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Low energy ion measurements at comet 67P

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Abstract

ESA Rosetta spacecraft studies of the 67P/Churyumov-Gerasimenko coma indicate the presence of an electric field capable of accelerating the cometary ions a factor of 2-10 times the neutral gas outgassing velocity and thus a decoupling of the cometary ions from the neutrals. The plasma instrumentation on-board Rosetta in the Rosetta Plasma Consortium (RPC) are all in situ measurements taken on an often significantly negatively charged spacecraft ($\approx$ -10 to -30 V) capable of perturbing ion measurements. Therefore simulations of the Spacecraft-plasma interaction were undertaken with the Spacecraft-Plasma Interaction System code (SPIS) to investigate the features and extent of this perturbation. In this study we report preliminary results of positive ion measurements using simulated voltage-bias sweeps of the Rosetta Langmuir Probes (RPCLAP), with varying random and ram flow velocity components, indicate a non-negligible decrease of ion flux to the probe with increasingly negative spacecraft potential. We also show that this spacecraft-plasma interaction effect would rarely be sufficient to return to an ion-neutral coupled environment model for typical Rosetta plasma observations.

1. Introduction

ESA's comet-chaser Rosetta arrived at comet 67P/Churyumov-Gerasimenko in August 2014 and completed its mission in September 2016. During all this time, the instruments of the Rosetta Plasma Consortium (RPC) were monitoring the plasma environment. The Langmuir probe instrument (RPC-LAP) [1], measures the current between the probe and surrounding space with the aim to characterise the plasma.

Previous simulations [2, 6, 5] show that a proper interpretation of the plasma measurements on Rosetta need to take spacecraft potential effects into account, as electrons and ions are attracted or repelled towards the spacecraft, as shown in Figure 1. The extent of which we attempt to quantify and study in this report with further, more detailed simulations focused on a comet-like environment using *Spacecraft-Plasma Interaction System* (SPIS) [4].

2. Method and Results

For supersonic ion flow of single positive charge, the ion current to a sphere such as the Rosetta Langmuir Probe can be shown[3] to be

$$I_i = \begin{cases} -I_{i0}\left(1 - \frac{eV_p}{E_i}\right) & \text{for } V_p < E_i/e \\ 0 & \text{for } V_p > E_i/e, \end{cases} \quad (1)$$

where V_p is the absolute potential of the probe relative to a plasma at infinity, e is the elementary charge, $E_i = \frac{m_i u^2}{2}$ is the energy of ions of mass m_i, and flow speed u, I_{i0} is the ram current, given by

$$I_{i0} = A_c e n u, \quad (2)$$

where A_c is the circular cross section of the probe, n is the plasma density. For typical cometary plasma as seen by Rosetta, I_{i0} is below the measurement resolution of RPCLAP [1] of 0.3 nA. Therefore we instead use the derivative of the ion current $\frac{dI_i}{dV_p}$ and plasma density estimates from RPC-MIP [7] to estimate the ion flow speed.

We can also obtain a second estimate the effective ion flow speed by a method proposed by Vigren et al. (2017) [8] using a simple flux conservation model assuming radial outflow. The results are plotted in Figure 2, at times where the outgassing velocity is just below 1 km/s. We have conducted nine simulated Langmuir Probe voltage-bias sweeps of a nominal case event study, with varying components of thermal and flow velocity to determine the degree of perturbation due to the presence of a highly negative spacecraft in SPIS, and found that the ion flux to the probe decrease by a factor of 1.5 to 2, which would result in the mean of the LAP ion slope method result approaching 2-3 km/s, much in agreement with the flux conservation method, but still above the neutral gas flow speed.

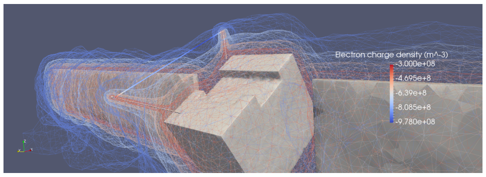

Figure 1: Electron density profile surrounding a -20 V charged Rosetta spacecraft model used in the simulations.

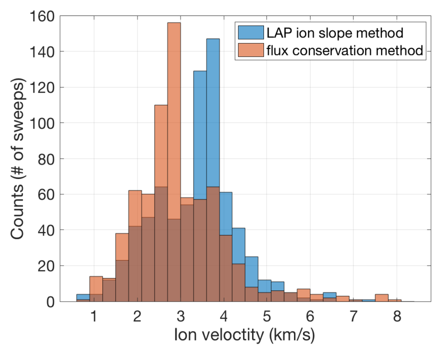

Figure 2: Comparison of effective ion drift speeds obtained from the flux conservation model [8] and the LAP ion slope method during all diamagnetic cavity crossings throughout the mission.

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