Vega dust counter and mass analyzer (DUCMA) measurements of Comet Halley's coma*

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The *Vega* passages through the dust coma of Comet Halley provided the first direct measurements of the space and time distributions for the mass and flux of dust particles emanating from the comet nucleus. These results are fundamental to an understanding of the physical processes whereby dust is emitted to form jets and the coma. A preliminary report is given of the DUCMA data, acquired with instruments that rely on a new principle of cometary-dust detection; they have a sharp time-resolution ($\approx 4\,\mu$sec) over wide ranges in particle flux and mass. The coma, whether quiescent (*Vega 2*) or containing prominent jet structure (*Vega 1*), displays large, short-term fluctuations throughout, occasionally quasiperiodic. Contrary to some models the integrated particle-mass spectra continue to rise down to the lowest masses detected, but the flux levels are approximately within the ranges previously estimated from ground-based observations. On all spatial and temporal scales the coma is remarkably dynamic, suggesting that the localized dust-emission zones have a complex structure.

The DUCMA dust-counter and mass-analyzer measurements of the particles being emitted from the nucleus of Comet Halley were taken continuously along the entire trajectories of the Vega 1 and Vega 2 spacecraft through the coma.

The overall character of our dust measurements from the two encounters is shown in Fig. 1, in which 2-sec averages of dust count rates are plotted against the time from closest approach to the nucleus (8912 ± 45 km for Vega 1, 8030 ± 45 km for Vega 2). These graphs display the integral count rates of all dust particles of mass $\geq 1.5\cdot 10^{-13}$ g. Until the onset of the spike in the Vega 1 count rate (Fig. 1a), the flux intensities and particle mass distributions were remarkably similar for the two spacecraft. This part of the count-rate curves represents the interval prior to closest approach. The subsequent abrupt jump in flux for Vega 1 probably corresponds to the dust jet emanating from the active side of the nucleus,[1] as seen in the Vega 1 television pictures. On the contrary the Vega 2 data convey phenomena taking place on the relatively inactive side of the nucleus, which by that time had rotated so as to face the spacecraft (the nucleus rotation period is $\approx 52^h$).

The DUCMA detector, of area 75 cm^2, was oriented within 10° of perpendicular to the velocity vector of the spacecraft relative to the dust.

A dust particle generates an electrical pulse when it enters the detector foil, composed of the polymer polyvinylidene fluoride (PVDF), the molecules of which are polarized, as shown in Fig. 1. The rapid depolarization in the volume destroyed by the dust particle induces a fast (nanosecond-range) pulse with amplitude proportional to $m^a v^b$, where m and v are the mass and relative velocity of the particle, respectively. Since v is the known spacecraft velocity (76-79 km/sec), particle mass can be determined. The pre-launch calibrations, responses and other details of the instrument have been published.[2,3] (All count rates designated here as M1, M2, M3, and M4 correspond in the published instrument description[3] to M1NV, M2NV, and so on.) Because there was no laboratory dust accelerator available which could calibrate our instruments up to the relative spacecraft velocities, we have extrapolated our calibrations into the spacecraft velocity range. The instruments on both spacecraft performed perfectly.

Figures 2 and 3 show in greater detail the intensity—time plots for the four mass thresholds specified in Table I. These plots illustrate the remarkable quasiperiodic fluctuations (such as those shown in Fig. 2 inset) which are present over a wide range of flux levels. These small-scale intensity variations, which correspond to spatial structures of 300-500 flux enhancements may be present over substantial periods of time, in which case they would represent fast dust streams, or microjets, moving say along a spiral that would map back to the nucleus over a rotation angle of 30°-35°. The fact that, at 8,000-9,000 km from the nucleus, some of these enhancements are only 200-300 km wide suggests that the dust source regions on the nucleus are local and discrete. A less likely cause of the flux enhancements might be sequences of dust bursts from the nucleus, in a geyser effect. Further study of the measurements should decide this question.

By relating the time of measurment to the spacecraft—nucleus distance R, we have found that within extensive regions of the coma (such as indicated in Fig. 3 for particle masses in excess of $1.5\cdot 10^{-13}$ g) the dust flux conforms to an R^{-2} law out to distances in the coma of order 10^5 km, well beyond the distances predicted by some models.[4,5]

Our integral mass spectra, sampled at four times by Vega 1 (T1-T4, Fig. 2) and Vega 2 (Fig. 3), have been obtained by assuming that the integral

*A slightly modified version of the article in Nature 321, 278-280 (May 15, 1986), reprinted by permission, with dust count-rate profiles of finer detail.

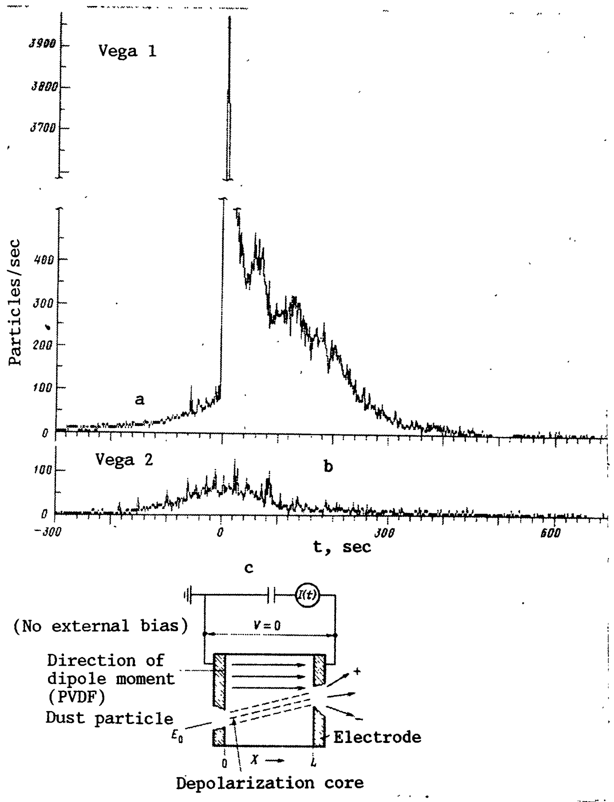

FIG. 1. a, b) Time profiles of the dust-particle count rates ($m \gtrsim 1.5 \cdot 10^{-13}$ g) recorded by the two spacecraft (2-sec averages) near the time of closest approach to the comet (t = 0). For Vega 1 the vertical scale is interrupted to accommodate the intensity peak. c) Schematic diagram illustrating the PVDF detection principle.[2,3].

TABLE I. Peak Particle Flux F and Peak Number Density N Measured in Vega DUCMA Experiments

Count-rate curve	Mass threshold for detected particles, g	Averaging interval, sec	Vega 1		Vega 2	
			F, cm^2/sec	N, cm^{-3}	F, cm^2/sec	N, cm^{-3}
M1	$\geqslant 1.5 \cdot 10^{-13}$	2	53	$7 \cdot 10^{-6}$	–	–
		10	25	$3 \cdot 10^{-6}$	1	$1 \cdot 10^{-7}$
M2	$\geqslant 9 \cdot 10^{-13}$	2	1.7	$2 \cdot 10^{-7}$	–	–
		10	0.9	$1 \cdot 10^{-7}$	0.1	$1 \cdot 10^{-8}$
M3	$\geqslant 9 \cdot 10^{-12}$	2	0.1	$2 \cdot 10^{-8}$	–	–
		10	0.07	$8 \cdot 10^{-9}$	0.03	$4 \cdot 10^{-9}$
M4	$\geqslant 9 \cdot 10^{-11}$	2	0,007	$8 \cdot 10^{-10}$	–	–
		10	0,001	$2 \cdot 10^{-10}$	–	–

TABLE II. Integral Mass-Spectrum Index

Spacecraft	Epoch			
	T1	T2	T3	T4
Vega 1	1.6	2.0	1.0	0.9
Vega 2	1.4	1.3	1.0	1.0

All values are uncertain to ±0.1.

spectra in the DUCMA mass range can be represented by a power law in mass, so that the flux F(m) is proportional to $m^{-\alpha}$. Values of α for each sampling time are listed in Table II, which shows that there is a significant, progressive reduction in α at increasing (outbound) radial distances.

It is noteworthy that: a) the mass spectra from the two encounters are similar, in spite of the presence or absence of a jet;

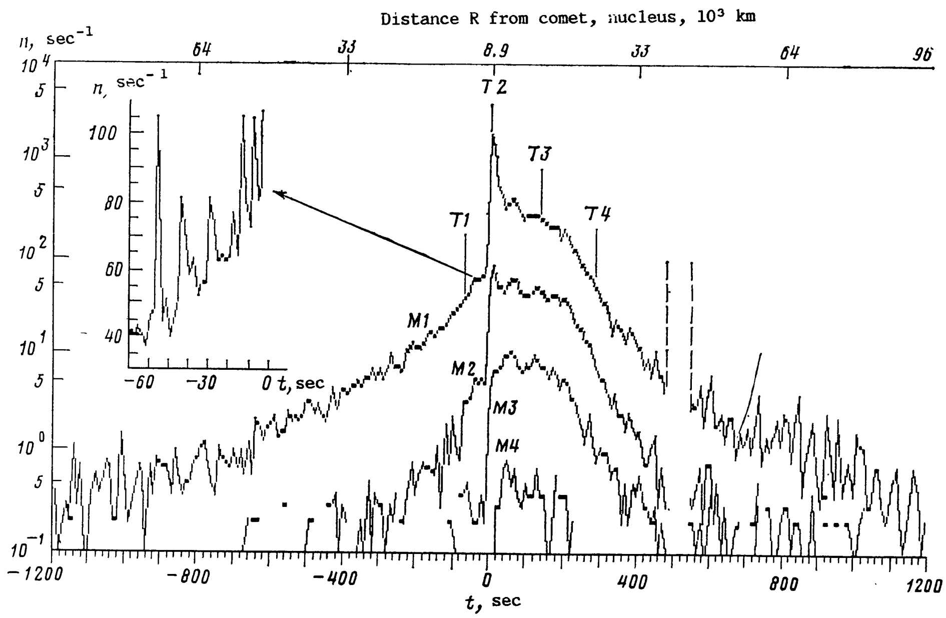

FIG. 2. Dust-particle count rates n for Vega 1, averaged over 20-sec intervals, for the four mass threshold specified in Table I. Between the dashed vertical lines there was a telemetry dropout. T1-T4 mark the times at which the mass spectra of Table II were derived. Inset, detail of a portion of the M1 spectrum, illustrating the quasiperiodic fluctuations.