INFRARED AND RADIO EXCESSES OF LATE-TYPE STARS

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The IRAS catalogues have been searched for cool (G,K,M) giant and supergiant stars to investigate the occurrence of circumstellar (C/S) silicate dust, revealed by its emission features at 9.7 and 18μm. Low Resolution Spectrograph (LRS) spectra covering the 7-23μm range were used, plus the 60 and 100μm photometric points. M Supergiants were found in White & Wing (1978), other stars by correlating the Bright Star Catalogue with the LRS catalogue: this discriminated against very cool stars reddened by dust; however it can be seen in Table I that there is a clear trend for cooler and more luminous stars to have a dust shell. M Supergiants almost all have dust shells, whilst only the cooler M bright-giants and giants do. Of the G and K stars, only a very few of the Supergiants have dust shells. The silicate features fell into two categories:
(1) narrow, sharply peaked 9.7 and 18μm features, typified by μ Cephei, observed in C/S shells of solitary cool giants/supergiants;
(2) much broader 9.7 and 18μm features (e.g. VX Sgr), reminiscent of the features seen in the Trapezium region, often seen in binary systems where the companion is a hot star. Few radio observations have been made of the continua of late-type stars; only the closest and brightest stars are above current observing thresholds. These observations are summarised in Drake & Linsky (1986), and it is apparent that the stars they observed have excesses at cm-wavelengths attributable to free-free emission from extended chromospheres. It is concluded that most stars in the present survey have radio excesses, while only the cooler and more luminous have infrared excesses (C/S dust shells).
An attempt has been made to model the prototype M-Supergiant α Ori (Skinner & Whitmore). Of the optical data available for amorphous silicate dust, that of Kratschmer & Huffman (1978) was found to give the best fit. With an optically thin C/S shell, and a photosphere approximated by a blackbody of 3600K appropriate to an M2Iab star, the observed spectrum cannot be satisfactorily reproduced. It was found necessary to change the spectral index of the IR continuum by invoking free-free emission from the extended chromosphere in order to fit the spectrum. The electron -density and -temperature distributions used were in keeping with those derived from chromospheric line-profile

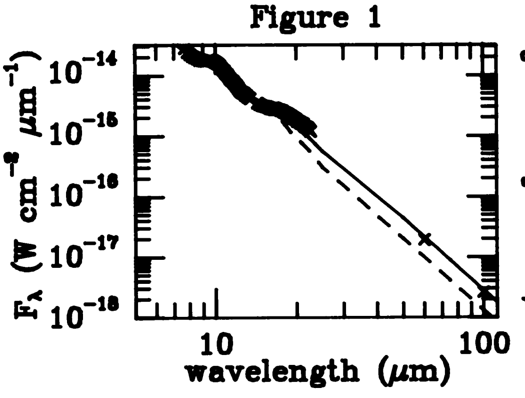
I. Appenzeller and C. Jordan (eds.), Circumstellar Matter, 379–380.

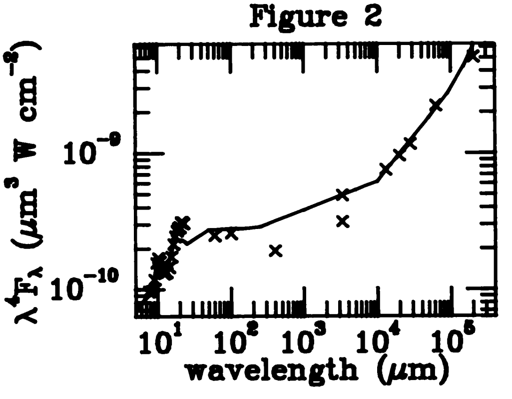
https://doi.org/10.1017/S0074180900156785 Published online by Cambridge University Press

Table I

Stars with/without silicate dust shells.

	I	II	III
M	74/74	2/15	13/206
K	1/6	0/25	0/125
G	1/10	0/3	0/23





x observations - - - dust-only model ——— dust+chromosphere model
Figure 2 : a black-body would be represented by a horizontal line

fitting, and the resulting spectrum fitted the IRAS observations and all available radio observations. It appears that other M-Supergiants can be fitted in the same way, the chromospheric contribution to the continuum varying from star to star.

Free-free emission seems more important in M-Supergiants than other cool, luminous stars, and mass loss is also more pronounced. Schwarzschild (1975) suggested convective hot spots caused the irregular variability of these stars, and speckle observations indicate that mass is lost episodically in blobs, rather than continuously. Mullan (1981) suggested that closed flux loops would be unstable above the photosphere of cool giant/supergiants, and this author suggests that convective cells may draw out bubbles of magnetic flux, which are driven away from the star carrying plasma with them. In the hotter stars, convection is less important and the magnetic field is more stable.

This work was carried out whilst in receipt of an SERC studentship which I gratefully acknowledge.

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