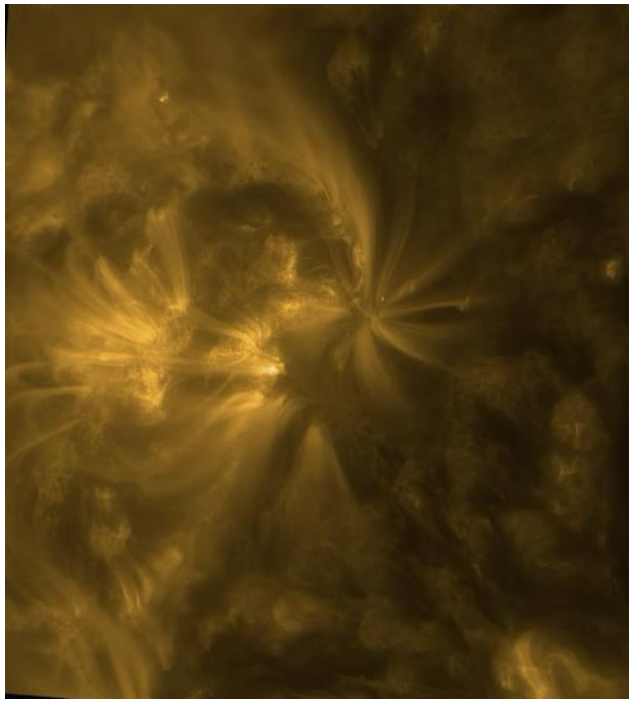
RS Burst SOOP

Krzysztof Barczynski, Daye Lim, Luis Bellot Rubio, Sebastian Castellanos Durán, Sudip Mandal, Yingjie Zhu

Overview of RS Burst SOOP

Aim based on Solar Orbiter Science Activity Plan (Zouganelis et al. 2020):

- To perform coordinated high-resolution, high-cadence observations using EUI, PHI, and SPICE
- To capture rapid solar dynamics at the highest spatial resolution over short period of time (order ten min.)
- To discover new small-scale physical phenomena, especially those evolving on timescales shorter than 10 s.
- To compare high-cadence dynamics across different solar regions
- To investigate coronal density fluctuations at high-cadence (1–20 s)



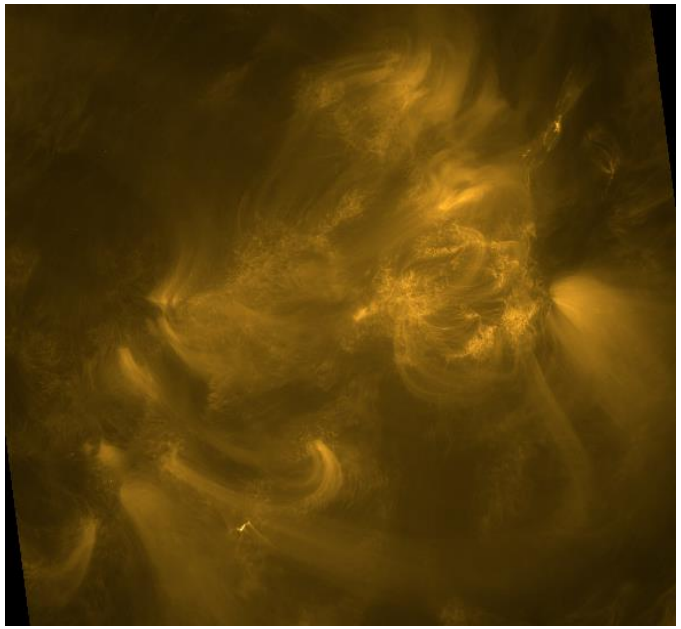
Observations:

- AR observations
- QS observations
- polar region observation
- border of AR observations

Overview of RS Burst SOOP

Start Date	End Date	LTP	Target	SOOP Coordinators	Scientific Outcome
2022-10-12 04:17	2022-10-12 07:17	9	QS	Hardi Peter	Lim et al. 2024, A&A, 689, A16 (oscillation study); Narang et al. 2025, A&A, 699, A138 (campfire study); Lim et al. 2025, A&A, 698, A65 (oscillation study)
2022-10-13 11:55	2022-10-13 15:47	9	AR	Hardi Peter	Lim et al. 2024, A&A, 689, A16 (oscillation study)
2023-03-29 11:10	2023-03-29 19:40	11	AR	Hardi Peter, Susanna Parenti	Lim et al. 2024, A&A, 689, A16 (oscillation study); McKevitt et al. 2026 ApJ in press
2023-04-07 03:20	2023-04-07 06:50	11	AR	Hardi Peter, S. Castellanos Durán	Lim et al. 2024, A&A, 689, A16 (oscillation study); Nóbrega-Siverio et al. 2025, A&A, 702, A188 (jet study); Li et al. 2025, A&A 702, A201
2023-04-10 20:10	2023-04-10 23:20	11	QS	Hardi Peter, S. Castellanos Durán	Lim et al. 2024, A&A, 689, A16 (oscillation study)
2023-10-06 08:20	2023-10-06 12:40	13	QS	Sudip Mandal, Azaymi Siu Tapia, Chris Nelson, Laura Hayes, Hardi Peter	Narang et al. 2025, A&A, 699, A138 (campfire study); Lim et al. 2025, A&A, 698, A65 (oscillation study)
2023-10-10 11:30	2023-10-10 15:50	13	AR	Sudip Mandal, Azaymi Siu Tapia, Chris Nelson, Laura Hayes, Hardi Peter	
2024-04-03 20:30	2024-04-03 23:30	15	AR	Dan Ryan, Azaymi Siu Tapia	
2024-10-19 19:04	2024-10-19 19:32	17	Border of AR	Daye Lim, Krzysztof Barczynski	Lim et al. 2025, A&A, 704, A58 (campfire and oscillation study)
2025-03-21 09:30	2025-03-21 15:30	19	Polar Region	Luis Bellot Rubio	Chitta et al. 2025, ApJL, 993, L45 (polar supergranulation study)
2025-04-01 19:00	2025-04-01 20:00	19	Border of AR	Krzysztof Barczynski, Nils Janitzek	
2025-09-23 19:00	2025-09-23 20:00	21	Border of AR	Krzysztof Barczynski, Nils Janitzek	
2026-02-12 03:00	2026-02-12 04:00	22	Border of AR	Krzysztof Barczynski, Muriel Stiefel, Yingjie Zhu	

RS Burst SOOPs –AR



Observation time (AR)

Observation time

- LTP 9 2022-10-13 11:55 - 2022-10-13 15:47
- LTP 11 2023-03-29 11:10 - 2023-03-29 19:40
- LTP 11 2023-04-07 03:20 - 2023-04-07 06:50
- LTP 13 2023-10-10 11:30 - 2023-10-10 15:50
- LTP 15 2024-04-03 20:30 - 2024-04-03 23:30

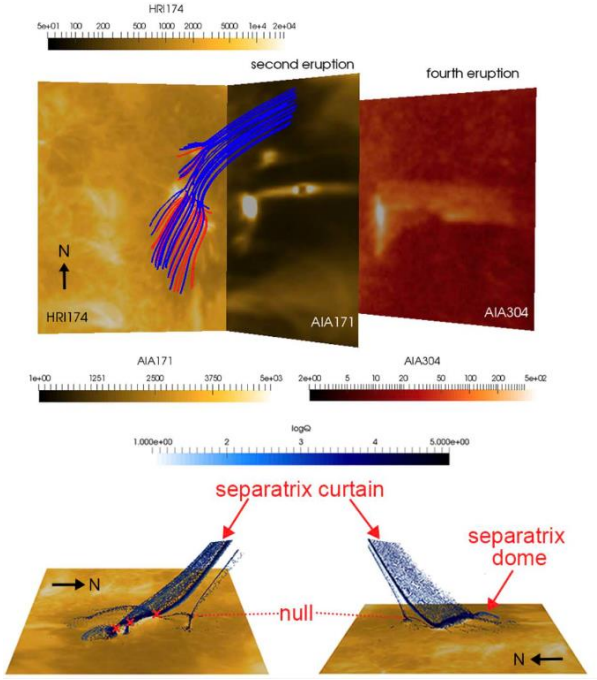
Instruments

- Solar Orbiter: EUI, SPICE, PHI
- IRIS: SJI, raster
- Hinode: XRT, EIS

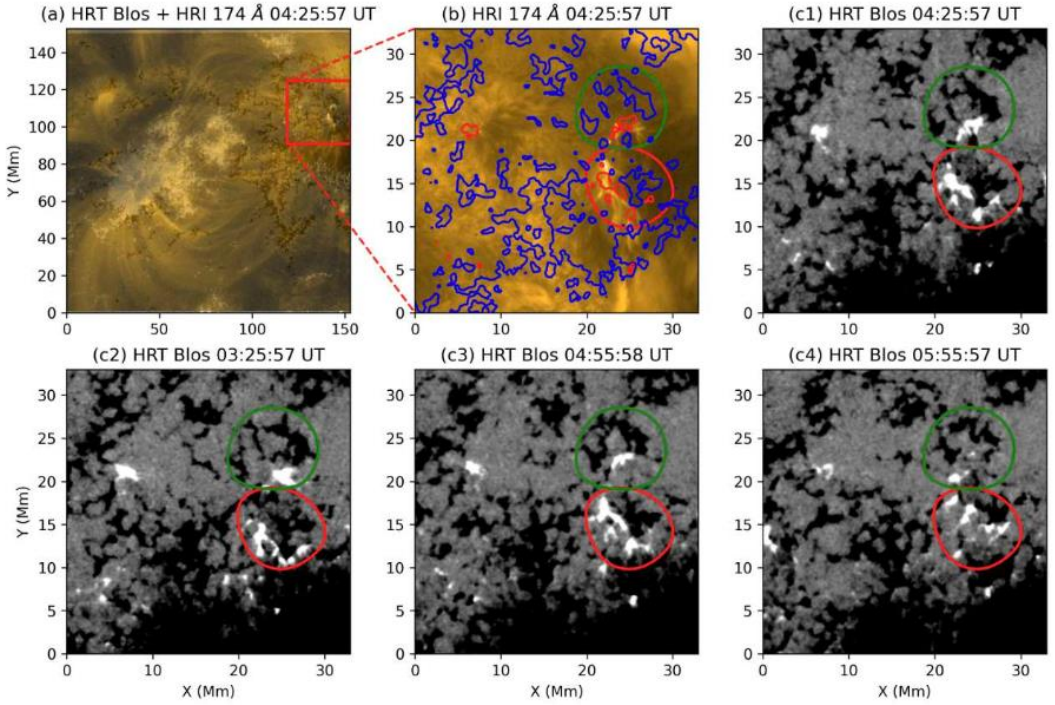
Scientific goal of the SOOP (AR)

- observation structures in an active region

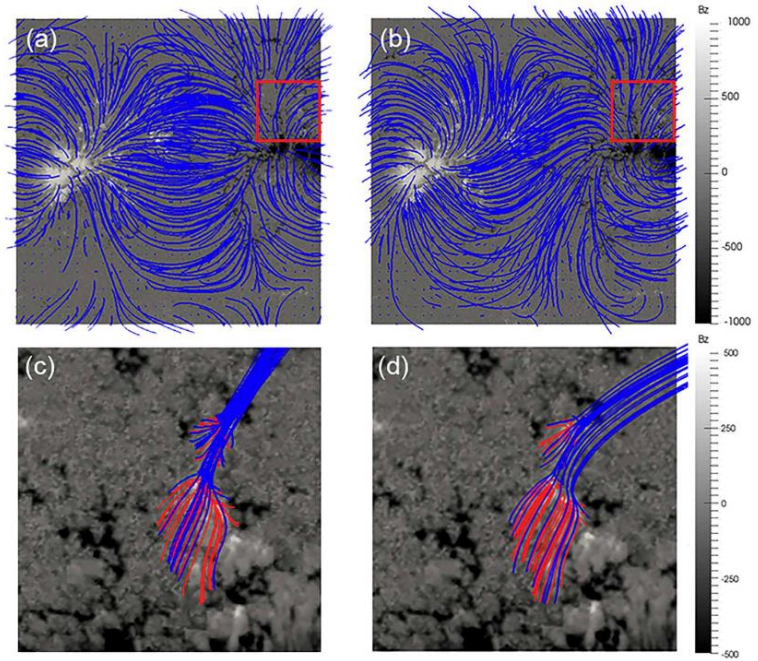
3D structure of jets



Flux cancellation derived with PHI



Extrapolations using PHI



Li et al. 2025 (A&A) 702 , A201

Difference between runs (AR)

Related to setup

- Observations from different vantage points (2 – 109 deg)
- Different setup coordinated observations
- Distance to Sun (0.29 – 0.39 AU)
- EUI –cadence: between 3 and 10 sec

Related to AR physics

- Active region age, size, location at the solar disk, flaring activity

Scientific outcom(AR)

- Published

A&A, 702, A201 (2025)
https://doi.org/10.1051/0004-6361/202555972

Astronomy & Astrophysics

3D structures of the base of small-scale recurrent jets revealed by Solar Orbiter

Xiaohong Li*, Sami K. Solanki, Thomas Wiegelmann, Gherardo Valori, Daniele Calchetti, Johann Hirzberger, Juan Sebastián Castellanos Durán, Joachim Woch, Achim Gandorfer, and the Solar Orbiter team

Max Planck Institute for Solar System Research, Göttingen D-37077, Germany

Received 16 June 2025 / Accepted 6 September 2025

ABSTRACT

Context. Solar jets, characterized by small-scale plasma ejections along open magnetic field lines or the legs of large-scale coronal loops, play a crucial role in the dynamics of the solar atmosphere. They are often associated with other solar active phenomena, including campfires, filament eruptions, coronal bright points, flares, and coronal mass ejections.
Aims. Although spectral and extreme-ultraviolet images have been widely used to analyze the formation and evolution of jets, the detailed 3D structure at the base of the jet has not been studied in detail, due to the limitations in the spatial resolution of observations.
Methods. Solar Orbiter enables us to investigate the structure of solar jets with much higher spatial and temporal resolutions and from a different angle than from Earth. By combining observations made by instruments on board Solar Orbiter with data from the Solar Dynamics Observatory, we analyzed recurrent solar jets originating in a mixed-polarity region near an active region. Additionally, we employed potential field and magneto-hydrostatic extrapolation techniques to determine the magnetic field topology associated with the jets.
Results. The jets display dynamic, multistrand outflows emanating from compact bright kernels above the magnetic inversion line, with apparent speeds exceeding 100 km s^{-1}. Magnetic field evolution reveals continuous flux cancellation at the jet footpoints. Throughout the sequence, base flows are confined within quasi-separatrix layers, with the highest velocities and temperatures located near coronal null points. Over four eruptions, the magnetic topology evolves from a simple fan–spine configuration with a single null to a more complex dome-shaped base containing multiple nulls with a separatrix curtain, accompanied by a morphological transition from a narrow, well-collimated spire to broader, fragmented outflows.
Conclusions. These results provide the first direct observational evidence that dynamic changes in null-point geometry modulate jet morphology and energetics via successive reconnection episodes.

Key words. Sun: activity – Sun: atmosphere – Sun: corona – Sun: magnetic fields – Sun: photosphere

- Under revision in ApJ.

The non-eruptive reconfiguration of a quiescent filament after a nearby active region emergence

James McKevitt[1,2] Louise Harra[3,4] Gherardo Valori[5] Deborah Baker[1] Nils Janitzek[4,3] Stephanie Yardley[6,1,7] Sarah Matthews[1] Hamish Reid[1] Alex James[1] Muriel Stiefel[8,4] David H. Brooks[9,1] Ryan Dewey[10] Jim M. Raines[10] Susan T. Lepri[10] Liang Zhao[10] and Juan Sebastián Castellanos Durán[5]

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[2] *University of Vienna, Institute of Astrophysics, Türkenschanzstrasse 17, Vienna A-1180, Austria*
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[7] *Donostia International Physics Center (DIPC), Paseo Manuel de Lardizabal 4, 20018 San Sebastián, Spain*
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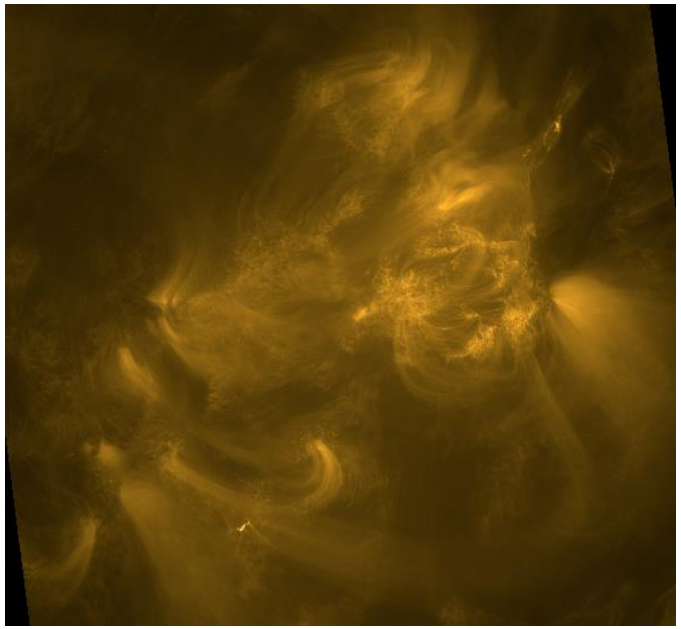
ABSTRACT

The unpredictability of solar filament eruptions presents major challenges for forecasting space weather, as such eruptions frequently drive coronal mass ejections (CMEs) that impact the heliosphere. While nearby flux emergence is often linked to their destabilisation, the specific characteristics of both the emerging flux and the filament that determine whether an eruption occurs remain unclear. We report observations of a quiescent filament that did not erupt following the nearby emergence of active region NOAA 13270 and a subsequent C-class flare in April 2023. Our analysis combines multi-viewpoint extreme ultraviolet (EUV) imaging and X-ray imaging with EUV spectroscopy, radio imaging and measurements of, and extrapolations from, the photospheric magnetic field. We identify the formation of a coronal null point and fan-spine topology at the interface between the active region and filament which exhibited persistent slow reconnection, indicated by chromospheric brightenings, persistent radio emission, and plasma upflows. Our results indicate that ongoing reconnection and jets can relieve magnetic stress and enable filament stability, even when under strong perturbation. We suggest that the orientation of emerging flux relative to the ambient field is a critical parameter in filament evolution, and provide observational constraints for models of filament stability and eruption.

Under revision in ApJ after first referee report

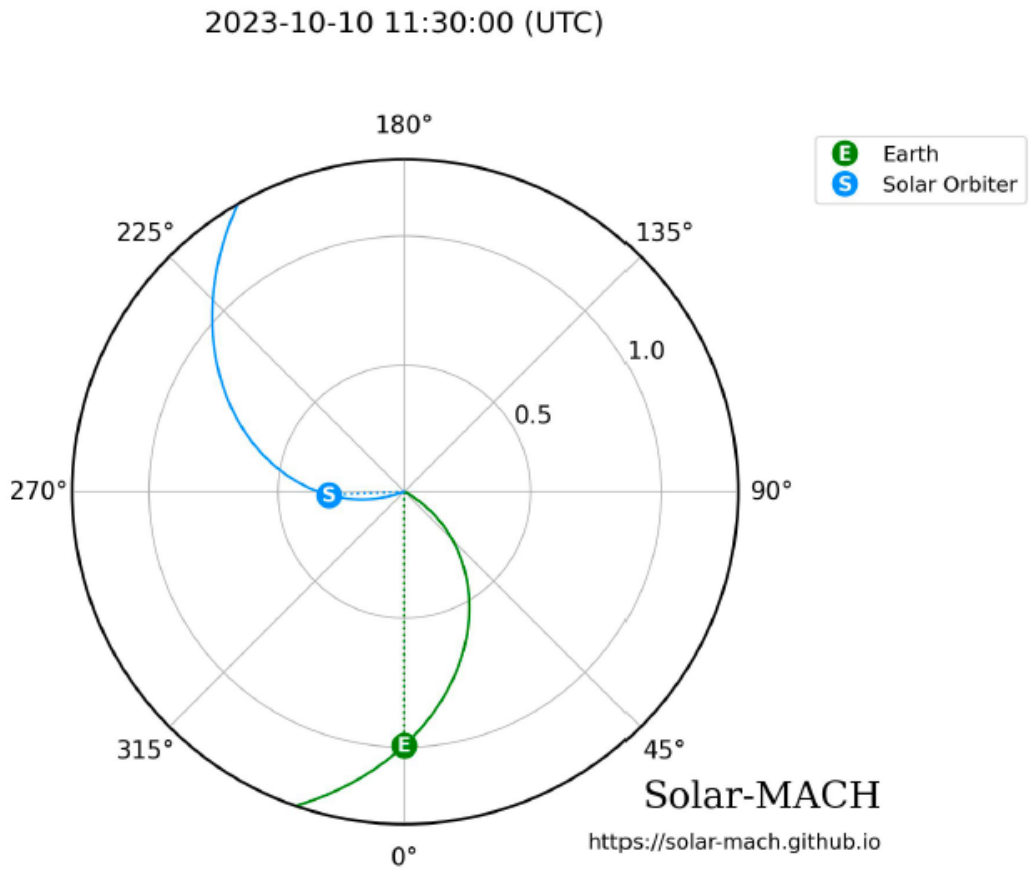
Zoom on one AR observation



RS burst- AR Observation on October 10, 2023
Coordinators: S. Mandal, C. J. Nelson, A. Siu, H. Peter

Science goal:

Small-scale brightening in AR core or loop footpoints;
Flux cancellation events similar to Sunrise observations;



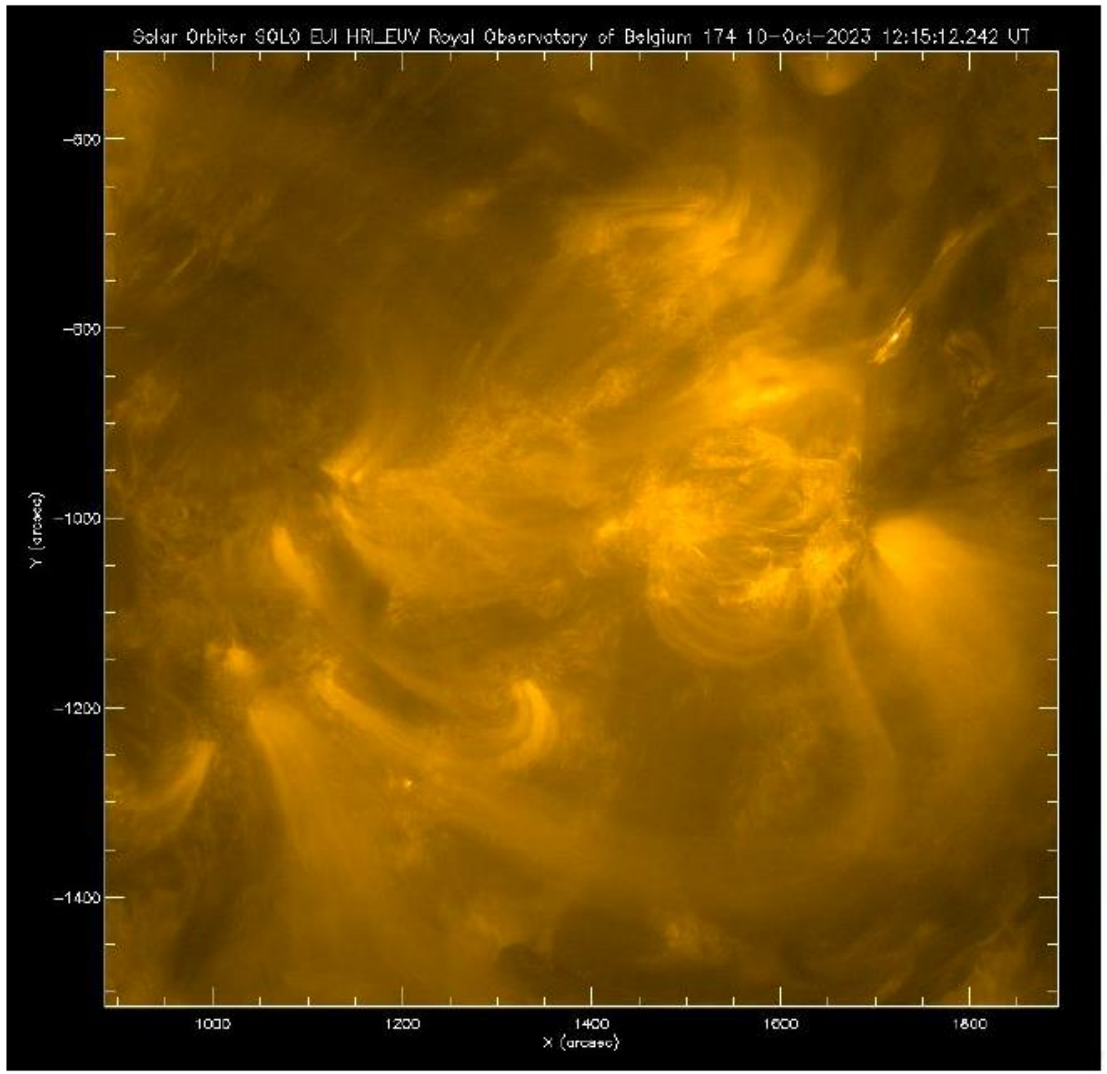
EUI (11:30 to 15:50):
11:30:00-13:10:00 → 10 s
13:10:00-14:10:00 → 3 s
14:10:00-15:50:00 → 10 s

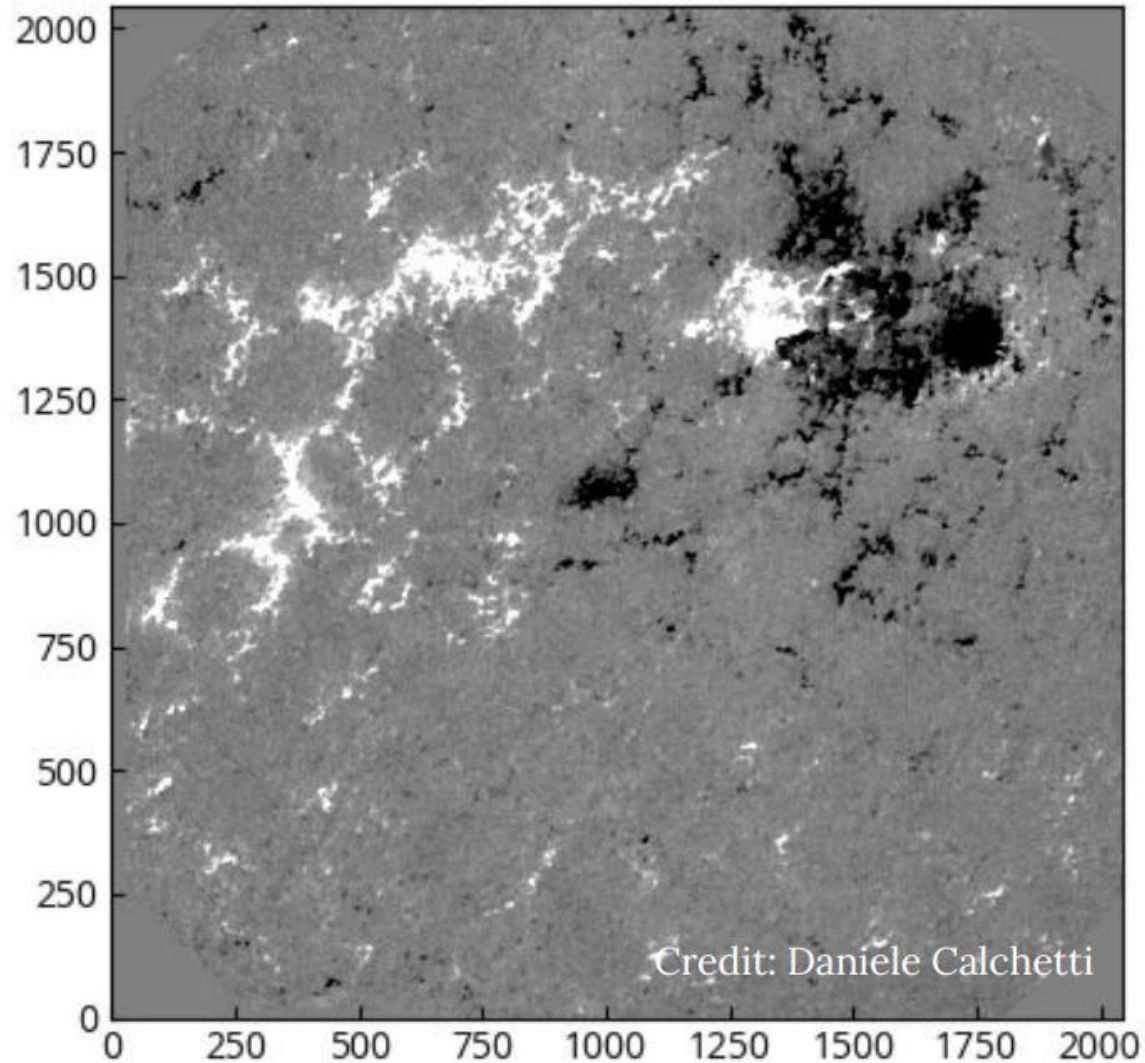
PHI:
12:25:00-13:10:00 → 5 min
13:10:00-14:10:00 → 1.6 min
14:10:00-14:55:00 → 5 min

SPICE:
08:45:00-09:51:28 → context raster
09:55:00-19:32:57 → dynamics
19:35:20-20:41:48 → context raster

External support: IRIS

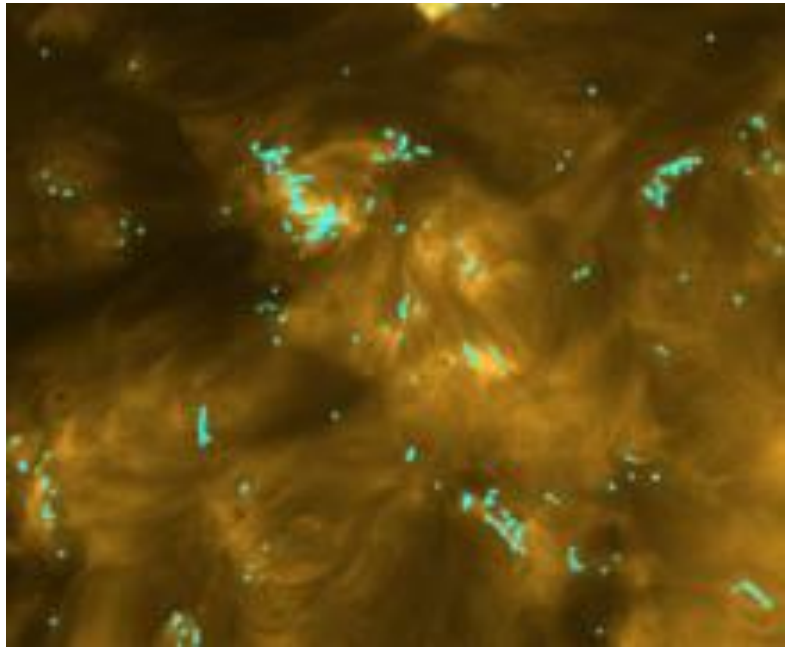
RS burst- AR Observation on October 10, 2023
Coordinators: S. Mandal, C. J. Nelson, A. Siu, H. Peter





Feedback: Well planned coordination; clear documentations; Everything went smoothly.

RS Burst SOOPs –QS



Observation time (QS)

Observation time

- LTP 9 2022-10-12 04:17 - 2022-10-12 07:17
- LPT 11 2023-04-10 20:10 - 2023-04-10 23:20
- LPT 13 2023-10-06 08:20 - 2023-10-06 12:40

Instruments

- Solar Orbiter: EUI, SPICE, PHI
- IRIS: SJI, raster
- Hinode: XRT, EIS

Scientific goal of the SOOP (QS)

- observation structures in a quiet Sun

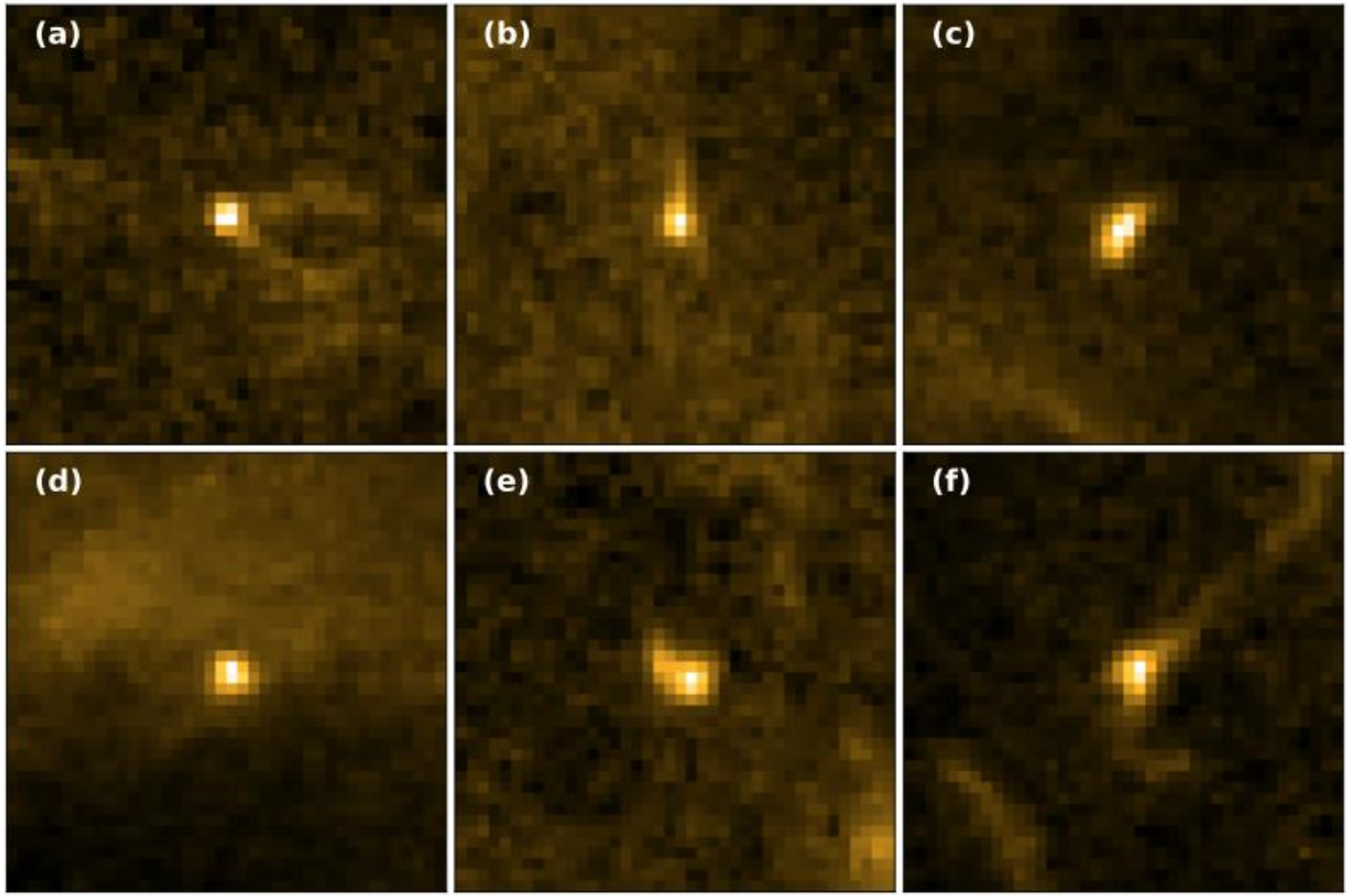


Fig. 2. Illustrative examples of close-up view of six EUV brightenings. The FoV of each panel is 4 Mm × 4 Mm.

Narang, N et al. 2025 (A&A) 699, A138

Difference between runs (QS)

Related to setup

- Observations from different vantage points (68, 113, 117 deg)
- Different setup coordinated observations
- Distance to Sun (0.29)
- EUI –cadence: between 3 and 10 sec

Scientific outcom(QS)

- Published

A&A, 699, A138 (2025)
https://doi.org/10.1051/0004-6361/202554650

Astronomy & Astrophysics

Extreme-ultraviolet transient brightenings in the quiet-Sun corona

Closest perihelion observations with Solar Orbiter/EUI

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[2] Université Paris-Saclay, CNRS, Institut d'Astrophysique Spatiale, 91405 Orsay, France
[3] Centre Spatial de Liège, Université de Liège, Av. du Pré-Aily B29, 4031 Angleur, Belgium
[4] Max-Planck-Institut für Sonnensystemforschung, Justus-von-Liebig-Weg 3, 37077 Göttingen, Germany
[5] Mathematics Institute, St Andrews University, KY16 9SS St Andrews, UK
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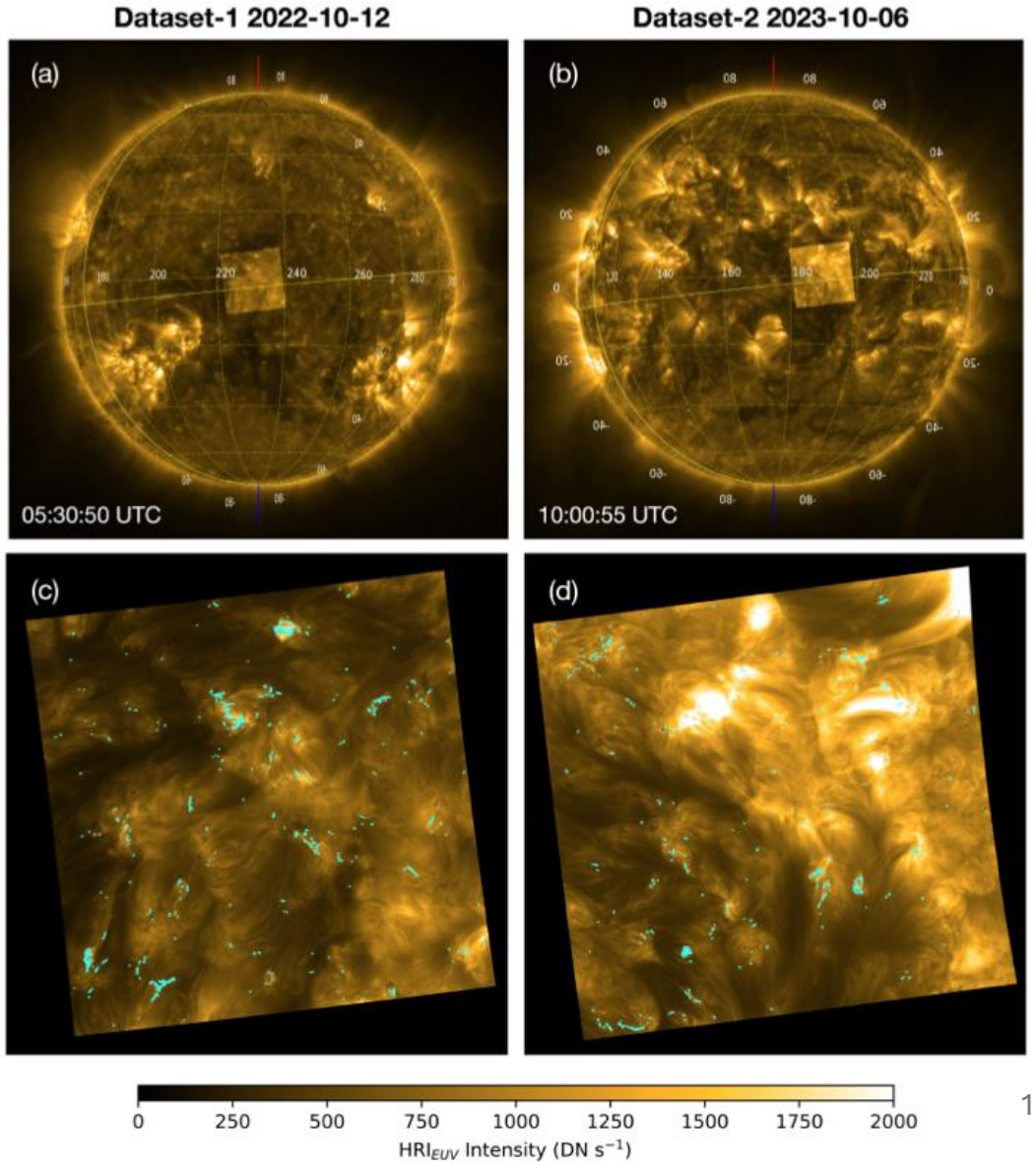
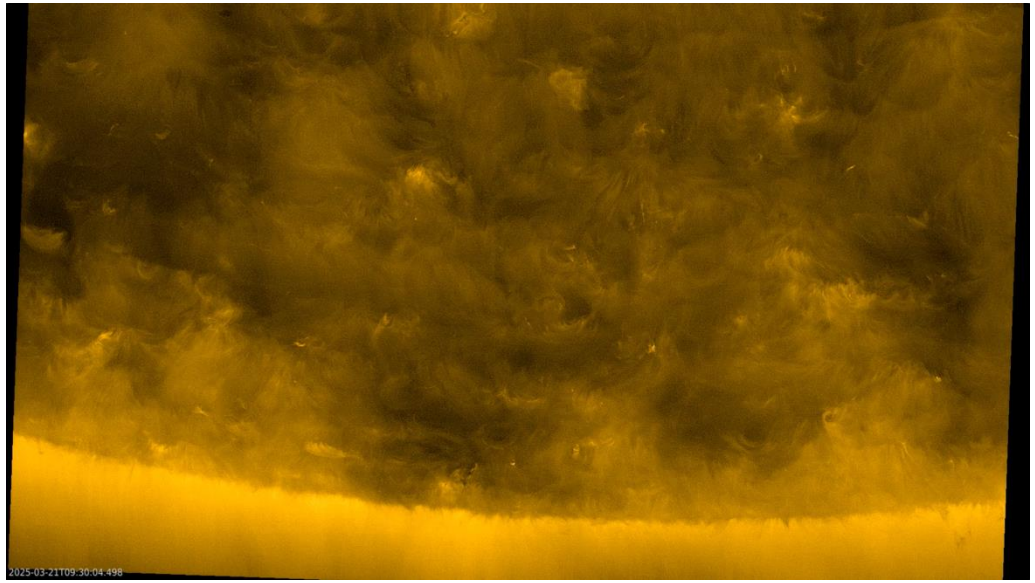
ABSTRACT

Context. The extreme-ultraviolet (EUV) brightenings identified by Solar Orbiter, commonly known as campfires, are the smallest transient brightenings detected to date outside active regions in the solar corona.
Aims. In order to understand their possible contribution to quiet-Sun heating, we investigated the spatio-temporal distribution of a large ensemble of the finest scale EUV transient brightenings observed by the Extreme Ultraviolet Imager (EUI) aboard Solar Orbiter.
Methods. We performed a statistical analysis of the EUV brightenings by using quiet-Sun observations at the highest possible spatial resolution ever obtained by the EUI. We used observations in the 17.4 nm passband of the High Resolution EUV Imager (HRI_{EUV}) of EUI acquired during the closest perihelia of Solar Orbiter in 2022 and 2023. Solar Orbiter being at a distance 0.293 AU from the Sun, these observations have an exceptionally high image scale of 105 km, recorded at a fast cadence of 3 seconds. We used a wavelet-based automatic detection algorithm to detect and characterise the events of interest, and we studied their morphological and photometrical properties.
Results. We report the detection of the smallest and shortest lived EUV brightenings to date in the quiet Sun. The size and lifetime of the detected EUV brightenings appear power-law distributed down to a size of 0.01 Mm^2 and a lifetime of 3 seconds. In general, their sizes lie in the range of 0.01 Mm^2 to 50 Mm^2, and their lifetimes vary between 3 seconds and 40 minutes. We find an increasingly high number of EUV brightenings on smaller spatial and temporal scales. We estimate that about 3600 EUV brightenings appear per second on the whole Sun. The HRI_{EUV} brightenings thus represent the most prevalent, localised, and finest scale transient EUV brightenings in the quiet regions of the solar corona.
Conclusions. Using observations from EUI/HRI_{EUV} at the highest possible achievable spatial resolution with the fastest cadence ever attained for quiet-Sun EUV observations, we detect the smallest and shortest lived EUV brightenings to date. Future studies that can provide estimates of the thermal energy content of the smallest-scale EUV brightenings will help to provide better insights into their role in the coronal heating.

Key words. magnetic reconnection – instrumentation: high angular resolution – Sun: corona – Sun: transition region – Sun: UV radiation



RS Burst SOOPs –polar region



RS-Burst SOOP (March 21, 2025): science goals

Science goals

1. Characterize network properties and evolution at high latitudes (polar regions)
2. Study ephemeral region emergence at high latitudes
3. Assess atmospheric heating by cancellation of opposite polarity flux concentrations

Observing strategy

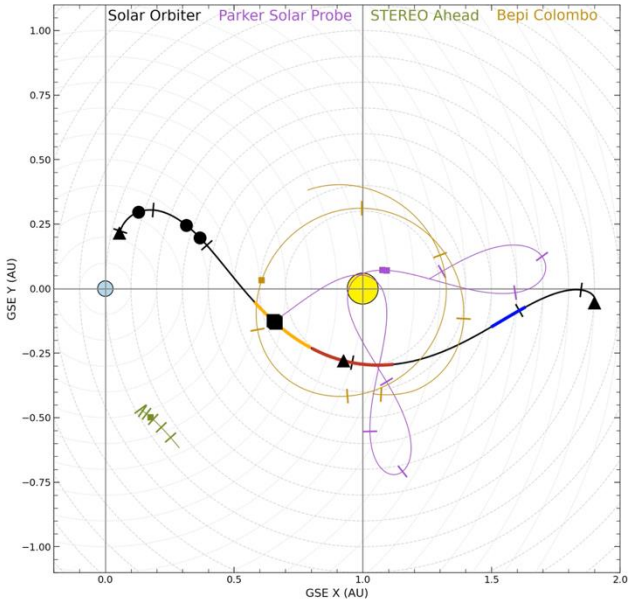
- Target same polar region from SOLO and Earth
- Very high-cadence observations, for 6 hours
- Monitor different atmospheric layers
- Coordinate observations with Hinode+IRIS (IHOP 503)

RS-Burst SOOP (March 21, 2025): target and observations

Run in LTP19

- 21 March 2025, from 09:30 to 15:30 UT
- Target: South polar region
- r=0.44-0.37 au, lat=-14.8º -> -16.7º , Earth-Sun-SO angle: 20º
- Followed by R_SMALL_MRES_MCAD_Supergranulation (2025-03-21T15:35:00->2025-03-22T00:35:00)

2025-03-21 10:55

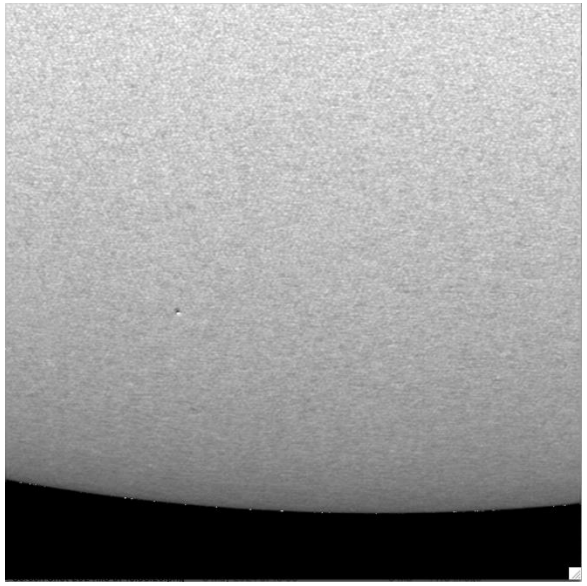


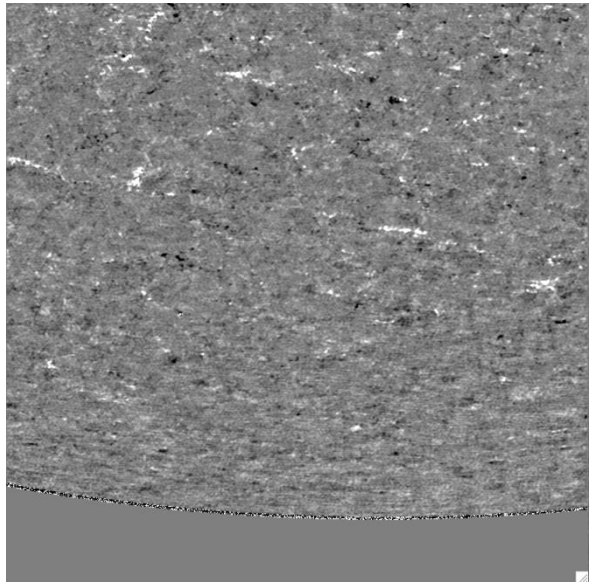
Instrument	Observations
PHI	HRT, vector mode, 170”x170”, cadence 120s, 6h, ISS on
EUI	HRIEUV, full FOV, cadence 10s, 6h FSI 174 + 304 Eruptive_B, full FOV, 180 s, 6h
SPICE	Polar mini-raster (ID2233), slit 4”, 20” x 660”, texp 9.7s, cadence 55s, 6h Context raster (ID2234), slit 4”, 256” x 660”, texp 19.7 s, 21 minutes
Hinode/SP	8 normal maps, 1-sided, 82” x 82”, 45 min cadence
Hinode/EIS	Raster, slit 2”, 10”x144”, texp 30s, 2m 47s cadence Context raster (study 248), slot 40”, texp 30s, 104”x512”
IRIS	8-step raster (OBS3420508630), slit 1”, 7”x119”, 73s cad + SJI Si IV 10s cad

RS-Burst SOOP (March 21, 2025): dataset

2025-03-21

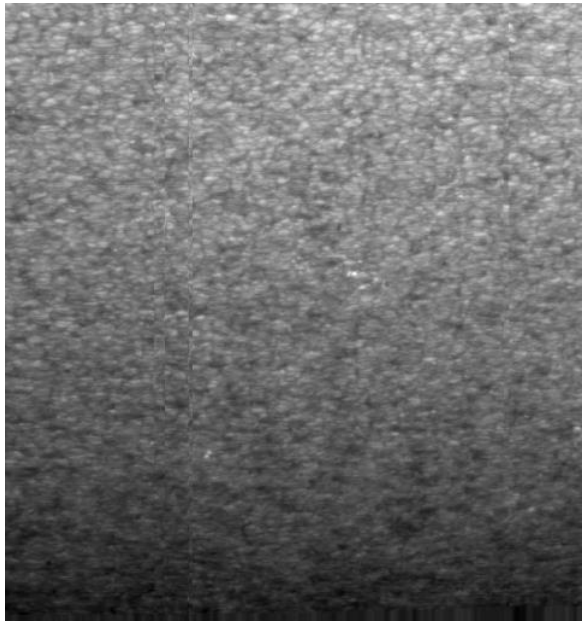
T09:30:09->T15:30:09

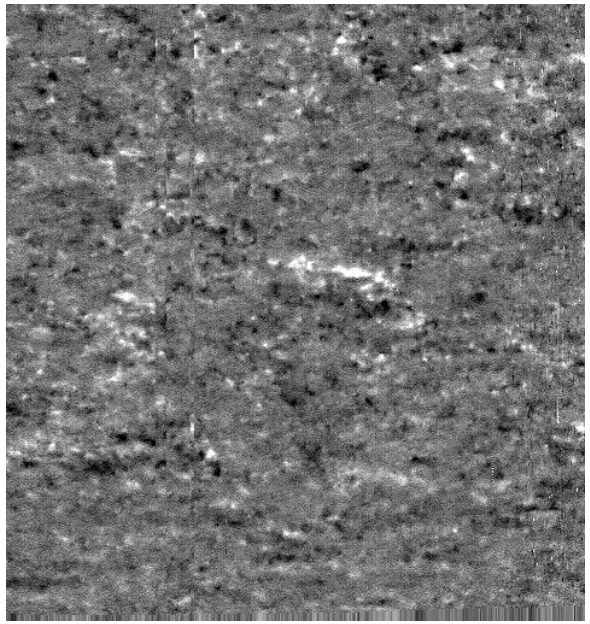




PHI/HRT Icont & Blos

2025-03-21 09:30 UT





Hinode/SP Icont & Blos

2025-03-21 09:30-10:18 UT

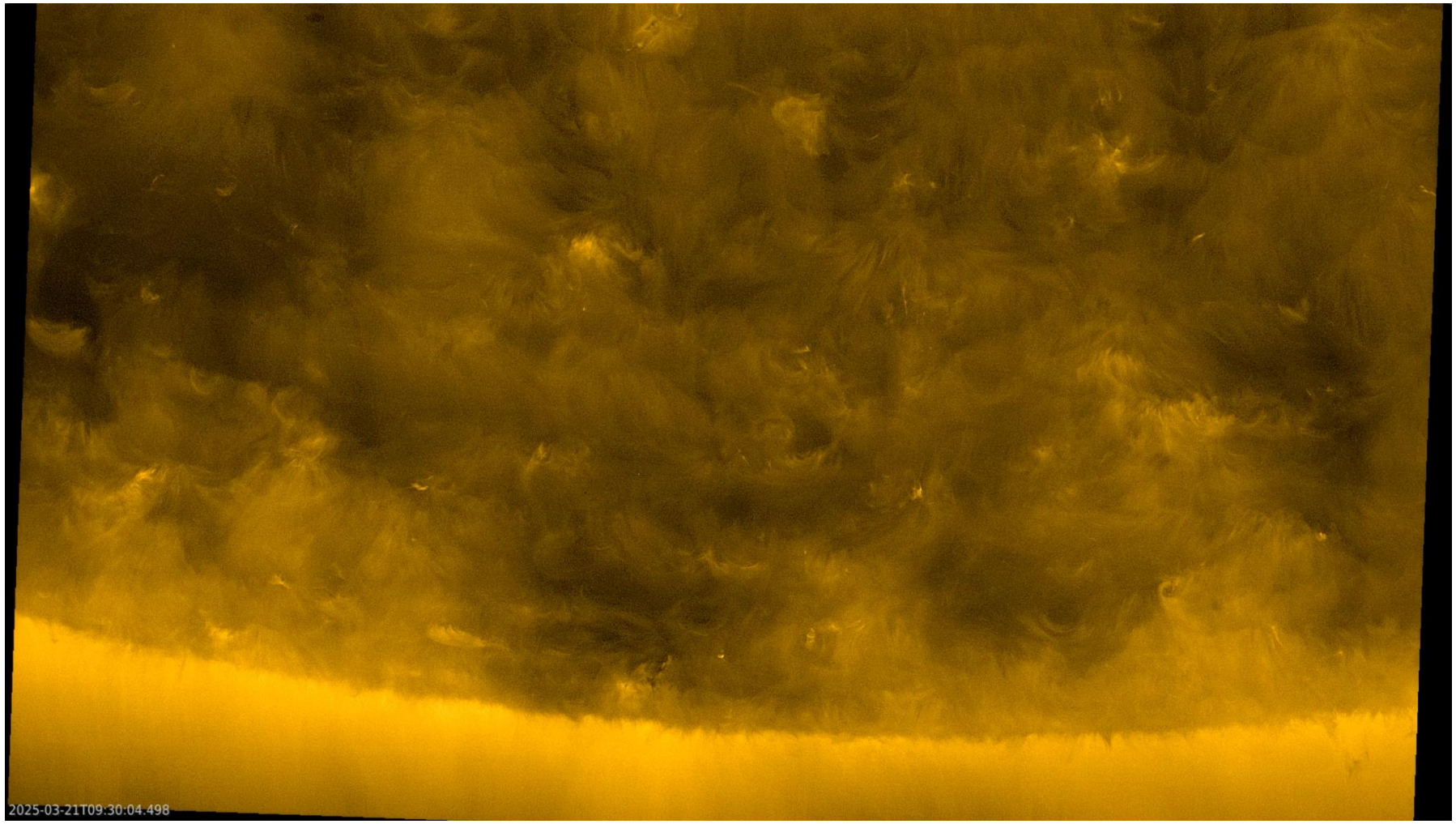
RS-Burst SOOP (March 21, 2025): dataset

2025-03-21

T09:30:09->T15:30:09

EUI HRIEUV

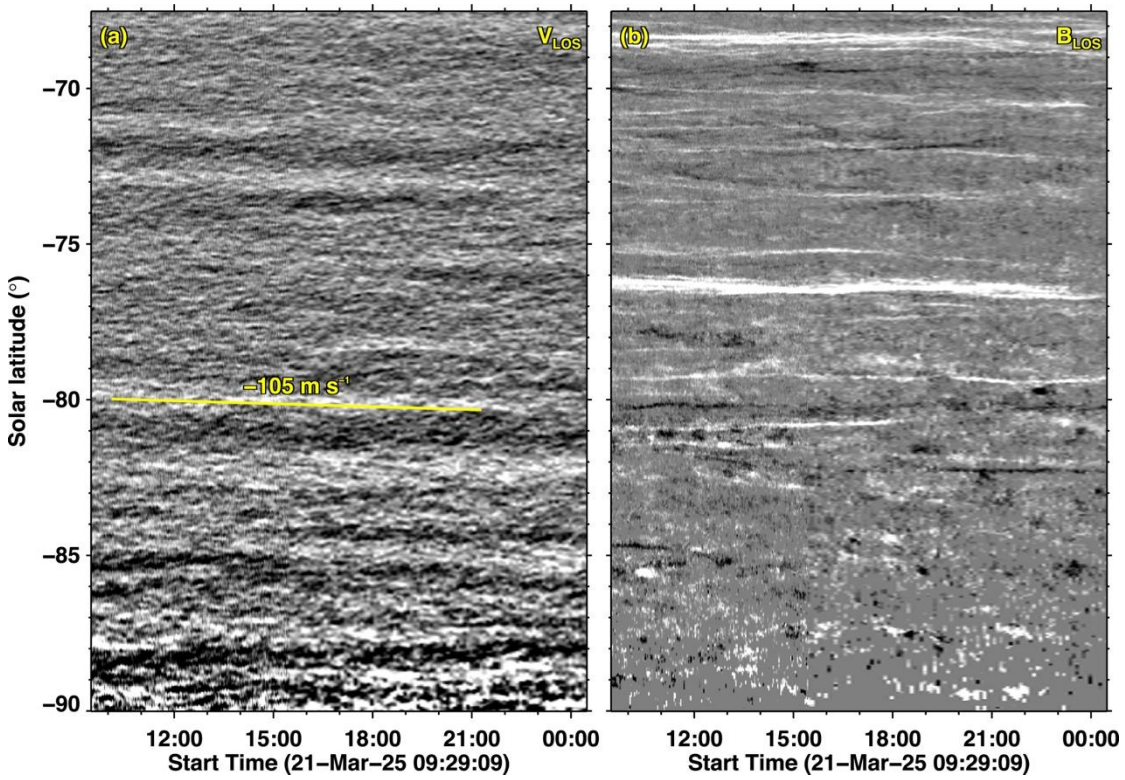
2025-03-21 09:30:05 UT

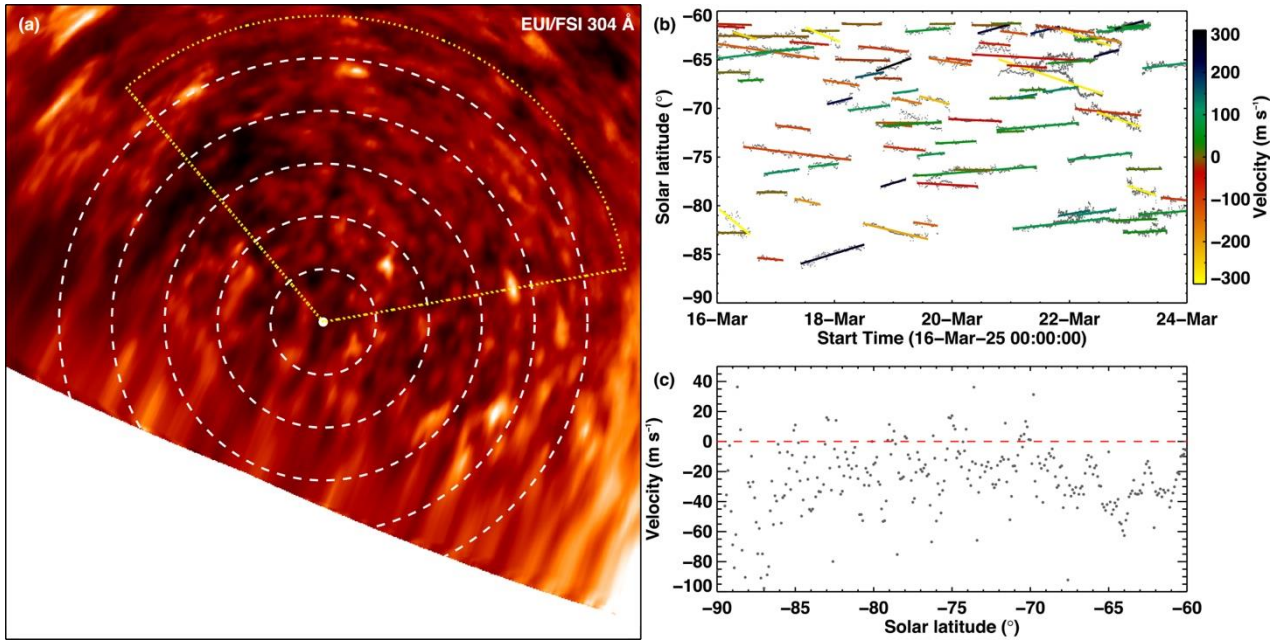


RS-Burst SOOP (March 21, 2025): Science outcomes

Published papers

- Chitta, L.P., et al. “Supergranulation and poleward migration of the magnetic field at high latitudes of the Sun”, ApJL 993:L45, 9 pp. (2025)





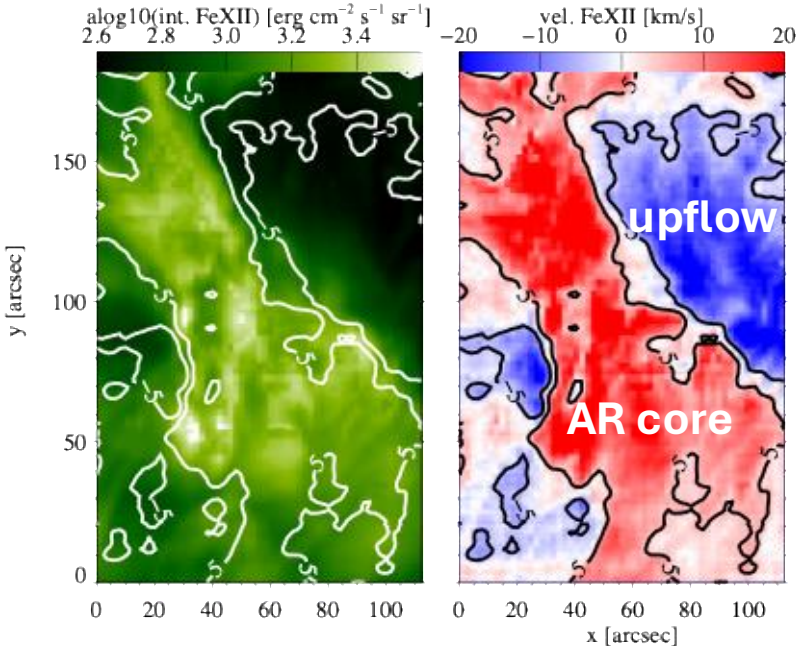
RS-Burst SOOP (March 21, 2025): Assessment

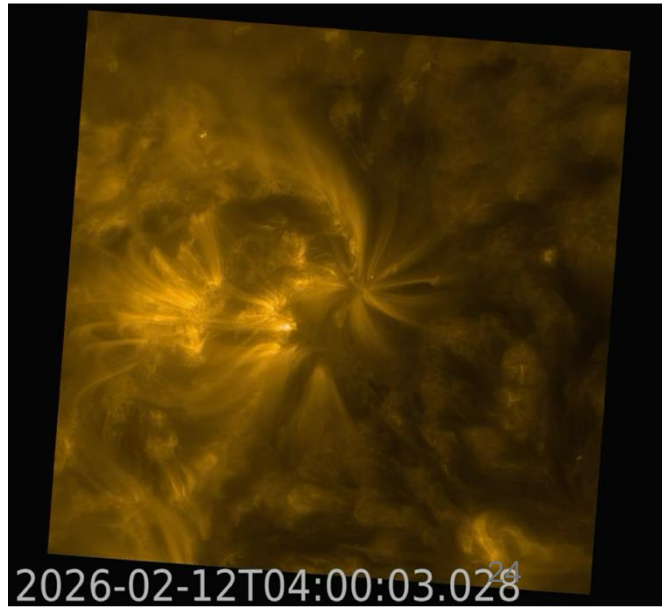
- Acquired data are excellent
- Continuous PHI/HRT observations at 2 minute cadence show evolution of many magnetic features near the South pole
- High-cadence EUI HRI observations with lots of transient brightenings and small-scale loops

- Acquired dataset is sufficient to fullfil science goals
- SOOP does not need to be rerun until higher latitudes are reached (more favorable viewing angle for magnetic field measurements)
- Possible improvement: extend duration by a few hours (even at lower cadence)

- PHI data released only in January 2026 and EUI data not released yet, so very little time for use of dataset by community at large

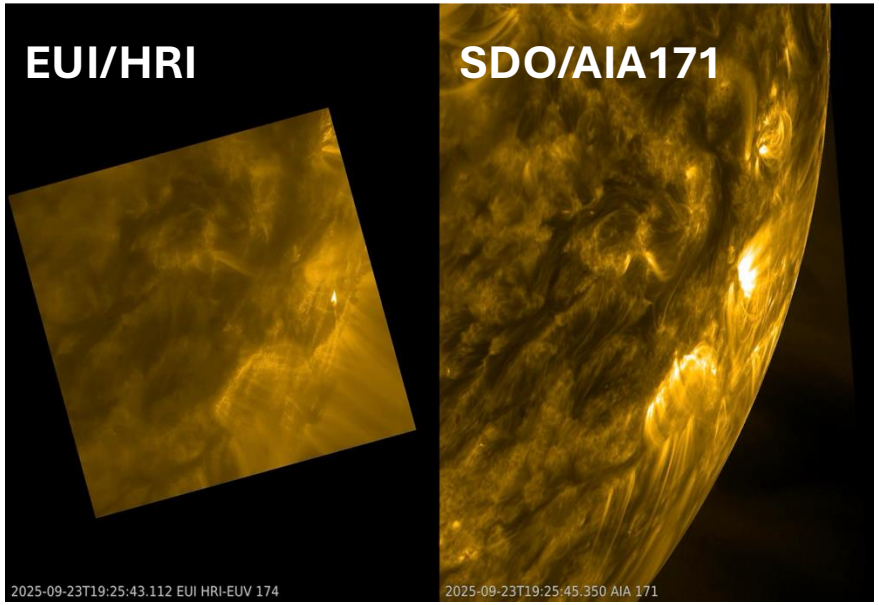
RS Burst SOOPs -border of AR

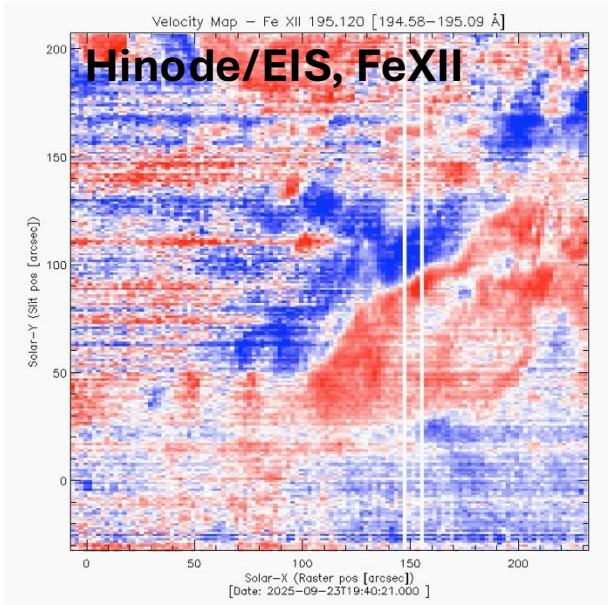


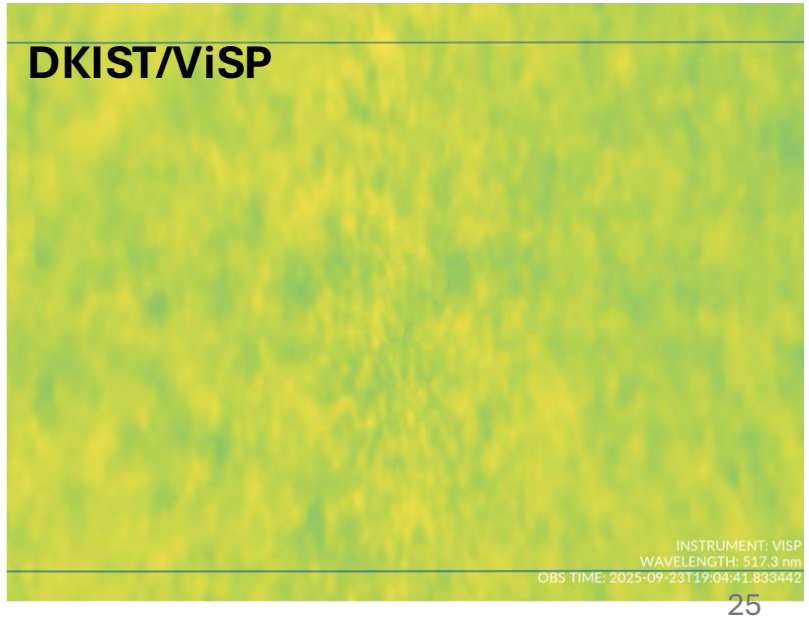


Scientific goal of the SOOP (Border of AR)

- The characterization of the physical and dynamical properties of small-scale brightenings in coronal upflow regions
- The investigation of the physical mechanisms driving plasma upflows at the boundaries of active regions (ARs)
- A comparative analysis of the physical and dynamical properties of coronal upflow regions and active region cores







Observation time (Border of AR)

Observation time

- LTP 17 →19 Oct 2024 T 19:04 – 19:32 UT –coord. IRIS, Hinode, DKIST*
- LTP 19 →01 Apr 2025 T 19:00 – 20:00 UT –coord. IRIS, Hinode, DKIST*
- LTP 21 →23 Sep 2025 T 19:00 – 20:00 UT –coord. IRIS, Hinode, DKIST
- LTP 22 →12 Feb 2026 T 03:00 – 04:00 UT –coord. IRIS, Hinode

*obs. not possible due to weather condition

Instruments

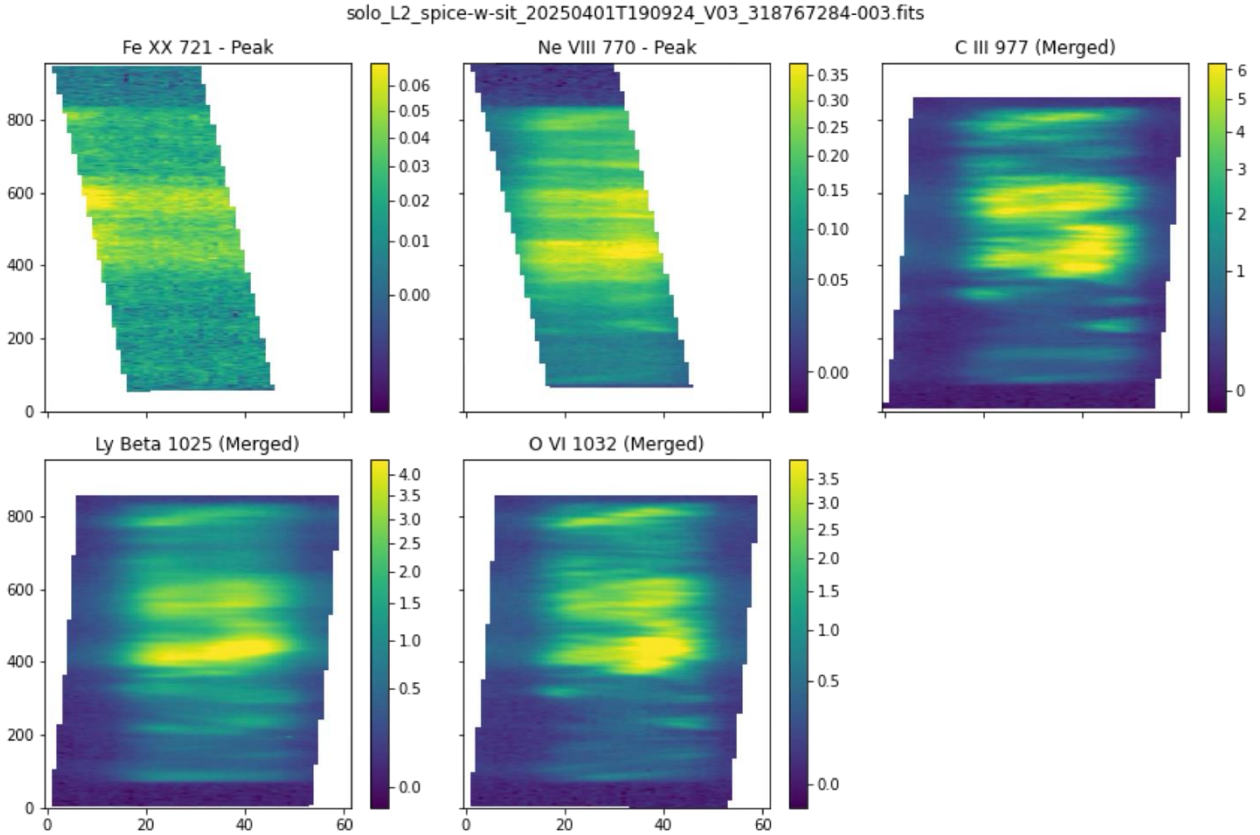
- Solar Orbiter: EUI, SPICE, PHI
- IRIS: raster & SJI
- Hinode: EIS, XRT, SOT
- DKIST: VBI (under processing), ViSP

Difference between runs (Border of AR)

Related to setup

- Coordinated observations from different vantage points (23 – 90 deg)
- Different coordinated observation setups
- Distance to Sun (0.3 – 0.5 AU)
- EUI cadence: between 1 and 5 s.

  →duration: 28 min - 60 min
- SPICE: raster and slot observation modes



Related to AR physics

- Active region age, size, location of AR at the solar disk, flaring activity

Scientific outcom(Border of AR)

- Published:

A&A, 704, A58 (2025)
https://doi.org/10.1051/0004-6361/202557135

Astronomy & Astrophysics

Accessing the fine temporal scale of EUV brightenings and their quasi-periodic pulsations: 1-second cadence observations by Solar Orbiter/EUI

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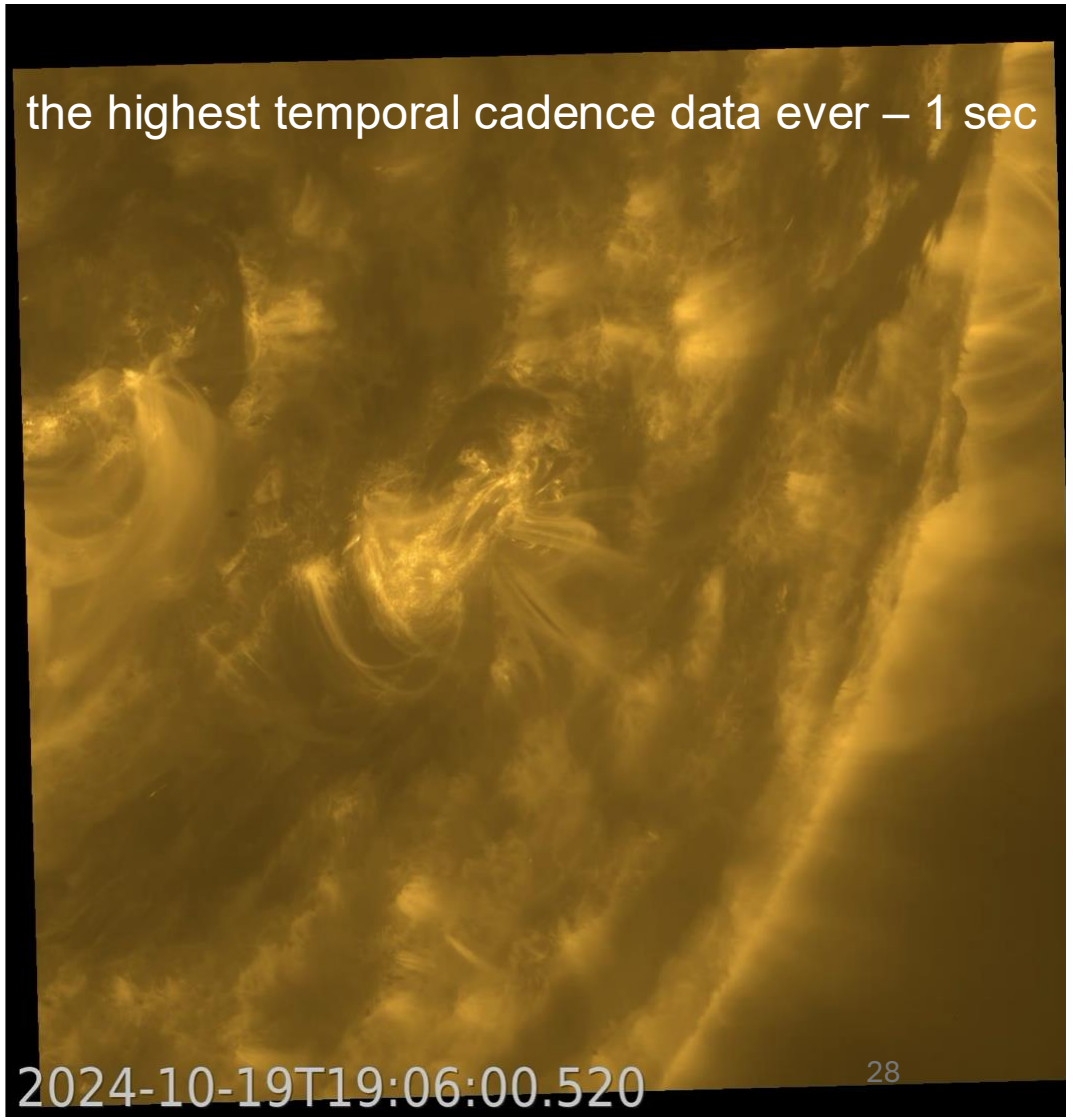

- On going:

-High-resolution observations of the dynamics at the border of the active region (Barczynski et al.)

Assessment (Border of AR)

Scientific goals achievement:

- observations of the upflow region obtained from different vantage points and coordinated with multiple instruments to provide complementary perspectives

- analysis of the data to investigate the physical mechanisms governing the upflow region (ongoing study)

- observations of the solar corona with the highest temporal resolution achieved to date

Scientific goals for further observations:

- investigation of the long-term evolution of the upflow region based on two one-hour observations of the same active region (AR), obtained at the beginning and at the end of the LTP

Thank you for your attention