LPP

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# About terrestrial substorms

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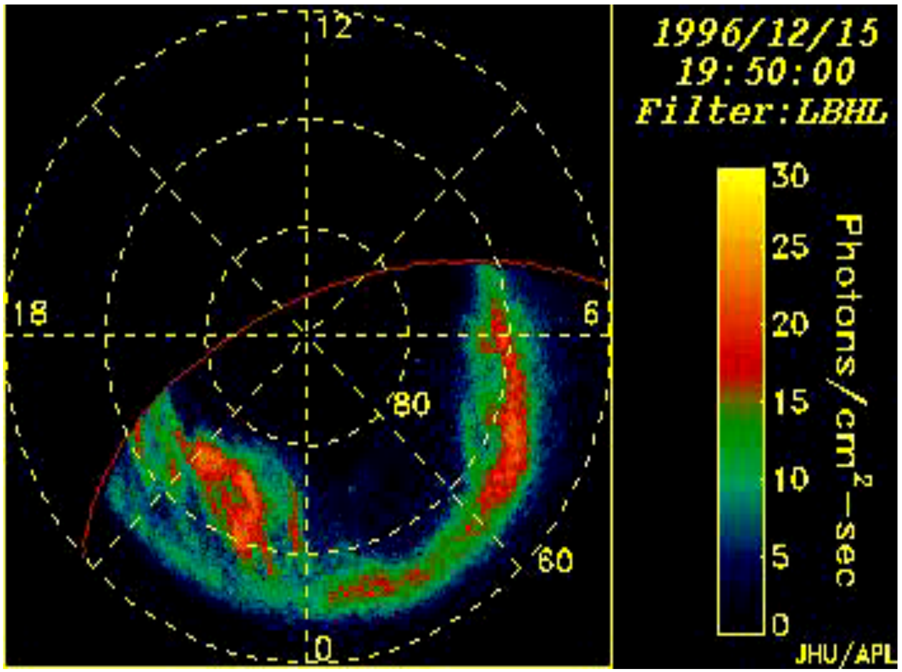
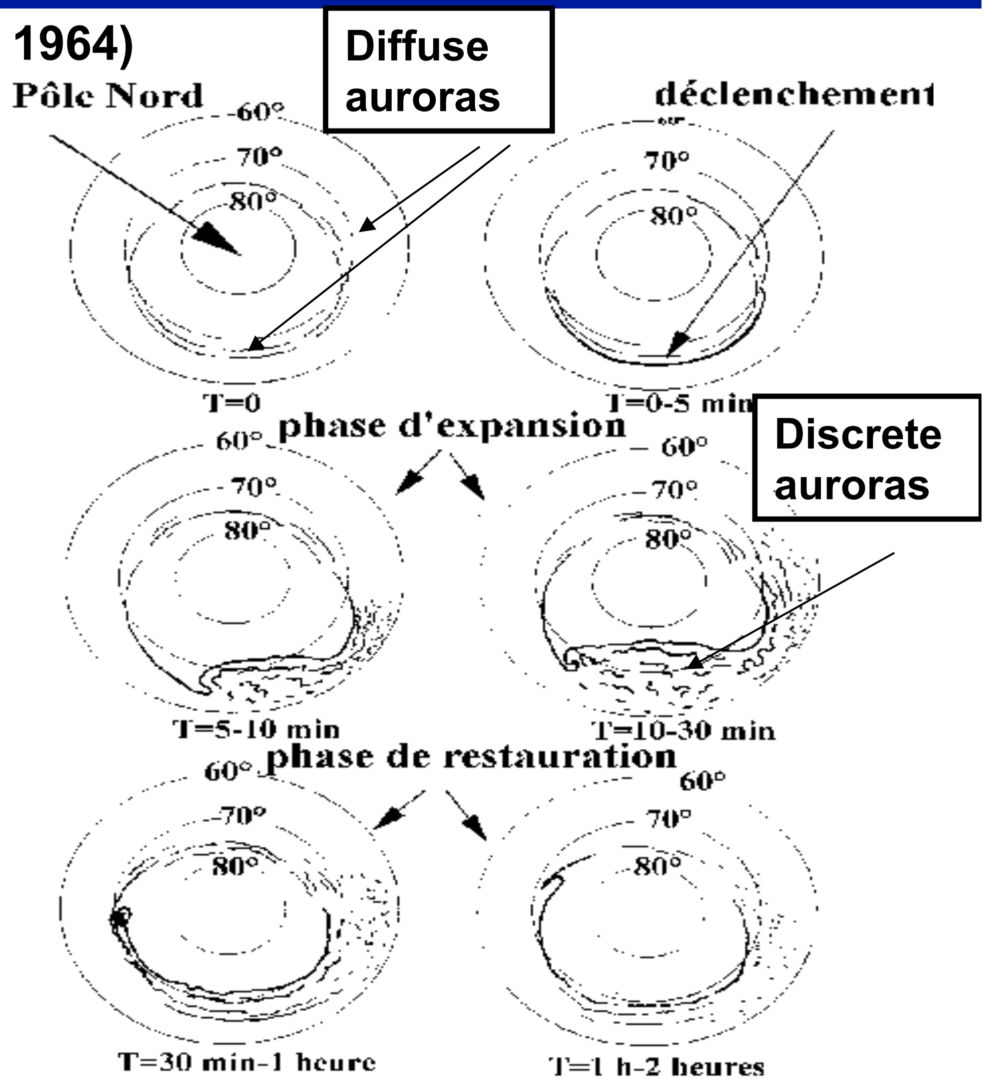
# Auroral substorm

( from Akasofu, 1964)

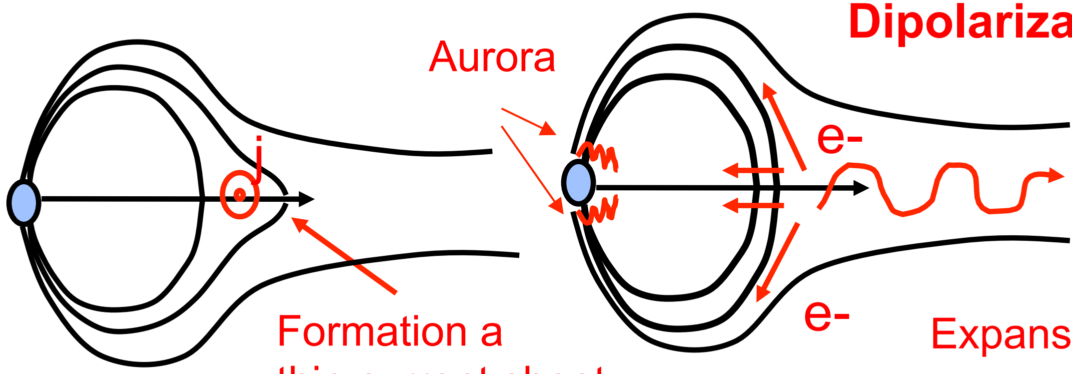



UV Imager from POLAR satellite,
Time resolution: 36 s
G. Parks, UCB



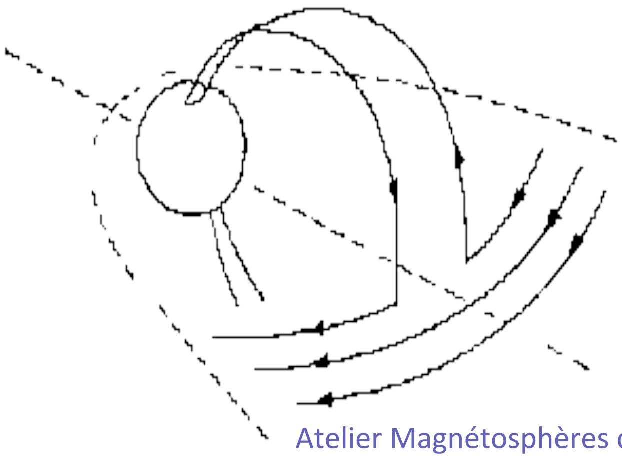
# Substorm from magnetotail

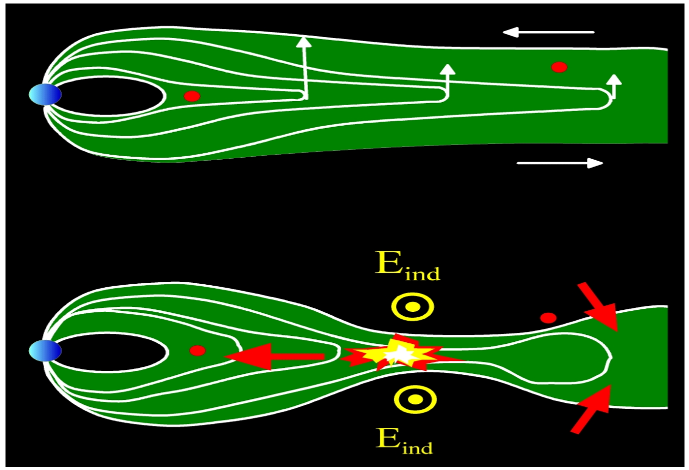
Current disruption
X~7-15 RE




Substorm current wedge

Magnetotail reconnection X~23 RE

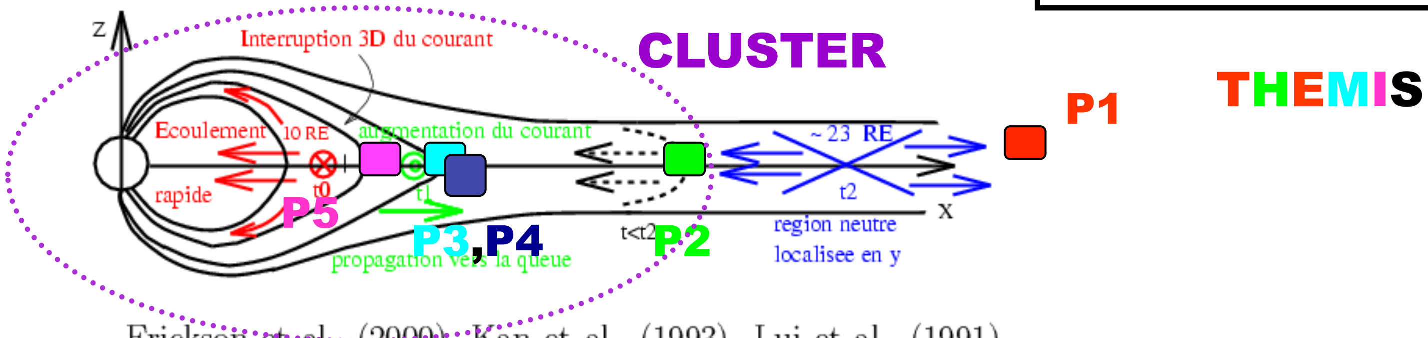




# Two categories of models

**Instabilities kyρi~1**

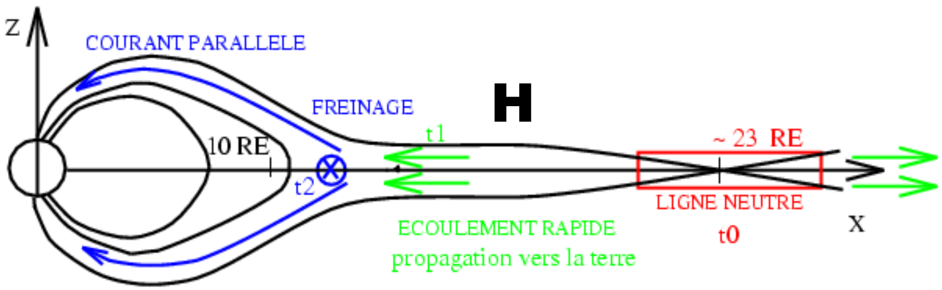
⊙ **Déclenchement entre 7 et 15 $R_T$**




Erickson et al. (2000), Kan et al. (1993), Lui et al. (1991), Roux et al. (1991), **Lui et al., (2008) ...**

⊙ **Déclenchement entre 20 et 30 $R_T$**

**Instabilities kxH<1**

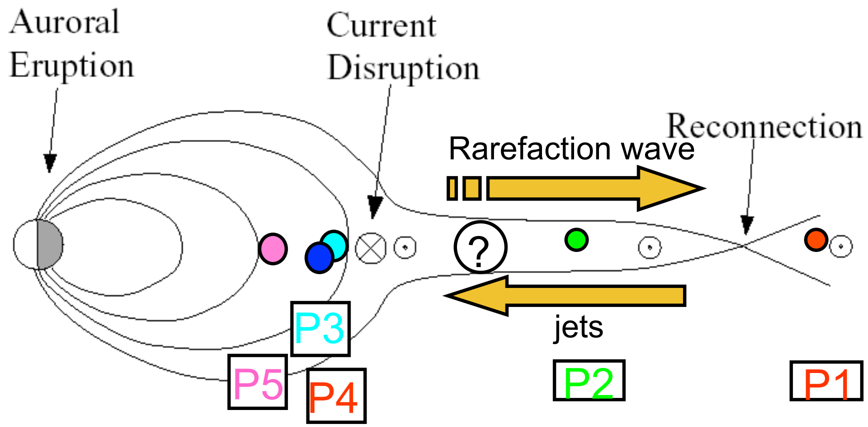



Baker et al. (1996), Birn et al. (1999), Nagai et al. (2000), Sergeev et al. (1995), Shiokawa et al. (1998), **Angelopoulos et al., (2008), ...**

# THEMIS objectives

| Models of current disruption | |
|---|---|
| Time | Event |
| 0 s | Disruption |
| 30 s | Auroral emission |
| 60 s | Reconnection |

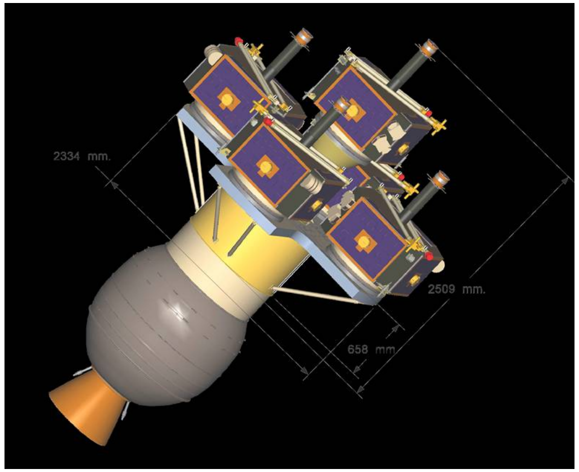
| Models of reconnection | |
|---|---|
| Time | Event |
| 0 s | Reconnection |
| 90 s | Disruption |
| 120 s | Auroral emission |

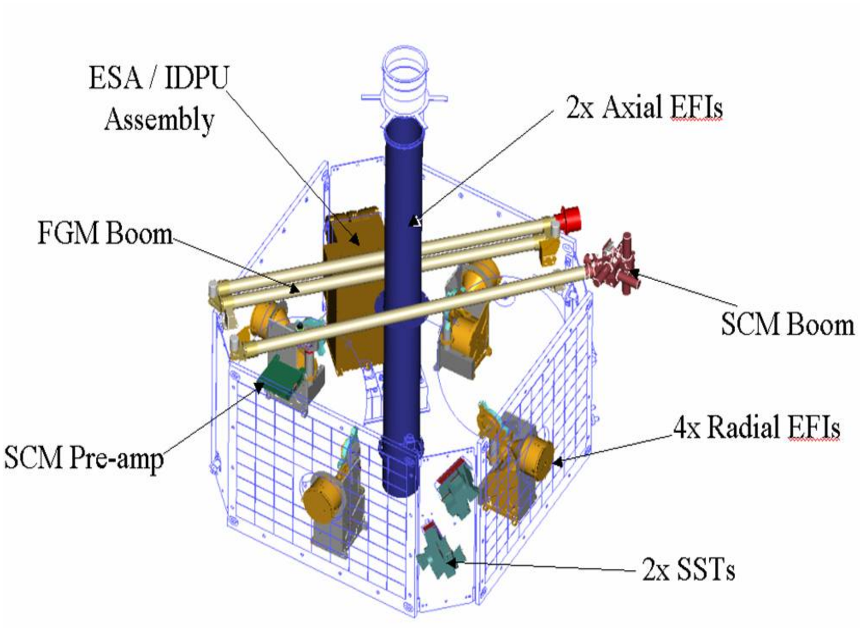


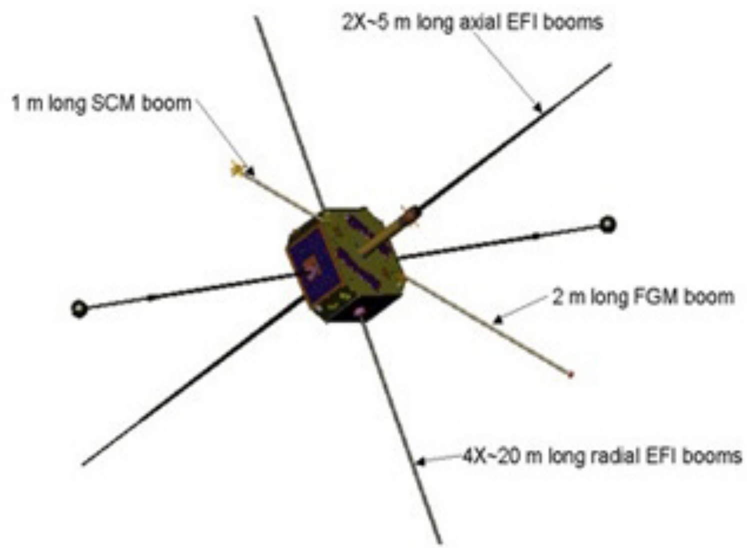

- **Delay between current disruption, reconnection and intense auroral emissions with 30s time resolution**
- **Large scale interactions (causality)**
  - Detection (1600km/s) of the rarefaction wave and earthward flows.
- **Ionospheric/magnetospheric coupling**
  - Reduction of the cross-tail current (P5/P4/P3) related to fast flows?
  - Field aligned currents related to the vorticity of the plasma flows, pressure gradients (dP/dz, dP/dx).
- **Multi-scale coupling**
  - Field line resonance (10RE, 5min)
  - Ballooning modes, Kelvin Helmholtz instability (≤1RE, 1min)
  - Microinstabilities : Weibel, CCI, Kinetic Alfvén waves (0.1RE, ~ 6Hz)

# THEMIS instrument suite

IDPU: Instrument Data Processor Unit
SPB : Spin Plane Booms (4x)
AXB : Axial Booms (2x)
SST : Solid State Telescope (2x)
ESA : Electrostatic Analyzer
FGM : Fluxgate Magnetometer
SCM : Search Coil Magnetometer

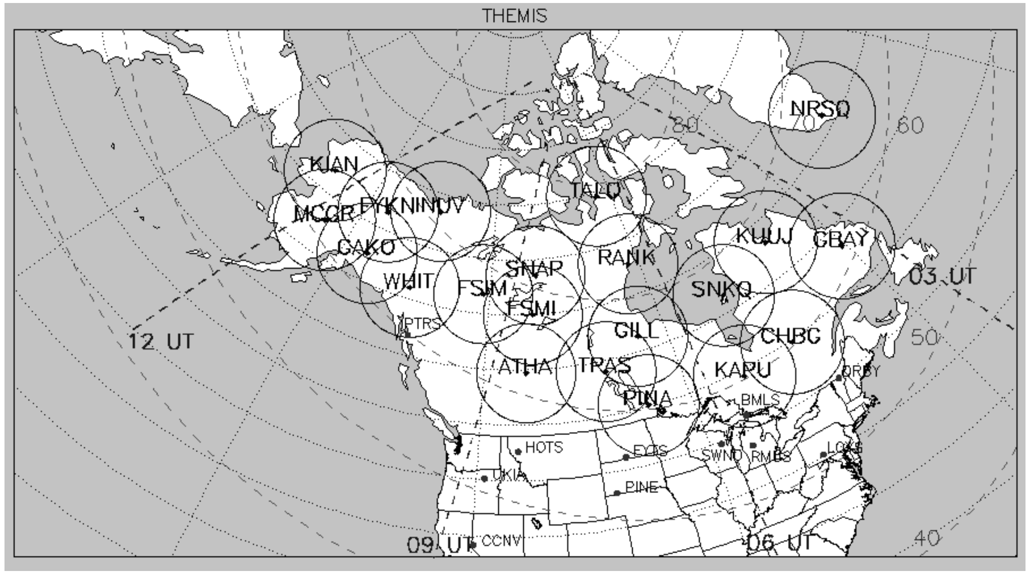


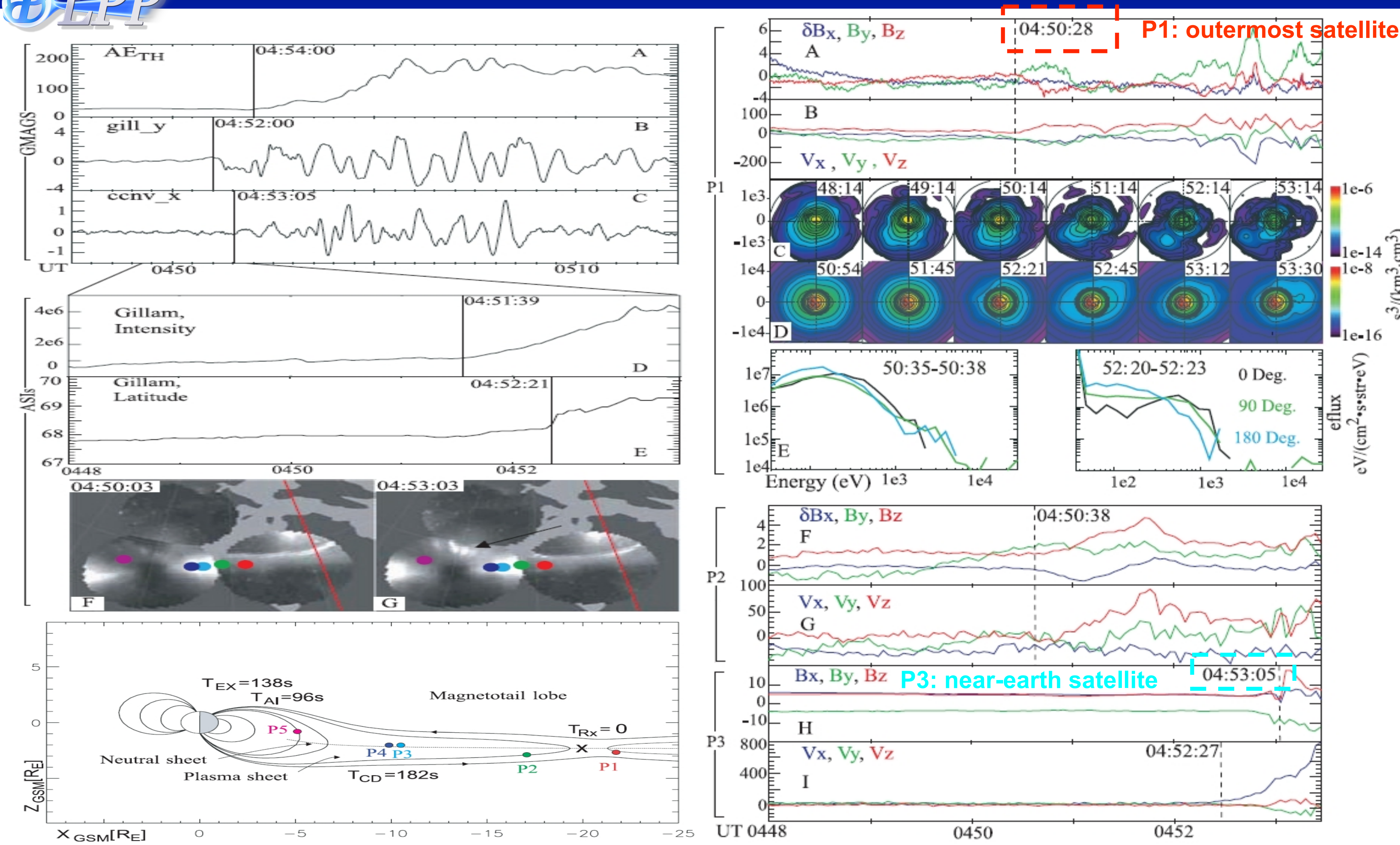
# THEMIS ground-based observatories


Spatial resolution ~1 km
Time resolution = 3 s

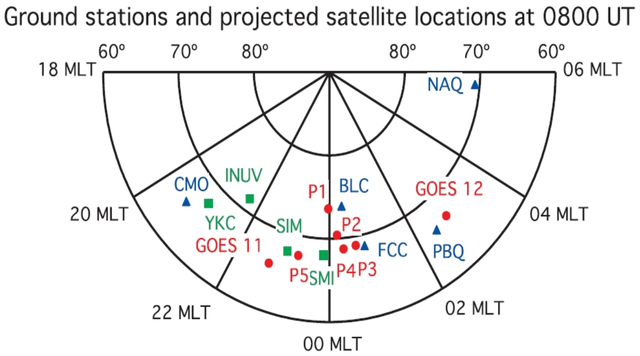


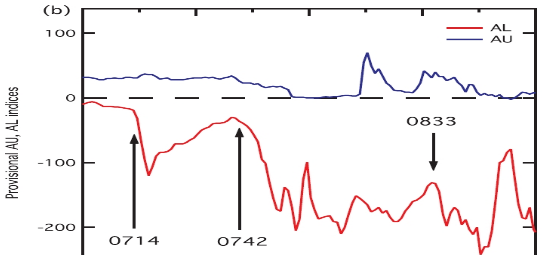
# Mid-tail reconnection

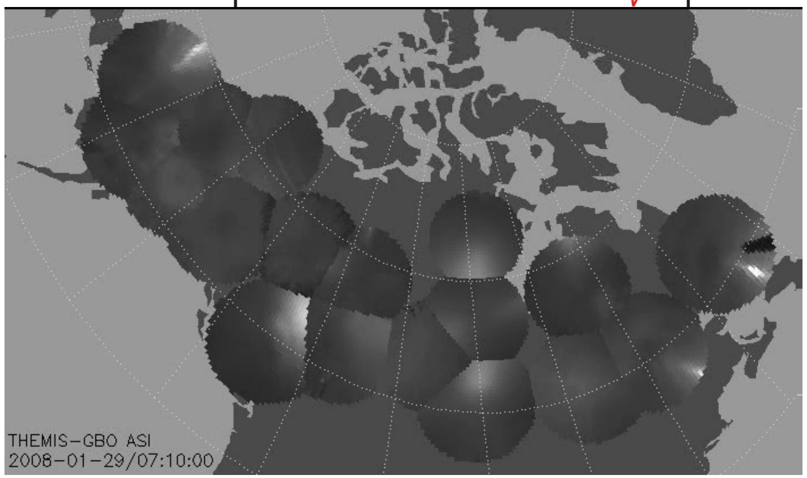
(Angelopoulos et al., Science, 2008)

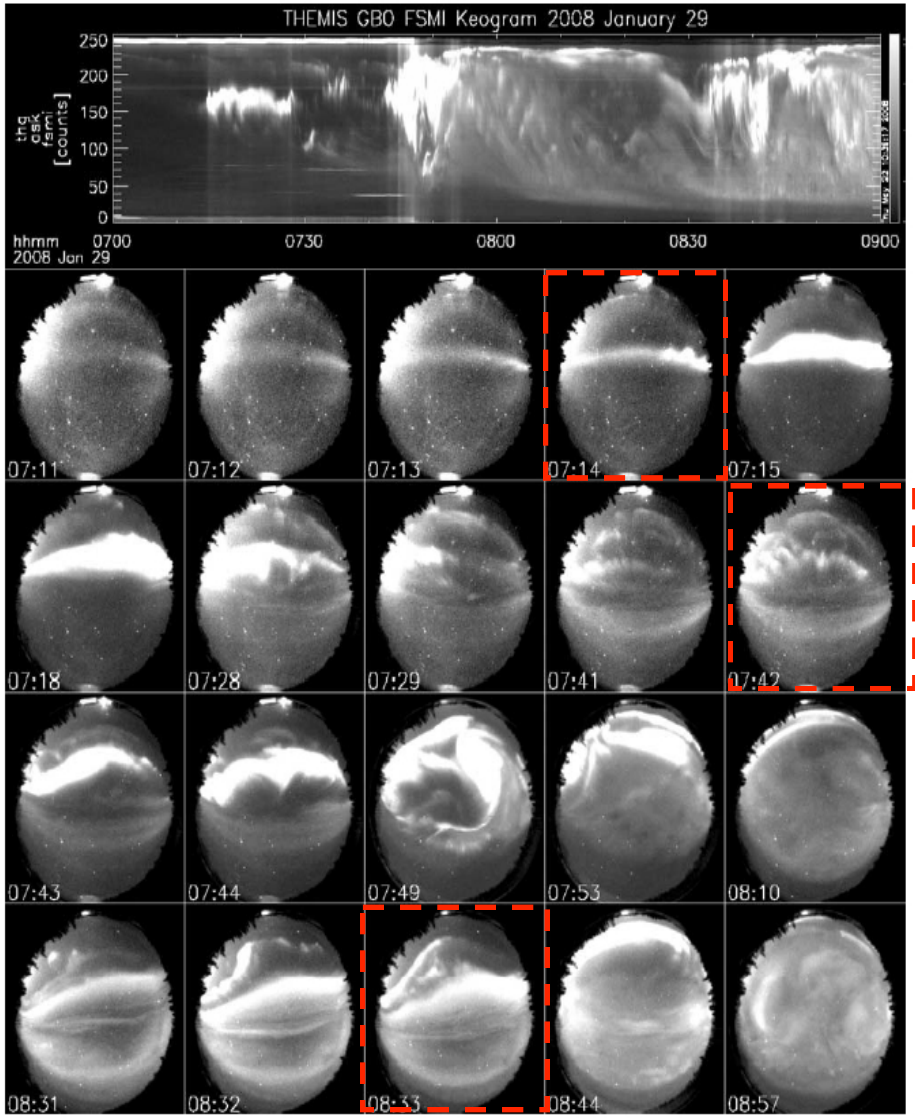


# Near-earth onset (I)
## (Lui et al., JGR, 2008)



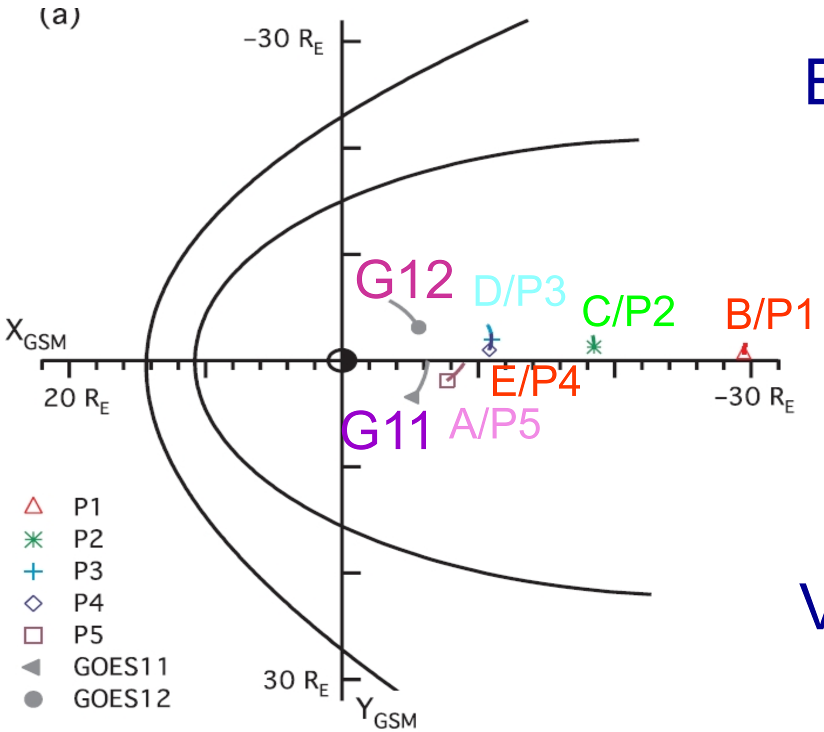



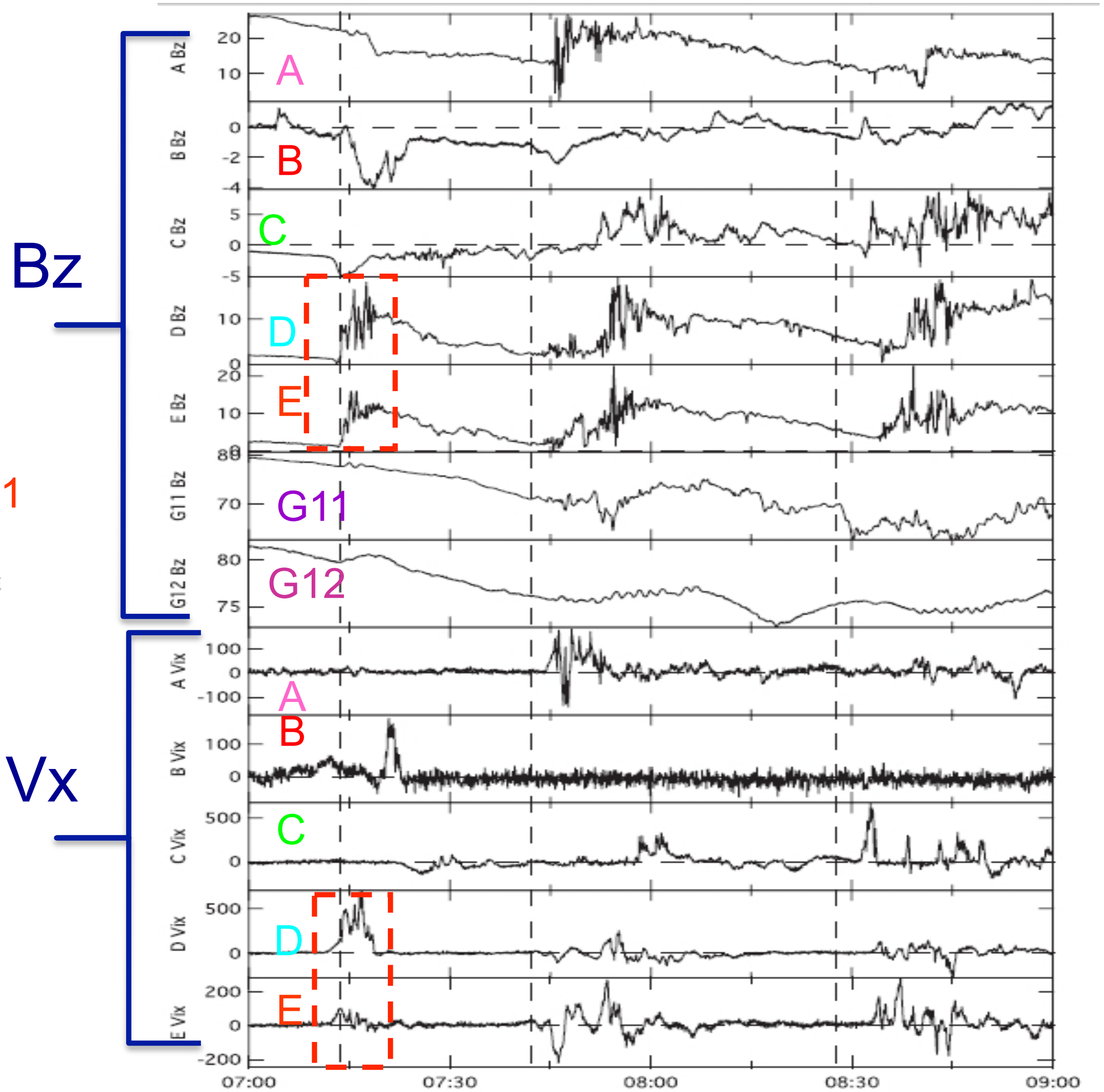



# Near-earth onset (II)

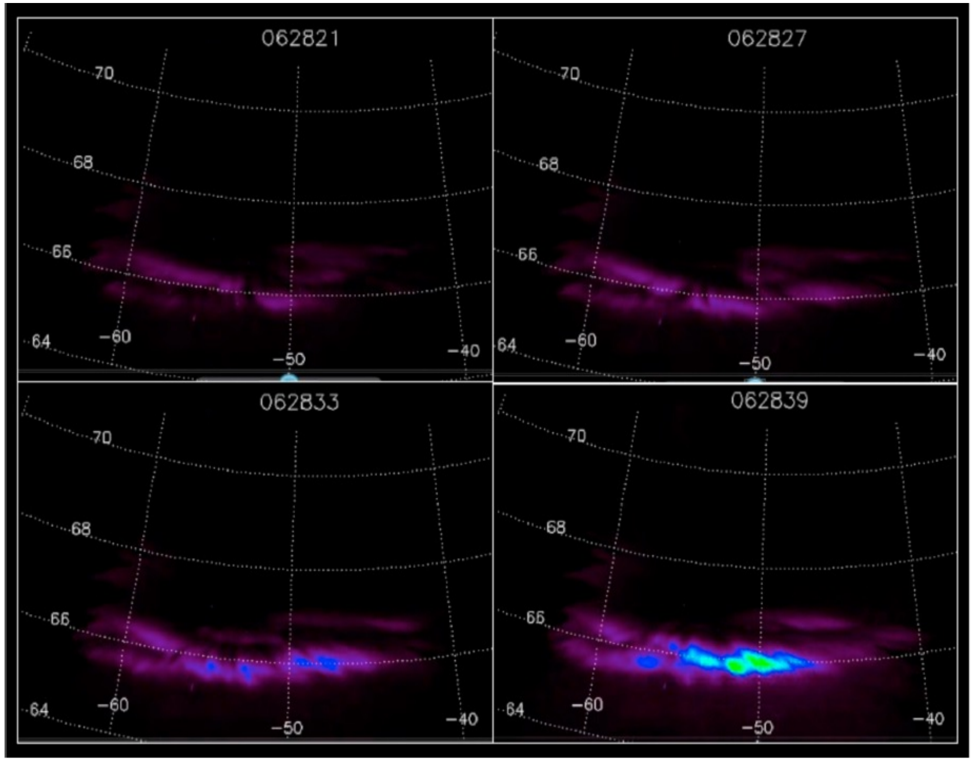
(Lui et al., JGR 2008)



# Ballooning modes

(Liu et al., JGR, 2012)




Onset arc ~ 66°ML

e folding time of luminosity
growth~9 s

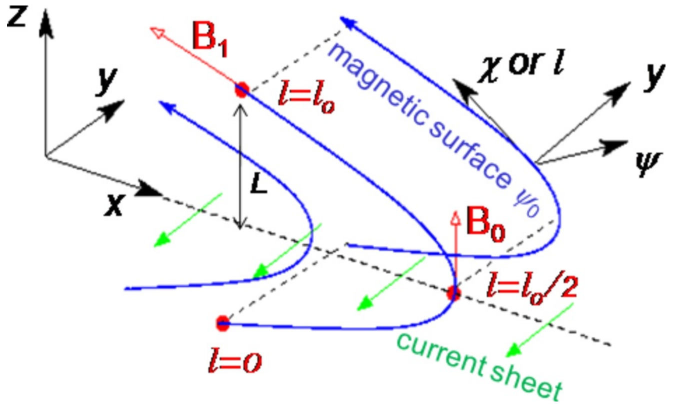
Emission modulation ~ 1.9°
of magnetic longitude
⇒ Finite azimuthal wave length

At geostationnary distance:
⇒ $\lambda$ ~1500 km ~ ion Larmor radius
⇒ Kinetic effects related to ion scales

Hall MHD results:
Ballooning instability
stabilized for very small wave length
and high beta
Instability shifted to $k_y\rho_i$~1 and beta~1-10
What about kinetic effects related to e- scale?

# Electron bounce instability

(Tur et al., PoP 2014)




Normal mode at electron bounce frequency and with wavelength of the order of the current sheet half thickness (L)

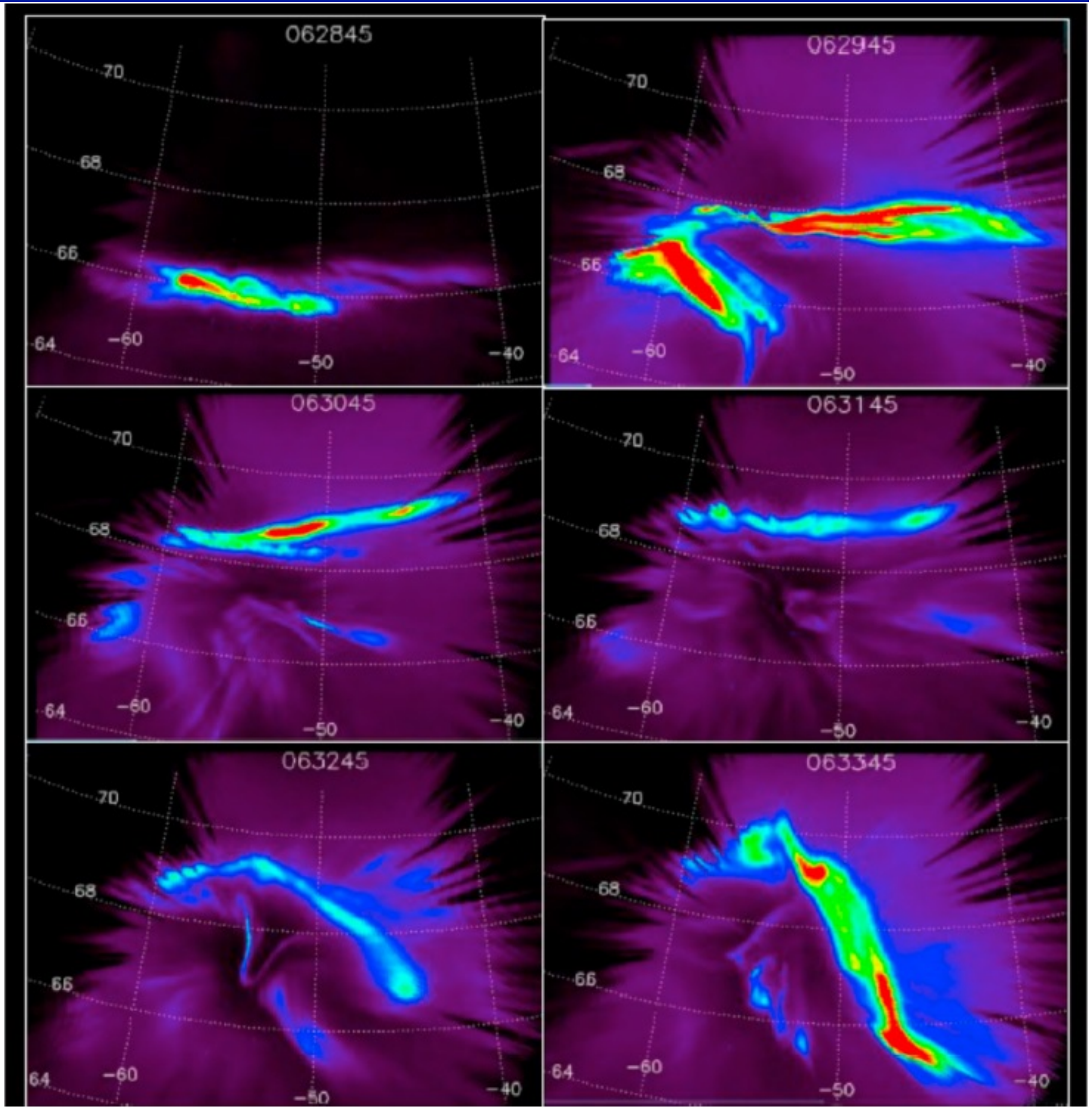
As the current sheet becomes more stretched ($B_0/B_1 \rightarrow 0$), the mode can become explosive with a growth rate about a few tens of seconds and kyL~1 (with L~1 RE)

# Near-earth onset (II)

(Liu et al. JGR, 2012)

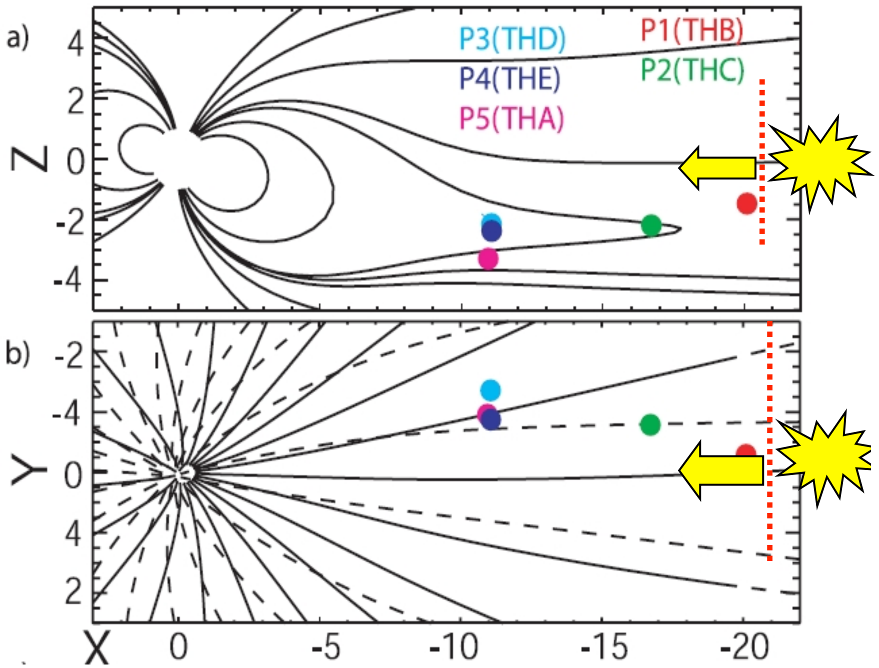
Arc moving poleward
Up to 69 °ML
Equatorial speed ~125 km/s

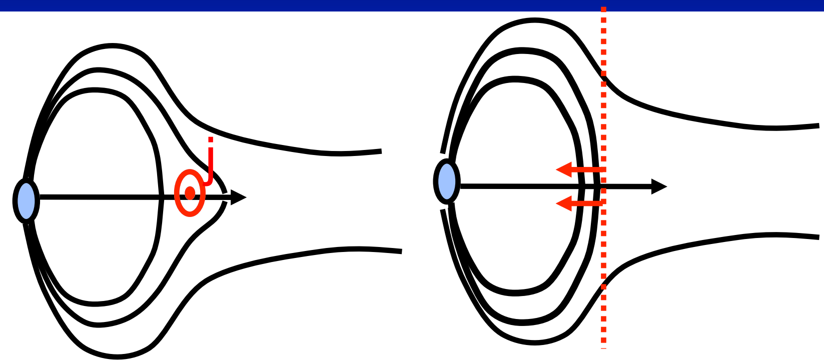
North-South Auroral streamer
From 70 to 65 ML consistent with
Reconnection of open field lines.

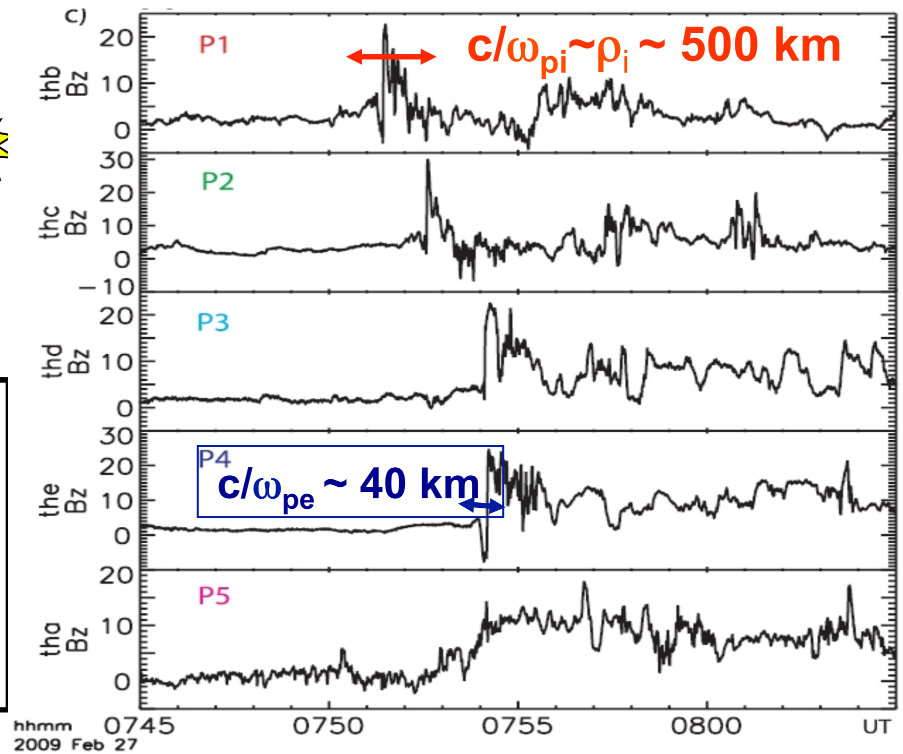


# Dipolarization fronts

(Runov et al., JGR, 2009)






Radial propagation of a thin dipolarization front at 300 km/s generated by mid-tail magnetic reconnection

⇒Kinetic theory (Sitnov et al., JGR, 2009)

⇒Energy conversion site (Angelopoulos et al., Science, 2013)

# Entropy reduction & Interchange

(Pritchett&Coroniti, JGR, 2013)

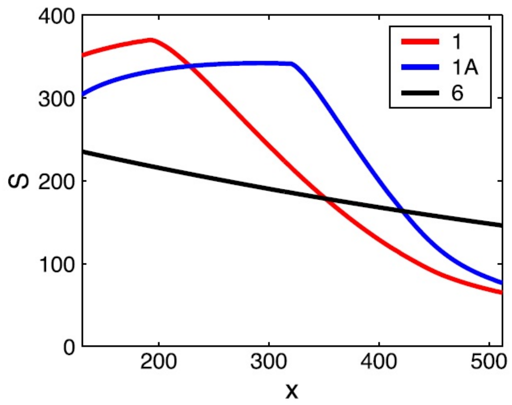
Entropy

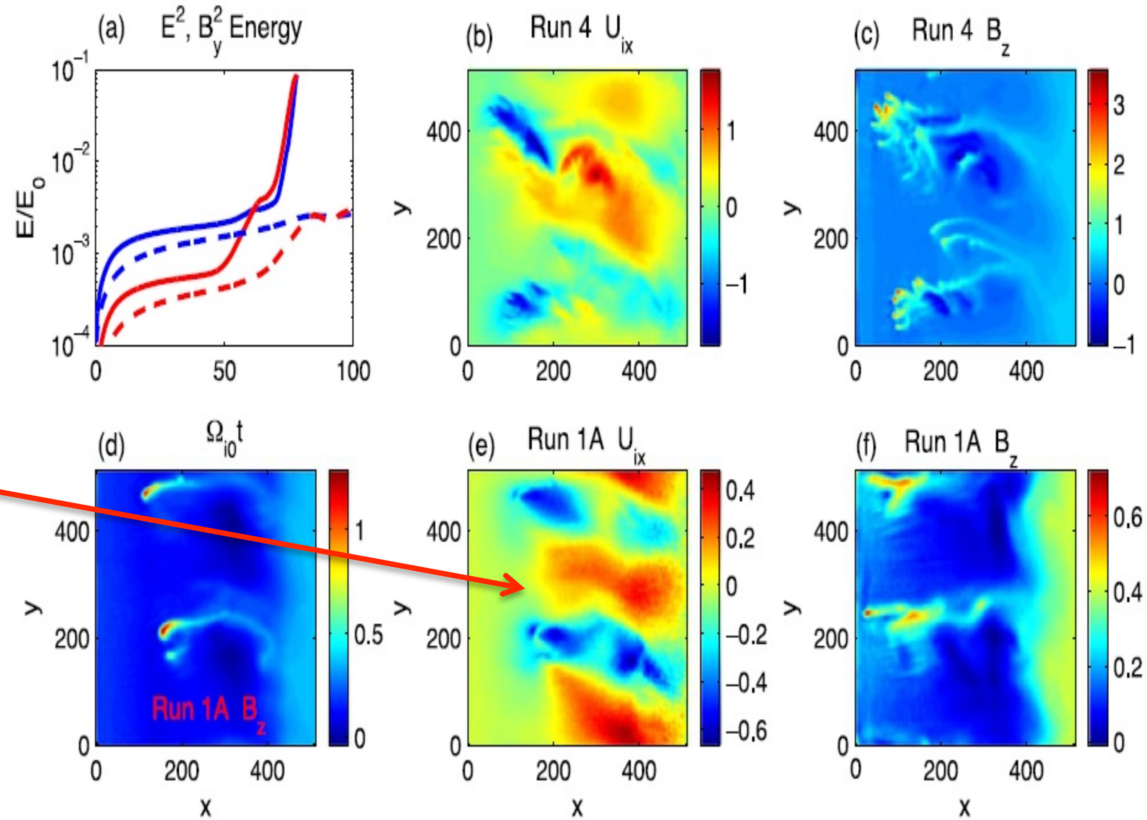
$S = \int P^{1/\gamma} ds/B$

Local minimum of entropy

⇒Interchange/Ballooning

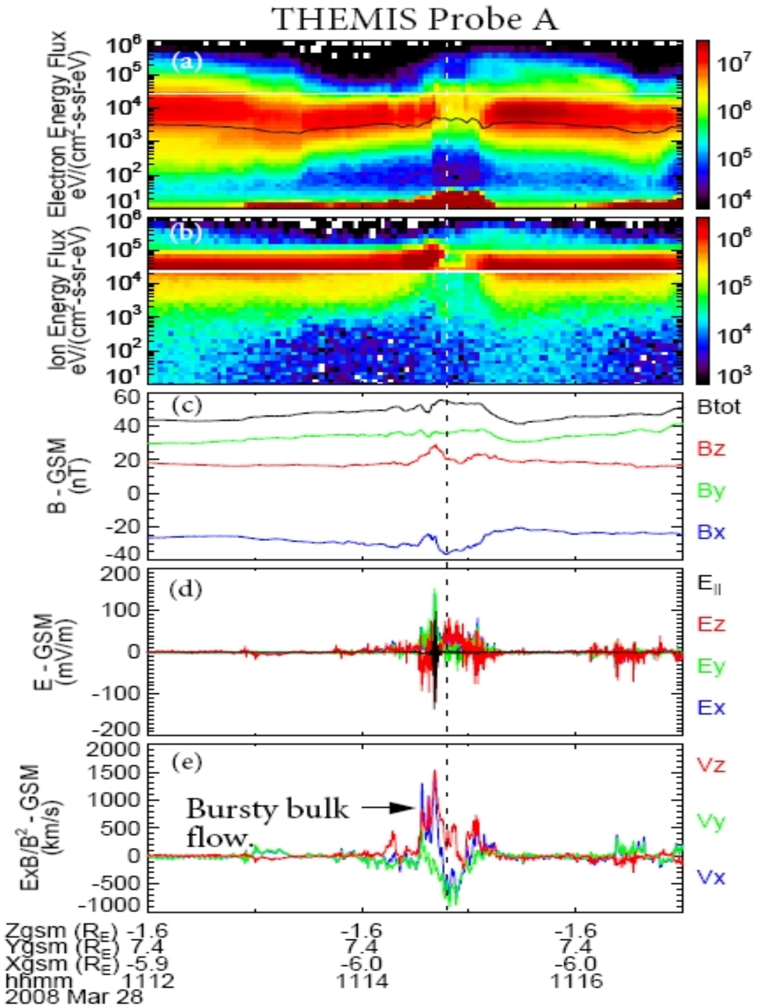
⇒ Jets



# Non linear electron scale structures

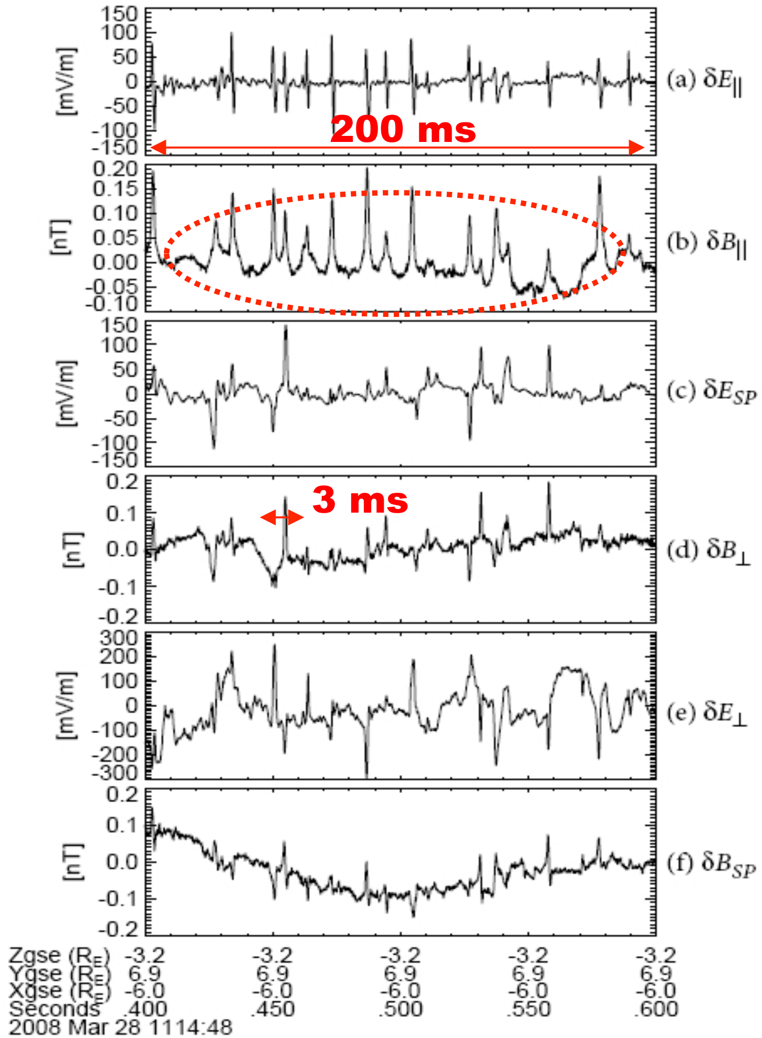
(Ergun et al., Andersson et al., PRL 2009)




**« electron holes » detected during substorms**

**Relativistic nonlinear structures:**

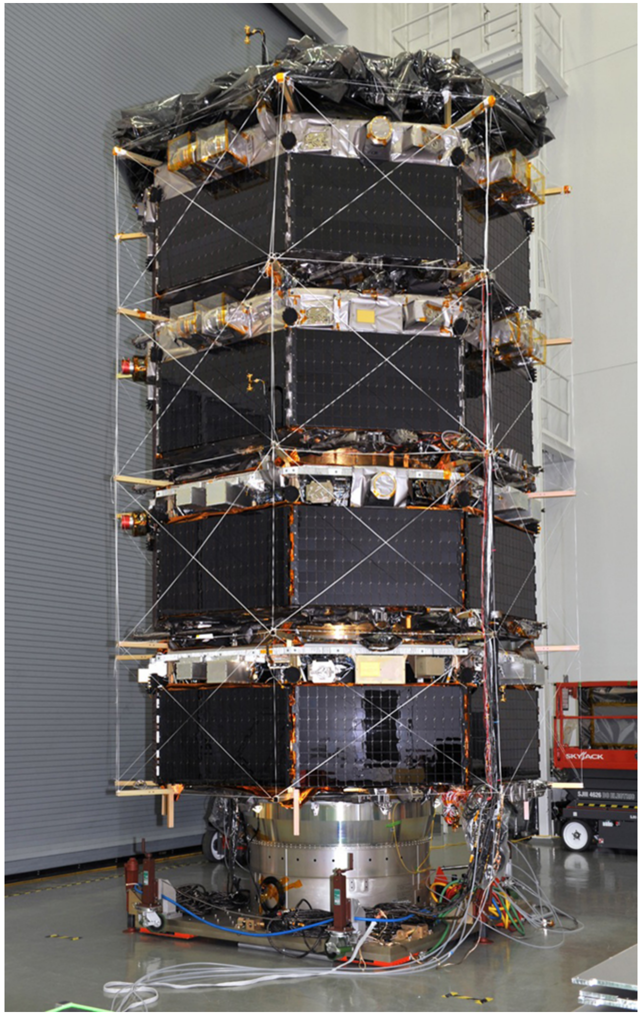
**$V \sim 10^8$ m/s**
**$L \sim 50\ \lambda_{de}$**



# Summary

- Some substorm events correspond to mid-tail destabilization possibly by magnetic reconnection then followed by fast earth/tail-ward flows (jets) associated with dipolarization fronts.
- Other substorm events correspond to cross-tail current/drift instability  at geostationary distance followed by tailward propagating perturbations which can lead to mid-tail reconnection
- Fast plasma flows (jets) and dipolarization fronts can be associated with substorm process or can occur as isolated processes.
- Kinetic effects at large, ion and electron scales need to be taken into account.

# MMS at KSC



Launch scheduled
on March 12, 2015
at 10:44 pm
from Cape Kennedy

Calibration
softwares are
currently tested at
LASP (SOC),
Boulder