The In-situ Cometary Particulate Size Distribution Measured For One Comet: P/Halley;

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The close approach of Giotto to comet Halley during its 1986 apparition offered a unique opportunity to study the particulate mass distribution to masses of up to one gram. Data acquired by the front end channels of the highly sensitive mass spectrometer PIA (1) and the dust shield detector system, DIDSY (2), provide definition of the detected distribution as close as 1000km to the nucleus.

Dynamic motion of the particulates after emission leads to a spatial differentiation affecting the size distribution in several forms:

(i) Ejecta velocity dispersion. Ejection velocities are governed by gas drag from the nucleus surface and are sensitive to grain cross-sectional areas. This results in mass distributions changing significantly (and independently of (ii) below) far from the nucleus .Velocity dispersion is of particular importance in locating nucleus source regions for grains measured simultaneously, but of differing masses.

(ii) Radiation pressure. After emission from the nucleus, solar radiation pressure provides a force which can effectively be considered as a radially reduced heliocentric gravitational field, but size dependent. Under the differential effect of radiation pressure combined with (i), spatial segregation results. The familiar envelopes (3) may change drastically according to grain optical properties.

(iii) Varying heliocentric distance. Earlier approaches to dust modelling excluded the effect of changing heliocentric distance over the relatively short times of flight concerned. This does however cause the very slowly moving particles(< $100 ms^{-1}$) to move ahead of the comet orbit (ejection sunward) or behind, producing spiralling trajectories (4) rather than simpler parabolae . Envelopes become less distinct with decreasing particles terminal velocity, until no such behaviour is observed.

(iv) Anisotropic nucleus emission. Spatial (active nucleus spots) and temporal (burst) variations result in jetting enhancements; together with rotational behaviour of the nucleus, these may provide complex time varying changes to mass distributions throughout the coma.

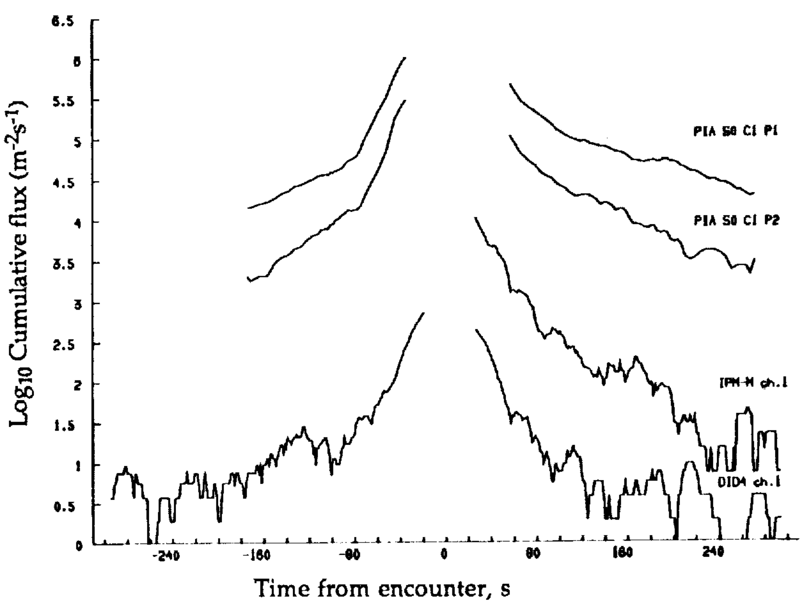

Figure 1: Cumulative flux - time profiles are given for the following Giotto dust sensors: PIA (masses > 10^{-17}kg), PIA (> 5×10^{-15}kg), IPM-M channel 1 (> 5×10^{-13}kg) and DID 4 (small sector) channel 1 (> 5×10^{-12}kg) - see (2) for instrument details. The mass distribution is seen to close together the profiles at smaller masses.

Examining time profiles of the PIA and DIDSY fluxes over 10 minutes around closest approach (figure 1), we ask firstly how these effects are observed and secondly how they may be incorporated to yield a size distribution close to the probable refractory particulate distribution in the nucleus:

Jets and Nucleus Anisotropy. Clear enhancements (jets) above a fountain model distribution are observed to produce flux increases of up to an order of magnitude (DID4 channel 1 at +220s in figure 1). Displacements in each mass range indicate that velocity dispersion as a result of nucleus rotation is present (5). In containing dust over a large mass range, each jet has a mixed history: a lack of large

grains may indicate recent spot switch-on. Since however jets are seen across the mass spectrum, it is likely that active regions are long-lived, staying active over the greater part of the nucleus' day.
Coma Dynamical Processes. Distinct envelopes early and later on during the encounter (~ 10^5km away from the nucleus) are not clearly seen, indicating velocity spread at a given grain size. No sharp terminator either is seen, although an asymmetry at smaller masses is observed with fluxes over sunlit regions enhanced by a factor of three. The changing mass distribution is clear, with a 2.7 order of magnitude mass difference between PIA channels showing less than 1 order of magnitude in flux.
Particulate Metamorphosis Within The Coma. Relative to known processes in the coma, most phenomena are explicable without the need for substantial changes in particle nature, at least to nuclear distances of 1000 km. Data from camera observations (6) suggest that this is not substantially different down to the scale of less than the cometary radius, although departures from a $1/R^2$ spatial dependence are often observed. This departure does not imply directly that the source size distribution is changing, perhaps more the effects of anisotropy of the emission processes and coma dynamics.

Fragmentation has been suggested variously by Simpson (7) and yet the data presented here does not call for this being significant in terms of the measured in-situ distribution. The friable nature and low density of cometary particulates is well known and it would be rare is these did not fragment. A destruction of *one* large grain could result in some 10^{10} particles detectable by DIDSY and 10^{16} particles detectable by PIA! This mechanism is not therefore dominant and scarcely affects the relationship between in-situ and nucleus particulate distributions.

Transformation of the in-situ distribution from PIA and DIDSY weighted heavily by the near-nucleus fluxes leads to the presumed nucleus distribution of figure 2. The data lead to a puzzling distribution at large masses, not readily explained in an otherwise monotonous power law distribution. Although temporal changes in nucleus activity could and do modify the in-situ size distribution, such an explanation is not wholly possible, because the same form is observed at differing locations in the coma where the time of flight from the nucleus greatly varies. Thus neither a general change in comet activity nor spatial variations lead to a satisfactory explanation. The paper will examine possible reasons for this and implications arising from the distribution relevant to remote and in-situ sampling operations in the vicinity of a cometary nucleus.

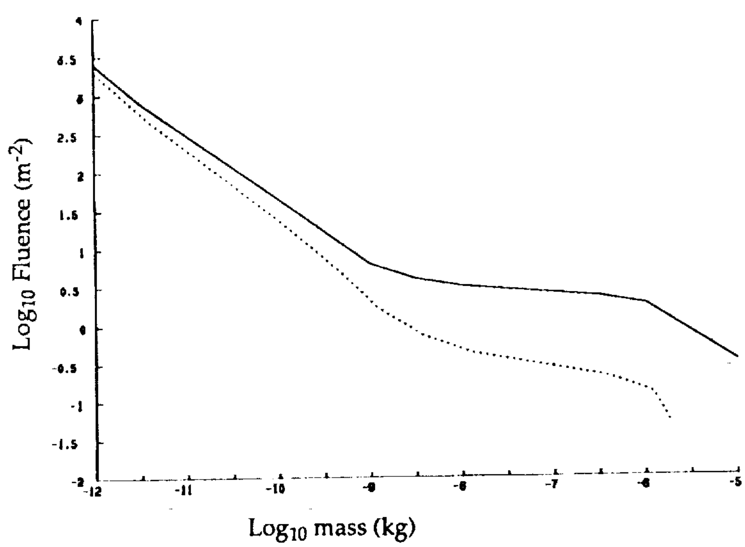

Figure 2: The mass distribution measured by DIDSY sensors is shown (solid line) during the period -450s to -169s (before encounter). A second distribution is also given (dotted line), transformed to the nucleus with a specific velocity assumption. This results in a steeper distribution, since the source fluence ~ velocity ~ $\text{mass}^{-0.18}$.

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