

# Long-Term Surveys of Interplanetary CMEs, Stream Interaction Regions, and Shocks Using STEREO

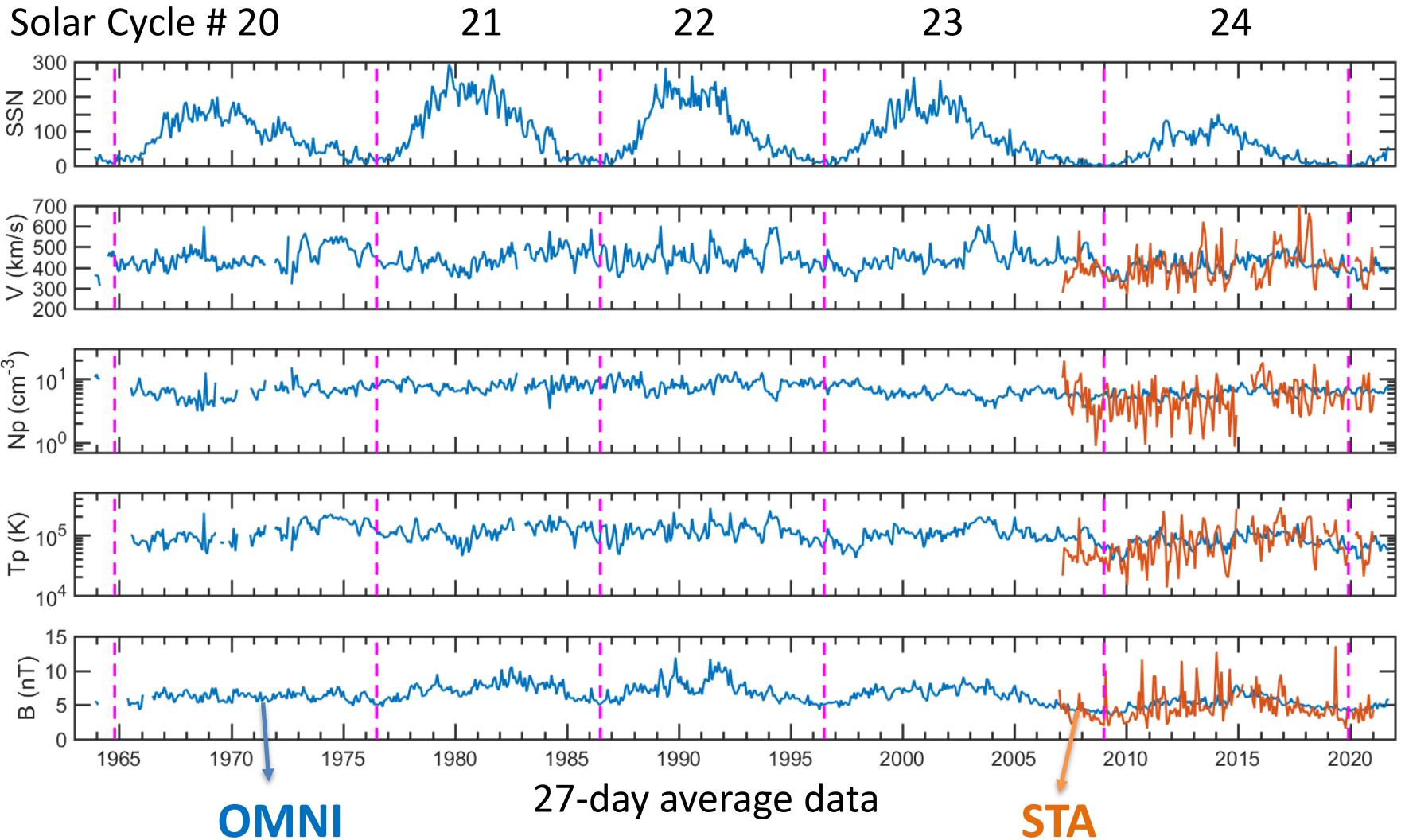
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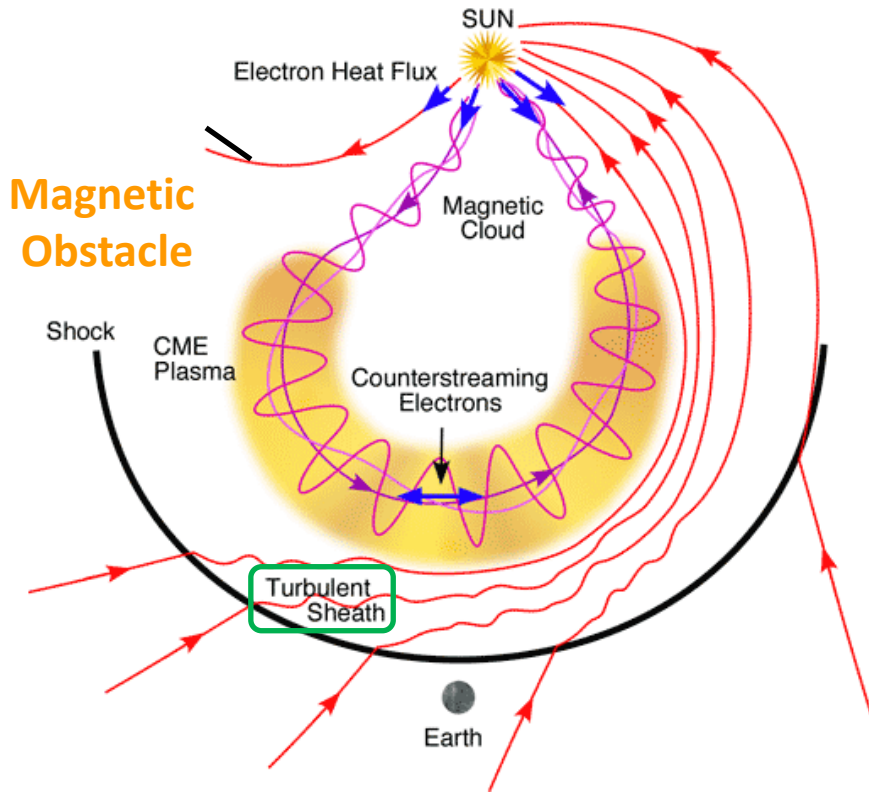
STEREO Science Team Meeting  
January 19, 2022

# Solar Wind Variations in 1965 – 2021

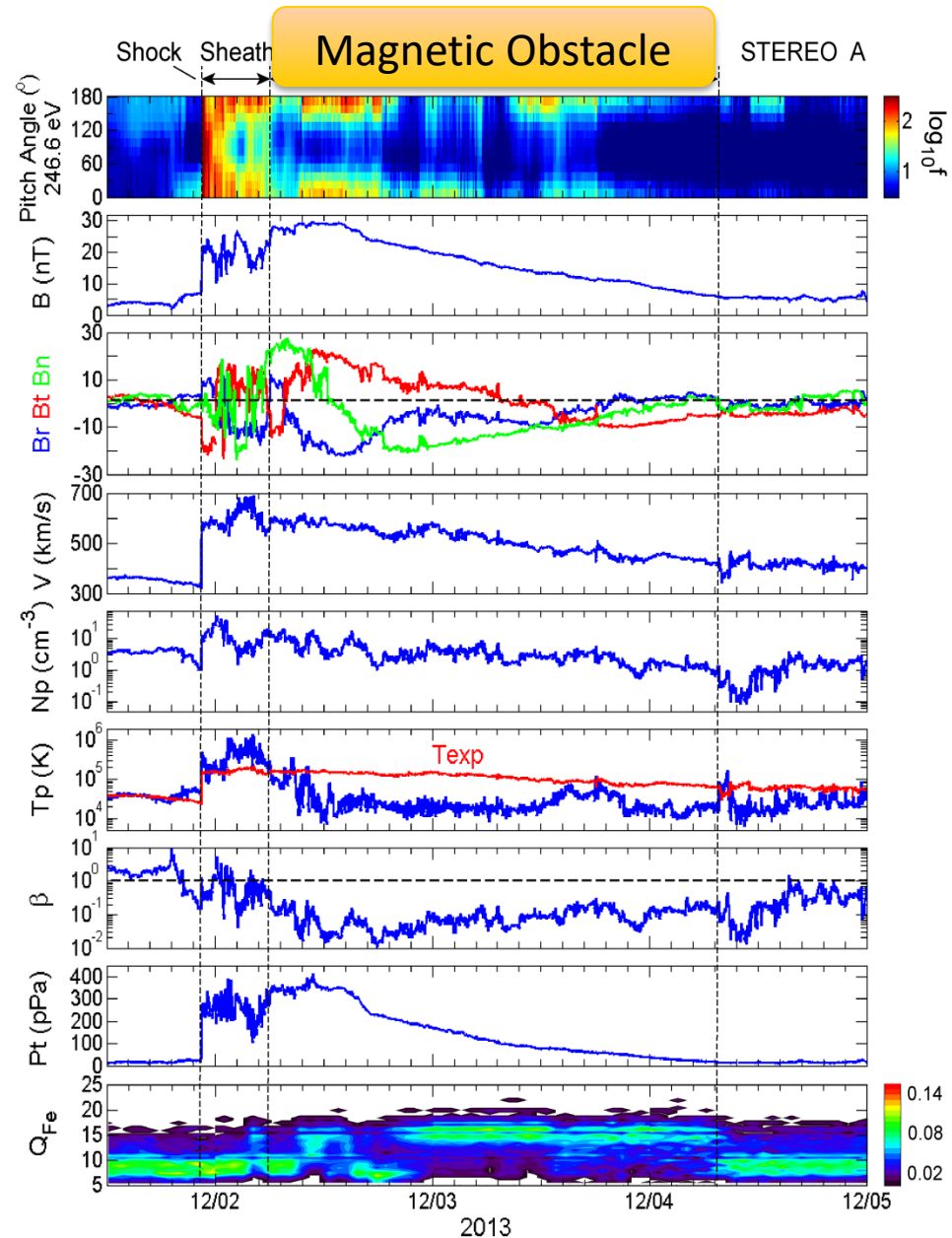


STA merged 1-min plasma and magnetic field data  
are updated to the end of February 2021

# Interplanetary Coronal Mass Ejection (ICME)

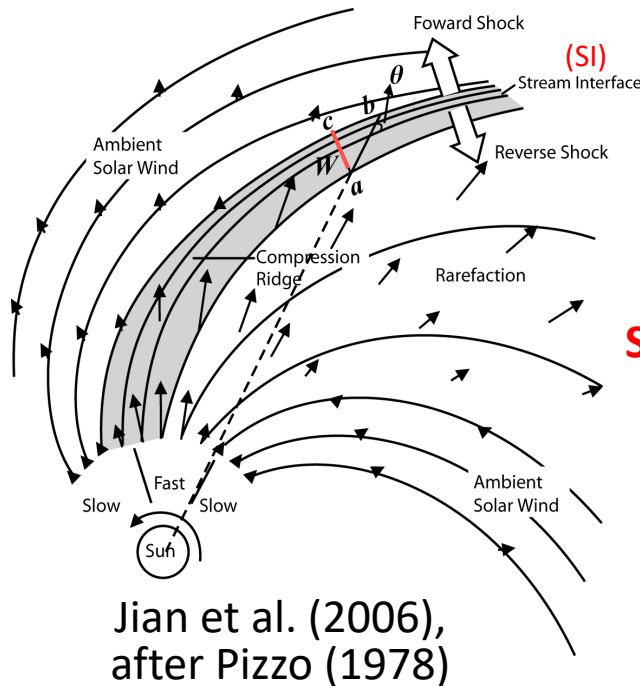


Zurbuchen and Richardson (2006)



Jian et al. (ApJ 2018)

# Stream Interaction Regions (SIRs)

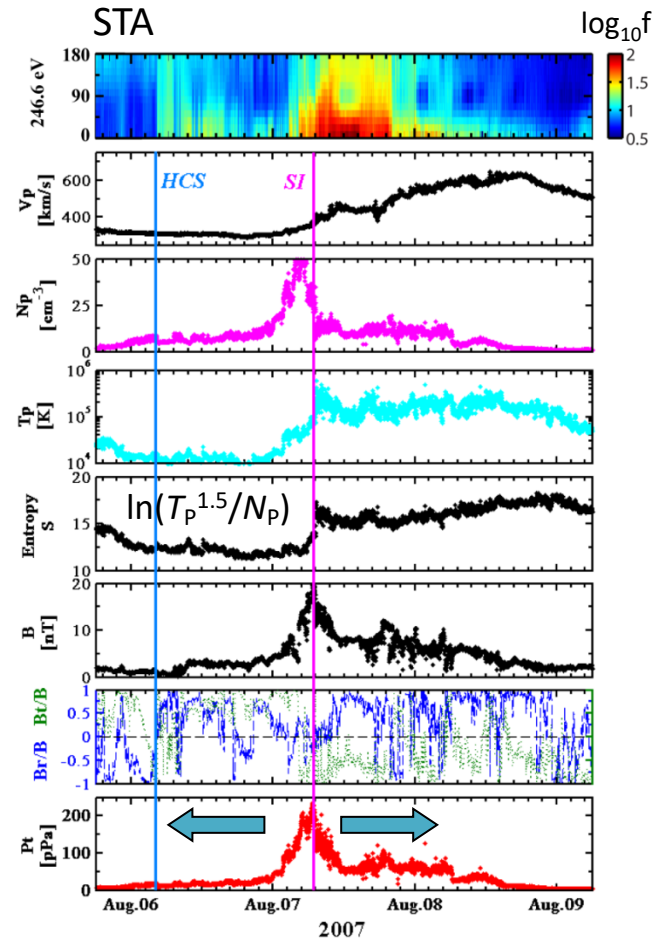


SIRs

Corotating  
Interaction Regions  
(CIRs)

Transient SIRs (~17%)  
which do not recur in  
one or more Carrington  
rotations

- **Stream Interface (SI):** peak of  $P_t$ , sometimes co-occur with  $N_p$  decrease and  $T_p$  increase
- Heliospheric Current Sheet (HCS) identified using magnetic field data and suprathermal electron pitch angle distribution



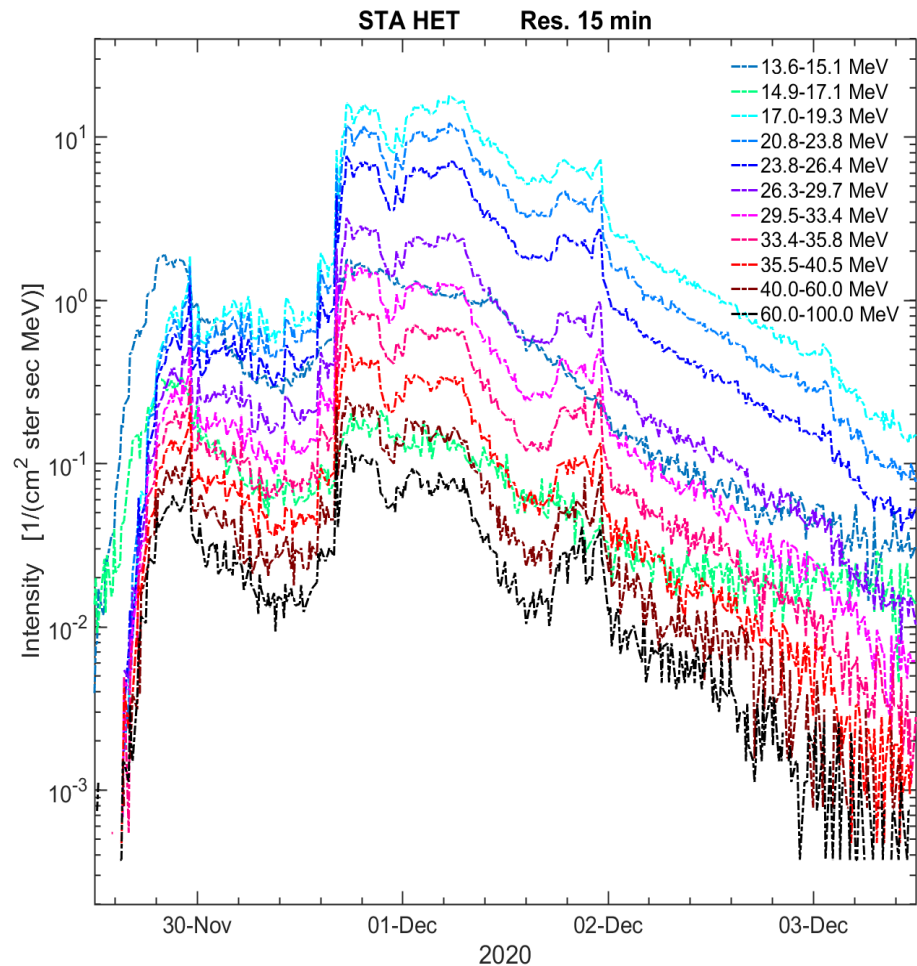
Jian et al. (2009)

# Level 3 Event Lists of STEREO

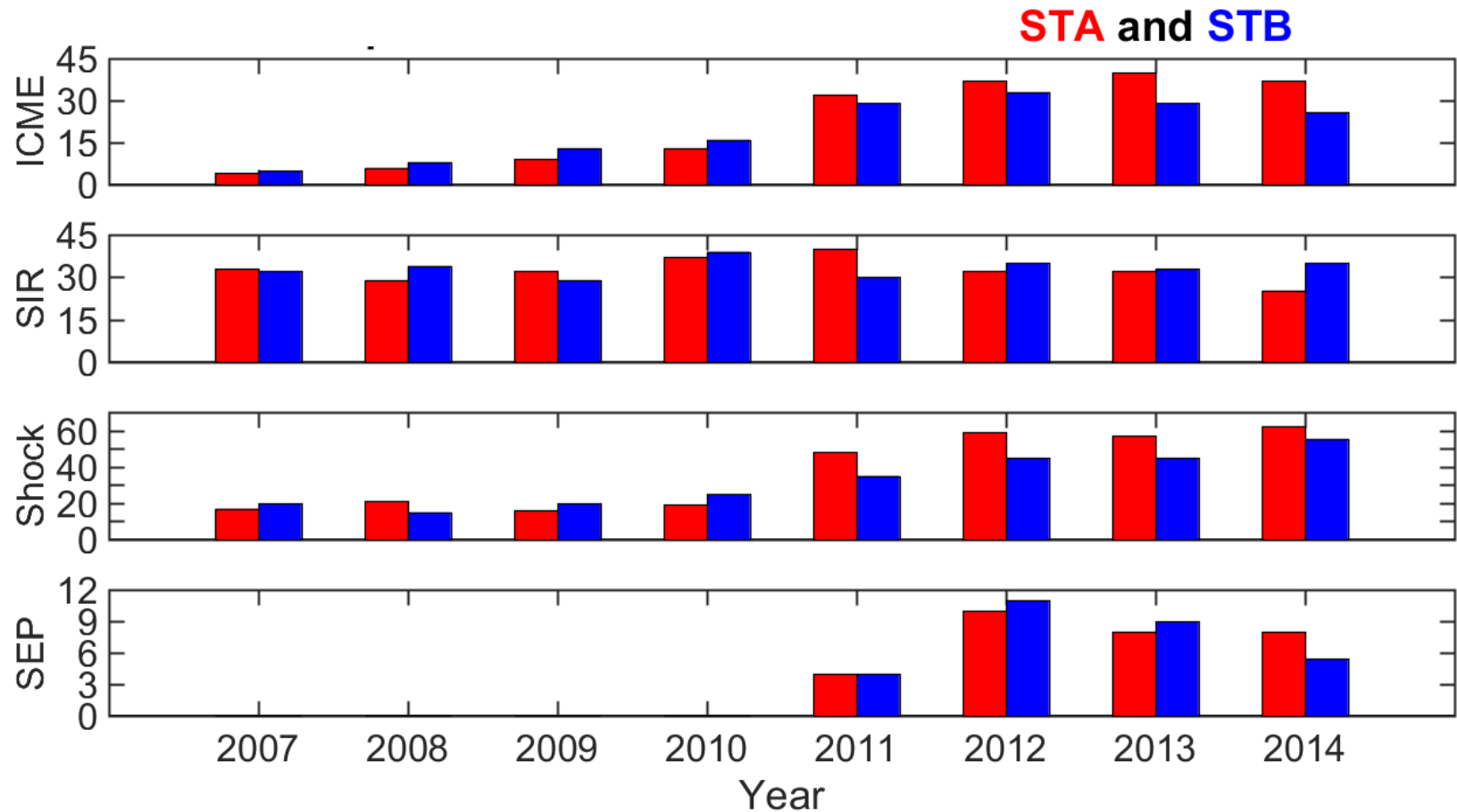
[https://stereo-dev.epss.ucla.edu/l3\\_events](https://stereo-dev.epss.ucla.edu/l3_events)

[https://stereo-ssc.nascom.nasa.gov/data/ins\\_data/impact/level3/](https://stereo-ssc.nascom.nasa.gov/data/ins_data/impact/level3/)

- ICMEs (with magnetic clouds marked), SIRs/CIRs, and shocks: 2007 – 2020
  - 12.9% of ICMEs and 6.1% of SIRs are **hybrid events**, which are caused by multiple ICME interactions or ICME-SIR interaction
- Solar Energetic Proton (SEP) Events: 2006 December – 2021 November, requiring the flux of 13-100 MeV protons > 10 pfu
- Including the **Space Physics Archive Search and Extract (SPASE)** Heliophysics Event list format (<https://spase-group.org/docs/conventions/HDMC-Event-List-Specification-v1.0.4.pdf>)

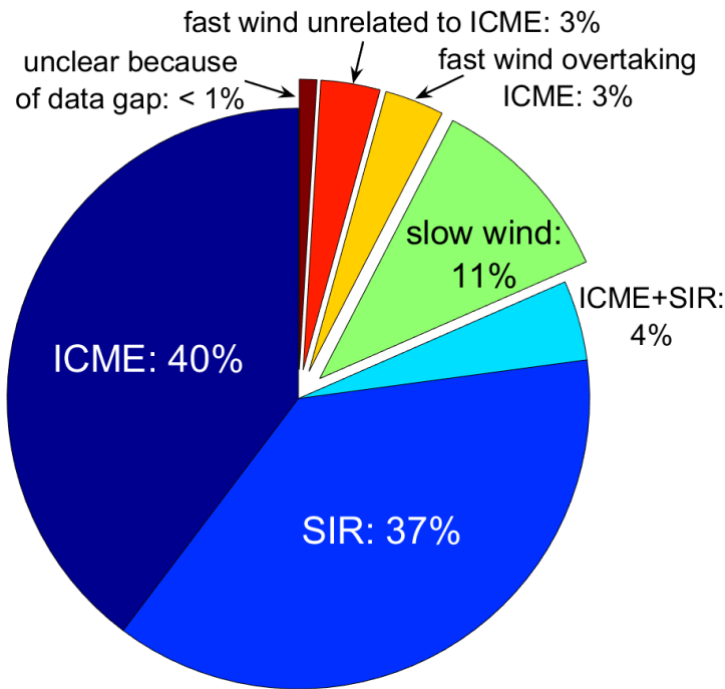


# Comparison of the Event Occurrence at STEREO Twin Spacecraft



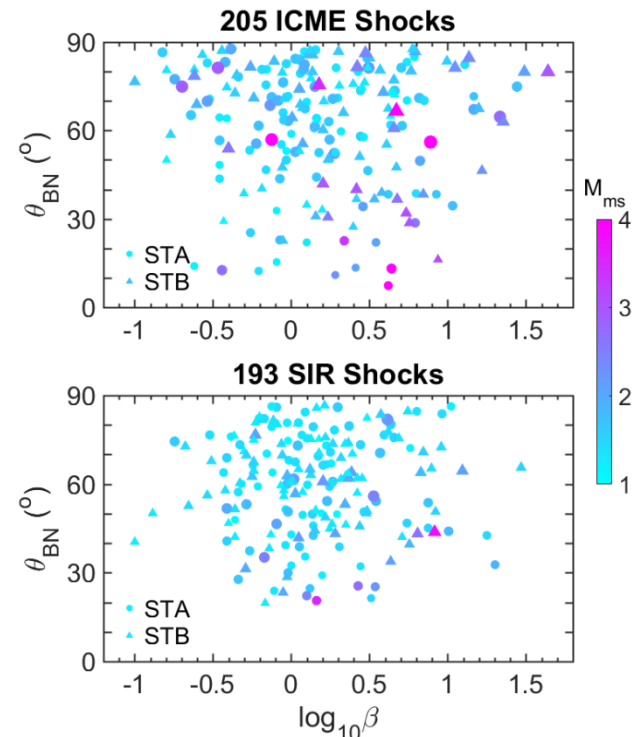
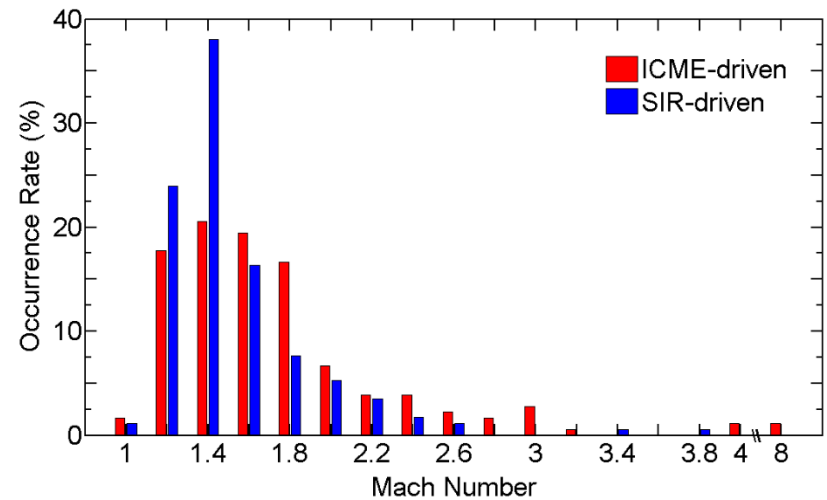
The event numbers at two STEREO s/c can differ much from each other, so it is important to have multipoint observation and more statistics

# Statistical Results of Shocks



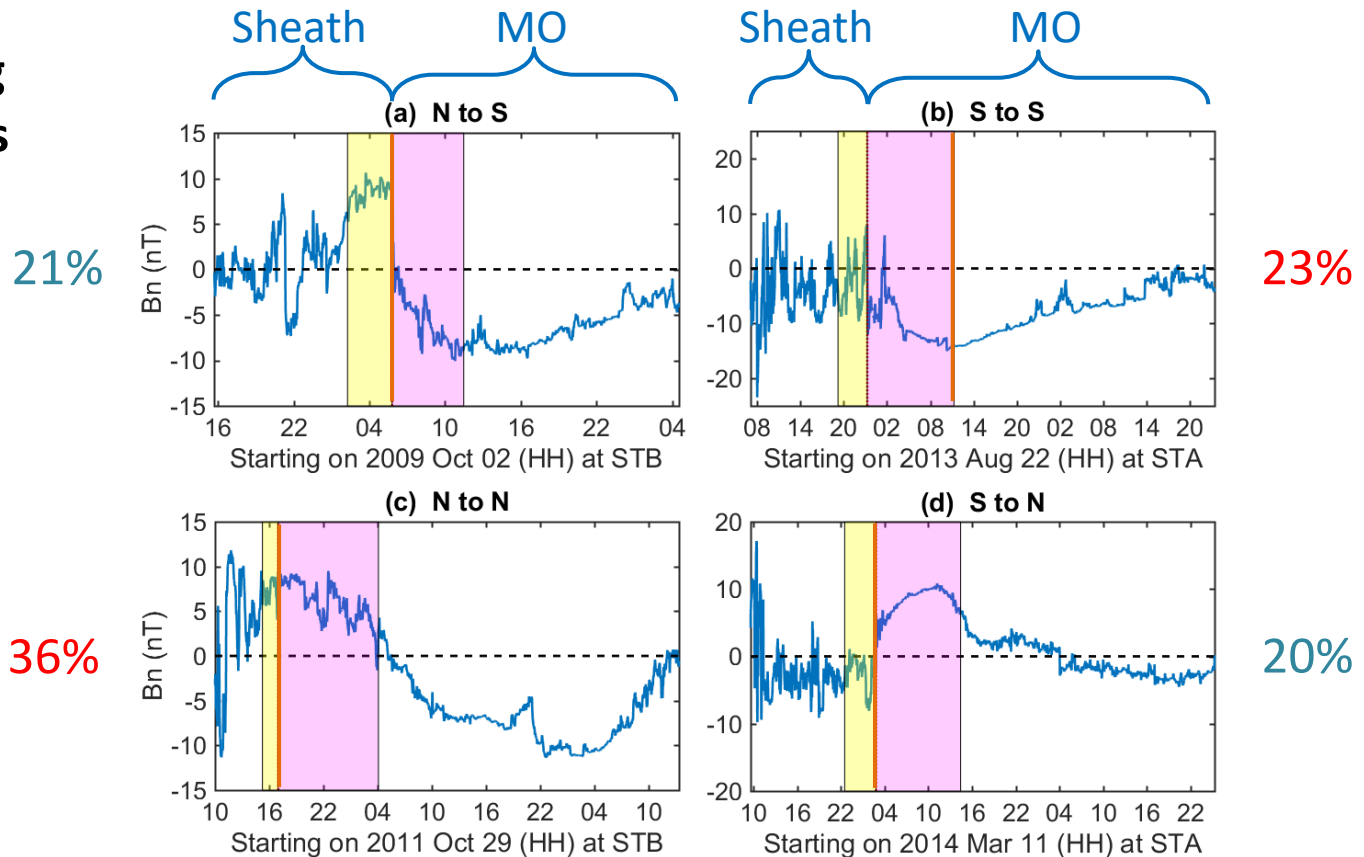
Updated after Jian et al. (2013)

- Although SIRs have a lower shock association rate, they drive nearly the same total amount of shocks as ICMEs at 1 AU
- The ICME-driven shocks have slightly higher Mach number and shock normal angle than SIR-driven shocks



# Bz Variation: Sheath → Magnetic Obstacle (MO)

Among  
95 MCs



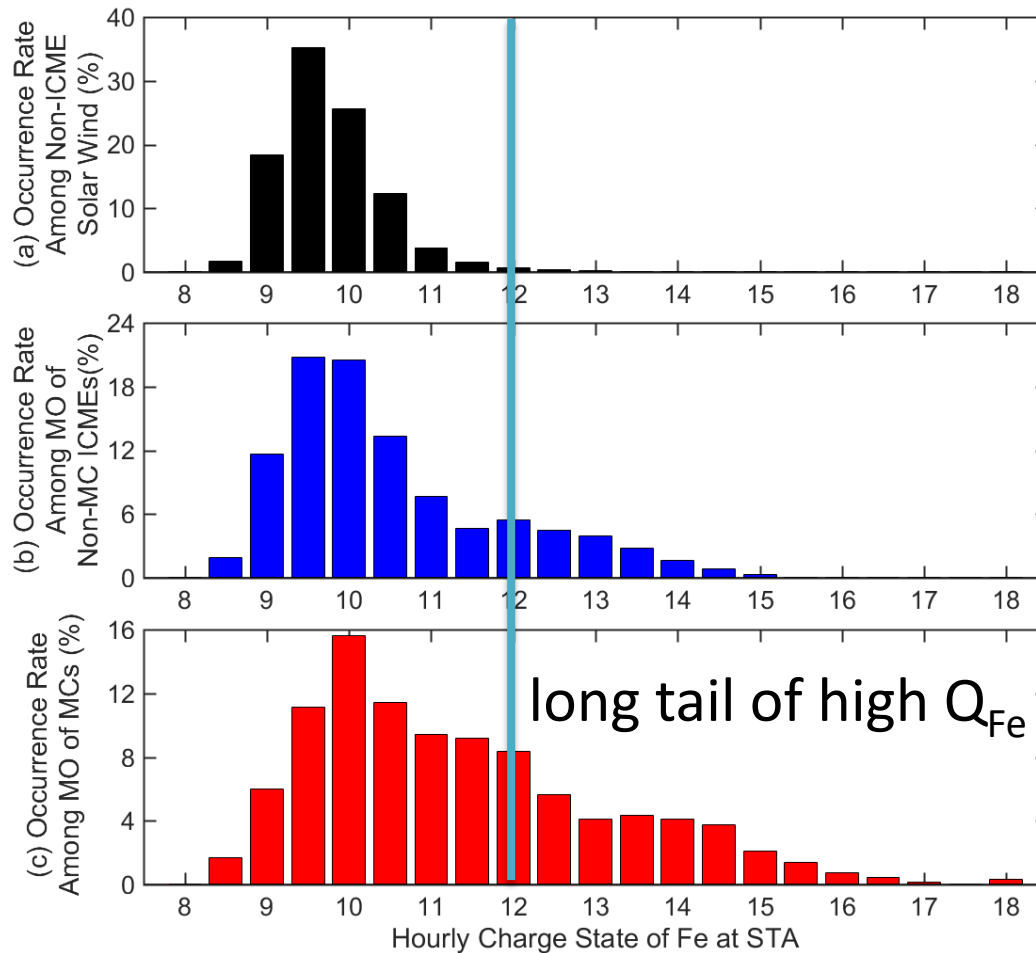
Jian et al. (2018)

- The dominant direction of  $B_n$  does not change from the last quarter of sheath to the first quarter of MO in 59% of MCs
- In  $\chi^2$  test, the p value is slightly  $> 0.1$ , so the correlation is not statistically significant
- If we compare the last half (sixth) of the sheath and the first half (sixth) of MO, the variation is nearly random
  - We cannot predict Bz direction in MO from real-time sheath observation
- Salman et al. (ApJ 2020, 2021) compared the properties of the ICME sheath regions with and without shocks



# Histogram Distribution of $\langle Q_{Fe} \rangle$

- STA provides the hourly  $\langle Q_{Fe} \rangle$  and 2-hour  $Q_{Fe}$  distribution up to present.
- STB provides 2-hour  $Q_{Fe}$  distribution up to July 2011



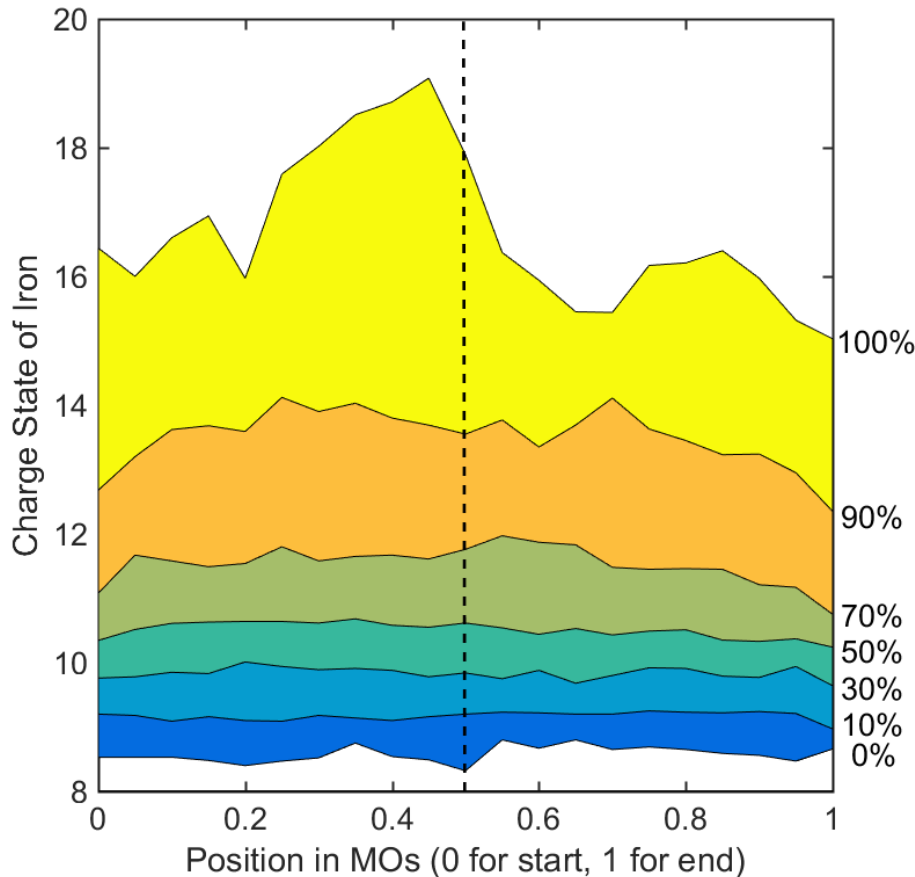
Non-ICME  
Solar Wind  
1%  $Q_{Fe} > 12+$   
 $T \approx 1.7$  MK

Non-MC  
ICMEs  
16%  $Q_{Fe} > 12+$

MCs  
31%  $Q_{Fe} > 12+$

# Superposed Epoch Analysis of $\langle Q_{\text{Fe}} \rangle$ Distribution

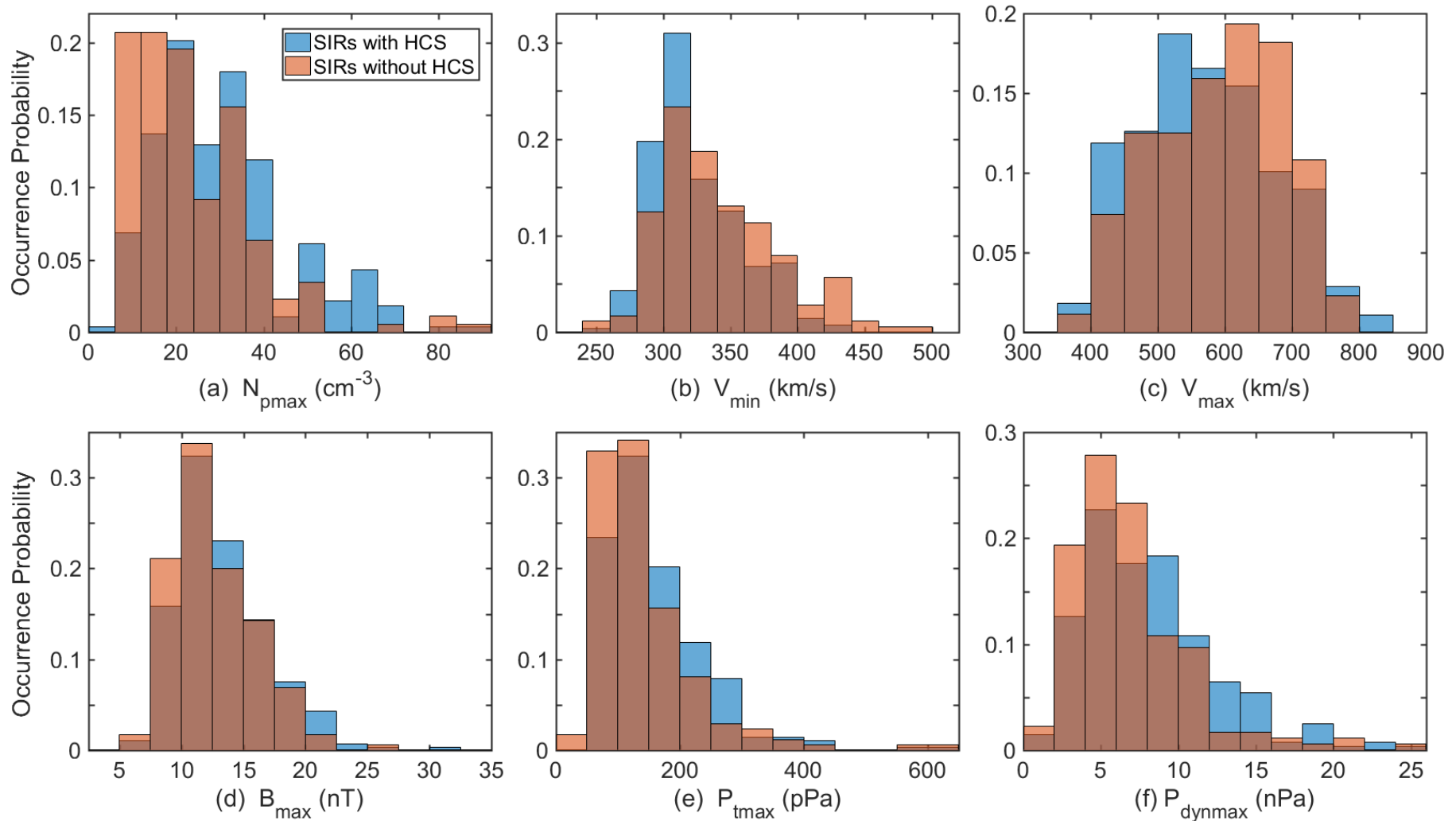
127 ICMEs at STA



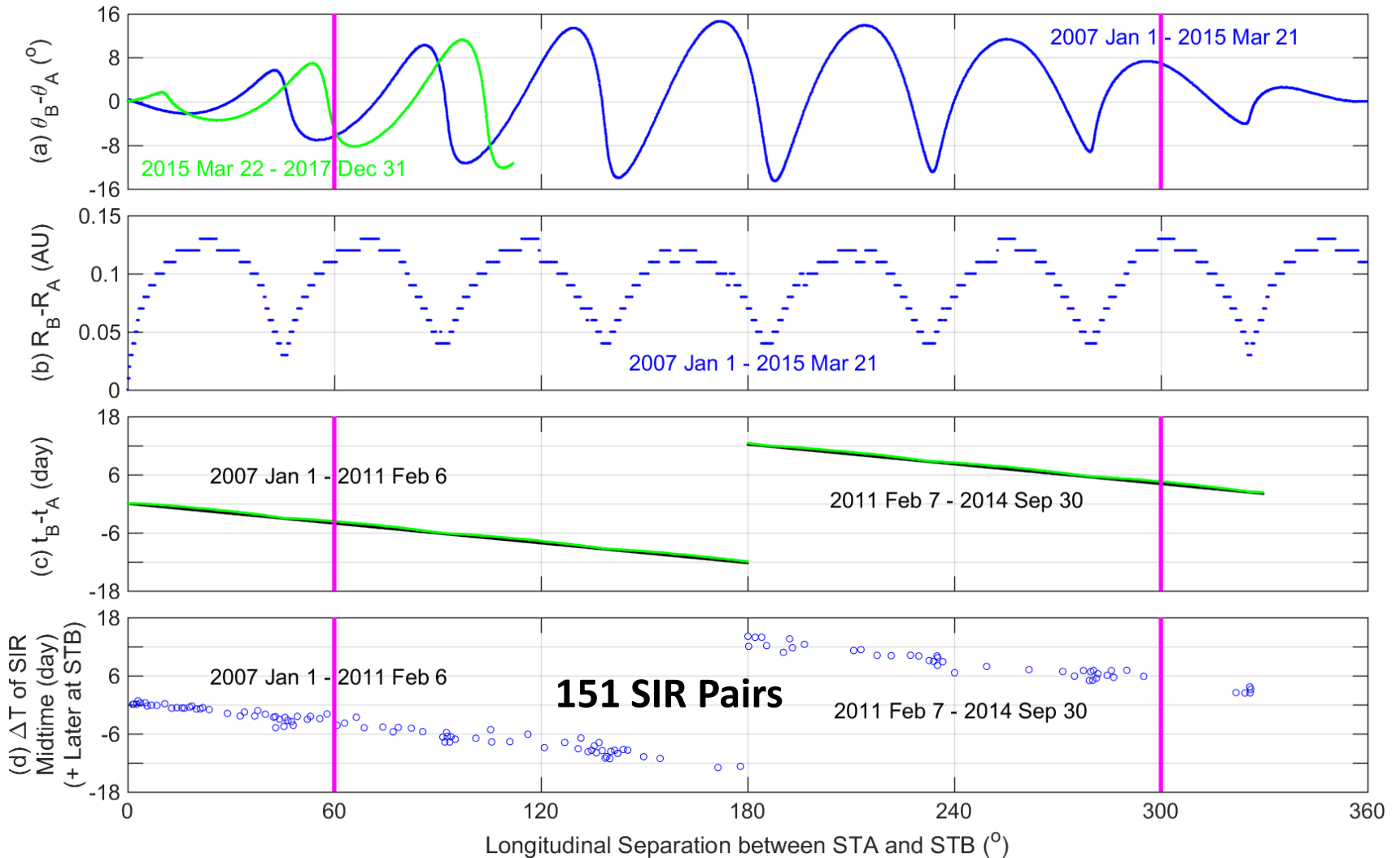
Jian et al. (2018)

- ◆ The period of high  $\langle Q_{\text{Fe}} \rangle$  does not always overlap with the MO period, consistent with Richardson and Cane (2010)
- ◆ According to a scenario proposed in Song et al. (2016), the distribution of  $Q_{\text{Fe}}$  can be used to infer the magnetic flux rope formation time and the current sheet temperature during the eruption
- ◆ The bimodal distribution of  $\langle Q_{\text{Fe}} \rangle$  in about 10% of MCs were attributed to a scenario that the flux rope exists before the eruption by Song et al. (2016)

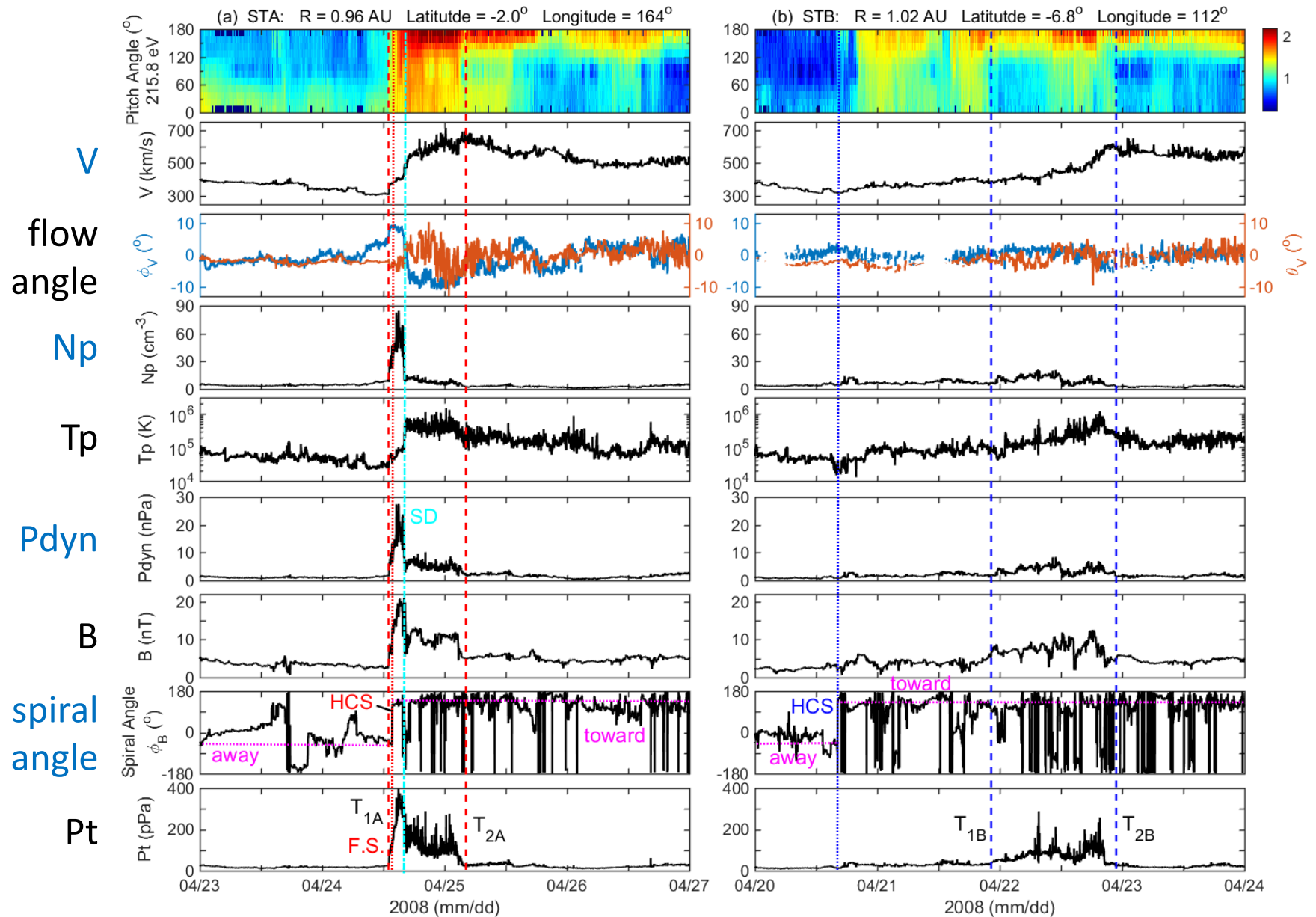
# Comparison between SIRs with and without HCS



# Orbital Difference and SIR Time Offset between STEREO A and B

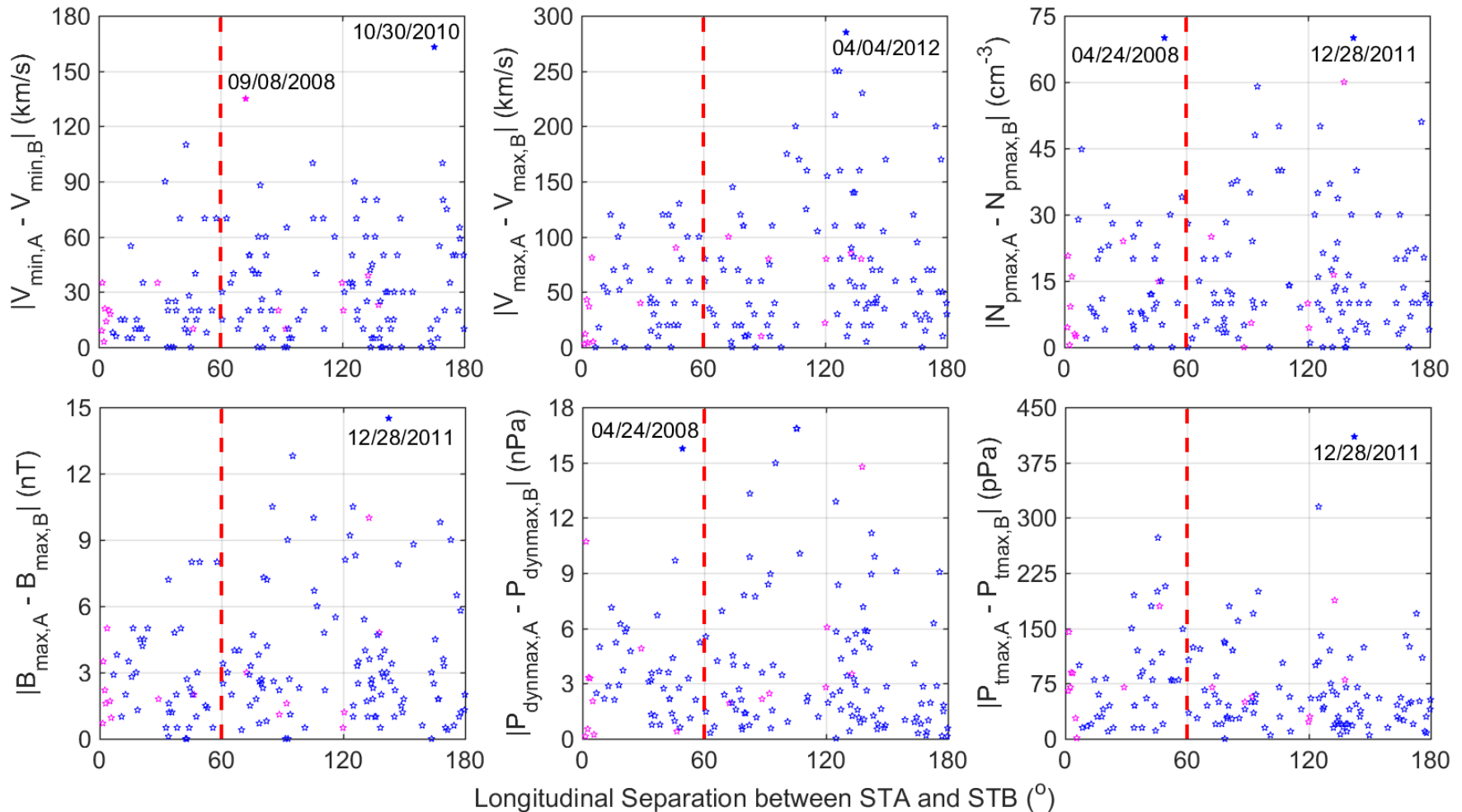


# Example of Dual Observations of SIRs



# SIR Parameter Differences vs. Longitudinal Separation

★ latitudinal difference < 1°



# Summary

- ☀ We have been updating STEREO surveys of ICMEs, SIRs/CIRs, shocks, and energetic proton events as the Level 3 products
- ☀ We have compared the event occurrence between twin s/c
- ☀ We have studied the shock drivers and parameters
- ☀ We cannot predict Bz direction in magnetic obstacle from sheath
- ☀ The hourly  $\langle Q_{\text{Fe}} \rangle$  reaches  $> 12+$  about 31% of the time for MCs, and about 16% of the time for non-MC ICMEs
- ☀ The SIRs with HCS generally have higher maximum number densities, magnetic field strengths, and pressures than the SIRs without HCS
- ☀ The variability of SIR structures from dual observations are related to the HCS relative location, tilt of stream interface, etc.