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Correction of Low-Energy Ion Measurements from Rosetta-ICA for the Effects of Spacecraft Charging

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Abstract

One common and unwanted effect of spacecraft charging is the interference with scientific measurements. The Ion Composition Analyzer (ICA) onboard the Rosetta spacecraft is designed to make in situ measurements of positive ions in the environment of comet 67P/Churyumov-Gerasimenko. The spacecraft is often charged to a substantial negative potential, which is problematic for the measurements. The ions are attracted to the spacecraft, which for low-energy ions results not only in a change of energy, but also direction of travel. This study aims at determining the influence of the spacecraft potential on the low-energy ion measurements performed by ICA, with the ultimate goal of reconstructing the original ion energies and directions of travel.

1. Introduction

In 2004 the Rosetta spacecraft was launched to study the comet 67P/Churyumov-Gerasimenko. It arrived at the target in 2014 and the mission ended in September 2016 by a controlled impact. Onboard the spacecraft the Rosetta Plasma Consortium (RPC) is a group of instruments designed to study the plasma environment around the comet [2]. One of these instruments is the Ion Composition Analyzer (ICA), an ion spectrometer designed to study the interaction between the solar wind and the cometary particles. Problematic for the measurements is, however, the charging of the spacecraft. A spacecraft in space will interact with the surrounding plasma and acquire an electrostatic potential [1]. In the case of Rosetta the spacecraft was almost exclusively charged to a negative potential throughout the mission. ICA is able to measure ions down to a few eV, but the ions with the lowest energies are heavily affected by the charged spacecraft. This results in a change in both energy and direction of travel. The purpose of this study is to investigate what influence the spacecraft potential has had on the low-energy ion measurements performed by ICA in order to be able to correct the measurements for this effect.

2. Method

The tool used for this study is the Spacecraft Plasma Interaction Software (SPIS). This software can be used to simulate and model the interactions between the spacecraft and the plasma [3]. In SPIS the plasma environment around the spacecraft is simulated from which the plasma potential is obtained. An example of a simulation output is shown in Figure 1. SPIS also offers the possibility to define a scientific instrument to perform advanced calculations, e.g. particle tracing. We use SPIS to implement backward tracing of particles from a particle instrument to analyze the expected deviations in travel direction for different energies.

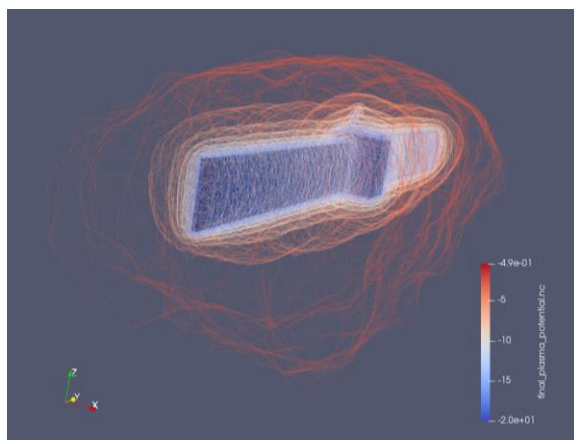

Figure 1: Simulated potential surfaces around the spacecraft. The spacecraft potential was for this simulation set to a fixed value of -20 V, the ion (H_2O^+) and electron densities were set to 1000 cm^{-3}, and the ion and electron temperatures were set to 0.5 and 10 eV respectively. The drift velocity of the ions was set to 4 km/s in the –z direction.

3. First Results

Figure 2 shows simulated selected ion trajectories close to the Rosetta spacecraft. The figure shows that the ion trajectories are clearly affected by the spacecraft. In this case the ions are entering the simulation volume from the –z direction with an initial velocity of 4 km/s (corresponding to an energy of approximately 1.5 eV). They are then accelerated in the potential field around the spacecraft.

The ion spectrometer ICA has a field of view (FOV) of 360°×90°. In the azimuthal direction (360°, corresponding to rotation in the x-z plane in Figure 3) this FOV is divided into 16 segments referred to as sectors, each with a FOV of 22.5° each. This is also the nominal resolution of the instrument in this direction.

By back tracing ions hitting ICA we find their original energy and direction of travel. Figure 3 shows an example where we have back traced ions detected by one of the 16 azimuthal sectors of the instrument. From Figure 3 it is clear that the nominal FOV is distorted for low energies, and the original travel direction of the ions can differ significantly from the travel direction at detection.

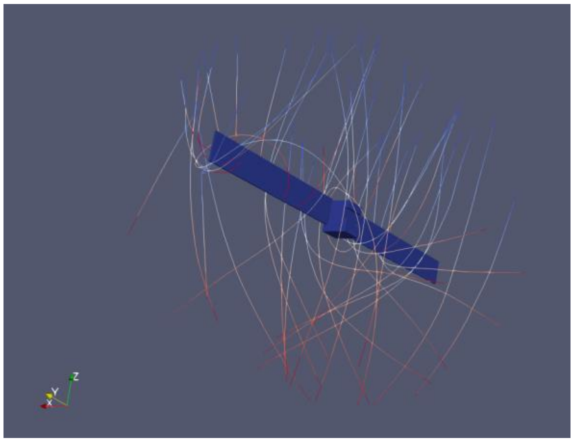

Figure 2: Simulation result from SPIS showing the influence of the spacecraft potential on low-energy H_2O^+ ion trajectories. For further details about the simulation, see Figure 1.

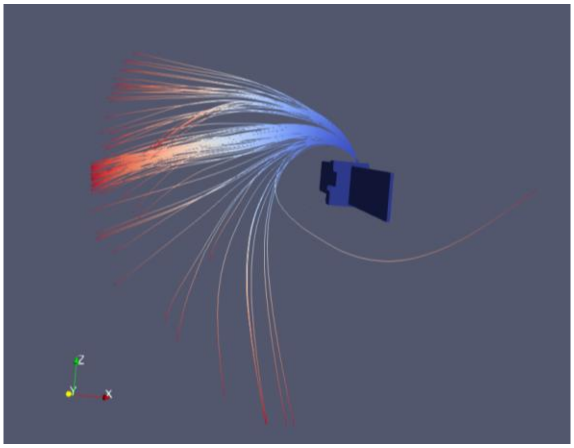

Figure 3: Simulation result from SPIS where low-energy H_2O^+ ions are traced backwards from one of the sectors of the instrument. At the edge of the simulation volume these ions have an energy of approximately 2 eV. For further details about the simulation, see Figure 1.

4. Expected Results

The first results of the study will be presented, including an analysis of the deviation in travel direction for the ions at different energies for each sector of the instrument. We expect the distortion to be more severe for lower energies, and we expect to be able to find an energy threshold above which it is possible to correct the data to reconstruct the original direction and energy of the ions.

References

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