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ELECTRON EMISSION BY GAS AND DUST IMPACTS DURING THE FLYBYS OF COMET HALLEY

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Abstract. The space probes which flew through the environment of Comet Halley have been bombarded by a flow of molecules and dust particles which impacted their surface with a relative velocity of the order of 70-80 km s^{-1}. The emission of secondary electrons and sputtered ions caused by these impacts was a potential source of interference for the experiments which analyzed the gas and plasma environment of the comet. The impact plasma detector is a simple device which measured the saturation current of the secondary electrons emitted from a gold target mounted on Vega-1 and Vega-2. The effects of the gas and dust impacts can be easily separated; the total gas production rate of the nucleus is estimated to be of the order of 10^{30} molecules/s at 0.8 AU.

Introduction

During the encounter with Comet Halley the leading sections of the Giotto and Vega spacecraft have been submitted to the bombardment of cometary dust particles and molecules (neutrals and ions) which impacted their surface with kinetic energies of 24 to 27 eV per amu.

Secondary emission and ionization of sputtered materials may have influenced the potential of their surface and given rise to a plasma cloud which contaminated their environment. This phenomenon has been the subject of several preliminary meetings organized by the European Space Agency [Reinhard and Longdon, 1981; Grard and Burke, 1982; Pedersen et al., 1983; Reinhard and Battrick, 1984] and has been reviewed in many publications [Grard et al., 1981; Grard, 1983; Young, 1983, 1986].

Measurements of the flux of secondary electrons emitted from a reference surface were therefore attempted on Vega-1, Vega-2, and Giotto during the cometary flybys, but only the results obtained with the Vega 1 and Vega 2 spacecraft are presented here. These results confirm and extend those independently obtained with a different instrument working along a similar principle [Gringauz et al., 1986]. It will be possible to use this information at a later stage as input parameter in simulation programmes which model the charge distribution on the surface and in the environment of the cometary probes [Thiemann et al., 1986].

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Experiment

The sensor is a target exposed to the impact of dust and gas molecules; it is mounted in a plane perpendicular to the velocity vector of the probe relative to the cometary nucleus. This electrode is made of an insulating substrate lined with a copper foil (printed circuit board) on which a gold covering has been deposited; a thin intermediate layer of nickel has been added in order to facilitate the adhesion of gold upon copper.

The sensor is made in three parts (Figure 1). The central part has an area A = 1 cm^2 and is connected to the input of the current measuring device by means of a coaxial cable. The probe and the electric guard are held at a negative electric potential of -17 V with respect to the surrounding ground [Grard, 1984].

Experimental Results

The time variation of the electron current emitted from the target during the flyby of Vega-1 is shown in Figure 2.

Time t is shown relative to the closest approach (t = 0). The observed signal consists of two distinct components: a slowly varying background signal which reaches a maximum at t = 0, on which are superimposed a large number of spikes which are seen mostly around the time of closest approach.

A limited telemetry resolution is responsible for the discontinuities which are observed whenever a variation of the signal entails a change of quantization level.

For this paper we considered only the variation of the quasi-continuous signal associated with gas bombardment and we keep the investigation of the discrete dust impacts for a further study. Figure 3 gives the current density j obtained after taking out the spikes and applying a 10s running average to the data.

It is seen in Figure 2 that the target emits a constant current of photoelectrons at large distances from the nucleus: i_1 = 8 nA before the encounter and i_2 = 3 nA after the encounter; these currents have very similar values on Vega-1 and Vega-2. The fact that i_1 differs from i_2 results most likely from a modification of the emissive properties, and/or a reduction of the metallized area, of the target surface caused by the impacts.

Figure 4 illustrates the variation of the electron current density due to gas impact against r, the distance from the nucleus. The quantity plotted is $j_s = j-i_1/A$ during the approach

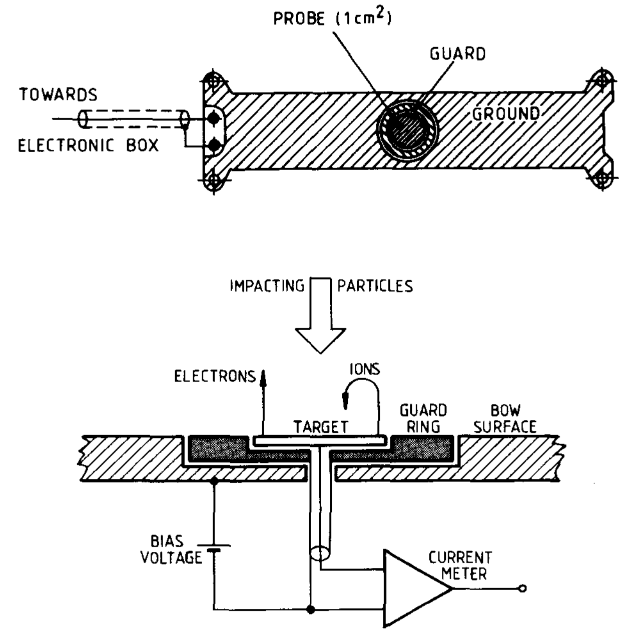

Fig. 1. The target configuration and experiment schematic diagram.

($t < 0$, full line) and $j_S = j - i_2/A$ during the exit ($t > 0$, dashed line); the straight line gives the slope r^{-2} for reference. The Vega-2 results are limited to the beginning of the approach because an experimental anomaly interrupted the data flow for about 20 minutes during flyby.

Gas Density and Production Rate

The secondary electron current density, j_S, is related to the gas molecule density, n, through the relation $j_S = nVYe$, where V is the relative velocity of the spacecraft, Y is the electron yield (average number of electrons emitted per impacting molecule) and e is the elementary charge. The molecule density is given along the left axis of Figure 3 assuming V = 79.2 km/s (Vega-1) and Y = 0.3 [Arends and Schmidt, 1983].

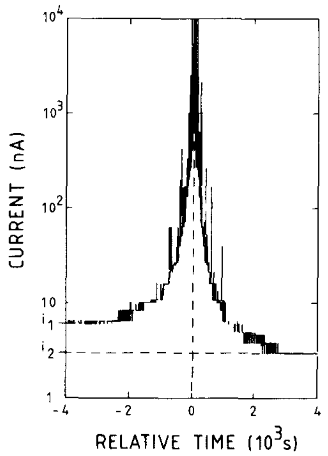

Fig. 2. The electron current emitted by the target during the Vega-1 flyby on 6 March 1986; the closest approach occurred at 07.20.06 UT, at a distance of 8889 km.

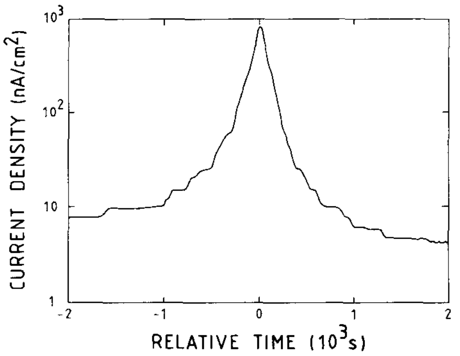

Fig. 3. The electron current density emitted from the probe after taking out the dust impact contribution.

The neutral density is of the order of 10^6 cm^{-3} at closest approach compared to about 10^3 cm^{-3} for the electron density [Grard et al., 1986]; the cometary gas can therefore be considered as being weakly ionized at this distance.

The current density measured by Vega-1 during the exit for $r > 3 \times 10^4$ km is consistently below that measured during the approach (Figure 4); the reason for this discrepancy is possibly the same as that which explains the reduction of the photoelectron current, namely a progressive deterioration of the probe effective surface by impacts.

The current measured by Vega-2 on 9 March appears to be lower than that measured by Vega-1 on 6 March by a factor of about 2. One must however take into account the fact that the relative velocity of Vega-2 is 76.8 km/s, as compared to 79.2 km/s for Vega-1. The secondary electron current is indeed proportional to VY, that is V^3 if one considers as a working hypothesis that the yield is approximately proportional to the kinetic energy of the incident molecules. Introducing a corrective factor of 1.1, i.e. $(79.2/76.8)^3$, on the Vega-2 results is certainly not sufficient to make up for the observed discrepancy. One must therefore conclude that the gas density encountered on 9 March was reduced to about half its level of 6 March.

Assuming isotropic emission and fitting the Vega-1 results to a function of the form

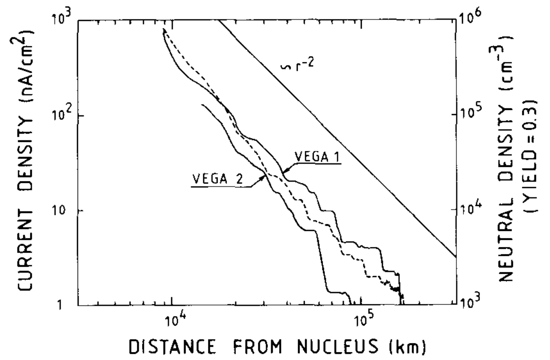

Fig. 4. The electron current density induced by gas impacts against the distance from the nucleus for Vega-1 (6 March 1986) and Vega-2 (9 March 1986) during the approach (full lines) and exit (dashed line) phases.

$Q = 4\pi r^2 n v_g$, where the velocity of the molecules v_g is taken equal to 900 m/s [Krankowski et al., 1986], yields for the gas production rate a value of about 10^{30} molecules/s.

Conclusion

The secondary electron current due to gas impact on a gold surface has been measured both on Vega-1 and Vega-2. The uncertainty inherent to the choice of a value for the secondary electron yield, Y, is such that one can only claim an order of magnitude for the gas density and production rate. Adopting the value Y = 0.3 and assuming that the gas emission is isotropic leads to a total gas production rate of 10^{30} molecules s^{-1} from the nucleus at a distance of about 0.8 AU from the Sun, a number very similar to those quoted by other experimenters on Vega and Giotto. These measurements indicate in addition that the gas distribution profiles are reasonably similar during the approach and the exit of Vega 1. The gas production rate of Halley's nucleus was about twice as large on the 6 than it was on the 9 March 1986 if one assumes isotropic emission.

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