Lunar surface charging: a comparison of ARTEMIS data and particle-in-cell modeling

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Outline

- Lunar Surface Charging
- Lunar Prospector Measurements
- Simulation / Data Comparison
- ARTEMIS Measurements
Plasma Environment at the Moon
Lunar Photoelectron Sheath

Solar Wind / Geomagnetic Plasma

Plasma

Presheath

Sheath Dust? +

Surface + + + + + + + + + +

Photoelectrons
Photoelectron Sheath Theory

- Previous theoretical work has analyzed photoelectron sheaths with kinetic theory [Guernsey and Fu, 1970; Nitter et al., 1998]

- Depending on the relevant parameters, the photoelectron potential distribution falls into three categories:
  - A: Non-monotonic sheath
  - B: Positive, monotonic sheath
  - C: Negative monotonic sheath

- In some cases, simultaneous solutions can exist for the same set of parameters

Nitter et al., 1998
Lunar Prospector Observations
LP Observations

Observations of negative lunar surface potentials in sunlight, while in the current sheet!

Halekas et al., 2008
LP ER Timeseries

- Lunar Prospector Electron Reflectometer

- Data taken during a terrestrial current sheet crossing
  - Energy spectrogram in 5 pitch angle bins
  - Sunlight / mag. Polarity flags

- Cold electron beam seen originating from the lunar surface

Poppe et al., GRL, 2011
LP ER Spectrogram

- Single observation at low solar zenith angle
  - Downgoing electrons: 90-180°
  - Upcoming electrons: 0-90°

- Clear flux enhancement seen < 45° for energies ≈ 200-500 eV

- Energy dependent loss cone implies surface potential ~ -200 V, in daylight!
Particle-in-cell Modeling and Data Comparison
Particle-in-Cell Model

• Custom, electrostatic 1-dimensional PIC
  – Tailored to the lunar surface:
    • Photoelectrons emitted from left boundary
    • Plasma sheet electrons/ions enter at right boundary
    • Lunar surface charge density continuously calculated
Electron Fluxes – Model v. Data

- Low-energy flux is reflected plasma sheet electrons (red)
- Narrow beam of photoelectrons accelerated away from surface (blue)
- Low-energy photoelectrons are trapped near surface (green)

Poppe et al., GRL, 2011
ARTEMIS P1 Observation
ARTEMIS Dayside Connection

THB, 2011-07-16
ARTEMIS Dayside Connection

THB, 2011-07-16
ARTEMIS Dayside Connection

THB, 2011-07-16
Conclusion

• Observations of negative potentials on the dayside lunar surface seem to contradict pointwise charging theory

• PIC modeling of Lunar Prospector electron reflectometry results confirms non-monotonic potentials above the lunar surface

• ARTEMIS is already seeing several great examples of dayside charging – much more to explore!
Variability of Photoelectron Beams

LP Observations in the Solar Wind

Halekas et al., EPS, 2011
ARTEMIS

Two THEMIS probes re-directed to the Moon

- Electrostatic Analyzer (ESA)
- Solid State Telescopes (SST)
- Fluxgate Magnetometer (FGM)
- Search Coil Magnetometer (SCM)
- Electric Field Instrument (EFI)

March 2010 Lunar Fly-by Measurements

Field Vectors:
- Magnetically Connected
- Unconnected

-500 V dayside potential in plasma sheet
LADEE

- Investigate the lunar atmosphere and dust environment
  - Lunar Dust Experiment (LDEX)
  - Ultraviolet Spectrometer (UVS)
  - Neutral Mass Spectrometer (NMS)