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Evolution of the ion environment of comet 67P

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Abstract

The Rosetta mission has been designed to rendezvous with and escort comet 67P/Churyumov-Gerasimenko from a heliocentric distance of 3.6 AU, when the comet still has a low activity level, until perihelion passage at 1.25 AU where the comet reaches the maximum of its activity. During the initial low activity stage the solar wind permeates the thin comet atmosphere that has just begun to form from sublimation. Eventually the size and plasma pressure of the ionized atmosphere leads to the formation of plasma boundaries: a magnetosphere is born. Using the Rosetta Plasma Consortium Ion Composition Analyzer, we study the gradual evolution of the comet ion environment as the comet activity increases. Mass loading caused by picked-up comet ions deflect the solar wind. Charge exchange between the solar wind and comet atmosphere gradually increases with comet activity, leading to a situation where a significant fraction of the solar wind has charge-exchanged close to the comet nucleus. Pick up ions created upstream of the comet nucleus are accelerated by the solar wind electric field and are seen with energies up to a few keV as they move back towards the nucleus. Locally produced water ions are seen moving with velocities similar to the neutral outgassing velocity of the order of 1 km/s (10 eV), but with their direction and speed influenced by the solar wind electric field. High charge state solar wind ions (O^{6+}, O^{5+}) are also seen at times. We quantify the ion environment near a low activity comet and show how it depends on the solar wind intensity and the distance to the sun.

1. Introduction

Rosetta is the first mission to visit and follow a low activity comet (Glassmeier et al., 2007). Rosetta carries a plasma instrument suite, the Rosetta Plasma Consortium (RPC, Carr et al. (2007)). We use data from the mass resolving ion spectrometer RPC-ICA (Nilsson et al., 2007). The initial measurements obtained using the RPC-ICA showed the first presence of water ions at a distance of about 100 km from the nucleus, while the comet was at 3.6 AU from the Sun (Nilsson et al., 2015a). These initially observed ions were picked up by the solar wind electric field and moved perpendicular to the solar wind flow. As the spacecraft approached the comet and the comet approached the sun, a significant deflection of the solar wind could be seen, up to about 45° from the anti-sunward direction. It was also shown that the alpha particles of the solar wind were less deflected than the protons (Nilsson et al., 2015a). Single charged helium, He^{+} was also observed, resulting from charge exchange between the solar wind He^{2+} and the comet atmosphere. Intermittently accelerated water ions with an energy up to 800 eV were seen coming from the upstream direction.

2. An evolving environment

Observations using RPC-IES data (Burch et al., 2007) confirm the initial picture of the early pick up ion process (Goldstein et al., 2015) as reported in Nilsson et al. (2015a). They could also show how the low energy ion environment is modulated by the comet rotation. Details of the mass loading process have later been studied in more detail (Broiles et al., 2015; Behar et al., 2015).

A description of the evolution of the ion environment around comet 67P from 3.6 to 2.0 AU has been reported by Nilsson et al. (2015b). They show how the water ion flux can typically be divided into a cold population where the neutral gas velocity still has a significant influence on the flow velocity, and an accelerated water ion population coming from the upstream direction. The accelerated water ion population increased by 2 to 4 orders of magnitude from 3.6 AU to 2.0 AU heliocentric distance. Simultaneously the solar wind was deflected and gradually showed more variability and possibly heating. At 2.0 AU heliocentric distance there was still no observation of the formation of any plasma boundaries such as a bow shock or ionopause. The accelerated water ion flux at 2.0 AU sometimes equals that of the solar wind. The cold water ions by far dominate the local plasma density.

3. Conclusions

The solar wind interaction with comet 67P is constantly evolving as the comet activity increases. In the initial phase we can study the effect of mass-loading of the solar wind and the details of solar wind - atmosphere interaction on spatial scales much below a comet pick-up ion gyroradius.

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