The Moon: A Unique Laboratory for Study of the Fundamental Physics of Magnetized Collisionless Plasmas. R. P. Lin[1,2], J. S. Halekas[1], G. T. Delory[1], S. D. Bale[1,2], D. Krauss-Varban[1], M. Oieroset[1], T. Phan[1], [1]Space Sciences Laboratory, University of California, 7 Gauss Way, Berkeley, CA 94720-7450; [2] Physics Department, University of California, Berkeley, CA 94720-7300.

The discovery of lunar magnetism was a major scientific surprise of the Apollo program. Solving the enigmas of this remanent field will provide fundamental insights into the thermal history of the lunar core/dynamo and crust, and into the process of magnetization and demagnetization in large basin-forming impacts. The Moon does not have an active core dynamo. However, like Mars, it has numerous localized remanent crustal magnetic regions distributed over its surface, with a spatial scale of a few kilometers well below the solar wind thermal ion gyro-diameter, to a few hundred kilometers, large enough to produce shocks for some solar wind conditions (Colburn et al., 1971; Russell and Lichtenstein, 1975; Lin et al., 1998; Halekas et al., 2006). The existence of these regions points to the presence of strong magnetizing field in the past (Hood et al., 2001; Halekas et al., 2001).

The behavior of collisionless plasmas at the transition from kinetic (particle) to fluid scales is a research topic of fundamental important in plasma physics, especially for astrophysical plasmas. The interaction of solar wind, magnetosheath, and magnetotail plasmas with the Moon is important for fundamental (space) plasma physics studies. First, the Moon has numerous patches of surface magnetic fields, ranging in size from kilometer scale, well below the solar wind thermal ion gyro-diameter, to hundreds of kilometers, large enough to produce fluid magnetohydrodynamic (MHD) behavior (Colburn et al., 1971; Russel and Lichtenstein 1975; Lin et al., 1998; Halekas et al., 2005b). Thus, studies of the plasma interactions with these magnetic patches allow us to explore the fundamental physics of the transition from kinetic to fluid (MHD) scales and the related phenomena of shock formation. The Moon appears to be the only place where we can conduct these studies. In the plasma interactions with crustal fields, the ions decouple from the magnetic field first (an ion diffusion region) because of their much larger gyroradii, and then (depending on crustal field scale size) the electrons may also decouple. This behavior is thought to be similar to many fundamental collisionless plasma phenomena, such as magnetic reconnection, magnetopause, and shock formation.

The energy coupled from the solar wind into the Earth's magnetosphere goes primarily into the formation of a long (>200 Re) magnetotail. The dynamical behavior of the Earth's distant magnetotail, where about half of the total energy coupled into the magnetosphere from the solar wind is stored, is completely different from the near-Earth [<30 Earth radii (Re)] tail and is presently not understood. In the near-Earth magnetotail (<30 Re), the stored energy is released in transient substorms, but the distant tail undergoes near-continuous magnetic reconnection. Magnetic reconnection occurs nearly continuously in the distant magnetotail. Thus, despite the sparse spacecraft coverage, the Earth's magnetotail provides some of the best measurements possible of the reconnection process (Oierset et al., 2001, 2002). Magnetic reconnection in the distant magnetotail is physically different (Egedal et al., 2005) from that which occurs in other environments, and it is associated with the acceleration of electrons to energies of hundreds of kiloelectron volts (similar to what is observed fro solar flares). Observations around the Moon

as it traverses the Earth's distance magnetotail have unique advantages for understanding the physics of the essentially unexplored and poorly understood region.
Observations in the lunar environment thus provide a probe for fundamental plasma physics and magnetospheric physics. In addition, lunar shadowing of ambient electrons provides a unique and powerful probe of the topology and convection belocity of magnetic fields (McCoy et al.,1975; Lin et al, 1977). The Moon spends ~5 days each month crossing the distant magnetotail, enabling the extensive observations needed to understand the physics. Observations at lunar orbit are also ideal for studying the dynamics of plasmoids that travel down the Earth's magnetotail after a substorm occurs closer to Earth.

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