EPSC Abstracts
Vol. 11, EPSC2017-818, 2017
European Planetary Science Congress 2017

Resolving the Mass Production and Surface Structure of the Enceladus Dust Plume

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Abstract

There are ongoing arguments with regards to the Enceldaus plume, both on the total mass of ice particles produced by the plume in kg/s, as well as the structure of plume ejection along the tiger stripes. Herein, results from Cassini?s Cosmic Dust Analyzer (CDA) and Imaging Science Subsystem (ISS) are used in conjunction with large-scale plume simulations to resolve each of these issues. Additional results are provided on the short-term variability of the plume, and the relation of specific surface deposition features to emissions along given areas of the tiger stripes.

By adjusting their plume model to the dust flux measured by the Cassini dust detector during the close Enceladus flyby in 2005, Schmidt et al. (2008) obtained a total dust production rate in the plumes of about ∼5 kg/s. On the other hand, Ingersoll and Ewald (2011) derived a dust production rate of 51 kg/s from the total plume brightness. More recently, plasma models and data from the Cassini Plasma Spectrometer suggest a more modest 12 kg/s; however, this result is based solely on nanograins, which make up a small percentage of plume mass. Knowledge of the production rate is essential for estimating the dust to gas mass ratio, which in turn is an important constraint for finding the plume source mechanism.

Here we report on measurements of the plume dust density during the last close Cassini flyby at Enceladus in October 2015. The data match our numerical model for the Enceladus plume. The model is based on a large number of dynamical simulations including gravity and Lorentz force to investigate the earliest phase of the ring particle life span. The evolution of the electrostatic charge carried by the initially uncharged grains is treated self-consistently. Our numerical simulations reproduce all Enceladus data sets obtained by Cassini's Cosmic Dust Analyzer (CDA). Our model calculations together with the new density data constrain the Enceladus dust source rate to < 5 kg/s. Based on our simulation results we are able to draw conclusions about the emission of plume particles along the fractures in the south polar terrain.

In 2014, Porco et al. produced a set of ~ 100 jet locations for the Enceladus plume based on the triangulation of several years worth of images. Spitale et al. (2015) instead suggested a continuous emission along the tiger stripes, demonstrating that some of the jets published in Porco et al. could in fact result from viewing multiple continuous emissions in an overlapping manner. Simulations run herein demonstrate that it is likely both emissions exist and are active, with surface deposition dominated by the continuous, "curtain" emissions, while temporally variable jetting activity likely contributes primarily to the E-ring. Surface deposition patterns from a curtain-style emission are shown to agree well with recent, global color maps of Enceladus, further confirming the accuracy of the underlying model. Surface deposition structure is shown to be robust under changes in model parameters, and certain prominent areas seen in color maps are associated with emission areas of the plume.