# MASS DISTRIBUTION AND BULK DENSITY DISTRIBUTION OF INTERPLANETARY DUST

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ABSTRACT. Mass distribution of the interplanetary dust is reexamined taking into account bulk density distribution of the dust and larger particles. It can be shown that the mass index of particles depends on the evolutionary stage of the population and changes along the mass scale. The flattening of the mass distribution at the higher mass range may explain the problem of the equilibrium between the source and sink of the interplanetary dust.

## 1. MASS DISTRIBUTION OF PARTICLE POPULATIONS

Classical models of meteor stream formation suggested that old showers have lower mass index (s) values because Poynting-Robertson drag and solar radiation pressure gradually eliminate small particles from the stream. It was argued similarly that large particles should dominate in the inner side of the stream. However, these theoretical conclusions have not been confirmed by observations, at least for particles with masses $m \geq 10^{-6}$ kg, corresponding to the visual and radar range of detection. As shown recently by Šimek (1987), in contrary, showers without an active parent body (e.g. Geminids or Quadrantids) are characterized by higher values of the mass index, implying a lower proportion of larger particles. This is in agreement with the results of spaceprobes, indicating the dominant role of large particles in P/Halley mass production (McDonnell et al., 1987; Hajduk, 1987a) supported also by the improved dust/gas ratios for comet Halley, showing much higher dust contribution (Crifo, 1987; Hajduk, 1987b) than previously reported. Moreover, as shown in the same papers, the mass index is not constant over the mass scale and clearly indicates the superposition of two populations of particles with considerably different mass distribution. This result obtained from spaceborne experiments coincides totaly with results of radar meteor observations showing two separate levels of the mass index for the Halley showers, with values s = 1.8 and s = 2.2 (Hajduková et al., 1987). As it is seen in Figure 1 (A) different particle flux distribution corresponds to these two populations of particles within the shower. Ceplecha (1987) has classified different



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types of cometary material, having different bulk densities, not necessarily originating in different comets. However the bimodal nature of particle size distributions has been reported also from infrared and optical observations of different comets (Liu and Kimura, 1985).

The question arises, whether the coincidence of the same particle flux and the same abundance of particles with different bulk densities ($\rho$ = 0.75 and 2.0) at the mass range between $10^{-5}$ kg - $10^{-4}$ kg is accidental or dependent. (See Figures 1 A and 1 B. Figure 1 B is based on Ceplecha's data quoted above.) The mass distribution of meteor showers, in general, has a maximum mass contribution between the limits of $10^{-6}$ - $10^{-4}$ kg. Fig. 1 C is constructed for the Halley showers. The coincidence with the flux curves crossing is, of course, not accidental; it shows the meaning of particle populations in the stream: the derived mass contribution of particles of different mass categories is very sensitive to the value of the mass index. We will deal here with the integrated mass index S, as defined by Millman (1970) On the balance near the critical value of S = 1 depends the mass contribution to the stream. In Figure 1 D it is shown that the observed values of S for the showers (SH) (Hajduková et al., 1987) are between the values derived for the cometary halo (H) from space observations (McDonnell et al., 1987; Hajduk and Kapišinský, 1987) and for the large particles from fireball (F) observations (Rendtel and Knöfel, 1989). The differences in the mass distribution correspond clearly to the age of these populations, as it was shown by Hajduk (1989). As a consequence of a mixture of old and new particle populations, different mass distribution may be observed, depending on the combination of stream filaments met by Earth in a particular return of the shower. Hence we can conclude that showers with an active parent body cannot be characterized by a single mass index value. However, the separation of populations corresponding to the stream structures dynamically bound to possible ejection times, coould be used for the determination of the oldest fraction with the highest value of the mass index.

## 2. EROSION OF LARGE PARTICLES

Classical theories of the stream formation supposed a quick elimination of small particles from the stream by the action Poynting-Robertson effect and solar radiation pressure. The formula of Wyatt and Whipple (1950) gives the age of the spiralling particle depending on the particle radius and density and on the orbital parameters. However, the physical erosion processes change drastically along the particle mass scale. As shown by Kapišinský (1984), direct light pressure, solar wind corpuscular pressure, Poynting-Robertson effect and other processes have much less effect on the lifetime of particles with m > $10^{-12}$ kg than the destructive processes. The greatest influence on the larger particles is the effect of impact erosion and of corpuscular sputtering. These two effects dominate in the range of meteoroid size particles (Kapišinský, 1987). (See Figure 1 E). Grün (1987) considers collisional fragmentation to be the dominating process for particles with masses m $\geq 10^{-8}$ kg. The maximum mass contribution in meteor streams comes from $10^{-5\pm1}$ kg and the

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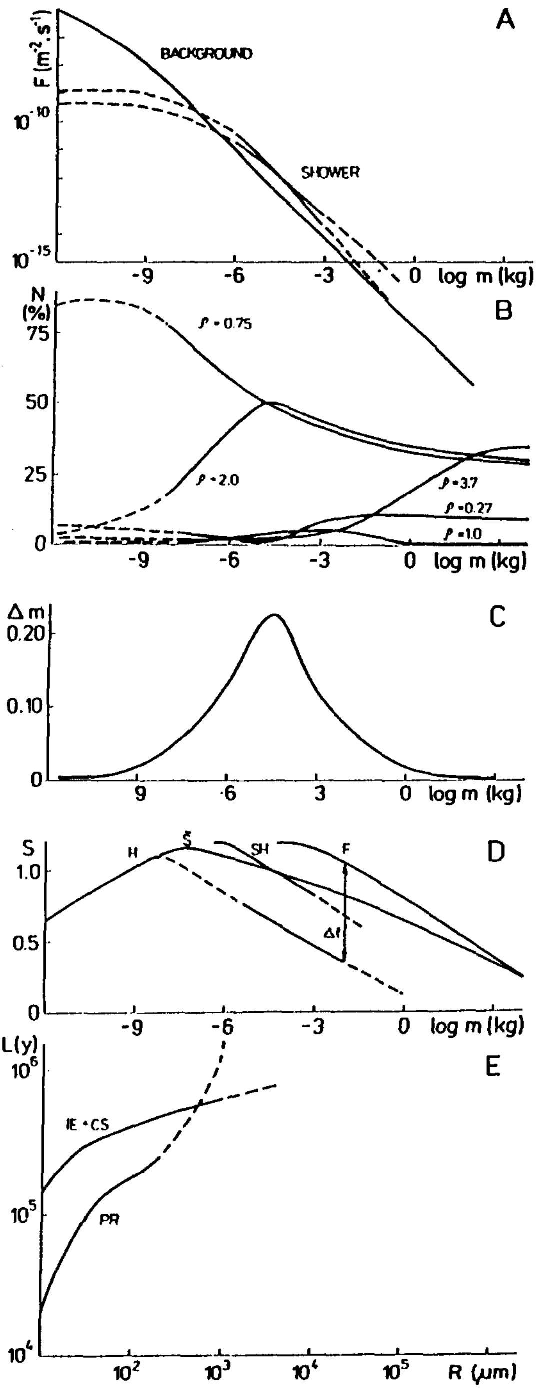


Figure 1
A: Particle flux to mass relation for shower and background.
B: Particle bulk density distribution along the mass scale.
C: Mass distribution in meteor shower (Halley showers data).
D: Integrated mass index S for the halo (H) population (space probes data), Halley showers (SH) (radar observations) and fireballs (F). $\bar{S}$ denotes the mean values of S.
E. Lifetimes of particles due to combined impact erosion (IE) with corpuscular sputtering (CS) compared with Poynting-Robertson (PR) effect.

maximum mass contribution of back ground meteoroids is at $m = 10^{-8\pm1}$ kg (Millman, 1975). This corresponds to the change of the slope of the flux for the background particles (Fig. 1 A). The erosion is, of course, more rapid for low density particles. Packing forces, produced by an anisotropic sublimation of mantle material of grains at the surface of fluffy particles, shift the grains towards the center, reduce the voids and increase the mass density of such particles with time (Mukai and Fechtig, 1983). Sublimation, at least on the orbits with $q \leq 7$ AU, is also the main process by which water-ice grains lose their ice parts (Mukai et al., 1989). Hence, by determining the shift of the maximum mass contribution of particles in different meteor showers, the relative age of these showers can be determined. Showers with a decreasing supply of larger particles will show a shift of the

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maximum mass contribution towards smaller masses. This effect, verifiable from the magnitude distributions of meteors, can then be applied as an independent ageing scale of streams.

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