IRF Scientific Report 307

Plasma Interactions with Icy Bodies in the Solar System

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Akademisk avhandling

som med vederbörligt tillstånd av Rektor vid Umeå universitet för avläggande av teknologie doktorsexamen framläggs till offentligt försvar i aulan vid Institutet för rymdfysik, Rymdcampus 1, Kiruna,
tisdagen den 31 maj, kl. 09:00.
Avhandlingen kommer att försvaras på engelska.

Fakultetsopponent: Dr. Elias Roussos,
Max Planck Institute for Solar System Research, Göttingen, Tyskland.

Solar System Physics and Space Technology
Swedish Institute of Space Physics
Kiruna, 2016

Department of Physics
Umeå University
Umeå, 2016

Organizations
Umeå University
Department of Physics

Swedish Institute of Space Physics
Solar System Physics and Space Technology

Document type
Doctoral Thesis
Comprehensive Summary

Date of publication
10 May 2016

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Title
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Abstract

Here I study the "plasma interactions with icy bodies in the solar system", that is, my quest to understand the fundamental processes that govern such interactions. By using numerical modelling combined with in situ observations, one can infer the internal structure of icy bodies and their plasma environments.

After a broad overview of the laws governing space plasmas a more detailed part follows. This contains the method on how to model the interaction between space plasmas and icy bodies. Numerical modelling of space plasmas is applied to the icy bodies Callisto (a satellite of Jupiter), the dwarf planet Ceres (located in the asteroid main belt) and the comet 67P/Churyumov-Gerasimenko.

The time-varying magnetic field of Jupiter induces currents inside the electrically conducting moon Callisto. These create magnetic field perturbations thought to be related to conducting subsurface oceans. The flow of plasma in the vicinity of Callisto is greatly affected by these magnetic field perturbations. By using a hybrid plasma solver, the interaction has been modelled when including magnetic induction and agrees well with magnetometer data from flybys (C3 and C9) made by the *Galileo* spacecraft. The magnetic field configuration allows an inflow of ions onto Callisto's surface in the central wake. Plasma that hits the surface knocks away matter (sputtering) and creates Callisto's tenuous atmosphere.

A long term study of solar wind protons as seen by the *Rosetta* spacecraft was conducted as the comet 67P/Churyumov-Gerasimenko approached the Sun. Here, extreme ultraviolet radiation from the Sun ionizes the neutral water of the comet's coma. Newly produced water ions get picked up by the solar wind flow, and forces the solar wind protons to deflect due to conservation of momentum. This effect of mass-loading increases steadily as the comet draws closer to the Sun. The solar wind is deflected, but does not lose much energy. Hybrid modelling of the solar wind interaction with the coma agrees with the observations; the force acting to deflect the bulk of the solar wind plasma is greater than the force acting to slow it down.

Ceres can have high outgassing of water vapour, according to observations by the Herschel Space Observatory in 2012 and 2013. There, two regions were identified as sources of water vapour. As Ceres rotates, so will the source regions. The plasma interaction close to Ceres depends greatly on the source location of water vapour, whereas far from Ceres it does not. On a global scale, Ceres has a comet-like interaction with the solar wind, where the solar wind is perturbed far downstream of Ceres.

Keywords
plasma interactions, icy bodies, solar system, space physics, plasma physics, hybrid model, numerical model, solar wind, magnetosphere, sub-Alfvénic, subsonic, non-collisional, atmosphereless, exosphere, coma, subsurface ocean, induction, magnetic dipole, pick-up ion, mass-loading, moon, natural satellite, dwarf planet, comet, Jupiter, Jovian, Callisto, Ceres, 67P, Churyumov-Gerasimenko

Language	ISBN	ISSN	Number of pages
English	978-91-982951-1-5	0284-1703	80 + 4 papers