radicals. In spectra *b* and *c*, obtained at two positions located symmetrically with respect to the maximum in continuum emission, two discrete features appear near 500 nm, on the short-wavelength side of the C_2 ($\Delta v = 0$) bands. These are believed to be due to the NH_2 (0, 13, 0) band; the distortion of the C_2 ($\Delta v = -1$) bands probably results from a strong contamination by the NH_2 (0, 10, 0) band. The exceptional strength of the NH_2 bands compared with other features indicates that either we are observing NH_2 radicals which have a very short-lived parent or, as in the case of both OH and CN, some of the NH_2 radicals are produced in the upper state, leading to the production of the ammonia bands.

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Neutral gas measurements of comet Halley from Vega 1

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The neutral gas experiment (ING) aboard the Vega 1 spacecraft detected cometary gas within a distance of 60,000 km from the nucleus of comet Halley. A preliminary inspection of the data permits an analysis of the variation in neutral gas density. Fine structure was detected in the spatial distribution of lower-mass species.

The ING instrument comprises two independent gas detection systems, pointed in the direction of the spacecraft-comet relative velocity[1]. We report here results obtained by the field ionization system (FIS), which uses a high-gradient electric field to ionize incoming atoms or molecules, while preserving their identity. After ionization these particles are accelerated to 50 keV and their respective masses determined by measuring their flight time over a distance of 7 cm, with a resolution of $\sim$1 ns. The flight time t_f is related to the particle mass M through the equation $M = Kt_f^2$. The instrumental constant K is slightly mass-dependent due to the energy which particles lose in the thin carbon foil which they have to traverse in order to enter the time-of-flight device. As energy straggling increases with mass, the resolution decreases with increasing mass. On the other hand, ionization is only slightly dependent on the incident gas velocity; thus, particles detected by the FIS sensor could originate from the spacecraft environment as well as from cometary gas. In order to minimize the background from such locally produced gas, the instrument was mounted on the top of the spacecraft, viewing the comet at an angle of 52° to the Sun-spacecraft direction. It is inclined to the ecliptic plane by 7°. The aperture field of view is 1°×2°; an exit port makes the instrument a 'fly through' design. Field ionization is achieved near the surface of 40 needles, the tips of which have radii of curvature of $\sim 0.1\ \mu m$. The overall sensitivity of the FIS (defined as the count rate per unit incident flux) is $\sigma_{\text{eff}} = 10^{-10}$. This, however, is a preliminary value.

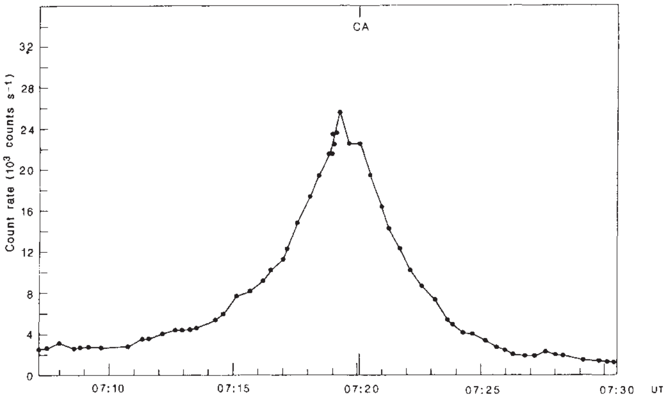

Fig. 1 Total count rate of Vega 1 FIS sensor versus time on 6 March 1986. Closest approach to the comet (CA) was at 07:20:06 UT; count rate is proportional to total gas density.

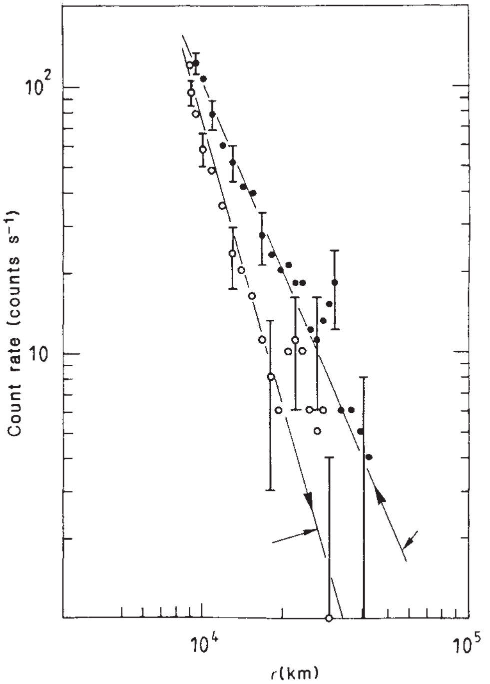

Fig. 2 Count rate versus distance r from the comet nucleus for one FIS channel, relatively assigned to mass $M = 32$. The count rate is proportional to gas density. Dots, inbound leg; circles, outbound leg; arrows show the direction of time. Closest approach to the nucleus was at 8,890 km. The data are fitted to two power laws of the form $r^{-\alpha}$: for the inbound leg, $\alpha = 2.3$, and for the outbound leg, $\alpha = 3.5$. Error bars show 1σ confidence limits.

During flight the Vega 1 instrument performed much as expected. The instruments started to record rates larger than background at a distance of $\sim$60,000 km from the cometary nucleus and before the onset of large dust fluxes. Figure 1 shows the total count rate of the FIS sensor as a function of time. This rate is the sum of all counts recorded by the instrument, and thus the sum of all possible contributions by cometary neutrals to the rates.

Figure 2 shows count rates for a single channel, plotted as a function of radial distance r from the cometary nucleus. The data have been fitted to a power-law dependence $r^{-\alpha}$ for both the inbound (dots) and outbound (circles) legs. For the inbound portion we find roughly an r^{-2} dependence, whereas for the outbound leg $\alpha \simeq 3.5$. For the density $n(r)$ of cometary neutrals, model calculations[2] provide a dependence $n(r) \simeq r^{-2}\exp(-r/u\tau)$. For distances $r \ll 10^6$ km, $n(r) \simeq r^{-2}$ is in agreement with our inbound observations. The steeper slopes observed outbound might be due to the highly variable, non-spherically-symmetric expansion of the cometary atmosphere during that time, or to a finite region of enhanced outflow in conjunction with jets, entered after closest approach.

In our low-mass channels on the outbound leg, we observe spikes superimposed on the general trend. These spikes were not observed in channels corresponding to higher mass numbers. The spikes have typical durations of up to 10 s, implying high-density structures with dimensions of $\sim$500–700 km. The widths of these structures resemble those which have been observed by the DUCMA dust experiment on Vega 1 (ref. 3). The time-resolution of our instrument is 2 s, implying that structures of dimensions larger than 150 km can be readily identified. This is of great interest, as a series of prominent spikes appeared over a 200-s period at a distance of 4.5×10^4 km from the nucleus on the outbound leg.

Because the FIS sensor is of a new design, being applied in spaceflight for the first time, the evaluation of the instrument's performance will require further data analysis and calibration.

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Dust coma structure of comet Halley from SP-1 detector measurements

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The SP-1 detectors aboard the Vega 1 and Vega 2 spacecraft measured the spectral and spatial distributions of dust grains, with the aim of investigating the dust release process and other properties of the comet nucleus[1–3]. The dust particle mass spectra do not exhibit the expected low-mass cutoff[4] at 10^{-14} g; instead, they continue to rise to $\sim 10^{-16}$ g. The apex of the dust paraboloid resulting from scattering of sunlight is estimated to lie at a distance of $40\text{–}45 \times 10^3$ km from the nucleus, although there is a small number density of particles well beyond this boundary. Particles of mass $10^{-12}\text{–}10^{-14}$ g are relatively depleted at large distances from the nucleus, due to stronger light scattering by these particles. Strong inhomogeneity of the dust number density suggests the existence of a sunward-pointing cone of enhanced dust emission, of width 70–80°. The spatial dispersion of a narrow dust jet has been used to estimate the sense and period of rotation of the nucleus and the approximate azimuthal location of the jet source, as well as the mass-dependent velocity dispersion of the dust particles.

Each dust particle that hits the solid target of the SP-1 detector gives rise to a charged plasma cloud[5]; the amplitude of each charge pulse is measured and recorded by decade counters. A preliminary estimate for the mass range Δm_n of the nth channel is obtained by using an empirical conversion factor[6], $\simeq 10^3$ C g^{-1}: thus, Δm_n is 10^{-n-9} to 10^{-n-10} g for $n = 1$ to 6, and Δm_7 is 10^{-16} to 3×10^{-17} g. The sensitive area of the detector is 81 cm^2 and the sampling rate is 0.5 Hz. For a detailed description of the instrument, see ref. 7.

The SP-1 data reported here were obtained on Vega 2 on 9 March 1986. Vega 1 recorded higher number fluxes at closest approach, and a slightly different spatial distribution.

The scattering of sunlight forces cometary dust particles away from the Sun, so that their trajectories lie within a 'dust paraboloid'[8], with its focus at the comet nucleus. The dust number density should decrease as R^{-2}, where R is the distance from the nucleus, although deviations from the R^{-2} law will be observed closer to the paraboloid and within dust jets. To reveal the large-scale structure of the dust coma we have normalized the measured count rate by a factor $(R_0/R)^2$, where R_0 is the distance of closest approach (8,030 km).

Figure 1 shows that the dust coma is quite inhomogeneous; nevertheless, the profiles in different mass ranges show similar features. We have identified several boundaries (vertical lines in Fig. 1), separating regions of differing dust characteristics. The outermost boundaries (a and e in Fig. 1) are believed to be those of the dust paraboloid, which must therefore have its apex at $40\text{–}45 \times 10^3$ km (curve f in Fig. 1). A lower but significant dust number density was observed well beyond these boundaries (the first particle was recorded at a distance of 3.2×10^5 km from the nucleus); this may be the result of velocity dispersion.

The most striking large-scale feature in the SP-1 data from both Vega 1 and Vega 2 is the region of strong, narrow jets contained within a cone of width 70–80°, oriented approximately towards the Sun (boundaries c and d in Fig. 1). This cone of dust ejection is easily seen in television images taken from both Vega spacecraft at distances of several hundred kilometres[9]; these images also show the cone angle to be $\sim$75° (Fig. 1). If we assume that the most pronounced jet examined (with external boundary b in Fig. 1) is reflected from the calculated paraboloid, then it may originate from the edge of the active cone. We believe that a sunward-pointing cone of dust ejection, with relatively sharp boundaries, is an important and long-lived feature of the dust emission of comet Halley (it could also be seen in images taken from the Giotto spacecraft).

One of the jets in the sunward-pointing dust cone exhibited mass dispersion along the spacecraft path; that is, heavier particles were observed before lighter ones (Fig. 2a). As shown in Fig. 2b, this may reflect the traversal by the spacecraft of a very narrow jet (not necessarily continuous), emitted by a rotating nucleus. If we assume velocities v_1 and v_5 for the particles