Simultaneous Electron Diffusion Regions at the Magnetopause

J. M. Webster[1], J. L. Burch[2], P. H. Reiff[1], A. Marshall[1], S. Sazykin[1], K. J. Genestreti[3], B. L. Giles[4], R. B. Torbert[3,2], R. E. Ergun[5]
(1)Rice University, Houston, TX, USA, (2)Southwest Research Institute, San Antonio, TX, USA,
(3)University of New Hampshire, Durham, NH, USA, (4)NASA Goddard Space Flight Center, Greenbelt, MD, USA, (5)University of Colorado, Boulder, CO, USA

Abstract:

Magnetopause reconnection is almost always conceptualized as an electron diffusion region (EDR) embedded inside of a larger ion diffusion region. We present evidence of a magnetopause EDR host to fast reconnection, but with only modest ion demagnetization. This EDR is likely in operation simultaneously with another reconnection site. Two separate events on the magnetosphere-side separatrix inside of the demagnetized ion exhaust outflow exhibit instabilities, minor electron demagnetization, and organized **j • E**′ (**E**′ = **E** + **v**$_e$ x **B**). Although the configuration seen in the first event closes many magnetic field lines and creates a large-scale flux rope, the second two events do not. We compare features of these events to encounters that more closely match the typical picture of magnetopause reconnection.

Method:

We use the results of Shay et al. [2016] to determine where MMS resides in the reconnection system:

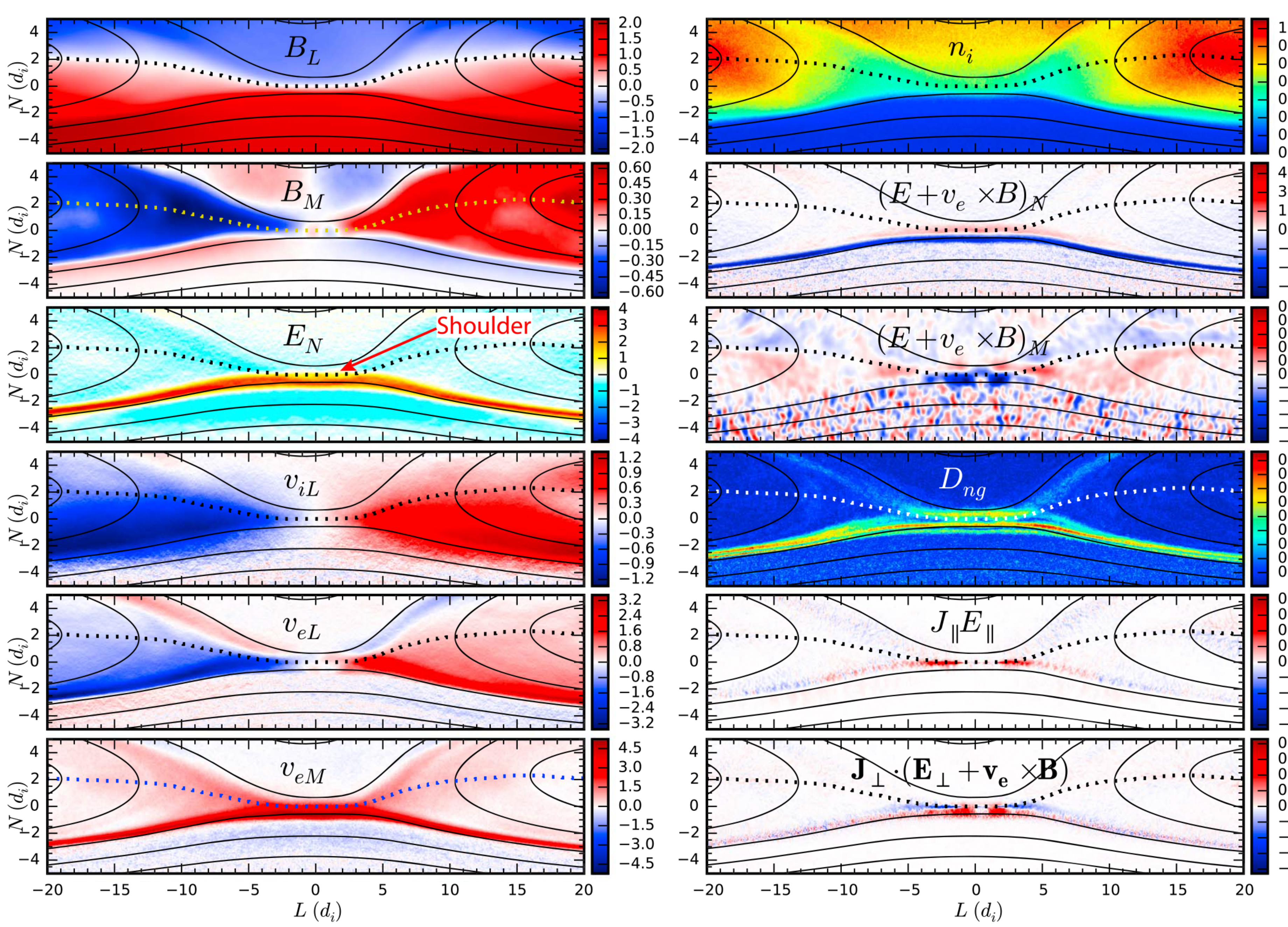


Figure 1: PIC simulation results for various quantities. D_{ng} is a measure of electron agyrotropy. Other quantities are normalized to upstream magnetosheath conditions.

Conclusions:

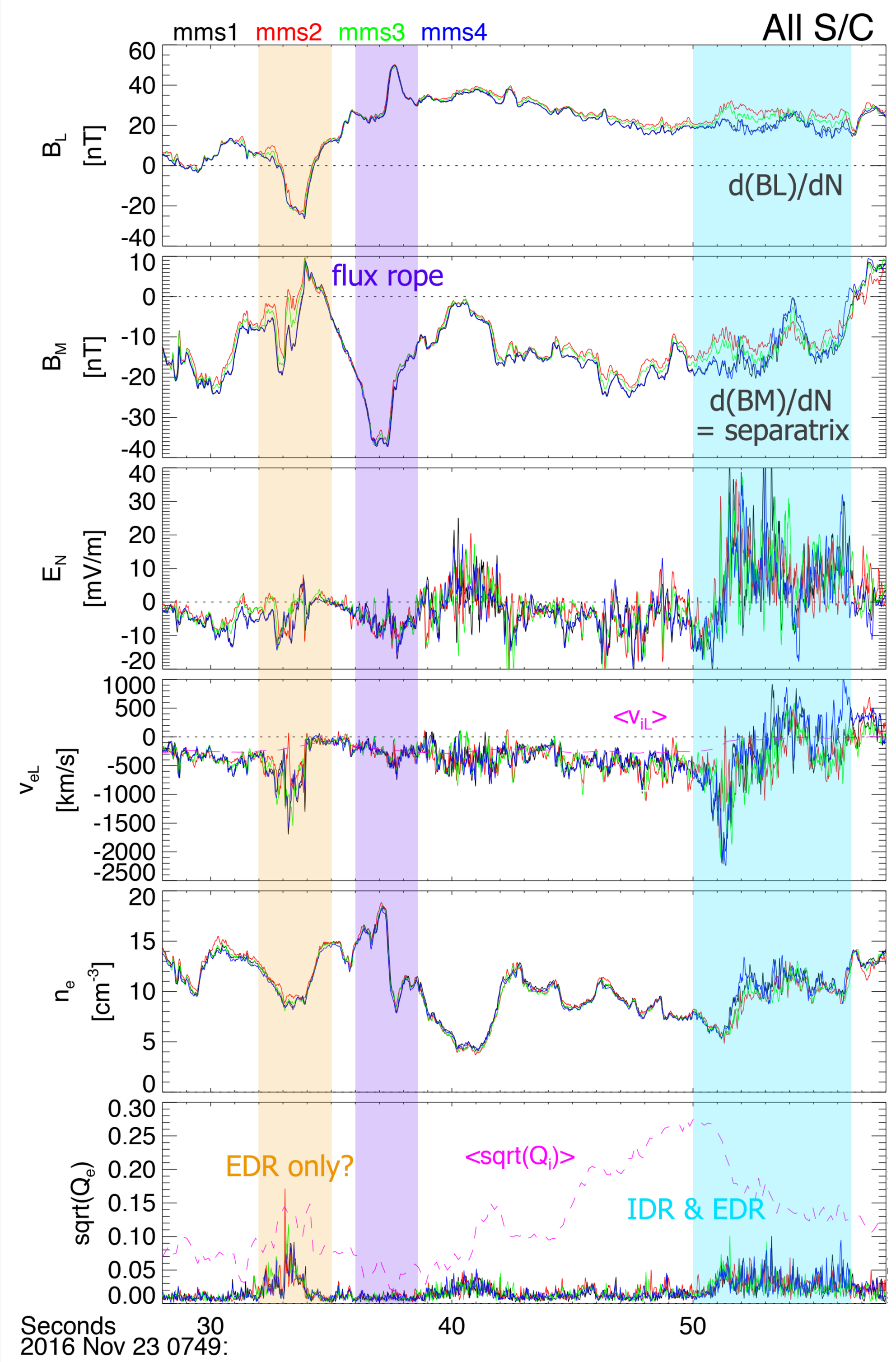
- EDRs can be in simultaneous operation for only ~1 ion gyro period, or long enough to create ion-scale flux ropes.
- Electron-scale structures related to plasma instabilities in the outflow jets near the magnetosphere separatrix likely provide a mechanism to facilitate EDR migration.
- Ohmic energy exchange inside the outflow jets is large (~1 nW/m^3) and can be relatively organized.

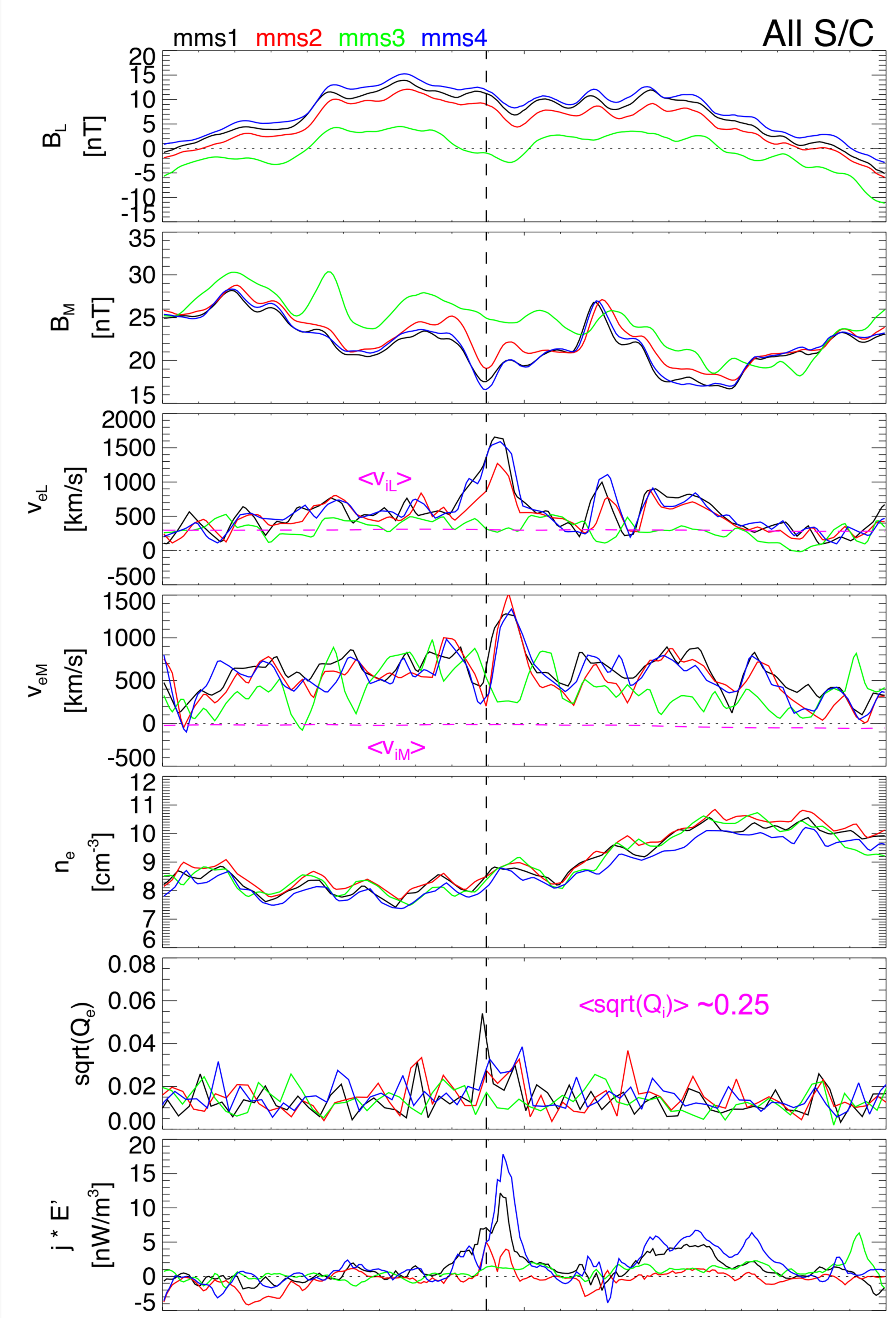
References:

Shay, M. A. et al., 2016, Kinetic Signatures of the Region Surrounding the X-line in Asymmetric (Magnetopause) Reconnection, doi: 10.1002/2016GL069034

Webster, J. M. et al., 2018, Magnetospheric Multiscale Dayside Reconnection Electron Diffusion Region Events, doi: 10.1029/2018JA025245

Figure 2: Ion-scale flux rope between two EDRs.





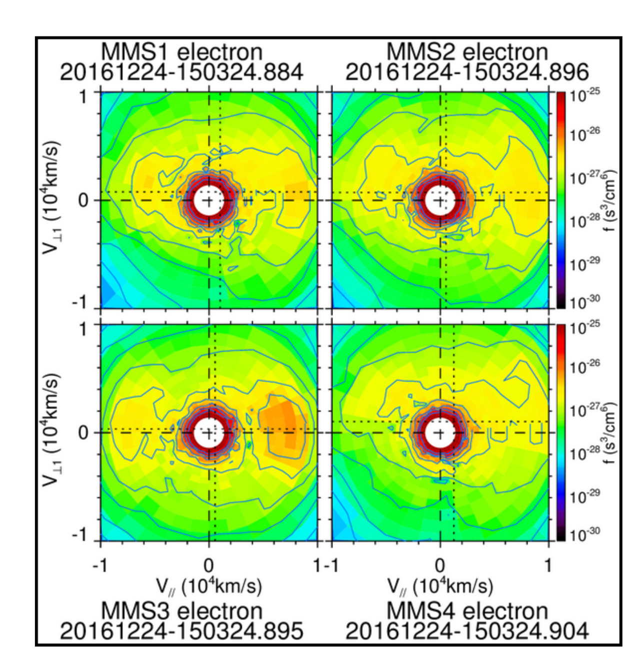
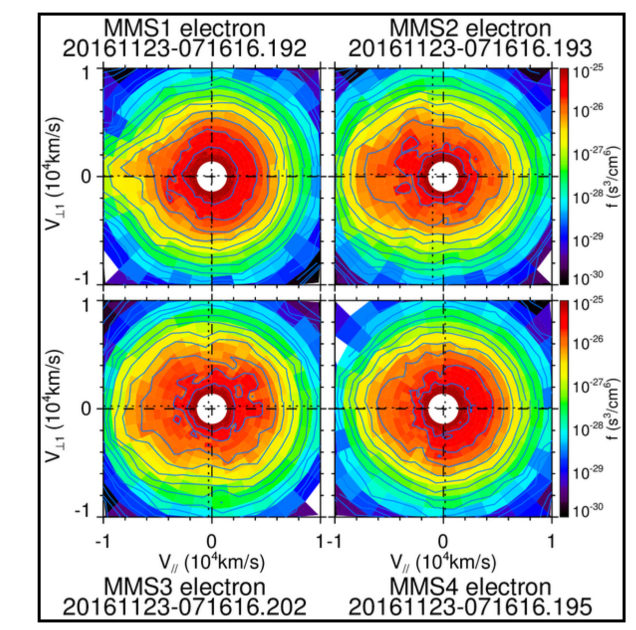


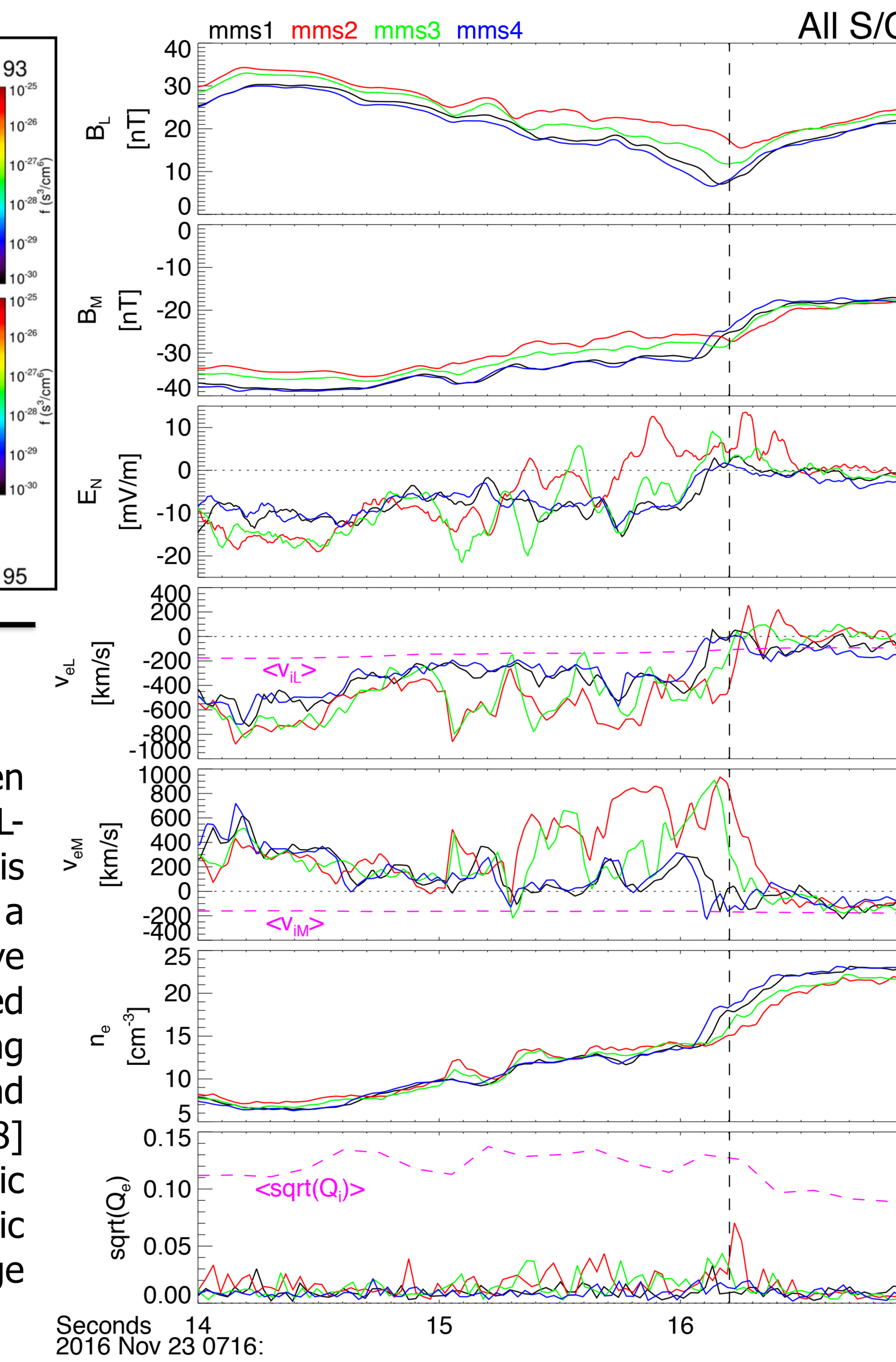
Figure 4: EDR inside of the ion outflow.

Video:

Scan the QR code to watch a YouTube video showing the first EDR encounter from Figure 2

Figure 3: Dissolving reconnection site?





Discussion:

Figure 2 shows an ion-scale flux rope that has formed between two EDR encounters, with no reversal of the negative L-component of ion bulk velocity throughout the interval. This suggests that the first EDR was operating at the same time as a separate reconnection site residing to the north. Relative spacecraft (S/C) positions in the N-direction are easily deduced by examining the largest gradient of B_L. Significant ion coupling in the ion diffusion region (IDR) only occurs prior to the second encounter. Using these two EDRs, Webster et al. [2018] confirmed predictions from the PIC community that Ohmic energy exchange is much more chaotic on the magnetospheric side of the EDR, where turbulence drives especially large fluctuations in **E**.

Figure 3 shows a thin and oscillating current sheet inside of the ion exhaust, south of a reconnection site. The bipolar behavior of v_{eL} and v_{eM} on the edge of the current sheet is a common feature between all four EDR candidates presented here. The gradient of n_e points Earthward on the edge of the current sheet. The velocity distributions suggest a relatively complex magnetic field topology. Shortly after 07:16:16.2, a rapid de-escalation of reconnection indicators implies the dissolution of a previously active EDR.

Figure 4 depicts an EDR inside of a 300 km/s (northwards) ion jet. Again, relative S/C position in the N-direction is easily deduced by the behavior of B_L. The upstream magnetosheath conditions (not shown) for this interval include a 30 nT reconnecting component and a 10 nT guide field. The reconnection rate is large enough to facilitate a ~30 nT Hall magnetic field component. The electron velocity distribution shown for MMS2 suggests closed magnetic field lines, while MMS3 sees open field lines. A hot population meandering perpendicular to the magnetic field is visible for MMS1, 2, and 4. After 15:03:25, distributions become more gyrotropic and show open field lines once again. Using the plots from Shay et al. [2016], we infer that the event takes place near +6 d_i in the L-direction and -1 d_i in the N-direction. A forthcoming analysis by Li et al. studies electron Bernstein waves generated by an EDR at 15:03:32.

A video showing clear evidence of an electron-scale flux rope sweeping by the spacecraft is available by request.

Next:

- Can the magnetic field shear across the near-EDR separatrix exceed the shear across the larger-scale topology for finite guide field events?
- Can a changing guide field component/direction upstream (sheath) influence the direction (in +/-L) of EDR migration?
- Bipolar v_{eL} and v_{eM}: eddy currents, electron K-H, wave-particle instabilities, on-off reconnection, surface/LHDI waves?
- d(n_e)/dN gradient reversal, but only sometimes? Double layer? Instrumental?
- Temporal evolution: curl(E) and curl(E′) vs. measured dB/dt