KINETIC MODELING OF THE MOON-SOLAR WIND PLASMA INTERACTION.

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Introduction: A renewed interest in lunar exploration in the last two decades and proposed manned missions to near-earth asteroids demand deep understanding of the plasma environment around these objects. The physics of the solar wind plasma interaction with the Moon is very dynamic and complex [1]. In addition to in-situ plasma and field measurements at the Moon (i.e., ARTEMIS), a three-dimensional kinetic model of the lunar plasma environment is a necessary and complementary tool for understanding this complex interaction. We have used a three-dimensional self-consistent hybrid model of plasma (kinetic ions, fluid electrons) to understand the details of the Moon-solar wind plasma interaction. Our model has been extensively used for this context and validated through comparison with WIND, Lunar Prospector, and ARTEMIS observations [2,3,4].

Lunar plasma wake: Due to the lack of a global intrinsic magnetic field and dense atmosphere most of the solar wind ions impacting the lunar surface are absorbed by the Moon. This forms a wake structure downstream and leaves a plasma cavity behind the Moon [1,5]. Our hybrid simulations have provided detailed structures of the lunar wake [2]. Consistent with observations, we showed that the structure of the wake is highly controlled by the direction of the interplanetary magnetic field (IMF), plasma thermal pressure, and solar wind beta [2,4]. We also modeled the lunar wake current systems and examined the effects of IMF changes on the topology of the wake currents [6].

Plasma interaction with magnetic anomalies: Lunar crustal fields are extensively spread over the entire lunar surface with various field intensities [1]. We have used our hybrid model to understand the physics of plasma interaction with lunar magnetic anomalies on global and local scales [7,8,9]. Consistent with observations we showed that the lunar crustal fields are, for typical solar wind conditions, not strong enough to form a bow-shock upstream but rather reflect plasma and drive compressive interactions [7]. Compressed magnetic fields form upstream above strong crustal fields and convect downstream in the vicinity of the lunar wake, forming limb compressions [7]. We also examined the effects of solar wind dynamic pressure on plasma interaction with localized crustal fields near the Gerasimovich crater [8]. Our simulations suggested that Gerasimovich mostly deflects solar wind plasma during low dynamic pressure, while a large reflection (over 20% as shown in Figure 1) is expected during high dynamic pressure. This is due to the different electrostatic potentials built up under various dynamic pressure [8]. In addition, we used our hybrid model to examine different source magnetizations for the Reiner Gamma magnetic anomaly [9]. We characterized the plasma interaction with these fields and compared plasma precipitation flux to the surface with optical albedo measurements of Reiner Gamma. The model results constrained the proposed source magnetizations for Reiner Gamma and suggested that vertical crustal magnetic fields are required to produce the observed albedo patterns for Reiner Gamma [9].

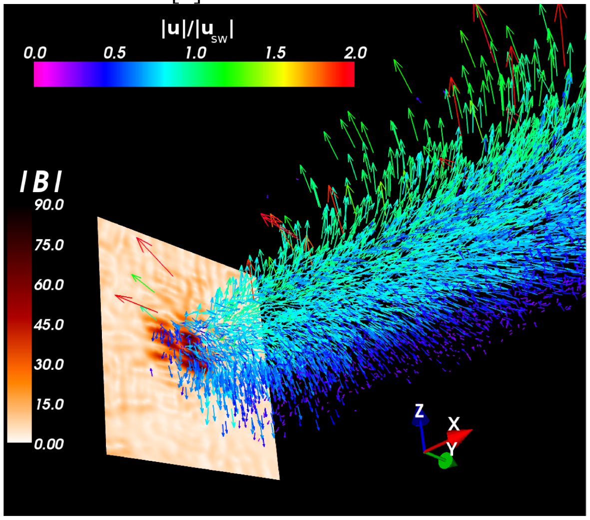

Figure 1. A snapshot of solar wind plasma reflected from the Gerasimovich magnetic anomaly (From [8]).

Lunar interior structure: One of the most fundamental yet unanswered questions in lunar science is the structure and conductivity of the lunar interior. Our hybrid model is capable of answering this question. Recently, we examined the effects of plasma interaction and lunar wake on the confinement of the induced magnetic fields on the lunar day side and night side [10]. We showed that the induced fields are confined on the day side, but in contrast to previous work, they are not confined within the lunar wake, and may penetrate outside the wake [10].

References: [1] Halekas J. et al. (2011) *PSS, 59(14)*. [2] Holmström M. et al. (2012) *EPS, 64(2)*. [3] Fatemi S. et al. (2012) *JGR, 117(A10)*. [4] Poppe A. et al. (2014) *GRL, 41(11)*. [5] Lyon E. et al. (1967) *JGR, 72(23)*. [6] Fatemi S. et al. (2013) *GRL, 40(1)*. [7] Fatemi S. et al. (2014) *JGR, 119(8)*. [8] Fatemi S. et al (2015a) *JGR, 120(6)*. [9] Poppe A. et al. (2016) *Icarus, 266*. [10] Fatemi S. et al. (2015b) *GRL, 42(17)*.