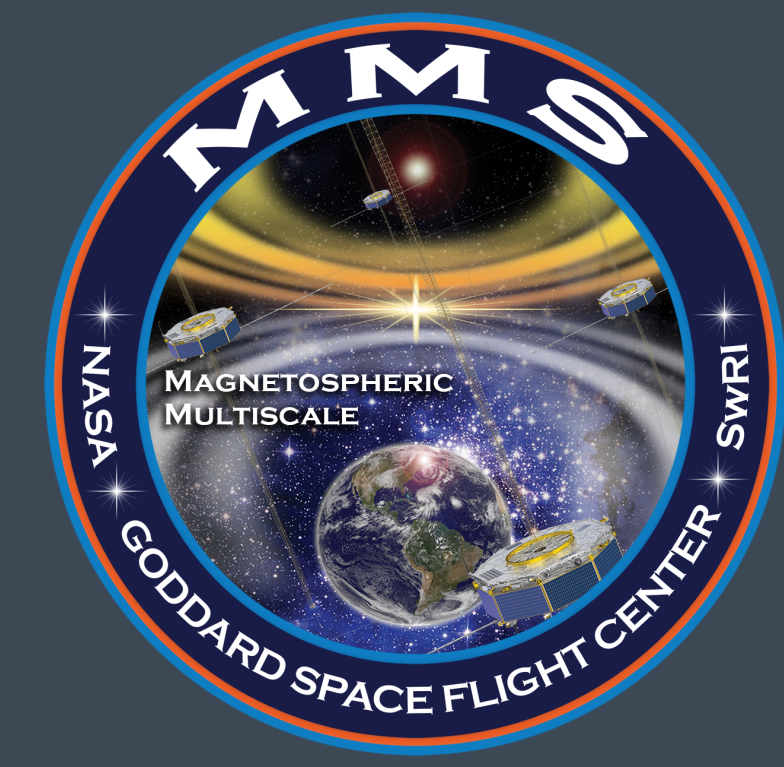




Contrasting Dipolarization Front Structure and Dynamics with MMS

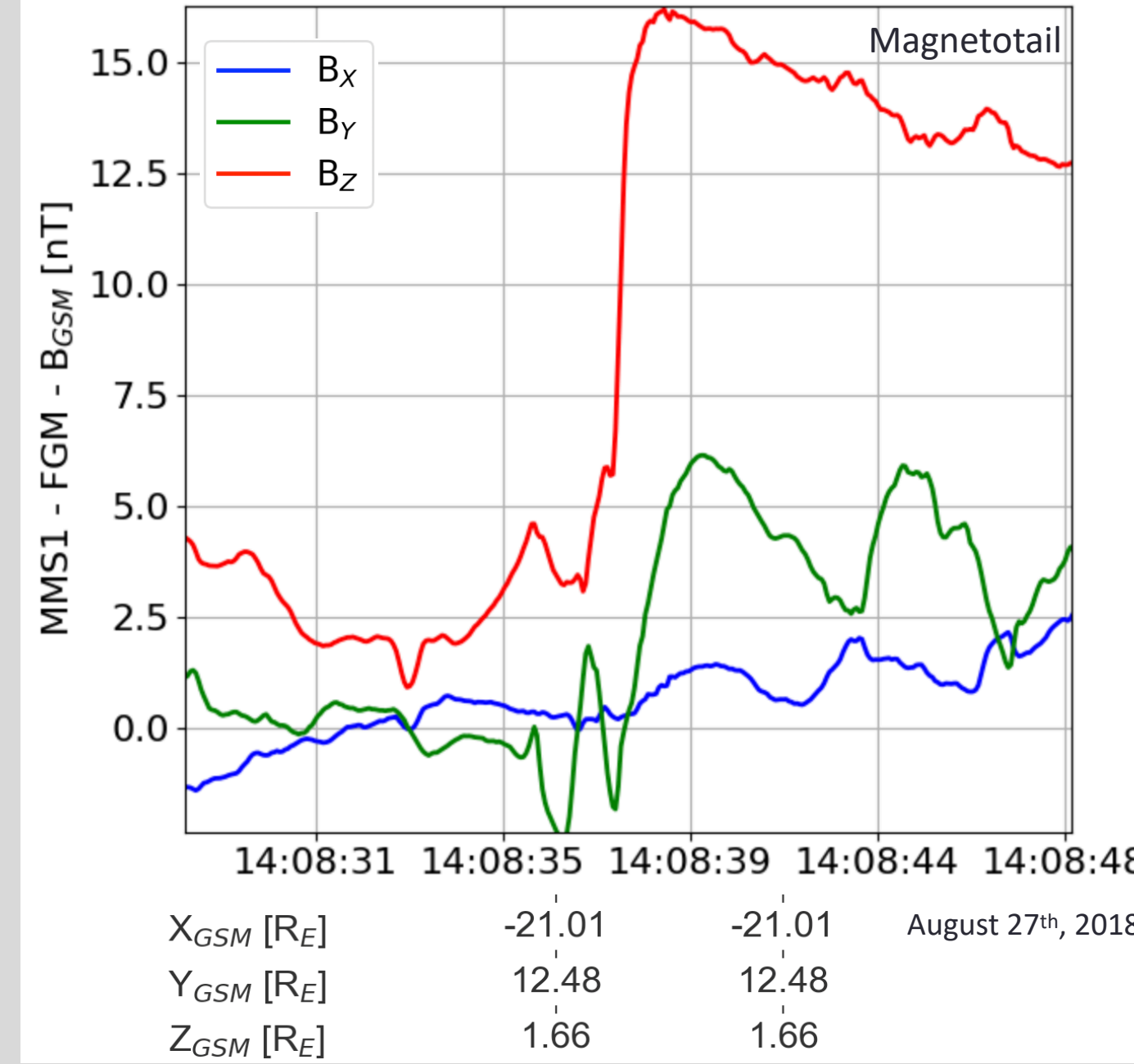
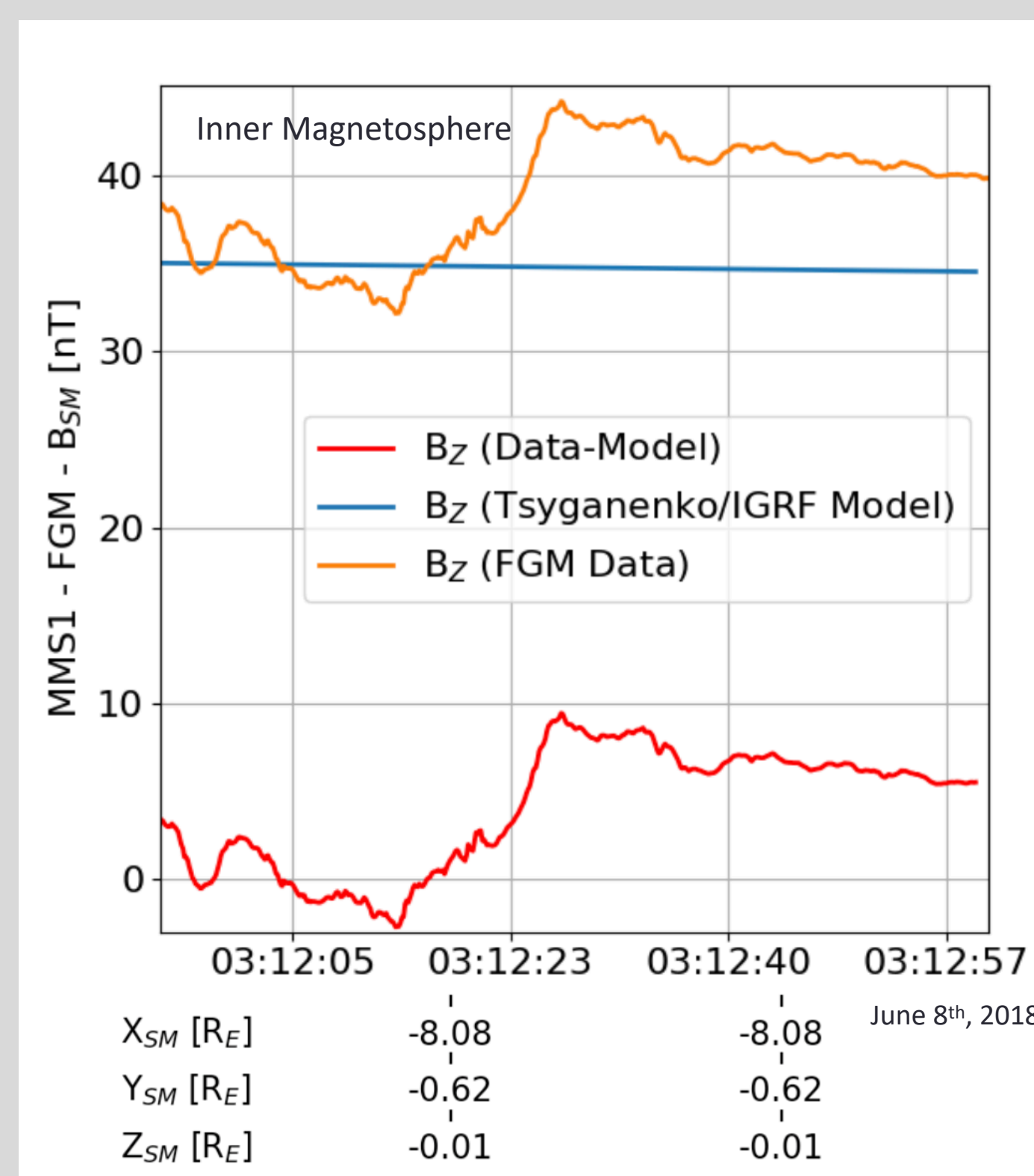
Tyler J. Metivier, Hiroshi Matsui, Charles J. Farrugia, Roy B. Torbert
Space Science Center, University of New Hampshire



BACKGROUND

- The Earth's magnetosphere is a very active environment. Under certain interplanetary conditions such as a significantly negative B_z or interactions between fast and slow solar wind streams, magnetic reconnection can occur in the magnetotail — associated with this reconnection is an Earthward traveling plasma and magnetic structure.
- The boundary of this structure is referred to as a “dipolarization front” (DF) - as this front carries an enhanced northward magnetic field component (the Z-direction in GSM or SM coordinates).
- The Magnetospheric Multiscale (MMS) mission comprises 4 identical probes that orbit the magnetosphere. Each probe contains a variety of instruments including fluxgate-magnetometers, double-probe electric-field sensors, and ion and electron spectrometers.

DIPOLARIZATION FRONTS

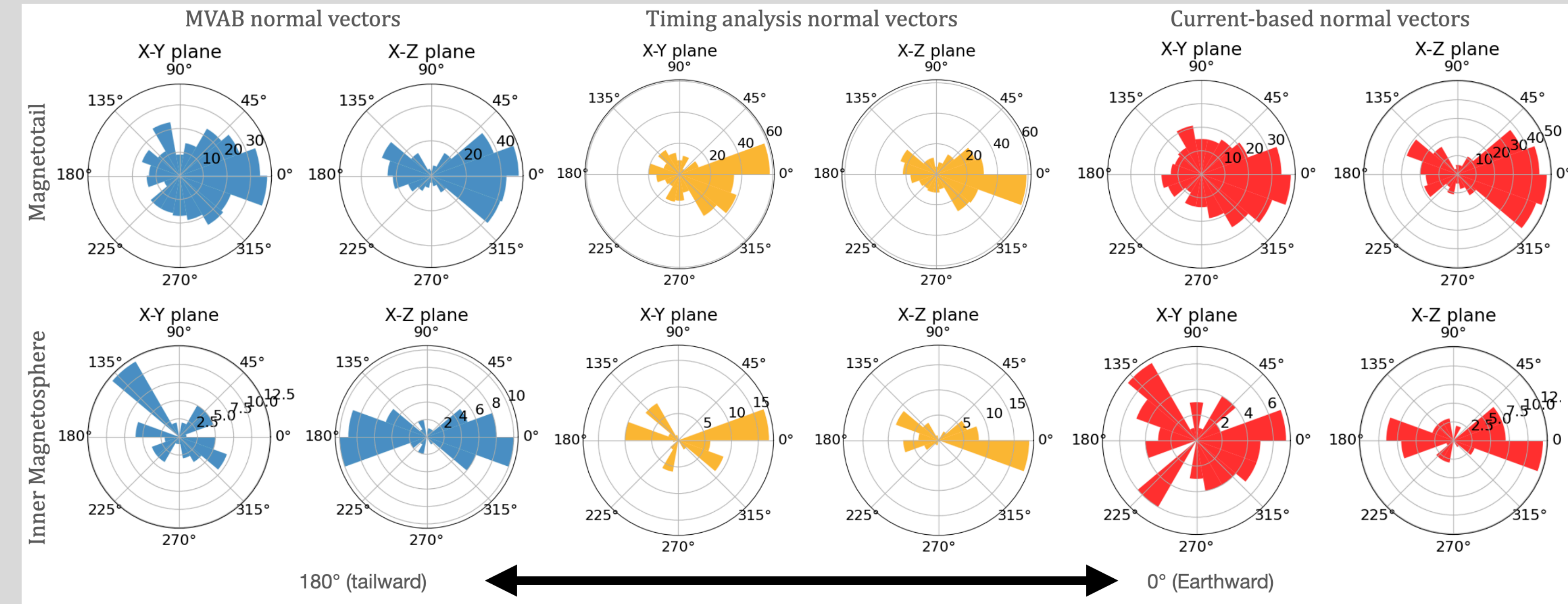


- DFs in the magnetotail appear to propagate at faster speeds and decelerate as they move Earthward towards the inner magnetosphere
- In order to find DFs, we wrote an algorithm to automate this process.
- We search for DFs beyond $X_{GSM} = -9 R_E$ in 30 s sliding windows with 15 s increments.
- Each DF must be separated by at least 2 minutes from the prior detection.
- We define DFs based on the criteria detailed in Schmid et al. (2014)¹ with some modifications: (1a) $\delta B_z > 8$ nT, (2a) $\arctan(B_z/B_{XY}) > 45^\circ$ for at least one data point, (3a) time at B_z maximum $>$ time at B_z minimum, and (4a) location of spacecraft restricted to $X_{GSM} \leq -9 R_E$, $|Y_{GSM}| \leq 15 R_E$, & $|Z_{GSM}| \leq 5 R_E$.
- These criteria ensure that MMS is located in the plasma sheet and eliminate false positives.
- For the inner magnetosphere ($X_{SM} \geq -9 R_E$), we use SM coordinates and the Tsyganenko-89 (T89)² and the International Geomagnetic Reference Field (IGRF) models³.

- We then subtract the model from the data in order to find δB_z , eliminating the quickly increasing or decreasing dipolar field.
- We use 120 s sliding windows with slightly different criteria from before: (1b) $\delta B_z > 8$ nT, (2b) time at B_z maximum $>$ time at B_z minimum, (3b) location of spacecraft restricted to $X_{SM} \geq -9 R_E$. In the inner magnetosphere, criteria regarding the plasma sheet becomes unnecessary (such as (2a)).
- Much is still unknown regarding the properties of DFs, such as: the frequency of occurrence, how they evolve as they propagate, and under what kind of specific geomagnetic conditions are they favored.

ORIENTATION AND DYNAMICS

- To obtain a normal direction of the DF, we use three different methods: minimum variance analysis of the magnetic field (MVAB)⁴, timing analysis⁴, and a current-based method detailed in Runov (2005)⁵. Timing analysis also provides an estimate on the velocity of the DF.
- The current-based normal vector is obtained with the cross product of the maximum variance direction vector from MVAB (L) and the current measured using the curlometer technique⁴ and then normalized.
- Due to ambiguities in the X-direction, we set the sign of the MVAB and the current-based normal vectors from the X-component of the timing normal vector.



- For the magnetotail, there is quite good agreement between the current-based method and MVAB-derived normal vectors. Roughly 56% of normal vectors between the current-based method and MVAB have an angle $< 20^\circ$ apart.
- Comparing MVAB/timing analysis normal vectors and current-based/timing analysis normal vectors in the magnetotail gives about the same amount of agreement. Roughly 14% of MVAB and timing normal vectors are in agreement. About 12% percent of current-based and timing analysis normal vectors are in agreement.
- Results for the inner magnetosphere are largely similar: about 41% of current-based and MVAB normal vectors are in agreement, about 6% for timing analysis and MVAB normal vectors, and about 5% are in agreement for timing analysis and the current-based method.
- Despite differences between individual normal vectors, there is better agreement over all methods from a statistical view, especially for the magnetotail. We see that the majority of events are mostly Earthward and the overall distributions in the X-Z planes are oriented along the X-axis.

DISCUSSION AND CONCLUSIONS

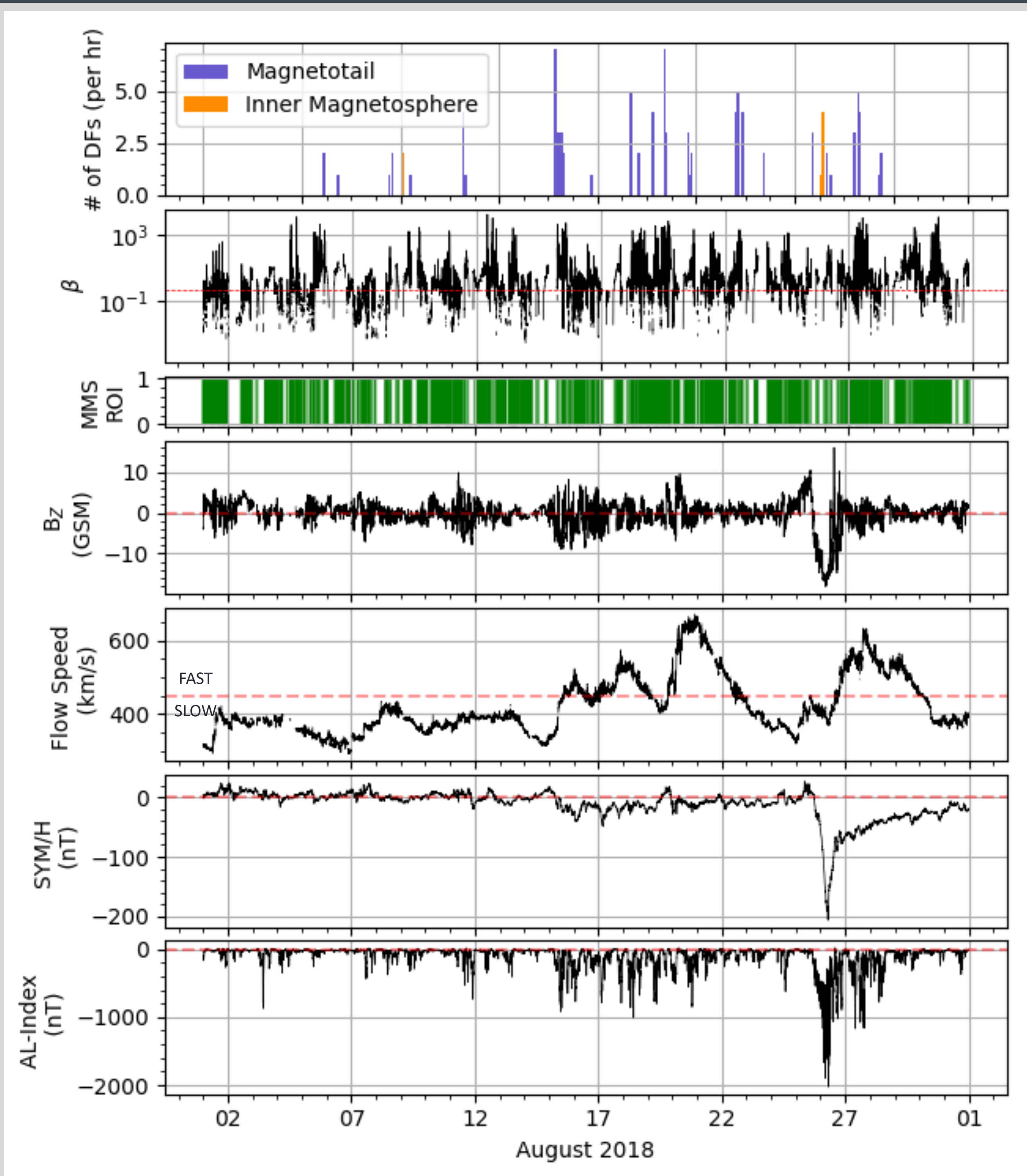
- Our algorithm has detected 409 DF events in the nightside magnetosphere during several months in 2017 and 2018.
- While it seems clear that geomagnetic disturbances are correlated with DFs, it is not yet clear which specific conditions are favorable.
- In general, normal vectors obtained from MVAB and timing analysis often disagree with each other (~14% agreement). However, the current-based and MVAB are in much better agreement with each other (~56% agreement).
- For the inner magnetosphere, the distributions in the X-Z planes are still mainly the same as the tail but there are more tailward events. Some of the inner magnetosphere DFs have larger Y values and may be closer to the lobes and therefore be false positives. In order to assure our events are truly in the inner magnetosphere, we will apply more conservative criteria to these events in the future.
- For future work, beyond further scrutinizing the discrepancies between normal vectors, we intend to categorize DFs based on their associated plasma properties.

REFERENCES

- D. Schmid, R. Nakamura, F. Plaschke, M. Volwerk, W. Baumjohann (2014), Two states of magnetotail dipolarization fronts: A statistical study, *J. Geophys. Res.*, 120(2)
- Tsyganenko, N. A. (1989), A magnetospheric magnetic field model with a warped tail current sheet (*Planet. Space Sci.*, v.37(1), pp.5-20
- Alken, P., Thébault, E., Beggan, C.D. et al. (2021), International Geomagnetic Reference Field: the thirteenth generation. *Earth Planets Space* 73, 49
- Paschmann, G. & Daly, P. W. (2008). Multi-spacecraft Analysis Methods Revisited. *ISSI, The International Space Science Institute.*
- Runov, A., Sergeev, V. A., Baumjohann, W. (2005), Electric current and magnetic field geometry in flapping magnetotail current sheets. *Annales Geophysicae* 23, 4

This work was supported by NASA's MMS Contract NNG04EB99C and NASA Grant 80NSSC22K0526.

INTERPLANETARY CONDITIONS



- A variety of interplanetary and geomagnetic conditions occurred during the month of August 2018. These conditions include calm/quiet periods, corotating interaction regions, and a very strong storm associated with an interplanetary coronal mass ejection (ICME).
- The top two panels are the DF detection frequency (1 hour bins) and the plasma beta calculated with HPCA from MMS1. The bottom four panels are the interplanetary B_z , solar wind speed, SYM/H, and the AL-index obtained from OMNI.
- As seen above, the detection of dipolarization fronts is correlated with one (or more) of the aforementioned conditions.