TEMPERATURE DISTRIBUTIONS IN CIRCUMSTELLAR DUST SHELLS

Th. Henning and J. Gürtler
University Observatory
Schillergäßchen 2
Jena 6900
German Democratic Republic

1. ANALYTICAL TEMPERATURE DISTRIBUTIONS IN CIRCUMSTELLAR SHELLS

The knowledge of the temperature distribution in circumstellar dust shells (CDS) is needed for both the calculation of the emergent IR spectrum and the modelling of physical processes, e.g., dust formation.

For an optically thin CDS (i.e. re-emission neglected) we have derived analytical expressions (power laws) of the radial dependence of grain temperature $T_d(r)$ from the equation of energy balance, assuming three different types of dust opacity (for the procedure see Henning et al. 1983).

(1) Absorption efficiency $Q_\lambda(a) \sim \lambda^{-n}$

$$T_d(r)=\left(\frac{r}{r_*}\right)^{-2/(4+n)}\left[\int_0^\infty \pi F^* \lambda^{-n}\, d\lambda\right]^{1/(4+n)} \frac{hc}{k}\, \left[8\pi hc^2 \Gamma(n+1)\, \zeta(n+4)\right]^{-1/(4+n)} \quad (1)$$

(2) The star is presumed to radiate primarily in the UV, where for silicate dust $Q_{UV}(a) \approx 1$. The PLANCK means are represented by power laws.

(a) Absorption efficiency based on observations of thin IR emission of supergiant CDS (Henning et al. 1983); $Q_{10\ \mu m}(a) = 0.1$

$$T_d(r) = \begin{cases} 0.255\ (r_*^2\ T_*^4)^{0.335}\ r^{-0.671} & (1500\ K > T_d > 250\ K) \\ 8.939\ (r_*^2\ T_*^4)^{0.162}\ r^{-0.324} & (250\ K > T_d > 30\ K) \end{cases} \quad (2)$$

(b) Astronomical silicate (Draine and Lee 1984); grain radius a=0.1 µm

$$T_d(r) = \begin{cases} 0.523\ (r_*^2\ T_*^4)^{0.300}\ r^{-0.600} & (1500\ K > T_d > 275\ K) \\ 6.477\ (r_*^2\ T_*^4)^{0.179}\ r^{-0.358} & (275\ K > T_d > 30\ K) \end{cases} \quad (3)$$

Symbols used: F^*, r_*, T_* - flux, radius, and temperature of the star; $\Gamma(x)$ and $\zeta(s)$ Gamma and RIEMANN Zeta functions; h, c, and k - usual meaning.

Schwartz et al. (1983) obtained in the outer regions of S 140 IRS

I. Appenzeller and C. Jordan (eds.), Circumstellar Matter, 557–558.

$T_d(r) \sim r^{-0.3}$ in good agreement with Equations (2) and (3).

For optically thick CDS we developed a rapid-converging procedure for approximating $T_d(r)$. It starts from a linear combination of the upper (only geometrical dilution; no re-emisison) and lower limits (geometrical and optical dilutions; no re-emission) of the temperature. The coefficients are determined by satisfying iteratively the energy balance equations at the inner and outer boundaries of the CDS (Henning 1983). The resulting $T_d(r)$ could be fitted satisfactorily by a power law with an exponent between -0.5 and -0.7, depending on the model parameters.

2. ANALYSIS OF THE SPECTRA OF BECKLIN-NEUGEBAUER (BN) OBJECTS

For BN objects (catalogue - Henning et al. 1984; analysis - Gürtler et al. 1985) we found an inverse correlation between the strength of the silicate absorption feature and the colour temperature in the NIR, extending the analogous relation for Miras and OH/IR stars to higher optical depths (Fig. 1). There is a poor correlation between the optical depths of the silicate and of the ice bands (Fig. 2).

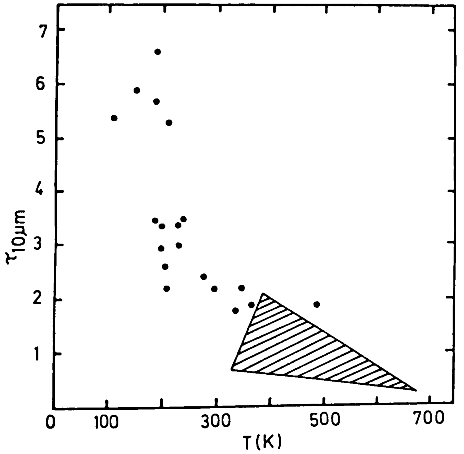

Fig. 1

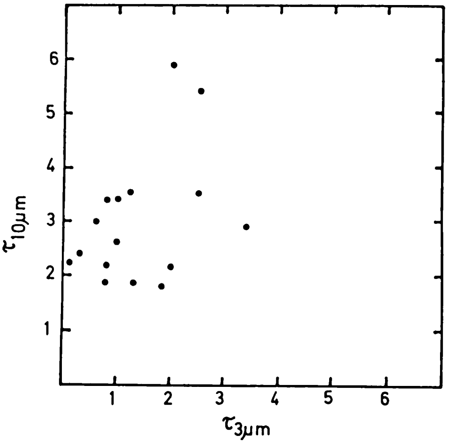

Fig. 2

REFERENCES

Draine, B.T. and Lee, H.M.: 1984, Astrophys.J. **285**, 89.

Gürtler, J., Henning, Th., Dorschner, J., and Friedemann, C.: 1985, Astron.Nachr. **306**, 311.

Henning, Th.: 1983, PhD Thesis, University of Jena.

Henning, Th., Friedemann, C., Gürtler, J., and Dorschner, J.: 1984, Astron.Nachr. **305**, 67.

Henning, Th., Gürtler, J., and Dorschner, J.: 1983, Astrophys.Space Sci. **94**, 333.

Schwartz, P.R. et al.: 1983, Astrophys.J. **271**, 625.