Detection of current sheets and associated reconnection in the magnetosheath using Cluster data

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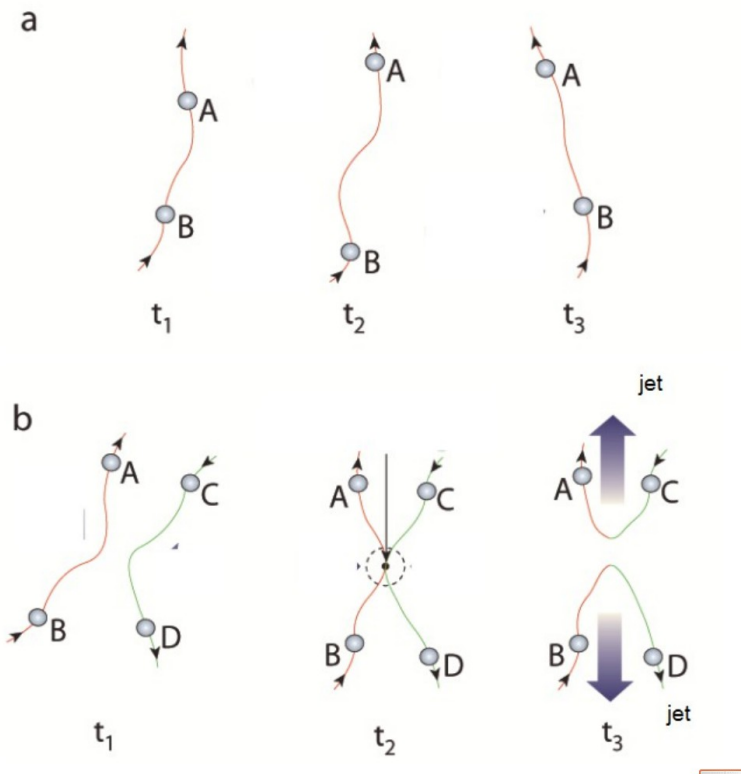
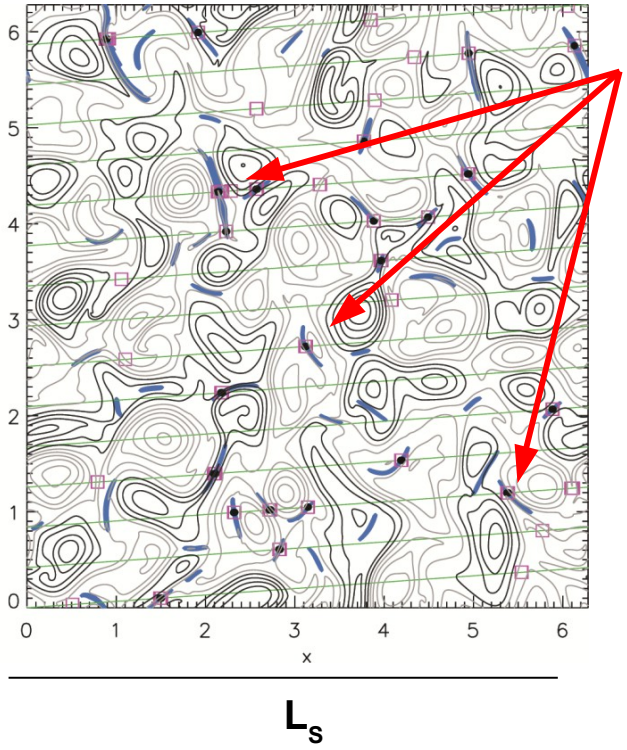
Reconnection in Turbulent Plasma



Numerical simulation [Servidio+ JGR 2011]

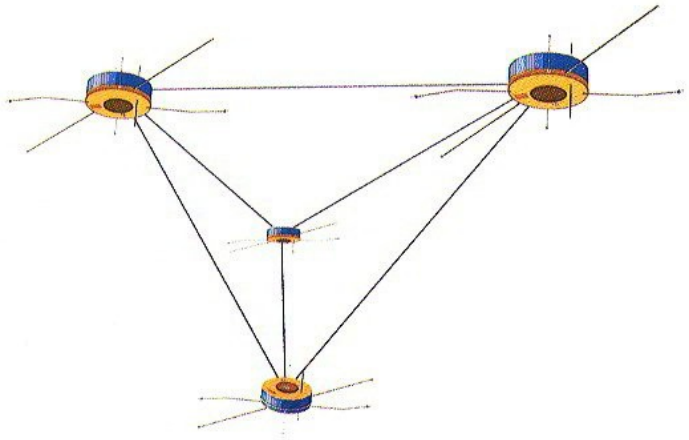


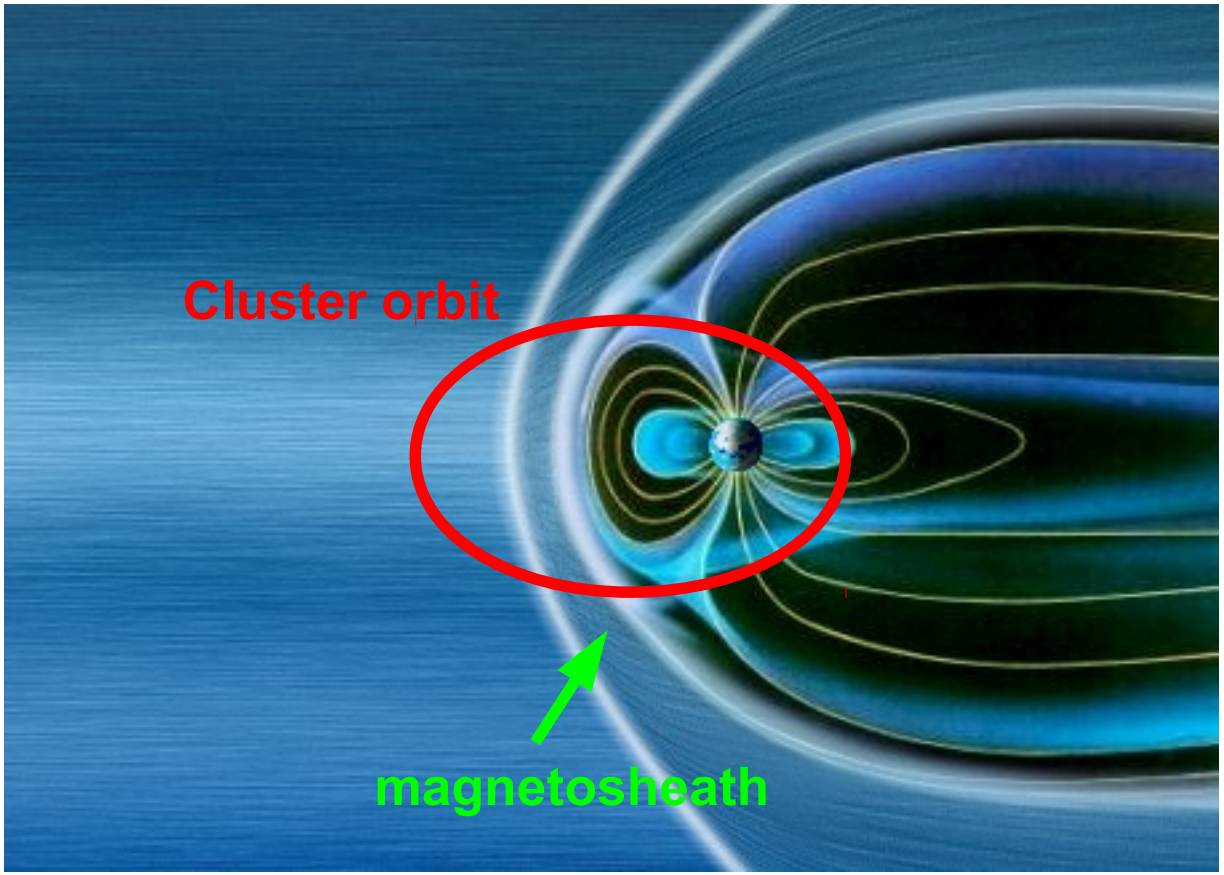
Turbulent reconnection

$L_{cs} << L_s$

- reconnection in small –scale current sheets ($L_{CS} \sim \rho_{gi}$) spontaneously forming in turbulence
- considered important for heating of plasma, bulk plasma acceleration and non-thermal particle acceleration
- very few in situ observations

ESA Cluster Spacecrafts





Cluster mission :

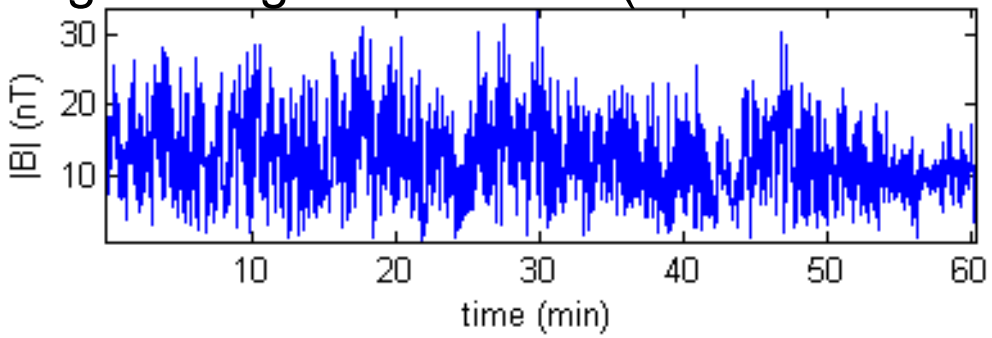
• 4 Spacecrafts in formation
→4 points in situ measurements of B, E, and electron/ion distribution functions

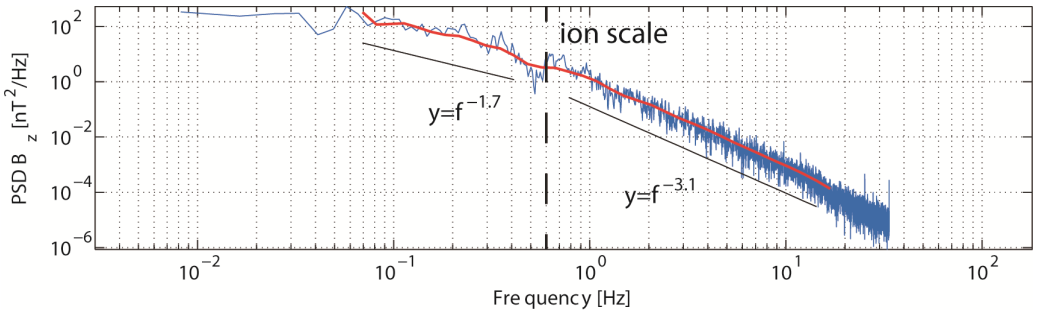
Multispacecraft methods allow :
• measurement of 3D quantities (e.g. $\nabla \times \vec{B}$, $\nabla \cdot \vec{B}$)
• distinguishing spatial from temporal variations

• observations in the terrestrial magnetosheath downstream of quasi-parallel shock
• one of the most turbulent regions in near-Earth space

In situ Cluster observations in near-Earth space

fluxgate magnetomer data (burst mode: 67 Hz)

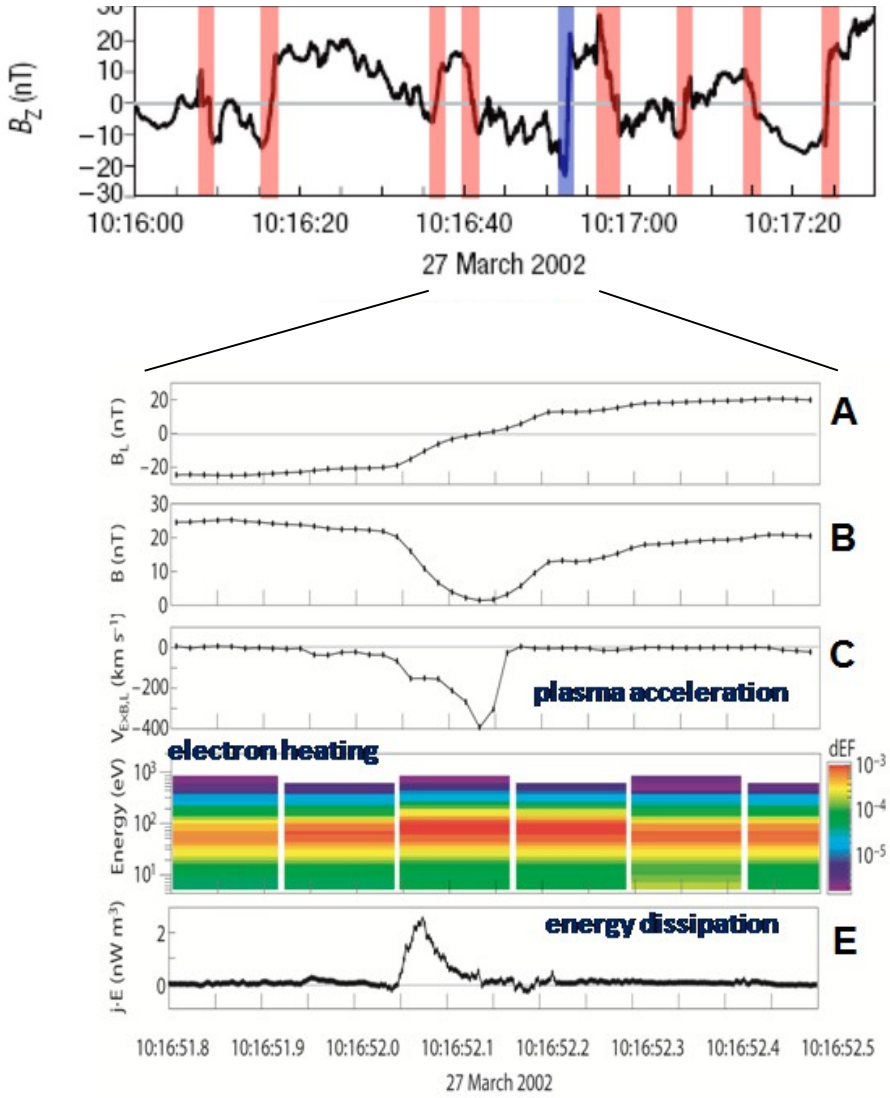




- intermittency at scales ~ ρ_{gi}
- energy dissipation mechanism at kinetic scales

[Sundkvist+ PRL 2007]

reconnecting thin current sheets

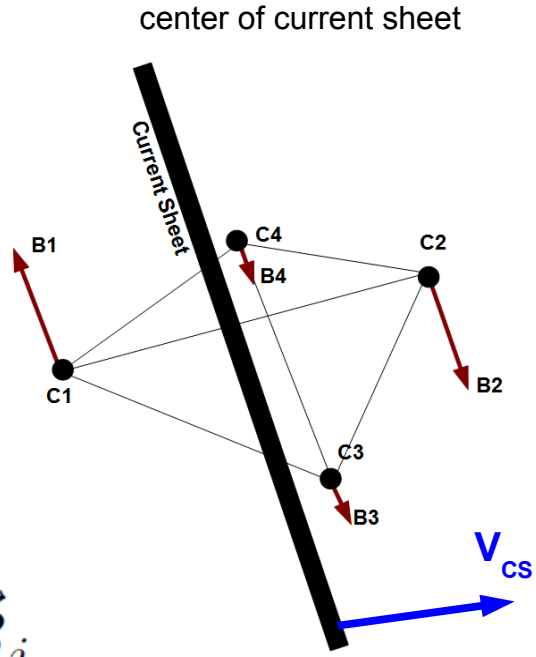


[Retinò+, Nature Physics. 2007]

also Gosling+, ApJLett,2007 in fast solar wind; Chian+,ApJLett,2011 in ICMEs

Detection of current sheets using magnetic field data

We look for strong variations of the magnetic field expected when crossing a current sheets



→ Magnetic shear angle:
rotation of the magnetic field across the current sheet

$$\theta = cos^{-1} \frac{\vec{B}_i \cdot \vec{B}_j}{|\vec{B}_i| \cdot |\vec{B}_j|}$$

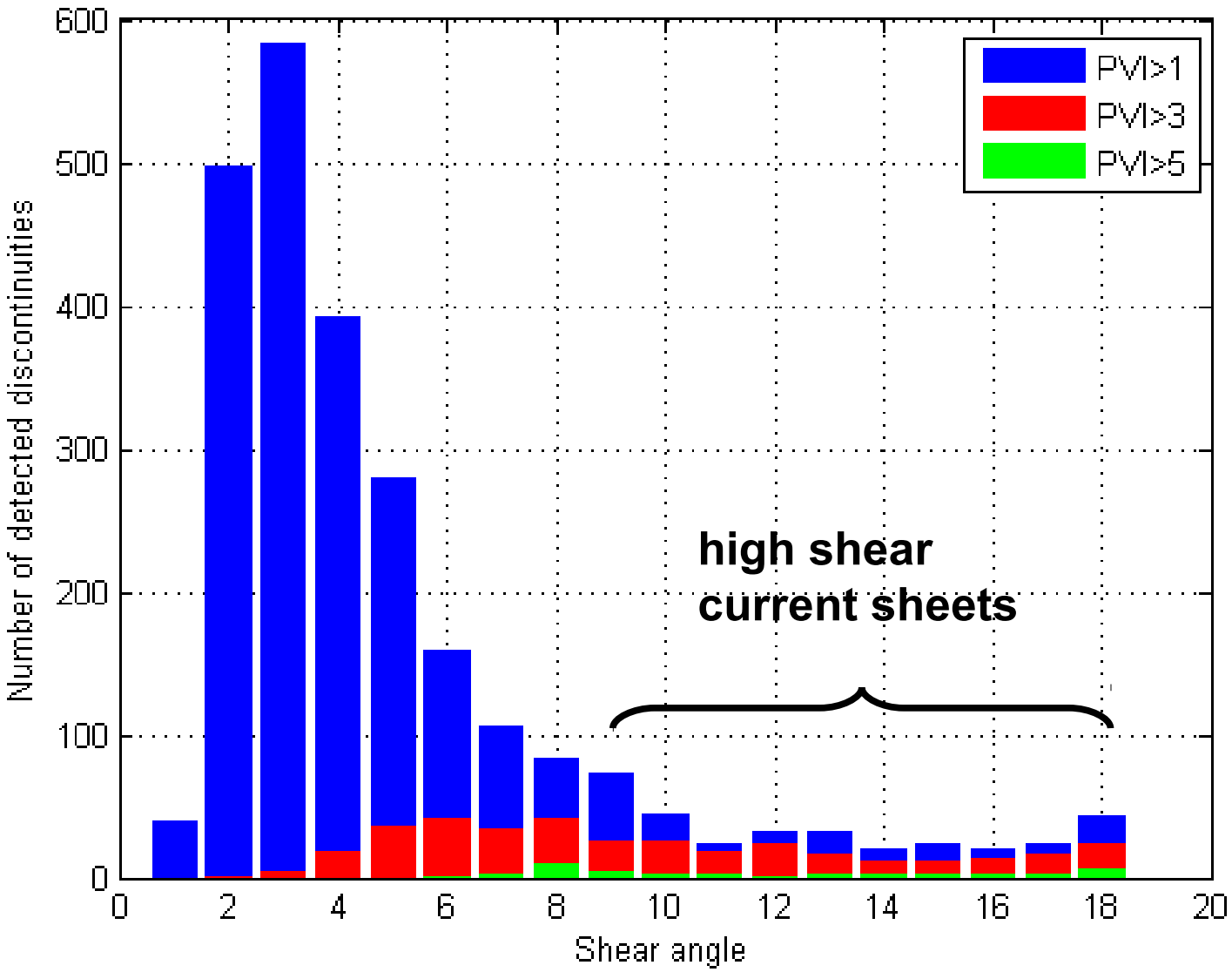
→ Partial Variance of Increments:
variation of the magnetic field across the current sheet

$$|\Delta\vec{B}_{ij}(t)| = |\vec{B}(t)_i - \vec{B}(t)_j|$$

$$PVI = \sqrt{\frac{|\Delta\vec{B}|^2}{<|\Delta\vec{B}|^2>}}$$

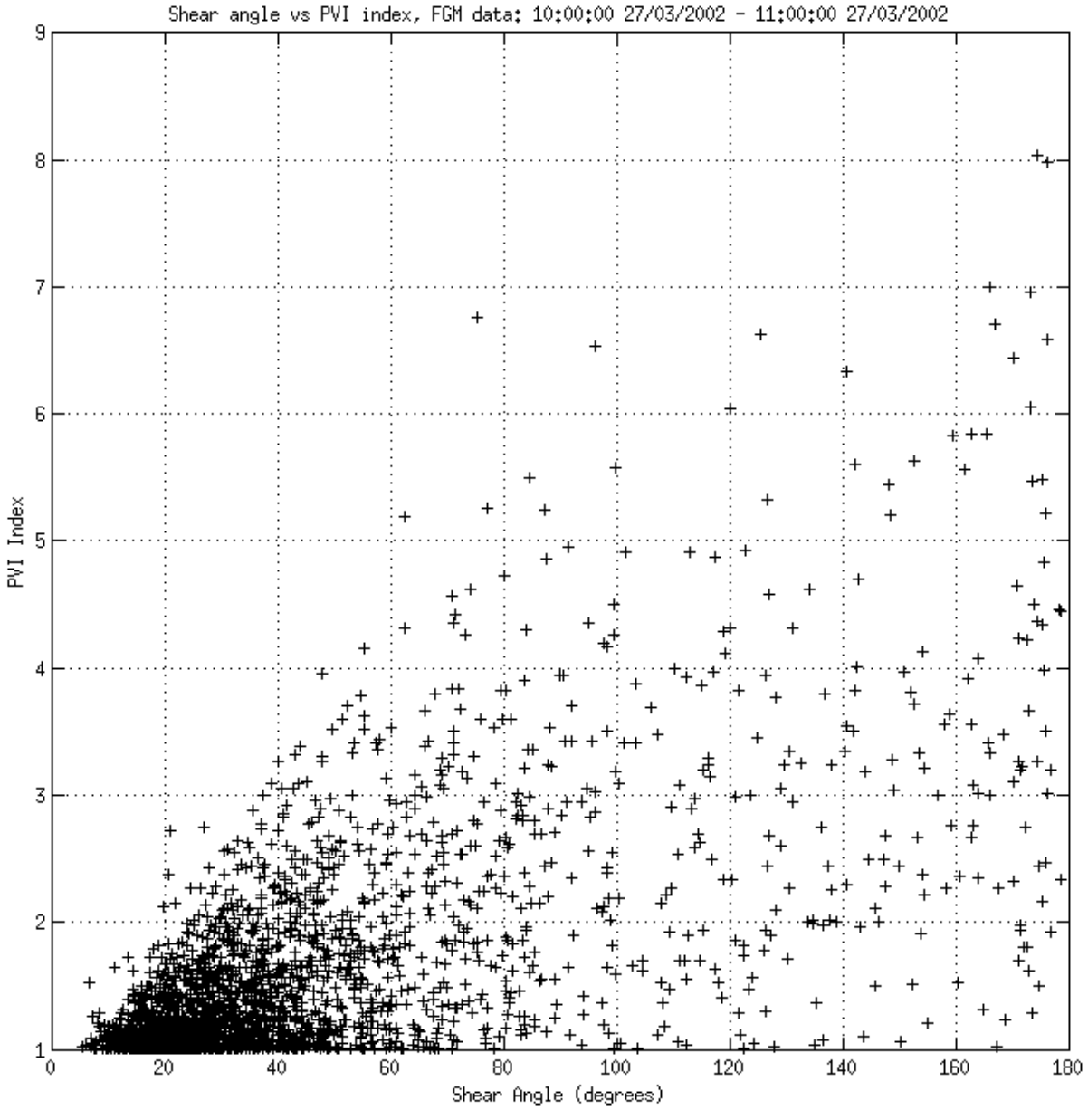
[Greco+ GRL 2008]

Statistical properties of current sheets I



- **distribution not uniform**
- **high shear (θ>90°):**
  - **~20% of the cases**
  - **reconnection rate higher → stronger magnetic energy dissipation**

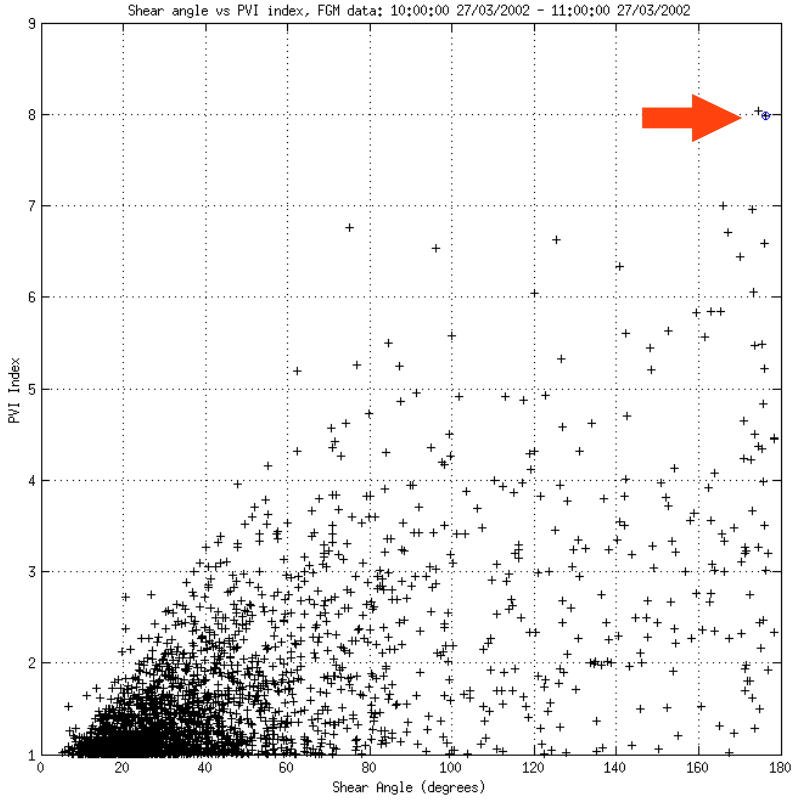
Statistical properties of current sheets II



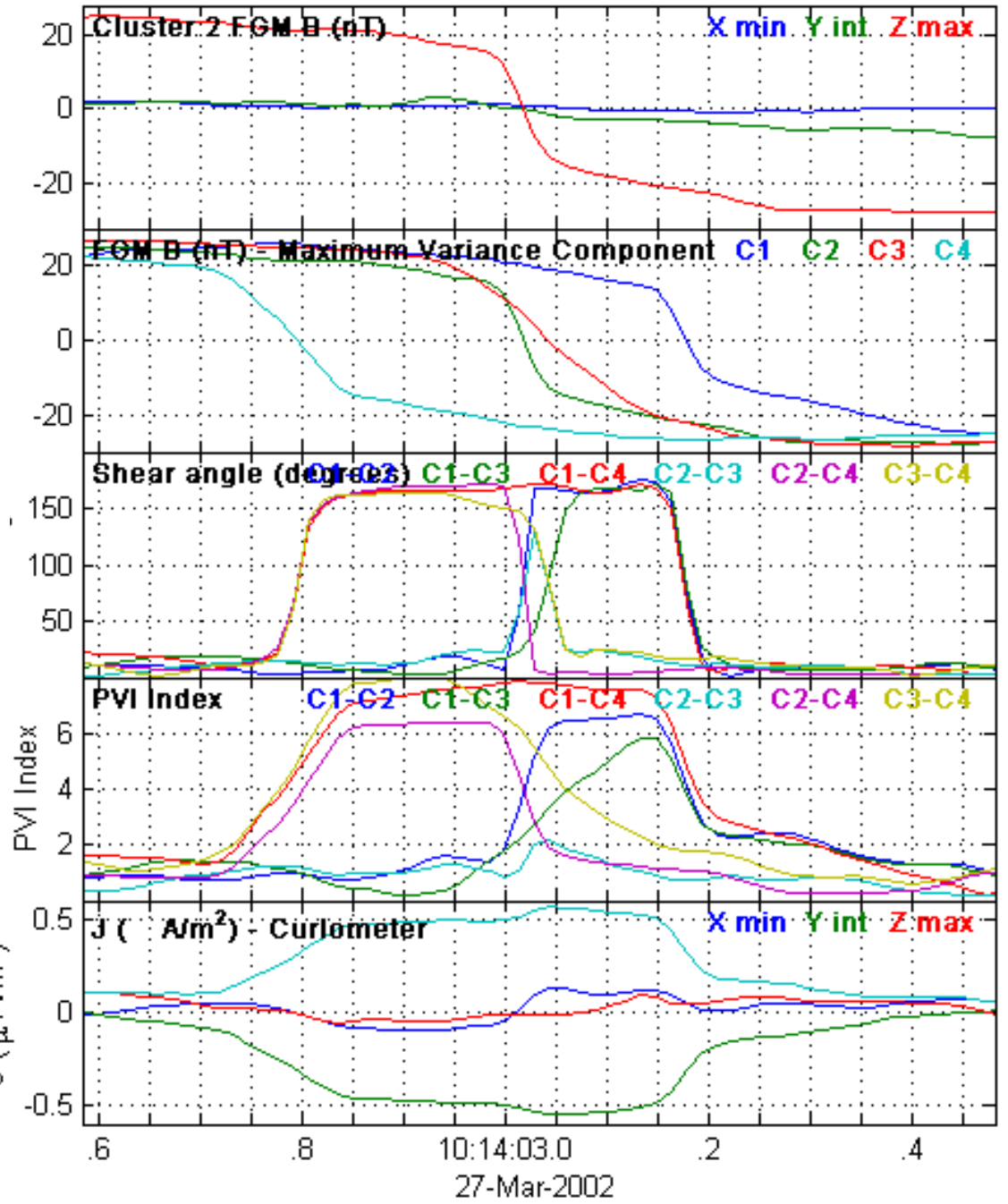
→ high PVI/high shear current sheet = reconnection expected by simulations (Servidio+,11) to be tested
→ low shear current sheets less probable to reconnect. However recent solar wind observations show reconnection at low shear is important (Gosling+,12)

PVI threshold	% of CS reconnecting
[Servidio+ JGR 2011]	
1	9.8
2	23.0
3	34.8
4	43.7
5	57.5
6	72.0
7	93.7
8	100

Case study

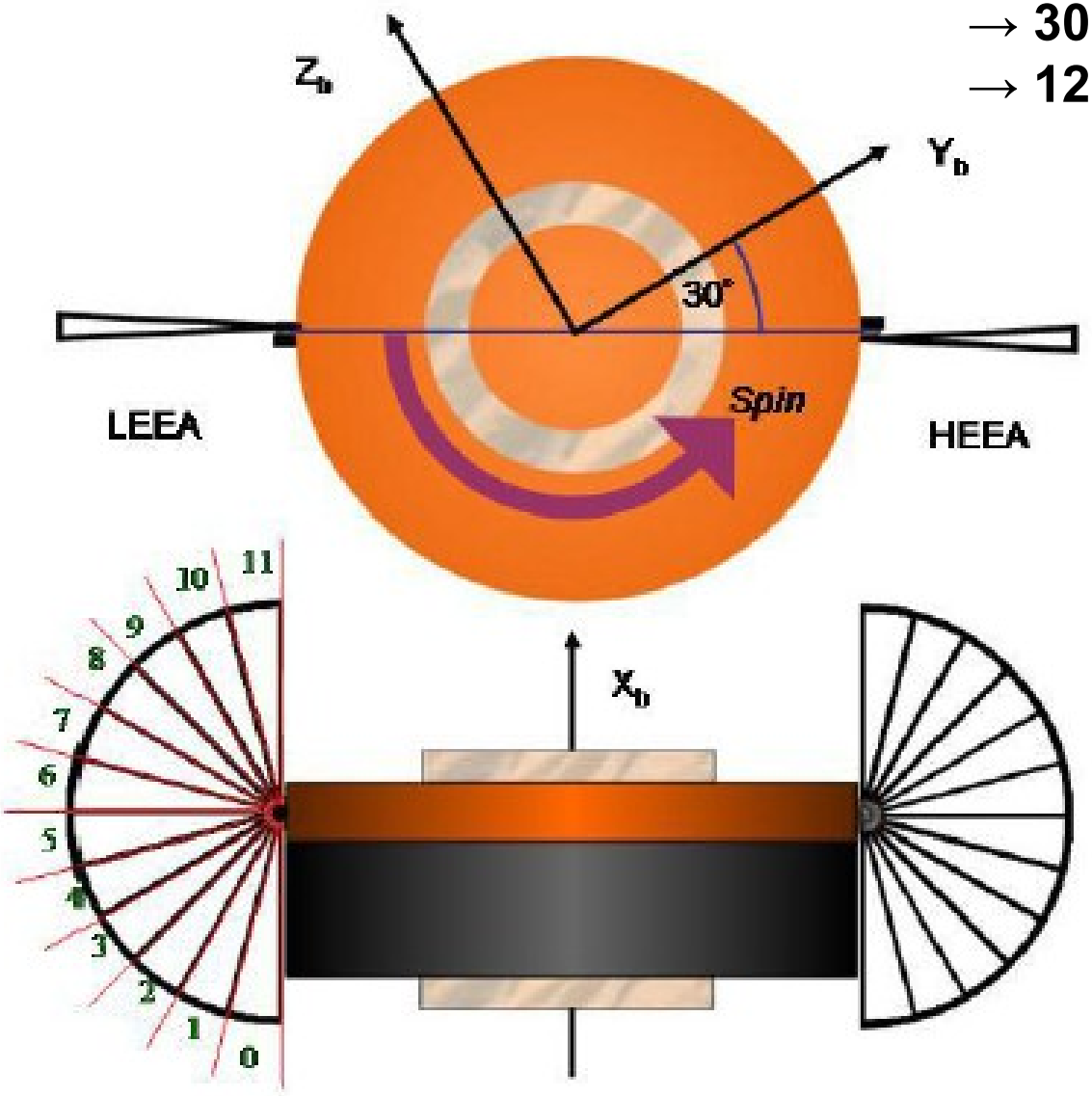


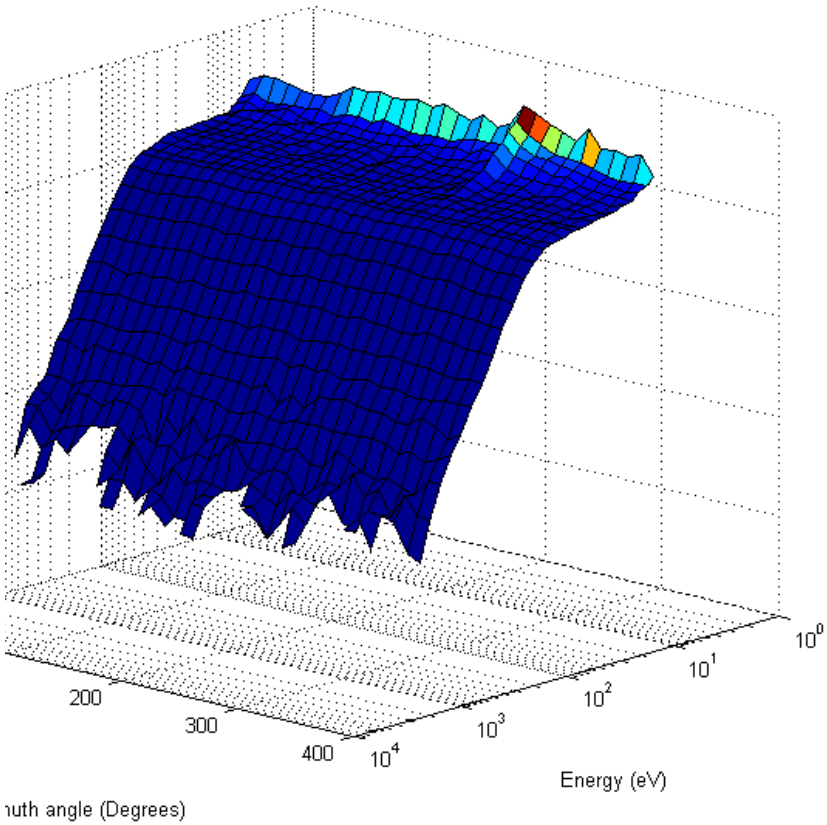
→ **High shear & high PVI index**
→ **Hall field present**
→ **Reconnection rate: B_z/B_x~10%**



PEACE instrument: Electron energy distribution

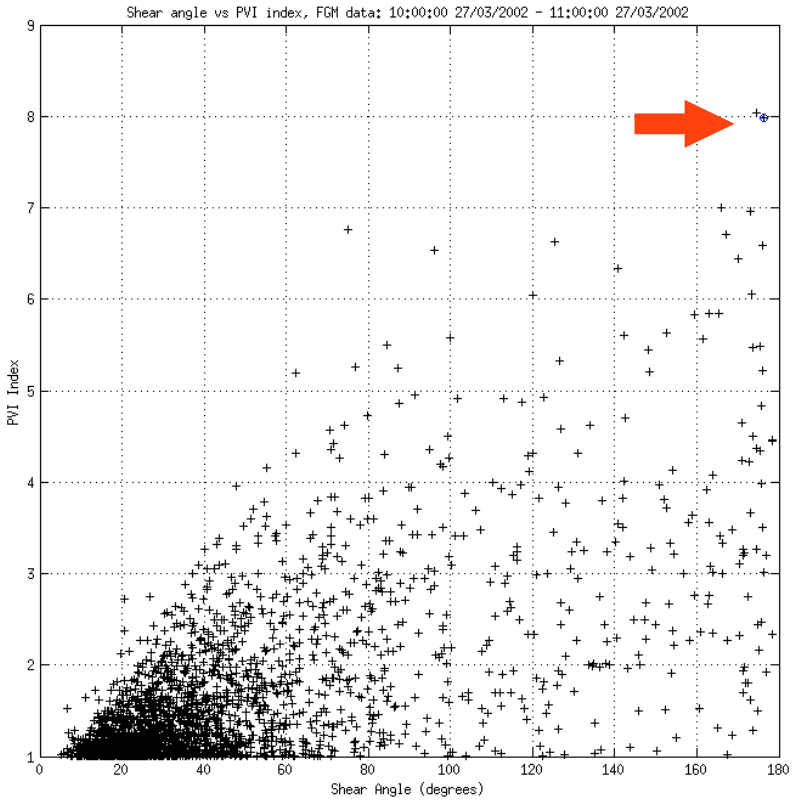
- → Subspin time resolution: 125ms
  → 30 Energy bins
  → 12 Pitch angles

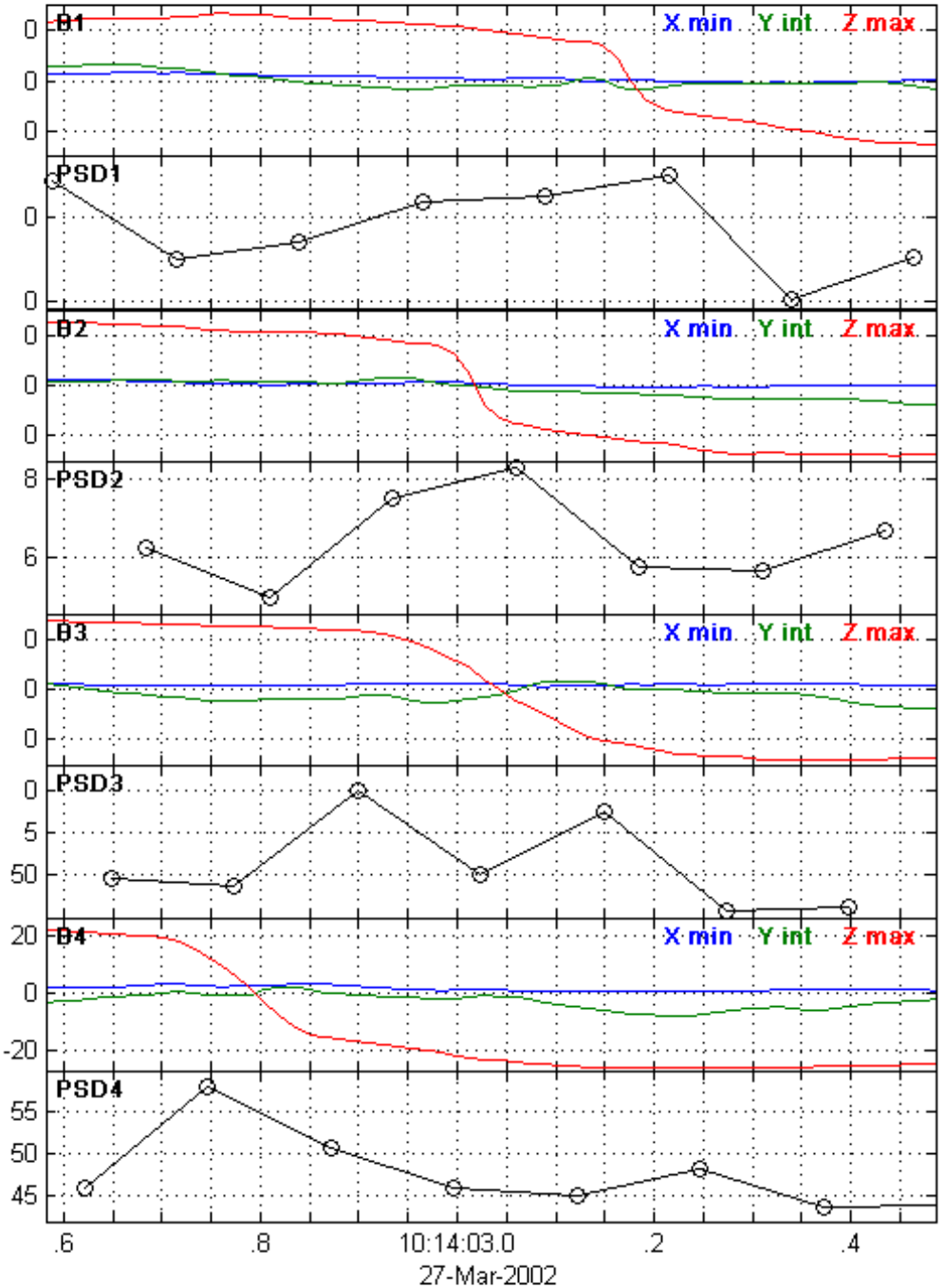




* not all pitch angles always covered
* low energy bins dominated by photoelectrons

Case Study – ElectronTemperature Proxy

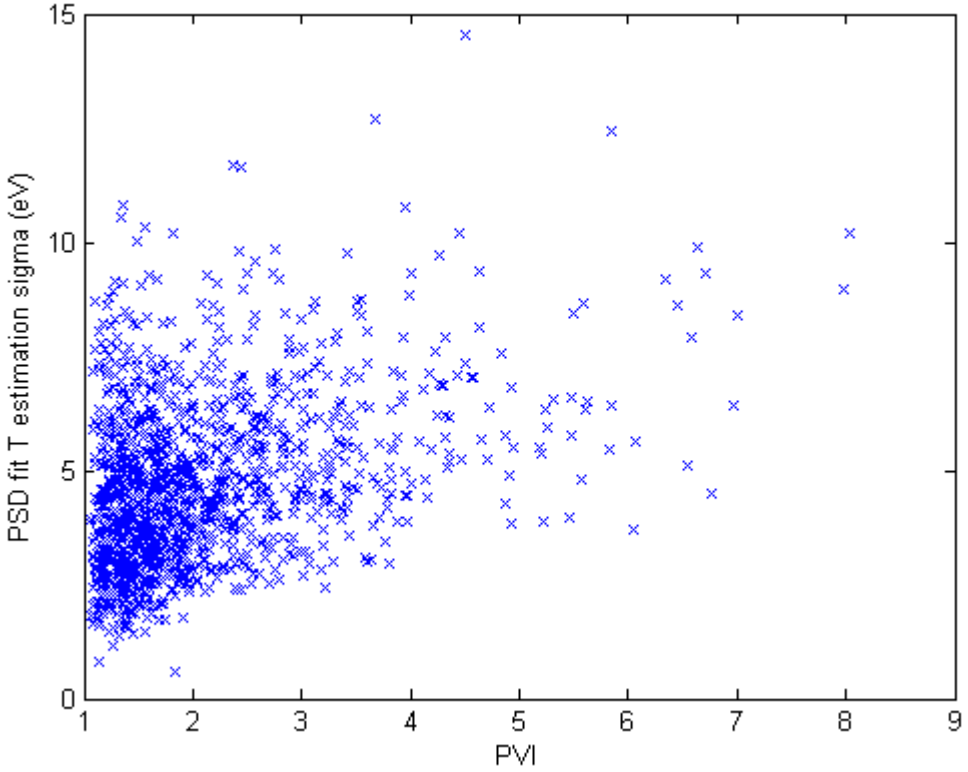


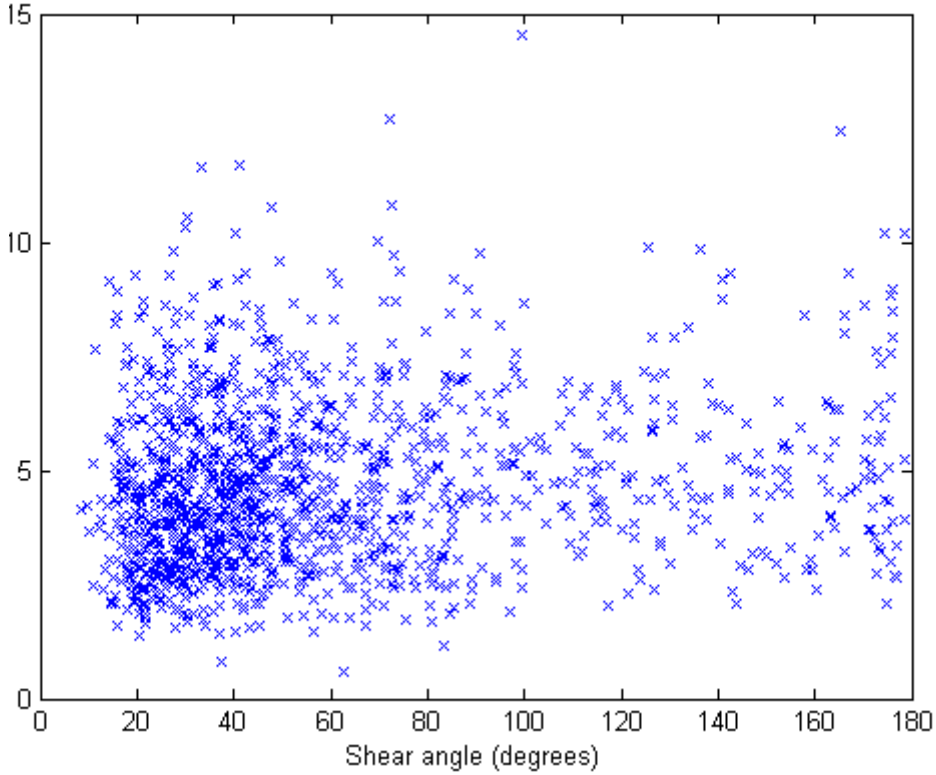


Fit of the PSD:
Electron temperature proxy

Assumptions and caveats
→ Gyrotropy
→ Isotropy
→ Quality of the fit

Electron Temperature proxy - Statistics





→ **Heating for high shear and high PVI**

- **Low correlation**
- **Instrument limitations**
- **Validity of assumptions to be tested**
- **Not much heating expected from theory and simulations**

Discussion

Preliminary Results:

→ **results generaly in agreement with previous work (Retinò+, 2007; Sundkvist+, 2007)**

→ **distribution of current sheets not uniform with differences between low PVI and high PVI/high shear**

→ **different current sheet formation mechanisms (?)**

→ **high PVI current sheets have almost exclusively high shear (>90^o)**

→ **likely candidates for reconnection (Servidio+,11)**

→ **Electron heating – PVI trend**

Future Work:

→ **Characterize low PVI index structures**

→ **Test validity of assumptions for electron temperature and verify trend**

→ **Test in data the correlation between high PVI and high probablity of reconnection shown in (Servidio+,11)**