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The far-infrared (IRAS) excess in luminous F–G stars

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Summary. The far-infrared IRAS excesses are found in ten luminous F-G stars. The far-IR fluxes from these stars are due to large amounts of dust around them. The far-IR flux distribution, far-IR luminosities and dust masses are similar to those in observed planetary nebulae. The mass of the dust around HD 187 885 and HD 179 821 is of the order of $10^{-2}\,M_{\odot}$. These ten stars may be in the AGB – post-AGB stage of evolution.

Key words: dust – F-G supergiants and giants – AGB stars – planetary nebulae – far infrared radiation

1. Introduction

In an earlier paper (Parthasarathy and Pottasch, 1986, Paper I) we have reported that the high galactic latitude F supergiant HD 161 796 (F 3 Ib) and related stars are found to show strong far-infrared (IRAS) excesses and dust masses similar to those seen in planetary nebulae (Pottasch et al., 1984), and that these stars are most likely low mass stars in the AGB, post-AGB stage of evolution. We have continued to search for far-infrared excesses in similar luminous F-G stars of low and intermediate mass which are likely in that same evolutionary stage.

In this paper we report the detection of far-infrared (IRAS) excesses and colours similar to those observed in planetary nebulae in ten luminous F-G stars. IRAS LRS spectra are given when available. We derive the temperatures, luminosities, and masses of the dust envelopes around these stars.

2. IRAS observations

The IRAS fluxes of HD 187 885 (SAO 163 075, see Paper I), HD 179 821, BD + 54°2787, HD 144 432, HD 142 527, HD 143 006, HD 95767, HD 108 015, −62°5428, and HD 319 896 at 12 μm, 25 μm, 60 μm, and 100 μm from the IRAS point source catalogue (Beichmann et al., 1985) are given in Table 1. The observed IRAS positions are in excellent agreement with their optical positions, the deviations are less than 10″. The percentage deviations of the fluxes given in Table 1 are of the order of 4% to 12%. Five of these stars were also observed from 8 μm to 21 μm with the Low Resolution Spectrograph. We have also used the LRS fluxes of these stars in the present analysis.

The LRS 8–21 μm spectrum (Fig. 1a) of HD 187 885 (SAO 163 075) shows only continuum radiation by the dust; there are no emission lines, either they are extremely weak or absent. The large far-infrared excess suggests large amounts of dust around this star. This is even a more extreme case than HD 161 796, since the infrared radiation is almost the same, but its visual magnitude is 9.0 instead of 7.04. Thus more radiation is emitted in the far infrared than in the visual and ultraviolet. The dust must absorb the optical radiation of the F 8 star and re-emit it in the far-IR region. Equating the far-IR flux to the optical region flux of F 8 I star suggests a distance of 5 to 6 kpc. The galactic latitude is −21° and the z distance is ≃ 2 kpc. In all respects this star appears to be similar to the high galactic latitude F supergiant HD 161 796.

HD 179 821 is a G 5 Ia star (Buscombe, 1984). HD 179 821 shows very large far-infrared excess at 25 μm and 60 μm (Table 1) similar to that observed in planetary nebulae. The recent MK–M_v calibrations (Corbally and Garrison, 1984) indicate $M_v = -8.0$ for a G 5 Ia star, which would give it a distance of 2.9 kpc. The LRS spectrum (Fig. 1B) shows no spectral features. It shows no flux at 9 μm, but a strongly increasing flux toward 20 μm. Again there is more energy in the far IR than in the visual.

BD + 54°2787 has a flux maximum in the far-IR at 25 μm. The ratio of the fluxes $F(12\,\mu\mathrm{m})/F(25\,\mu\mathrm{m}) < 0.3$ is similar to that observed in most of the planetary nebulae. It's K 5 (I) spectrum, if interpreted in the normal way, puts it at a distance of almost 3 kpc. The LRS spectrum (Fig. 1 c) shows broad features which could be interpreted as silicate absorption at 9.7 μm and 18 μm. The IR emitting shell appears hotter than that of the previous two stars. Again more energy is in the far-IR than in the visual, indicating strong absorption of the starlight.

HD 144 432 is a F 0 emission line star (He 3–1141; Henize, 1976). Henize notes H_α absorption shortward of the emission. Olsen (1983) and Olsen and Perry (1984) made *uvbyβ* photometry of this star: $v = 8.188$, $b{-}y = 0.239$, $m_1 = 0.165$, $c_1 = 0.766$ and $\beta = 2.73$. This data suggests it to be a F 0 III star. The flux ratio $F(12\,\mu\mathrm{m})/F(25\,\mu\mathrm{m}) = 0.81$ suggests the presence of 10 μm silicate emission.

HD 142 527 is an emission line star (HE 3–1119; Henize (1976)). Henize notes that the H_α emission strength is variable. In Houk's (1978) catalogue it is listed as a normal F 6 III star. Olsen (1983) obtained *uvbyβ* photometry of this star: $v = 8.361$, $b{-}v = 0.502$, $m_1 = 0.113$, $c_1 = 0.523$ and $\beta = 2.616$. These colours and spectral type suggest $E(b{-}v) = 0.2$.

HD 143 006 (He 3–1126; Henize, 1976). H_α in emission is not certain. The flux ratio $F(12\,\mu\mathrm{m})/F(25\,\mu\mathrm{m}) < 0.3$ is similar to that

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Table 1. IRAS observations

	R.A. (1950) IRAS	Decl.	Galactic				Observed IRAS fluxes (Jansky)				LRS spectrum
			Longitude l	Latitude b	V	Sp.	12 µm	25 µm	60 µm	100 µm	
	h m s	° ′ ″	°	°							
HD 187885 SAO 163075	19 50 01.5	−17 09 38	24	−21	9.0	F8 (I)	27.88	165.0	72.66	12.66	Yes
HD 179821 SAO 124414	19 11 25	+00 02 18	36	−05	8.3	G5 Ia	31.37	647.69	515.84	166.84	Yes
BD+54°2787 SAO 34504	22 27 13.2	+54 35 41	103	− 3	9.2	K5 (I)	73.92	302.13	96.16	40.19	Yes
HD 144432 SAO 184124	16 03 53.7	−27 35 08	347	+18	8.19	F0IIIe	7.60	9.41	5.65	3.18	–
HD 142527 SAO 226389	15 53 16.8	−42 10 46	336	+08	8.36	F6IIIe	10.45	21.3	104.6	83.46	–
HD 143006 SAO 183986	15 55 38.9	−22 48 45	350	+23	9.5	G5 (I)e	0.87	3.18	6.45	4.71	–
HD 95767 SAO 251227	11 00 03.6	−61 53 41	291	− 2	8.8	F0Ib	22.21	15.73	10.64	57.4	Yes
HD 108015 SAO 223420	12 22 12.1	−46 52 29	298	+15	8.0	F3Ib	32.54	33.21	7.86	2.32	Yes
−62°5428 SAO 253680	16 39 58.8	−62 47 54	326	−11	10	F2	0.25	1.29	2.10	–	–
HD 319896 −35°11646	17 27 43.6	−35 06 37	353	− 1	10	F8e	2.53	2.49	6.8	–	–

observed in planetary nebulae. HD 143 006 and HD 144 432 are at relatively higher galactic latitudes.

HD 95767 is an F 0Ib star (Houk and Cowley, 1975). Rufener (1981) listed the photometric observations on the Geneva system. The flux ratio $F(12\,\mu\mathrm{m})/F(25\,\mu\mathrm{m}) = 1.41$ suggests the presence of 10 µm silicate emission, but the LRS spectrum (Fig. 1 d) does not confirm this. There appear to be abnormally strong emission over the whole range between 8 and 13 µm. The large far-IR at 100 µm suggests the presence of much cooler dust around this star, *if it is real.* Since the star is close to the galactic plane, this increased emission may not be of circumstellar origin. There is also an indicator of cirrus emission in the vicinity.

HD 108 015 is a F 3 Ib star (Houk, 1978). It is found to be a variable star (BV 707) by Stromhmeier et al. (1965). It is at a higher galactic latitude relative to HD 95767. The flux ratio $F(12\,\mu\mathrm{m})/F(25\,\mu\mathrm{m}) = 0.98$ suggests the presence of 10 µm silicate emission, but again the LRS spectrum (Fig. 1e) shows a rather broad emission feature. HD 108 015 and HD 95767 may be similar to 89 Her.

HD 319 896 is a F type emission line star (He 3–1418; Henize, 1976). The far-IR flux maximum is at 60 µm. The 12 µm and 25 µm fluxes are almost equal, suggesting the presence of 10 µm silicate emission.

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. The flux distributions are shown in Fig. 2. The far-infrared flux integrated between 12 µm and 100 µm are listed in Table 2. The temperatures of the dust envelopes (Table 2) around these stars are estimated from the far-IR energy distribution and colours. We have not considered the temperature gradient in the dust envelopes, although the rather broad emission suggest a temperature gradient in the dust envelopes of these stars. The total luminosities (far-IR) of the dust envelopes around these are estimated and given in Table 2. The IR-luminosities ($L_{\mathrm{IR}}/L_\odot$) of the dust envelopes directly depends on the distances or absolute luminosities of the central stars. In estimating the distances we have used the luminosities, photometric data and optical and IR energy balance considerations. The visual extinction A_v in the direction of these stars are estimated from the data of Neckel and Klare (1980) and Lucke (1978) and are given in Table 2. The A_v values given in Table 2 are rather preliminary. In order to determine accurate luminosities of the stars listed in Table 1 we need detailed spectroscopic observations. The masses of the dust envelopes are estimated (for details see Pottasch et al. (1984); Parthasarathy and Pottasch (1986)) and are given in Table 2.

Likkel et al. (1987) detected CO $J = 1 \rightarrow O$ emission from HD 161 796, and HD 187 885. Zuckerman and Dyck (1986) detected CO $J = 1 \rightarrow O$ emission from HD 179 821 (AFGL 2343) (G 5I a, Odenwald (1986) estimates it to be a K 4 I star). They suggested that it is an unusual oxygen-rich supergiant located far from the galactic plane. They find that its CO outflow velocity is also large ~34 km s^{-1}, suggestive of a star of supergiant class

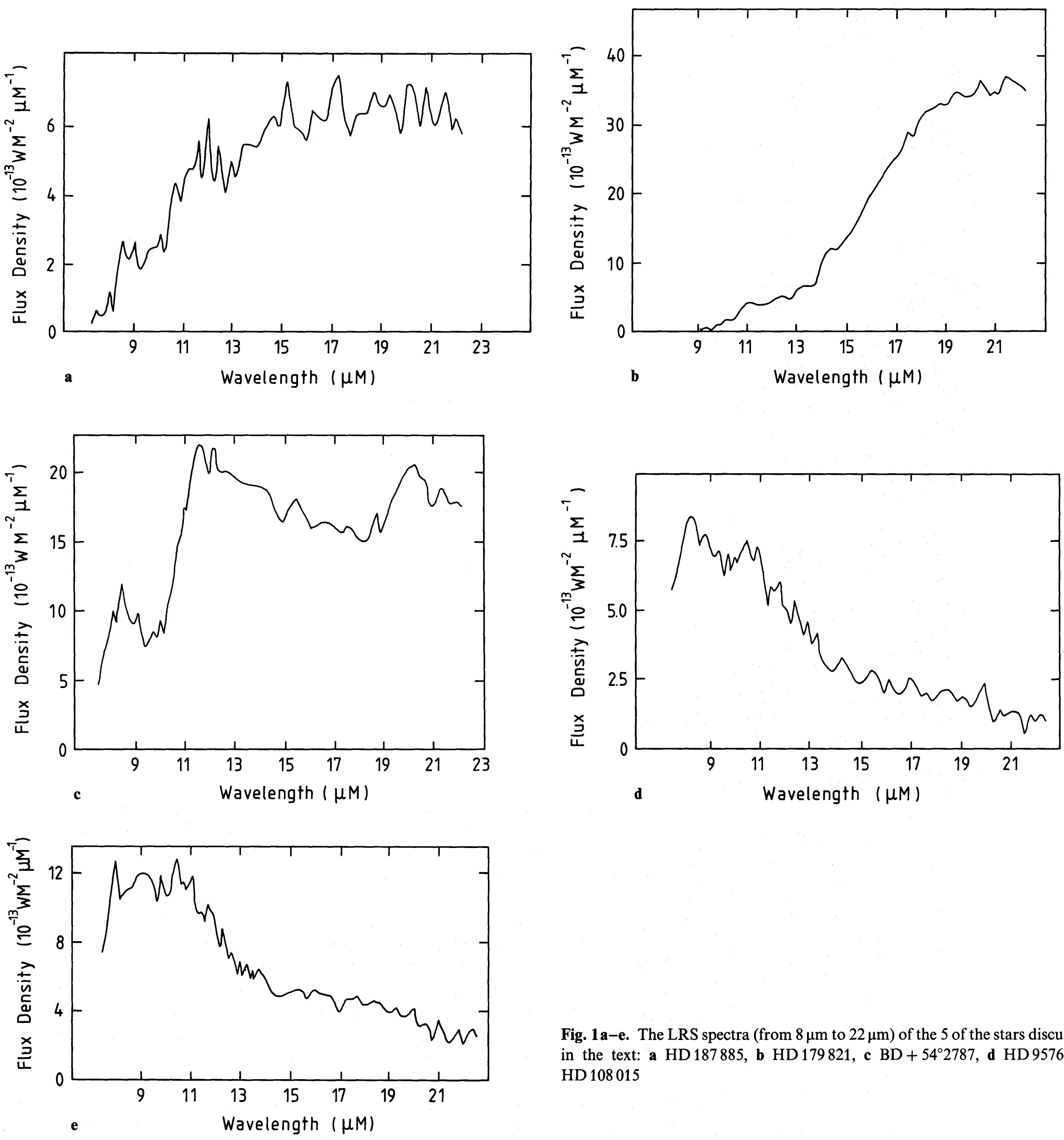

Fig. 1a–e. The LRS spectra (from 8 μm to 22 μm) of the 5 of the stars discussed in the text: **a** HD 187 885, **b** HD 179 821, **c** BD + 54°2787, **d** HD 95767, **e** HD 108 015

luminosity at a distance of 6 kpc. They suggest that HD 179 821 may once have been a runaway *O*-type star. Zuckerman et al. (1986) detected CO emission from BD + 54°2787 (IRAS 2227 + 5435). They suggest that it may be an oxygen rich star.

4. Conclusions

The far-infrared flux distributions, temperatures, luminosities, sizes and masses of the dust envelopes (M_d) around these stars (Tables 1 and 2) are similar to that observed in planetary nebulae (Pottasch et al., 1984). The observed far-infrared (IRAS) excess from these stars is due to the large cool dust envelopes or disks around these stars. Most of these stars (Table 1) are F–G supergiants and giants. The presence of large dust masses around these stars is most likely due to extensive mass loss during their AGB – post-AGB stage of evolution. The far-IR luminosities and masses of the dust envelopes or disks around HD 187 885 and HD 179 821 are similar to that observed in HD 161 796 (Parthasarathy and Pottasch, 1986). For these stars $L_{\rm IR}$ and M_d given in

Table 2. Luminosities, temperatures and masses of dust envelopes

	d (kpc)	F_{IR} Total ($=10^{-12}\,\mathrm{w\,m}^{-2}$)	A_v	L_{IR} ($L_\odot$)	T_d (K)	M_d ($M_\odot$)
HD 187885	5.5	21.3	0.3	$2.0\ 10^4$	100	$2.0\ 10^{-3}$
HD 179821	2.9	96.2	1.0	$2.5\ 10^4$	100	$2.6\ 10^{-3}$
BD +54°2787	2.9	41.9	0.9	$1.1\ 10^4$	150	$2.0\ 10^{-4}$
HD 144432	2.4	1.90	0.3	$3.4\ 10^2$	200	$2.2\ 10^{-6}$
HD 142527	1.4	10.6	0.6	$6.6\ 10^2$	100	$6.7\ 10^{-5}$
HD 143006	3.4	0.83	0.8	$3.0\ 10^2$	100	$3.0\ 10^{-6}$
HD 95767	2.0	5.6	1.0	$7.0\ 10^2$	200	$4.5\ 10^{-6}$
HD 108015	1.6	6.2	0.5	$4.9\ 10^2$	200	$3.1\ 10^{-6}$
−62°6428	–	0.3	–	–	140	–
HD 319896	2.5	0.73	2.0	$1.4\ 10^2$	300	$0.2\ 10^{-6}$

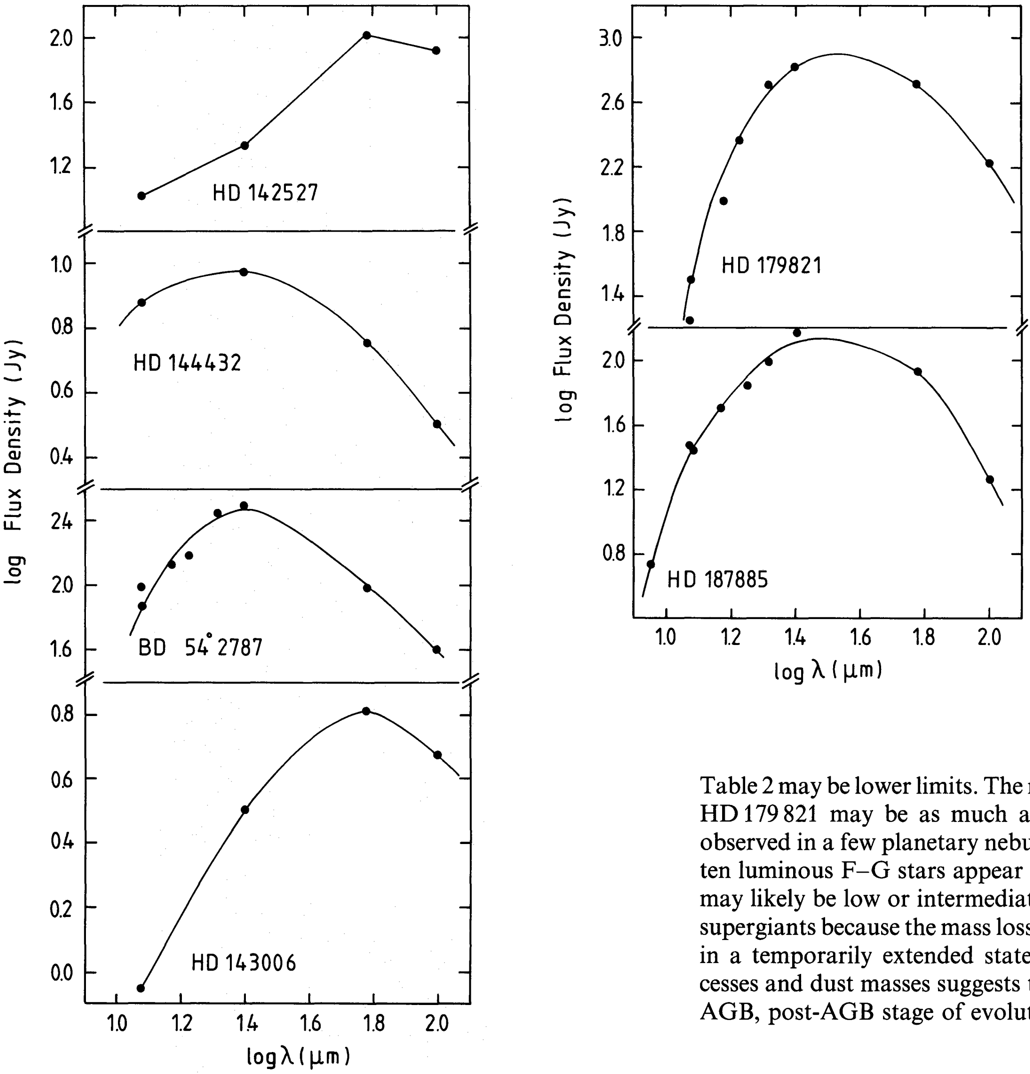

Fig. 2. The continuum flux density measurements for 6 of the stars discussed in the text between 10 μm and 100 μm

Table 2 may be lower limits. The mass of the dust envelope around HD 179 821 may be as much as 4.1 10^{-2} $M_\odot$, similar to that observed in a few planetary nebulae (Pottasch et al., 1984). These ten luminous F–G stars appear to be similar to HD 161 796 and may likely be low or intermediate mass stars which appear to be supergiants because the mass loss has caused the atmosphere to be in a temporarily extended state. The observed far-infrared excesses and dust masses suggests the mass loss occurs during their AGB, post-AGB stage of evolution.

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