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Computer Simulations on Long-Range Influences of Space Plasma Interactions with Airless Planetary Bodies

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The interaction between space plasma and airless solid bodies is one of the outstanding problems in the space science community, in the context of its application to understand the plasma environment near the terrestrial and Martian moons, asteroids, spacecraft, and small dust grains. A solid object immersed in space plasma absorbs most of the incident plasma electrons and ions, and also releases charged particles. Consequently, the object in space will get electrically charged. The solid surfaces and electric potential of the object also alter the dynamics of charged particles in its vicinity, giving rise to a sheath or wake around it, where the plasma quasi-neutrality is locally broken. It is generally believed that the spatial extent of such non-neutral regions is characterized by the Debye length, the shortest characteristic length in the plasma.

The presence of a solid object not only breaks down the charge neutrality but also modifies the velocity distribution function (VDF) of a plasma in contact with the object surface. This is attributed to a particular role of the object as a “plasma sink”, where impacting charged particles are captured by its surface and removed from the plasma space. Depending on the geometric shapes of the solid surfaces, this boundary effect has the ability to produce loss-cone, loss-conics, an effective temperature anisotropy, non-gyrotropic, or further complicated VDFs.

Our particular interest is on a magnetized plasma in contact with solid bodies, whose dimensions (D) are greater than the average electron gyroradius (ρ_{eg}) of the environment. Attributed to the strong magnetization of the electrons, electric and VDF perturbations generated at the solid surface will survive for a long distance along the magnetic field lines and extend much farther than the local Debye length of the plasma. Such sufficient spatial ex- tent of the disturbance will support wave-associated phenomena generated away from the bodies. The considered condition ($D > \rho_{\mathrm{eg}}$) will be met for some types of solar-system bodies such as the terrestrial and Martian moons in the solar wind, as well as manmade spacecraft in the ionospheric plasmas. In fact, plenty of low-frequency wave activity has been identified by satellite observations in lunar precursor regions [1]. We study the plasma and wave environment near airless solid bodies based on the particle-in-cell numerical simulations. We will discuss the technical issues, and preliminary numerical results showing the “electron wings” [2] and electrostatic waves associated with plasma cavities as well as electromagnetic waves above a solid surface.

1. Y. Harada, and J. S. Halekas, “Upstream Wave and Particles at the Moon” Low-Frequency Waves in Space Plasmas, (eds A. Keiling, D.-H. Lee and V. Nakariakov), 2016, doi:10.1002/9781119055006.ch18.

2. Y. Miyake, W. J. Miloch, S. H. Kjus, and H. L. Pécseli, “Electron Wing-like Structures Formed at a Negatively-charged Spacecraft Moving in a Magnetized Plasma” Journal of Geophysical Research: Space Physics, 124, 2019, doi:10.1029/2019JA027379.