A STATISTICAL STUDY OF DIPOLARIZATION FRONTS OBSERVED BY MMS

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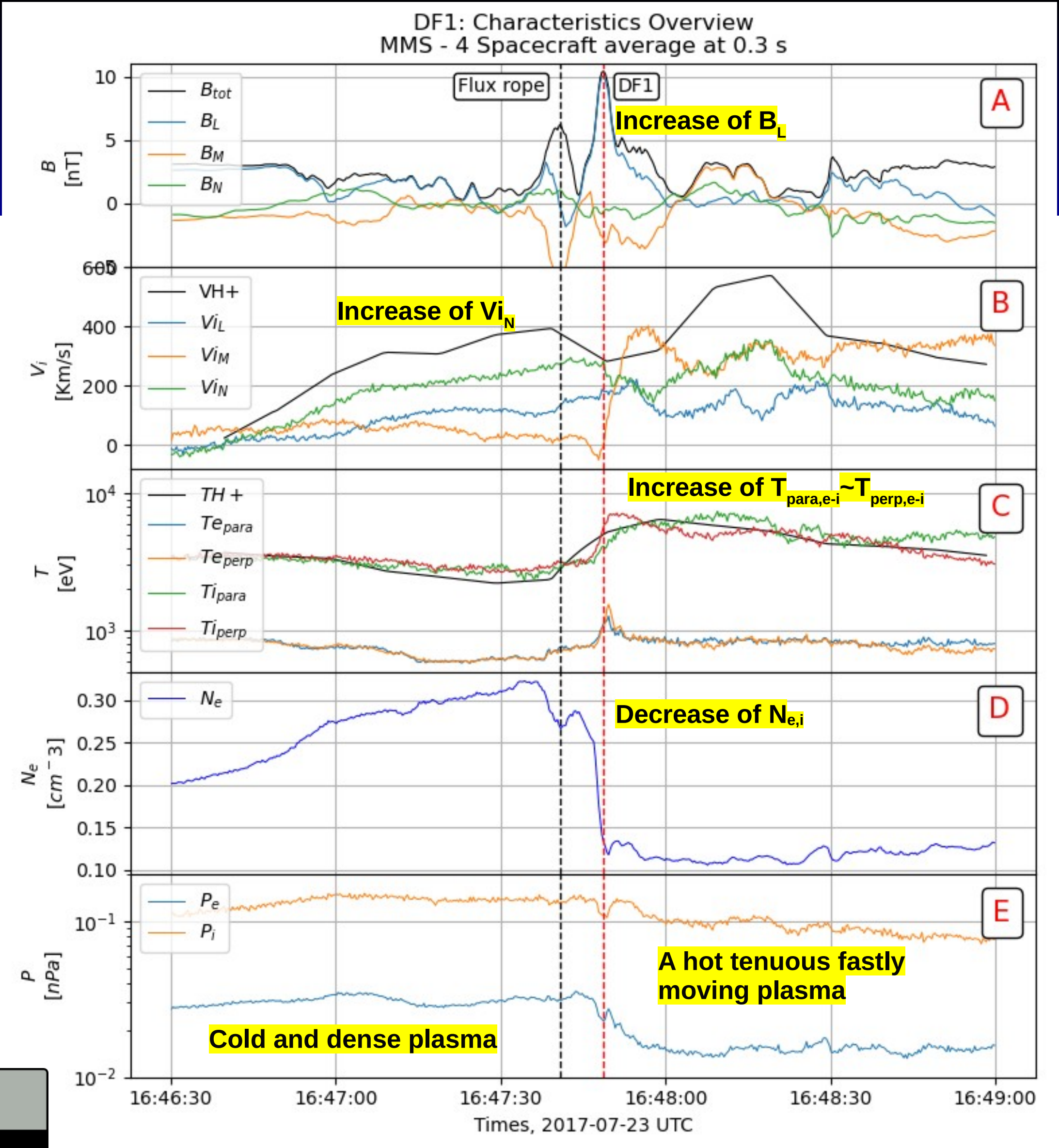
One MMS DF example 16:46:30-16:49:00 UT

Alqeeq et al. 2021

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
- **MVA analysis** at (16:47:45/16:48:00): **LMN** frame of DF:
  L =(0.370 , 0.231, 0.899)
  M=(-0.485, 0.873,-0.025)
  N=(-0.791, -0.427,0.436)
- Increase of $\mathbf{B}_L$
- Increase of $\mathbf{Vi}_N$
- Increase of $\mathbf{T}_{para,e}$~$\mathbf{T}_{perp,e}$ ~1 keV
- Increase of $\mathbf{T}_{para,i}$~$\mathbf{T}_{perp,i}$~6 keV
- Decrease of $\mathbf{N}_{e,i}$



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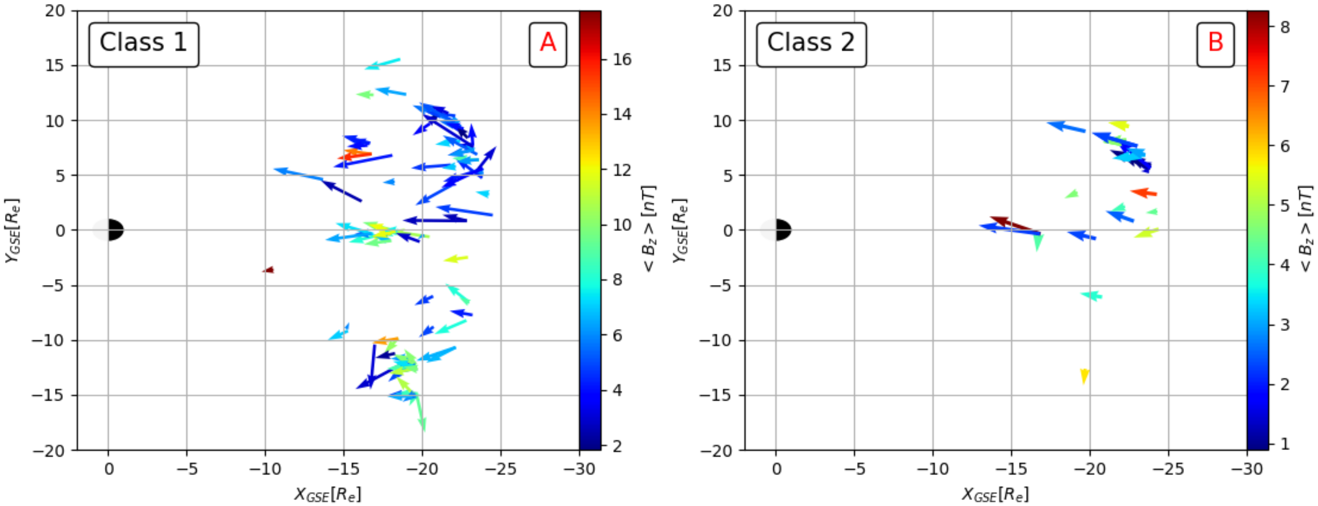
A statistical study of DFs

Alqeeq et al. 2022 In Prep.

- The statistical study include the full magnetotail season of 2017 in order to compare with Zhong et al., 2019 study.
- We found 133 DF events near the Earth's magnetotail equator (|**Bx**|<5nT), using an AIDApy tool to request **Bz** and **Vi** increase and **Ne** decrease.
- This first automatic selection is then adjusted manually with the following criteria:
- Burst mode (partmoms) data are available at least 30s before and after the DF. The head of the DF denotes the time t0.
- **Bz** increase > 5 nT
- **Vi** > 150 km/s
- $\mathbf{N_{e,i}}$ decrease
- $\mathbf{T_{para,e\text{-}i}}$~$\mathbf{T_{perp,e\text{-}i}}$ increases.



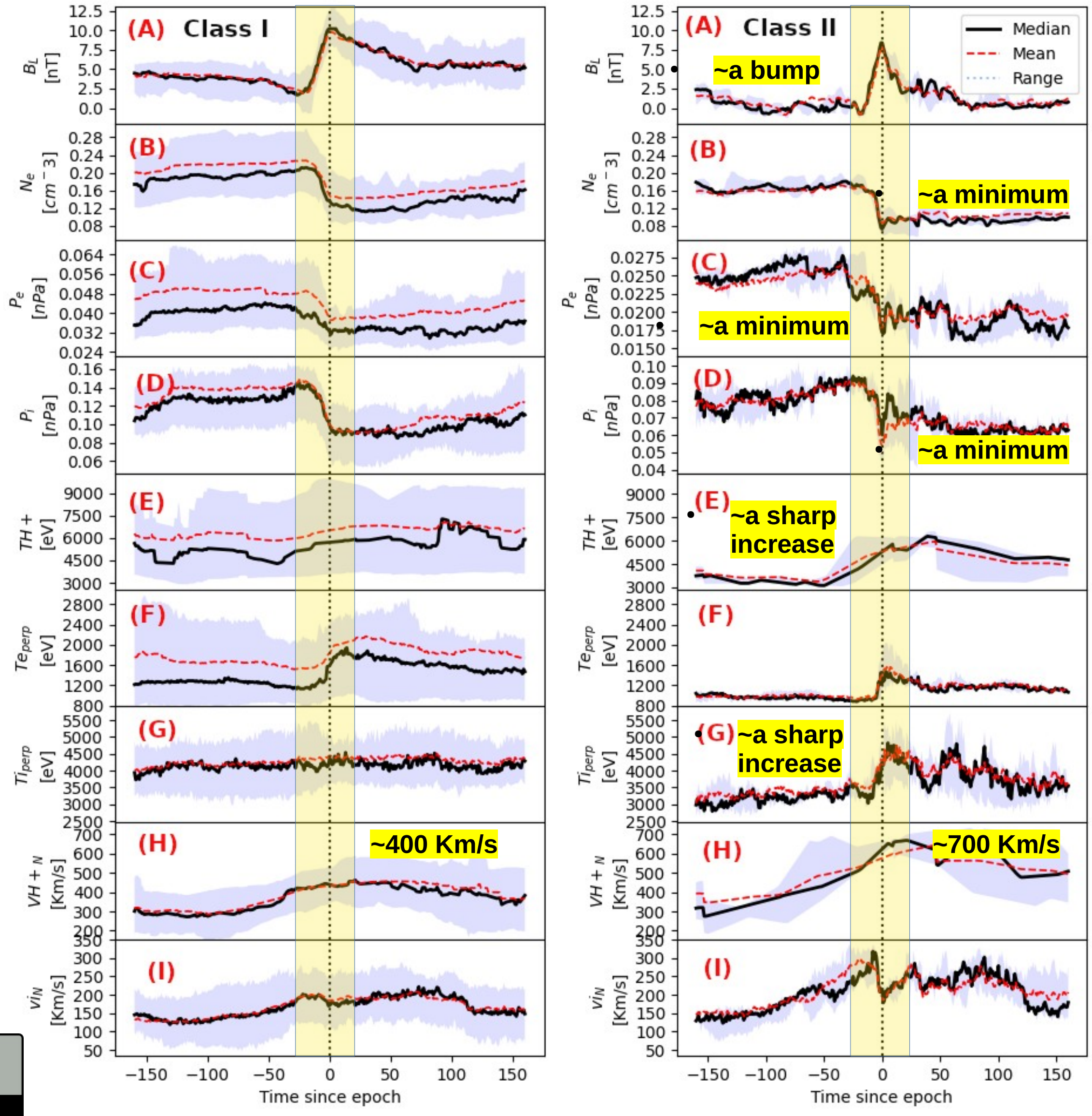
The colors represent the change in the northward magnetic field component during the DF, <**Bz**>, and the arrows represent the DF propagation direction perpendicular to the boundary (obtained by the timing method), projected onto the X/Y plane in GSM.

An overview of DFs

Characteristics overview of DFs

- **The Class 1** (74.4%) corresponds to a slow decrease of the magnetic field after the DF and is associated with smaller ion velocity and hotter plasma.

- **The Class 2** (25.6%) has the same time scale for the rising and the falling of the magnetic field (a bump) associated with a minimum of ion and electron pressures and faster velocity as shown in **Alqeeq et al. 2021.**



Current density comparisons

MMS - 4 Spacecraft average at 0.3s

Current density comparison between:

$Jpart_M = en(vi-ve)_M$

$Jcurl_M = (CurlB/mu)_M$

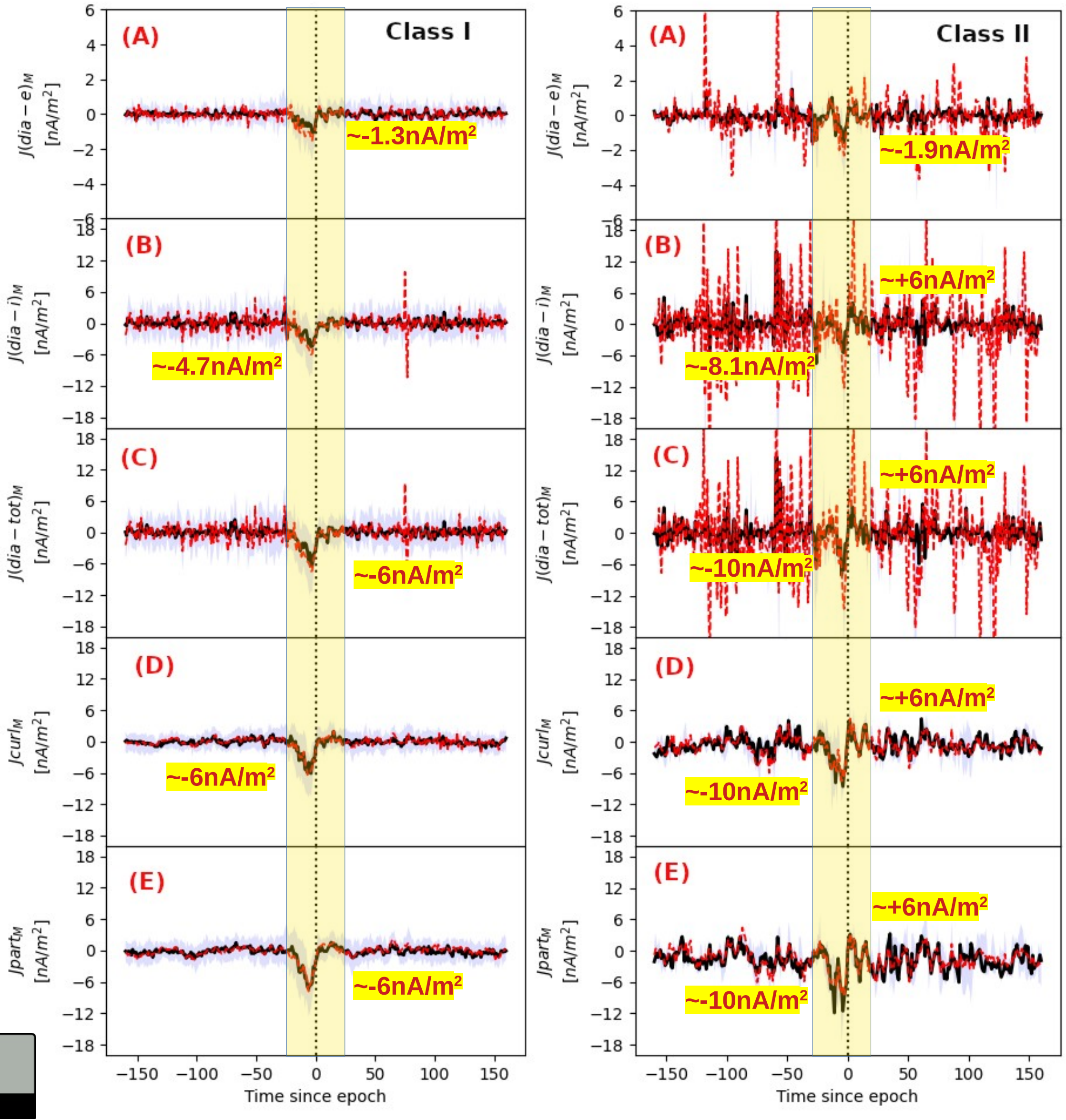
$Jdia_M = B_L/B^2 \nabla n\ (Pi+Pe)$

$Jdia_{\{M,i\}} > Jdia_{\{M,e\}}$

Ion diamagnetic current is dominant (~72%).

Small values but good agreement within <10nA/m2

In Class 2 the reversal in $Jpart_M$ is due to the reversal of the diamagnetic current.



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Energy conversion comparisons, MMS - 4 Spacecraft average at 0.3s

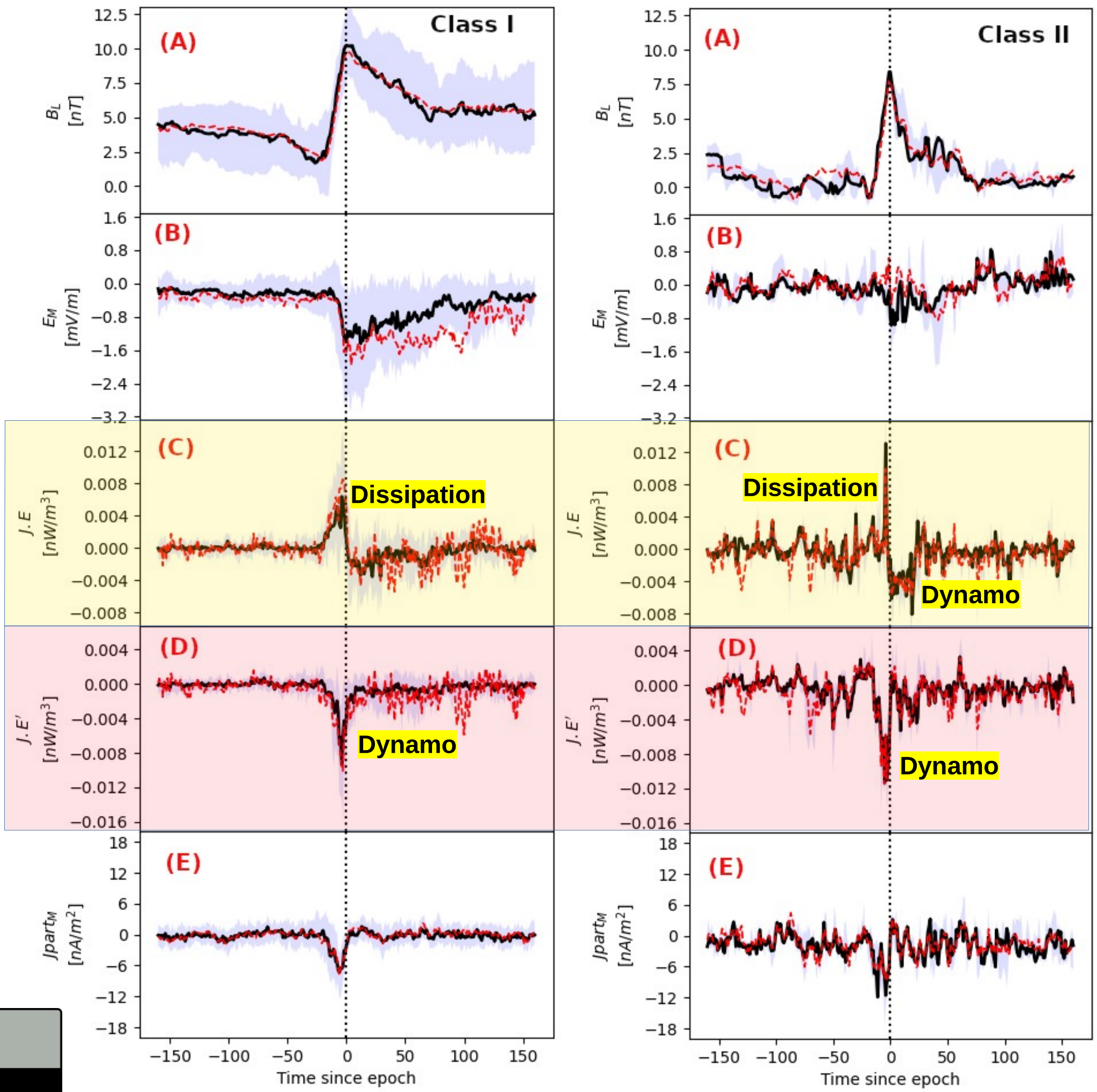
Class1:

- **In (s/c frame):**
  Ahead of DF, Jpart.E >0 The energy is dissipated from the electromagnetic field to the particles.
- **In (Ion & electron frames):**
  Ahead of DF, Jpart.E'<0 Dynamo (energy goes from particles to field).

Class2:

- **In (s/c frame):**
  Ahead of DF, Jpart.E >0 The energy is dissipated from the electromagnetic field to the particles.
  Behind of DF, **Jpart.E** <0 The energy is transferred from the particles to the electromagnetic field.
- **In (Ion & electron frames):**
  Ahead of DF, Jpart.E'<0 Dynamo (energy goes from particles to field)

In Class 2 the reversal in (S/C & ion/electron frames) is due to the reversal of the diamagnetic current.



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Summary & Conclusion

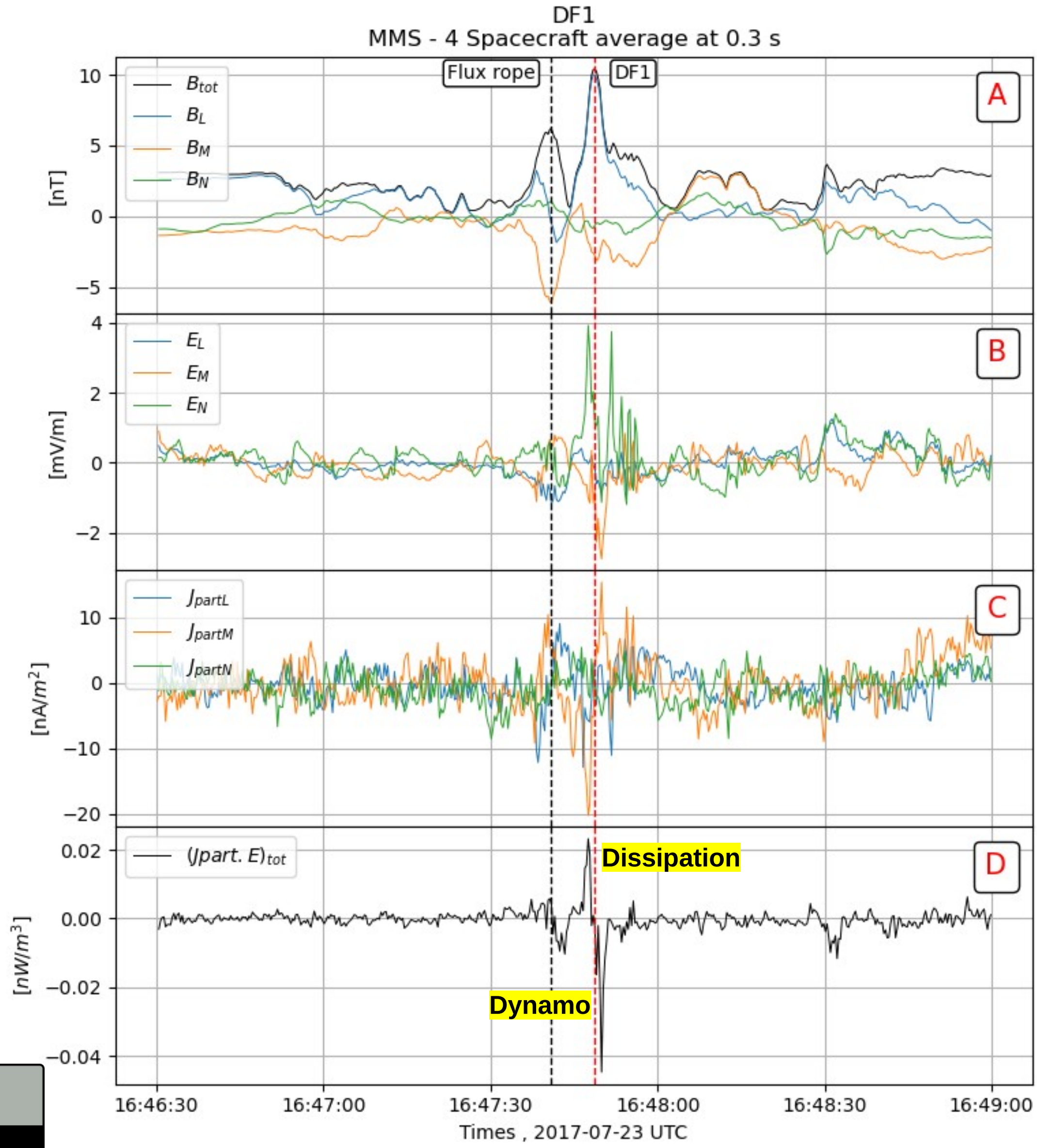
For the full magnetotail season of 2017:

- Based on a superposed epoch analysis of DF basic properties (magnetic field, density, velocity, …) we distinguish two subcategories of events depending on the shape of the DF.
- The **Class 1** (74.4%) corresponds to a slow decrease of the magnetic field after the DF and is associated with smaller ion velocity and hotter plasma.
- The **Class 2** (25.6%) has the same time scale for the rising and the falling of the magnetic field (a bump) associated with a minimum of ion and electron pressures and faster velocity as shown in Alqeeq et al. 2021, and it found mostly on the duskside.
- For both categories we found a good agreement between current densities calculated from particles, Curl B and single S/C method ($Jdia_M$).
- For both categories we found that ions are mostly decoupled from the magnetic field by the Hall fields.
- The electron pressure gradient term is also contributing to the ion decoupling and likely responsible for an electron decoupling at DF. We also analyzed the energy conversion process.
- For the **Class 1** we found that the energy dissipation in the **S/C frame** is transferred from the electromagnetic field to the plasma ($\mathbf{J}\cdot\mathbf{E}>0$) ahead or at the DF.
- For the **Class 2**, we found the same behavior ahead or at the DF whereas it is the opposite ($\mathbf{J}\cdot\mathbf{E}<0$, Dynamo) behind due to the reversal of the diamagnetic current.
- **In the fluid frame**, we found that the energy dynamo is mostly transferred from the plasma to the electromagnetic field ($\mathbf{J}\cdot\mathbf{E}'<0$) ahead or at the DF for both subcategories.

Backup/ Energy conversion (I)

In (s/c frame):

- Max of $Jpart_M$ ~ -20 nA/m2
- E_M ~ -2.5 mV/m around 1647:45 UT at DF.
- **Ahead of the front**, the energy is dissipated from the electromagnetic field to the particles.
- **Behind the front**, the energy is transferred from the particles to the electromagnetic field.
- Max of J.E +0.023 nW/m³ at DF and J.E - 0.043 nW/m³ after DF.
- Max of J.E - 0.01 nW/m³ at Flux rope.

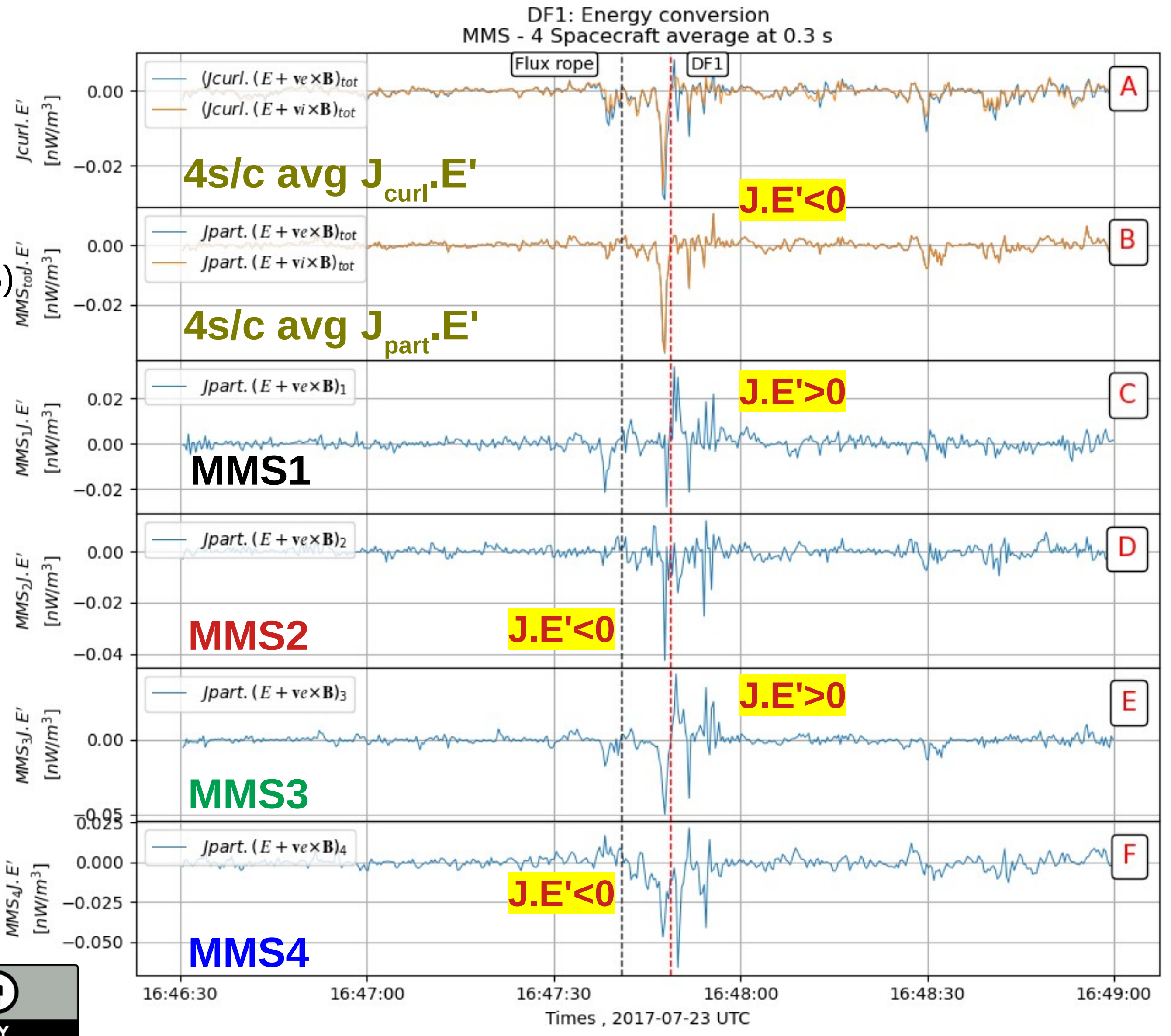


Energy conversion (II) 16:47:30-16:48:40 UT

LPP

In (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.
- J.E'>0, Dissipation (energy goes from field to particles) ~ after the DF (from single s/c MSS1, 3)
- J.E'<0, Dynamo (energy goes from particles to field) ~ at DF (from 4 s/c and all singles s/c)
- These results are consistent with [Yao et al., 2017, JGR].
- The energy conversion is not homogeneous at the scale of the tetrahedron (elecron scales).



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