) from the line profiles find $\log T_{\rm eff} = 4.52$ and $\log g = 3.2$ leading to a distance of 1.9 kpc. Milne and Aller (1982) measure continuum radio emission at 2 cm (400 mJy) and 6 cm (320 mJy). The LRS spectrum shows a clear silicate emission feature at 9.7 μm and a strong [Ne II] emission line at 12.8 μm. The IRAS flux distribution is shown in Fig. 8. It is clearly a young planetary nebula.

4. Summary of results

The temperatures of the dust envelopes derived from the IRAS data are listed in Table 2. All the objects described above have cool dust envelops and most of them show flux maximum around 25 μm. However few show flux maximum around 60 μm. The 12 μm/25 μm flux ratio of most of the objects listed in Table 1 is <0.3 However for M 2–9 and Hen 1336 the 12 μm/25 μm flux ratio is 0.46. The near infrared flux distribution of several of these objects (Figs. 1–8) suggests the presence of hotter dust component (800 K to 1000 K) in addition to the colder dust (100 K). From *JHK* photometry of M 2–9 Aspin et al. (1988) find a dust temperature of ~1100 K. This value is reasonably consistent with the earlier estimate of 800 K by Allen and Swings (1972). The far-infrared characteristics of these objects are similar to that observed in planetary nebulae. The total far-infrared luminosities $L_{\rm IR}/L_{\odot}$ of the dust envelopes around these objects are estimated and are given in Table 2. The far-infrared luminosities of the dust envelopes directly depend on the distance of the central stars. In estimating the distance, we have used the luminosities, photometric data and optical and far-infrared energy balance considerations. The visual extinction $A_{\rm V}$ values in the direction of some of these stars are estimated from the data of Neckel and Klare (1980) and Lucke (1978). The distance estimates given in Table 2 are rather uncertain.

The mass of the dust shell ($M_{\rm d}$) is computed from (e.g. Hildebrand, 1983; Barlow, 1983; Pottasch et al., 1984)

$$M_{\rm d} = \frac{4}{3}\frac{a\varrho}{Q_{\nu}}\frac{d^2 F_{\nu}}{B_{\nu}(T_{\rm d})},$$

where $a\,(10^{-5}$ cm) and $\varrho\,(3\,{\rm g\,cm^{-3}})$ are the radius and mean density of the emitting dust grains of temperature $T_{\rm d}$ which have an emissivity $Q(\nu_{\rm max})$ at the peak of the infrared energy distribution ($Q_{25}\,\mu{\rm m} = 3\,10^{-3}$), $B_{\nu}(T_{\rm d})$ is the Planck function and d is the distance to the source. Thus the determination of the dust mass (Table 2) depends on the distance, flux density, $T_{\rm d}$, $Q(\nu)$ and the size of the dust grains. The accuracy of the dust mass determination is limited primarily by the uncertainties in distance, grain size and emissivity.

The spectra of HD 51585 and M 2–9 is often compared with the spectra of well known BQ[ ] or B[e] stars HD 45677, MWC 349, MW 645, and MWC 819 (Klutz and Swings, 1977; Swings, 1973; Allen and Swings, 1976). Swings and Andrillat (1979) discussed the spectrum of M 2–9 and its possible relation to B[e] stars (HD 45677, MWC 349, MWC 645 and MWC 819) and/or to protoplanetary nebulae. The far infrared (IRAS) fluxes of the peculiar Be stars HD 45677, MWC 819, η Car, MWC 349, and MWC 645 are given in Table 3. All the five objects show far infrared excess. Their far IR colours, and energy distributions are different from that of planetary nebulae. The flux ratio $F_{\lambda}(12\,\mu{\rm m})/F_{\lambda}(25\,\mu{\rm m})$ is of the order of 1, however this flux ratio for planetary nebulae is <0.3. For η Car it is 2.4. η Car is a peculiar object and may be a multiple system (Davidson and Humphreys, 1986 and references therein). The nature and evolutionary status of MWC 349 is not clear, it may be a young or an evolved object. Recent observations suggest that MWC 349 is a bipolar nebula with a hot object at the center, the central hot object appears to be a binary (White and Becker, 1985; Cohen et al., 1985).

5. Conclusions

From the IRAS data of peculiar emission line objects we have found 13 objects with far-infrared characteristics similar to that of planetary nebulae. The optical region spectra of HD 51585 and M 2–9 etc. show some similarities to the optical region spectra of BQ[ ] or B[e] stars HD 45677, MWC 349, MWC 645 etc., however their far-infrared characteristics are different.

Table 3. IRAS observations

	R.A. (1950)	DEC	Galactic longitude	Galactic latitude	Observed IRAS fluxes (Jy)			
	h m s	° ′ ″	l_0	b_0	12 μm	25 μm	60 μm	100 μm
HD 45677	06 25 59	−13 01 13	222	−11	146.3	143.4	24.5	5.7
MWC 819	06 42 01.9	+01 22 43	211	− 1	3.3	2.6	3.3	5.2
η Car	10 43 06.1	−59 25 21	288	− 1	11008	4619	13467	8236
MWC 349	20 31 1.5	+40 29 37	80	0	179	112	75	85
MWC 645	21 51 40.5	+52 45 47	98	− 1	9	14.3	4.6	

The BQ[ ] or B[e] stars having far-infrared (IRAS) characteristics similar to that of planetary nebulae are few in number (Table 1). The far-infrared flux distribution, colours, temperatures, luminosities and masses of the dust envelopes of the objects (Tables 1 and 2) discussed here are similar to that observed in planetary nebulae. None of these objects (Table 1) are in the regions of young clusters, associations and star formation. We conclude that HD 51585, Hen 401, Hen 591, Hen 1013, HD 141969, M 2–9, HD 326971, Hen 1357, Hen 1428, Tc 1, Hen 1475, and M 1–26 are post-AGB stars evolving from the tip of AGB towards the left in the HR diagram. Except M 2–9, Hen 401, Tc 1, and M 1–26 rest of the objects are stellar in appearance. The circumstellar dust shells around these 13 objects discussed here are most likely the result of severe mass loss on the AGB stage of evolution. These 13 objects may be in a transition stage and may be described as proto-planetary nebulae. The central stars of these objects are evolving towards hotter spectral types. Some have already produced considerable ionization in the emitted material (He 2–138, Tc 1, M 1–26), some an order of magnitude less. He 2–138, Tc 1, M 1–26, M 2–9 are clearly far enough advanced and may be called planetary nebulae. Determination of CNO abundances and if possible determination of $^{12}C/^{13}C$ isotope ratio from CO $J=1\rightarrow 0$ and $2\rightarrow 1$ data may enable us to further understand the evolutionary stage of the these objects.

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