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Cassini-plasma interactions in the Enceladus torus

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This study reports the results of the first simulations of spacecraft-plasma interactions within the proposed Enceladus torus, a radially narrow toroidal region surrounding Saturn that contains a high density of water-group neutrals. Charge exchange collisions scatter these neutrals and replace a fraction of the co-rotating ions with a new and slower-moving ion population. The newly-created ions are moving near the local Keplerian speed, slower than the co-rotation speed, and are "picked-up" by Saturn's magnetic field. These water-group ions are detected throughout the Enceladus torus including regions far from Enceladus [1,2].
Three-dimensional particle-in-cell self-consistent code is applied to find the potential and plasma distributions around the spherical model of Cassini in a complicated plasma environment of the Enceladus torus. The modeling includes two types of water group ions (co-rotating, and non-thermalized pick-up ions), plasma flows, photoemission due to solar UV radiation, and flyby geometry. As input data the parameters derived from the Cassini plasma spectrometer measurements obtained in 2005 on Oct. 11, and 29, Nov. 27, and Dec. 24 [1] are employed. The numerical simulations show that the pick-up ions significantly modify the spatial structure of the plasma perturbations, arising in the vicinity of the orbiter in comparison to that obtained for only co-rotating ions [3]. The plasma species produce a specific strongly inhomogeneous configuration with a self-consistent charge separation between the different plasma components in the electric field of the orbiter. The highly energetic co-rotating water group ions are mainly responsible for the configuration of the plasma wake. The region extending up to a few electron Debye lengths downstream of the spacecraft reveals negative potentials that are a significant fraction of the thermal electron energy. Arising wake electric fields capture the cold, pick-up ions and lead to a strong enhancement of their density in the direct vicinity of the orbiter downstream. Here the ratio of the trapped to primary ion density reaches values of 5. Simulations reveal also the existence of an extended region with extremely low density of the pick-up ions upstream of the spacecraft. The obtained results can be of importance for understanding the main physical processes occurring in Saturn's magnetosphere and for reliable interpretations of Cassini electric field and plasma measurements near the icy moon Enceladus.

[1] R. L. Tokar et al. Geophys. Res. Lett., 35, L14202 (2008).
[2] R. L. Tokar et al. Geophys. Res. Lett., 36, L13203 (2009).
[3] V. V. Yaroshenko et al. J. Geophys. Res., 116, A12218 (2011)