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

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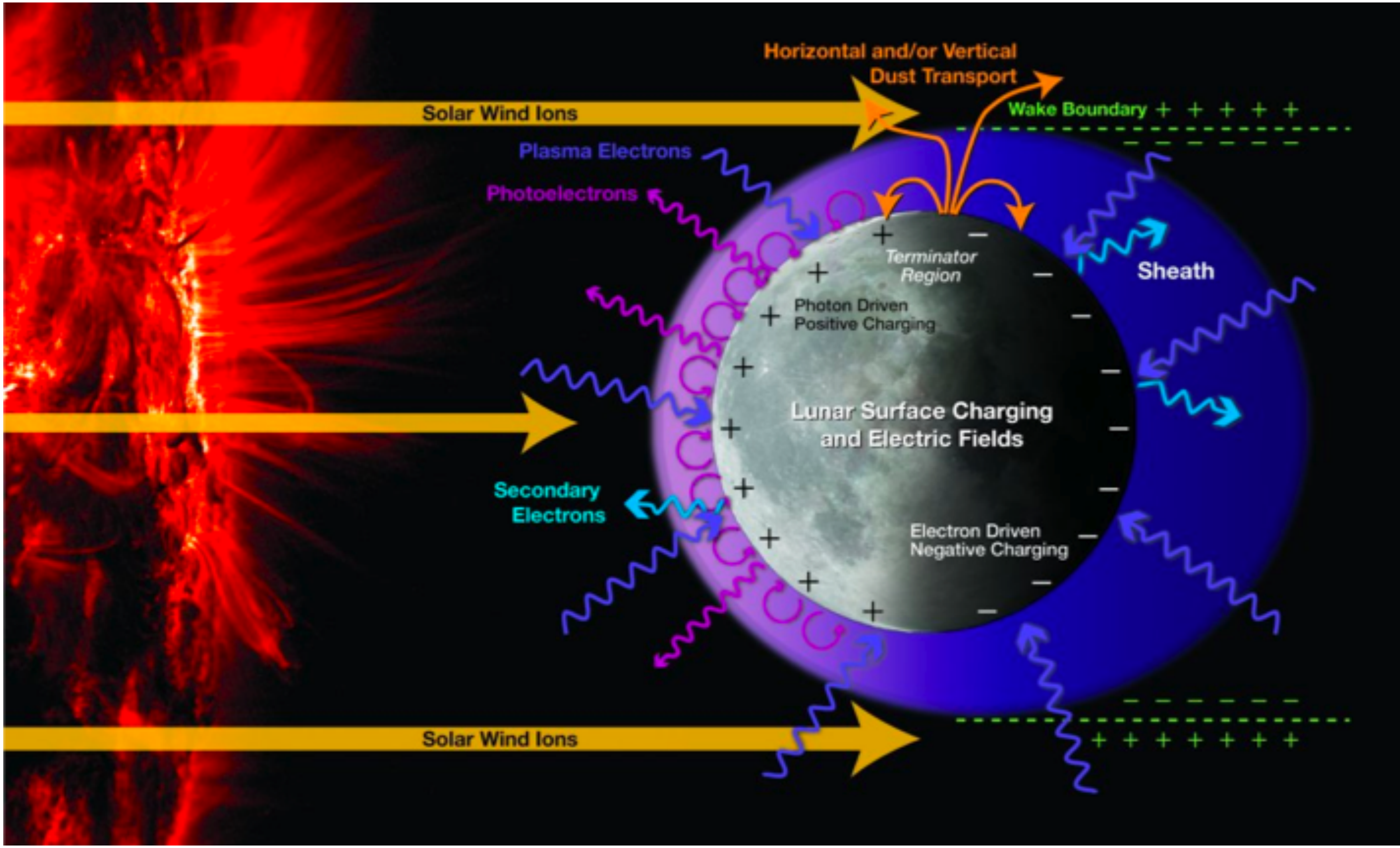
Outline

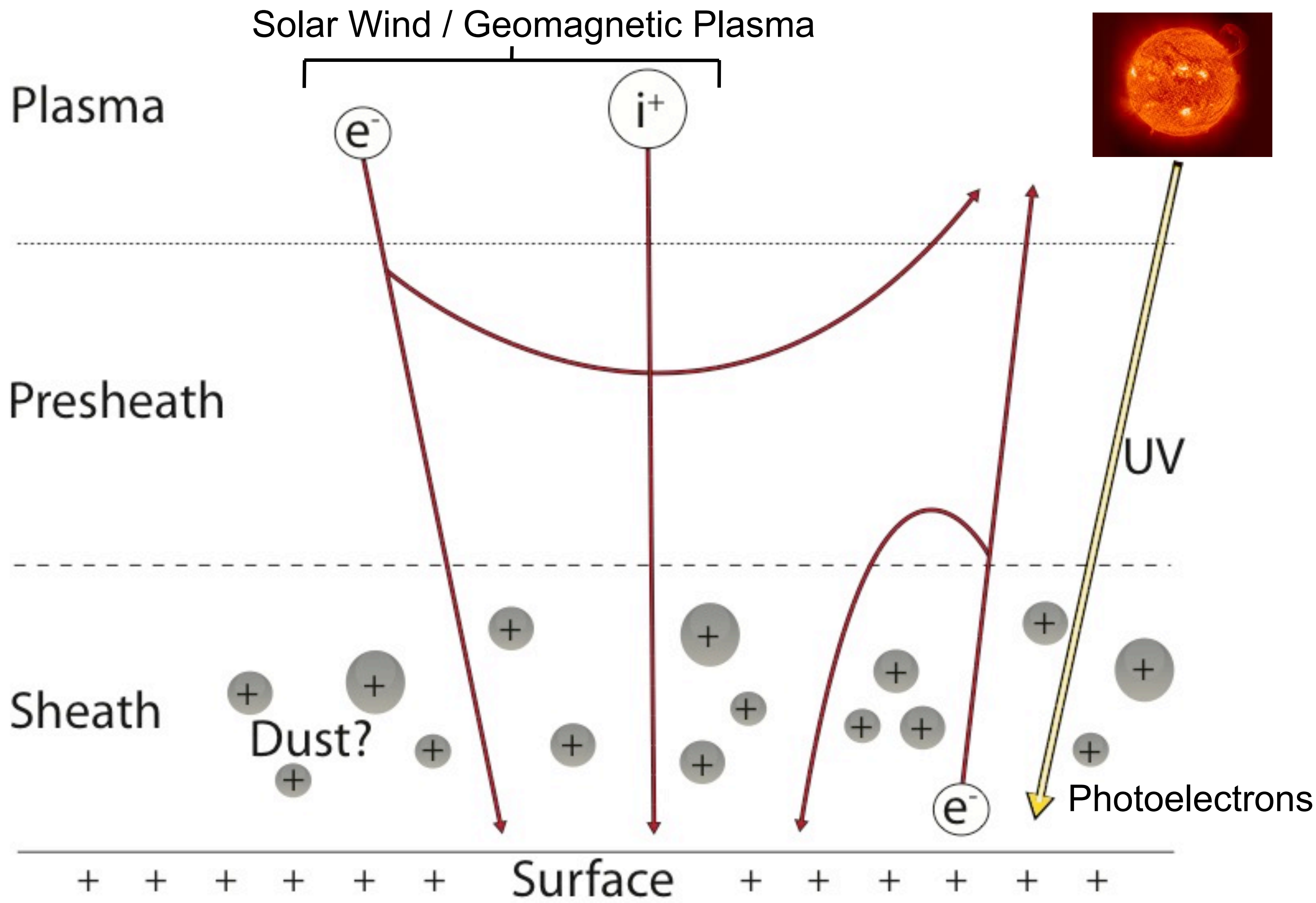
- Lunar Surface Charging
- Lunar Prospector Measurements
- Simulation / Data Comparison
- ARTEMIS Measurements

Plasma Environment at the Moon

Lunar Plasma Environment



Lunar Photoelectron Sheath

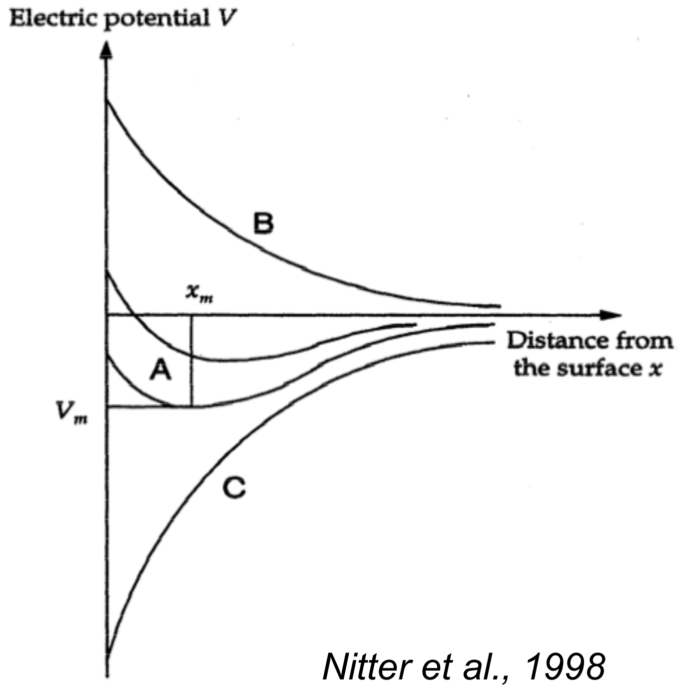


Photoelectron Sheath Theory

- 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

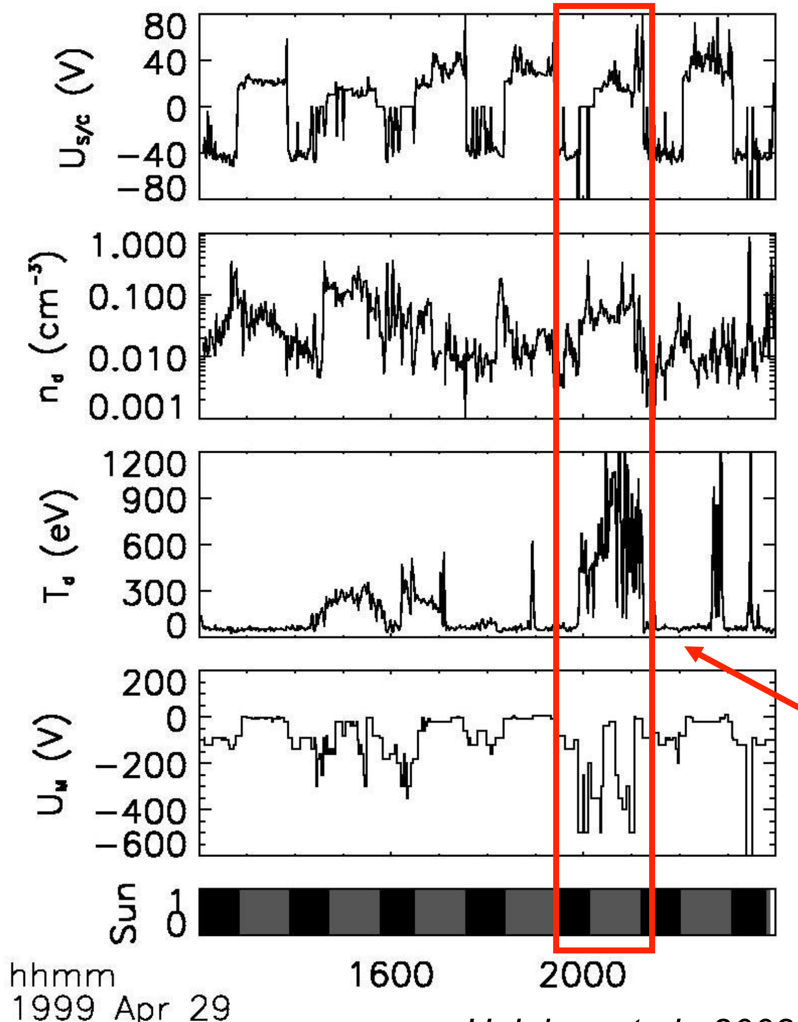
- In some cases, simultaneous solutions can exist for the same set of parameters



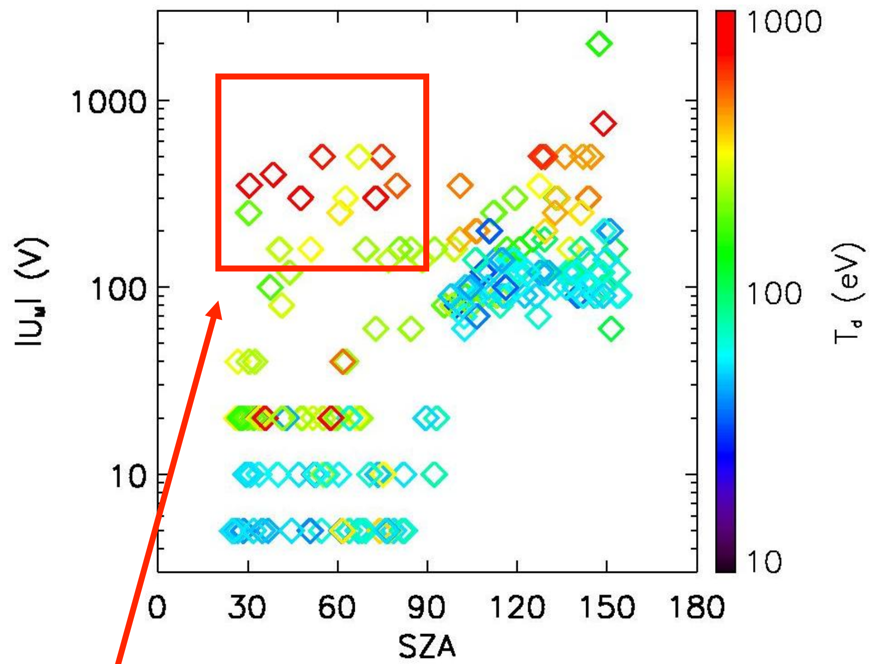
Nitter et al., 1998

Lunar Prospector Observations

LP Observations



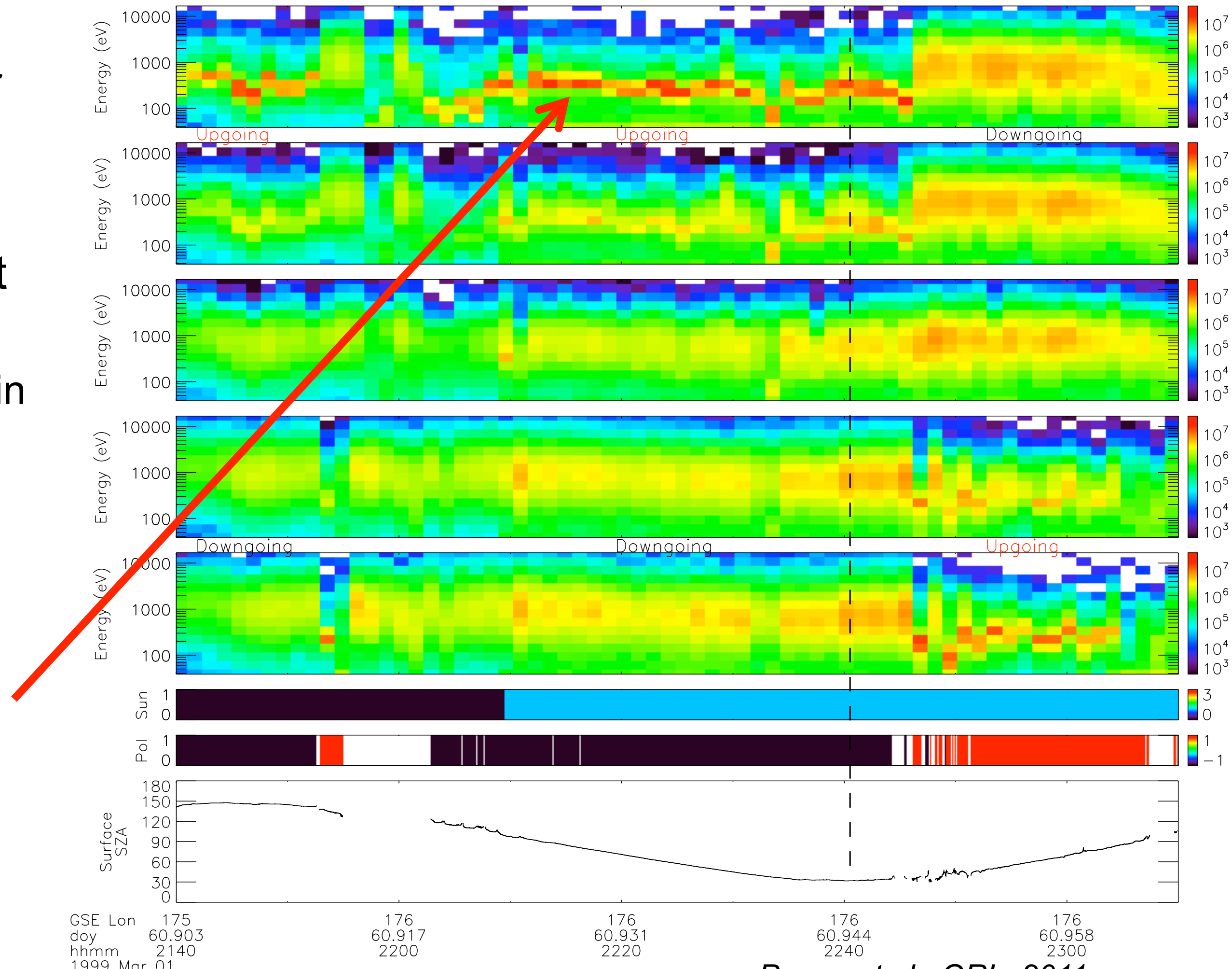
Halekas et al., 2008



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

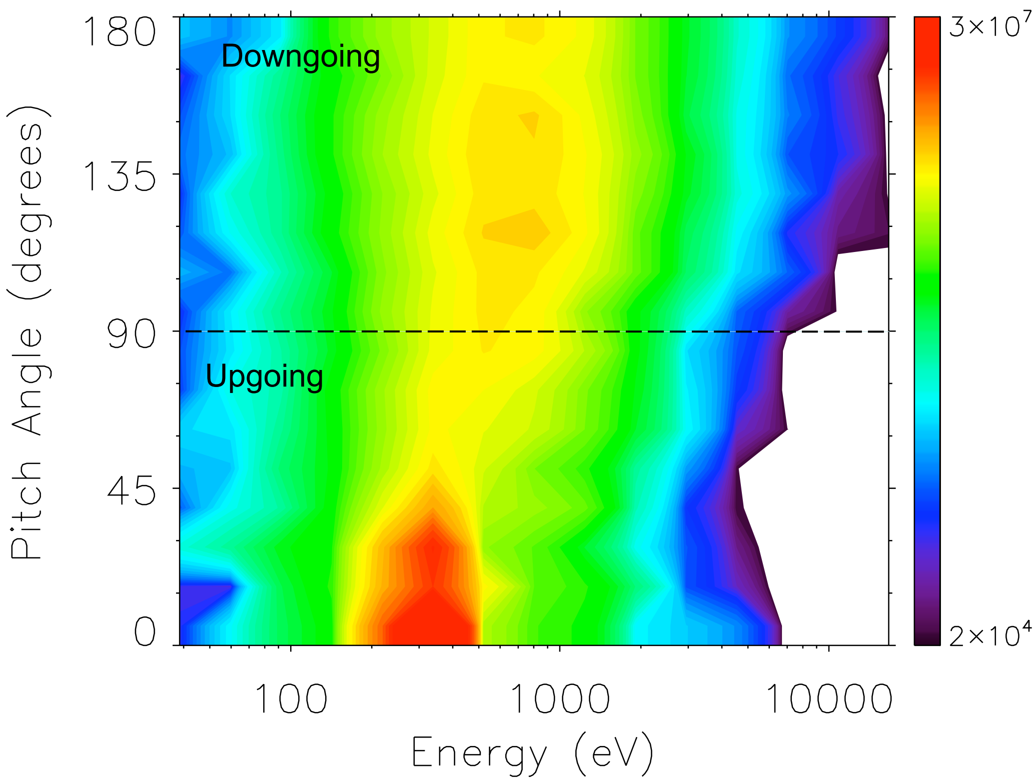
LP ER Timeseries

- 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

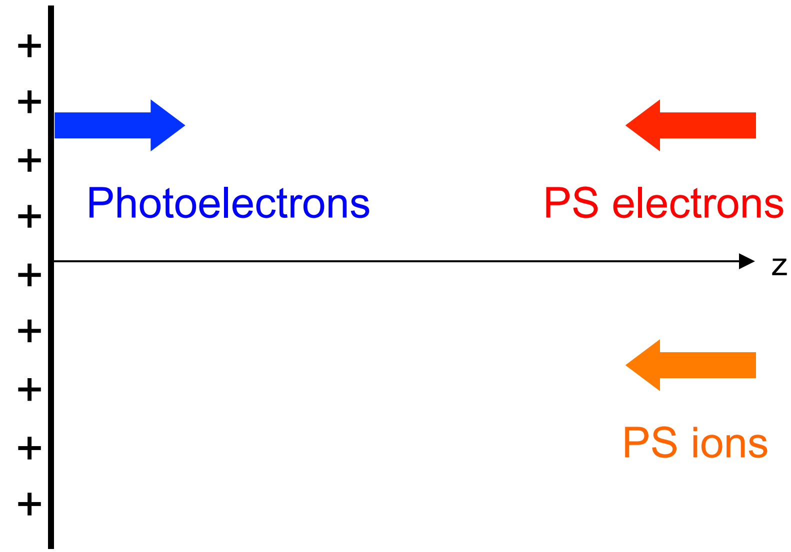


- Single observation at low solar zenith angle
  - Downgoing electrons: 90-180°
  - Upcoming electrons: 0-90°
- Clear flux enhancement seen < 45° for energies ≈ 200-500 eV
- Energy dependent loss cone implies surface potential ~ -200 V, *in daylight!*

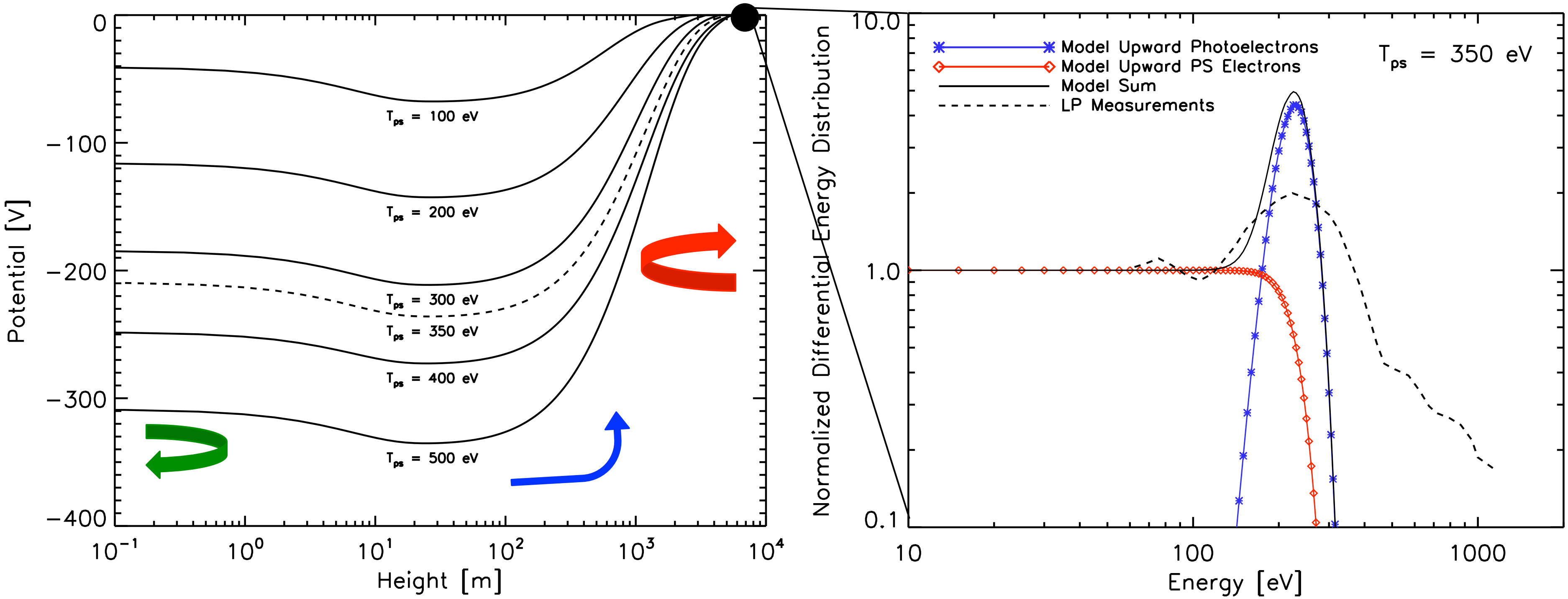
Particle-in-cell Modeling and Data Comparison

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



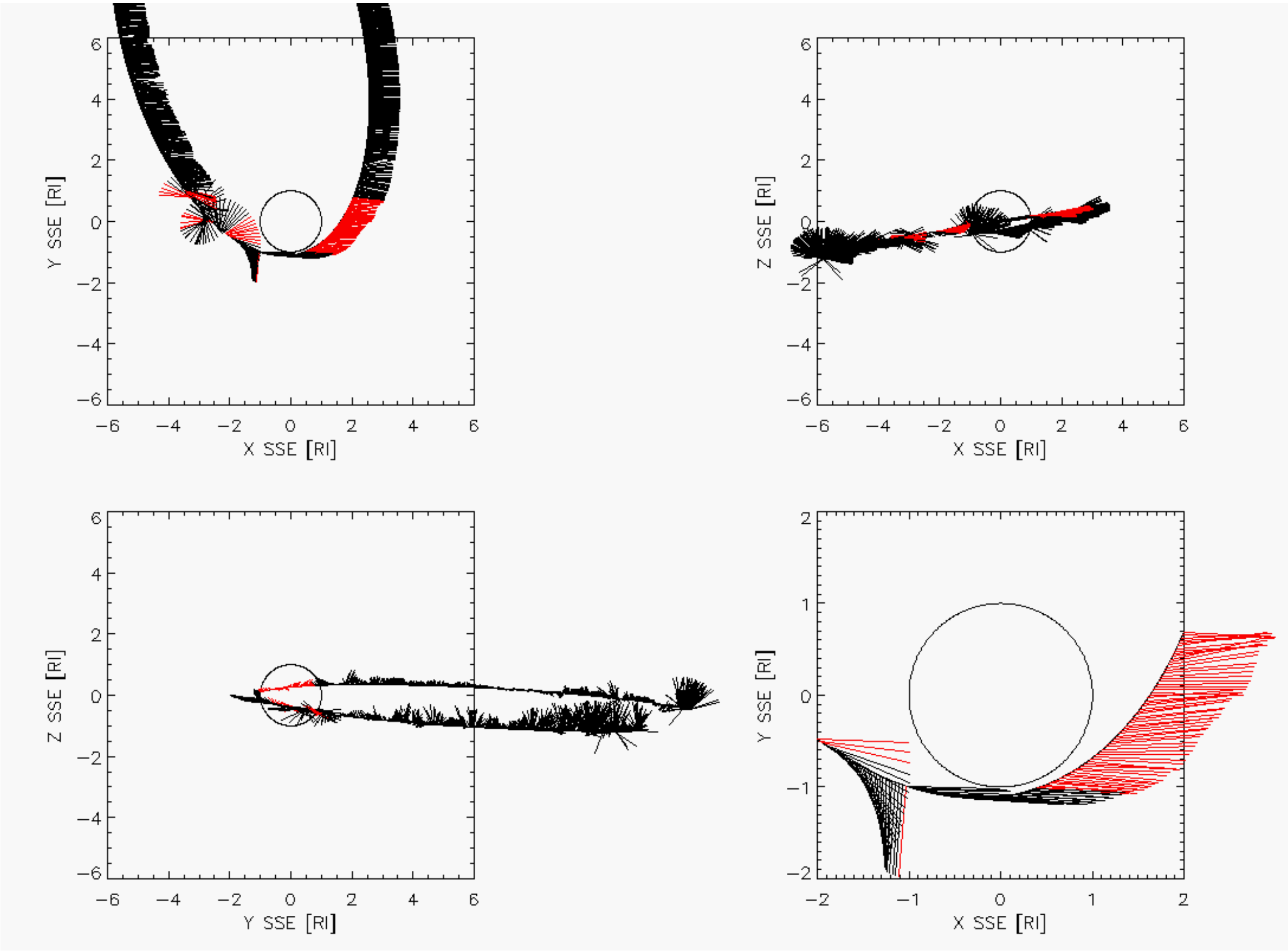
Poppe et al., GRL, 2011

- 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)

ARTEMIS P1 Observation

ARTEMIS Dayside Connection

THB, 2011-07-16



ARTEMIS Dayside Connection

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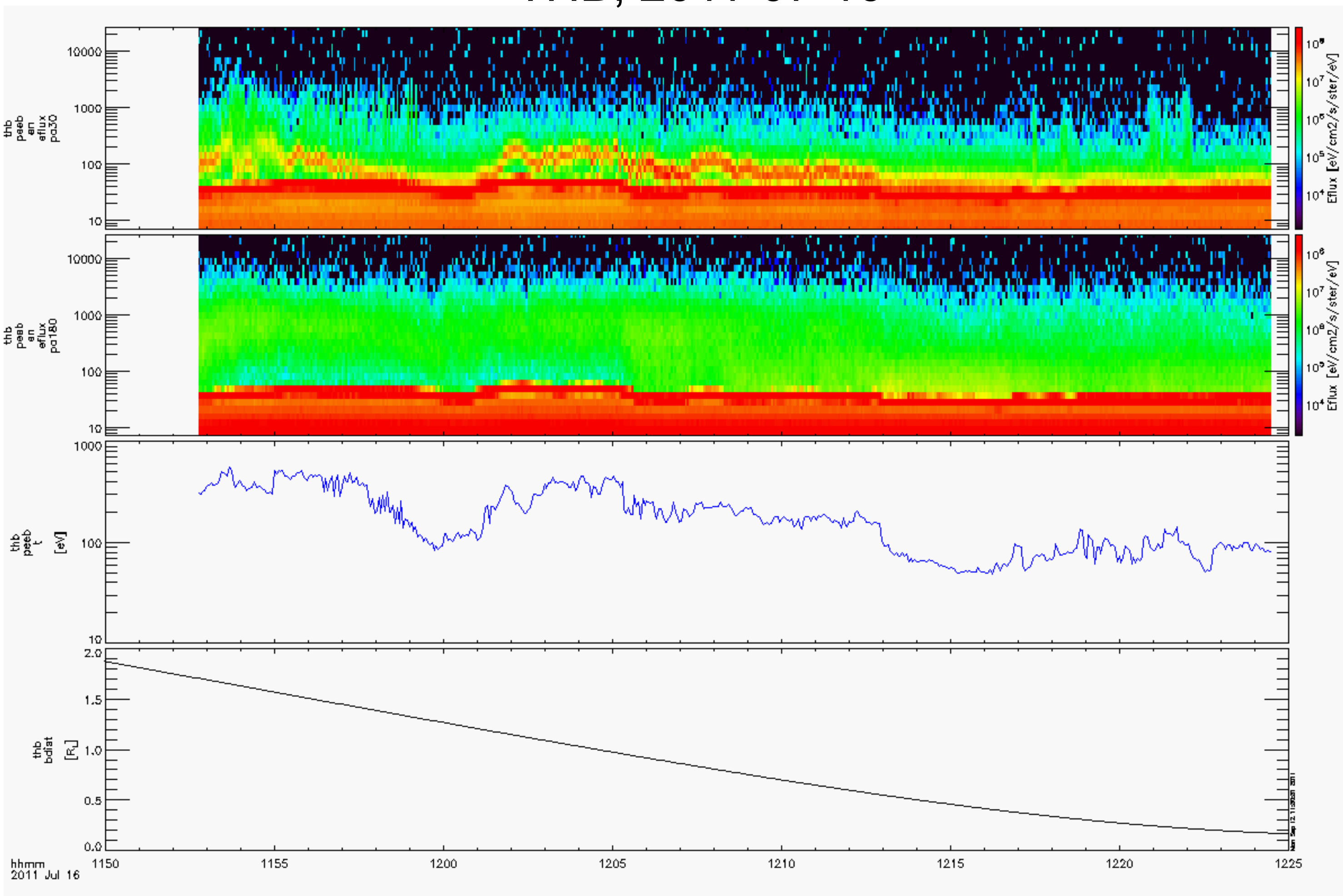

ARTEMIS Dayside Connection

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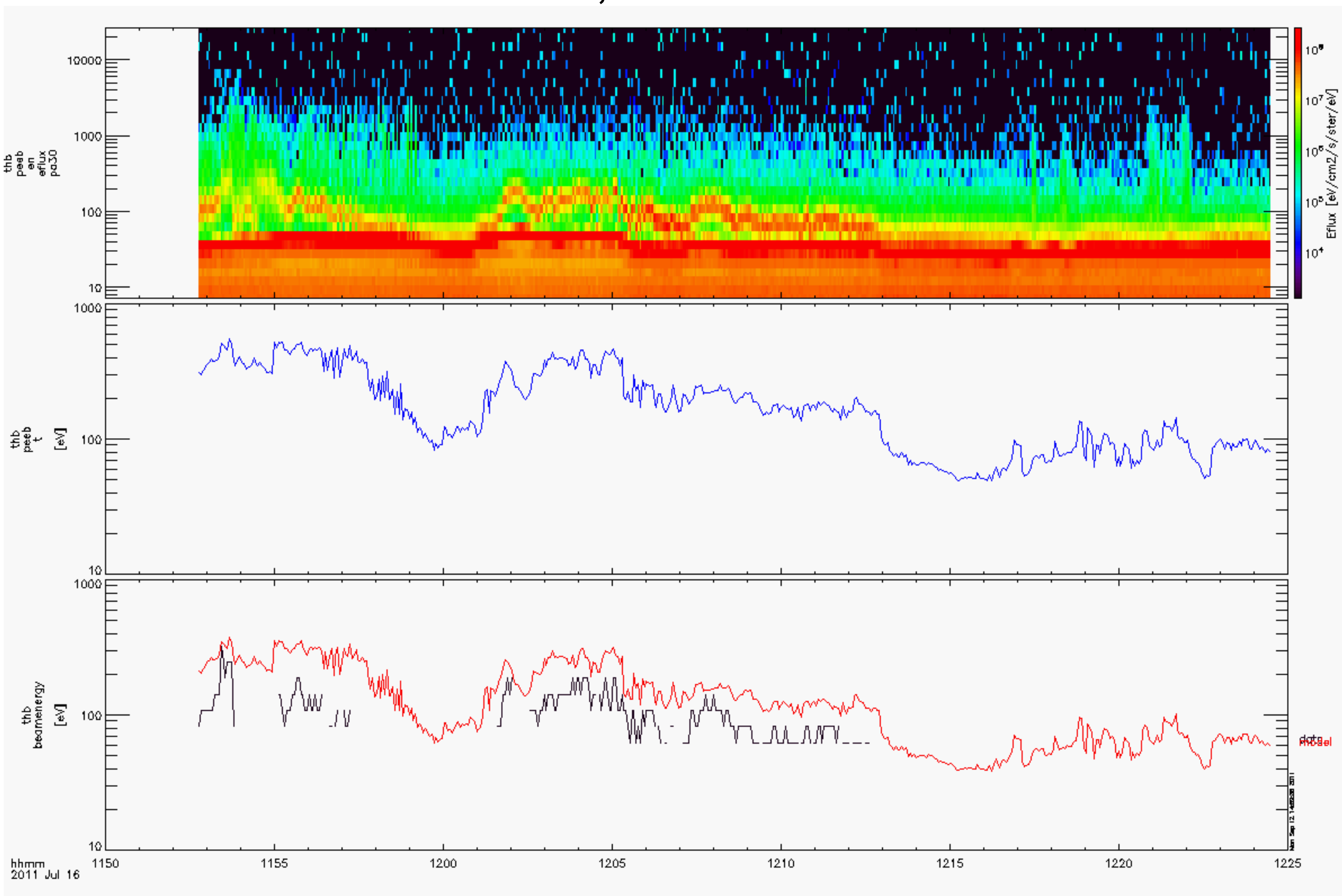
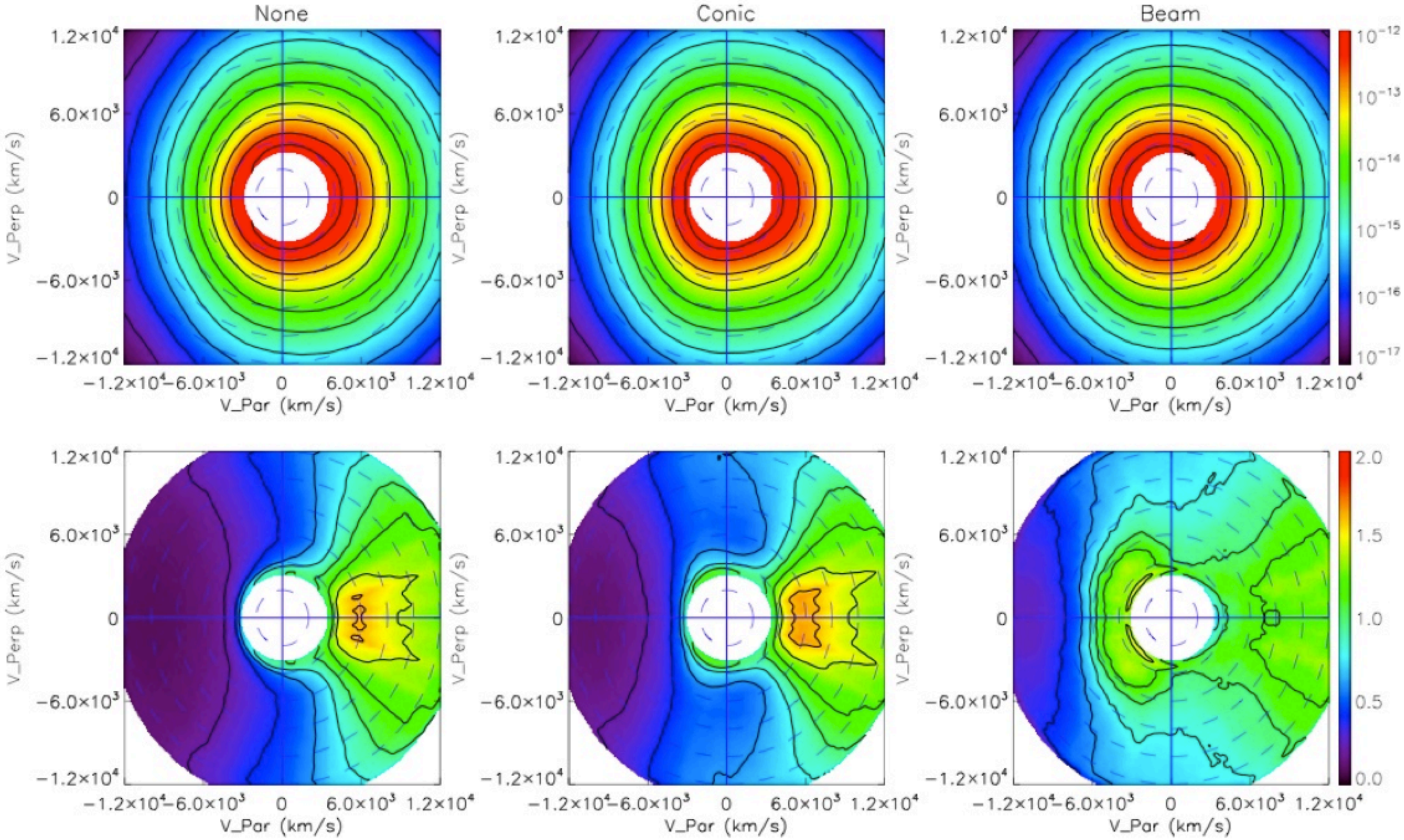


Conclusion

- 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!

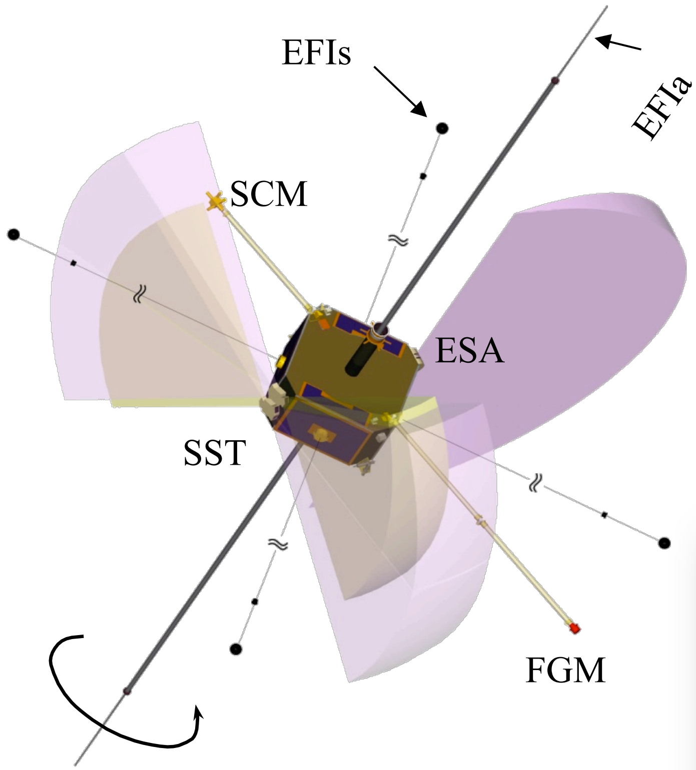
Variability of Photoelectron Beams

LP Observations in the Solar Wind



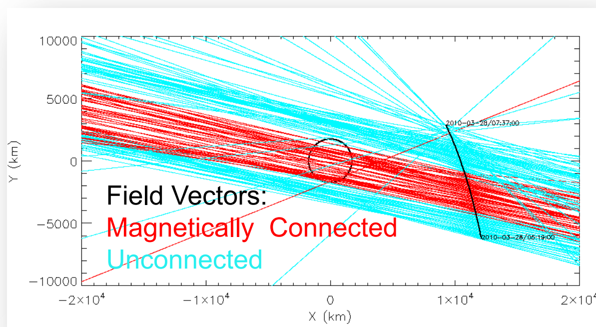
Halekas et al., EPS, 2011

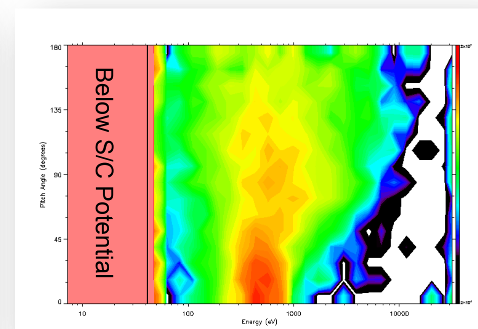
ARTEMIS



- 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)

<u>March 2010 Lunar Fly-by Measurements</u>





-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)