DIPOLARIZATION FRONTS OBSERVED BY THE MMS MISSION

Laboratoire de Physique des Plasmas

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The starting date: 5th of November 2019

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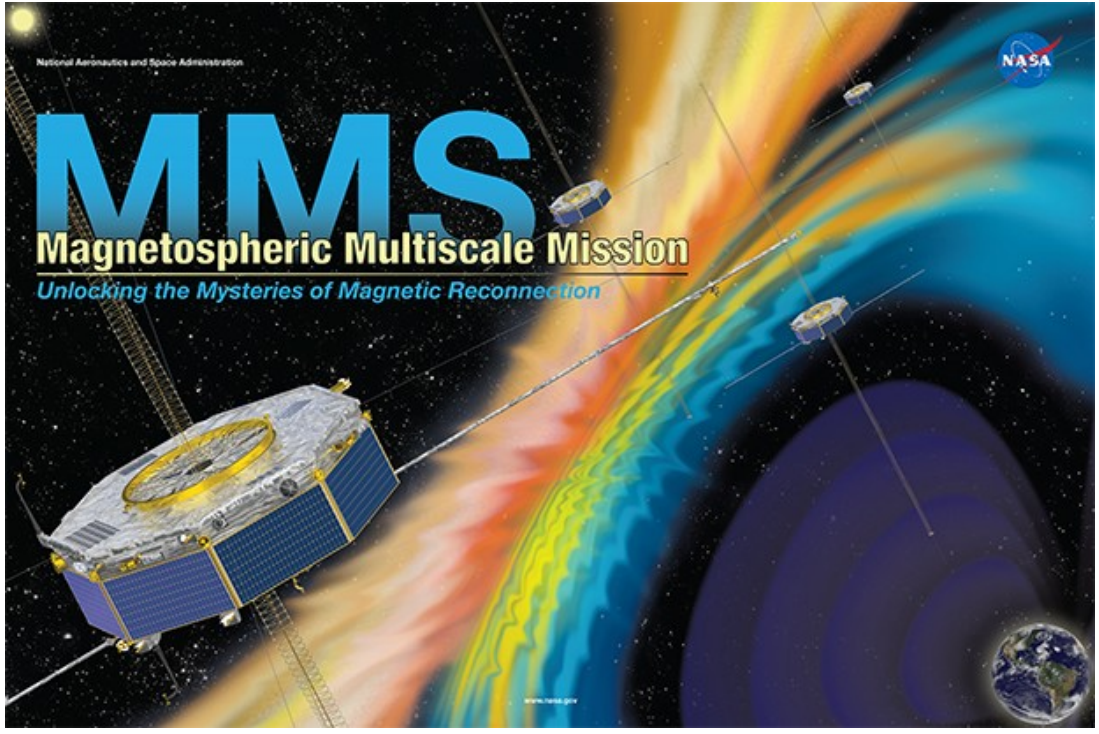
The Magnetospheric Multiscale Mission

MMS is constituted by four identical satellites evolving in a tetrahedron formation separated at electron scales.

investigates:

- how the Sun's and Earth's magnetic fields connect and disconnect, explosively transferring energy?
- It targets the very small electron diffusion region.
- Unprecedented high spatial and time resolutions.
- The key to understanding reconnection regions near Earth, where the most energetic events originate.



What is a Dipolarization Fronts?

Definition: DF is a sharp increase in the northward component of the magnetic field (Z-direction) associated with a fast plasma flow which can be generated by reconnection or flux tube interchange instability. it corresponds to a boundary between a relatively cold and dense plasma at rest and a hot tenuous fastly moving plasma.

Why is studying DF interesting and important?

It has been suggested that they could play an important role in the global energy dissipation process inside the magnetosphere.

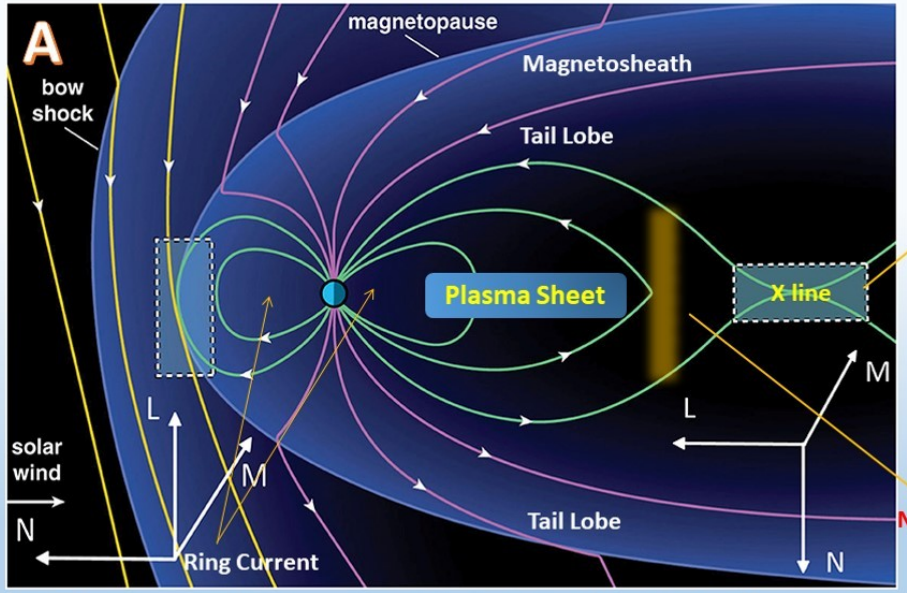
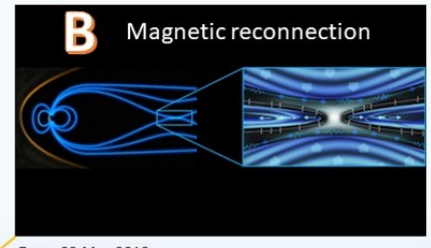
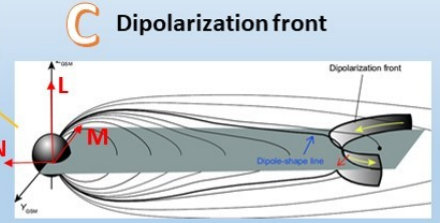


Figure 1. Magnetic reconnection in the magnetosphere during southward magnetic field in the solar wind. Reconnection sites are indicated by two box areas. The LMN coordinate system represents the local normal boundary coordinate system for reconnection at different locations: L is the direction of the reconnecting magnetic field line, M is tangential to the normal and in the direction of the electric current, and N is the normal direction to the boundary layer. The figure is modified from Figure 1 of Burch et al. [2] under the terms of the Creative Commons Attribution 4.0 International License (http://creativecommons.org/licenses/by/4.0/). [L Dai et al, 2020]



Date: 02 May 2013
Satellite: Cluster
Depicts: Magnetic reconnection in the tail of Earth's magnetosphere
Copyright: ESA/ATG medialab



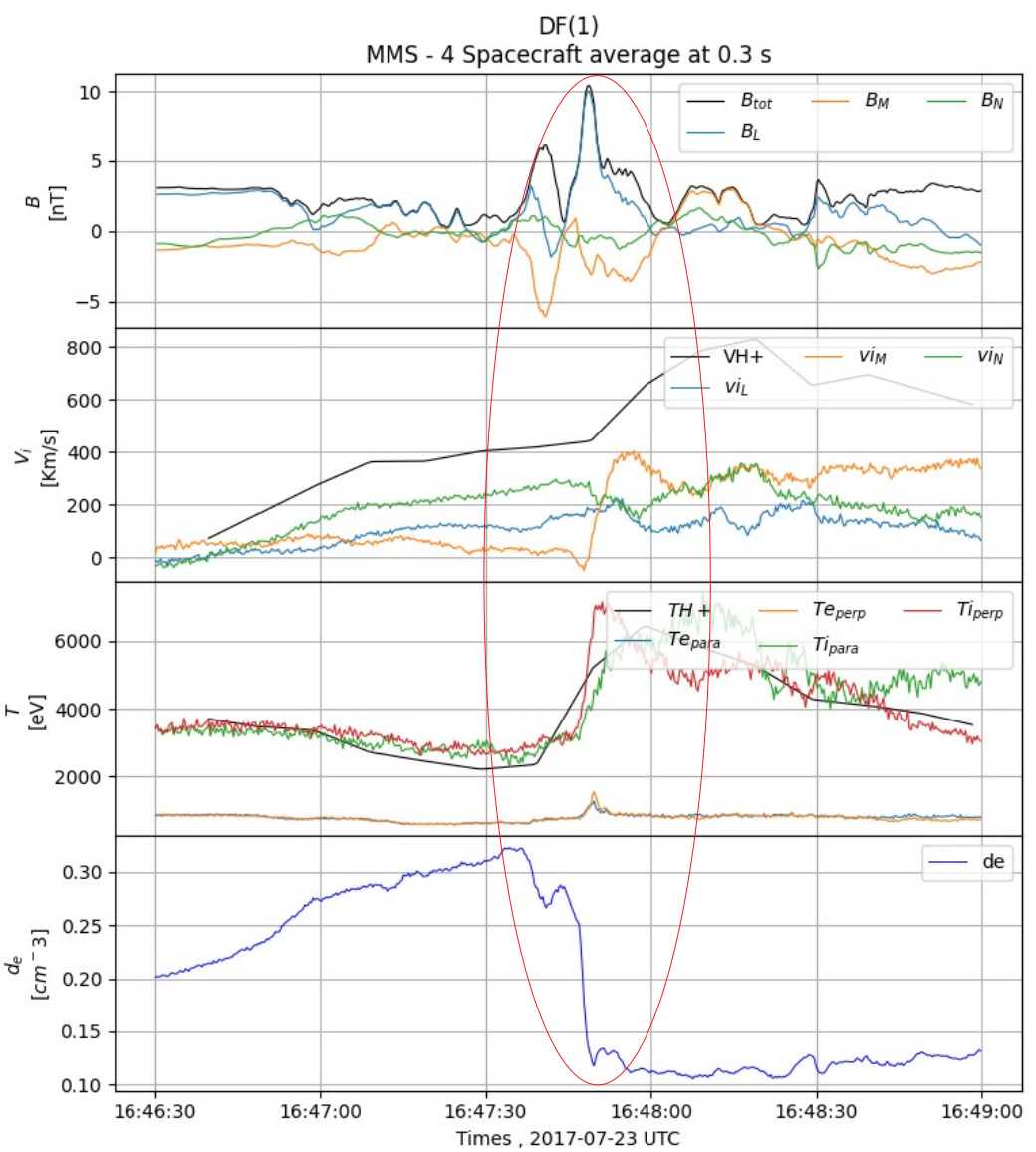
Schematic of the dipolarization front structure in the Earth's magnetotail (modified from Fu et al. (2012c)). [H Fu et al, 2020]

[e.g., (M. S. Nakamura et al., 2002; Fu, Khotyaintsev, Vaivads, Andre, & Huang, 2012; Runov et al., 2009; Angelopoulos et al., 1992; Baumjohann et al., 1990)].

One MMS DF example 16:46:30-16:49:00 UT

DF/fast flow properties [e.g. Runov et al., GRL 2009, Sergeev et al., GRL, 2009]

- Transition between cold dense plasma at rest to hot tenuous fastly moving plasma
- Increase of BL
- Increase of Ve,N&Vi,N
- Decrease of density
- Increase of Tpara,e~Tperp,e ~1 keV
- Increase of Tpara,i~Tperp,i~6 keV

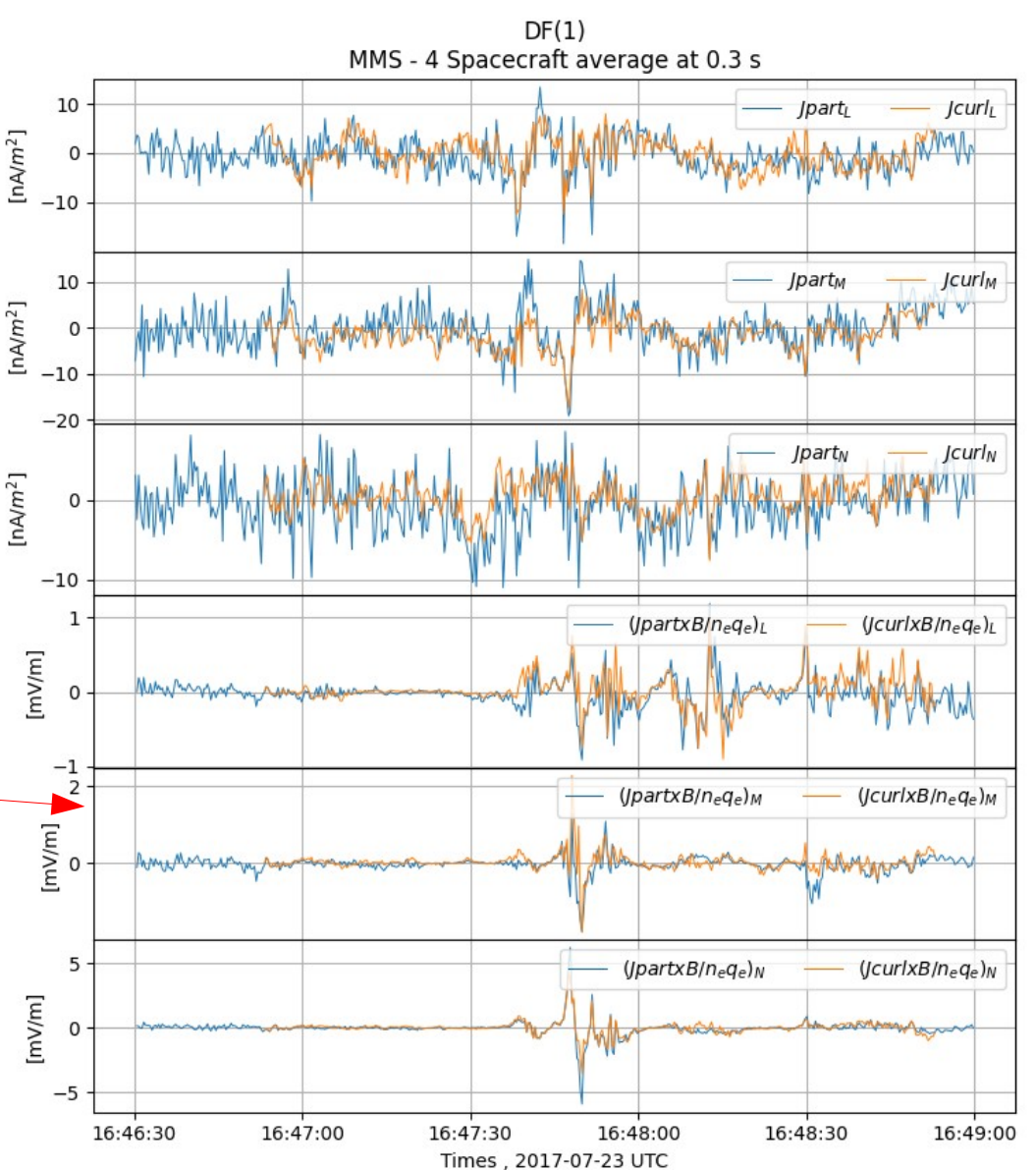


Current density comparisons

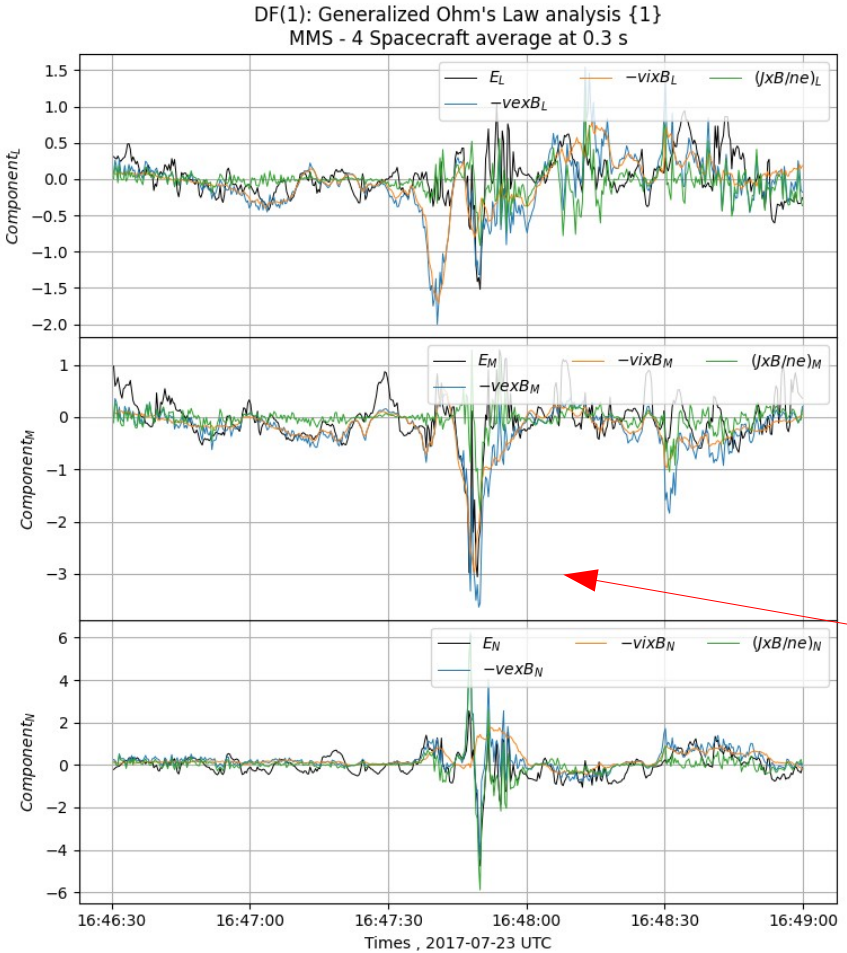
Current density comparison between
Jpart = en(vi-ve) & Jcurl = (CurlB/mu0)
Jpart is calculated from particle (FPI) data and Jcurl from magnetic field (FGM) data, all data are time average 0.3 s.

Small values but good agreement within <10nA/m2

Hall electric field comparison between
E_Hall = JpartxB/(nqe) & (JcurlxB/(nqe)
=> Good confidence in curl and particle moments calculations.
Good agreement within 1 mV/m



Ion Ohm's Law & electron Ohm's Law 1646:05-1649:00 UT

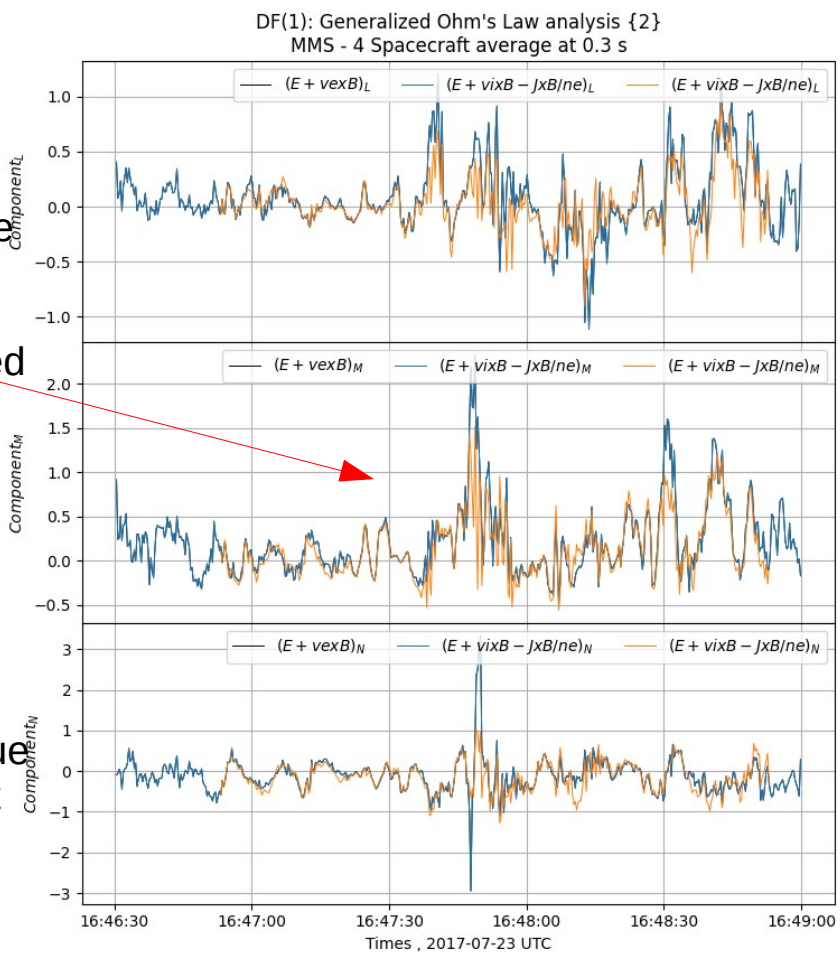


Ohm's Law Electrons

- Good agreement E&(-vexB)~1mV/m, except at the DF.
- Electrons most of the time are magnetized but more investigations needed at DF (curl (E+vexB)=0 ?).

Ohm's Law Ions

- Good agreement E, (-vixB)M,L and (JxB/ne)
- Ions can be decoupled from B due to large Hall fields at DF



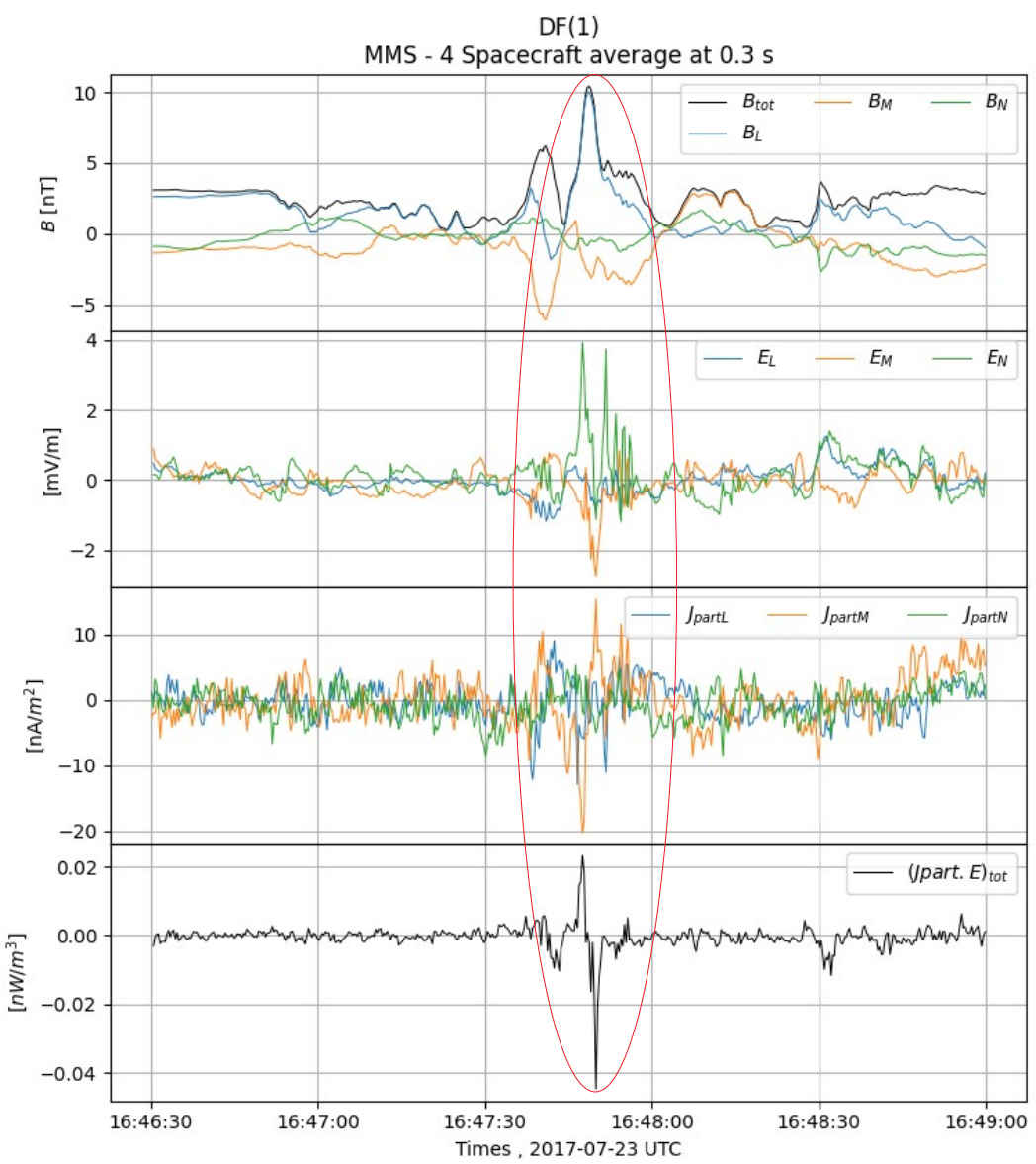
Energy conversion (I)

Right Fig. (s/c frame):

- Max of Jpart,M ~ -20 nA/m2
- EM ~ -2.5 mV/m around 1647:45 UT at DF.

- Max of J.E ~+ 0.023 nW/m3 at DF but negative values before and after DF.

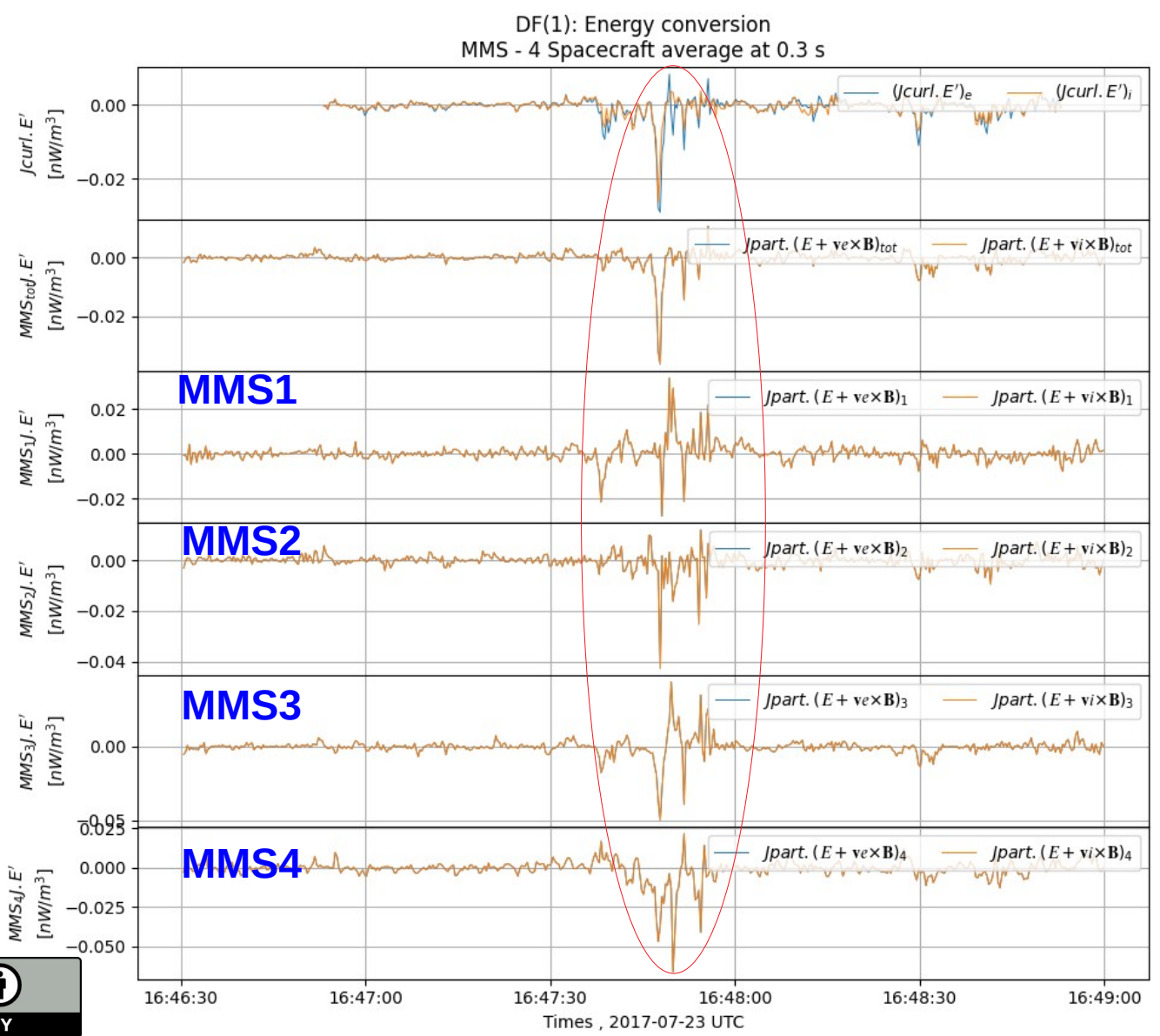
- >0 The energy is dissipated from the electromagnetic field to the particles.
- <0 The energy is transferred from the particles to the electromagnetic field



Energy conversion (II) 16:47:30-16:48:40 UT

Right Fig. (Ion & electron frames):

- We checked that J.(E+vexB) = J.(E+vixB) for each MMS as J.(vixB-vexB)=J.(JxB/ne)=0, [Yao et al., 2017, JGR]
- Using 4 s/c avg J.(E+vexB) = J.(E+vixB) also for both Jpart & Jcurl
- => Good confidence with all J.E' calculations.
- Positive value = Dissipation (energy goes from field to particles) ~ after the DF (from single s/c MSS1, 3 J.E')
- Negative value = Dynamo (energy goes from particles to field) ~ at DF (from 4 s/c and single s/c)
- These results are consistent with [Yao et al., 2017, JGR].



Summary

- I have shown a DF event detected by MMS with classical signatures consistent with general properties of DF.
- I have found a good agreement between current densities calculated from particles and curl B.
- From Ohm's law, I have shown that electrons are almost always magnetized whereas ions can be decoupled from B due to Hall field.
- Energy conversion given by (J.(E+vexB) or (J.(E+vixB)) is not homogeneous at the scale of the tetrahedron:
- In s/c frame: at 4 s/c average value indicates an energy transfer from field to particles (dissipation ~ + 0.023 nW/m3) at the DF crossing.
- In Ion & electron frames: individual s/c values can be positive or negative, Wave activity related to DF will be studied as well as its role in energy conversion processes.

My participation and activities (I)

Communications:

1. EGU, May 4-8, 2020 (virtual), Poster with discussion
   hal-02953918v1 Poster
   Soboh Alqeeq, Olivier Le Contel, Patrick Canu, A. Retino, Thomas Chust et al. Analysis of energy conversion processes at kinetic scales associated with a series of dipolarization fronts observed by MMS during a substorm EGU General Assembly 2020, May 2020, Vienna, Austria. ⟨10.5194/egusphere-egu2020-19750⟩
2. Fall MMS SWT organized by GFSC, Online, Oct. 6th, 2020, oral presentation.
3. PLAS@PAR scientific day, Oct. 5th, 2020, Conference Center at Sorbonne Université, Poster.
4. AGU, Dec. 1-17, 2020 (virtual), Poster with discussion
   S. Alqeeq et al., Energy conversion associated with a series of dipolarization fronts observed by MMS, Virtual Poster Session SM041, Dec. 15, AGU 2020.
5. EGU, April 19-30, 2021 (virtual), Poster with discussion
   Title: Investigation of energy conversion processes and wave activity related to dipolarization fronts observed by MMS.
6. PhD Day, organized by LPP, Feb. 3th, 2021, on line, oral presentation.
7. Elbereth conference, organized by PhD students, Feb. 10th, 2021, on line, oral presentation.

Publications:

I am preparing a draft to present these results and including three similar events and to be submitted to JGR.
Alqeeq, S., O. Le Contel, P. Canu, et al., title: Homogeneity of energy conversion processes at DF.


LPP
Thank you for your attention