EPSC Abstracts
Vol. 7 EPSC2012-17-1 2012
European Planetary Science Congress 2012

Analysis of Cassini magnetic field observations over the poles of Rhea

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We analyze Cassini magnetic field observations from the only two polar flybys of Saturn's largest icy satellite Rhea (R2 on 02 March 2010 and R3 on 11 January 2011) which are scheduled between Saturn Orbit Insertion and the end of the mission in 2017. For the interpretation of these data, we apply estimations from simple analytical models as well as results from numerical hybrid simulations (kinetic ions, fluid electrons) of Rhea's interaction with the incident magnetospheric plasma (see figure 1).

It is demonstrated that although in-situ observations of exospheric neutral gas and pick-up ions suggest Rhea to be embedded in a tenuous gas envelope, the interaction of this gas with the magnetospheric flow does not make any measurable contributions to the magnetic field perturbations detected above the poles of the moon. Instead, the field perturbations observed in these regions mainly arise from the absorption of magnetospheric particles with large field-aligned velocities, impinging on the north and south polar surface of Rhea.

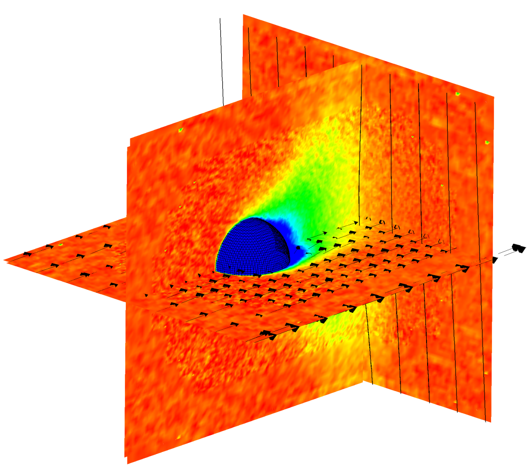

Figure 1: Simulated magnetospheric ion density near Rhea (blue: low, orange: background value).

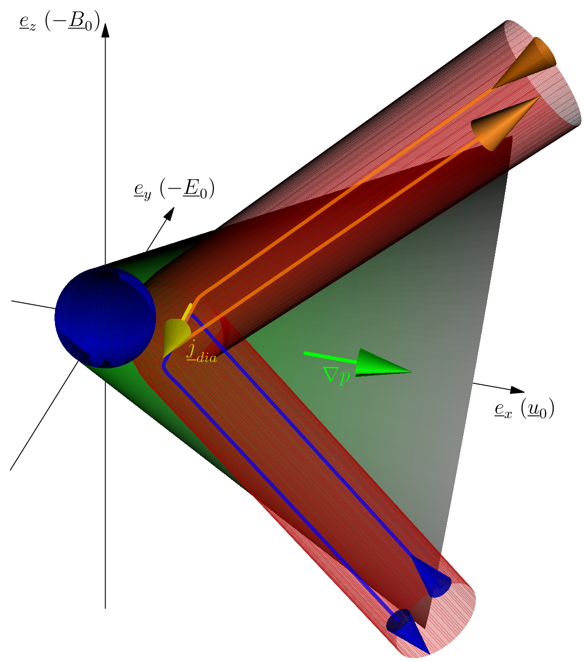

Figure 2: Key elements of Rhea's magnetospheric interaction, as described in this paper. The finite length of Rhea's plasma wake (shaded in green) along the corotational flow direction gives rise to a density gradient ∇p along the positive x axis, corresponding to a diamagnetic current j_{dia} in $(-y)$ direction. This diamagnetic current is (partially) closed by the currents (orange and blue) in a weak Alfvén wing (red tubes), emerging from the regions of depleted plasma density over Rhea's poles and in the wake.

In addition to numerous interaction features known from preceding Cassini flybys of Saturn's plasma-absorbing moons, the magnetic field data acquired above Rhea's poles surprisingly reveal perturbations of the flow-aligned field component, corresponding to a draping/Alfvén wing pattern. Based on our hybrid simulations, we suggest that these signatures arise from the finite extension of Rhea's wakeside plasma void along the corotational flow direction, yielding a density gradient in corotation direction, and thereby generating a diamagnetic current from the Saturn-facing into the Saturn-averted hemisphere of the moon.

This transverse current is responsible for generating a weak Alfvén wing pattern at Rhea which has been detected by the Cassini spacecraft during the R2 and R3 flybys (see figure 2). Due to the large gyroradii of the incident magnetospheric ions, this structure features a pronounced asymmetry with respect to the direction of the convective electric field. Our simulation results, considering only the plasma-absorbing body of the moon, are in good agreement with Cassini magnetometer data from both flybys. At Saturn's icy satellites Tethys and Dione, the low value of the magnetospheric plasma beta most likely prevents the formation of similar currents and measurable flow-aligned magnetic field distortions.