SECONDARY ELECTRON EMISSION INDUCED BY GAS AND DUST IMPACTS ON GIOTTO, VEGA-1 AND VEGA-2 IN THE ENVIRONMENT OF COMET HALLEY

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ABSTRACT

Giotto, Vega-1 and Vega-2 have been bombarded by a flow of gas and dust particles during their flyby of comet Halley. The emission of secondary electrons and sputtered ions caused by the large impact velocities (70-80 km/s) perturbed the plasma density in the spacecraft vicinity and was a possible source of interference for field and particle measurements. Identical impact plasma detectors were mounted on the three space probes; the saturation currents of secondary electrons emitted from gold targets were measured once per second. The results obtained during the three flybys are presented and compared. Information about the gas density profile and nucleus gas production rate can be derived from the measurements. Conclusive evidence is given about the time of opening of the cover which protected the Giotto target from contamination by the spacecraft propulsion system.

Keywords: Giotto, Vega, Comet Halley, Cometary Atmosphere, Dust Impacts, Secondary Electron Emission, Spacecraft Charging.

1. INTRODUCTION

The interaction between a spacecraft and a cometary environment during a high relative velocity flyby has been the subject of numerous studies and review papers prior to the encounters with comet Halley in March 1986 (Ref. 1-8).

In short, the impact of molecules and dust particles causes the emission of sputtered ions and secondary electrons from the fore section of the spacecraft surface. This mechanism is responsible for the existence of an artifical plasma cloud around the space probe and the possible perturbation of the surface potential during the flyby.

This situation can be simulated numerically (Refs. 9-11) but requires input information about the flux and energy of the emitted charged species. Some of these parameters can be obtained from laboratory measurements (Refs. 12-14) but it seemed nevertheless essential to measure in-situ the most important quantity, namely the secondary electron flux.

Identical detectors were therefore flown on Giotto, Vega-1 and Vega-2. The results obtained from the Vega missions have already been presented elsewhere (Refs. 15, 16); this paper focuses more on the Giotto data and the consistency of the three sets of measurements.

The Giotto instrument was mounted behind a protective cover which was intended to protect another instrument from contamination during the operation of the orbit insertion motor, but it became subsequently doubtful whether the cover opening command has been properly executed. The analysis of the Giotto data brings also a crucial contribution to this controversial issue.

2. THE INSTRUMENT

The sensor consists of a circular target surrounded by a guard ring and polarized at a potential of -17V with respect to the spacecraft structure. The probe is planar, gold plated and mounted in a plane perpendicular to the flow direction (Figure 1). The saturation electron current

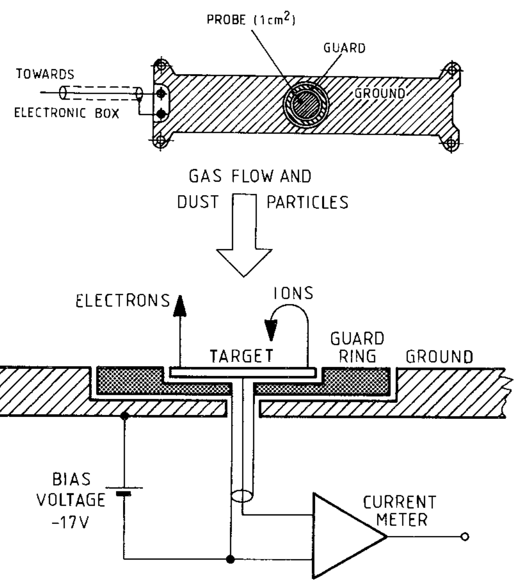

Figure 1. Target configuration and simplified diagram of sensor and electronics

emitted from the central electrode is measured once per second with a nominal 8 bit resolution and a time constant of the order of 1 s. More detail about the instrument is given in Refs. 17-19.

The Giotto sensor is protected at launch with a cover made of a thermal blanket which consists of three 7 μm thick insulating layers. This cover is loaded with three flat springs and is rolled up to one side of the aperture when released.

3. THE MEASUREMENTS

3.1. The Vega Results

The measurements performed during the flybys of Vega-1 and Vega-2 are shown in Figures 2 and 3, respectively. Time is measured relative to closest approach; the scales for current and time are identical on both plots.

The Vega-1 and Vega-2 profiles are similar, but the later is incomplete because of an experimental anomaly which interrupted the data flow for nearly 27 minutes.

Limited resolution is responsible for the step-like discontinuities observed in both figures. The current consists of two components: a slowly varying background signal, and a series of superimposed discrete spikes.

The quasi-continuous current is associated with secondary electron emission due to molecular bombardment; it may also include the effect of the incoming flow of small dust particles which is integrated by the electronic circuitry. The discrete spikes are caused by the random impact of relatively larger particles; their amplitudes can exceed 10^4 nA near closest approach as shown in Figure 2, but they never reach the upper limit of the dynamic range of the instrument which is approximately 10^5 nA.

The target emits a constant current of photoelectrons at large distances from the nucleus; the magnitude of this current is about 8 nA before encounter and is subsequently reduced by half. This phenomenon is observed identically on Vega-1 and Vega-2 and can be explained by surface degradation during the flyby due to erosion or contamination.

3.2. The Giotto Results

The Giotto results are illustrated in Figure 4. The current scale is the same as in Figures 2 and 3, but the time scale has been expanded to improve legibility. Before encounter, the average current intensity equals 4 nA, typically half the value observed on the Vega spacecraft under similar circumstances (solar distance and aspect angle), which leads to assume that the protective cover is still closed. This hypothesis is all the more convincing as the darkness current did not exhibit the expected variation when the cover release was ordered by telecommand in January 1986; it had indeed been predicted that photoemission caused by exposure to sunlight should have given rise to a measurable current increase.

Following a series of negative impulsive events such as those seen as discrete spikes at -93 s and -75 s but which are probably overlaping in the interval -70 to -39 s, the intensity of the current suddenly jumps by more than three orders of magnitude up to 10^4 nA. Thereafter the current increases and reaches the upper limit of the telemetry dynamic range at -20 s; superimposed negative spikes are still observed at -33, -26, -19 and -11 s.

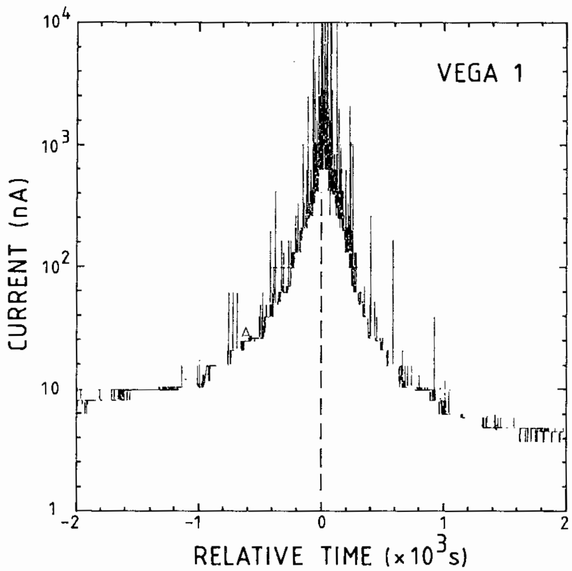

Figure 2. Secondary electron current emitted by the target during the Vega-1 flyby on 6 March 1986; the closest approach occurred at 07:20:06 CET (cometary event time), at a distance of 8889 km.

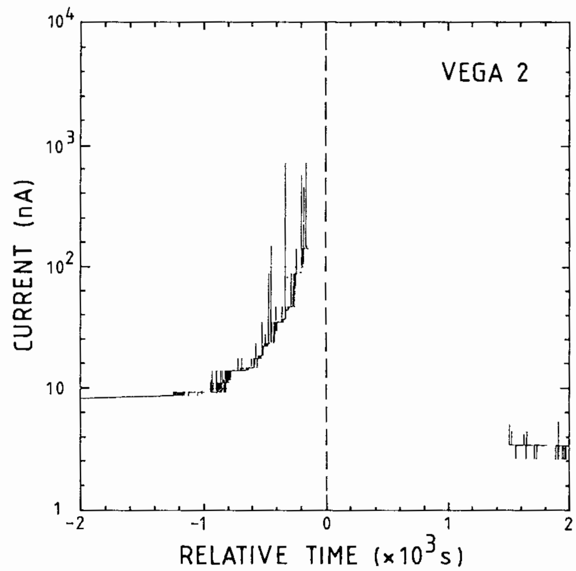

Figure 3. Secondary electron current emitted by the target during the Vega-2 flyby on 9 March 1986; the closest approach occurred at 07:20:00 CET, at a distance of 8030 km. The data flow is interrupted for about 27 min due to an instrumental anomaly.

The negative pulses observed before -60 s are observed simultaneously on an other instrument which is also mounted behind the cover. These events are believed to be linked to the collection of electrons with energies larger than 17 eV generated during the perforation of the cover by dust particles. The occurrence of a few additional evens after -40 s leads to assume that the cover is not completely released but progressively eroded.

The absence of positive spikes after -40 s, such as those seen superimposed on the VEGA background signals in Figures 2 and 3 may simply be due to the combined effect of the high dust impact rate and the long time constant of the instrument (1 s).

Giotto was hit by a relatively large particle at -14 s; the impact caused the spacecraft to perform a nutation with an amplitude such that the telemetry link could not be maintained continuously. For time larger than 40 s, the average current level varies very little, decreasing very slowly from 4.7×10^3 nA down to 3.5×10^3 nA in about 25 minutes. The latter data are erroneous since they are probably dominated by a stray current due to sensor damage or electronic failure.

The information contained within the dashed rectangle is possibly valid as it was taken before the instrument failure and after the cover was opened, whether it was released or abraded. This information is plotted in a different format, current density vs. distance from the nucleus, in Figure 5; the full and dashed lines link the measurements taken during the approach and the exit, respectively.

4. DATA COMPARISON AND CONSISTENCY

The data shown in Figures 2, 3 and 5 are plotted in Figure 6 against distance from nucleus, r; the discrete spikes associated with dust impacts are not shown. Measurements performed during the outbound leg of the trajectories are indicated by dots (Giotto) or a dashed line (Vega-1).The slope r^{-2} is shown for reference.

The three sets of data exhibit a reasonable degree of compatibility; the Vega-1 and Vega-2 profiles differ by an amount which can be easily explained in terms of variation in nucleus activity and the Giotto results appear as an acceptable extrapolation of the Vega measurements. It can therefore be inferred that the Giotto impact plasma detector was exposed during the approach to the incoming flow of dust and gas at a distance of 2600 km from the nucleus.

5. CONCLUSION

We shall conclude with the following remarks:

(1) The knowledge of the secondary electron flux emitted from the surface elements exposed to the cometary gas and dust flows can be used to improve the models of electric charge and potential distributions around the spacecraft (Ref. 11).

(2) Information about the neutral density profile can be derived if one knows the secondary electron yield. The right axis of Figure 6 has been graduated for a yield of 0.3 and a relative gas flow velocity of 78 km/s (Ref. 15).

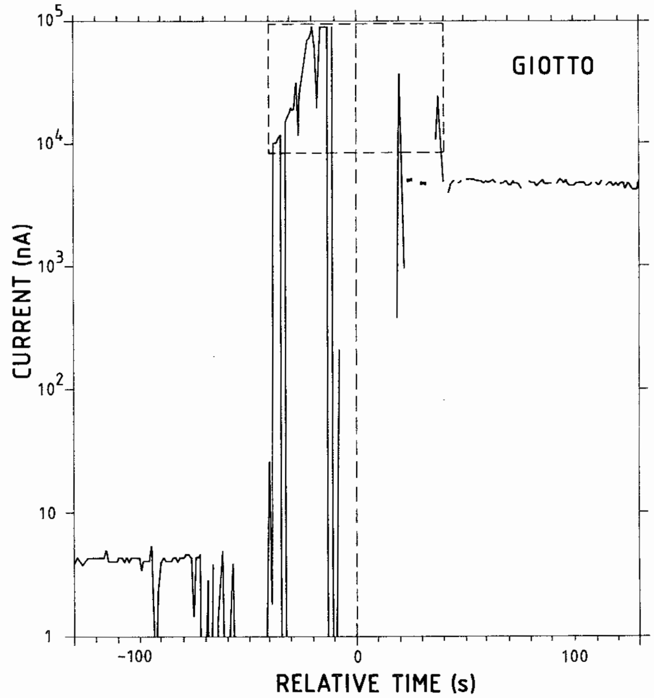

Figure 4. Secondary electron current emitted by the target during the Giotto flyby on 14 March 1986; the closest approach occurred at 00:03:02 CET, at a distance of 605 km. The protective cover was opened 40 s before transit through pericenter. The data contained within the dashed rectangle are plotted, in a different format, in Figure 5.

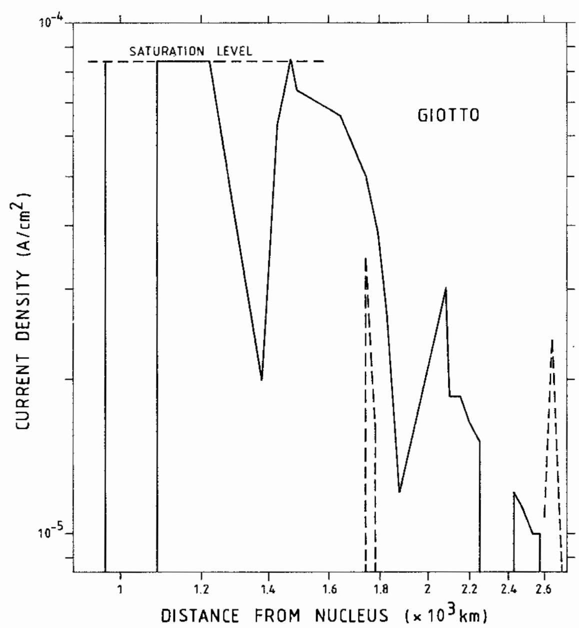

Figure 5. The secondary electron current emitted from the Giotto target plotted against distance from nucleus during the approach (full line) and exit (dashed line).

(3) The cometary nucleus gas production rate can be computed assuming an isotropic emission; a value of the order of 10^{30} molecules/s is derived (Ref. 16), in fair agreement with other measurements (Ref. 20).

(4) The Giotto cover was certainly not released before the encounter; it was opened or, more likely, abraded a few seconds before closest approach.

(5) It is possible to estimate, by extrapolation, that a secondary electron current of the order of 27 A was emitted from the Giotto shield during its flyby at the cometary pericenter (600 km).

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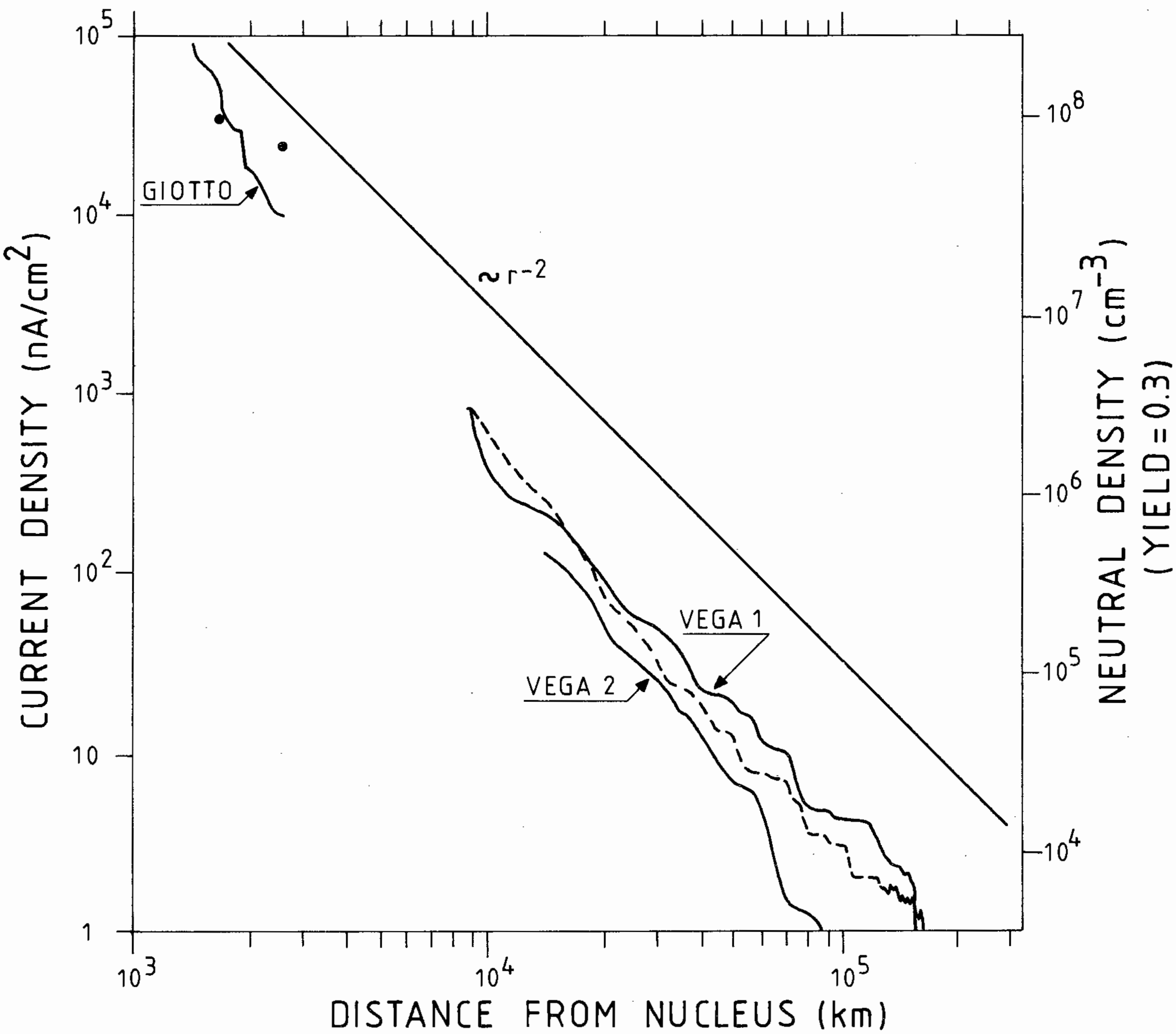

Figure 6. The envelopes of the secondary electron emission measured during the three flybys plotted against the distance from nucleus during the approach (full line) and exit (dashed line for Vega-1 or dots for Giotto). The left ordinate axis gives the current density; the right ordinate axis gives the equivalent neutral density evaluated for a yield of 0.3 and a flyby velocity of 78 km/s.

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