Extreme Solar Wind – Planetary Coupling at Mercury

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Mercury's magnetosphere is formed by the interaction of the solar wind with its small (~ 200 nT–R_M^3) intrinsic magnetic field. The mean altitude of the subsolar magnetopause is only ~ 0.5 R_M. Induction currents in Mercury's highly conducting iron core resist the compression of the magnetosphere during coronal mass ejections. The contribution of these induction currents has been observed to increase the planetary magnetic moment by as much as ~ 25% (to ~ 250 nT–R_M^3). Although the weak conductivity of Mercury's regolith severely limits field-aligned current intensity, Region 1 currents driven by the solar wind interaction have been measured with intensities up to several tens of kilo-Amperes. These currents flow radially through Mercury's thin (~ 400 km) regolith to close across its iron core.

Magnetic reconnection at Mercury's magnetopause is far more frequent and intense than at Earth. The underlying reason is the low Alfven Mach number of the solar wind at Mercury. Under these upstream conditions, a thick plasma depletion layer forms adjacent to the magnetopause and it enables fast, symmetric reconnection, even for small magnetic shears. "Showers" of flux transfer events (FTEs) consisting 100+ small flux ropes are seen during a single magnetopause traversal. These FTEs are encountered near or above the magnetopause and they connect to the cusp plasma filaments within the magnetosphere. These cusp filaments are formed by reconnection-driven solar wind inflow and they map to Mercury's surface in the vicinity of the cusps. During deep erosion events the rate of transfer of magnetic flux from the dayside magnetosphere is so great that the dayside magnetosphere disappears and the solar wind has direct access to the surface on Mercury's dayside.

Mercury's surface-bounded exosphere is maintained by sputtering and other surface interactions that eject neutrals from the regolith. The direct access of the solar wind to the surface via cusp filaments and deep erosion events is expected to enhance sputtering and it may explain the exospheric variability observed by ground-based telescopes. The plasma within Mercury's magnetosphere is primarily of solar wind origin (H^+ and He^{++}) with Na^+ and other heavy planetary ions, derived from the exosphere, making up ~ 1 to 10% of the magnetospheric plasma. H^+ and Na^+ injected into the cusp by dayside reconnection are observed to mirror and enter the high-latitude magnetotail where they form the plasma mantle. Kelvin-Helmholtz waves on the magnetopause are observed at all of the planets. However, in the case of Mercury these waves are found primarily on the dusk-side magnetopause. The reason for this curious asymmetry is not understood, but the possible explanations all involve the dynamics of the Na^+ ions at the magnetopause.

Magnetic flux loading and unloading of Mercury's magnetotail is observed with durations of ~ 2 to 3 mins and amplitudes up to a factor of 2. These cyclic changes in magnetospheric configuration at Mercury strongly resemble the substorms seen at Earth. Early in the unloading phase the near-Mercury magnetic field is observed to dipolarize and flux ropes form in the cross-tail current layer just as seen during terrestrial substorms. Energetic particle acceleration in the Earth's magnetotail is a defining feature for magnetospheric substorms. Charged particles, especially electrons, are accelerated in the vicinity of reconnection X-lines, at the leading edges of dipolarization fronts and within magnetic flux ropes in the magnetotail. Although the situation at Mercury and Earth differ with respect to the final energies attained, similar charged particle acceleration processes appear to operate within both magnetospheres.