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# Global Magnetospheric Dynamics of Jupiter and Saturn Revealed by ENA Imaging

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## Abstract

Jupiter's magnetosphere is by far the largest object in the sky if it would be visible from Earth. Its stellar-like transfer of angular momentum from the fast rotating planetary magnetic field to the space plasma environment is the engine that makes the Jovian magnetosphere also the biggest planetary particle accelerator within the solar system. Dense plasma originating from the Io and Europa region loads the fast rotating planetary magnetic field, stretching it into a magnetodisk until a multi-step process involving magnetic field ruptures ("reconnection") and plasma instabilities accelerates ions and electrons up to very high energies that bombard the surfaces of moons.

Saturn's magnetosphere and its dynamics is similar to that of Jupiter, but contains more neutral gas and is less corotationally dominated. Its rotation axis is aligned (to within $1^\circ$) with its dipole axis, whereas Jupiter's rotation axis is tilted about $10^\circ$ with respect to its dipole axis. Yet, Saturn's magnetosphere displays periodic phenomena (radio emission, magnetic field, particles) just like Jupiter's. It is therefore of high interest to compare the global dynamics of these two giant magnetospheres.

Energetic Neutral Atom (ENA) imaging is so far the only technique capable of obtaining global images of the magnetospheric energetic ion population in the 3-300 keV range, which otherwise would have remained invisible. The technique is based on detecting the direction, energy and species of ENAs that are produced by charge exchange between singly charged ions and the background neutral gas within the magnetosphere. While the technique has primarily been used to image the global ion distributions, ENA images are also very sensitive to very low neutral gas densities and can provide information on the neutral gas in low-density regions where in-situ measurements are not sufficiently sensitive. ENA cameras on Cassini and the terrestrial IMAGE mission have revealed global, explosive ion acceleration processes and their connection to the ionosphere, aurorae and radio emissions.

In this presentation we report on how ENA images obtained by the Ion Neutral Camera (INCA) on board Cassini has helped us understand the global dynamics and transport of energetic particles in the Saturnian magnetosphere [*Brandt et al.*, 2008] and how they relate to other phenomena such as periodic radio emissions, auroral emissions [*Mitchell et al.*, 2009], and periodic field perturbations [*Khurana et al.*, 2009; *Provan et al.*, 2009; *Brandt et al.*, 2010]

Given the success of ENA imaging at Saturn, we discuss if, and how this success can be repeated by the Europa Jupiter System Mission (EJSM). The Jovian magnetosphere has already been successfully imaged in ENAs by INCA during the Cassini fly-by (closest approach $\sim$120 $R_J$) and it is clear that ENA imaging would potentially provide unprecedented insights in to the quasi-periodic injections [*Woch et al.*, 1998; *Selesnick et al.*, 2001], their interaction with the neutral gas torus region of Europa, and their possible role in controlling the source rates of sputtered material from Europa. However, the Jovian magnetosphere is also a very harsh radiation environment that presents limits to what is technically feasible.

To address these issues, we use past measurements and a data-derived model to simulate ENA images through a realistic camera response function along the EJSM orbits and explore the scientific value added by in-situ and imaging measurements from the additional Jupiter Magnetosphere Orbiter (JMO) considered by JAXA. The presentation is concluded by summarizing the critical technical requirements of ENA cameras, such as energy and mass range, geometrical factor and background/foreground rejection that must be met in order to operate in the harsh Jovian environment while achieving the highest priority science objectives.

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