Cluster science at IRFU

Scientists

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- A. I. Eriksson
- G. Gustafsson
- M. Khotyaintsev (PhD)
- Y. Khotyaintsev
- A. Kullen
- M. Morooka
- A. Retino (PhD)
- L. Rosenqvist (PhD)
- K. Stasiewicz
- G. Stenberg
- A. Vaivads
- E. Yordanova

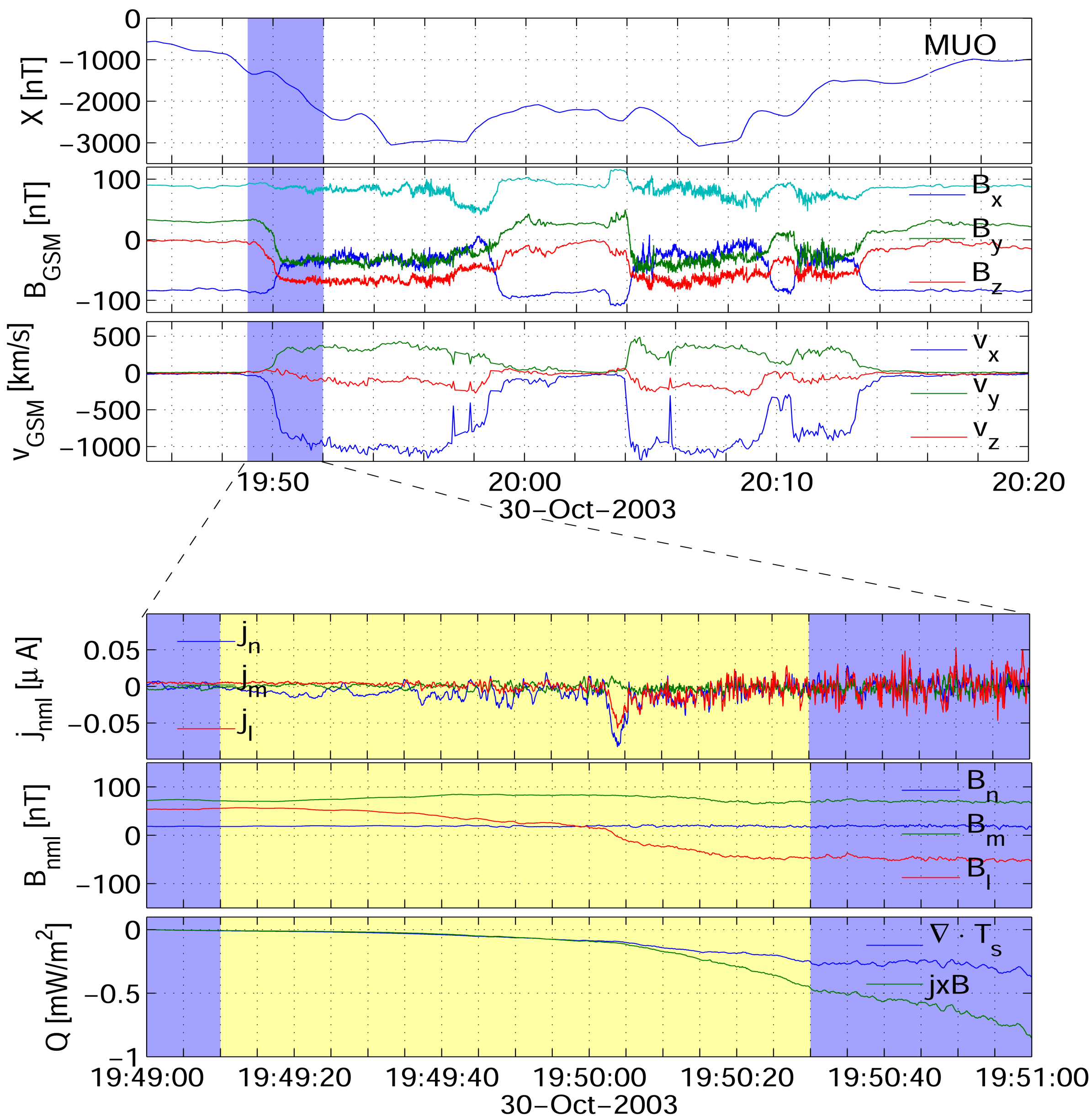
Topics

- Magnetic reconnection
  - diffusion region
  - separatrix region
  - magnetic islands
- Energy transfer across MP
- Polar wind
- Plasma waves at MP, cusp, tail
- Turbulence
- Energy transfer down to ionosphere
- Auroral physics

L. Rosenqvist

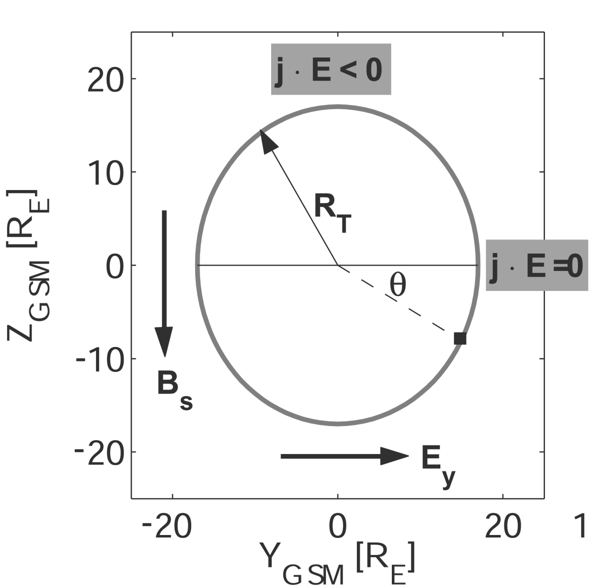
Magnetospheric energy budget using Cluster and groundbased data

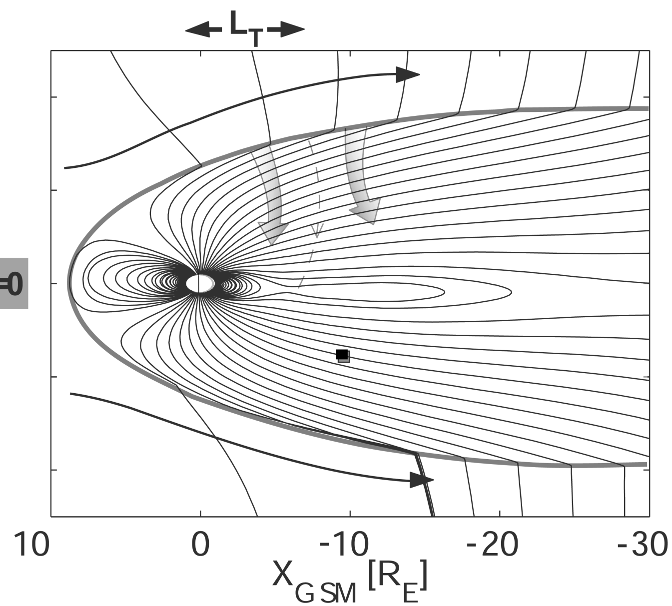
- Observational method to determine magnetospheric power input
- Test of empirical model (proxy) of energy transfer during extreme storm/substorm
- Energy budget during extreme geomagnetic activity

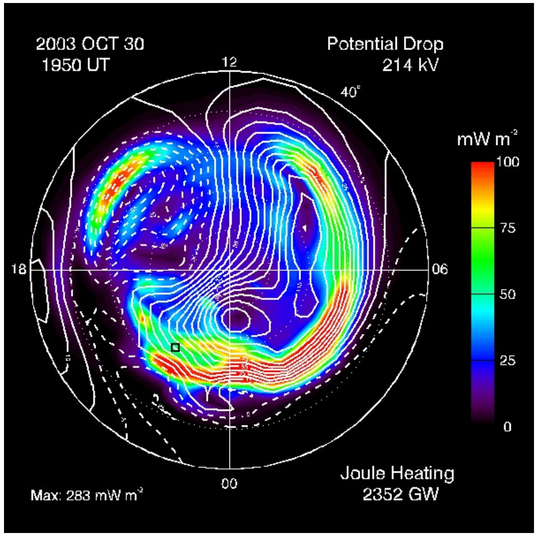


L. Rosenqvist

Global system







Summary

U_{mp} ~ 17 TW → 30 % of input deposited via Joule heating

First observational estimate of solar wind power input using Cluster observations, w_{mp} = 0.5 mW/m², 0.25 mW/m² due to tangential stess

Global power input ~17 TW.

30 % of sw power to Joule heating according to obervations

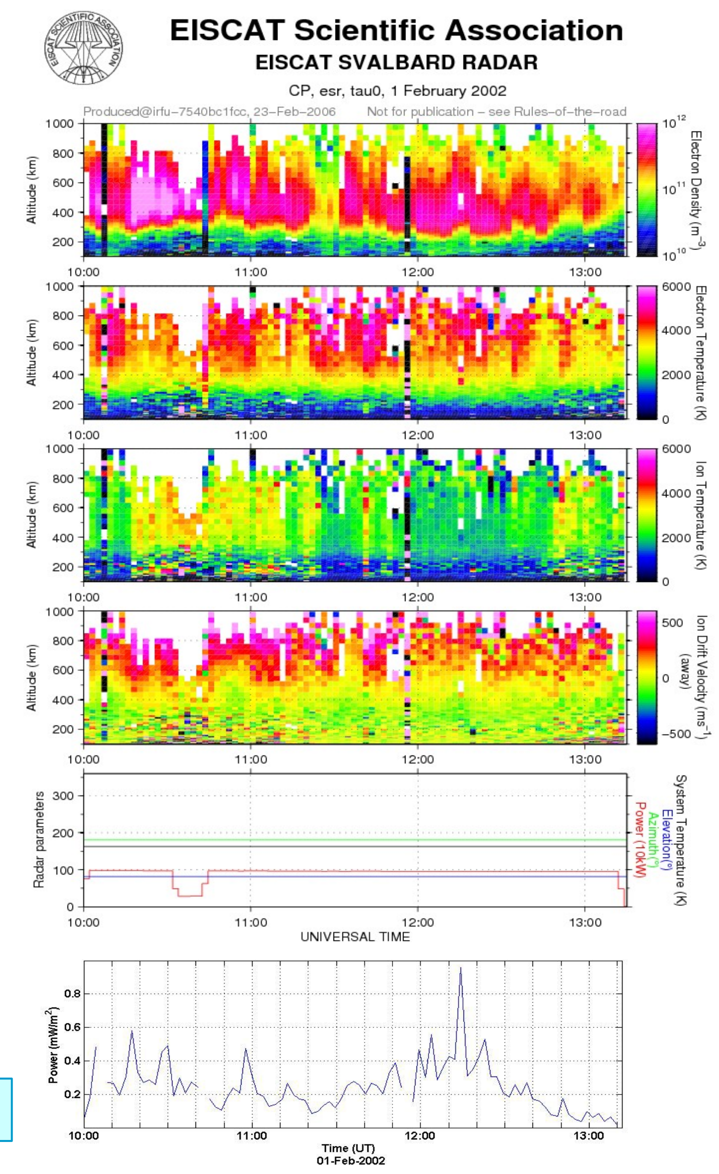
Empirical proxies overestimate/underestimate energy input/output

E. Yordanova

Study of energy input into the ionospheric cusp using correlated ground-based and satellite observations

1) Energy into the ionospheric F-layer:

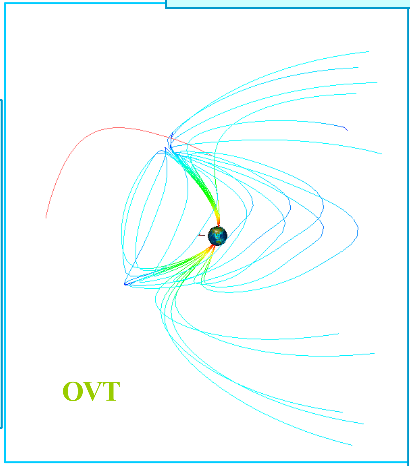
The estimated power is derived calculating the heating/cooling rates of the precipitating particles due to elastic and inelastic processes. The rates' calculations are based on EISCAT measurements of electron density, and electron, and ion temperatures.

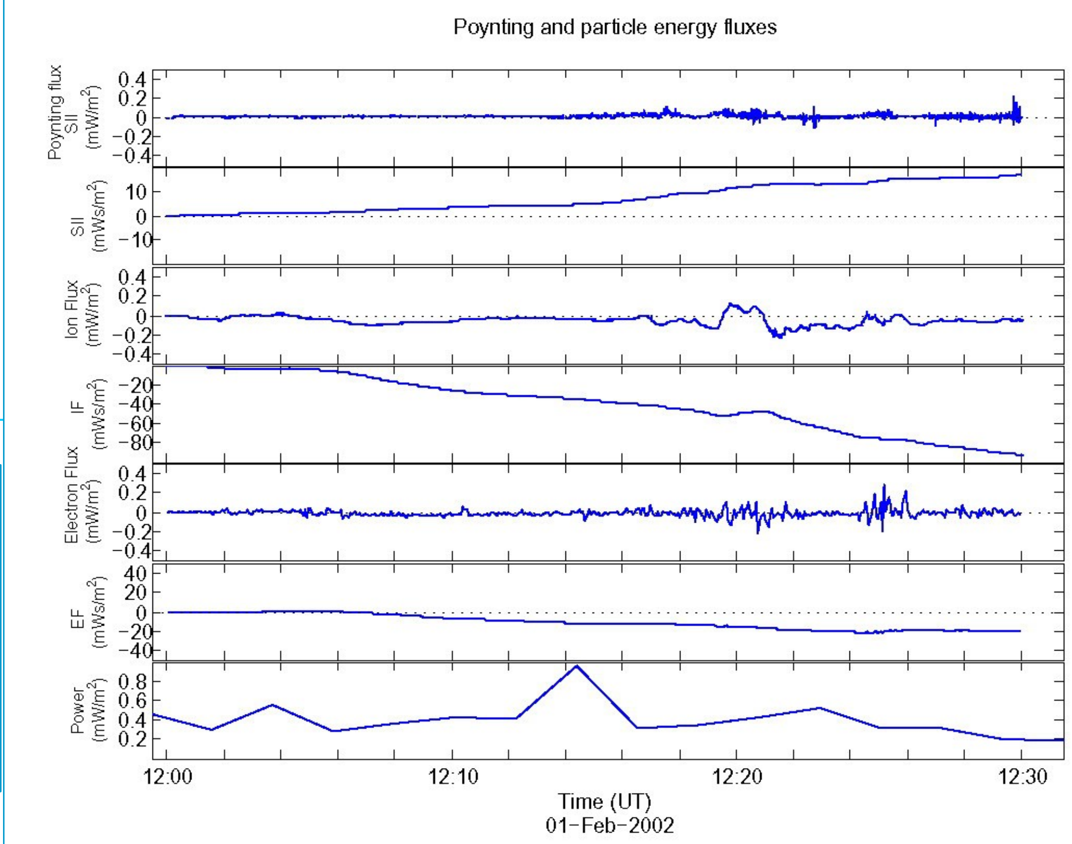


EISCAT energy input for 1 Feb 2002

1 Feb 2002 EISCAT/CLUSTER conjunction event

On 1 Feb 2002 Cluster is in the high altitude cusp. A close magnetic conjunction with EISCAT - 12 UT.





2) Energy in the high – altitude cusp:

The energy is calculated in terms of Poynting, ion and electron fluxes

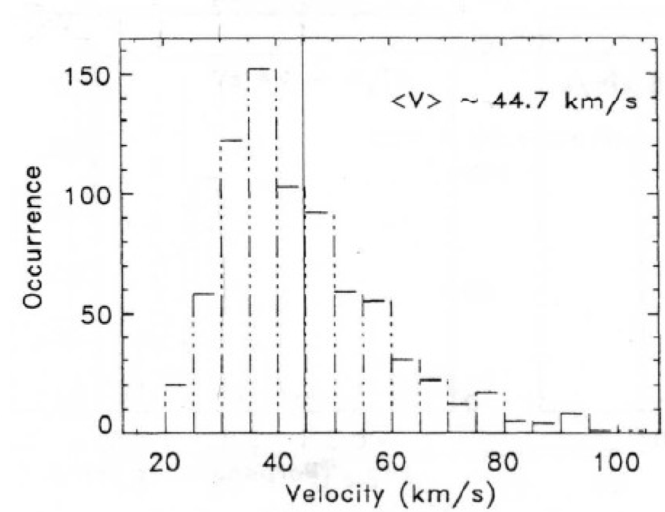
Results

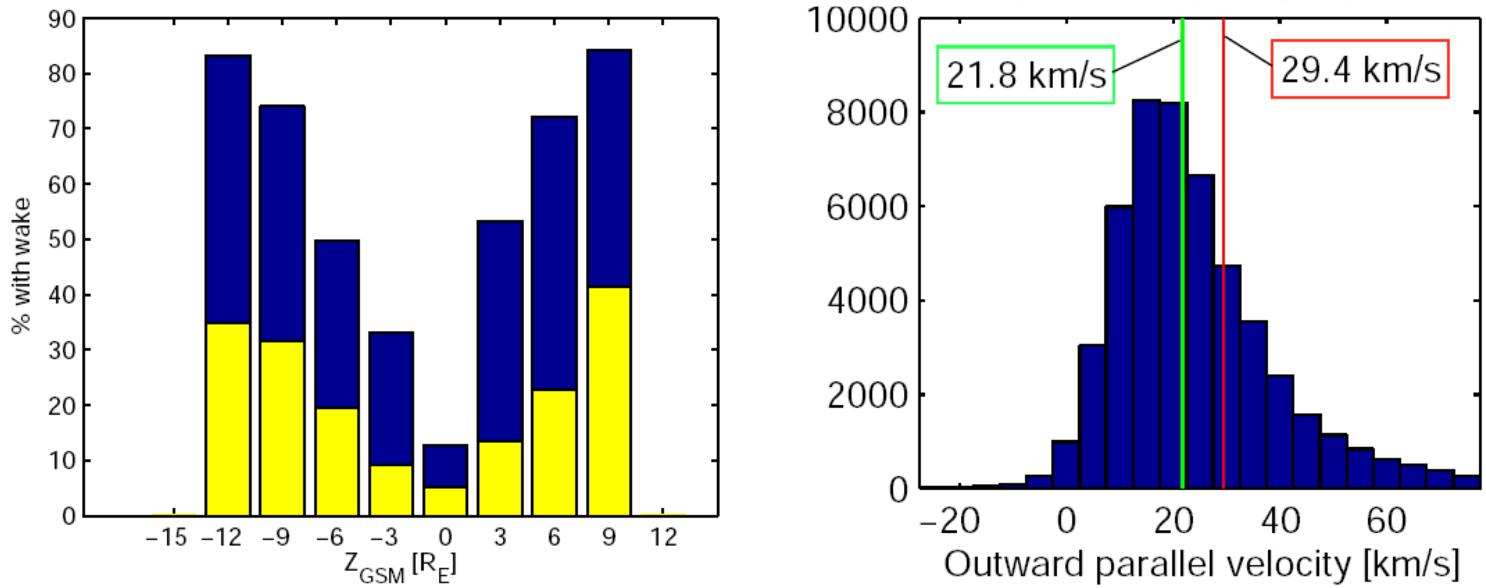
The incoherent radar measurements reveal a significant amount of energy in the ionospheric cusp which is due to particle precipitation. **Cluster observations show a much larger downward Poynting flux** (~ 10 [mW/m^2]) and upward particle energy fluxes (ions ~50 and electrons ~ 10) **than is necessary to explain the simultaneous conjugated ionospheric energy input**. This means that enough energy is found to heat the plasma locally in the cusp. This heating could then contribute to the origin of hot plasma in the plasma sheet after reconnection in the tail takes place.

Polar wind statistics

E. Engwall

- Comparison to Su et al., POLAR, 1998 (top right; they miss most of the fun despite PSI and all...)





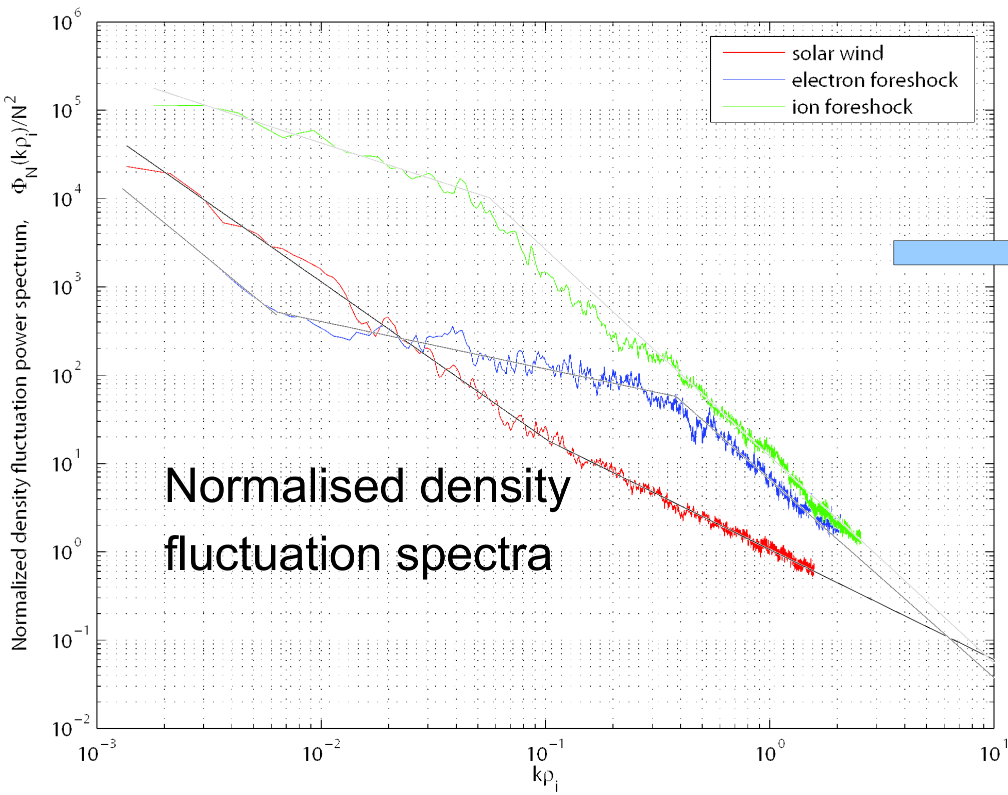
(a) (b)

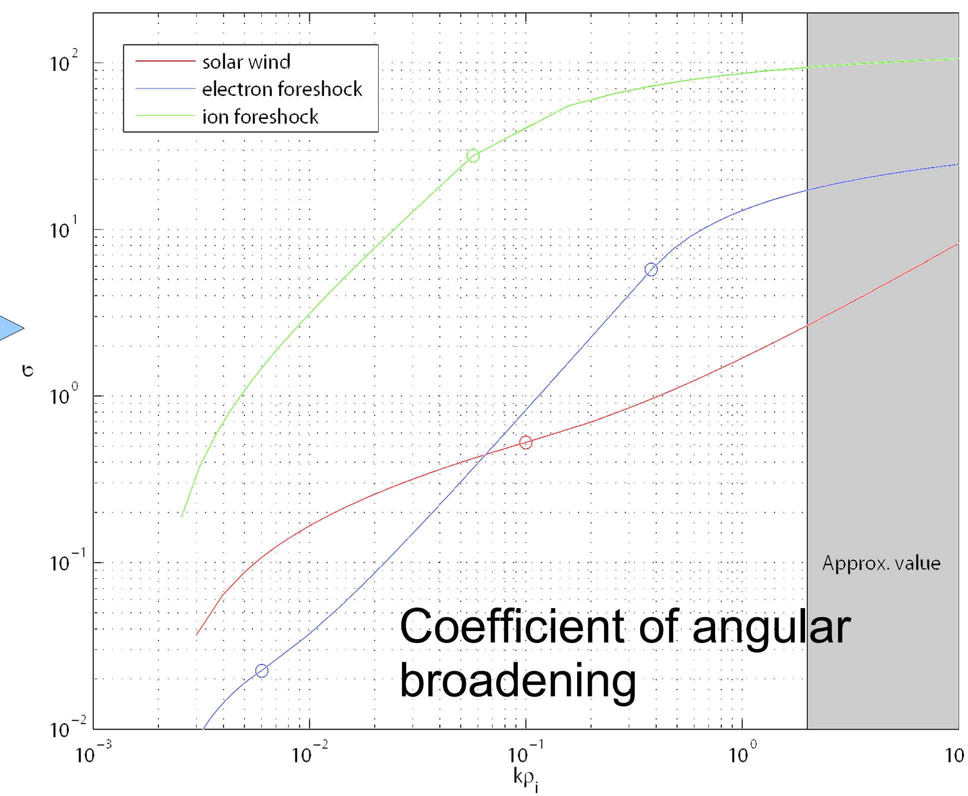
Figure 6.2: (a) Fraction of all events where cold ions have been detected as a function of Z_{GSM} using two different criteria: 1. $\mathbf{E}^{\mathrm{w}} > 2$ mV/m (yellow and blue), and 2. $\mathbf{E}^{\mathrm{w}} > 2$ mV/m, and $u_{\|} > 25$ km/s (yellow). (b) The outward velocity distribution along the magnetic field. The mean (red line) and median (green line) values are displayed.

M. Khotyaintsev

Scattering of radio waves on density fluctuations

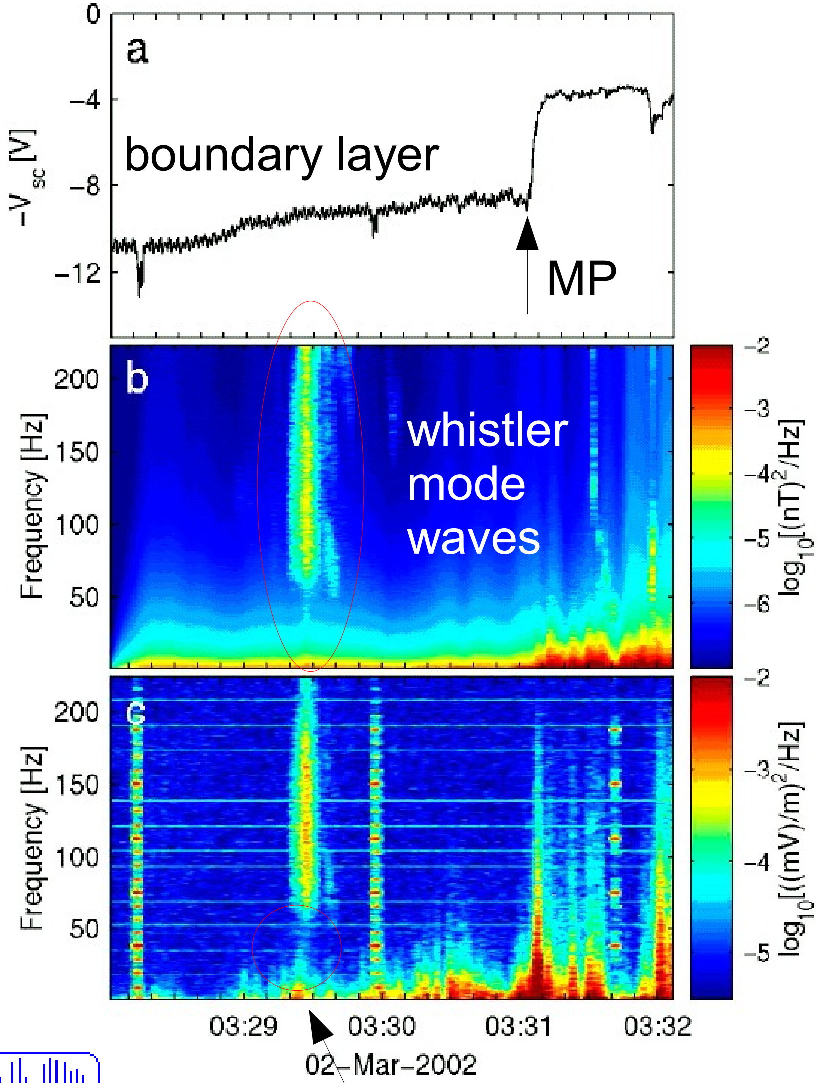
LOIS inspired





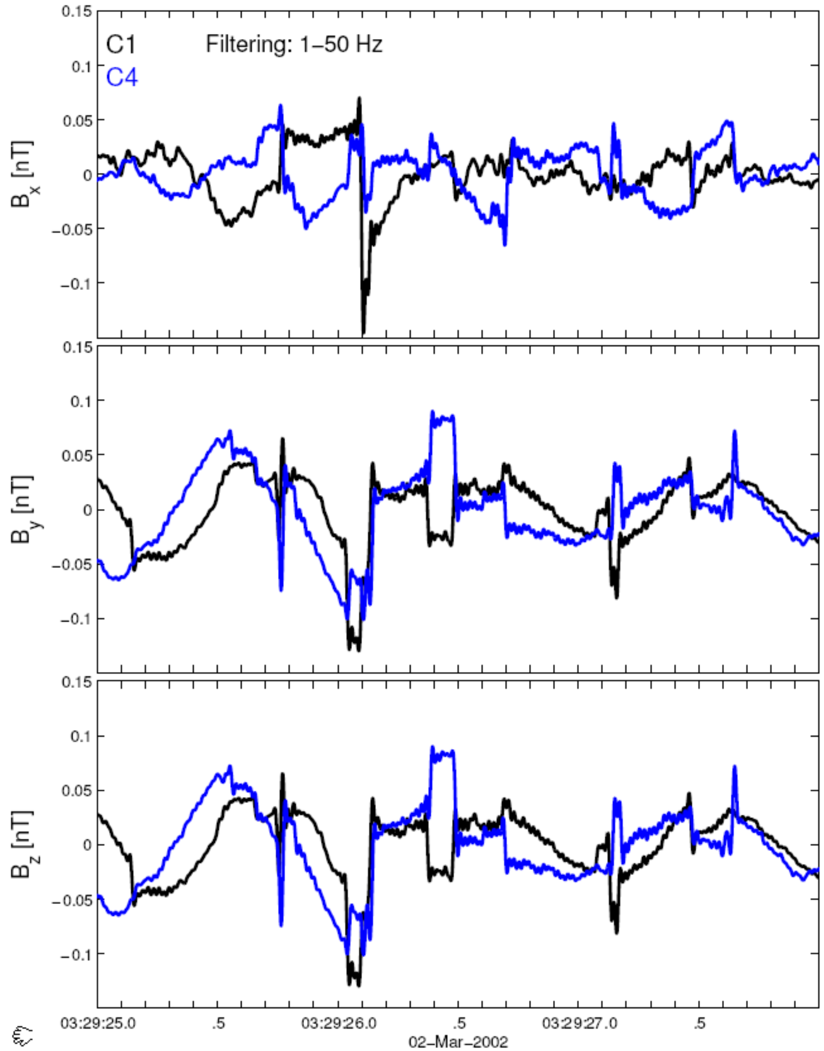
G. Stenberg

Whistler mode waves close to the magnetopause



low-frequency signature seen by C1 and C4

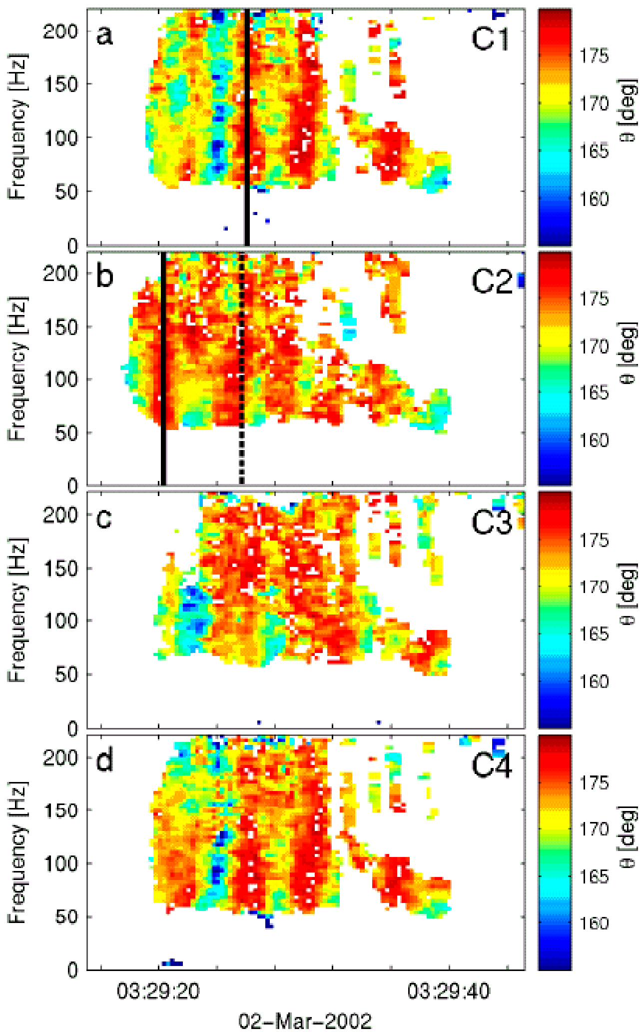
The low-frequency part...



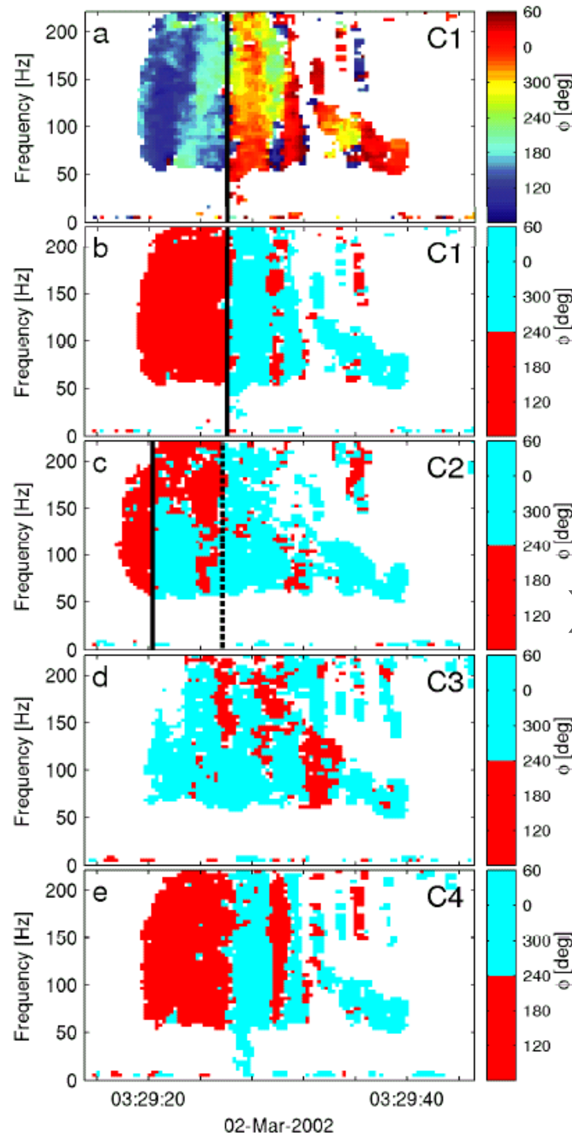
...the high-frequency part...

G. Stenberg

Means' method

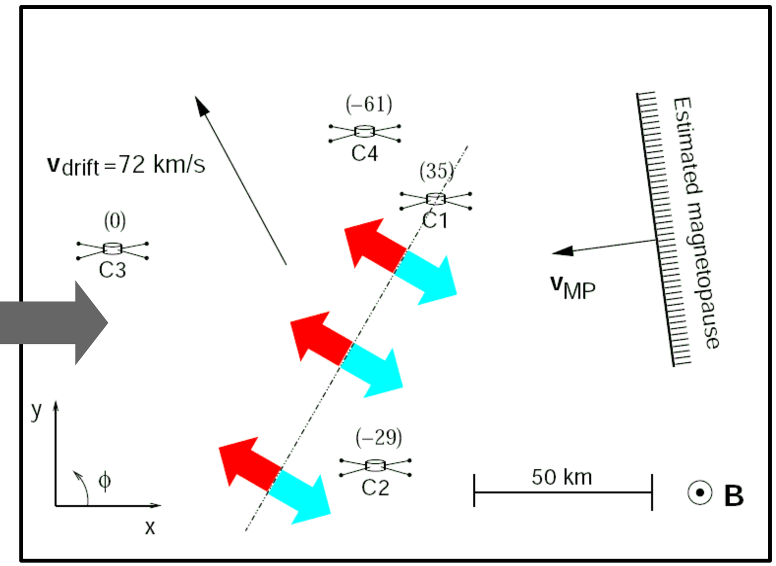


-almost anti-parallel propagation
-a "striped" pattern



-sudden changes in the azimuthal angle

...and the conclusion

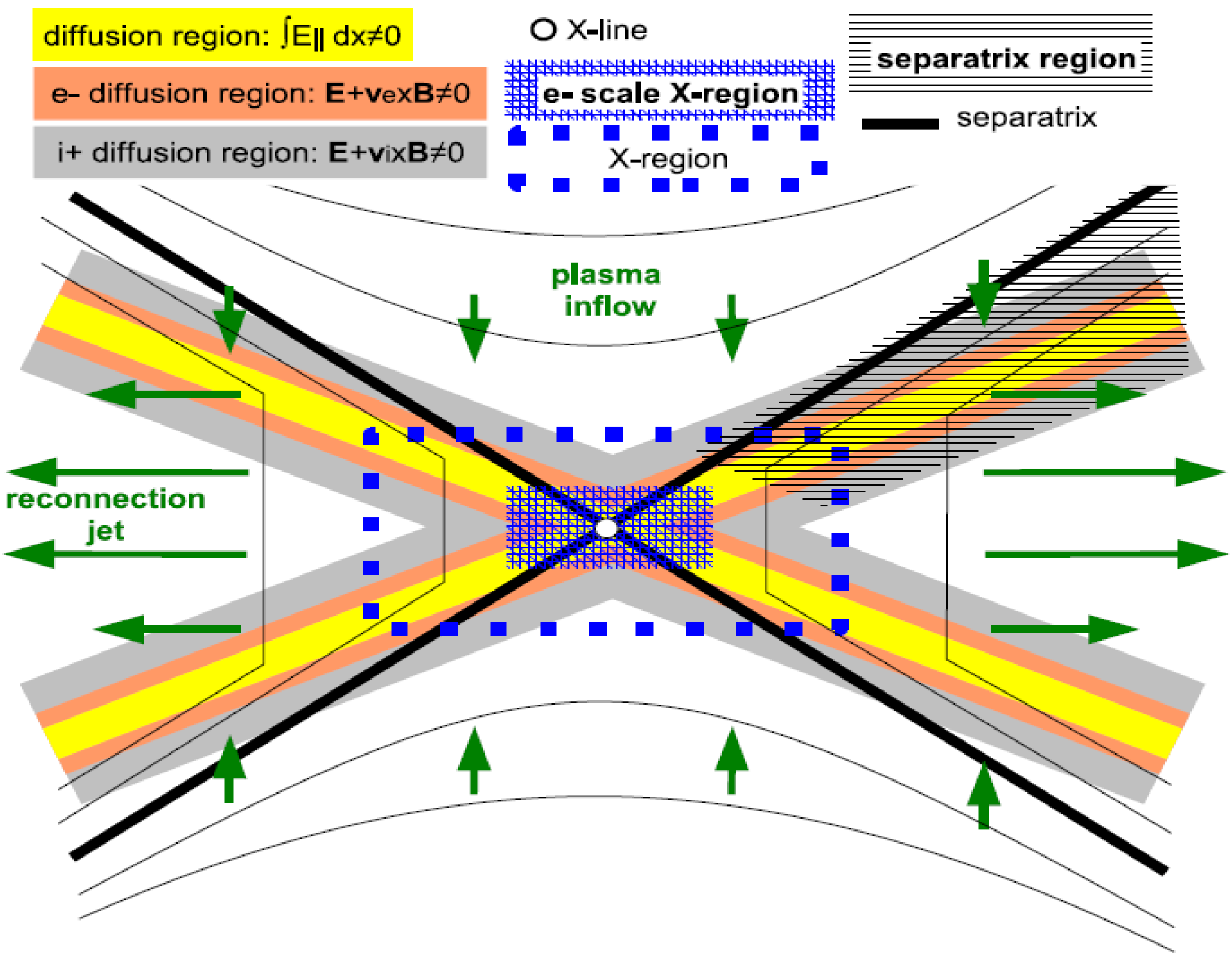


Interpretation: Thin sheets generating whistler mode waves pass over the spacecraft

Vaivads, A., A. Retinò, and M. André,

Microphysics of Reconnection

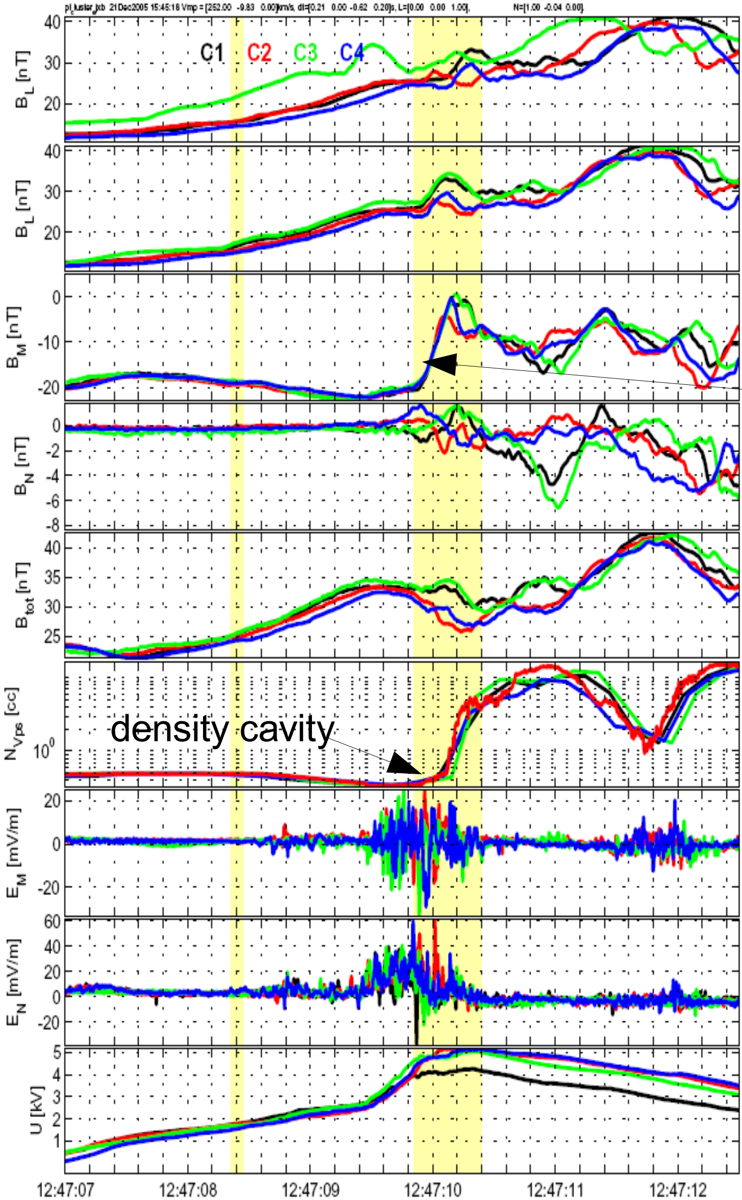
in print, Space Science Reviews



- Two regions of high interest
  - X-region
  - separatrix regions
- Probability of crossing
  - X-region is small
  - separatrix regions is high
- Separatrix regions important
  - energy conversion
  - remote sensing of the X-region
  - magnetosph/ionosph coupling

Y. Khotyaintsev

Formation of Inner Structure of a Reconnection Separatrix Region



out of plane component

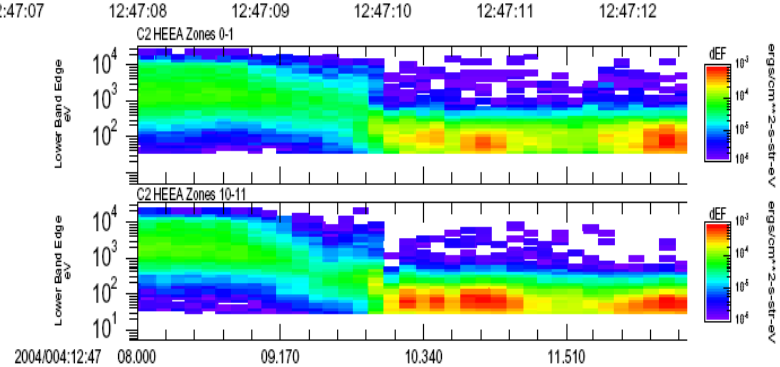
strong $j_{||}$

normal B component

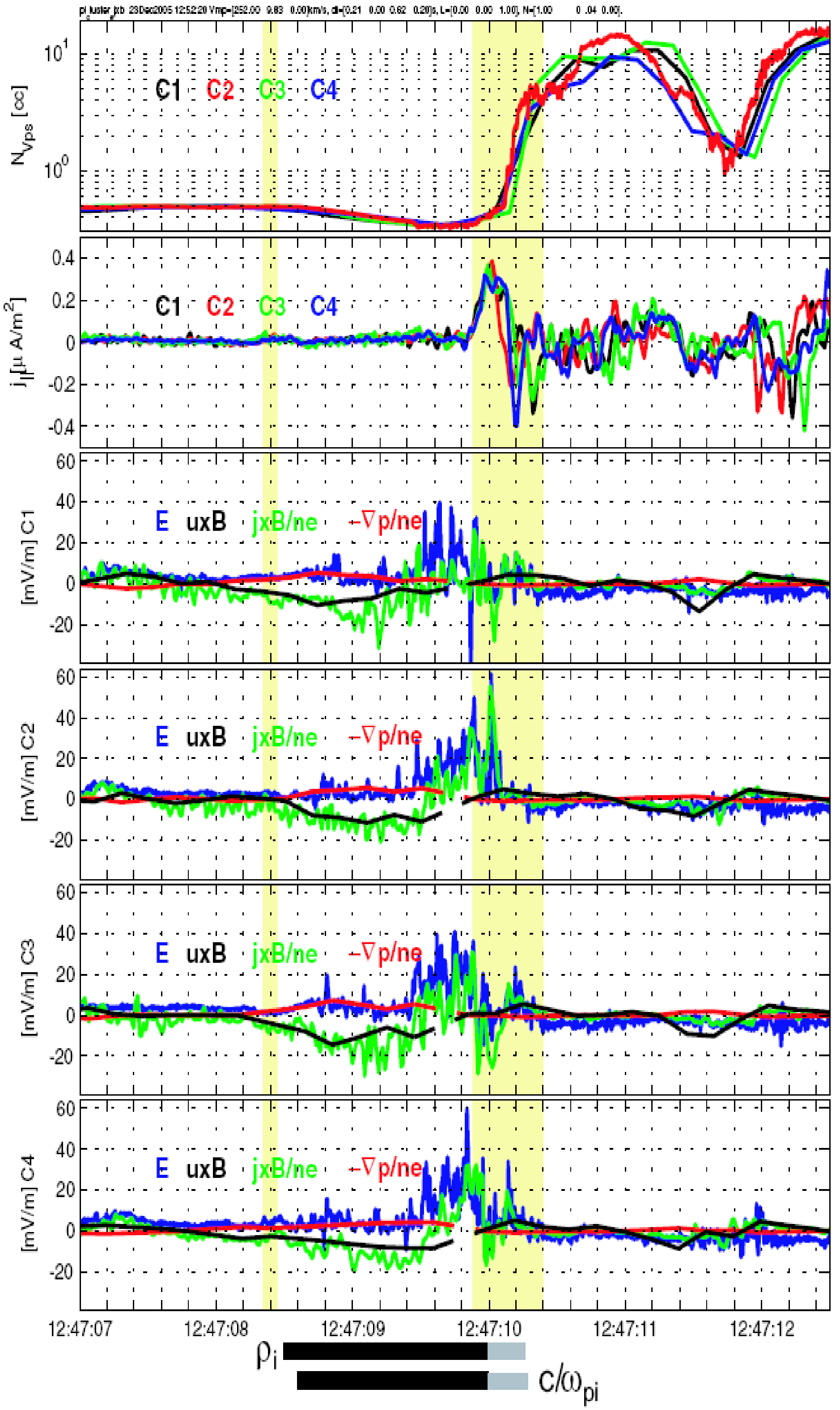
- Crossing of the boundary layer (open/closed field lines)
- Boundary velocity V=[-252 10 0] km/s GSE
- Density cavity of ~50%

Tangential electric field.

Normal electric field, within cavity potential jump of several kV.



Cavity forms where high energy plasma sheet electrons are lost to magnetosheath



Y. Khotyaintsev

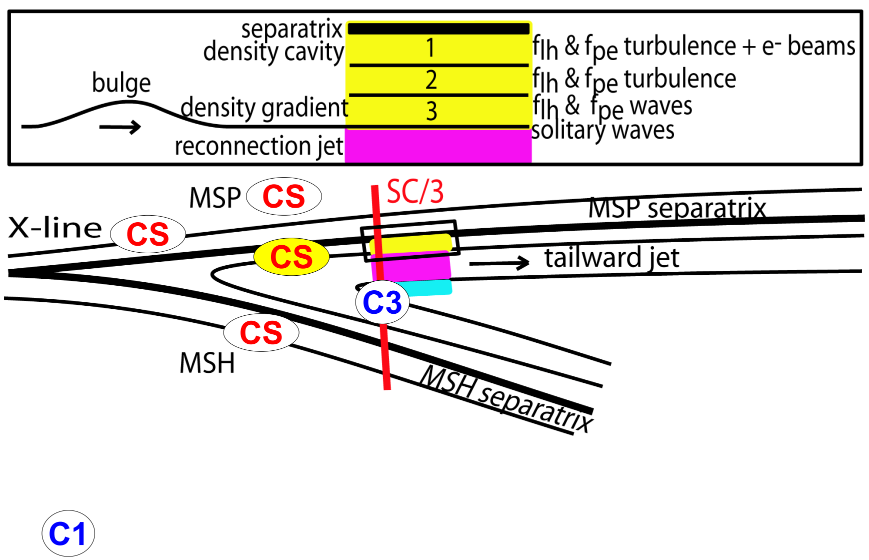
Estimates of four out five terms in Generalized Ohm"s Law. Good identification of balancing terms can be achieved.

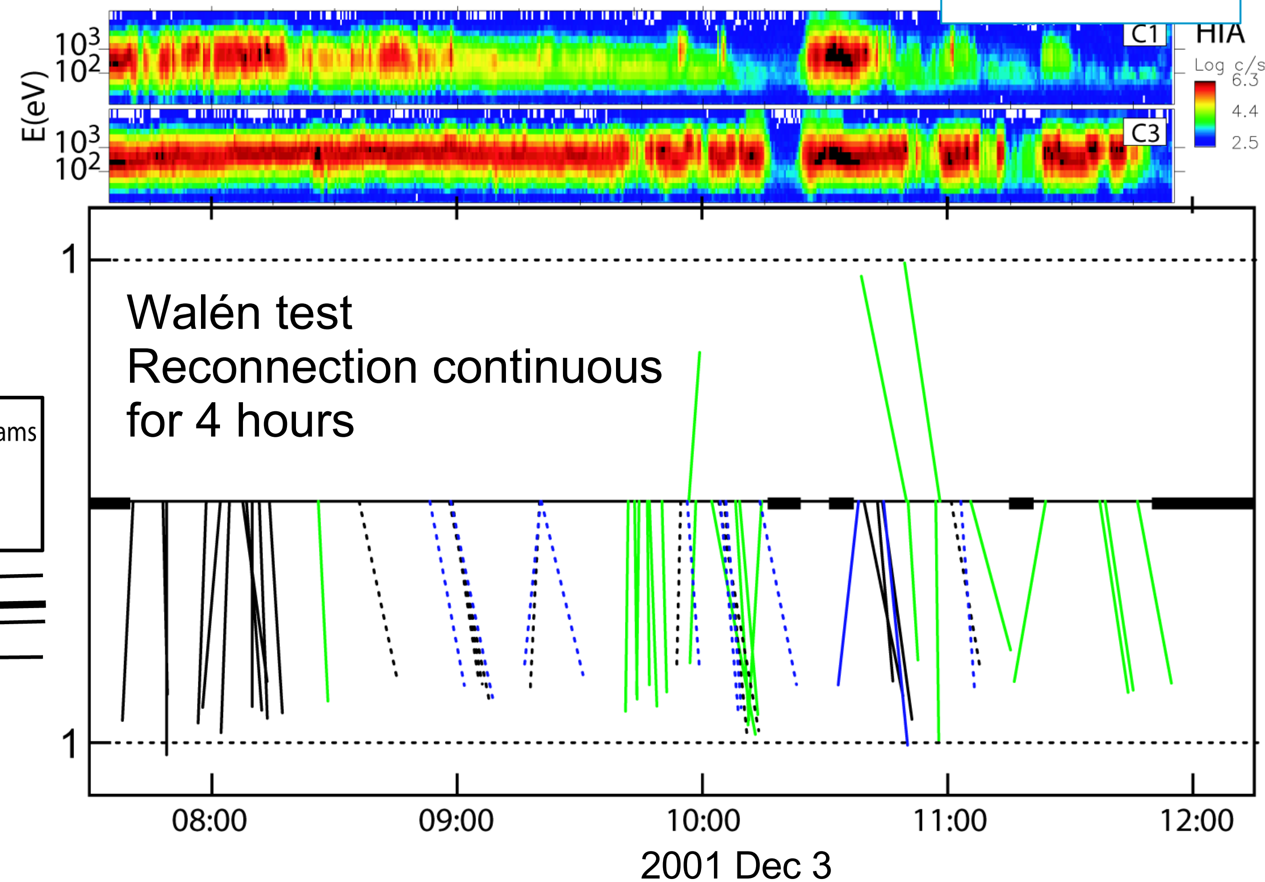
$$\mathbf{E} = \frac{1}{ne}\mathbf{j} \times \mathbf{B} - \frac{1}{ne}\nabla \mathbf{p}_e - \mathbf{u}_i \times \mathbf{B} - \frac{m_e}{e}\mathbf{u}_e \cdot \nabla \mathbf{u}_e$$

Cluster on MHD scale

A. Retino

Magnetic reconnection
Cluster crossing separatrix region at some distance from X-line





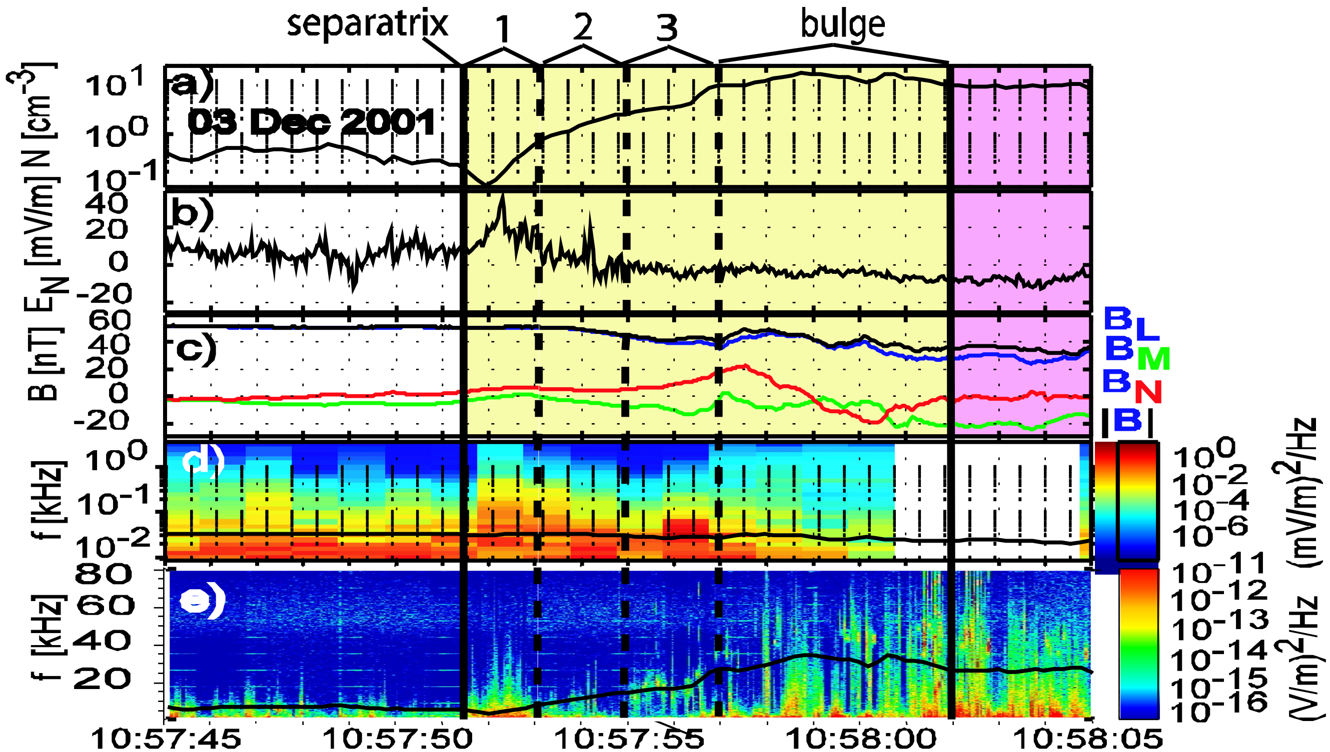
[Retinò et al., 2005 subm Geophys. Res. Lett.]

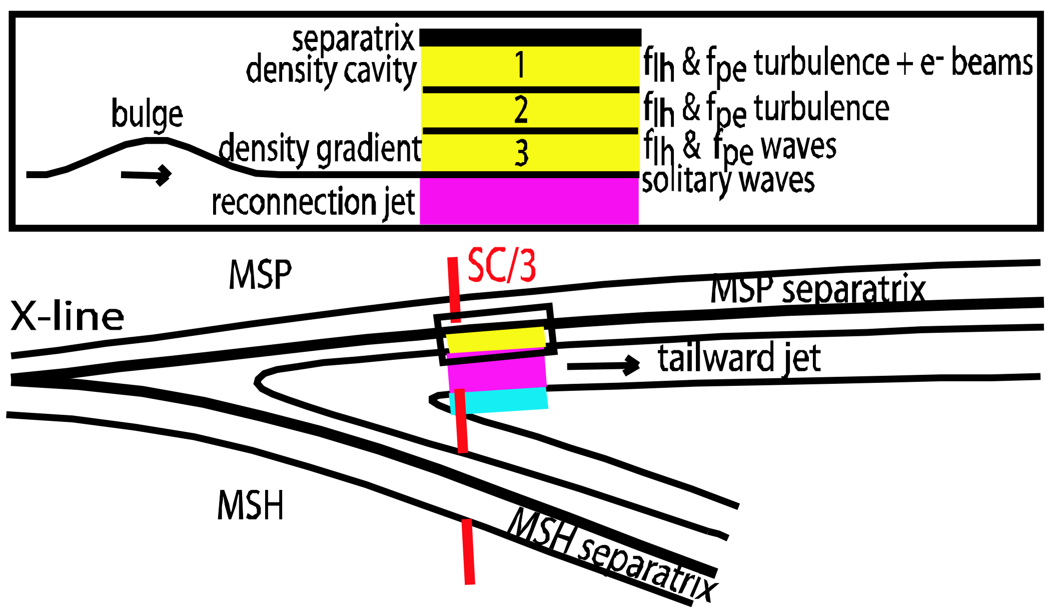
[Retinò et al., 2005 Annales Geophys.]

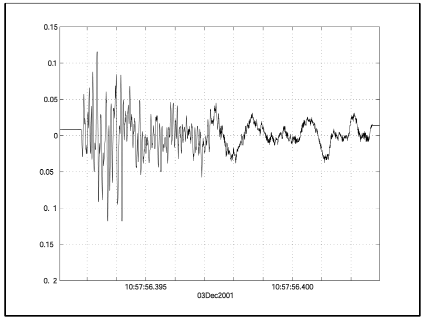
electron scales	ion scales	MHD scales
• electron beams and their acceleration • wave-particle interaction • dynamics of solitary waves, double layers	• spatial/temporal separation • structure of magnetic islands and micro-FTEs • structure and dynamics of separatrices	• IMF control • Large scale reconnection jets, jet reversal • Continuity of reconnection
Cross-Scale CS	Cross-Scale CS	Cluster C

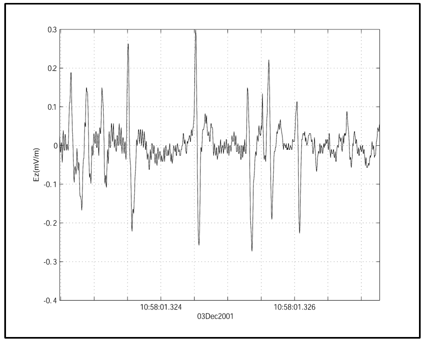
Microphysics of magnetic separatrices

A. Retino









magnetic separatrix identified as boundary in waves

separatrix region ~ 5 $\lambda_{sh,i}$ wide

inside the separatrix region few subregions ~ $\lambda_{sh,i}$ wide

density cavity adjacent to the separatrix

bipolar magnetic signature (micro-FTEs)

inside subregions structures below $\lambda_{sh,i}$

ESW at the boundary with jet but not inside the separatrix region

Separatrix region highly structured and dynamic suggests tat ongoing reconnection at X-line provides much free energy even away from it

The next mission we need is **Cross-Scale**

Cross-Scale covers electron/ion/fluid scales simultaneously
“Astroplasma observatory”

?? June 2006 – AO on Cosmic Vision

5/6 July 2006 workshop on Cross-Scale

- community support
- strengthen and widen base for proposal