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Observations of low energy ions around the diamagnetic cavity at comet 67P

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Abstract

We investigate the variations in low energy cometary ions around comet 67P. Detailed measurements of these ions were made possible by implementing a new instrumental mode of the ion mass spectrometer on the Rosetta spacecraft. The nominal time resolution was increased from 192 s to 4 s at the expense of the energy range and the field-of-view. In this study we focus on ion observations made outside of, but in the vicinity of, the diamagnetic cavity. The ion dynamics here is clearly linked to variations of the magnetic field strength and properties of the electrons velocity distribution, manifested by the spacecraft potential.

1. Introduction

The ion environment around comet 67P/Churyumov-Gerasimenko is highly variable. Already the first observations by the mass-resolving ion mass spectrometer ICA (Ion Composition Analyzer) [3] on Rosetta indicated this, even if the nominal time resolution was limited to 192 s. In order to study faster variations we implemented a new operation mode, focusing on a more limited energy range (0.3-82 eV compared to the original 5 eV-40 keV). The chosen energy range quite often captures a large part of the cometary ion population. We also restricted the instrument field-of-view to 5×360° compared to the nominal 90×360°. The result is a 2D-measurement of the differential ion flux with a time resolution of only 4 s. An example is shown in Figure 1.

During the Rosetta mission 1462 hours of data were taken with the 4-s mode, with the initial tests in May 2015 when the mode was implemented. In a first study we found that more than 80% of the data could be classified into one of five different types based on the appearance in an energy-time spectrum. In the vicinity of the diamagnetic cavity the observations typically look like in Figure 1, with clear dispersive structures [4].

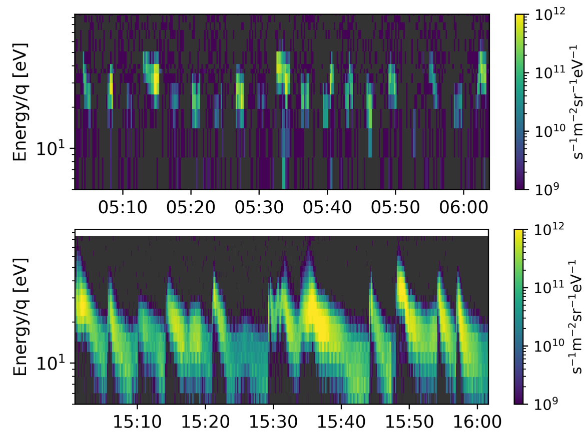

Figure 1: Example of low energy cometary ion data recorded by ICA in its nominal mode (top) and in its high time resolution mode (bottom). The observed differential flux is color-coded and showed as a function of energy and time. Data are from 4 September 2015.

The apparent energy variations can be shown to result from fast variations of the spacecraft potential, which suddenly becomes more negative and thus accelerates ions to higher energies before they reach the instrument.

2. Data and Modelling

In addition to the data recorded by ICA, described above, we use data observed by the Langmuir probe [1] and the magnetometer [2] on Rosetta. From the Langmuir probe we get the spacecraft potential, which also is a proxy for the electron density (assuming the electron temperature can be regarded constant). For the magnetic field we use data resampled to 1 Hz, which removes unwanted high-frequency, time-dependent artificial magnetic fields.

The substantially negative spacecraft potential does not only affect the energy of a measured ion but it does also change the ion's trajectory when approaching the spacecraft. Hence, even if the instrument detect that ions at the lowest energies arrive from all directions, this may entirely be an effect of the spacecraft potential. We use the Spacecraft Plasma Interaction Software (SPIS) [5] to evaluate how the ion trajectories are affected by the spacecraft. We especially want to know if a cometary ion flux from only one direction is consistent with the observations of isotropic ions.

3. Preliminary results

We try to reconstruct what the ion fluxes look like far away from the spacecraft, where the ions are unaffected by the presence of a strongly negatively charged body. Preliminary results show that the ion flux seems to correlate with the changes of the spacecraft potential. The maximum ion flux is, however, observed about 20 seconds after a sudden decrease of the potential (corresponding to an increase in electron density if electron temperature is constant). We also find evidence of small ion temperature increases both when the spacecraft potential changes fast and at the time of maximum ion flux. Both these findings can be seen in Figure 2. An increase in temperature corresponds to a broadening of the energy spectra.

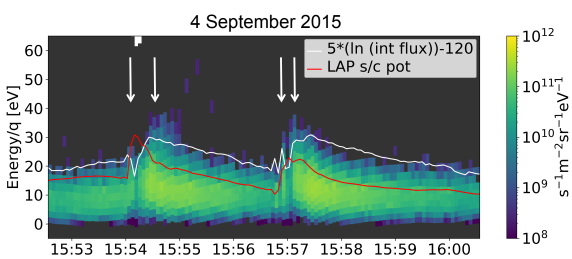

Figure 2: The maximum in the ion flux (white solid line) occurs some 20 s after a sudden change in the spacecraft potential (red solid line). Possible ion temperature increases are shown with arrows.

The magnetic field strength also follows the changes of the spacecraft potential but the direction of the field often changes suddenly. Sometimes the component along the comet-sun direction dominates but at other times the magnetic field is almost complete perpendicular to the comet-sun-line.

4. Summary

Close to the diamagnetic cavity we observe highly variable fluxes and temperatures of cometary ions. Their apparent energies changes quickly as the spacecraft potential varies. Typical variations are on timescales of tens of seconds to minutes. The observed differential flux (integrated over all observed energies) and the magnetic field strength vary together with the spacecraft potential but the ion flux peaks about 20 s after the spacecraft potential reaches its lowest value.

Acknowledgements

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