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Solar wind and internally-driven motions of Saturn's magnetotail

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Abstract

Saturn's magnetosphere is replete with magnetospheric periodicities. Magnetic fields, plasma parameters, energetic particle fluxes, and radio emissions have all been observed to vary at a period close to that of Saturn's assumed sidereal rotation rate. In particular, periodicities in plasma, energetic particles and magnetic fields in Saturn's magnetotail can be interpreted in terms of periodic vertical motion of Saturn's outer magnetospheric plasma sheet [e.g., Khurana et al., 2009; Jackman et al., 2009; Arridge et al., in preparation]. In this paper the forces driving the motion of Saturn's magnetotail will be examined to better understand the origin of magnetotail motions, both driven internally (e.g. in relation to global periodicities) and controlled externally by the solar wind.

1. Introduction

Periodicities in the outer magnetosphere can be interpreted in terms of a periodic vertical motion of Saturn's magnetodisc [e.g., Arridge et al., 2008a; Khurana et al., 2009; Jackman et al., 2009] perhaps also including periodic thickening of the plasma sheet [Morooka et al., 2009]. Such periodic motion of the plasma has been observed in energetic particles [Carbary et al., 2008b]. Additionally, warping (displacements) of plasma and current sheets in the terrestrial, jovian, saturnian, uranian and neptunian magnetospheres have all been observed by spacecraft. Most recently this has been observed at Saturn using Cassini magnetometer data [Arridge et al., 2008b] and ENA imaging [Carbary et al., 2008a]. This warping is interpreted qualitatively in terms of the interaction between the magnetosphere and the solar wind.

In this study we are interested in quantitatively understanding the forces driving the motion of Saturn's magnetotail. In particular we are interested in understanding: i) how both DC and AC offsets of the plasma and current sheet location arise, ii) how quickly the plasma and current sheet can respond to changes in forcing, and iii) the relationship between forcing and the resulting displacement.

2. Plasma sheet motion

To quantitatively understand vertical motions of the plasma sheet we consider the vertical component of the MHD momentum equation:

$$\varpi \frac{Dv_z}{Dt} = -\frac{\partial p}{\partial z} + j_\rho B_\phi - j_\phi B_\rho \qquad (1)$$

In stress balance the vertical pressure gradients are balanced by vertical magnetic stresses. The imposition of perturbation fields B_ρ' and B_ϕ' can then produce additional accelerations. In this poster we consider the perturbation fields that are generated by solar wind dynamics and inside the magnetosphere by periodic mechanisms. The equation of motion for the plasma sheet is then solved to understand how the plasma sheet responds to changes in these perturbation fields. Stress-balanced configuration models are used as a basis for these studies (Achilleos et al., 2010).

Calculations of time constants for plasma sheet response compare favourably with observations. Although self-consistent calculations should be performed. Flapping (wavy magnetodisc) models [e.g., Arridge et al., in prep.] imply vertical plasma sheet accelerations of <5 m/s. Perturbation fields of around 0.5 nT are sufficient to produce this acceleration. The theoretical development that will be described in the poster helps explain why apparently thicker more dipolar field configurations might not flap as effectively (as inferred by Arridge et al., [2008b]) as thin current sheets. In the thicker case the current sheet has a smaller current density and hence smaller **j**×**B** force for the same perturbation field strength.

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