MSSL

UCL

Magnetotail Science with Double Star and Cluster

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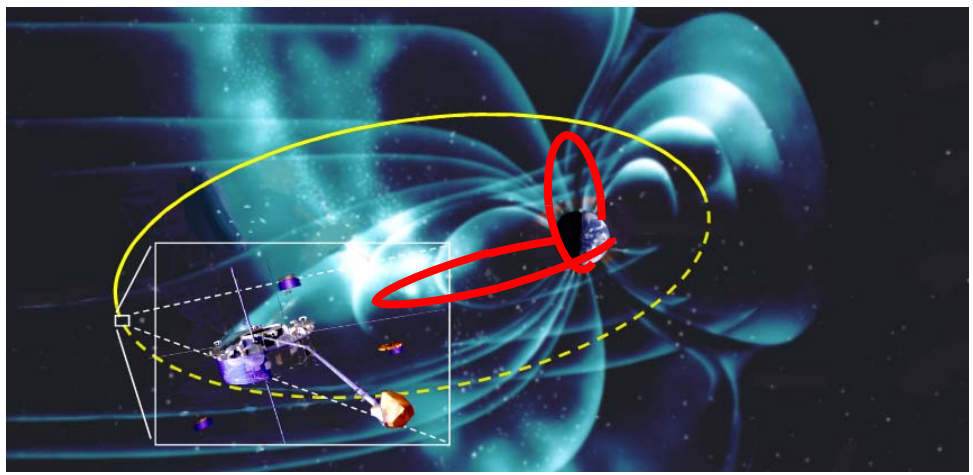
[1]: MSSL, [2]: ICSTM, [3]: CESR, [4]: DMI, [5]:BAS



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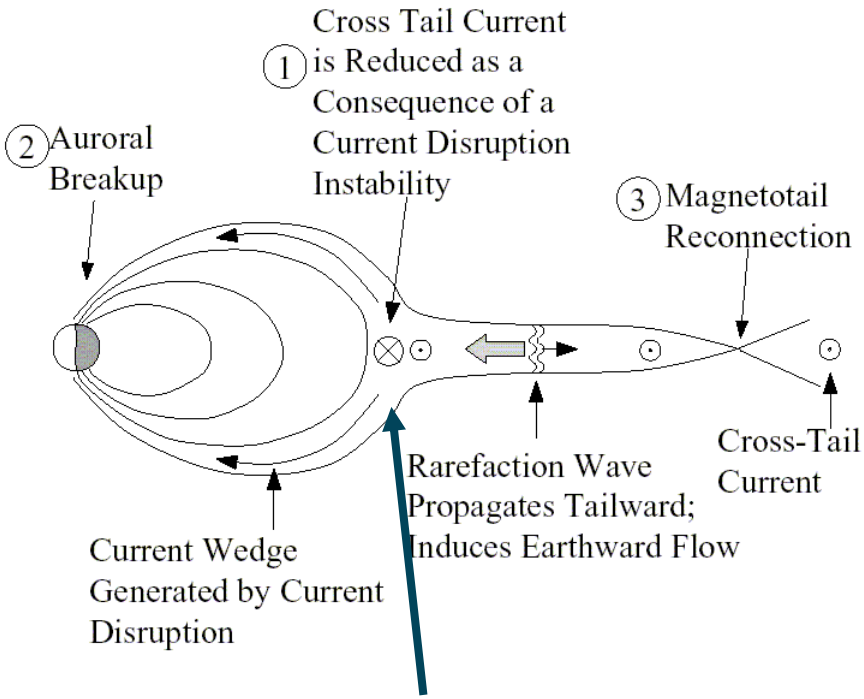
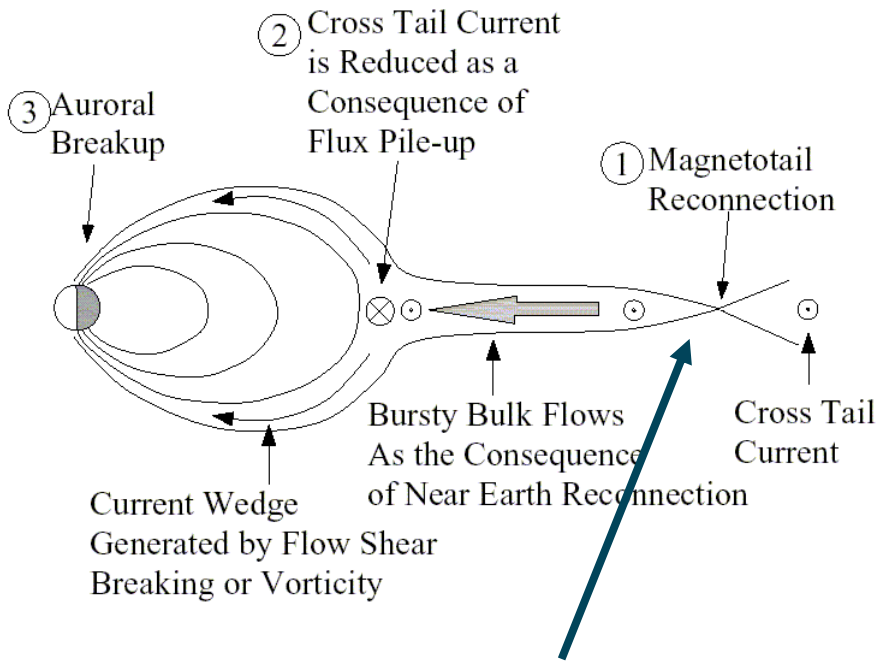
Cluster and Double Star Symposium: 5th Anniversary of Cluster in Space: 22 September 2005

Testing Substorm Models: Question posed by THEMIS team

Current Disruption Scenario



Near-Earth Neutral Line Scenario

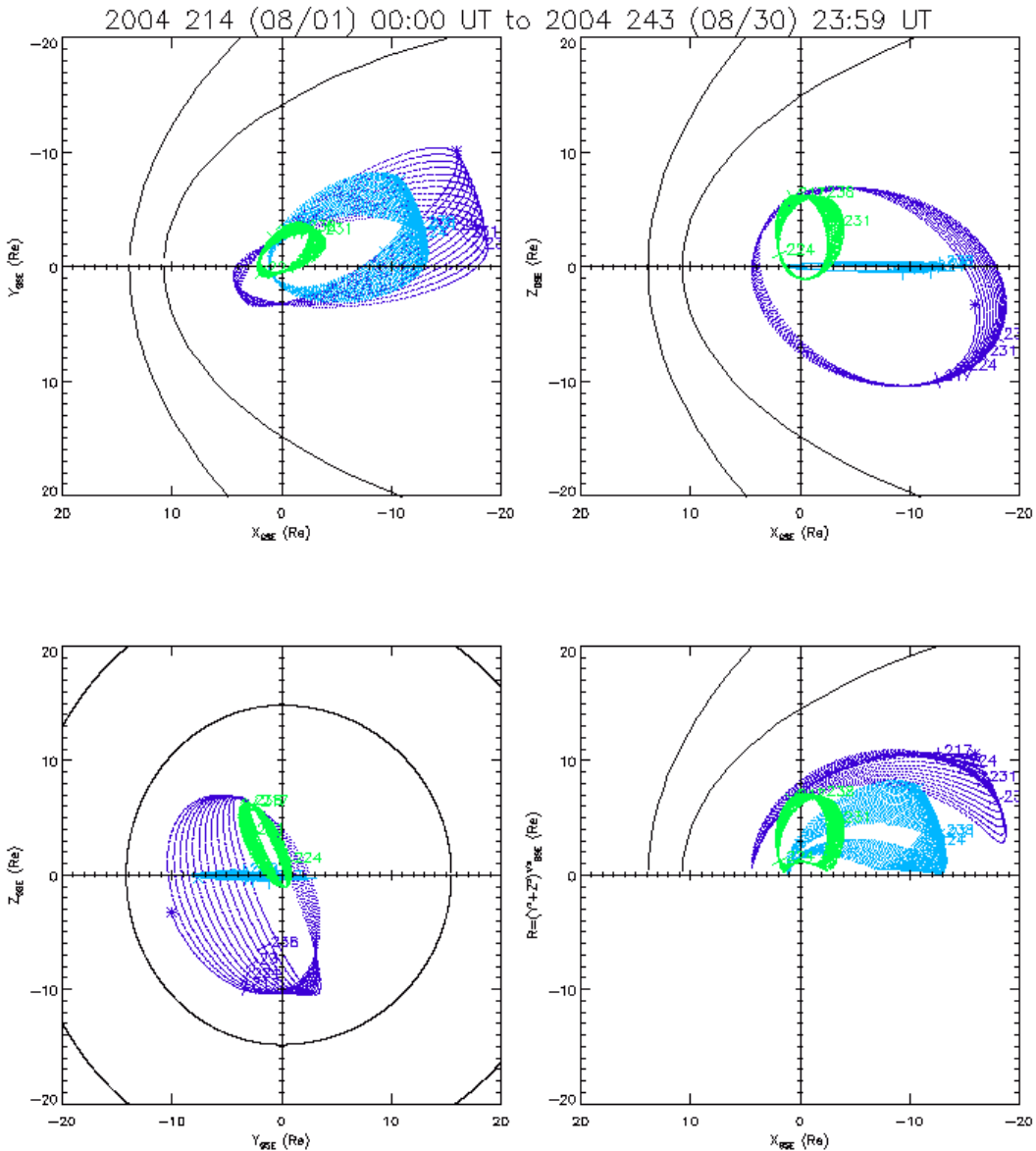


Onset aurorae likely map to current disruption region 8 to 10 R_E

Reconnection onset typically 20 to 30 R_E (some < 20)

Source: http://sprg.ssl.berkeley.edu/themis/pdf/Mission_Science.pdf

Double Star Orbit Design and Conjunctions with Cluster



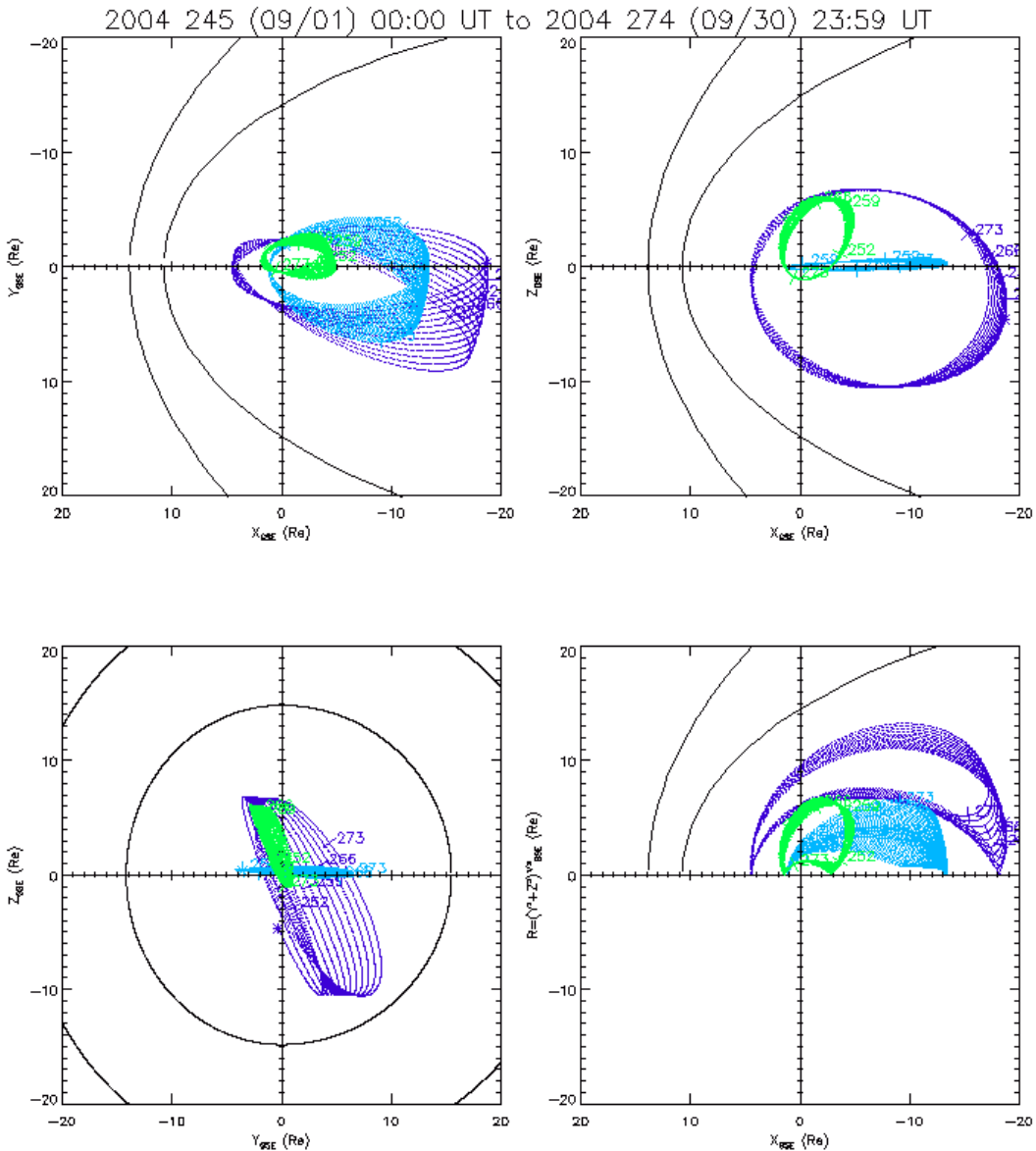
TC-1
TC-2
Cluster

TC-1, TC-2 and Cluster in August 2004

Note that TC-2 and Cluster are both in polar orbit locked at very similar apogee MLT. TC-1 initially shares apogee MLT, but this will change.

(Figure courtesy SSCweb)

Double Star Orbit Design and Conjunctions with Cluster



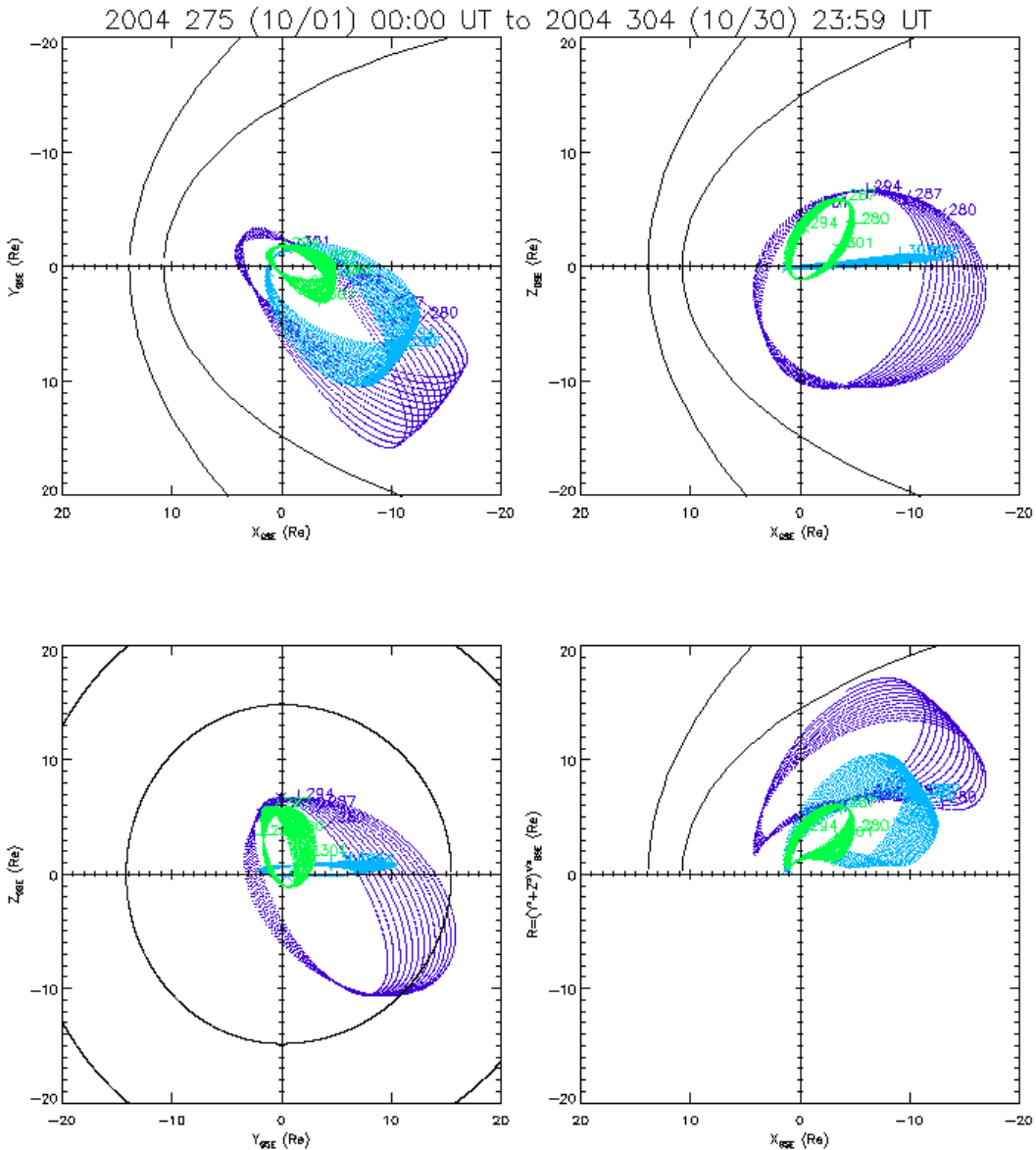
TC-1
TC-2
Cluster

TC-1, TC-2 and Cluster in September 2004

Note that TC-2 and Cluster are both in polar orbit locked at very similar apogee MLT. TC-1 initially shares apogee MLT, but this will change.

(Figure courtesy SSCweb)

Double Star Orbit Design and Conjunctions with Cluster



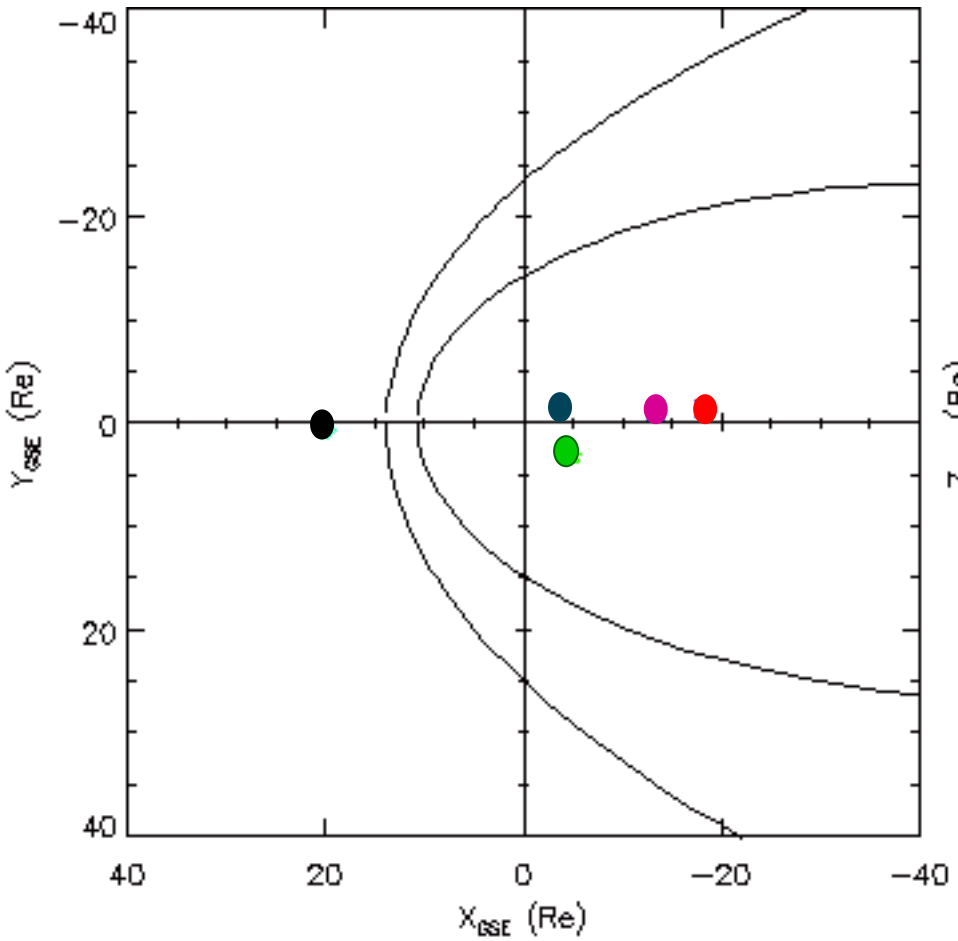
TC-1, TC-2 and Cluster in October 2004

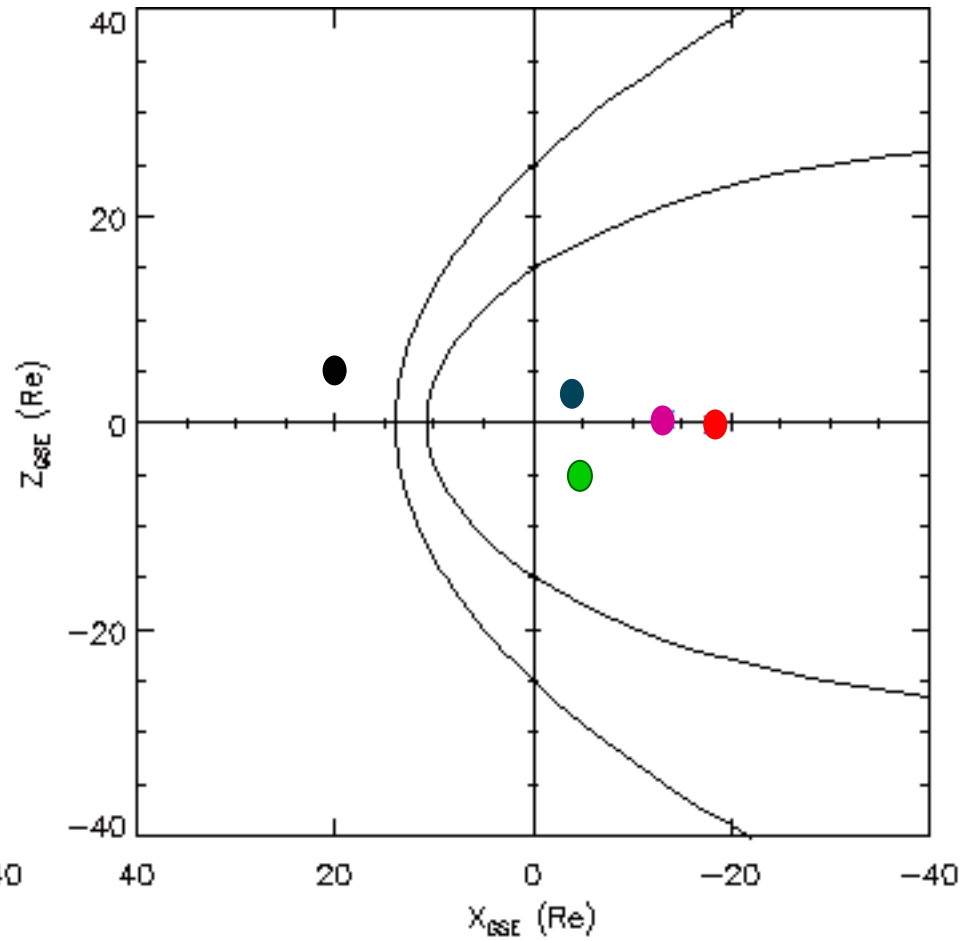
(complemented by Polar and Geotail)

Note that TC-2 and Cluster are both in polar orbit locked at very similar apogee MLT. TC-1 initially shares apogee MLT, but this will change.

(Figure courtesy SSCweb)

Conjunction Example: 03 September 2004: 02:00 - 03:00 UT
Spacecraft Locations (GSE)





Geotail ● (+20, +1, +5) R_E

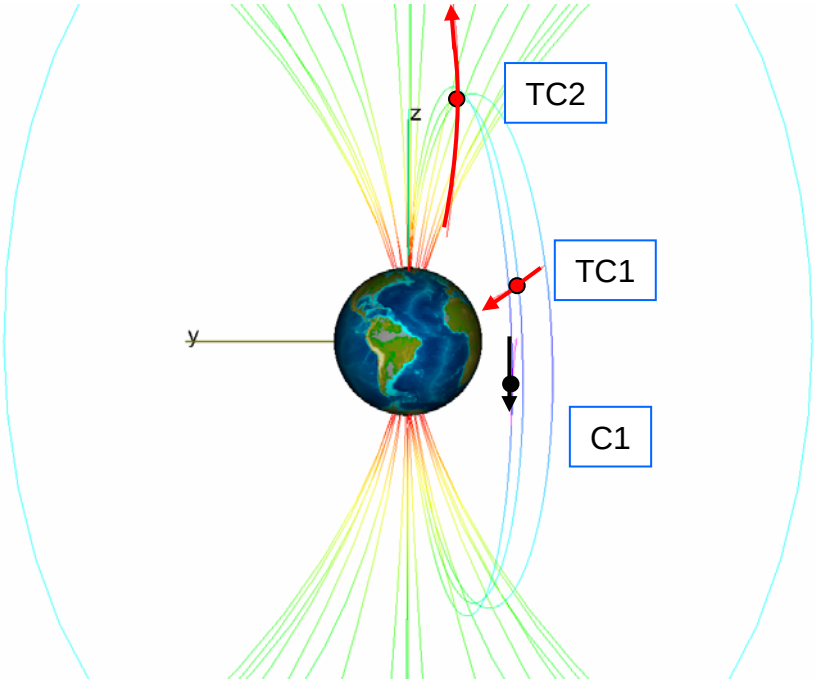
Cluster ● (-19, -1, -1) R_E

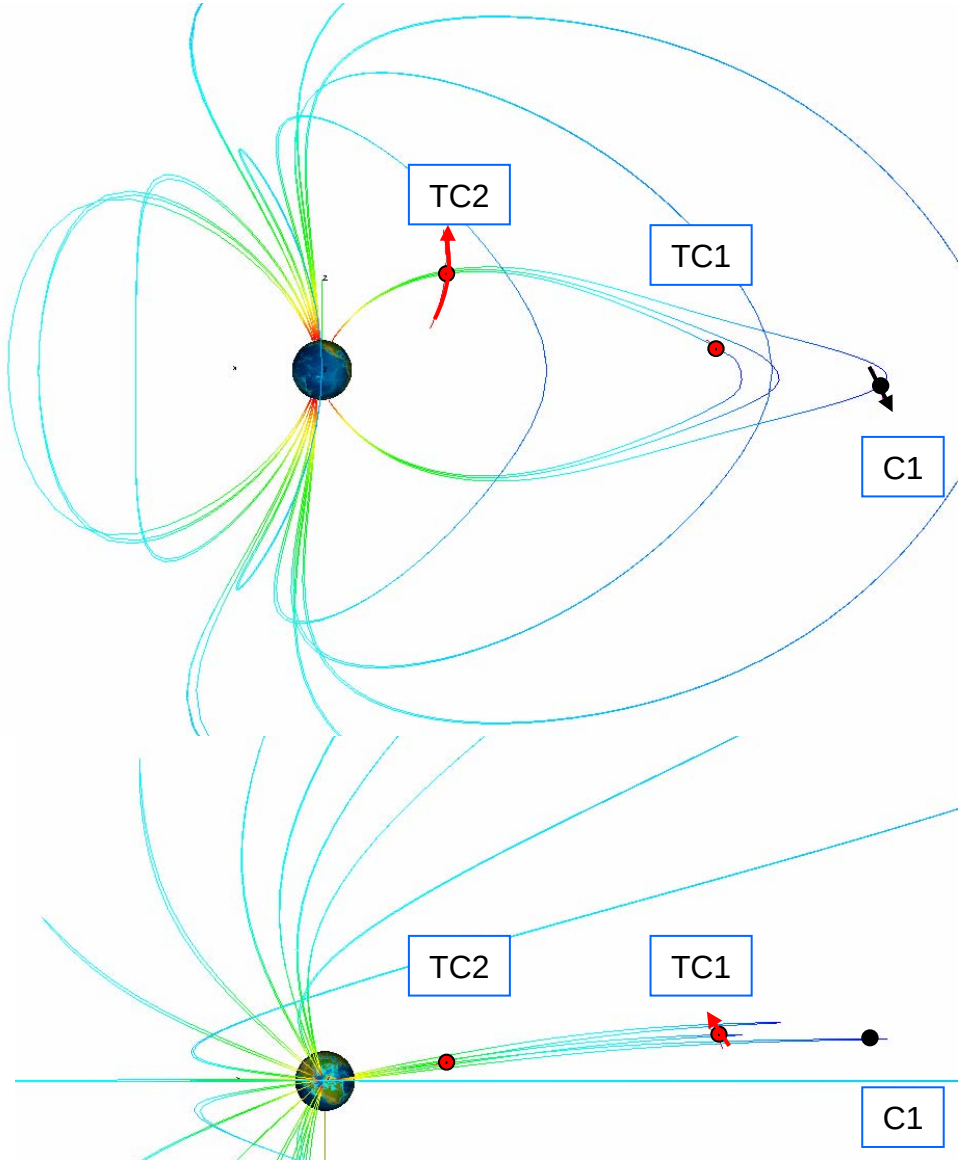
TC-1 ● (-13, -1, 0) R_E

TC-2 ● (-4, -1, +2) R_E

Polar ● (-5, +3, -5) R_E

Illustration of possible magnetic conjunction: (magnetic field model inputs not set to prevailing conditions)





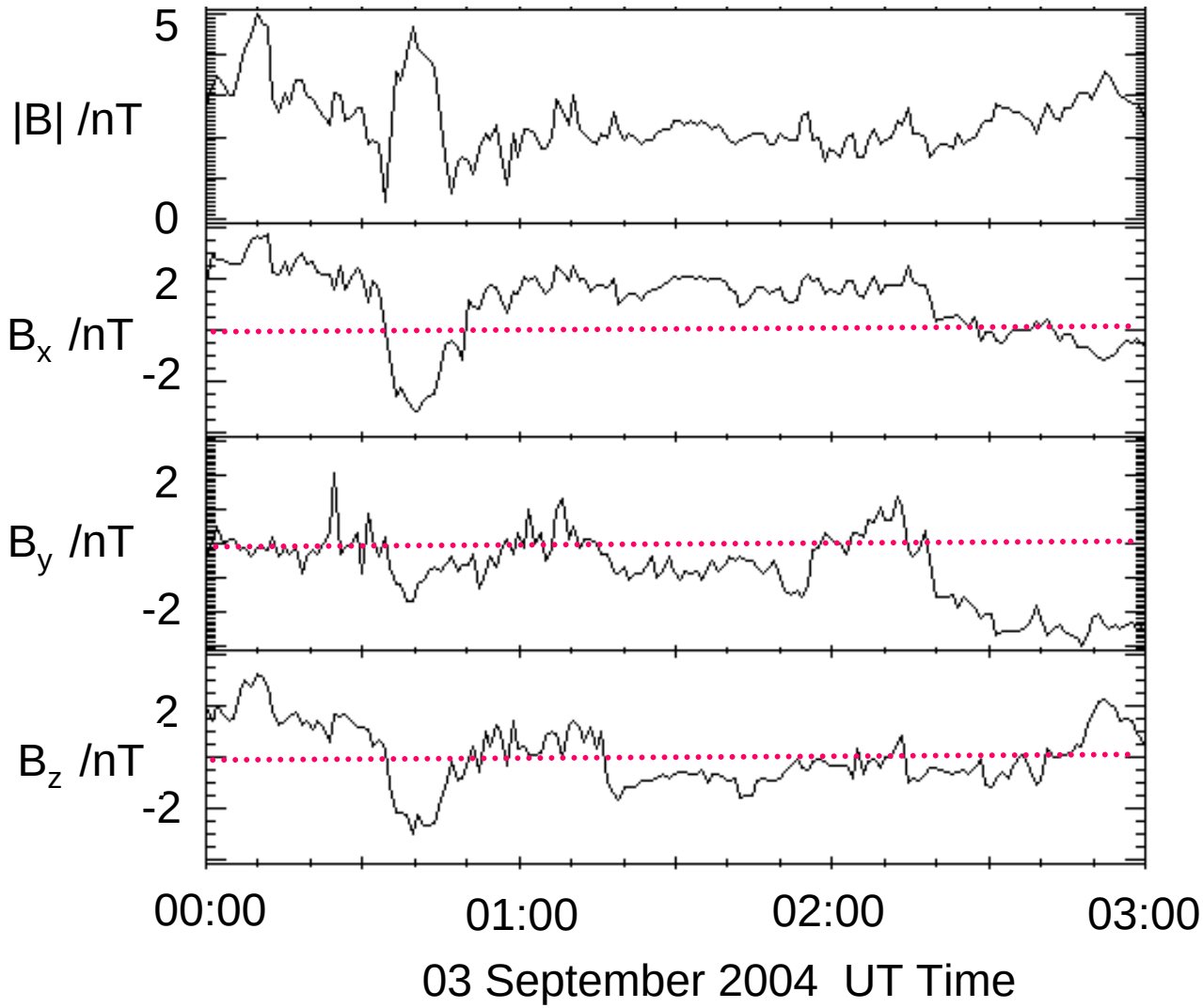
Orbital positions and motion of Cluster, TC-1 & TC-2

03 September 2004
02:00 – 04:00 UT
GSM Positions at 03:00 UT

Solar Wind conditions:

GEOTAIL

- Lies 20 R_E upstream
- GSE
- Speed: 425 km/s
- Time lag to Earth ~5 min



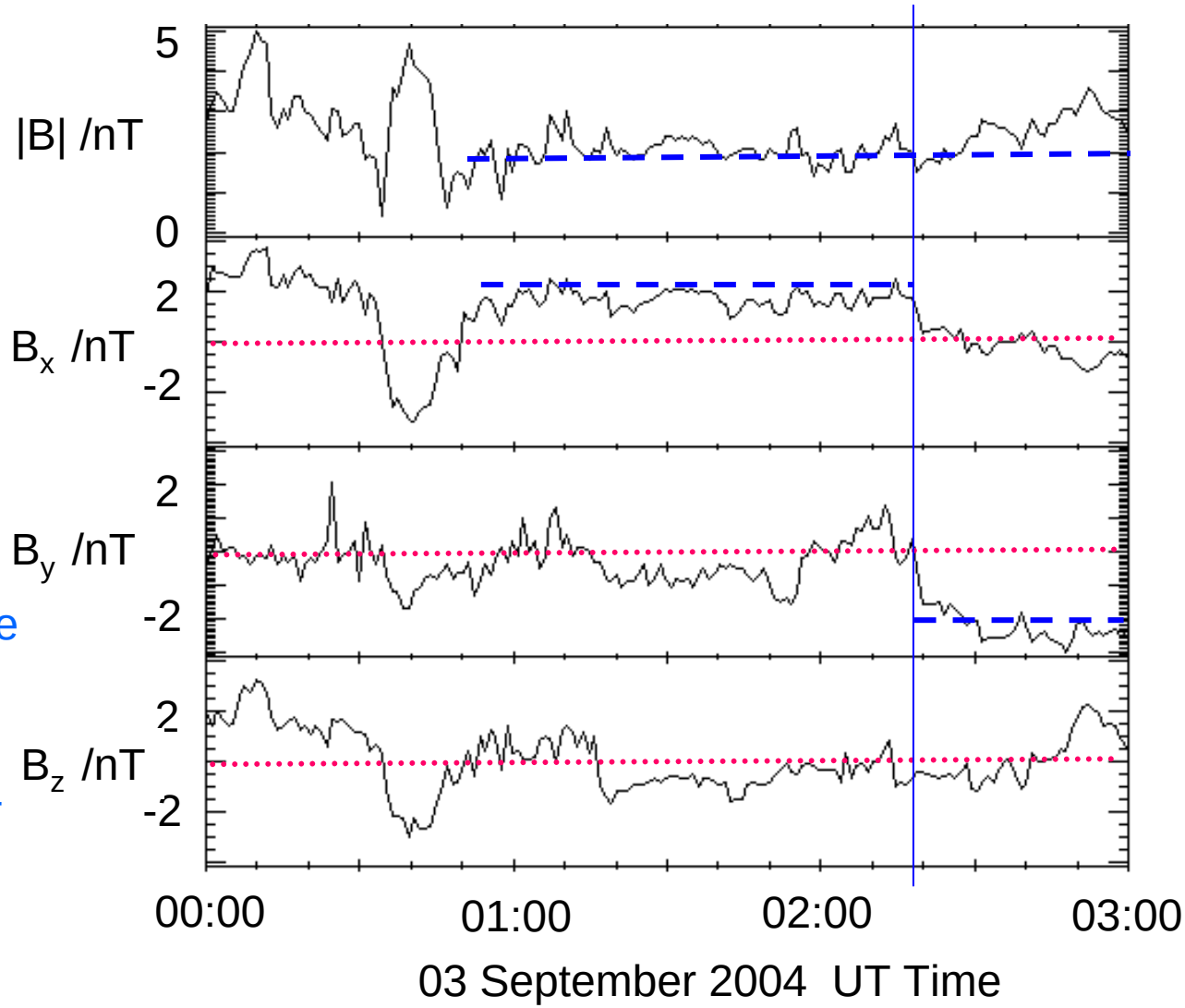
Solar Wind conditions:

GEOTAIL

- Lies 20 R_E upstream
- GSE
- Speed: 425 km/s
- Time lag to Earth ~5 min

- IMF southward
  01:00 – 02:45 UT
  Substorms probable

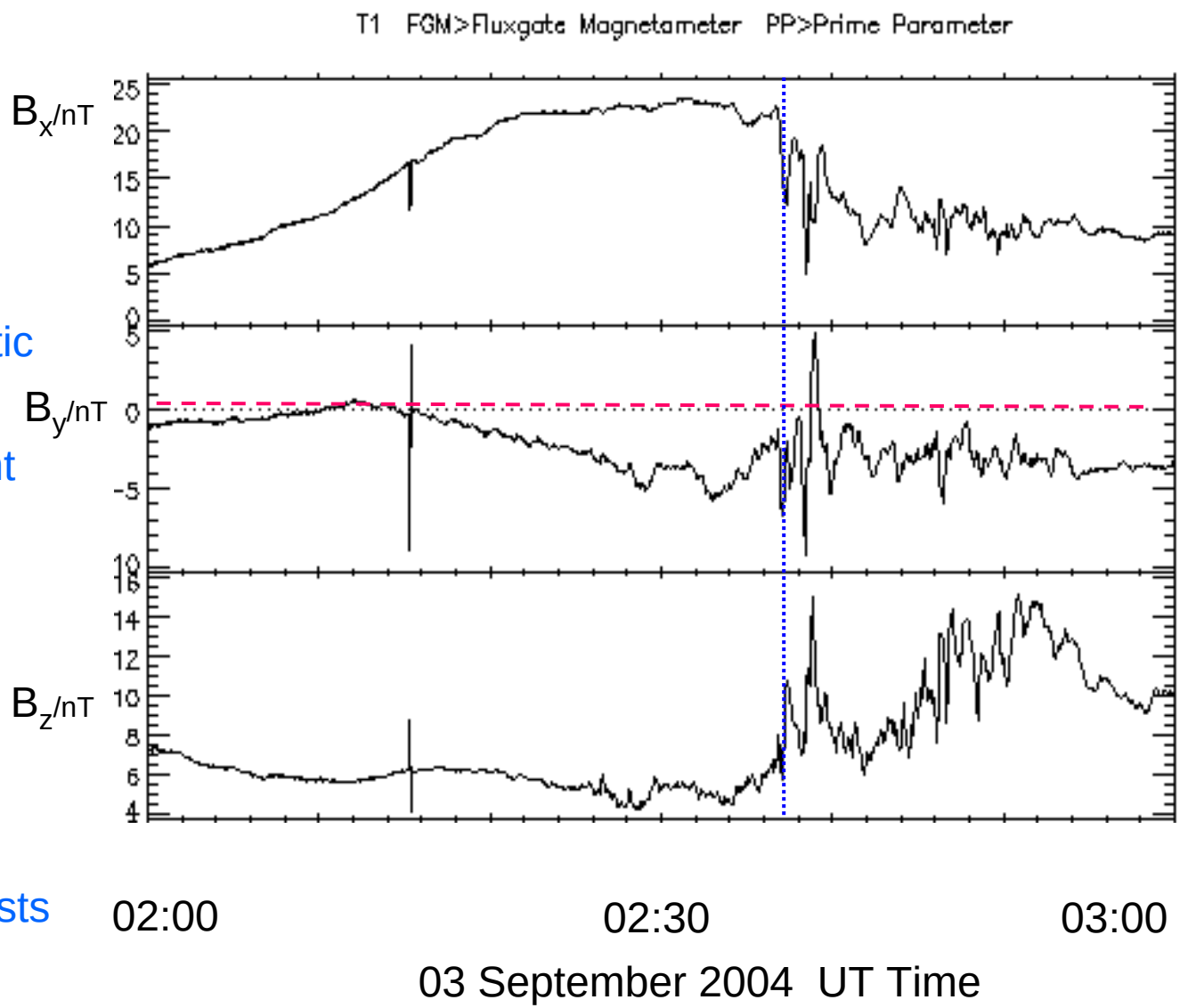
- IMF sunward
  01:00 to ~02:18 UT
- IMF dawnward
  02:18 to 03:00 UT



Double Star TC-1: Overview

TC-1 FGM
02:00 – 03:00 UT

- TC-1 is north of the current sheet
- The increase in magnetic field strength until ~ 02:37 UT is consistent with a substorm growth phase
- At ~ 02:37 a classic dipolarisation signature is seen to begin
- No ion velocity data exists



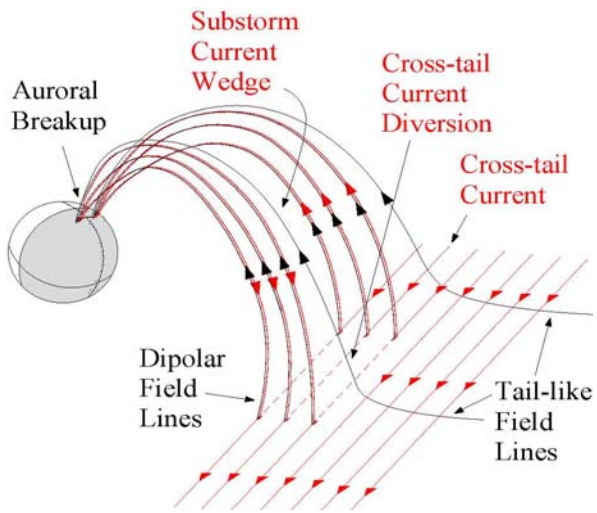
Double Star TC-2

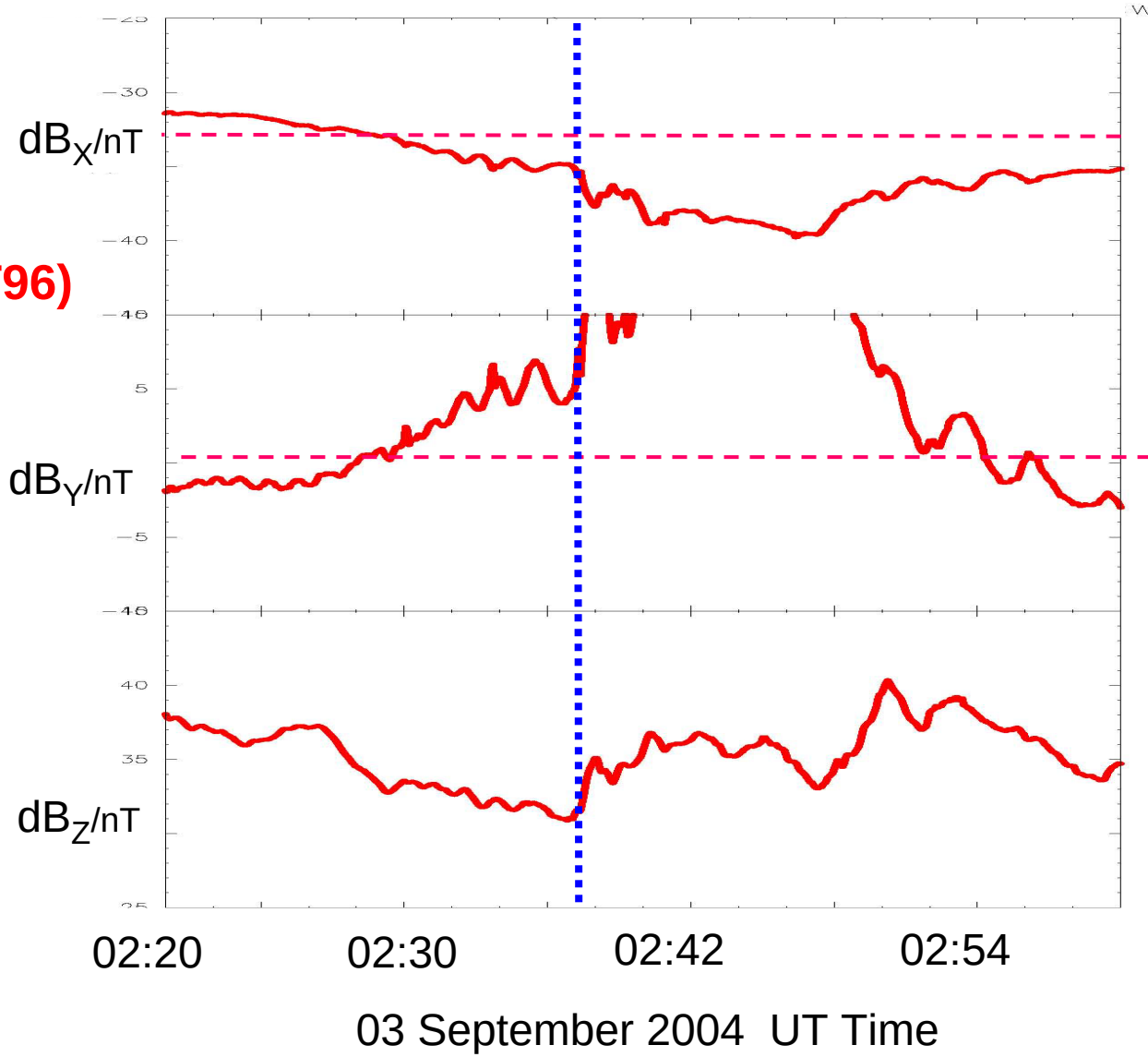
TC-2 FGM
02:20 – 03:00 UT

TC-2 FGM – model field (T96)

Major +ve By deflection starts ~ 02:37:30 UT; the substorm current wedge?

The 2 m. period perturbations, Pi2s tbc, starting ~02:30 UT



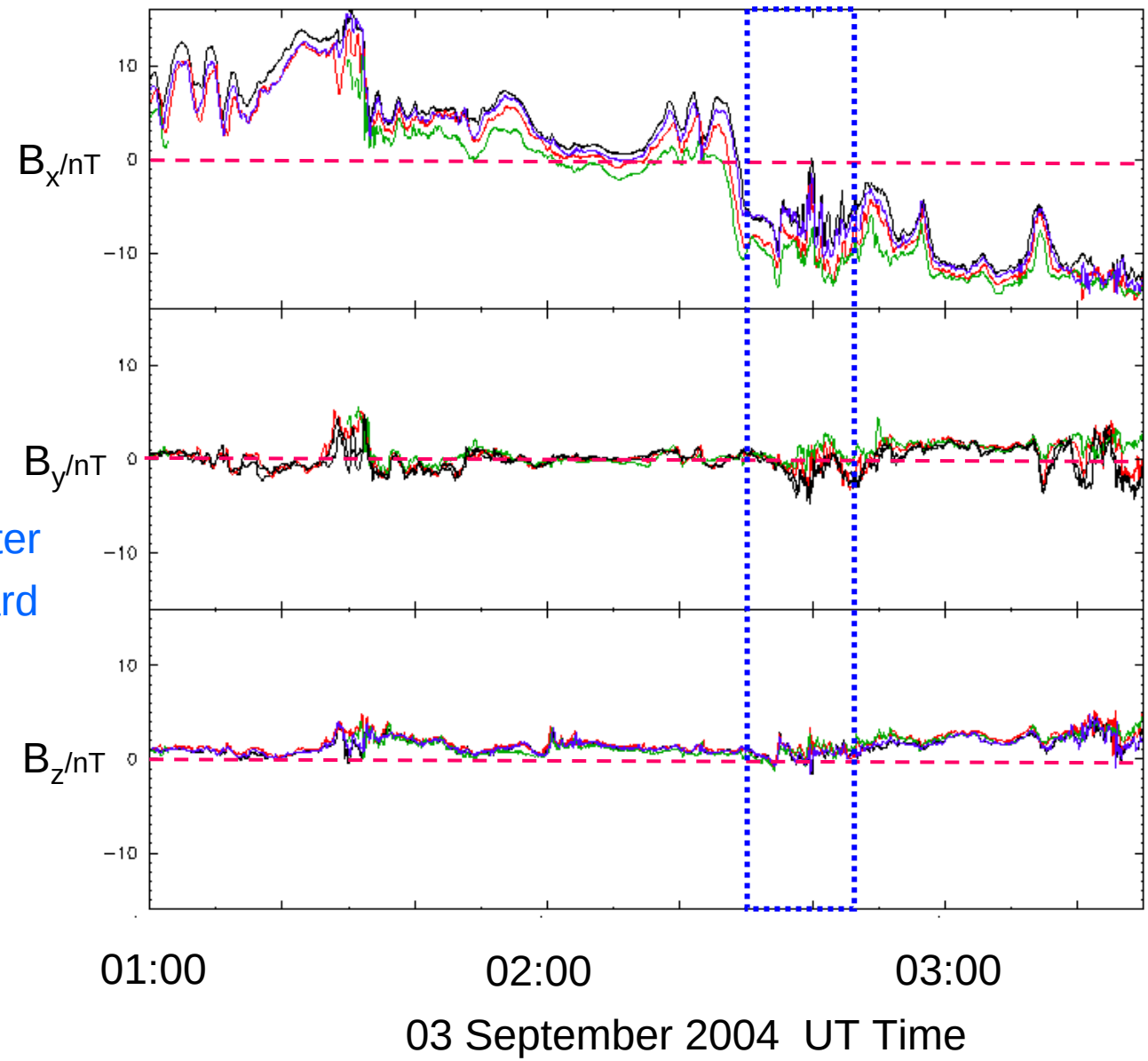


Sketch Source: http://sprg.ssl.berkeley.edu/themis/pdf/Mission_Science.pdf

Cluster: Overview

Cluster FGM
01:00 – 03:30 UT

- Cluster crosses the current sheet, from North to South, during this interval
- Little sign of tilt, even after the IMF swings dawnward



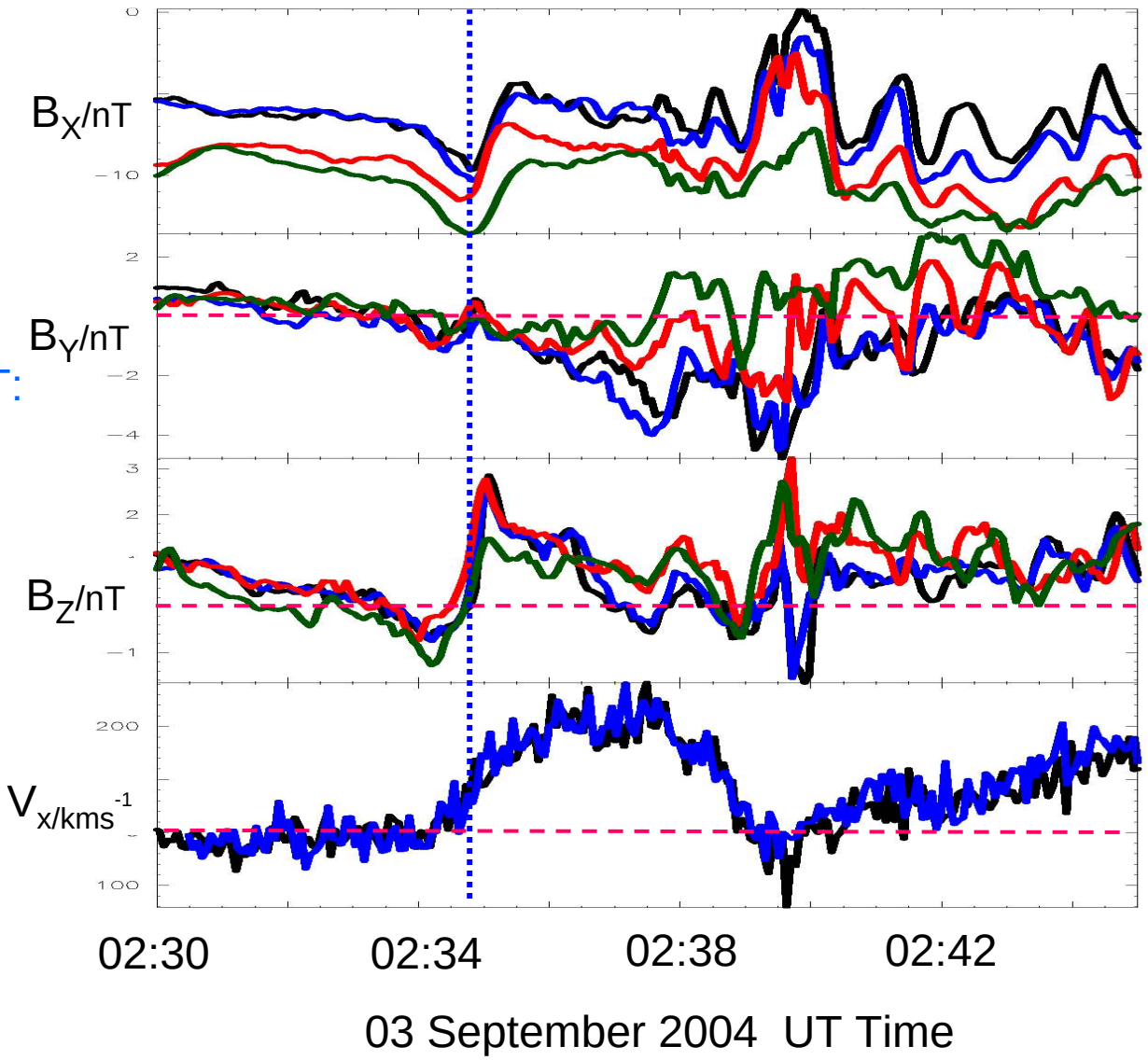
Cluster:

Cluster : FGM & CIS 02:30 – 02:45 UT

Dipolarisation with fast Earthward flow (BBF)

Beginning just before 02:35 UT:

- the plasma sheet expanded ($|B_x|$ decreased)
- the B_z magnetic field component increased.
- a fast Earthward ion flow (~200 km/s) began and was observed for ~ 4 minutes
- the dipolarisation front was moving Earthwards and dawnward (4 point timing)



Double Star and Cluster

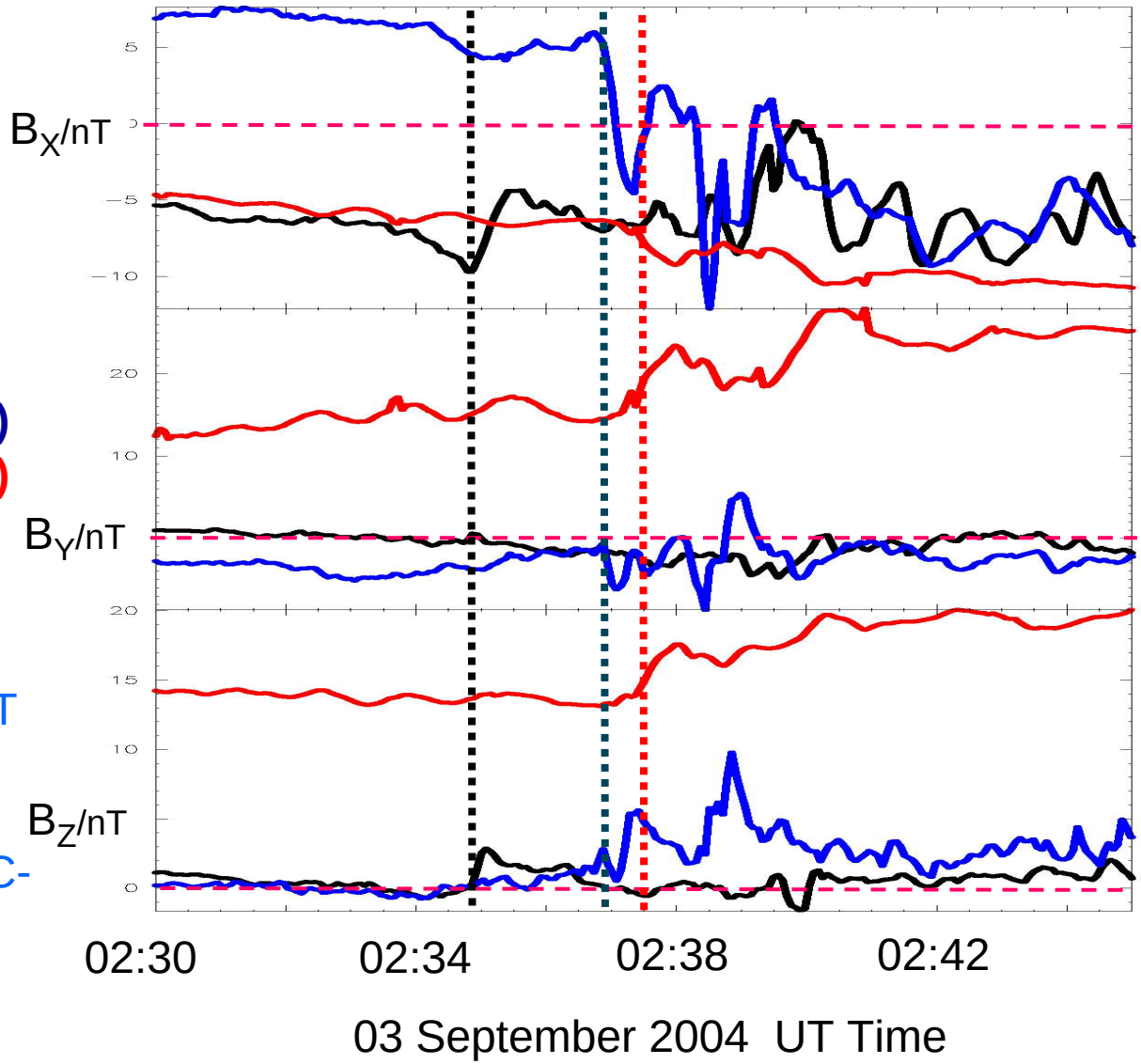
Disturbance onset times

Magnetic Field
02:30 – 02:45 UT

Cluster FGM,
TC-1 FGM – model field (T96)
TC-2 FGM – model field (T96)

Beginning:

- at Cluster just before 02:35 UT
- at TC-1 at 02:37 UT
- at TC-2 ~ 02:37:30 UT (but TC-2 timing could be due to s/c motion relative to L-shells)



Double Star and Cluster

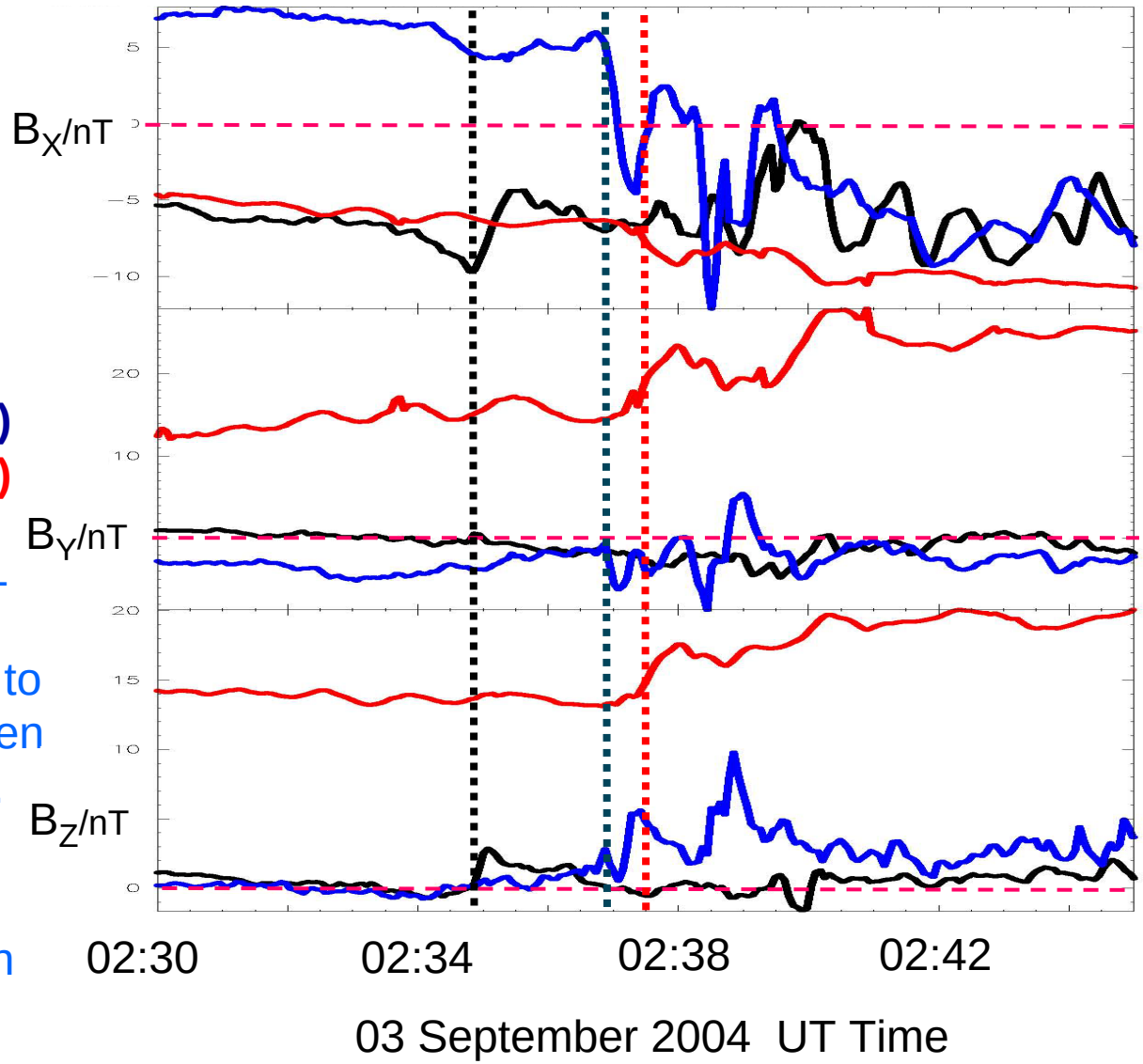
Disturbance onset times

Magnetic Field
02:30 – 02:45 UT

Cluster FGM,
TC-1 FGM – model field (T96)
TC-2 FGM – model field (T96)

The disturbance occurs at TC-1 about 2 minutes later than at Cluster, roughly corresponding to the plasma convection time given the BBF speed seen at Cluster.

This is consistent with the possibility that the dipolarisation front travels with the BBF



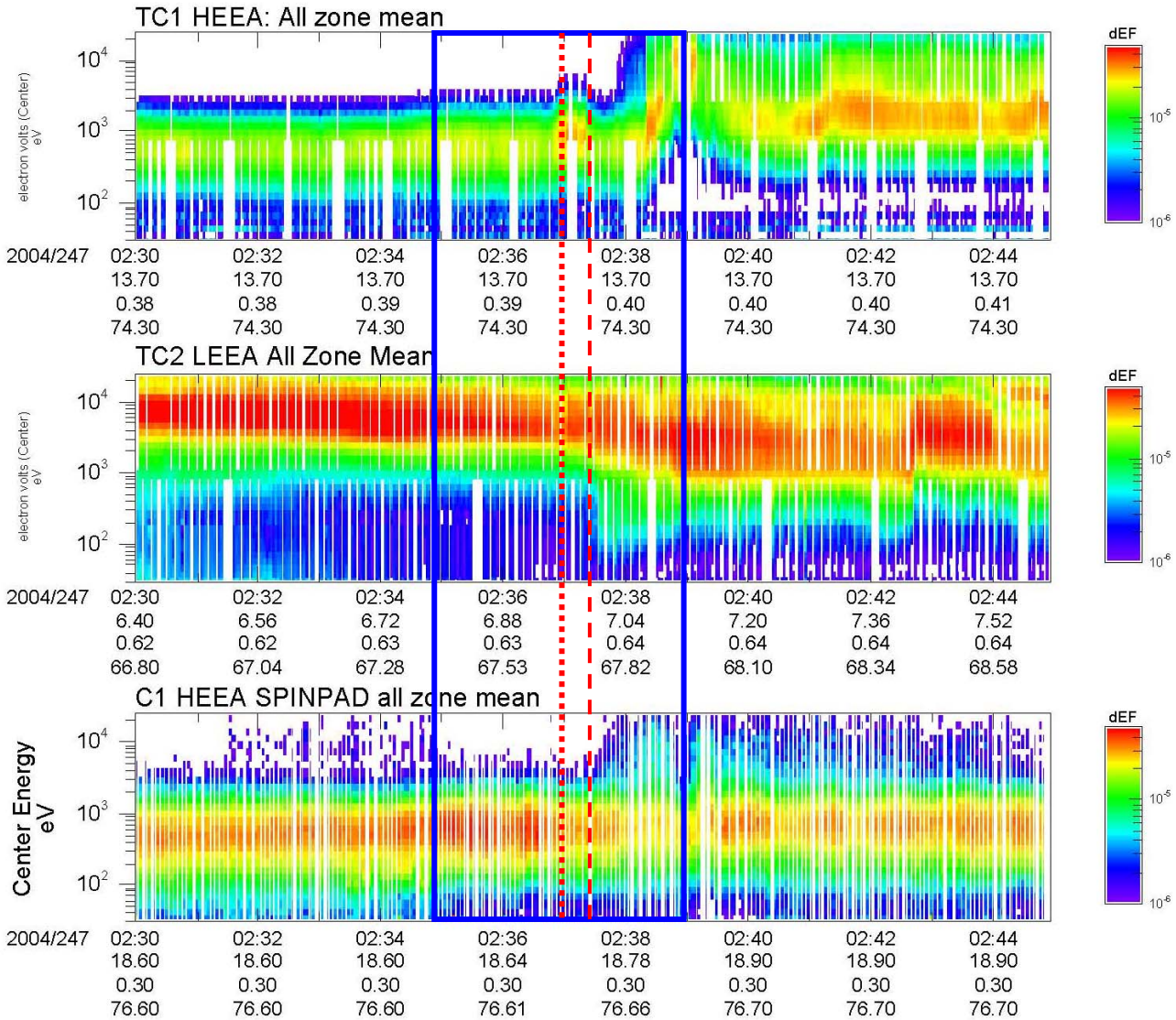
Double Star and Cluster

PEACE Electron data 02:30 – 02:45 UT

At TC-1 a heated and higher flux population appears as the dipolarisation proceeds.

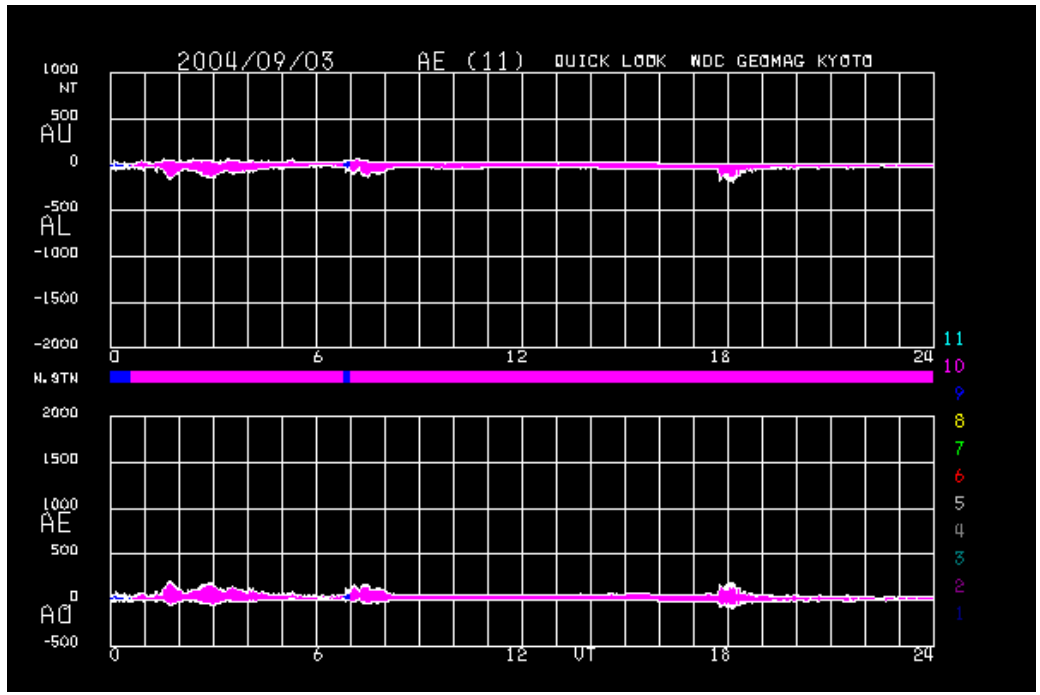
These may be part of the electron population measured by Cluster, after experiencing adiabatic (or even non-adiabatic) heating

We are using Liouville mapping to test this; the outcome may strengthen the case that the spacecraft are in fact magnetically conjugate



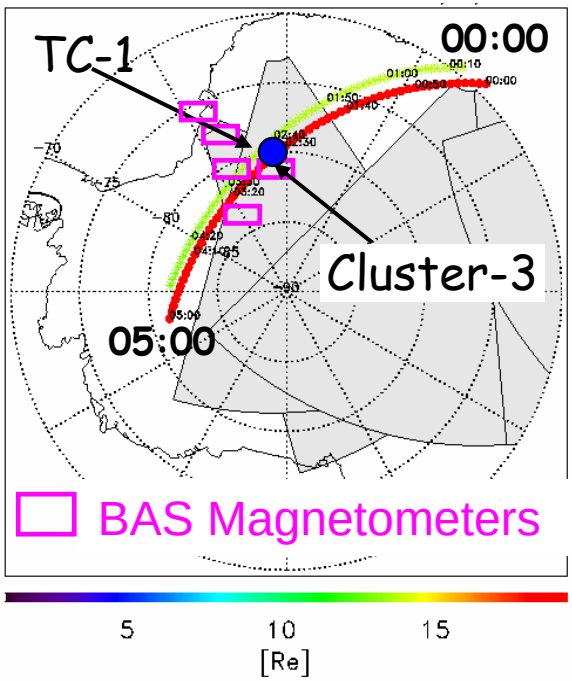
Ionospheric Evidence: Summary

- AE shows weak-moderate activity
- Ground magnetometers provide evidence for an enhanced ionospheric current near the spacecraft footprint
- SuperDARN radar show small convection enhancements, however not all radar data is available yet.
- Ground-based auroral monitors have not yet been investigated
- Unfortunately, no auroral imaging spacecraft can provide data.

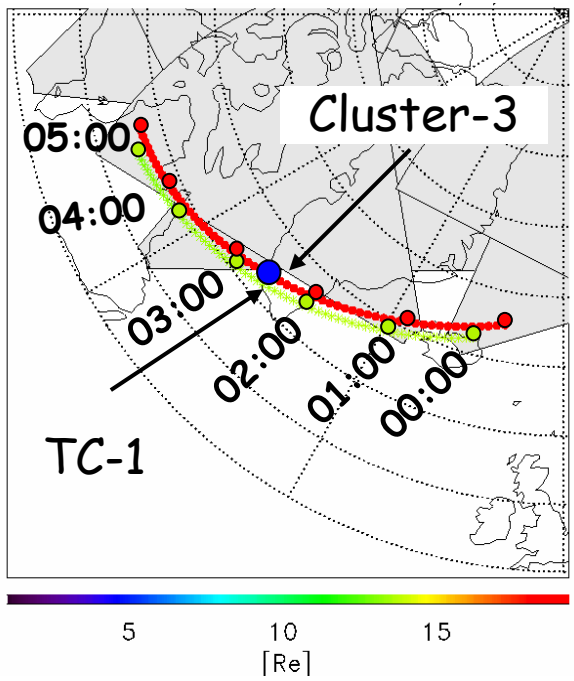


Cluster and Double Star Ground Tracks, with SuperDARN fov

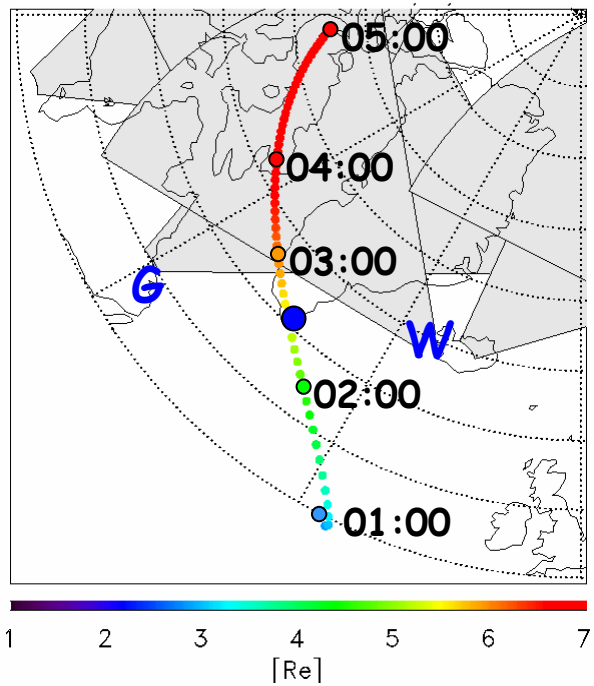
Cluster-3 and TC-1 orbits ~02:40 UT TC-2 orbit



Antarctica



Greenland



Greenland

Only one magnetometer station available so far.

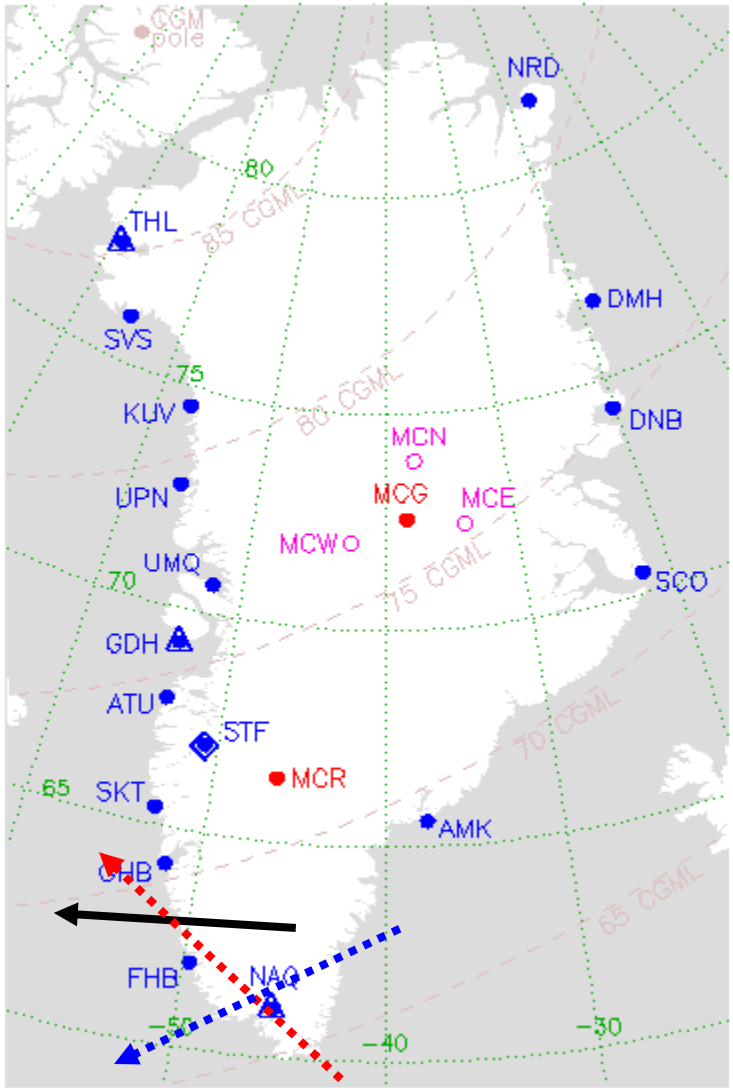
VLF substorm chorus seen

Southern radar data not yet available

Cluster, TC-1 and TC-2 in closest conjunction with the Iceland West (W) and Goose Bay (G) SuperDARN radars

Little useful SuperDARN data is available…

Near Conjugate Ground Magnetometer Chain: Greenland



● **Greenland Magnetometer Stations**

Cluster, TC-1 and TC-2 are in closest conjunction with the NAQ, FHB, GHB, SKT, AMK magnetometer stations

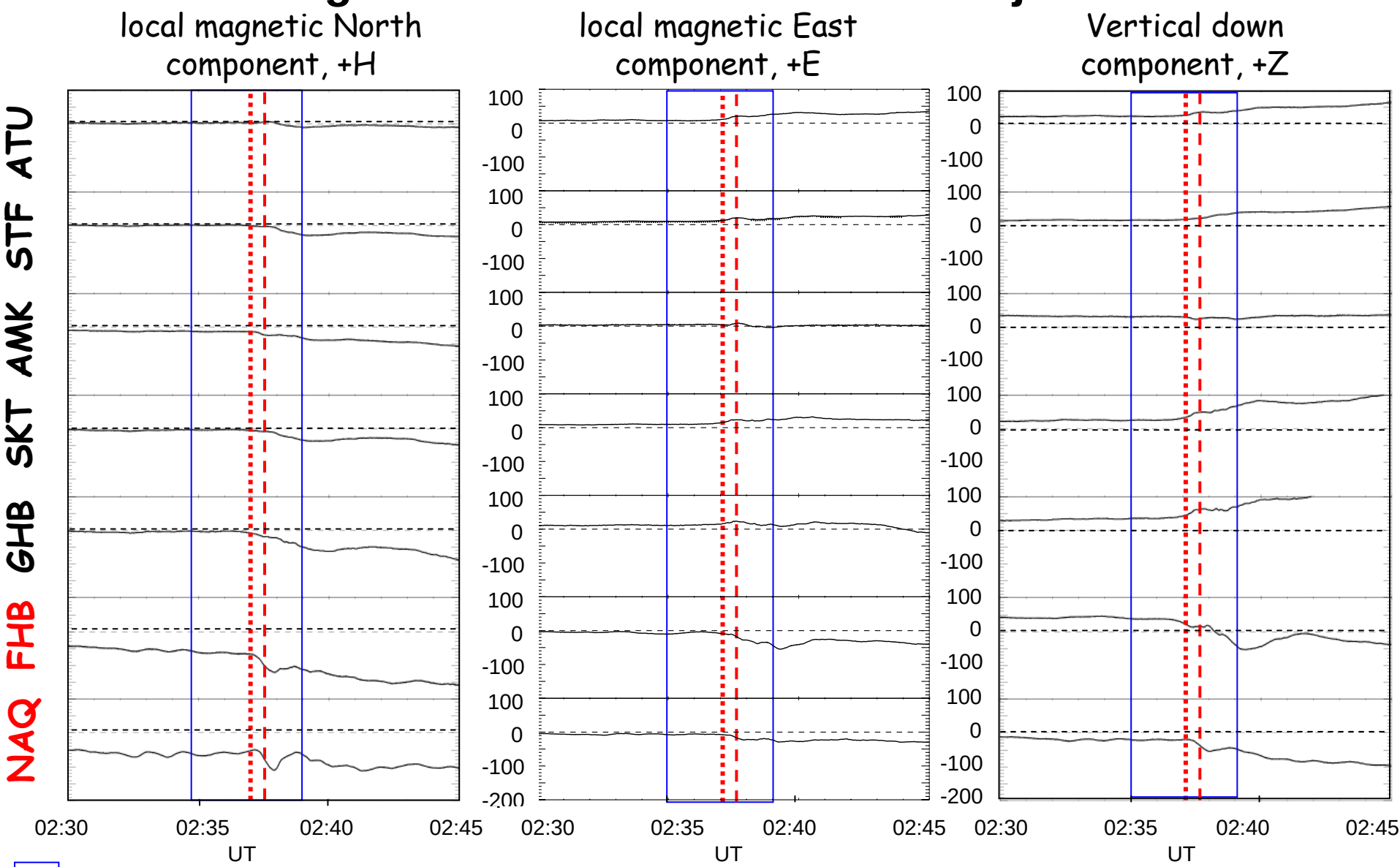
The ionospheric current enhancement is detected at about the same time as the dipolarisation on TC-1, and after the fast flow starts at Cluster

Ionospheric current appears to flow between NAQ, FHB and GHB, SKT, AMK magnetometer stations

Cluster and TC-1: Approx path

TC-2: Approx path

Greenland magnetometer data in closest conjunction with s/c



Summary

- A well-aligned Cluster/Double Star/Ground-facility conjunction takes place during weak-moderate substorm activity.
- A dipolarisation front associated with a fast flow burst is seen propagating from tailwards of Cluster toward the Earth.
- A dipolarisation event is seen 2 mins later at TC-1
- This time delay consistent with assumption that the dipolarisation front convects with the plasma.
- Ground magnetometers suggest that an enhanced ionospheric current appears at about the time that TC-1 sees the dipolarisation
- These data are more consistent with the NENL model than the CD model of substorm processes

Future Work / Work in progress

- Obtain Polar Data (Magnetic Field not yet available) to better understand motion of dipolarisation front near the Earth
- Find auroral imager data
- Electron anisotropy analysis to study accleration/further evidence for magnetic connection of the spacecraft
- Current sheet evolution with Cluster curlometer
- Flow braking at TC-1 – use PEACE flows to investigate
- Investigate geosynchronous datasets – preliminary data indicate no significant signatures for this event