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Rotational periodicies in Saturn's magnetosphere: A theory of coupled thermospheric and magnetodisk oscillations

Frank Crary
University of Colorado, Laboratory for Atmospheric and Space Physics, Boulder, United States (fjcrary@gmail.com)

Periodic phenomena have been observed in virtually all measurements of Saturn's magnetosphere, including auroral radio emissions and plasma waves, magnetic field perturbations, plasma density and flow, energetic particles and energetic neutral emissions. These phenomena share two common periods, which are close to the rotation rate of the planet and which vary by a few percent over the course of months and years. The origin of this periodicy is unclear, especially given Saturn's highly symmetric magnetic field.

A magnetospheric source, associated with the production and transport of plasma near Enceladus, has been proposed (e.g. Gurnett et al., 2007, Goldreich and Farmer, 2007.) Such an magnetospheric system does not easily explain the long-term stability (varying by only a few percent) and apparent coupling to the planetary rotation rate. Processes in the neutral atmosphere or ionosphere have also been suggested (e.g. Gurnett et al., 2009) and Jia et al., 2012, recently modeled this by simulating the magnetospheric response to an imposed, m=1 vortex in the ionospheric flow pattern. However, the origin of such a vortex is not clear, and the model required very large thermospheric speeds.

The theory presented here is one of natural modes in both the neutral thermosphere and the magnetodisk. Such global oscillations are known to exist in planetary atmospheres. A Rossby mode of order five or six and degree one, in Saturn's thermosphere, would probagate westward at a few percent of the planetary rotation rate and have a structure similar to that modeled by Jia et al. A global m=1 MHD mode may also exist in a rotating magnetodisk. There exists a radial wave number for which the period and phase velocity match that of the thermospheric Rossby mode. These global oscillations, with matching frequencies/azimuthal phase velocities, would efficiently couple. Relatively weak forcing from the magnetosphere could drive the thermospheric mode. The large angular momentum of the thermosphere could sustain the coupled oscillation despite perturbations to or disruptions of magnetospheric circulation.