INVESTIGATION OF ENERGY CONVERSION PROCESSES AND WAVE ACTIVITY RELATED TO DIPOLARIZATION FRONTS OBSERVED BY MMS


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Substorm event on July 23rd, 2017 around 16:19 UT

Substorm event AE~ 400nT

MMS located in pre-midnight sector near magnetic equator
X~ -23.9RE, Y~ 5.8RE, Z~ 5.4 RE
Substorm overview 16:05-17:30 UT

Small substorm \( \text{AE} \sim 400 \text{ nT} \)
Local onset \( \sim 1619 \text{ UT} \)

- **Quasi-stationary earthward flow**
  \( \text{Vx(HPCA)} \sim 800 \text{ km/s} > \text{Vx(FPI)}, \)
  low density \( \sim 0.1 \text{ p/cc} \) and \( B < 15 \text{ nT} \)
  with current fluctuations \( |\delta j(fpi)| < 30 \text{nA/m}^2 \)

- **Intermittent earthward jets** with embedded DFs

- \( 0 < \text{Vx(HPCA)} < 800 \text{ km/s} \)
  higher density and smaller \( B < 10 \text{ nT} \)
  with smaller current fluctuations \( < 15 \text{nA/m}^2 \)

- Electrostatic fluctuations up to \( Fce \) at the CS edge (\( Bx > 15 \text{ nT} \))
  associated with electron heating

**Two regimes of plasma transport?**

- Flow reversal at the end of event: +800 km/s to -400 km/s
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 \( B_L \)
- Increase of \( V_{i_N} \)
- Increase of \( T_{\text{para},e} \sim T_{\text{perp},e} \sim 1 \text{ keV} \)
- Increase of \( T_{\text{para},i} \sim T_{\text{perp},i} \sim 6 \text{ keV} \)
- Decrease of density
Current density comparison between
$J_{\text{part}} = e(n\mathbf{v}_i - n\mathbf{v}_e)$
and $J_{\text{curl}} = (\text{Curl}\mathbf{B}/\mu_0)$
$J_{\text{part}}$ is calculated from particle (FPI) data
and $J_{\text{curl}}$ from magnetic field (FGM) data,
all data are time averaged at 0.3 s.

Small values but good agreement
within $<10\text{nA/m}^2$.

Hall electric field comparison between
$E_{\text{Hall}} = J_{\text{part}}\mathbf{B}/(nqe)$
and $(J_{\text{curl}}\mathbf{B}/(nqe))$
=> Good confidence in curl and particle
moments calculations.
Good agreement within 1 mV/m.
Ohm’s Law Electrons
- Good agreement $E \& (-v \times B) \sim 1\text{mV/m}$, except at the DF.
- Electrons most of the time are magnetized but more investigations needed at DF ($\text{curl}(E+v \times B)=0$?).

Ohm’s Law Ions
- Good agreement $E, (-v \times B)_{M,L}$ and $(J \times B/\text{ne})$
- Ions can be decoupled from $B$ due to large Hall fields at DF.
Energy conversion \(^{(I)}\)

Right Fig. (s/c frame):

- Max of \(\text{Jpart}_M\) \(-20\) nA/m\(^2\)
- \(E_M\) \(-2.5\) mV/m around 1647:45 UT at 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.
- Max of \(J.E\) \(+0.023\) nW/m\(^3\) at DF and \(J.E\) \(-0.043\) nW/m\(^3\) after DF.
- Max of \(J.E\) \(-0.01\) nW/m\(^3\) at Flux rope.
Right Fig. (Ion & electron frames):

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

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

MMS1

MMS2

MMS3

MMS4
Investigation of the homogeneity in the energy conversion by used the standard deviation (SD), if it is come from E electric field or Jpart current density, and we have normalized SD by the error bars as Delta E=1 mV/m and Delta J = 8 nA/m2.

From SD we noticed a symmetry between all direction and values for Jpart but the opposite for E that mean the non homogeneity come from the electric field.
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.
➢ In s/c frame: 4 s/c average J.E value indicates max of J.E +0.023 nW/m³ at DF crossing and max. of J.E - 0.043 nW/m³ after DF, and max of J.E - 0.01 nW/m³ at Flux rope.
➢ In Ion & electron frames the energy conversion given by (J.(E+vexB)) or (J.(E+vixB)) values indicates that 4 s/c average values are negative and that individual s/c values can be positive or negative are showing that energy conversion is not homogeneous at the electron scale (scale of the tetrahedron).

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