Space and ground-based coordination for the Solar Orbiter mission

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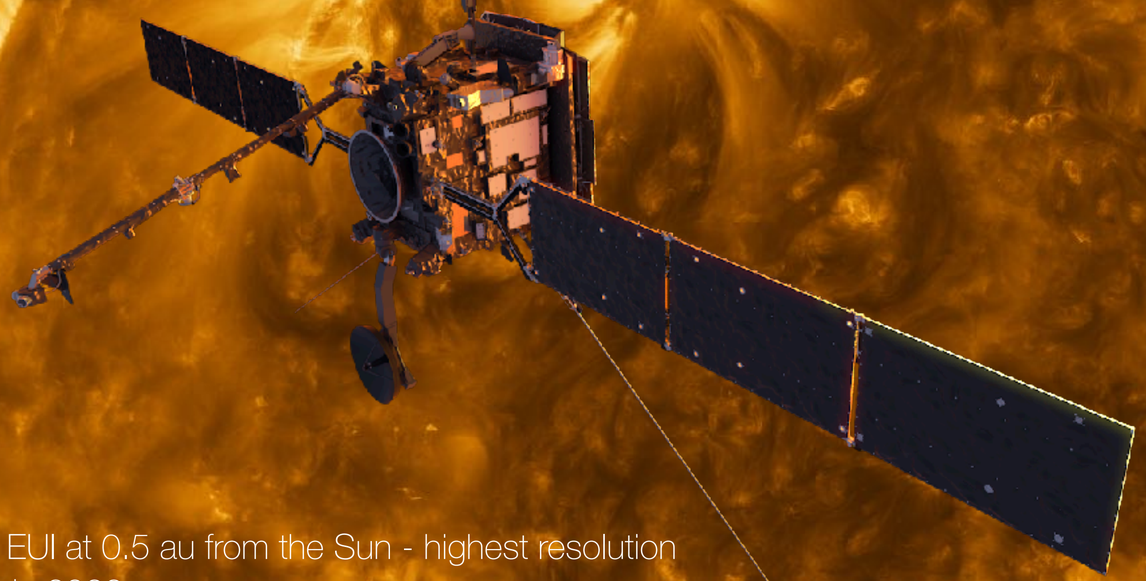


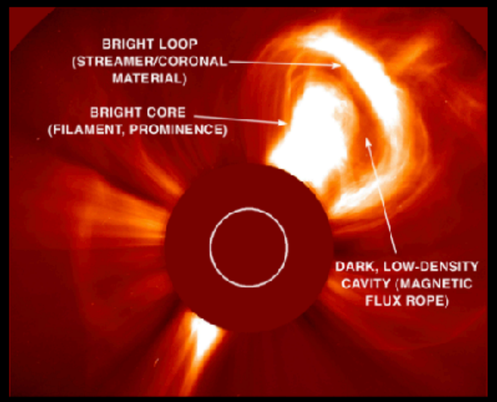
Solar Orbiter EUI at 0.5 au from the Sun - highest resolution picture taken in 2022

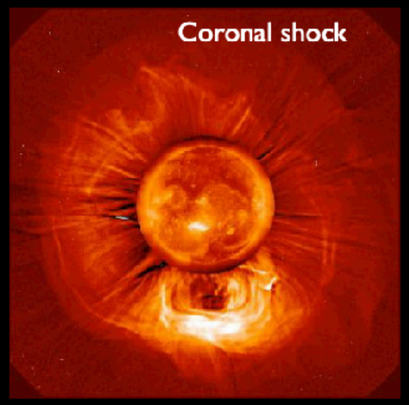
Credit: ESA/NASA Solar Orbiter / EUI / HRI

Solar Orbiter: a true “heliophysics” spacecraft

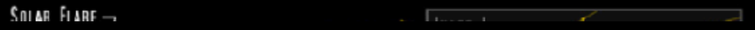
#1: Where does the solar wind come from? How is it generated? Why is it so variable?

#2: How are solar flares/solar eruptions happening?

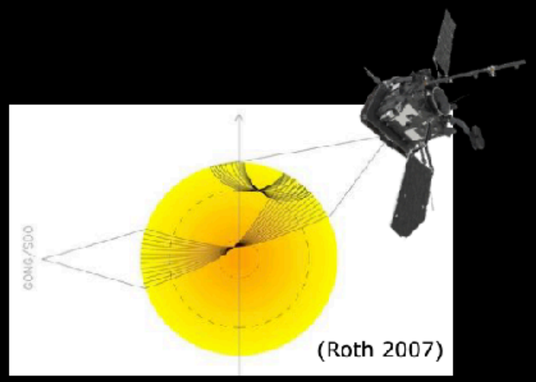


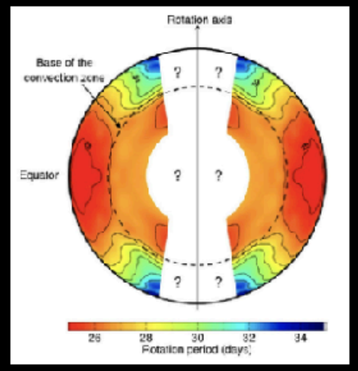


#3: How does the Sun inject high-energy particles in space?

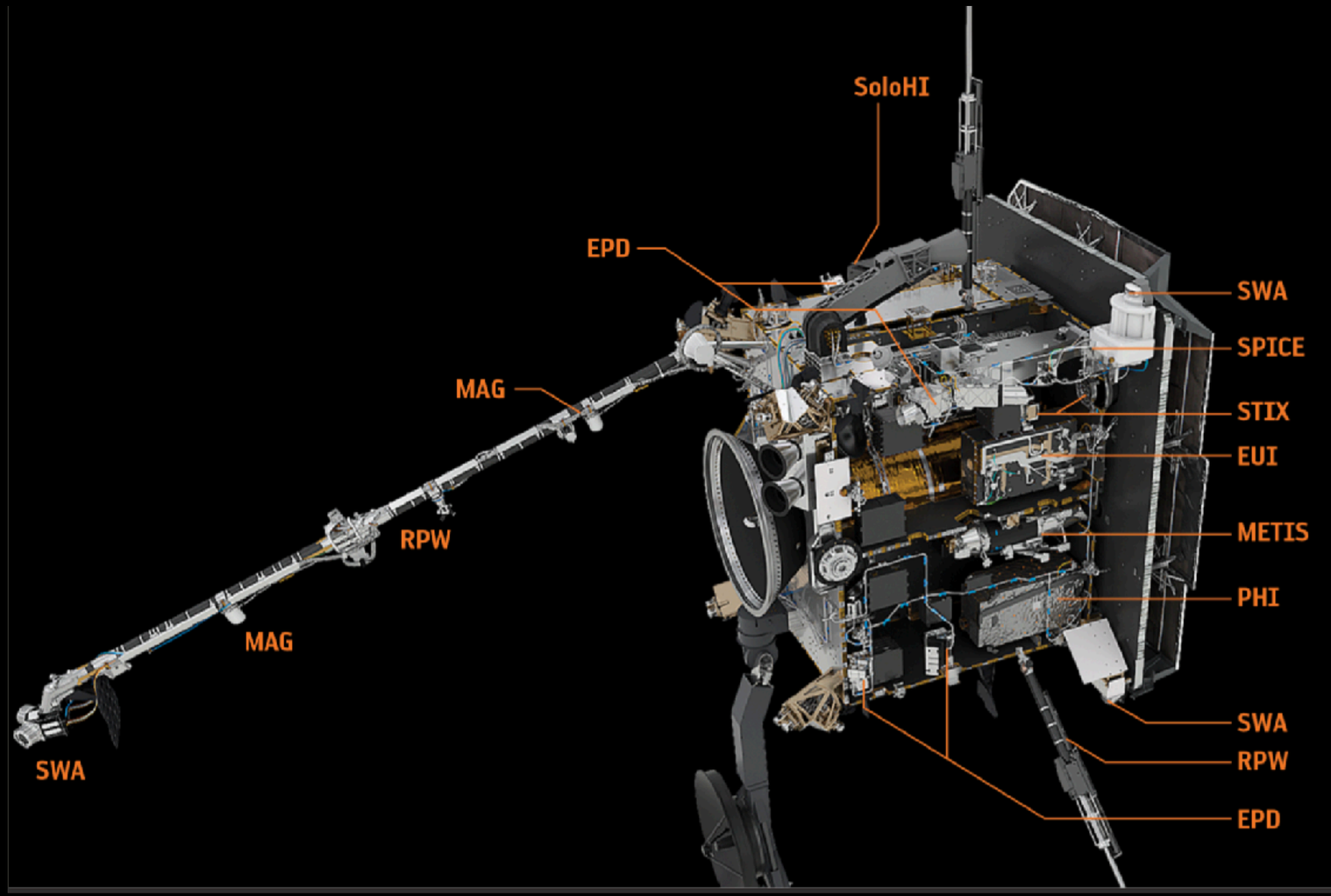


#4: How is the Sun’s magnetic field and cycle generated?





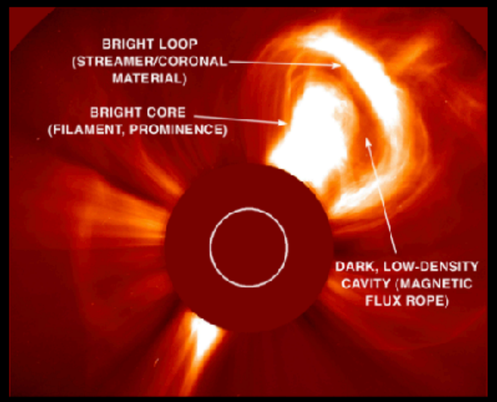
6 remote-sensing instruments, 4 in situ

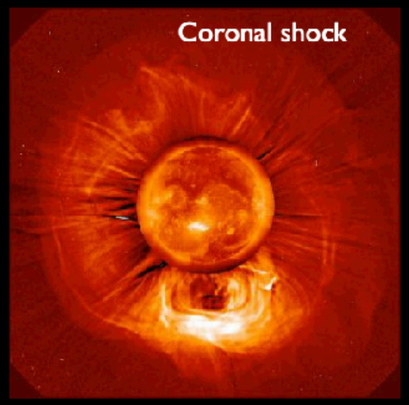


Mission summary

#1: Where does the solar wind come from? How is it generated? Why is it so variable?

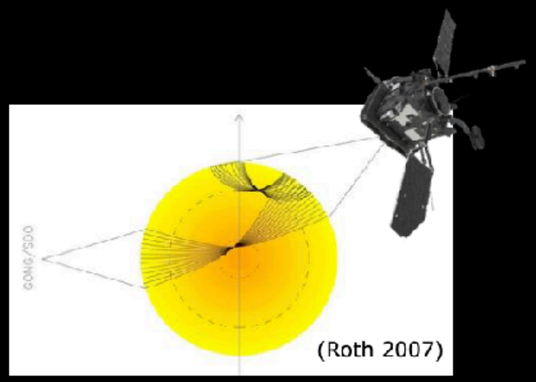
#2: How are solar flares/solar eruptions happening?

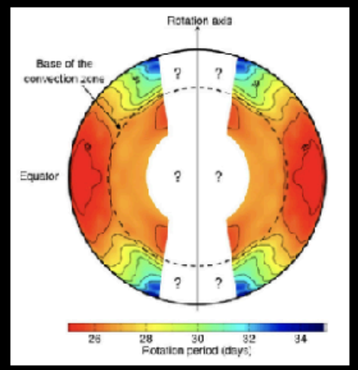




#3: How does the Sun inject high-energy particles in space?

#4: How is the Sun's magnetic field and cycle generated?





30 days of "remote-sensing" observations per orbit (~ every 6 months) + synoptic program

First polar pass > 17° latitude
Mar 2025

First polar pass > 24° latitude
Jan 2027

First polar pass > 30° latitude
Apr 2028

Polar pass > 33° latitude
July 2029

Close approaches to the Sun

Feb 2021 – within 0.5 au*
Oct 2022 – within 0.3 au

Launch

9 February 2020 (EST)
10 February 2020 (GMT)

Earth gravity assist manoeuvre

27 Nov 2021

Venus gravity assist manoeuvre

27 Dec 2020
09 Aug 2021
04 Sep 2022
18 Feb 2025
24 Dec 2026
18 Mar 2028
10 Jun 2029
03 Sep 2030

Coordinated observations (w/ external parties)

Different points of view

- At angles allowing stereoscopy
- Compare corona vs on disk features
- Out of ecliptic / in ecliptic comparisons
- Radial, Parker alignments, footpoint connectivity

Complementary observation dataset

- Multi wavelengths observations (e.g. Halpha w/ EUV, radio)
- Multi temperature observations (e.g. IRIS + EIS + SPICE)
- In situ + Remote-sensing, alignment permitting
- Small vs large spatial and temporal scales covered

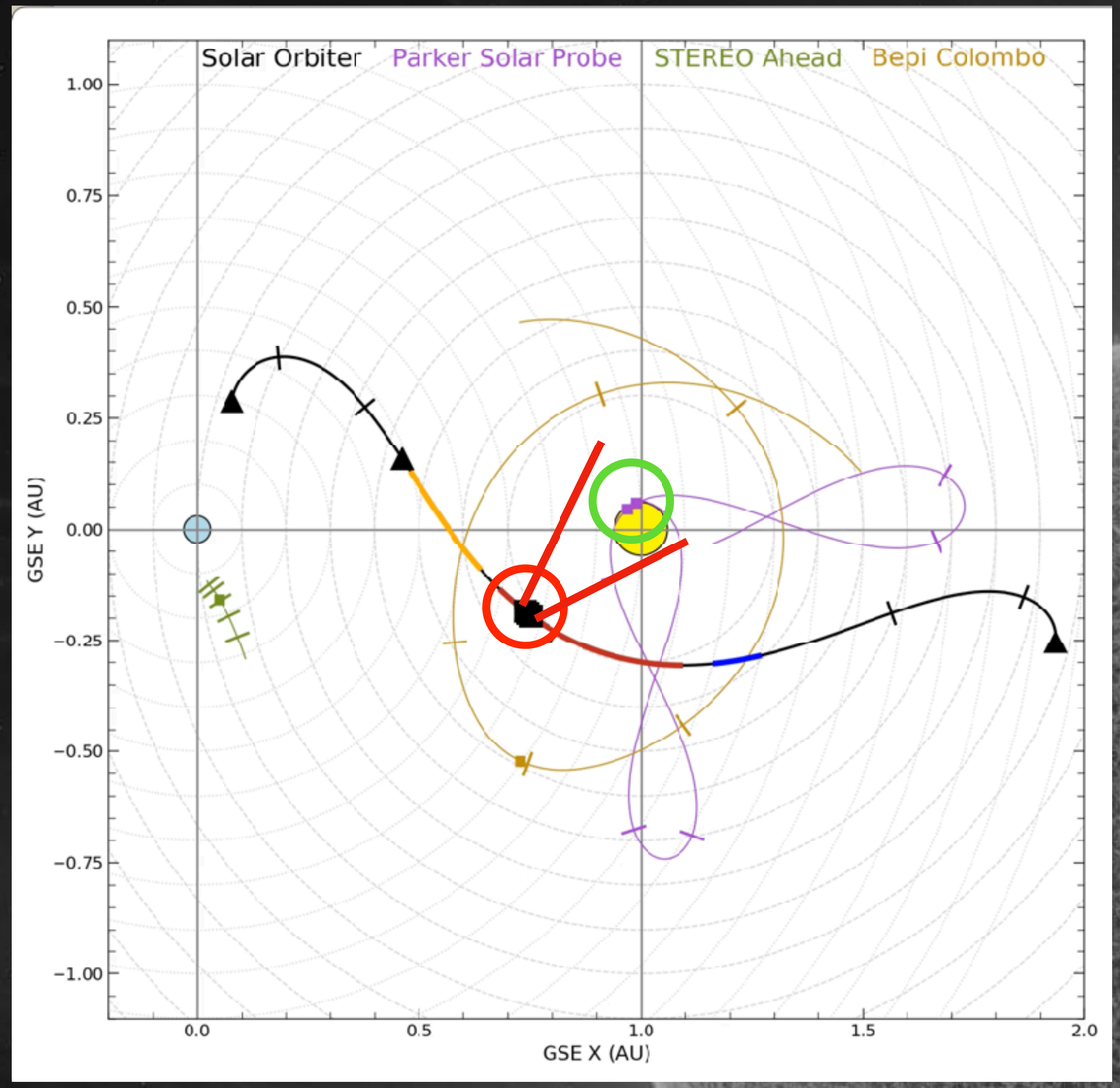
"Multi-messenger" solar and space physics

Longer target follow-ups

- Persistent features (e.g. coronal holes, active regions) followed by different instruments missions/ground
- Temporal evolution can be captured via RS + in situ over a longer period due to orbit position

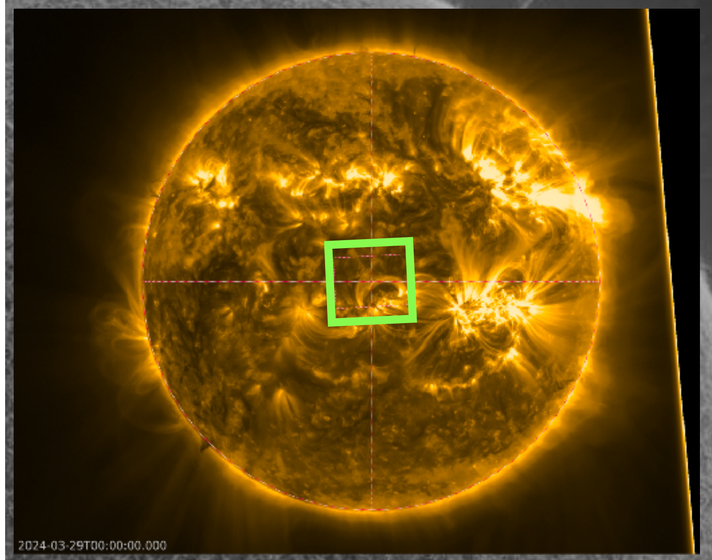
Parker Solar Probe / Solar Orbiter

Science goal: observe above the limb the SW source region later sampled by PSP close to the Sun.

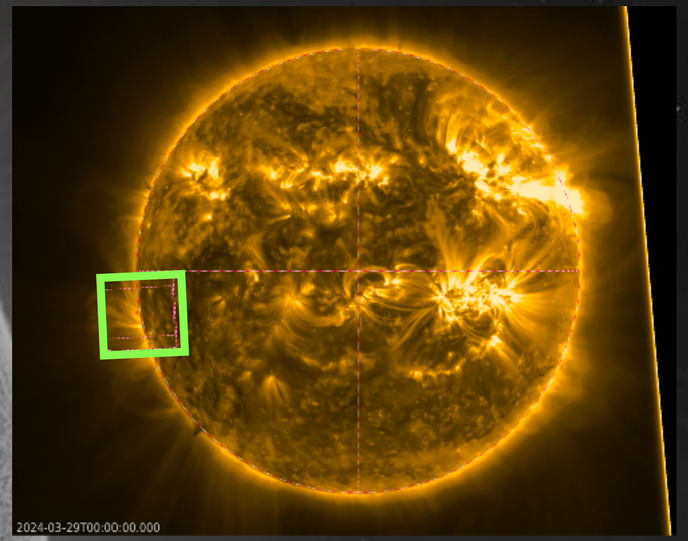


29 March 2024 (PSP @0.121 au, SO @0.34)

Point Centre (~14h before, 12h after)
Metis + SoloHI for coronal environment



2x East Limb pointing (4/5h)
Look at the source region w/ high res



Parker Solar Probe / Solar Orbiter

Previous coordinated observations

2022:

- 3 Solar Orbiter - PSP quadratures on 23 + 27 February 2022 & 11 December 2022
- Outside of RSW (only off-points scheduled in advance allowed).
- PSP moves very fast; SO starts observations ~1day before a quadrature
- All RS instruments participated (SoloHI for East limb quadrature only)

TI,dr: Solar Orbiter and PSP have coordinated for almost all of the PSP perihelia;

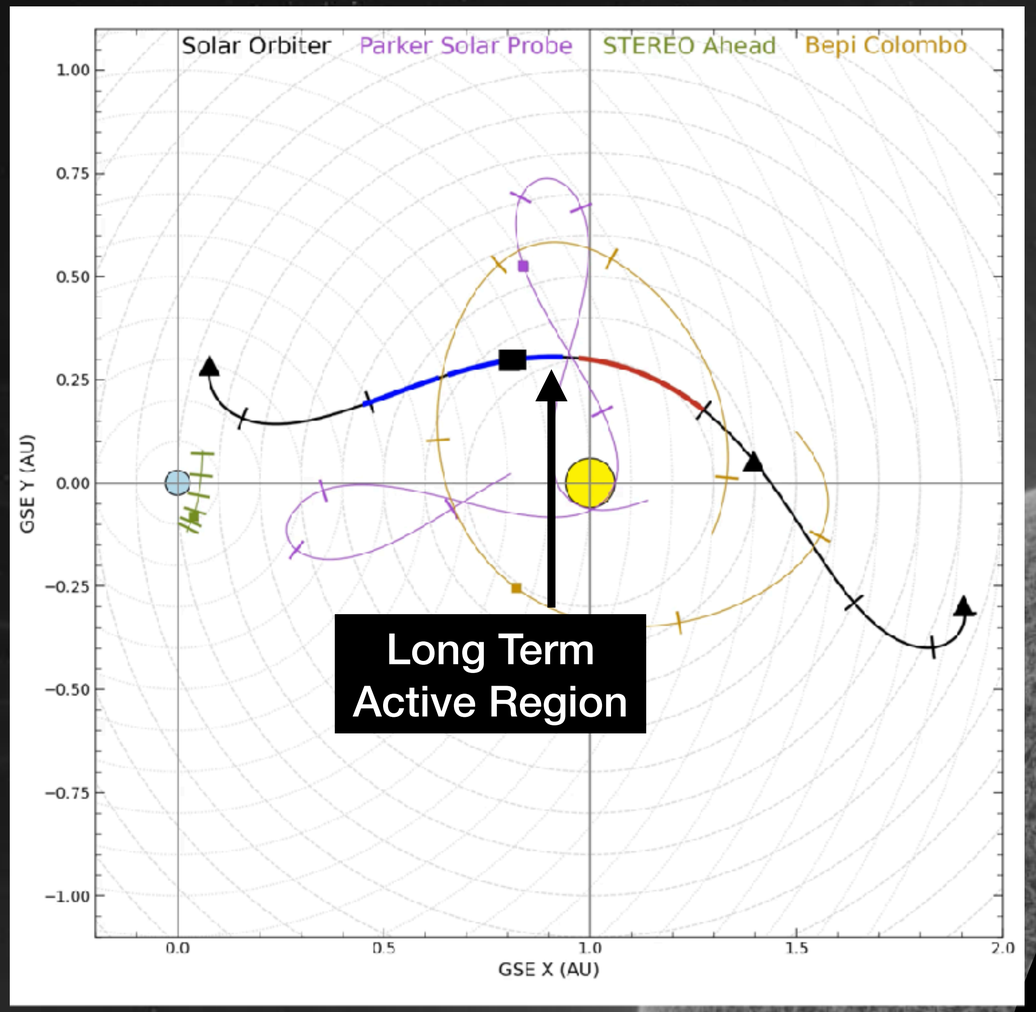
2023:

- 5 Solar Orbiter - PSP quadratures on 16 + 20 March, 22 June, 27 September and 28 December.
- 20 March 2023 not observed (incompatible Metis observations)
- Disk centre pointing restored so that Metis & SoloHI could observe
- 28 December: off pointing combined with spacecraft roll to have PSP in the Metis FOV ✳ESA press release

2024:

- Limb scan w/ SPICE and HRI (3 pointings) added to the quadrature on 30 March 2024.
- No special observations for the June 2024 quadrature (SO far from Sun & Earth)

DKIST / Solar Orbiter



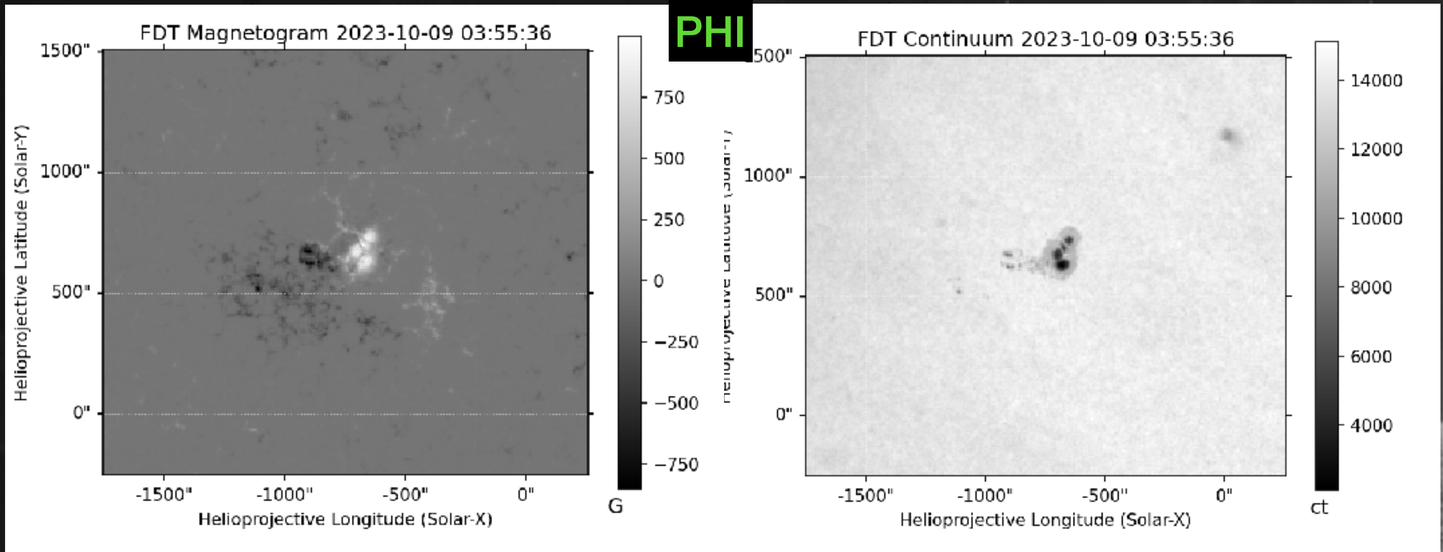
12 Oct - 20 Oct 2023 (SO <0.4au)

8 days of AR tracking with daily high-resolution observations:

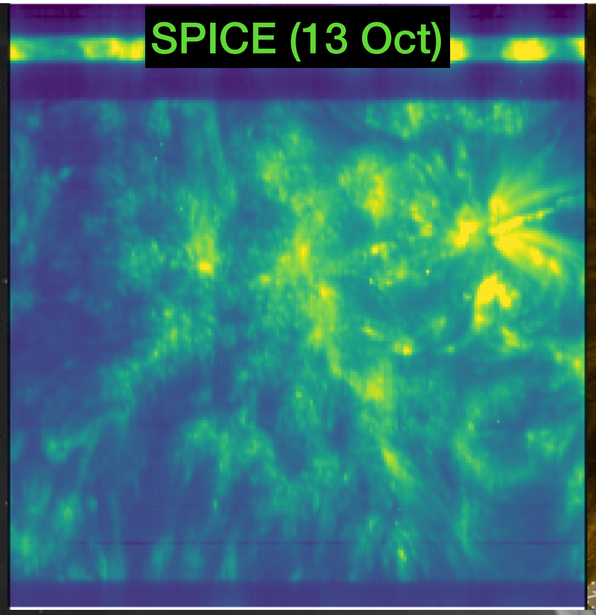
- 1h of daily burst at high cadence (5’) for EUI/HRI
- 1 SPICE composition raster / day (~4h)
  + 15’ dynamics raster all day long
- Continuous PHI/HRT observations

DKIST / Solar Orbiter

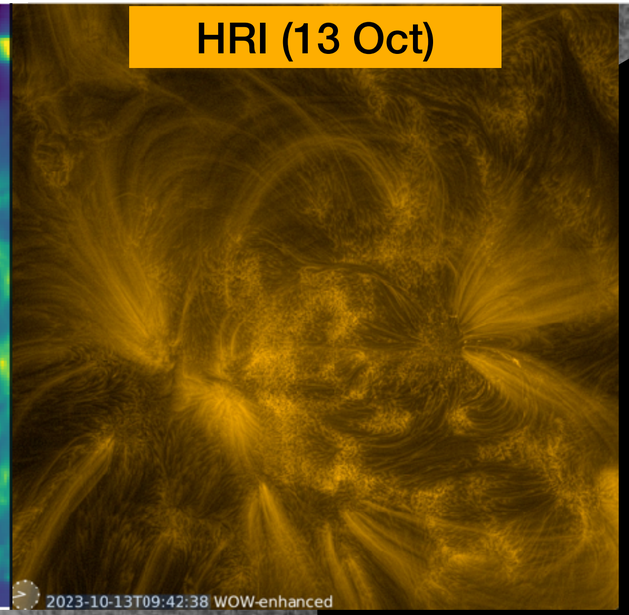
PHI



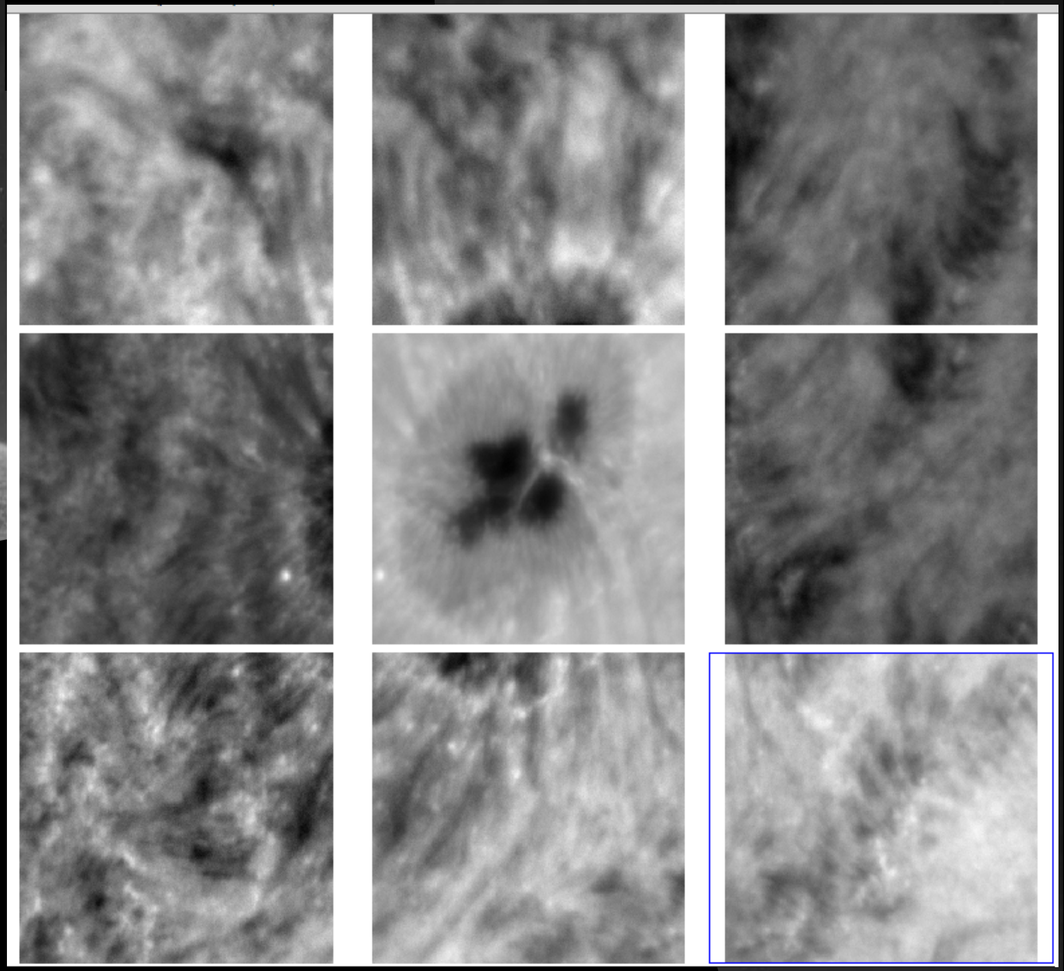
SPICE (13 Oct)



HRI (13 Oct)



DKIST observations: Livestream raw images



mosaic of the Hbeta data from VBI-Blue instrument (Courtesy L. Tarr)

Other coordinations / Solar Orbiter

	Optical (space)	Optical (ground)	Others
H1 2022	Hinode, IRIS		
H2 2022	Hinode, IRIS, CHASE (Halpha)	DKIST (1st paper about to be submitted), Mauna Loa (Hawaii, service mode) Big Bear Solar Observatory (California, proposal) Swedish Solar Telescope (Canaries), Themis (Canaries, proposal), Gregor (Canaries)	ALMA (Chile, DDT)
H1 2023	Hinode, IRIS		
H2 2023	Hinode, IRIS	DKIST Big Bear Solar Observatory (California, proposal) Swedish Solar Telescope (Canaries) + Gregor Hida Observatory (Japan)	MWA + ASKAP radio telescopes (Australia) ~~ALMA (Chile, proposal)~~
H1 2024	Hinode, IRIS	DKIST, ACES, Working groups set w/ several topics, workshop on Thursday (tomorrow)	
H2 2024	Hinode, IRIS	DKIST Swedish Solar Telescope (Canaries) + Gregor	

Lessons learned

What works:

- Coordination works best directly w/ people
- Possibility to systemise the process, workflow eased on all parties
- Rewarding outcomes (numerous working groups, unique datasets)
- Data generally publicly accessible : solar physics very open source mindset

What doesn't:

- No easy way for telescopes w/ cycle proposals (e.g. ALMA)
- Difficult to understand science opportunities for certain missions (e.g. during their cruise phase)
- Difficulties to gather all the datasets when coordination is not known (+ prioriary period different for some infrastructures)
- Only solar / space. Opportunities to link with e.g. Earth or other planetary exploration missions/infrastructures?

3 ideas

- A database of infrastructures (with a structured information workflow to understand when they observe, who to contact, quicklooks at the data)
- A converging place where to find information on the datasets (e.g. notebooks, archives)
- How to efficiently spread the word? (For Solar Orbiter: cosmos pages, webinar series)

Conclusions

Examples of PSP and DKIST coordination

Planning happens at different levels (mission, instruments, external parties)

Several papers published/in prep

April 8th Solar Eclipse: Solar Orbiter in “Eruption Watch”

2025: first orbit w/ portions out of the ecliptic plane (SWT)

“Multi-messenger” solar and space physics

All SOOPs + details to be found in the SOOP summary