How to search, retrieve and analyse IRIS data

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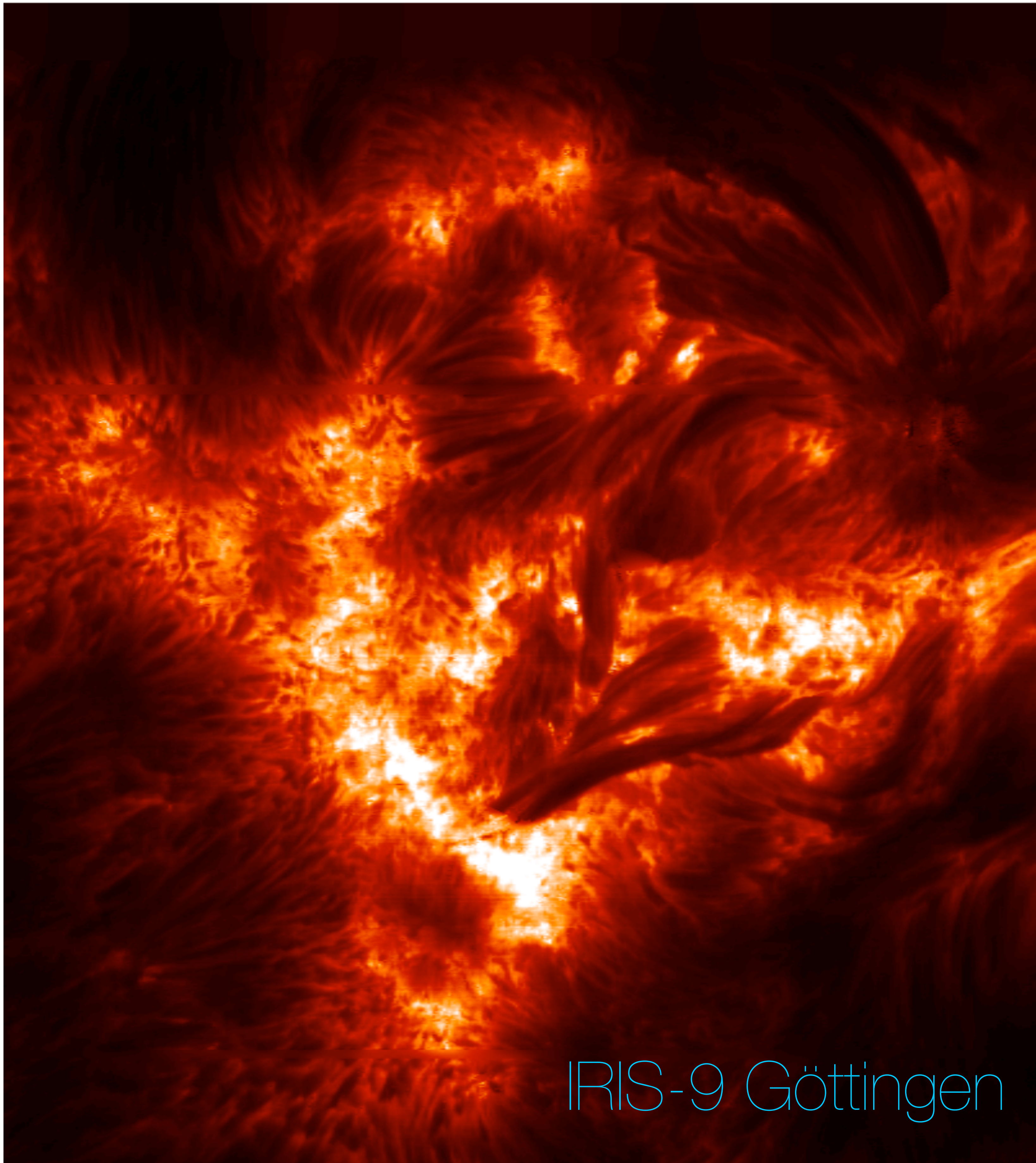
09:30–10:45 IRIS data analysis

10:45–11:00 IRISpy by D. Ryan

11:00–11:30 Coffee

11:30–12:45 Hands-on tutorials

Rosseland Centre for Solar Physics



Course Resources

Slides and tutorials:

https://folk.uio.no/tiago/iris9

Lecture Overview

Part 1

- Introduction and structure of IRIS data
- Getting the data, quicklook tools
- Working with IRIS data in Python
- Working with IRIS data in IDL
- Additional Data Calibration
- CRISPEX

Tutorial

- Hands-on tutorials

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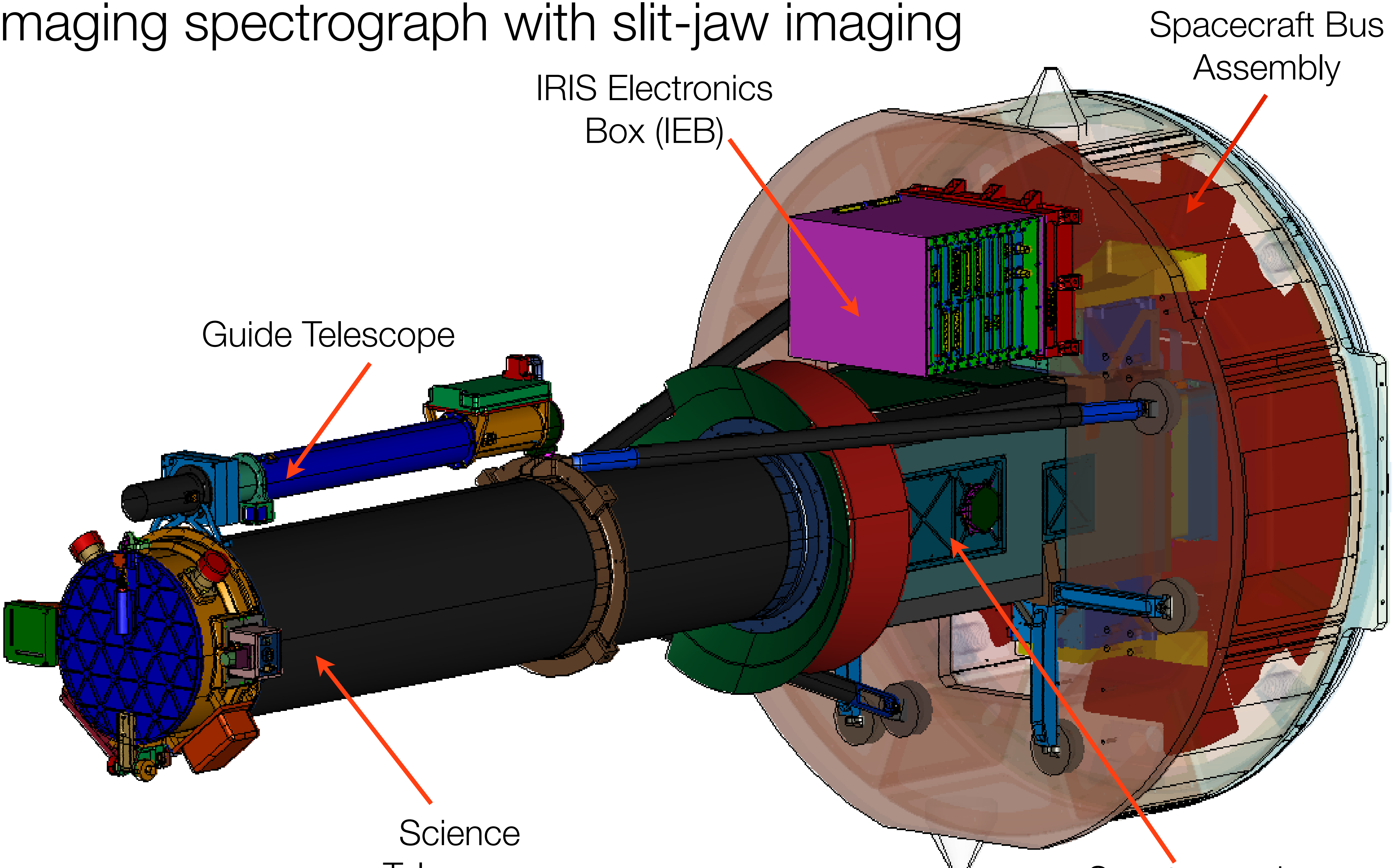
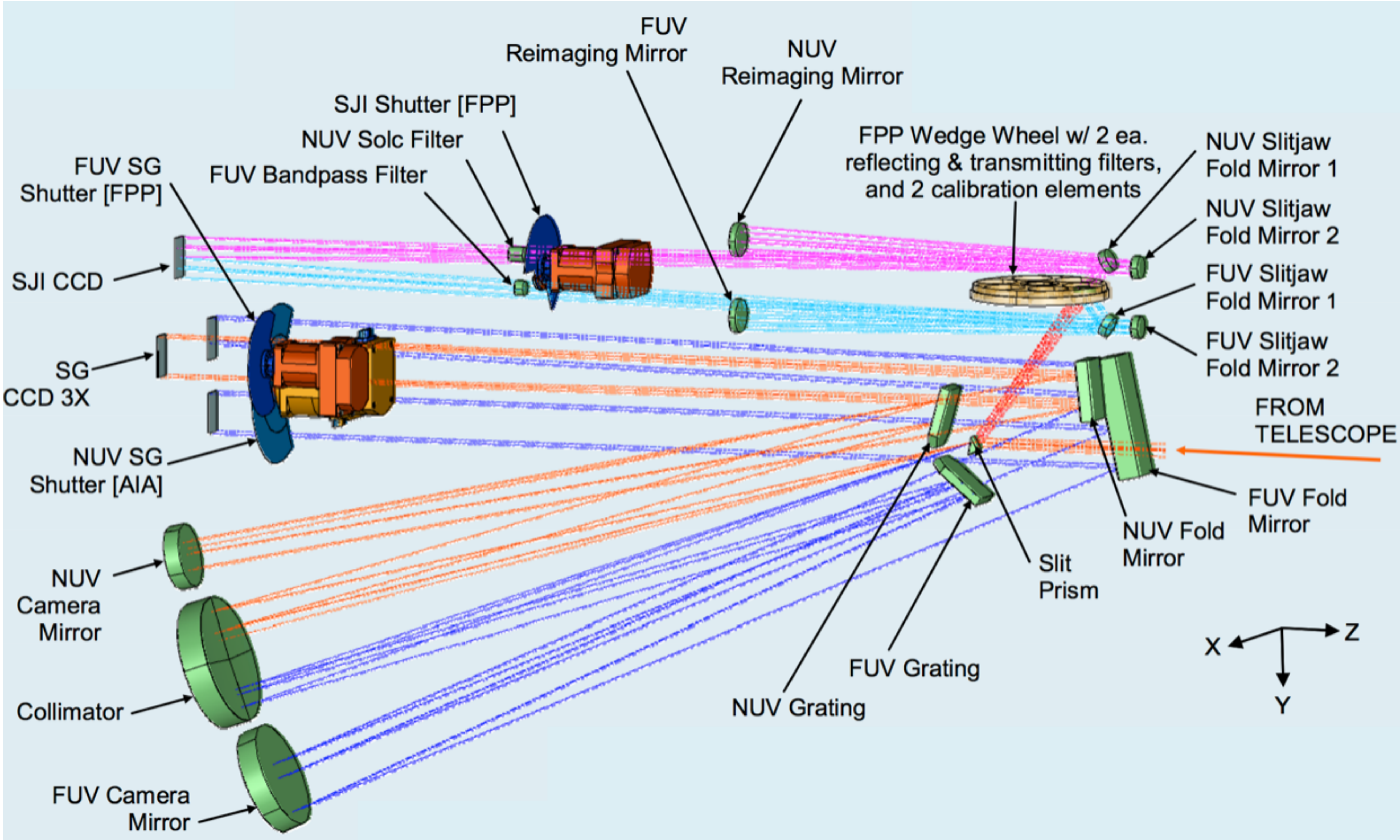
What is IRIS?

High resolution, far/near UV imaging spectrograph with slit-jaw imaging



Courtesy Bart De Pontieu



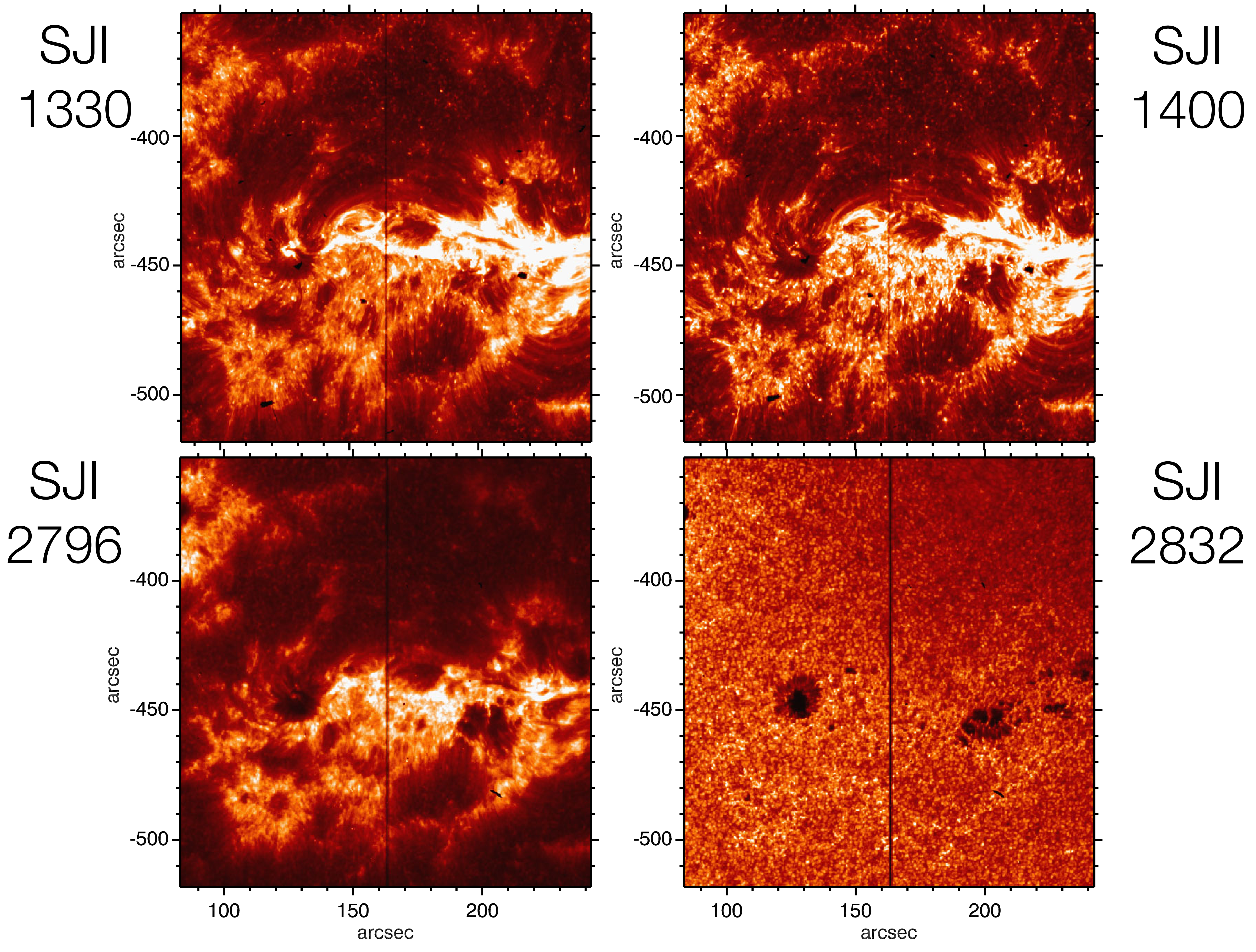
Schematic diagram of path taken by light in the FUV spectrograph (dark blue), NUV spectrograph (orange), FUV slit-jaw (light blue) and NUV slit-jaw (purple) path.

Table 2 IRIS spectrograph channels. Dispersion, Camera Electronics Box (CEB), and Effective Area (EA) vary for the three bandpasses.

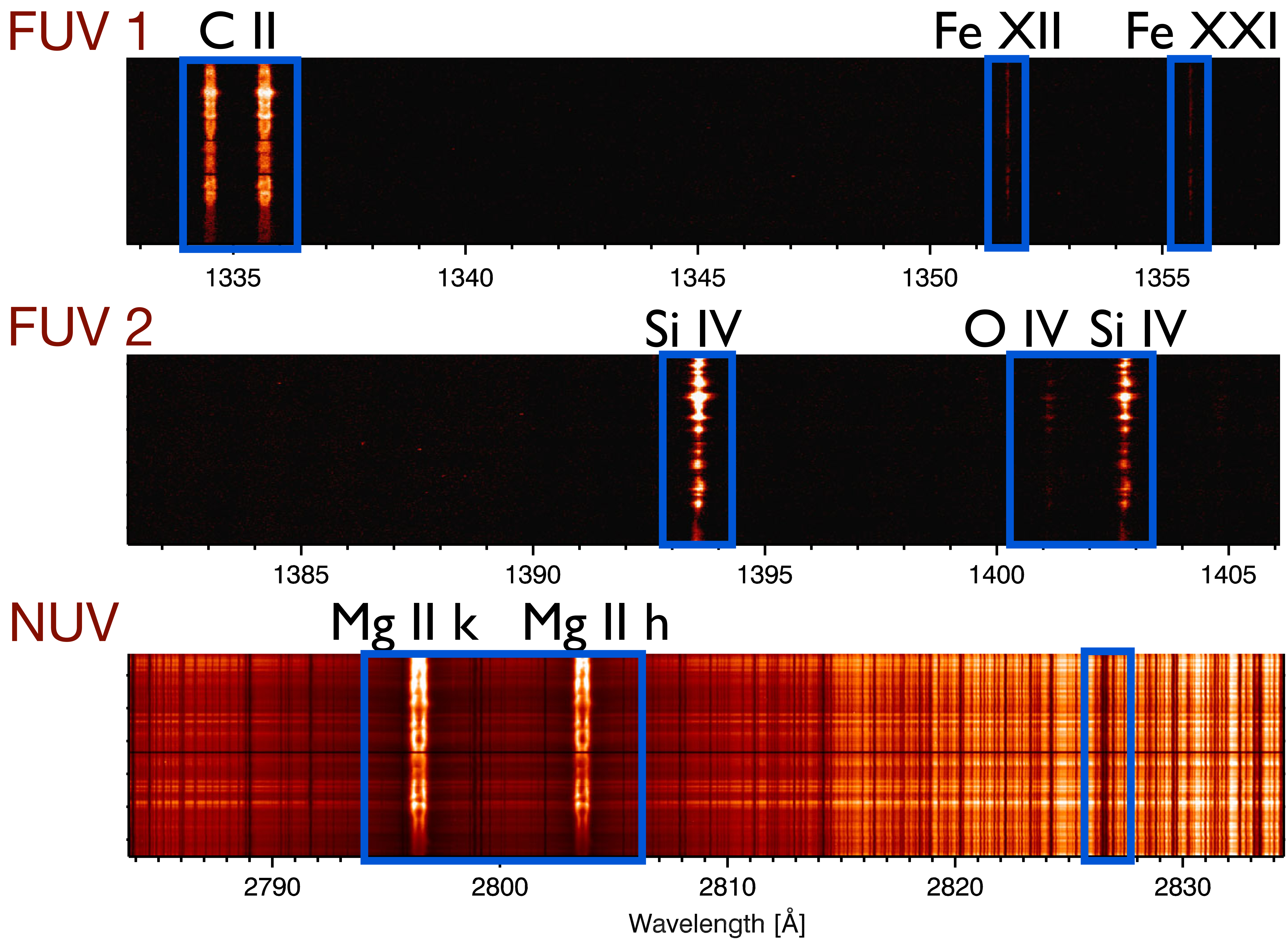
Band	Wavelength [Å]	Disp. [mÅ pix^{-1}]	FOV [$''$]	Pixel [$''$]	CEB	Shutter	EA [cm^2]	Temp. [$\log T$]
FUV 1	1331.7 – 1358.4	12.98	175	0.1663	1	FUV SG	1.6	3.7 – 7.0
FUV 2	1389.0 – 1407.0	12.72	175	0.1663	1	FUV SG	2.2	3.7 – 5.2
NUV	2782.7 – 2835.1	25.46	175	0.1664	2	NUV SG	0.2	3.7 – 4.2

Table 3 IRIS slot channels. Filter-wheel positions can be either transmitting (T) or reflecting/mirrors (M).

Band-pass	Filter wheel	Name	Center [Å]	Width [Å]	FOV [$'' \times ''$]	Pix. [$''$]	EA [cm^2]	Temp. [$\log T$]
Glass	1 T	5000	5000	broad	175^2	0.1679	–	–
C II	31 M	1330	1340	55	175^2	0.1656	0.5	3.7 – 7.0
Mg II h/k	61 T	2796	2796	4	175^2	0.1679	0.005	3.7 – 4.2
Si IV	91 M	1400	1390	55	175^2	0.1656	0.6	3.7 – 5.2
Mg II wing	121 T	2832	2830	4	175^2	0.1679	0.004	3.7 – 3.8
Broad	151 M	1600W	1370	90	175^2	0.1656	–	–

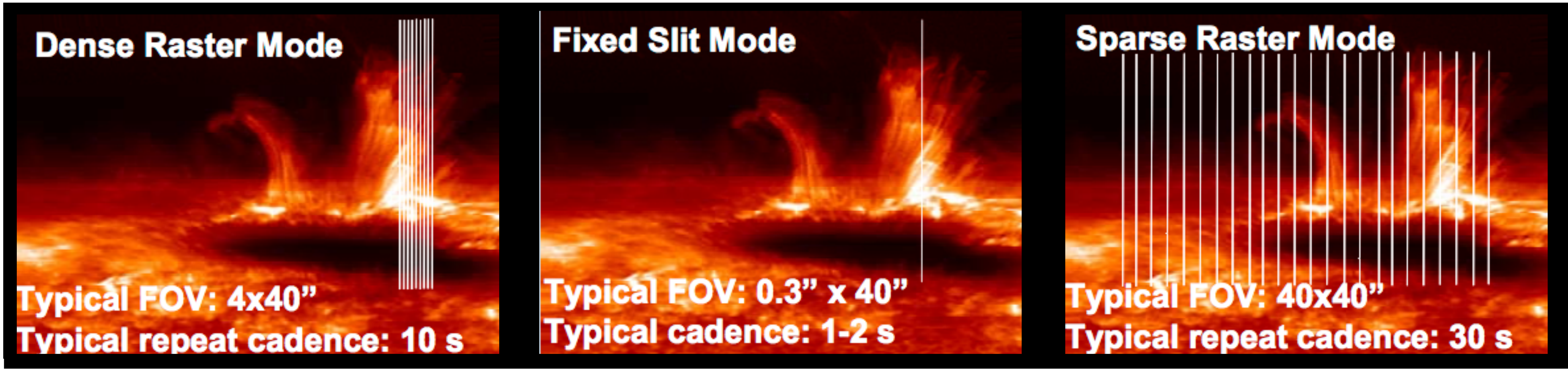


SJI 1330
SJI 1400
SJI 2796
SJI 2832
arcsec
-400
-450
-500
100
150
200

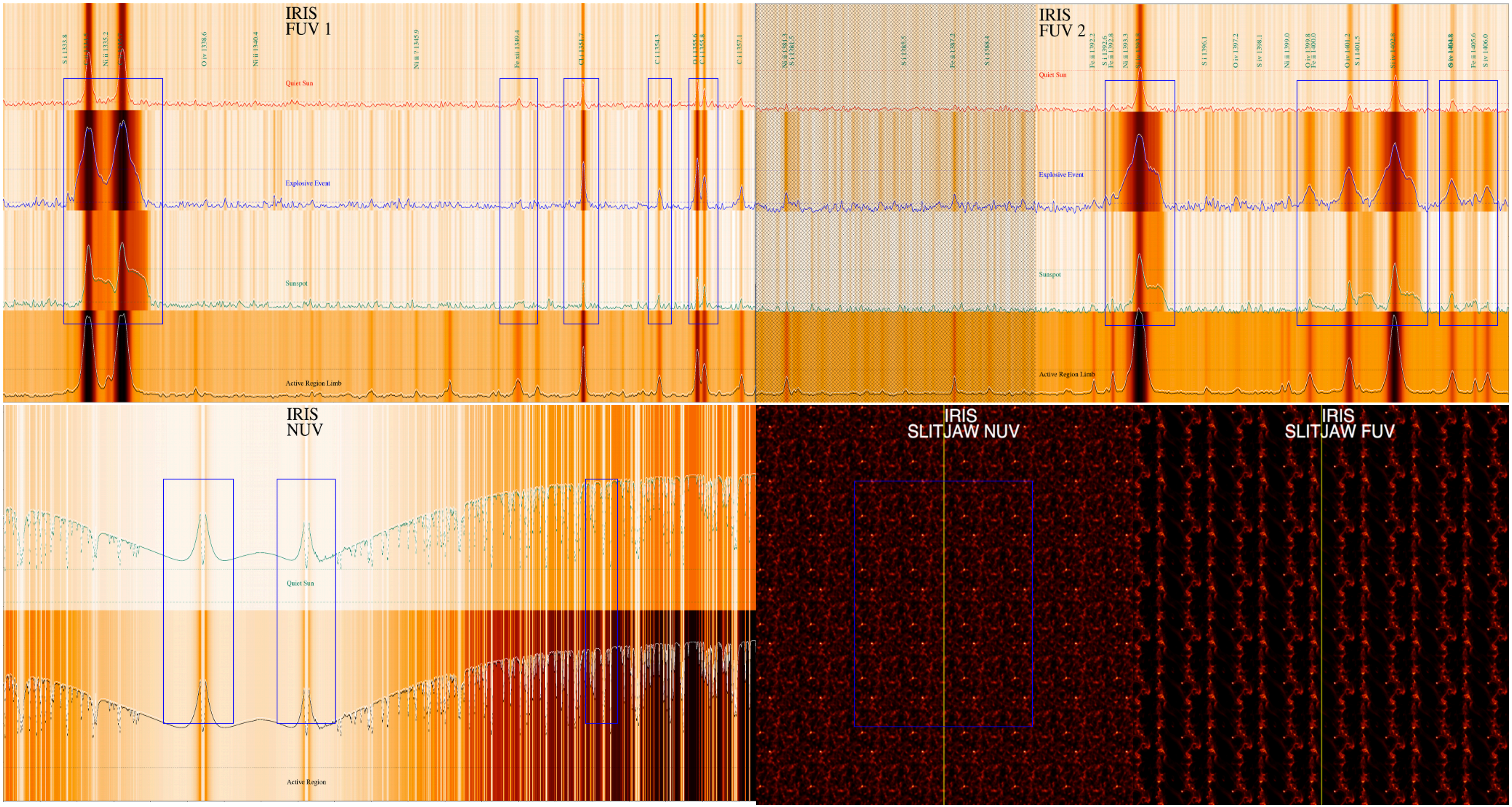


FUV 1
C II
Fe XII
Fe XXI
1335
1340
1345
1350
1355
FUV 2
Si IV
O IV
Si IV
1385
1390
1395
1400
1405
NUV
Mg II k
Mg II h
2790
2800
2810
2820
2830
Wavelength [Å]

IRIS also performs sparse rasters to improve cadence (resulting in reduced data rate)

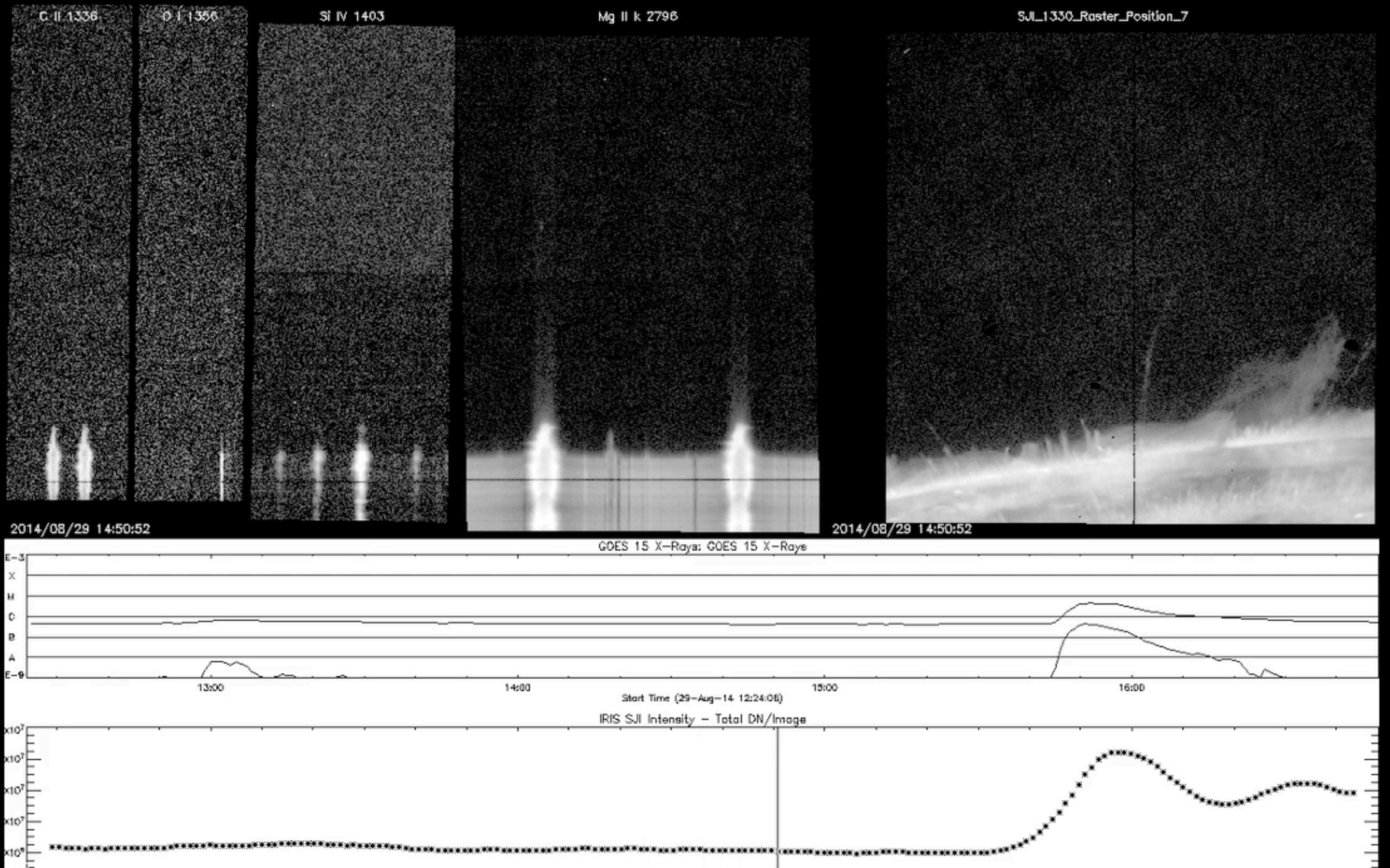


IRIS camera layout



C II O I Si IV Mg II SJI 133 (C II + Fe XII)

133.6 135.5 140.3



Observing tables

OBS ID codifies the observing mode

OBS ID parent	Description
0-100	Basic raster type (sit-and-stare, rasters, …)
0-2,000	SJI choices
0-12,000	Exposure times
0-220,000	Summing modes (applied to FUV, NUV, SJI)
0-750,000	FUV summing modes
0-4,000,000	SJI cadence
0-10,000,000	Compression choices
0-180,000,000	Linelists
3.8-4 billion	OBS table generation number

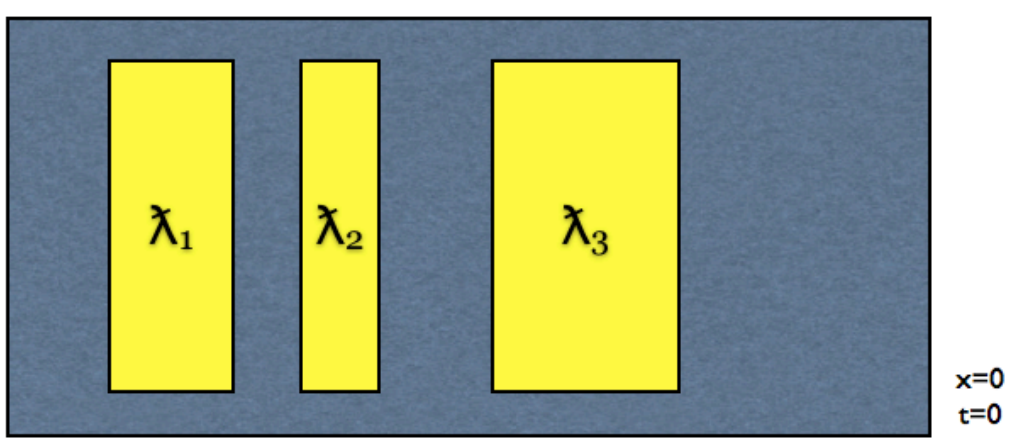
See IRIS paper or ITN 31 for a detailed listing of the different modes.

IRIS data levels

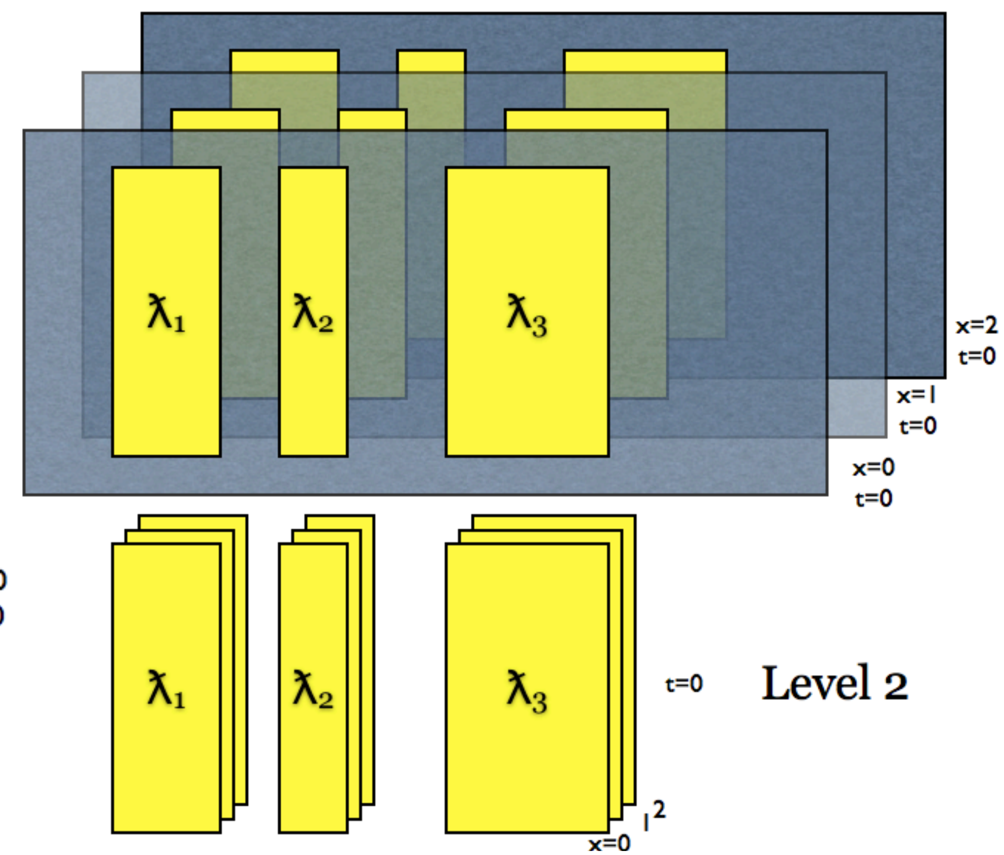
Level	**Processing**	**Notes**
TLM	Capture	Raw telemetry
0	Depacketized	Raw images with basic keywords
1	Reorient images to common axes: North up (0^{o} roll), increasing wavelength to right	Lowest distributed level
1.5	Dark current and offsets removed Flag bad pixels and pixels with spikes Flat-field correction Geometric and wavelength calibration	Transitory data product for level 2 production. Not distributed, for internal use only. Use iris_prep to go from level 1 to 1.5
2	**Recast as rasters and SJI time series**	**Standard science product. Scaled and stored as 16-bit integer.**
3	Recast as 4D cubes for NUV/FUV spectra.	*CRISPEX* format. May include transposed (sp) version. No SJI.

IRIS data levels

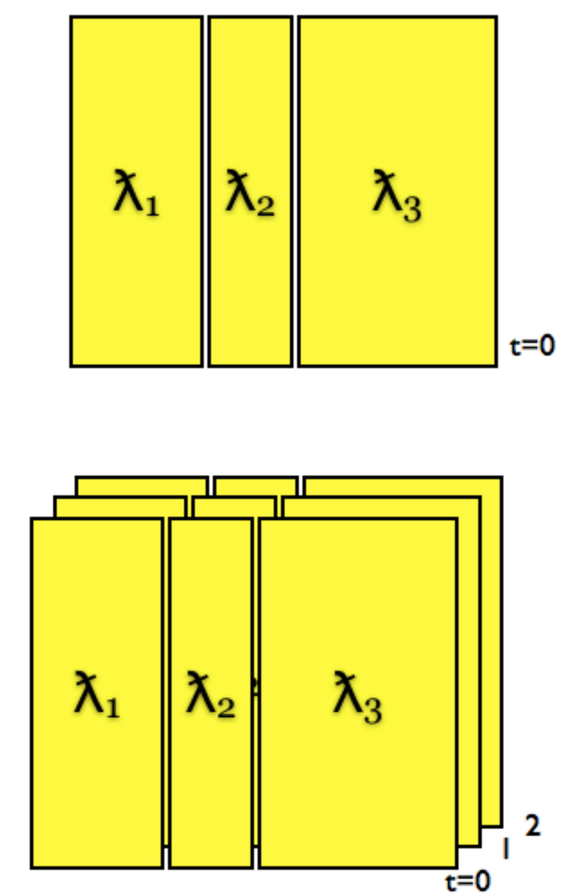
Level 1



Level 2



Level 3



Level 2 FITS structure: raster (SP)

HDU #	HDU type	Contents	Data dimensions
0	Primary	Main header	No data
1	Image Extension	Data for wavelength window 1	[`nwave_1`, `ny`, `nrt`]
2	Image Extension	Data for wavelength window 2	[`nwave_2`, `ny`, `nrt`]
…			
n	Image Extension	Data for wavelength window n	[`nwave_n`, `ny`, `nrt`]
n + 1	Image Extension	Auxiliary metadata	[47, `nrt`]
n + 2	Table Extension	Technical metadata	[`nrt`, 7]

Level 2 FITS structure: SJI

HDU #	HDU type	Contents	Data dimensions
0	Primary	Main header and data	[`nx`, `ny`, `nt`]
1	Image Extension	Auxiliary metadata	[30, `nt`]
2	Table Extension	Technical metadata	[`nt`, 5]

INTERFACE REGION IMAGING SPECTROGRAPH

Online guide to IRIS data analysis *[NEW]*

Operations/Planning

ITN 1 - IRIS Operations Overview
ITN 2 - Manual for Table Creator
ITN 3 - Manual for Timeline Tool
ITN 4 - Manual for Synthetic Observations Tool
ITN 5 - Operations Under Roll Conditions
ITN 6 - AEC Operations
ITN 7 - Compression Approach
ITN 8 - Checklist for IRIS planner
ITN 9 - Periodic Calibration Activities
ITN 50 - How to request IRIS coordinated observations [NEW]

Data Flow

ITN 10 - General Approach to Data Flow and Archiving
ITN 11 - Definition of Data Levels
ITN 12 - Definition of Keywords
ITN 13 - VSO and IRIS
Level 2 keywords

Calibration

ITN 14 - Dark Current/Offset
ITN 15 - Despiking
ITN 16 - Flat-field
ITN 16b - FUV background
ITN 19 - Geometric Calibration
ITN 20 - Wavelength Calibration
ITN 21 - Recasting into Level 2/3 Data
ITN 22 - Co-alignment, Plate Scale Analysis
ITN 23 - MTF/PSF Determination
ITN 24 - Stellar Calibration
ITN 25 - Gain Determination

IRIS mission/instrument paper

Data Analysis

ITN 26 - User Guide To Data Analysis
ITN 27 - Quicklook Tools Manual
ITN 28 - IRIS IDL Data Structure
ITN 29 - Deconvolution Approach
ITN 30 - 60 Day Observing Plan
ITN 31 - IRIS science planning: tables, linelists, targets
ITN 32 - Co-aligned IRIS, SDO and Hinode observations
SolarSoft Tree and UVSP Database
Data analysis tutorial at AAS 2014
List of Flares observed with IRIS

Numerical Modeling

ITN 33 - General Overview of Numerical Simulations
ITN 34 - Numerical Simulations Quicklook Tools
ITN 35 - Numerical Simulations Synthetic Observables
ITN 36 - RH 1.5 D Manual
ITN 37 - How to Derive Physical Information from Mg II h/k

IRIS Technical Notes List (ITN)

Tutorials

Data Analysis Tutorials
IRIS-7 Tutorials
- Data Analysis
- Radiative Transfer
- Bifrost Simulation
- Operation of IRIS
- Flare Simulation
- UV Spectroscopy and IRIS Lines

Questions

Go to www.menti.com and use the code **40 80 40**

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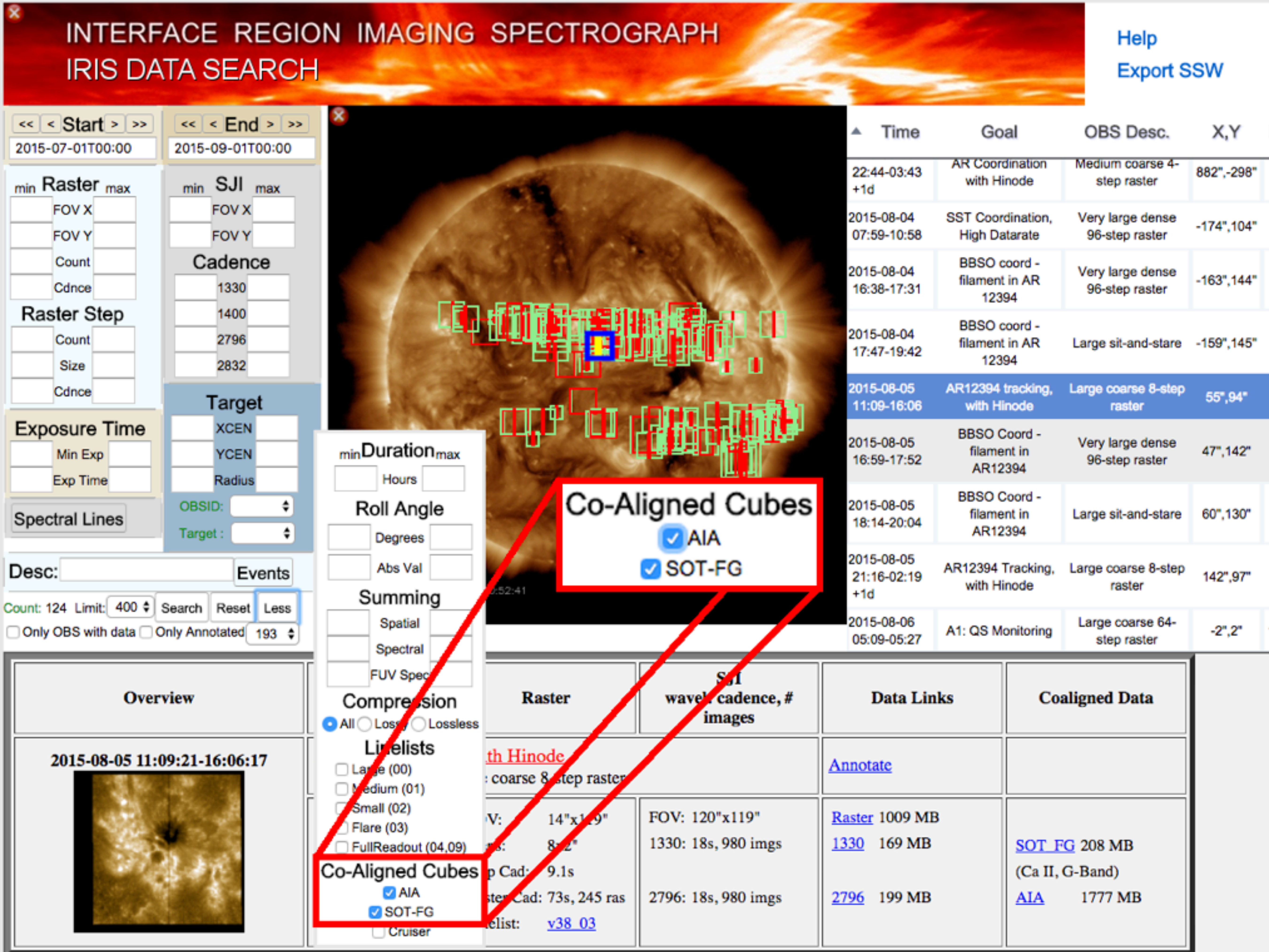
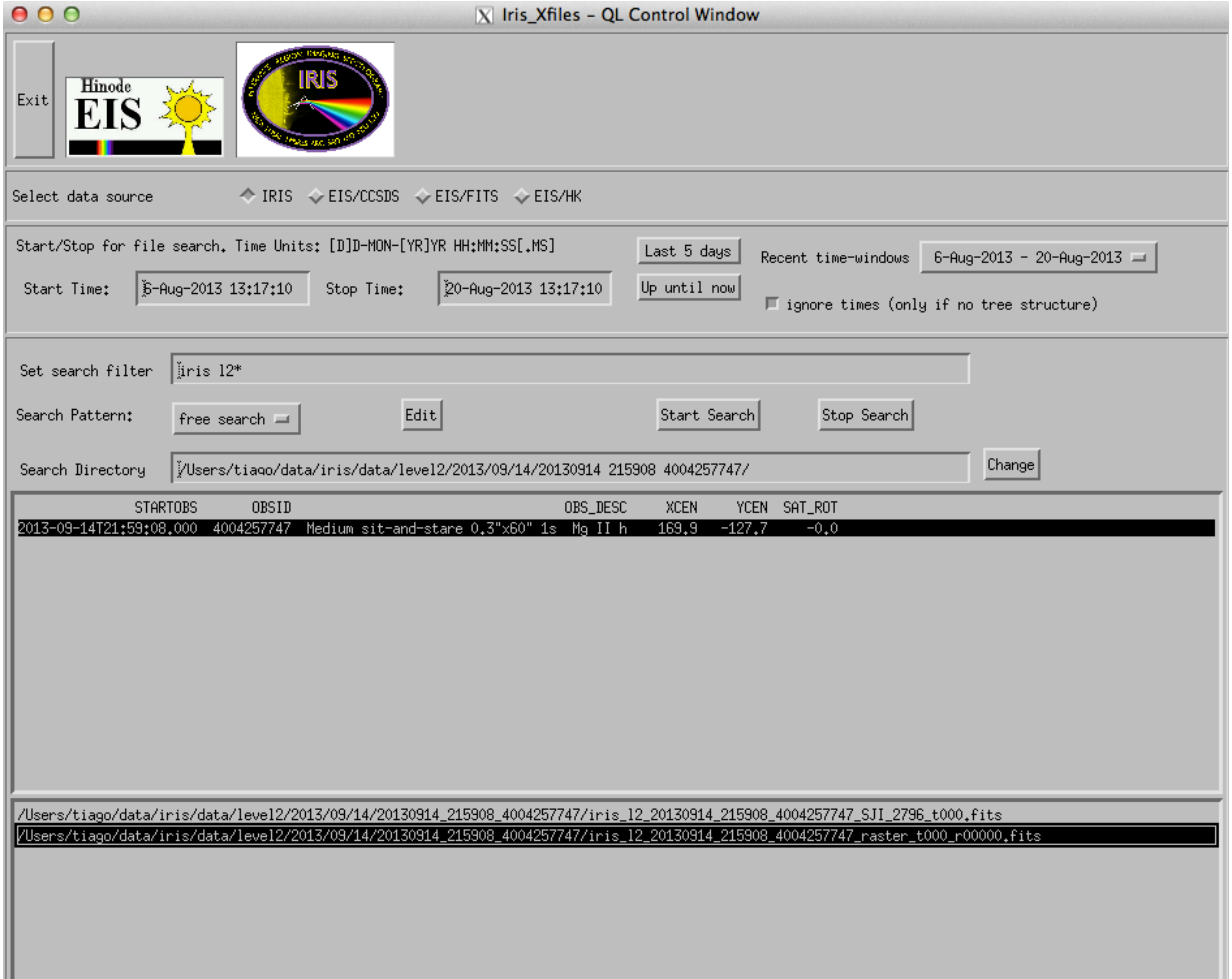
Searching, downloading, browsing data

- IRIS search webpage http://iris.lmsal.com/search/
- Hinode SDC Europe http://sdc.uio.no/search/API
- SolarSoft IDL
- IRIS today: http://iris.lmsal.com/iristoday/
- HEK recent observations: http://www.lmsal.com/hek/hcr?cmd=view-recent-events&instrument=iris

Live demo:
searching and downloading


INTERFACE REGION IMAGING SPECTROGRAPH
IRIS DATA SEARCH
Help
Export SSW
Start
2015-07-01T00:00
End
2015-09-01T00:00
Raster
SJI
FOV X
FOV Y
Count
Cdnce
Cadence
1330
1400
2796
2832
Raster Step
Count
Size
Cdnce
Target
XCEN
YCEN
Radius
OBSID:
Target :
Exposure Time
Min Exp
Exp Time
Spectral Lines
Duration
Hours
Roll Angle
Degrees
Abs Val
Summing
Spatial
Spectral
FUV Spec
Compression
All Lossy Lossless
Linelists
Large (00)
Medium (01)
Small (02)
Flare (03)
FullReadout (04,09)
Co-Aligned Cubes
AIA
SOT-FG
Cruiser
Desc:
Events
Count: 124 Limit: 400 Search Reset Less
Only OBS with data Only Annotated 193
Time
Goal
OBS Desc.
X,Y
22:44-03:43 +1d AR Coordination with Hinode Medium coarse 4-step raster 882",-298"
2015-08-04 07:59-10:58 SST Coordination, High Datarate Very large dense 96-step raster -174",104"
2015-08-04 16:38-17:31 BBSO coord - filament in AR 12394 Very large dense 96-step raster -163",144"
2015-08-04 17:47-19:42 BBSO coord - filament in AR 12394 Large sit-and-stare -159",145"
2015-08-05 11:09-16:06 AR12394 tracking, with Hinode Large coarse 8-step raster 55",94"
2015-08-05 16:59-17:52 BBSO Coord - filament in AR12394 Very large dense 96-step raster 47",142"
2015-08-05 18:14-20:04 BBSO Coord - filament in AR12394 Large sit-and-stare 60",130"
2015-08-05 21:16-02:19 +1d AR12394 Tracking, with Hinode Large coarse 8-step raster 142",97"
2015-08-06 05:09-05:27 A1: QS Monitoring Large coarse 64-step raster -2",2"
Co-Aligned Cubes
AIA
SOT-FG
Overview
Raster
SJI wavel, cadence, # images
Data Links
Coaligned Data
2015-08-05 11:09:21-16:06:17
Annotate
FOV: 120"x119"
1330: 18s, 980 imgs
2796: 18s, 980 imgs
Raster 1009 MB
1330 169 MB
2796 199 MB
SOT_FG 208 MB
(Ca II, G-Band)
AIA 1777 MB
v38_03


Iris_Xfiles - QL Control Window
Exit
Hinode
EIS
IRIS
Select data source
IRIS
EIS/CCSDS
EIS/FITS
EIS/HK
Start/Stop for file search. Time Units: [D]D-MON-[YR]YR HH:MM:SS[.MS]
Last 5 days
Recent time-windows
6-Aug-2013 - 20-Aug-2013
Start Time:
6-Aug-2013 13:17:10
Stop Time:
20-Aug-2013 13:17:10
Up until now
ignore times (only if no tree structure)
Set search filter
iris l2*
Search Pattern:
free search
Edit
Start Search
Stop Search
Search Directory
/Users/tiago/data/iris/data/level2/2013/09/14/20130914 215908 4004257747/
Change
STARTOBS OBSID OBS_DESC XCEN YCEN SAT_ROT
2013-09-14T21:59:08.000 4004257747 Medium sit-and-stare 0.3"x60" 1s Mg II h 169.9 -127.7 -0.0
/Users/tiago/data/iris/data/level2/2013/09/14/20130914_215908_4004257747/iris_l2_20130914_215908_4004257747_SJI_2796_t000.fits
/Users/tiago/data/iris/data/level2/2013/09/14/20130914_215908_4004257747/iris_l2_20130914_215908_4004257747_raster_t000_r00000.fits

Live demo:
IRIS xfiles

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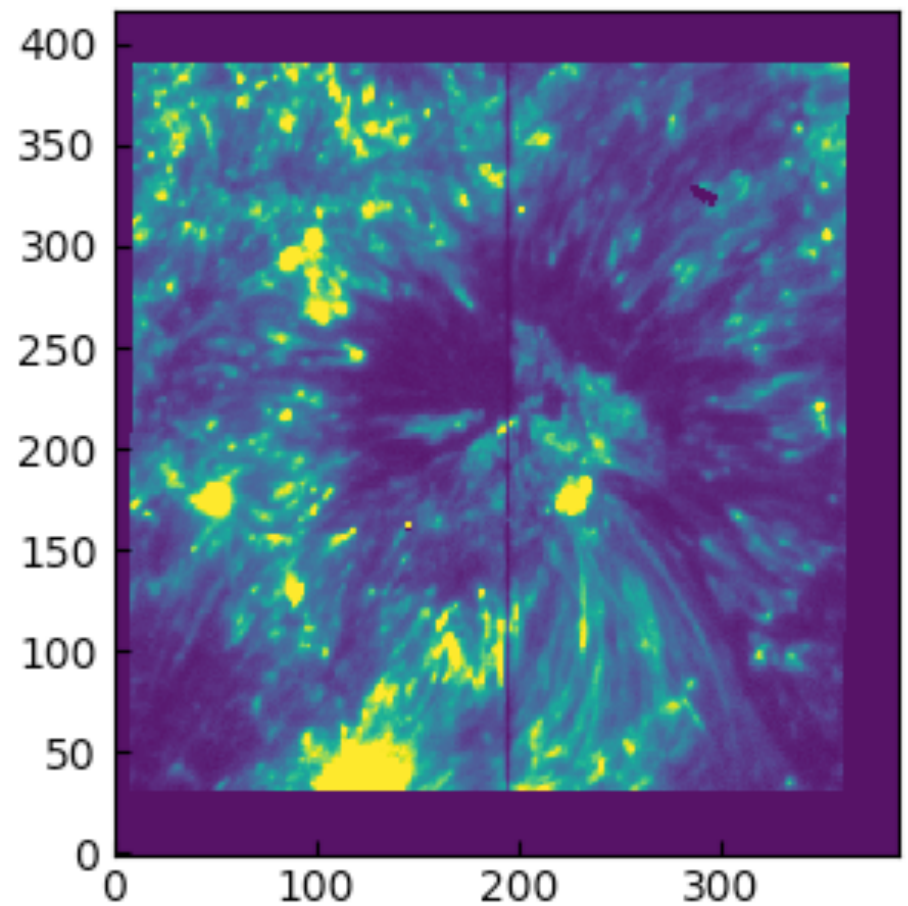
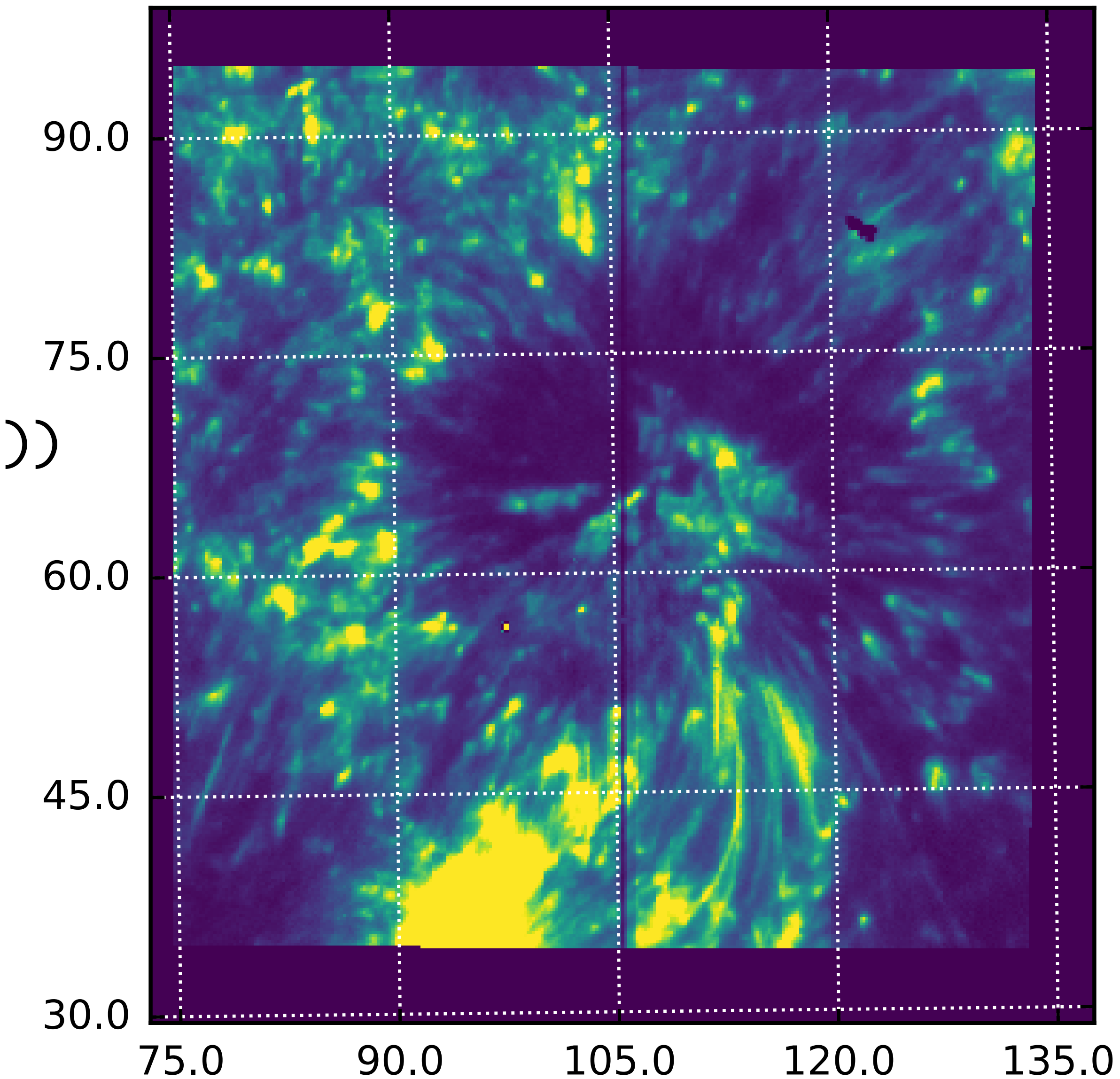
Using astropy.io.fits

```
>>> from astropy.io import fits
>>> import matplotlib.pyplot as plt
>>> MYFILE = "iris_l2_20130902_163935_4000255147_SJI_1400_t000.fits"
>>> f = fits.open(MYFILE)
>>> f[0].header
(...)
>>> f[0].data   # SJI
>>> f[n].data   # Spectrograph
>>> data = fits.getdata(MYFILE)
>>> hd = fits.getheader(MYFILE)
>>> plt.imshow(f[0].data[100], cmap='viridis', vmin=0, vmax=200)
```



Plotting SJI with coordinates

```
>>> from astropy.wcs import WCS
>>> hd = fits.getheader(MYFILE)
>>> sji = fits.getdata(MYFILE)
>>> wcs = WCS(hd)
>>> ax = plt.subplot(projection=wcs.dropaxis(-1))
>>> ax.imshow(sji[0], vmin=0, vmax=200)
>>> ax.coords[0].set_major_formatter('s.s')
>>> ax.coords[1].set_major_formatter('s.s')
>>> ax.grid(color='w', ls=':')
```



Live demo:
Read IRIS data in Python

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IDL object interface for level 2 data

```
IDL> f = 'iris_l2_20131010_100202_3820259146_raster_t000_r00000.fits'
IDL> d = iris_obj(f)
```

```
IDL> d->show_lines
Spectral regions(windows)
0   1335.71   C II 1336
1   1349.43   Fe XII 1349
2   1355.60   O I 1356
3   1393.78   Si IV 1394
4   1402.77   Si IV 1403
5   2832.76   2832
6   2814.50   2814
7   2796.20   Mg II k 2796
```

Read IRIS L2

```
IDL> sjifile = 'iris_l2_20131010_100202_3820259146_SJI_2796_t000.fits'
IDL> read_iris_l2, sjifile, header, data
(...)
IDL> help, header, data
HEADER          STRUCT    = -> <Anonymous> Array[100]
DATA            FLOAT     = Array[1860, 1092, 100]
```

Live demo:
Read IRIS data in IDL

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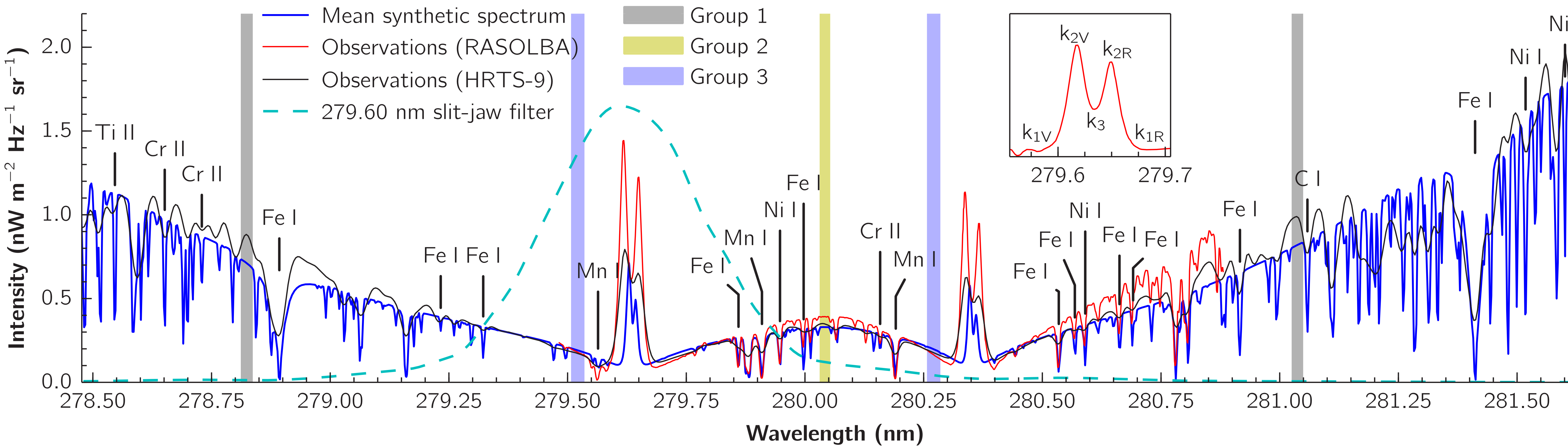
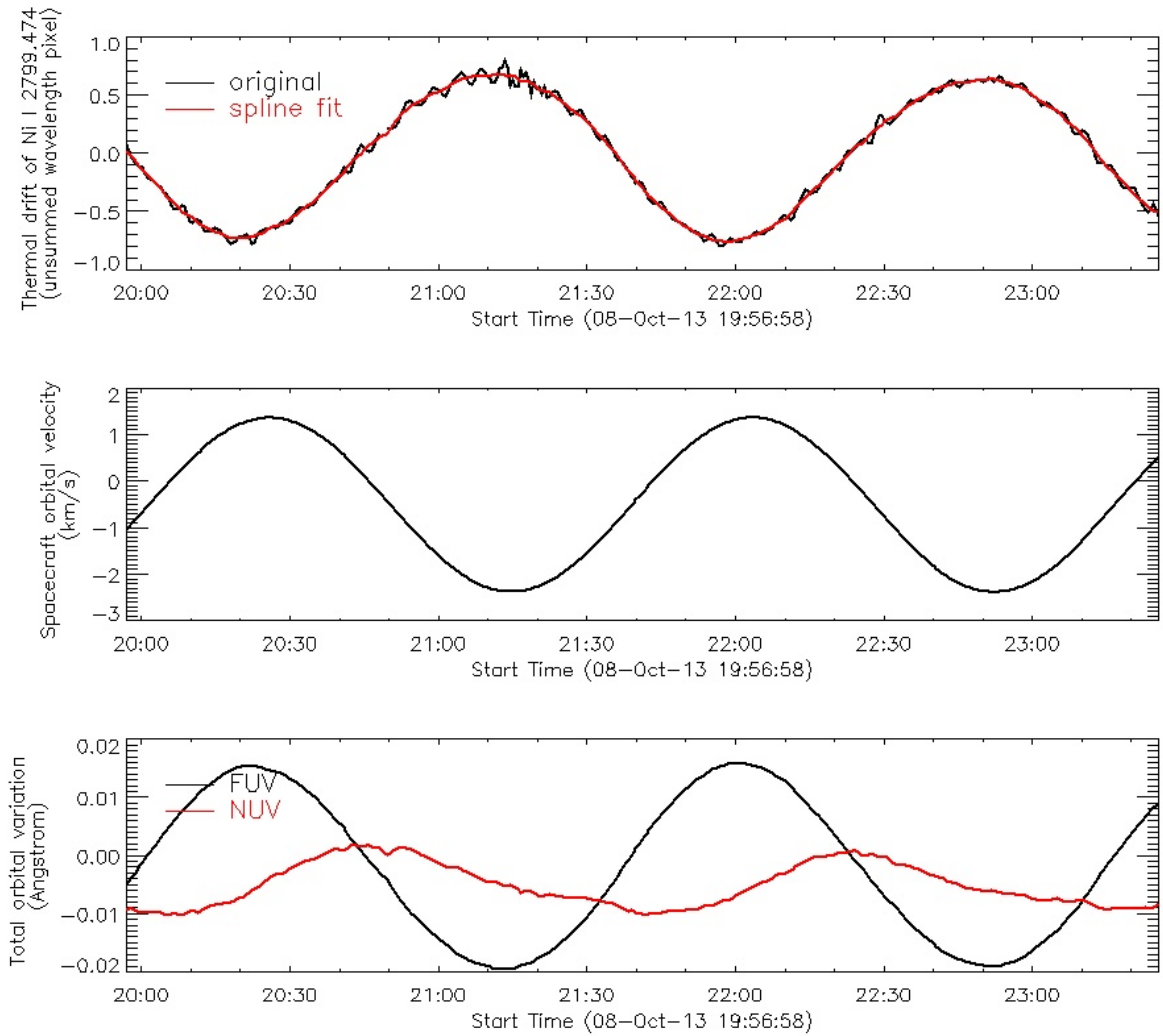
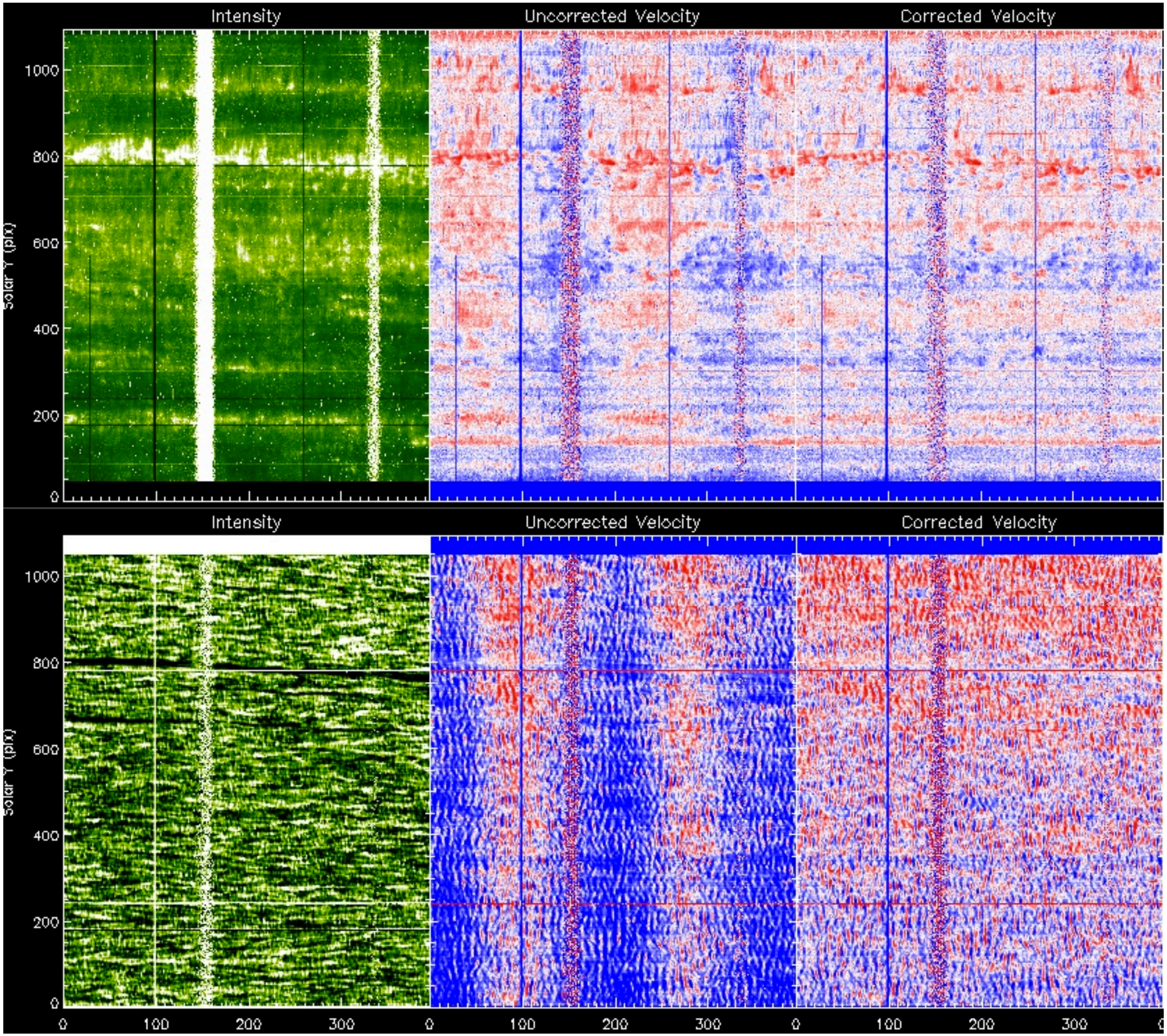
Precise wavelength calibration

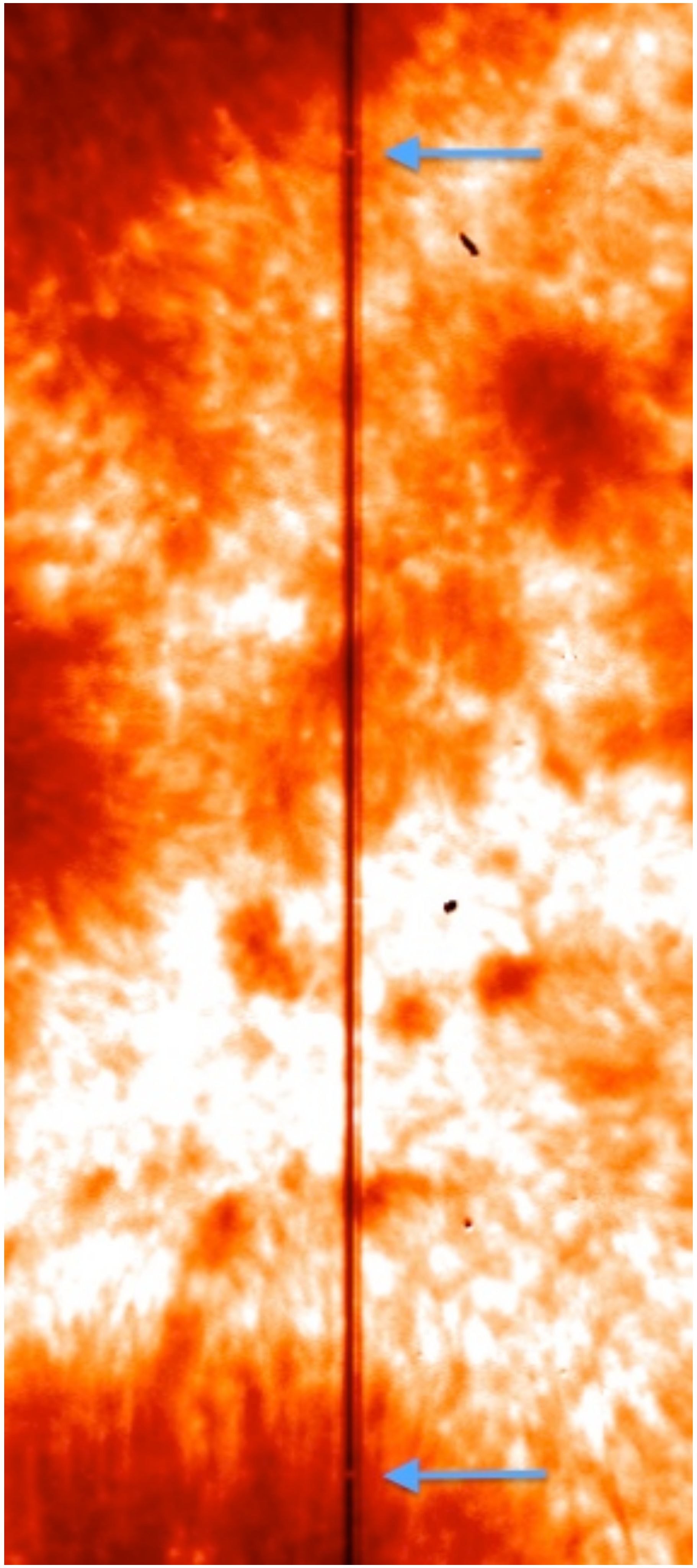


Precise wavelength calibration



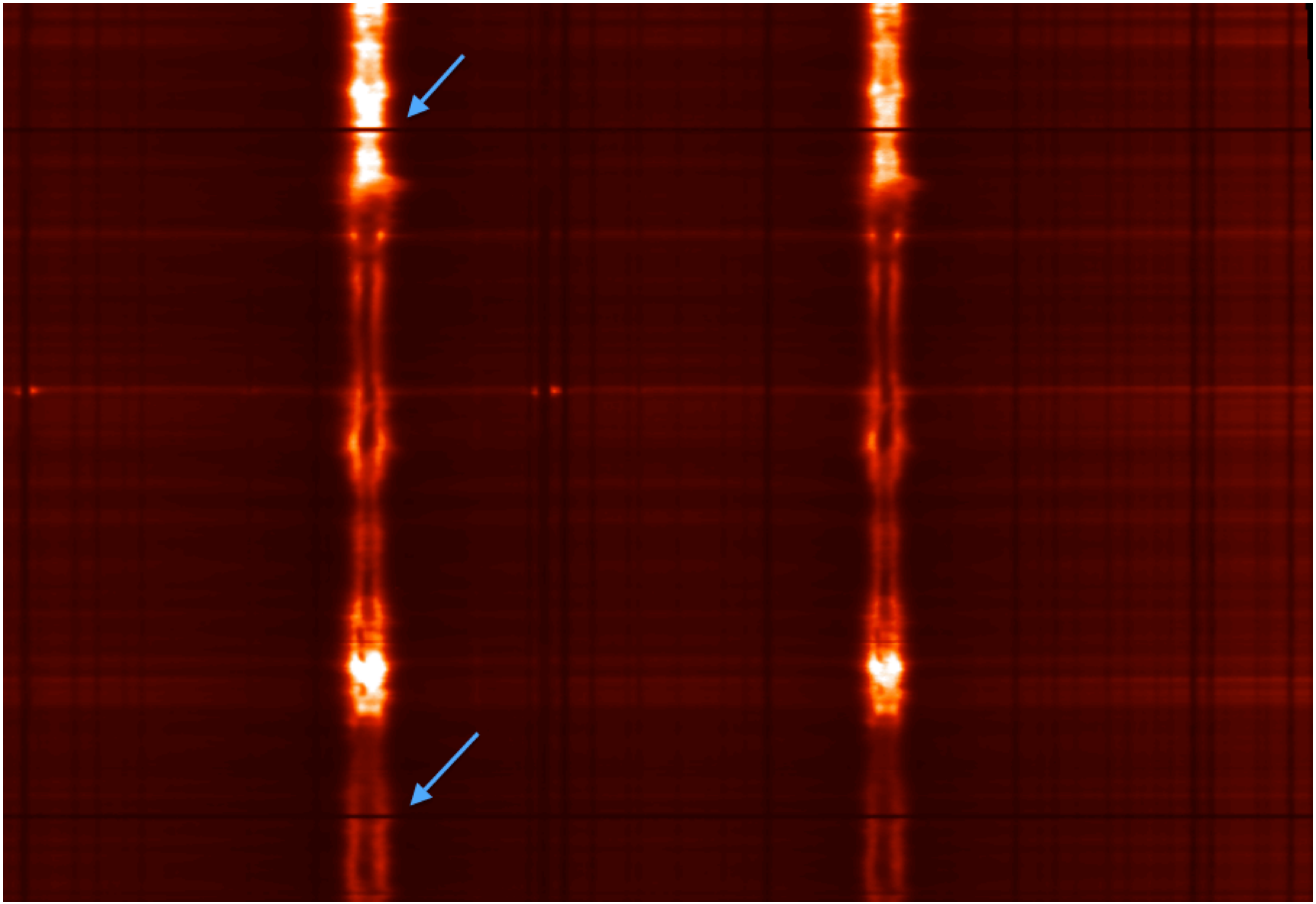
Precise wavelength calibration





Co-alignment between SJIs

Co-alignment between spectra



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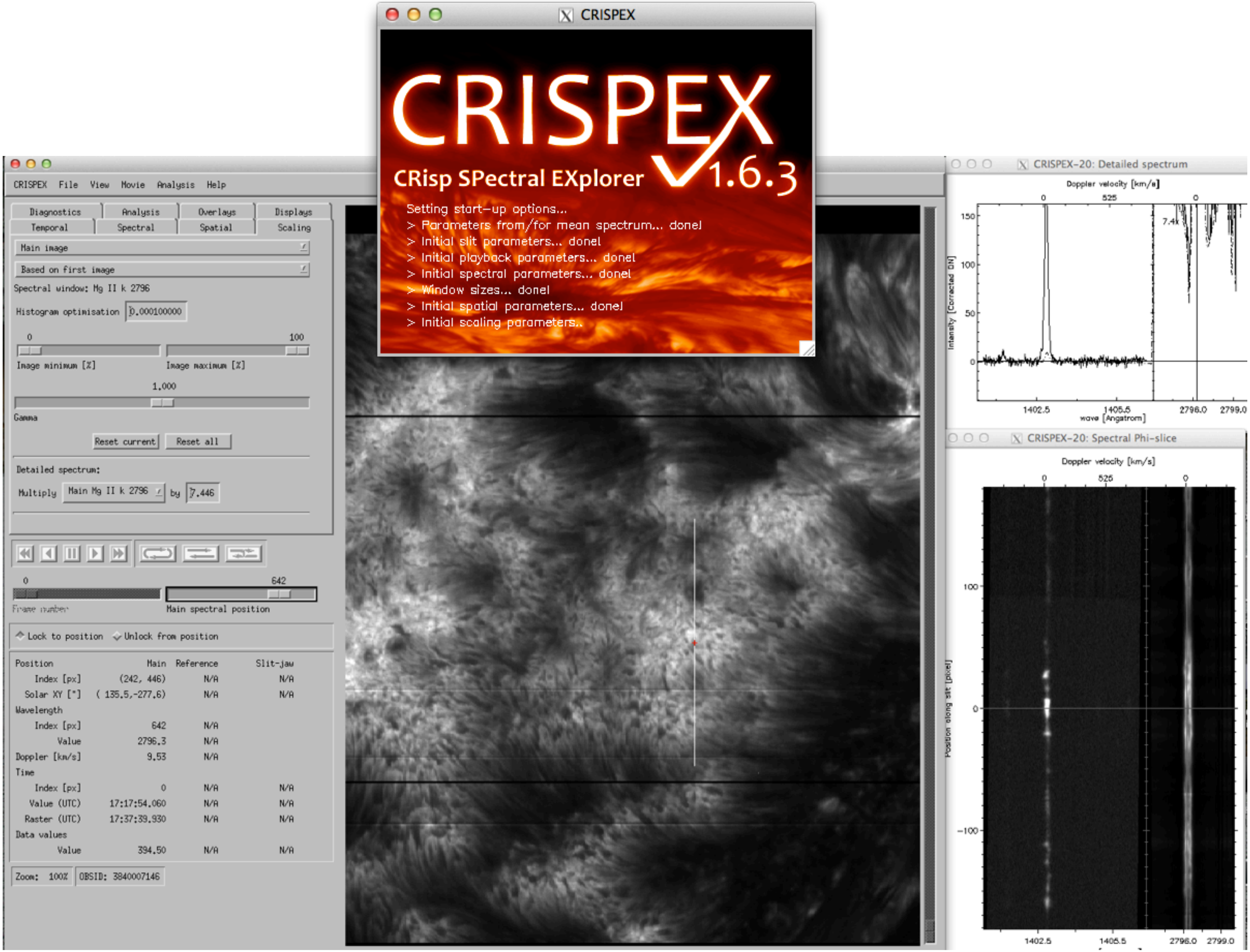
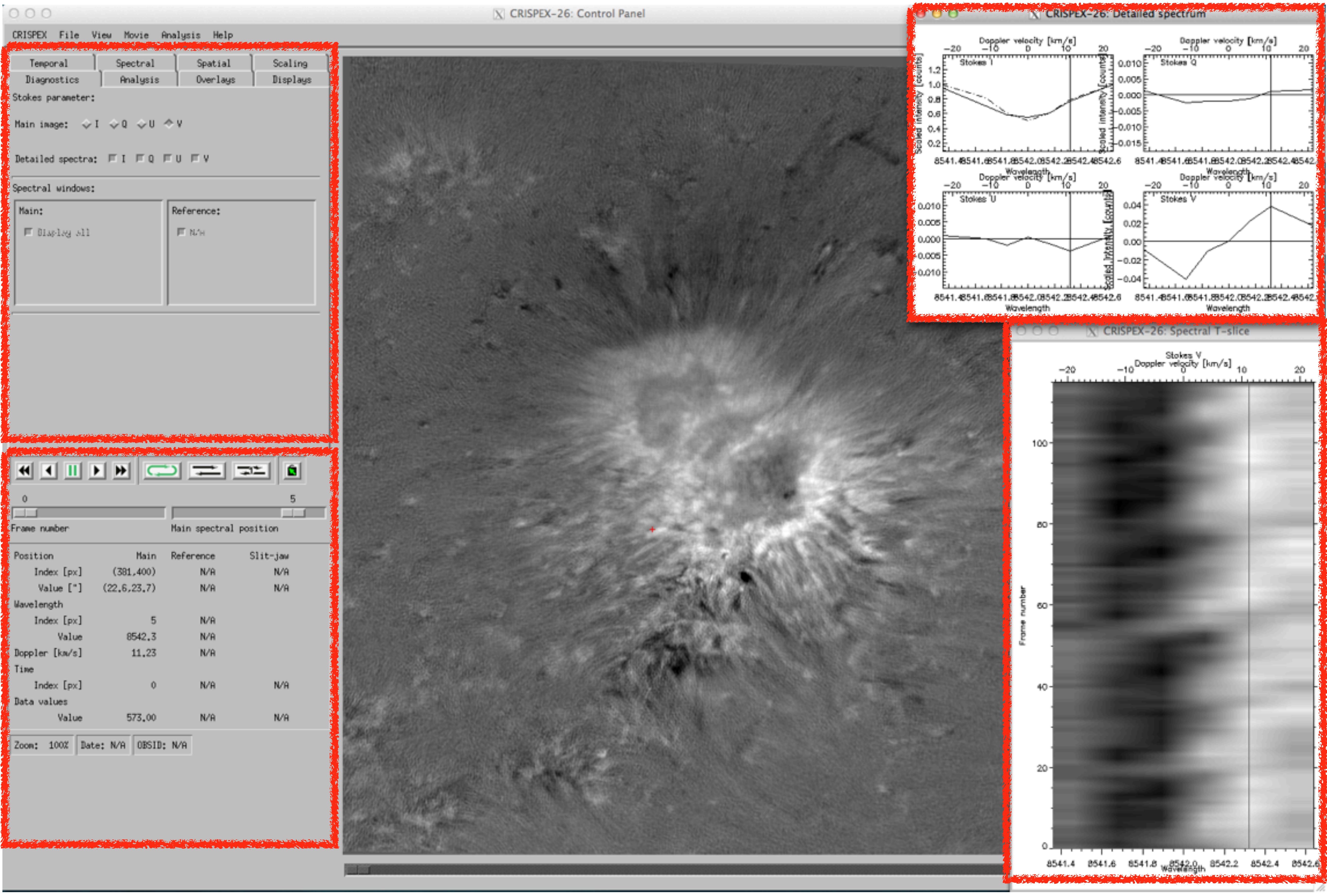

CRISPEX
CRISPEX
CRisp SPectral EXplorer
1.6.3
Setting start-up options...
> Parameters from/for mean spectrum... done!
> Initial slit parameters... done!
> Initial playback parameters... done!
> Initial spectral parameters... done!
> Window sizes... done!
> Initial spatial parameters... done!
> Initial scaling parameters...
CRISPEX File View Movie Analysis Help
Diagnostics Analysis Overlays Displays
Temporal Spectral Spatial Scaling
Main image
Based on first image
Spectral window: Mg II k 2796
Histogram optimisation 0.000100000
Image minimum [%] Image maximum [%]
Gamma
Reset current Reset all
Detailed spectrum:
Multiply Main Mg II k 2796 by 7.446
Frame number
Main spectral position
Lock to position Unlock from position
Position Main Reference Slit-jaw
Index [px] (242, 446) N/A N/A
Solar XY ["] (135.5,-277.6) N/A N/A
Wavelength
Index [px] 642 N/A
Value 2796.3 N/A
Doppler [km/s] 9.53 N/A
Time
Index [px] 0 N/A N/A
Value (UTC) 17:17:54.060 N/A N/A
Raster (UTC) 17:37:39.930 N/A N/A
Data values
Value 394.50 N/A N/A
Zoom: 100% OBSID: 3840007146
CRISPEX-20: Detailed spectrum
Doppler velocity [km/s]
Intensity [Corrected DN]
wave [Angstrom]
CRISPEX-20: Spectral Phi-slice
Doppler velocity [km/s]
Position along slit [pixel]

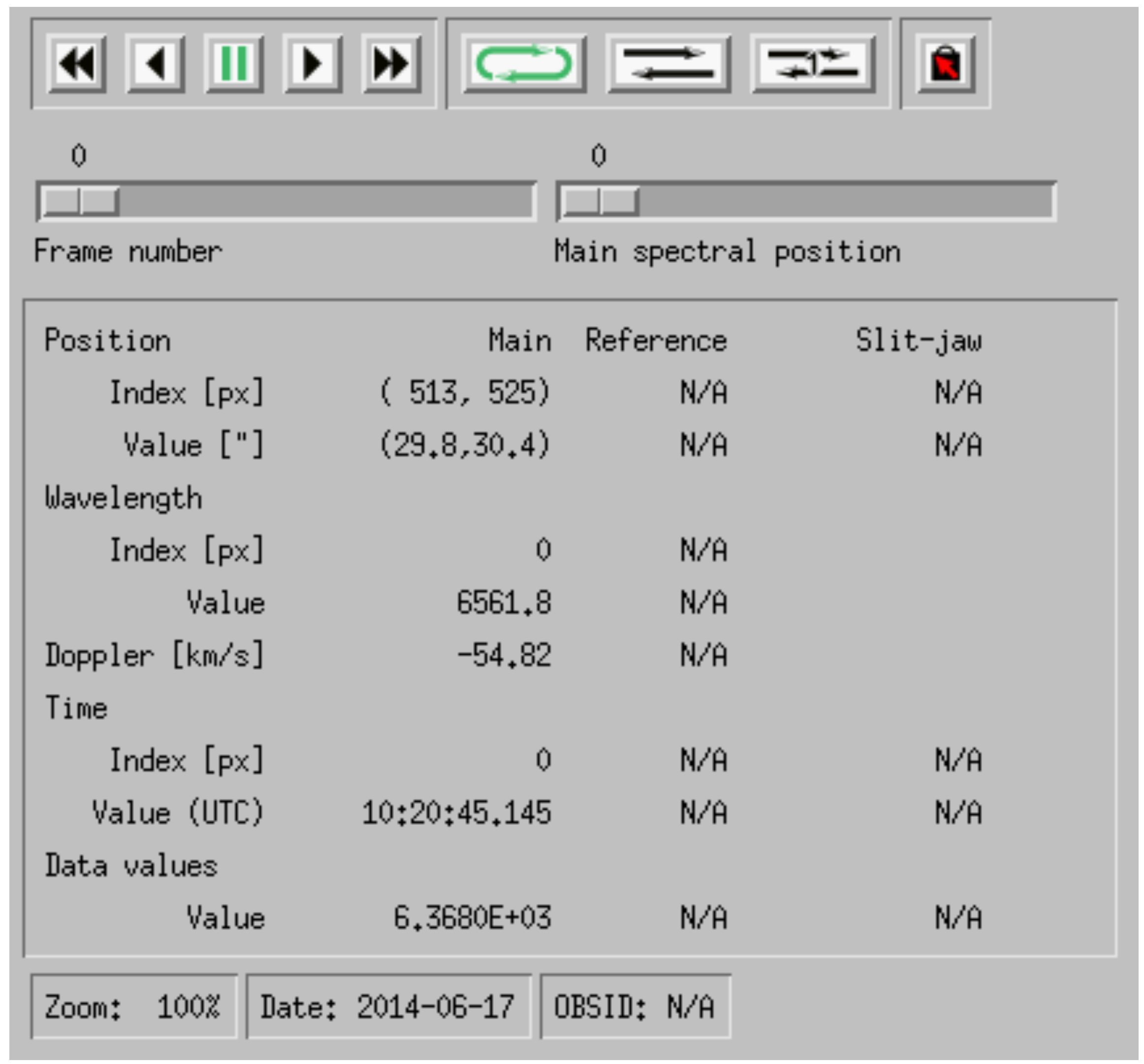
CRISPEX file formats

- “La Palma cubes”
  - ★ Simple cubes of (nx, ny, nwave * nt * nstokes)
  - ★ Combined with “spectfile”
- IRIS level 3 fits files
  - ★ FITS file with main image (nx, ny, nwave, nt)
  - ★ FITS keywords used for coordinates, time
  - ★ Extensions with wavelength and time values
  - ★ Not limited to IRIS data; to be further standardised

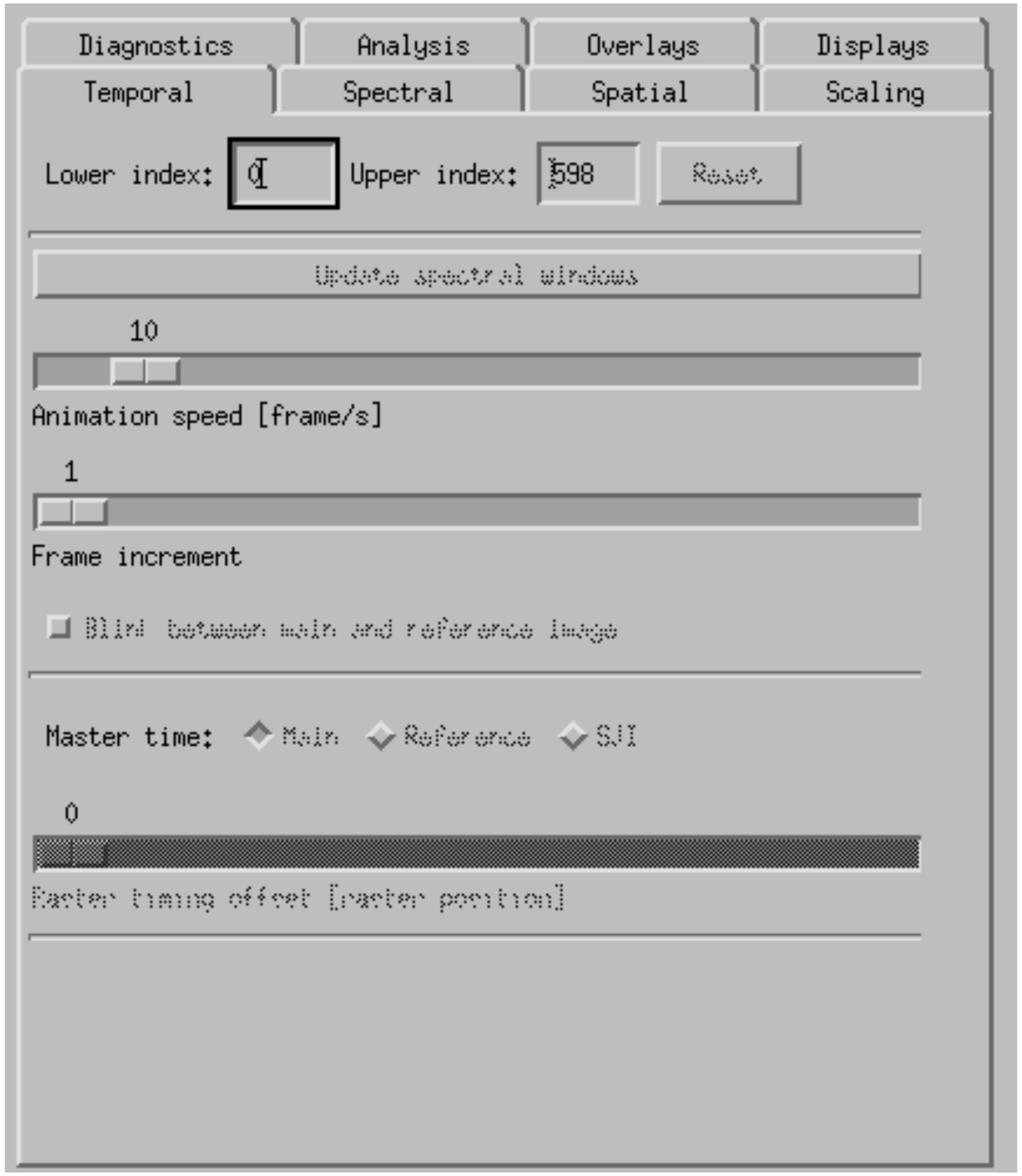
Two types of files: (same data)
‘im’ (nx, ny, nw, nt) and ‘sp’ (nw, nt, nx, ny)

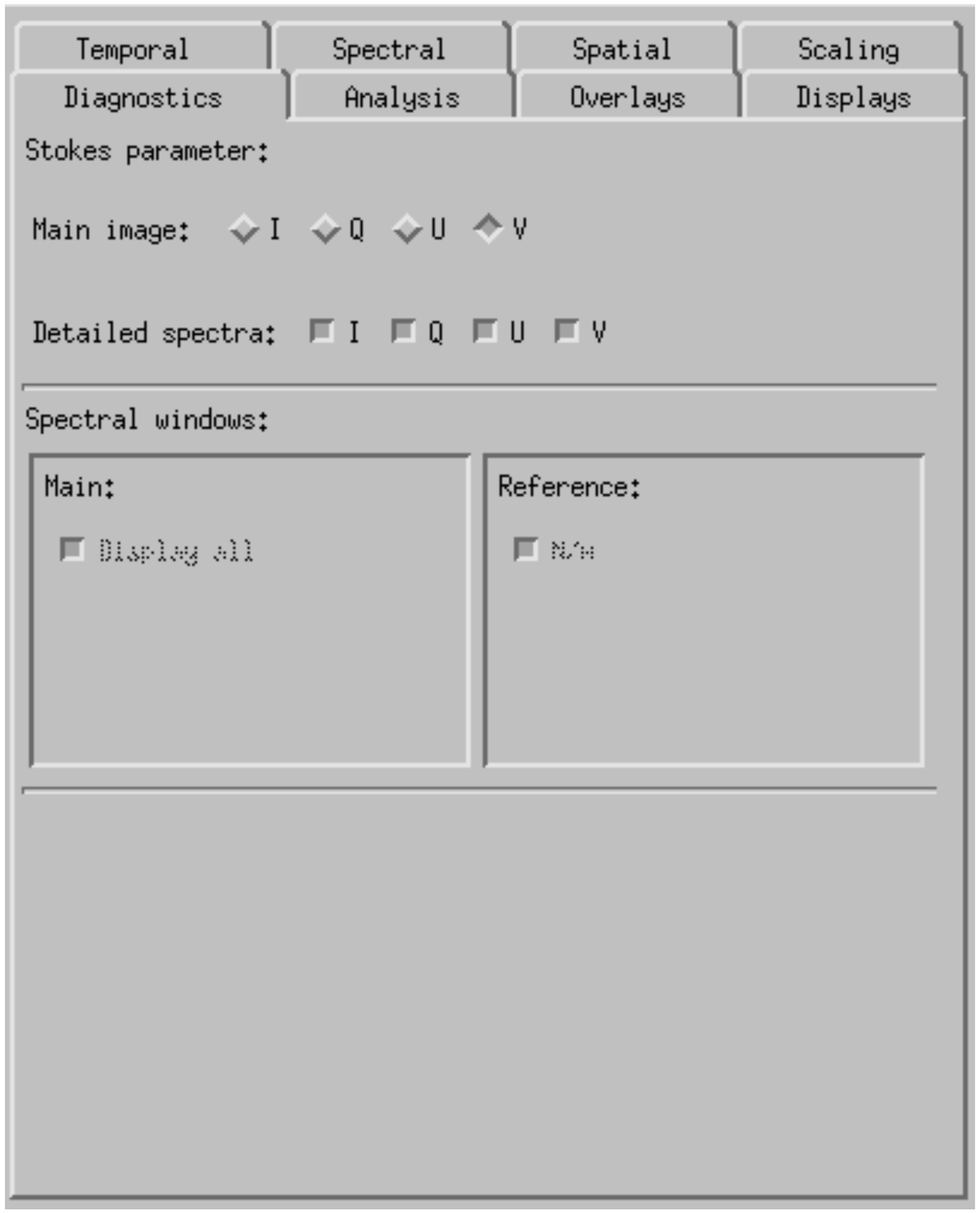

CRISPEX-26: Control Panel
CRISPEX File View Movie Analysis Help
Temporal Spectral Spatial Scaling
Diagnostics Analysis Overlays Displays
Stokes parameter:
Main image: I Q U V
Detailed spectra: I Q U V
Spectral windows:
Main:
Display all
Reference:
N/A
0
5
Frame number
Main spectral position
Position Main Reference Slit-jaw
Index [px] (381,400) N/A N/A
Value ["] (22.6,23.7) N/A N/A
Wavelength
Index [px] 5 N/A
Value 8542.3 N/A
Doppler [km/s] 11.23 N/A
Time
Index [px] 0 N/A N/A
Data values
Value 573.00 N/A N/A
Zoom: 100%
Date: N/A
OBSID: N/A
CRISPEX-26: Detailed spectrum
Doppler velocity [km/s]
Stokes I
Stokes Q
Stokes U
Stokes V
Scaled intensity [counts]
Wavelength
CRISPEX-26: Spectral T-slice
Stokes V
Frame number
8541.4 8541.6 8541.8 8542.0 8542.2 8542.4 8542.6

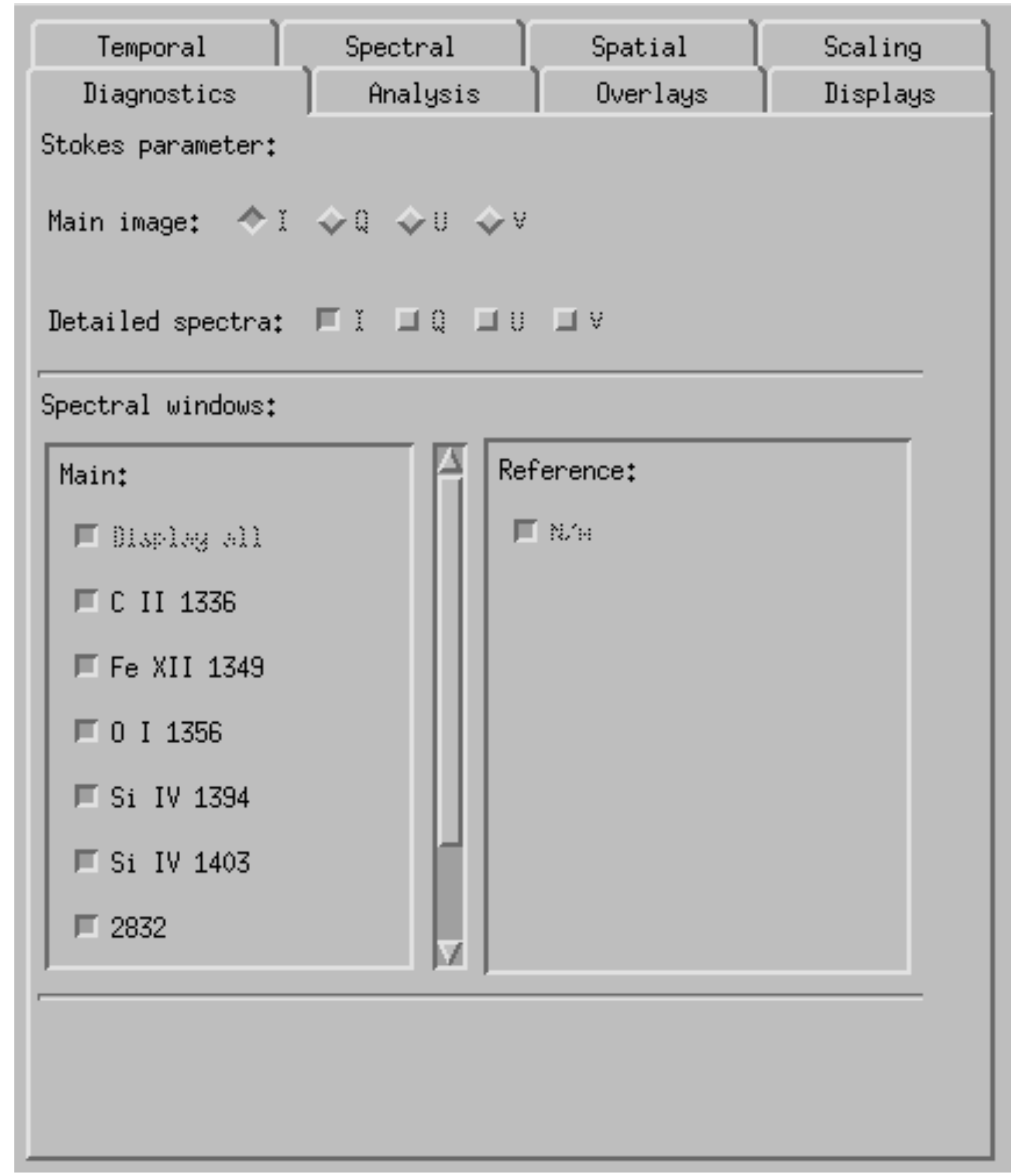
Bottom control panel

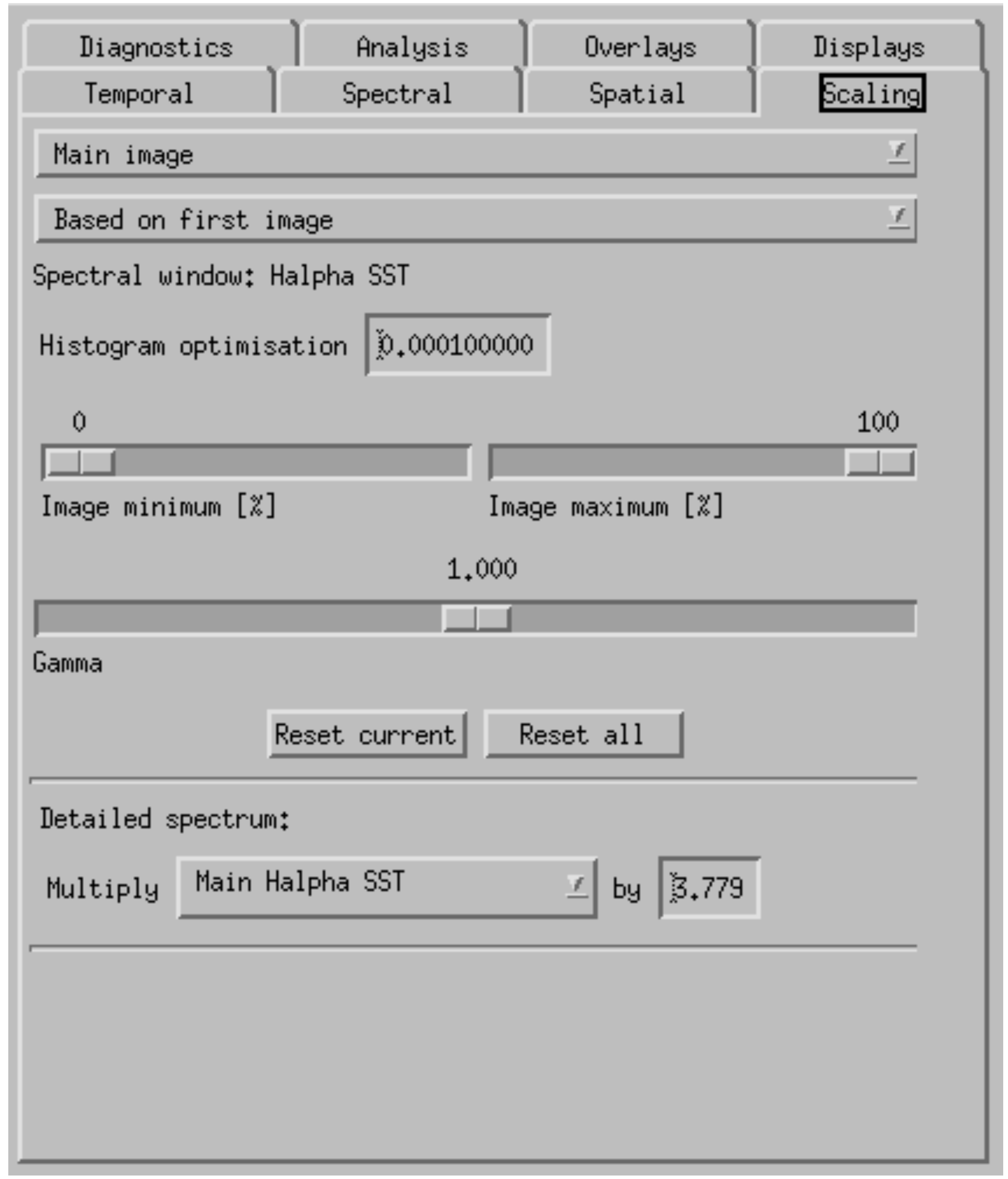


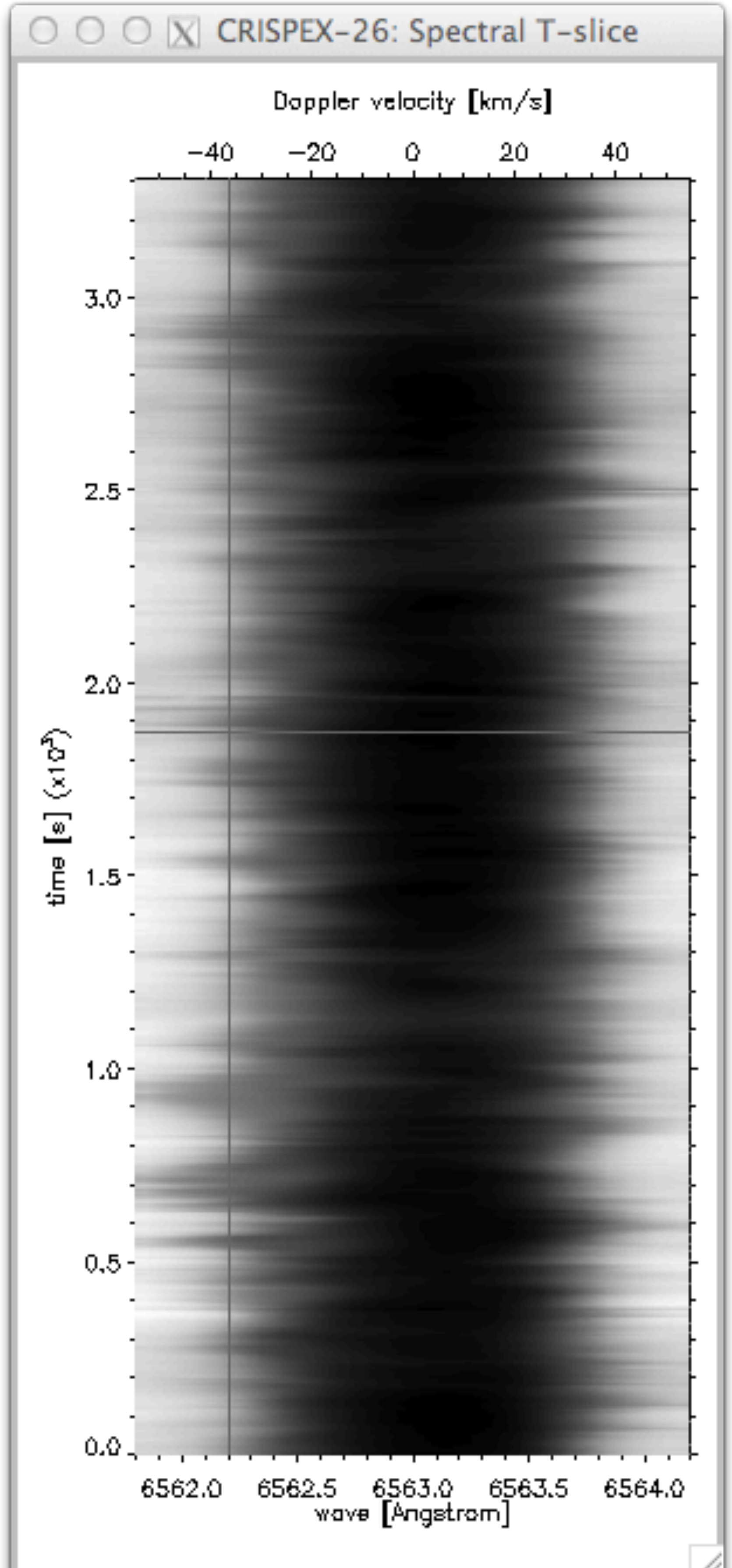
Tabs


Diagnostics
Analysis
Overlays
Displays
Temporal
Spectral
Spatial
Scaling
Lower index:
0
Upper index:
598
Reset
Update spectral windows
10
Animation speed [frame/s]
1
Frame increment
Blink between main and reference image
Master time:
Main
Reference
SJI
0
Raster timing offset [raster position]


Temporal
Spectral
Spatial
Scaling
Diagnostics
Analysis
Overlays
Displays
Stokes parameter:
Main image: I Q U V
Detailed spectra: I Q U V
Spectral windows:
Main:
Display all
Reference:
N/A


Temporal
Spectral
Spatial
Scaling
Diagnostics
Analysis
Overlays
Displays
Stokes parameter:
Main image: I Q U V
Detailed spectra: I Q U V
Spectral windows:
Main:
Display all
C II 1336
Fe XII 1349
O I 1356
Si IV 1394
Si IV 1403
2832
Reference:
N/A


Diagnostics
Analysis
Overlays
Displays
Temporal
Spectral
Spatial
Scaling
Main image
Based on first image
Spectral window: Halpha SST
Histogram optimisation
0.000100000
0
100
Image minimum [%]
Image maximum [%]
1.000
Gamma
Reset current
Reset all
Detailed spectrum:
Multiply
Main Halpha SST
by
3.779


CRISPEX-26: Spectral T-slice
Doppler velocity [km/s]
−40
−20
0
20
40
time [s] (x10^3)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
6562.0
6562.5
6563.0
6563.5
6564.0
wave [Angstrom]

Live demo:
CRISPEX

Questions

Go to www.menti.com and use the code **40 80 40**

Lecture Overview

Part 1

- Introduction and structure of IRIS data
- Getting the data, quicklook tools
- Working with IRIS data in Python
- Working with IRIS data in IDL
- Additional Data Calibration
- CRISPEX

Tutorial

- Hands-on tutorials

Tutorial preparation

```
$ mkdir ~/iris9
$ tar xvf iris9_files.tar -C ~/iris9
$ cd ~/iris9
$ gunzip *.gz
$ find . -name '*tar' -exec tar xvf {} \;
```

Python

```
$ ipython --pylab
```

IDL

“iris” in SSW_INSTR

```
$ cp ssw.zip ~/iris9
$ cd ~/iris9
$ unzip ssw.zip
$ export IRIS_DATA=$HOME/iris9
$ export SSW_IDL=$HOME/iris9/ssw
$ idl
(...)
IDL> !PATH = Expand_Path('+$SSW_IDL') + ':' + !PATH
IDL> imagelib
IDL> devicelib
```