DUST FORMATION IN M-STARS

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ABSTRACT. A mechanism is proposed for the initiation of dust formation in stellar winds of M-type giants and supergiants. If Mg and Fe are ionized (MO...M4) dust formation is initiated by homogeneous nucleation of SiO, otherwise (later ≈ M2) by homogeneous nucleation of MgS. The condensation temperatures for these mechanisms agree well with observations.

1. INTRODUCTION

The temperature of the hottest grains at the inner edge of circumstellar dust shells according to model calculations for the radiative transfer problem range from ≈ 1000K down to ≈ 500K (R.-R. & H., 1982, 1983). High condensation temperatures are observed for stars later than ≈M2 while low temperatures are observed for spectral types between MO and ≈ M4.

From experiment and theory it is known that nucleation suddenly occurs above a critical supercooling of the gas below the stability limit against vapourization of the bulk condensate. The observed large temperature range for condensation in stellar winds is incompatible with a single mechanism for all types of M-stars.

2. CHEMICAL COMPOSITION OF THE GAS

Crucial for the chemistry of dust formation is the composition of the gas phase. This determines which atoms and molecules are available. One has to consider two cases:

(i) In early type M-stars the chromosphere ionizes elements of low ionization potential. The chemistry is determined by ion-molecule reactions in this case (Clegg et al., 1983). The most abundant particles are H, H^-, H_2, O, Si^+, SiO, Si, OH, O_2 and H_2O.

(ii) Late type M-stars show no indication for the presence of a chromosphere and ion-molecules. The chemistry is determined by neutral radicals in this case. The most abundant particles are H, H_2, H_2O, Fe, SiO, MgS and Mg.

C and N are blocked in CO and N_2 in both cases.

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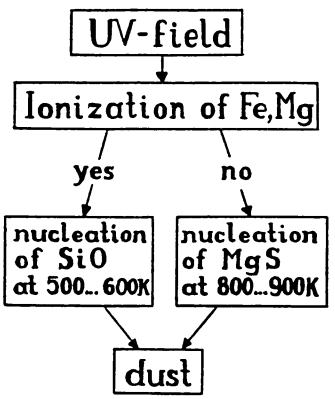
3. THE INITIAL DUST FORMATION PROCESS

From observations it is known that dust forms rapidly once the temperature in the wind has dropped to sufficiently low values. This requires that (i) only particles with high number density and (ii) only chemical reactions with a high rate coefficient are involved in the condensation process.

The first condition can be met only with particles formed from elements of high abundance (H, O, C, N, Fe, Si, Mg, S). C and N are blocked in the extremely stable molecules CO and N_2. No H-O-compound exists which condenses at high temperatures. Hence, in the first case (Fe, Mg, ...ionized) only SiO and in the second case (Fe, Mg not ionized) Fe, SiO, MgS and Mg are available for the nucleation process. All these molecule tend to form condensates at high temperatures.

The second requirement cannot be met by Fe and Mg since diatomic assoziation reactions are slow. Clustering of SiO and MgS is fast, however, since it involves no activation energy barrier and radiative assoziation of the collision complex is easy since already the dimer contains four atoms. This favours high reaction rates.



Hence we have to conclude that in early type M-stars dust formation is initiated by clustering of SiO (at 500 .....600K) while in late type M-stars clustering of MgS (at 800 .....900K) initiates dust formation (Gail et al., 1986).

This does not mean that the observed dust material is solid SiO or MgS since once stable clusters are formed they will collect the remaining condensable elements and the material is subject to oxidation by water vapour.

4. CONCLUSION

By simple arguments based on the chemical composition of the gas and the velocity of chemical reactions it is possible to isolate two chemical reaction paths (clustering of SiO and MgS) which are responsible for the onset of dust formation in early and late type M-stars, respectively. The two mechanisms explain the observational facts.

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