Electron Transport and Precipitation at Mercury during the MESSENGER Flybys

David Schriver, Pavel Trávníček, Maha Ashour-Abdalla, Robert L. Richard
Petr Hellinger, James A. Slavin, Brian J. Anderson, Daniel N. Baker
Mehdi Benna, Scott A. Boardsen, Robert E. Gold, George C. Ho, Haje Korth
Stamatios M. Krimigis, William E. McClintock Thomas M. Orlando
Menelaos Sarantos, Ann L. Sprague, Richard D. Starr

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Science Goals

- Understand Mercury's magnetosphere on a kinetic level and relationship with exosphere
  - global magnetic and electric field configuration and connectivity between solar wind and planet surface
  - ion and <u>electron</u> transport, energization and circulation within the magnetosphere (including wave-particle interactions & non-adiabatic motion)
  - solar wind ion and <u>electron</u> precipitation
  - transport of heavy ions emanating from planetary surface in and around Mercury's magnetosphere

Magnetosphere $\Leftrightarrow$ Exosphere/Heavy Ion Cloud

Simulation Approach

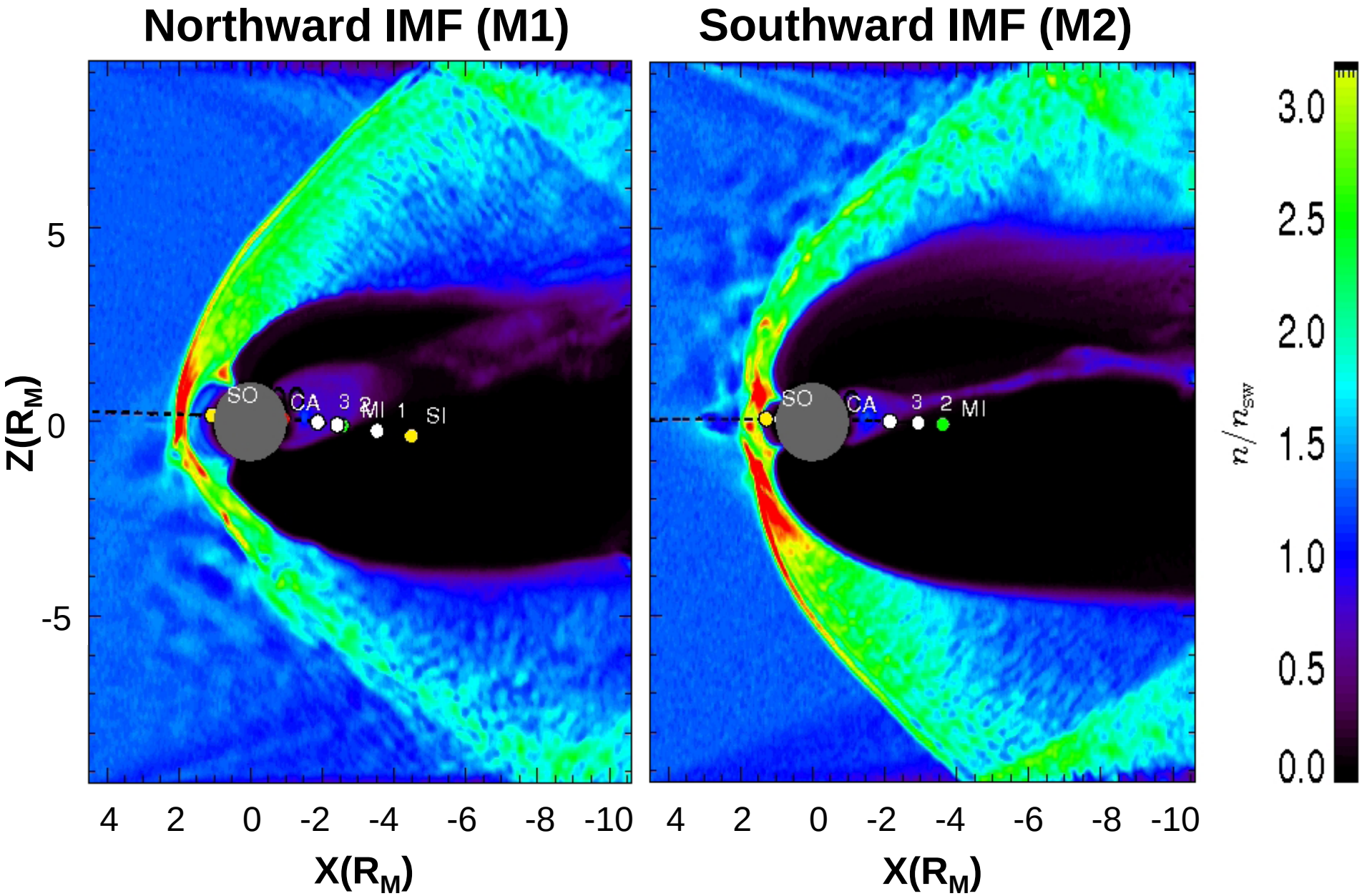
- 3D global self-consistent hybrid code
  - kinetic ions, (massless) fluid electrons
  - use realistic spatial scales and solar wind parameters to drive the system
- Particle trajectory tracing in global **E** and **B** fields specified by the hybrid simulations
  - launch full 3D electron distribution functions from the solar wind and collect data at virtual detectors
  - examine kinetic particle transport and acceleration through the magnetosphere
  - determine electron energies and precipitation fluxes

Solar Wind During MESSENGER Flybys

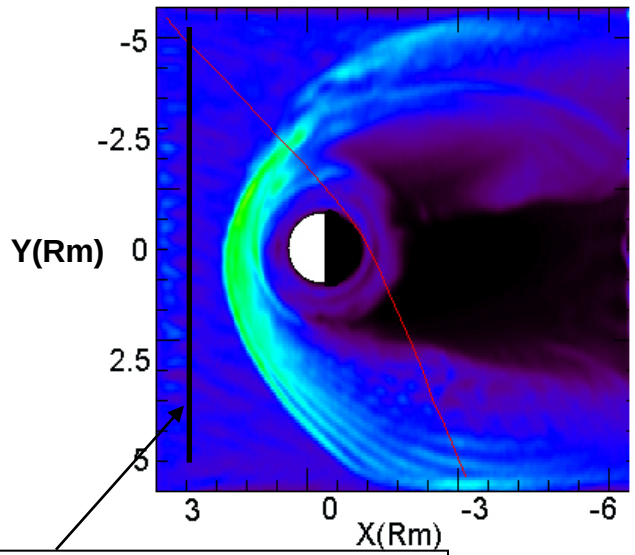
- M1 on January 14, 2008
  - speed = 450 km/s, density = 15 cm^{-3} (inferred)
  - northward interplanetary magnetic field (IMF)
  - large radial IMF component (sun-planet direction)
- M2 on October 6, 2008
  - speed = 450 km/s, density = 15 cm^{-3} (inferred)
  - southward interplanetary magnetic field (IMF)
  - large radial IMF component (sun-planet direction)

Ideal control experiment to study reconnection as a function of north/south IMF

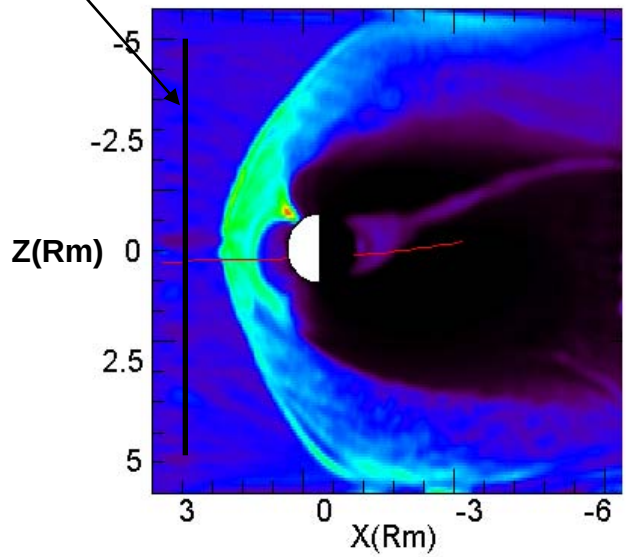
Density Contours: North-South View



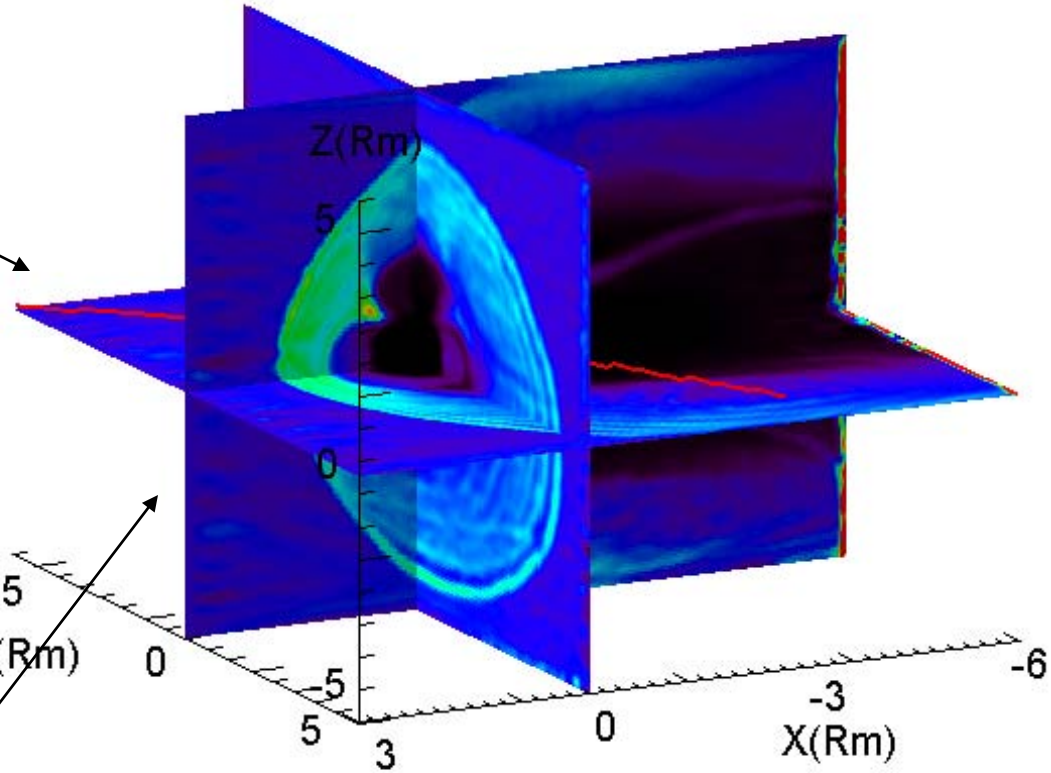
Electron Particle Launches



SW electron launches



density contours

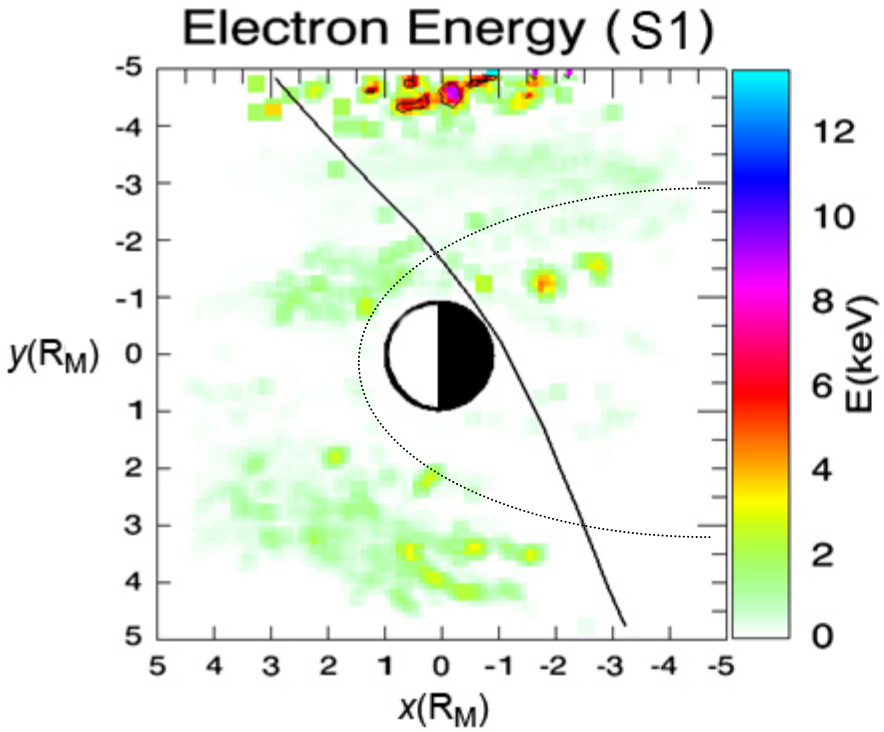


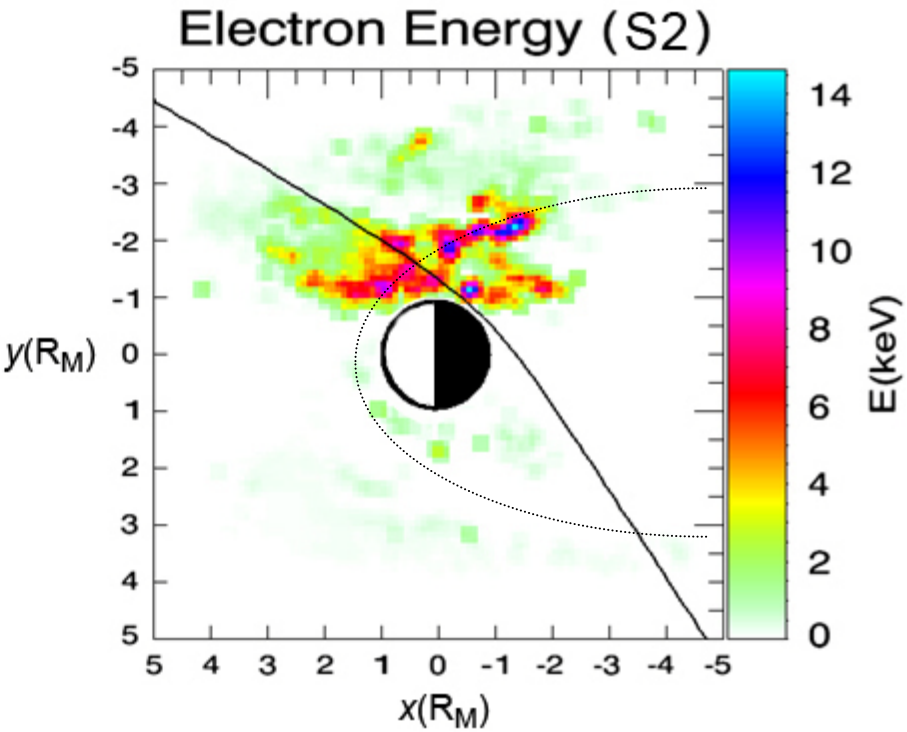
Use fields from the hybrid simulations for M1 and M2 conditions with:

n_{sw} = 15 cm^{-3}

v_{sw} = 450 km/s

Equatorial Plane Energy Profiles



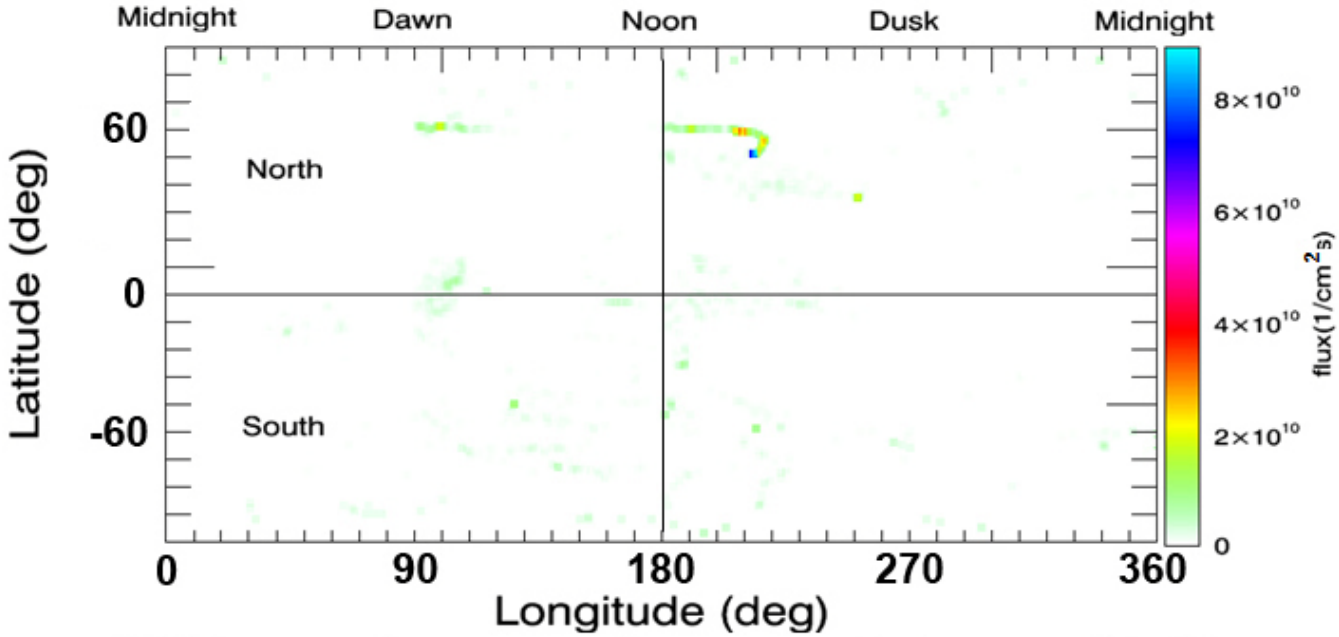


Average energies higher in southward IMF case (M2)

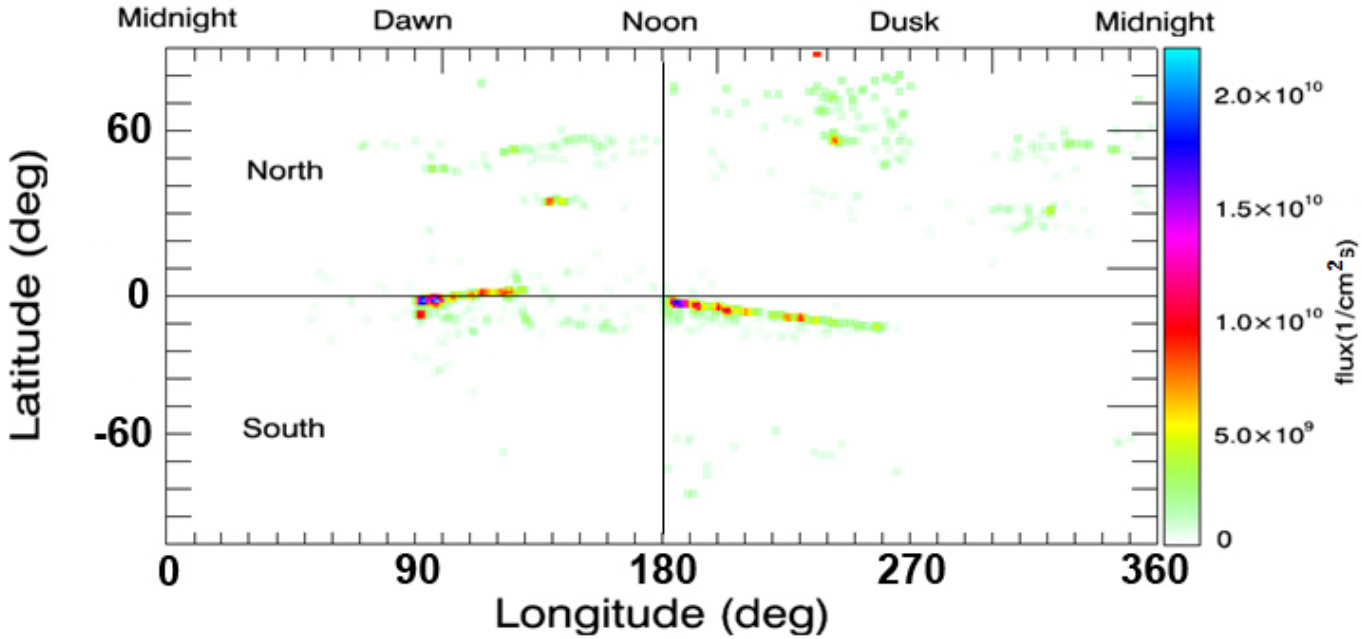
- more efficient reconnection
- energization occurs due to non-adiabatic motion

Electron Precipitation Flux Maps

S1
(north IMF)

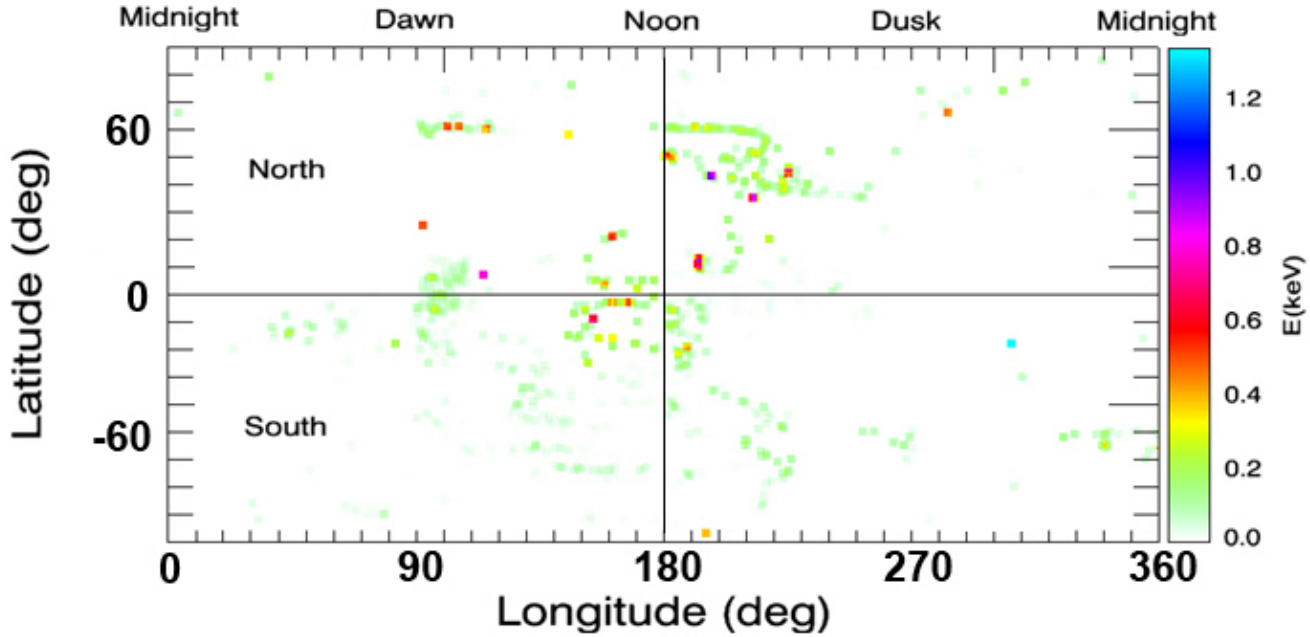


S2
(south IMF)

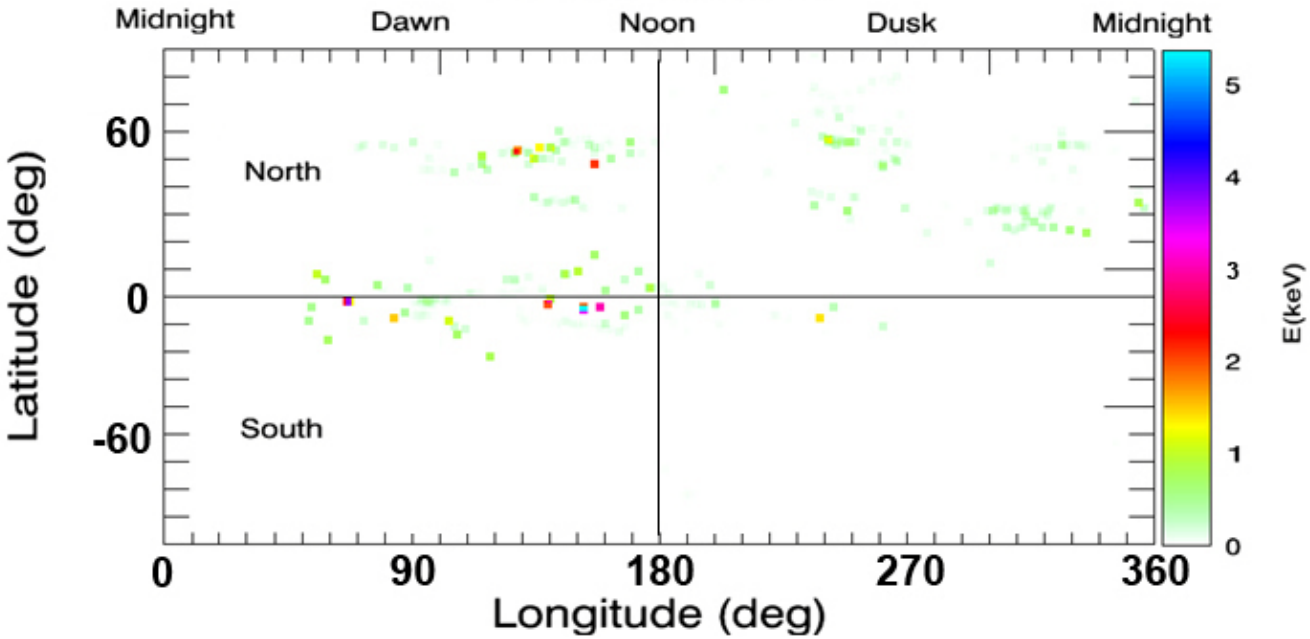


Electron Precipitation Average Energy

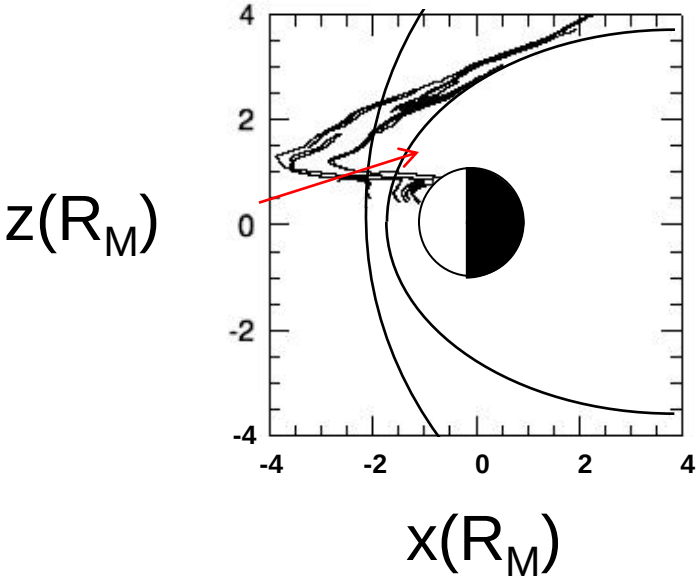
S1
(north IMF)

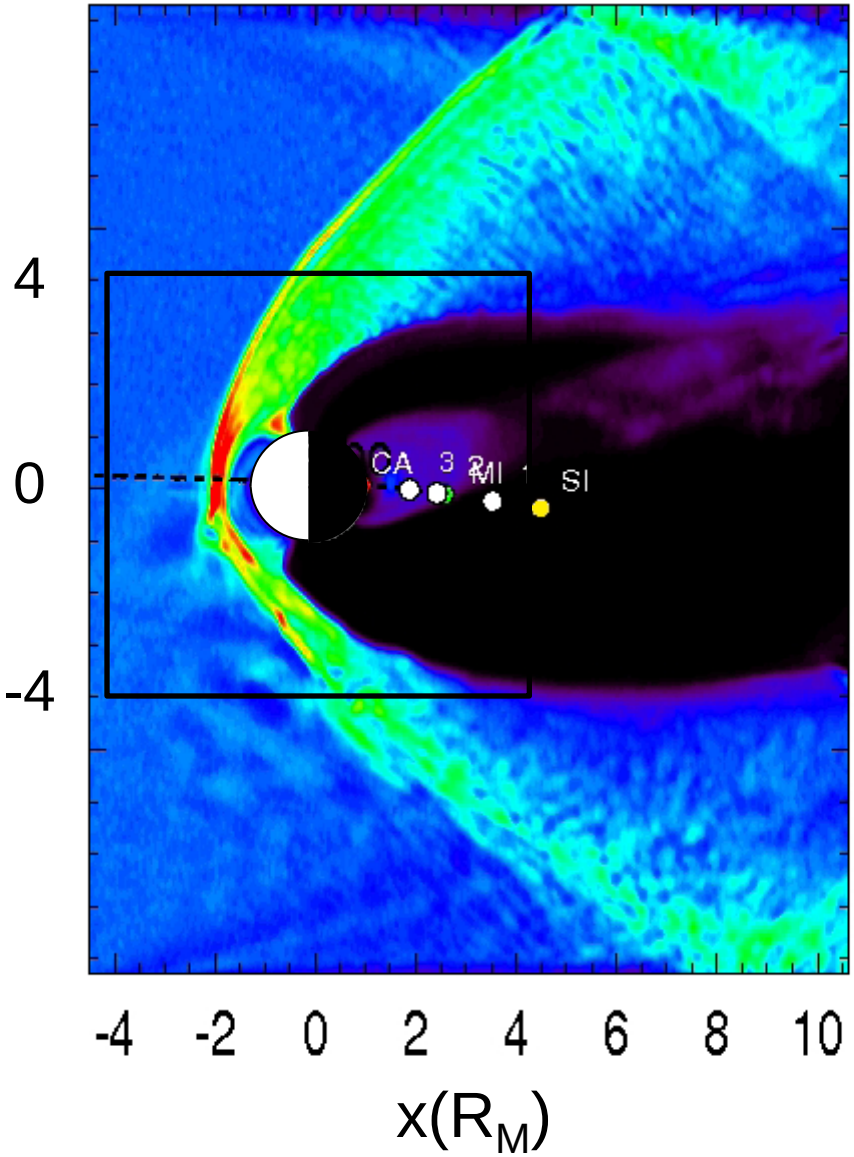


S2
(south IMF)



Single Electron Trajectory (Northward IMF)

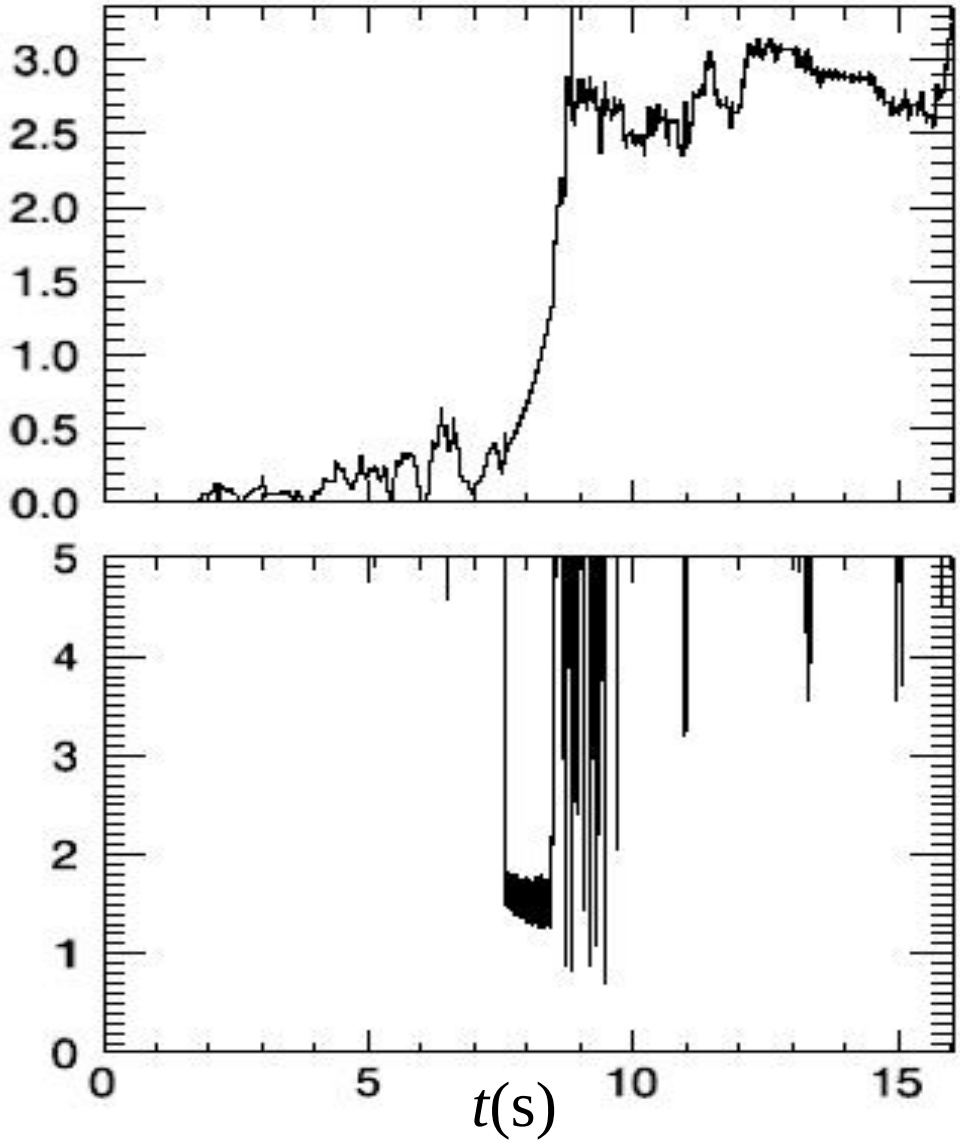




Electron Energization (Northward IMF)

E (keV)

$\kappa = (R/\rho)^{1/2}$



$\kappa < 3$ indicator of non-adiabatic (demagnetized) motion

Conclusions

- Transport
  - large radial component of IMF influences solar wind magnetic connectivity with Mercury, which affects transport and entry into magnetosphere
  - magnetospheric entry rate into equatorial region higher for southward IMF (M2)
- Energetics
  - non-adiabatic motion is important for <u>electrons</u>
  - energies higher for southward IMF (~ 10 keV) compared to northward IMF (~ 1 keV)
  - highest magnetospheric energy ~ 25 keV (M1/M2)
- Precipitation (next slide)

Precipitation Numbers

- Northward IMF (M1)
  - higher precipitation fluxes in northern hemisphere
  - fluxes: ~ 1.0×10^{10} $cm^{-2}s^{-1}$, avg. energy ≤ 1 keV
  - total precipitation area: ~ 1.6×10^{6} km^{2}
  - total electrons precipitating: 1.0×10^{26} (per second)
- Southward IMF (M2)
  - higher precipitation fluxes equator to north
  - fluxes: ~ 1.5×10^{10} $cm^{-2}s^{-1}$, avg. energy ≥ 1 keV
  - total precipitation area: ~ 1.5×10^{6} km^{2}
  - total electrons precipitating: 1.1×10^{26} (per second)

Implications for Electron Stimulated Desorption

Model Limitations – Future Directions

- Flux normalization depends on solar wind parameters, e.g, density, flow speed & direction
  - no solar wind monitor, thus no hard SW numbers
  - use magnetopause location to infer solar wind pressure; use ENLIL SW model to further constrain
- Only solar wind considered for electron source
  - electrons from planet, from deep magnetotail can populate open lobe field lines act as another source
- Simulation runs for relatively small number of steady, low pressure solar wind conditions
  - will consider higher solar wind pressure events
  - new runs with variable solar wind