Ion Scale Flux Rope Observed at the Trailing Edge of the Hot Flow Anomaly

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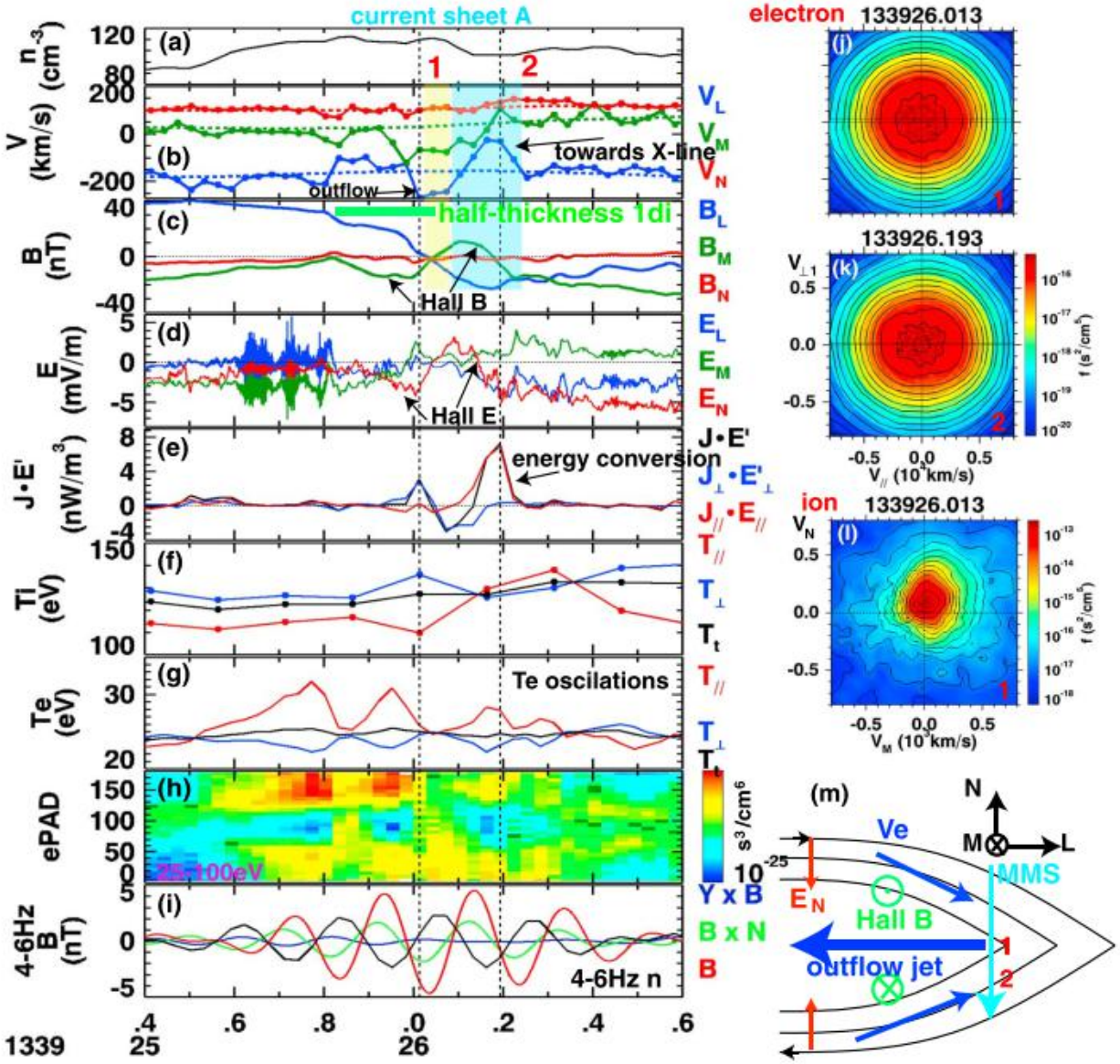
Introduction

Recent works on bow shock reconnection

- Wang et al., (2018) observed both **electron and ion reconnection jets upstream of quasi-parallel shock** which is related to the reflected solar wind ion beams.

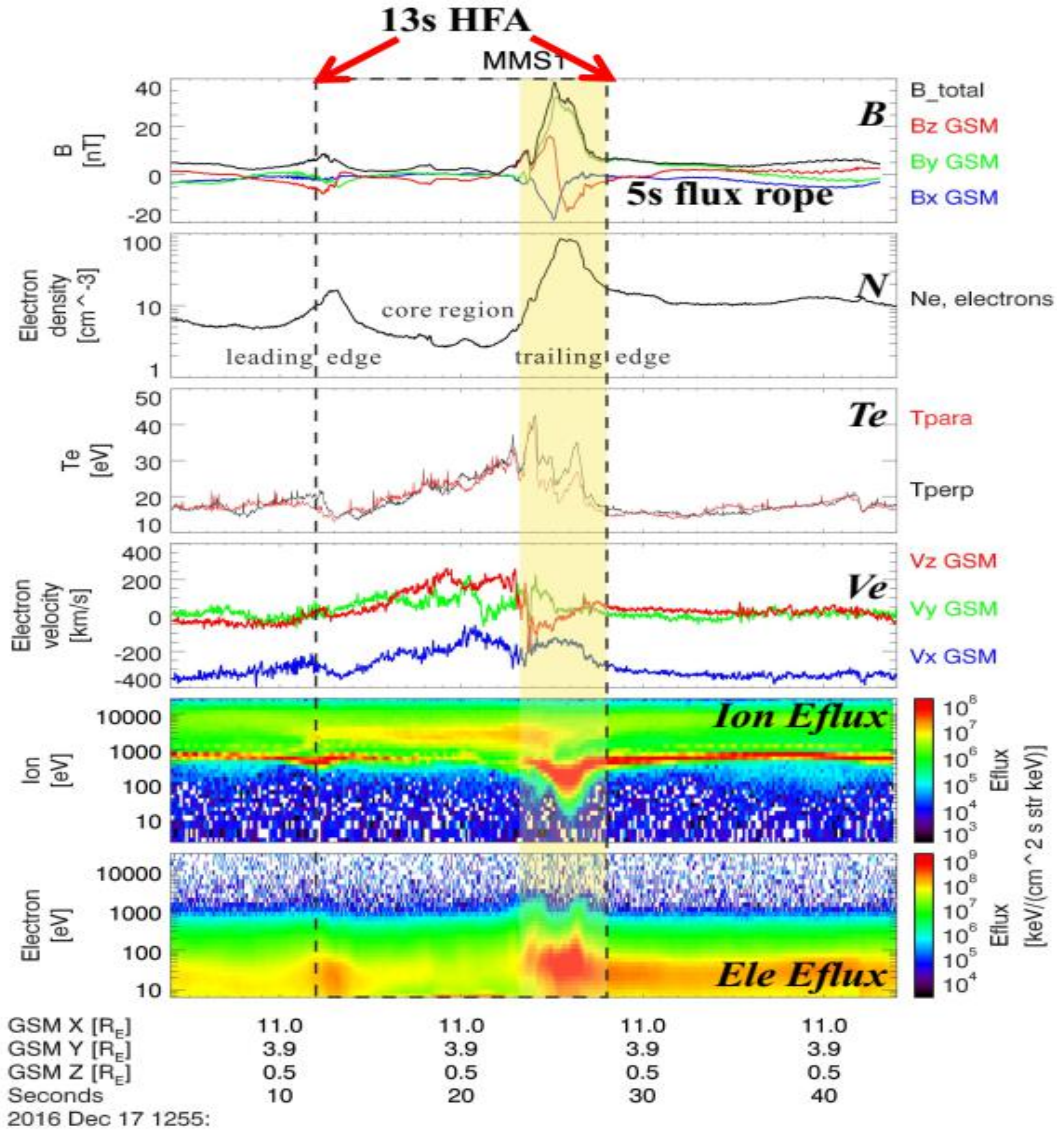
- Gingell et al., (2019) observed **electron-mode reconnection upstream from the quasi-penperdicular shock**, which is probably related to the **tubulance reconnection excited by Weibel instability**.

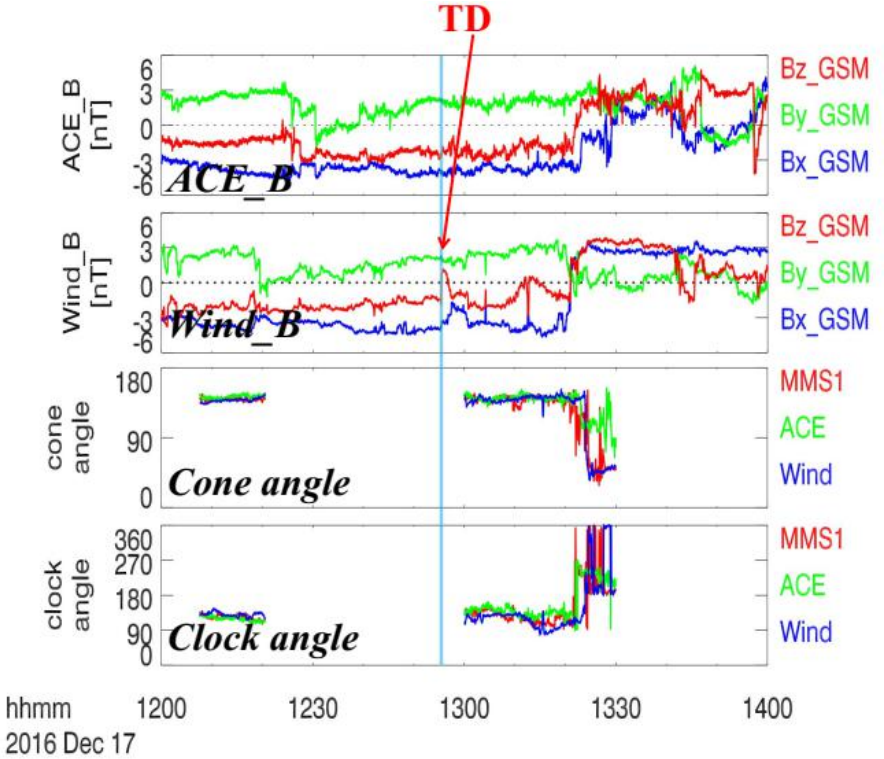
- Harmin et al., (2019) observed the **externally driven reconnection in the bow shock ramp region** for the first time.



[*Wang et al.*, 2018]

Overview of the Hot flow anomaly

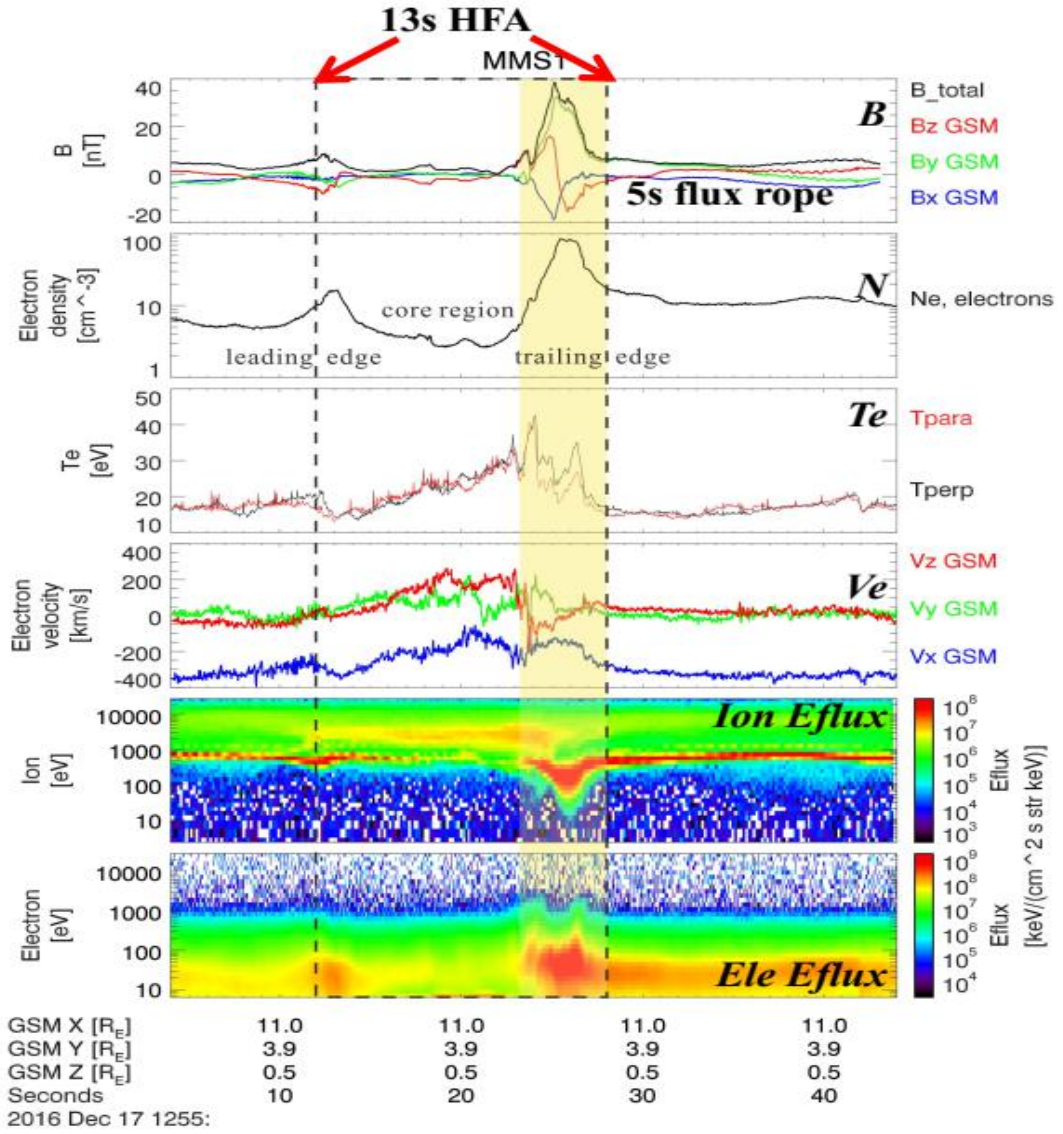


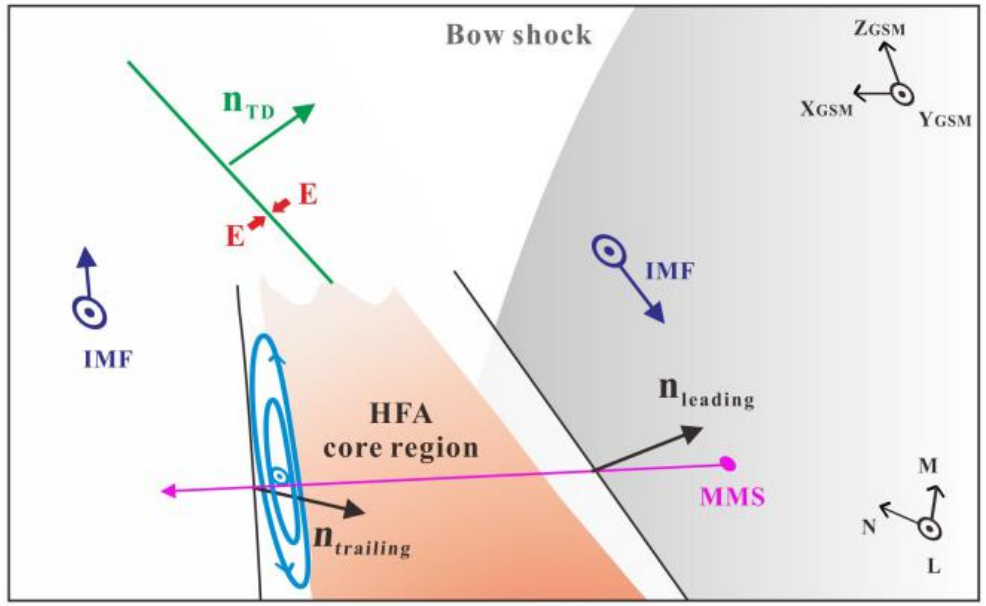


- **The HFA observed in the ion foreshock region in the Quasi-parallel shock (θ_{Bn}=41˚) and triggered by the tangential discontinuity.**

- **No flux rope signiture observed in the solar wind → not generated in the solar wind.**

Overview of the Hot flow anomaly





Timing analysis

Leading edge of the flux rope

113.5 ± 5.9 x[-0.84, -0.32, -0.43] km/s

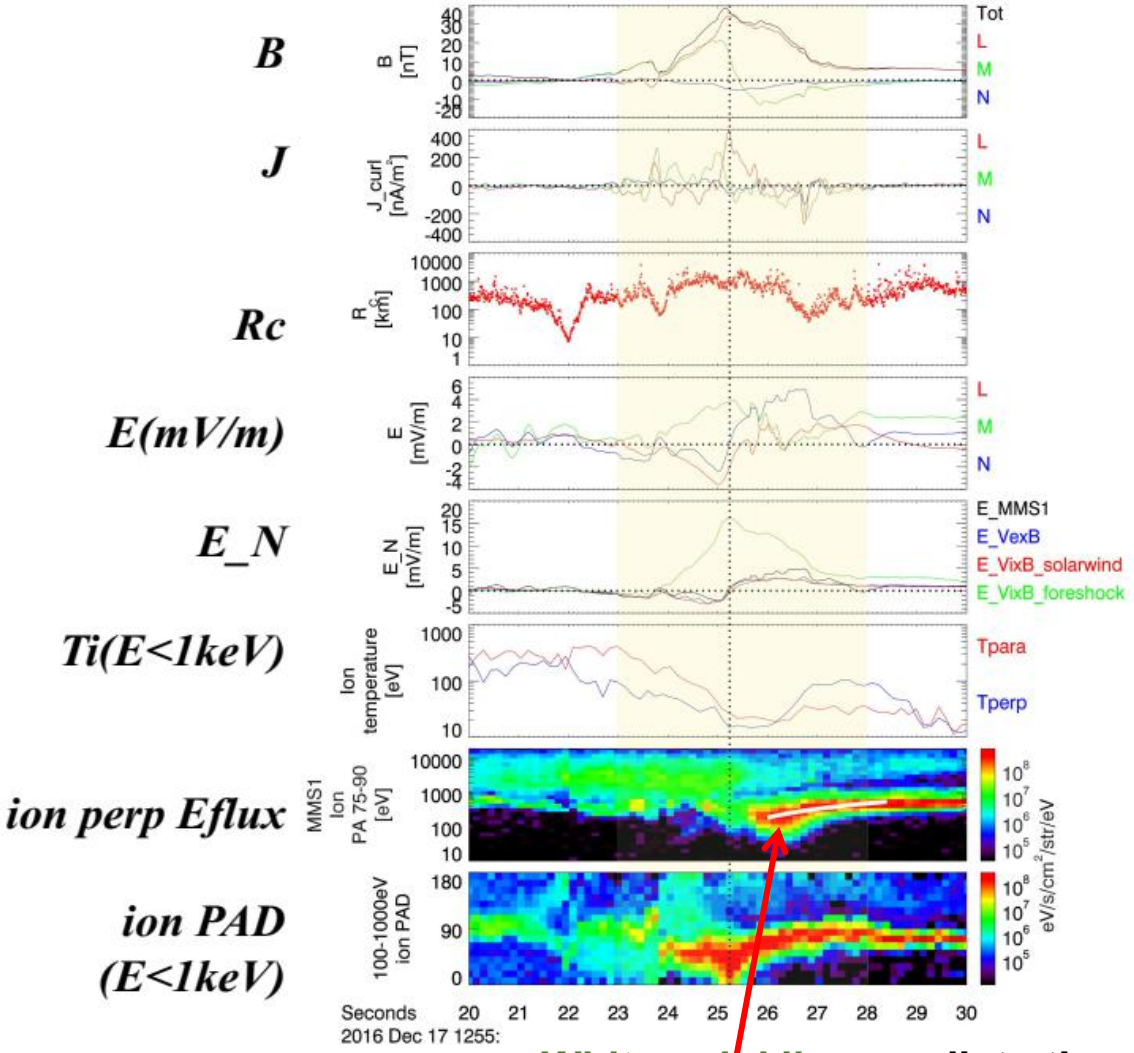
Trailing edge of the flux rope

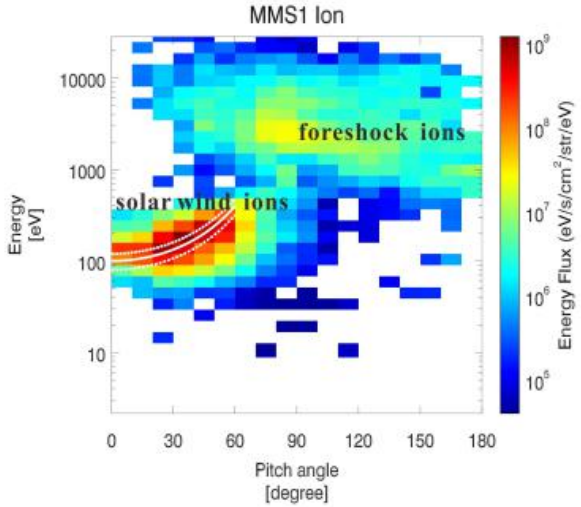
91.93 ± 3.6 x[-0.90, -0.29 -0.31] km/s GSM

This flux rope is expanding and propagating with the HFA toward the bow shock → not generated in the magnetosheath and propagate to the HFA.

Ion scale flux rope

ion scale flux rope with 6.1-7.5 ion inertial length





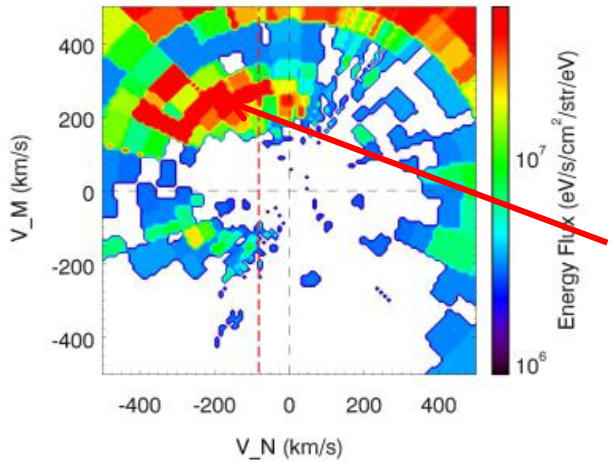
Features of flux rope:

B_M Bipolar,

strong core field,

strong field aligned current and increased radius of curvatures

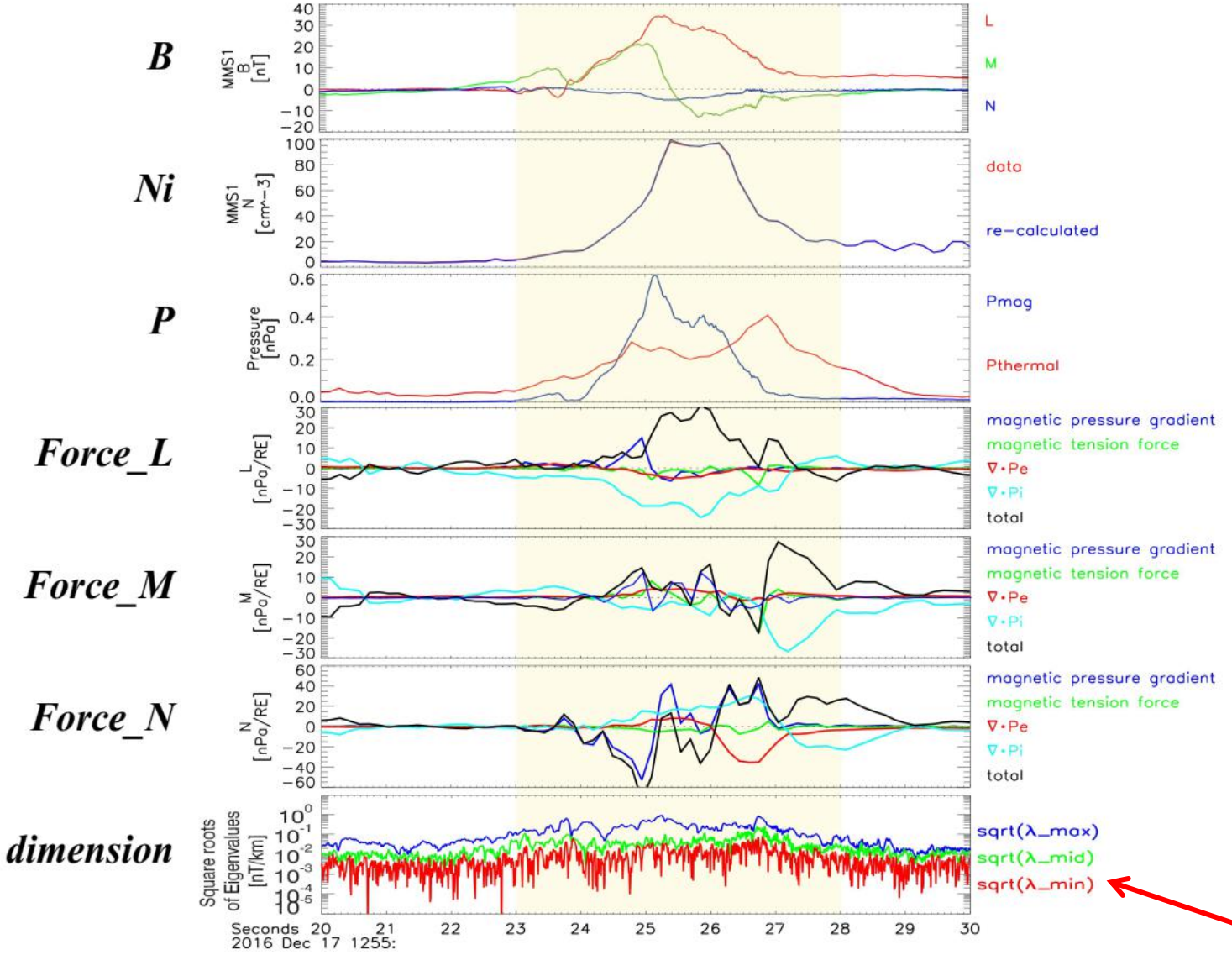
seen in yellow shaded region



deceleration mainly in N direction

White solid line predicts the deceleration result from the static electric field caused by charge seperation of solar wind particle in +N direction and matches with the observation very well.

Force analysis inside the flux rope



magnetic pressure gradient ∇·Pe ∇·Pi

$$\rho\left(\frac{\partial}{\partial t}+\vec{V}\cdot\nabla\right)\vec{V}=-\nabla_{\perp}\left(\frac{B^2}{2\mu_0}\right)+\frac{B^2}{\mu_0}\left(\vec{b}\cdot\nabla\right)\vec{b}-\nabla\cdot\vec{P}$$

magnetic tension force

- **The magnetic pressure gradient force changes directions in M direction, suggesting that the satellite passes through the flux rope center.**
- **The magnetic pressure gradient force determines the expansion of the flux rope in N direction.**

Quasi-1D structure

Summary

1. **An ion scale flux rope with 6.1-7.5 ion inertial length is observed at the trailing edge of a hot flow anomaly.**
2. **Solar wind ions were decelerated inside the flux rope and the kinetic energy of solar wind ions was likely converted to the magnetic energy.**
3. **The flux rope is close to a one-dimensional structure and expands due to the strong magnetic pressure gradient force.**

Bai, S.- C., Shi, Q., Liu, T. Z., Zhang, H., Yue, C., Sun, W.- J., et al. (2020). Ion- scale flux rope observed inside a hot flow anomaly. Geophysical Research Letters, 47, https://doi.org/10.1029/2019GL085933
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Thanks