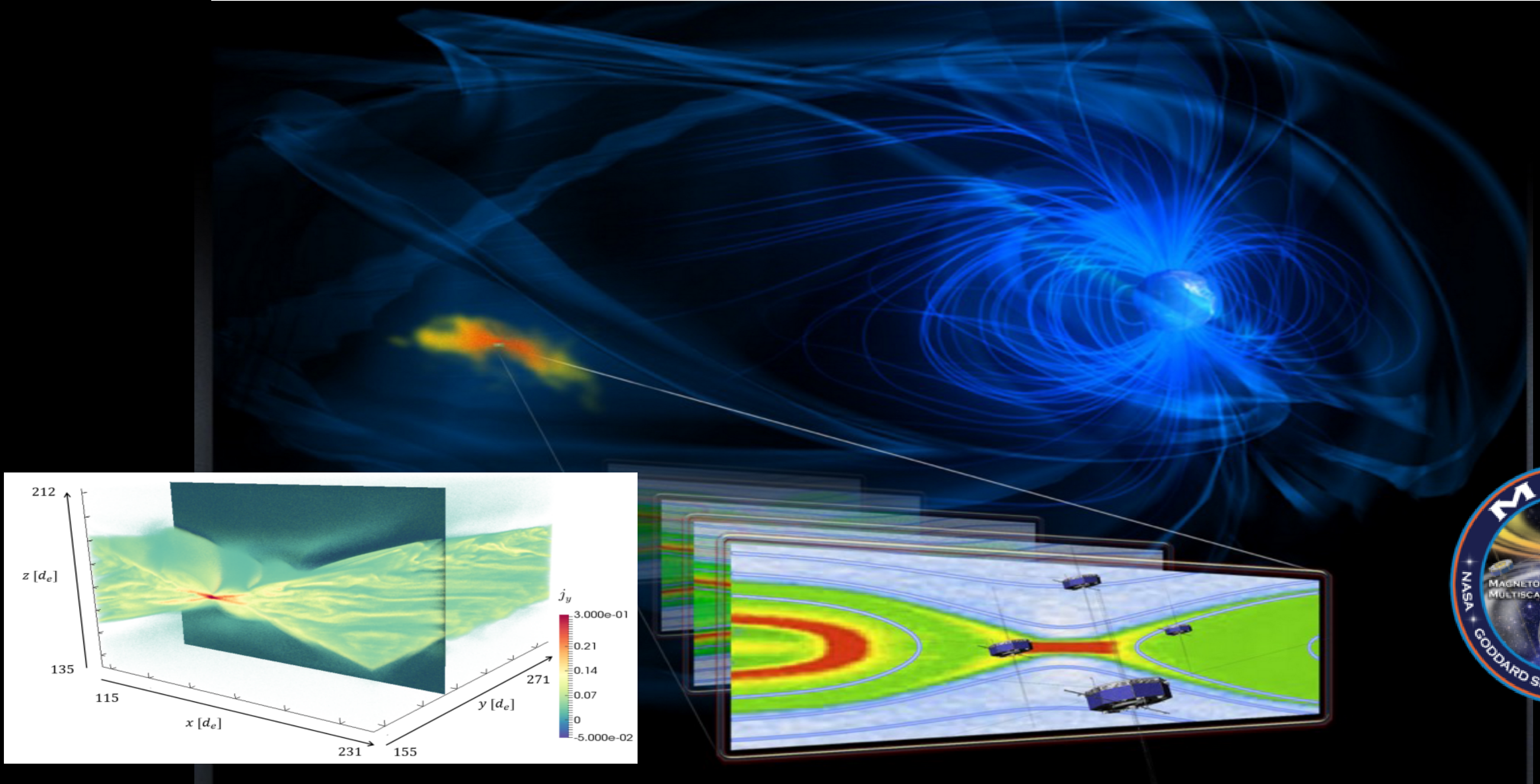
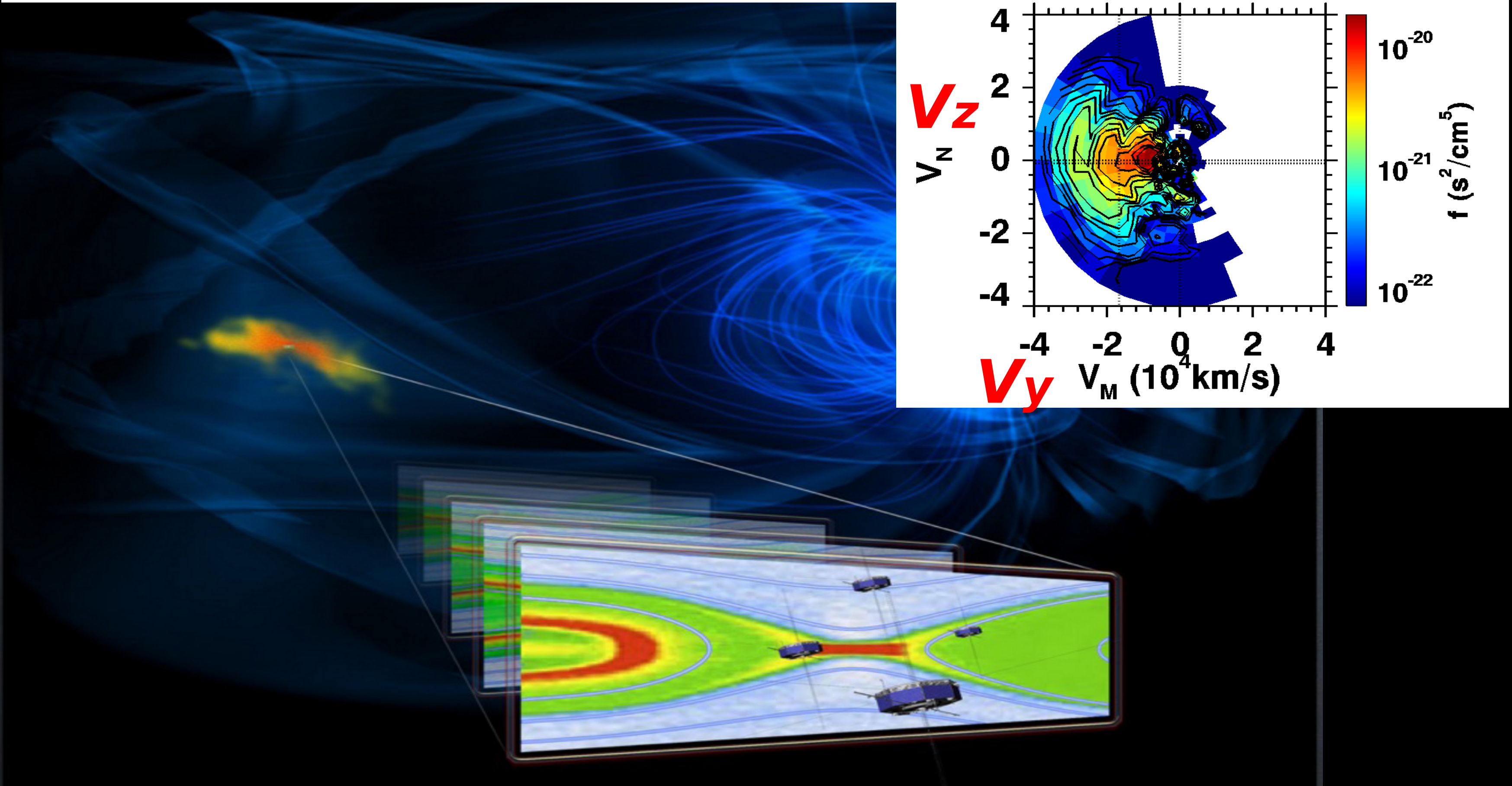
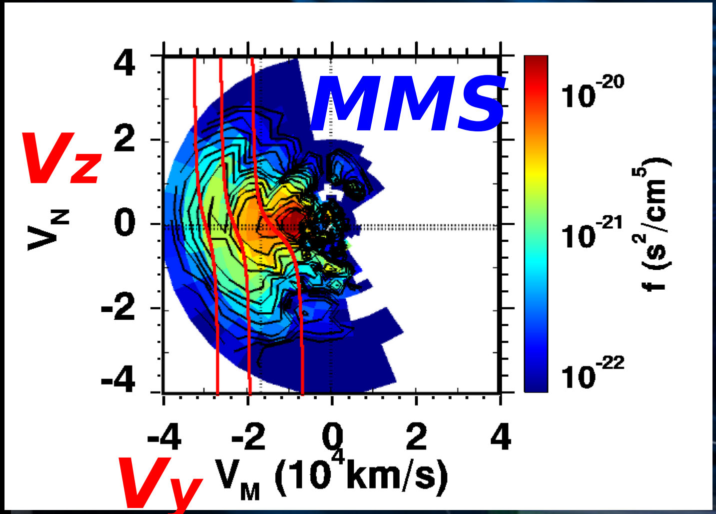
Faces of the reconnection layer: laminar vs. turbulent



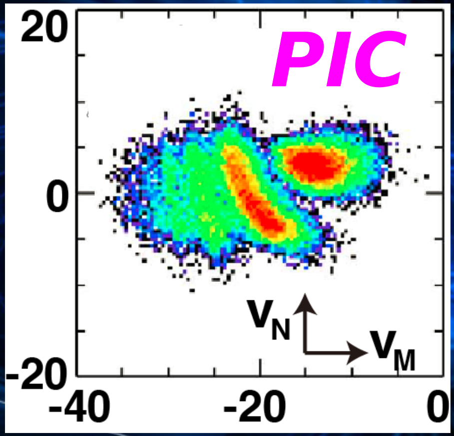
Laminar reconnection layer
Bg~0



Laminar EDR:
multi-crescents ↔ multi- bounce electrons



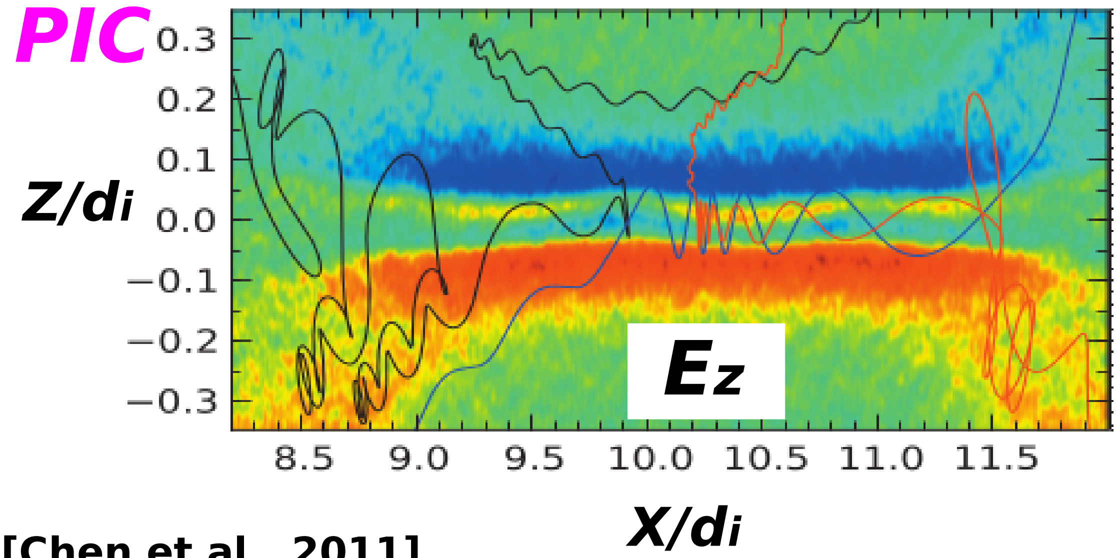
[Bessho et al., 2018]



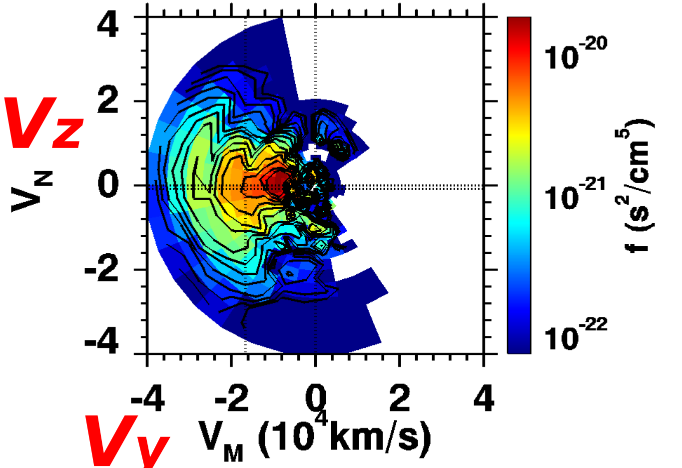
[Shuster et al., 2015]

See also similar PIC DFs in [Hesse et al., 2018; Torbert et al., 2018; Bessho et al., 2018]

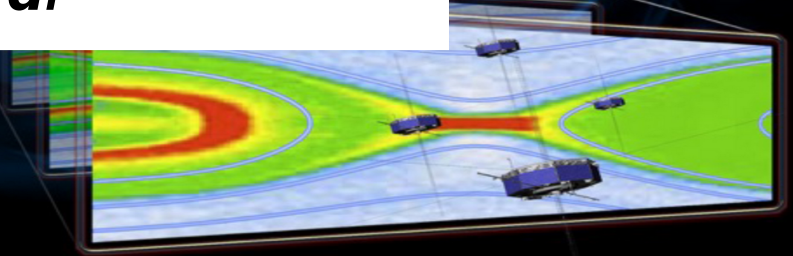
Laminar EDR: dominated by e crossing orbit dynamics



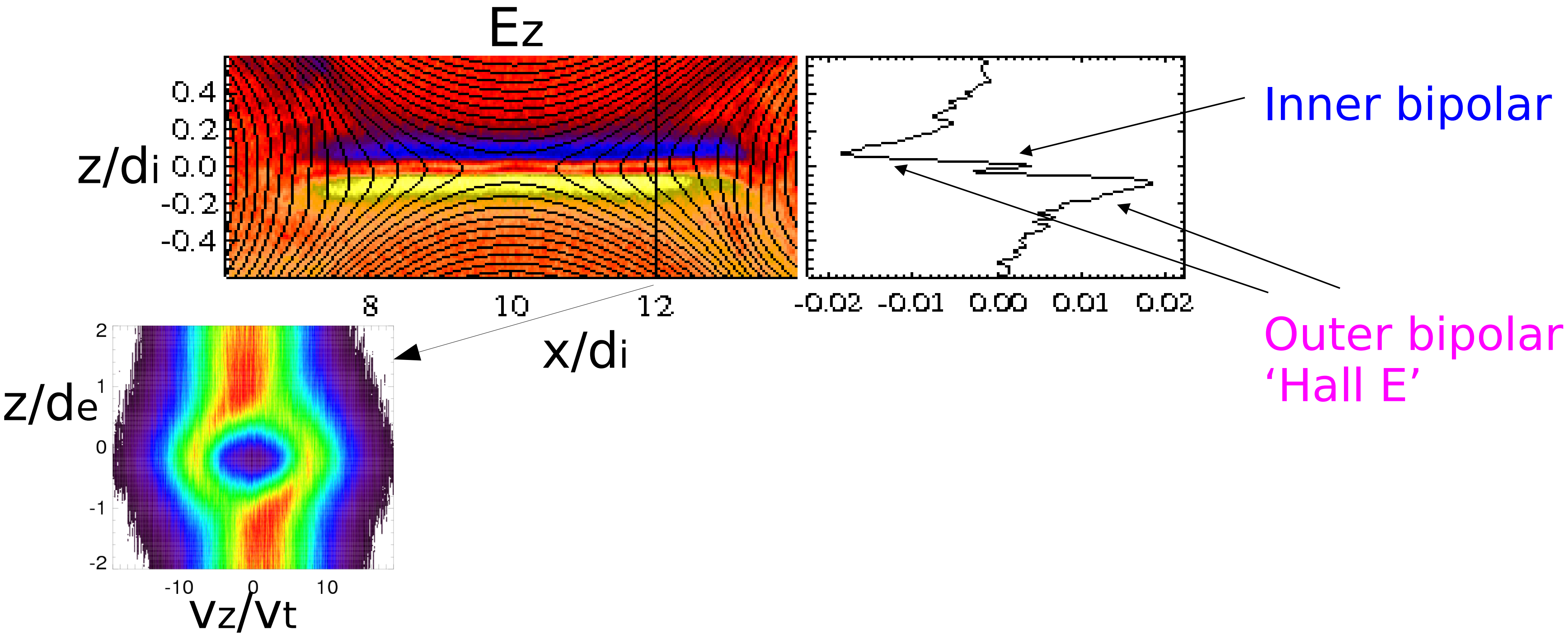
[Chen et al., 2011]



[Torbert et al., 2018]

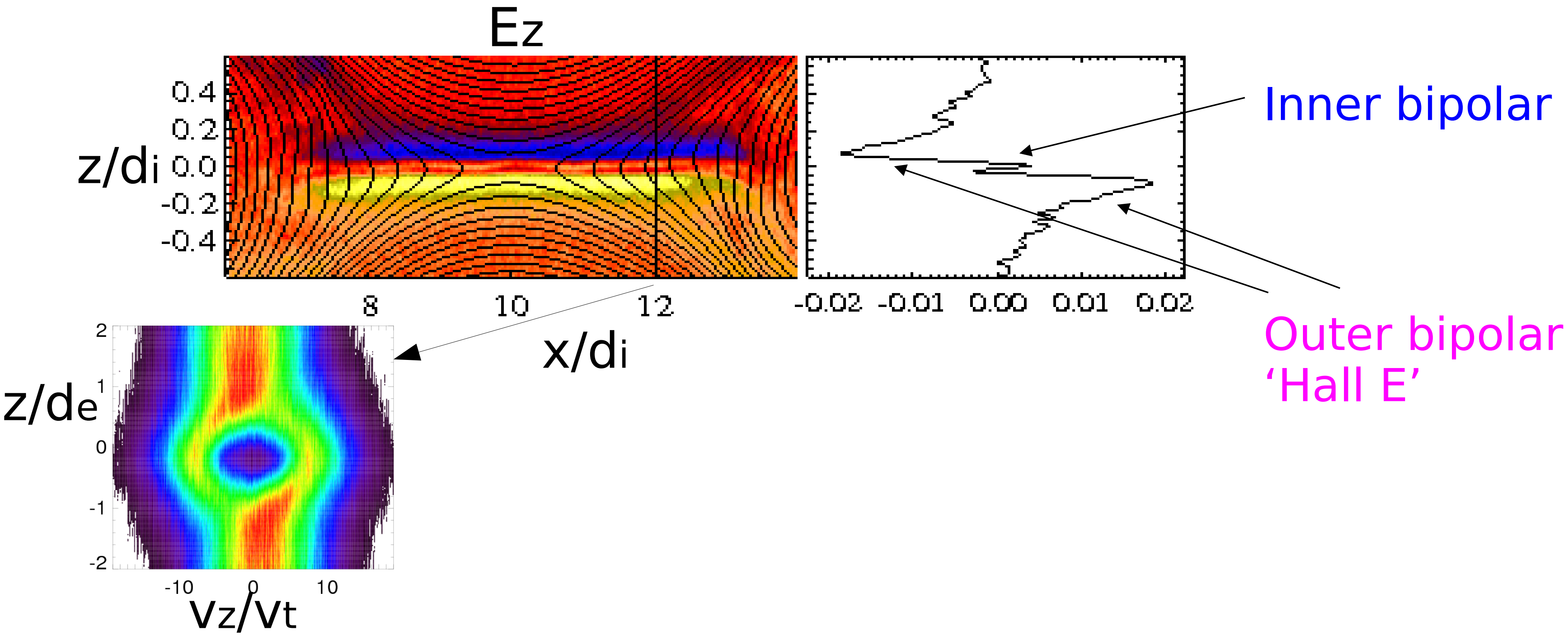


Laminar EDR: A standing electron phase-space hole

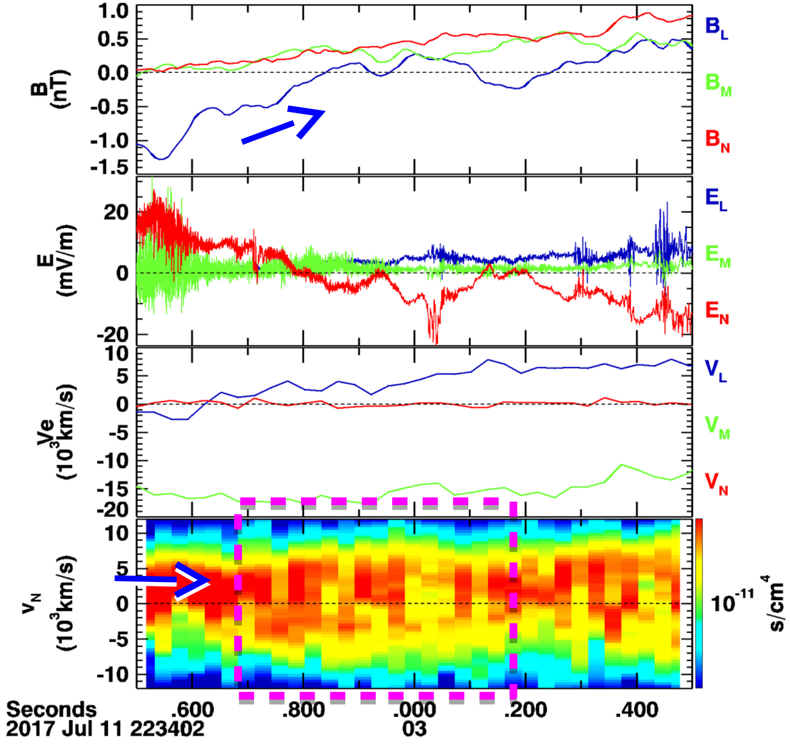


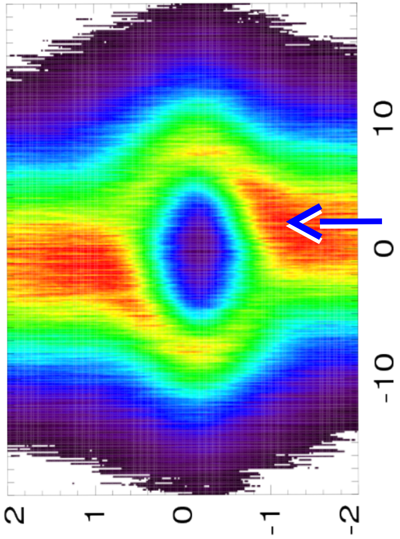
Laminar EDR Q1: Does MMS see a standing electron hole?

"The electron DF will be sampled every 30 ms ~ 0.3de. The phase-space holes at various phases of reconnection should be easily observable," Roy Torbert, 2011.



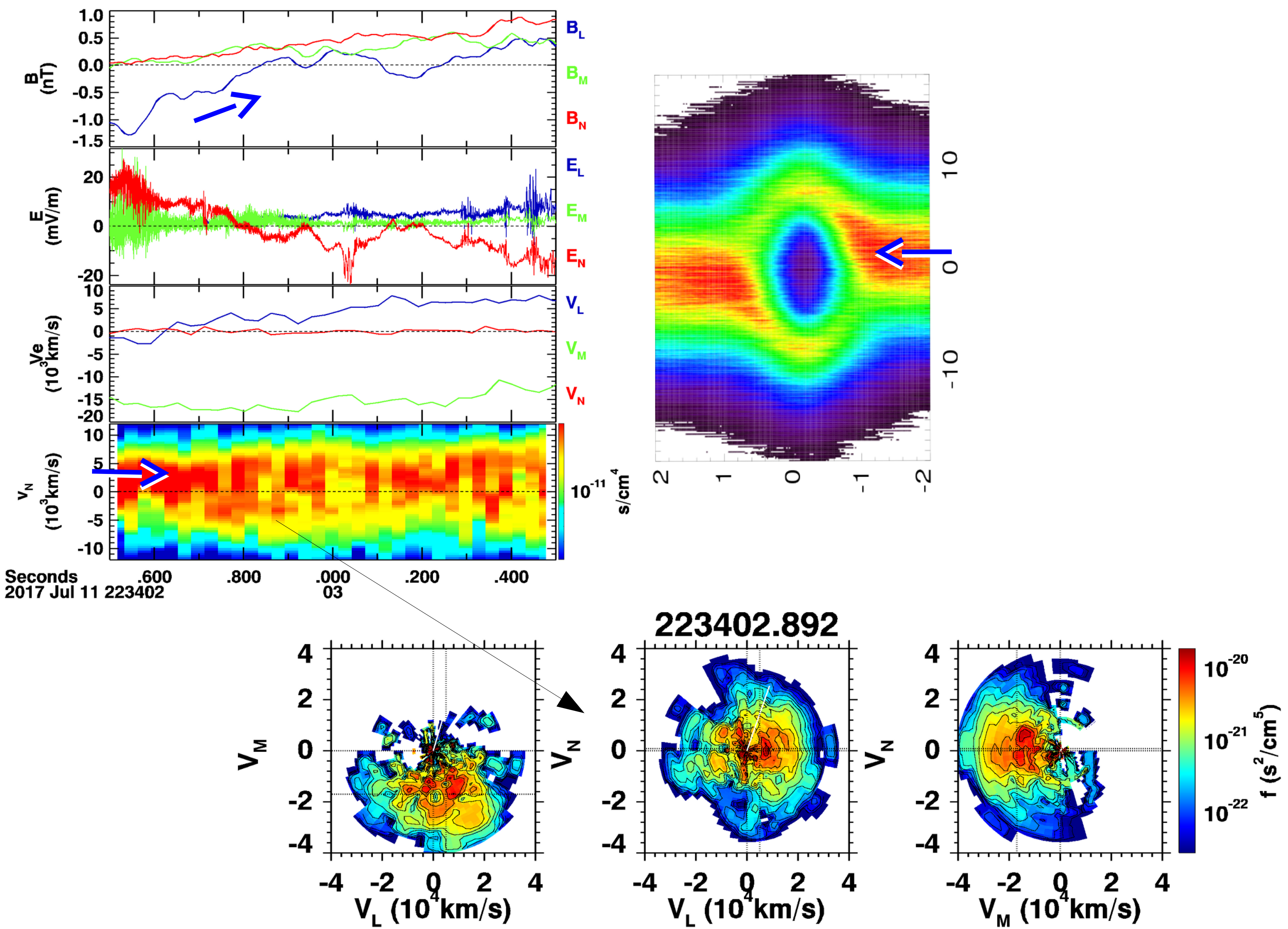
Laminar EDR Q1: Does MMS see a standing electron hole?



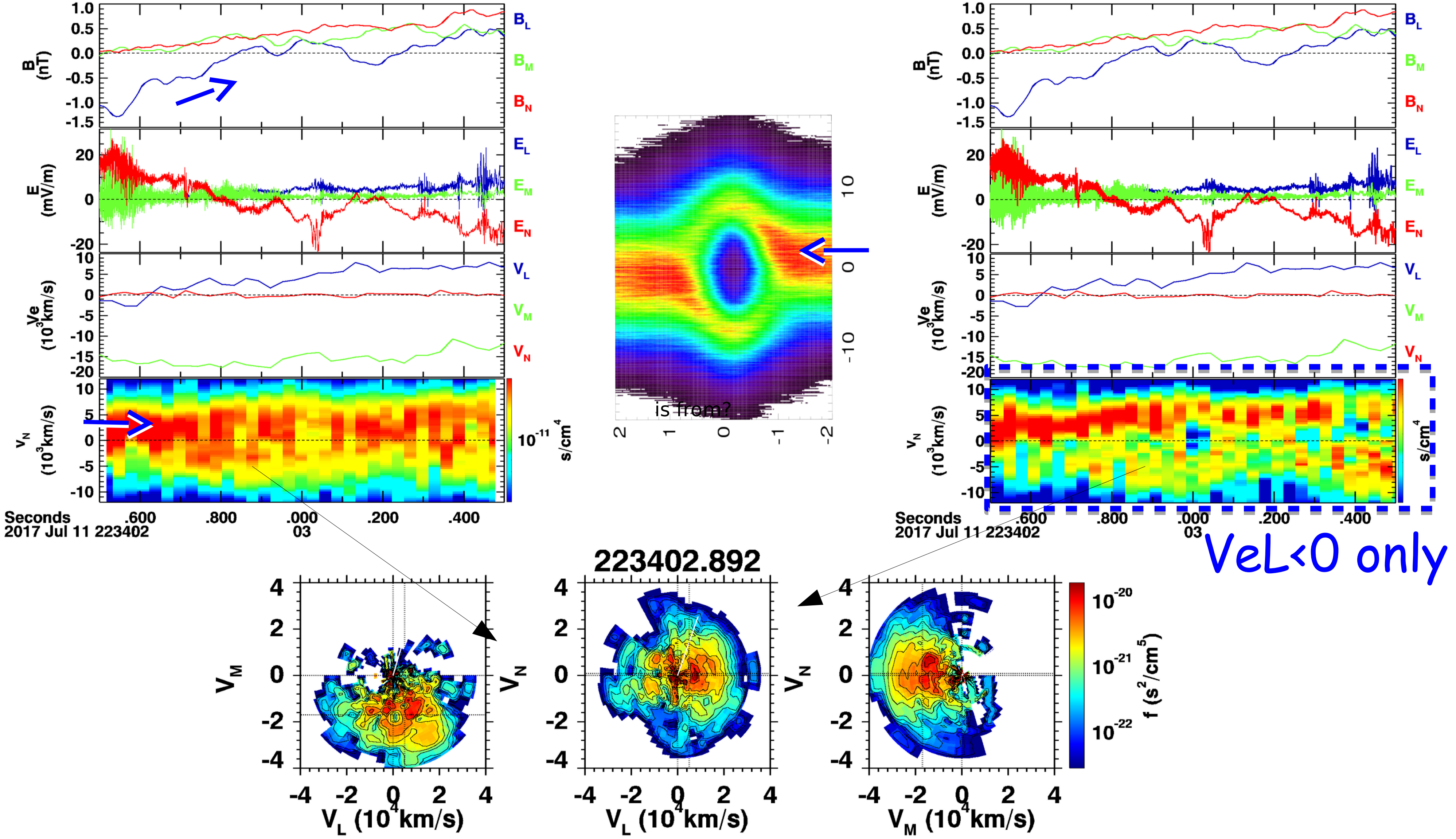


Papers on the event, e.g., [R. Nakamura et al., 2018; Genestreti et al., 2019; T. Nakamura et al., 2019]

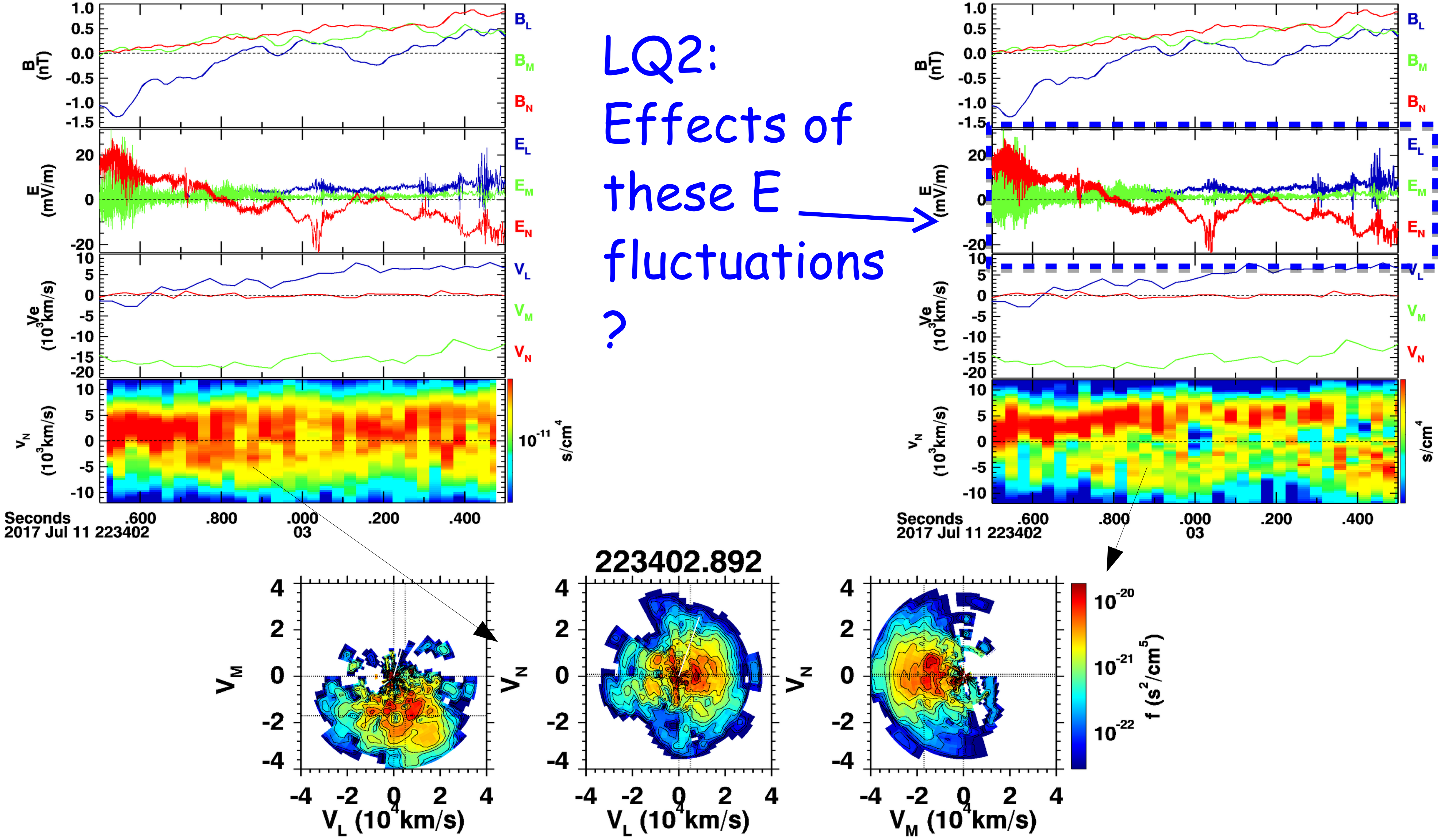
Roy was right!



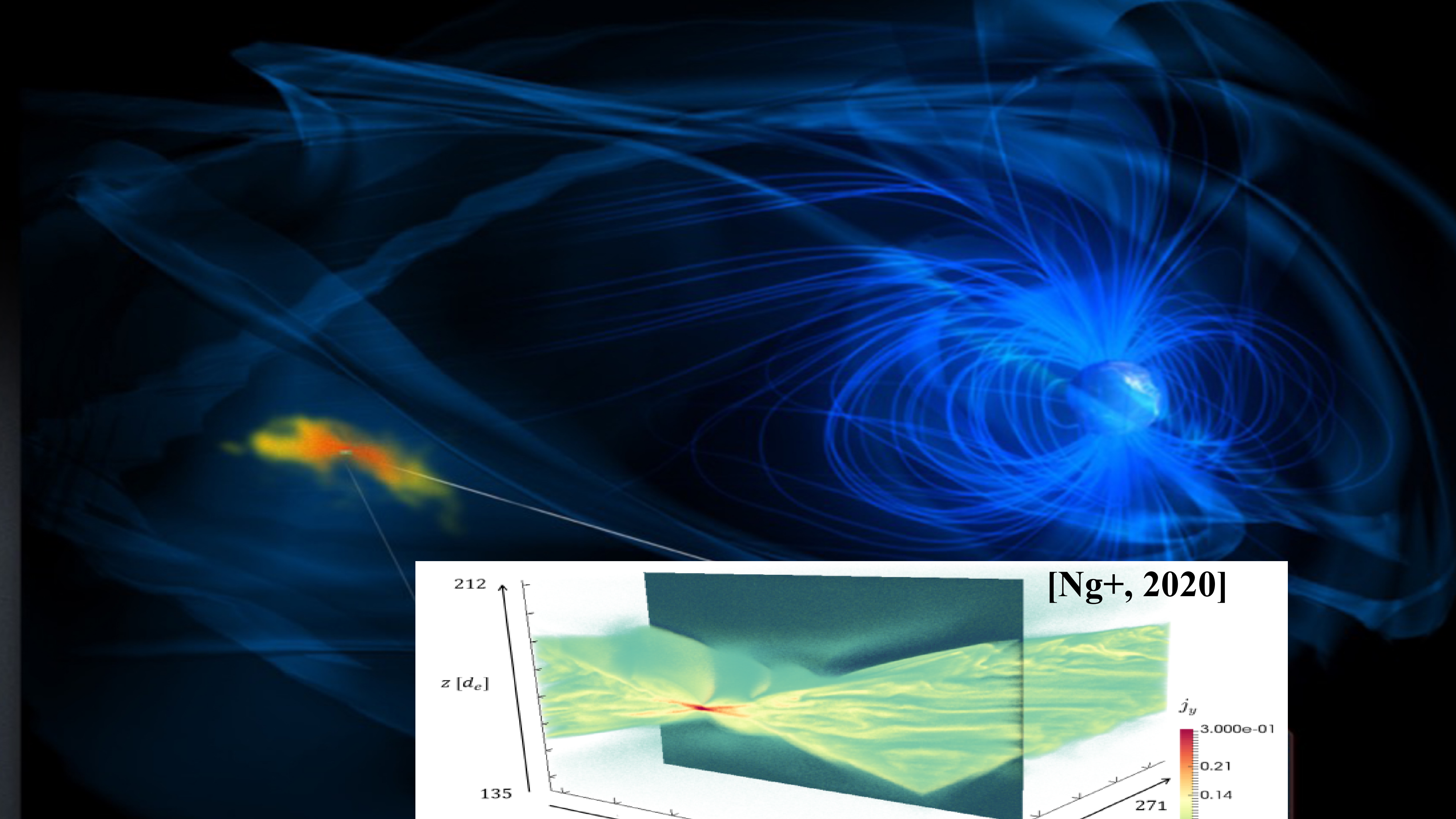
B (nT)
B_L
B_M
B_N
E (mV/m)
E_L
E_M
E_N
Ve (10^3km/s)
V_L
V_M
V_N
v_N (10^3km/s)
10^{-11}
s/cm^4
Seconds
2017 Jul 11 223402
.600
.800
.000
03
.200
.400
223402.892
V_M
V_N
V_L (10^4km/s)
V_M (10^4km/s)
10^{-20}
10^{-21}
10^{-22}
f (s^2/cm^5)



B (nT)
B_L
B_M
B_N
E (mV/m)
E_L
E_M
E_N
Ve (10^3km/s)
V_L
V_M
V_N
v_N (10^3km/s)
10^{-11} s/cm^4
Seconds .600 .800 .000 .200 .400
2017 Jul 11 223402 03
is from?
VeL<0 only
223402.892
V_M
V_N
V_L (10^4km/s)
V_M (10^4km/s)
f (s^2/cm^5)
10^{-20}
10^{-21}
10^{-22}



LQ2:
Effects of
these E
fluctuations
?
B (nT)
B_L
B_M
B_N
E (mV/m)
E_L
E_M
E_N
Ve (10^3km/s)
V_L
V_M
V_N
v_N (10^3km/s)
10^{-11}
s/cm^4
Seconds
2017 Jul 11 223402
.600
.800
.000
03
.200
.400
223402.892
V_M
V_N
V_L (10^4km/s)
V_M (10^4km/s)
10^{-20}
10^{-21}
10^{-22}
f (s^2/cm^5)


[Ng+, 2020]
212
z [d_e]
135
j_y
3.000e-01
0.21
0.14
271

Fully kinetic simulations predict:

Nonlinear evolution of lower hybrid waves in a di-scale current sheet
→ formation of a thinner current sheet & preferential electron perp heating
→ enhancing the tearing instability growth rate by orders of magnitude

[e.g., Daughton, 2003; Ricci et al., 2004; Daughton et al., 2004; Shinohara & Fujimoto, 2005; Tanaka et al., 2005]

The prediction found no experimental evidence...until this MMS tail pass brought to us by Kevin Genestreti.

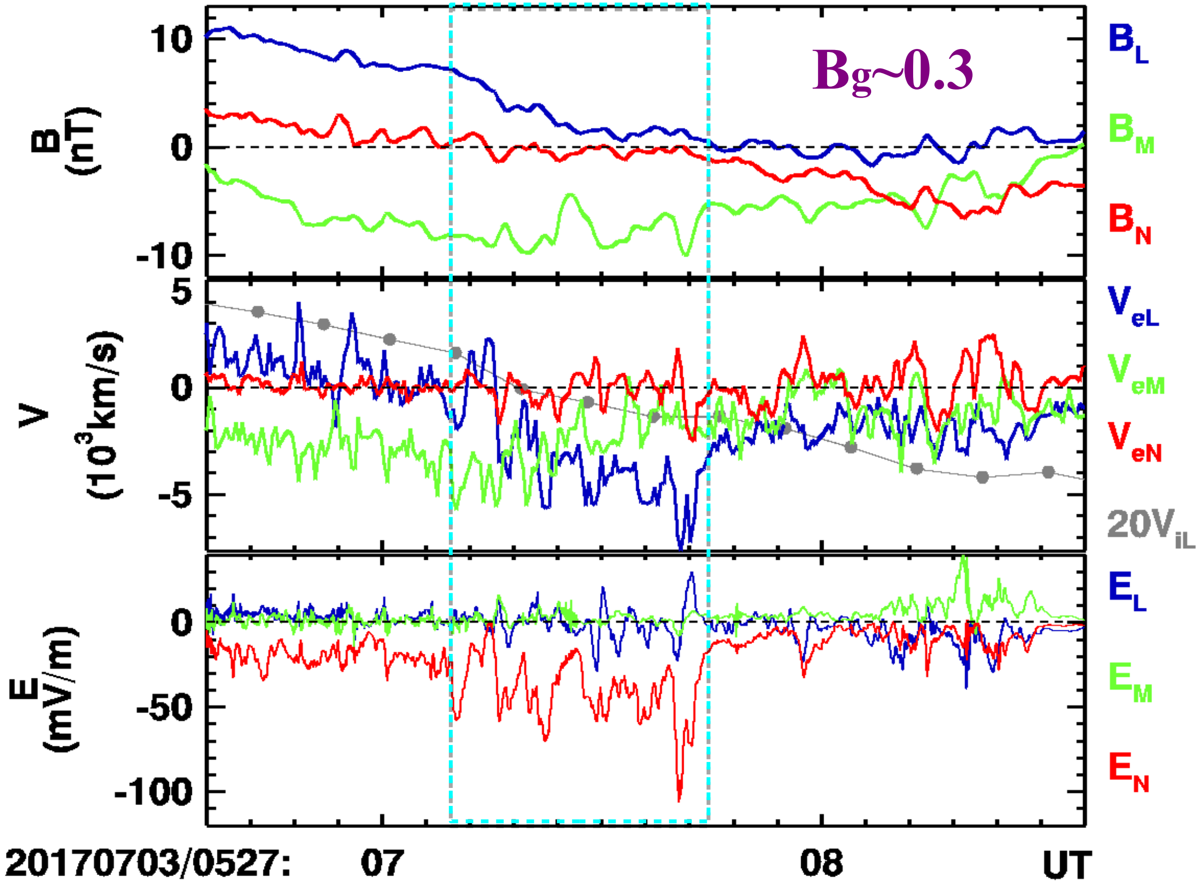
Lower hybrid drift waves driving electron nongyrotropic heating and vortical flows in a magnetic reconnection layer *(PRL, 2020)*

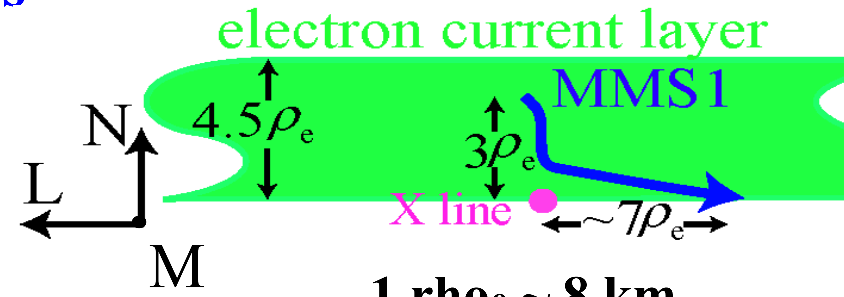
L.-J. Chen[1], S. Wang[1,2], O. Le Contel[3], A. Rager[1], M. Hesse[4], J. Drake[2], J. Dorelli[1], J. Ng[1,2], N. Bessho[1,2], D. Graham[5], L. B. Wilson III[1], T. Moore[1], B. Giles[1], W. Paterson[1], B. Lavraud[6], K. Genestreti[7], R. Nakamura[8], Yu. V. Khotyaintsev[5], R. E. Ergun[9], R. B. Torbert[7], J. Burch[10], C. Pollock[11], C. T. Russell[12], P.-A. Lindqvist[13], L. Avanov[1,2]

Electron diffusion regions in magnetotail reconnection under varying guide fields *(GRL, 2019)*

L.-J. Chen[1], S. Wang[1,2], M. Hesse[3], R. E. Ergun[4], T. Moore[1], B. Giles[1], N. Bessho[1,2], C. Russell[5], J. Burch[6], R. B. Torbert[6,7], K. J. Genestreti[7], W. Paterson[1], C. Pollock[8], B. Lavraud[9], O. Le Contel[10], R. Strangeway[5], Yu. V. Khotyaintsev[11], P.-A. Lindqvist[12]

Turbulent reconnection layer: Intense dE at correlated B and V reversals





1 rhoe ~ 8 km

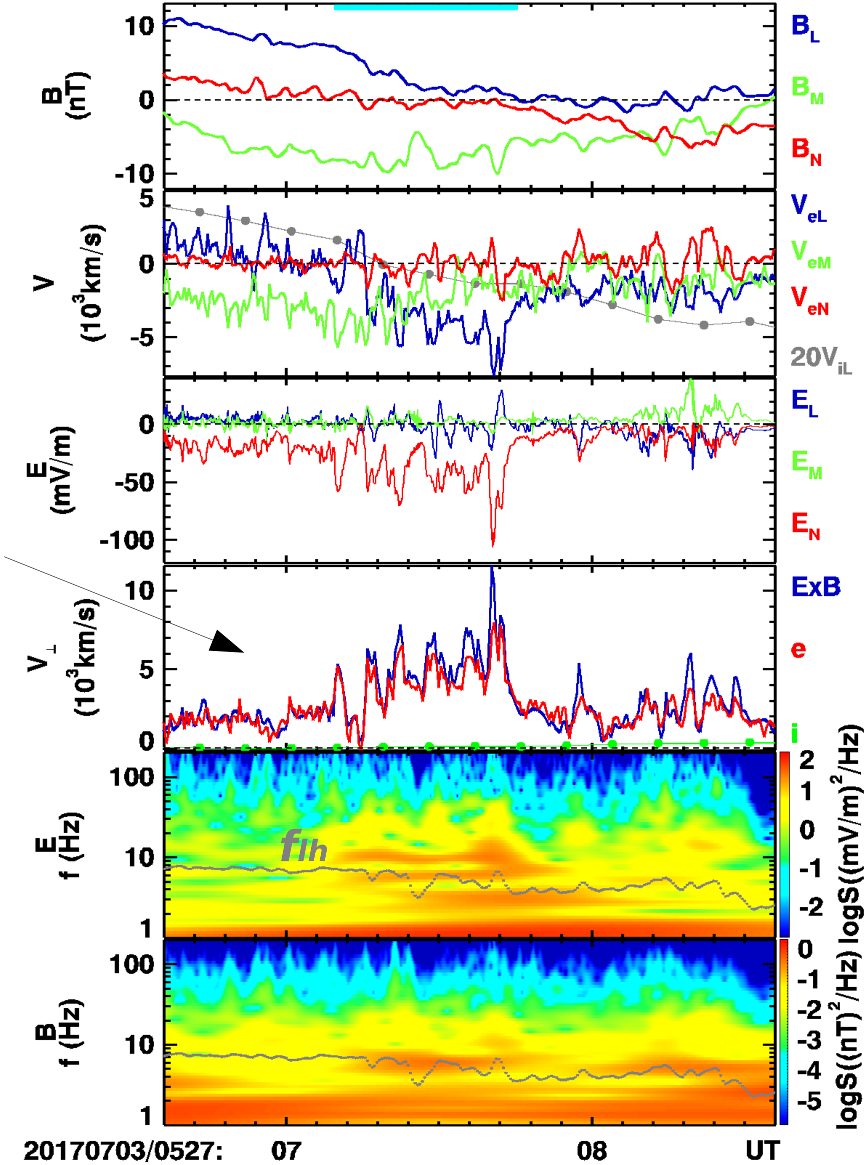
- ! **correlated B_N, V_{eL}, & V_{iL} reversals**
- ! **fluctuations in E_{LN} drive electron flows via V_{ExB}**
- ! **large dE_N only at V_{eL}<0**

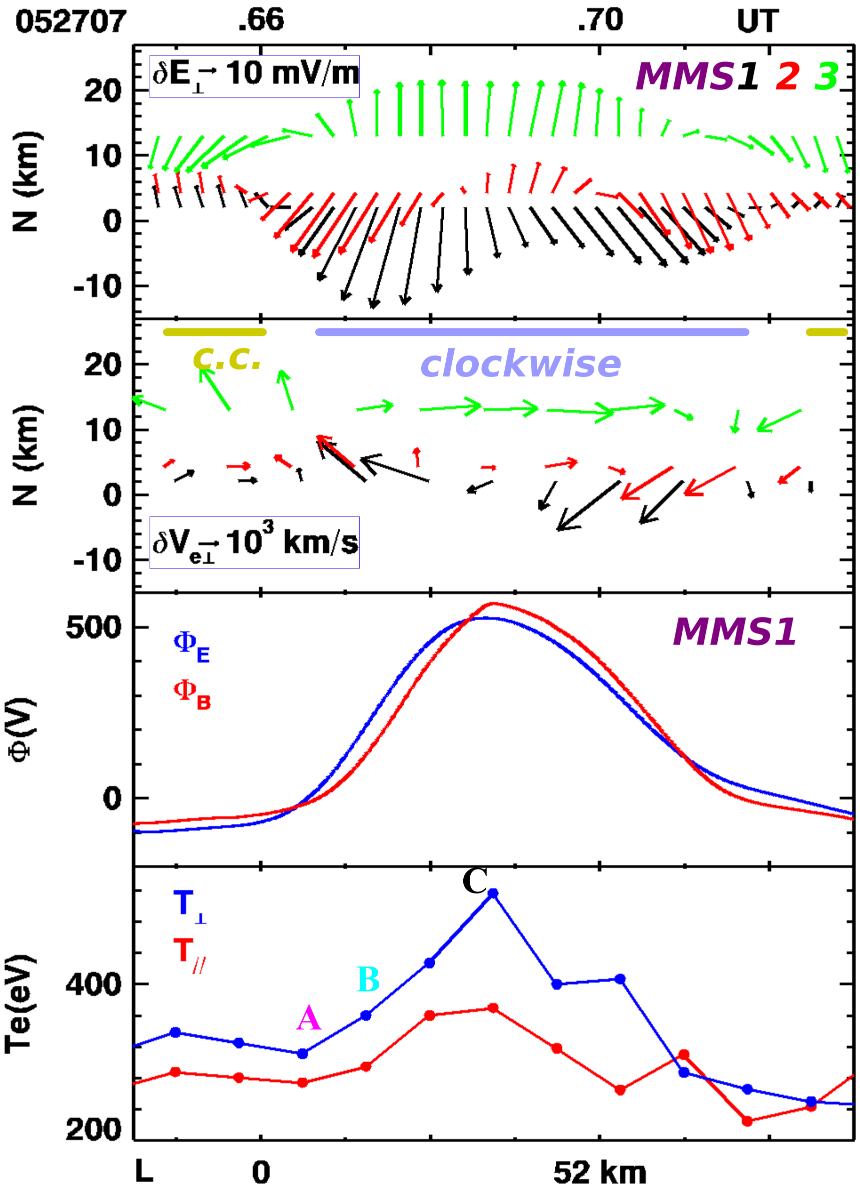
LHDWs in active reconnection

Veperp ~ 70-100% VExB >> Viperp

wave properties:

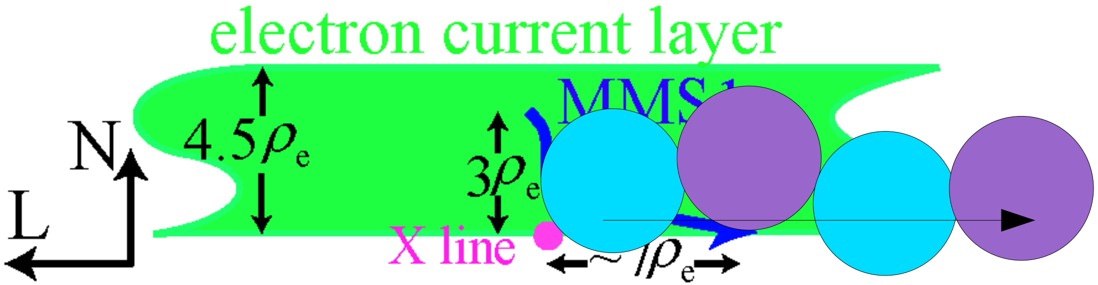
- **$f \sim f_{lh}$: 3-8 Hz**
- **Propagate along outflow**
- **V_{ph} ~ 1300 km/s**
- **k*rhoe ~ 0.1-0.3**
- **angle (k, B_0) ~ 83 degrees**





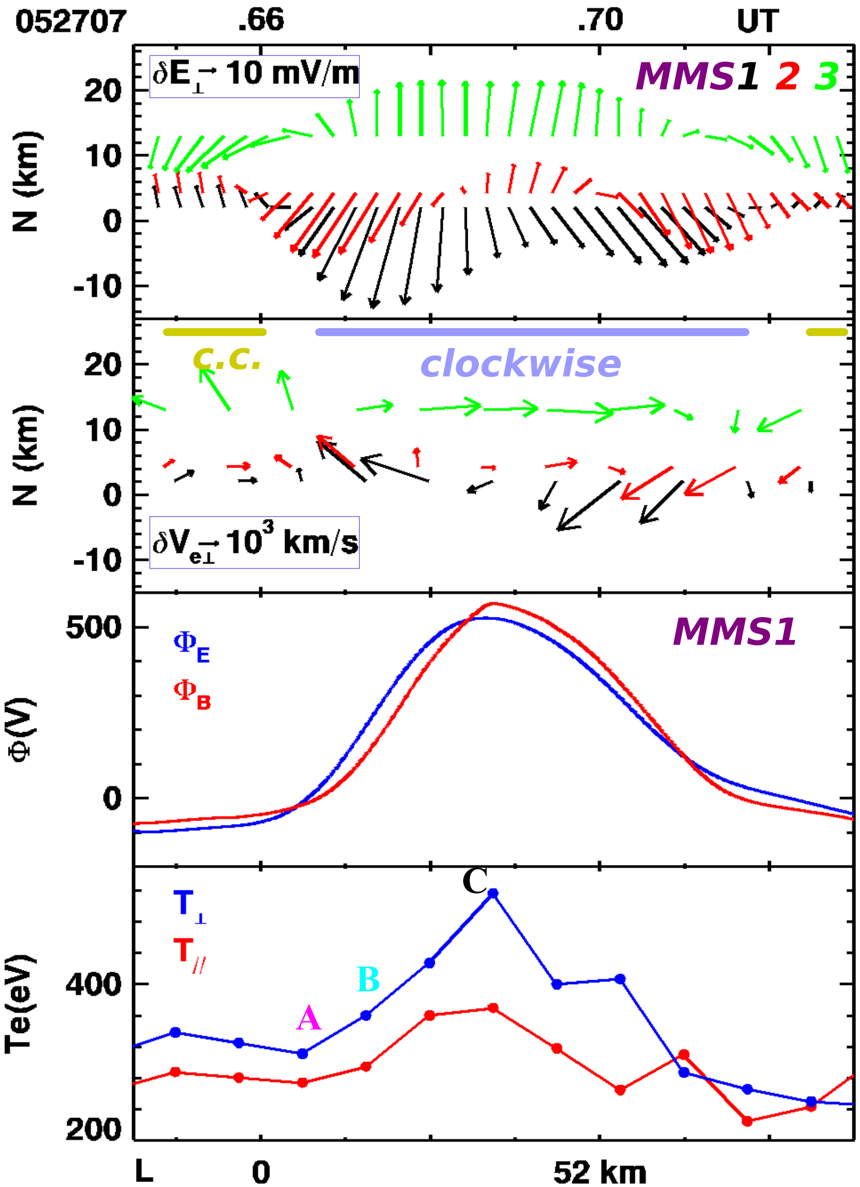
Alternating diverging and converging 2D Eperp

Vortical Veperp



ePhi >~ Te

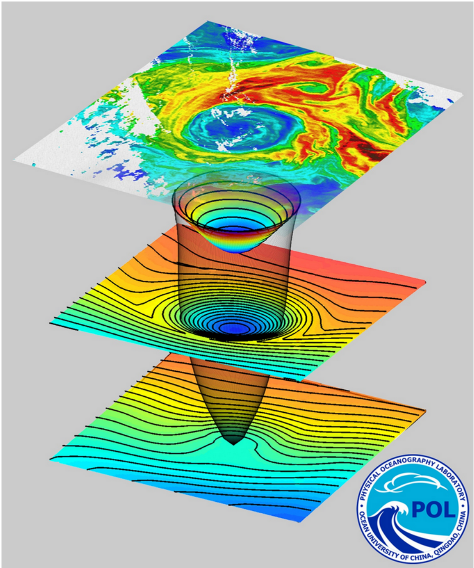
Electron heating, preferentially perp



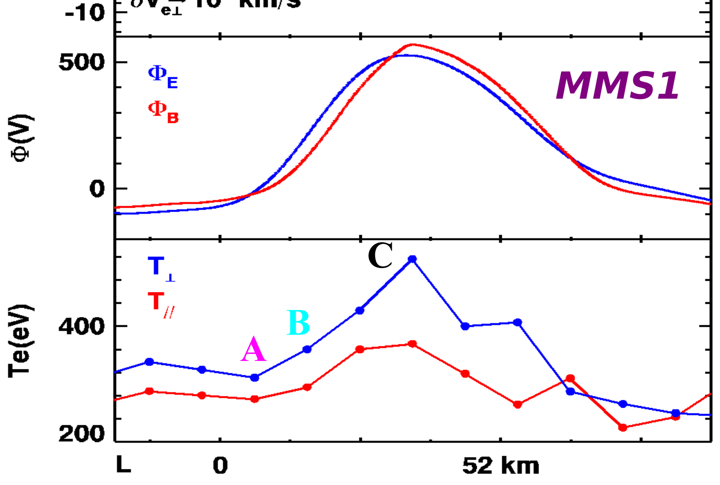
preferential electron perp heating → enhances tearing instability growth rate by orders of magnitude [e.g., Ricci+, 2004]

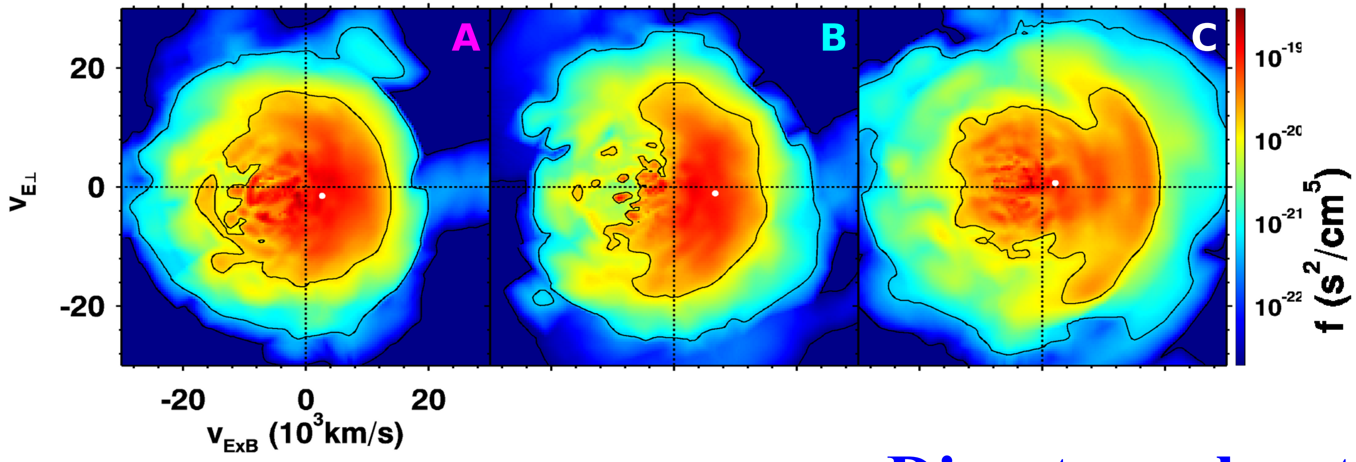
TQ1: Can any reconnection go off within the vortices?

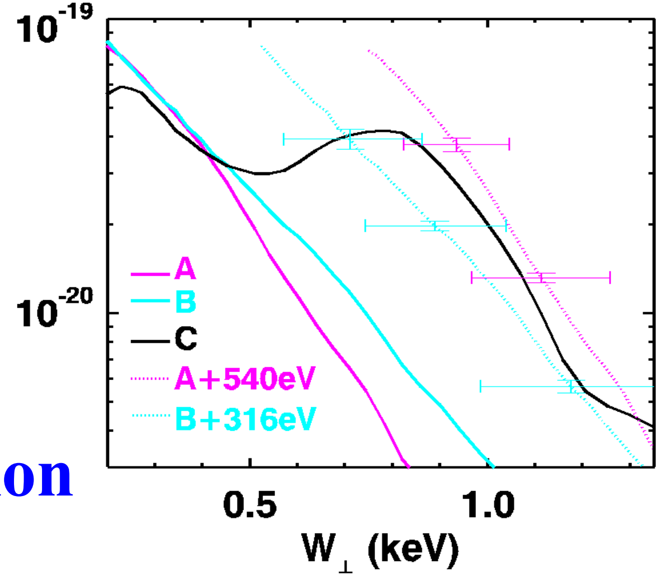
TQ2: 3D?



Nongyrotropic perp heating

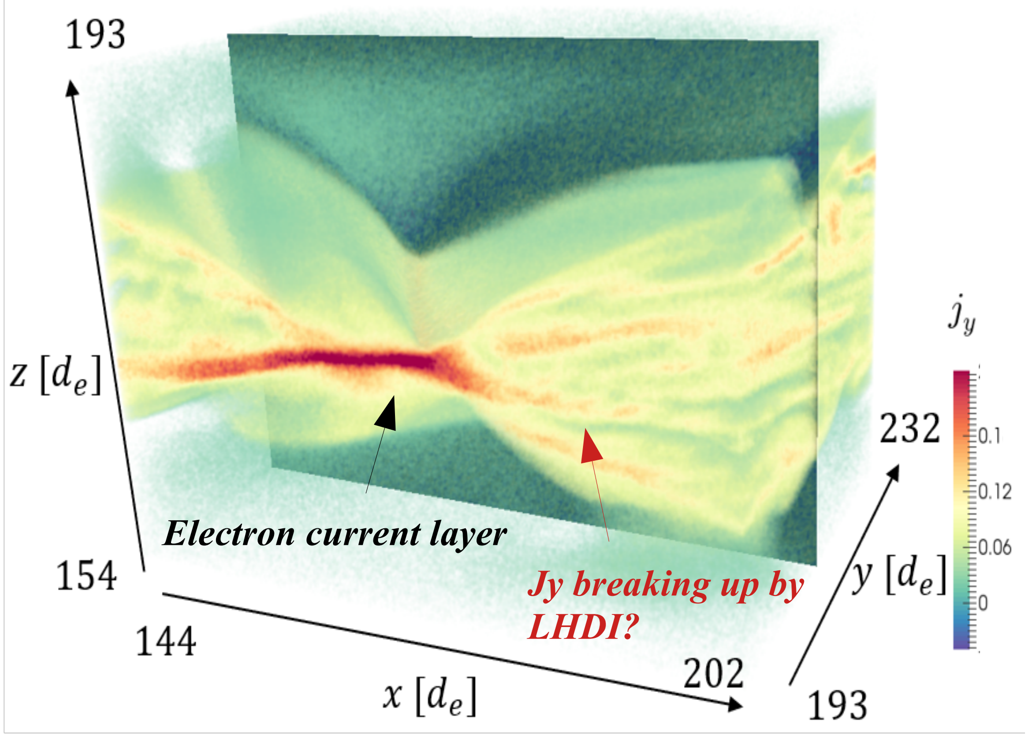


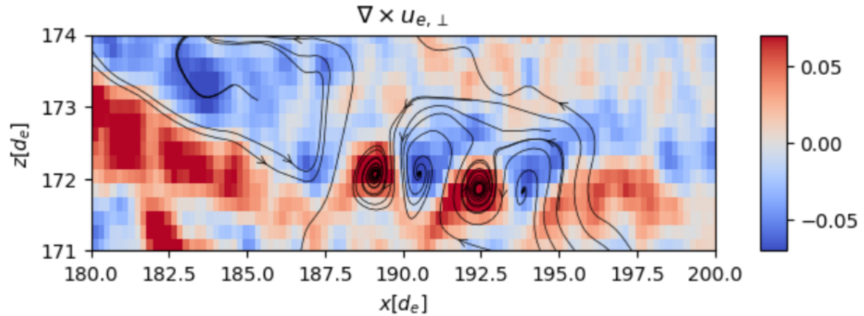


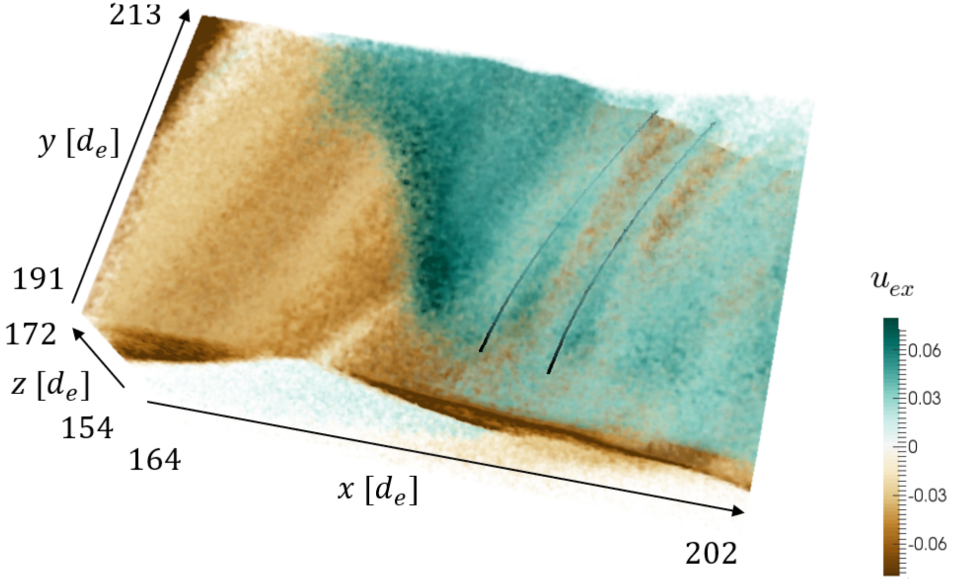


Direct acceleration by Phi

TQ3: Effects of the LHD vortices on reconnection structure and dynamics?







[Ng et al., 2020, under review]

Summary

- Two reconnection layers: One laminar (Bg~0) yet with wave fluctuations and a partially filled EH; one (Bg~0.3) seems largely modified by the LHDWs but still exhibiting correlated flow and B reversals.

- Open LQ: Roles of wave fluctuations? Do they partially fill the EH?

- Open TQ: Can tearing occur at localized sites of preferential perp e heating?