ANALYSIS OF ENERGY CONVERSION PROCESSES AT KINETIC SCALES ASSOCIATED WITH A SERIES OF DIPOLARIZATION FRONTS OBSERVED BY MMS DURING A SUBSTORM

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

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 \( \text{AE} \approx 400 \, \text{nT} \)
Local onset \( \approx 1619 \, \text{UT} \)

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

- **Intermittent earthward jets** with embedded DFs
  \( 0 < V_x(\text{HPCA}) < 800 \, \text{km/s} \)
  higher density and smaller \( B < 10 \, \text{nT} \)
  with smaller current fluctuations \( < 15 \, \text{nA/m}^2 \)

- Electrostatic fluctuations up to \( F_{ce} \) at the CS edge \( (B_x > 15 \, \text{nT}) \)
  associated with electron heating

**Two regimes of plasma transport?**

- Flow reversal at the end of event:
  \(+800\,\text{km/s} \to -400 \, \text{km/s}\)
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 Bz
- Increase of Ve,x&Vi,x
- Decrease of density
- Increase of Tpara,e~Tperp,e ~1 keV
- Increase of Tpara,i~Tperp,i~6 keV but not simultaneous
- Current density <20nAm2
- Ey field ~ 4 mV/m
Current density comparison between 
\[<J_{\text{part}}>= e\langle n \rangle \langle v_i-v_e \rangle\]  
\(<...>\) denotes 4 s/c averaging 
& \(J_{\text{curl}} = (\text{CurlB/mu0})\)

Small values but good agreement within <10nA/m²

Hall field comparison between 
\[<J_{\text{part}}x\text{B}/(nqe)>\]  
& \((J_{\text{curl}}x\text{B}/(nqe))\)

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 $E \& (-v \times B) \sim 1 \text{mV/m}$
- Electrons mostly magnetized

Ions
- Good agreement $E$, $(-v \times B)$ and $(J \times B/\text{ne})$
- Ions can be decoupled from B due to large Hall fields at DF
Energy conversion (I)

- Jpart,y and E field maximums around 1647:45 UT

  Max of Jpart,y $\sim +23$ nA/m$^2$
  Max $(E+vxB)x$ $\sim +8.3$ mV/m
  Max $(E+vxB)y$ $\sim +4.3$ mV/m
  Max $(E+vxB)y$ $\sim 4.3$ mV/m

- Due to high frequency fluctuations energy conversion also appears to be very fluctuating at the DF yet this 4 s/c average suggests a negative value just at the beginning of the DF crossing (sharp increase of Bz).
Energy conversion is not homogeneous at the scale of the tetrahedron:

1/ with regions of dissipation (>0) transfer from field to particles
   Ex: MMS3
2/ regions of energy transfer from particles to field (<0)
   Ex: MMS2
Yet the 4 s/c average is negative
Local electron & ion heating?
Need further investigations
Summary

➢ We have shown a DF event detected by MMS during a subsorm event on July 23rd 2017 with classical signatures consistent with general properties of DF.
➢ We have found a good agreement between current densities calculated from particles and curl B.
➢ From Ohm’s law, we 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:
   4 s/c average value indicates an energy transfer from particle to field at the beginning of the DF crossing (region of temperature and density gradients)
➢ Whereas individual s/c values can be positive or negative which require further investigations.

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