

## DUST FORMATION IN SUPERNOVA EJECTA

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**Abstract.** The role of non-steady state effects in the chemistry and dust formation kinetics for the ejecta from a supernova is estimated. The effects of medium ionization are briefly discussed.

**Key words:** circumstellar matter – supernovae

Dust formation in the ejecta of SN 1987A is a well established fact. According to Lucy et al. (1989), the dust condensation occurred at  $t = 500$  days after the explosion. This process is usually treated in terms of the homogeneous nucleation theory and the neutral particle chemistry in chemical equilibrium.

The chemical equilibrium and the homogeneous nucleation theory may be used if the following conditions are met:

$$\tau_T, \tau_\rho \gg \tau_{\text{chem}}, \tau_{\text{cond}},$$

where  $\tau_T, \tau_\rho$  are characteristic times of  $T$  and  $\rho$  variations,  $\tau_{\text{chem}}$  and  $\tau_{\text{cond}}$  are the relaxation times for chemical and dust condensation processes.

Since  $\rho$  is proportional to  $t^{-3}$  ( $t$  is the expansion time), we have  $\tau_\rho = t/3$ . Taking into account that dust formation begins at  $t \approx 500^d$ , one gets  $\tau_\rho \approx 10^7$  s. According to Fransson and Chevalier (1989), between days 400 and 700 the temperature of the ejecta varies from 3100 K to 1200 K, i.e., 2.58 times during 300 days and, as a rough estimate, we can adopt  $\tau_T \approx 10^7$  s.

In the dust formation region ( $T = 1500$  K, the total number density about  $10^9$ ), the rate coefficient for neutral-neutral reactions is

about  $5 \cdot 10^{-12} \text{ cm}^3 \text{ s}^{-1}$  and for abundances of the “key species” given by Kozasa, Hasegawa and Nomoto (1989) the relaxation times of Al, Mg, Si and C chemistry are of the order of 1 s. So, the equations of chemical equilibrium can be used to investigate the dust formation region.

In order to estimate  $\tau_{\text{cond}}$ , we can use the expression of the homogeneous nucleation theory:

$$\tau_{\text{cond}} = i_*^2 (2\pi m k T)^{1/2} (4\alpha \pi r_*^2 p_{\text{mon}})^{-1},$$

where  $i_*$  is the number of particles in the cluster of the critical size,  $r_*$  is its radius,  $m$  is the mass of a monomer particle,  $p_{\text{mon}}$  is the partial pressure of the monomer and  $\alpha$  is the sticking coefficient. For the case of dust condensation, if we take  $i_* = 100$  and abundances of the “key species” given by Kozasa, Hasegawa and Nomoto (1989), this expression gives  $\tau_{\text{cond}} \approx 10^6 \div 10^7$  s. So, the non-steady processes may play some role in the dust condensation.

Another factor which may affect the dust condensation is the ionization of the species. The ion-molecular chemistry may have a great influence on the abundances of condensable species and the ionization may slow down the condensation process due to lower concentration of neutral condensing particles. Ion nucleation (with ions as nucleation centers) should be taken into account. The result may strongly differ from the results of calculations with neutral equilibrium chemistry and homogeneous nucleation theory. For instance, the abundances of atomic carbon given by Rawlings and Williams (1990) differ from those given by Kozasa, Hasegawa and Nomoto (1989).

## References

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