

Solar Wind Connectivity

with Solar Orbiter



Stephanie Yardley

Northumbria University

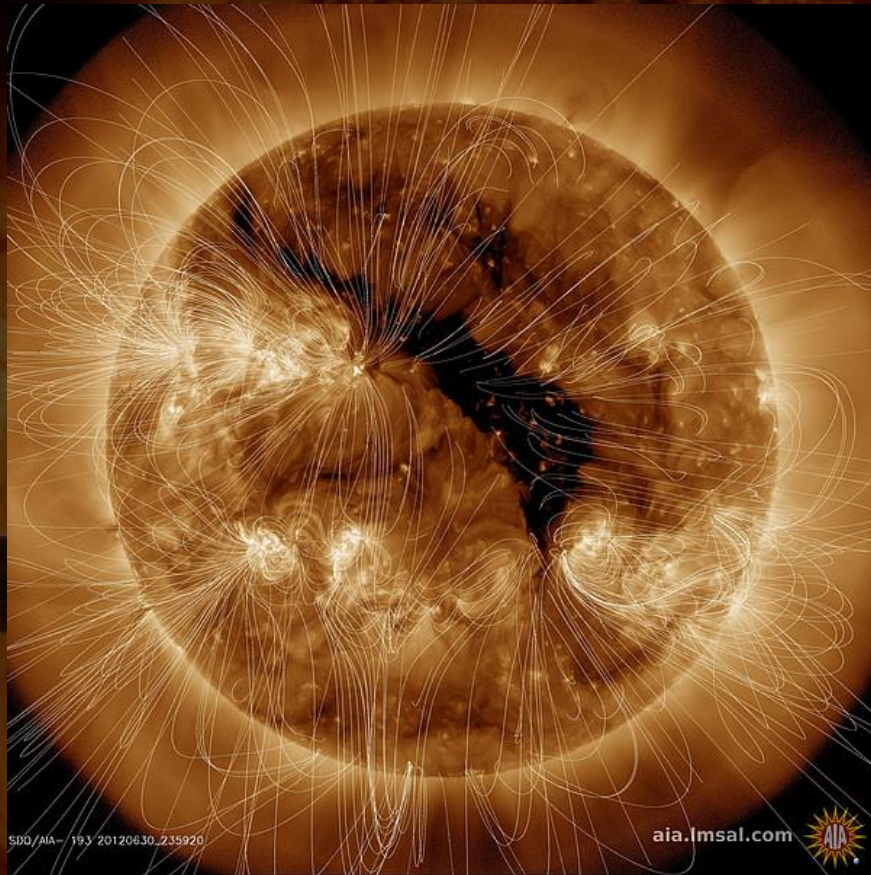
steph.yardley@northumbria.ac.uk

 @slyardley

◆ Solar Orbiter Community Building Webinar ◆ Wednesday 5th February 2024 ◆

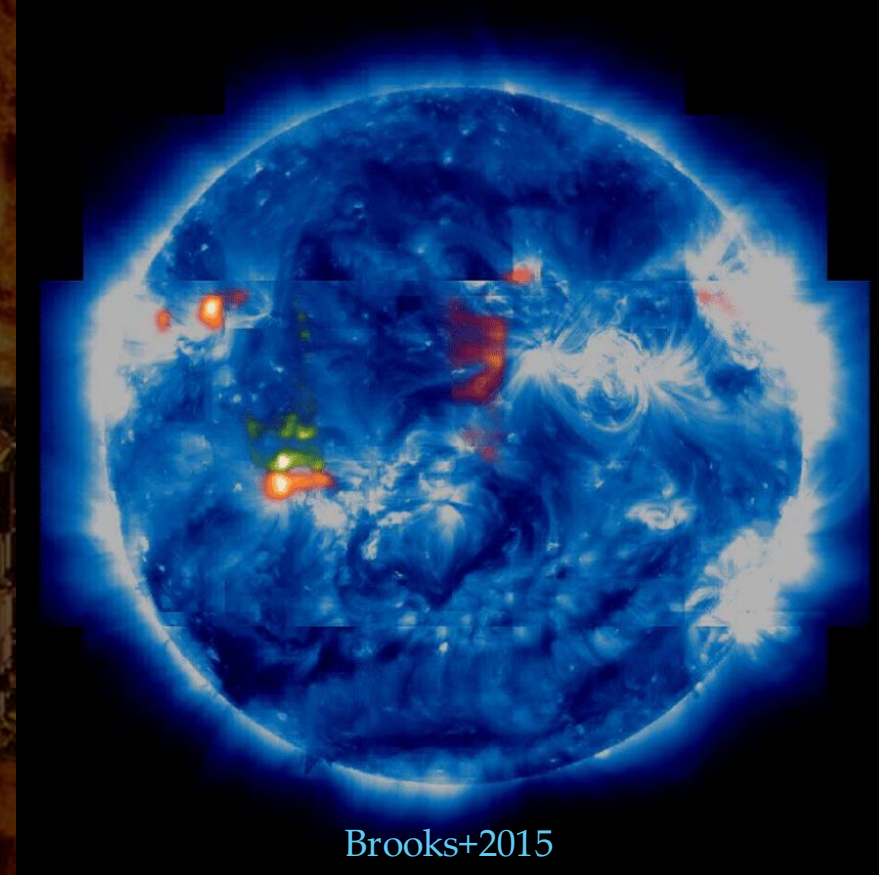
Sources of the Solar Wind

Fast Solar Wind > 500 km/s



Origins => Coronal Holes

Slow Solar Wind $\lesssim 500$ km/s

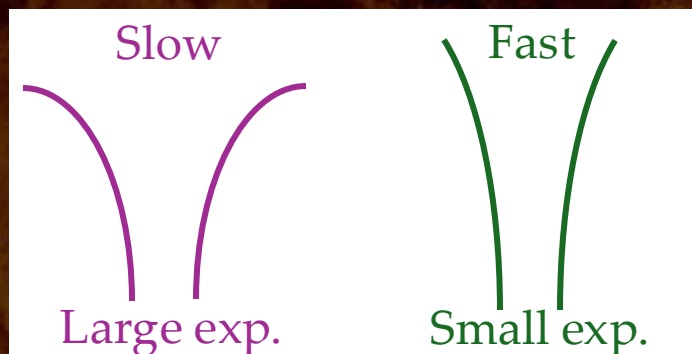


Origins => ???

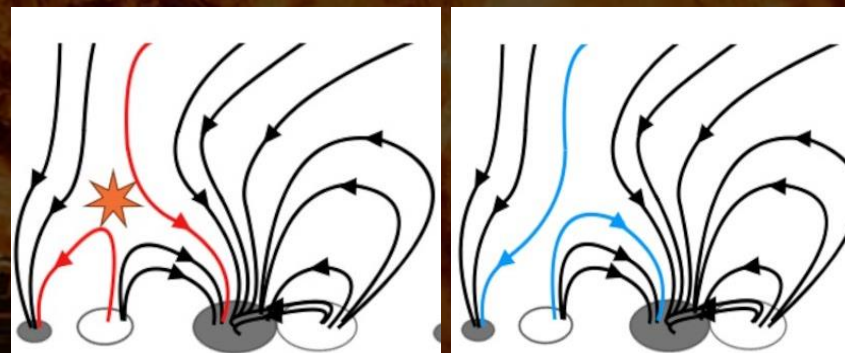
Active Region/Coronal Hole
boundaries
Small low-latitude coronal holes
Coronal Helmet Streamers

Solar Wind Formation Mechanisms

Expansion factor
Flux tube expansion
 \Leftrightarrow solar wind speeds
(Wang+2009)



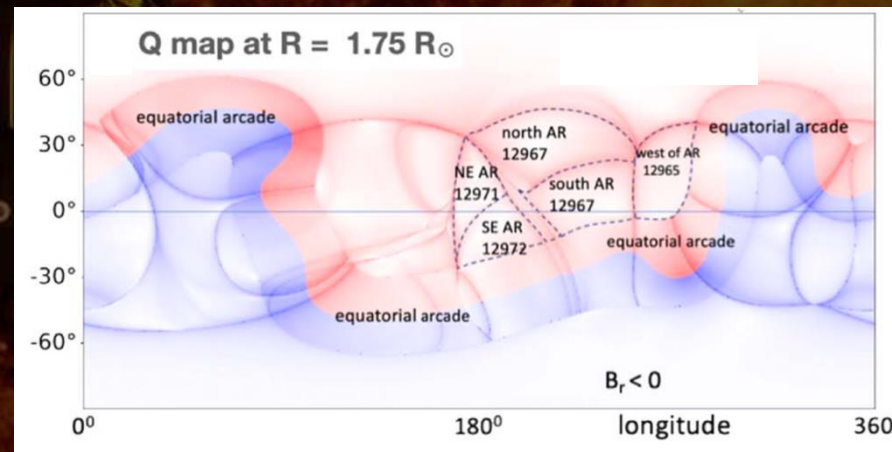
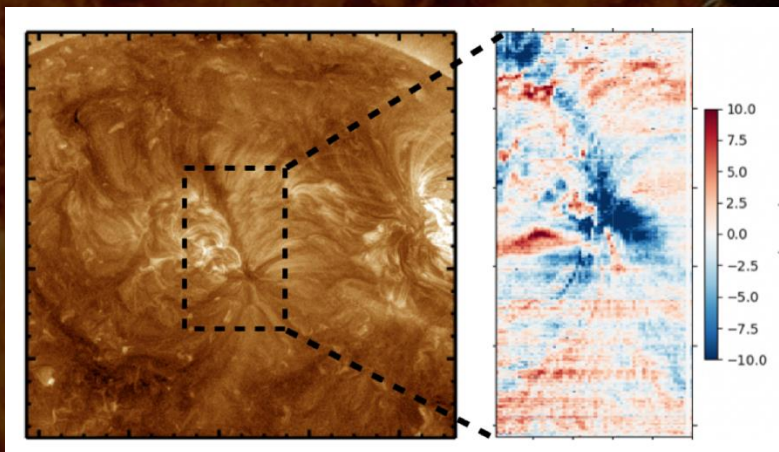
Interchange Reconnection
Magnetic reconnection at open-closed
magnetic field boundaries
(e.g. Fisk 1999, Crooker 2002)



(Brooks & Yardley 2021)

S-web

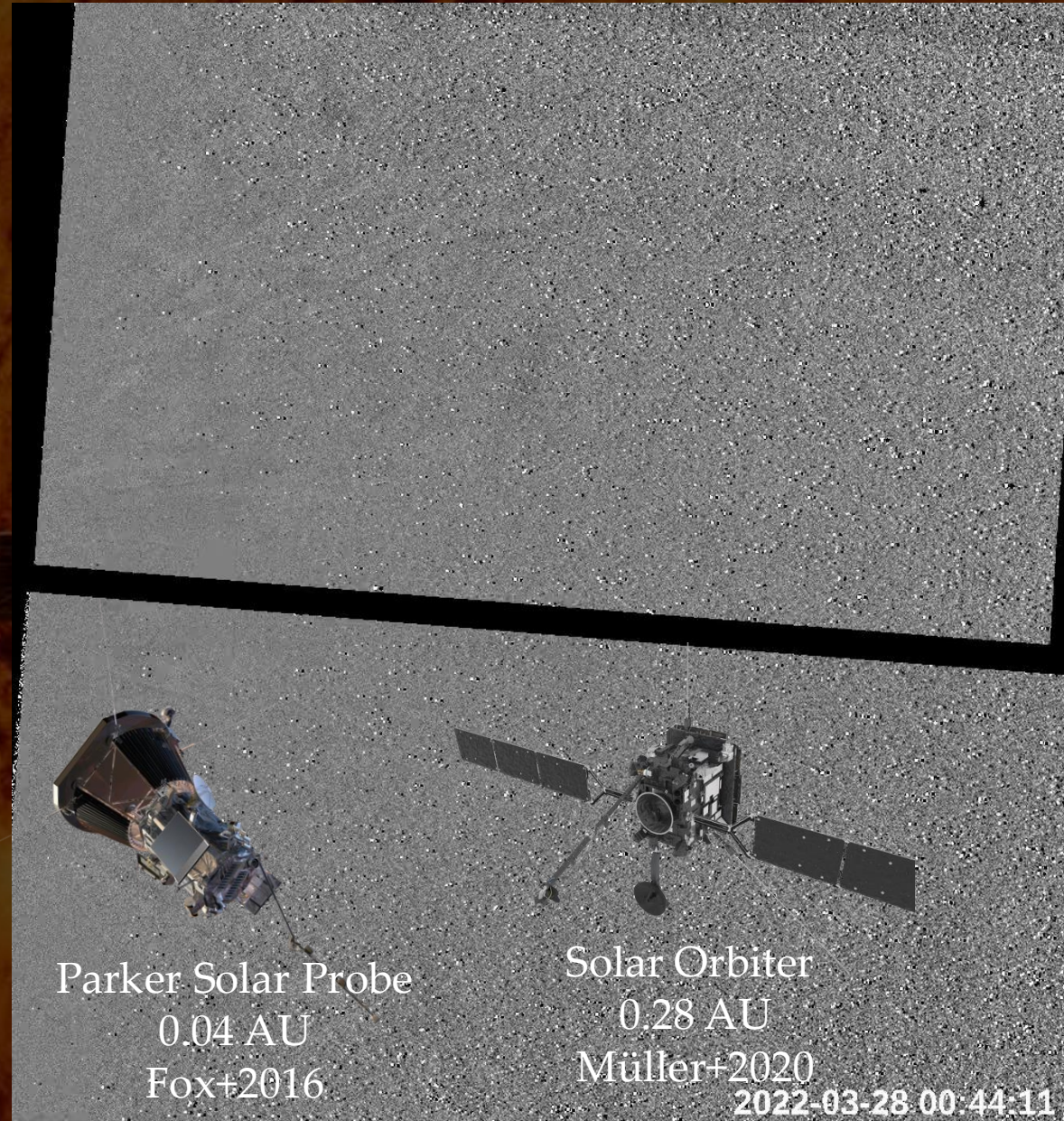
Combination of the two models
(Antiochos+2011)



Baker+2023

Solar Wind Variability

Small-scale variability is lost at large distances from the Sun



Two complementary spacecraft
studying the Sun at close
proximity

Providing solar wind
measurements in the inner
heliosphere coupled with close up
views of the solar atmosphere

Solar wind: Abbo+2016,
Cranmer+2017, Viall+2020

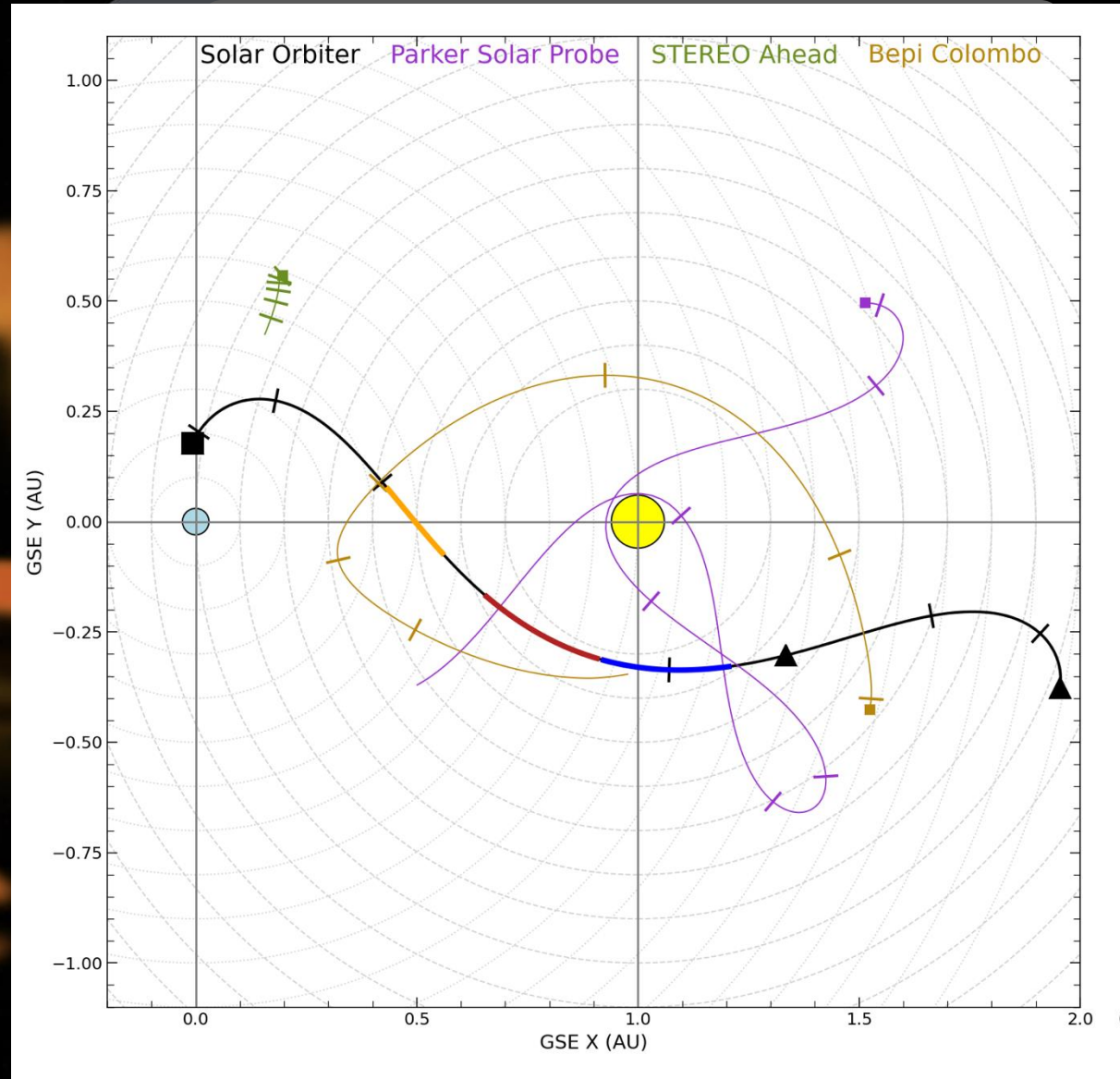
Remote-sensing windows
(RSWs: 3x10 days)

High-latitude
Observations

Top-level Science Goal:
What drives the solar wind and where
does the coronal magnetic field
originate from?

Perihelion
Observations

High-latitude
Observations



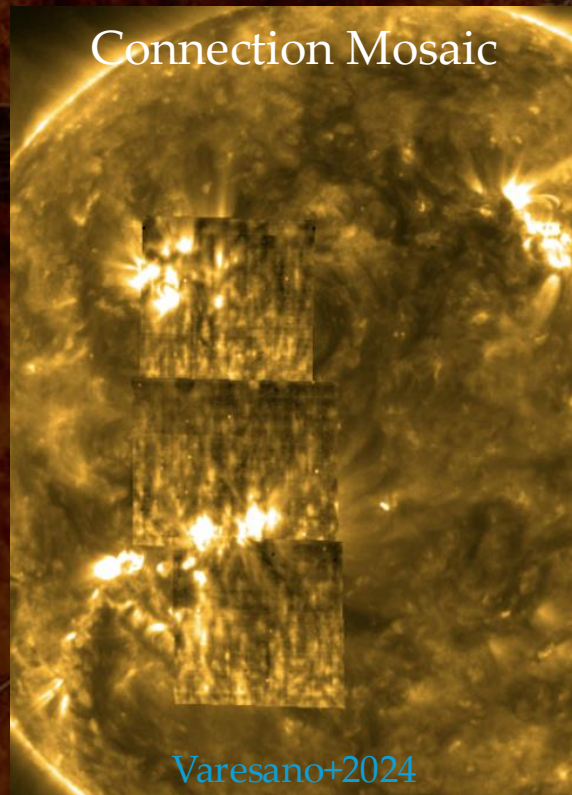
Solar Wind Related SOOPs

L_SMALL_MRES_MCAD_Ballistic-Connection
L_SMALL_MRES_MCAD_Connection-Mosaic
L_SMALL_HRES_HCAD_Fast-Wind
L_SMALL_HRES_HCAD_Slow-Wind-Connection
L_BOTH_MRES_MCAD_Farside-Connection
L_BOTH_HRES_LCAD_CH-Boundary-Expansion
R_SMALL_HRES_HCAD_PDF-Mosaic

<https://www.cosmos.esa.int/web/solar-orbiter/soops-summary>

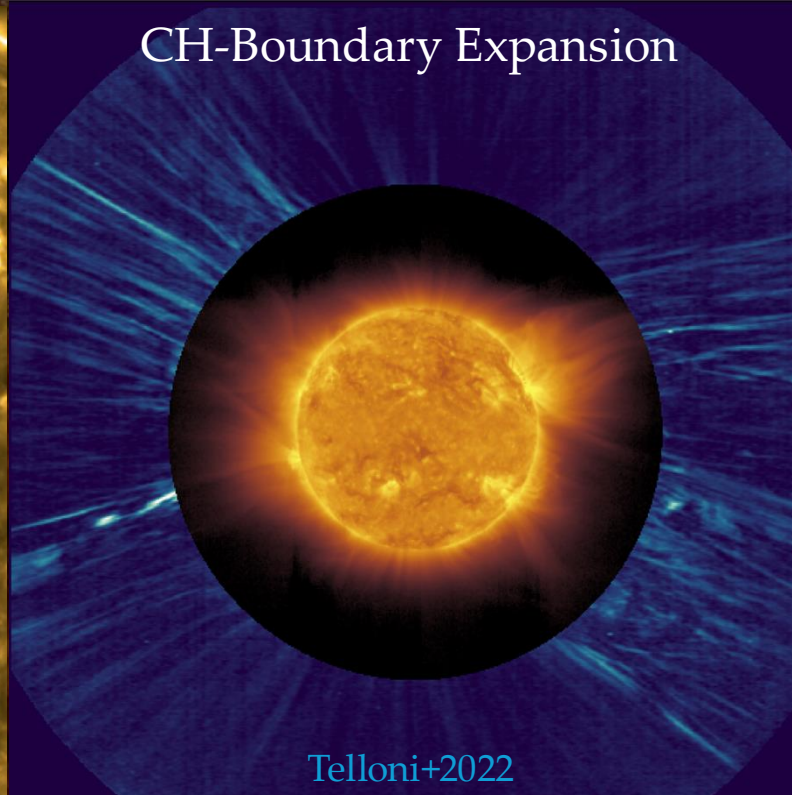
Zouganelis+2020

Connection Mosaic



Varesano+2024

CH-Boundary Expansion



Telloni+2022

Solar Wind Related SOOPs

L_SMALL_MRES_MCAD_Ballistic-Connection

L_SMALL_MRES_MCAD_Connection-Mosaic

L_SMALL_HRES_HCAD_Fast-Wind

L_SMALL_HRES_HCAD_Slow-Wind-Connection

L_BOTH_MRES_MCAD_Farside-Connection

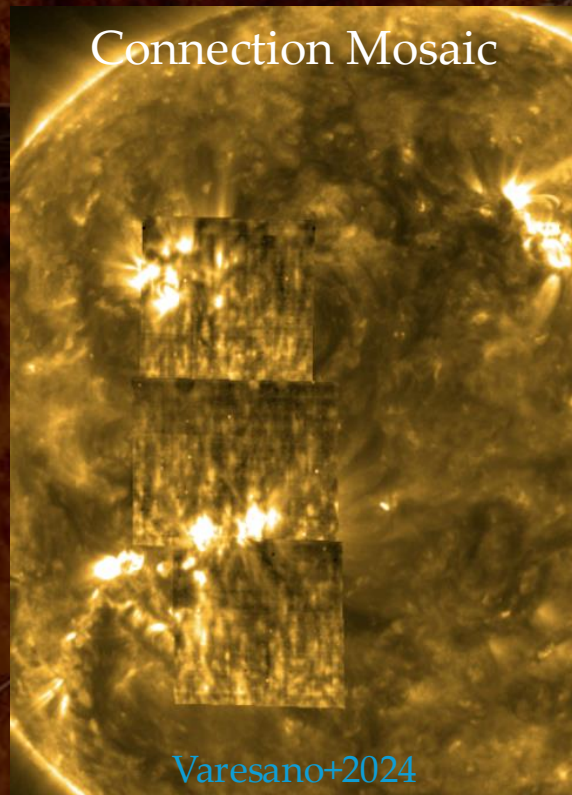
L_BOTH_HRES_LCAD_CH-Boundary-Expansion

R_SMALL_HRES_HCAD_PDF-Mosaic

<https://www.cosmos.esa.int/web/solar-orbiter/soops-summary>

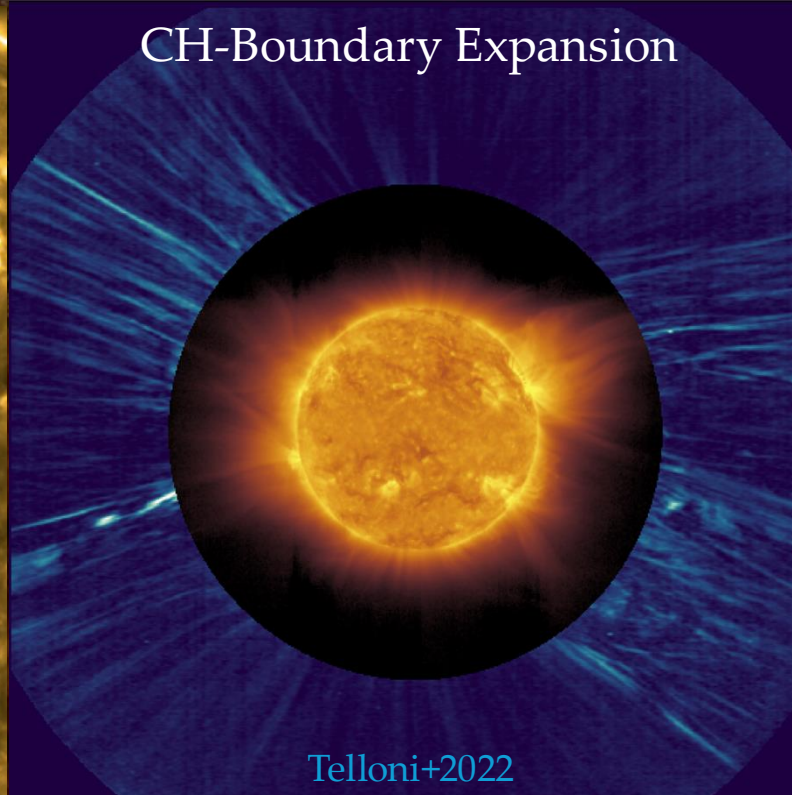
Zouganelis+2020

Connection Mosaic



Varesano+2024

CH-Boundary Expansion



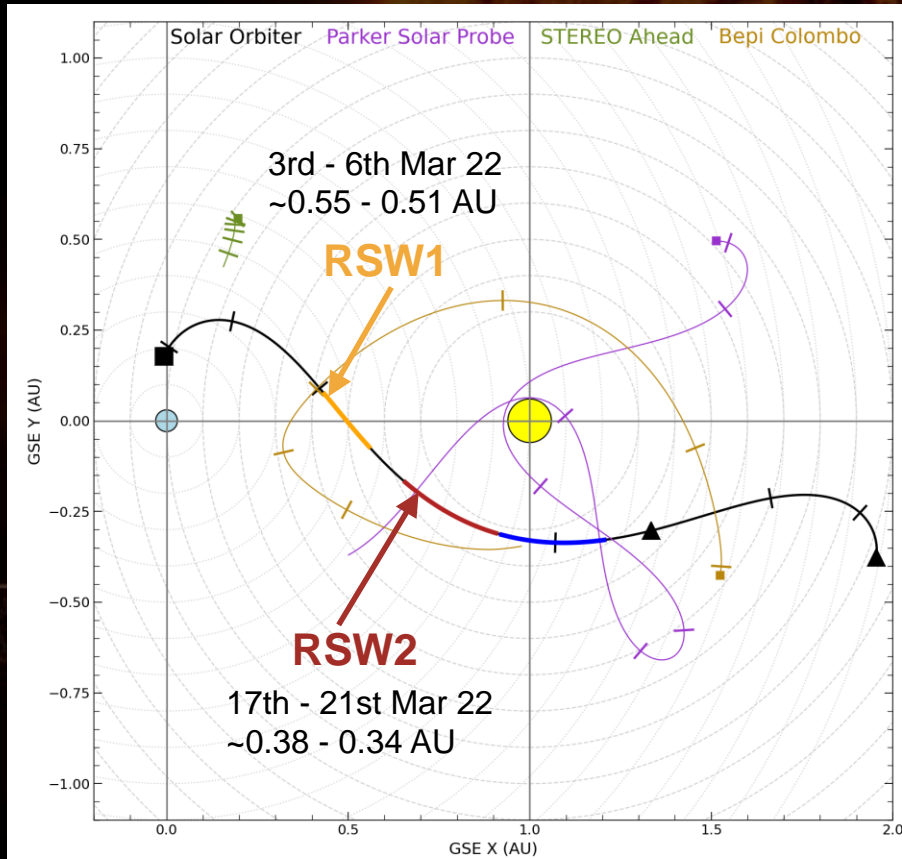
Telloni+2022

Slow Solar Wind Connection Science SOOP

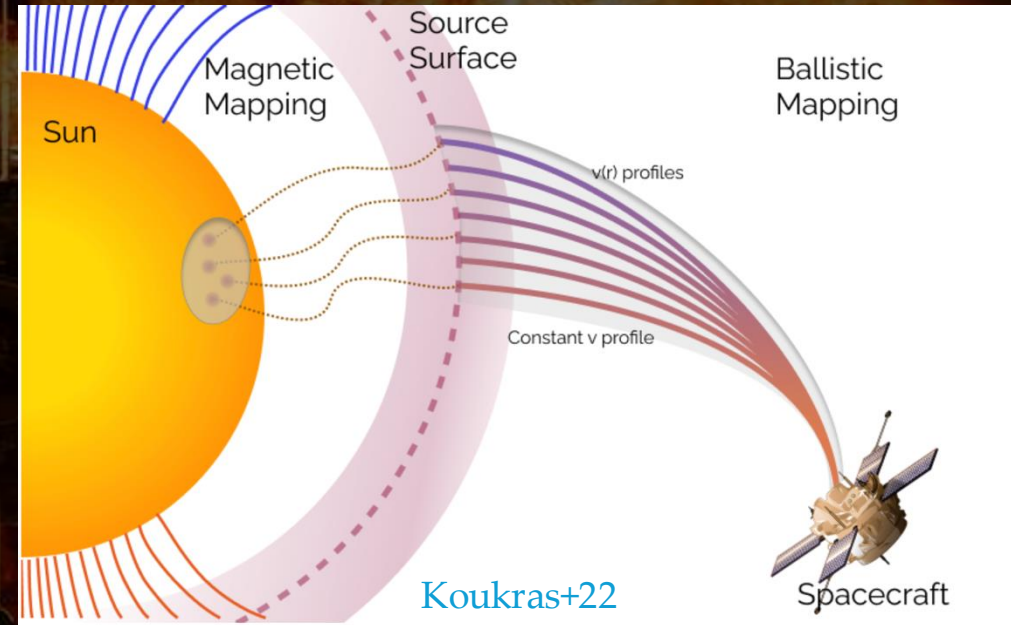
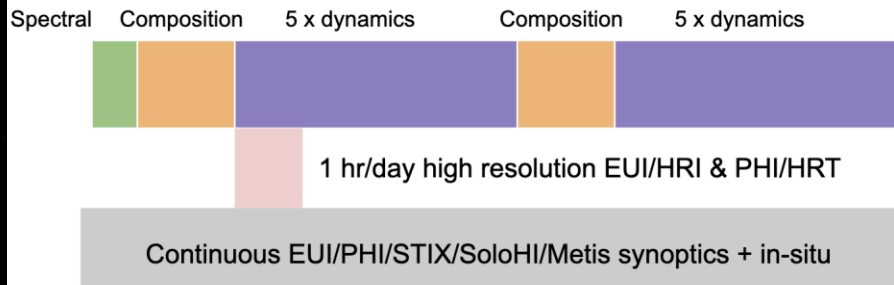
L_SMALL_HRES_HCAD_Slow-Wind-Connection

Science Goal: Slow solar wind release mechanisms at open-closed magnetic field boundaries

Target: Active Region/Coronal Hole Boundaries



SPICE



Depends upon connectivity of spacecraft!

(Rouillard+2020)

<http://connect-tool.irap.omp.eu/>

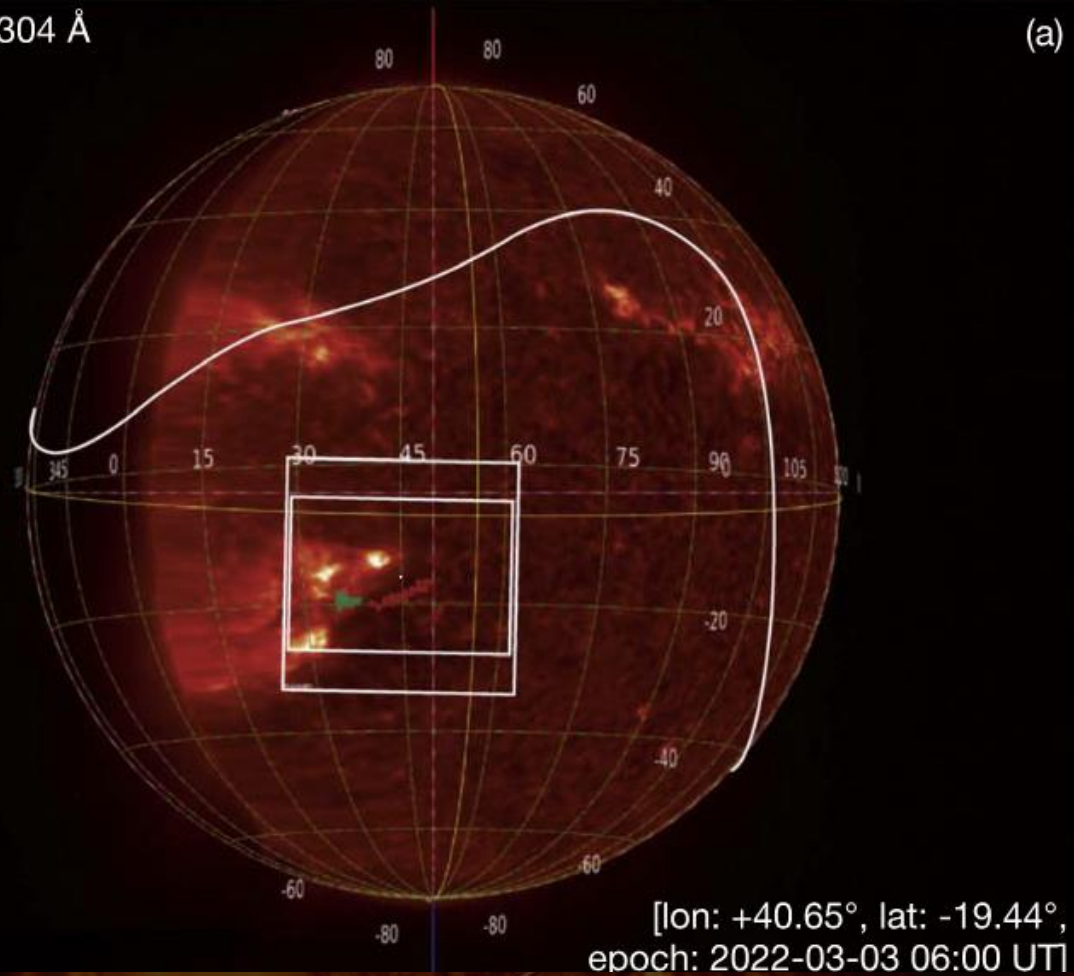
Supporting observations from

Hinode & IRIS

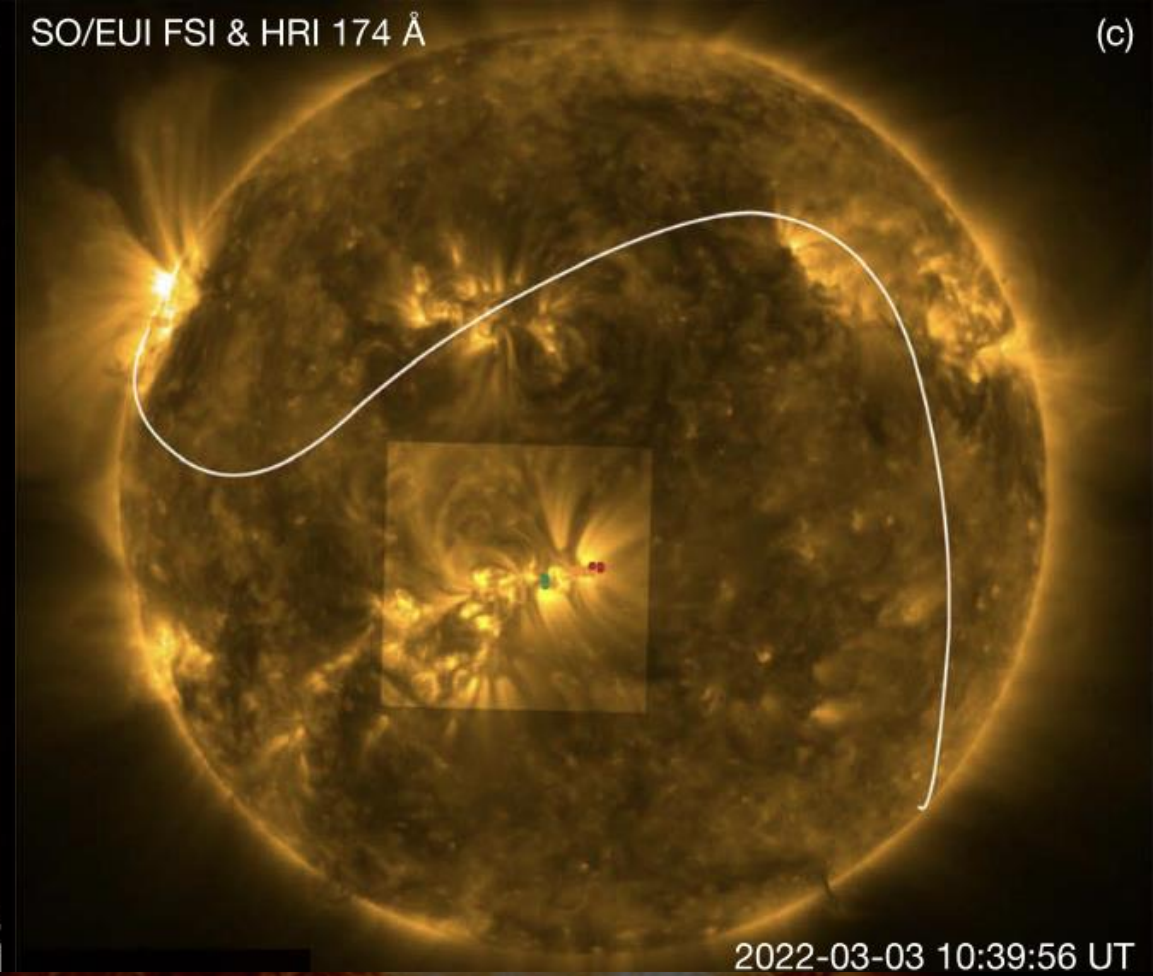
Yardley+2023

Target Selection for RSW1

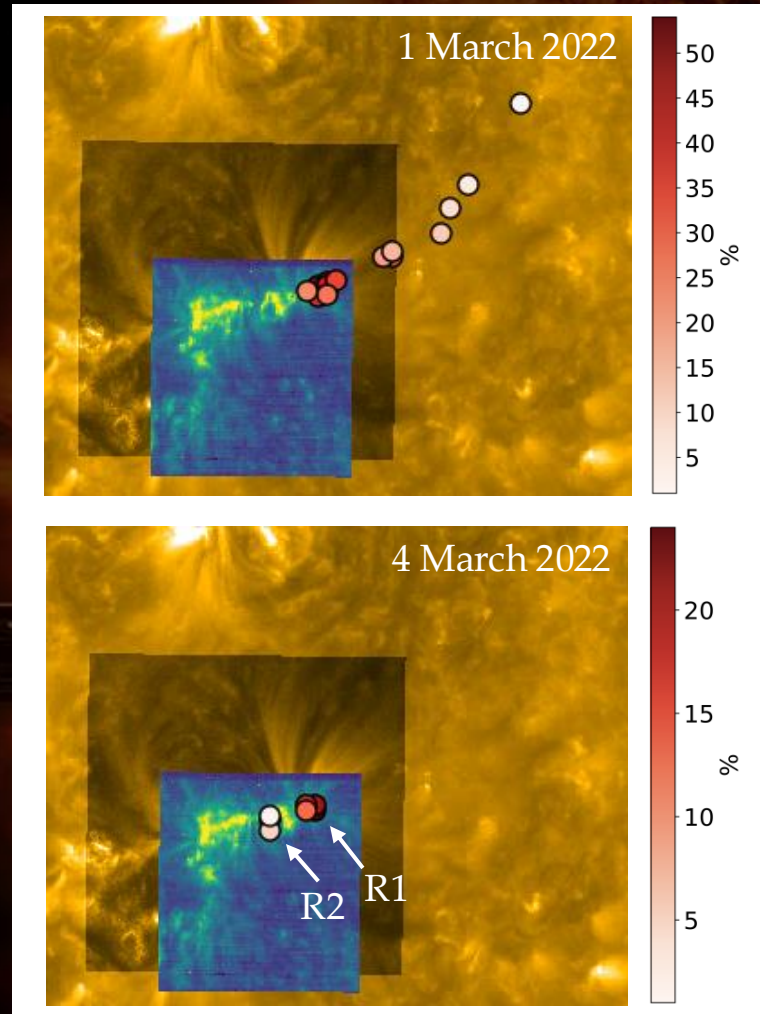
SO/EUI FSI 304 Å



(a) SO/EUI FSI & HRI 174 Å

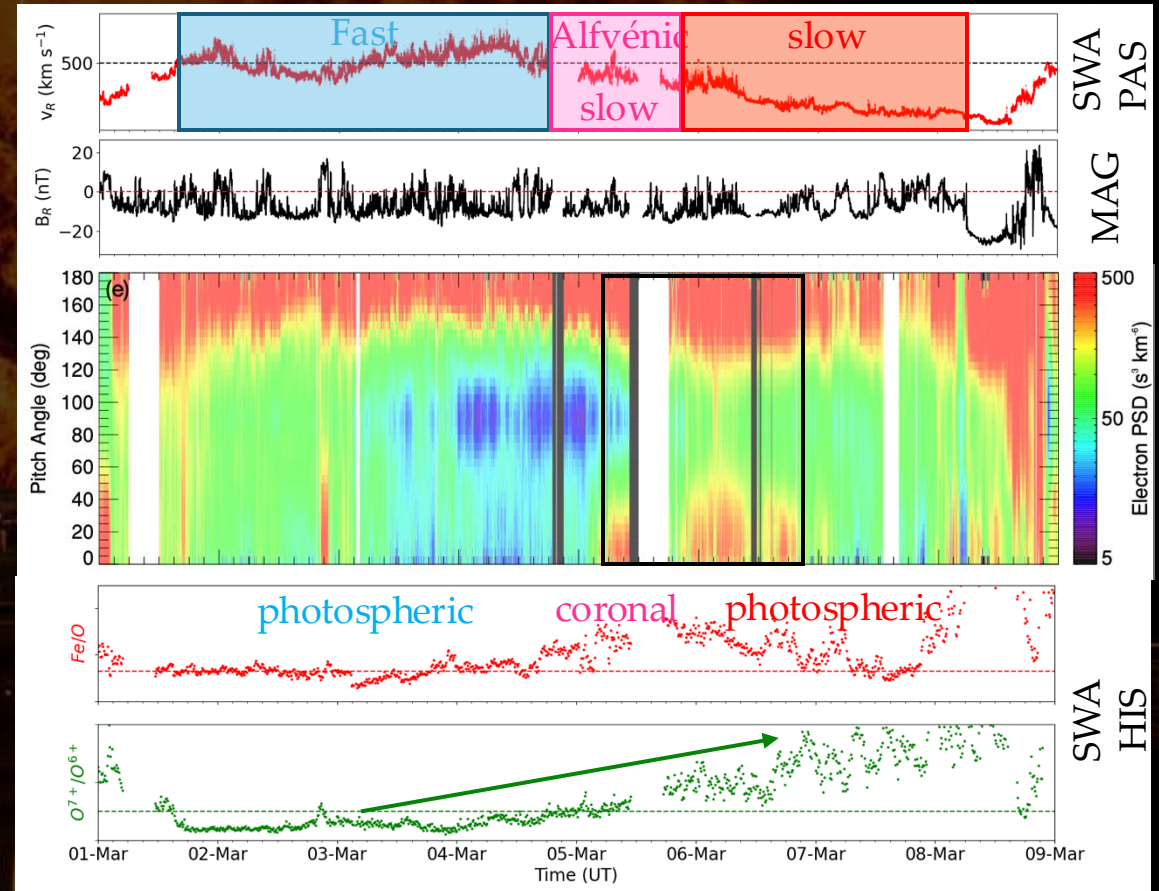
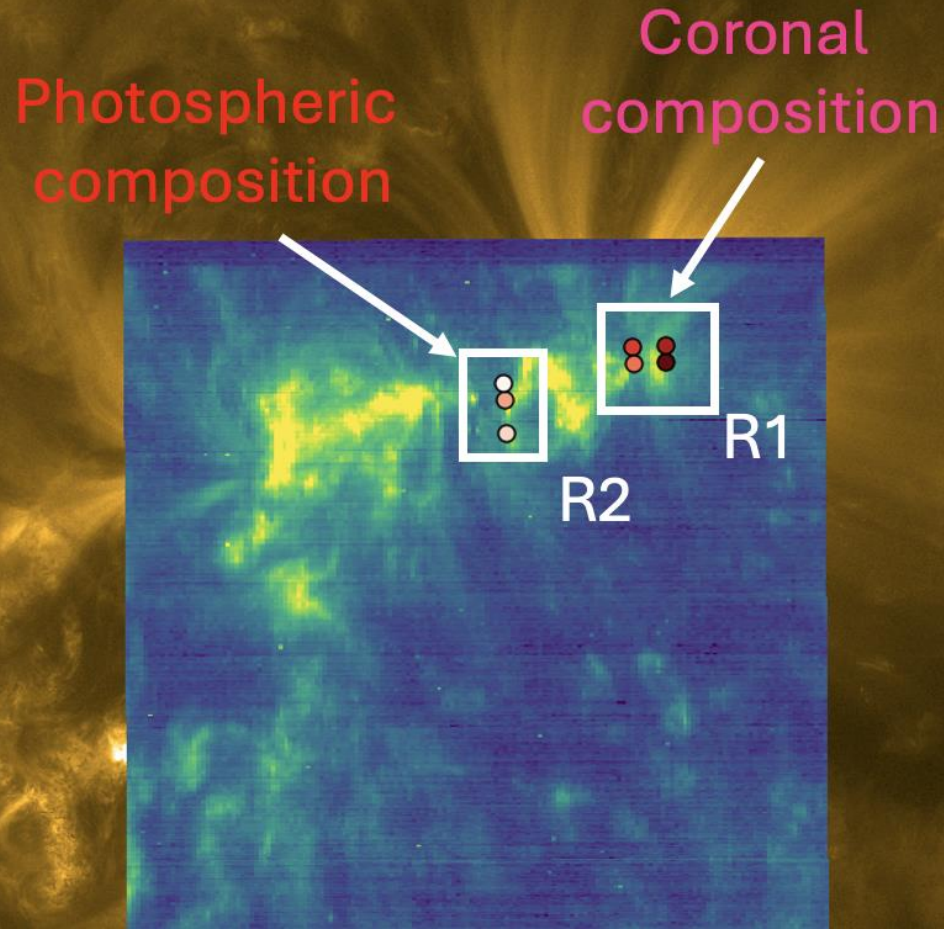


Multi-source connectivity drives solar wind variability



Magnetic connectivity of Solar Orbiter transitions across
the CH-AR complex
Solar wind travel time ~ 2-3 days

Multi-source connectivity drives solar wind variability



Magnetic connectivity of Solar Orbiter transitions across the CH-AR complex
Solar wind travel time ~ 2 -3 days

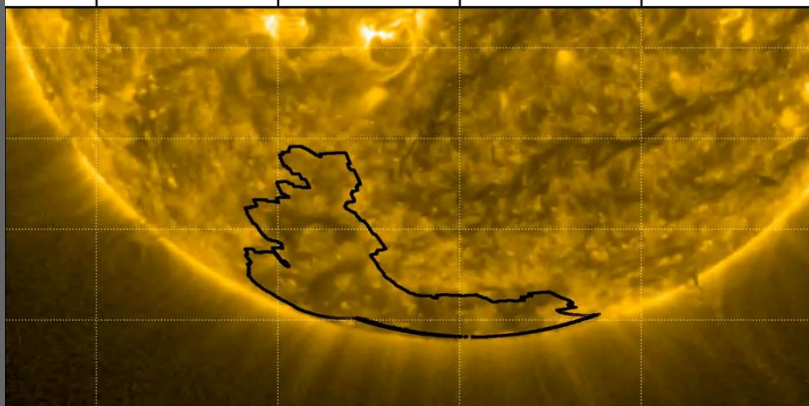
Small-scale variability is driven by the changing connectivity across multiple sources, where the topology also changes due to interchange reconnection at closed-open field boundaries

High-Resolution Observations from other RSWs

RSW2: 17-22 March 2022, RSW7: 30 March - 4 April 2023, RSW9: 21 - 24 April 2023

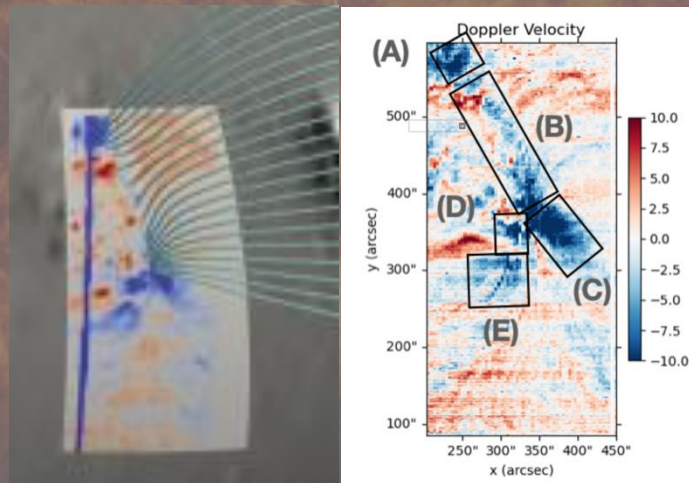
Merging of a CD & polar CH

FSI 174 Å 2022-03-18 00:06:02



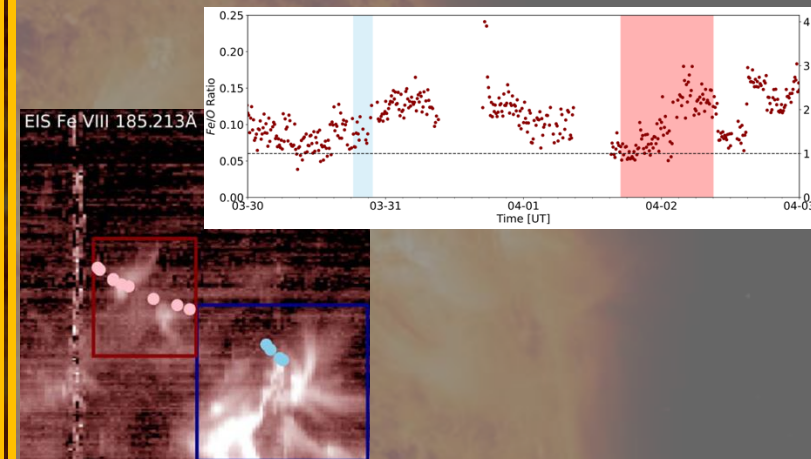
Component reconnection primary driver
Similar upflow profiles after merging
Jets inside CD similar to CH
(Ngampoopun+2023, ApJ, 950, 2, 150)

Observational Evidence of S-Web



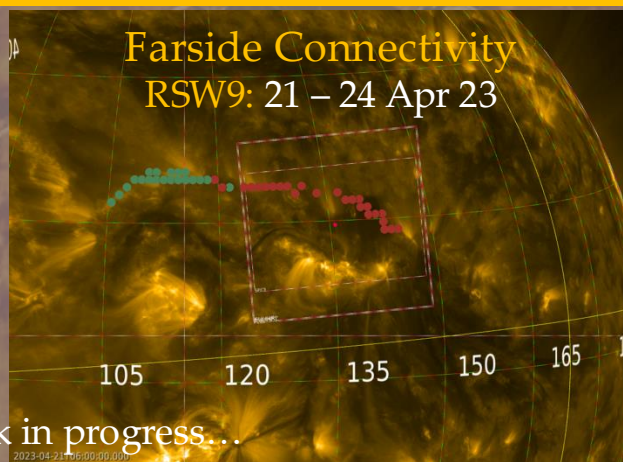
Super-radial expansion of narrow corridor
Interchange reconnection provides at corridor boundaries allows plasma to escape
(Baker+2023, ApJ, 950, 1, 65)

SPICE/EIS abundance diagnostic



Fe/Ne FIP bias diagnostic from combined SPICE/EIS data
Diagnostic useful for **Solar-C/EUVST**
(Brooks+2024, 976, 2, 188, ApJ)

Farside Connectivity RSW9: 21 - 24 Apr 23



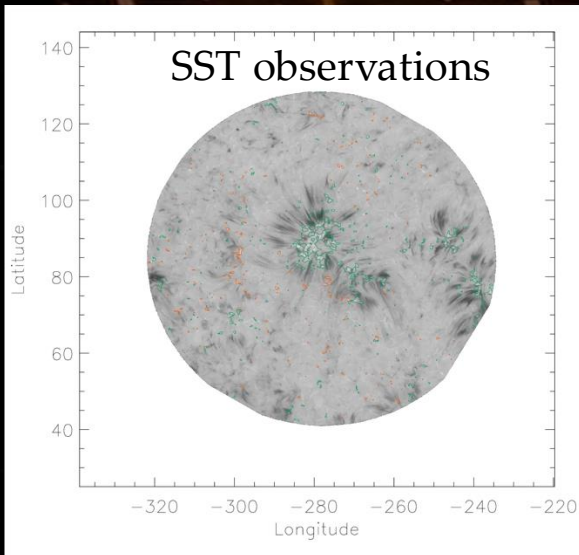
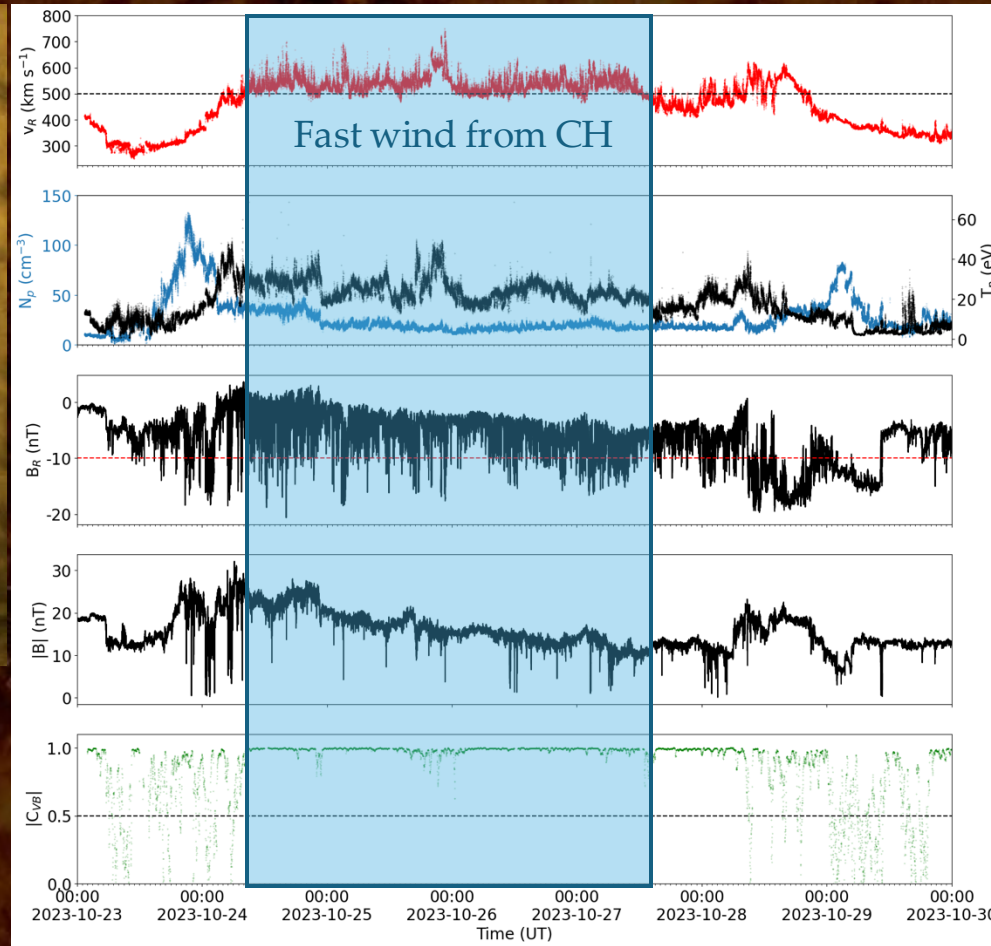
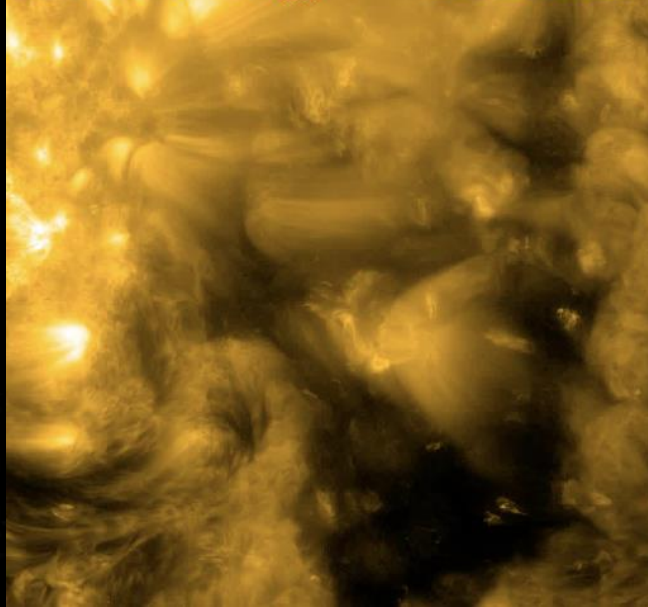
Work in progress...

Recent Fast Wind SOOP Observations

L_SMALL_HRES_HCAD_Fast-Wind

October 2023

EUI/HRI 174 Å 24 Oct 2023



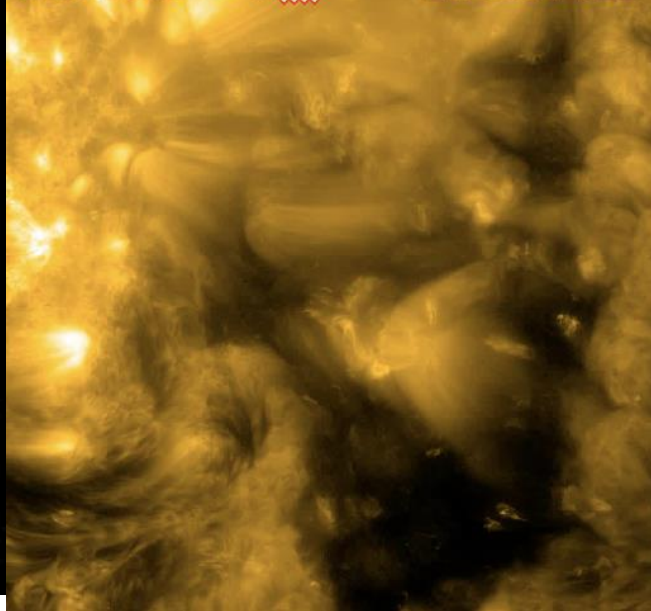
Coordinators: Alex James, Luca Franci, Eric Buchlin, Slimane Mzerguat

Recent Fast Wind SOOP Observations

L_SMALL_HRES_HCAD_Fast-Wind

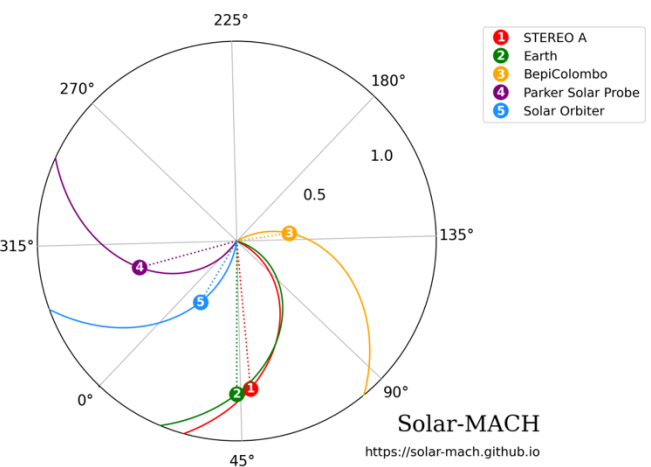
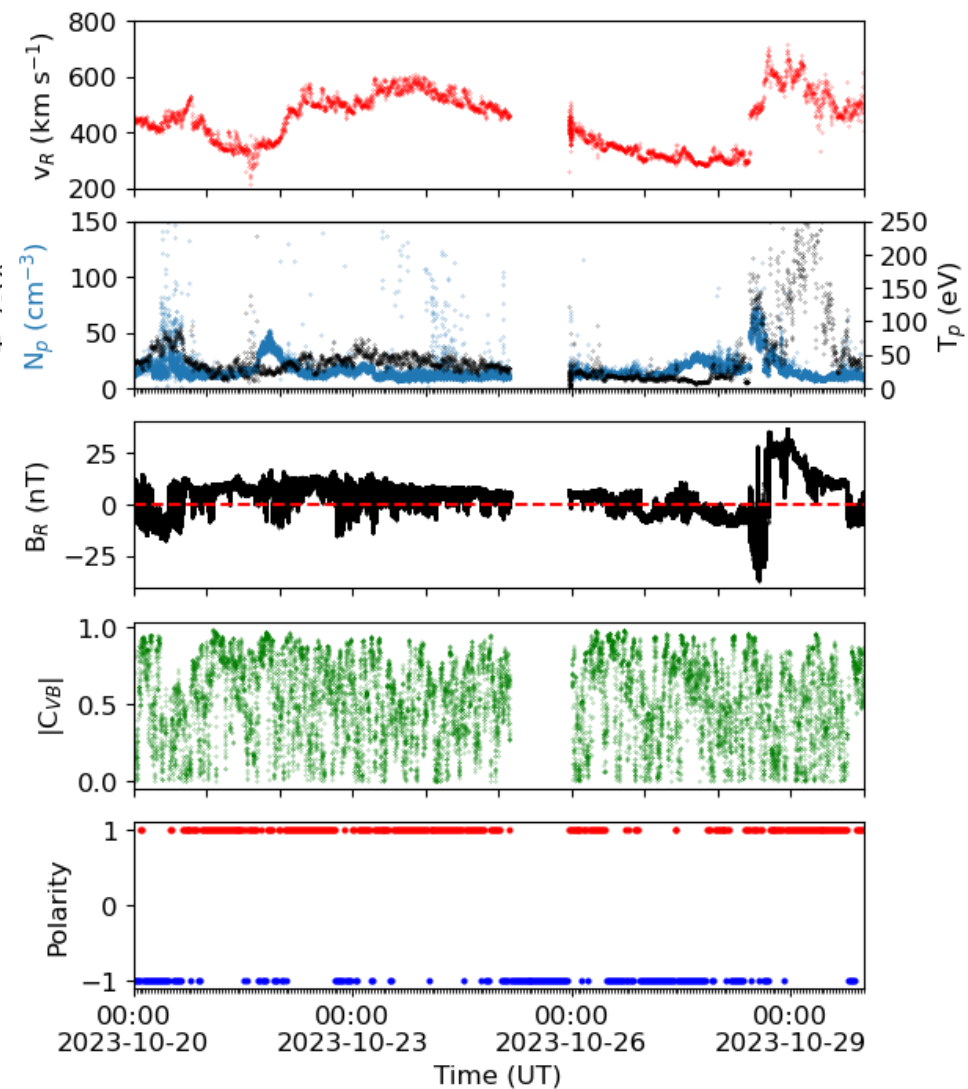
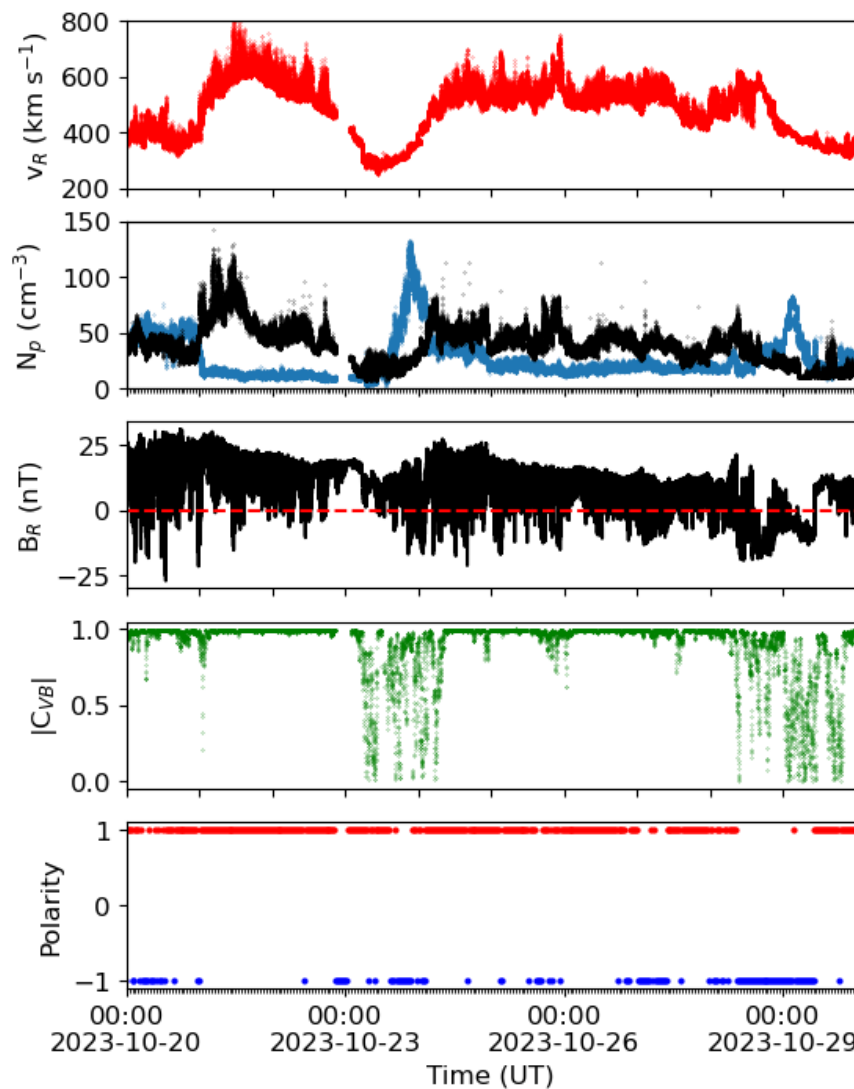
October 2023

EUI/HRI 174 Å 24 Oct 2023



Solar Orbiter

Parker Solar Probe

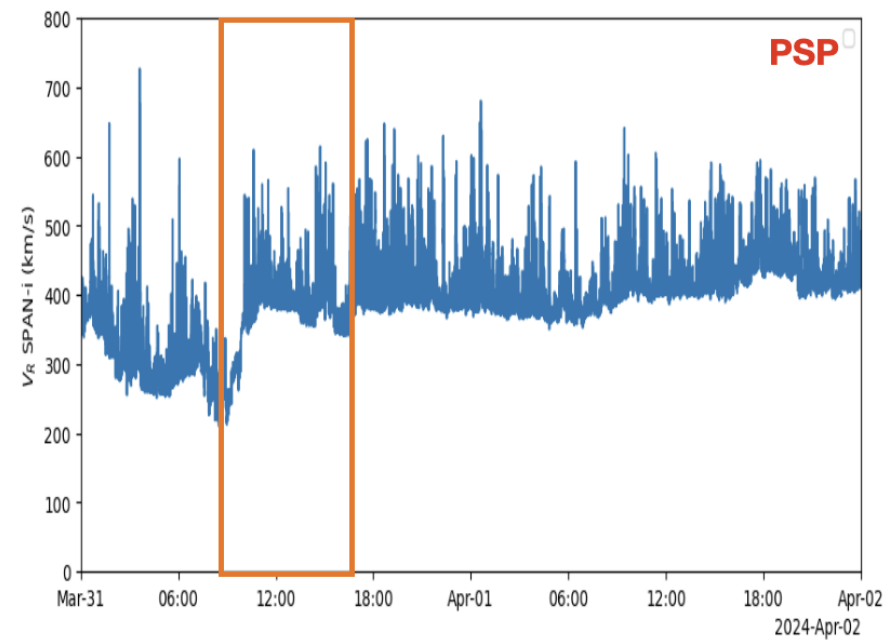
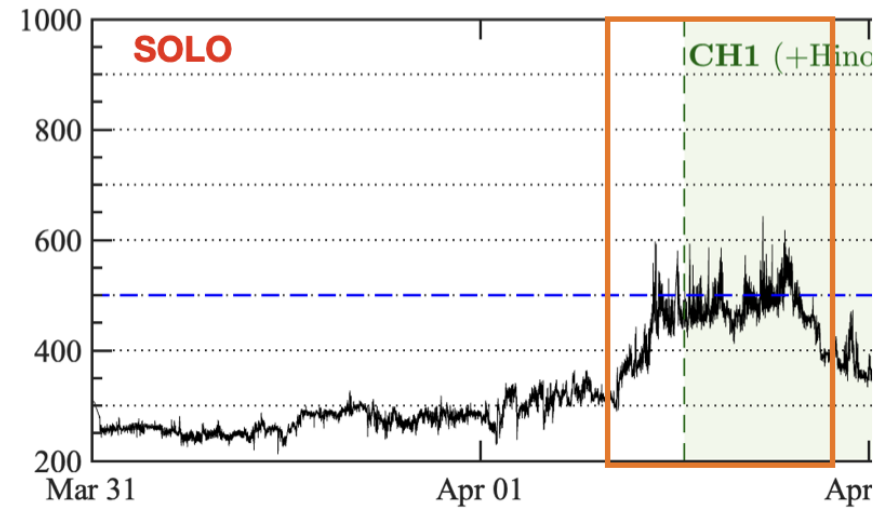
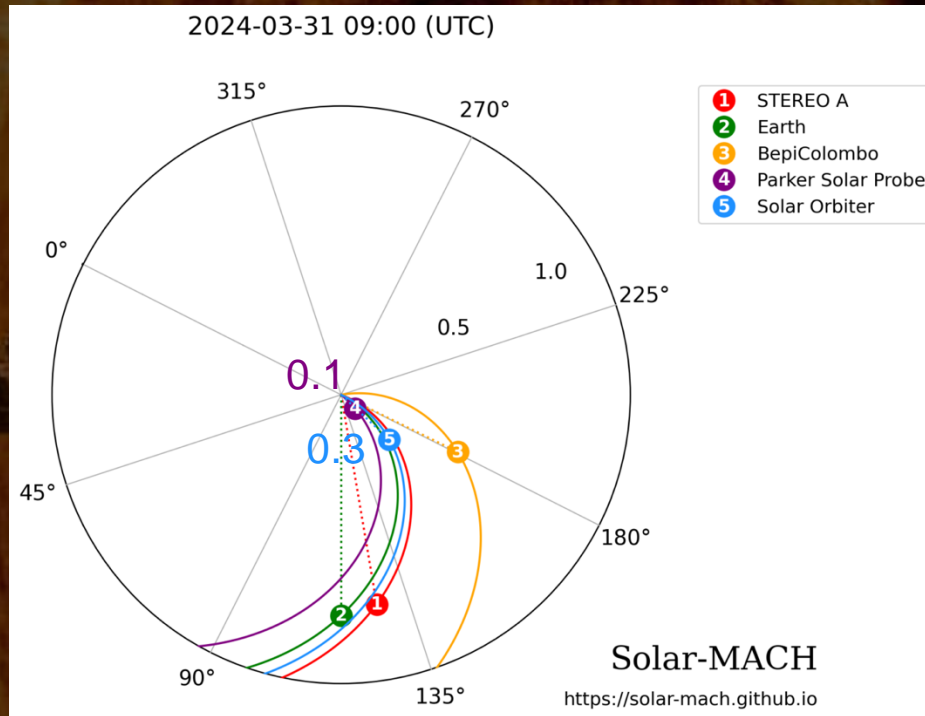


Coordinators: Alex James, Luca Franci, Eric Buchlin, Slimane Mzerguat

Recent Fast Wind SOOP Observations

L_SMALL_HRES_HCAD_Fast-Wind

April 2024



Coordinators: Alex James, Luca Franci, Eric Buchlin, Slimane Mzerguat



Solar Wind Connectivity

with Solar Orbiter

Summary

Importance of Solar Orbiter observations & measurements at close distances to the Sun in order to determine the source of solar wind variability

Ongoing analysis of SO (& PSP observations)

SO to observe the poles ($>17^\circ$ in Mar 2025)

Slow Solar Wind Overview
(Yardley et al. 2023, *ApJS*, 267, 11)

Multi-source Connectivity Drives Solar Wind Variability
(Yardley et al. 2024, *Nat Astr.*, 8, 953)

Merging of a Coronal Dimming with a Coronal Hole
(Ngampoopun et al. 2023, *ApJ*, 950, 2, 150)

Observational Evidence of the S-web Slow Solar Wind
(Baker et al. 2023, *ApJ*, 950, 1, 65)

Elemental Abundance Diagnostic for SPICE/EIS
(Brooks et al. 2024, 976, 2, 188, *ApJ*)

