UCLA

(Under revision)

Temporal Evolution of Flux Tube Entanglement at the Magnetopause as Observed by the MMS Satellites

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Presented by Yi Qi
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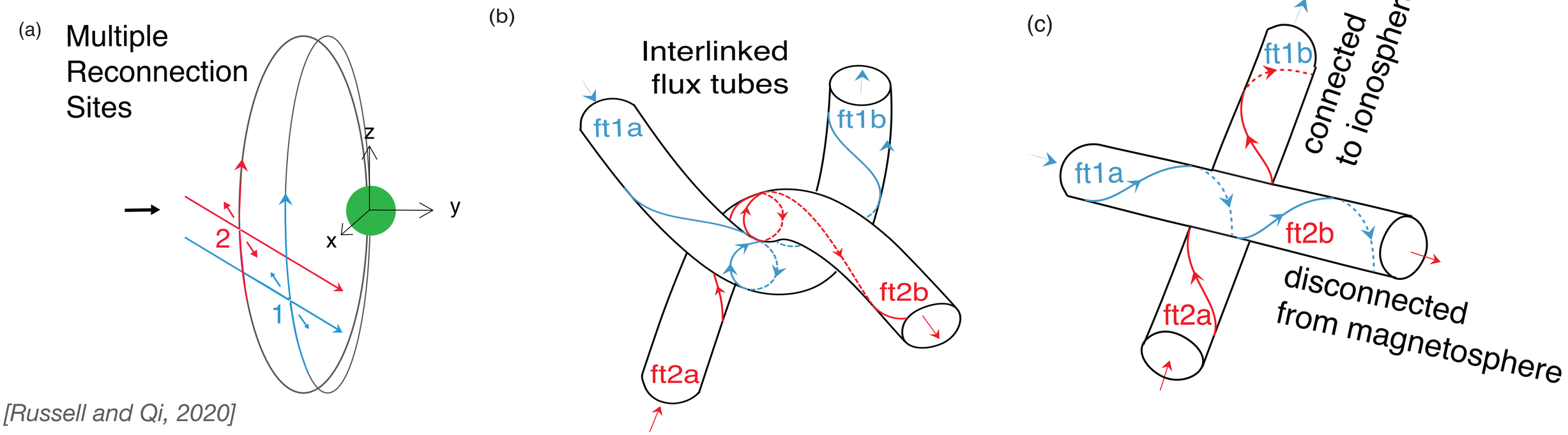
Flux tubes from two separate reconnection sites can collide and become entangled

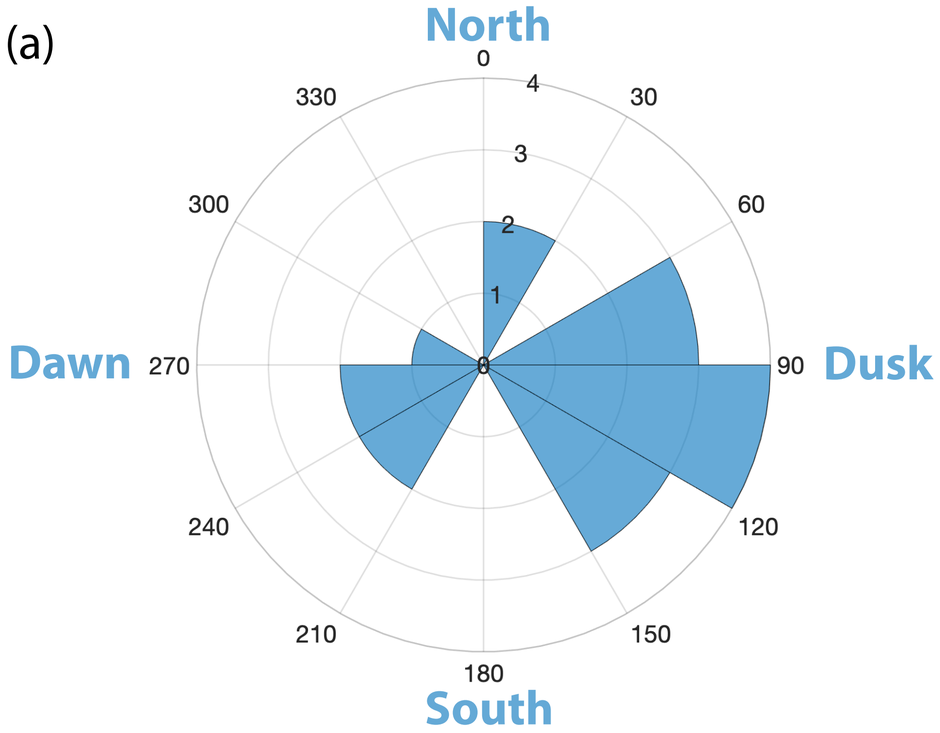
- Magnetic flux piles up at the interface, forming a sharp rotation of the magnetic field (i.e. a thin current sheet at the center)
- Reconnection at the point of entanglement has been observed by the MMS (Fargette et al., 2020; Hwang, Dokgo et al., 2020; Kacem et al., 2018; Kieokaew et al., 2020; Øieroset et al., 2019)

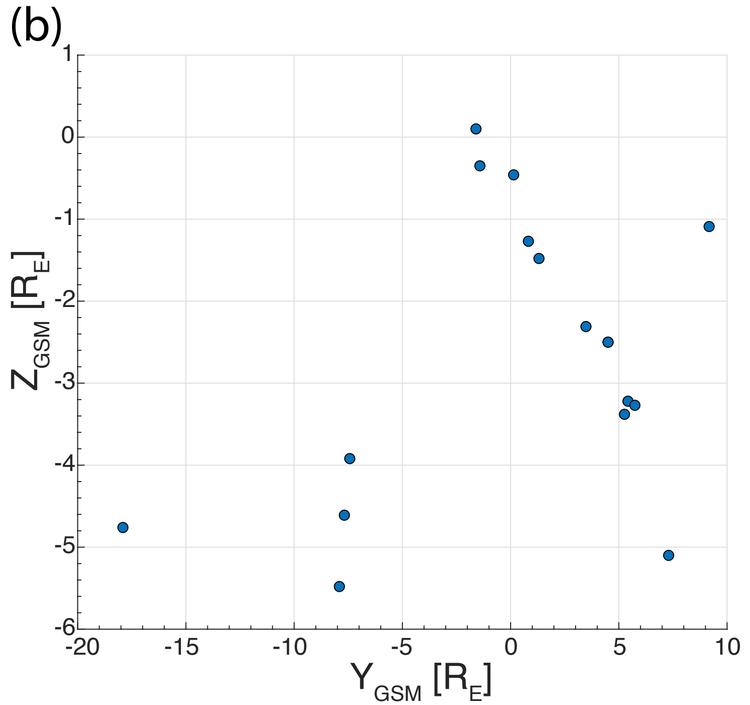


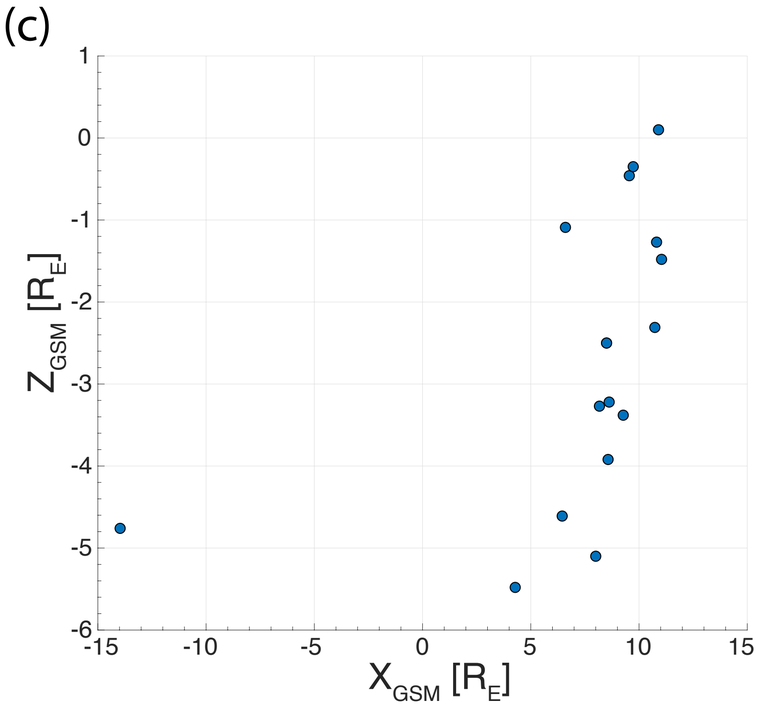
[Russell and Qi, 2020]

17 entanglement events

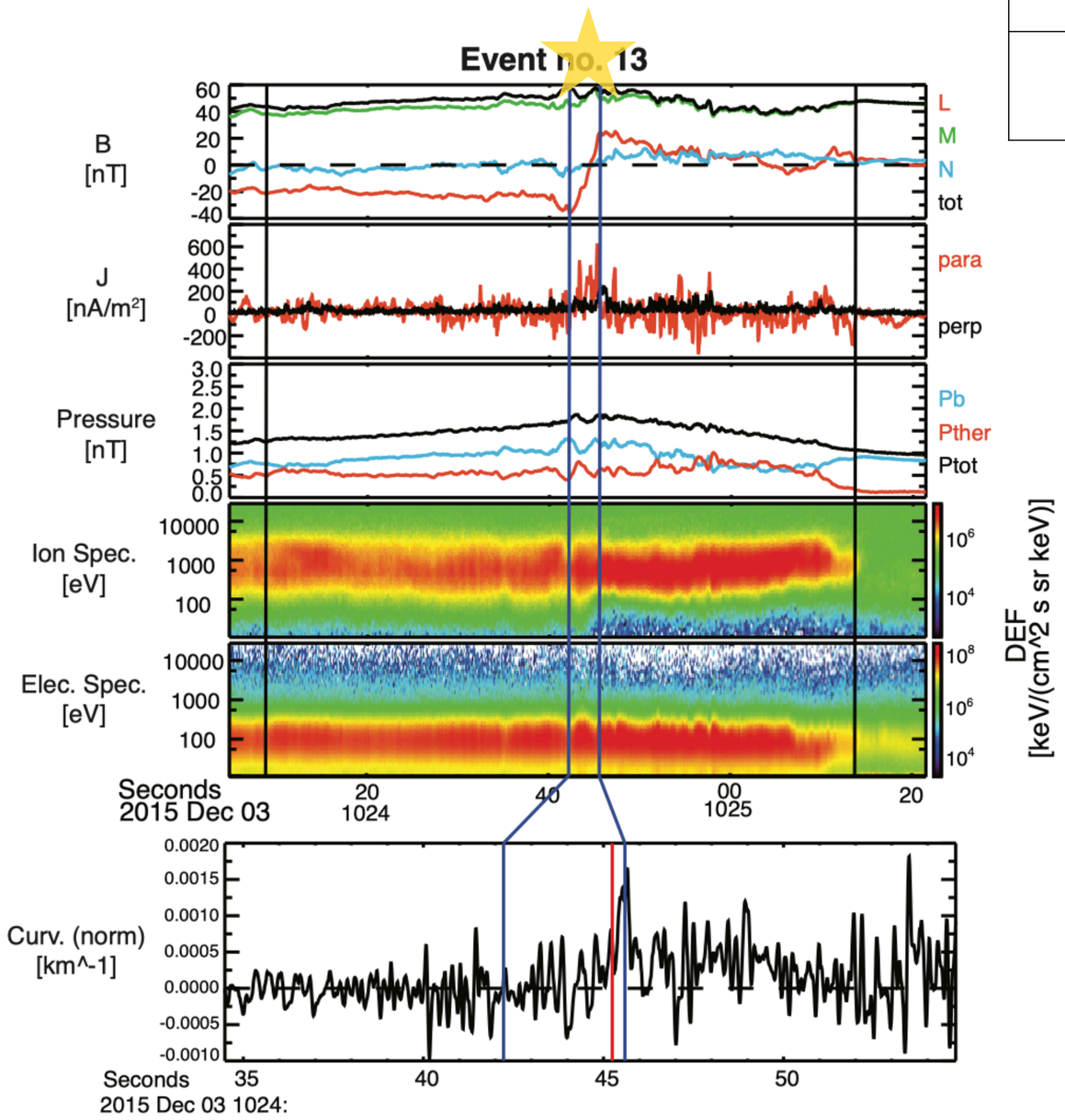
- A significant increase in both magnetic field strength and total pressure (delta P_{tot} ≳ 50%)
- A sharp rotation of the magnetic field (T_{cs} < 25%T_{event}) around the maximum pressure location
- A sudden change in the electron pitch-angle distribution across the central current sheet



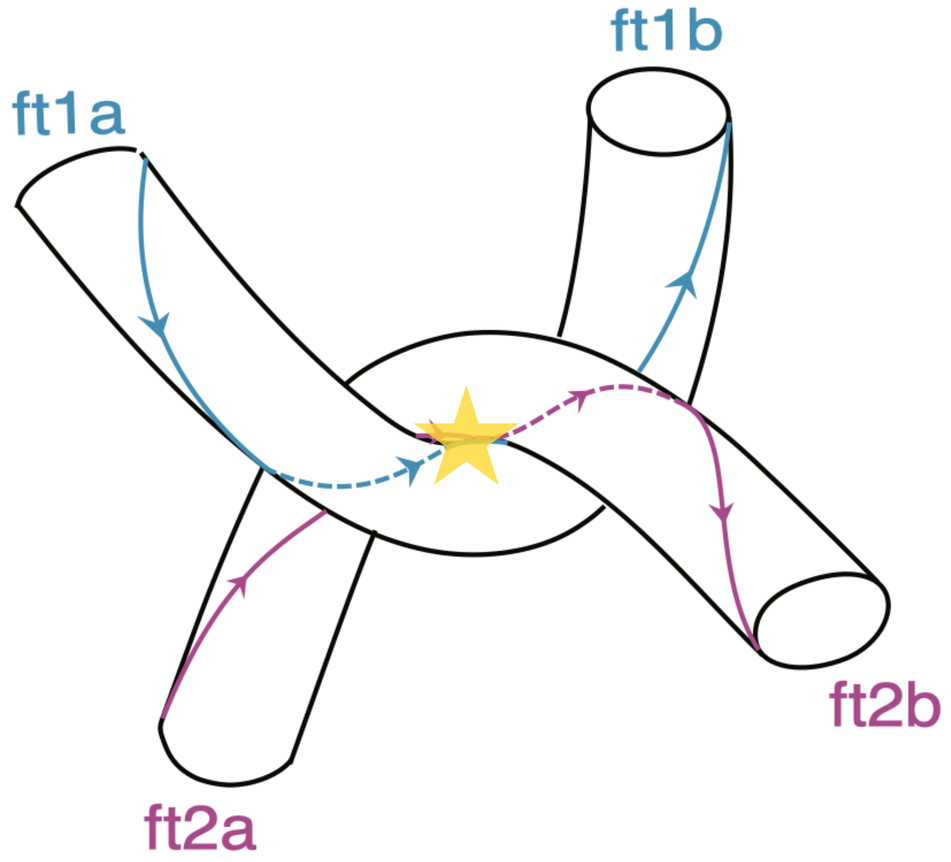




Early Stage

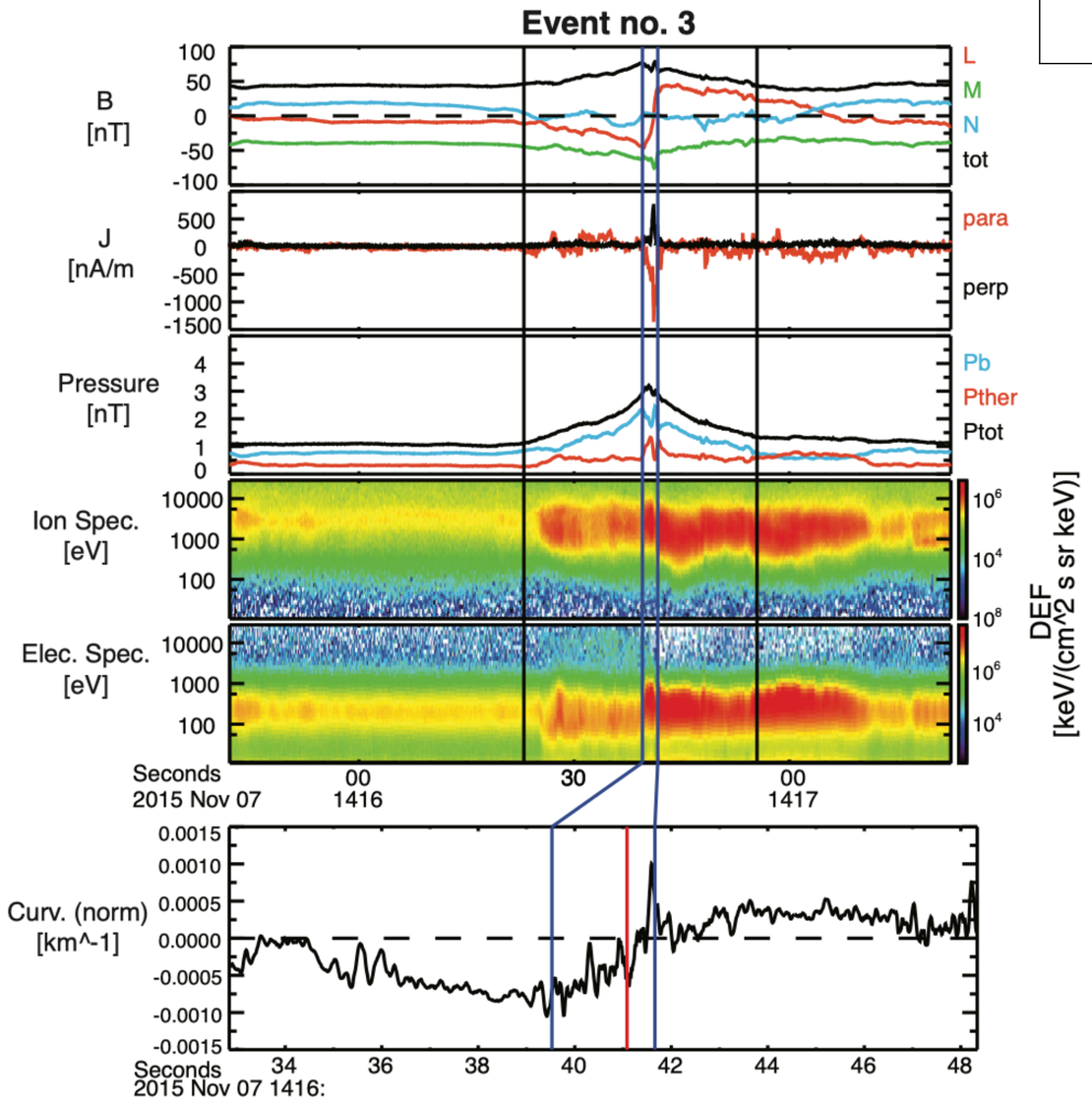


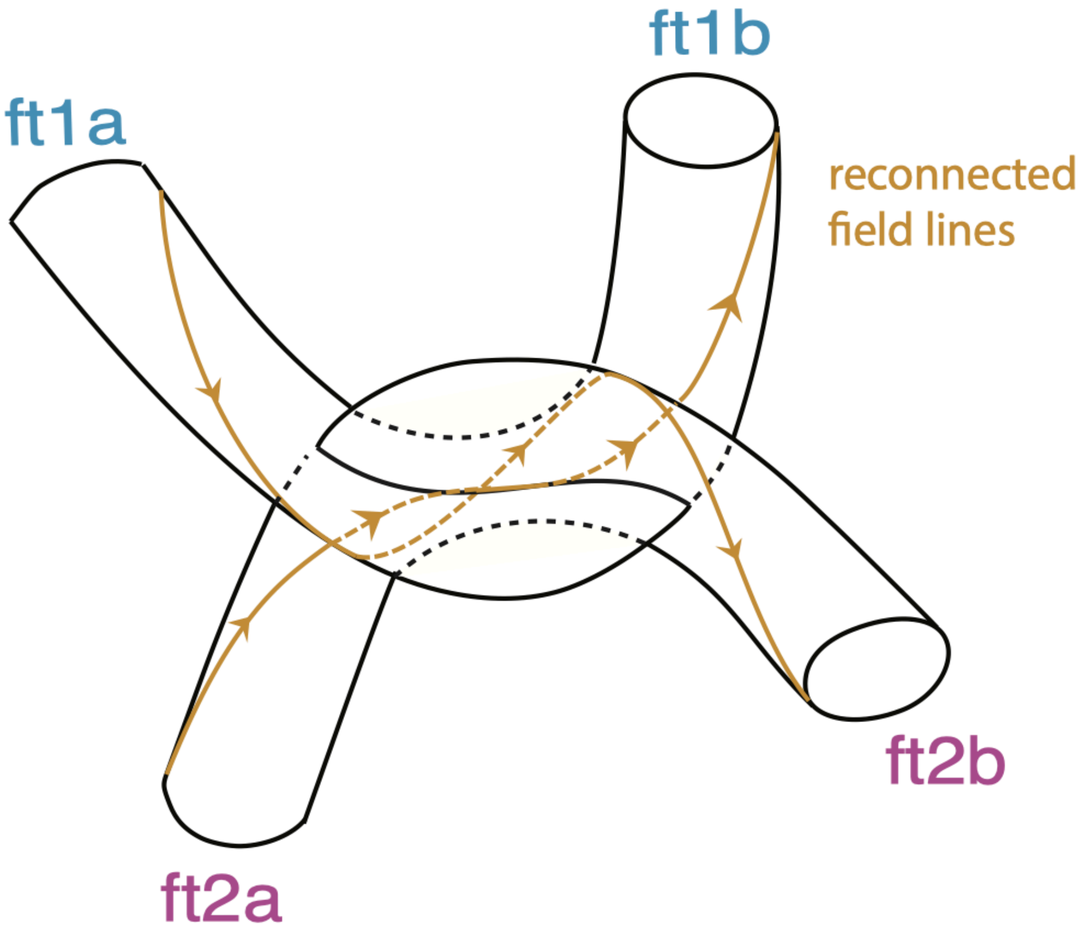
Pb + Pther	Increased, but not significantly (usually < 100%)
Curvature	No clear bipolar signature
Plasma	Despite of the differences in PAD, the electron energy spectrogram looks similar on two sides



Mid Stage

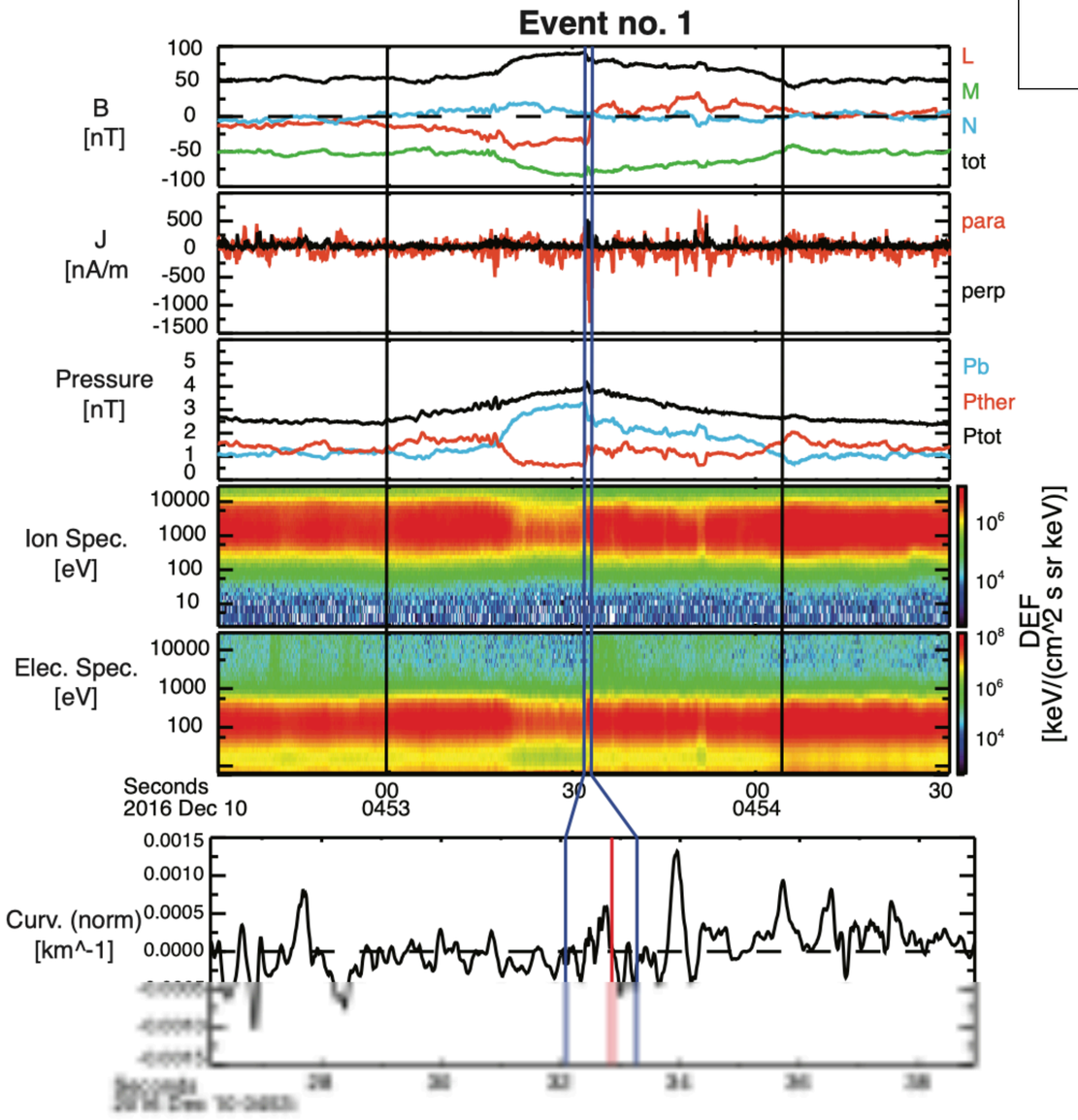
Pb + Pther	Increased significantly (at least 100%, usually several times)
Curvature	Clear bipolar signature (Strongly curved around the current sheet)
Plasma	Could be a mixture

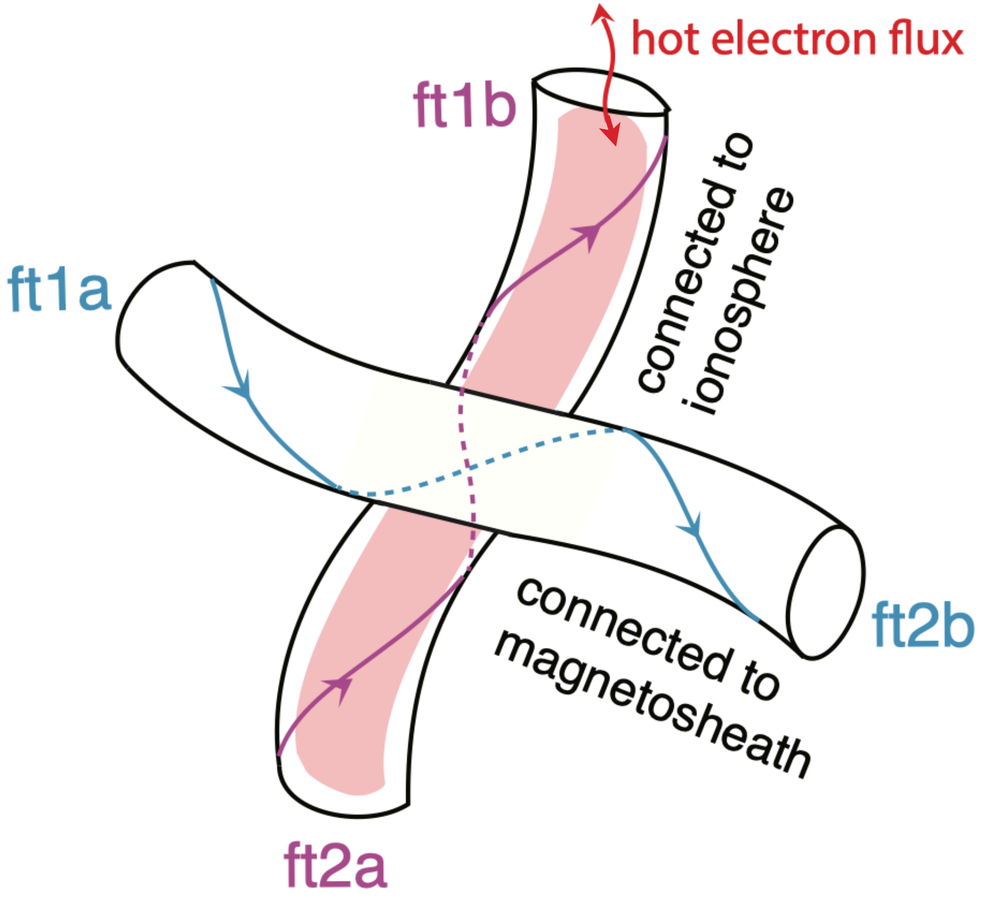




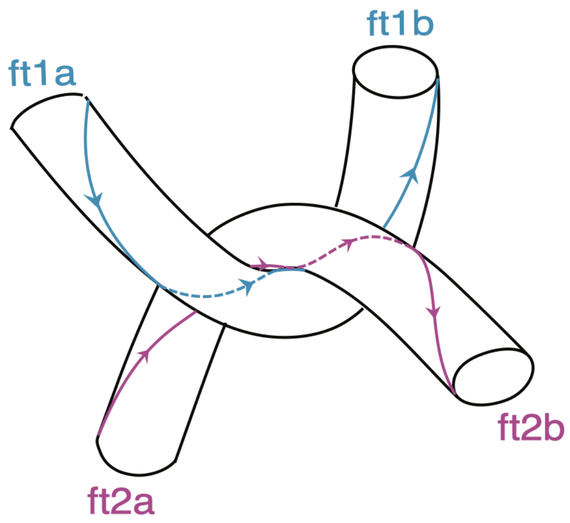
Late stage

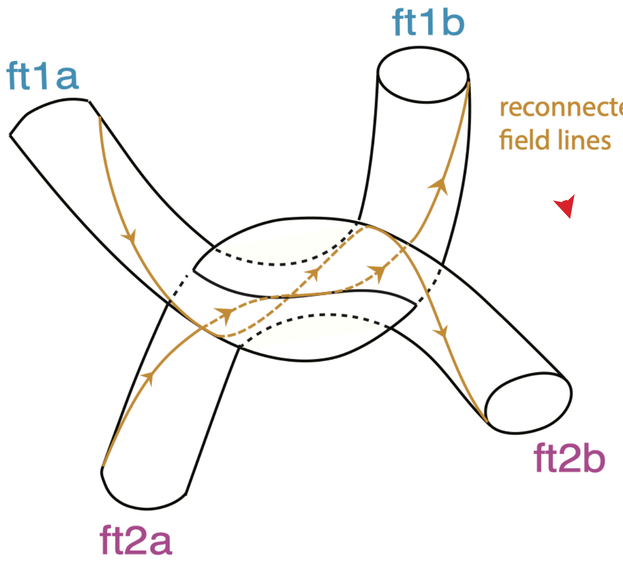
Pb + Pther	Increased, but not significantly (usually < 100%)
Curvature	No clear bipolar signature
Plasma	One side contains more energetic electrons

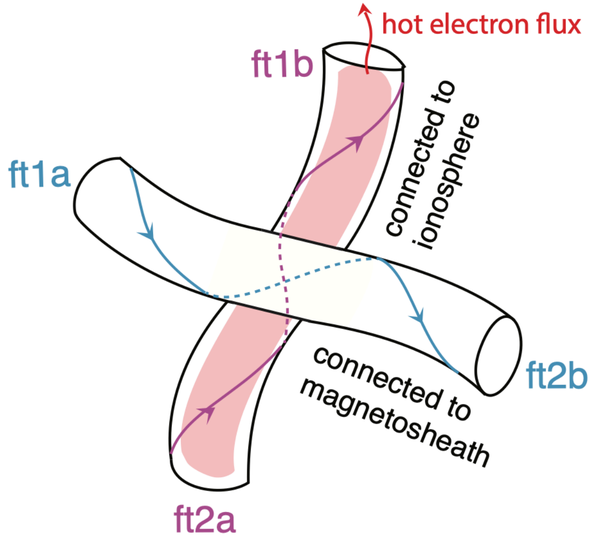




Characteristics of three evolutionary stages of flux tube entanglement







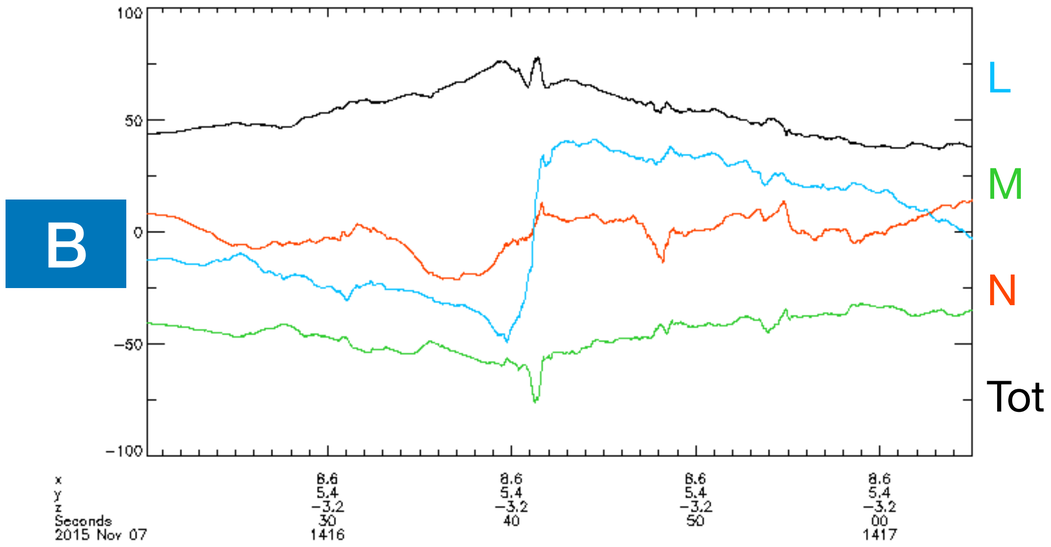
	Early	Mid	Late
Pb + Pther	Increased, but not significantly (usually < 100%)	Increased significantly (at least 100%, usually several times)	Increased, but not significantly (usually < 100%)
Curvature	No clear bipolar signature	Clear bipolar signature (Strongly curved around the current sheet)	No clear bipolar signature
Plasma	Despite of the differences in PAD, the electron energy spectrogram looks similar on two sides	Could be a mixture of magnetosheath and magnetospheric electrons	One side contains more energetic electrons

Backup slides

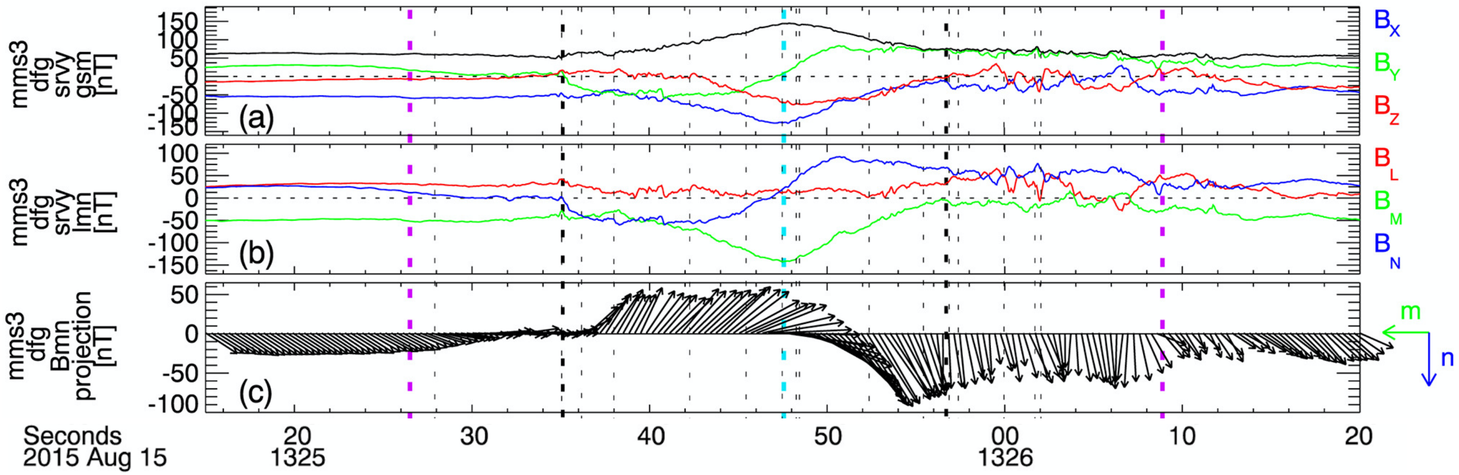
This structure is not a normal flux rope

- A sharp rotation of the field ONLY at the center of the field enhancement.

Flux tube entanglement

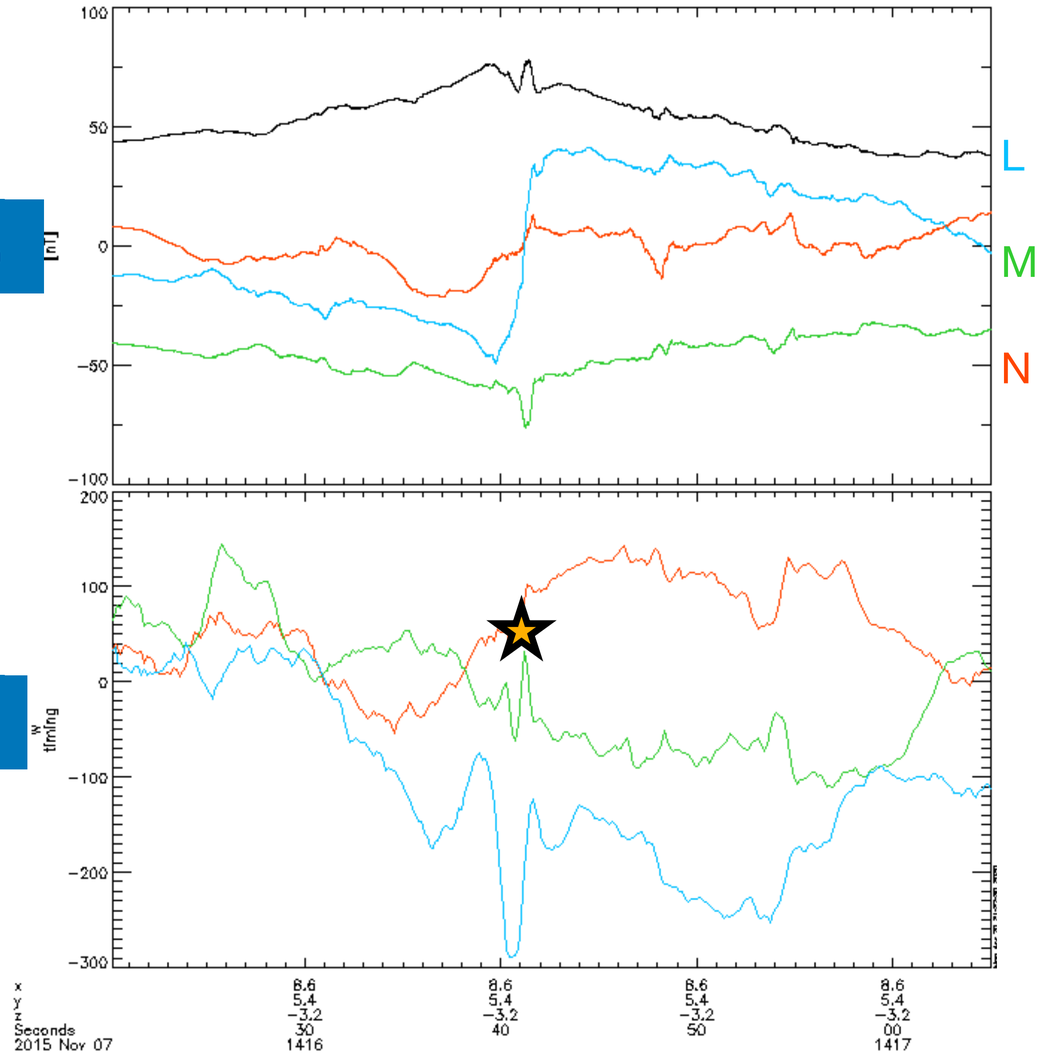


Normal flux rope



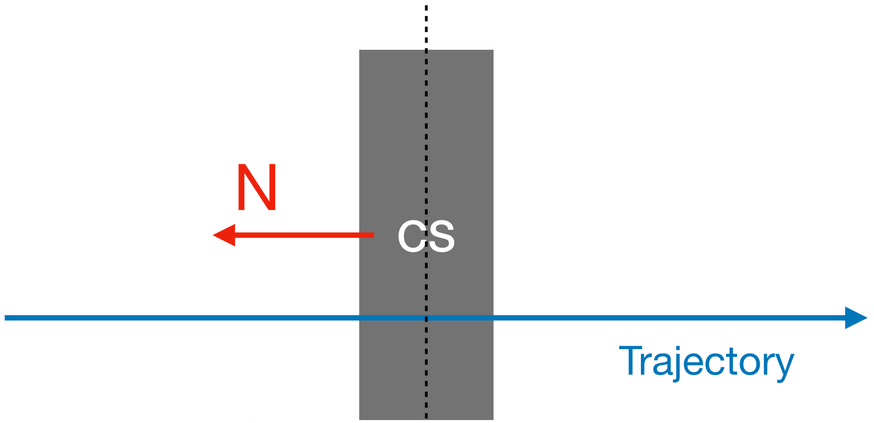
K. -J. Hwang et al., 2016

This structure is not a normal flux rope



- A sharp rotation of the field ONLY at the center of the field enhancement.
- The normal speed of the current sheet is 50 km/s. The normal direction is [0.02, -0.97, 0.22]GSM.
- The ambient plasma flows into the current sheet.
  - LMN coordinates:
    - N: the CS perpendicular moving direction
    - M: current direction perp to N (N × (J × N))
    - L: M × N

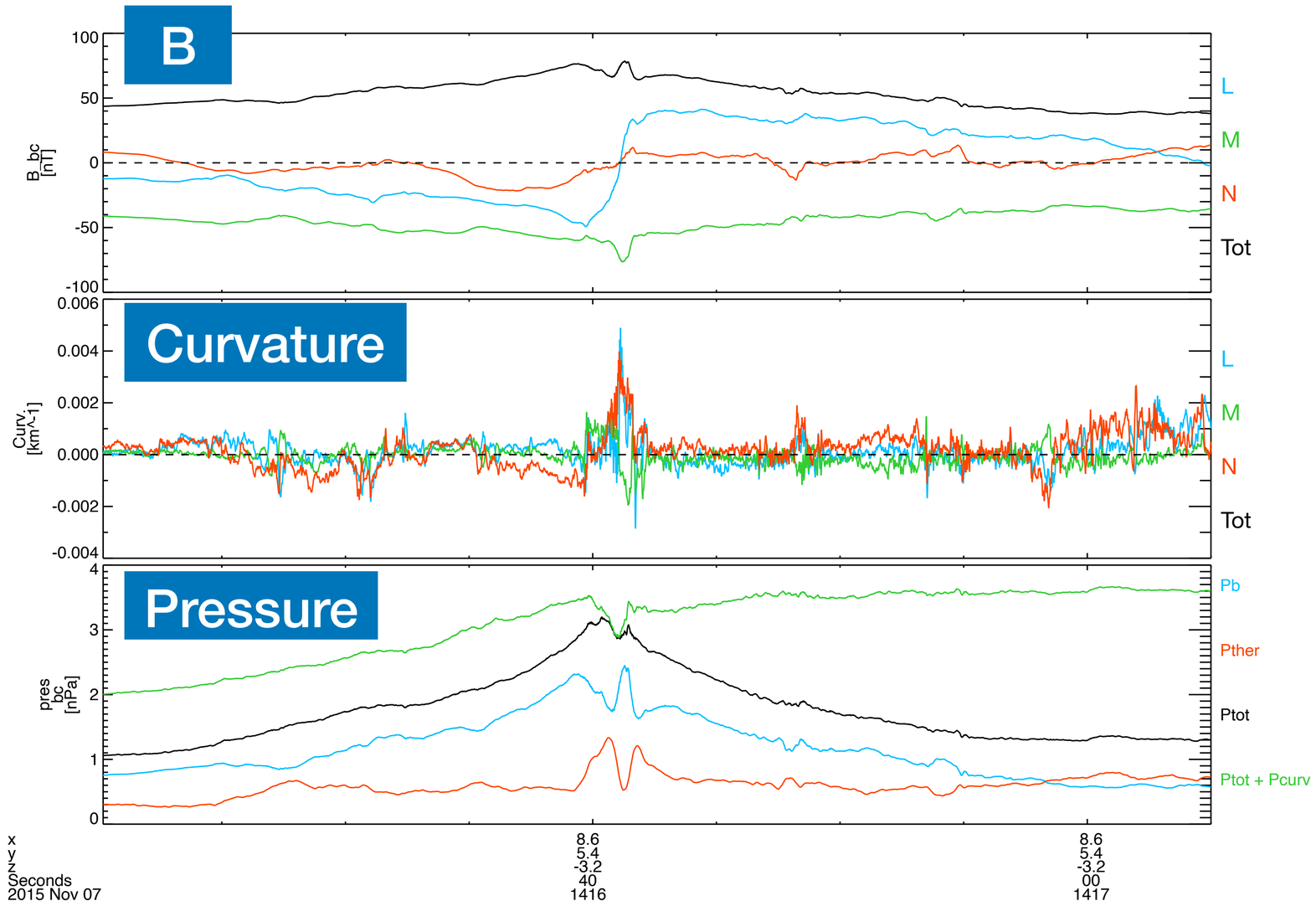
Curvature and Pressure



Negative Curv.
N component:
points toward
the current
sheet

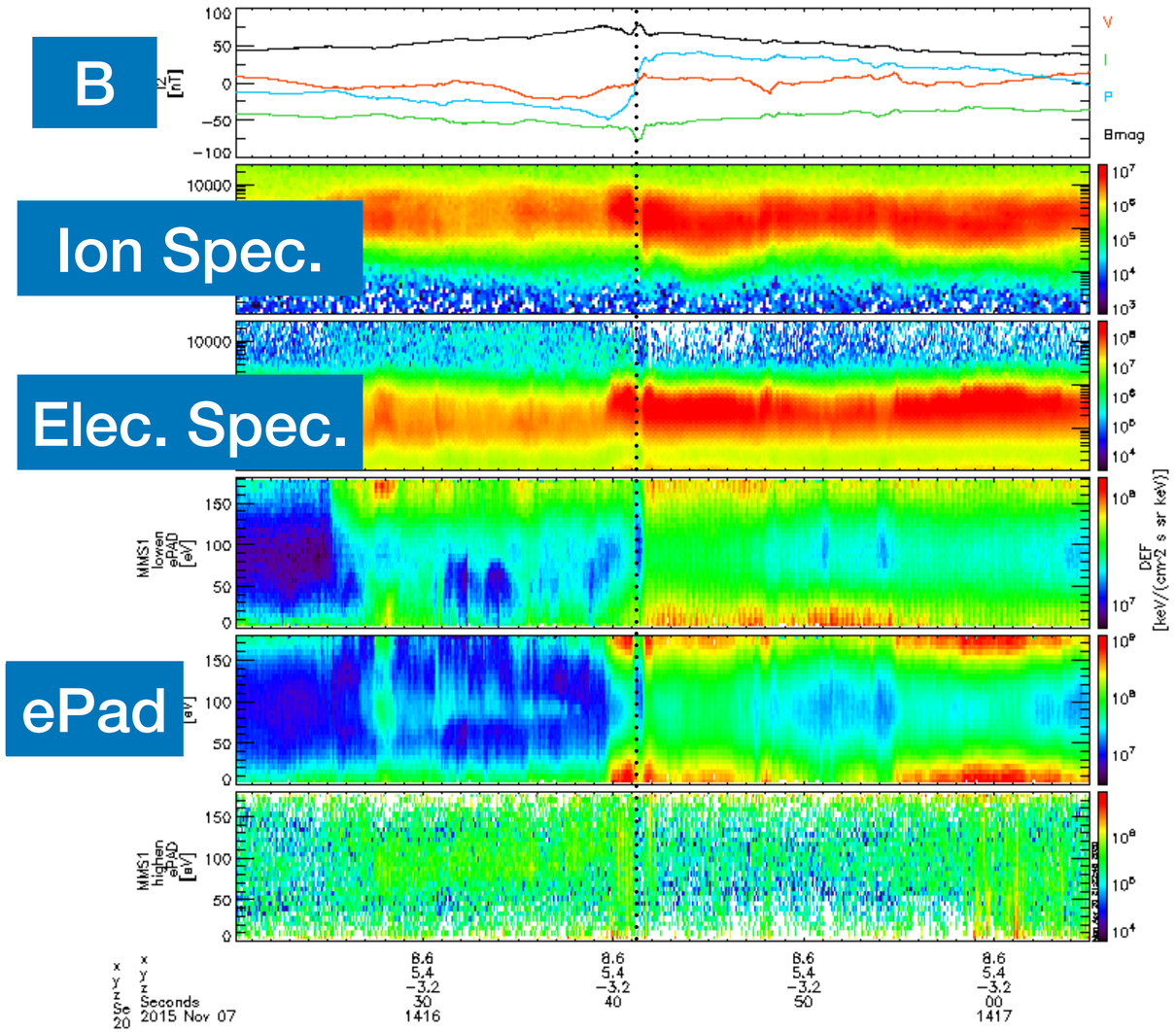
Positive Curv.
N component:
still points
toward the
current sheet

$$\vec{\kappa} = \vec{b} \cdot \nabla \vec{b}$$



[in preparation]

This structure is not a normal flux rope



- A sharp rotation of the field ONLY at the center of the field enhancement.
- The normal speed of the current sheet is 50 km/s. The normal direction is [0.02, -0.97, 0.22]GSM.
- The ambient plasma flows into the current sheet.
- Different plasma populations on two sides of the central current sheet