

Double Star, Cluster, and Ground-based Observations of Magnetic Reconnection During an Interval of Duskward-Oriented IMF

Jim Wild

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S.E. Milan, J.A. Davies, C.M. Carr, M.W. Dunlop, E. Lucek, A. Marchaudon, A.
N. Fazakerley, R. Fear, J.M. Bosqued, H. Rème, D.M. Wright and H. Laakso
(and many, many others!)

With grateful acknowledgements to...

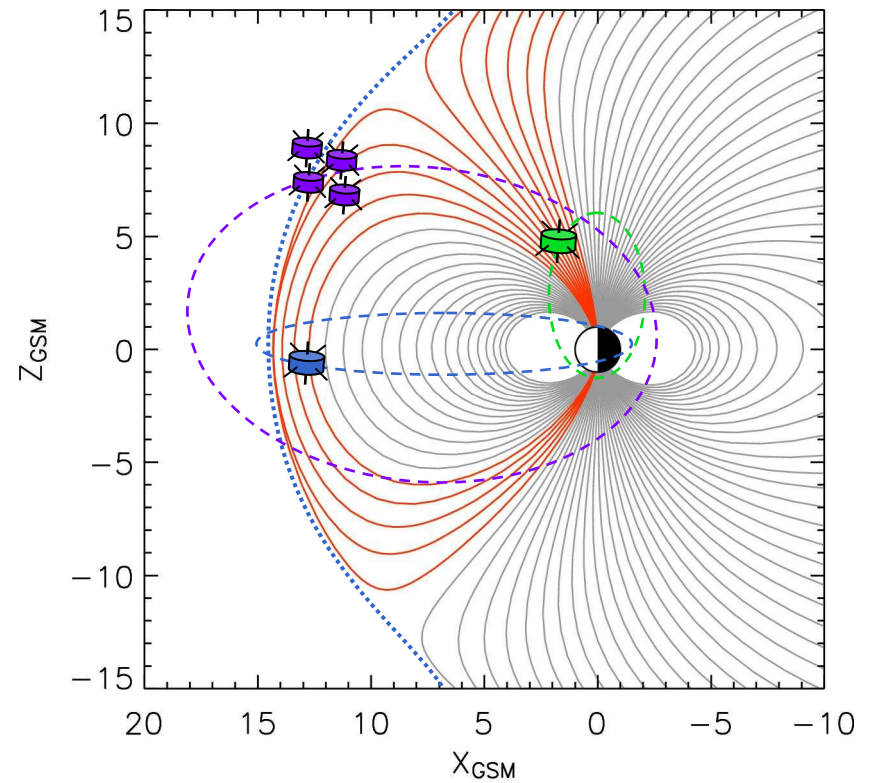
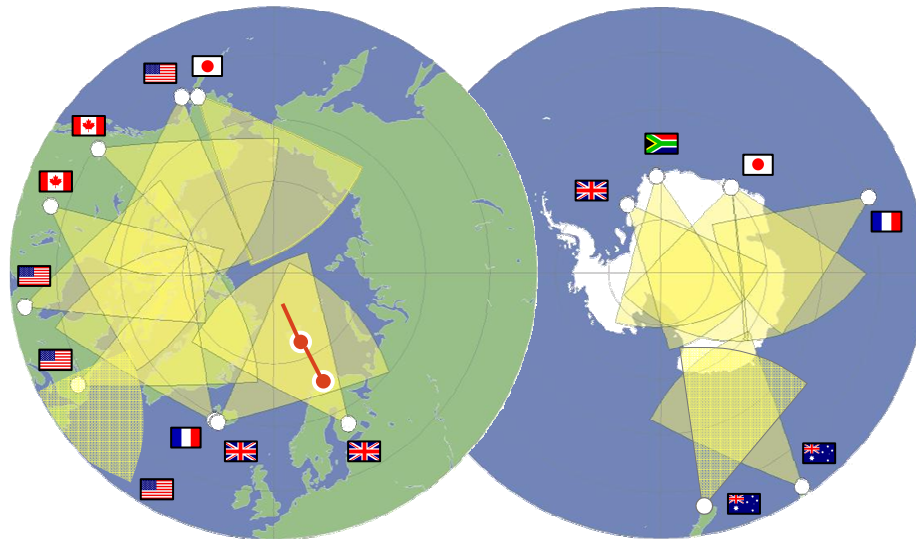
The EISCAT Scientific Association, SuperDARN PIs, the ACE Science Centre, the IMAGE and SAMNET
magnetometer networks and the Cluster & Double Star ground-based working group

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Combining remotely sensed & in situ measurements



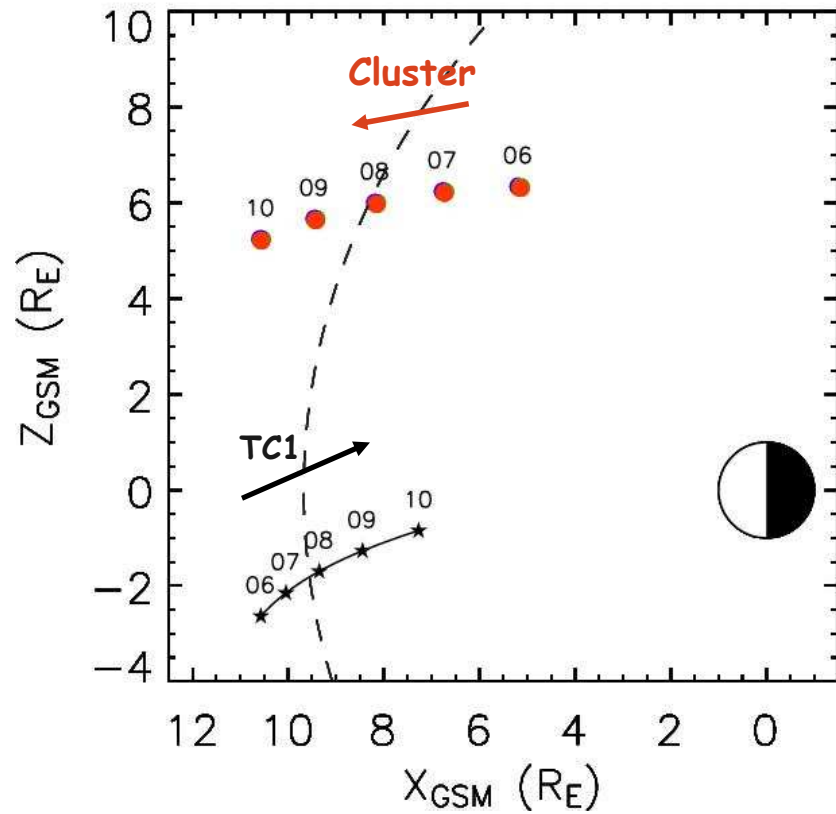
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Today I will talk about...

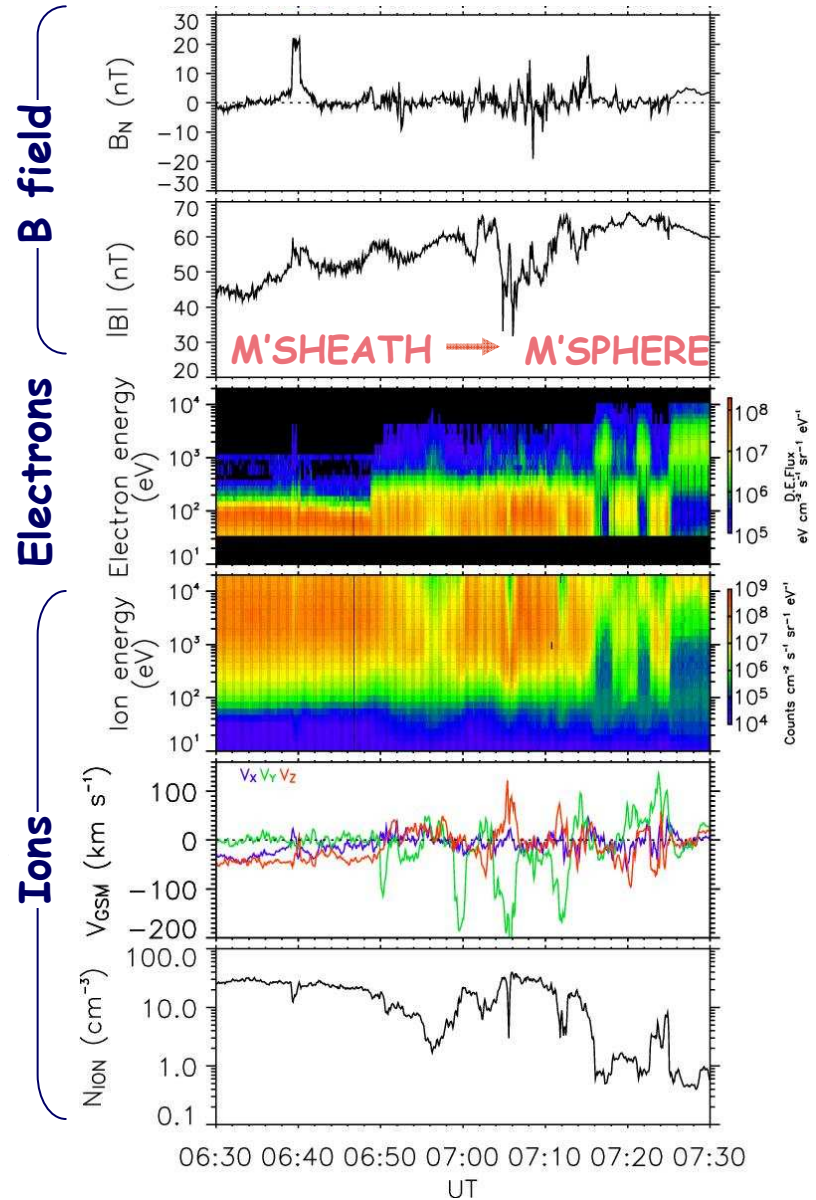
Present an example (25th March 2004):

- Demonstrate the efficacy of combined space- and ground-based investigations
- Dynamics associated with dayside reconnection
- Multi-instrument & simple modelling
 - Cluster
 - Double Star
 - EISCAT
 - SuperDARN
 - IMAGE & SAMNET ground magnetometers
 - Doppler Pulsation Experiment (DOPE)

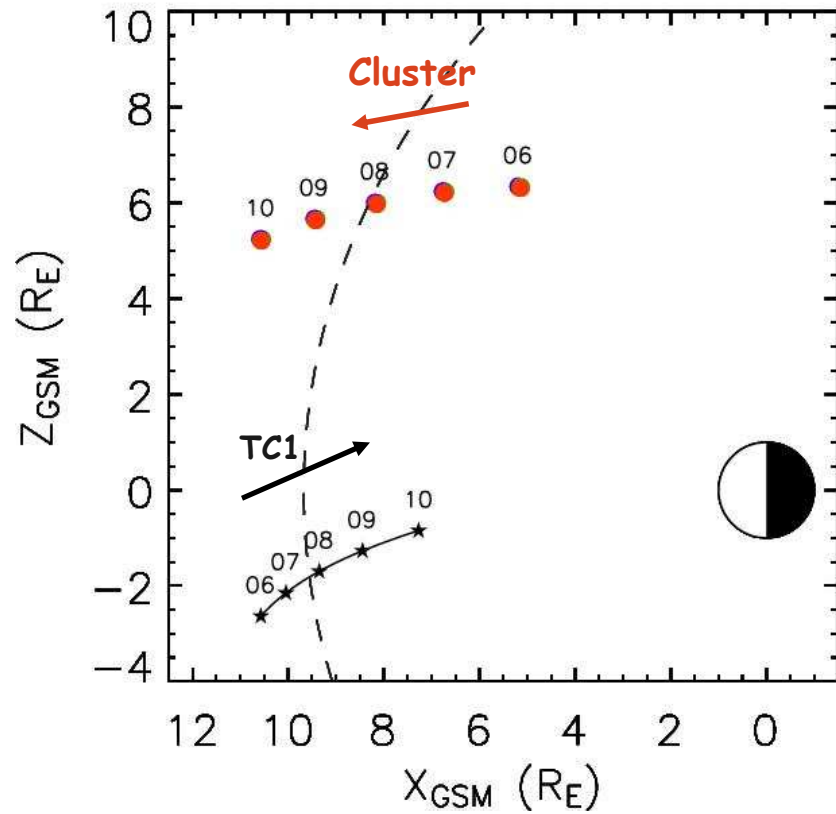
25th March 2004: Cluster & Double Star TC1



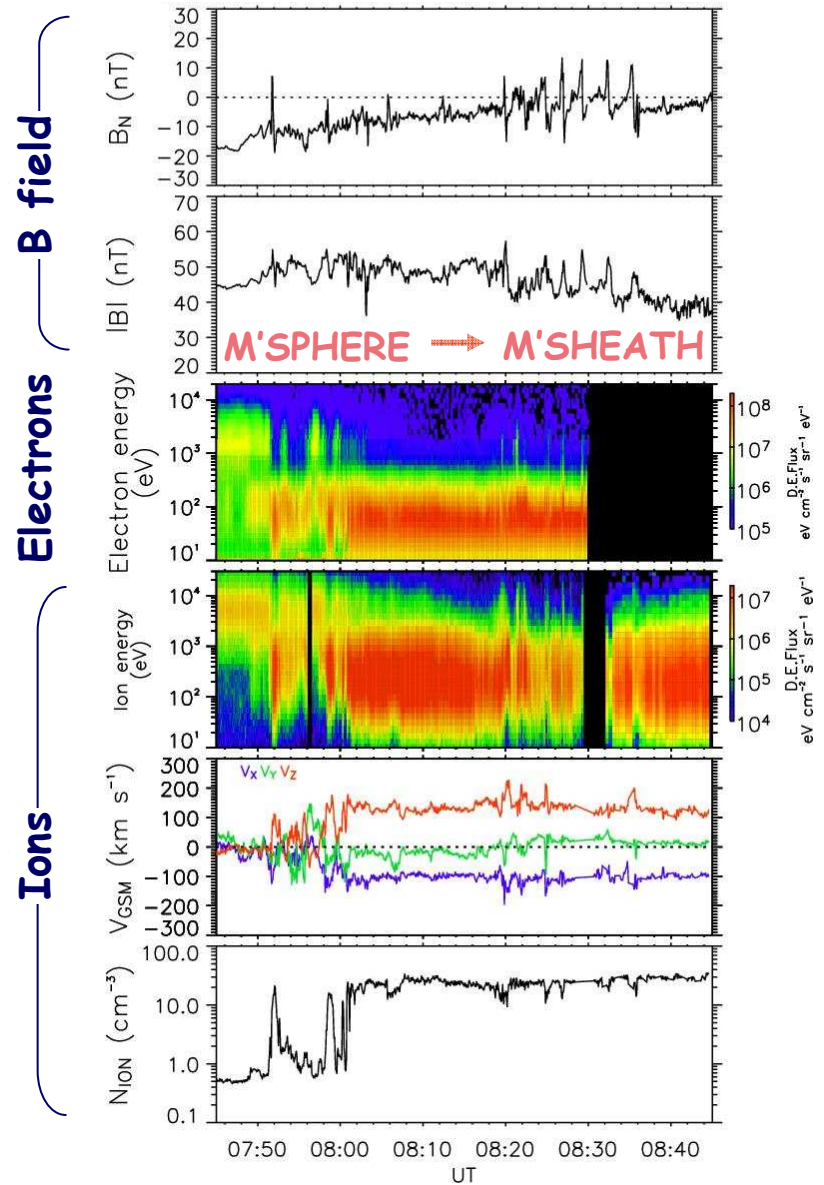
Double Star TC1 data 



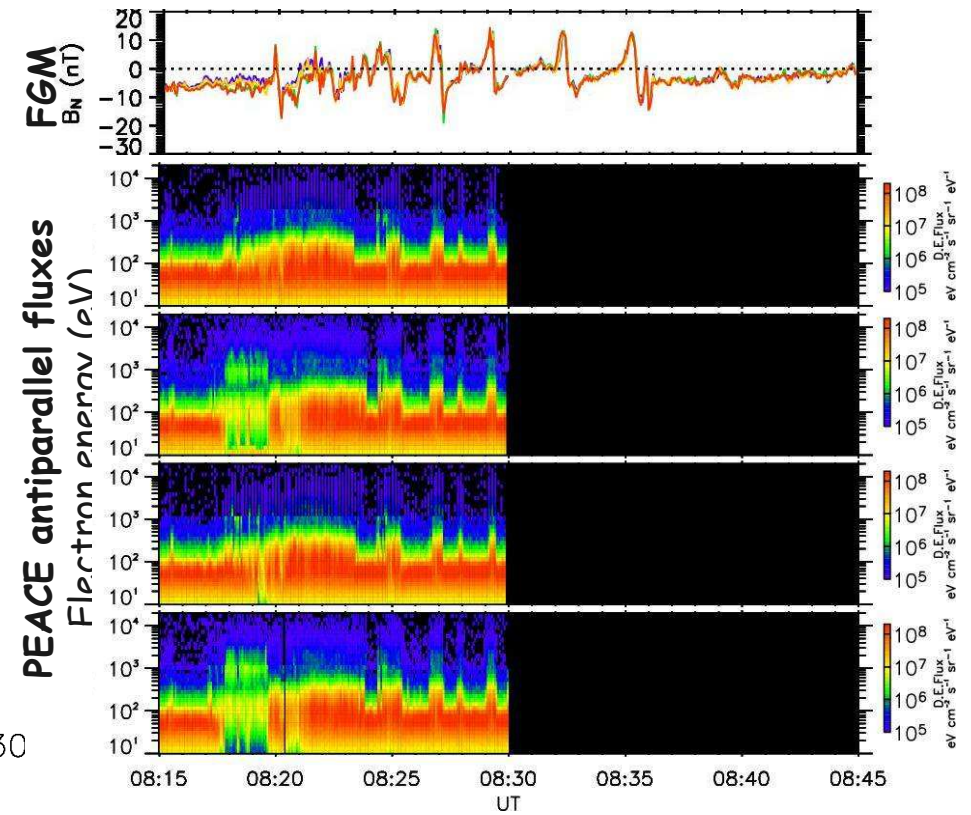
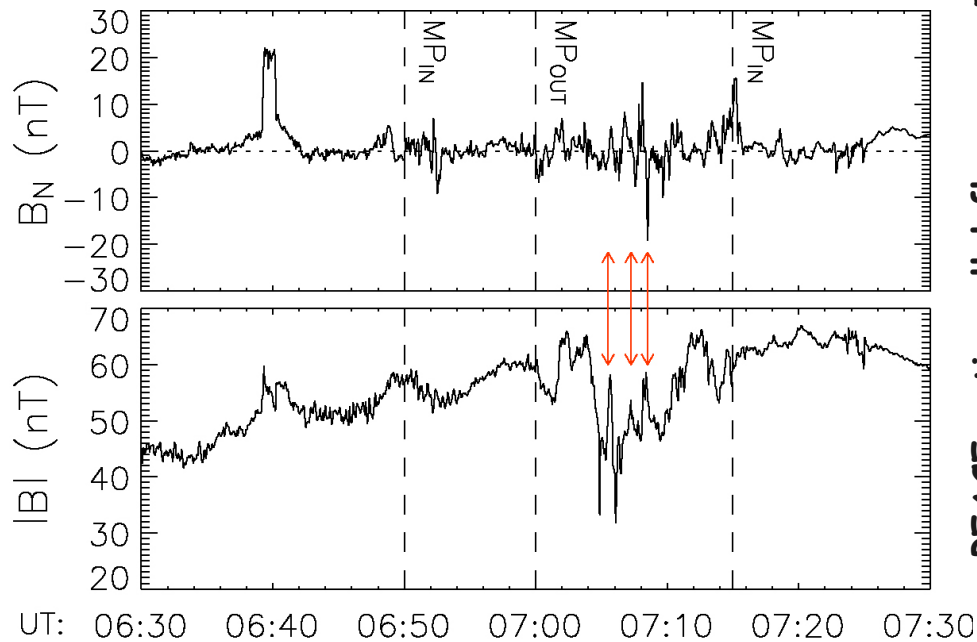
25th March 2004: Cluster & Double Star TC1



Cluster 1 data

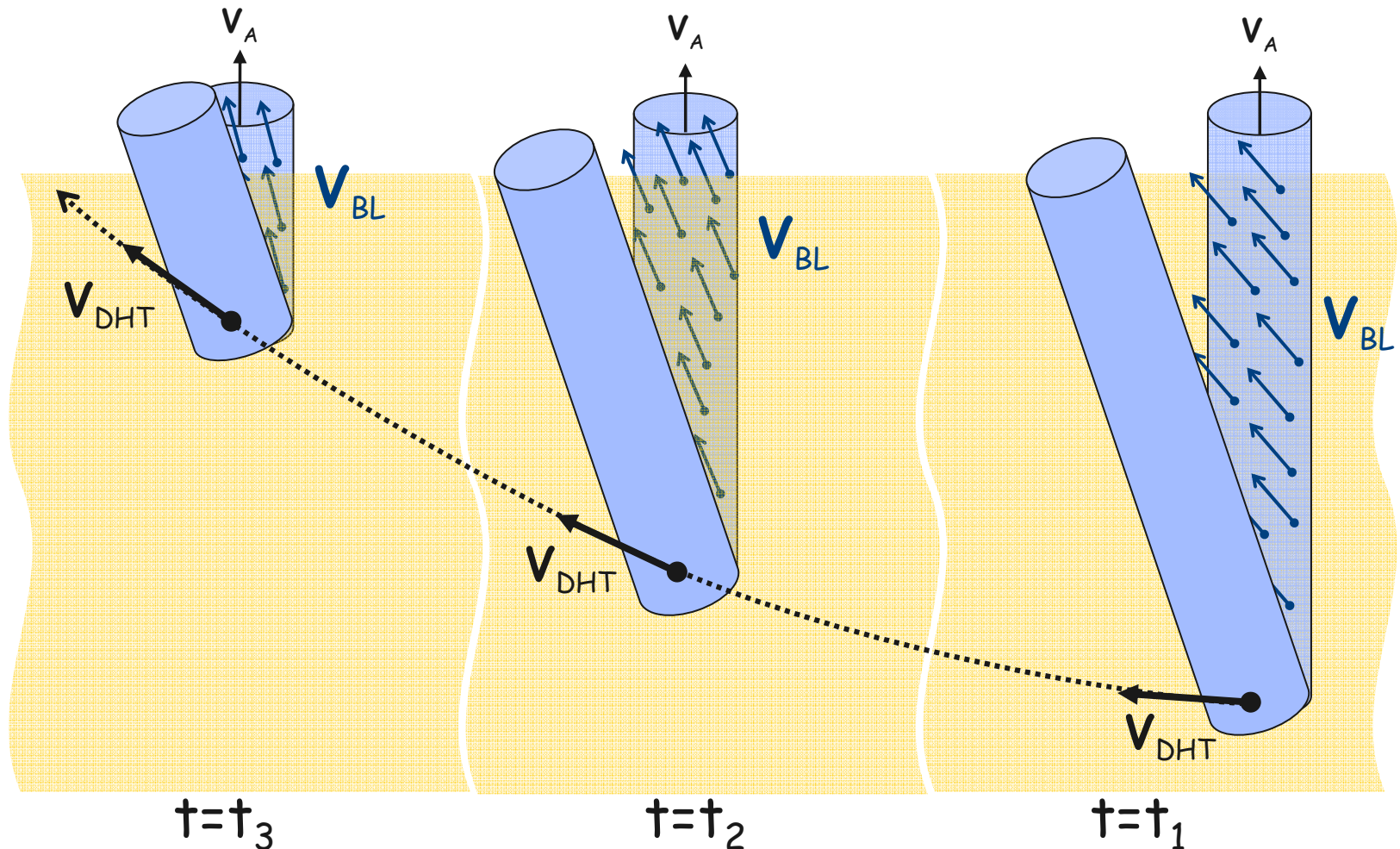


Bipolar signatures of FTEs



"Normal" (+/-) polarity bipolar B_N fluctuations observed at Cluster and Double Star!

The motion of open flux tubes in the magnetosheath

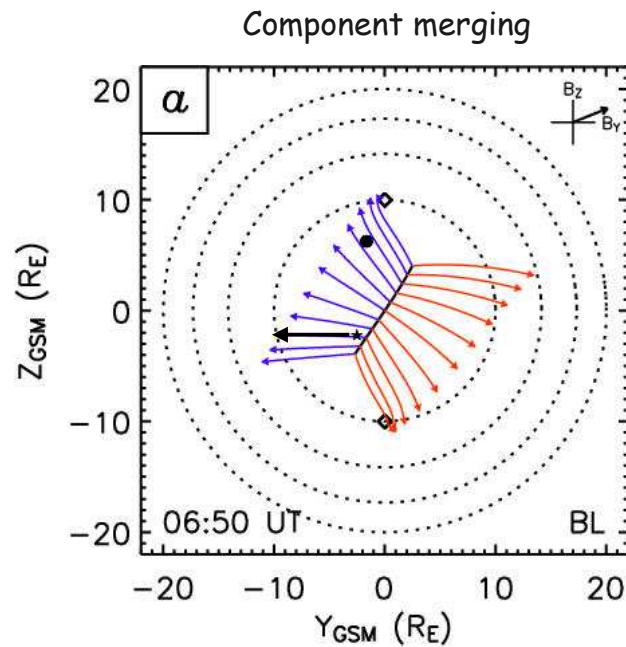


* "The role of the magnetosheath flow in determining the motion of open flux tubes", Cooling et al., JGR, Sept. 2001.

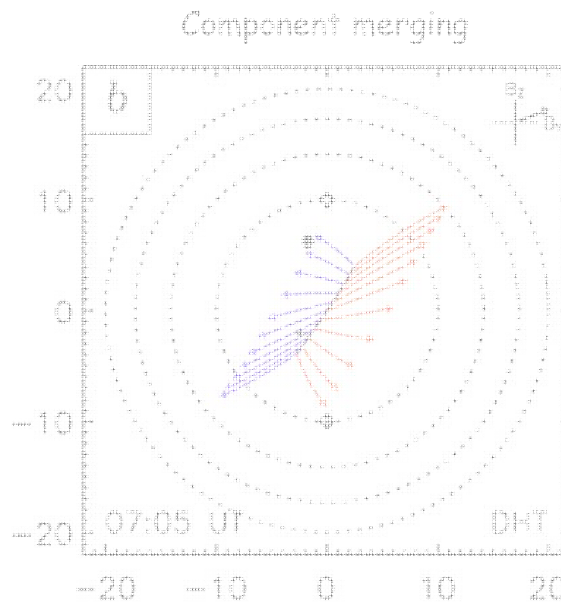
Reconnection at a subsolar/low-latitude X-line? (Comparison with TC1 observations)

Boundary layer flow streamlines

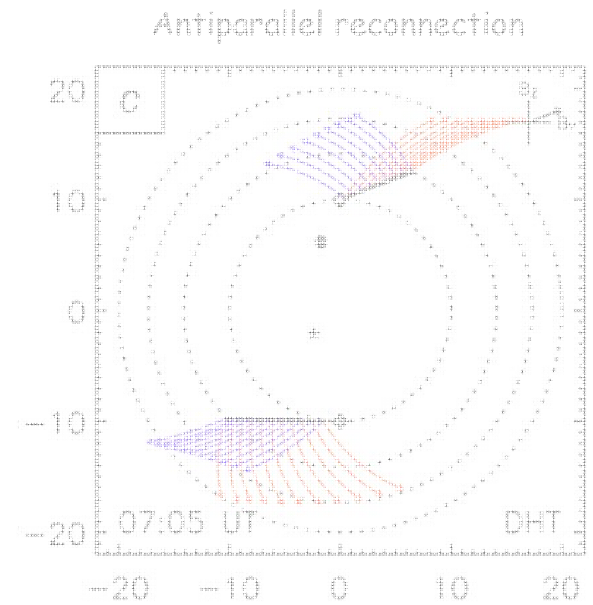
Loci of open flux tubes at points of intersection with magnetopause



Model: $V_{BL}[y, z] = [-146, +10]$
 Obs: $V_{BL}[y, z] = [-130, 0]$



$V_{DHT}[y, z] = [-136, -74]$
 $V_{DHT}[y, z] = [?, ?]$



NORTHERN HEMISPHERE FLUX TUBES AT TC1 \Rightarrow Consistent with "normal" polarity FTE signatures

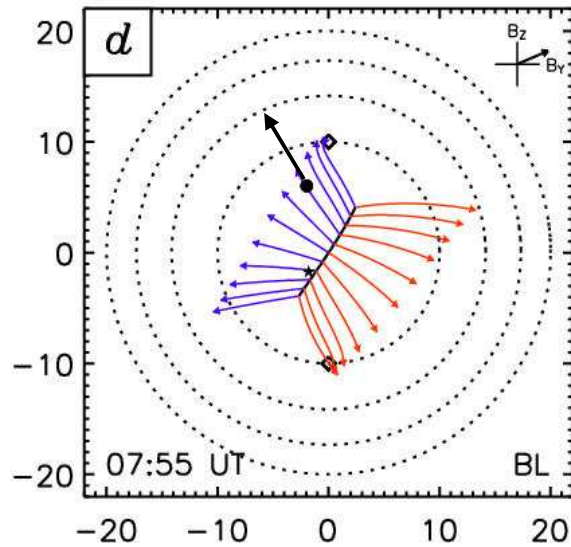
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Reconnection at a subsolar/low-latitude X-line? (Comparison with Cluster observations)

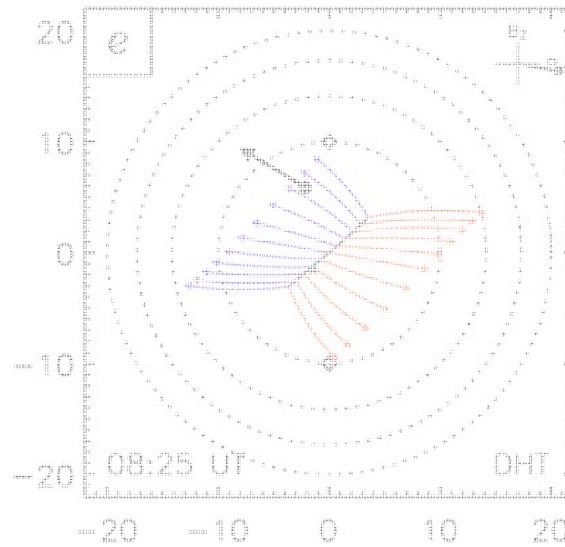
Boundary layer flow streamlines

Loci of open flux tubes at points of intersection with magnetopause

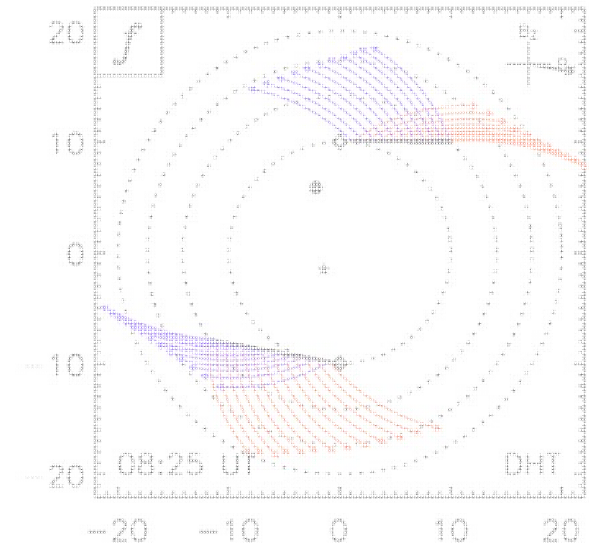
Component merging



Component merging



Antiparallel reconnection



Model: $V_{BL}[y, z] = [-90, +157]$

Obs: $V_{BL}[y, z] = [-60, +100]$

$\times 1.5$

$V_{DHT}[y, z] = [-163, +102]$

$V_{DHT}[y, z] = [-55, +33]$

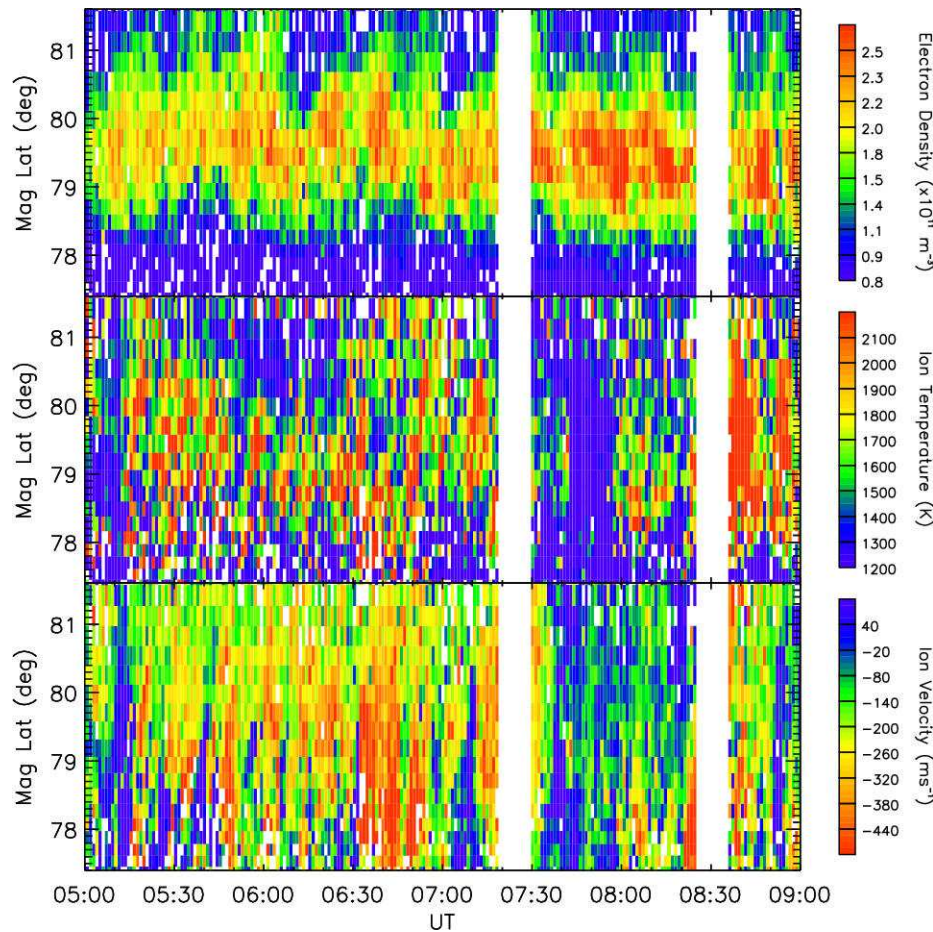
$\times 3$

FLUX TUBES & BOUNDARY LAYER MOTION AT CLUSTER \Rightarrow Consistent with low-latitude X-line

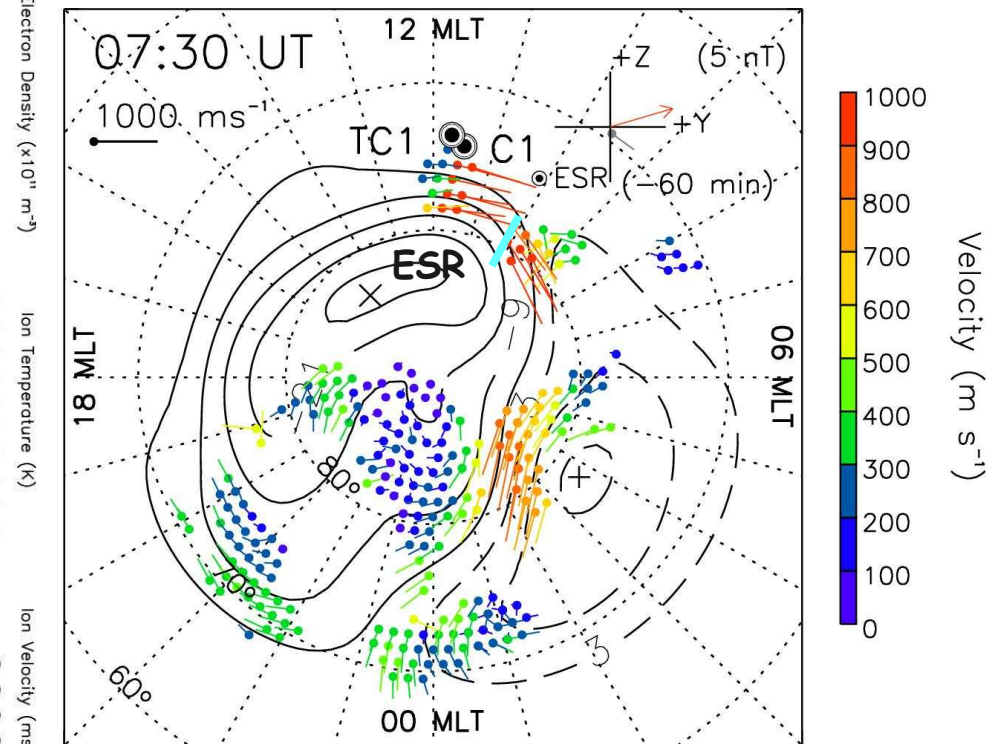
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Ground-based data: ESR & SuperDARN

EISCAT Svalbard Radar
Low elevation poleward pointing beam



SuperDARN global convection
mapping estimate



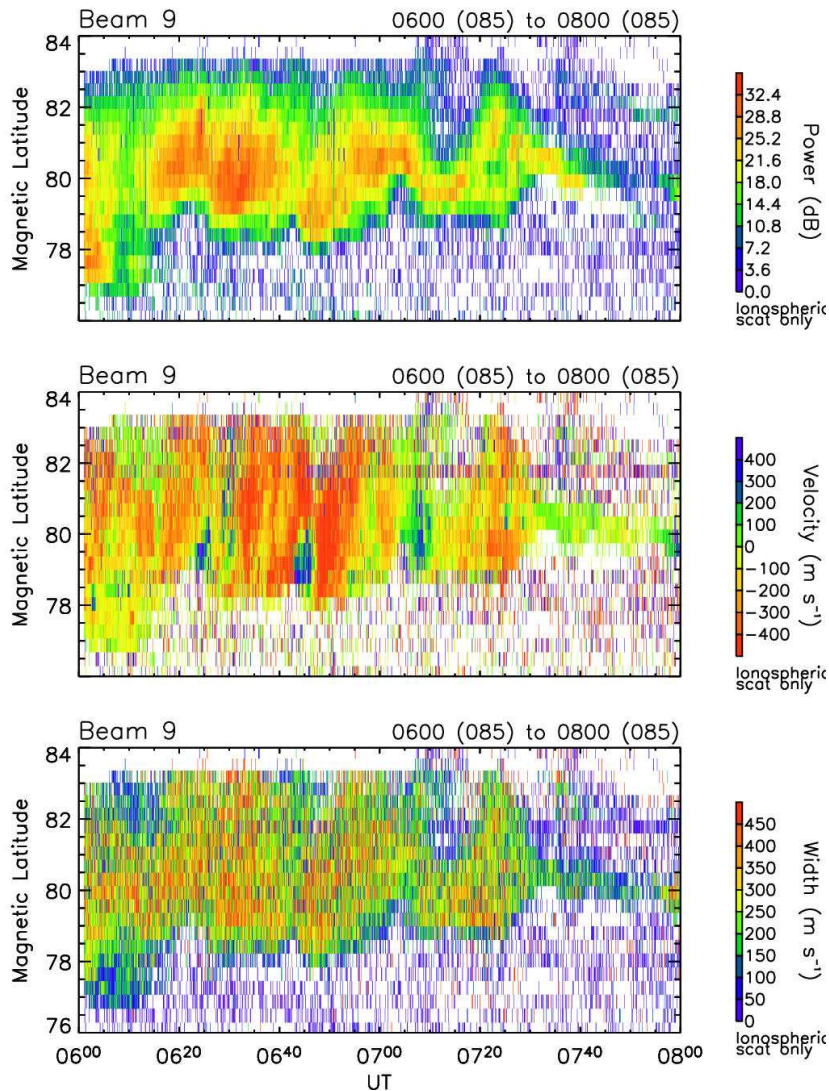
07:30 UT: Cluster and Double Star in magnetosphere

Ground-based data: ESR & SuperDARN

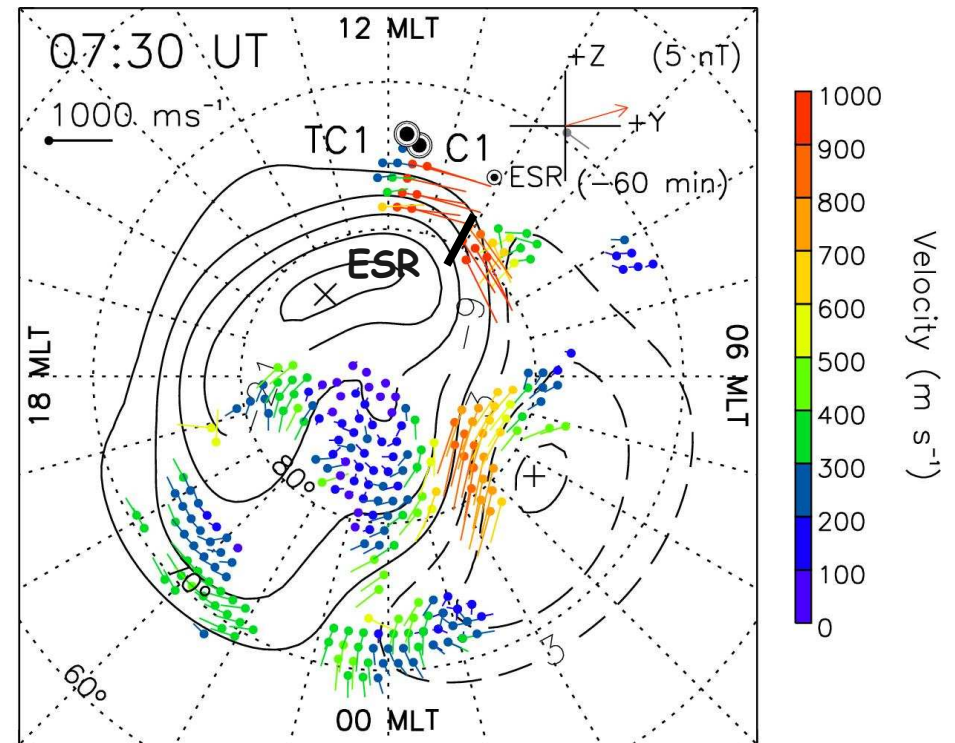
SUPERDARN PARAMETER PLOT 25 Mar 2004 ⁽⁸⁵⁾

Hankasalmi: Power/Velocity/Width

unknown scan mode (-26007)



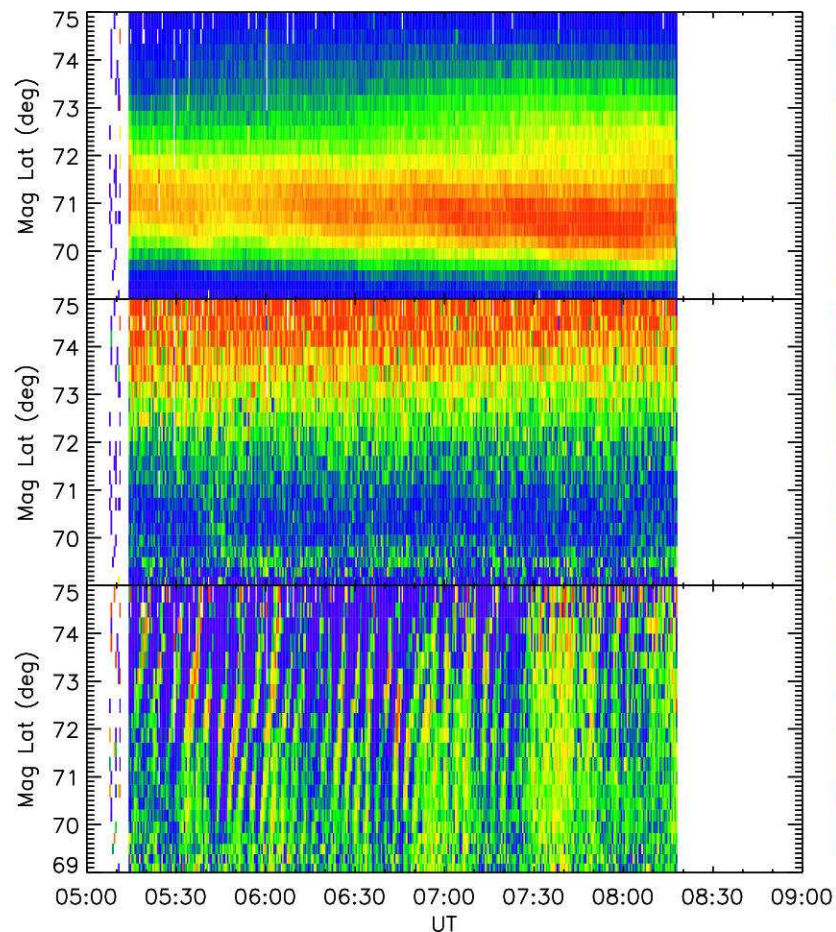
SuperDARN global convection mapping estimate



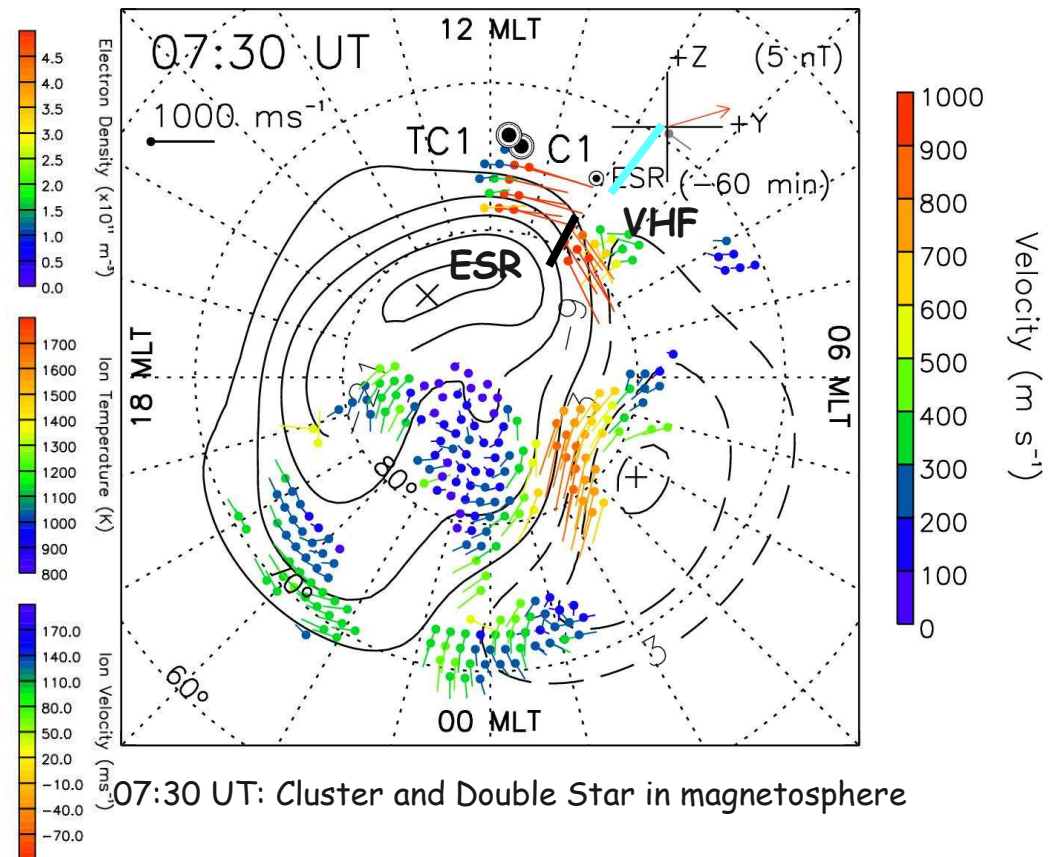
07:30 UT: Cluster and Double Star in magnetosphere

Ground-based data: VHF & SuperDARN

EISCAT Tromso VHF Radar
Low elevation ~poleward pointing beam



SuperDARN global convection
mapping estimate

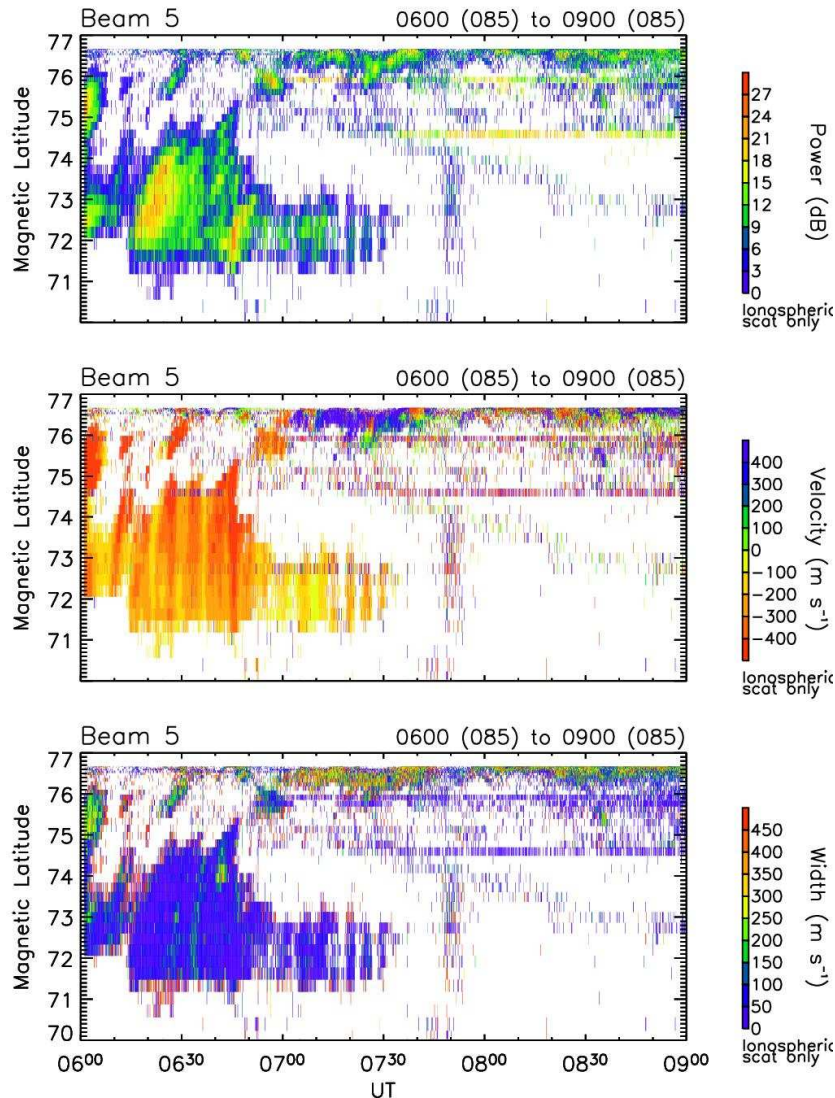


Ground-based data: VHF & SuperDARN

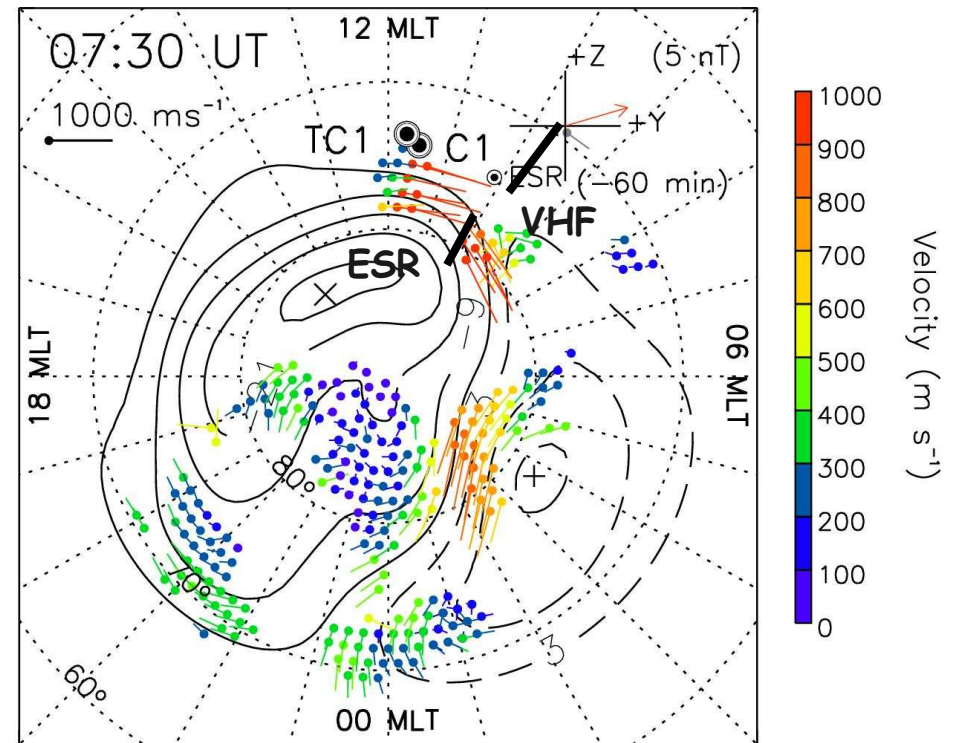
SUPERDARN PARAMETER PLOT 25 Mar 2004 ⁽⁸⁵⁾

Pykkvibaer: Power/Velocity/Width

unknown scan mode (-26007)



SuperDARN global convection mapping estimate

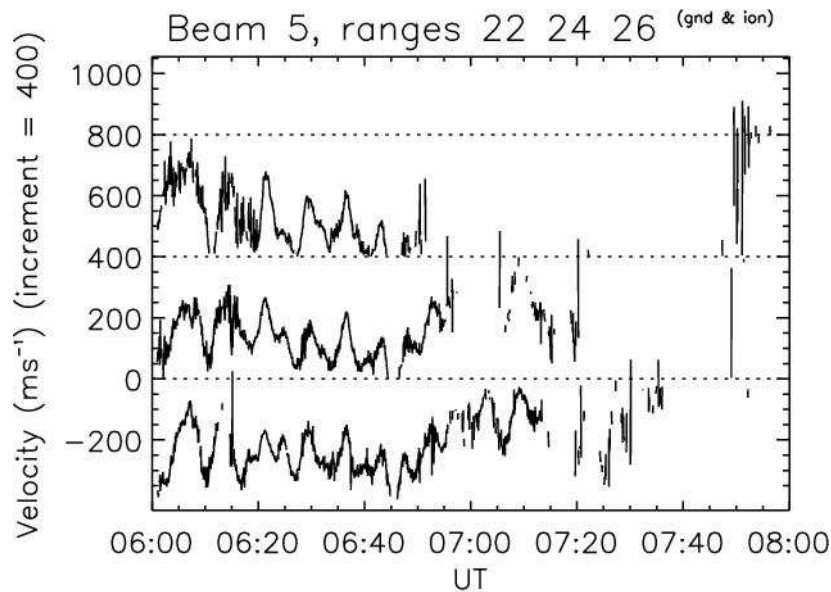


07:30 UT: Cluster and Double Star in magnetosphere

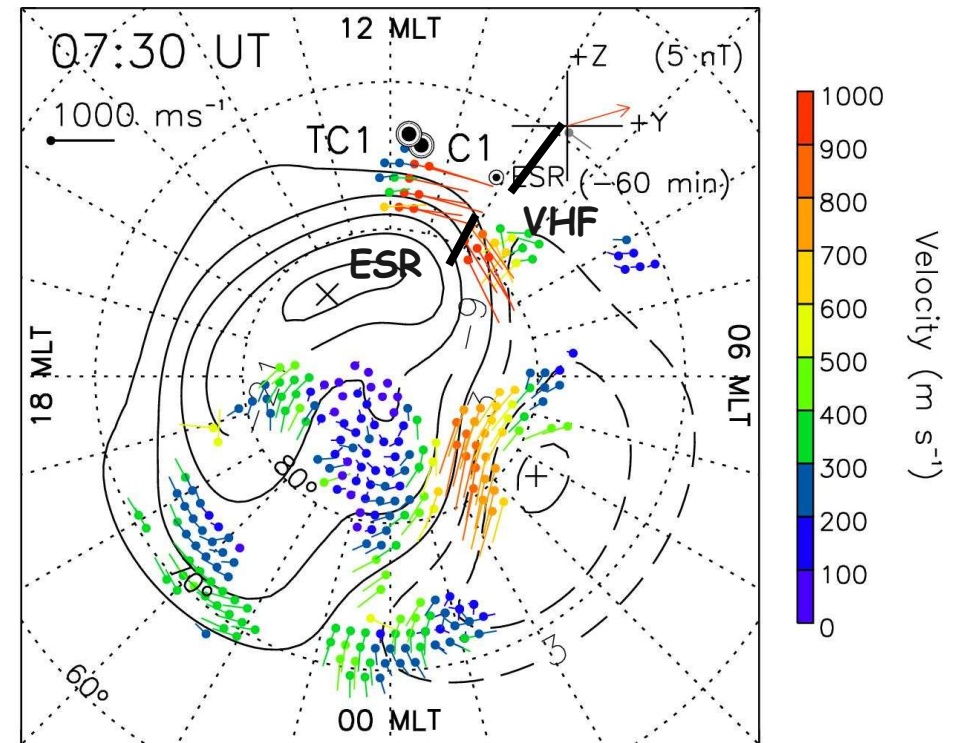
Ground magnetometer data (IMAGE/SAMNET)

SuperDARN global convection mapping estimate

CUTLASS Iceland



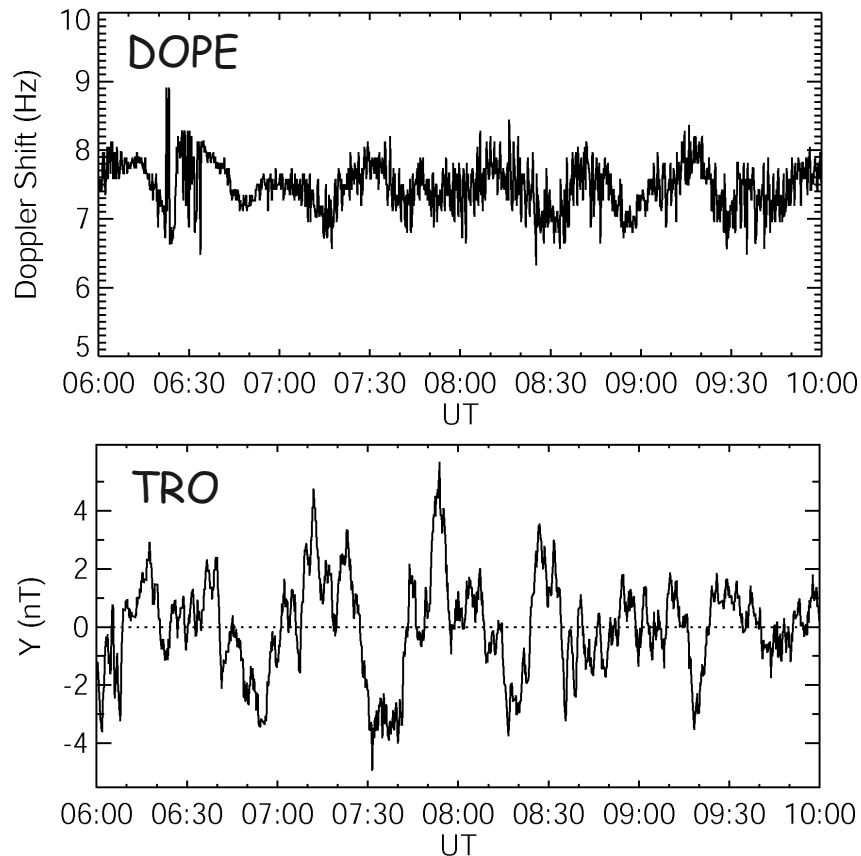
300-600 s periodicity



07:30 UT: Cluster and Double Star in magnetosphere

Doppler Pulsation Experiment

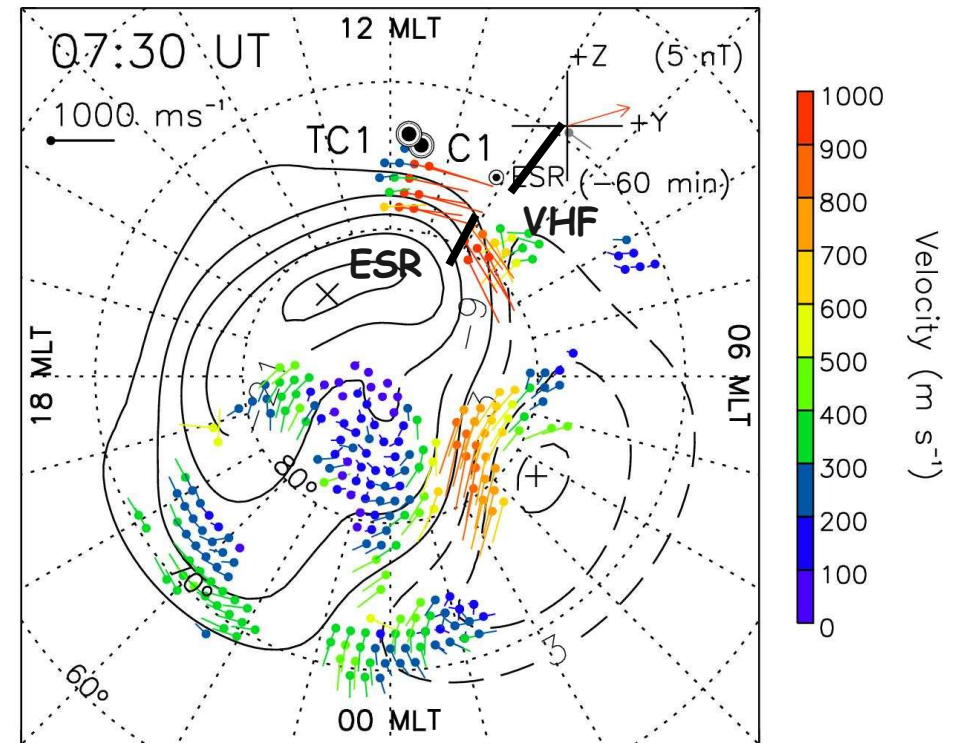
DOPE (Skibotn) & Tromsø IMAGE magnetometer



0.4 mHz (2500 s) 0.69 mHz (1450 s)
 1.5 mHz (666 s) 2.6 mHz (380 s)
 4.5 mHz (220 s)

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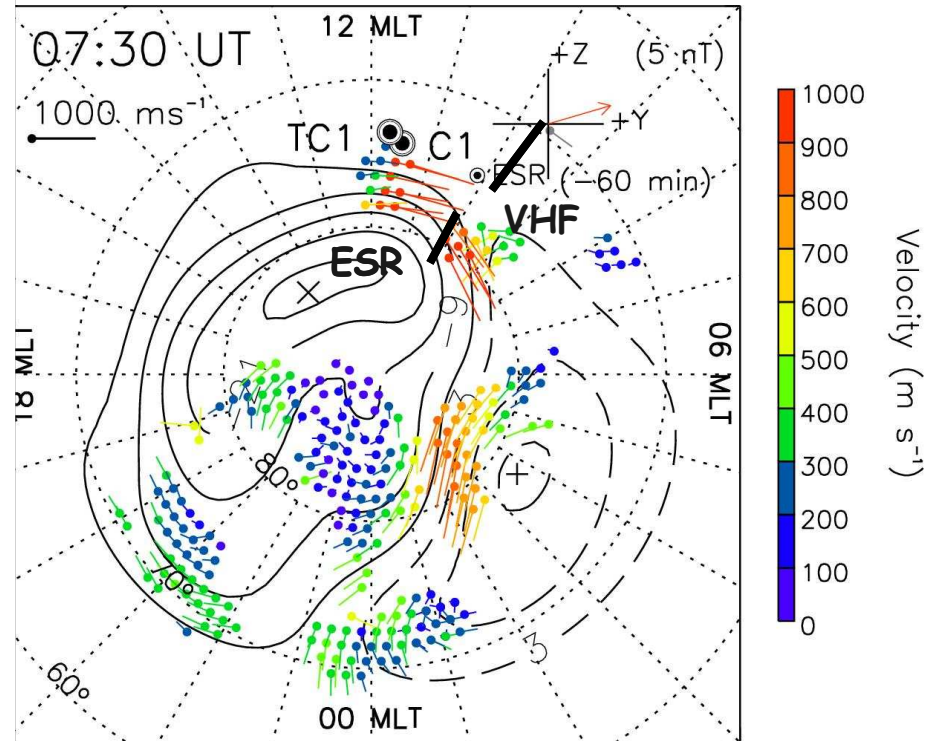
SuperDARN global convection mapping estimate



07:30 UT: Cluster and Double Star in magnetosphere

IMAGE & SAMNET

SuperDARN global convection mapping estimate



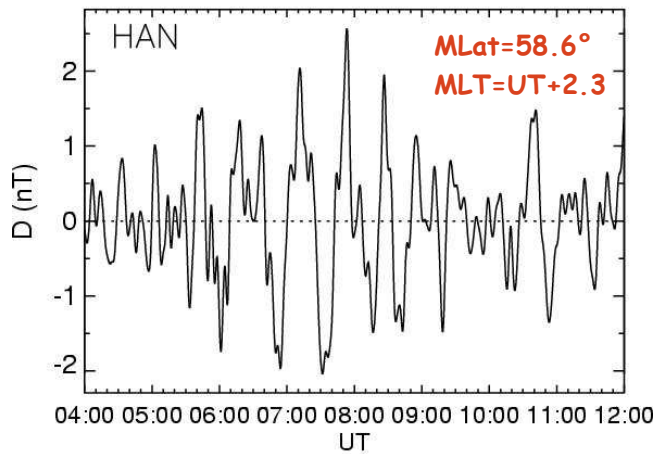
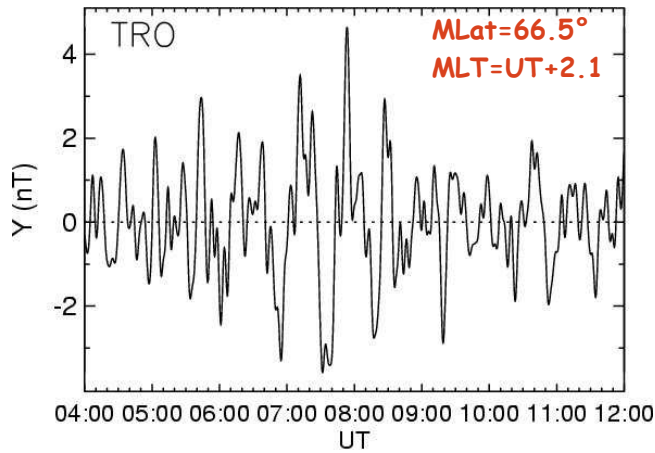
7:30 UT: Cluster and Double Star in magnetosphere

0.4 mHz (2500s) and 0.69 (1450 mHz)
Global scale waves

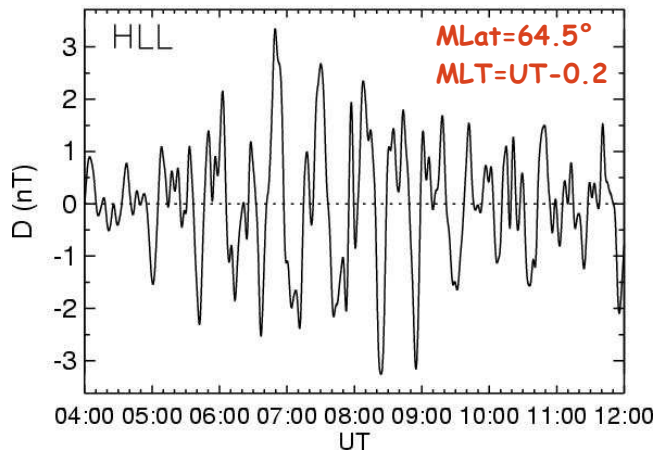
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Scandinavian sector



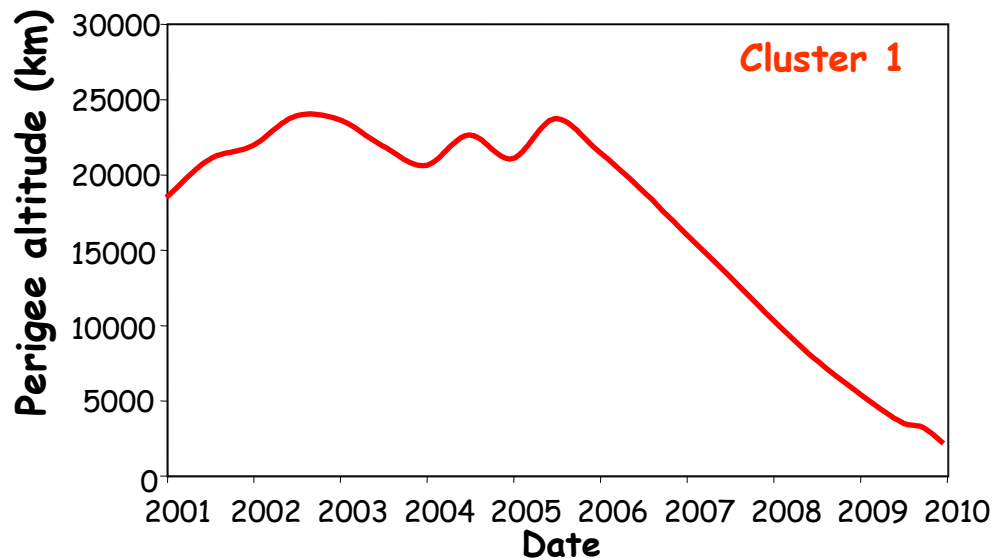
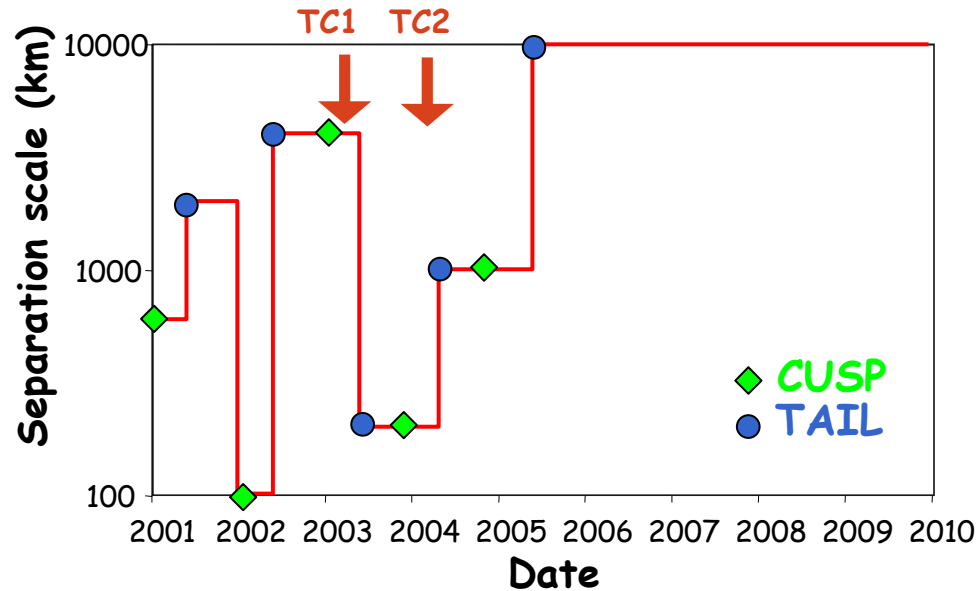
Icelandic sector



Conclusions

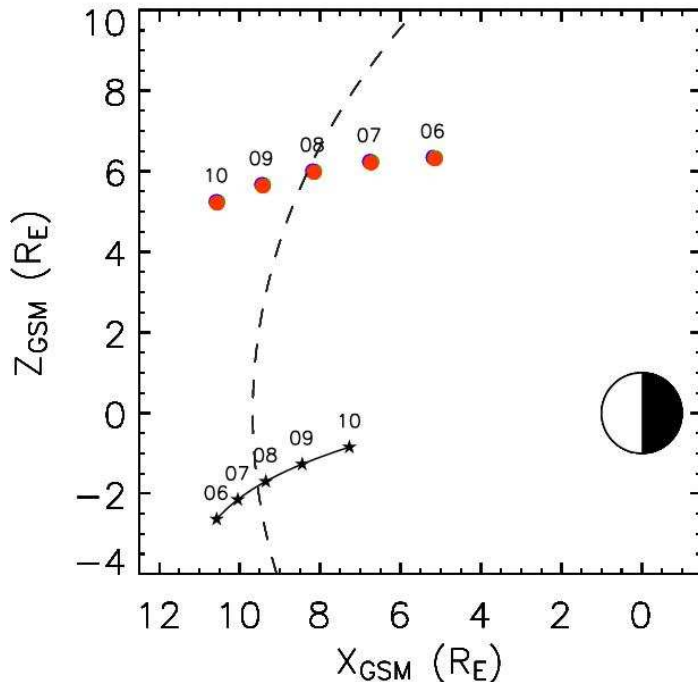
- Interval of B_y dominated IMF. "Typical" solar wind speed (~ 350 km/s)
- FTEs observed at high/low latitudes in the vicinity of the magnetopause
 - Normal polarity (+/-) bipolar signatures \Rightarrow NH flux tubes
 - Flux tube motion (estimated via multi-s/c) consistent with low latitude X-line
 - Boundary layer plasma flow consistent with low latitude X-line
- Ground-based instruments indicate ongoing dayside reconnection for ~ 5 h
- Simultaneous ULF wave activity (various frequencies) throughout the interval - related? (no obvious evidence of periodic perturbations in solar wind/IMF - further investigation required)
- Ground based data essential - spacecraft see no signs of ULF waves!

Cluster: future orbit evolution

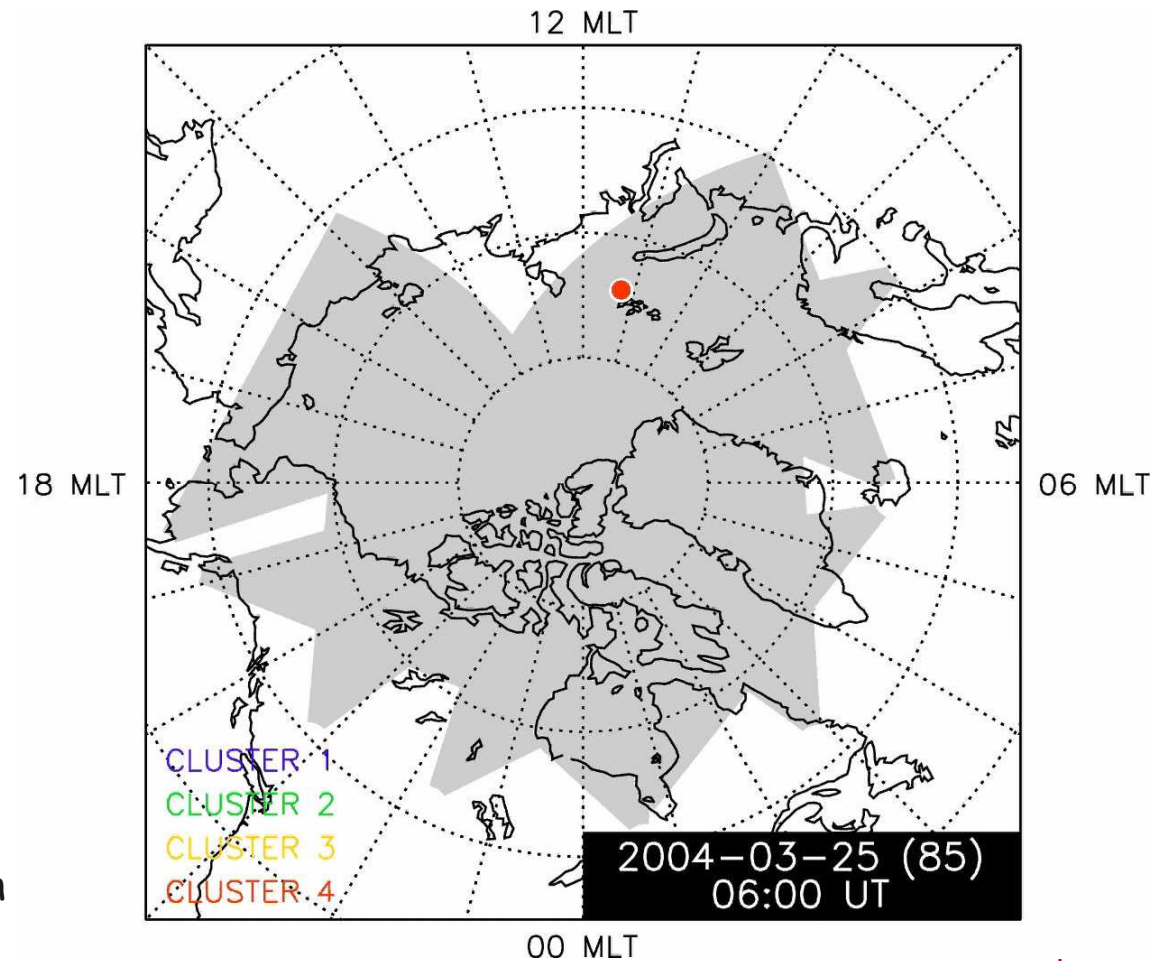


- Variety of separation strategies employed during the mission so far
- Next manoeuvre will permanently increase separation to ~10000 km
- Orbit perigee altitude has, until now, been steady at ~20000 km.
- During extended mission, the perigee will descend in altitude

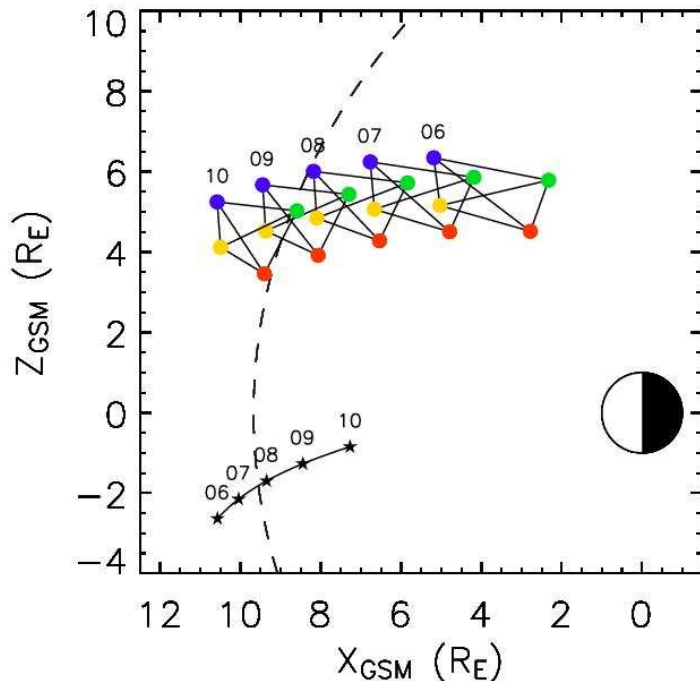
25 March 2004: Actual inter-spacecraft separation & footprint



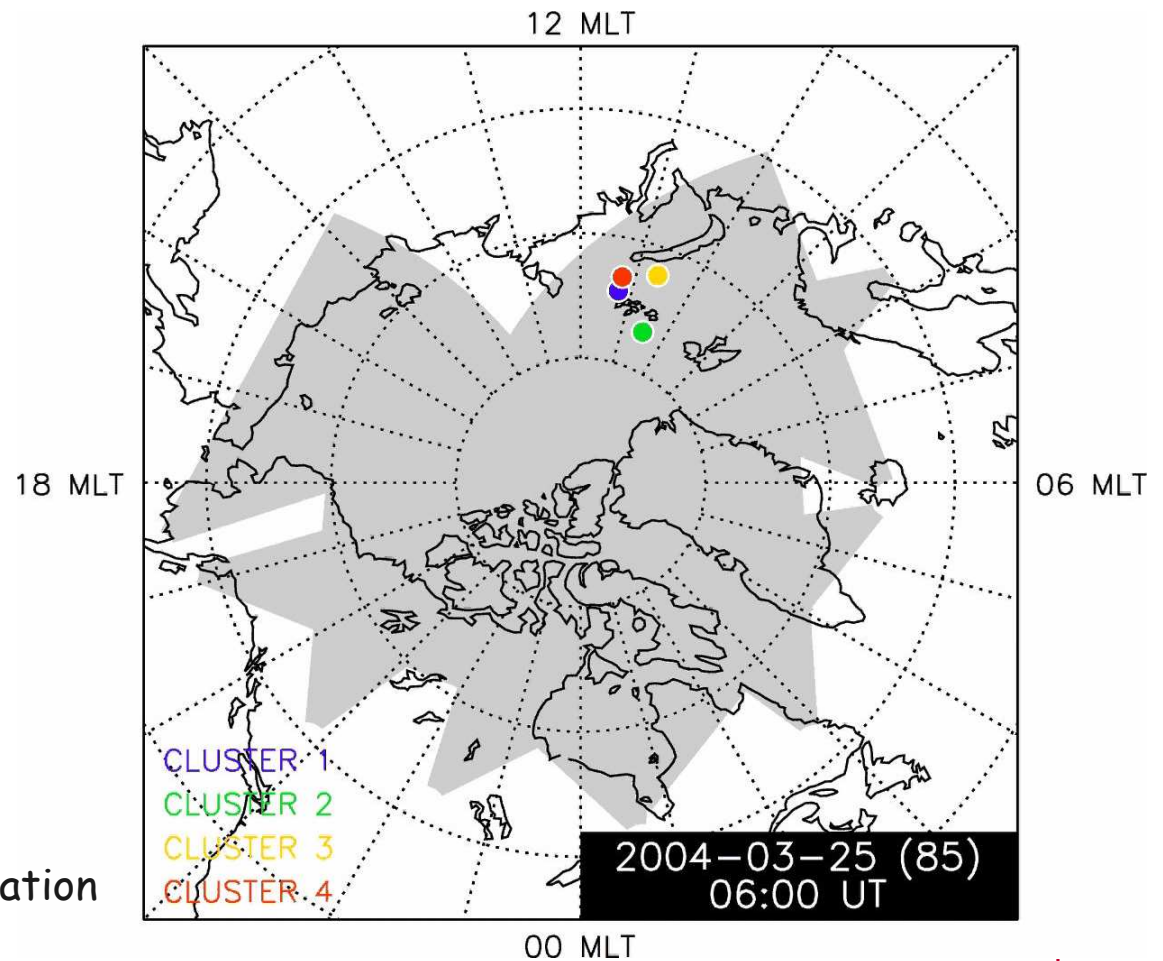
~200 km spacecraft separation



25 March 2004: Simulated inter-spacecraft separation & footprint

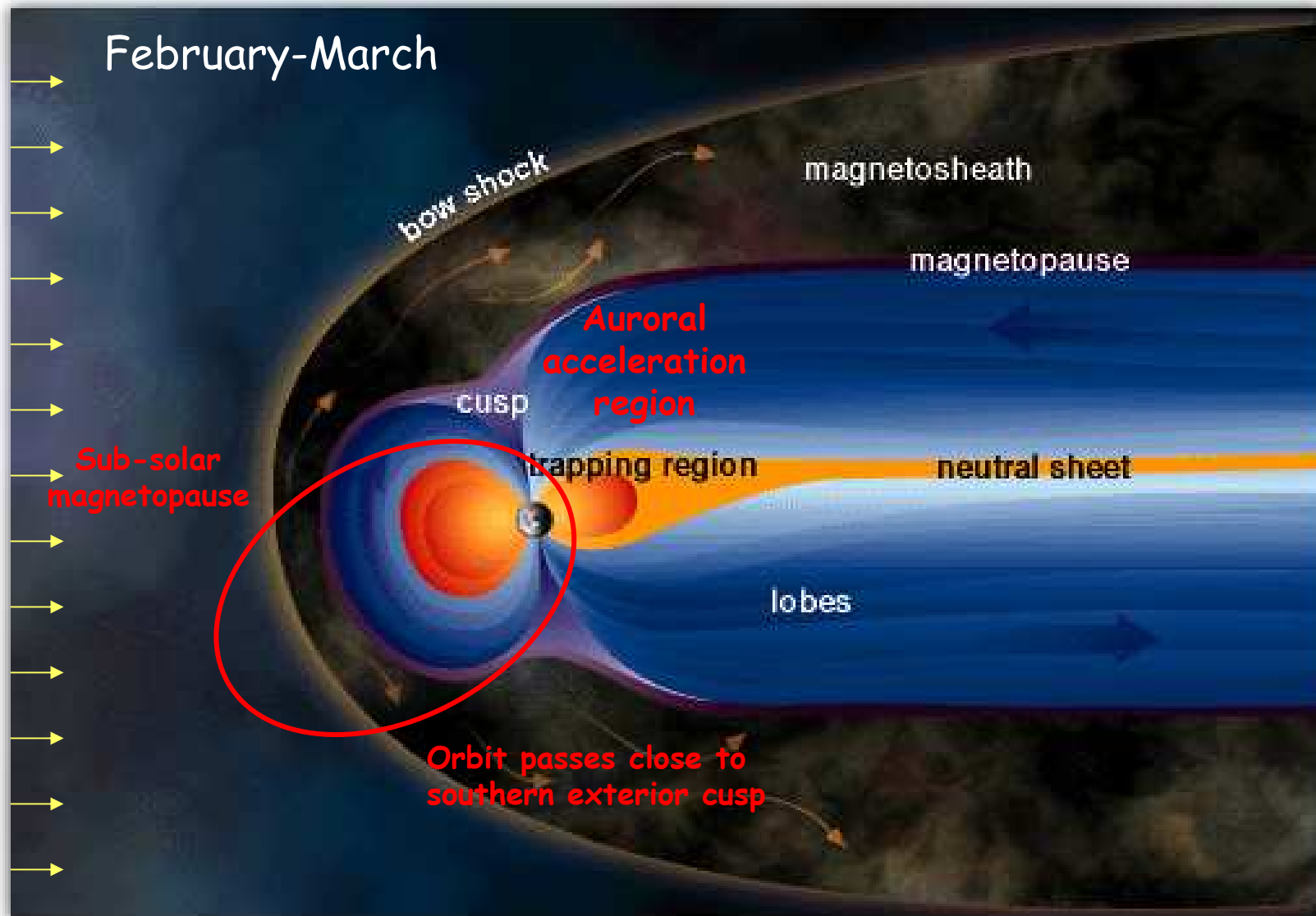


~10,000 km (50x) spacecraft separation



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Cluster: orbit evolution (2009)



Summary & conclusions

- Increased s/c separation will result in distinct footprints in the ionosphere
- Southern hemisphere ground-based coverage of Cluster cusp encounters will become more and more important during the next few years
- Reduced perigee altitude will allow multipoint observations of the auroral acceleration region
 - Implications for SuperDARN SWB/OCB determination
 - Lower altitude overflights over ESR/SPEAR/Tromsø heater
- When in the tail, Cluster will cross the current sheet nearer to Earth
 - Possible coordination with THEMIS?
- Other missions: e.g. Kua Fu/Swase

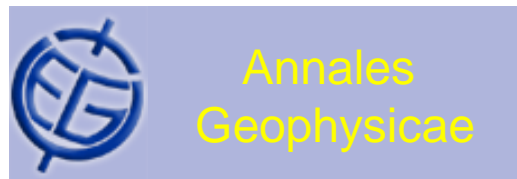
THE GROUND-BASED ELEMENT OF THE 2ND HALF OF THE MISSION IS LIKELY TO BE VERY DIFFERENT TO THE 1ST!

Further reading...

"Coordinated studies of the Geospace environment using Cluster, satellite and ground-based data: An interim review"

O. Amm, E. F. Donovan, H. Frey, M. Lester, R. Nakamura, J. A. Wild,
A. Aikio, M. Dunlop, K. Kauristie, A. Marchaudon, I. W. McCrea,
H. J. Opgenoorth, and A. Strømme

Annales Geophysicae, 23(6), 2129 - 2170, 2005



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A date for your diary...



Next meeting of the Cluster and
Double Star Ground Based
Working Group

5-7 September 2006

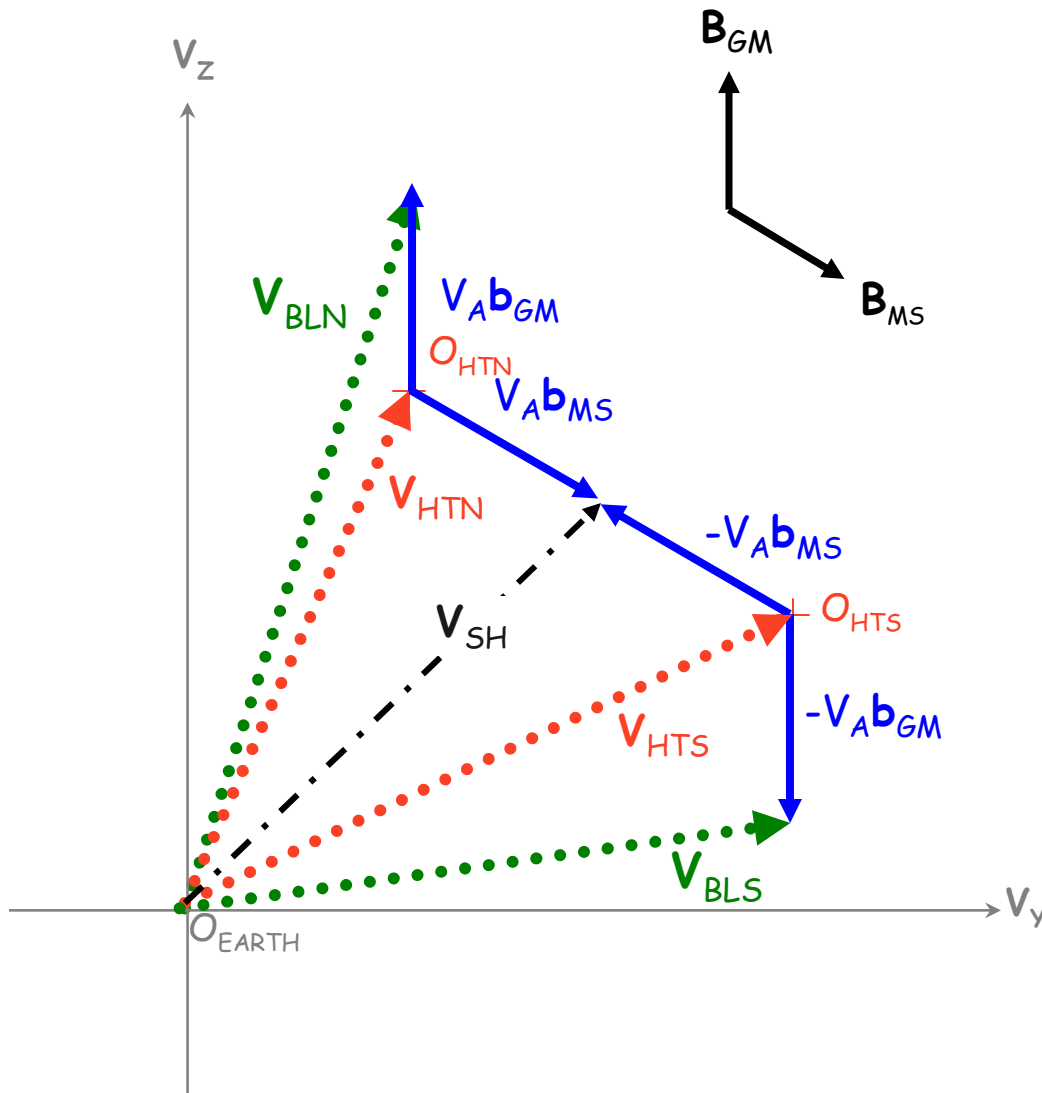
Infolab21, Lancaster University

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<http://www.ion.le.ac.uk/~cluster/>

The motion of open flux tubes in the magnetosheath



In the rest frame of the field line/flux tube (the de Hoffman-Teller frame)...

