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Angular momentum transfer and rotational effects in planetary magnetotails and polar caps

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In magnetospheres of rapidly rotating planets (e.g., Jupiter, Saturn), significant effects of planetary rotation are possible both within the polar cap (here taken to be the region of the ionosphere where the magnetic field lines extend into the lobes of the magnetotail) and within the magnetotail itself. Corotation of the neutral atmosphere at ionospheric altitudes tends to drag the plasma (by collisions); the resulting plasma motion deforms the magnetic field, producing currents that flow horizontally in the ionosphere and connect to vertical, predominantly Birkeland (magnetic-field-aligned) currents — in one direction over most of the polar cap, and in the opposite direction at its boundaries, closing somewhere in the outer magnetosphere/magnetotail/magnetosheath. The $\mathbf{J} \times \mathbf{B}$ force in the ionosphere implies a torque both on the neutral atmosphere (tending to slow down its corotation) and on magnetic flux tubes emanating from the polar cap. The net result is tranfer of angular momentum from the corotating neutral atmosphere upward along the magnetic field lines; above the ionosphere, the angular momentum flux density is essentially the Maxwell stress tensor $\times\mathbf{r}$. One possible result is to twist the field lines of the magnetotail; this has been modeled mostly by analogy to the Parker spiral in the solar wind, which is questionable because the ratio magnetic/plasma energy density in the magnetotail is drastically different from that in the solar wind. An aspect that so far does not seem to have received any attention is that, because magnetic field lines turn from nearly vertical at the polar cap to nearly solar-wind-aligned in the magnetotail, the angular momentum must correspondingly turn by $\sim 90°$; this requires appropriate torques, which can be shown to imply significant (mainly dawn-dusk) asymmetries in either the configuration of the magnetotail, the distribution of currents and disturbance fields in the polar cap, or both.