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F and G Supergiants with Large Infrared Excesses

INTRODUCTION

Since 1984 we have been carrying out a program of ground-based identification of cool (colour temperature 100-200 K) IRAS sources (Hrivnak et al. 1985, Kwok et al. 1987a,b). Many of the cool IRAS sources have no optical counterparts and can be identified with evolved stars with thick circumstellar envelopes. However, to everyone's surprise, a number of cool *IRAS* sources are found to be identified with bright stars (Hrivnak et al. 1988, 1989). This implies that while a large fraction of the energy output of the star is emitted in the infrared, yet the central star suffers from relatively little extinction. Such behaviour is similar to the famous F supergiant IRC+10420, which is one of the most luminous stars in the Galaxy.

ENERGY DISTRIBUTION

Figure 1 shows the energy distribution of the star HD 56126. This doubled-peaked spectral distribution is typical of a number of cool *IRAS* sources (Table 1). The cool component is due to emission from a circumstellar dust shell which is detached from the photosphere (the "hot" component). Radiative transfer model fits to the energy distribution suggests that the dust shell was detached several hundred years ago (Hrivnak et al. 1989; Volk & Kwok 1989).

OPTICAL SPECTROSCOPY

Optical spectroscopic classification shows that most of these objects can be classified as F or G spectral types with luminosity class Ia-Ib. The intermediate spectral class suggests that the star has been evolving to the blue since the termination of mass loss. The luminosity class indicates the low surface gravity in these objects, and not necessarily implies an intrinsic high luminosity.

Monitoring of the optical spectrum of these sources has shown that the Hα line undergoes profile changes on a monthly scale. The observed shapes of the Hα profiles include P Cygni, inverse P Cygni, as well as shell spectrum.

INFRARED SPECTROSCOPY

The sources can be classified as oxygen or carbon rich based on the presence or absence of the 9.7 μm silicate feature. For oxygen-rich objects, sometimes the 18 μm silicate feature can also be seen, as in IRC+10420 and IRAS 18095+2704. In five carbon-rich objects, an unidentified infrared emission feature at 21 μm has been detected (Kwok et al. 1989, Hrivnak & Kwok 1991). Features from the polycyclic aromatic hydrocarbon molecules have also been detected in two of these objects (Buss et al. 1991). It is likely that the 21 μm feature also arises from a large carbon-based molecule.

Several vibrational bands of CO, ranging from v=2-0 to v=8-6 have been detected. While these bands are normally in absorption, they have been detected to be in emission in IRAS 19114+0001 and IRAS 22223+4327.

Table 1

IRAS	Spectral Type	L_*/D^2 ($L_\odot$ kpc^{-2})
04296+3429	G5 I	556
07134+1005	F5 I	1,725
10215-5916	G5 I	72,000
12175-5338	A9 Iab	800
17436+5003	F3 Ib	3,654
17534+2603	F2 Ibe	7,834
18095+2704	F3 Ib	1,662
19114+0002	G5 Ia	15,873
19244+1115	F8 Ia	21,300
19500-1709	F3 I	2,335
20004+2955	G7 Iab	6,042
22272+5435	G5 Ia	3,852
23304+6147	G5 I	627

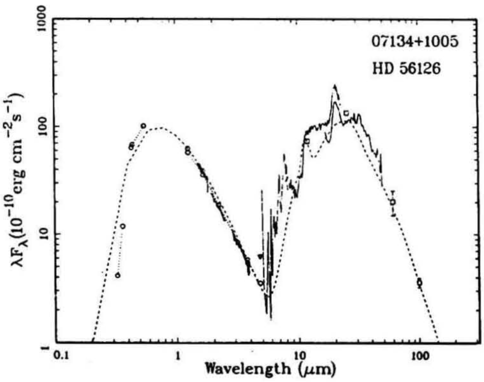

Fig. 1 The energy distribution of HD 56126. The 21 μm emission feature can be seen in the IRAS LRS (8-23 μm) as well as in the KAO spectrum (20-60 μm, Omont et al. priv. com.). The 7.7 μm PAH feature can be seen in the KAO spectrum between 5 and 8 μm (Buss et al. 1991).

Strong Brackett lines of hydrogen (n=10-4 to n=19-4) have also been detected in absorption in many of these sources. Sometimes an emission component can be seen blue shifted w.r.t. the absorption component (Kwok et al. 1990).

MOLECULAR LINE SPECTROSCOPY

Rotational transitions from OH (Likkel 1990) and CO (Woodsworth et al. 1990) have been detected. The profiles of the molecular lines suggest expansion at velocities of 10-20 km s^{-1}. The molecules are likely to be located in the dust envelope, confirming that the cool component

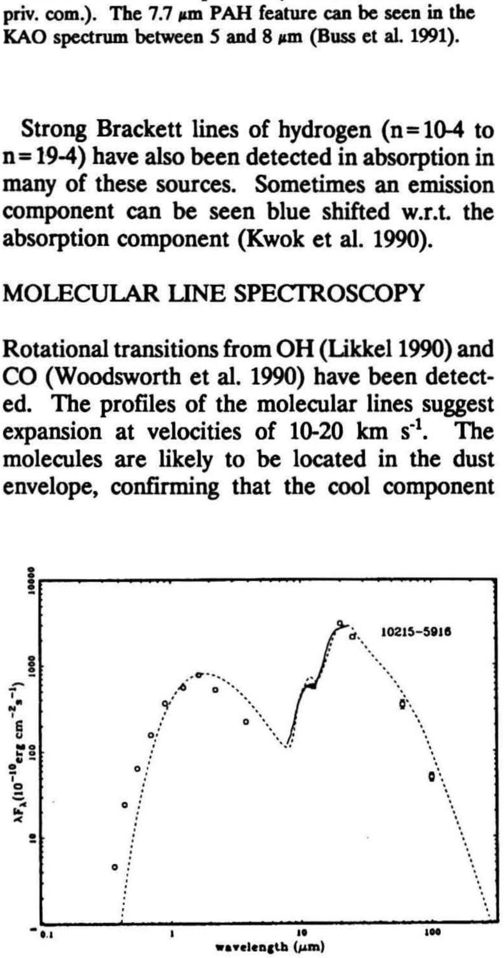

Fig. 2 The energy distribution of IRAS 10215-5916.

represents remnants of mass loss from an earlier phase of evolution. The observed expansion velocities can be used (together with the inner radius of the dust shell) to derive the time since the star left the red superginat stage. Kinematic distances can also be obtained from the observed V_{LSR}.

A NEW INFRARED SUPERGIANT

Most of these F-G supergiants are likely to be intermediate-mass stars in the post-asymptotic-giant-branch phase of evolution. This is especially true for those objects that are either off the galactic plane, or in the outer part of the Galaxy. However, one object (IRAS 10215-5916) stands out as a likely candidate for a new infrared supergiant similar to IRC+10420. This object has a spectral type of G5 I (Bidelman, private communication) and lies in the direction of the Carina complex and may be associated with it. This would suggest a distance of ~2 kpc and a bolometric magnitude of -9. The estimated mass loss rate (during the red supergiant stage) was $1.4x10^{-4}$ (V/km s^{-1})(D/kpc) $M_\odot$ yr^{-1}. The inner radius of the dust shell is $4.8x10^{16}$ (D/kpc) cm. Assuming that the envelope is expanding at 10 km s^{-1}, then the star must have left and red supergiant stage ~1,500 yr ago.

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