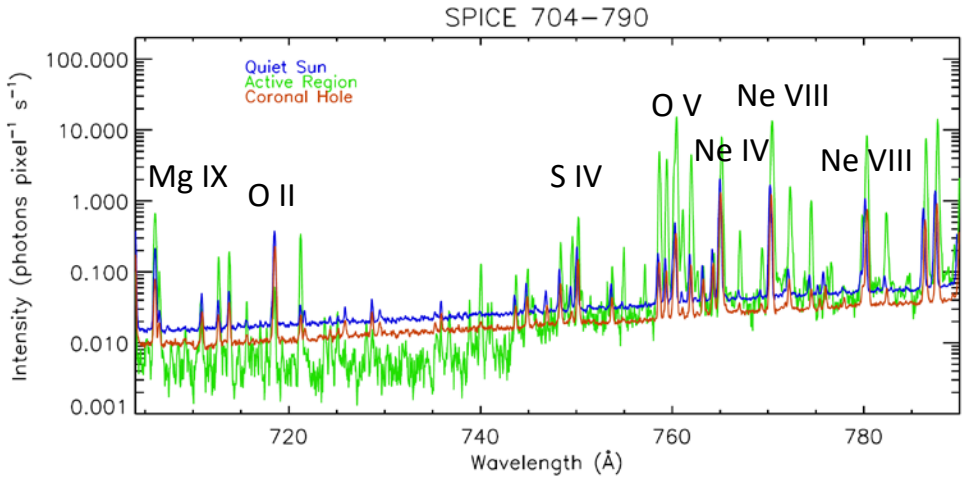
SPICE and EUI: overall characteristics and Observing modes. Synergies with Metis

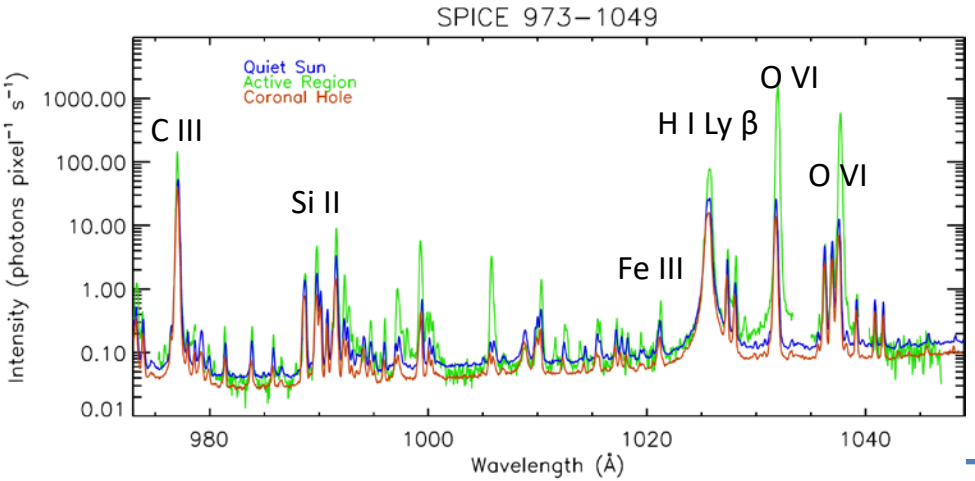
Susanna Parenti for the SPICE and EUI teams

Spectral Imaging of the Coronal Environment

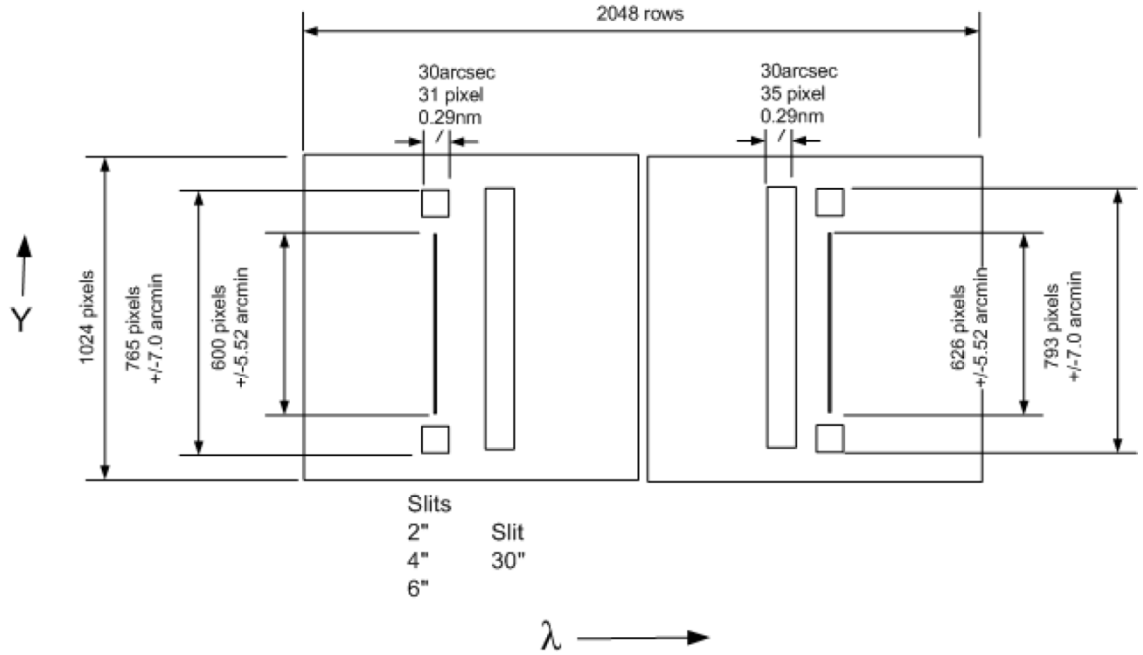
Parameter	Value
Raster FOV	11’ x 16’ narrow slits 14’ x 16’ slit 30’’
Spectral range	SW: 69.7 to 78.9 nm LW: 96.8 to 104.9 nm
Spatial resolution	4.4’’ – 5’’
Spectral resolution	0.04 nm
slits	2.5’’, 5’’ , 6.5’’ , 30’’
exptime	> 5 sec

Operating MODES:	
1. Full spectrum	3. Spatial Scan
2. Time Series	4. Two-Exposures



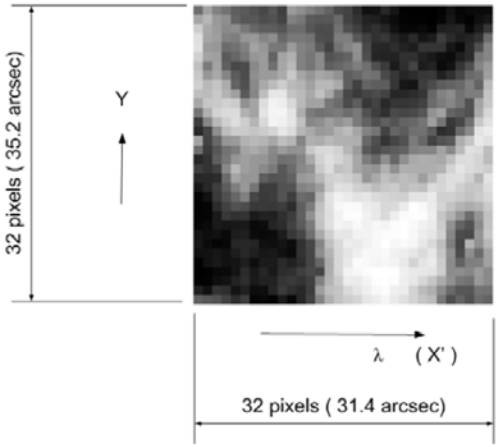


Spectral Imaging of the Coronal Environment



SW, y-direction: 1.1 “/pixel
LW, y-direction: 1.06 “/pixel

Dumb-bells for co-allignement:
one wavelength for each Study



Spectral Imaging of the Coronal Environment

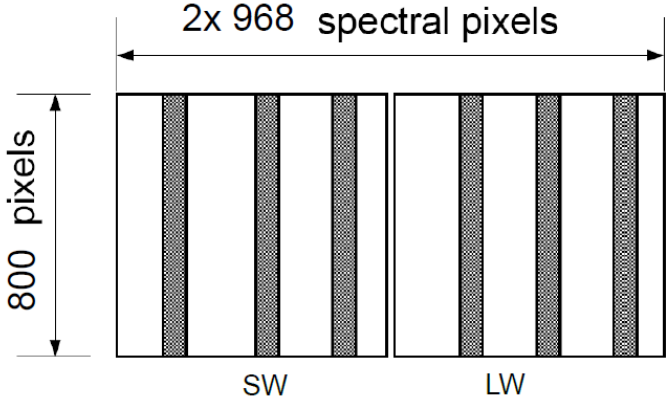
Table 1 – Selection of SPICE spectral lines.

Ion	Wavelength (Å)	Log T (K)	FIP (eV)	M/q
H I	1025	4.0	13.6	---
C II	1036	4.3	11.3	12.0
C III	977	4.5	11.3	6.0
O IV	787.7	5.2	13.6	5.3
O V	760	5.4	13.6	4.0
O VI	1032	5.5	13.6	3.2
O VI	1037	5.5	13.6	3.2
S V	786.5	5.2	10.36	8.0
Ne VI	1005	5.5	21.6	4.0
Ne VII	973	5.6	21.6	3.3
Ne VIII	770	5.8	21.6	2.8
Mg VIII	772	5.9	7.7	3.4
Mg IX	706	6.0	7.7	3.0
Mg XI	997	6.2	7.7	2.4
Si VII	1049	5.6	8.1	4.8
Si XII	521 (2^{nd})	6.5	8.1	2.6
Fe X	1028	6.0	7.9	6.2
Fe XVIII	975	6.9	7.9	3.3
Fe XX	721	7.0	7.9	2.9
Auxiliary lines:				
Ne VIII	780	5.8	21.6	2.8
Si XII	499 (2^{nd})	6.5	8.1	2.6

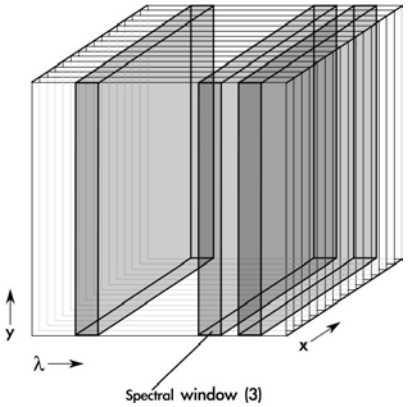
Type of windows
Spectral-profile without dumb-bells
spectral-profile with dumb-bells
Intensity (sum within the window)

Spectral Imaging of the Coronal Environment

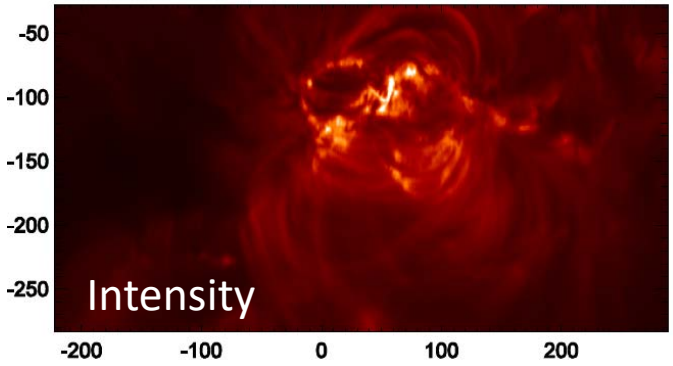
(y, λ) spectra & windows

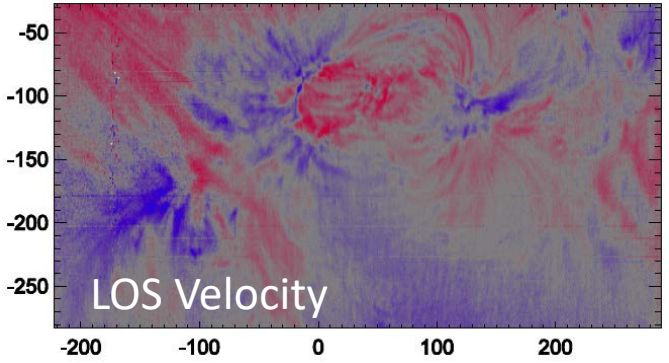


(x, y, λ) raster cubes



- **Detailed plasma diagnostics**
  - LOS Doppler velocity
  - Turbulent or unresolved motions
  - Electron density
  - Electron temperature
  - Emission measure (distribution)
  - Elemental abundances





OBSERVING MODE (STUDY)	LINE LIST , window parameters	STUDY PARAMETERS	No of repeats	Duration in hours (inc. 10sec per repeat)	Science data Compression	Header Data Vol, Mbytes	Net Data Vol, Mbytes	Net Data rate Kbit/s	Spectral-line performance (line-SNR and spatial resolution combinations)
Spectral Atlas	Full spectrum, Cal-mode (32 spectra x 64 pixels wide)	4" slit, 60 s exposure+5s readout+45s processing+0.1sec step, X-range=10 times 4" step X-start=arbitrary	2	0.67	Profiles 10:1 (note 1)	0.07	**8.484**	**28.26**	line-SNR>10 at 4"x2" in C-III, O-VI, Ne-VIII, and Mg-IX-AR
Composition Mapping	15 total 2 *Spectral* +13 *Intensity* 32 pixels wide	4" slit, 20+10s set-up, 180 s exp + 0.25 step, X=64 times 4" step X-start=arbitrary	1	3.21	Profile SHC 20:1 Intensity JPEG 10:1	0.01	**0.606**	**0.42**	line-SNR>10 at 4"x2" in C-III, O-VI, Ne-VIII, and Mg-IX-AR
Dynamics	4 *Spectral* (H I, C III, O VI, Ne VIII), 32 pixels wide 6 *Intensity*	2" slit,20+10s setup, 5 s exposure +0.3s step, X=128 times 2" step X-start=arbitrary	10	1.97	Profile SHC 20:1 Intensity JPEG 10:1	0.16	**15.756**	**17.79**	line-SNR>10 at 2"x2" in C-III, O-VI, in Ne-VIII-AR, and at 5"x5" in Ne-VIII-CH, QS
Limb (low corona above limb)	3 *Spectral* (C III, O VI, Ne VIII) 3 *Intensity* (coronal line)	4" slit, 20+10s setup, 60 s exp+0.3s step, X=224 times 4" step	1	3.76	Profile SHC 20:1 Intensity JPEG 10:1	0.05	**2.121**	**1.25**	line-SNR>10 at 4"x2" in C-III, O-VI, Ne-VIII, and Mg-IX-AR
CME Watch	5 *Spectral* , 10 *Intensity*	4" slit, 20+10s setup, 30 s exp +0.3s step, X=96 times 4" step X-start=arbitrary	30	24.49	Profile SHC 20:1 Intensity JPEG 10:1	0.45	**45.45**	**4.12**	line-SNR>10 at 4"x2" in C-III, O-VI, Ne-VIII, and at 4"x4" in Mg-IX-AR
30"-wide movie (sit & stare)	1 or 2 *Spectral* , 32 pixels per window (extract the full slit width)	30" slit, 20+10s setup, 5 s exp +0s step, X=128 times 0" step X-start=arbitrary	1	0.17	Profiles 10:1 (note 3)	0.03	1.3433	17.62	NA
90"-wide movie	1 or 2 *Spectral* , 32 pixels per window (extract the full slit width)	30" slit, 5 s exp +0.3s step, X=3 times 28" step X-start=arbitrary	40	0.51	Profiles 10:1 (note 3)	0.03	1.3433	5.85	NA
Waves (Sit & stare)	3 Spectral (C III, O VI, Ne VIII)	4" slit, 20+10s setup, 5 s exp + 0s step, X=480 times 0" step	5	3.38	Profiles 10:1 (note 2)	1.13	76.457	50.34	line-SNR>10 at 4"x2" in C-III, O-VI, Ne-VIII-AR, and at <4"x6" in Ne-VII-CH,QS
Two-exposure	2 *Spectral*. Combination of bright and faint lines. Use spectra to monitor saturation	4" slit, 20+10s, 5s + 55 s exp+0.3s step, X=64 times 4" step	5	5.40	Profiles 10:1 (note 2)	0.06	3.535	1.45	line-SNR>10 at 4"x2" in C-III, O-VI, Ne-VIII, and Mg-IX-AR

Notes

1 For *Cal-mode*, SHC cannot be used so compression is focal plane (JPEG) only. Also the readout pipeline is slower than other modes

2 for spatial X<64 the profiles compression is JPEG as series of (lambda,Y) images (SEB-0800)

3 limited ratio, JPEG not SHCas x-dimension is pseudo-spatial

SPICE Operations Center – IAS Lead

The **Observer** can freely access the STUDY GENERATOR, BOP, TIMELINES tools and databases through an Web GUI.

You are an Observer who want to use **SPICE** data and eventually design an observation:

- **STUDY**: observing program. Only the PLANNER has edit access. Read only for the Observer. Ask the SPICE team for a new Study design. It goes through a VALIDATION process.
- A **BOP** (Basic Operation Program) is the brick of a timeline and it can contain one or more Studies. The Observer has Read and Edit access but there is a VALIDATION to be applied by the planner.

In addition:

- Only 48 science Studies available on-board that have to be uploaded well in advance of the RSWs.
- The process from a new Study design to upload and run it is long and complex: try to use the already designed Studies in the SPICE database.

Low Latency Data

- No (very little) real time data
- It can take up to 6 months (1 orbit) to get the data down
- But need near real time images for
  - Planning purposes (i.e retargeting)
  - Verify instrument performances
  - Selective data downlink (not all the RS instruments)

Low latency data concept

- Dedicated packet store (~hard drive partition) in the S/C SSSM
- High priority, part of the daily TM dump
- 1 MB/d max for each instrument

SPICE data products

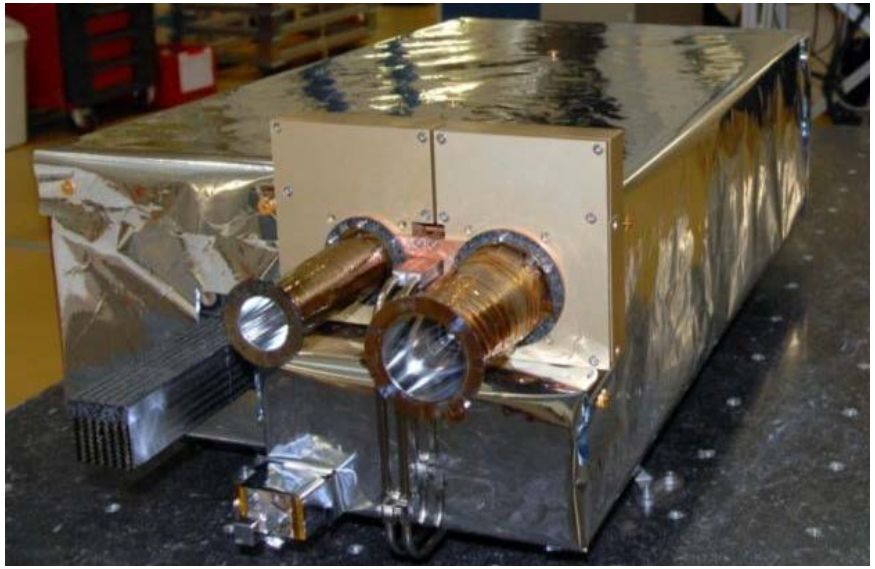
Low latency data: reduced version of each Study (smaller FOV, highest compression)

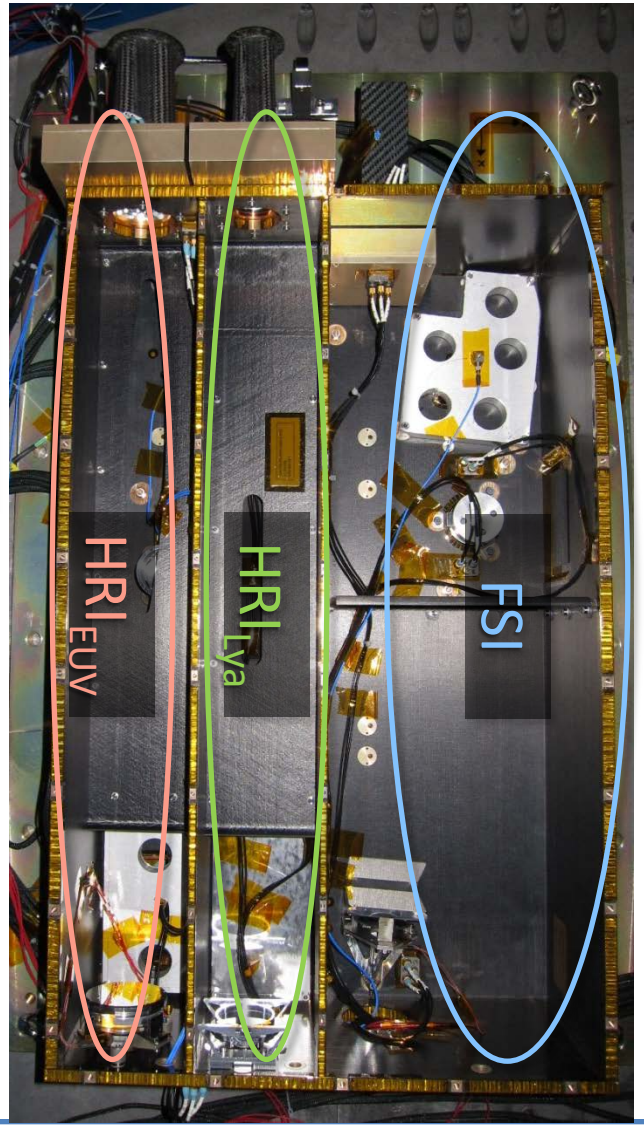
Science data:

- **L0**: raw decompressed data from telemetry pipeline
- **L1**: engineering data, uncalibrated, updated header (pointing and timing)
- **L2**: science data, corrected, calibrated to physical units
- **L3**: anything else derived from L2 (still under discussion)
  - For each spectral window and spatial pixel:
    - Total intensity (with background subtracted) or
    - Gaussian line fit parameters and quality indicators
  - For each raster, from fitted Gaussian lines parameters:
    - Abundances/FIP bias (new fast and reliable diagnostics under test)
    - Temperature/Density
    - …more to be decided: any request from METIS?
  - Concatenated L3 fits: time series of data products for multiple observations of the same kind
  - Quicklook MPEG and JPEG

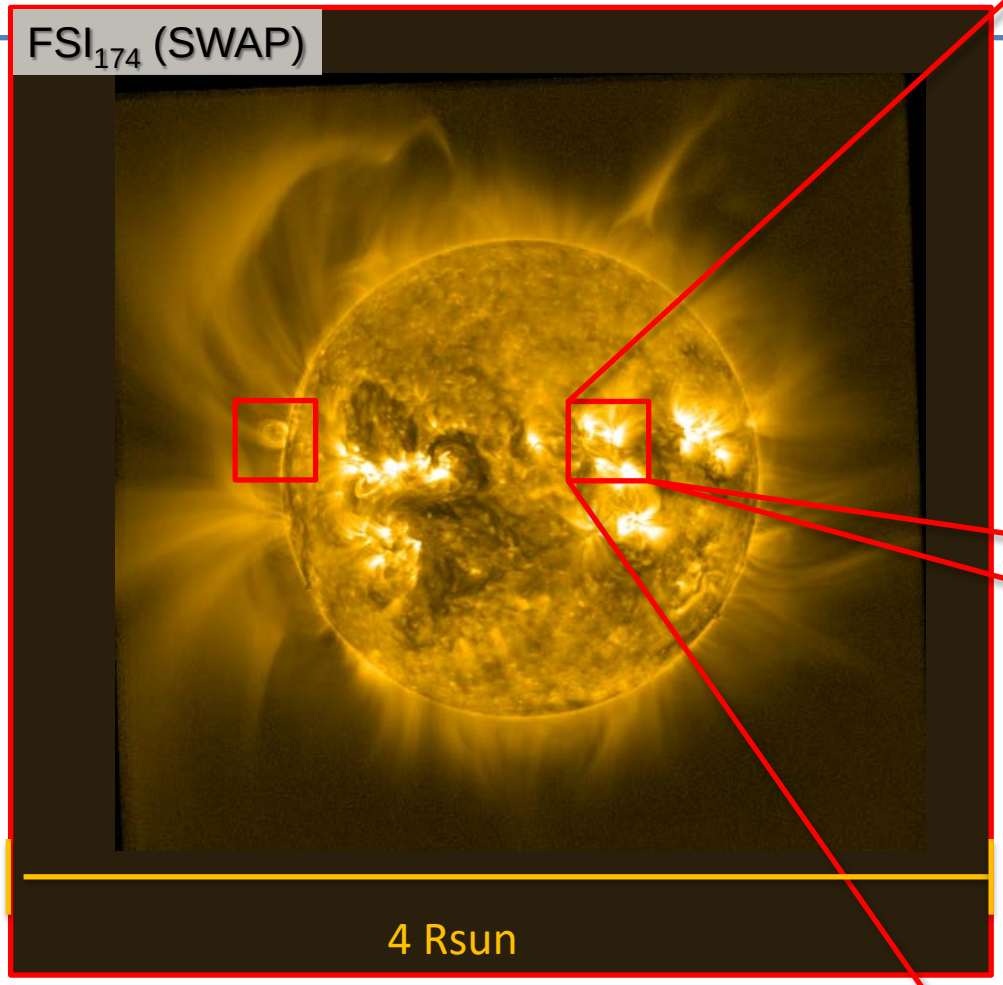
Extreme Ultraviolet Imager

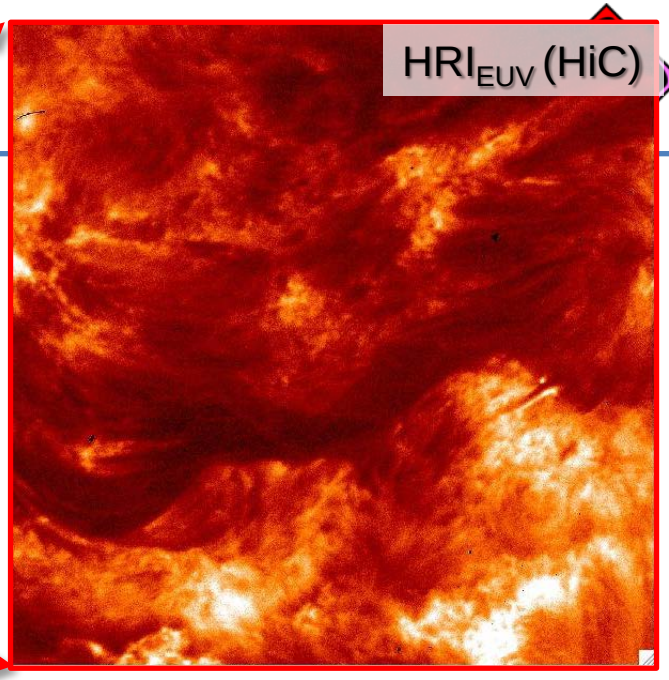
FSI dual EUV	Passband centre	17.4 nm(Fe x) & 30.4 nm (He II)
	Field of View	3.8 arcdeg × 3.8 arcdeg
	Resolution (2 px)	9 arcsec
	Typical cadence	600 s
HRI Lyman-α	Passband centre	121.6 nm (H I)
	Field of View	1000 arcsec square
	Resolution (2 px)	1 arcsec
	Typical high cadence	Sub-second
HRI EUV	Passband centre	17.4 nm (Fe X)
	Field of View	1000 arc sec square
	Angular resolution (2 px)	1 arcsec
	Typical high cadence	2 s

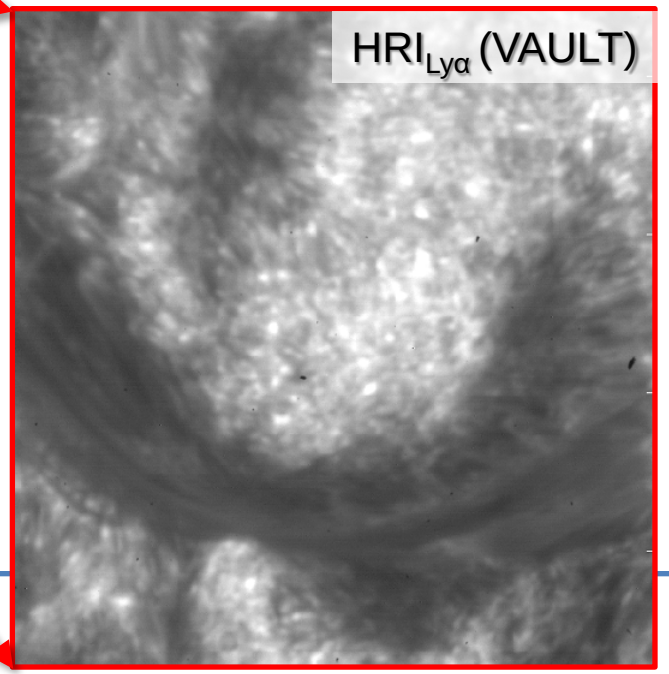




EUI @ perihelion





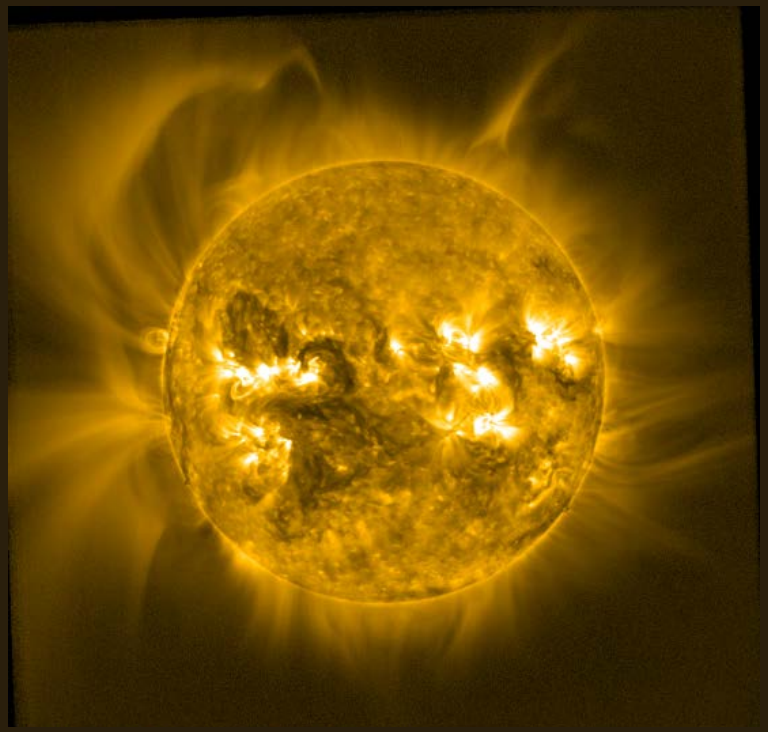


FSI: global morphology of the source regions
Active regions, coronal holes, CMEs, etc.
HRI: highest ever resolution UV images (200 km)
Fine scale structure, dynamics

FSI: Extremely Wide Field of View

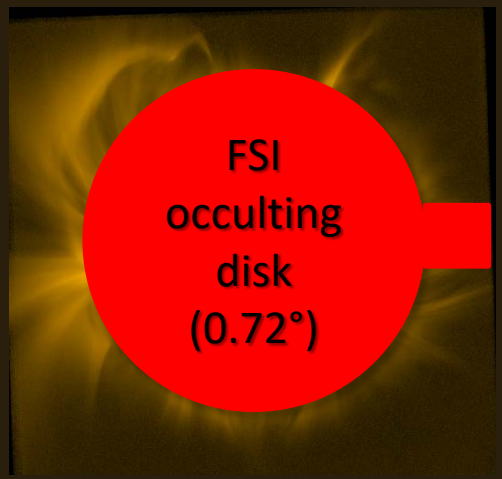
@ 0.28 A.U.

3.8°×3.8°



@ 0.43 A.U.

3.8°×3.8°



Terra incognita

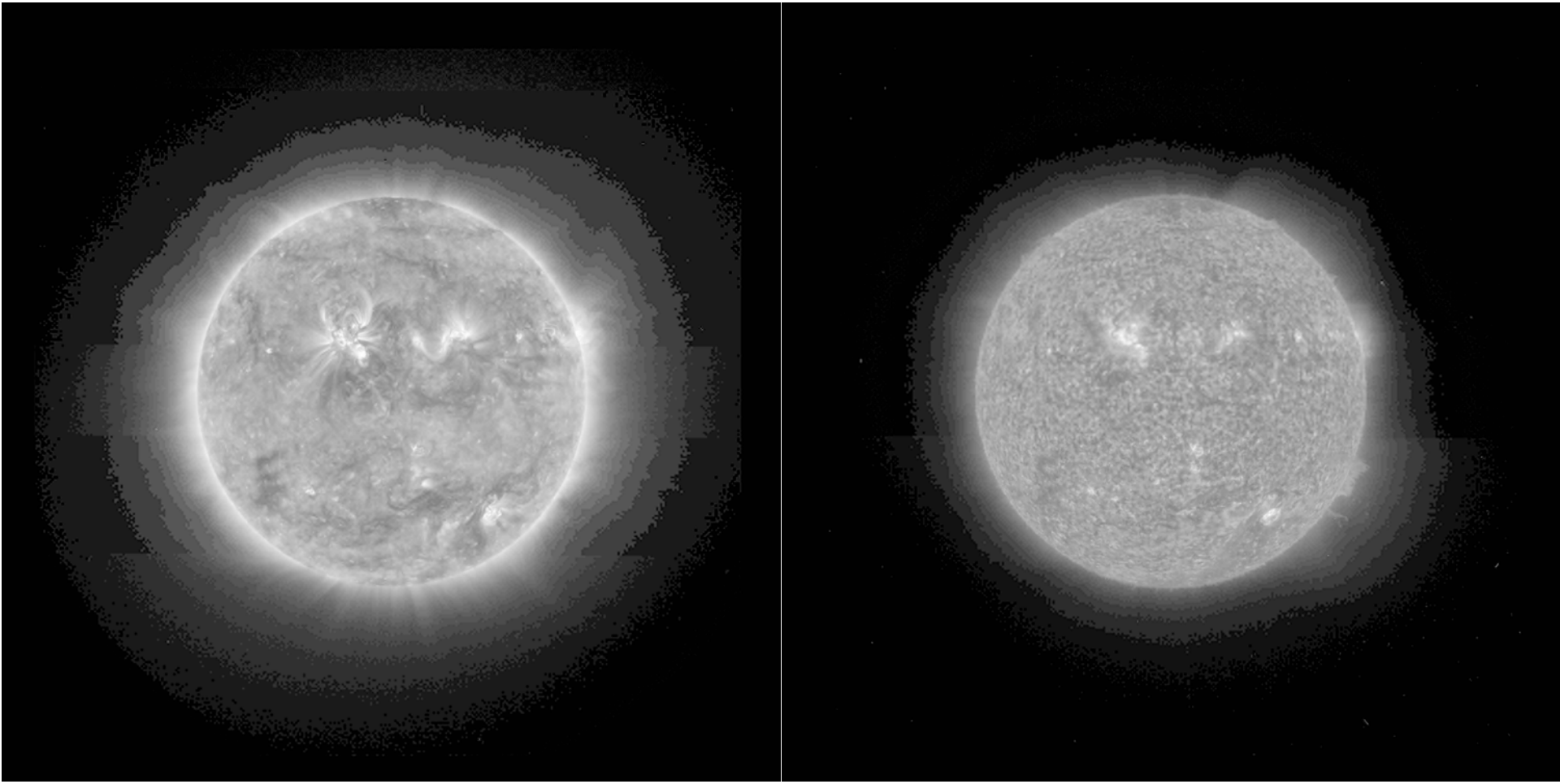
EUI Observing Programs

Science Program	Science Data Requirements	Channel	Cadence (sec)	Compression	TM (Gbits / h)
Synoptic	4 x 4 Rsun window centered on disc center	FSI_{174} FSI_{304}	600	50	0.0075
Reference Synoptic	4 x 4 Rsun window centered on disc center	FSI_{174} FSI_{304}	1day	4	0.0025
Global eruptive event	Full FOV centered on event.	FSI_{174} or FSI_{304}	10	10	4.43
Coronal Hole	Full FOV centered on CH with boundary and/or plumes. High lat., perihel., possibly near co-rot.	HRI_{174} $HRI_{Ly\alpha}$	30 30	5 15	1.75
Quiet Sun	Full FOV centered on QS. Perihelion/encounter, near co-rotation	HRI_{174} $HRI_{Ly\alpha}$	8 1	7 15	16.6
Active region	Full FOV centered on AR. Perihelion/encounter, near co-rotation	HRI_{174} $HRI_{Ly\alpha}$	2 1	15 15	19.7
Eruptive event	Perihelion/encounter, near co-rotation Full FOV	HRI_{174} $HRI_{Ly\alpha}$	1 1	15 15	26.1
Discovery	High cadence dynamics Perihelion/encounter, near co-rotation, 645 x 645 FOV for Lyα	HRI_{174} $HRI_{Ly\alpha}$	1 0.1	15 15	26.1

EUI Low latency data

Beacon data	Low-resolution (high compression) FSI_{174} & FSI_{304} images	~15 minutes	Max. 1. MBytes / day
Synoptic data	Medium quality, But low cadence, FSI_{174} & FSI_{304} images	~15 minutes	
Sample HRI data	EUV & Lyα	1 set / day	

FSI beacon @ 0.0625 bpp (x192)



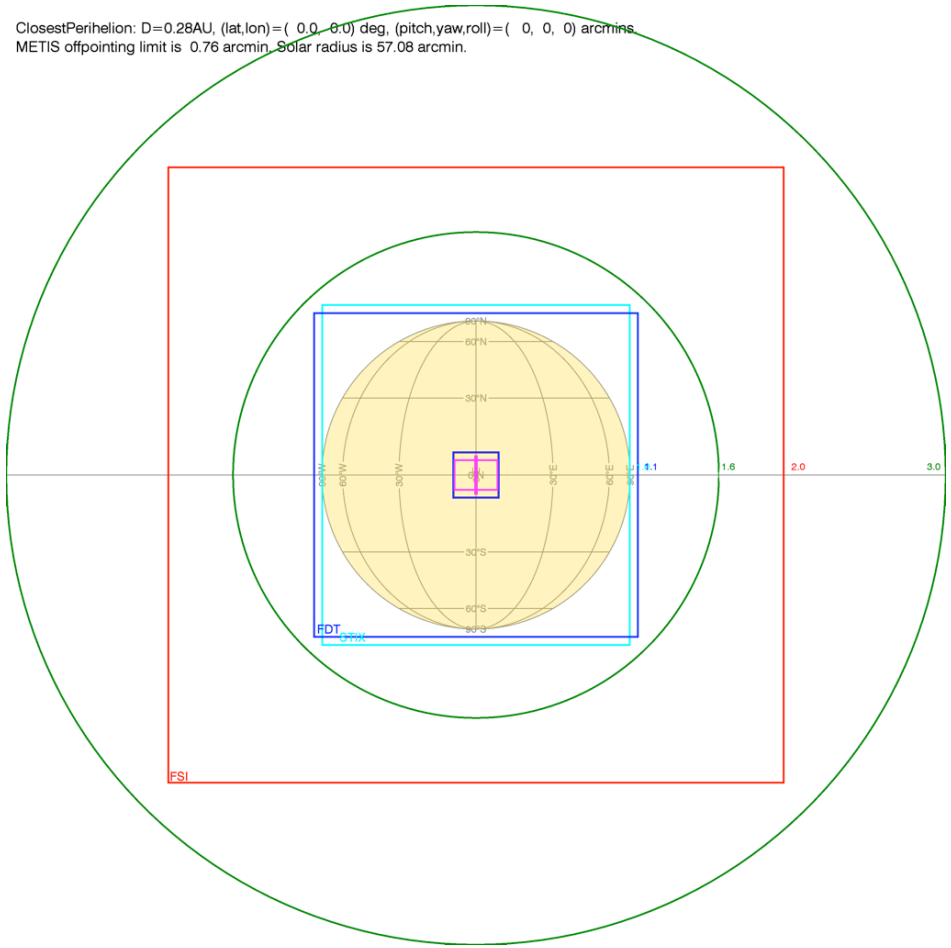
EUI Data Center (EDC) – ROB Lead

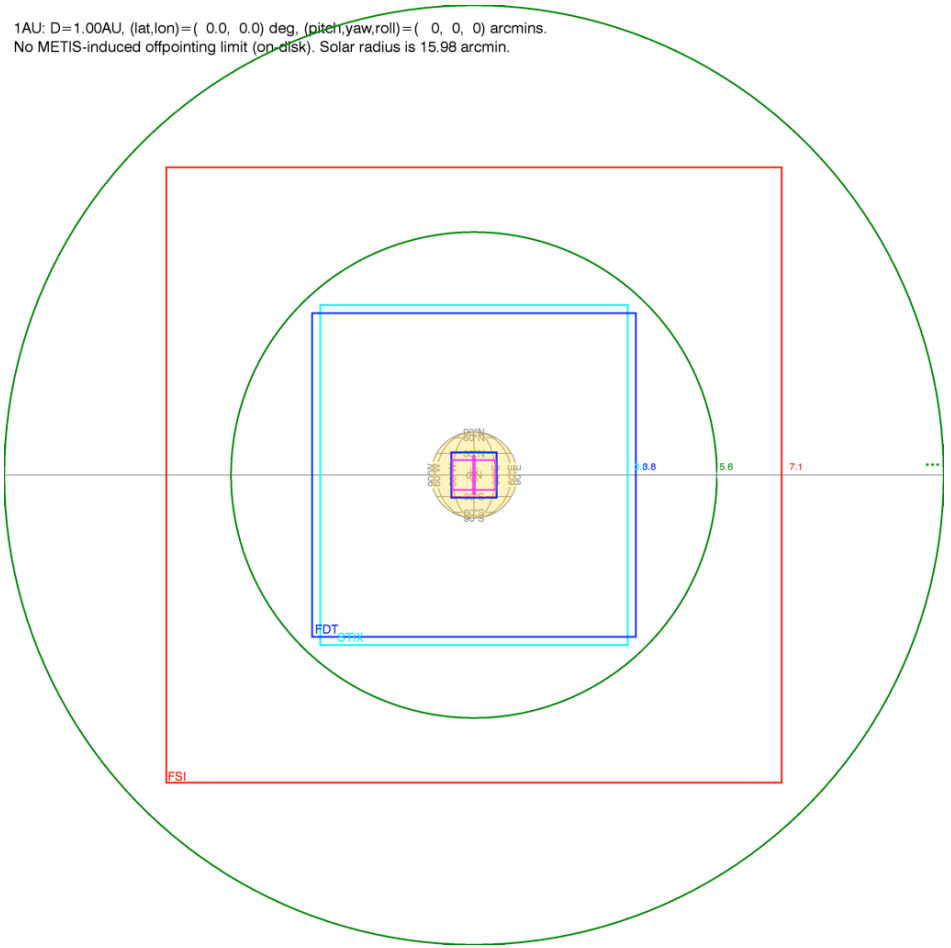
- To prepare the instrument operations, monitor EUI health and process dowlinked data to science products.
- Science data are prioritized:
  - on ground pre-determined priority number
  - on board software can change it
    - By event detection
    - By software to check the data quality
  - On ground Inspection of LL and non SOLO space weather data → new TCs to change the priority
- EUI quicklook to be run at SOC

EUI Data product

- L0: raw decompressed data from telemetry pipeline
- L1: engineering data, uncalibrated, updated header (pointing and timing)
- L2: science data, corrected, calibrated to physical units
- L3: anything else derived from L2
  - JPEG2000 to feed JHelioviewer.
  - Histograms of not dowloaded data (science and calibration).

RS Instruments relative FOVs





Closest Perihelion

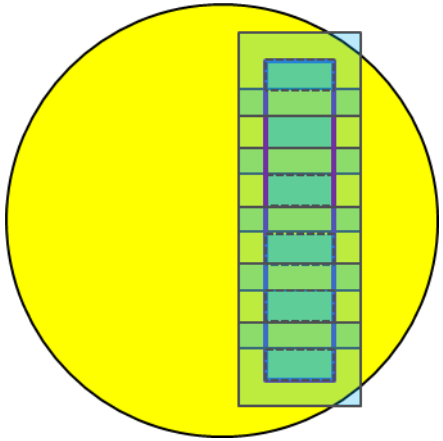
1 A.U.

SPICE MOSAIC

To provide extended synoptic data for connectivity:

- The best strategy to do it is under discussion
- N rasters to cover ~ 2 Rsun at perihelion (3% of disk at perihelion).
- TBD for other distances: compromise with telemetry, duration, S/C -METIS constraints.
- Products: Intensity, velocity and FIP bias maps

E W



From Chris Watson

- EUI/HRI H I-Lyα MOSAIC
- West extended EUI/FSI (& METIS) FOV
- East minimum height of METIS FOV close to the limb.

Synergies with Metis

- Several science cases in common: CMES Watch, ….
- Coordination:
  - Metis and EUI/FSI is easy
  - Metis and EUI/HRI – SPICE more difficult
    - During off point with a time delay if Metis is off (~10m minimum to re-centering the S/C and open the door)
    - Useful if we get a S/C directed halo CMEs (and we are super lucky to get the source region)

Eruptions observation plan

EUI

- The high cadence program is running non-stop
- Data are written in the cyclical buffer (1h)
- The EUI event trigger for filaments and flares runs on the incoming data
- When the flag goes ON the EUI buffer is transferred to the S/C buffer.
- On ground cross-check of the data

Metis

- CMEOBS activated by a CME event internal flag or (if CME_EXT on) by EUI and STIX flags. But not tested yet.

Flags work also in opposite direction: Metis (STIX, PHI) flags → EUI freezers the buffer

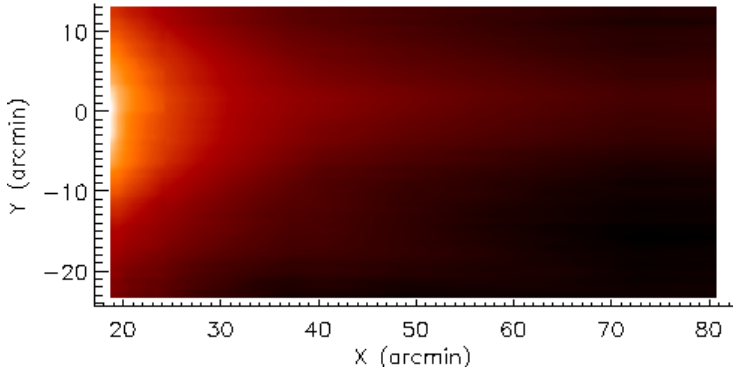
SPICE

- Runs the CMEWATCH Study. No cycling buffer, no telemetry problems. No reaction to flags for eruptions. VSTP plan under analysis

Coordinated observation at the limb

- In most of the cases Metis will be off
- But we want Metis! Need for a deeper thinking on how to act to increase the science return.
- Example, during eruption (perihelion):
  - S/C off pointed, METIS off.
  - Eruption with v ~ 500 km/s. Rsun=1.5 in ~ 11 min, Rsun=3 in ~ 40min
  - Pointing change + Metis open the door as quick as possible: ~ 10 min.
  - We can plan this in advance. But:
    - The chance to be at the right time at the right moment is low
    - Metis door can be open for a limited number of times.

Winds Source regions (see also Andretta talk)



Goal: map the plasma and magnetic field properties of the candidate source regions and link them to in-situ measures.

How: derive N, T, FIP bias, v, B from the (photosphere) chromosphere to the corona. H, p, He and heavy ions.
In-situ: FIP bias timelines and plasma properties
e.g. L_SMALL_HRES_HCAD_Fast_Wind

PHI: full FOV + high resolution

SPICE Composition Mapping/Dynamics: Te, Ne, FIP bias, DEM/EM maps

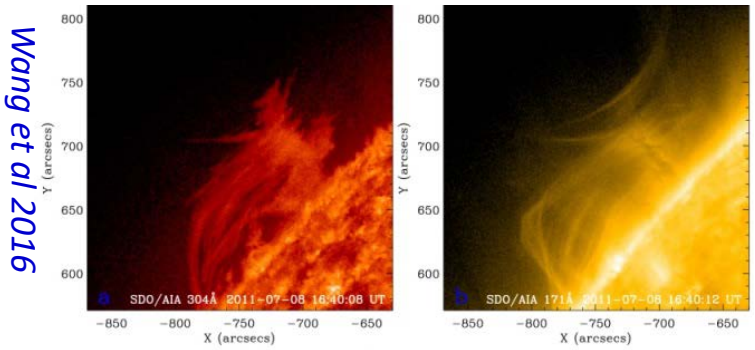
EUI/HRI: high resolution morphology and dynamics 174 & H-I Lya

EUI/FSI: morphology and dynamics in He II 304 and Fe X 174

METIS MAGTOP, WIND, FLUCTS: large scale structuring, turbulence

Maps of **N** (VL), **v** of H^0

SOLO-DKIST: Coronal prominence-cavity systems



Wang et al 2016

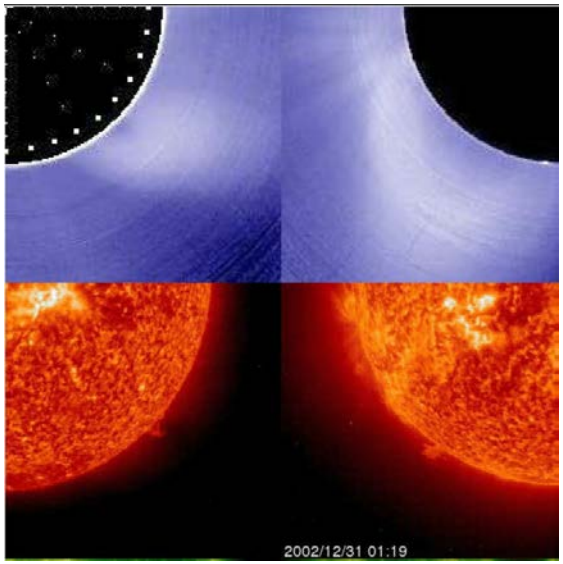
- PCTR is hot (> 4 10^5 K), *Parenti et al. 2012*
- Dynamics & exchange of material, *Schmit & Gibson 2013*
- Temperature substructures,T>1.4 MK in the cavity e.g. *Kucera & Landi 2012, Habbal et al. 2010*
- Cavity height goes up to 1.6 Rsun

Solar Orbiter:

- Cavity-prominence morphology and dynamics EUI/FSI 171 and 304
- Prominence morphology and dynamics EUI/HRI Lya and 171 (x 3 in resolution) (pointing change)
- PCTR-corona with SPICE: link 171 – 304, N-T, Doppler-V (pointing change)
- Can Metis see the cavity above 1.6-1.7 Rsun? (pointing change) Density, dynamics

DKIST at the limb: Magnetic structure, Coronal density

- SOLO in quadrature
- SOLO in conjunction or opposition



Furler et al. 2009

Actions for the upcoming months

- Synergies using the H-I Lyα, H-I Lyβ, He II
- He lines in SPICE: work in progress
- Metis observations after/during off-pointing
- Coordinate synoptic programs (out of RSW)
- Coordinate data products
- …

Thanks to V. Andretta, F. Auchère, E. Buchlin,
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