Particle-in-Cell Simulations of Plasma Interaction with Lunar Crustal Magnetic Anomalies

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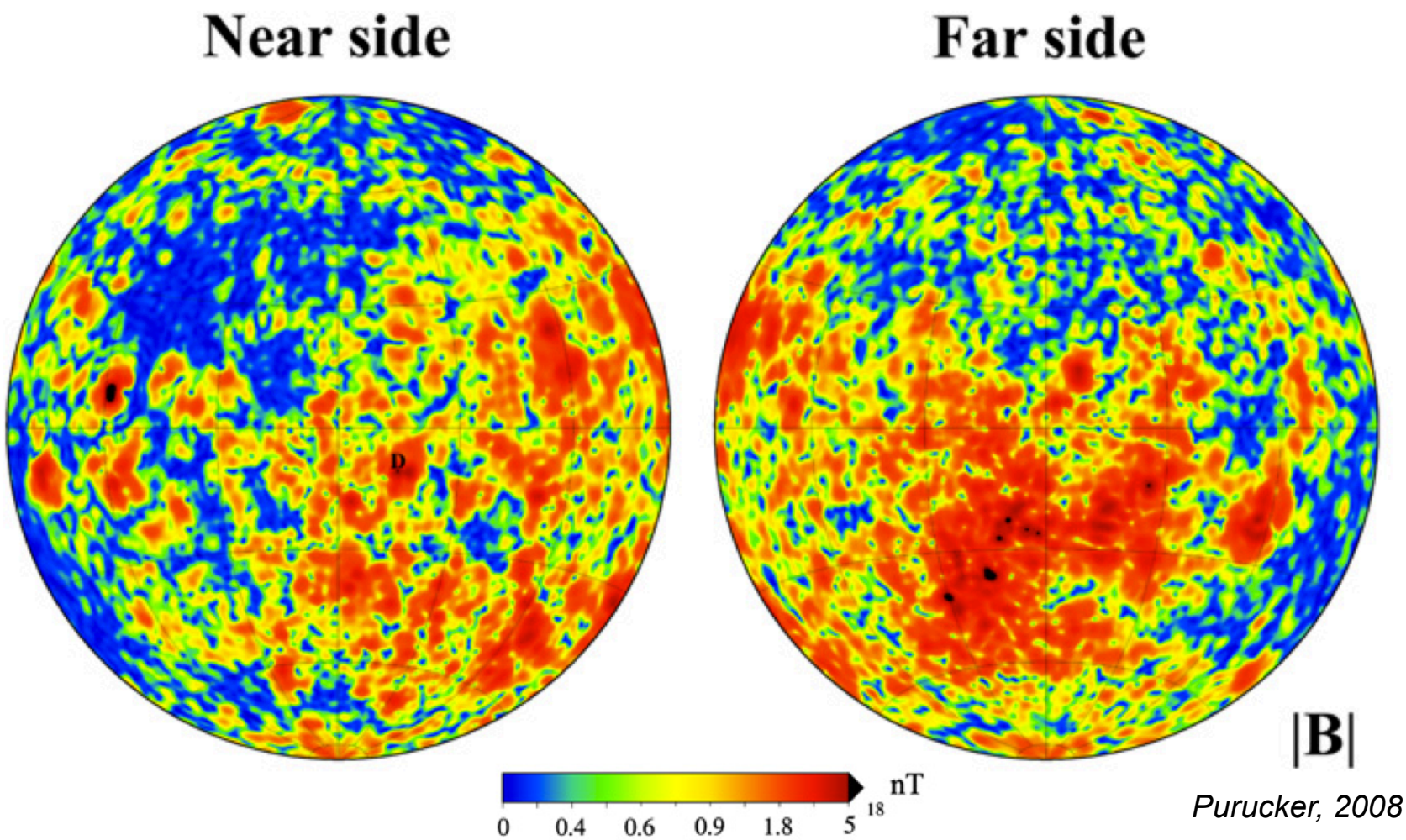
Outline

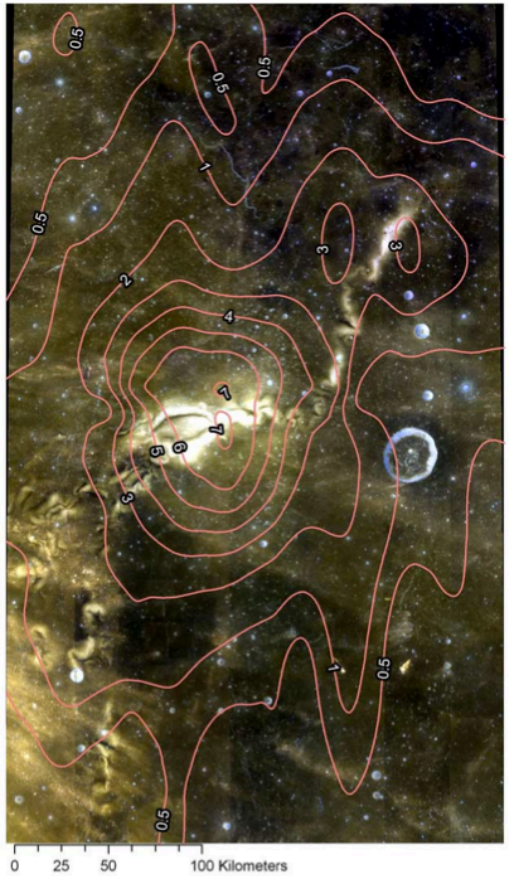
- Introduction & Scientific Motivation
- Particle-in-Cell Modeling
  - *Model Description and Geometry*
  - *Simulation Results*
- Conclusions and Ongoing/Future Work



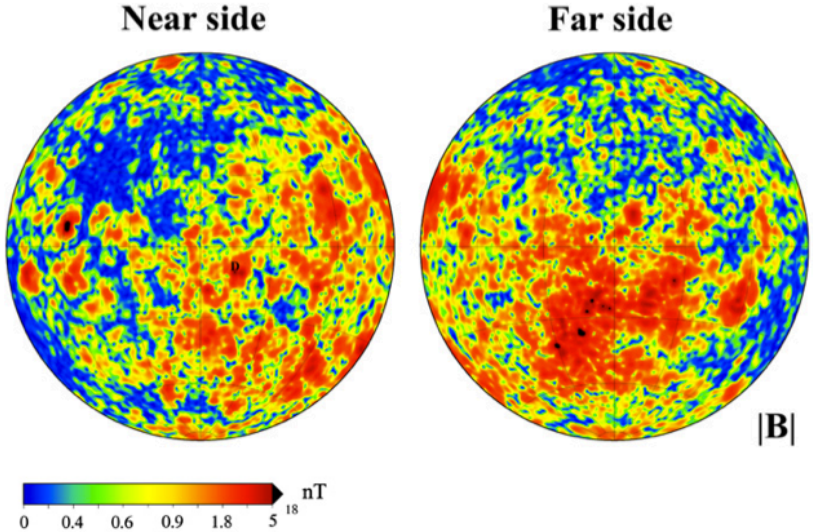
Purucker, 2008

Small scale ($L < R_L$), non-dipolar, incoherent magnetization

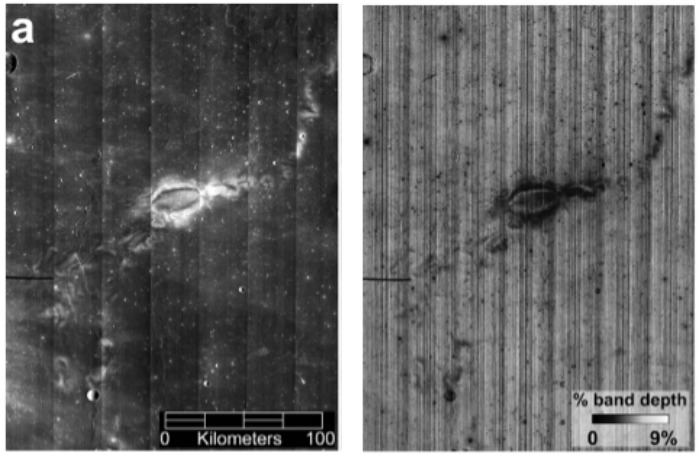
Blewett et al., 2007



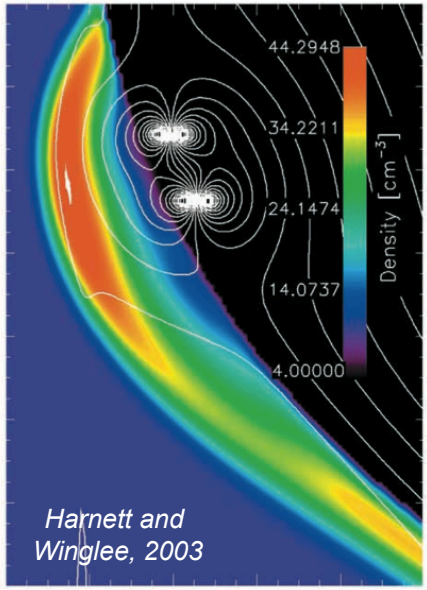
Correlation with lunar swirls – Reiner Gamma



Correlation with hydroxyl abundance

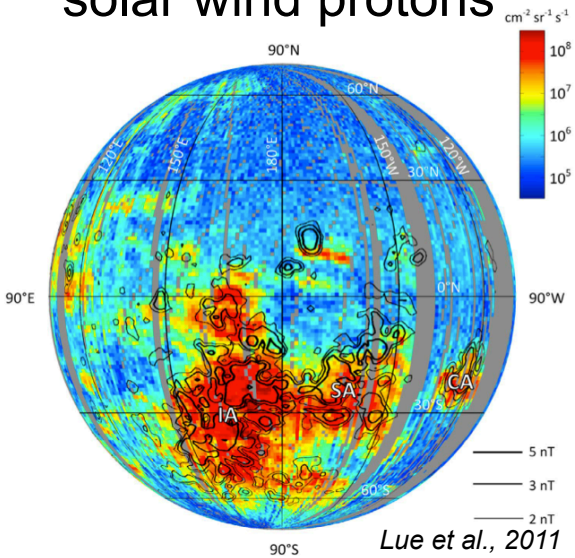


Kramer et al., 2011



Harnett and Winglee, 2003

Deflection of incident solar wind protons



Lue et al., 2011

SW/Magnetic Anomaly Electrostatics

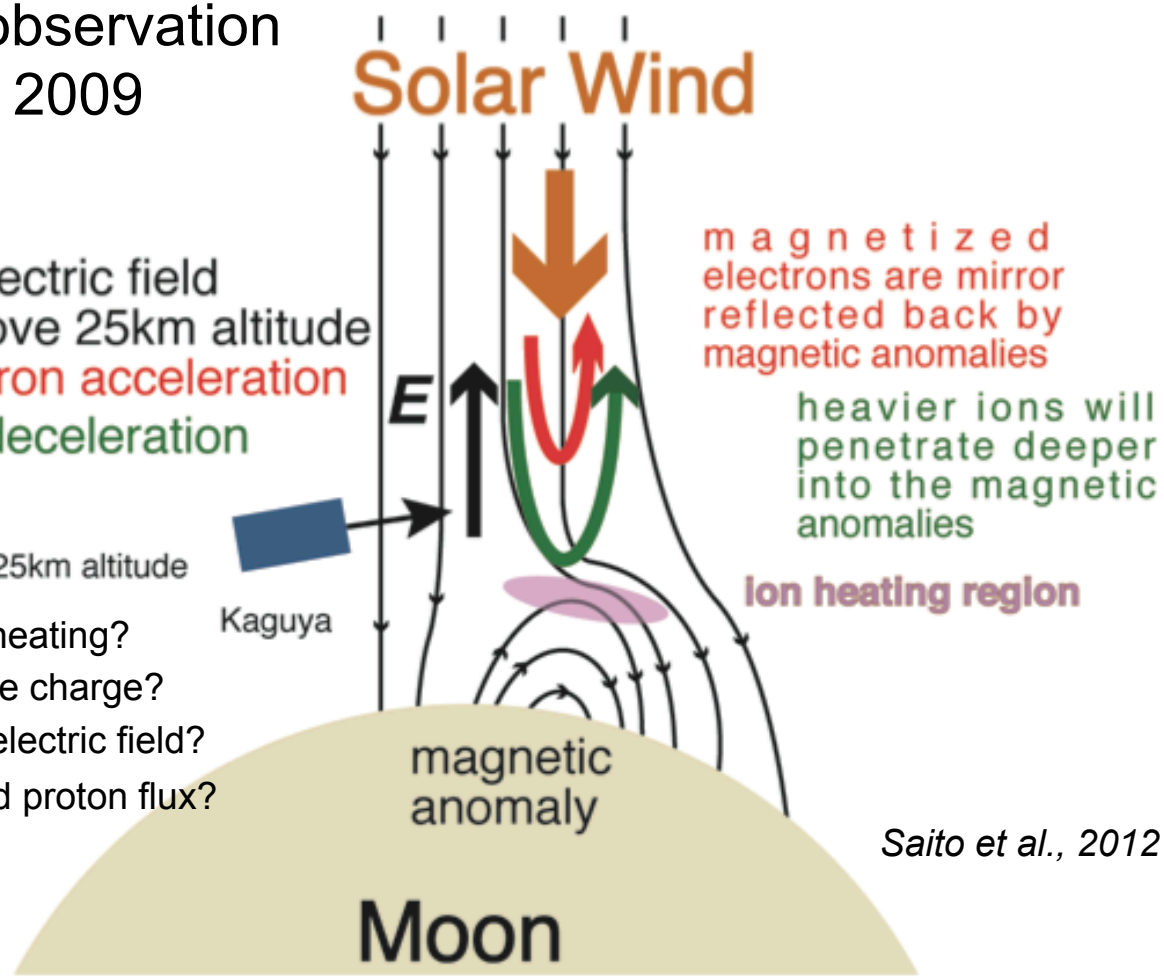
KAGUYA observation from 2009

High-altitude electrostatics

- DC electric field above 25km altitude
- electron acceleration
- ion deceleration

Low-altitude electrostatics?

- Ion heating?
- Surface charge?
- Surface electric field?
- Solar wind proton flux?



Saito et al., 2012

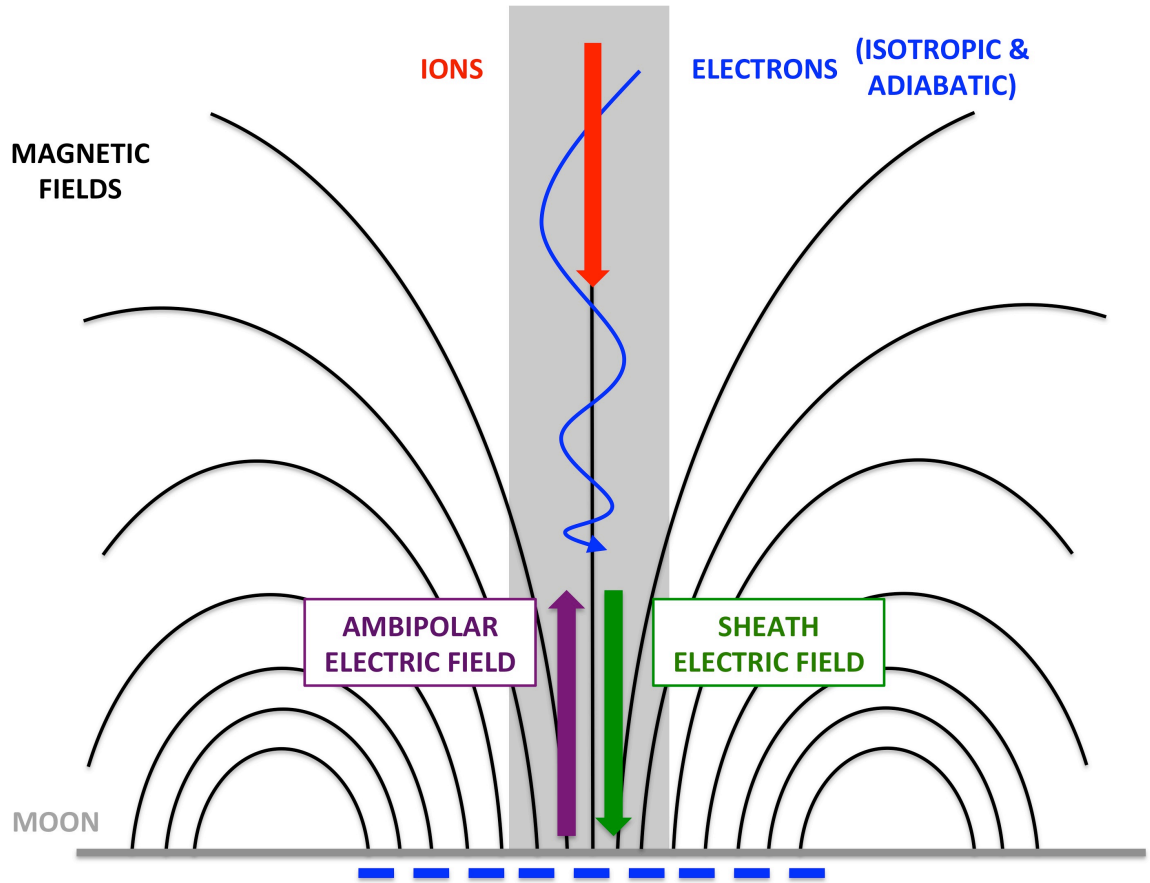
Modeling Geometry

Magnetic field geometry is arbitrarily complex

First topology modeled: *crustal field cusp regions*

For small scale anomalies, ions can be modeled as unmagnetized – only feel electrostatic fields

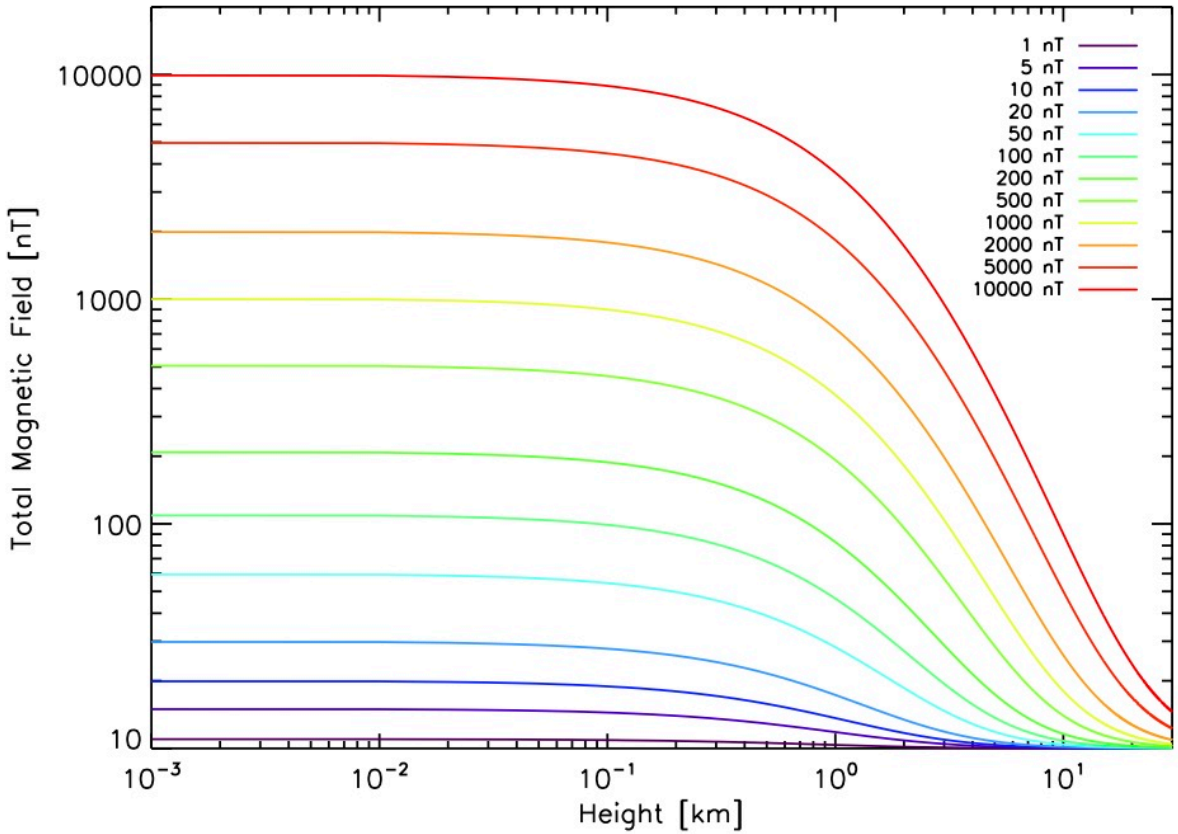
Electrons are fully magnetized



Modeling Geometry – Magnetic Fields

Constant background solar wind magnetic field – 10 nT

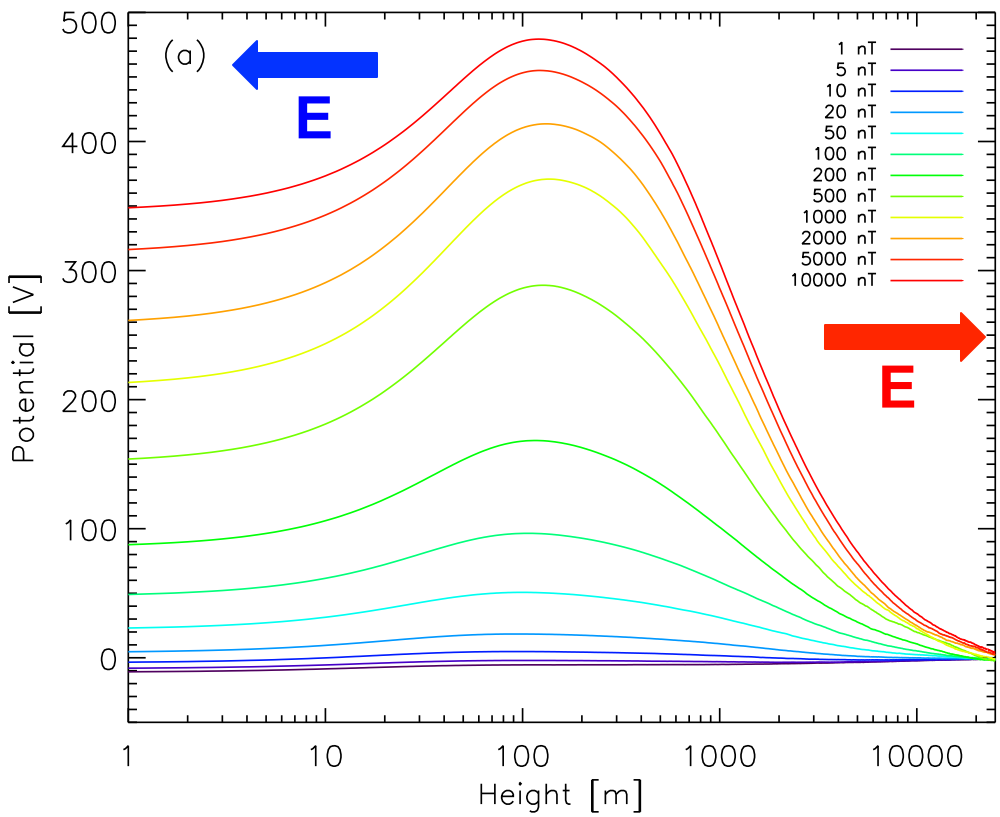
Dipolar crustal field at varying strengths: 1 nT to 10,000 nT



Electrostatic Potentials

High altitudes: upward pointing ambipolar electric field

Near-surface: downward pointing electric field

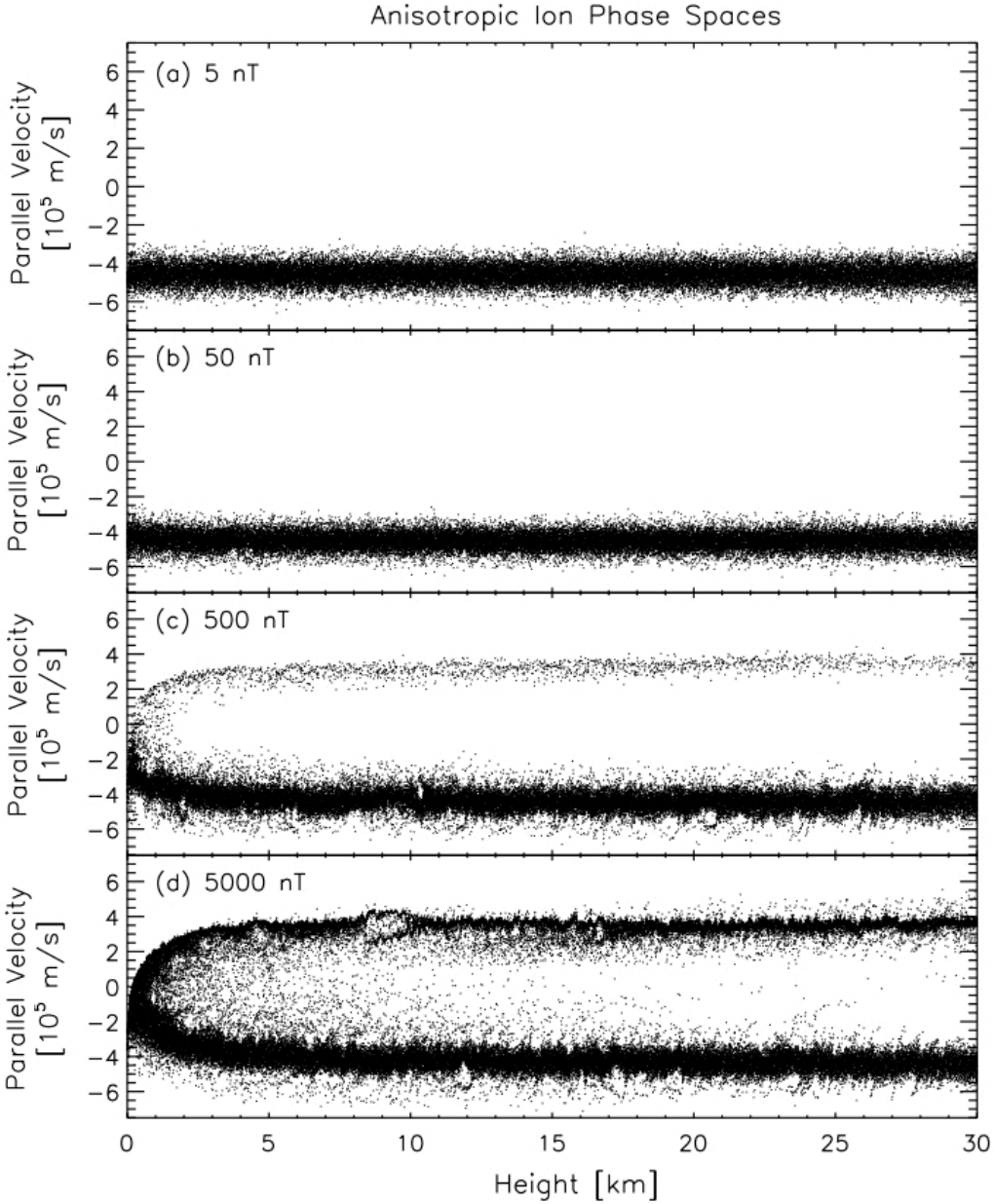


5 nT: no reflection

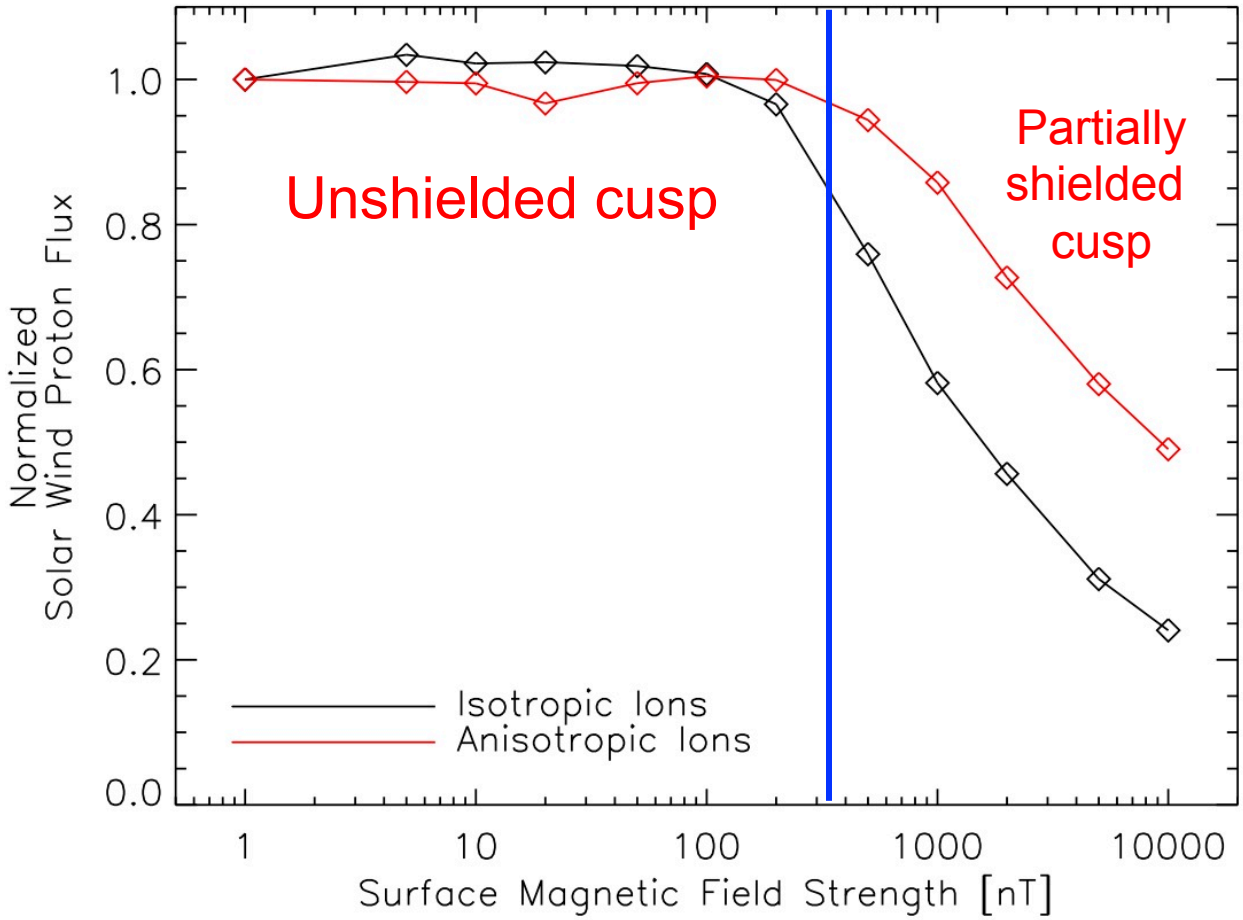
50 nT: no reflection

500 nT: some reflection and some ion heating

5000 nT: lots of reflection and ion heating



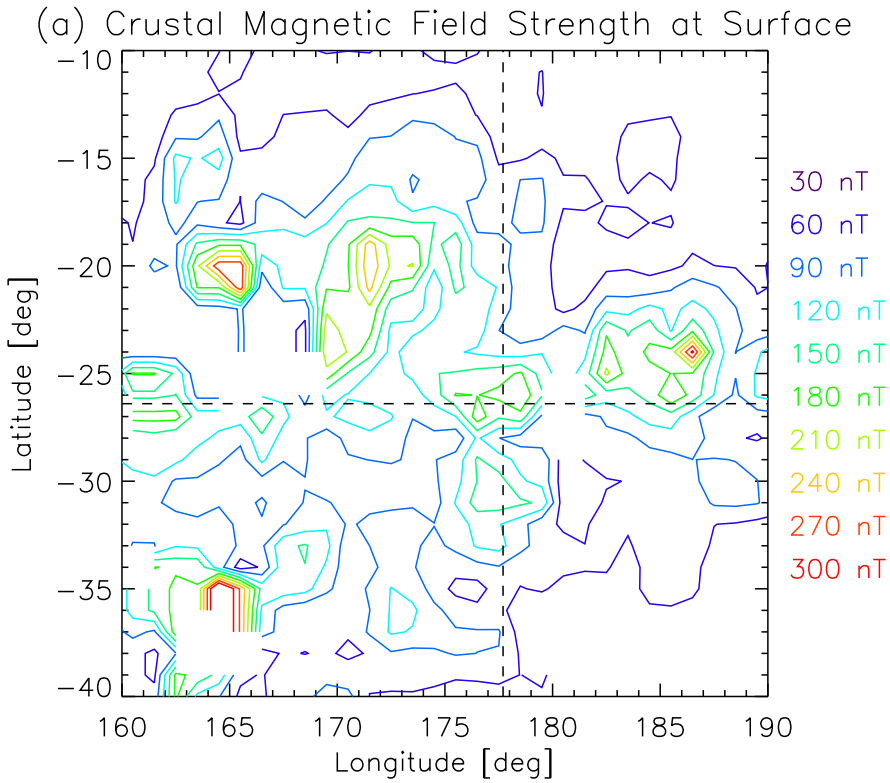
Proton Flux to the Lunar Surface



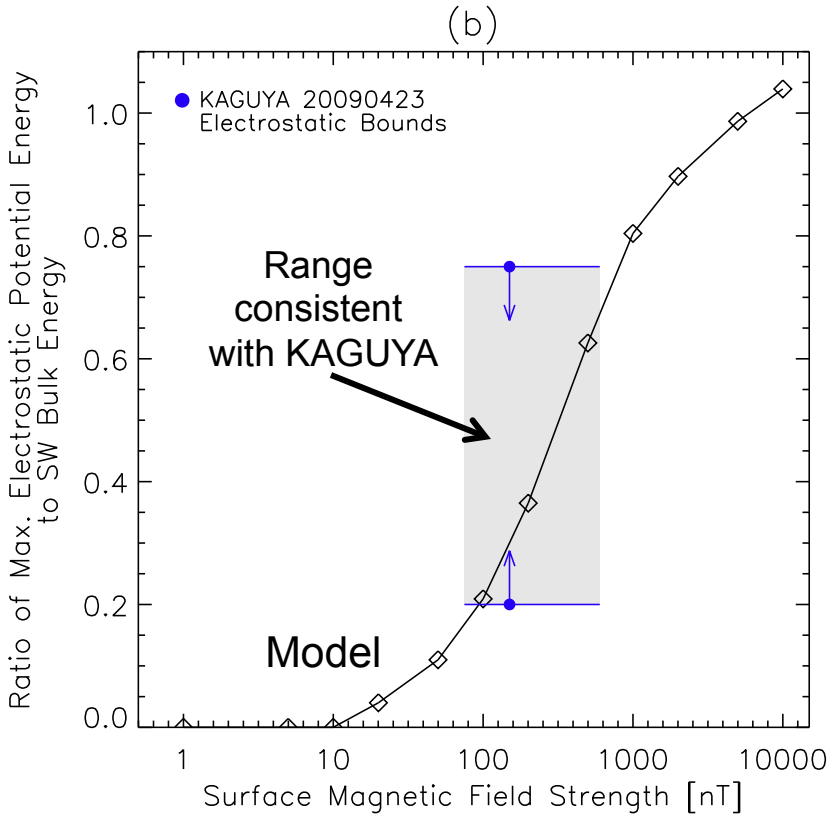
Maximum *in-situ* measured crustal field strength

327 nT at Apollo 16 landing site

Comparison to KAGUYA



Magnetic fields at KAGUYA 4/23/09 observation



ARTEMIS Measurements at the Moon

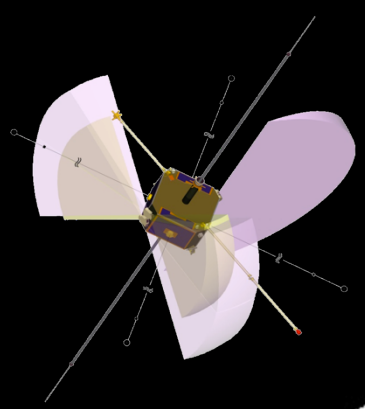
Two-satellite mission, entered lunar orbit in June and July 2011

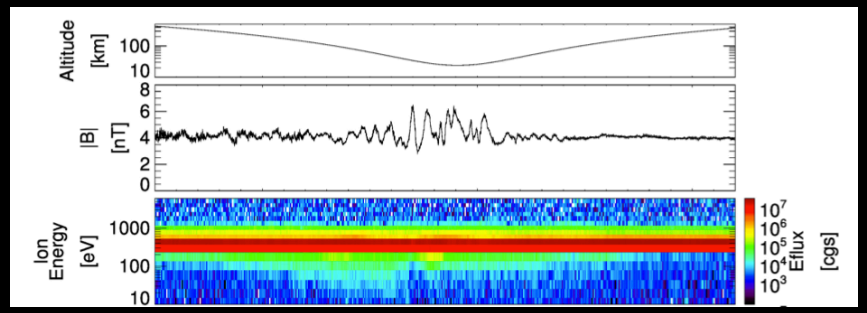
Electrons and Ion < 25 keV

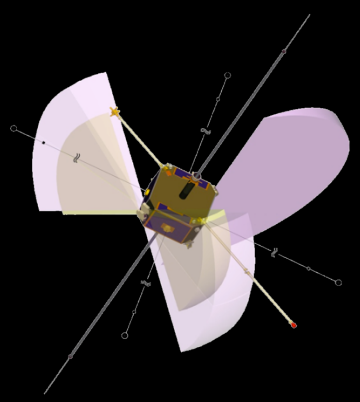
Magnetic and Electric fields

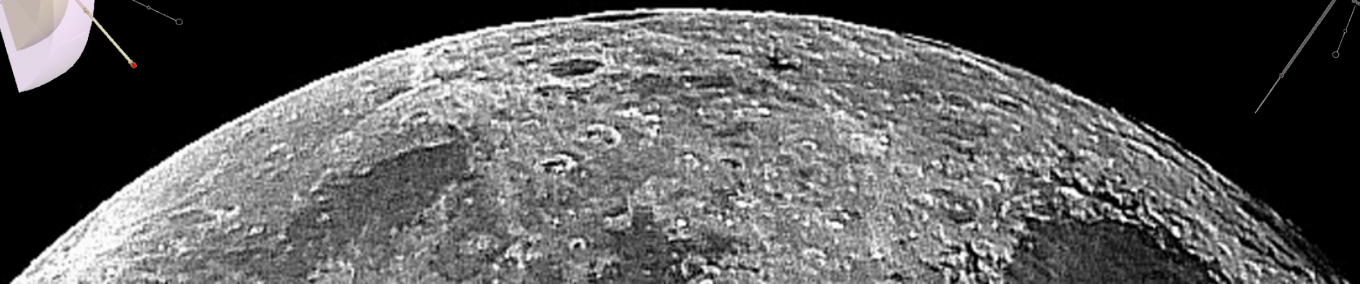
Electromagnetic waves

Accumulating measurements of SW & magnetospheric interaction with lunar crustal fields!





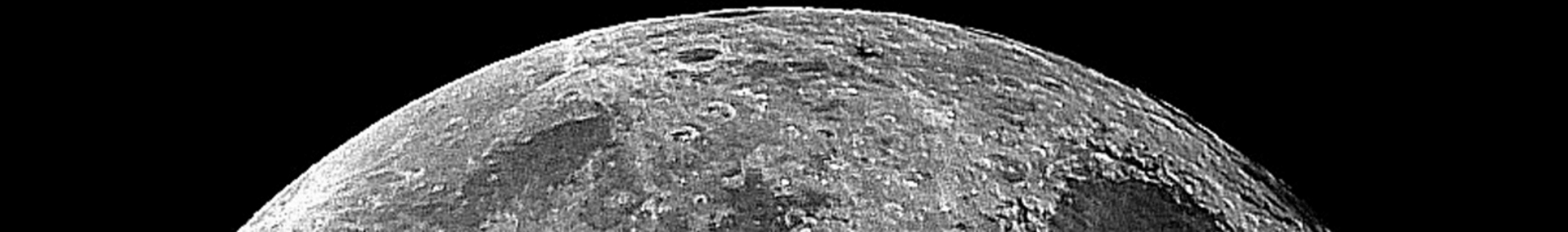




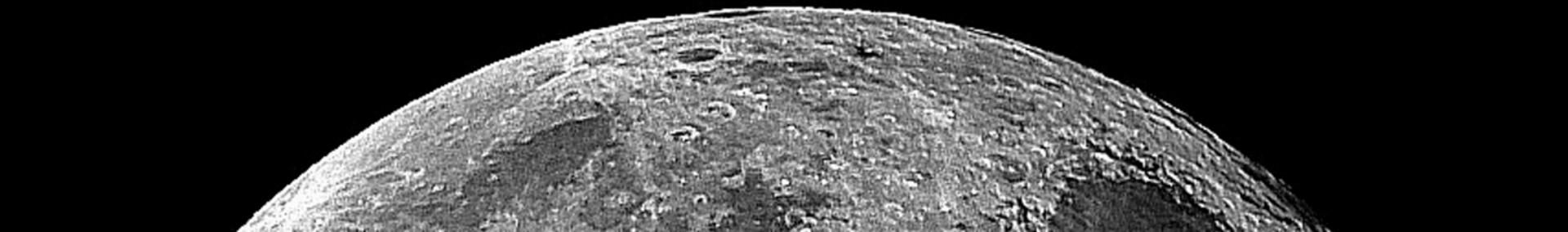
Conclusions & Future Work

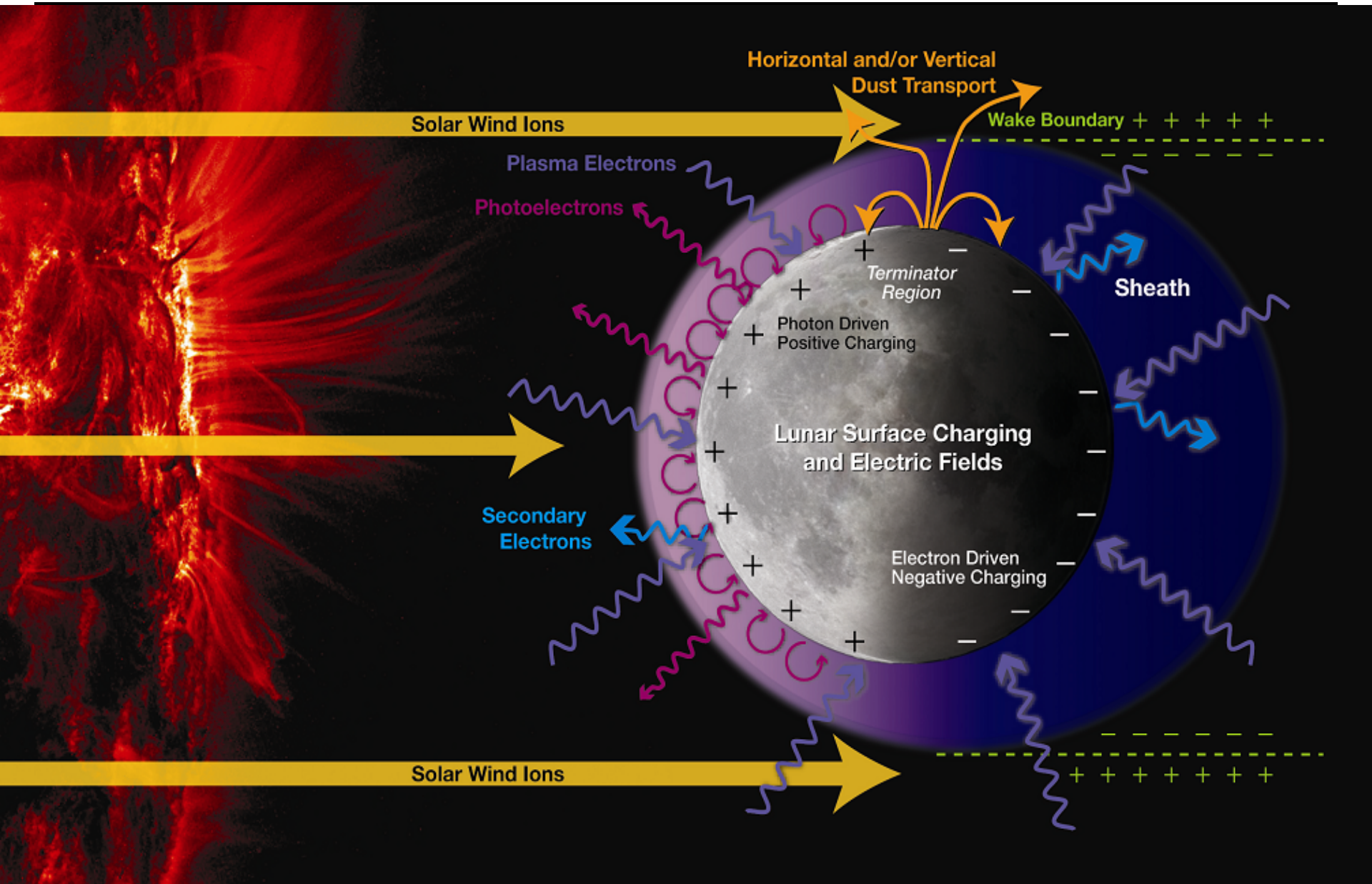
- 1.5-d PIC model developed and applied to crustal field cusp regions
  - Model reproduces high-altitude electrostatic field as observed by KAGUYA above crustal anomalies
  - Models near-surface electrostatics in addition to those observed at spacecraft altitude
  - Ion-ion two stream instability is a possible mechanism for heating
  - Cusp regions are electrostatically unshielded from the solar wind
    - A contributing factor to lunar swirl dark lanes?

- Future work: Surface photoemission, shielded topologies, comparison to ARTEMIS & KAGUYA data



The End



Backup Slides

Lunar Plasma Environment