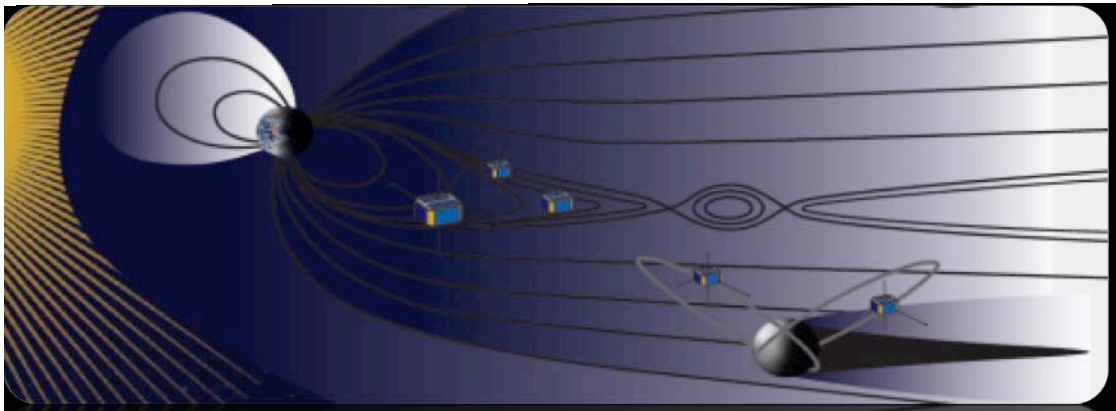
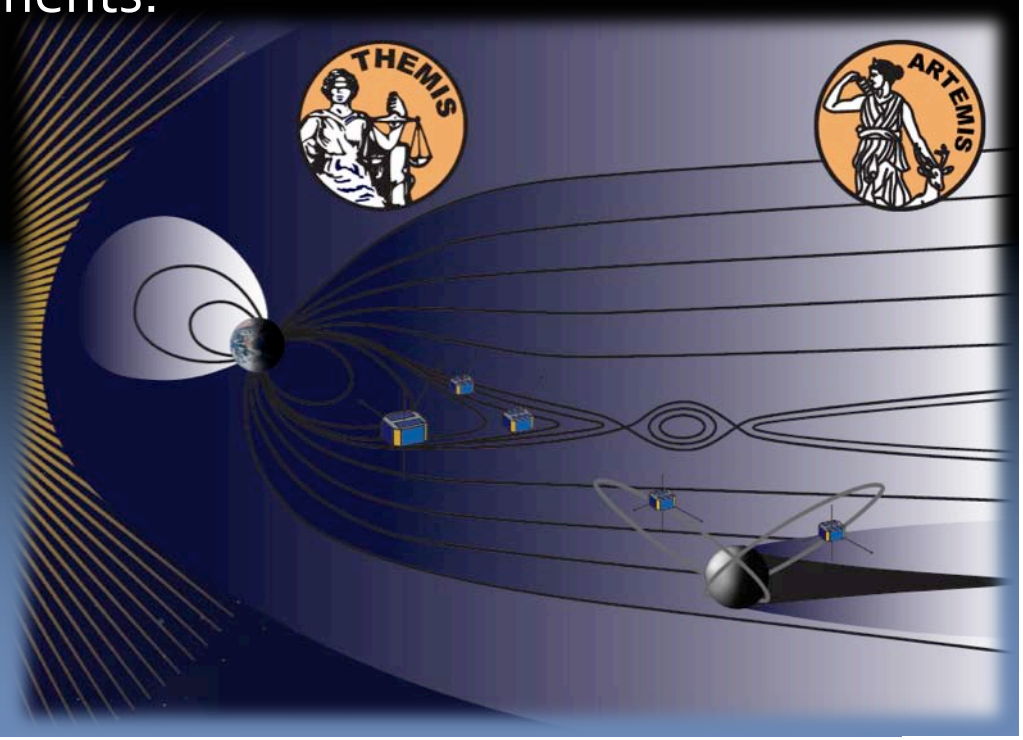


FIRST RESULTS FROM ARTEMIS, A NEW TWO-SPACECRAFT LUNAR MISSION

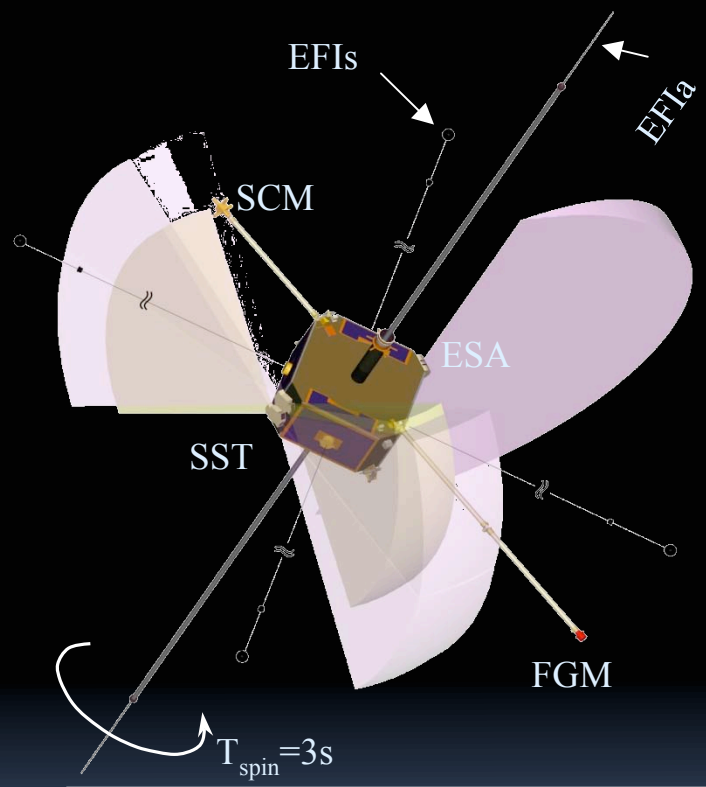
J.S. HALEKAS, V. ANGELOPOULOS, D.G. SIBECK, K. KHURANA, C.T. RUSSELL, G.T. DELORY, J.P. MCFADDEN, J.W. BONNELL, D. LARSON, F. PLASCHKE, K.H. GLASSMEIER

ARTEMIS = Acceleration, Reconnection, Turbulence, and Electromagnetics of Moon's Interaction With the Sun

- THEMIS Prime Mission (2007-2008)
  - Five spacecraft mission in Earth orbit to study magnetospheric dynamics
- Extended Phase (2010-2012)
  - Three probes (THEMIS) continue original mission
  - Two probes (ARTEMIS) pursue new objectives in lunar orbit
- ARTEMIS provides measurements:
  - From the Moon
    - Earth's magnetosphere
    - Basic plasma physics
  - Of the Moon
    - Interior structure
  - On the Moon
    - Surface/Plasma Interactions
    - Exosphere
    - Electric fields and dust
    - Support for other missions



THEMIS/ARTEMIS Payload



Probe instruments:

ESA: ElectroStatic Analyzer (*Carlson and McFadden*)
-Ions, Electrons ~3eV-30 keV

SST: Solid State Telescopes (*Larson*)
-Ions, Electrons > 25 keV

FGM: FluxGate Mag. (*Glassmeier, Auster, Baumjohann*)
-3-axis B measurements, 0.1 nT sensitivity

SCM: SearchCoil Mag. (*Roux*)
-B at frequencies 10Hz-4kHz

EFI: Electric Field Instrument (*Bonnell*)
-3-axis E fields: DC – 8kHz

ESA

SST

FGM

SCM

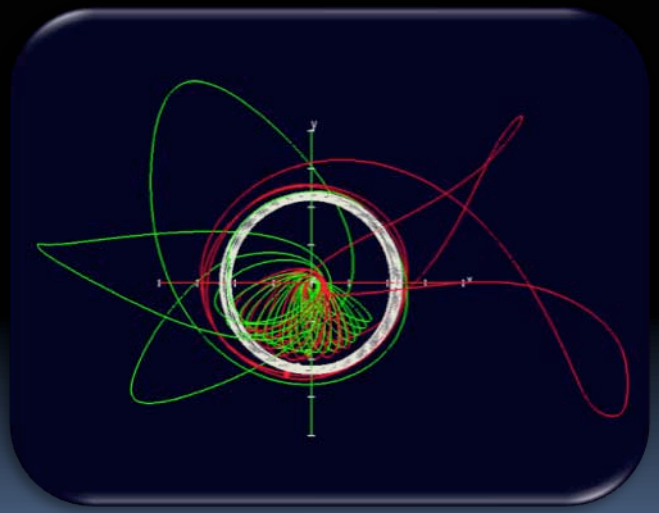
EFI

ARTEMIS Mission Phases

Translunar injection phase (Oct '09 – Oct '10)

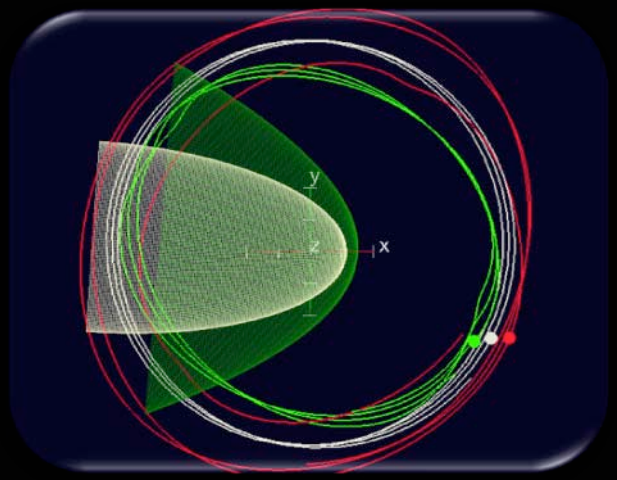
… getting there.

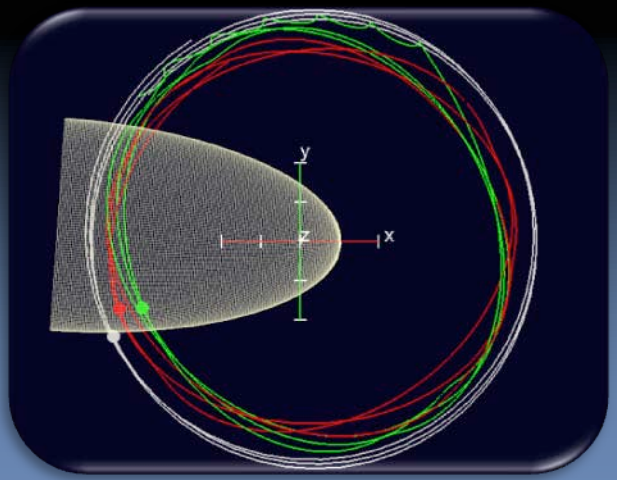
Note: Orbit Raise Maneuvers (ORMs) start: July 2009, in parallel with THEMIS 2nd dayside operations (THEMIS dayside requirements met already since 1st dayside season)



Lissajous Phase Science (Oct '10 – Apr '11)

Note: First 3 months: opposite sides, Next 3 months: same side





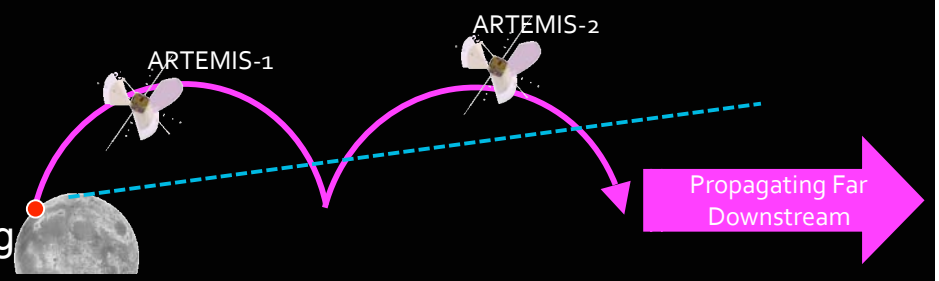
Lunar Orbit Science (May '11 – Sep '12)

Note: P1 retrograde, and P2 prograde, such that orbital separations and separation vectors cover full parameter space

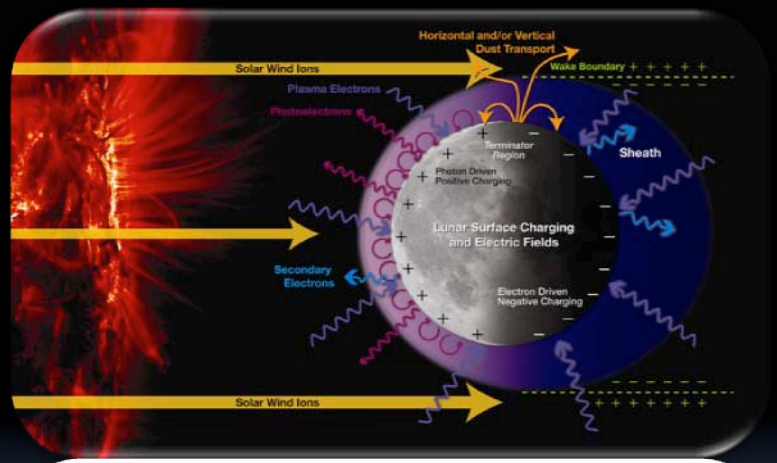
P1, P2 Periselene: 100 km, 1500 km
P1, P2 Aposelene: 10 RL

Planetary Objectives

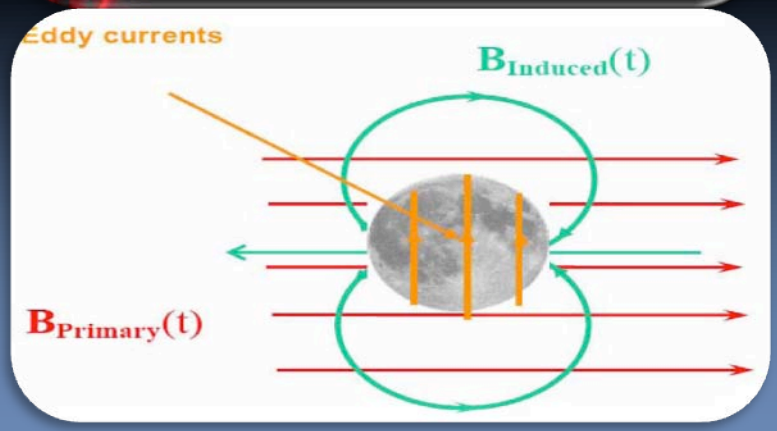
- Tenuous lunar exosphere:
  - Pickup acceleration of ionized exospheric neutrals
  - Remotely sense surface and exosphere properties
  - Measure sources and sinks to identify driving physics
  - Investigate dynamics and response to transient inputs



- Lunar electricity
  - Use reflectometry to measure surface fields
  - Two point measurements of drivers and response
  - Measure the fields that may control dust



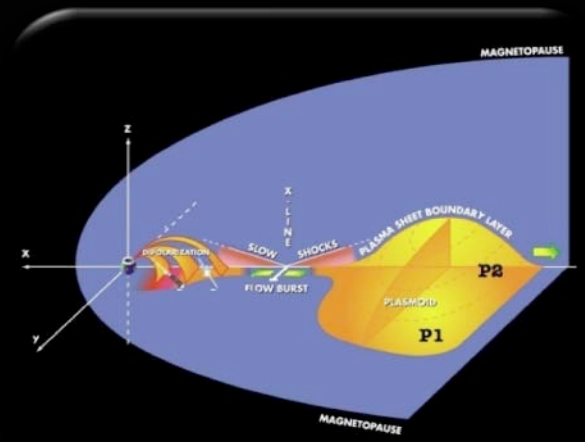
- Lunar interior
  - Use inductive sounding to probe the interior
  - Two point measurements of driver and response
  - Magnetotelluric sounding of subsurface



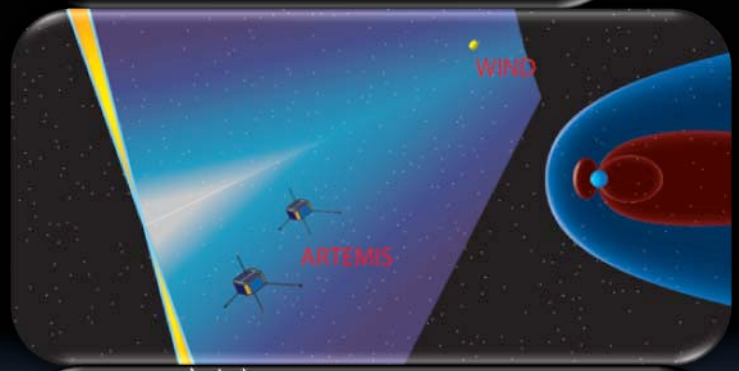
– ARTEMIS joins a lunar armada
  - Support LRO, LADEE, ILN, etc.

Heliophysics Objectives

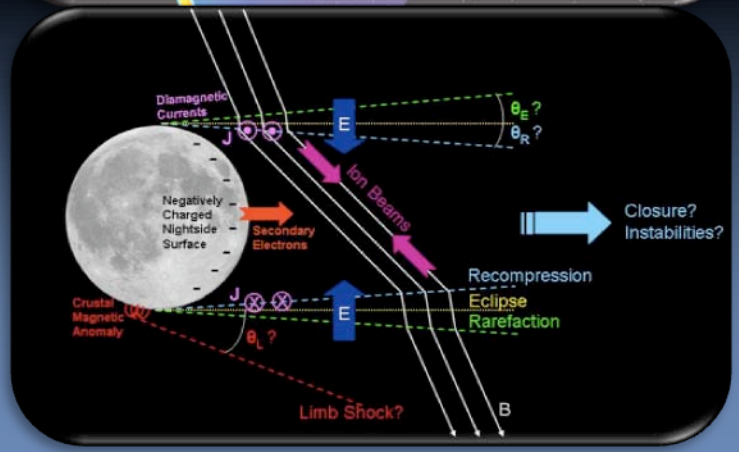
- When Moon is in the Magnetosphere:
  - Particle acceleration at lunar environment
  - Reconnection: 3D character; global effects
  - Turbulence: Drivers and effects



- When Moon is in the Solar Wind:
  - Seed population for solar energetic particles
  - Nature of elusive low-shear reconnection
  - Properties of inertial range of turbulence

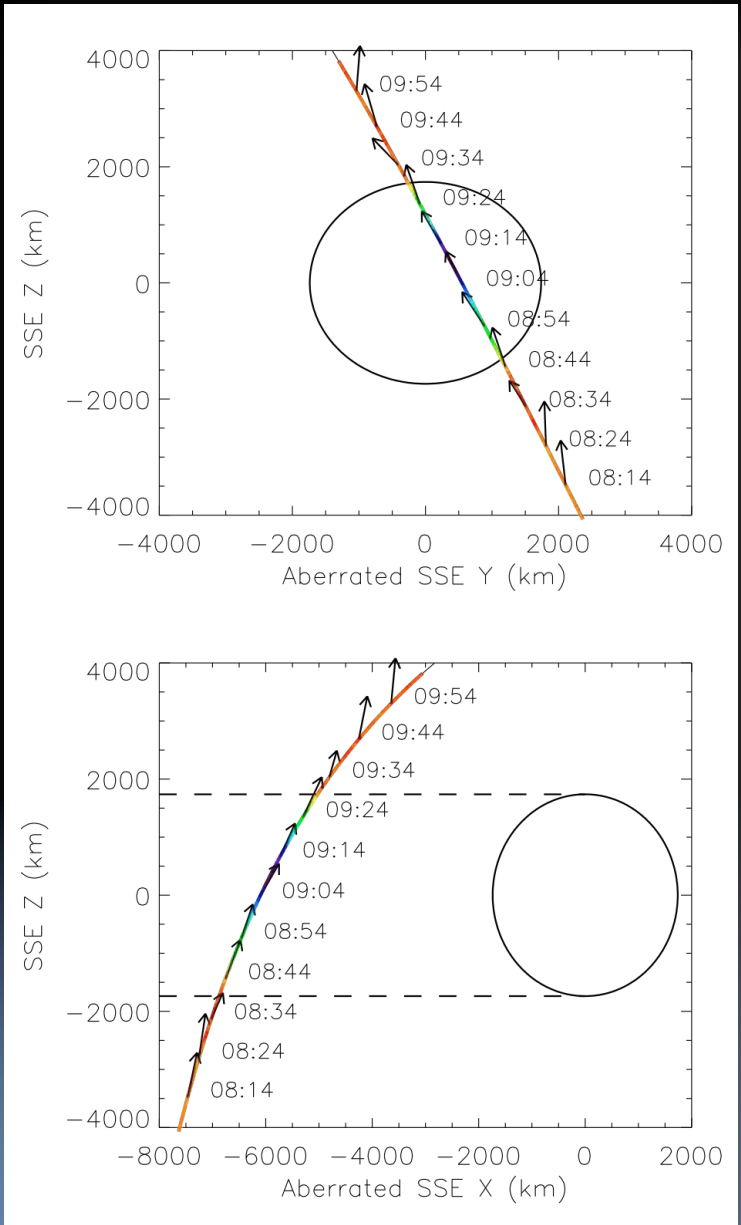


- Near the Moon:
  - Study the structure and evolution of lunar wake
  - Understand particle acceleration at wake
  - Understand formation of wake electric fields



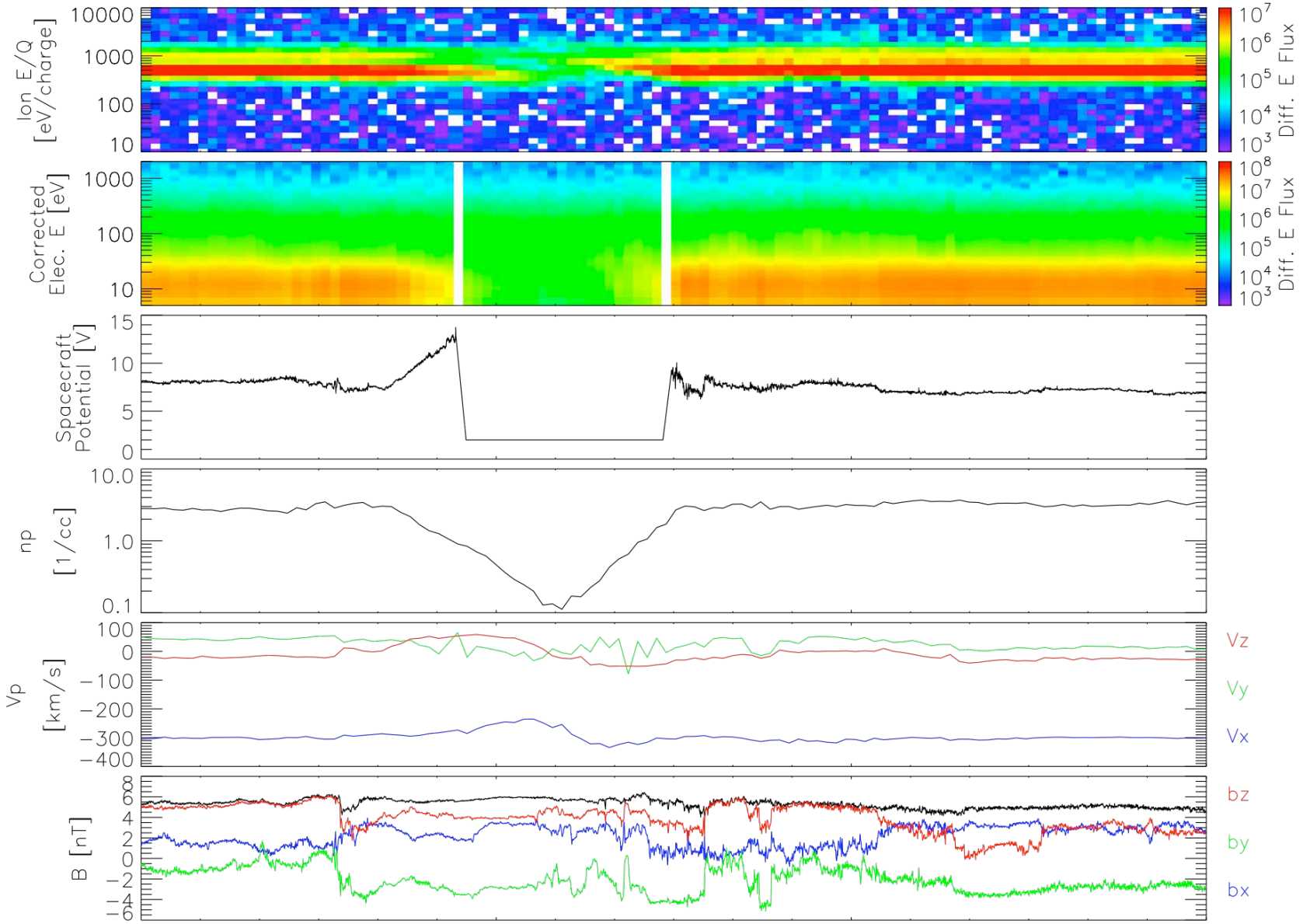
First Lunar Wake Flyby

- First flyby at ~3.5 R_L
- ARTEMIS P1 orbital trajectory nearly aligned with the magnetic field
  - Fortuitous for observing plasma refilling the wake along magnetic field lines
  - Did not allow us to measure perpendicular Type-I and Type-II entry



Halekas et al., 2010

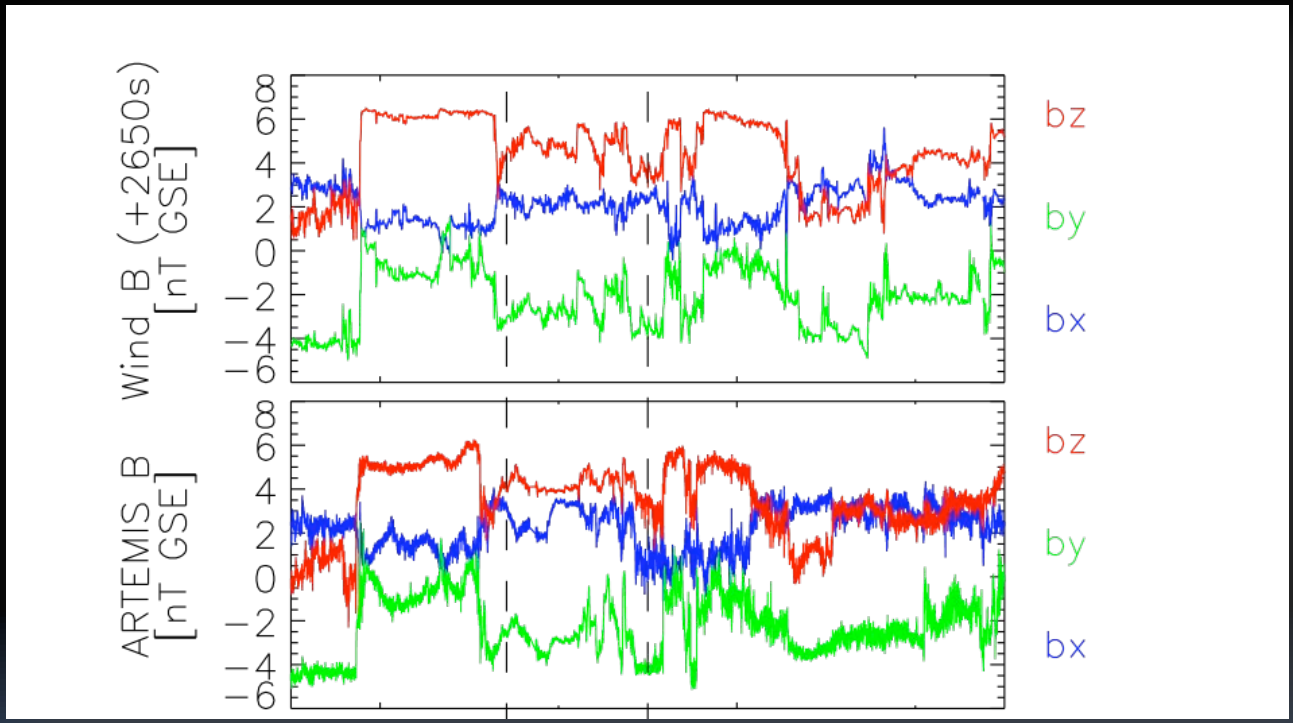
Flyby Overview



Halekas et al., 2010

Flyby Magnetic Field Data

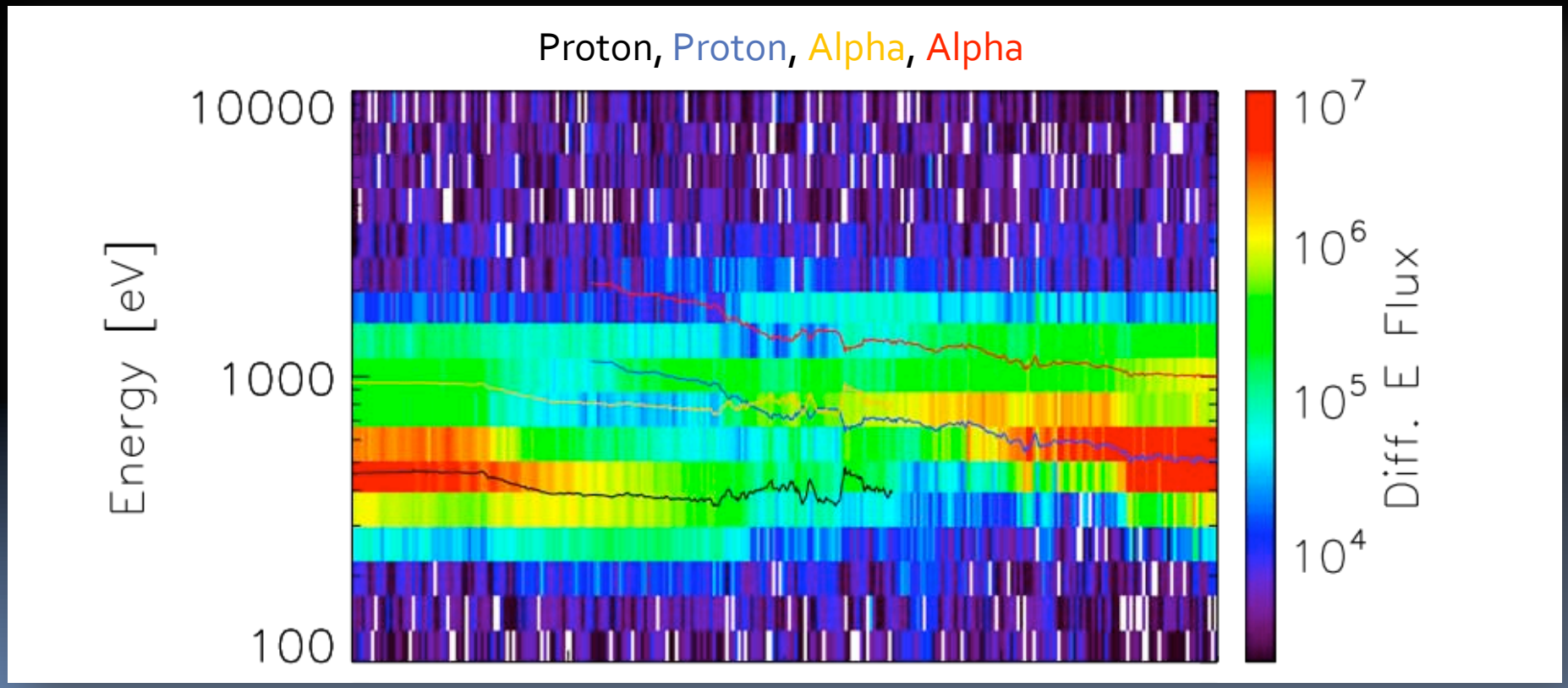
- Magnetic field data matches upstream data
- No clear lunar signature



Halekas et al., 2010

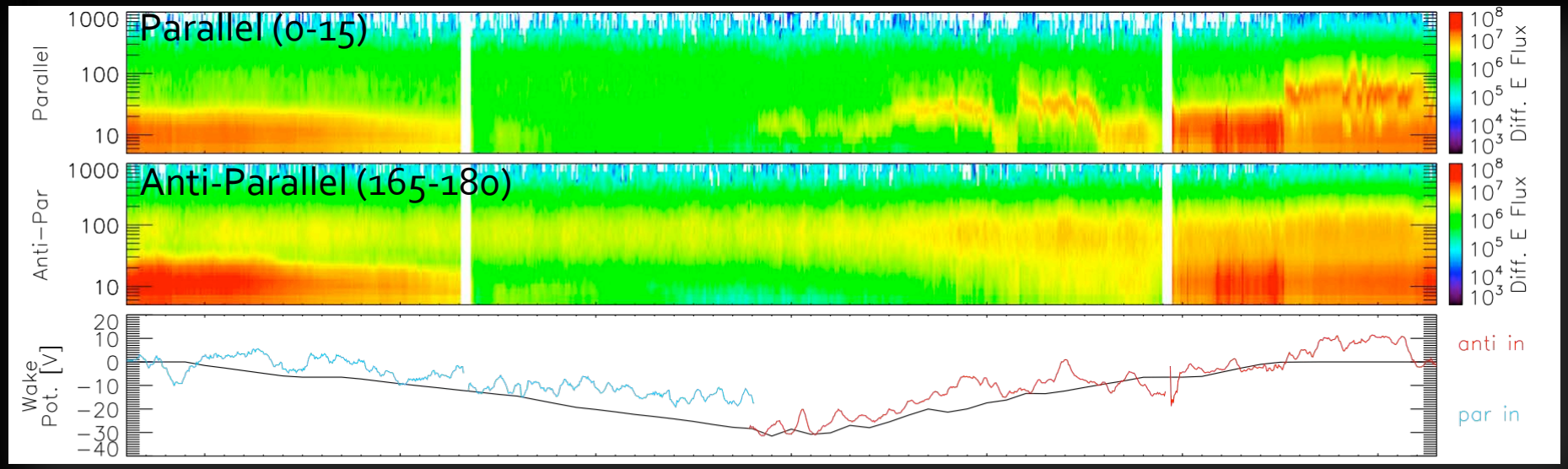
Flyby Ion Data

- Four refilling ion populations
- Data well fit by self-similar model predictions



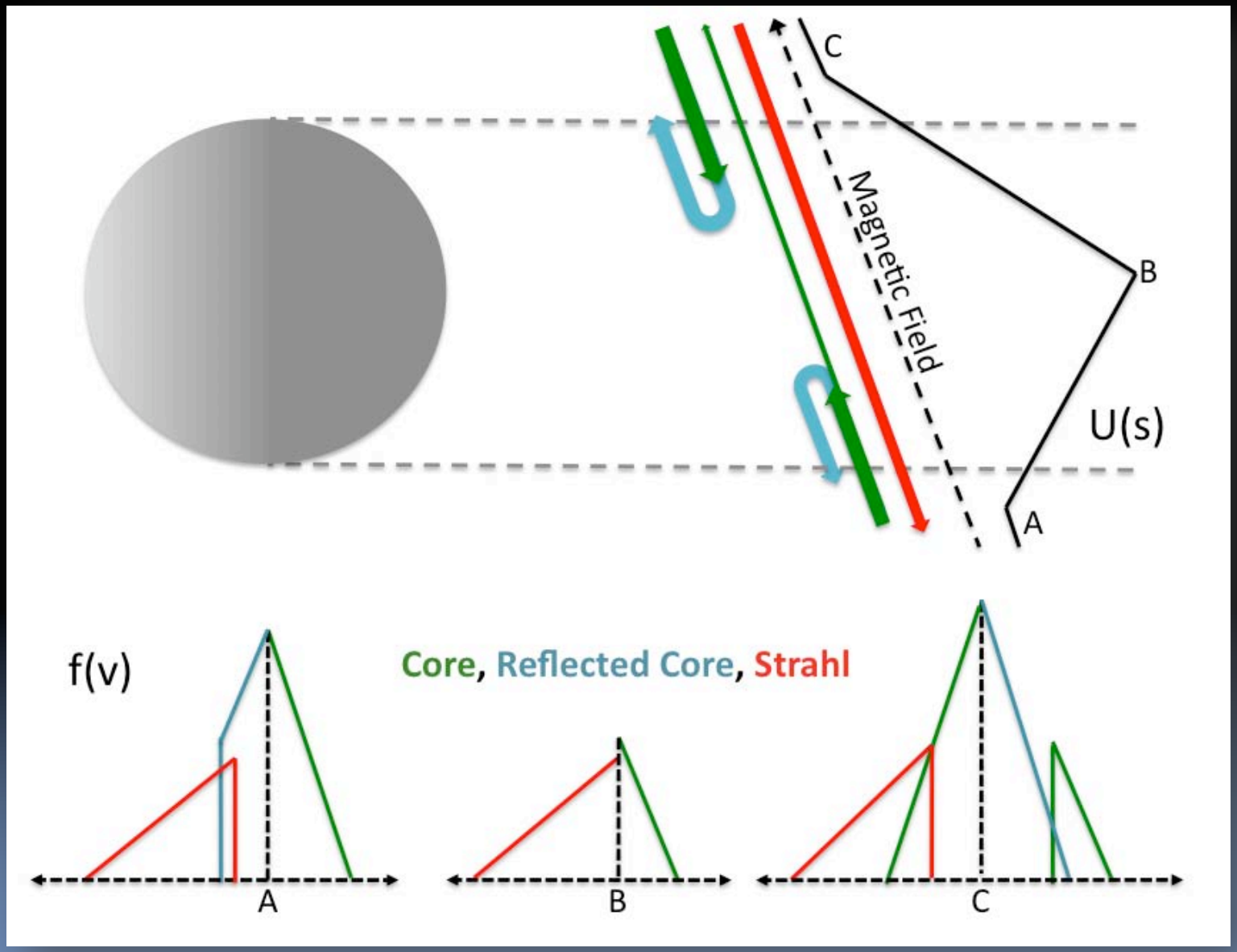
Halekas et al., 2010

Flyby Electron Data

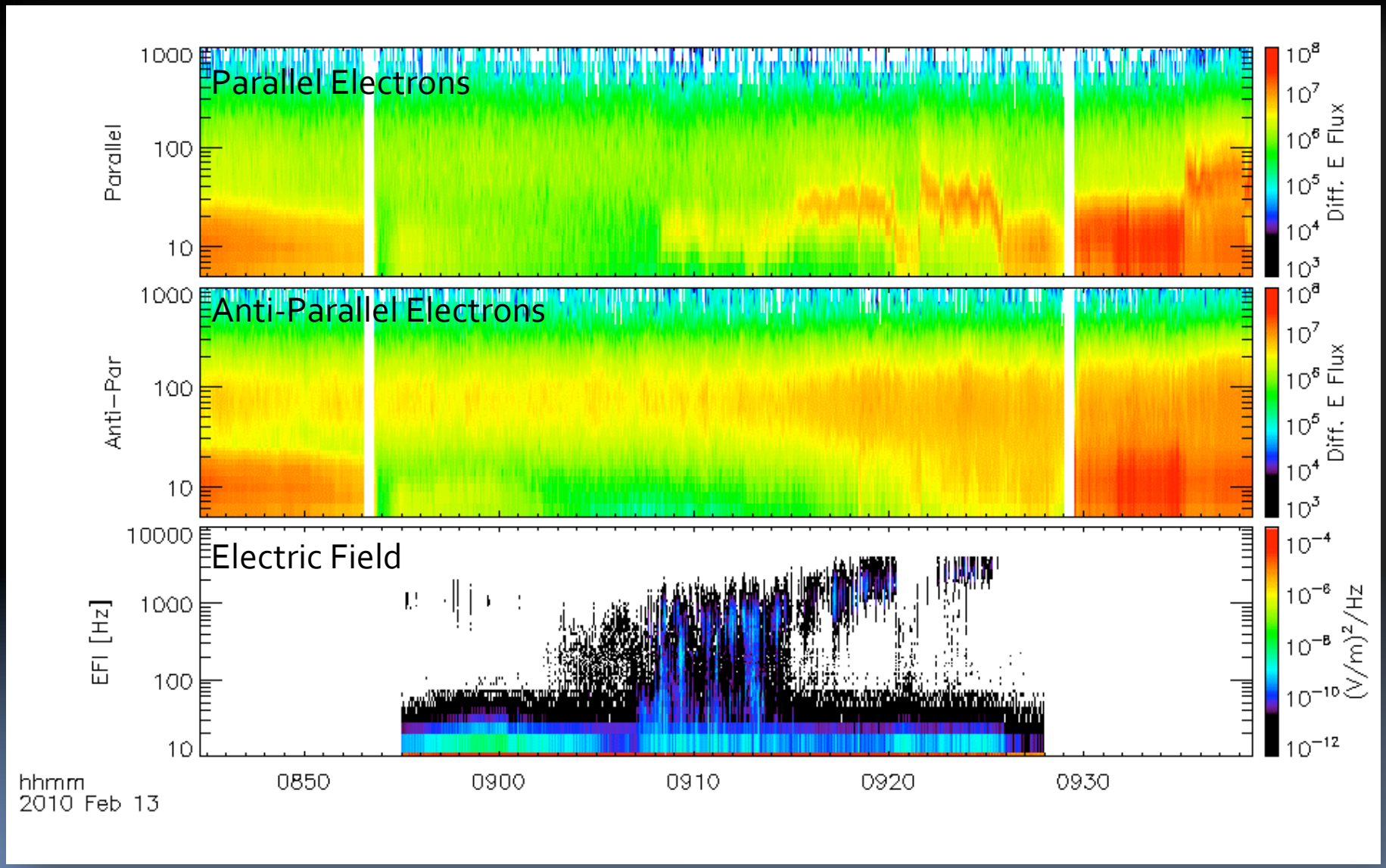


- Strong strahl component penetrates through wake
- Most of core population excluded by wake potential
- Remnant population accelerated out from central wake by wake electric field
- We derive wake potentials by measuring the shift in the electron spectrum
  - Good match to self-similar model predictions

Cartoon Overview



Flyby Wave Data



Halekas et al., 2010

Conclusions

- The lunar plasma environment is a natural plasma laboratory, rich in fundamental plasma physics
  - The wake is a natural generator of plasma instabilities
- The first ARTEMIS wake flyby has already demonstrated the mission's capability to contribute to lunar science
- We look forward to lunar orbit insertion and the chance to contribute to many more areas of lunar science, both planetary and heliophysics, in the coming years