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The Enceladus plume, particle impact ionization and Langmuir Probes: How dusty is the plasma in the plume?

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Abstract

Very large differences between ion and electron densities have been reported in the Enceladus plume. This difference is attributed to a high density of charge dust particles. This interpretation is sensitive to the analysis of Cassini Langmuir Probe data and, specifically, to how the current from the charged dust particles are included. We present a reanalysis of these data incorporating both the current from the charged dust particles themselves (as was done in past work) and the current due to the impact-generated plasma.

1. Introduction

All During many Enceladus flybys, the Cassini spacecraft's Langmuir Probe has measured ions and electrons in the Enceladus plume. Previous analysis of these data [1] have suggested that, in the core of the plume, the free electron density is much lower than the ion density, sometimes by over two orders of magnitude. The difference is attributed to charged dust particles within the plume. Particles smaller than a few nanometers in size have been directly measured by the Cassini Plasma Spectrometer, while those larger than a few hundred nanometers have been measured by the spacecraft's Cosmic Dust Analyzer. But the majority of the dust charge is on otherwise unmeasured particles in the few to few-hundred nanometer size range. Dust densities of over 50 particles per cubic centimeter have been reported.

2. Currents from charged dust

Given these dust densities, analysis of Langmuir Probe data must account for the currents produced by the dust particles, as well as the commonly-modeled currents from ions, electrons, secondary electrons, etc. Past work [1] has treated the current from charge on the dust particles, $I_d = q_d\ n_d\ u\ A$. However, dust impacts are also known to produce an ionized ejecta cloud. Depending on the size of the impacting particles, the charge from impact ionization may exceed the charge from the dust particles themselves. Based on laboratory measurements of impacts on typical spacecraft materials [2], and at the 7 to 18 km/s velocities of the Cassini encounters, this transition is at 20 to 90 nm.

3. Langmuir Probe Analysis

Here, we present a reanalysis of Cassini Langmuir probe data, including the current from impact ionization as well as that from the charge on the impacting particles. We also report the resulting correlated uncertainty and non-uniqueness of fits to the data.

References

[1] Morooka M. W., et al.: Dusty plasma in the vicinity of Enceladus, Journal of Geophysical Research, Vol. 116, 10.1029/2011JA017038, 2011

[2] Collette, A., Grün, E, Malaspina, D., and Sternovsky, Z.: Micrometeoroid impact charge yield for common spacecraft materials, Journal of Geophysical Research, 10.1002/2014JA020042, 2014.