Final Progress Report: "Asymmetries and Variations in Jupiter's magnetosphere"

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Progress made during the 3-year investigation

The investigation was carried out to infer the influence of solar wind on Jupiter's magnetosphere through studies of asymmetries and variations in the magnetosphere. We used the magnetic field observations from all of the pre-Galileo spacecraft and from the Galileo Prime and extended missions to understand asymmetries in magnetic field and various current systems in the magnetosphere.

In the first investigation resulting from this work, we computed the electric current density in the equatorial plane of Jupiter's magnetosphere by making certain appropriate assumptions. We found that in the middle magnetosphere, the azimuthal currents are much stronger on the nightside (~ 144 MA between the radial distances of 10 and 50 R_J) than they are on the dayside (~ 88 MA in the same distance range). From current continuity considerations, we concluded that the nightside partial ring current is fed and emptied by field-aligned currents in the dusk and the dawn sectors, respectively. These currents are similar (but opposite in polarity) to Region 2 field-aligned currents observed in the Earth's magnetosphere. Because, the presence of Region 1 or Region 2 sense field-aligned currents in a magnetosphere indicates the presence of solar wind driven convection in a magnetosphere, a surprising conclusion of the present analysis is that the solar wind influence reaches deep into the heart of Jupiter's magnetosphere. Other findings of this study were: (1) The equatorial field strength is remarkably constant over all local times; (2) The equatorial source of the outward field-aligned currents required for the generation of aurorae is located between the radial distances of 10 and 30 RJ with a peak near 20 RJ; (3) The Jovian magnetosphere displays a magnetic field configuration intermediate to a Parker spiral and a magnetosphere driven by solar wind. This work was published in a JGR article in 2001 [Khurana, 2001]

In the second investigation resulting from this work, we examined how the configuration of the magnetic field in the dusk sector of the Jovian magnetosphere varies with distance from the equatorial current sheet. For roughly 30 hours in December 2000, the Jovian plasma sheet was displaced northward of its normal near-equatorial position, leaving Galileo in the southern magnetic hemisphere for several planetary rotations. During this fortuitous event, the orientation of the field varied systematically in a way that enabled us to describe how the magnetic structure varies with distance from the current sheet. We found that the changing twist out of meridian planes is consistent with flows that lag corotation near the equator and lead corotation at higher latitudes. For 1930-2000 LT, the field-aligned current needed to account for the changing twist out of meridian planes flows toward Jupiter's ionosphere at distances beyond 100 R_J. The currents are consistent both qualitatively and quantitatively with the expectation that currents flowing from the Jovian ionosphere toward the equator within 30 R_J return to the ionosphere from the equator at large radial distances. The total current into the auroral ionosphere is of order 10 MA and this current flows into a narrow band of latitude (<2°)

poleward of the main auroral oval. The analysis accounts for the differing field orientations reported from the Galileo observations near the equatorial plane and those reported at higher latitudes from Ulysses. The shear in the azimuthal field component was found to be consistent with the presence of possibly ~10 MA field-aligned currents flowing from the current sheet into less than 2° of latitude in the Jovian ionosphere poleward of the zone of equatorward current flow associated with the main oval. This work was published in a JGR article [Kivelson, Khurana and Walker, 2002].

In the third investigation, magnetometer data acquired as the Galileo Orbiter apoapsis rotated from dawn to dusk across the magnetotail of the Jovian magnetosphere between late 1995 and the end of May 2000 were used to characterize the magnetic field and the distribution of magnetic pressure in the inner part of the Jovian magnetotail. The distances probed extend to ~150 R_J or roughly three times the distance to the nose of the magnetopause, analogous to distances within 30 R_E in the magnetotail of Earth. The magnetic pressure in the center of the plasma sheet is typically almost an order of magnitude smaller than the lobe pressure, which therefore is roughly equal to the peak thermal plasma pressure in the plasma sheet. The pressure decrease with radial distance can be described roughly as a power law with an exponent of –2.8, and the maximum field magnitude decreases with distance to the 1.4. We argue that near 150 R_J, only about 30% of the magnetic flux remaining in the lobes closes across the plasma sheet beyond 150 R_J. Systematic asymmetries of the field structure and magnetic pressure across the midnight meridian in the region beyond 25 R_J downtail are notable, with the flux tubes being less stretched (with larger equatorial Bz) near dusk than near dawn. The lobe pressure attains its minimum value in the dusk sector where the plasma sheet magnetic pressure maximizes. The properties of the magnetotail inferred from its average magnetic structure provide constraints that should prove useful for developing theoretical interpretations of the plasma processes of importance and for testing magnetohydrodynamic models of the Jovian magnetosphere. In particular, models that require reconnection in the magnetotail as an important aspect of the global dynamics [Khurana, 2001, Vasyliunas, 1983; Walker et al., 2001] must account for the structure and the asymmetries reported here. This work was published in a JGR article [Kivelson and Khurana, 2002].

The research work resulting from this proposal also inspired an invited review article on the subject and will appear in Khurana [2004].

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Talks presented at scientific meetings

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