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Ionosphere-magnetosphere coupling studies with Juno and Cassini proximal orbits

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Abstract

The magnetodisk of Jupiter is dragged into partial cororation with the planet by a current loop that connects the disk to the jovian upper atmosphere via intense field-aligned currents driving the main auroral emissions. Thanks to its unique orbital geometry, Juno will allow for the first time a quantitative study of the characteristics of the three key segments of this circuit. To a large extent, the Cassini proximal orbits will provide a similar opportunity at Saturn. We will describe our plans for a physical study of these three segments and their interconnections, and of the key processes that are at work in the enforcement of magnetospheric corotation and sub-corotation at Jupiter and Saturn.

1. Introduction

Juno offers a unique opportunity to understand how the largest magnetosphere in the solar system works [2]. Here is only one example of the many Juno scientific opportunities.

Figure 1 illustrates the three segments composing the current loop that transfers angular momentum between thermosphere-ionosphere and magnetodisk: Segment A – the plasmasheet/magnetodisk; segment B – the high-altitude auroral field lines: segment C – the auroral thermosphere-ionosphere.

The orbits of Juno will scan through segment A over the duration of the mission. Juno will directly fly through segment B at a variety of altitudes. Finally Juno will fly over the polar and auroral thermosphere-ionosphere and will monitor the auroral emissions. The geometry of Cassini proximal orbits will allow similar encounters with our three key segments. Through the synergistic use of data and models, it will be possible to untangle the key processes in the exchange of momentum between the two ends of our circuit.

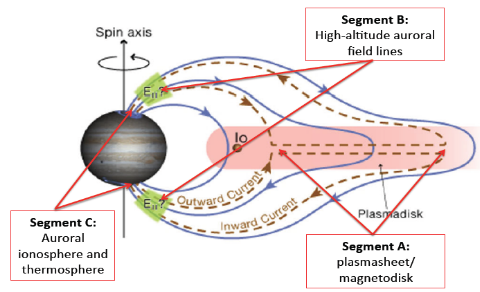

Figure 1: Geometry of the field lines and current loops that connect the magnetodisk to the ionosphere, with the three "key segments" shown.

2. Analysis of the circuit

2.1 The plasmasheet/magnetodisk

While the main "ring" current maintaining the plasmasheet magnetic field in its elongated configuration is azimuthal and produced by the pressure gradient and centrifugal forces, the current that closes the corotation-enforcing current loop is radial (e.g., figure 1). This current, related to the Coriolis force, is directly driven by the net outward radial transport of mass in the disk.

Therefore, to quantitatively evaluate this radial current, one must know first the equilibrium configuration of the plasmasheet, and then observe the different modes of radial transport developing in the disk **[1]** **[5]**. From a comprehensive analysis of these modes it will be possible to evaluate the net radial mass transport. By doing so, we will be able to determine the radial current in the disk (segment A).

2.2 The high-altitude auroral field lines

The closure of magnetospheric currents through the ionosphere involves intense current sheets flowing along field lines. At high altitudes, the Earth example shows that the upward currents are associated with a variety of phenomena organized at different scales: field-aligned precipitating electron beams, transversely accelerated upward-flowing ions, strong field-aligned electric potential drops, density cavities, and radio emissions that seem to develop inside these cavities before propagating in free space. At the largest latitudinal scales these phenomena seem to be controlled by the physics of closure of large-scale currents along field lines, involving a characteristic current-voltage relationship; at the smaller scales, Alfven waves interacting with the density structures would play the dominant role **[4]**.

Data from Juno and Cassini will make it possible to diagnose this host of phenomena for the first time on jovian and kronian auroral field lines, and to establish the integrated current-voltage relationship resulting from the interplay of the different scales.

2.3 The auroral ionosphere and thermosphere

Currents flowing along auroral field lines finally close in the ionosphere. Juno and Cassini will monitor the inputs to this ionosphere/thermosphere system: particle precipitation fluxes, field-aligned currents, and to some extent the intensity and geometry of auroral emissions, which will provide constraints on where and how deep the auroral energy is deposited.

With the help of thermosphere/ionosphere electrodynamic coupling models **[6] [3]**, it will then be possible to use these inputs to calculate the horizontal closure of magnetospheric currents, and the dynamic and thermodynamic response of the thermosphere to auroral forcing. This thermospheric response itself produces a feed back on magnetospheric motions, which will be evaluated **[7]**.

3. Conclusions

The regular Juno orbits, as well as the Cassini proximal orbits, provide a unique opportunity for a comprehensive study of the electrodynamic current loop that connects the plasmasheet/magnetodisk of gas giants to their auroral ionosphere and thermosphere. The three key segments of this current loop will be studied along the orbits, and analysed at a variety of scales to determine the resulting current characteristics. Closure through the ionosphere/thermosphere will be calculated with the support of specifically adapted electrodynamic models, and from that point the whole current circuit will be determined, thus resulting in a proper evaluation of the net transfers of angular momentum and energy between the magnetodisks and the upper atmospheres.

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