Three-dimensional particle-in-cell simulations of the lunar dusty plasma environment

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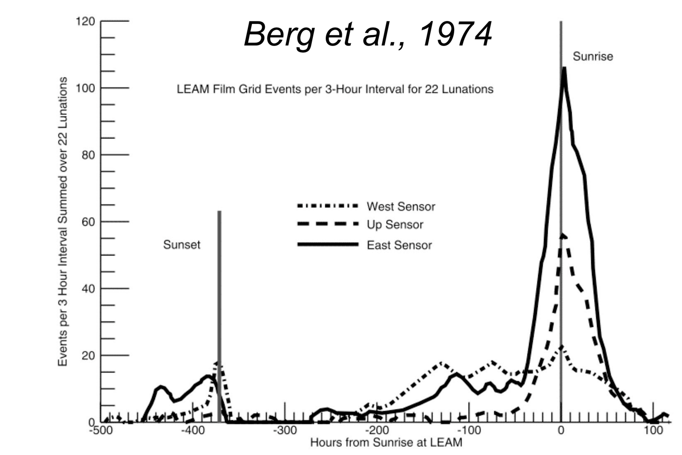
Abstract

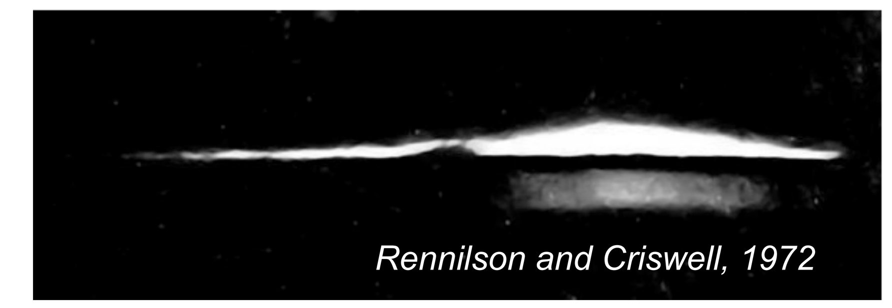
The lunar surface represents a complex plasma environment due to presence of incoming solar UV radiation, the impinging solar wind flux and micron-sized dust particles. The solar UV radiation will cause lunar dust to photoemit electrons and thereby create a photoelectron sheath immediately above the lunar surface. This sheath may represent a mechanism for the levitation of lunar dust, as observed by Apollo astronauts and the Lunar Ejecta and Meteorites Experiment (LEAM). Additionally, lunar surface relief, provide by boulders and craters is expected to result in "supercharging" of the lunar surface. A 3-dimensional particle-in-cell (PIC), VORPAL©, has been applied to various geometries on the lunar surface in order to investigate the possibility of supercharging. Initial simulations have focused on the role of craters and oblique UV/solar wind incidence in shaping the lunar surface plasma environment.

Motivation



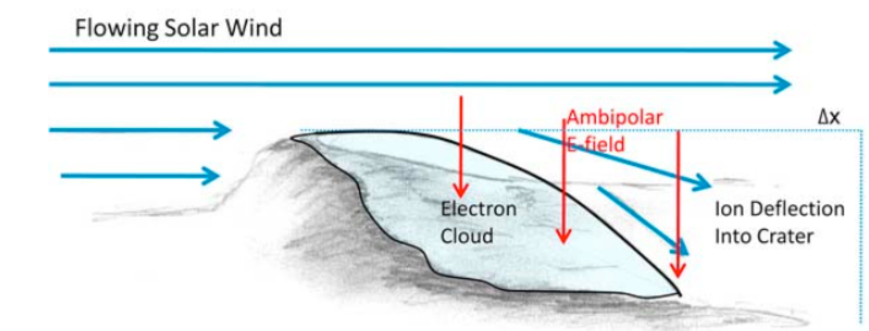
Lunar Ejecta and Meteorites Experiment

The LEAM experiment, deployed by the Apollo 17 astronauts, detected highly-charged dust grains moving horizontally across the lunar surface (<1m). These detections were clustered around the sunrise and sunset terminators.



Surveyor Images of Horizons Glow

Cameras on board the Surveyor 5,6 and 7 spacecraft detected "excess brighness", or Lunar Horizon Glow, shortly after local sunset. This phenomena could be caused by levitated or "hopping" dust grains at a height of less than 1m.



Farrell et al., 2010

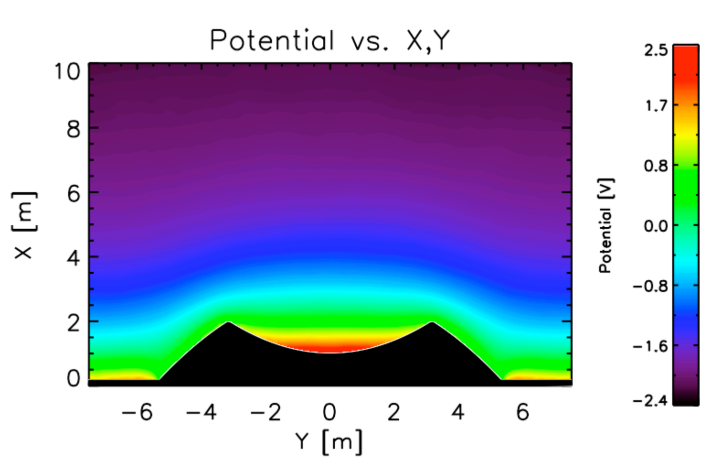
Role of Topography in the Lunar Plasma Environment

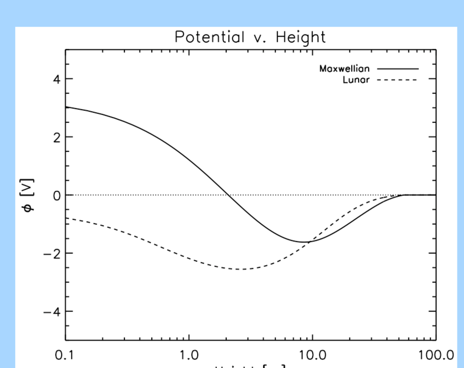
Previous work has suggested that non-trivial topography and illumination conditions on the lunar surface could generate complex plasma structures above the lunar surface, including ambipolar electric fields much stronger than typical fields generated at normal incidence. These fields could lead to increased dust "activity".

Results and Conclusions

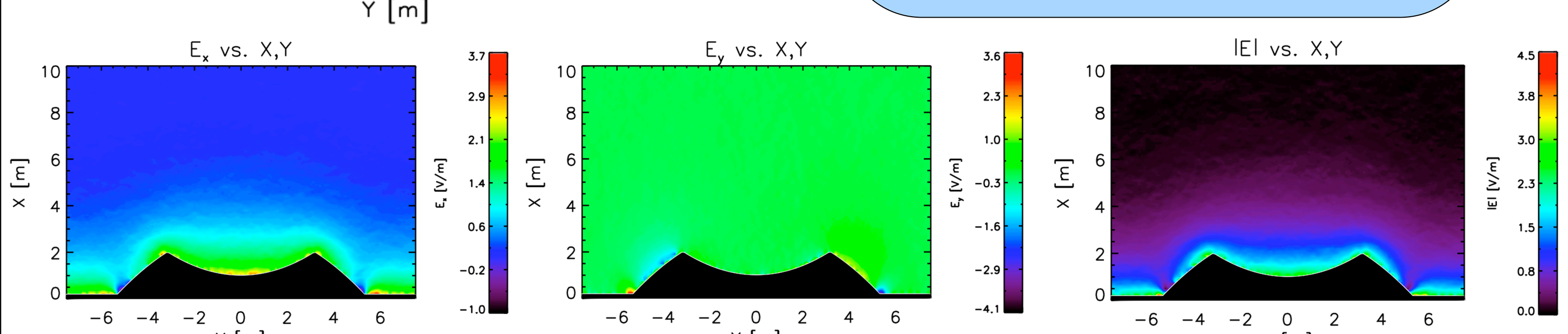
Normal Incidence

Potential and Electric Fields

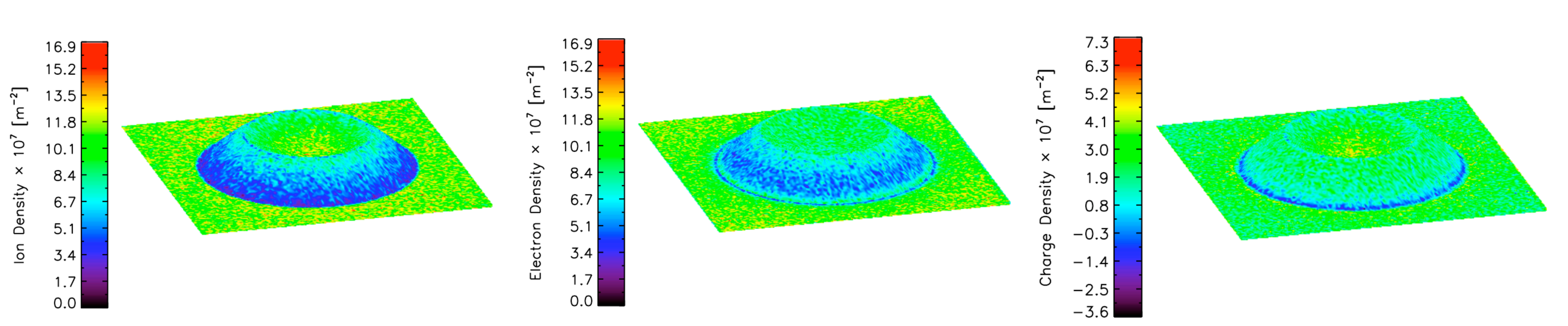




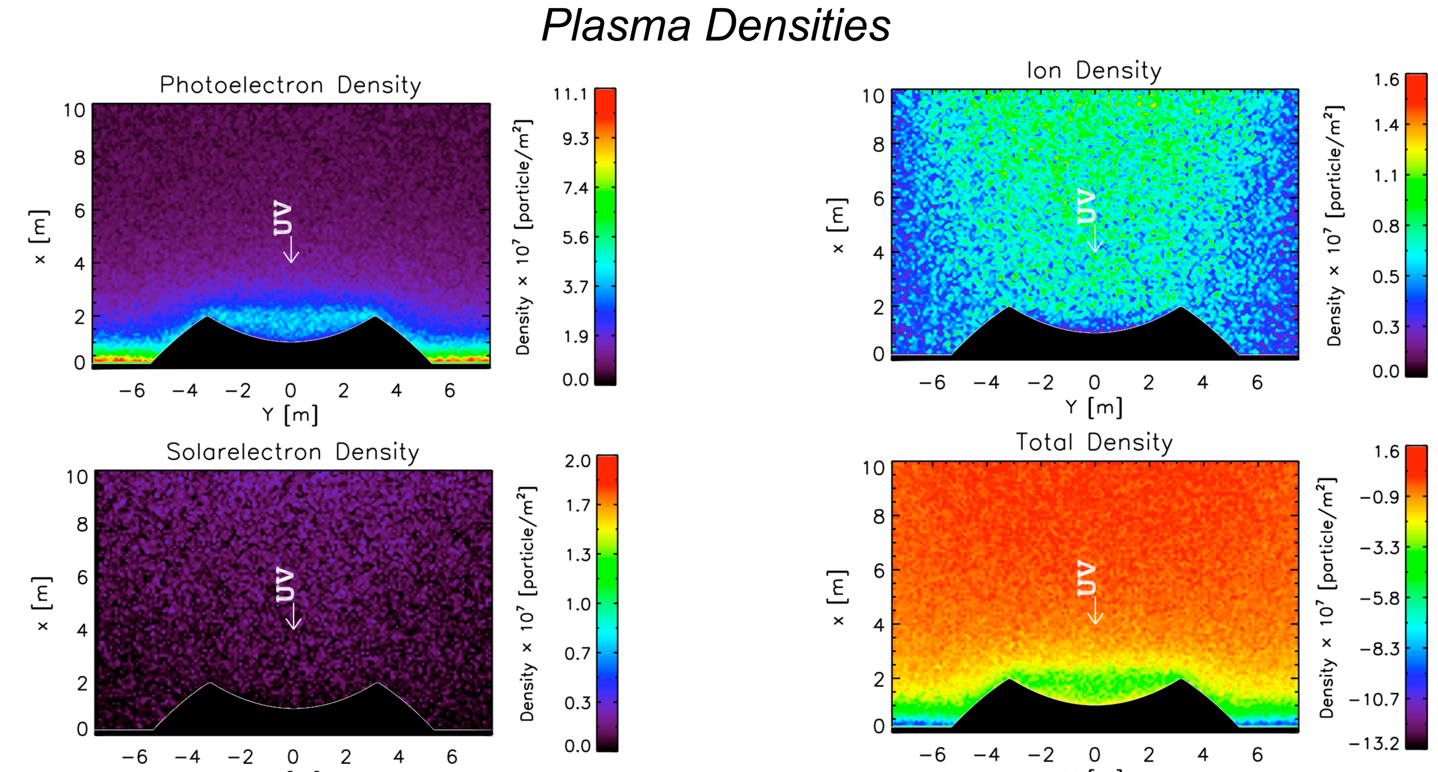
Comparison to the Potential from a 1-d Simulation [*Poppe and Horányi, 2010*]



Surface Charge Densities

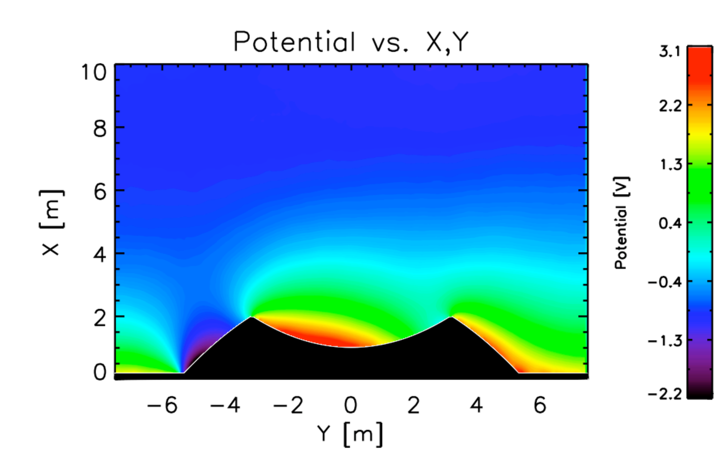


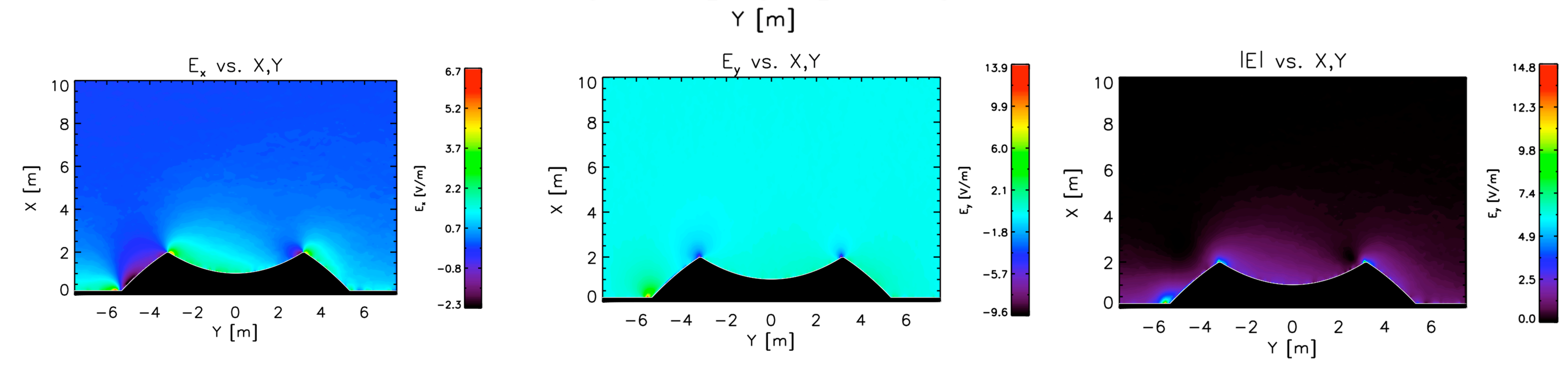
Plasma Densities



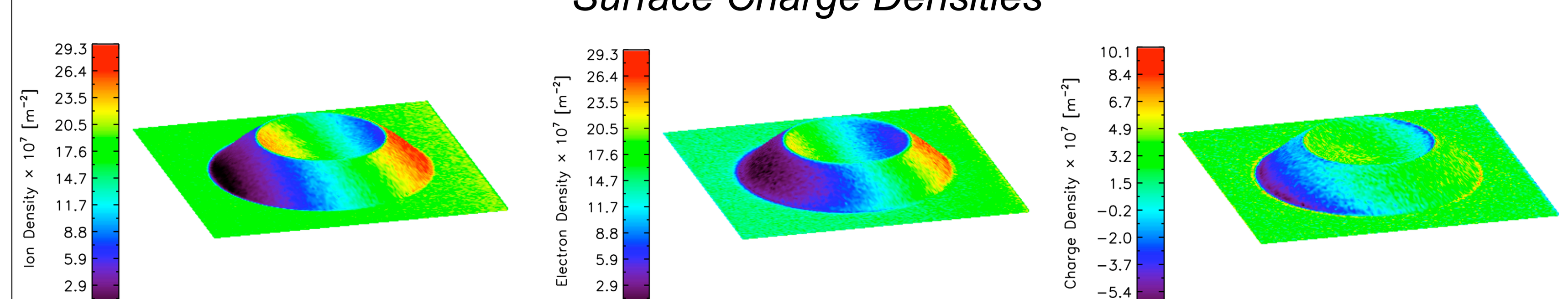
45° Incidence

Potential and Electric Fields

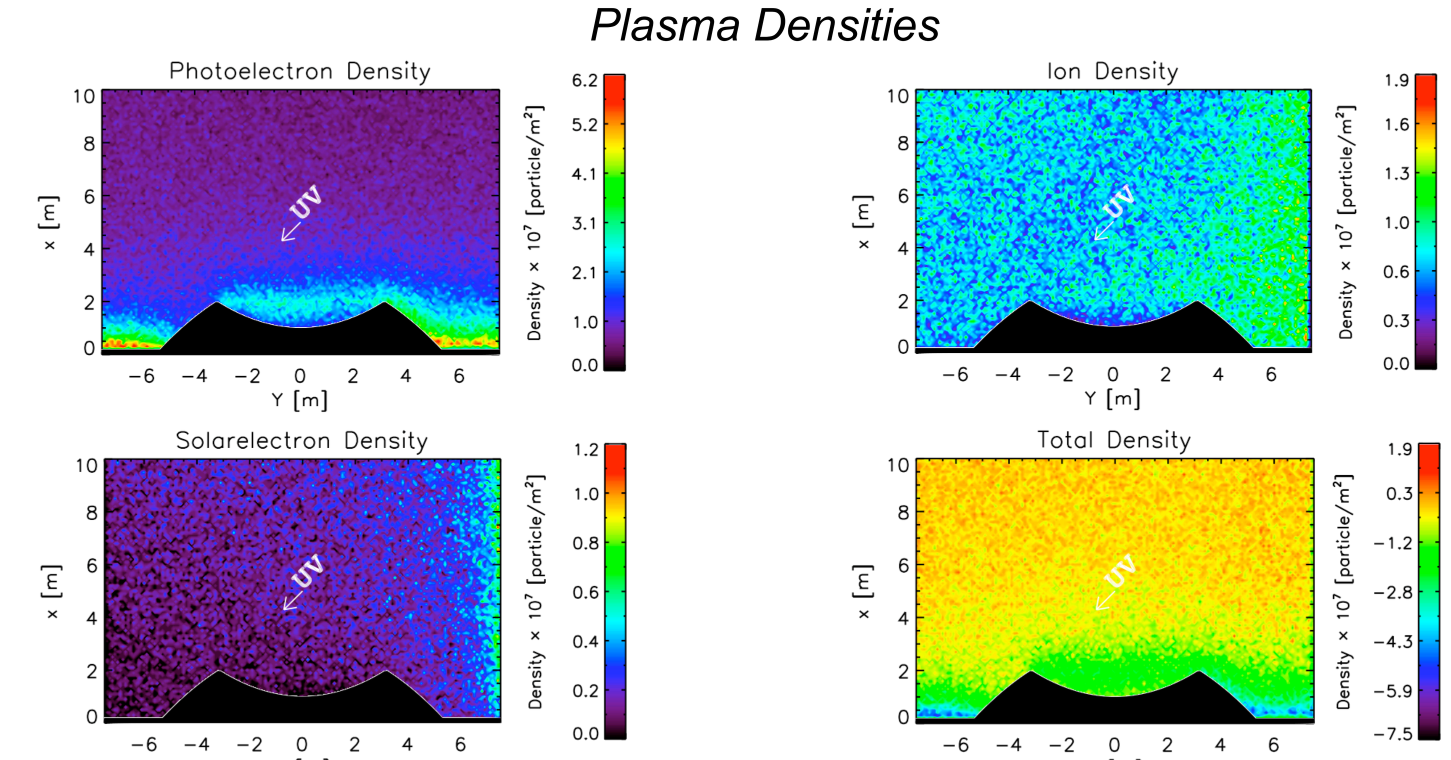




Surface Charge Densities



Plasma Densities



We have undertaken simulations of a "typical," meter-sized lunar crater on the dayside lunar surface with the VORPAL© kinetic code[1]. The crater is exposed to solar UV radiation and the solar wind at normal and 45° incidence.

As a preliminary comparison, we conclude:

- *Nominal electric field values are ~3 V/m at the lunar surface and rapidly die off on the scale of a Debye length (1m)*
- *Oblique incidence of UV/solar wind can cause electric fields to increase up to 5-fold locally*
- *Shadowed surfaces charge negatively due to both the absence of photoemission and the collection of photoelectrons from neighboring sunlit surfaces*

The increased electric fields may allow dust grains to be electrostatically lofted off the surface with greater ease. However, static levitation is highly unlikely given the complex spatial geometry of the fields. A study of time-dependent dust grain dynamics using these simulations is now underway.

[1] Verboncouer, J.P. *et al*., Com. Phys. Comm., **87**, 1995
[2] Berg, O. *et al*., Geo. Res. Lett., **1**, 1974
[3] Rennilson, J. and D. Criswell, The Moon, **10**, 1973
[4] Farrell, B. *et al*., J. Geophys. Res., **E115**, 2010
[5] Poppe, A. and M. Horányi, J. Geophys. Res., *in press*