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

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Collaborators:

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Solar Wind Variations in 1965 – 2021

OMNI

STA

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)

Stream Interaction Regions (SIRs)

Stream Interface (SI): peak of Pt, sometimes co-occur with Np decrease and Tp increase

Heliospheric Current Sheet (HCS) identified using magnetic field data and suprathermal electron pitch angle distribution

Corotating Interaction Regions (CIRs)

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

Jian et al. (2006), after Pizzo (1978)

Jian et al. (2009)
**Level 3 Event Lists of STEREO**

https://stereo-dev.epss.ucla.edu/l3_events

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.
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.

Updated after Jian et al. (2013)
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.

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% $Q_{Fe}>12+$

Jian et al. (2018)
Superposed Epoch Analysis of $\langle Q_{Fe}\rangle$ Distribution

The period of high $\langle Q_{Fe}\rangle$ 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 $Q_{Fe}$ can be used to infer the magnetic flux rope formation time and the current sheet temperature during the eruption.

The bimodal distribution of $\langle Q_{Fe}\rangle$ in about 10% of MCs were attributed to a scenario that the flux rope exists before the eruption by Song et al. (2016).

127 ICMEs at STA

Jian et al. (2018)
Comparison between SIRs with and without HCS

Jian et al. (Solar Phys., 2019)
Orbital Difference and SIR Time Offset between STEREO A and B

- Plot (a): $\theta_B - \theta_A$ ($^\circ$)
  - 2015 Mar 22 - 2017 Dec 31
  - 2007 Jan 1 - 2015 Mar 21

- Plot (b): $R_B - R_A$ (AU)
  - 2007 Jan 1 - 2015 Mar 21

- Plot (c): $t_B - t_A$ (day)
  - 2007 Jan 1 - 2011 Feb 6
  - 2011 Feb 7 - 2014 Sep 30

- Plot (d): $\Delta T$ of SIR Midtime (day) (+ Later at STB)
  - 2007 Jan 1 - 2011 Feb 6
  - 2011 Feb 7 - 2014 Sep 30

151 SIR Pairs

Longitudinal Separation between STA and STB ($^\circ$)
Example of Dual Observations of SIRs

- V
- flow angle
- Np
- Tp
- Pdyn
- B
- spiral angle
- Pt

(a) STA: R = 0.96 AU, Latitude = -2.0°, Longitude = 164°

(b) STB: R = 1.02 AU, Latitude = -6.8°, Longitude = 112°
SIR Parameter Differences vs. Longitudinal Separation

Latitudinal difference < 1°

L4/L5

Longitudinal Separation between STA and STB (°)
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 $\langle Q_{Fe} \rangle$ 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.