The structure of reconnection layers in Earth's quasi-parallel bow shock

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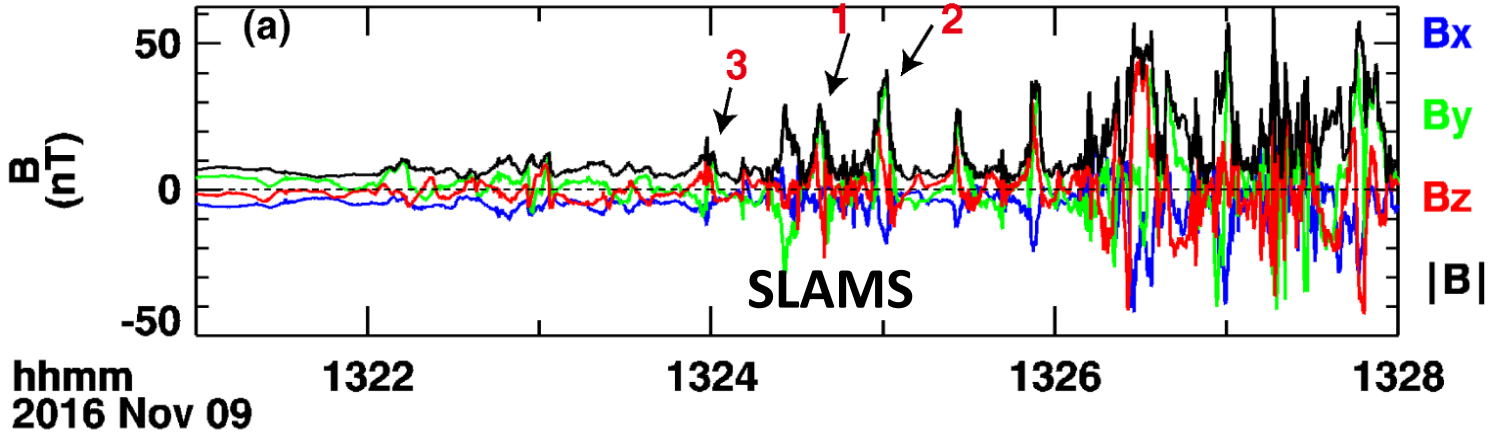
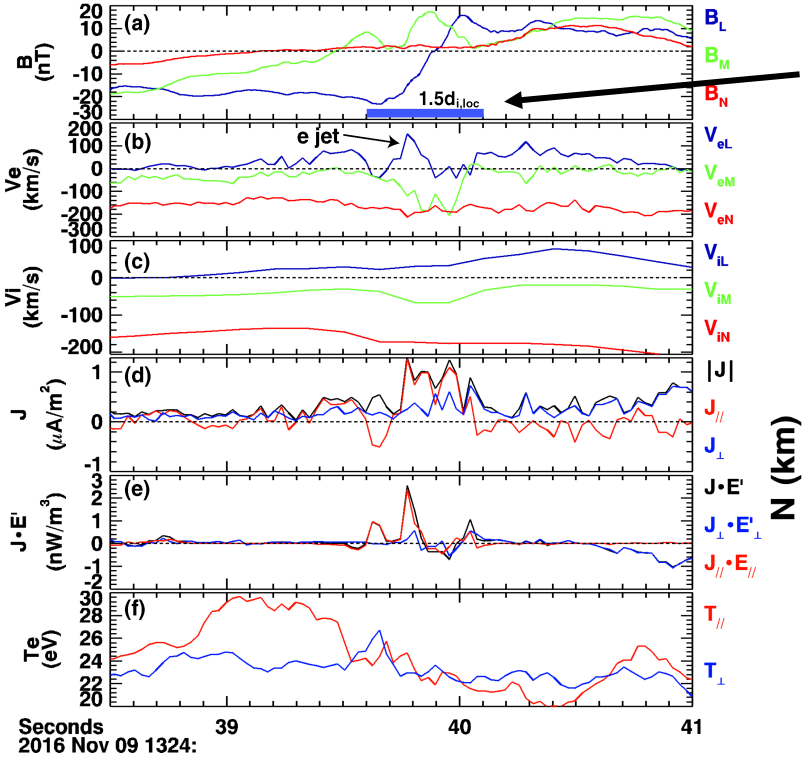
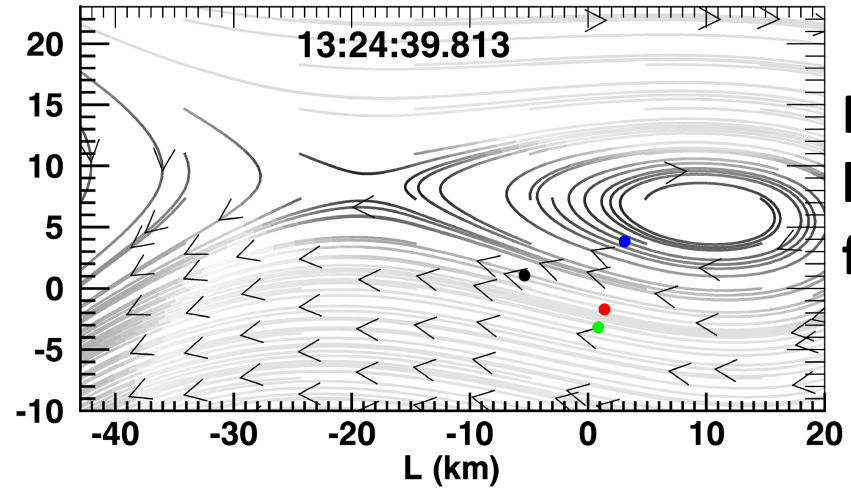
MMS has been observing active reconnecting current sheets in the Earth's bow shock, in the magnetosheath (shock downstream) (Yordanova et al. 2016, Vörös et al. 2018, Chasapis et al. 2018, Phan et al. 2018, Wilder et al. 2018) and the foreshock/transition region (Wang et al. 2019, 2020, Gingell et al. 2019, 2020).



[Wang et al., 2020]



Reconnecting current sheet inside amplified non-resonant mode waves ('SLAMS') with electron outflow jet in the foreshock

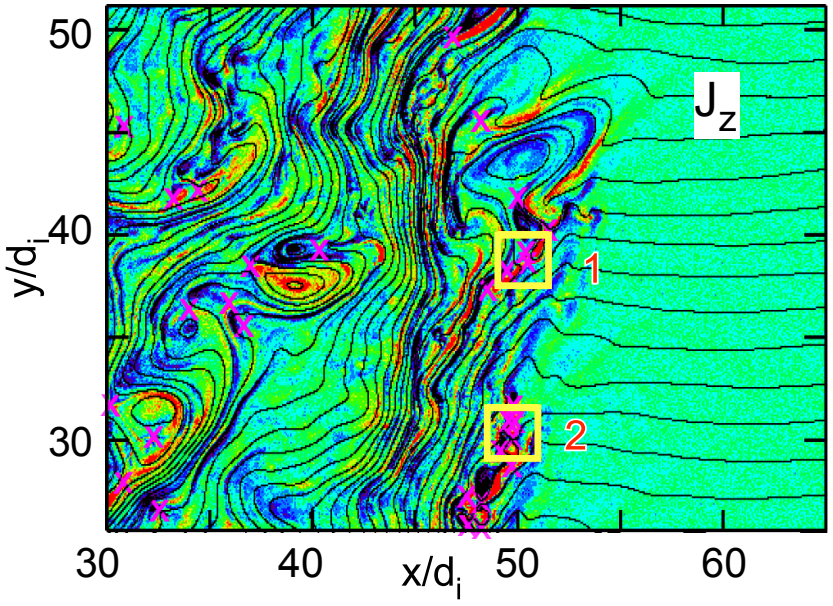


Reconstructed X-line magnetic field topology

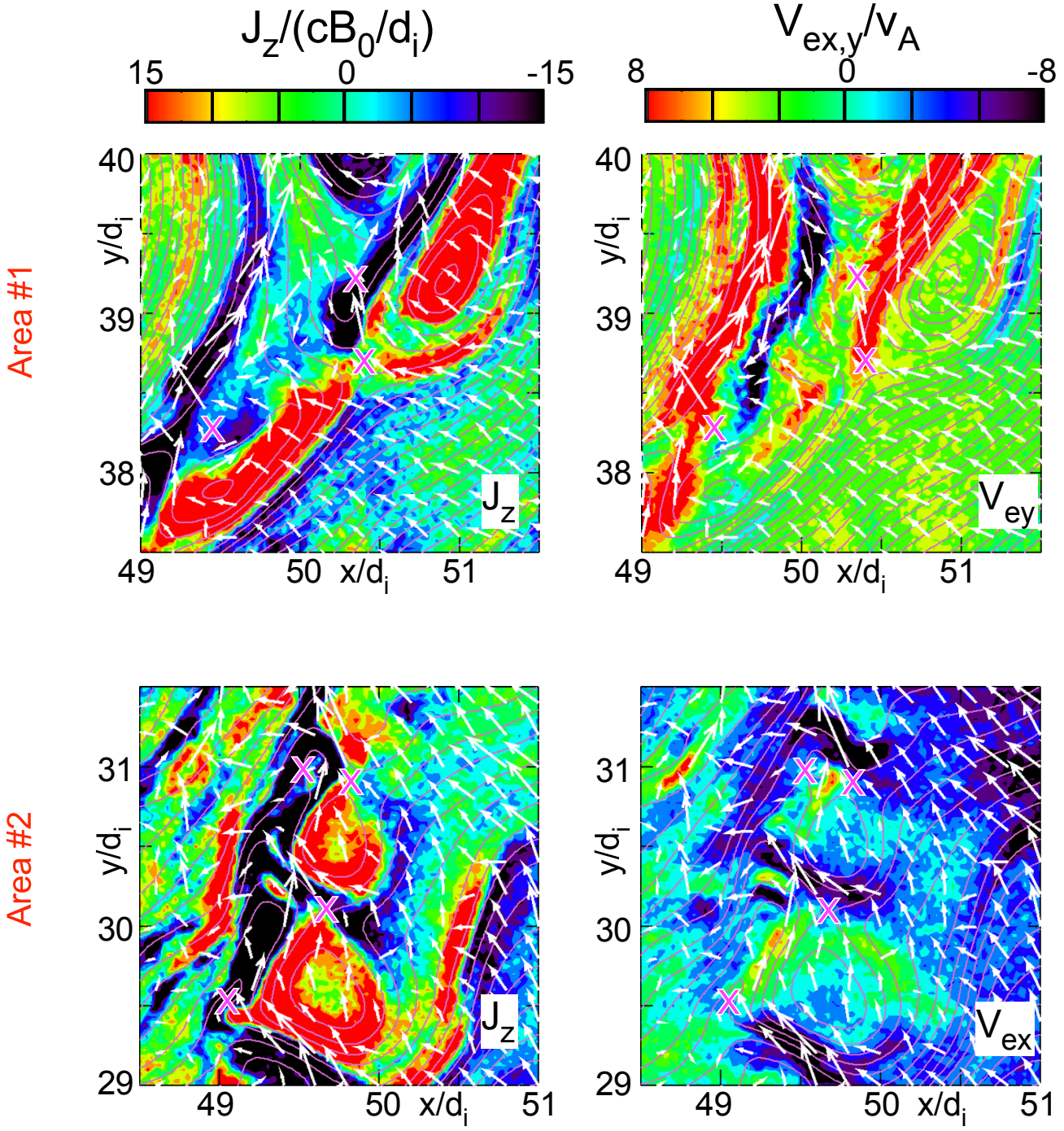
Reconnection layers in a shock

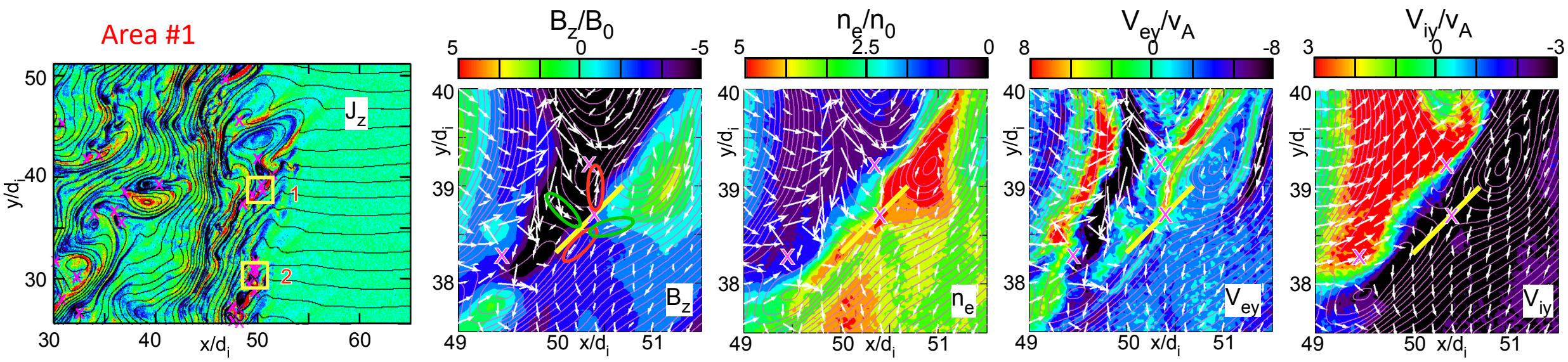
(Bessho et al. 2020, POP)

M_A=11.4, quasi-parallel shock (θ=25 degrees)



m_i/m_e=200, $\beta_i=\beta_e$=1, v_{Te}=14.4





Electron-only reconnection

Bipolar electron jets

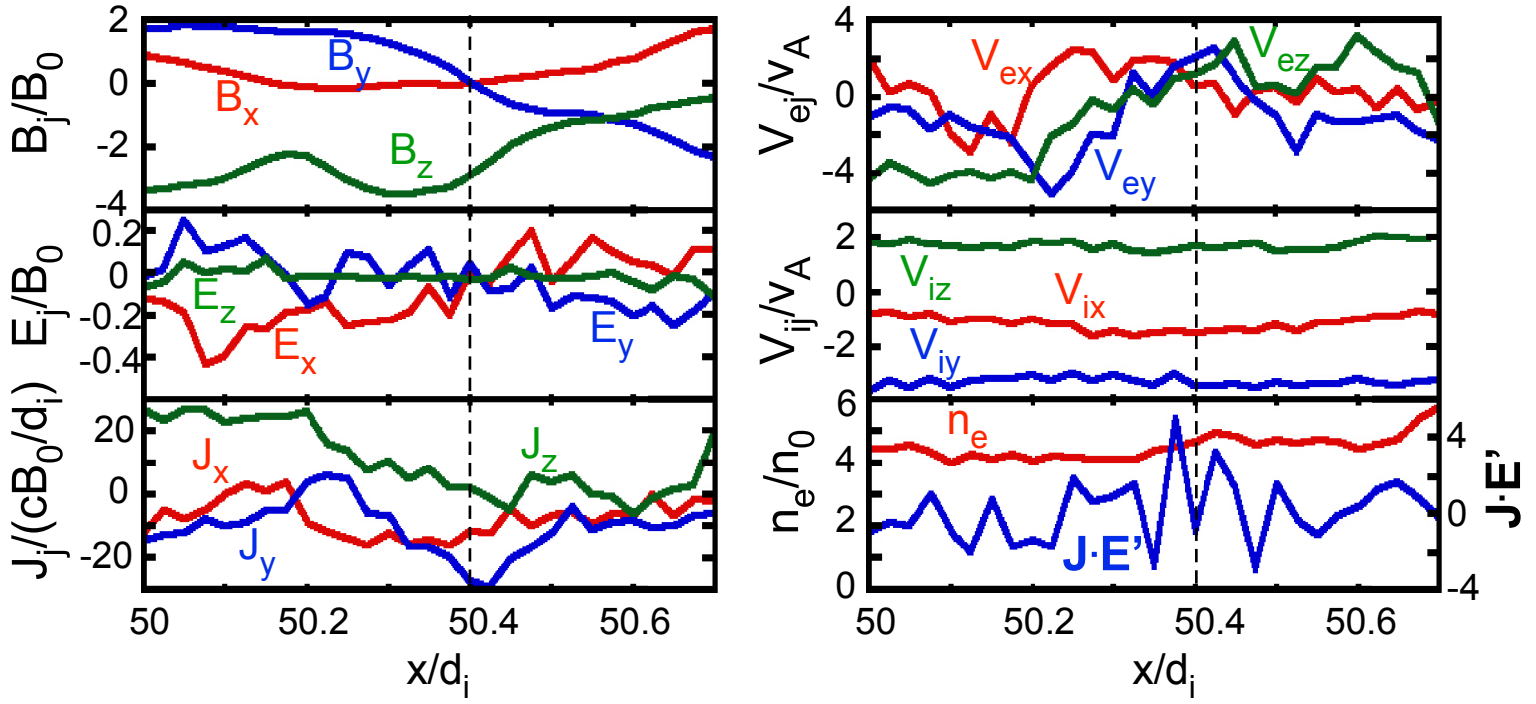
Guide field ~ -3 B_0 ~ reconnecting B

$V_{e\ out}$ ~ 7.3 V_{A0}

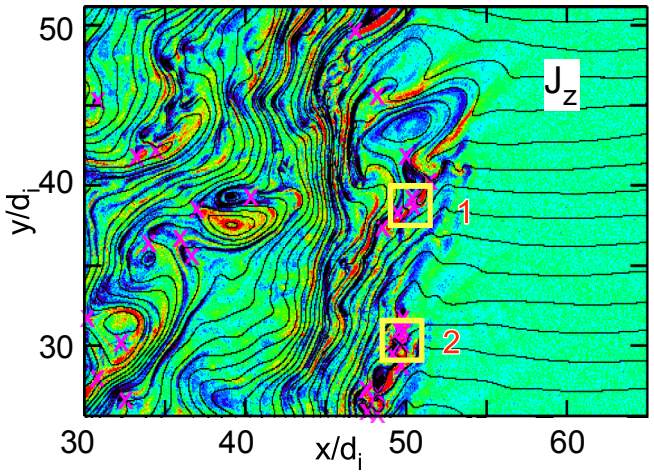
B and n ---- symmetric across J

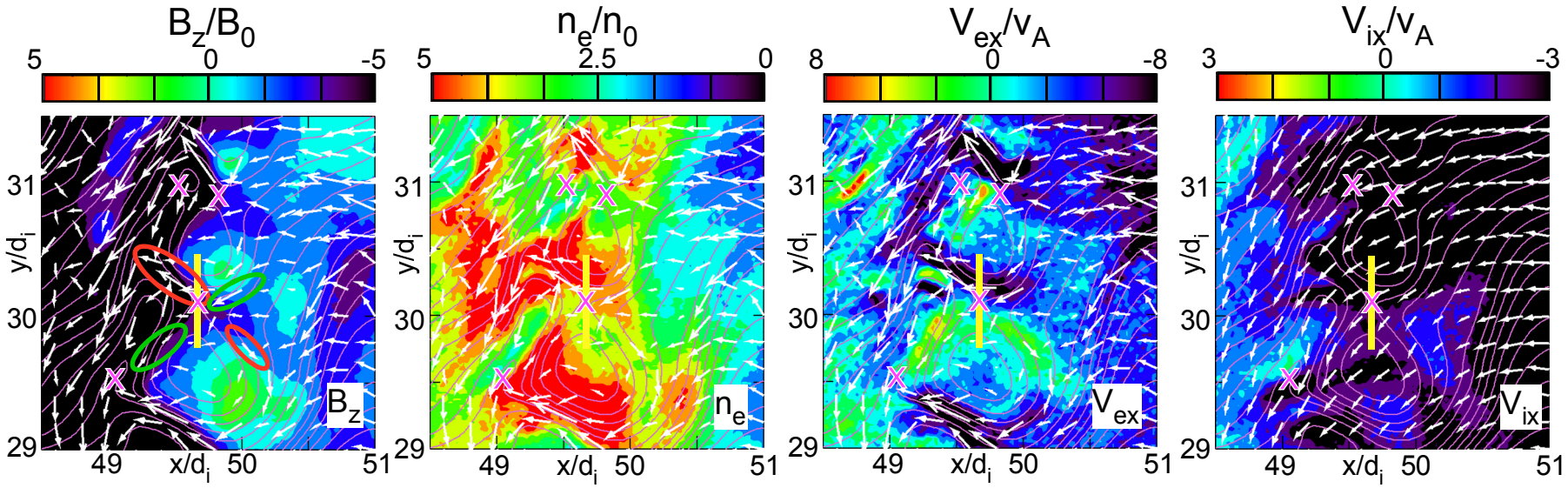
Reconnection E (E_z at the X-line)
~ -0.026B_0

Reconnection rate
= $|E_z|/(B_d\ V_{eout}/c)$=0.14



Area #2





Electron-only reconnection
One-sided electron jet

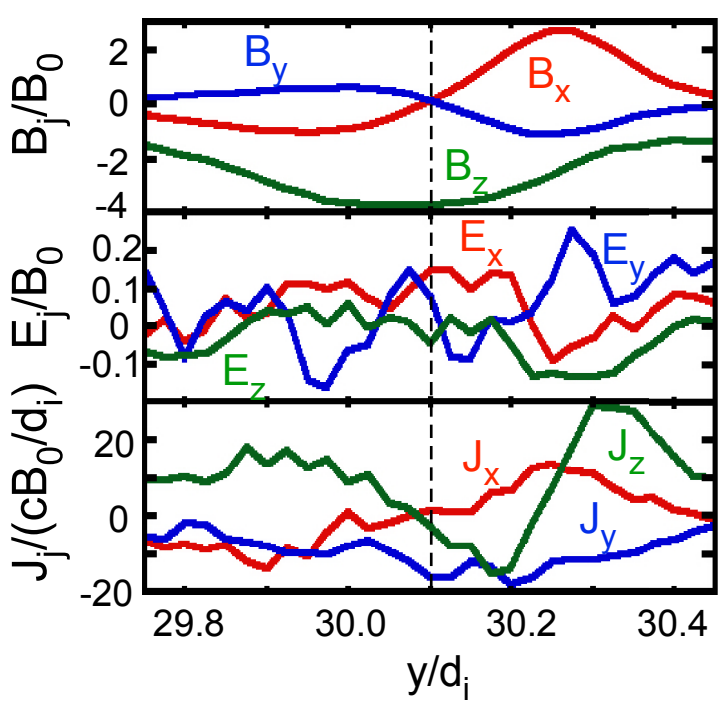
Guide field ~ -4 B_0 ~ reconnecting B

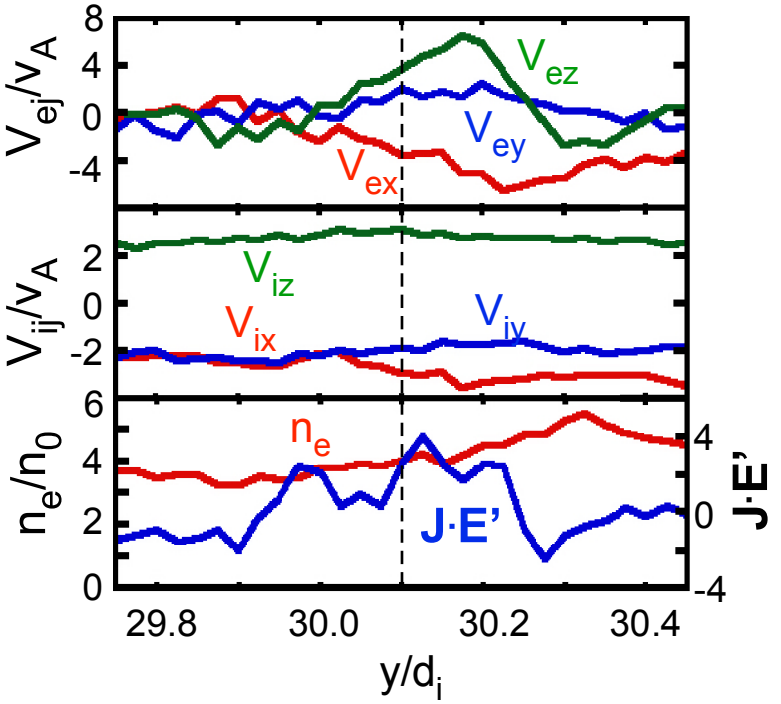
$V_{e\ out}$ ~ 10.4 V_{A0}

B and n ---- asymmetric across J

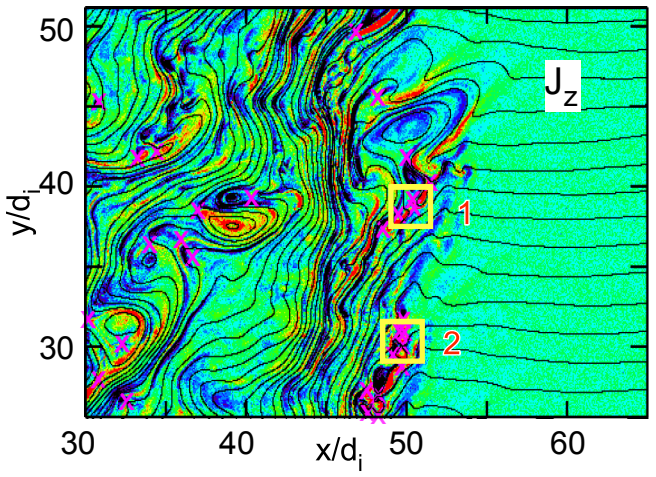
Reconnection E (E_z at the X-line)
~ -0.047B_0

Reconnection rate
= $|E_z|/(B_d\ V_{eout}/c)$=0.17

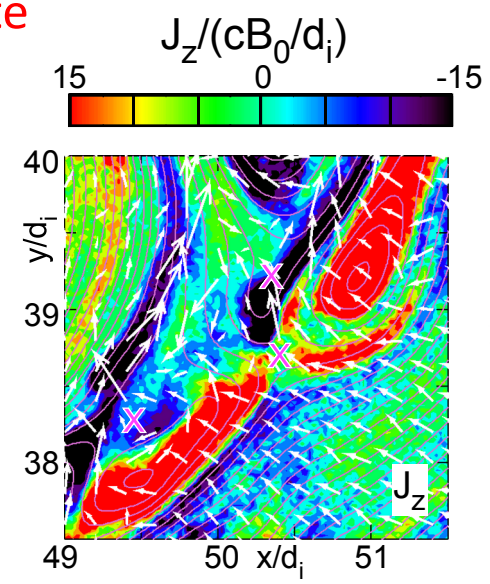




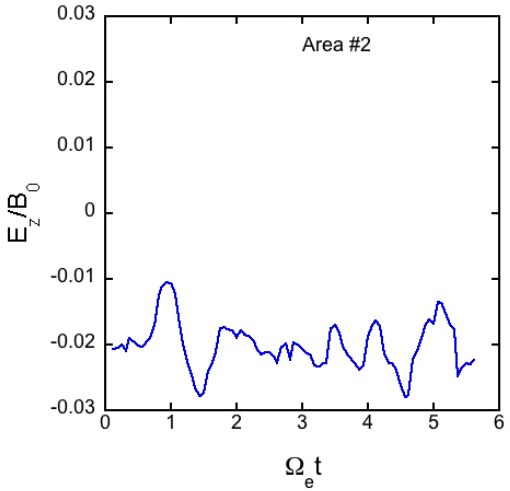
Oscillation of the reconnection rate



Area #1

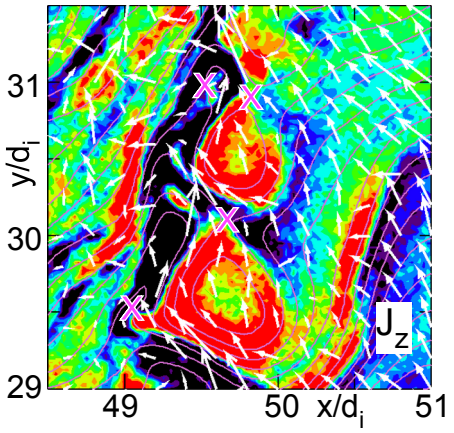


Reconnection E_z
(Averaged in $0.5d_i^2$)

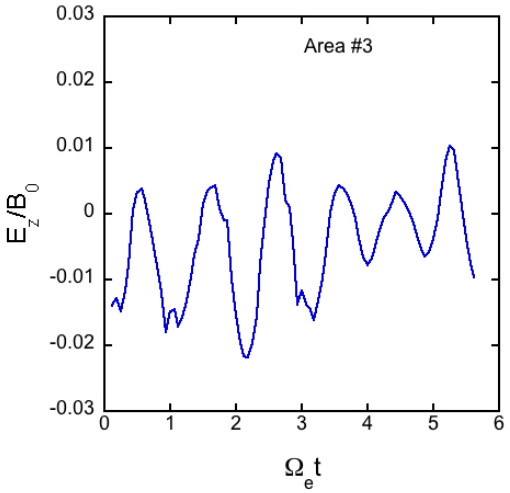


Reconnection rate
$0.11 \pm 0.054\ B_d V_{eout}/c$

Area #2



Reconnection E_z
(Averaged in $0.5d_i^2$)



Reconnection rate
$0.016 \pm 0.062\ B_d V_{eout}/c$

Oscillation frequencies ~ $1f_{ce}$ to $2f_{ce}$ based on local B

Electron cyclotron (drift) instability?

Summary

In a quasi-parallel shock, guide field reconnection occurs in the shock transition region. Since the scale size is small (electron scale to ion skin depth), reconnection is electron-only reconnection.

We have identified two types of layers: bipolar electron jets and a single (one-sided) electron jet.

Reconnection rates are of the order of 0.1. However, the reconnection electric field oscillates with the electron cyclotron frequency (or its harmonics).