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Models of Plasma in the Enceladus Plume: Grain Effects

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Abstract

Data from Cassini instruments revealed the existence of a strong interaction between Saturn's magnetospheric plasma and fields and the neutral gas and ice grains in the plume of Enceladus. We will review our understanding of the plume environment, particularly the plasma composition and will discuss how the plasma is affected by ice grains and by the surface of Enceladus. The role of grains in determining the composition and dynamics of the plasma remains poorly understood, but we will discuss this topic using model results. The electron spatial and energy distribution was modeled using a two-stream transport code taking into account electron impact collisional processes. Test particle/Monte Carlo simulations are used to understand the ion distribution functions in the plume for different ion species, taking into account interactions with dust grains.

1. Introduction

Measurements by the Ion and Neutral Mass Spectrometer (INMS) during E2, E3, E5, E7, and other Enceladus flybys [10] demonstrated that the plume contains neutral water vapor plus other species such as carbon dioxide and organic compounds [10]. Plume properties were measured by Cassini Plasma Spectrometer (CAPS) ion and electron sensors (both ions and electrons) [4, 9], by the Langmuir probe (LP) part of the Cassini Radio and Plasma Wave Spectrometer (RPWS) [3], and by the INMS [1, 10]. The Cassini plasma spectrometer detected suprathermal electrons, positive and negative ions [4, 5, 9] and nanometer-sized charged grains [4, 5].

INMS measured the plume ion composition during E3, demonstrating that H_3O^+ (mass 19) is the main ion species. Figure 1 shows a ion mass spectrum measured by the INMS in the plume [1]. Note the dominance of the mass 19 peak (H_3O^+) and also the presence of water cluster ions (H_3O^+ - H_2O and H_2O^+ - H_2O). Micron-sized grains have also been observed near Enceladus, and throughout the E-ring, by the Cassini dust experiment (CDA)(e.g., [8]). CDA investigators have explored the role of grain charging on the distribution of these grains, as well as determining the composition of the grains with important implications for grain origin. The Cassini CAPS detectors observed both positively and negatively charged nano-sized charged grains [4, 5, 9]. The role of grains in determining the composition and dynamics of the plasma remains poorly understood, requiring further work.

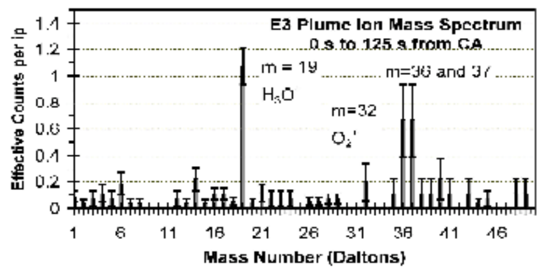

Figure 1: Mass spectrum measured by the Cassini INMS during the E3 Enceladus encounter. Effective count rate versus mass number (in atomic mass units). From Cravens et al. (2009) [1].

2. Models of Electron Distributions

We have studied the electron spatial and energy distributions using our two-stream transport code, both in the Enceladus torus [2] and in the plume [6]. We compared ours results with CAPS ELS (electron spectrometer) data [1]. We also found that the plume electron distribution depends on electron transport from the surrounding inner magnetosphere [6]. Figure 2 shows a model electron spectrum for the E3 plume flyby and comparisons with CAPS ELS data.

We show that photoelectrons produced by the photoionization of plume neutrals by solar radiation account for the electron population for energies greater than a few eV. The good agreement between modeled and measured electron energy spectra in the plume places limits on the dust density.

3. Ion Composition and Ion-Grain Interactions

We are also modeling the ion distribution function and ion composition in the plume using test particle/Monte Carlo simulations of ion trajectories in order to understand the ion distribution functions in the plume for different species and thus explain INMS and CAPS data. Ion production and charge exchange are included. Current results indicate that water group ions in the plume are slow, and thus able to be observed by the INMS. Our current work is starting to explain much of what is observed for plume plasma characteristics, but we have come across issues that our existing models cannot account for, mostly involving the role of ice grains and ice surfaces near Enceladus and how this affects the local plasma. We will present the results of preliminary calculations of ion distribution functions in the plume, taking into account ion-grains collisions.

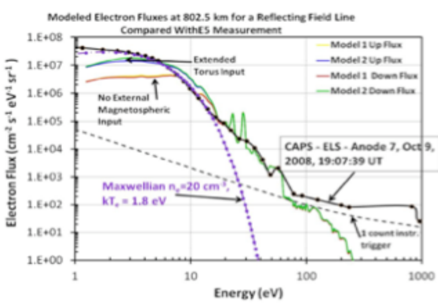

Figure 2: Electron fluxes versus energy in the Enceladus plume from the model and measured by the Cassini CAPS ELS. From Ozak et al. [2012] [6].

4. Summary and Conclusions

This paper will review our understanding of the plume environment, particularly the plasma composition and will discuss how the plasma is affected by ice grains and by the surface of Enceladus. The role of grains in determining the composition and dynamics of the plasma will be discussed with the help of model results of the electron and ion distribution functions for the plume and the Enceladus torus. Comparisons of model results will be made with data from several Cassini instruments.

Acknowledgements

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