The plasma wake downstream of lunar topographic obstacles: Preliminary Results from 2D Particle Simulations

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Summary

Anticipating the plasma and electrical environments in permanently shadowed regions (PSRs) of the moon is critical in understanding local processes of space weathering, surface charging, surface chemistry, volatile production and trapping, exo-ion sputtering, and charged dust transport. In the present study, we have employed the open-source XOOPIC code [1] to investigate the effects of solar wind conditions and plasma-surface interactions on the electrical environment in PSRs through fully two-dimensional particle-in-cell simulations.

By direct analogy with current understanding of the global lunar wake (e.g., references [2–5]) deep, near-terminator, shadowed craters are expected to produce plasma "mini-wakes" just leeward of the crater wall [6]. The present results (e.g., Figure 1) are in agreement with previous claims that hot electrons rush into the crater void ahead of the heavier ions, forming a negative cloud of charge. Charge separation along the initial plasma-vacuum interface gives rise to an ambipolar electric field that subsequently accelerates ions into the void.

However, the situation is complicated by the presence of the dynamic lunar surface, which develops an electric potential in response to local plasma currents (e.g., Figure 1*a*). In some regimes, wake structure is clearly affected by the presence of the charged crater floor as it seeks to achieve current balance (i.e. zero net current to the surface).

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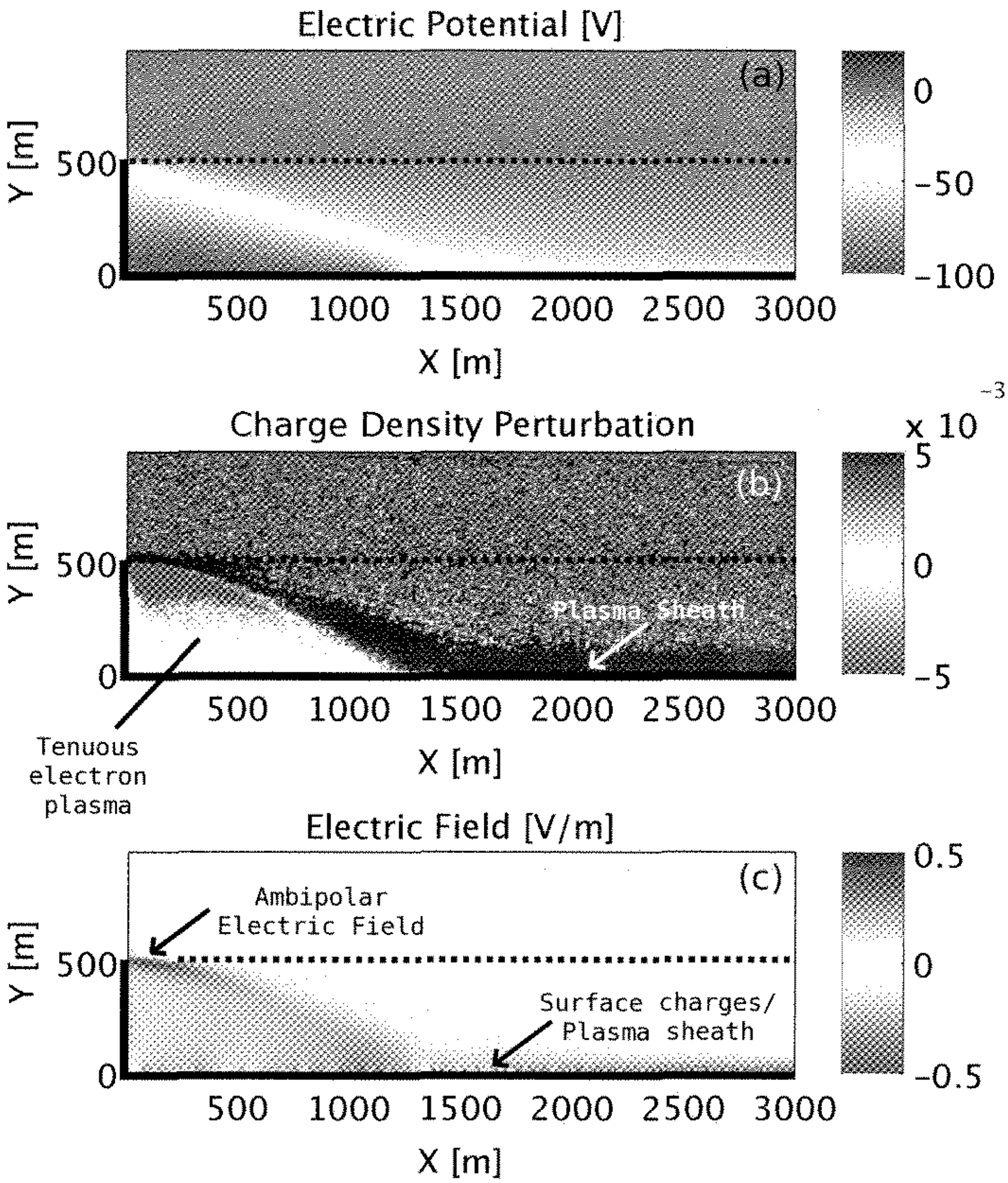

Figure 1: Fully 2D simulated plasma wake structure in a polar topographic depression. The lunar surface is denoted by a thick black line, and the initial plasma-vacuum interface is depicted as a dashed black line. Solar wind plasma flows from the left above a height of 500 m, with bulk plasma conditions $h_{crater}/\lambda_{De} \sim 50$, $v_{the}/v_{sw} \sim 5$, and $v_{thi}/v_{the} \sim sqrt(m_e/m_i) \sim 0.02$, where $h_{crater} = 500$ m is the crater depth and $v_{sw} = 400$ km/s is the solar wind convection speed. Thermal electrons initially rush into the wake ahead of the more massive ions (panel b), forming an ambipolar electric field just leeward of the crater wall (panel c) that serves to accelerate ions into the void. Large negative electric potentials occur where only the most energetic electrons can escape the bulk solar wind plasma, and surfaces exposed only to electrons charge highly negative (panel a).