

Parker Solar Probe

observations of interaction of slow streamer blow-out CMEs with their surroundings at ~ 0.5 AU

E. Kilpua¹, S. Pal¹, S. Good¹,
M. Ala-Lahti¹, B. Lynch², A.
Osmane¹, E. Palmerio², J.
Räsänen¹, L.-L. Zhao³, S.
Bale², and M. Stevens⁴

¹University of Helsinki, Finland

²University of California, Berkeley, US

³University of Alabama, Huntsville, US

⁴Smithsonian Astrophysical Observatory,
Cambridge, Massachusetts, US

- Both studies involved a **streamer blow-out CME**
- Both related interplanetary CMEs were **slow**
 - Pal et al. no shock
 - Kilpua et al. shock & sheath
- Both events were observed by **Parker Solar Probe** at **~0.5 AU**
- Both events were observed close to the **Heliospheric Current Sheet (HCS)**

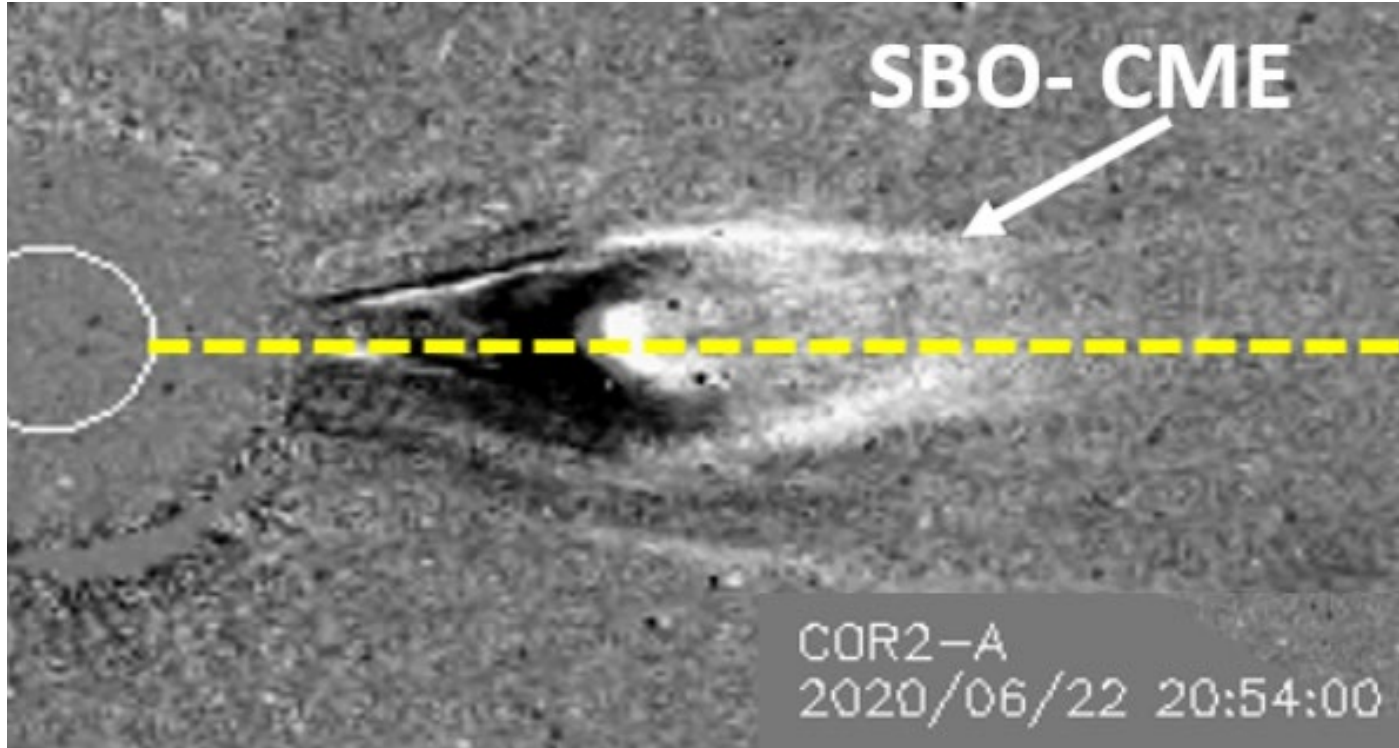
Two recent works

June 2020

Pal et al., Eruption and Interplanetary Evolution of a Stealth Streamer-blowout CME Observed by PSP at 0.5 AU, submitted soon to Geophys. Res. Lett.

March 2019

Kilpua et al., Structure and fluctuations of a slow ICME sheath observed at 0.5 AU by Parker Solar Probe, submitted to Astronomy & Astrophysics

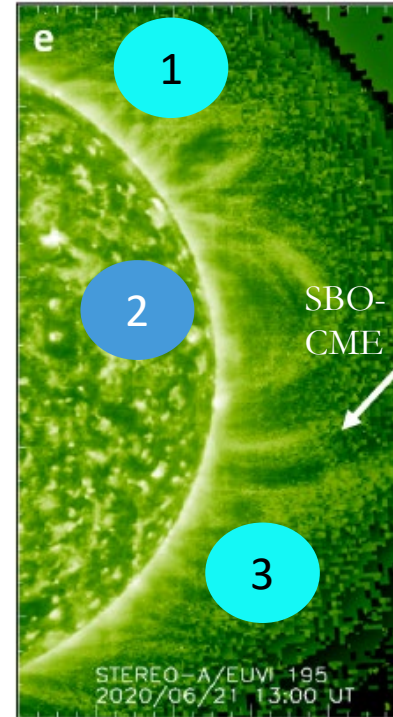
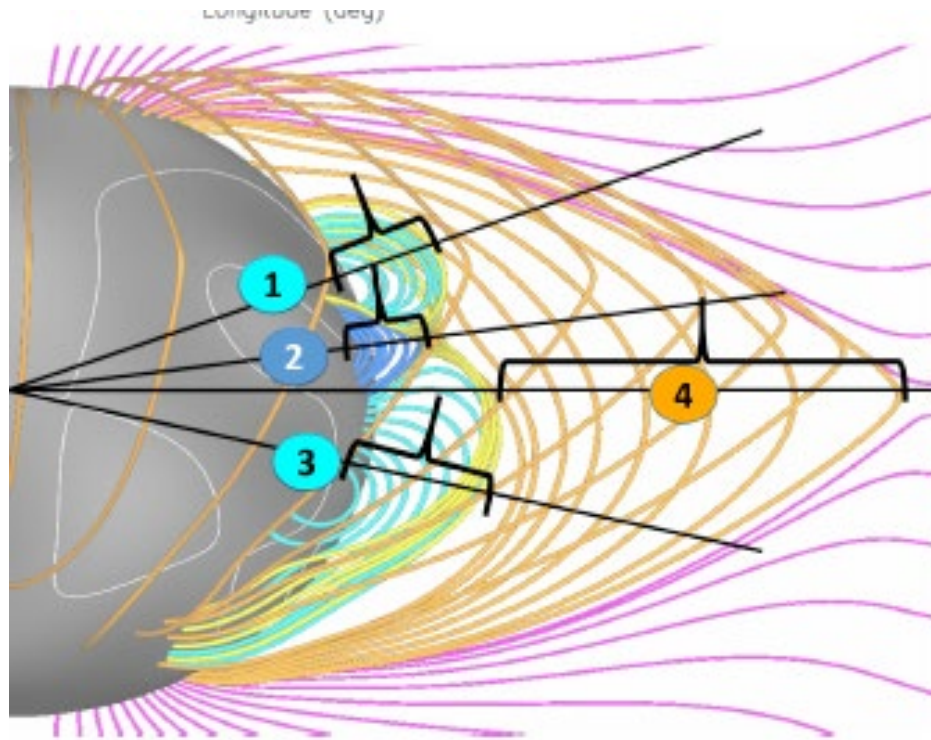


Streamer blow-out (SBO) CME on June 22, 2020

- In STA/COR2 first detection ~16:30 UT as limb event with classical 3-part structure
- STA/COR1 detected only a depletion
- Prior to the event the streamer gradually swelled
- SDO did not see any disk signatures → stealth CME
- GCS and ForeCAT coronal modelling show that the CME deflected towards the HCS (Palmerio & Kay, 2021)

June 2020

Pal et al., on-going work



Multistage, sympathetic break-out eruption*

- PFSS modeling results (shown on left correspond nicely STA/EUV observations and reveal complex multi-flux system structure
- Multi-stage eruption started already June 21, 03:05 UT (> 1 day before SBO-CME in COR2)
- Narrow/jet-CME (1) → cloud-like CME (2) → SBO-CME (3)**

*Lynch & Edmondson, 2013

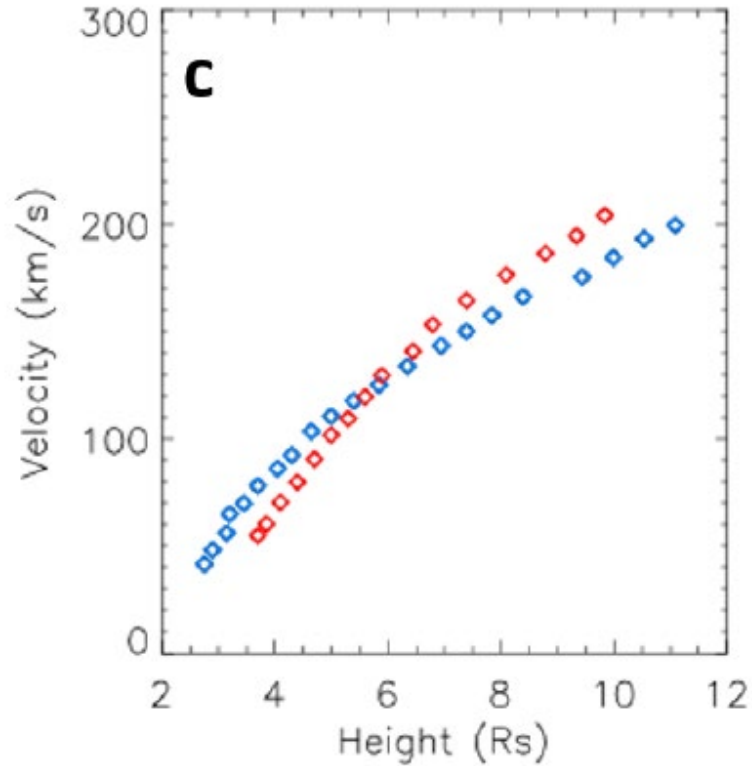
** flux system (4) likely contributes to all

June 2020

Pal et al., on-going work

Pal et al., on-going work

WHPI Workshop
September 13-17, 2021



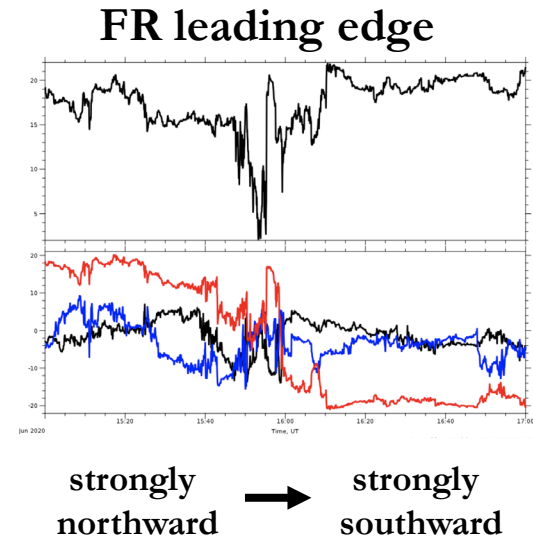
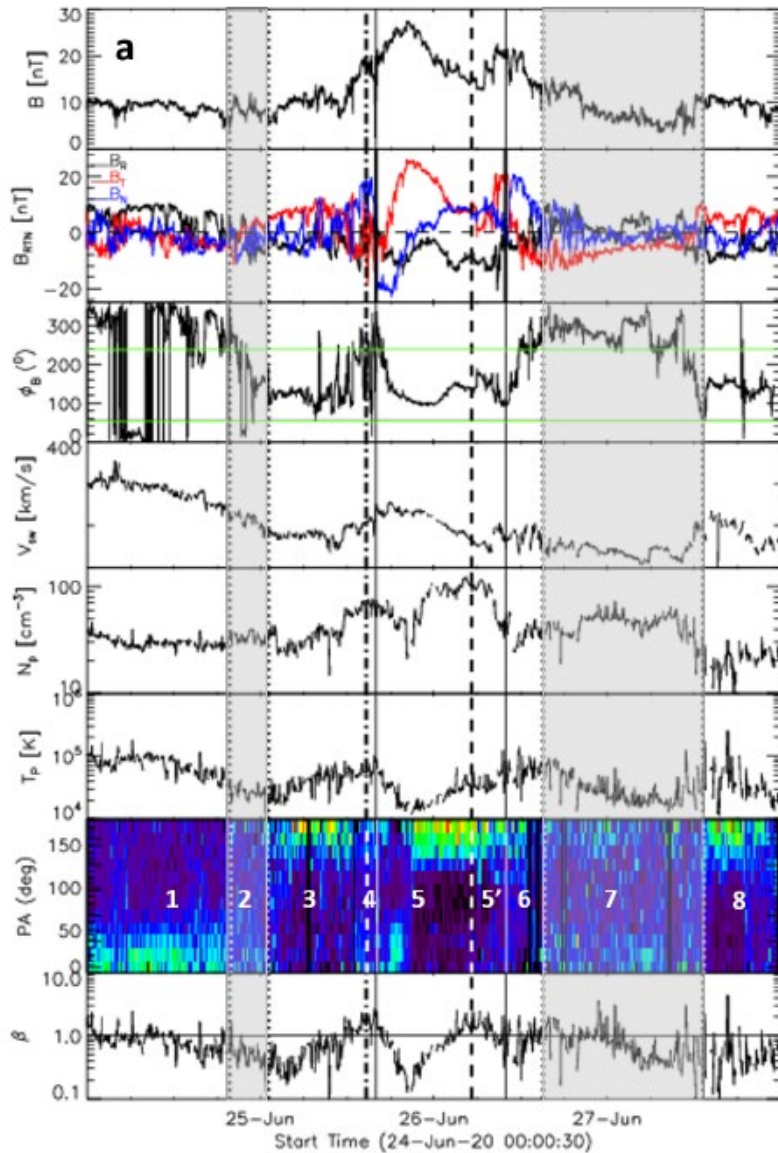
core
cavity

Reconnection below the SBO-CME

- The **core (blue)** is initially faster than the **cavity (red)** → core experiences **additional acceleration** from reconnection outflow
- Speeds derived from the height-time J-maps

June 2020

contact
Emilia.Kilpua@helsinki.fi

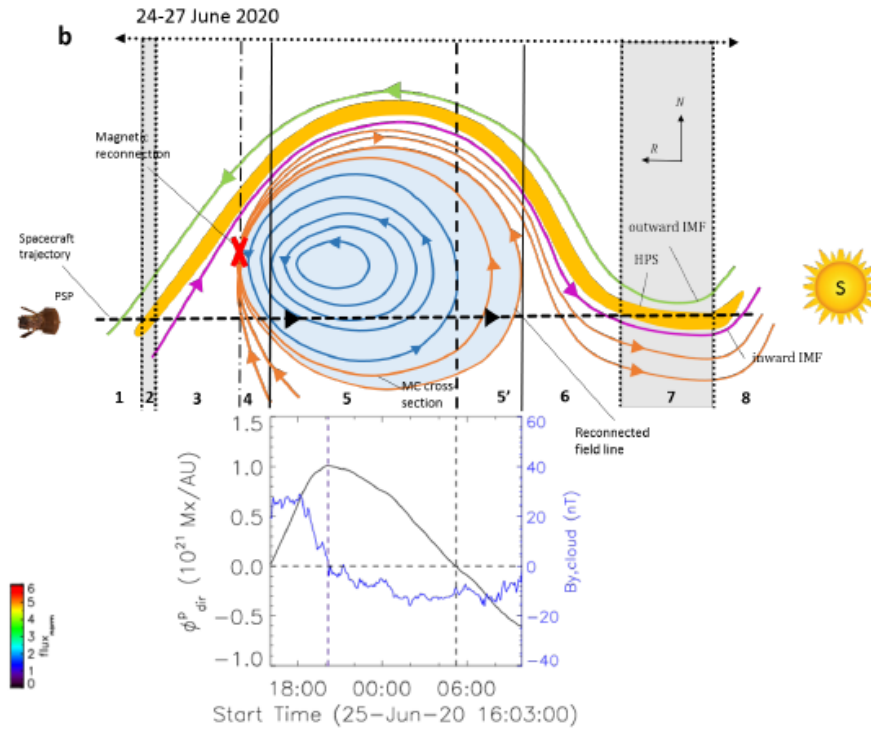
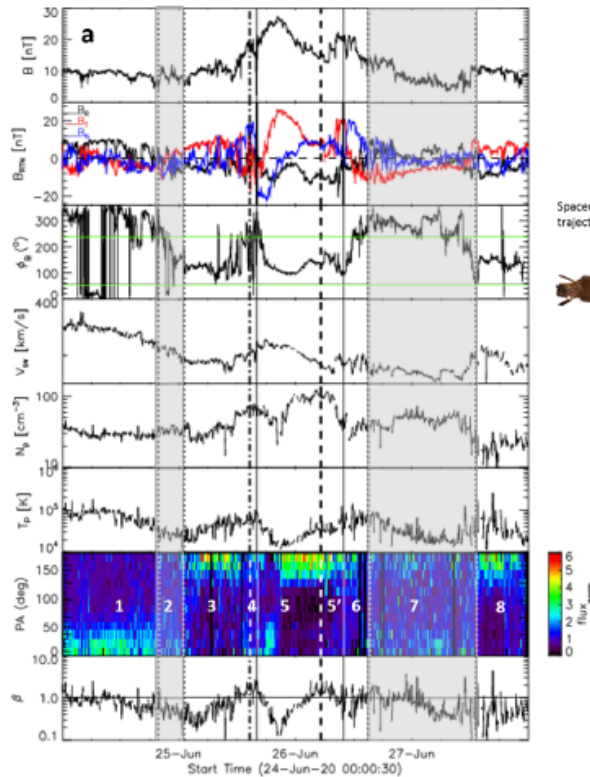


ICME identified at PSP

- PSP was located 20° from Sun-Earth line
- A clear **flux rope** (FR) ICME was detected on Jun 25-26, 2020
- Declining speed profile, gradient ~ 22 km/s
- relatively high density, but depleted temperature and low plasma beta
- Suprathermal electron PAD shows unidirectional flow → open fields
- Sector Boundary crossings with PA changes → HCS crossings

June 2020

Pal et al., on-going work



black: poloidal *accumulated* flux
blue: azimuthal field in FR (in FR frame)

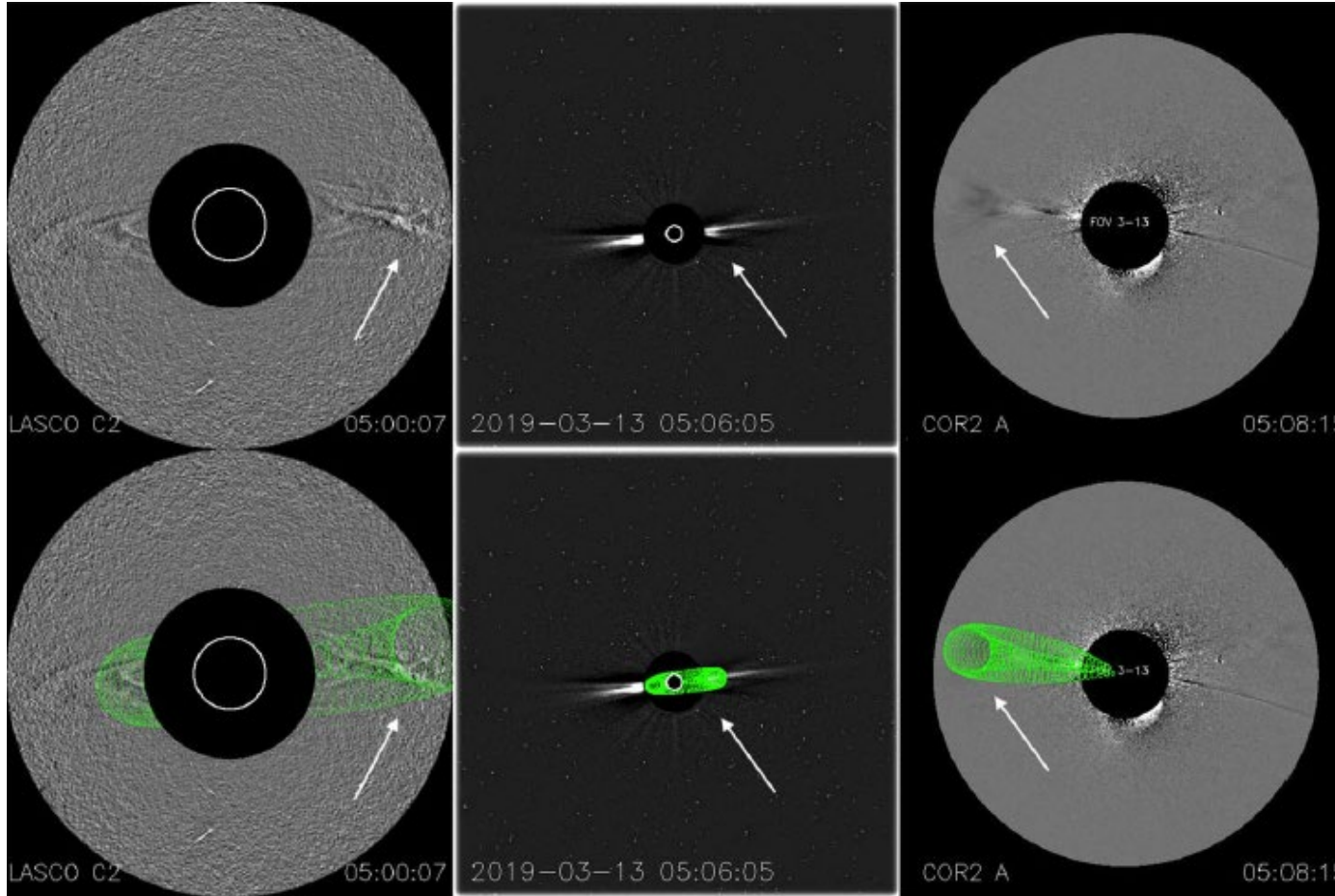
- 1: Outward sector
- 2: HCS/HPS crossing
- 3: Inward sector
- 4: Reconnection exhaust
- 5: MC
- 5': Reconnected field lines
- 6: Inward sector
- 7: Partial HCS/HPS crossing
- 8: Inward sector

ICME interaction with the HCS

- HCS was enclosed around the FR
- preceding field drapes around the FR
- FR was reconnecting with the field ahead → ~38% of the initial poloidal flux was eroded by the time it was detected at 0.5 AU
- Squeezing of FR with HCS made it more prone to reconnect and enhanced reconnection?

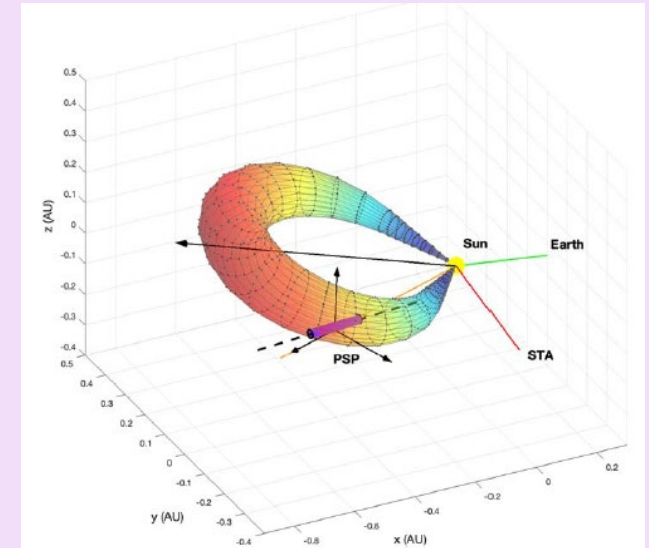
June 2020

Pal et al., on-going work



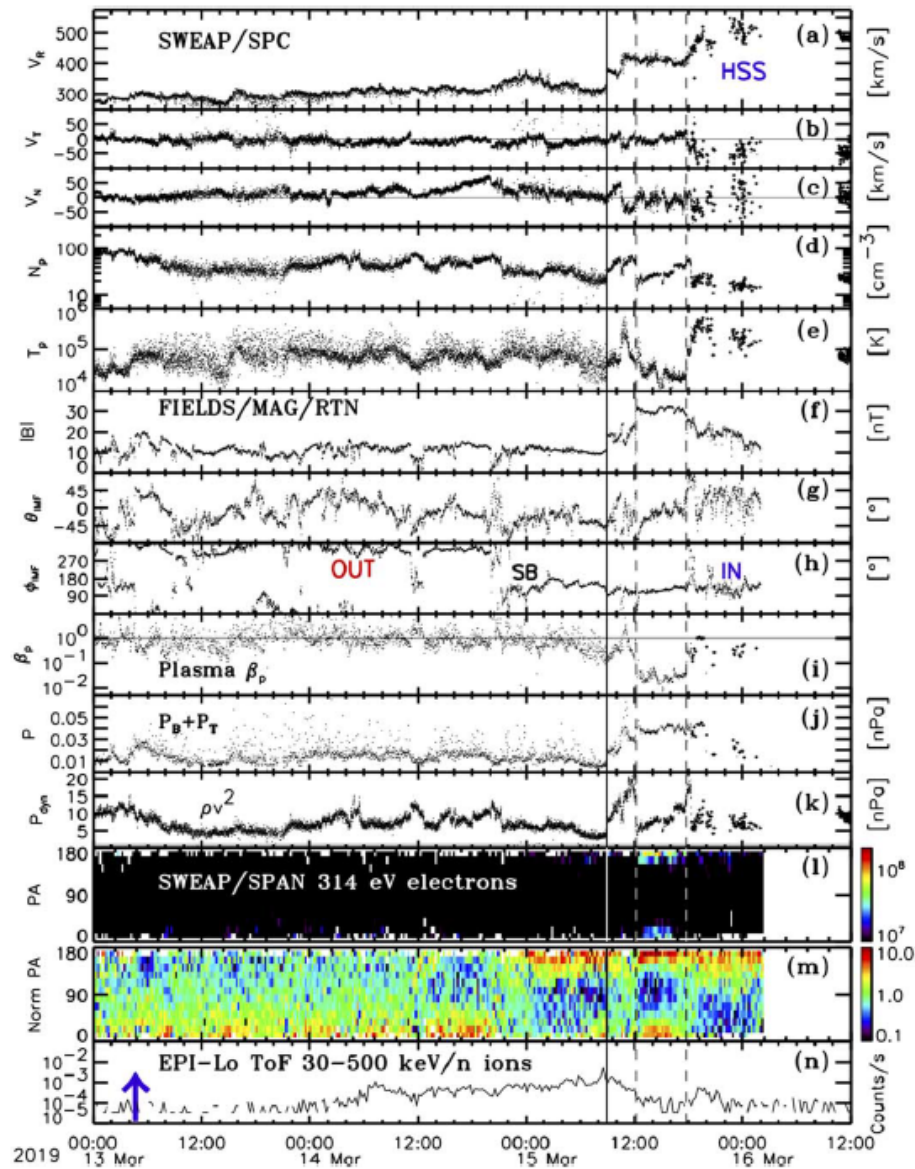
Streamer blow-out (SBO) CME on Mar 13, 2019

- CME erupted early March 13, 2019
- trajectory slightly north from the ecliptic



March 2019

Dario et al., ApJ, 2020

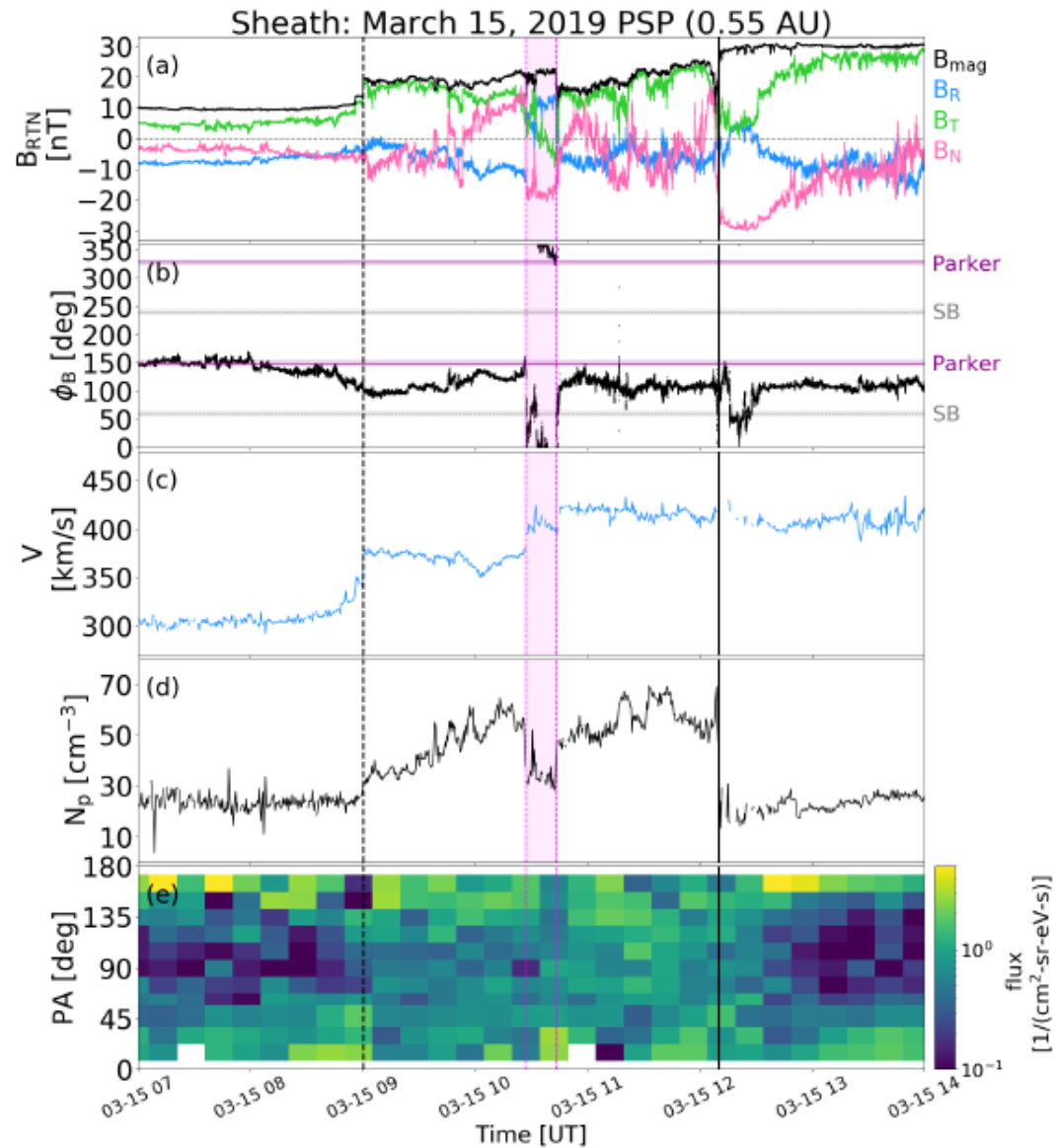


ICME identified at PSP

- ICME with FR structure detected on. March 15, 2019
- sandwiched between slow and faster wind
- sector boundary crossing March 14th
- FR had counterstreaming electrons
- ICME was preceded by two very closely-spaced and relatively weak and slow shocks ($M_{ms} \sim 2.0$ and $V_{sh} \sim 370$ km/s)

March 2019

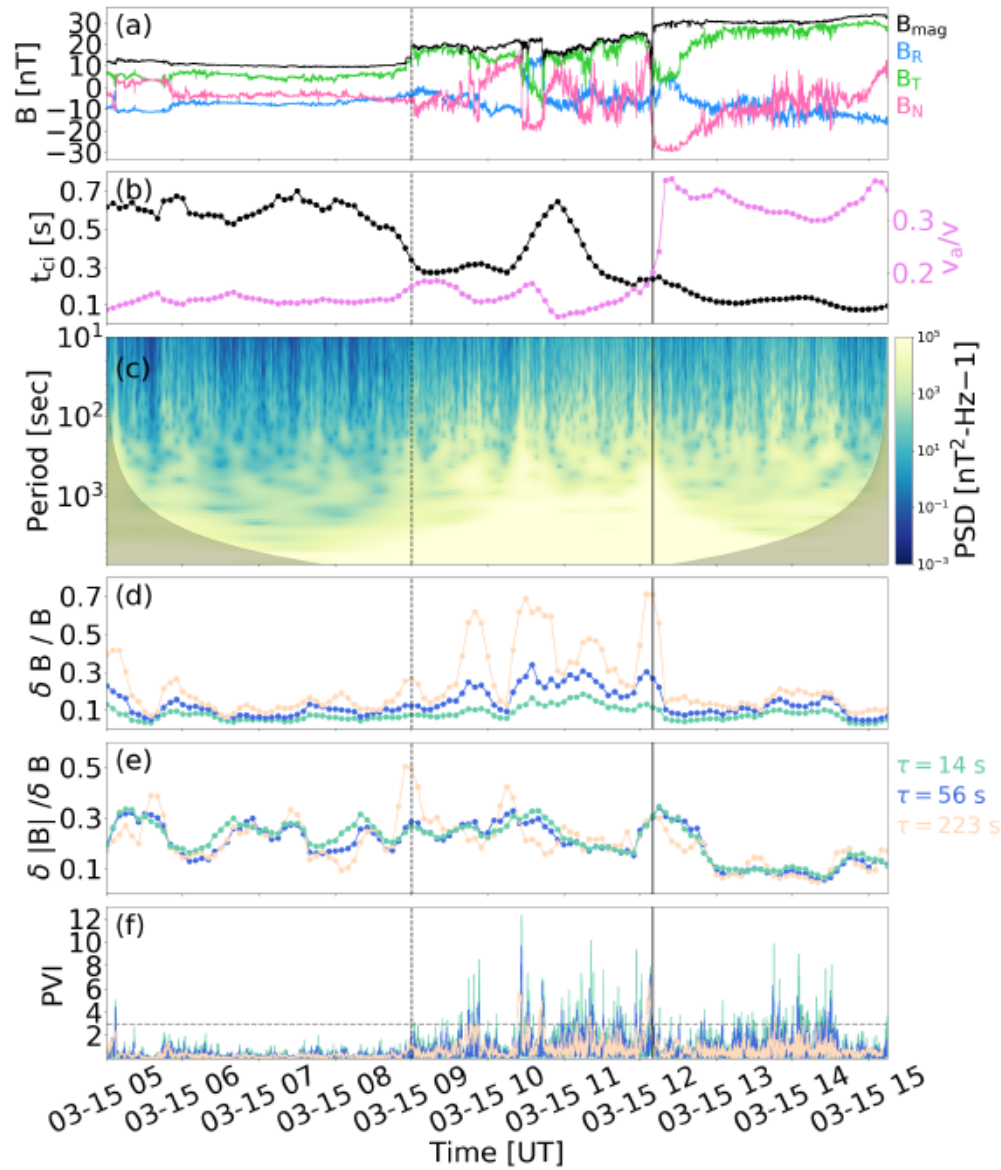
Dario et al., ApJ, 2020



Zoom-in to the sheath

- Sheath had a few sharp field directional changes \rightarrow likely reconnecting current sheets \rightarrow HCS crossings (see change in PAD)
- Two-step speed profile

Kilpua et al., submitted to A&A



Fluctuations in the sheath

- Sheath has enhanced level of fluctuations compared to the upstream
- Sheath has higher number of intermittent structures

$$PVI = \frac{|\delta \mathbf{B}|}{\sqrt{\langle |\delta \mathbf{B}|^2 \rangle}}$$

$$\delta \mathbf{B} = \mathbf{B}(t) - \mathbf{B}(t + \tau)$$

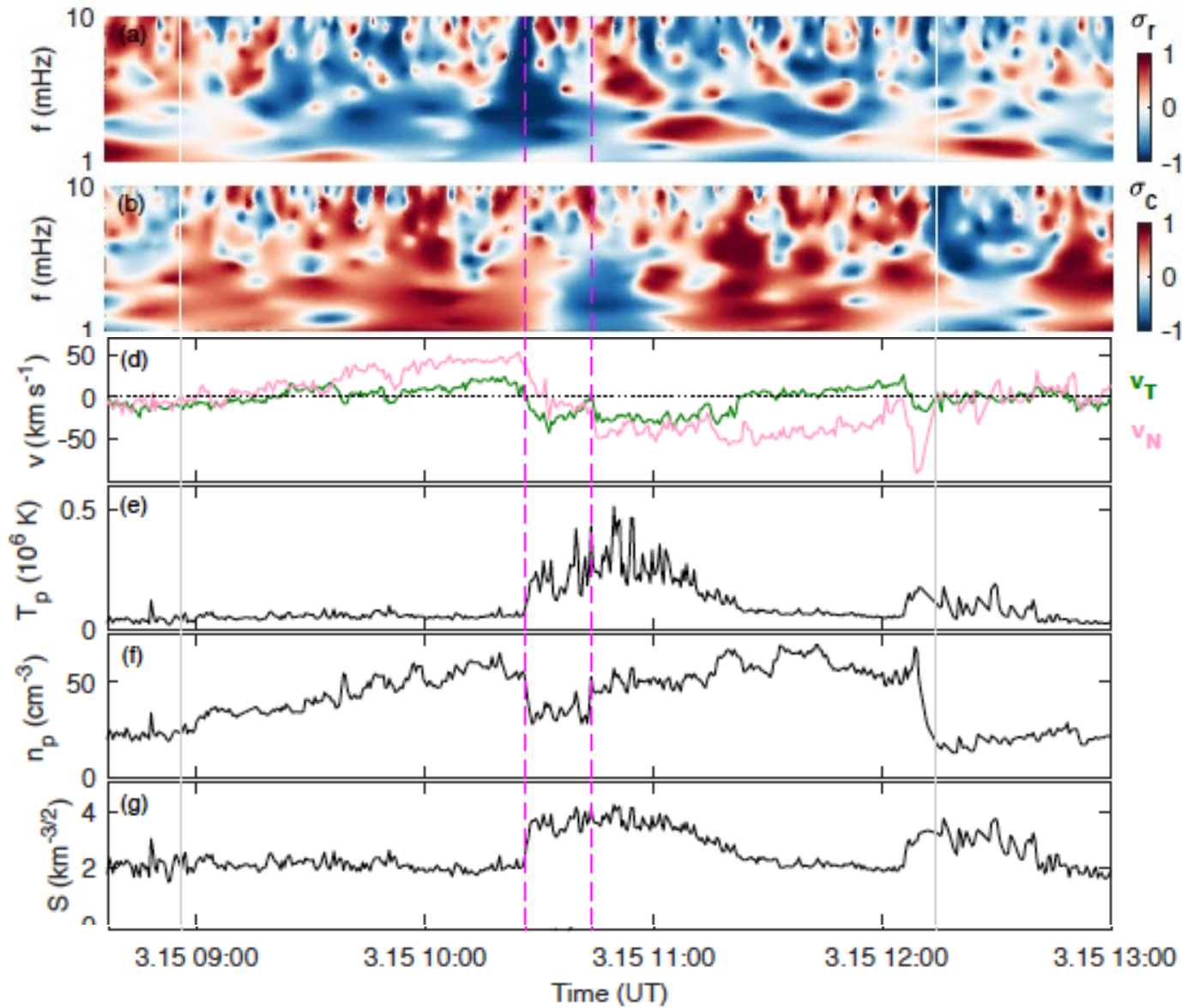
τ : time scale

$$\delta B = \sqrt{\delta B_x^2 + \delta B_y^2 + \delta B_z^2} \text{ and}$$

B is the magnetic field amplitude calculated over the interval τ

March 2019

Kilpua et al., submitted to A&A



Fluctuations in the sheath

- Velocity shear region
- heated region
- specific signatures in normalized cross helicity and residual energies

residual energy

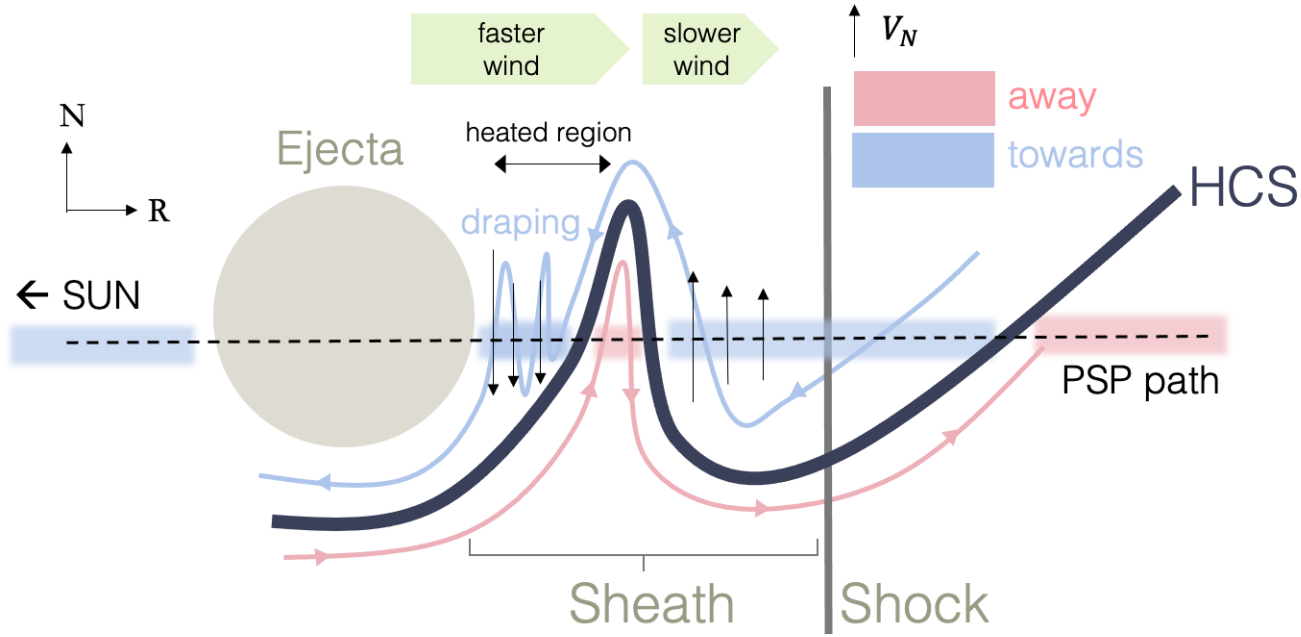
$$\sigma_r = \frac{E_v - E_b}{E_v + E_b}$$

cross helicity

$$\sigma_c = \frac{E_+ - E_-}{E_+ + E_-}$$

March 2019

Kilpua et al., submitted to A&A



Warp in HCS

- HCS made a warp within the sheath
- CME ejecta accelerated the wind that compressed into the slower wind ahead → heated region and Stream Interface like signature

Kilpua et al., submitted to A&A

March 2019

Two SBO-CME events studied

- Both events despite being slow interacted in an interesting manner with the solar wind ahead and with the HCS
- June 2020: Flux rope eroded significantly. Squeezing in at the HCS enhanced reconnection
- March 2019: Warped HCS swept into the sheath divided sheath into two different flows (different speeds and fluctuation properties)

Summary

Future (combined) observations by Solar Orbiter, Parker Solar Probe and BepiColombo will provide excellent opportunity for shedding light on the interaction of ICMEs and ambient wind

Kilpua et al., ApJ, 2021