THE ROYAL SOCIETY

Electron-only Reconnection at the Bow Shock

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Reconnection at the Bow Shock

Instabilities of waves in the shock foot and turbulence in the extended transition region can generate **reconnecting current sheets** and **magnetic islands**.

Observational Evidence:

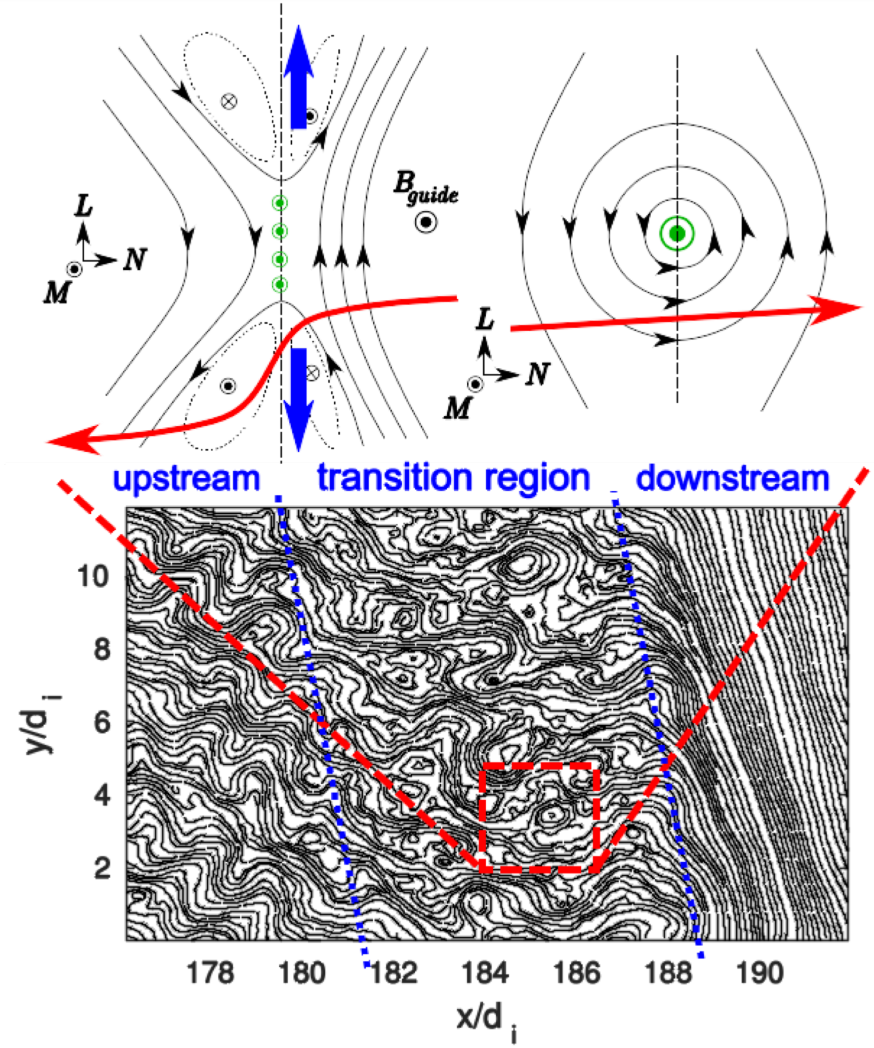
Gingell et al. 2019 – Case Study
Wang et al. 2019 – Case Study
Gingell et al. 2020 – Survey

Simulation of Mechanisms:

Matsumoto et al. 2015
Gingell et al. 2017
Bessho et al. 2020

What's the impact?

Schwartz et al. 2021



Current sheets & twisted field structures visible in the magnetic structure of the shock transition. (Gingell et al. 2019)

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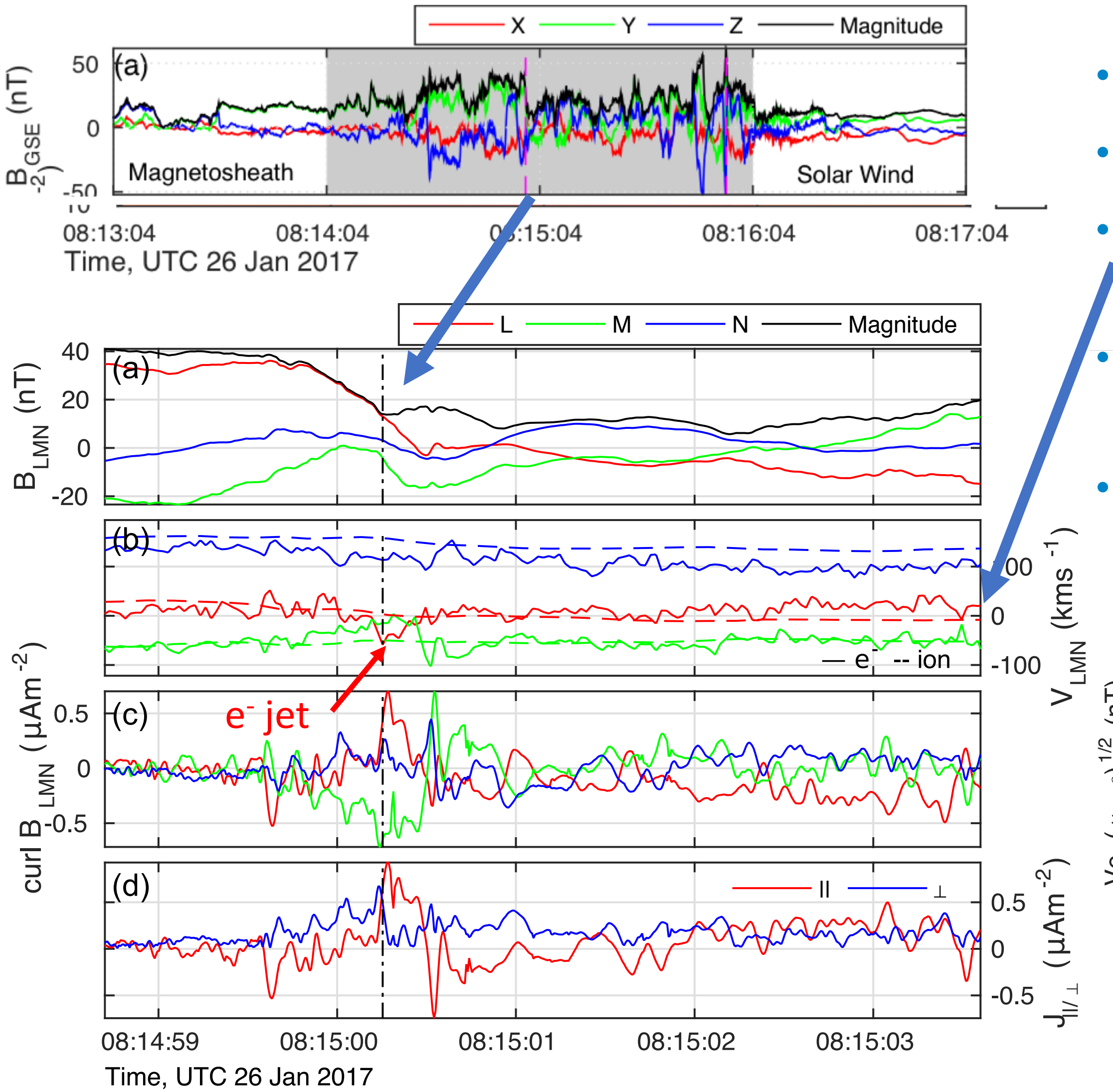
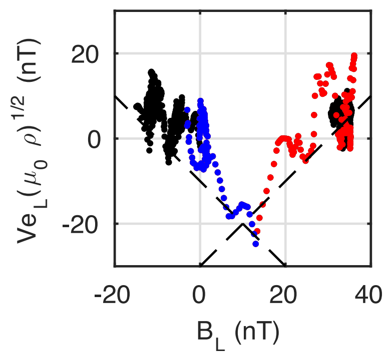
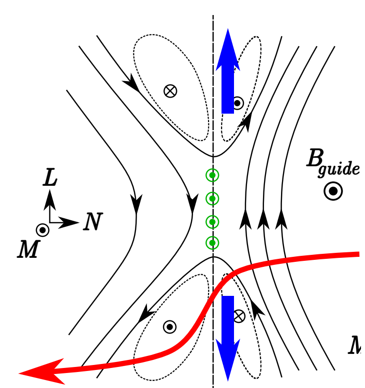
Electron-only Reconnection at the Shock: Case Study



- Gingell et al. GRL 2019
- B reversal over ~3s, sheet width $3d_i$
- **Jet** visible in **electron** V_L (solid red), but **not in ions** (dashed red).
- **Ion scale sheet with no ion response.**
- Walen Test: Correlation between B_L and V_{eL} reverses on crossing jet.





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Surveying Reconnection at the Shock

Gingell et al. (2020): survey of all 223 MMS shock crossings during Phase 1

Input list of shock burst intervals.

Calculate |J| from curlometer across the full burst interval.

Label regions with $|J| > 3\sigma_J$

Perform minimum variance analysis on $\mathbf{B}_{GSE}$ to get $\mathbf{B}_{LMN}$ for each interval.

Does the max variance component B_L change sign?

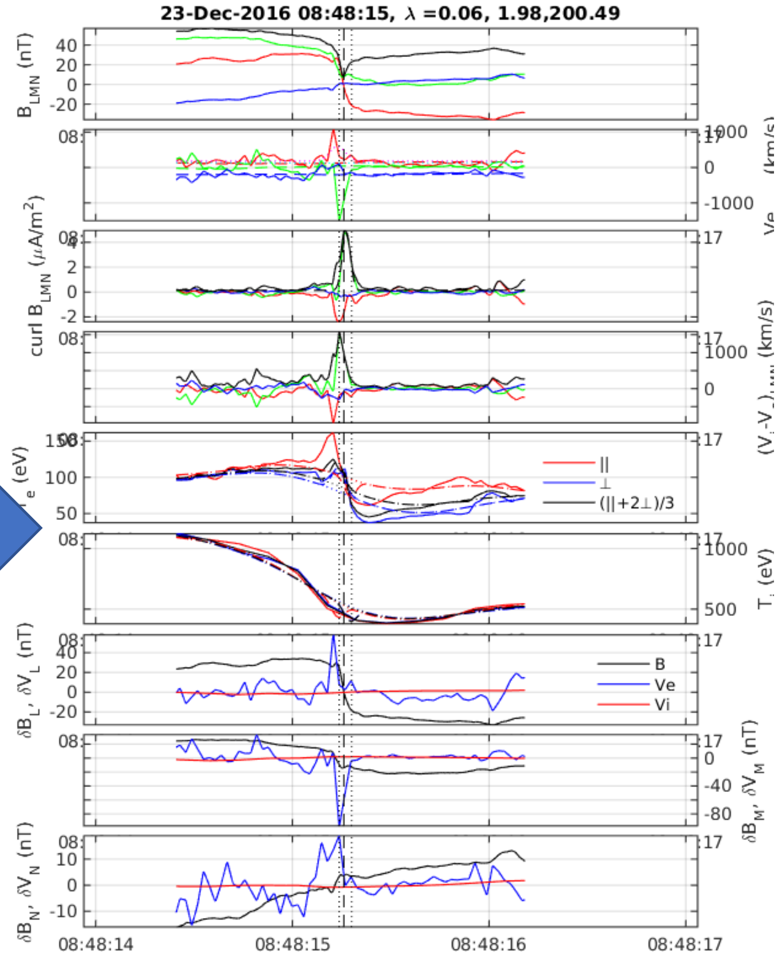
Is there a peak in V_{eL} within the current carrying region?

903 Candidates

Good sheet structure? MVAB worked?

Clear jets?

Walen Test



165 Events!

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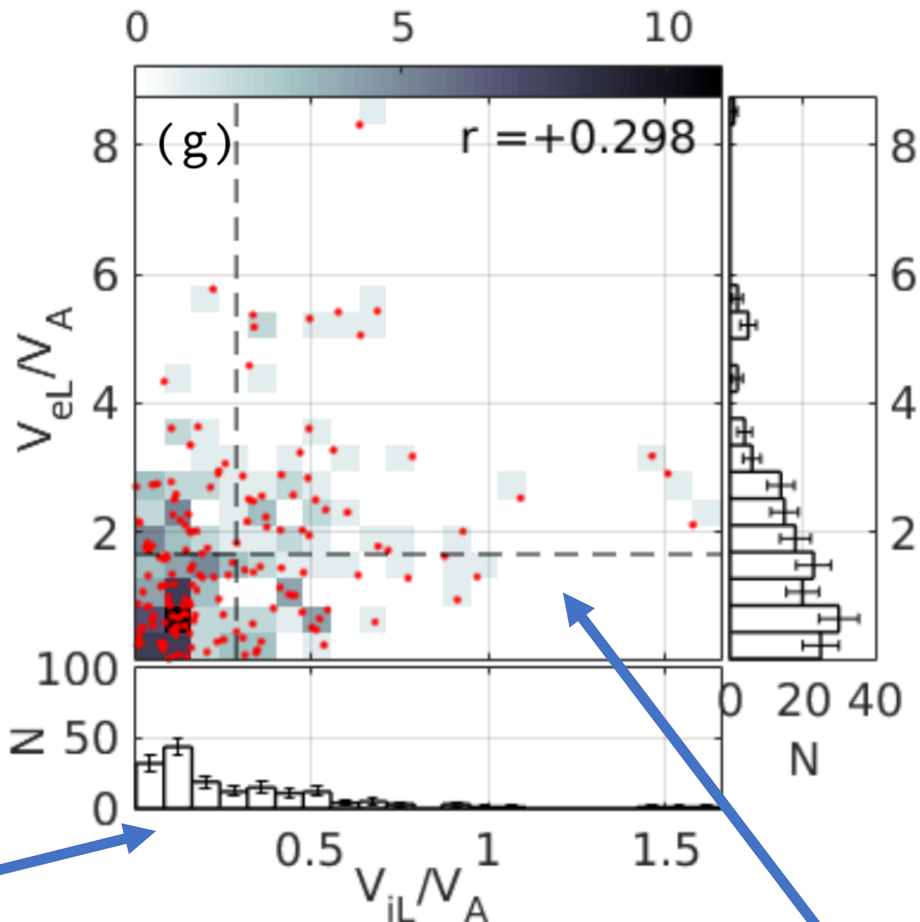
Properties of Current Sheets at the Shock – Ion vs Electron Jets

Ion jets are often absent despite measurement of electron jets

-> **electron-only reconnection** appears to be is common (or even dominant) in the shock transition region.



Most observe either no ion jet, or very weak ion jet

Some strong ion jets observed

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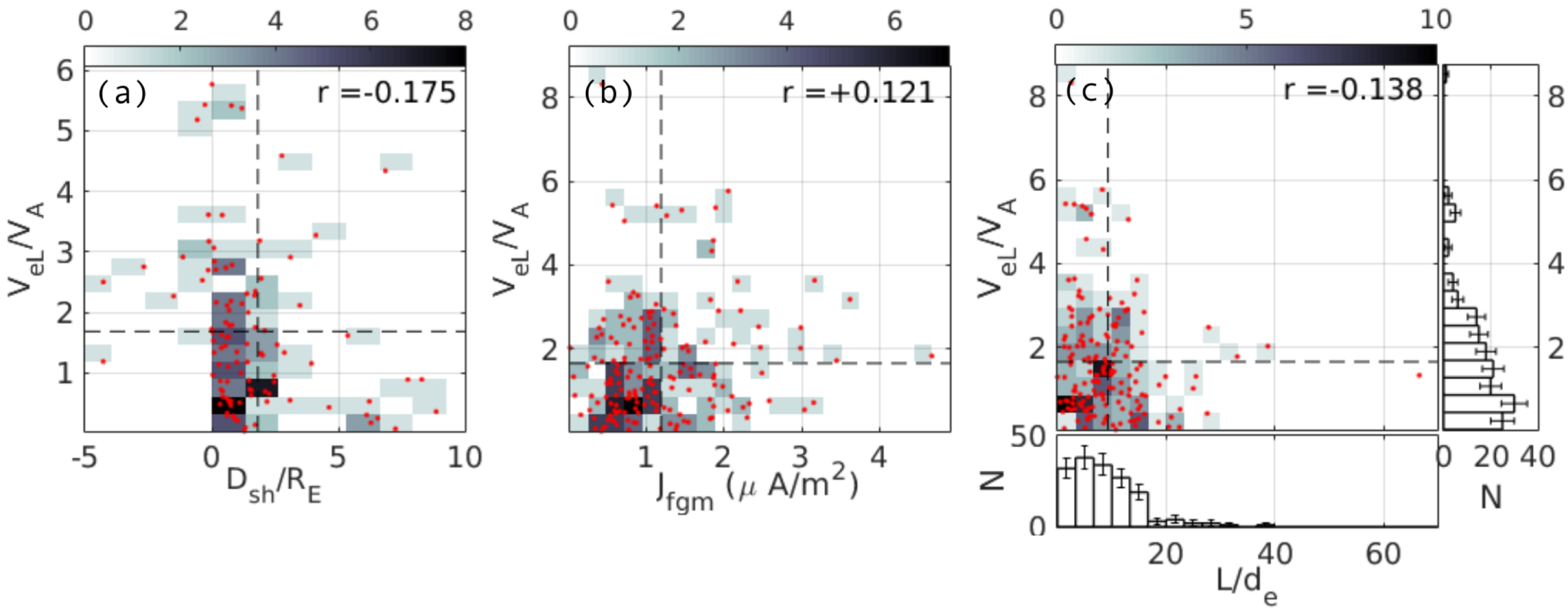
Properties of Current Sheets at the Shock – Electron Jet Velocities



- Electron jet speeds 1-2 V_A are typical, with a significant population up to 6 V_A
- Fastest (super Alfvenic) electron jets appear closest to the shock ramp.
- Otherwise, no clear correlations between jet speeds and other sheet properties.

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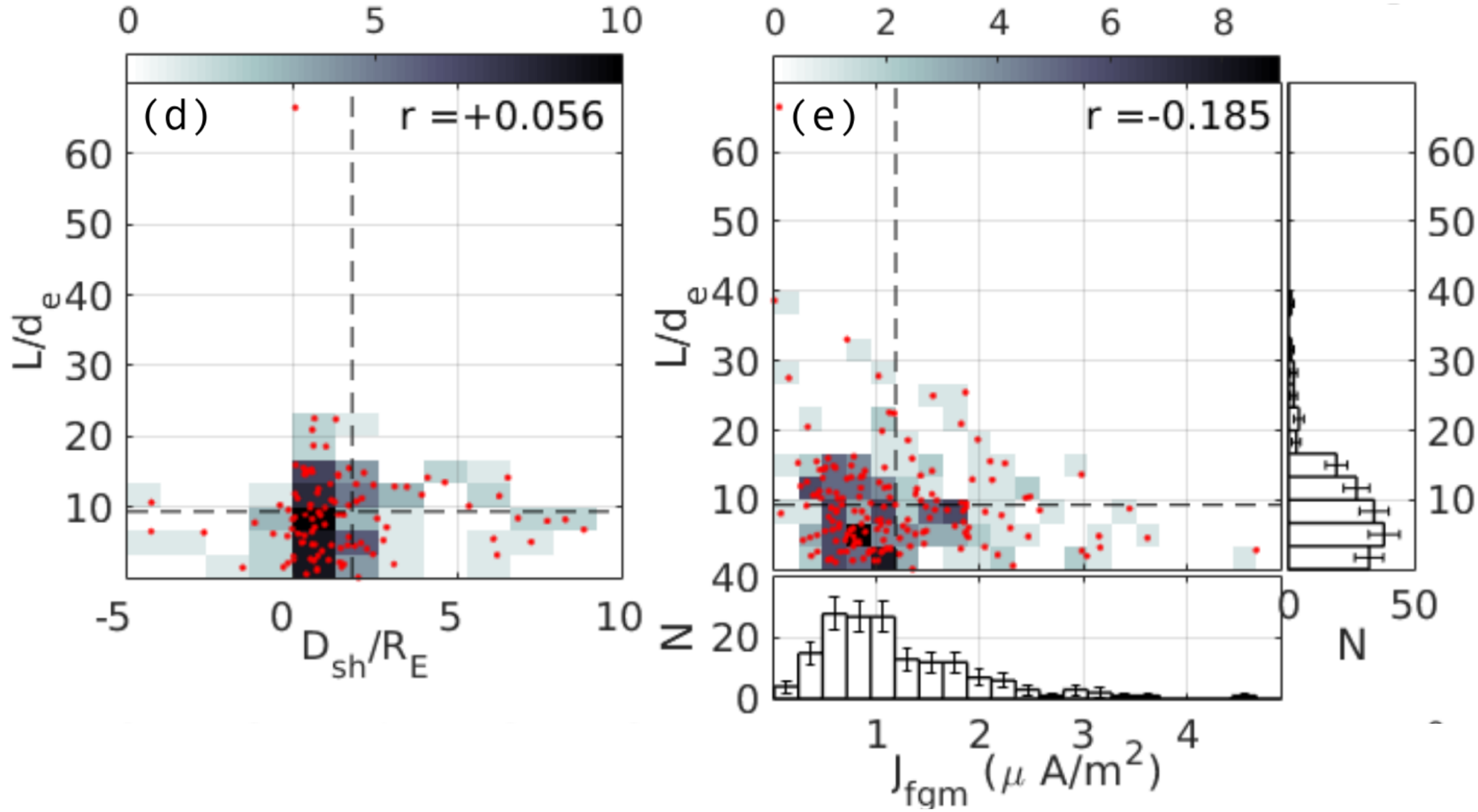
Properties of Current Sheets at the Shock – Sheet Widths

Sheet Widths



- Most current sheets are observed at electron scales, or between electron and ion scales.
- Current sheets are not wider further from the shock
  - Sheets are generated across the transition region at a broad range of scales.
  - i.e. Thin sheets (electron-only?) are not favoured nearer or further from the shock

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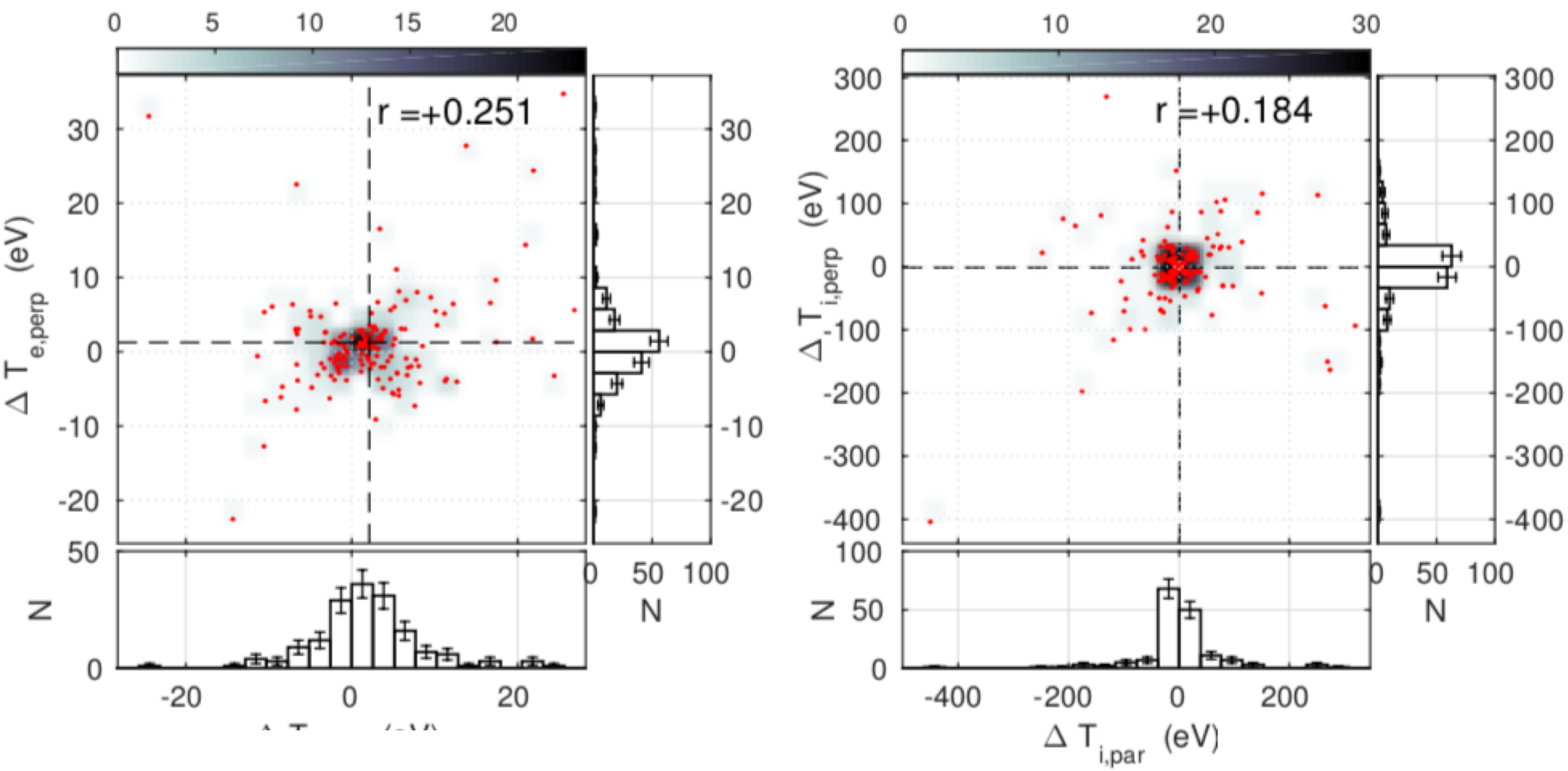
Properties of Current Sheets at the Shock – Heating



- Weak correlations and wide distributions attributed to difficulties extracting heating from inhomogenities in the transition region
- Extreme events may be more likely to exhibit isotropic heating or cooling ($\Delta T_{perp} \sim \Delta T_{par}$)
- Very slight positive mean for ΔT_e in both par and perp, zero or negative mean for ΔT_i – evidence of electron-only coupling?

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Conclusions

Current sheets with signatures of **active reconnection** are observed in the transition region (and downstream) of the **bow shock** (Gingell et al 2019, Wang et al 2019).

A survey Phase 1 shock crossings identified **165 current sheets** (Gingell et al 2020).

Very few of the recorded events exhibit clear ion jets – **electron-only reconnection appears to dominate**.

Fastest super-Alfvenic electron jets are most common close to the shock ramp – they are **localized to the shock** layer.

There is no trend in how close to the shock we observe electron-only reconnection – it is universal.

Heating statistics are difficult to extract – heating and cooling observed. Positive means observed only for electron temperatures.

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