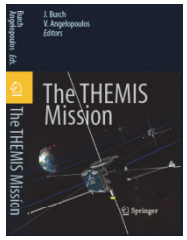
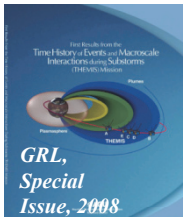
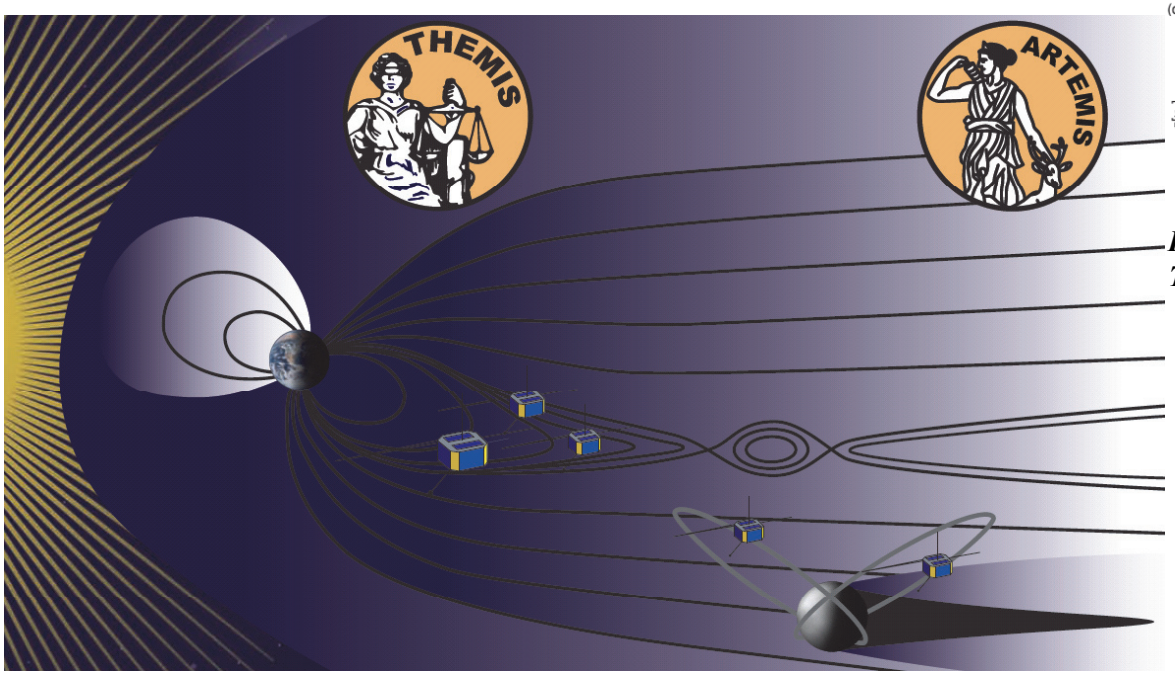
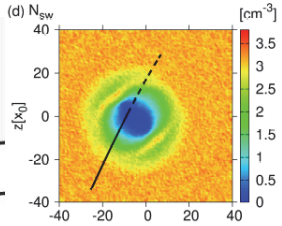
Mission accomplishments, status





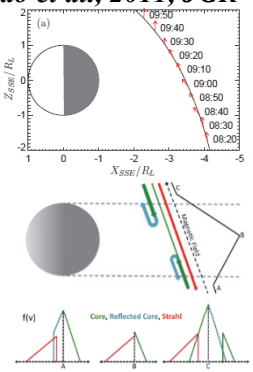


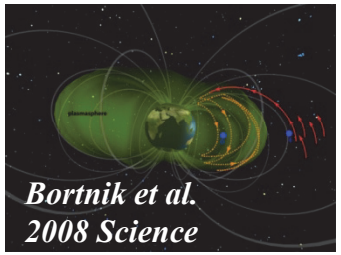
Wiehle et al. 2011, JGR

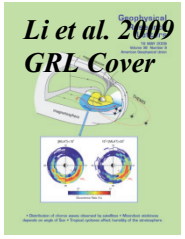


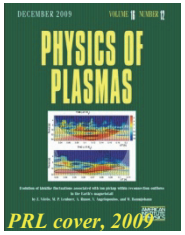
Halekas et al. 2010, SSR

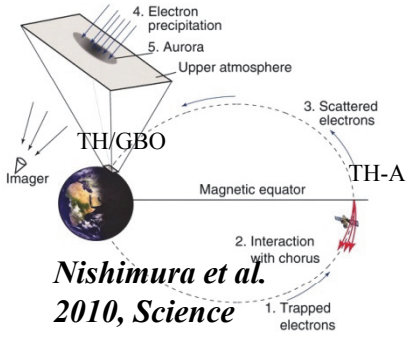
Tao et al., 2011, JGR



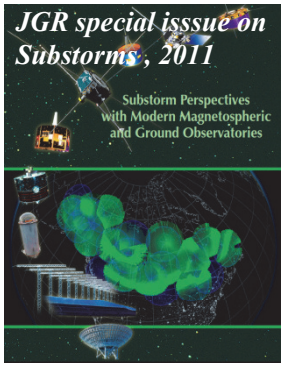


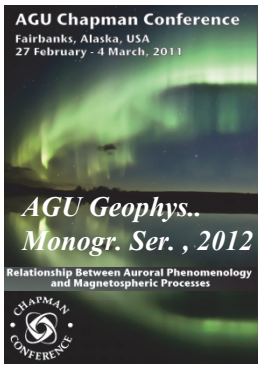


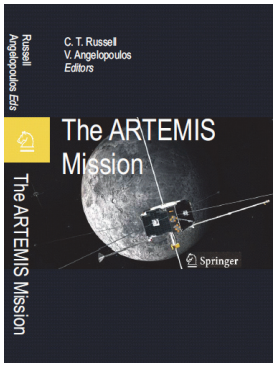




Nishimura et al. 2010, Science



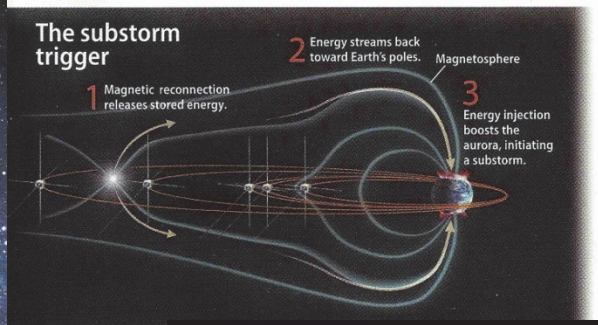




4 What powers auroral storms

A fleet of NASA spacecraft solved the greatest outstanding mystery of the northern and southern lights: the origin of sudden, explosive flare-ups called auroral substorms. Scientists knew substorms release energy trapped in Earth's magnetic field. However, the critical details of how and where the energy is released have remained controversial. To settle the question, NASA launched five identical spacecraft into orbit in February 2007 on the Time History of Events and Macroscale Interactions during Substorms (THEMIS) mission.

Every 4 days, the satellites lined up along Earth's magnetosphere — the volume of space under the influence of the planet's magnetic field. The satellites monitored electrical and magnetic fields and charged particles.



On February 26, 2008, the THEMIS dragnet caught a substorm, providing researchers the data they needed. "We discovered what makes the northern lights dance," says UCLA's Vassilis Angelopoulos, lead scientist for THEMIS.

The power source for substorms is magnetic reconnection. The "solar wind" of charged particles from the Sun flows around Earth's magnetosphere. This squeezes and compresses the magnetic field, storing energy.

When the lines of magnetic force can stretch no farther, they snap and reconnect to form U-shaped loops that channel energy toward Earth's poles. This injection temporarily supercharges the aurora. The critical event — magnetic reconnection — occurs about a third to a half of the distance to the Moon's orbit, the team reported August 14 in *Science*.

THEMIS data will help scientists build more accurate models of substorms and other aspects of "space weather." Major space storms can disrupt earthly communications and even damage satellites.

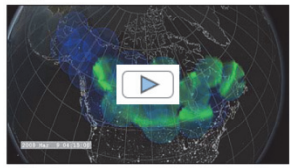
THEMIS spacecraft line up at midnight over North America every 4 days. Several of the satellites caught the triggering event for an auroral substorm February 26, 2008. The satellites confirmed that a process called magnetic reconnection powers auroral substorms. NASA

The Washington Post

Scientists Unveil Discovery About the Northern Lights

By Marc Kaufman
Washington Post Staff Writer
Thursday, July 24, 2008; 5:44 PM

VIDEO



Northern Lights

The mysterious sudden brightening and wavelike movements often seen in the aurora borealis, also called the Northern Lights, are caused by periodic explosions of magnetic energy 80,000 miles above Earth, NASA researchers reported today.

The New York Times

Friday, July 25, 2008

Scientists Find Trigger for Northern Lights

By KENNETH CHANG

David Bebee/Waterloo Region Record, via Associated Press

A NASA mission to study geomagnetic storms used satellites and ground observations to determine the order of events surrounding the aurora borealis, shown in Kitchener, Ontario, in 2004.

The researchers hope the finding will be a step in developing reliable forecasts of geomagnetic storms.

Inside Earth's magnetic shield

An invisible structure protects Earth from all but the Sun's worst outbursts. Scientists are starting to understand how it works.

by Francis Reddy; illustration by Roen Kelly

A magnetic shield envelops our planet, but the only visible evidence it exists are the rays and curtains of the nightside aurora. Such a structure, which scientists call a magnetosphere, forms wherever the Sun's outflow encounters a strong planetary magnetic field.

In 1958, America's first spacecraft, Explorer 1, began direct study of the magnetosphere when it discovered the Van Allen radiation belts — two regions of charged particles. Since then, scientists have worked to understand the magnetosphere's structure and the complex interactions occurring within it.

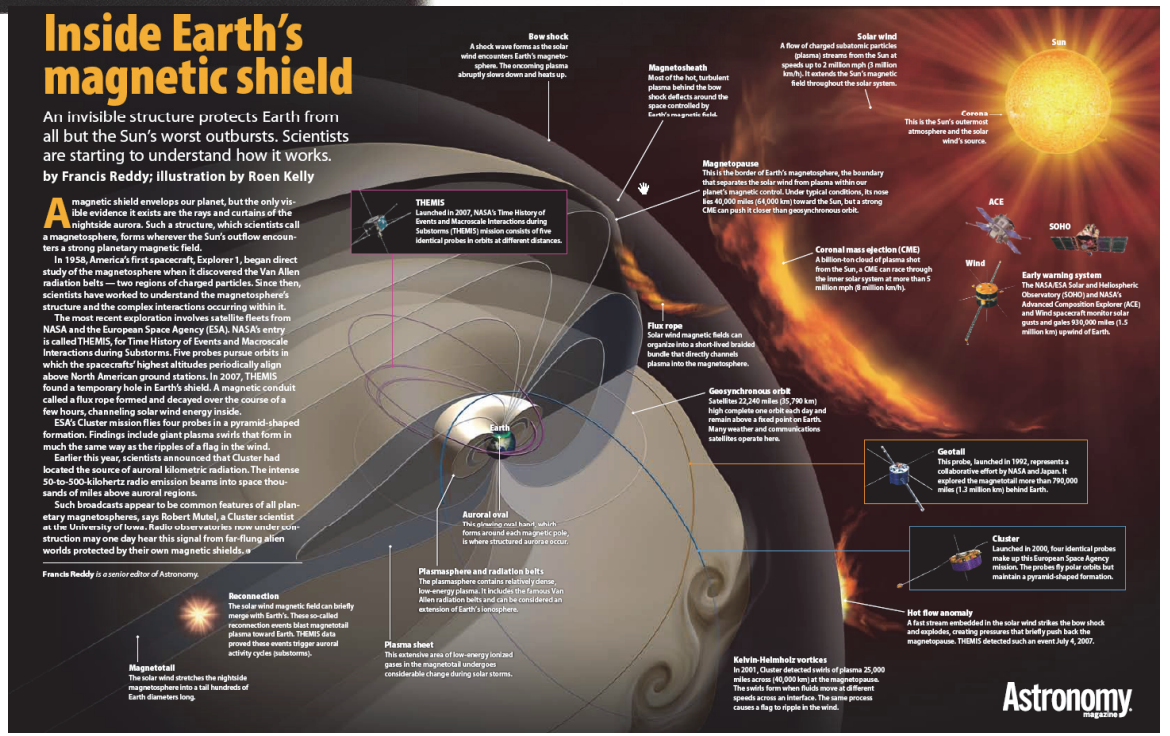
The most recent exploration involves satellite fleets from NASA and the European Space Agency (ESA). NASA's entry is called THEMIS, for Time History of Events and Macroscale Interactions during Substorms. Five probes pursue orbits in which the spacecrafts' highest altitudes periodically align above North American ground stations. In 2007, THEMIS found a temporary hole in Earth's shield. A magnetic conduit called a flux rope formed and decayed over the course of a few hours, channeling solar wind energy inside.

ESA's Cluster mission flies four probes in a pyramid-shaped formation. Findings include giant plasma swirls that form in much the same way as the ripples of a flag in the wind.

Earlier this year, scientists announced that Cluster had located the source of auroral kilometric radiation. The intense 50-to-500-kilohertz radio emission beams into space thousands of miles above auroral regions.

Such broadcasts appear to be common features of all planetary magnetospheres, says Robert Mutel, a Cluster scientist at the University of Iowa. Radio observatories now under construction may one day hear this signal from far-flung alien worlds protected by their own magnetic shields.

Francis Reddy is a senior editor of Astronomy.



Output

- Number of publications per year steadily increasing
  Source: http://themis.ssl.berkeley.edu/publications.shtml

	2007	2008	2009	2010	5/15/2011
THEMIS/ARTEMIS	3	68	67	74	36
TH/AR- monthly rate		5.7	5.6	6.2	8.0
% non-project led		14%	51%	43%	45%

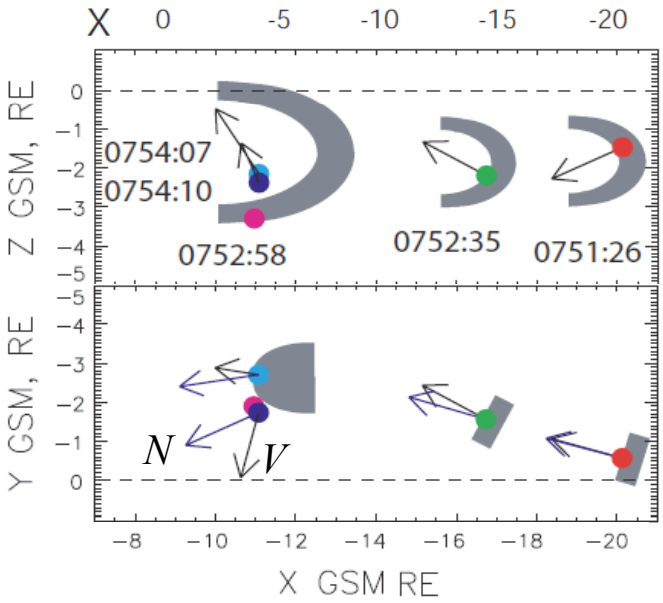
Programmatics

- Since Senior Review 2010:
  - ✓ THEMIS/ARTEMIS extended through 2014
  - ✓ Planetary Division has also endorsed ARTEMIS (w/ minimal funding)
  - ✓ No new/revised contract with GSFC to account for the Science uptick
  - ✓ Visiting scholars program in place (Quanqi Shi, Robert Michell, Marilia Samara)
  - ✓ Next Senior Review in 2013 (bridge plus option contract planning has started).
  - ➢ SST calibration issue is being remedied per Senior Review plans/recommendations:
    - ✓ Offloaded work from Davin who is busy on Maven, SP+
    - ✓ Performed calibrations and modeling at UCLA, cleanup software in place now (Drew Turner).
- THEMIS: a key player in the golden era of inner magnetosphere research
  - ✓ Collaboration with RBSP (joint software with RBSP EFI/FGM, Key Params routines)
  - ✓ Opportunity: Use White Sands 1 & Wallops (free) plus BGS (low cost) for 100% FS mode!!!
  - ✓ Collaboration with TWINS, ERG, ORBITALS and ground (SD) teams under way
- ARTEMIS
  - ✓ Lunar Orbit Insertions have occurred successfully on June 27th –July 17th 2011
  - ✓ Planetary: LADEE conjunctions and crustal anomaly targets have been designed
  - ✓ Instrument adjustments are under way
    - Shadow despining software (local expert is Ferdinand Plaschke)
    - ESA/SST mode changes – will be magnetospheric only from now on
- Beyond 2014: MMS conjunctions with THEMIS and ARTEMIS
  - ✓ Looking into orbit adjustments to line-up during MMS era – looking amazingly good!

Propagation of "bubble-like" jets from reconnection site to near-Earth

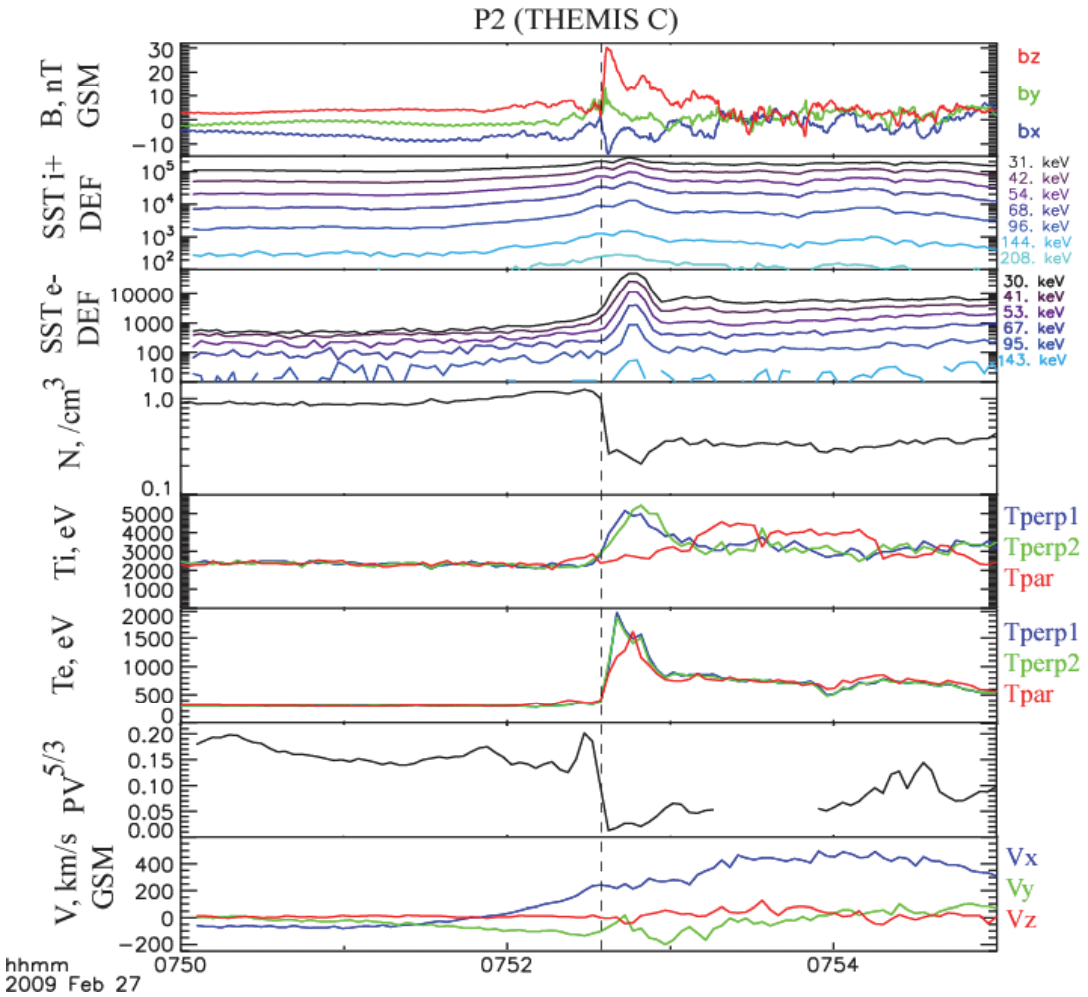
Runov et al., 2009, 2010, 2011; Zhang et al., 2010; Li et al., 2011; Zhou et al., 2011

- ✓ Curved flux tube
- ✓ Self-similar over global scales
- ✓ Low density
- ✓ Particle energization



V=velocity direction

N=flux tube normal direction

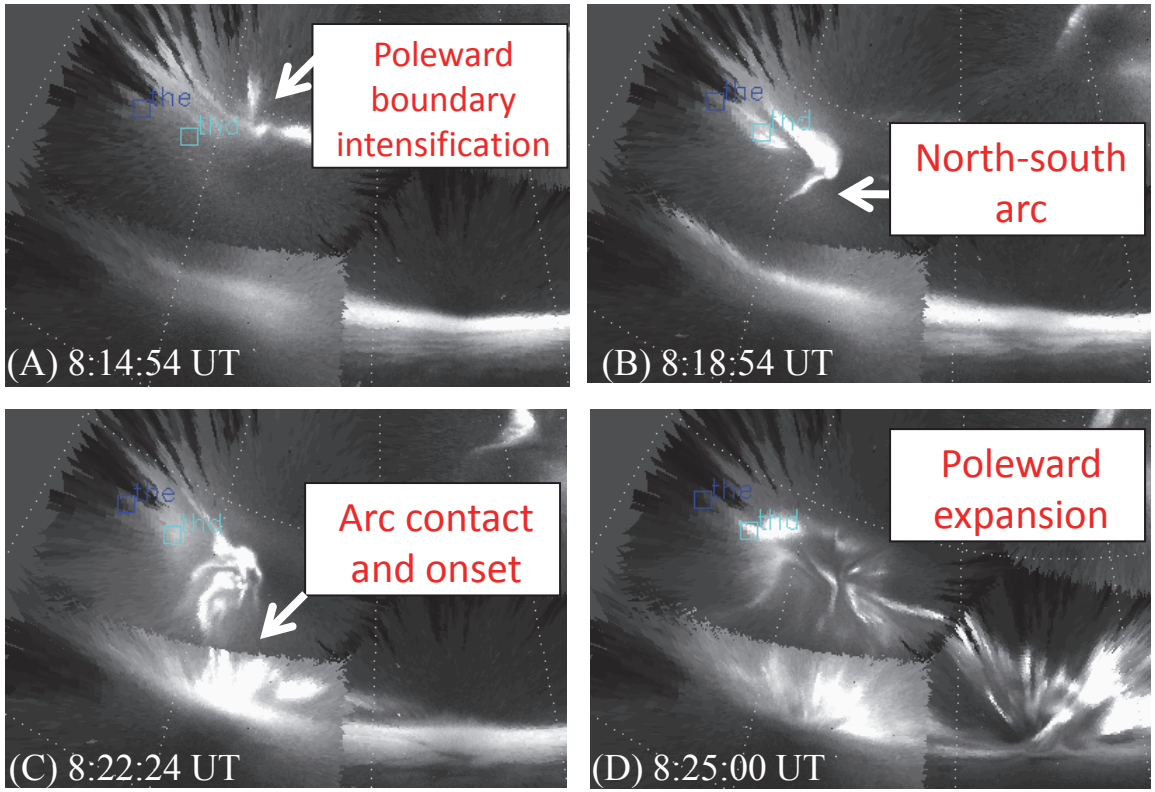


Substorm macroscale interactions can be seen from the ground [Kepko/Nishimura/Lyons].

THEMIS GBOs link Reconnection and Current Disruption models

- Poleward boundary intensifications (enhanced magnetotail reconnection) supply fresh magnetotail lobe plasma to closed field lines.
- When the new plasma has low entropy, it reaches the near-Earth plasma sheet and triggers substorm expansion
- How are the dipolarization fronts interacting with each other and the inner magnetosphere?
  - Interchange instability?
  - Deposition of energy?

THEMIS All-sky imagers 2008-02-29

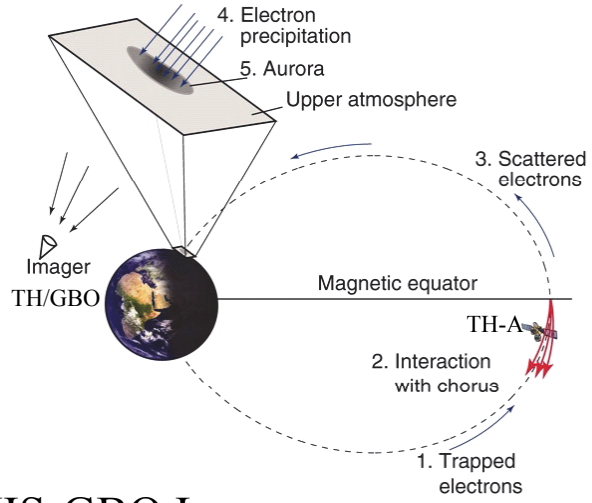


Answers require both:

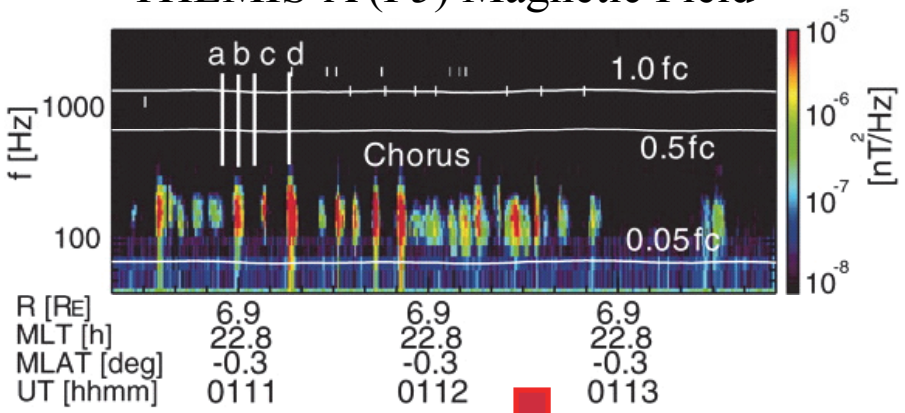
- Kinetic exploration (FY10/11/12) and
- Global exploration (FY13/14)

… of the equatorial magnetosphere inside of $12R_E$.

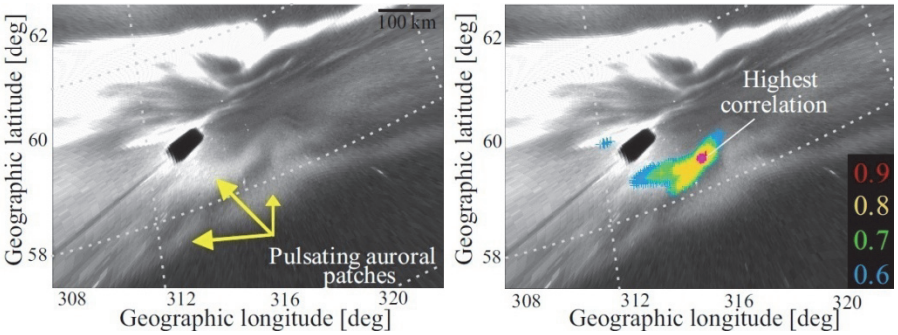
Non-substorm achievements: The origin of pulsating aurora in the plasma sheet



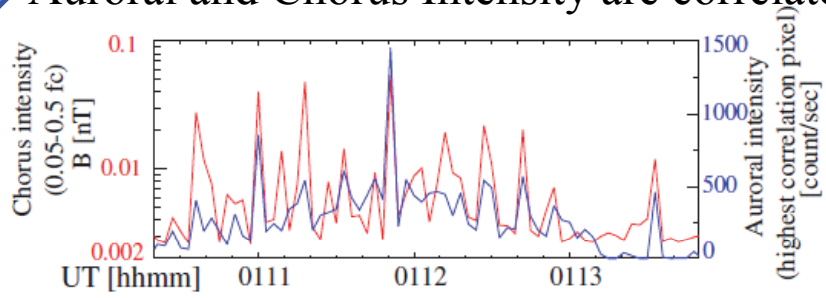
THEMIS-A (P5) Magnetic Field



THEMIS-GBO Imager

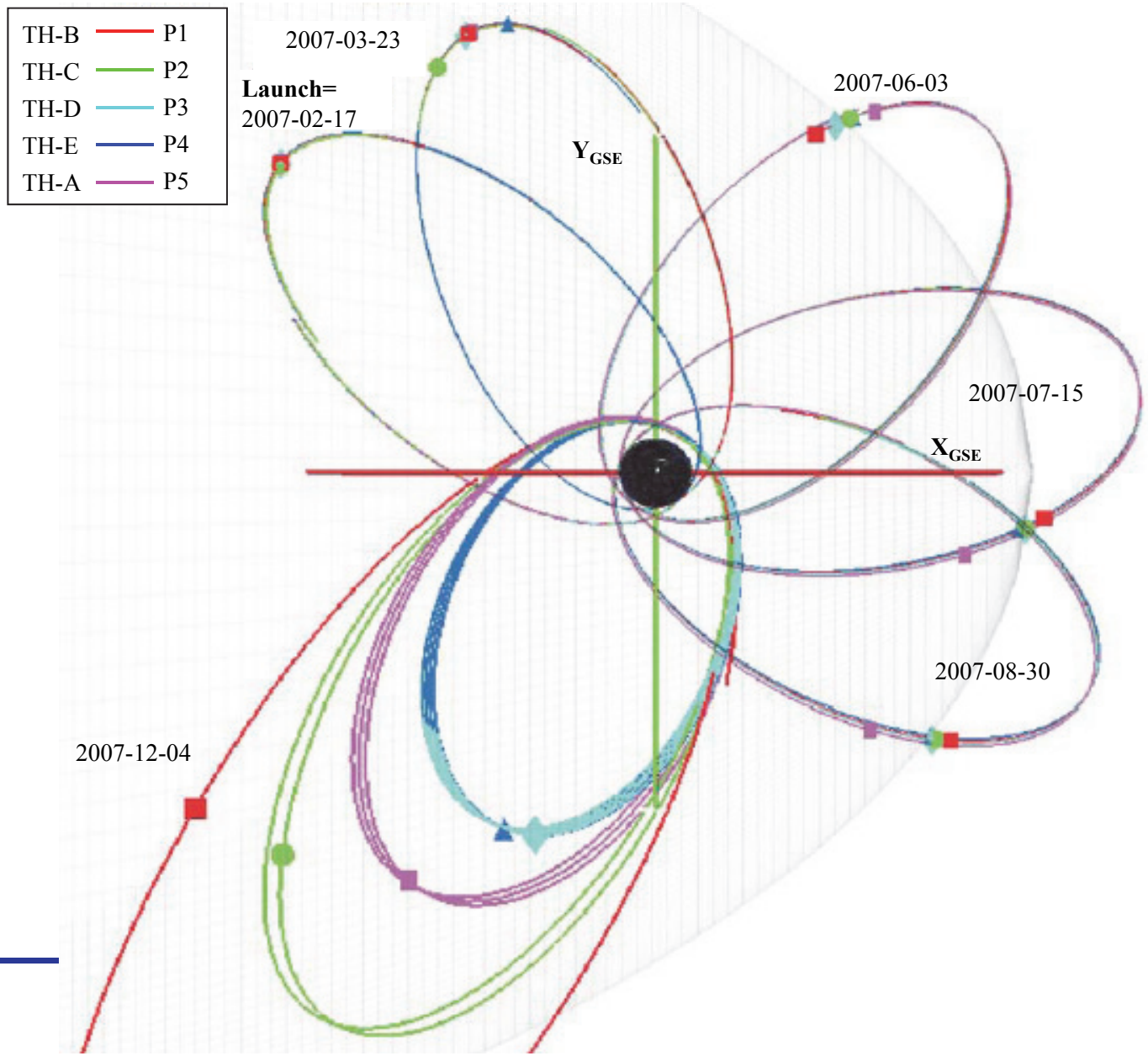


Auroral and Chorus Intensity are correlated

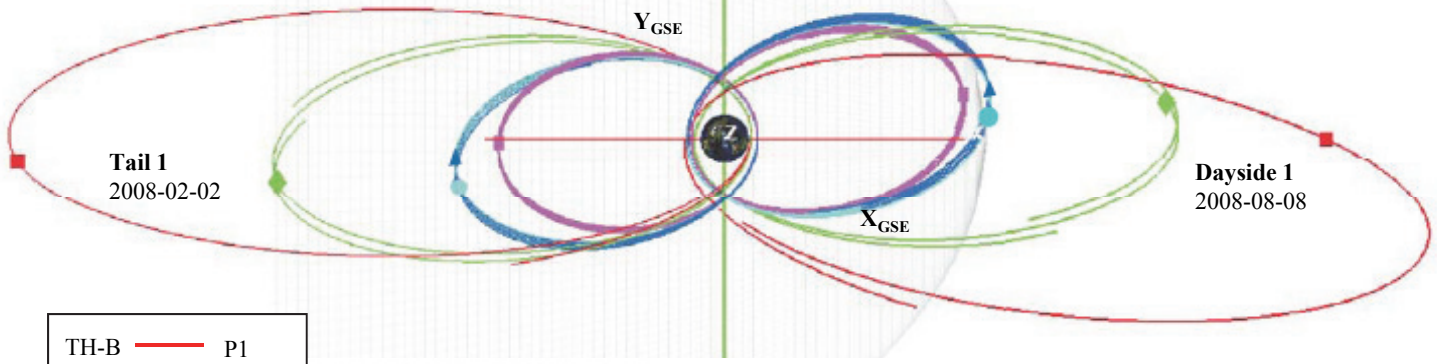


Using coordinated satellite and ground-based all-sky observatories (GBOs) from the THEMIS mission, ***Nishimura et al. (Science, 2010)*** provide the first evidence that localized lower-band chorus waves observed at the equator, drive the pulsating aurora at a given pulsating patch in the ionosphere. The findings can also be used to constrain magnetic field models, an otherwise notoriously difficult task.

First 10 months: Commissioning and Coast Phase Observations

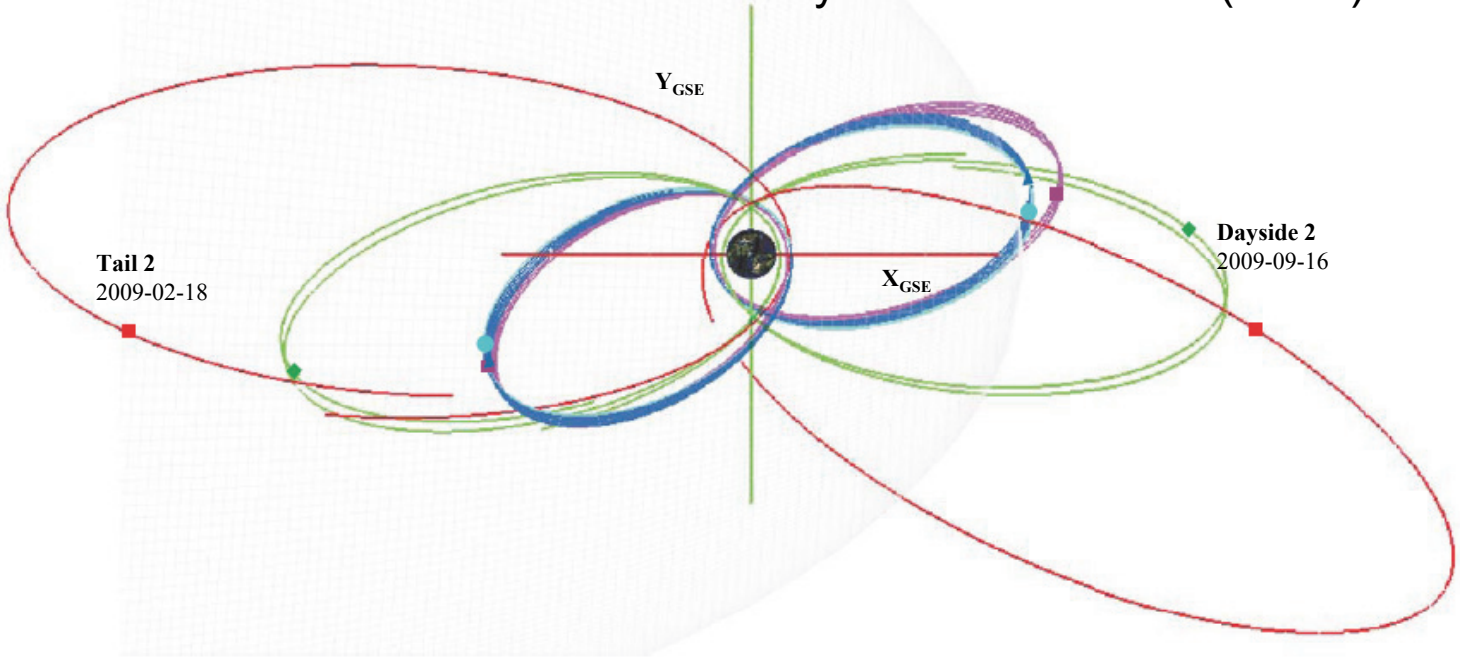


First year THEMIS baseline orbit (FY08)



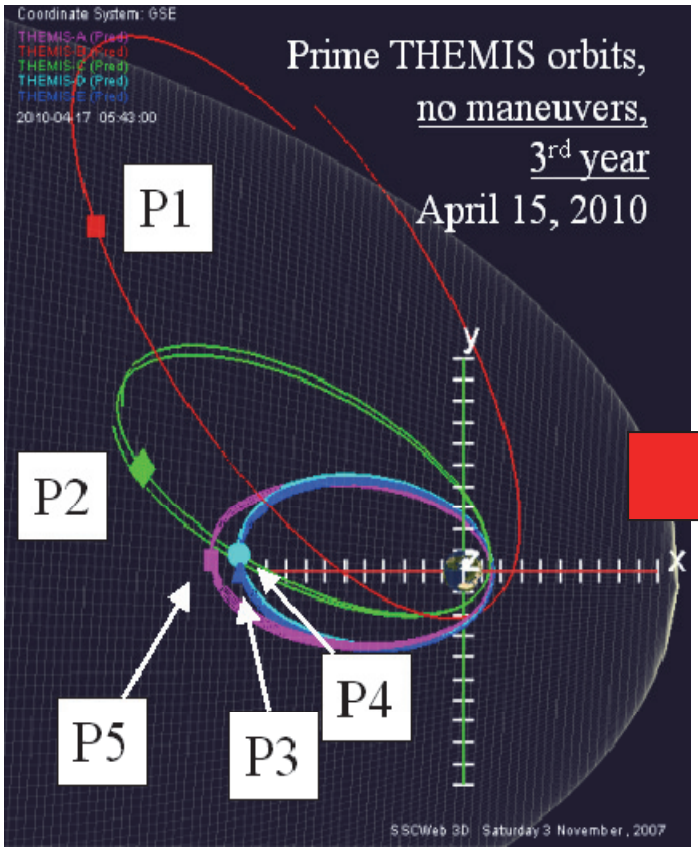
TH-B	P1
TH-C	P2
TH-D	P3
TH-E	P4
TH-A	P5

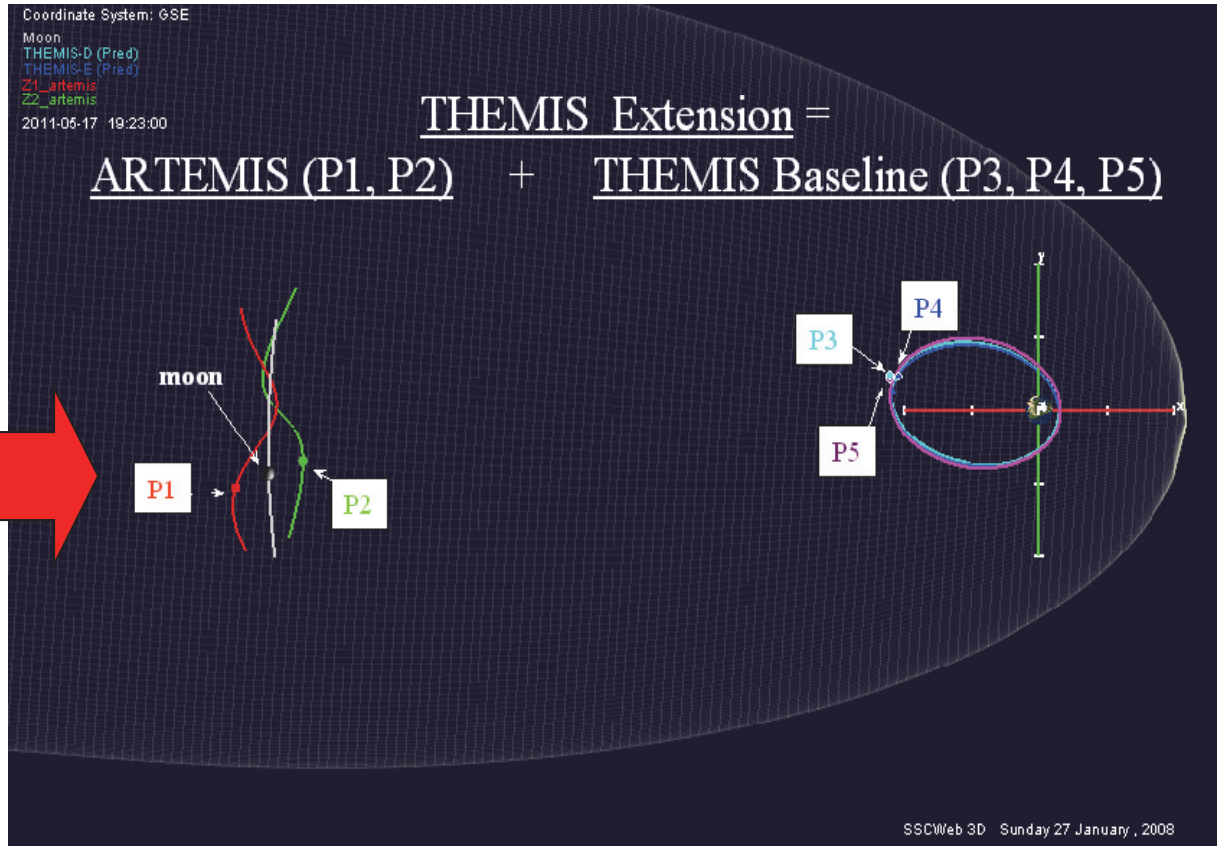
Second year baseline orbit (FY09)



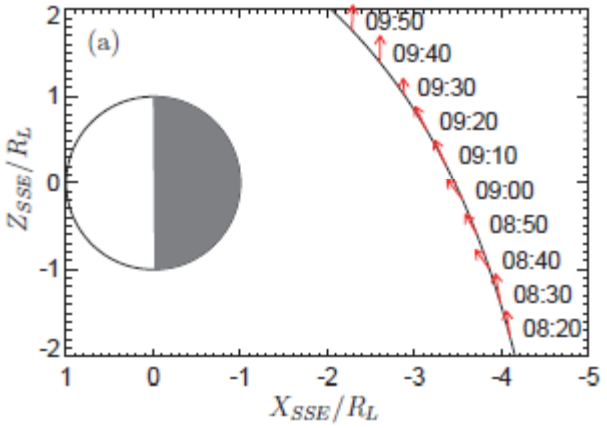
Angelopoulos, 2008
Space Sci. Rev.

THEMIS Extension (FY10,11,12)

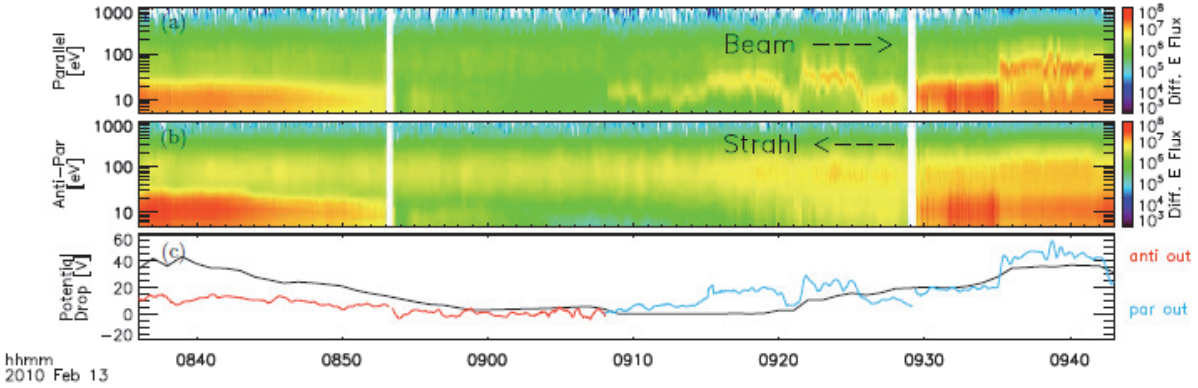


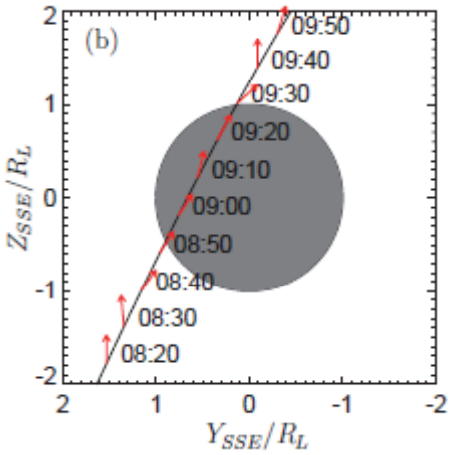


Electron beams accelerated by asymmetric wake potential



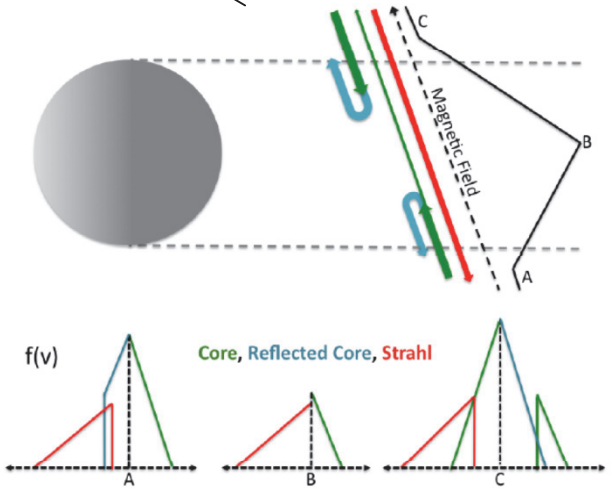
ARTEMIS P1 electron spectra (a, b) and wake potential (c) inferred from them





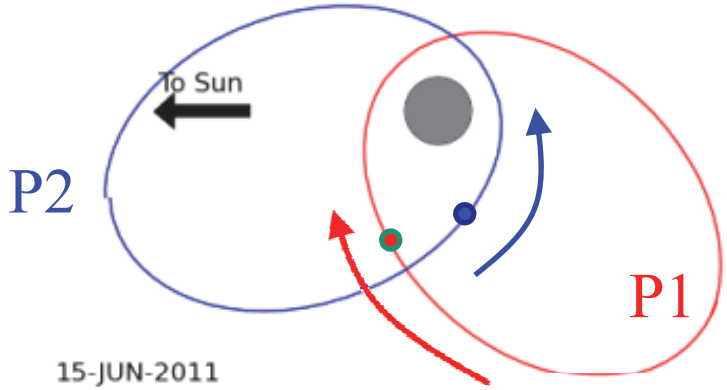
[Halekas et al., SSR, 2010]

Potential, V [Note: $V_C > V_A > V_B$]

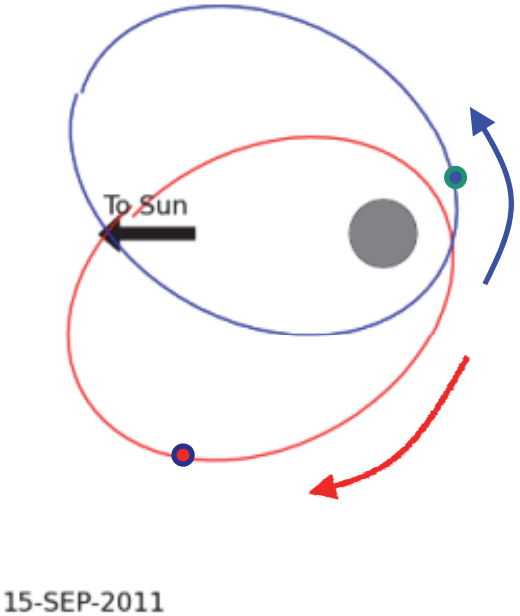


ARTEMIS orbits

Note: P1 retrograde, and P2 prograde.

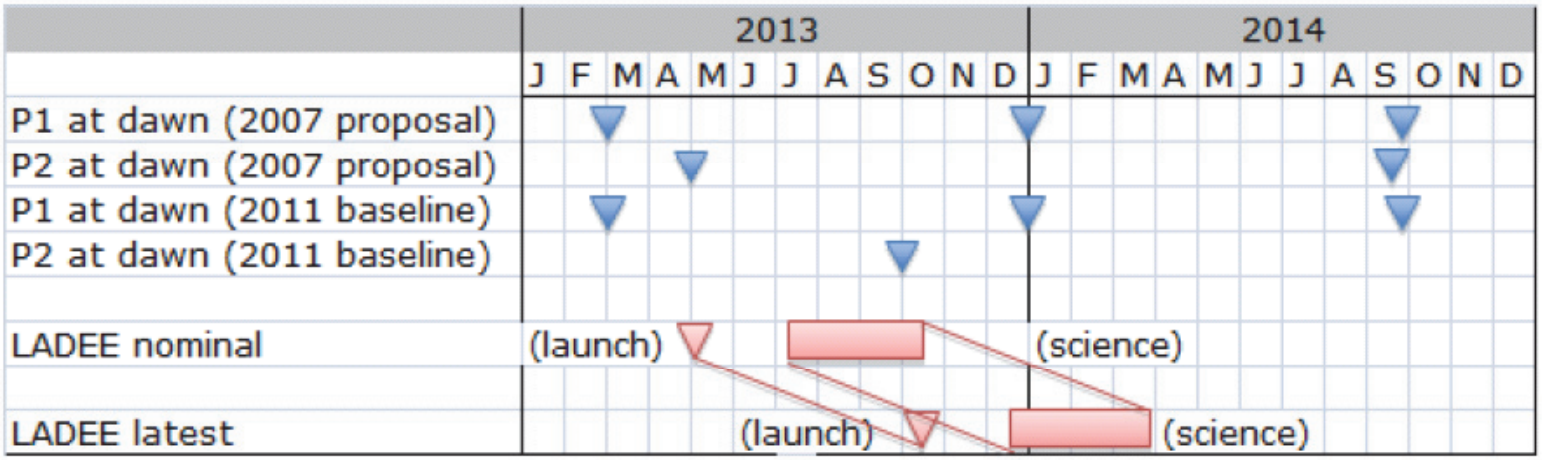


Here P1 monitors the primary field while P2 measures the nightside induction field.



Relay conjunctions permit more monitoring time at periapsis, for periods of up to an hour.

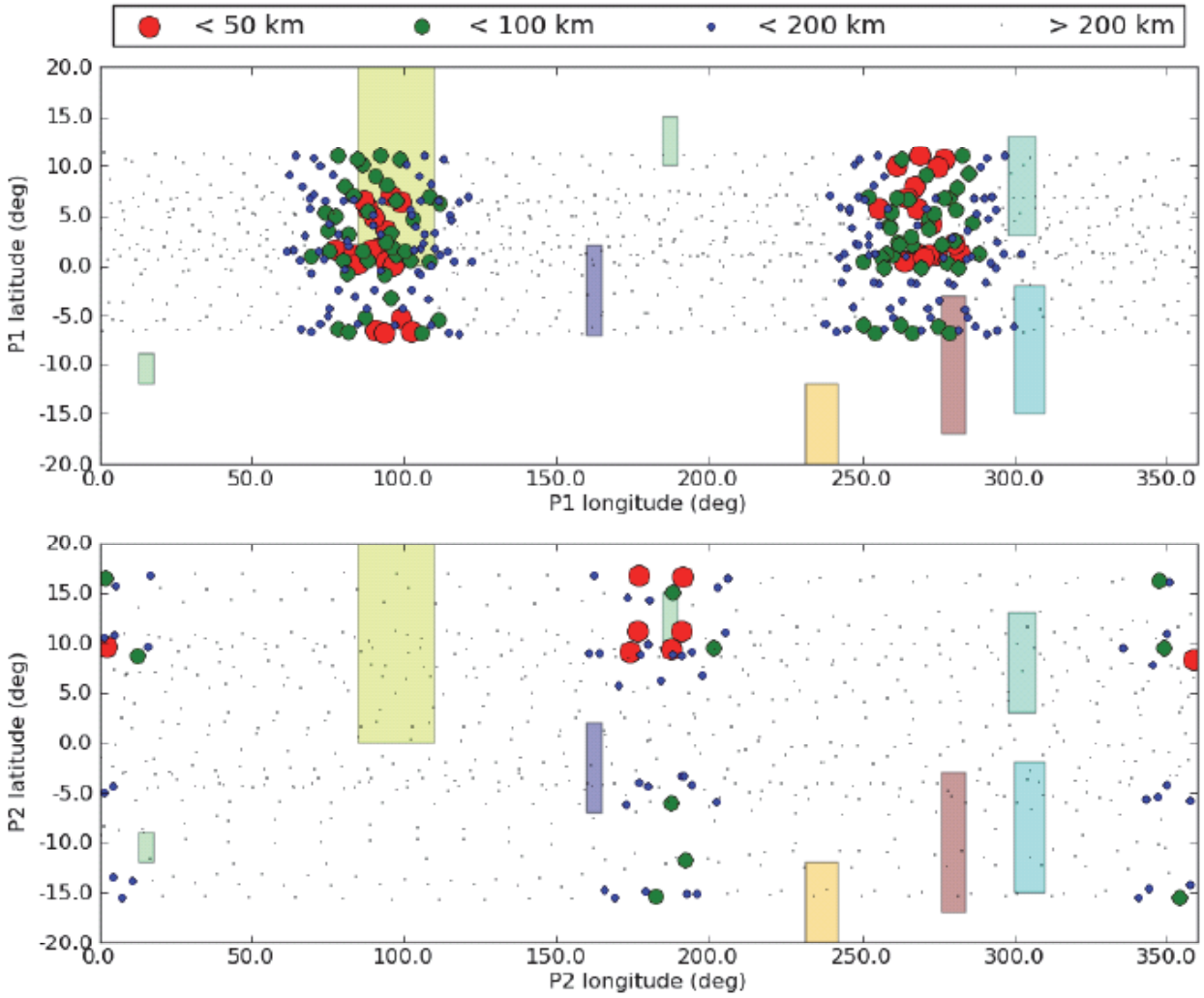
ARTEMIS's latest design satisfies LADEE conjunctions



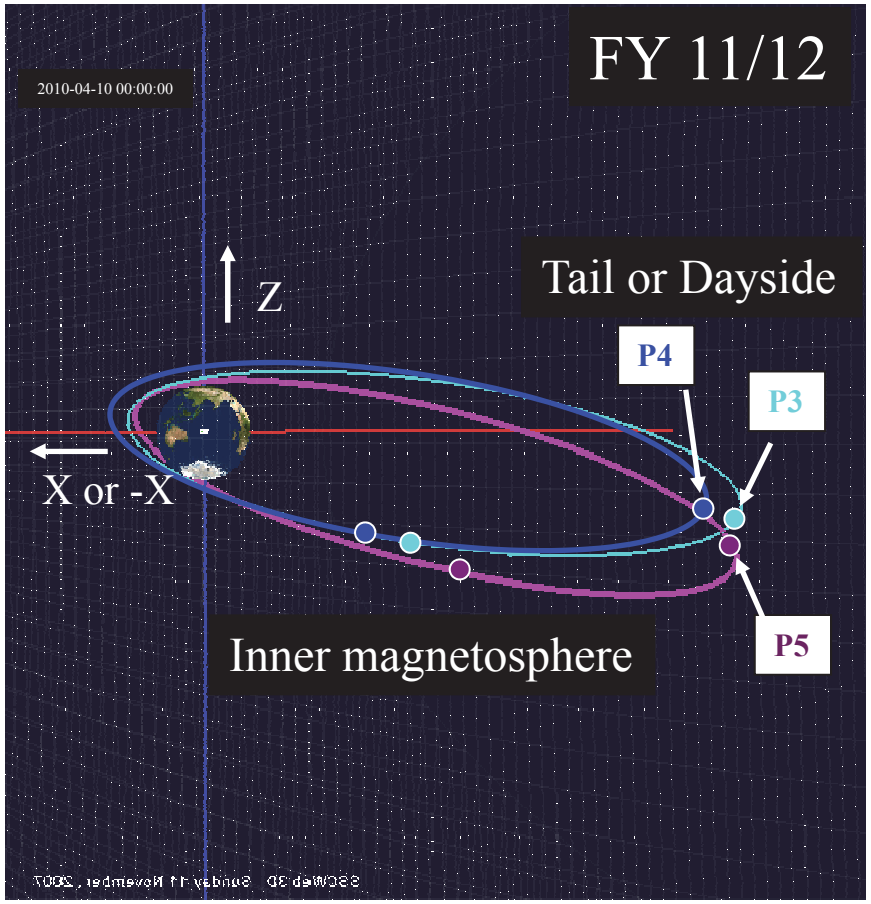
ARTEMIS's design has optimized observations of crustal anomalies.

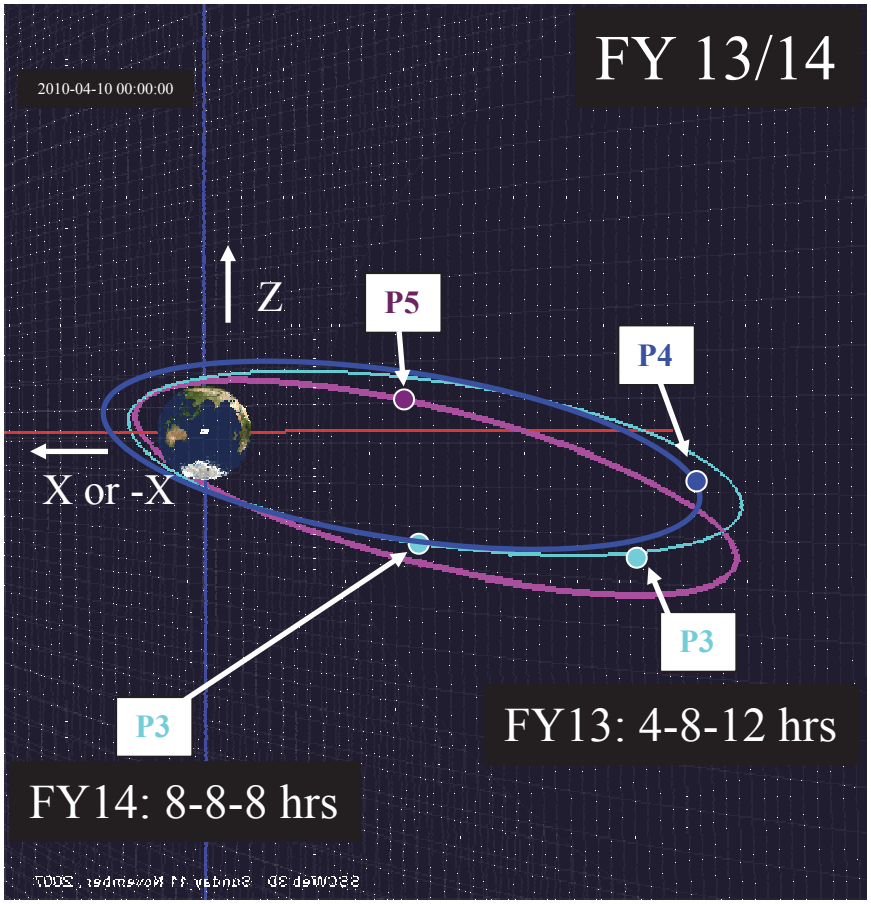
Name
Oriental Antipode
Unnamed
Unnamed
Descartes
Hartwig
Reiner Gamma
Rima Sirsalis
Crisium Antipode

List of known crusta



THEMIS probe separations

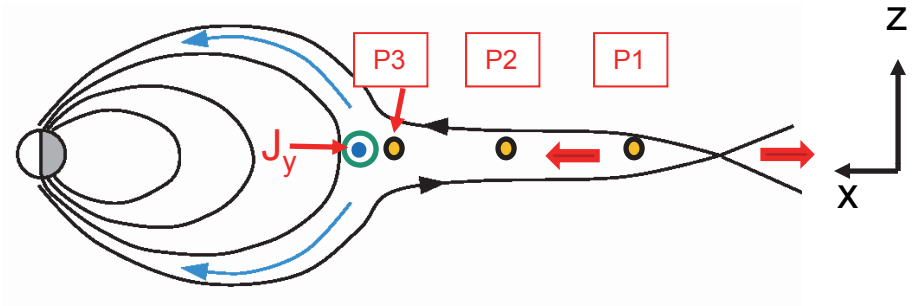




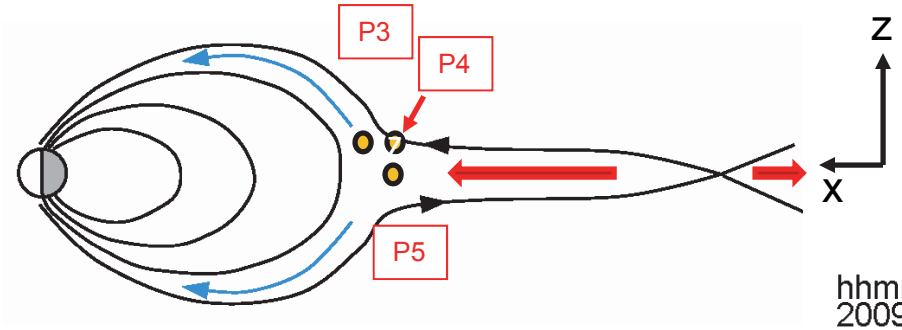
Magnetotail from kinetic scales: FY11/12

- Interaction of reconnection jet (or dipolarization front) with the inner magnetosphere and its role in triggering substorms

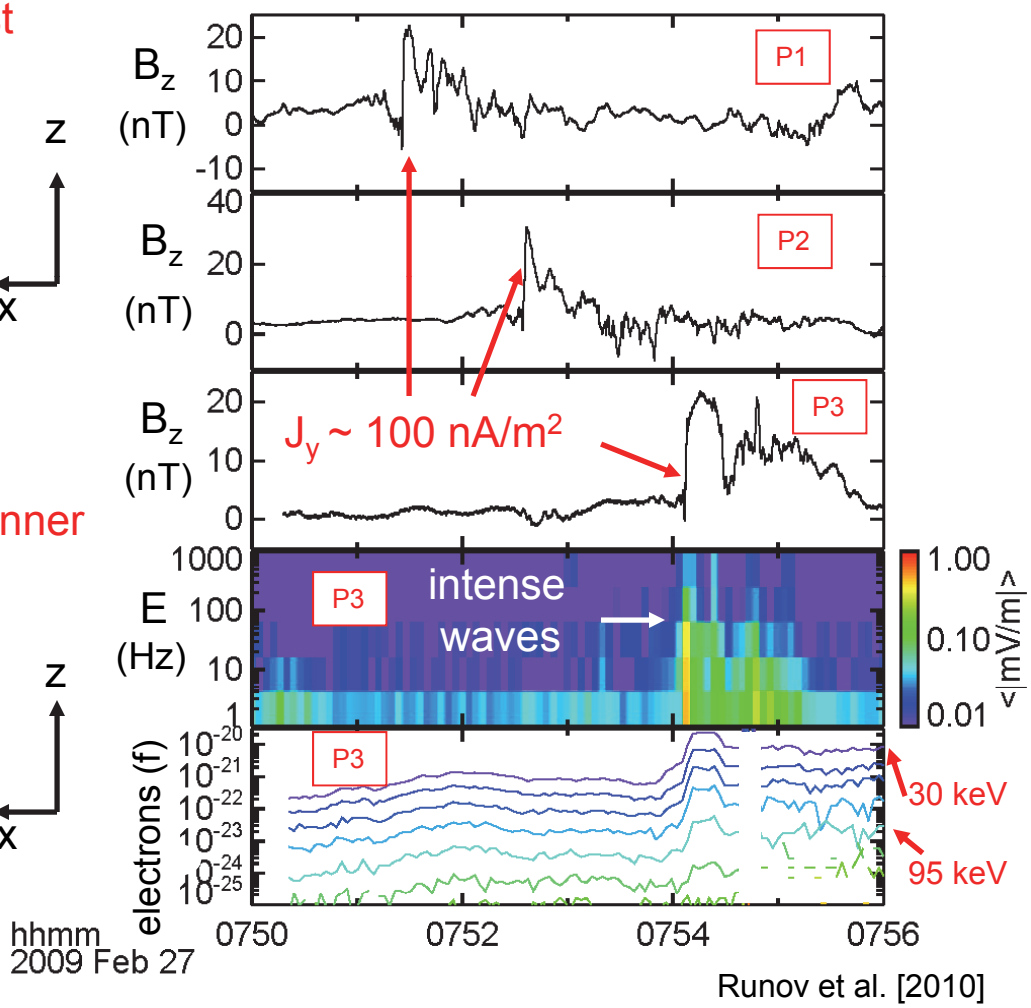
Prime mission result: Reconnection starts first



FY 11/12 objective: Physics of reconnection-inner magnetosphere interaction

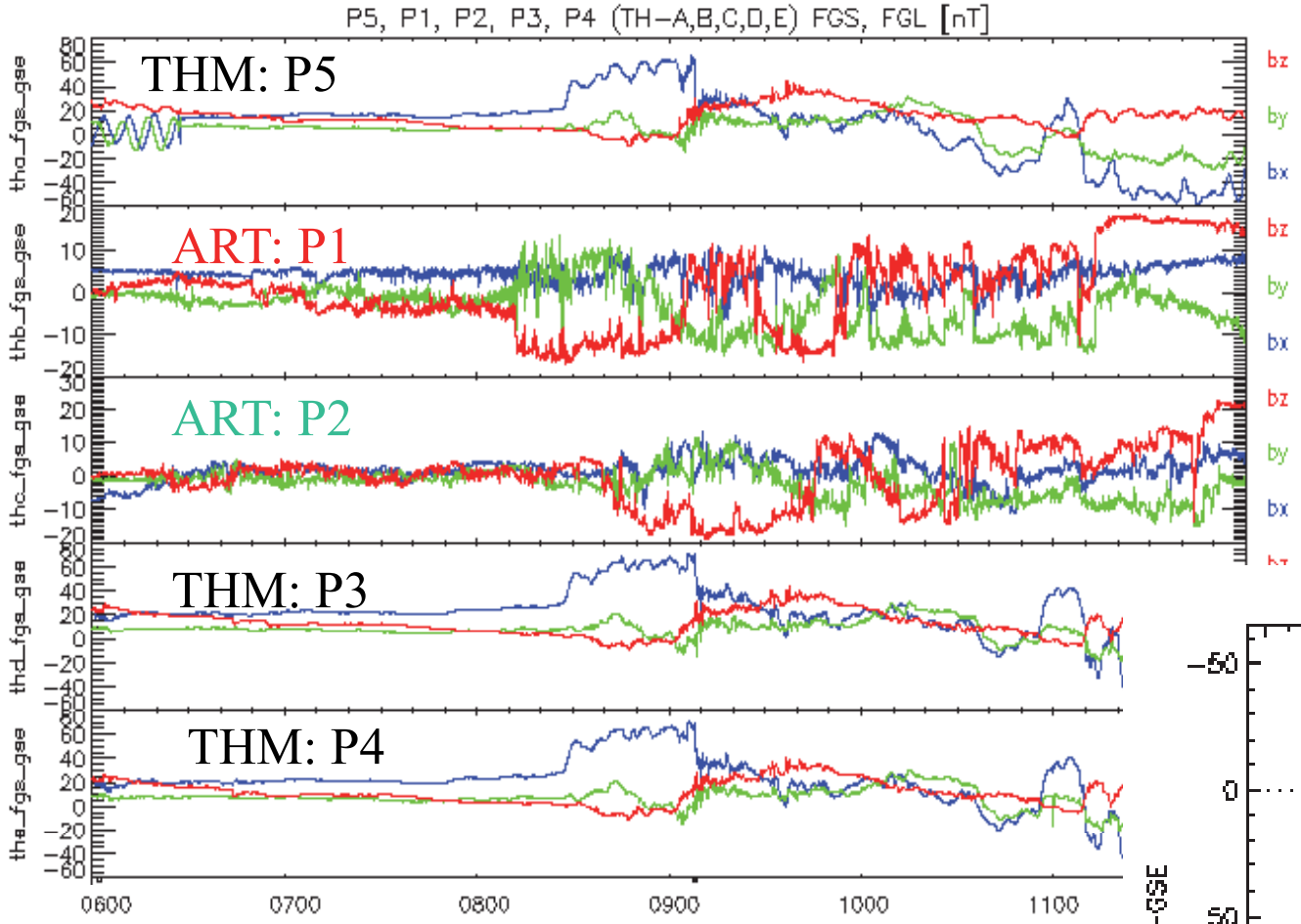


THEMIS Burst data

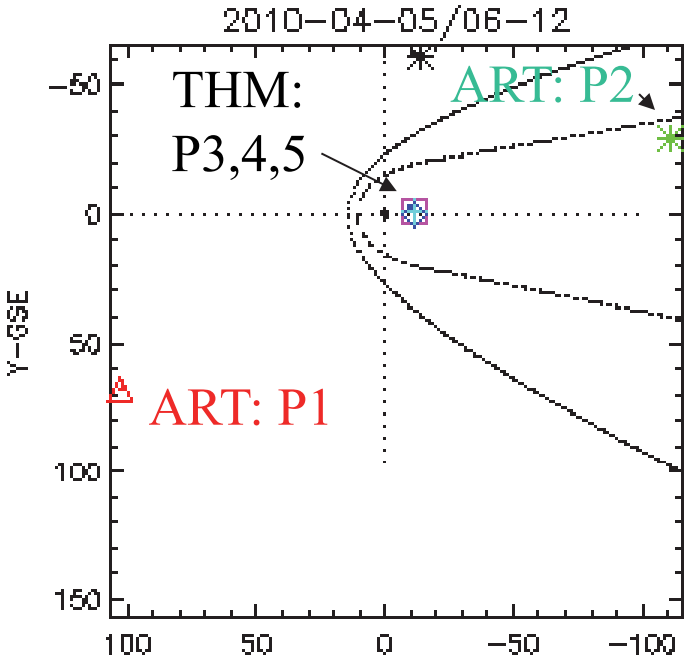


Runov et al. [2010]

The Galaxy 15 knock-out: AR-TH storm time conjunction



Connors et al., 2011 Ann. Geophys.

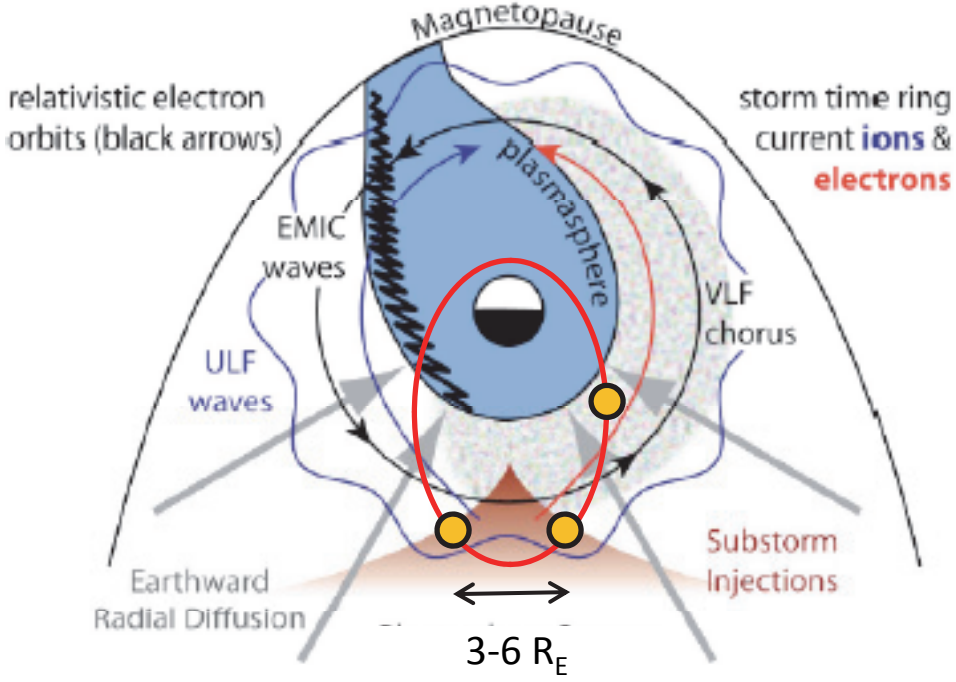


Connors et al., 2011 (Ann. Geophys.): GOES field over-dipolarized thanks to incoming flow bursts. How were particles accelerated? If only we had THEMIS in dispersed orbits, together RBSP there, we would now know!

Magnetotail from global scales: FY13/14

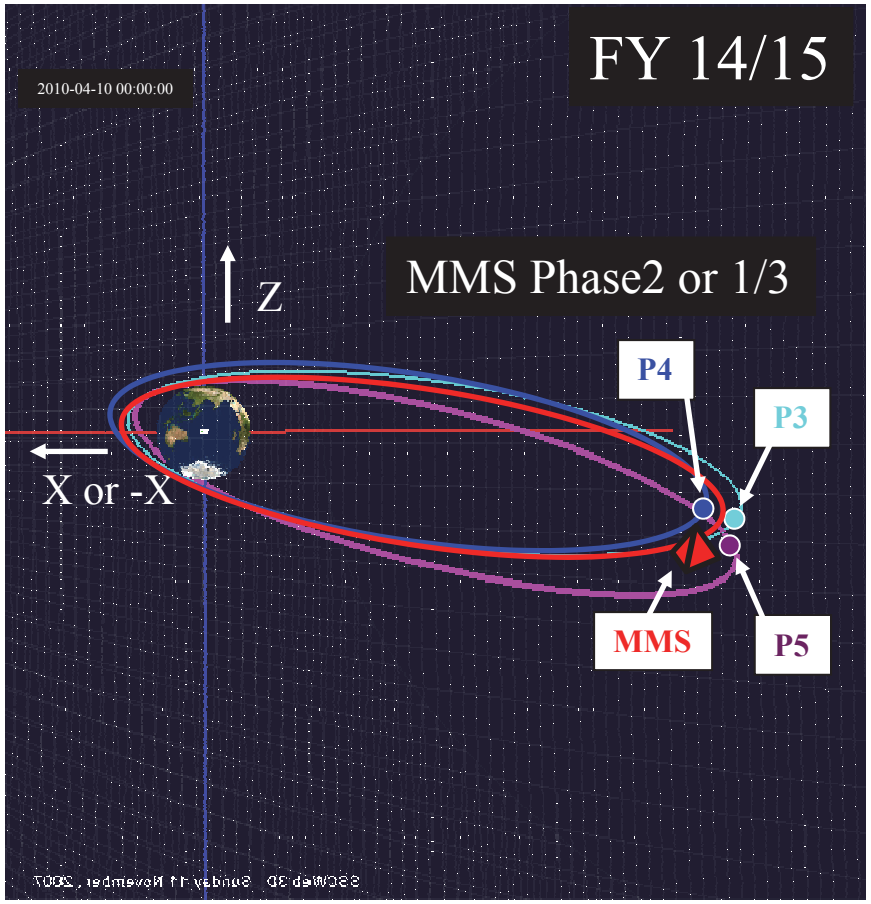
- Cross-magnetotail width of reconnection and energetic particle injection regions

- Global evolution of energetic particle injections during substorms

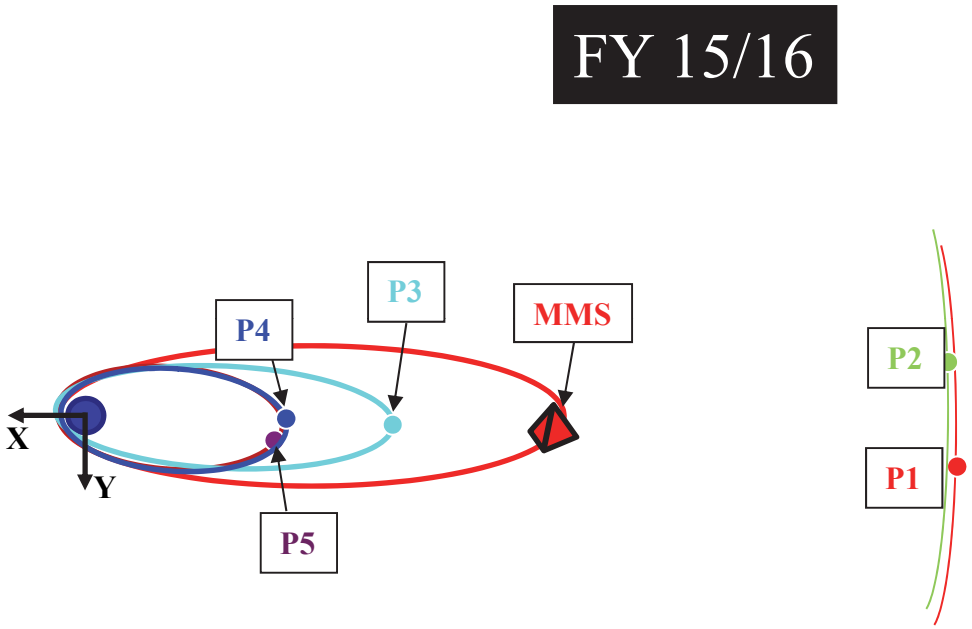


MMS era (FY13/14): THEMIS observes RX drivers

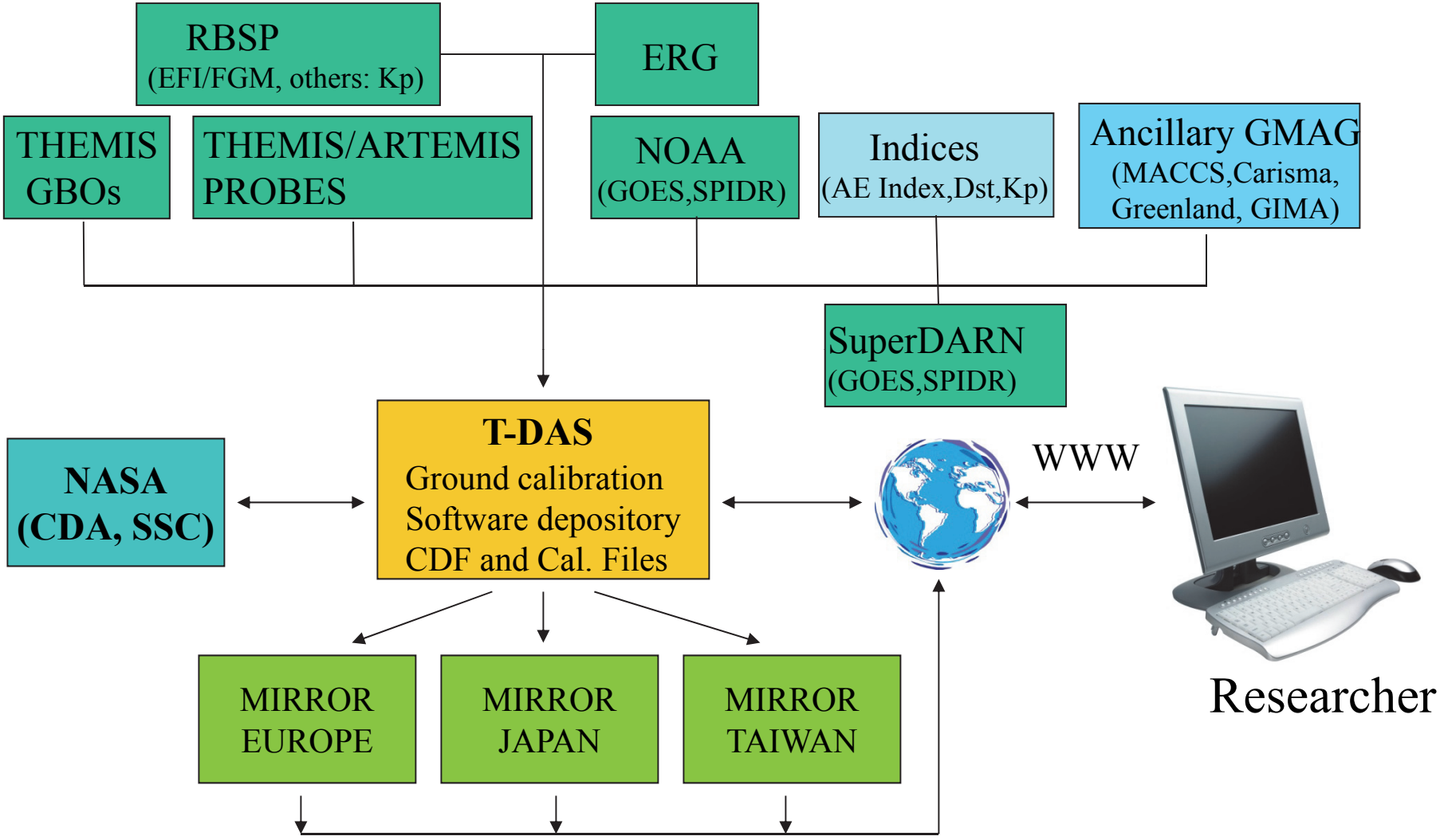
A tetrahedron within a tetrahedron



Resonant orbits: alignments at solar max



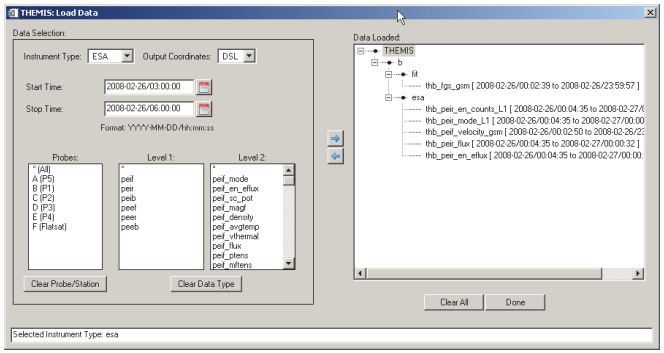
Data Collection and Distribution

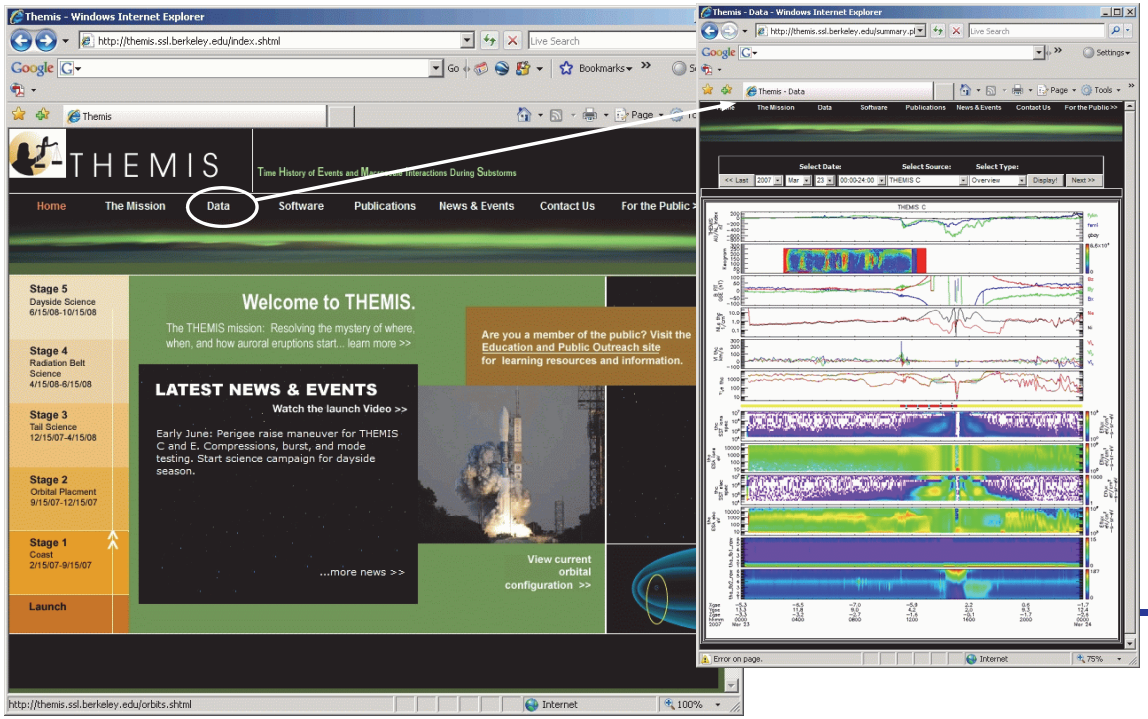


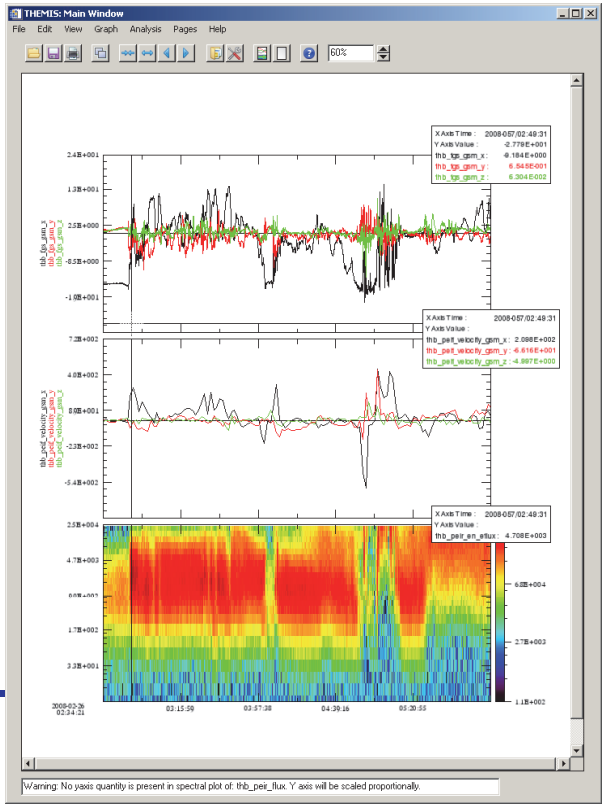
Backup slides

Data Processing and Community Support

- All data/plots available, calibrated 1 day after downlink (http://sprg.ssl.berkeley.edu)
- Routine data distribution in 4 ways
  - CDF downloads from SPDF, UCB, 4 mirror sites
  - HTTP and FTP socket connection through software (seemless)
  - Bundled downloads via UCB site (per instrument, spacecraft, product)
  - On-line at VMOs, and PDS (data is SPASE compatible).
- Free, powerful software distribution, on-line docs, tutorials
  - IDL-based, platform independent
  - Community demos biannually at GEM meetings + trainings on demand
- On-line Support (THEMIS_Science_Support@ssl.berkeley.edu)
- SVN configuraton-controlled: distributed, grass-roots effort
- Community training sessions twice a year (GEM and AGU)







THEMIS Software

- The main goal of the THEMIS software design is to provide researchers with tools to handle multiple missions, spacecraft, and instruments using the same interface.
- THEMIS software is free and available at the mission web site http://themis.ssl.berkeley.edu/software.shtml
- The software is an IDL-based library of utilities
  - Platform independent – works on Windows, UNIX/Linux, MacOS
  - Crib sheets also provided
- Two interfaces are available
  - Graphical User Interface
  - Command-line (based on TPLOT package).
- Software enables users to:
  - Download raw L1 and/or calibrated L2 data
  - Data Analysis
  - Ingestion of data from other missions
  - Publication Quality Plots
- Software distribution includes many functions written by community and is open for contributions.