A Hierarchy of Magnetospheres: From Crustal Remanence to Dynamo Driven

Chris T. RUSSELL

Institute of Geophysics and Planetary Physics and Department of Earth and Space Sciences, University of California, Los Angeles, CA, USA

The solar system presents the flowing magnetized plasma of the solar wind with a plethora of potential magnetic obstacles, from small magnetized rocks to rapidly rotating gas giants with dynamic magnetospheres. At the shortest scales, the ion inertial length and the ion gyroradius control whether and how strongly the solar wind will be deflected by the body and the nature of the waves produced in the interaction. Near Earth, a 100 km magnetic anomaly on the moon can deflect the solar wind, forming a limb compression, while at Saturn, a similar deflection by Iapetus requires an obstacle the size of the moon. Despite the supersonic nature of the flow, in neither case is a collisionless shock formed because the scale size of the interaction is close to the ion kinetic scale.

Once an obstacle to the solar wind flow is of the size of Mercury's magnetosphere relative to the ion-gyro scale, a bow shock will form. The strength of that shock increases greatly with heliocentric distance, altering the properties of the plasma that interacts with the magnetospheres downstream, and changing the nature of the interaction. The stronger shocks produce higher plasma betas and the coupling of the solar wind to the magnetosphere weakens greatly with distance from the Sun. Thus Jupiter and Saturn are less able to tap the solar wind energy flow. They can more than compensate for this loss because they have moons that create ion tori that in turn can extract rotational energy from the planets' interiors, leading to disk-shaped magnetospheres with very dynamic behavior.

Not all obstacles to flowing plasmas are produced by steady magnetic fields intrinsic to the obstacle. A number are produced by induction, the production of a transient current in a conductor by a time varying magnetic field. Venus and Mars have the most studied induced magnetospheres which shield their ionospheres and upper atmospheres from the solar wind and its varying magnetic field. Saturn's moon Iapetus also interacts strongly with the solar wind. Inside the jovian magnetosphere, both Europa and Callisto have induced magnetospheres which are created by the unsteady component of the magnetospheric field. Perhaps the most enigmatic magnetosphere is that of Ganymede, totally encased within the jovian magnetosphere, and buffeted by Jupiter's corotating plasma. But is Ganymede's magnetic field self-sustaining, driven by internal currents, or is it simply an amplification of Jupiter's field by the conducting fluids circulating in the interior of Ganymede? Overall, with its wide variety of scales and plasma conditions, the solar

system provides a rich hierarchy of magnetospheres, ample fodder for comparative studies that can bring deep understanding of the processes within.