ÖAW – AUSTRIAN ACADEMY OF SCIENCES

ENERGY CONVERSION BY ELECTRON BEAM-DRIVEN WAVES IN A COMPRESSED RECONNECTION SEPARATRIX

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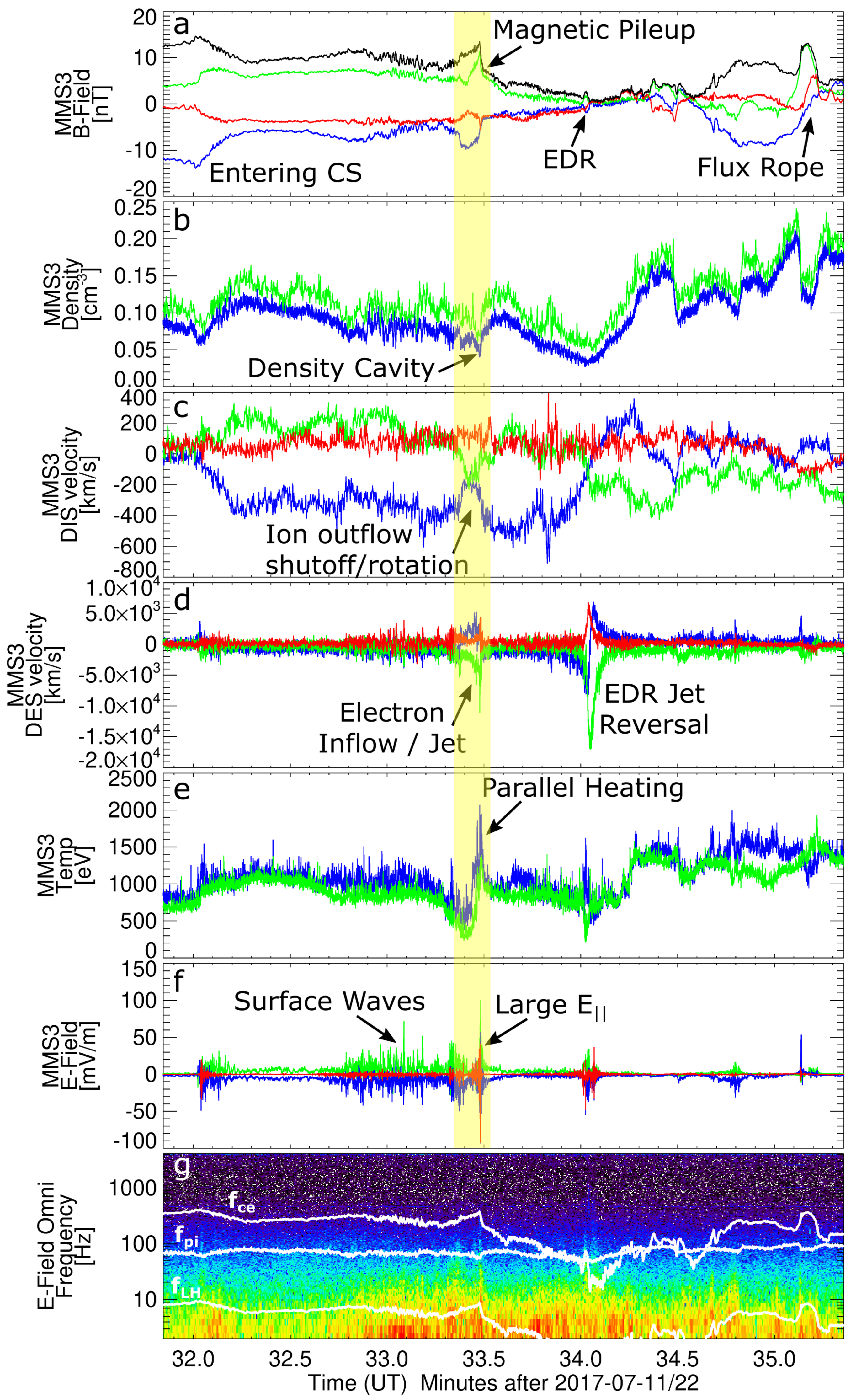
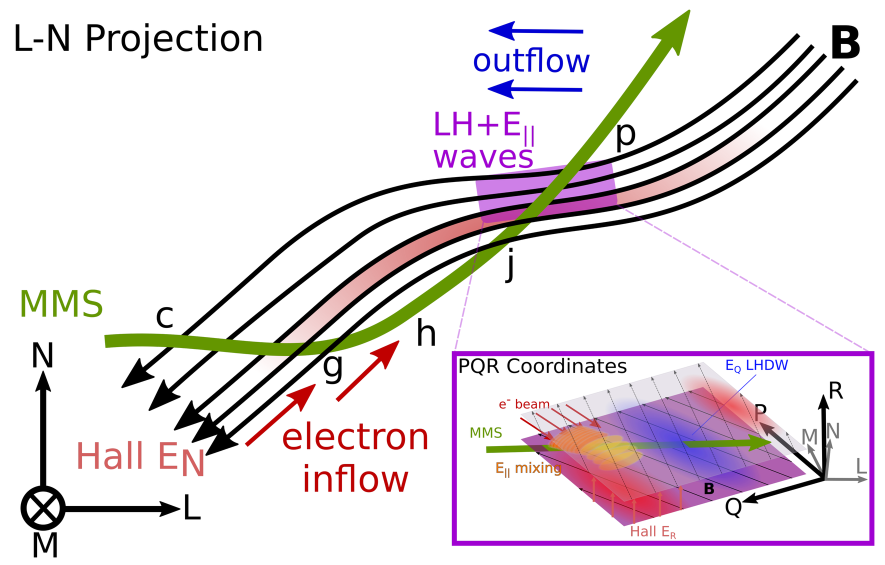
An ion scale magnetic structure with rapidly inflowing electrons was observed just prior to an EDR encounter [1] by MMS on July 11th 2017. Enhanced Hall magnetic field, velocity reversal, parallel heating, and large amplitude electrostatic waves are indicative of a violent mixing interaction at a sharp boundary near the reconnection separatrix. We investigate the nature of this boundary via multi-spacecraft timing, de Hoffmann Teller frame jump conditions, and dissipation in the form of **J·E**. Violent mixing between reconnection inflow and outflow appear coupled to compression of the separatrix.

EVENT OVERVIEW



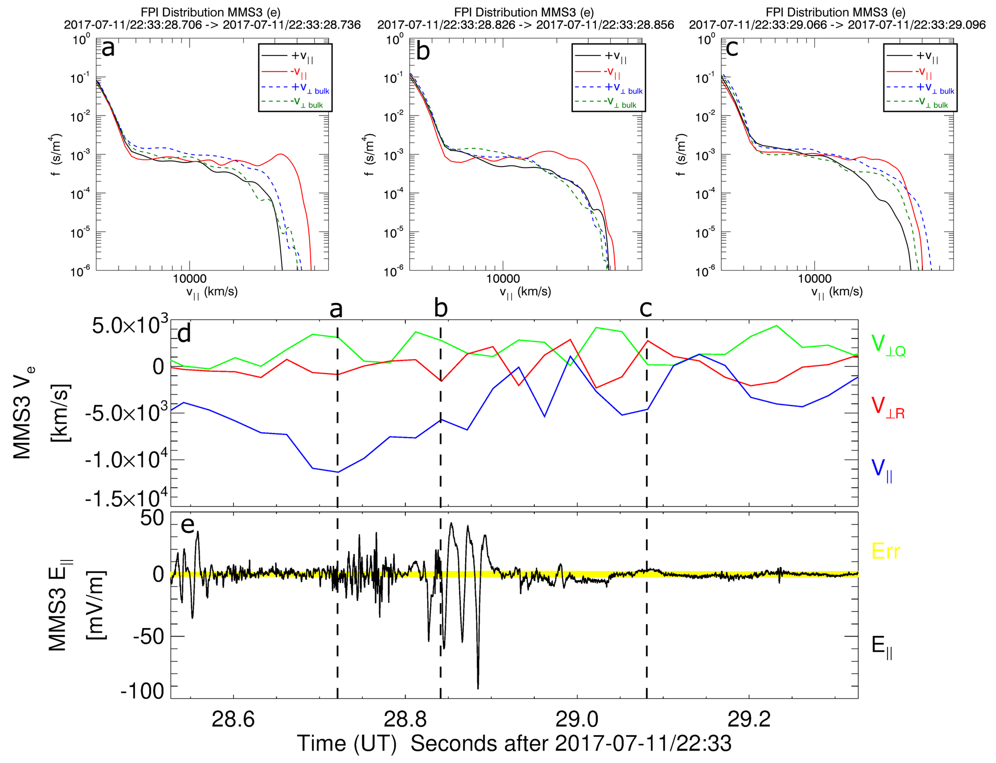
INFLOW STRUCTURE



P ~ parallel to **B**
Q ~ **E**×**B** direction
R ~ Normal to layer

- LMN coordinates defined based on reconnection event, PQR redefined for separatrix structure
- Second crossing exhibits magnetic pileup, high amplitude wave activity, and apparent coupling between lower hybrid drift waves and parallel mixing

PARALLEL MIXING IN SECOND CROSSING



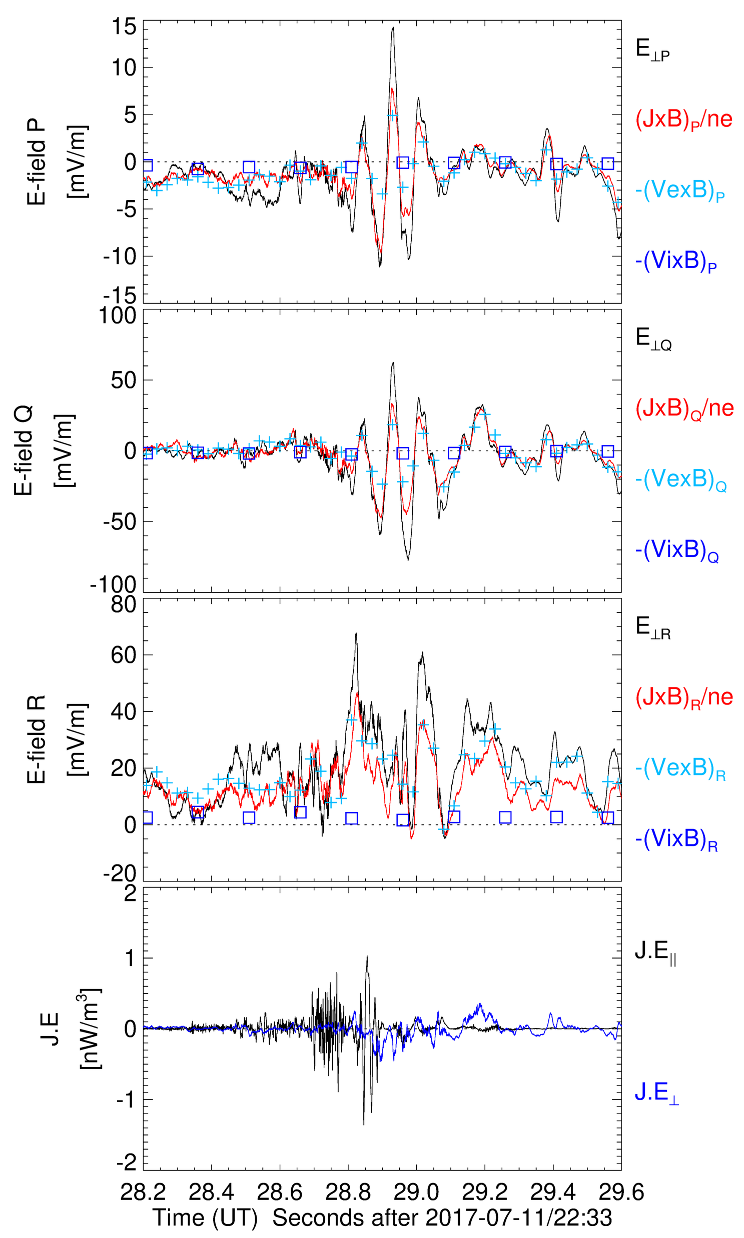
- Fast electron beam consistent with magnetic shear accompanied by high frequency beam-mode waves
- High amplitude Buneman spikes similar to mixing signatures in previous separatrix observations

OHM'S LAW AND DISSIPATION

- Generalized Ohm's Law assuming small inertial term:

$$\mathbf{E} + \mathbf{V} \times \mathbf{B} = \frac{\mathbf{J} \times \mathbf{B}}{ne} - \frac{\nabla \cdot \mathbf{P_e}}{ne} + \eta \mathbf{J}$$

- Compute **J** using curlometer technique, compare with $\mathbf{v}_e$
- $\mathbf{E}_R$ does not meet frozen in condition. Pressure gradient is in +**R** direction, so cannot make up the remainder.
- $\mathbf{J}\cdot\mathbf{E}_{\parallel}$ dissipation shown likely oscillatory – curlometer **J** not reliable at higher frequencies
- $\mathbf{J}\cdot\mathbf{E}_{\perp}$ overall negative contribution, possibly related to thinning of the separatrix



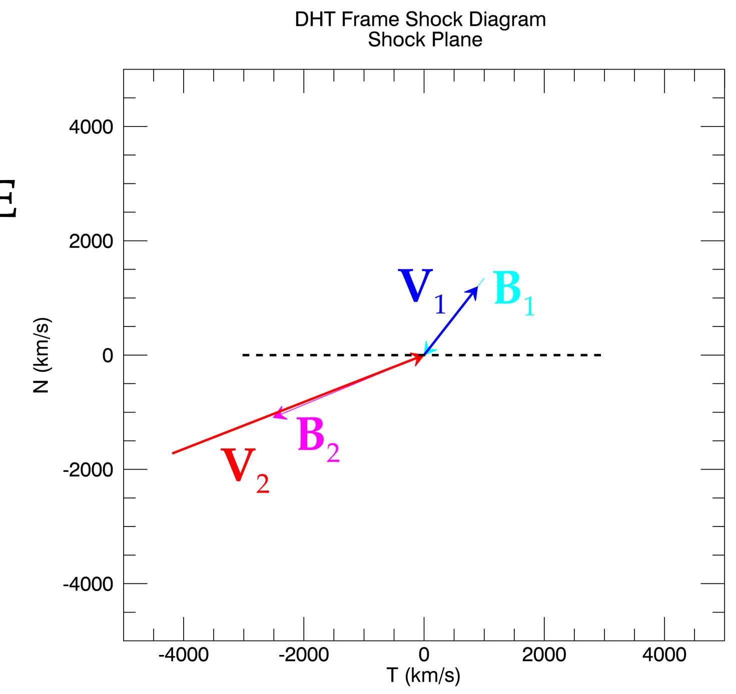
DISCONTINUITY ANALYSIS

DE HOFFMANN TELLER FRAME

Change to frame with no motional **E**

$$|\mathbf{v_e} \times \mathbf{B}| = 0$$

$$\mathbf{v}_{\mathrm{HT}} = \frac{\hat{\mathbf{n}} \times (\mathbf{v_1} \times \mathbf{B_1})}{\mathbf{B_1} \cdot \hat{\mathbf{n}}}$$



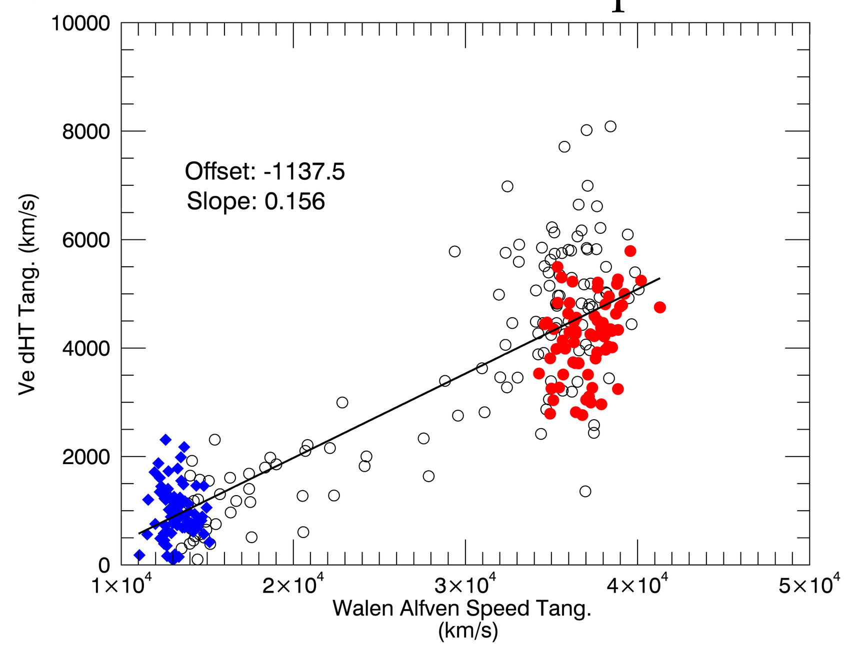
- de Hoffmann Teller frame is well defined and quasi-2D
- Structure has the form of a slow shock, but reversed from Petschek orientation [2], with the *inflow* as the fast population

JUMP CONDITIONS / WALÉN RELATION **NOT** SATISFIED

- Is tangential velocity ($\mathbf{V}_{\mathrm{T}}$) consistent with Alfvén speed?

$$\frac{\mathbf{v}'_{\mathrm{T}_1}}{\mathbf{v}'_{\mathrm{T}_2}} = \sqrt{\frac{\mathbf{v}'^2_{\mathrm{N}_1} - \mathbf{v}^2_{\mathrm{A}_2}}{\mathbf{v}'^2_{\mathrm{N}_1} - \frac{n_2}{n_1}\mathbf{v}^2_{\mathrm{A}_2}}}$$

- Assumed steady-state and diagonal pressure tensor
- Failure of tests implies non-ideal or time-evolving behavior at the boundary



SUMMARY

Magnetic pileup is observed along the separatrix of a confirmed magnetic reconnection site. Strong electrostatic waves with velocities both parallel and perpendicular to the magnetic field are found concurrent with parallel heating of electrons, ion velocity rotation, and a density cavity expected in the reconnection separatrix. Parallel modes are indicative of rapid thermalization of an anti-parallel electron beam. Coplanarity of **B** and **v** are consistent with a (reversed) slow shock model, but jump conditions are not satisfied. Likely, the failure of these tests relates to the active compression and non-ideal activity at the boundary, also indicated by unusual generalized Ohm's Law balance and an overall negative **J·E**.

REFERENCES

[1] Torbert, R. B. et al. (2018), Electron-scale dynamics of the diffusion region during symmetric magnetic reconnection in space, *Science*. 362, 1391-1395.
[2] Petschek, H. E. (1964), Magnetic field annihilation, *Physics of Solar Flares, NASA Spec. Publ.*, 50, 425–439.

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