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Physics of corotation in planetary magnetospheres

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Corotation results from the stress exerted on the plasma by the flow of the neutral atmosphere, acting through collisions between neutral and charged particles. The rotational motion that is directly involved is thus the rotation of the neutral atmosphere at ionospheric altitudes, related only indirectly to the rotation of the planet (through tangential drag that couples the upper atmosphere to the planet) and not at all to the rotation of spatial patterns (e.g. asymmetric magnetic field of a tilted dipole). The degree of corotation is governed by the relative strength of the collisional stress on the plasma in the ionosphere (proportional to the velocity difference between plasma and neutral atmosphere) compared to the inertial and thermal stress of the plasma in the magnetosphere, each being balanced by the magnetic stress in the respective region. Considering the ratio of plasma stresses in the ionosphere and in the magnetosphere and also the topology of the magnetic field, we can roughly divide the magnetosphere into three regions. (1) In the inner magnetosphere, the field lines are closed and ionospheric stresses are dominant. The plasma flow is nearly rigid corotation, possibly combined with interchange motions (magnetospheric convection); the combination of the two produces a topological flow boundary that gives rise to the plasmasphere. (2) In what is called, depending on context, either the middle or the outer magnetosphere, the field lines are still closed but the magnetospheric stresses are comparable to or even much larger than those in the ionosphere. The plasma flow becomes markedly sub-corotational and eventually is dominated by purely magnetospheric dynamical processes. Within this region, energy is extracted from planetary rotation by the magnetosphere, and auroral particles are accelerated at the Birkeland currents associated with the stressed magnetic field; both processes are of importance particularly in the magnetospheres of Jupiter and Saturn. (3) Within the lobes of the magnetotail, the local magnetospheric stresses again become negligible compared to those in the ionosphere, but the field lines are now open and (presumably) connected to the solar wind plasma, which is dense enough to be essentially unaffected by any

stresses from the magnetosphere; the plasma flow is governed entirely by the magnetic connection to solar wind flow, and any rotational effects appear only as a consequence of the deformation of the magnetic field by stresses at the polar cap ionosphere.