# Energy Transport in the Magnetosphere–Ionosphere System by Cluster and Swarm Observations

**Octav Marghitu, Dragoș Constantinescu,**

**Vlad Constantinescu, Adrian Blăgău, Horia Comișel**

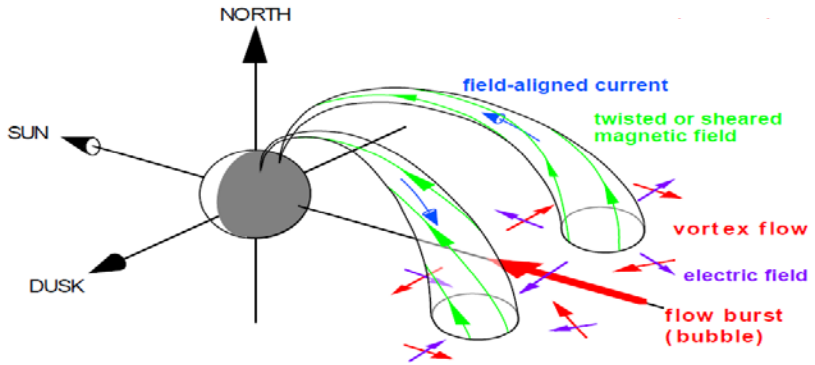
*Institute for Space Sciences, Bucharest, Romania*

Swarm 10 Year Anniversary & Science Conference

08 – 12 April 2024 | Copenhagen, Denmark

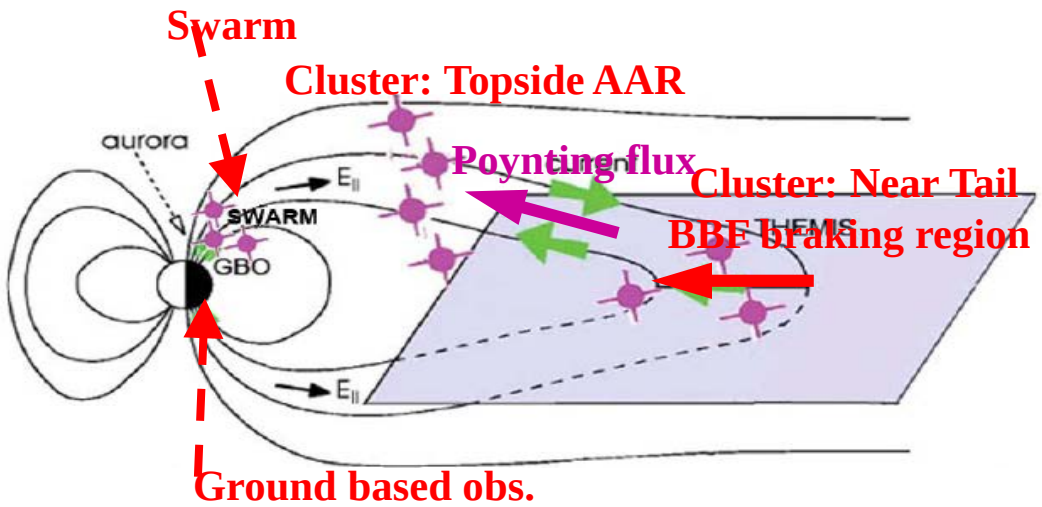
# Concept

Former studies => Mainly BBF dynamics




*Birn et al. (2004)*

Here => Emphasis on BBF energetics




- Poynting flux observed by Cluster and Swarm

# Overview

**A.** Intro – Poynting flux
- Poynting flux fed to ionosphere
- Poynting flux in the magnetosphere
- Poynting flux by Swarm

**B.** Two Cluster – Swarm events
- Selection
- Sep 29, 2014
- Aug 5, 2014

**C.** Caveats

**D.** Cluster – Swarm – GBO event

**E.** Summary and prospects

ISS INSTITUTE OF SPACE SCIENCE

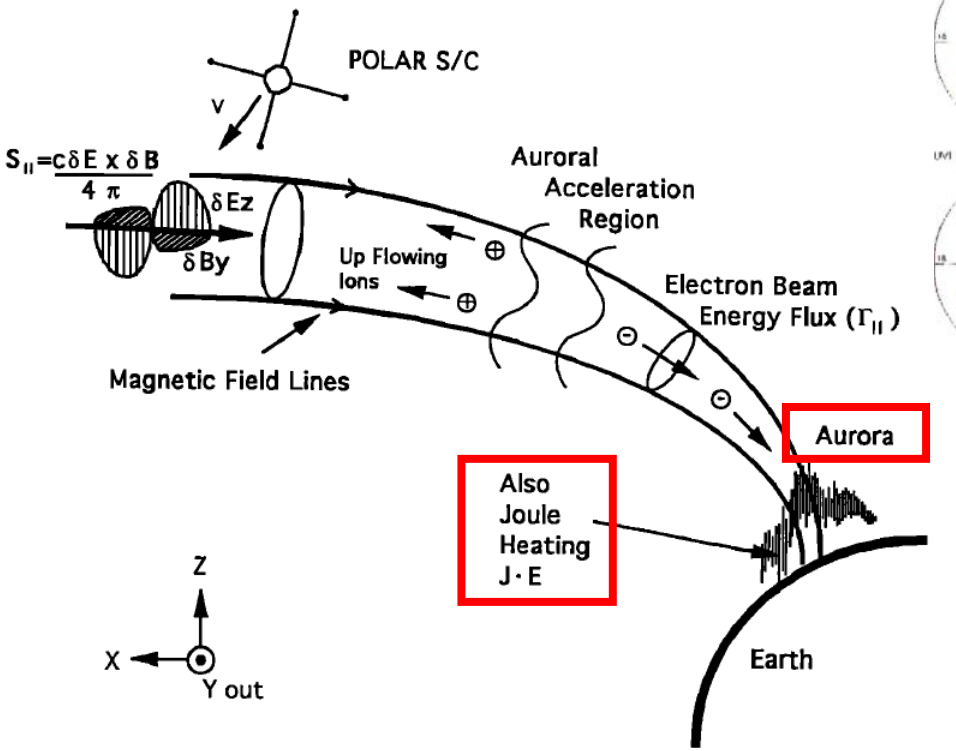
Cluster II

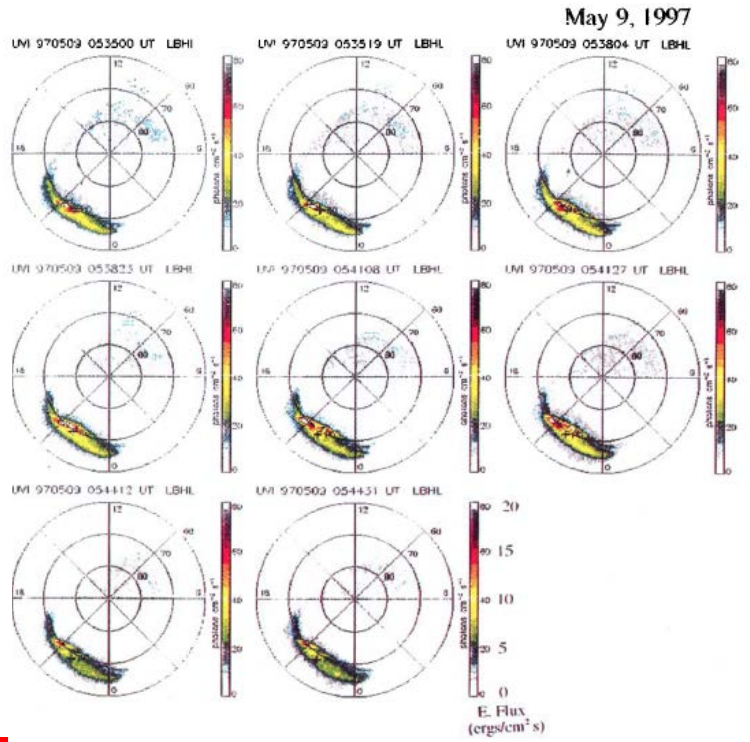
SWARM

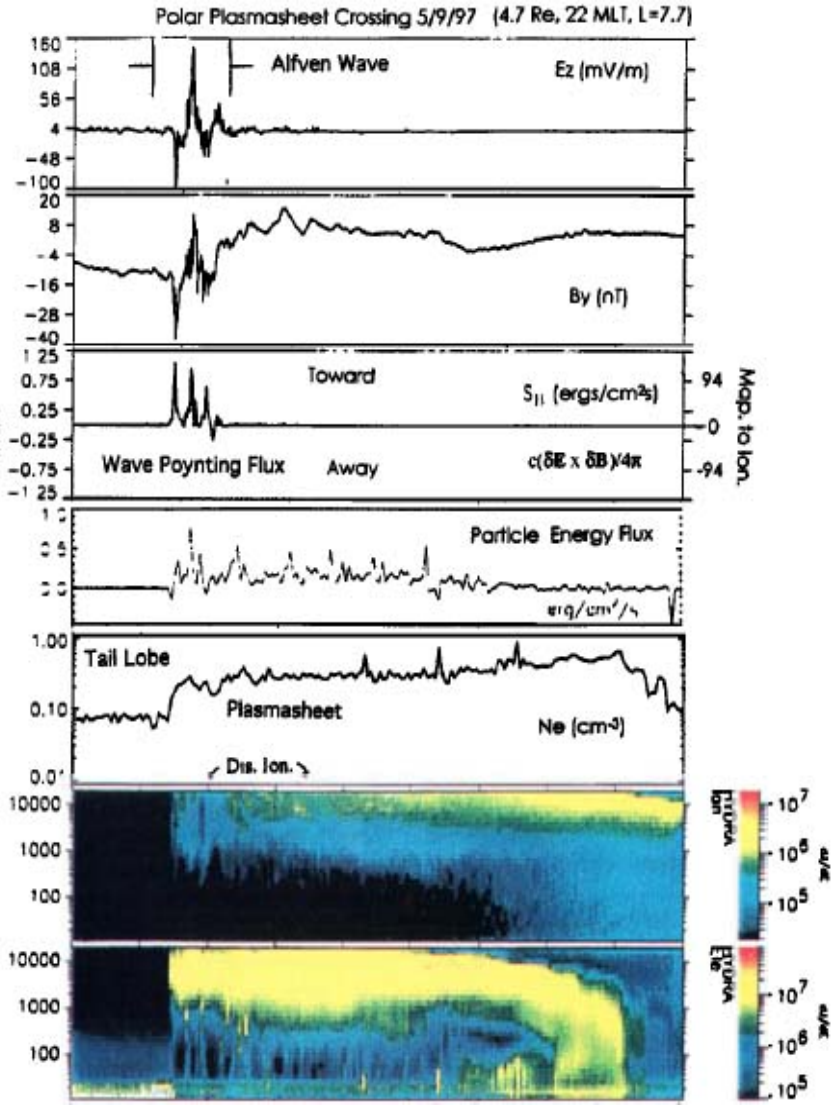
esa

# A. Intro: Poynting Flux Fed to Ionosphere

## Substorm event




***Wygant et al. (2000)***

***Polar UVI and E, B data***

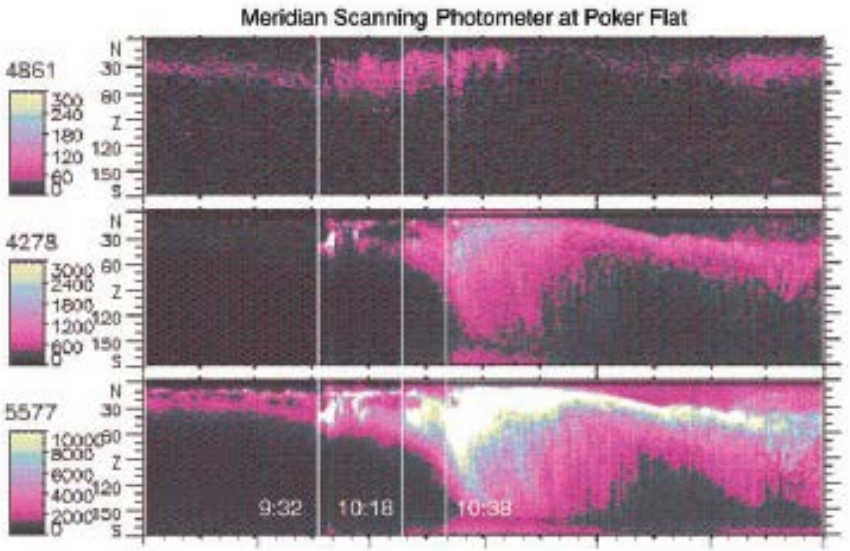
INSTITUTE OF SPACE SCIENCE

SWARM

esa

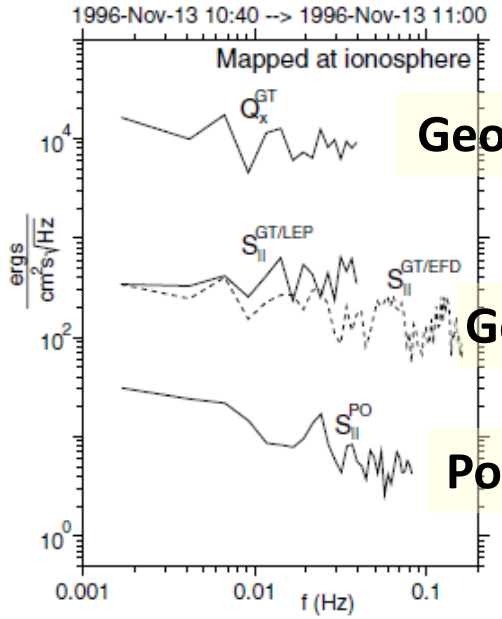
# A. Intro: Poynting Flux in the Magnetosphere

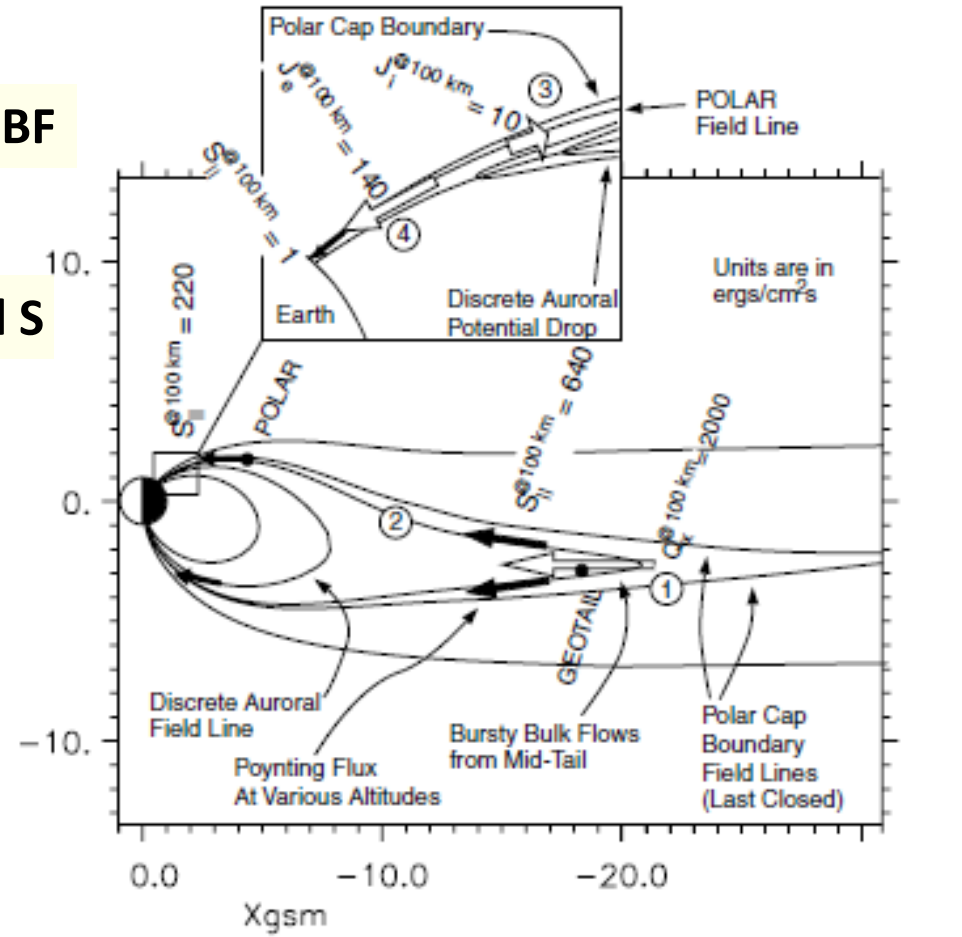
**Substorm event**




***Angelopoulos et al. (2002)***

***Geotail 18 $R_E$ and Polar 5 $R_E$ data***




① Earthward energy flux couples to localized, East-West fluctuations.
② Partial dissipation via kinetic Alfven wave interaction with electrons.
③ Further dissipation via inertial Alfven wave interaction with electrons.
④ Ion heating by electrons, and eventual upflow.

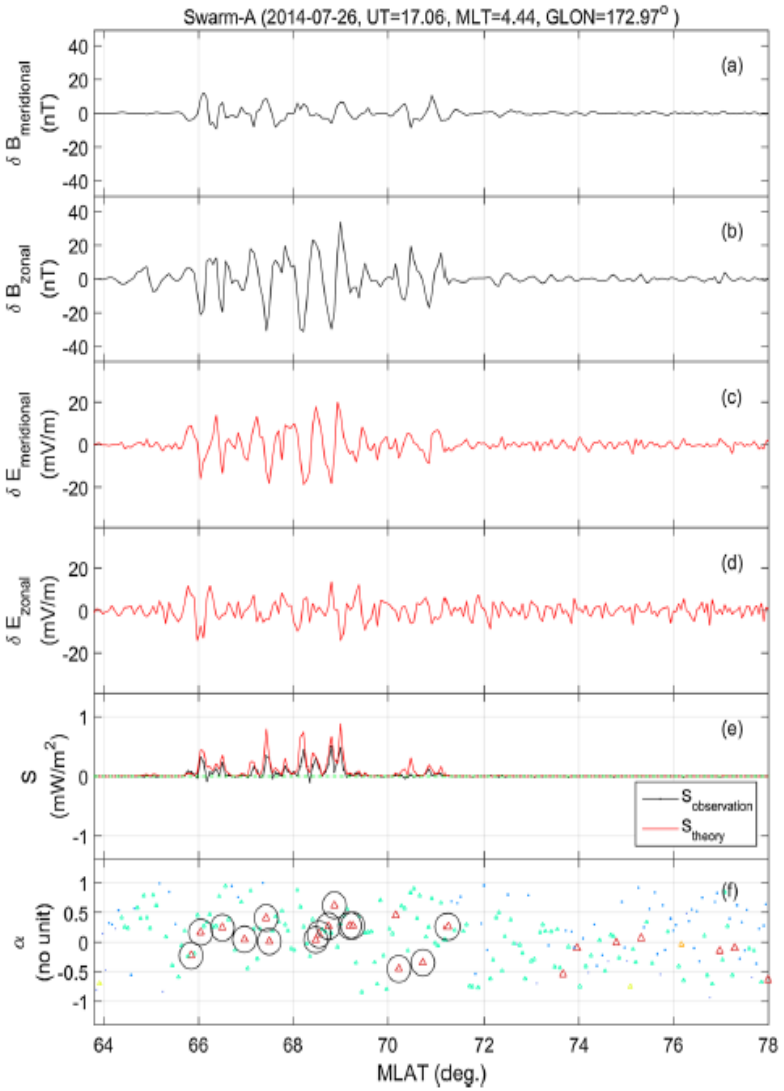
INSTITUTE OF SPACE SCIENCE

Cluster II

SWARM

esa

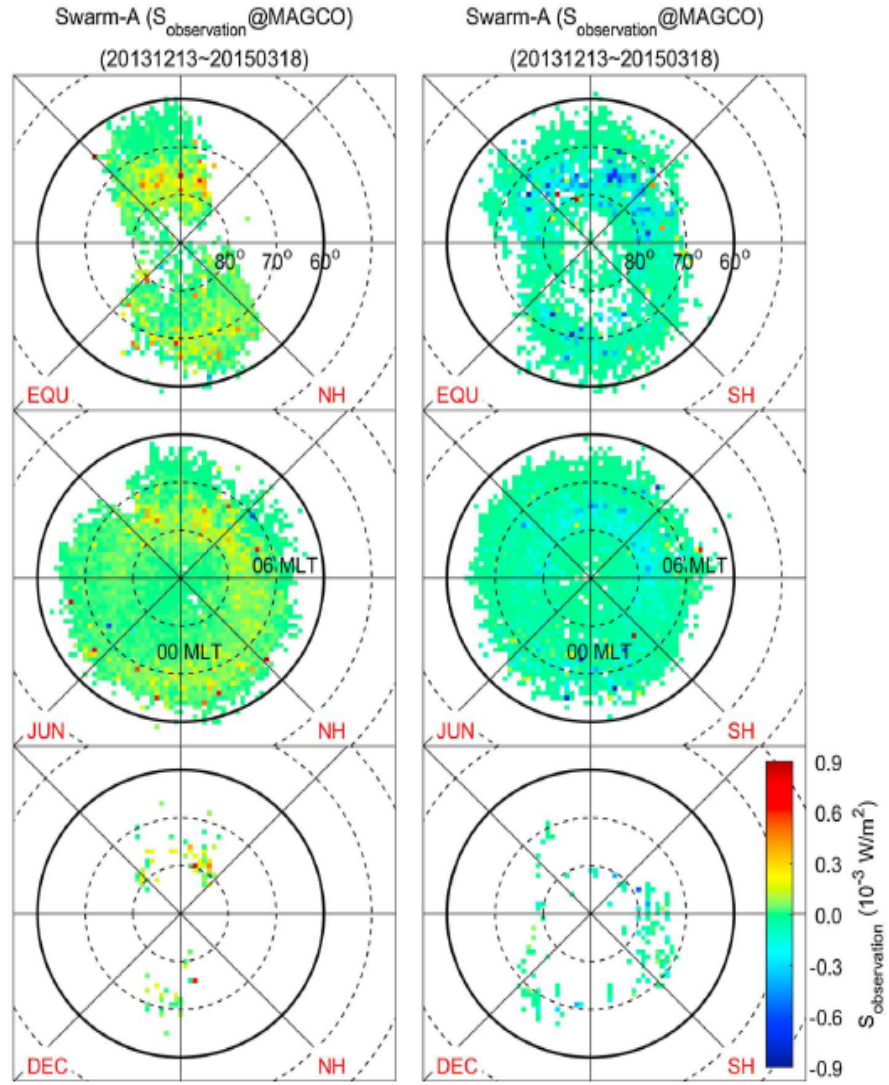
# A. Intro: Poynting Flux by Swarm




- Systematic examination of Poynting flux and reflection of Alfvén waves in the auroral region

  ***Park et al. [2017]***

- **Take over the systematic study based on just one satellite, in this case Swarm, to conjugate events, like Cluster – Swarm ?**




ISS INSTITUTE OF SPACE SCIENCE

Cluster II

SWARM

esa

# A. –> B. Cluster BBF – Swarm Events

- **Question: Can one aim for a systematic examination of Cluster BBF events conjugate to Swarm data? And ideally also with optical data, at least in a couple of cases?**
- The question is posed for Cluster and Swarm data, but can be extended to any properly equipped magnetospheric (MMS, THEMIS,…) and ionospheric (DMSP,…) satellites.
- Answering this question is important from a fundamental perspective, since BBFs are regarded as a key carrier of energy, momentum, and magnetic flux, in particular during disturbed times.
- The question is relevant also from a practical perspective, given the occurrence of potentially harmful space weather events during disturbed times.
- A systematic study is expected to consist of a broad range of specific cases, to include conjunctions with field-aligned potential drop in between (like the two events in the Intro), conjunctions without potential drop, various reflection coefficients of the Poynting flux at the ionosphere, etc.
- **In the following we start to address this question, by assembling a procedure illustrated with a couple of Cluster BBF – Swarm events. To be extended first by more Cluster BBF – Swarm events and later by further events from other spacecraft.**

ISS INSTITUTE OF SPACE SCIENCE

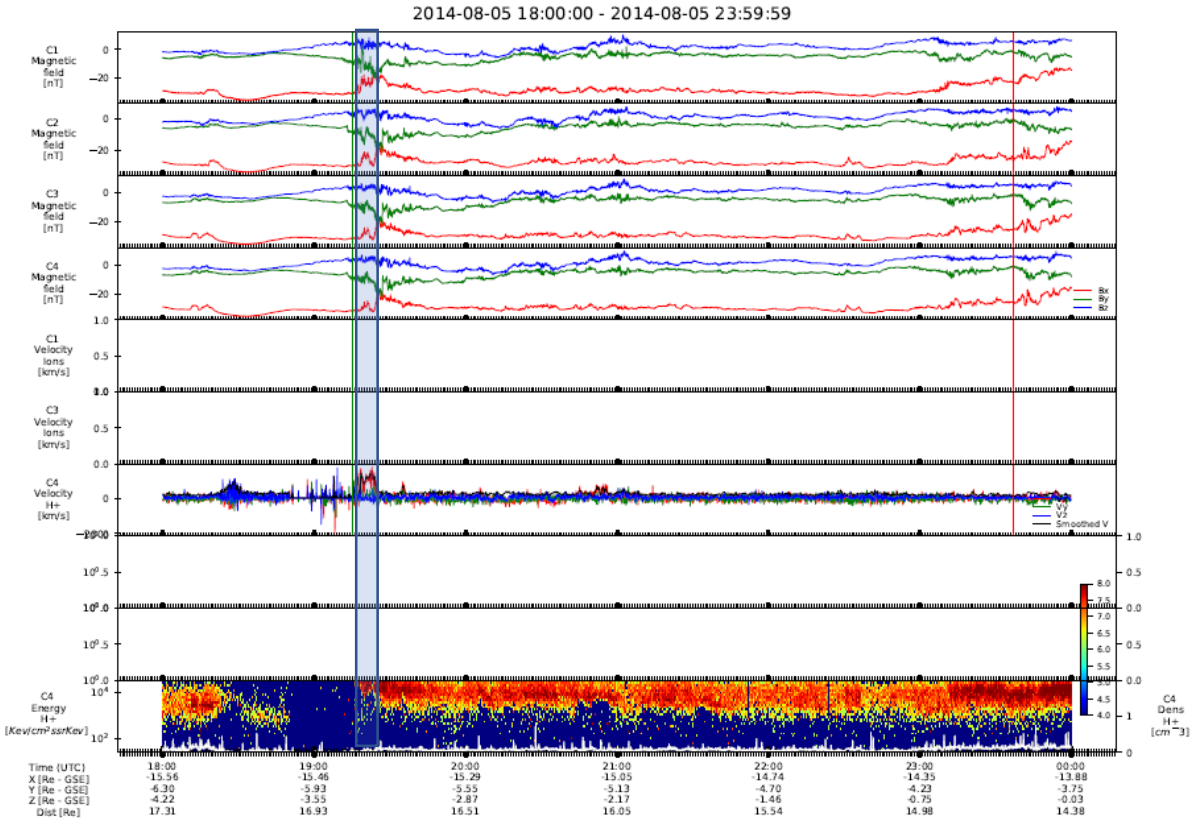
Cluster II

SWARM

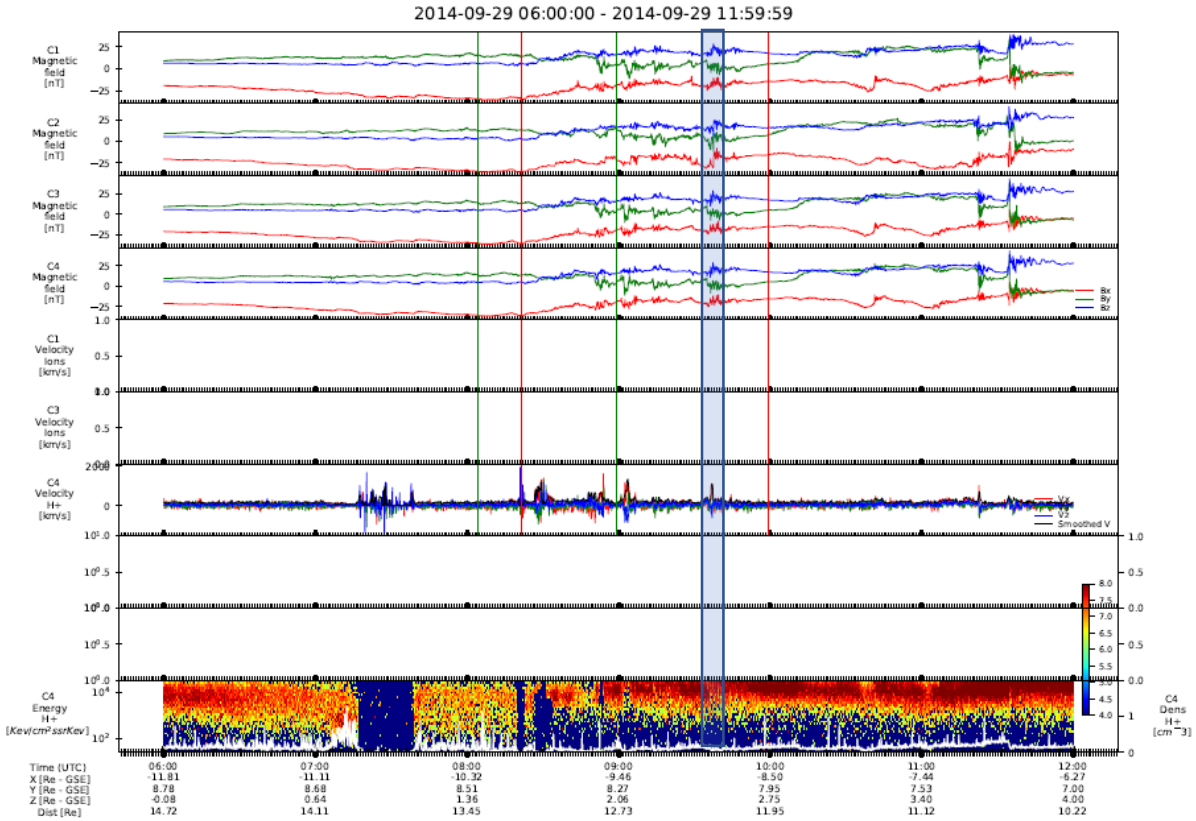
esa

# B. Two Cluster – Swarm Events: Selection

***5 August 2014 – 'Bad'***




***29 Septemeber 2014 – 'Good'***




- **Some 40 C4 – SA and 30 C4 – SB tentative conjugate BBF events in 2014**
- **Some 10 events selected for further examination, of which 3 about ok (e.g., 29 Sep – see next), the others not ok (e.g., 5 Aug – see next)**

ISS INSTITUTE OF SPACE SCIENCE

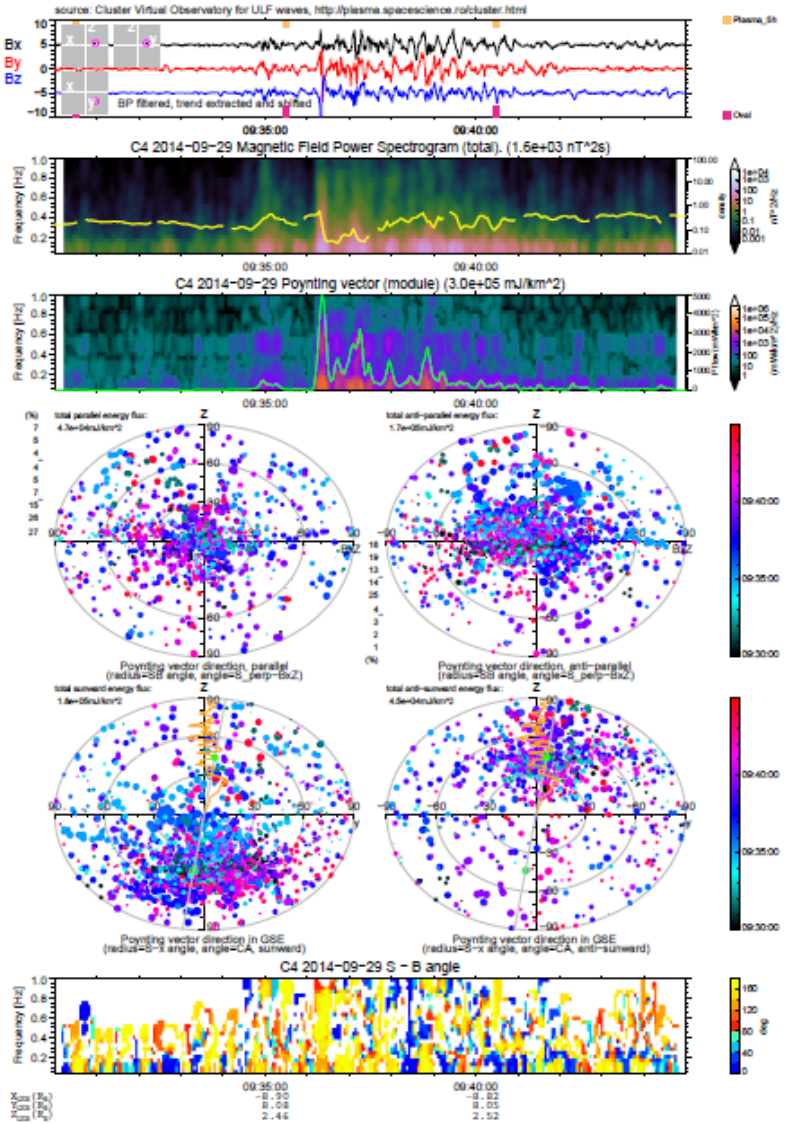
Cluster II

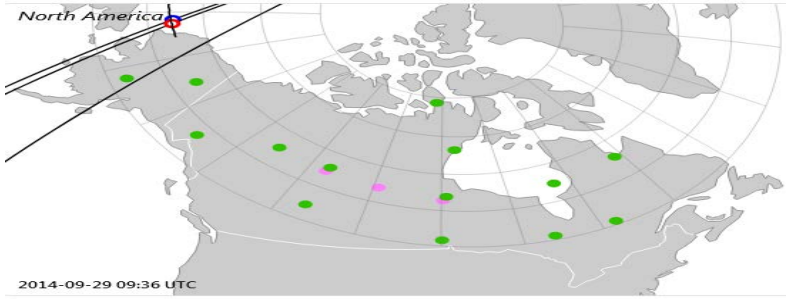
SWARM

esa

# B. Cluster – Swarm 'Good' Event, 29 Sep 2014

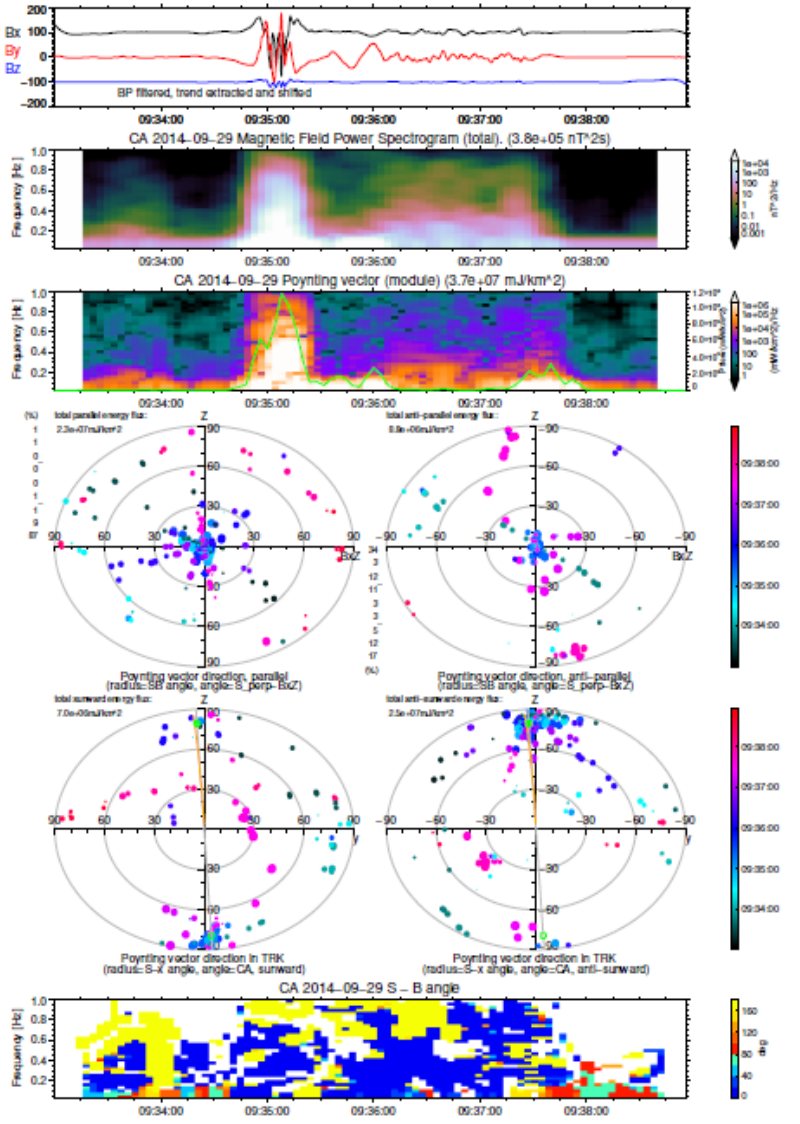
**Poynting Cluster**




- B and Poynting flux S band pass filtered between 40 mHz and 1 Hz
- Maximum S at Cluster ~5000 mW/km$^2$, mapping to some 10 mW/m$^2$ (mapping factor ~2000), but S is not strictly field-aligned.
- Maximum S at Swarm ~1 mW/m$^2$, less than at Cluster, but underestimate and perhaps comparable, given also field-alignment (top polar plots and blue-yellow bottom spectrograms).
- Cluster S, Swarm N, but Cluster close enouugh to the Earth and to the quasi-dipolar region.

**Poynting Swarm H**

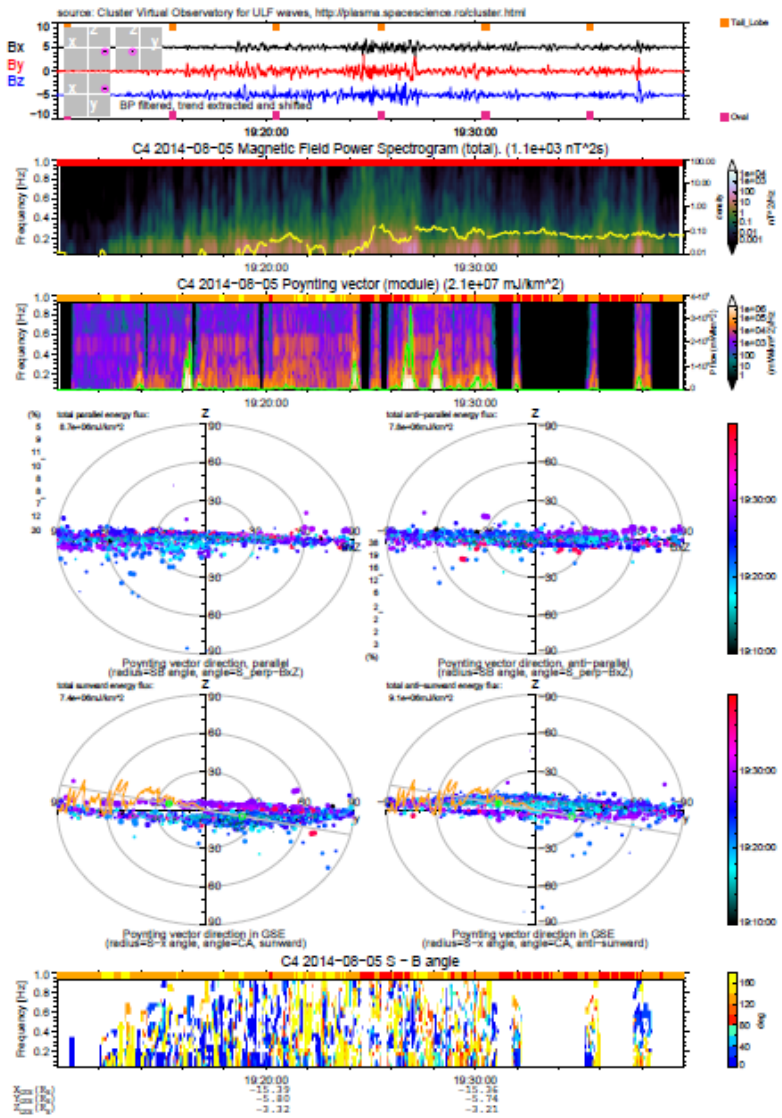


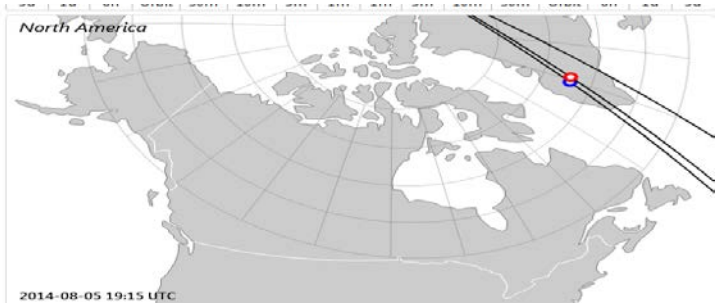

INSTITUTE OF SPACE SCIENCE

SWARM

# B. Cluster – Swarm 'Bad' Event, 5 Aug 2014

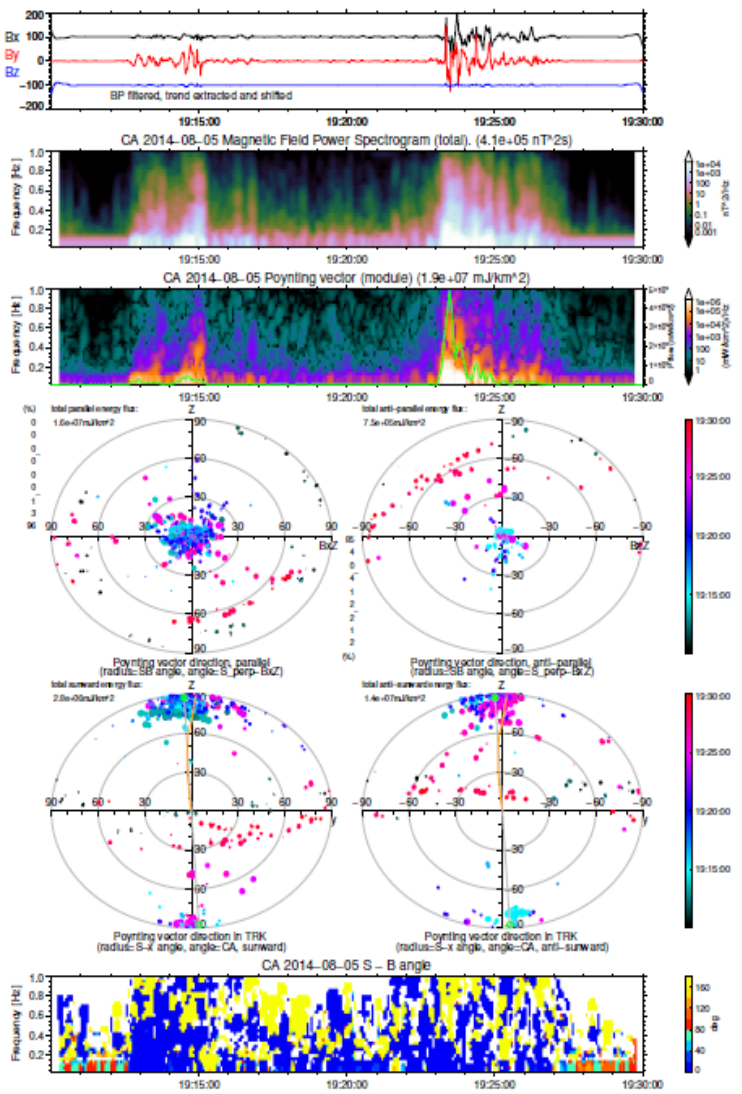
**Poynting Cluster**




- B and Poynting flux S band pass filtered between 40 mHz and 1 Hz
- Maximum S at Cluster ~400,000 mW/km², mapping to some 800 mW/m² (mapping factor ~2000), i.e., huge.
- However, in this case B is close to the Cluster spin plane => S not reliable!!
- Maximum S at Swarm ~0.5 mW/m², much less than at Cluster, but this is not a good event to compare.
- Cluster S, Swarm N, this time Cluster deeper in the tail, i.e., comparison even more problematic.

**Poynting Swarm H**



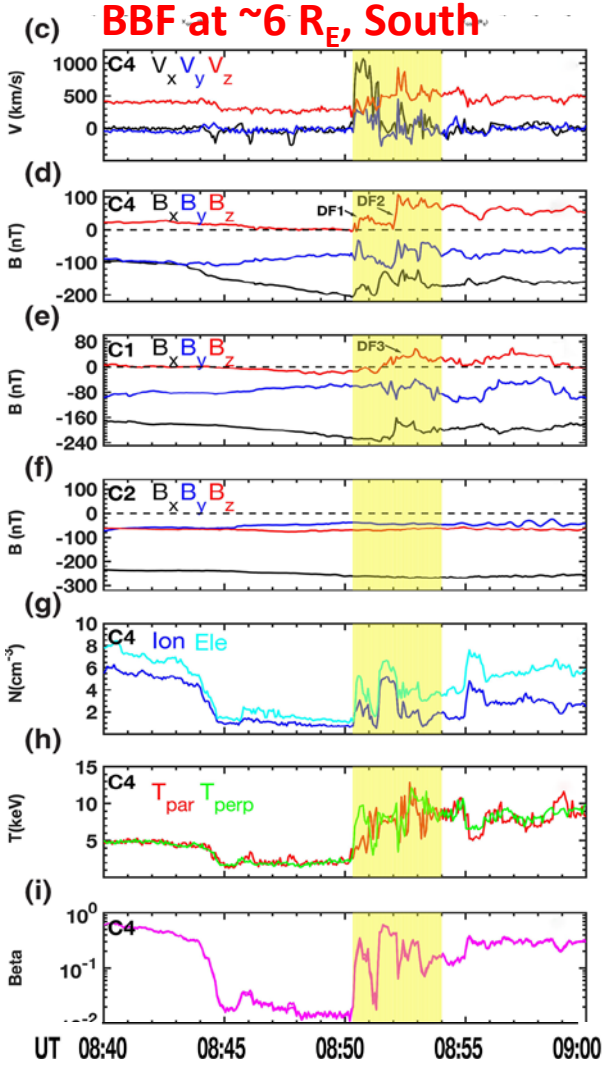

INSTITUTE OF SPACE SCIENCE

SWARM

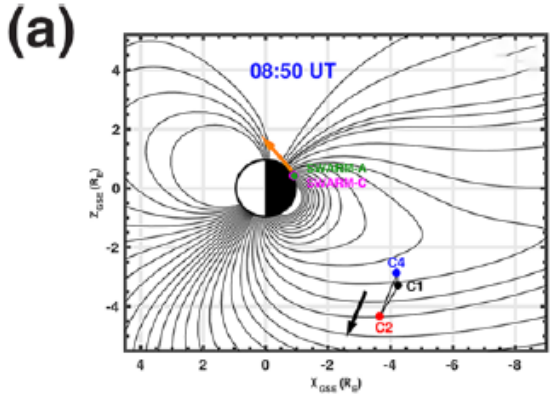
# C. Caveats

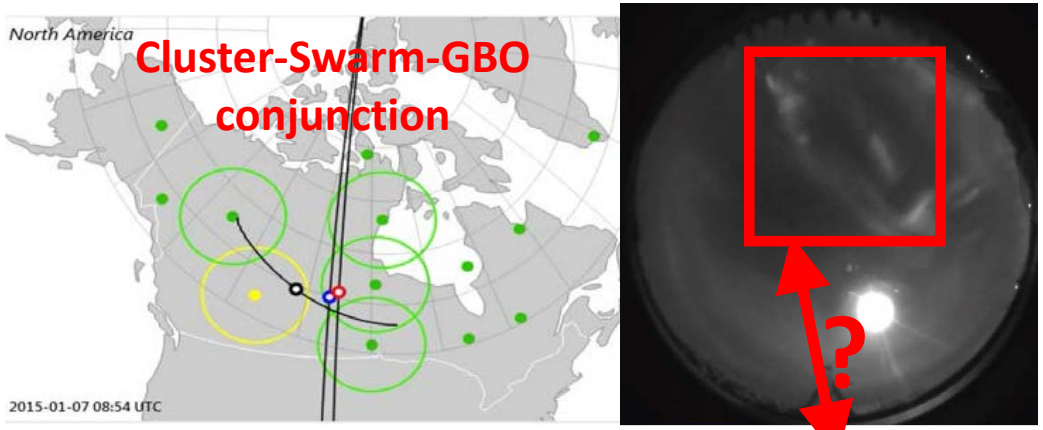
- Cluster
  - Just C1 and C4 with ion data during Swarm life
  - C1/HIA poor duty cycle, < 5% (< 1 h / day)
  - C4/CODIF large noise because of poor count statistics (mass resolution + MCP aging)
  - Angle between B and spin plane
  - …
- Swarm
  - Better accuracy for cross-track velocity, i.e., along-track electric field
  - …
- Both
  - Conjunction accuracy in space
  - Conjunction accuracy in time
  - Relationship to aurora scales and dynamics
  - …

# D. Cluster – Swarm – GBO Event (limited number): Jan 7, 2015

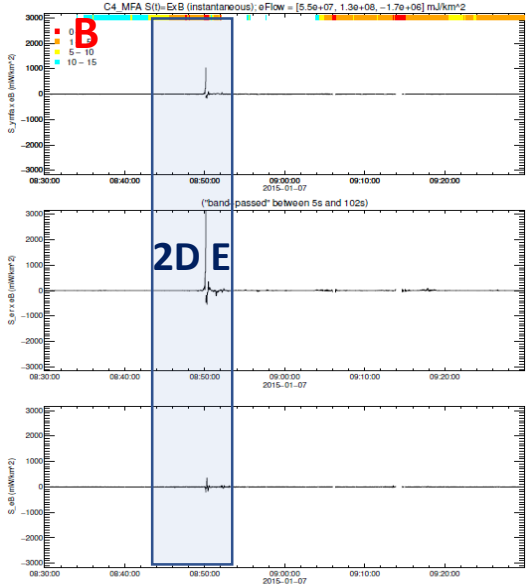


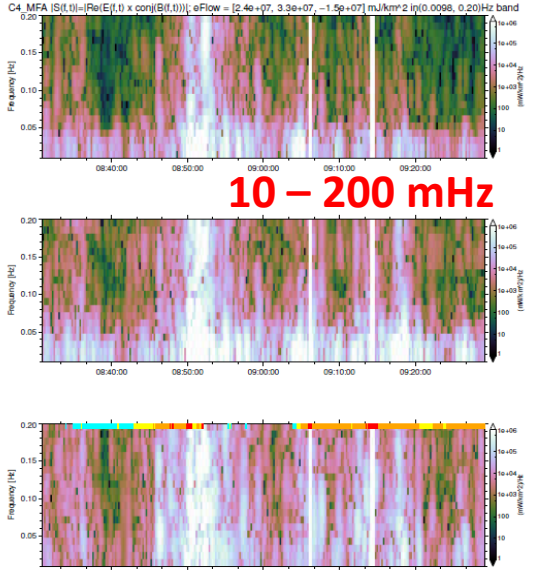

*Wei et al. (2021)*

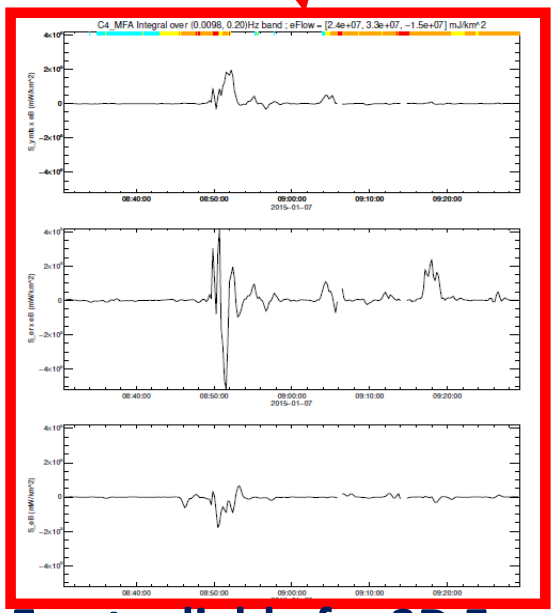



C4 Poynting flux E x



Angle (B, spin plane) in the range $0^O$ - $5^O$ => 2D E not reliable for 3D E

This nice event has to be discarded ☹

# E. Summary and Prospects

- Summary
  - Limited selection of Cluster – Swarm events because of caveats
  - Even more limited for triple conjunctions
  - Still, case studies show promises for further examination of Cluster–Swarm events
  - …
- Prospects
  - Improve event statistics by looking also at 2015 – 2023
  - Check as well triple conjunctions => hunt for at least one good event
  - Extend the study to other magnetospheric satellites like MMS and THEMIS, e.g., BBF database for MMS under project FBURST, poster by Vanina Lanabere
  - Merge energy transfer and momentum transfer perspectives
  - Relate to space weather studies, like correlation of in-situ FAC data, remote electrojet data, and ground magnetic perturbations under project SWESMAG, talk by Adrian Blăgău
  - …