# Introduction to IRIS data analysis

Tiago M. D. Pereira

Monday, April 11, 2016

14:00–15:30 Introduction to IRIS

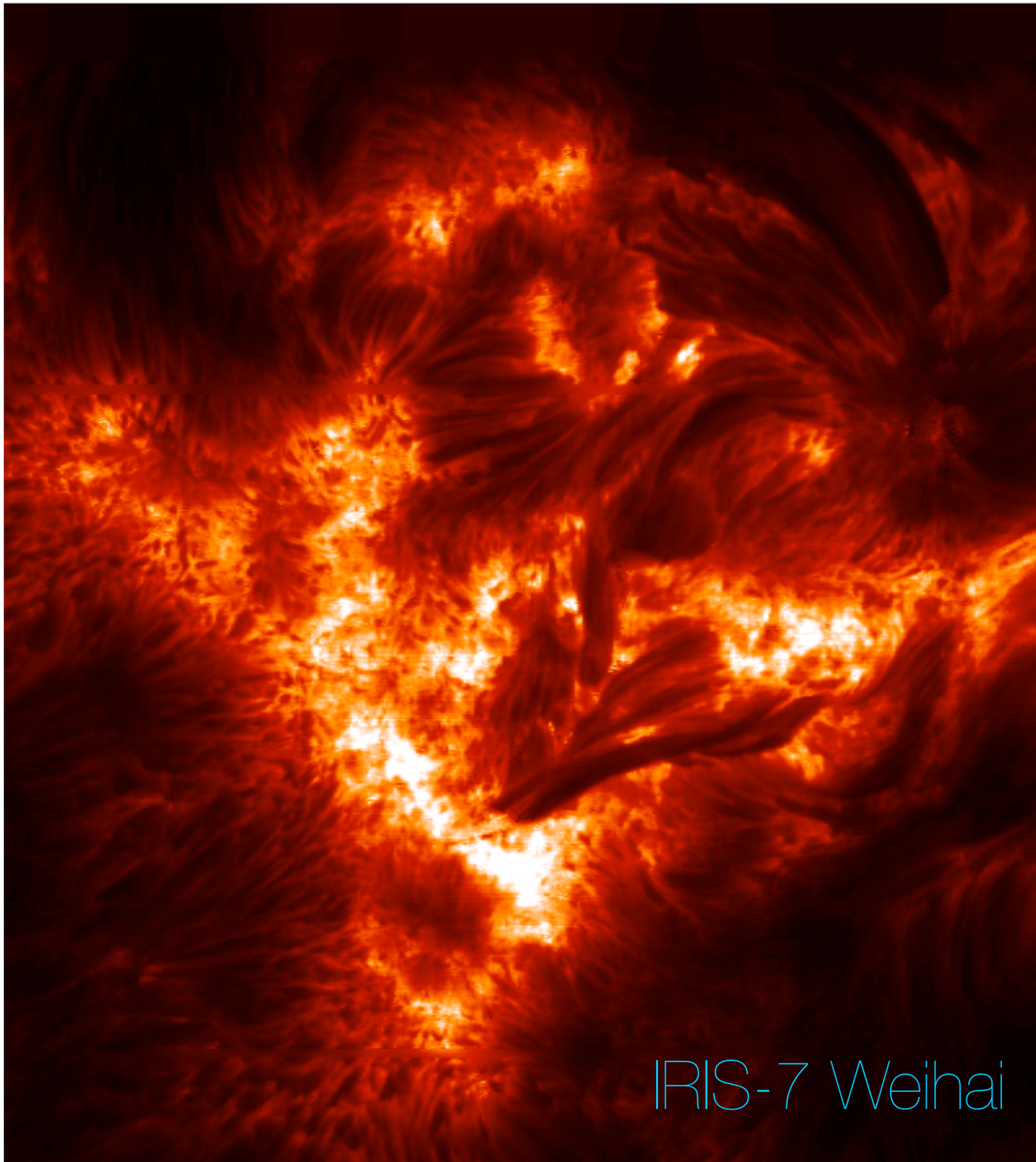
*15:30–16:30 Posters & Coffee*

16:30–17:00 Solving questions

17:00–18:00 Hands-on tutorials

Tuesday, April 12, 2016

09:00–10:30 Hands-on tutorials



# Lecture resources

Slides, notes, exercises:

http://folk.uio.no/tiago/iris7

# Lecture overview

## Part 1

- Overview of IRIS, capabilities and resources
- Getting the data, quicklook tools
- Working with IRIS data

## Part 2

- Additional Data Calibration
- Utility functions for Mg II lines
- CRISPEX
- Time to work on questions

## Tutorial

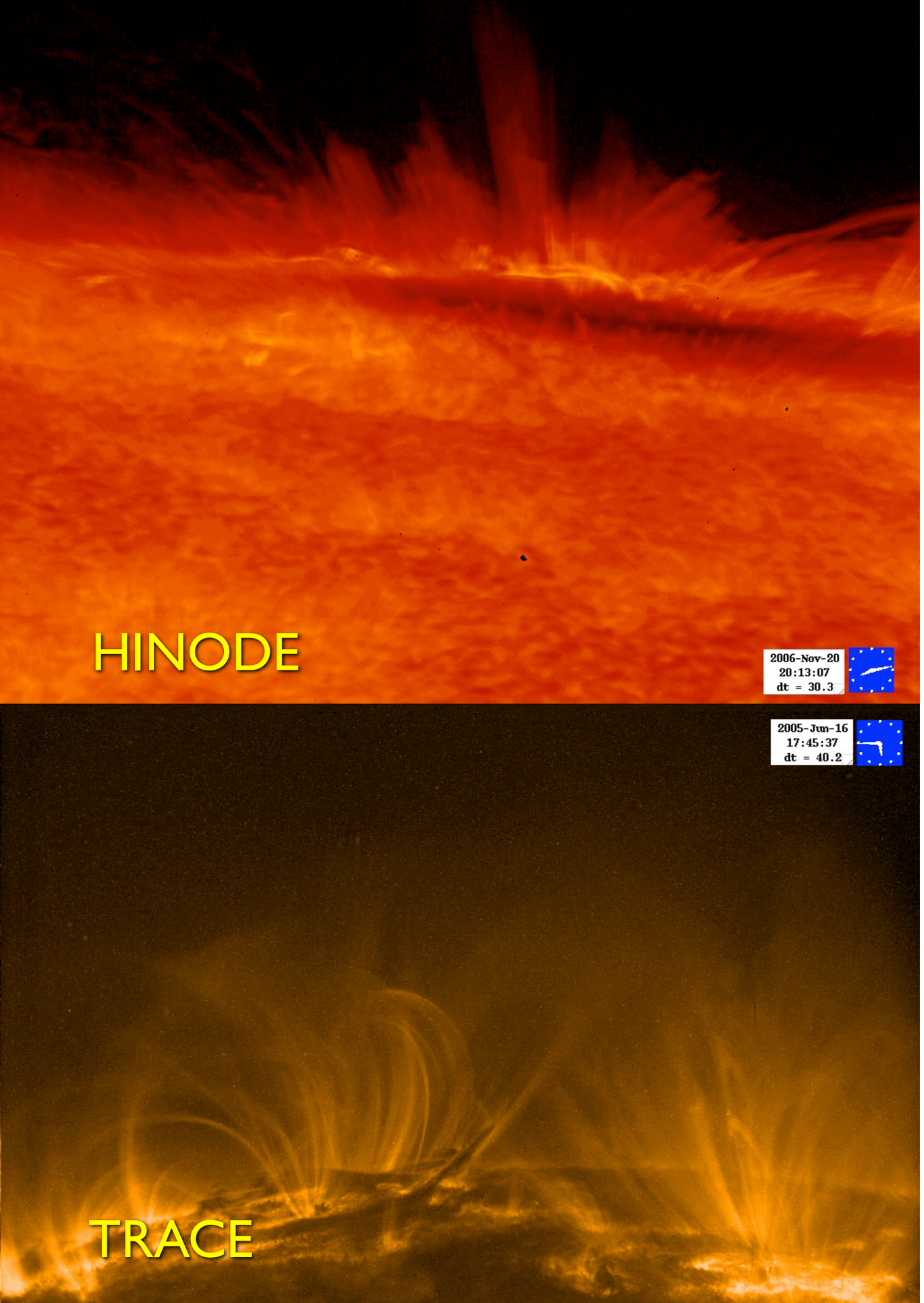
- Exercise questions
- Hands-on tutorials

# Lecture overview

- Overview of IRIS, capabilities and resources
- Getting the data, quicklook tools
- Working with IRIS data

- Additional Data Calibration
- Utility functions for Mg II lines
- CRISPEX
- Time to work on questions

- Exercise questions
- Hands-on tutorials




# Major Science Goals of IRIS

A. Which types of non-thermal energy dominate in the chromosphere and beyond?

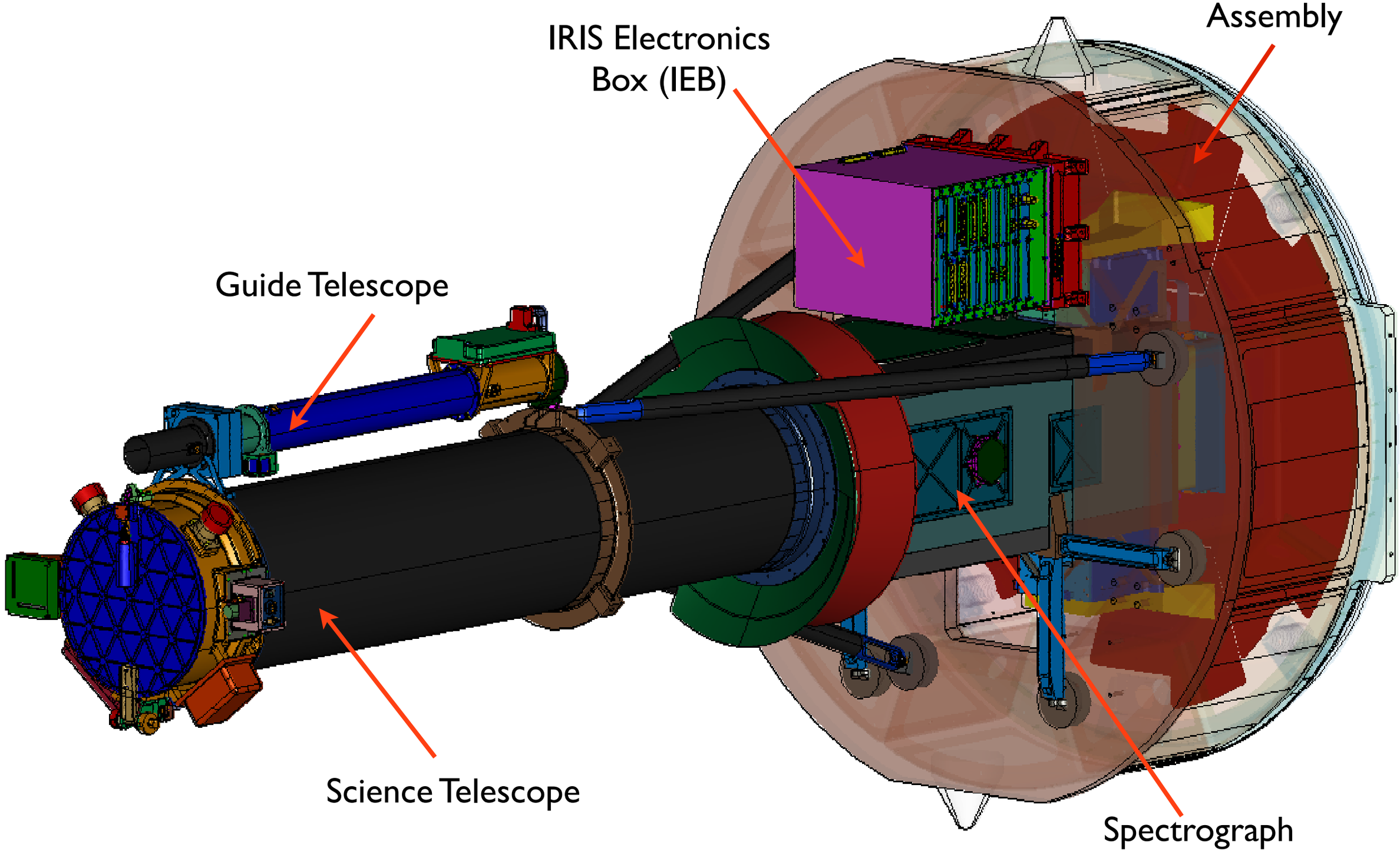
B. How does the chromosphere regulate the mass and energy supplied to the corona and heliosphere?

C. How does magnetic flux and matter rise through the lower atmosphere, and what is the role of flux emergence in powering flares and mass ejections?

Courtesy Bart De Pontieu

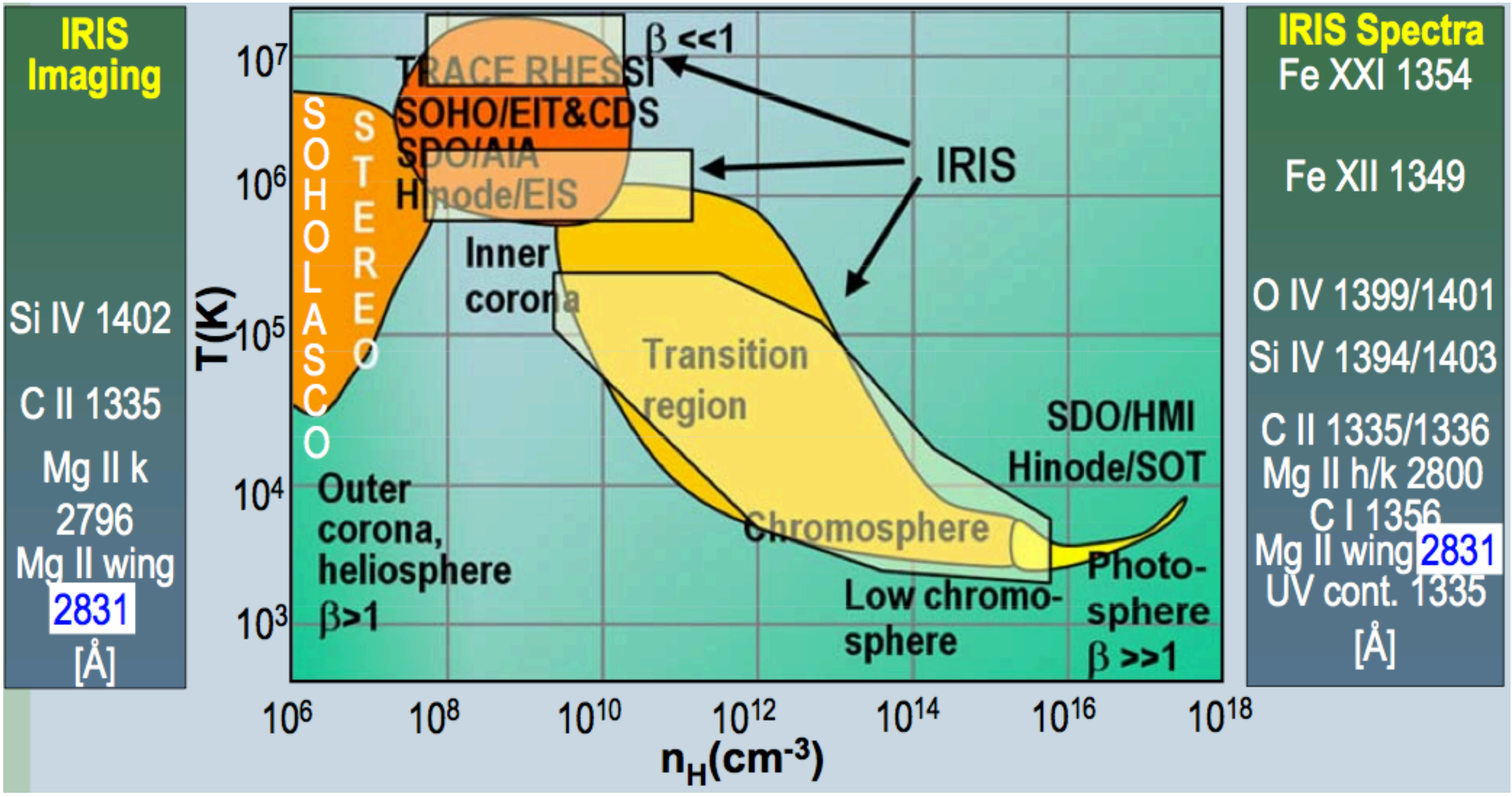
# What is IRIS?

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

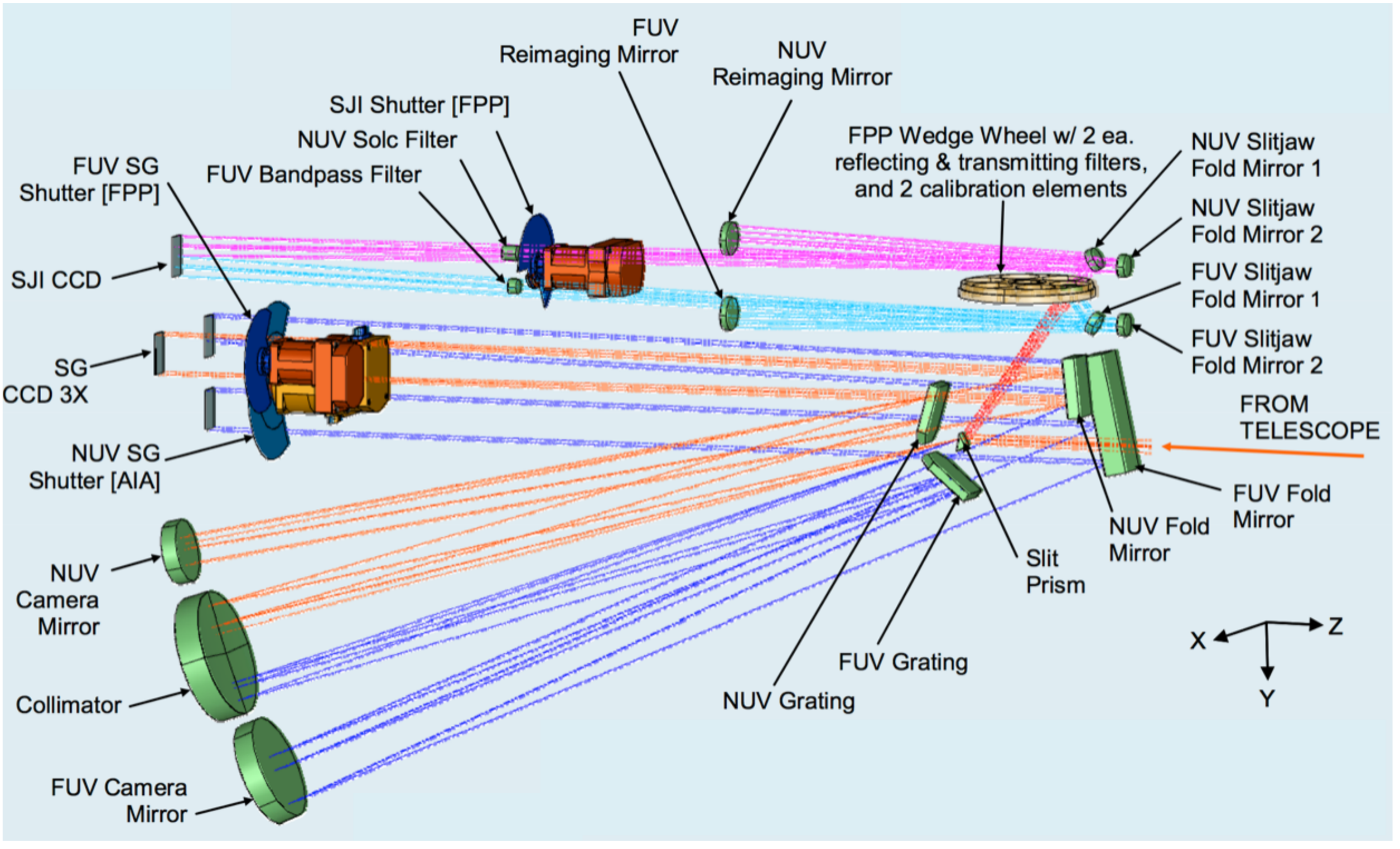



Courtesy Bart De Pontieu

# IRIS spectra and slit-jaw imaging cover the photosphere, chromosphere, transition region and corona - 4,500 to 10,000,000 K




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).

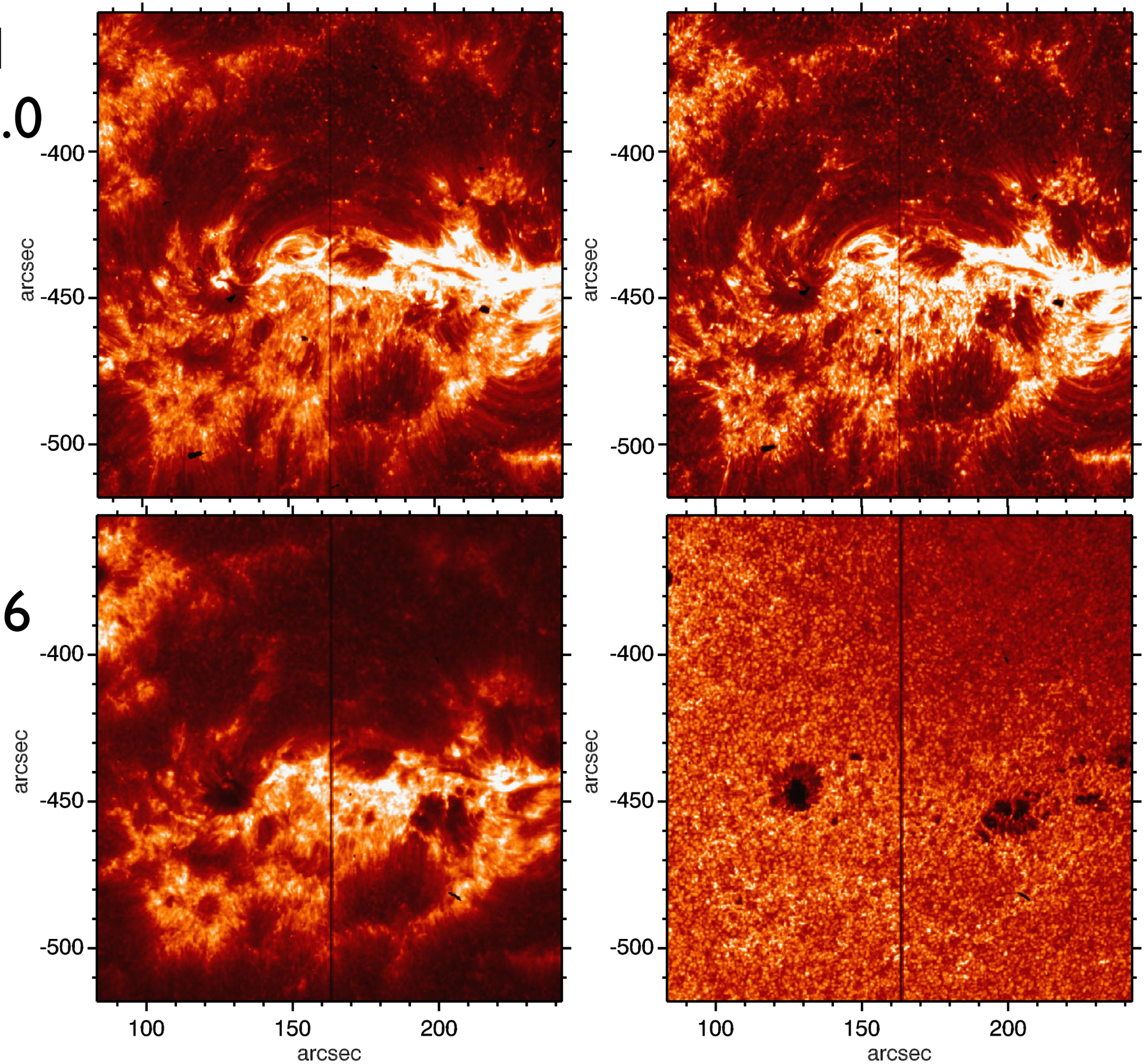
| Band-pass | Filter wheel | Name | Center [Å] | Width [Å] | FOV [″ × ″] | Pix. [″] | EA [cm$^2$] | Temp. [log $T$] |
|---|---|---|---|---|---|---|---|---|
| Glass | 1 T | 5000 | 5000 | broad | $175^2$ | 0.1679 | – | – |
| C II | 31 M | 1330 | 1340 | 55 | $175^2$ | 0.1656 | 0.5 | 3.7 – 7.0 |
| Mg II 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 133.0

SJI 140.0

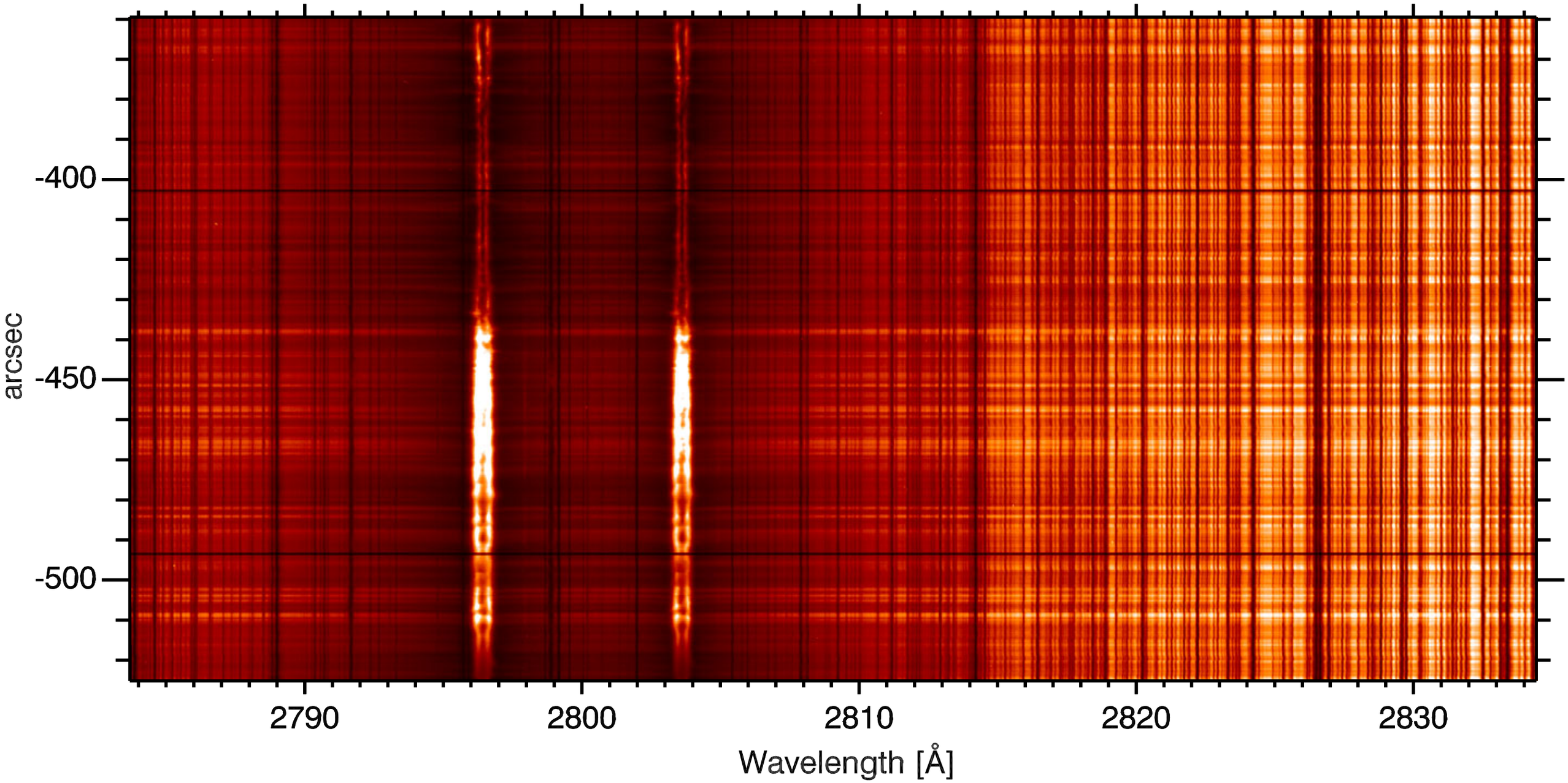
SJI 279.6

SJI 283.2



# NUV spectra

## Mg II



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

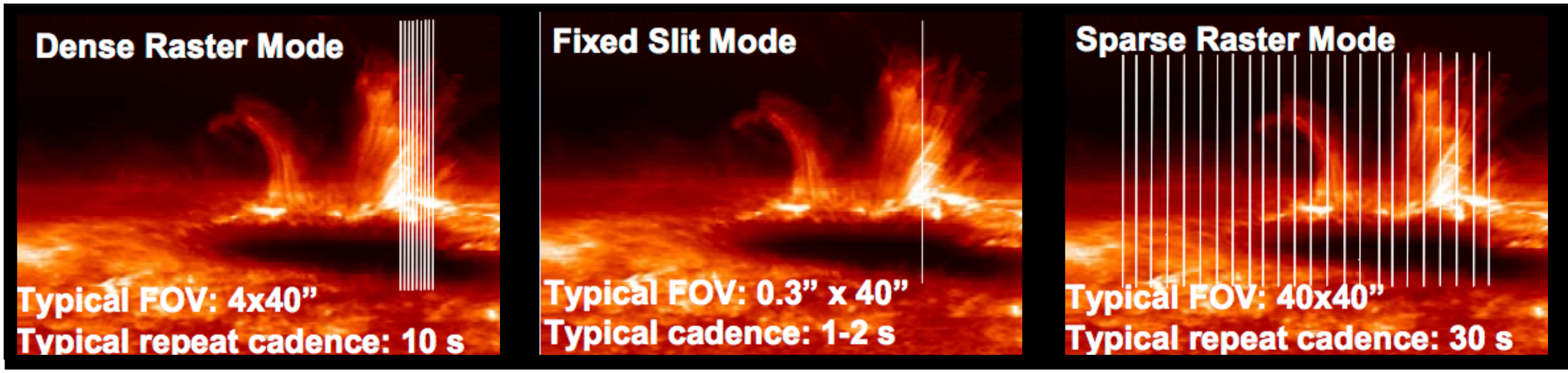
2810

2820

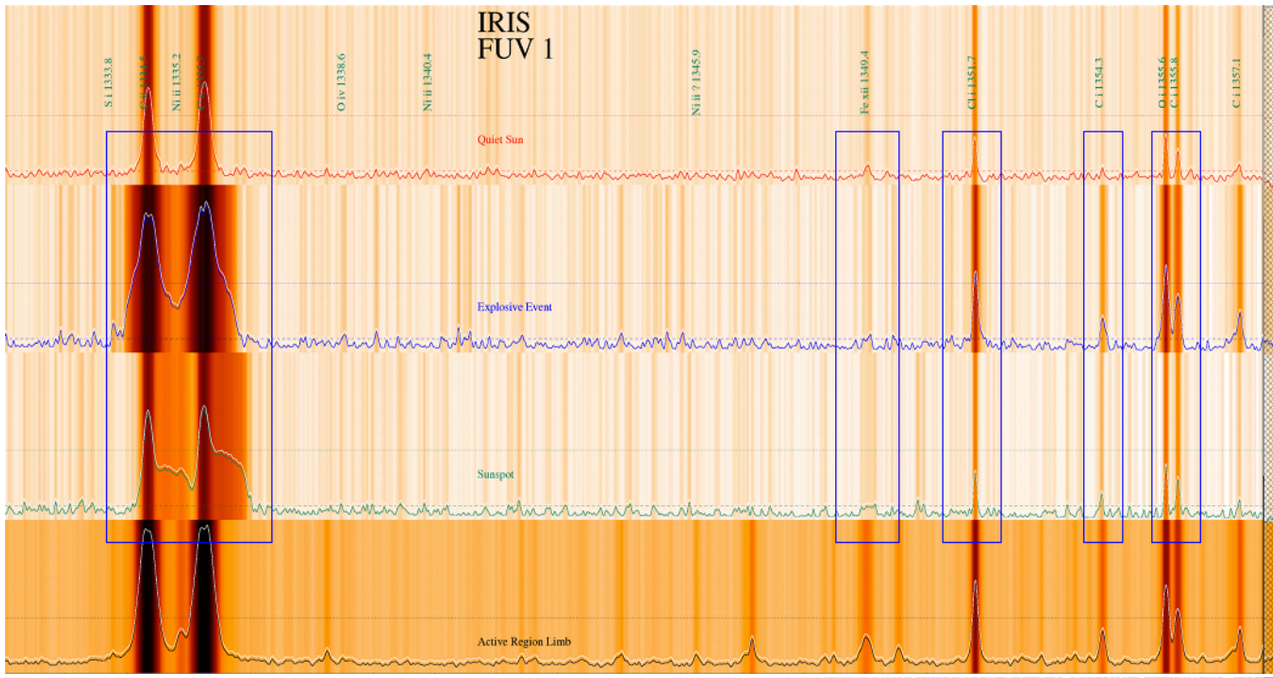
2830

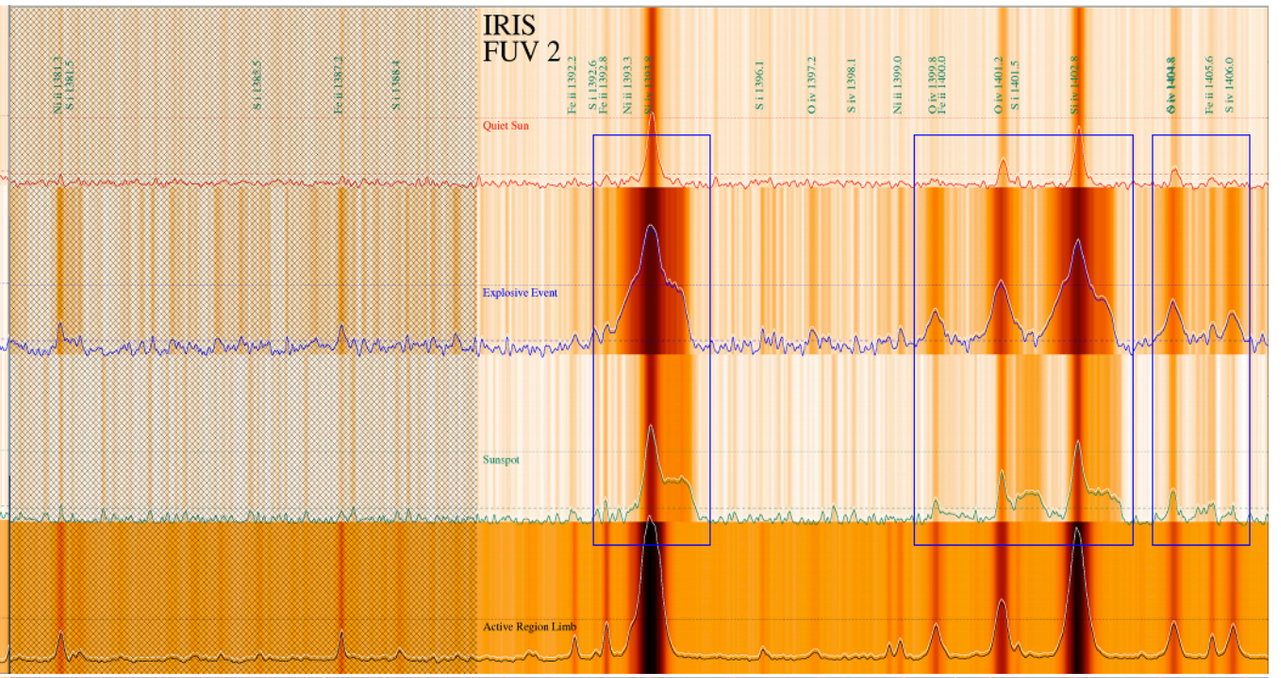
Wavelength [Å]

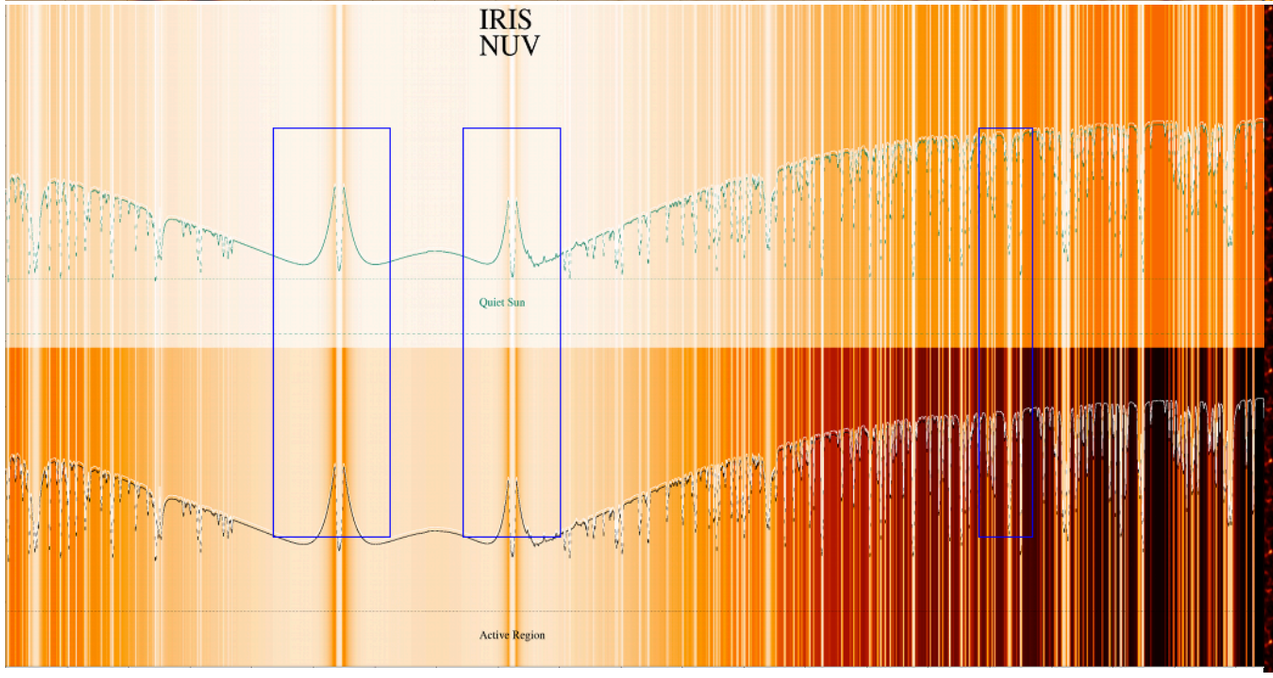
# IRIS also performs sparse rasters to improve cadence (resulting in reduced data rate)

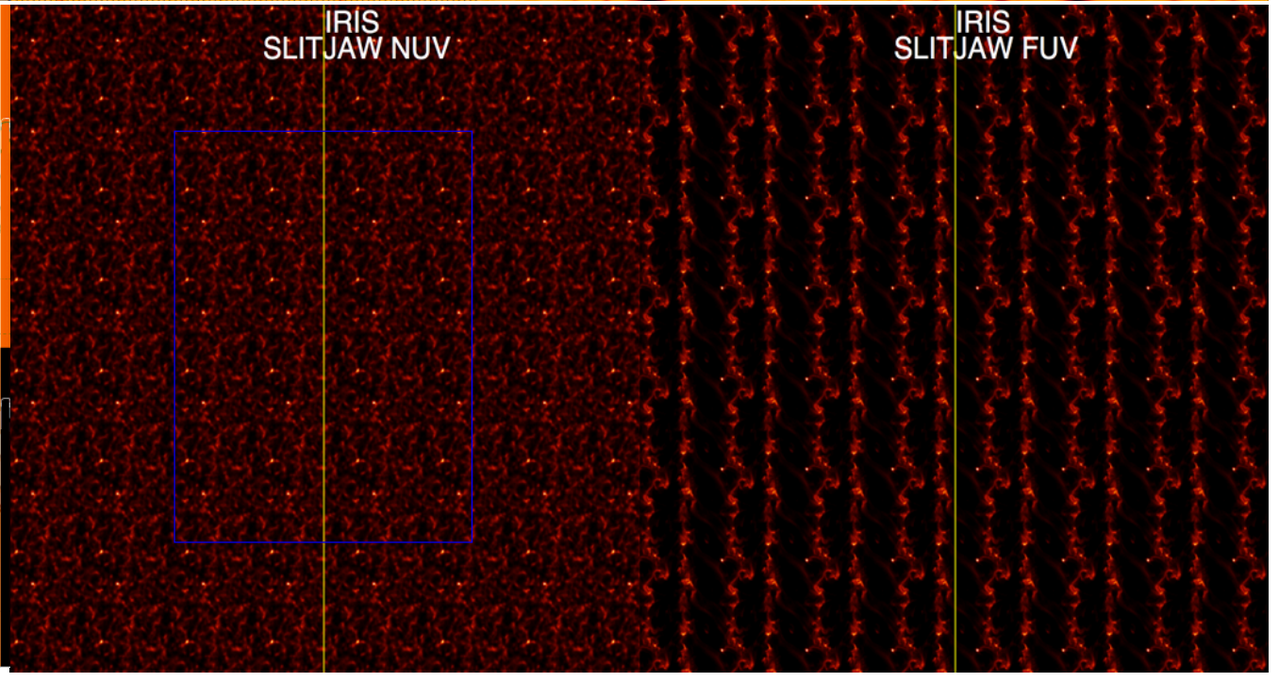


# IRIS camera layout



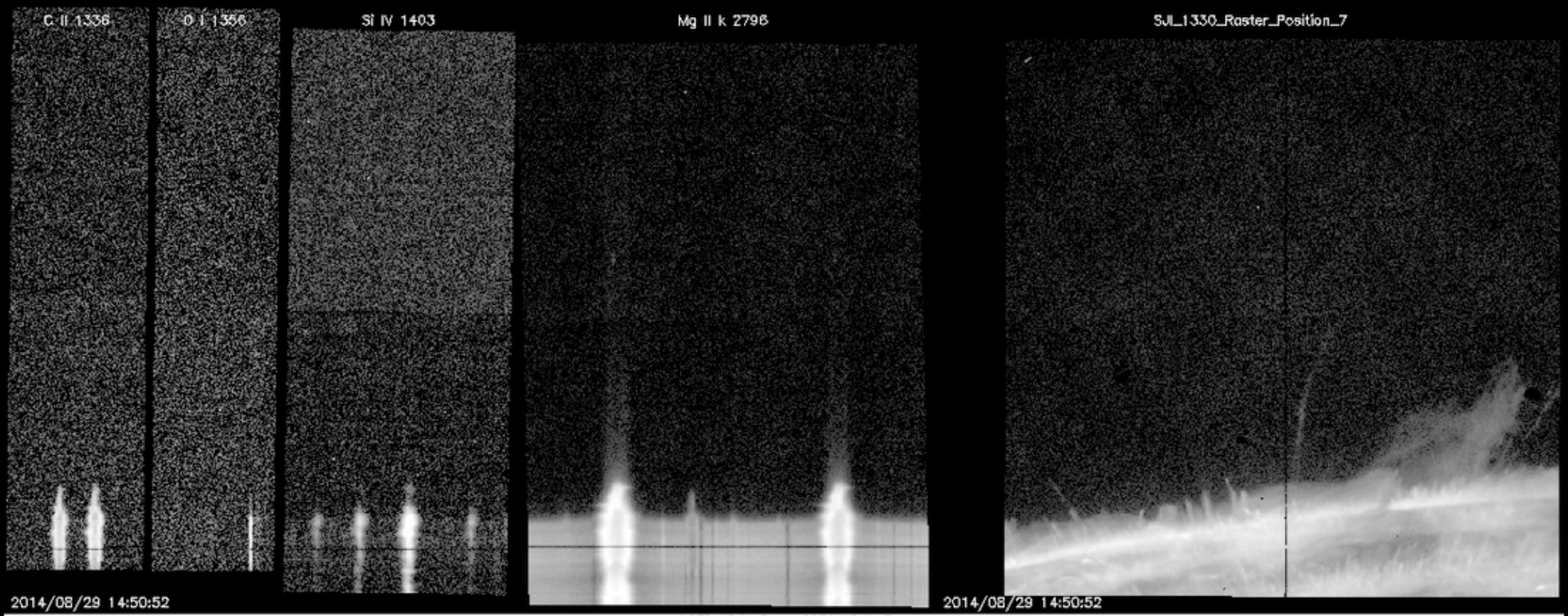



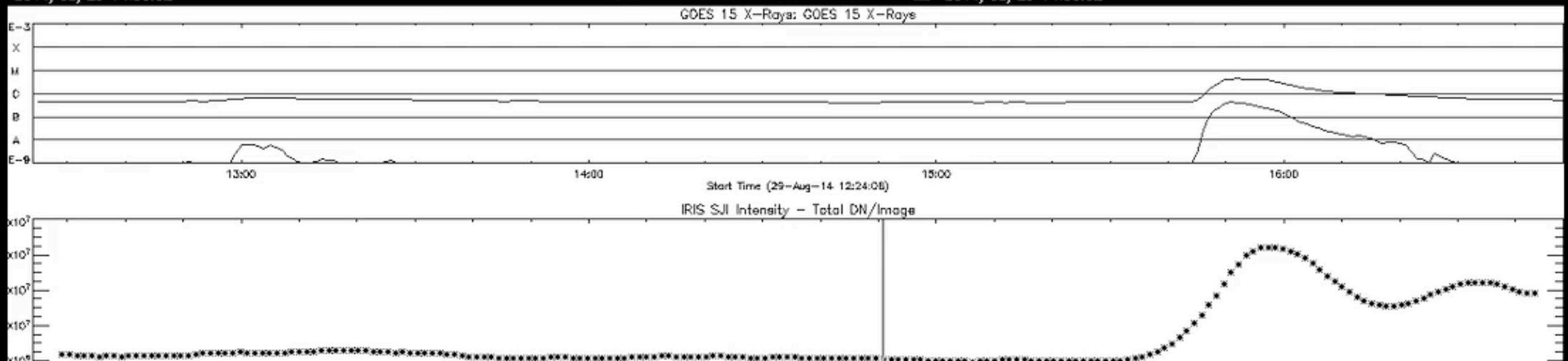



C II 133.6 O I 135.5 Si IV 140.3

Mg II

SJI 133 (C II + Fe XII)



# 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 |

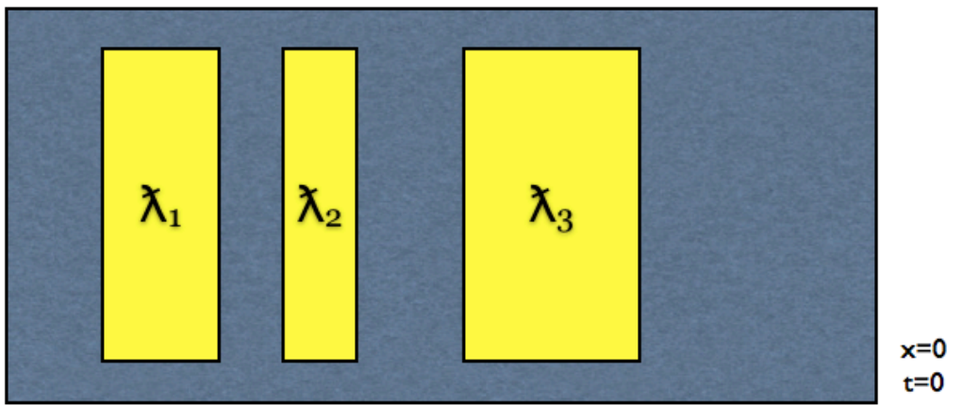
See IRIS paper or ITN 31 for a detailed listing of the different modes.

# IRIS data levels

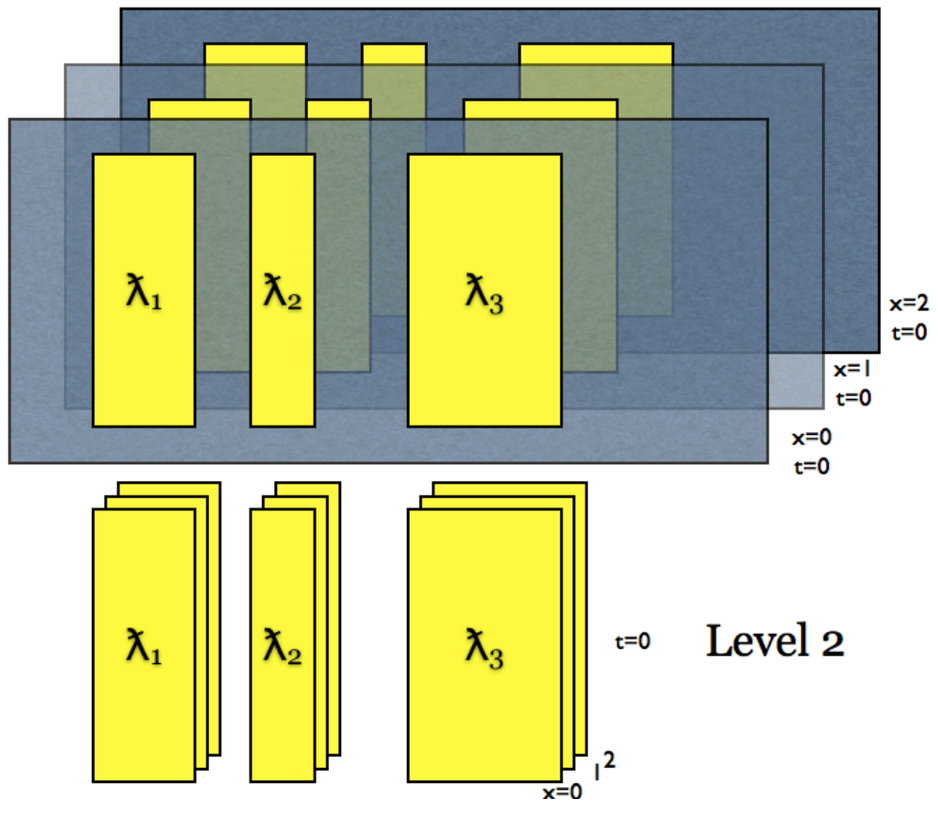
| Level | Processing | Notes |
|---|---|---|
| TLM | Capture | Raw telemetry |
| 0 | Depacketized | Raw images with basic keywords |
| 1 | Reorient images to common axes:<br>North up (0° roll), increasing wavelength to right | Lowest distributed level |
| 1.5 | Dark current and offsets removed<br>Flag bad pixels and pixels with spikes<br>Flat-field correction<br>Geometric and wavelength calibration | Transitory data product for level 2 production. Not distributed, for internal use only.<br>Use iris_prep to go from level 1 to 1.5 |
| **2** | **Recast as rasters and SJI time series** | **Standard science product.**<br>**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

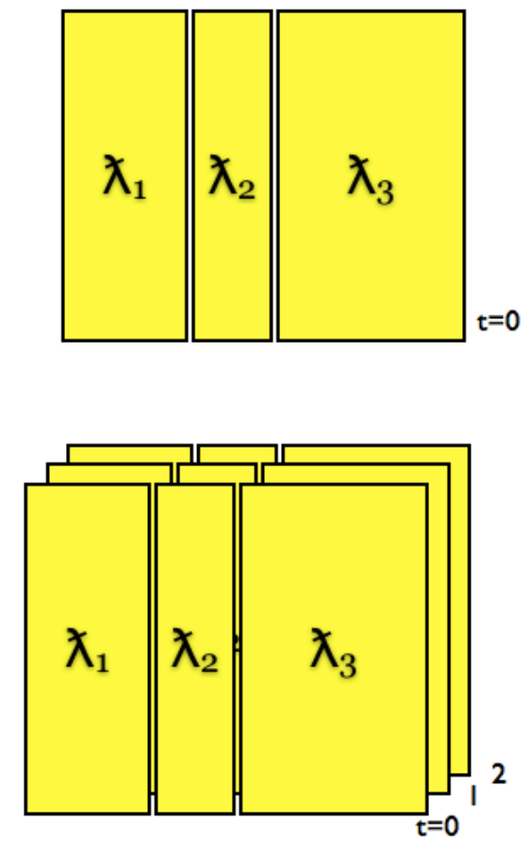
## Level 1




## Level 2




## Level 3



## IRIS mission/instrument paper

### 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

### 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

### Calibration

ITN 14 - Dark Current/Offset
ITN 15 - Despiking
ITN 16 - Flat-field
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

### 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
SolarSoft Tree and UVSP Database

### 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)

### Talks & Posters

Invited Talks at the SDO-4/IRIS/Hinode Workshop - March 2012
IRIS Talk Hinode 5 Meeting Keynote (430 MB) PDF (36 MB)
IRIS Poster
FUV Camera View
NUV Camera View

### Concept Study Report

Executive Summary
Science Goals
Instrument Description

# Lecture overview

- Overview of IRIS, capabilities and resources
- Getting the data, quicklook tools
- Working with IRIS data

- Additional Data Calibration
- Utility functions for Mg II and FUV lines
- CRISPEX
- Time to work on questions

- Exercise questions
- Hands-on tutorials

# 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

Iris_Xfiles - QL Control Window

Exit

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]

Start Time: 6-Aug-2013 13:17:10 Stop Time: 20-Aug-2013 13:17:10

Last 5 days | Up until now

Recent time-windows: 6-Aug-2013 - 20-Aug-2013

ignore times (only if no tree structure)

Set search filter: iris 12*

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

# Lecture overview

Part 1

- Overview of IRIS, capabilities and resources
- Getting the data, quicklook tools
- Working with IRIS data

Part 2

- Additional Data Calibration
- Utility functions for Mg II lines
- CRISPEX
- Time to work on questions

Tutorial

- Exercise questions
- Hands-on tutorials

# 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:

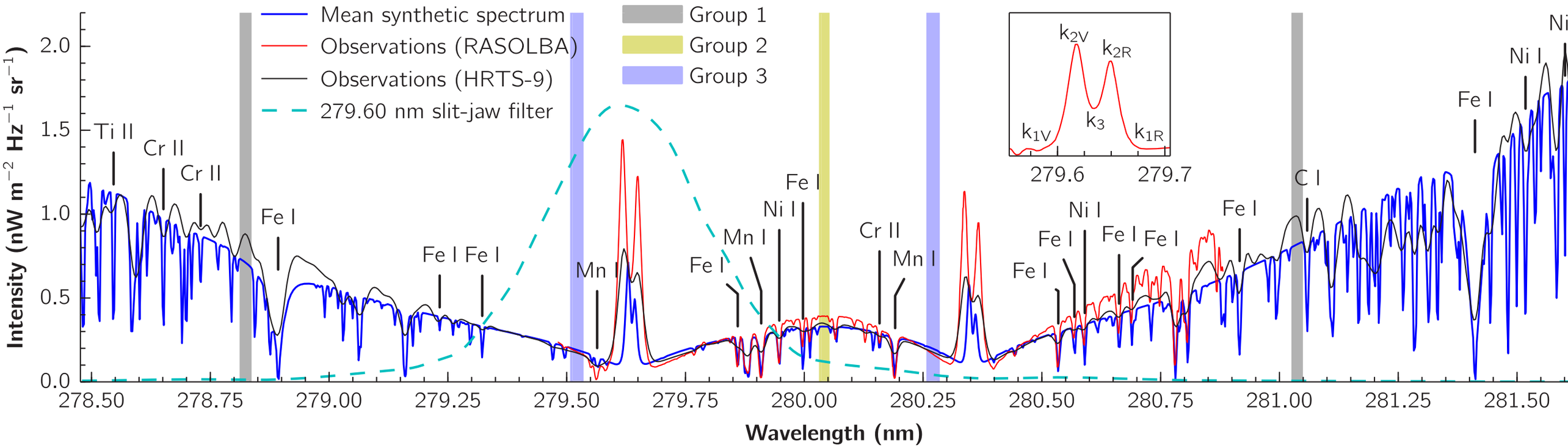
# Read IRIS data in IDL

# Lecture overview

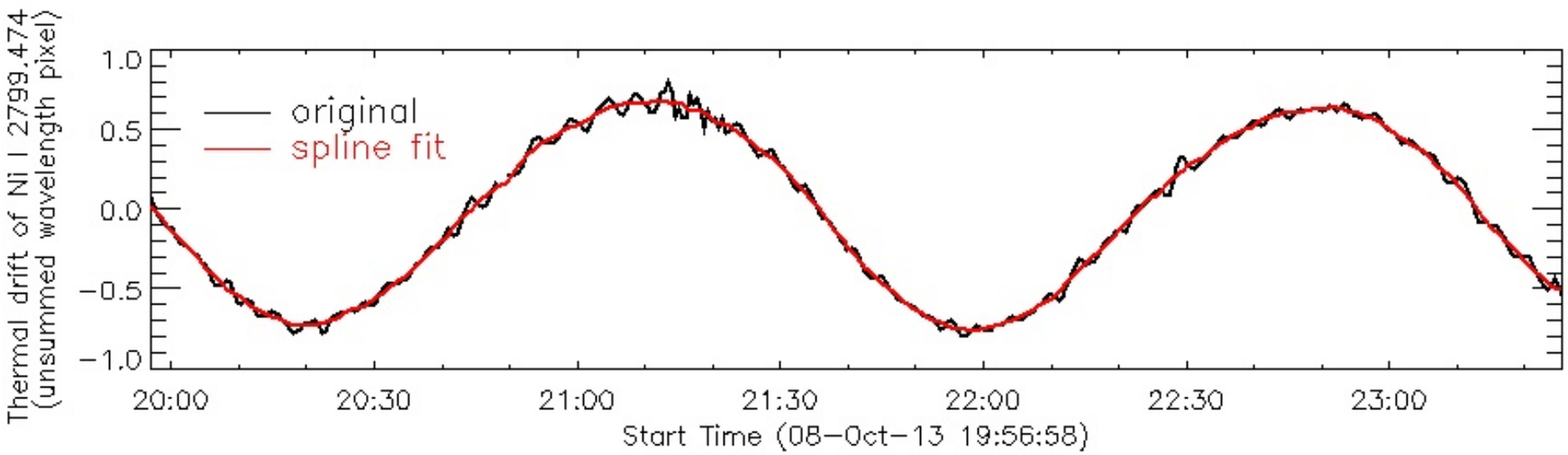
- Overview of IRIS, capabilities and resources
- Getting the data, quicklook tools
- Working with IRIS data
- Additional Data Calibration
- Utility functions for Mg II lines
- CRISPEX
- Time to work on questions

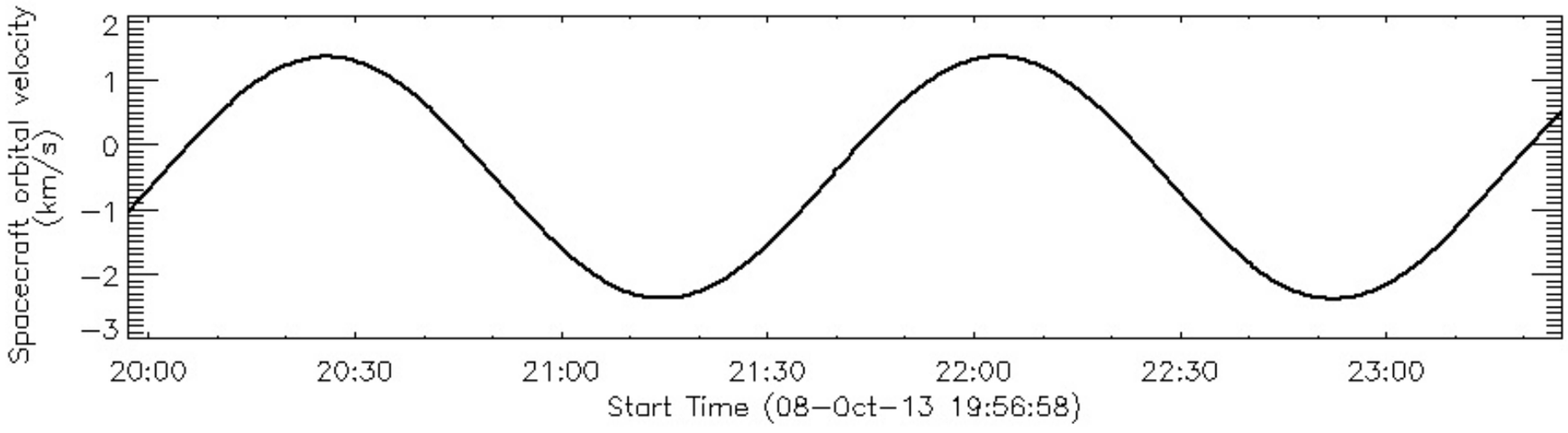
- Exercise questions
- Hands-on tutorials

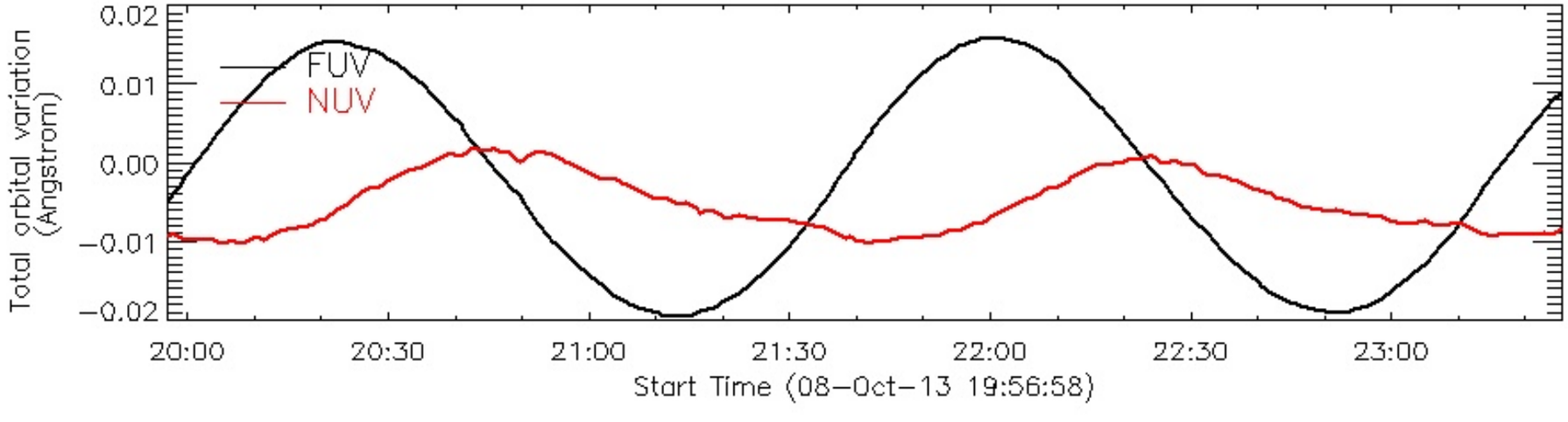
# Precise wavelength calibration



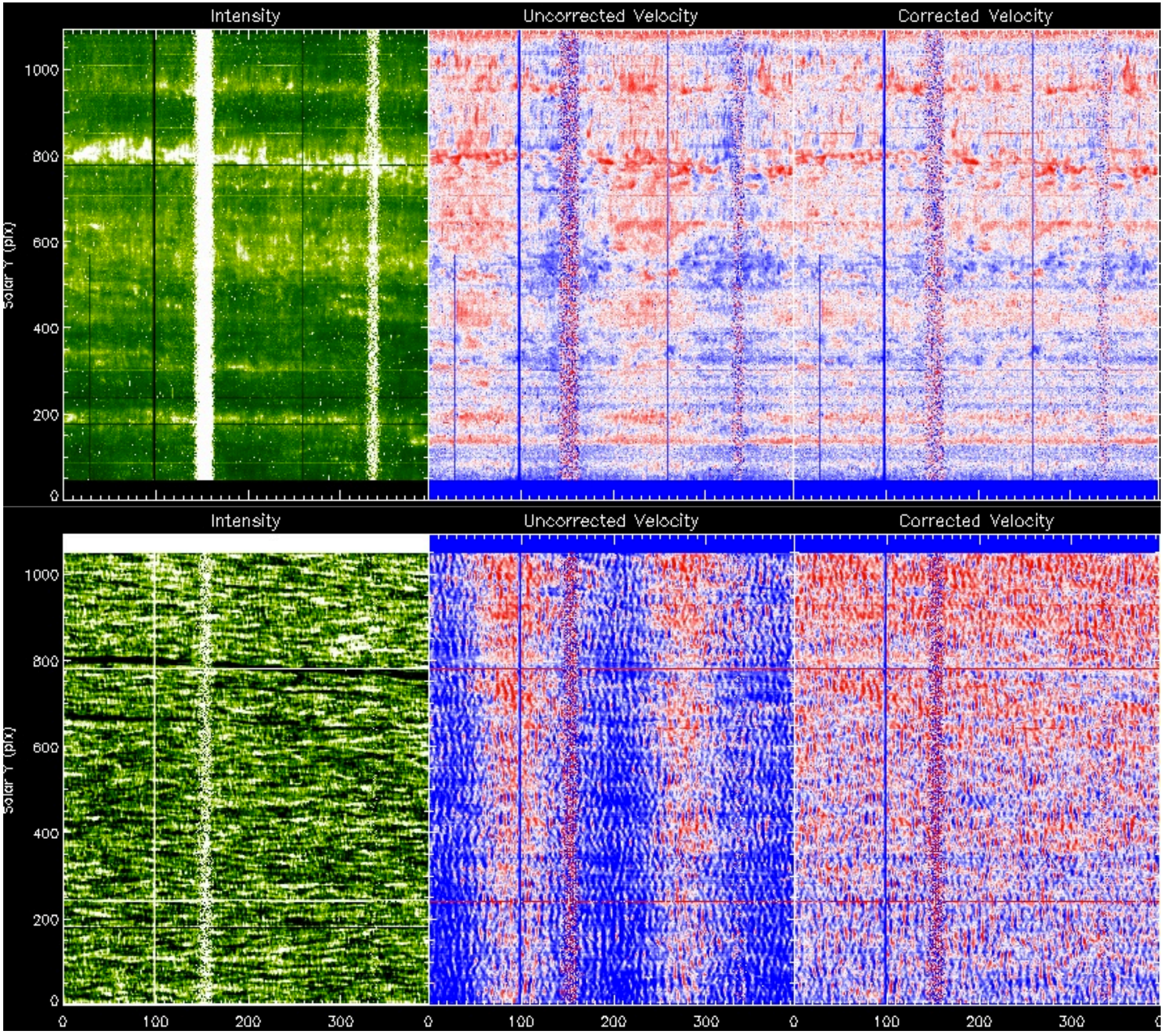
# Precise wavelength calibration

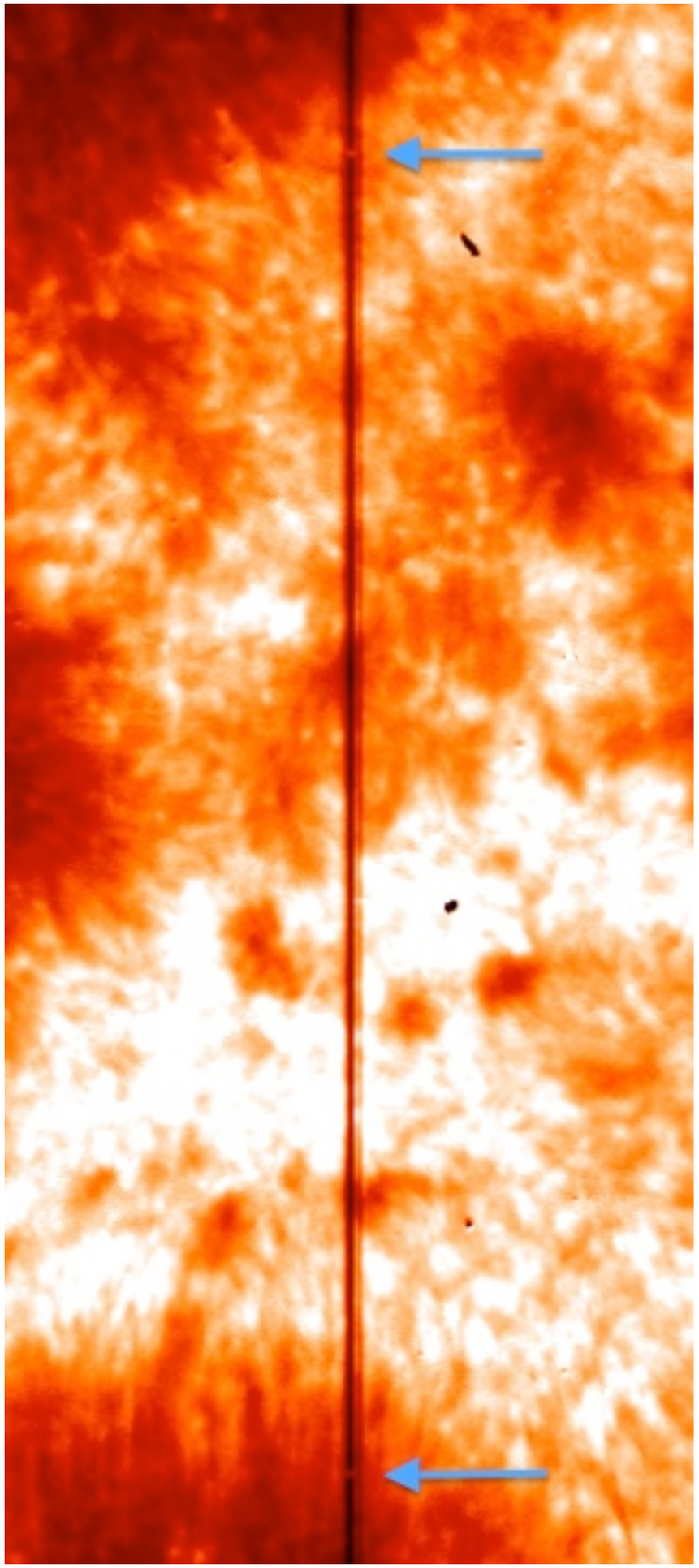


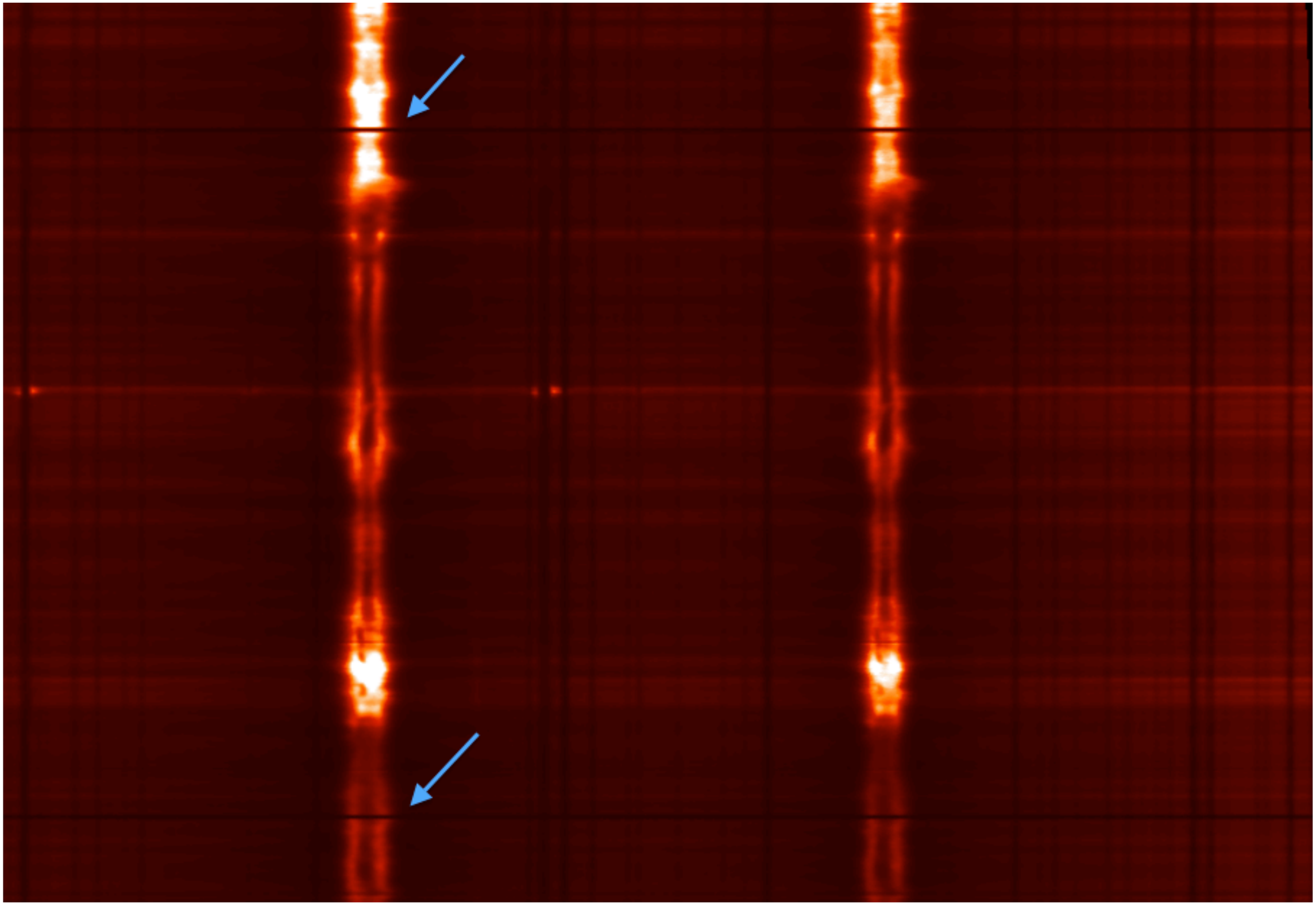
# Precise wavelength calibration





# Co-alignment between SJIs

# Co-alignment between spectra



# Lecture overview

Part 1

- Overview of IRIS, capabilities and resources
- Getting the data, quicklook tools
- Working with IRIS data

Part 2

- Additional Data Calibration
- Utility functions for Mg II lines
- CRISPEX
- Time to work on questions

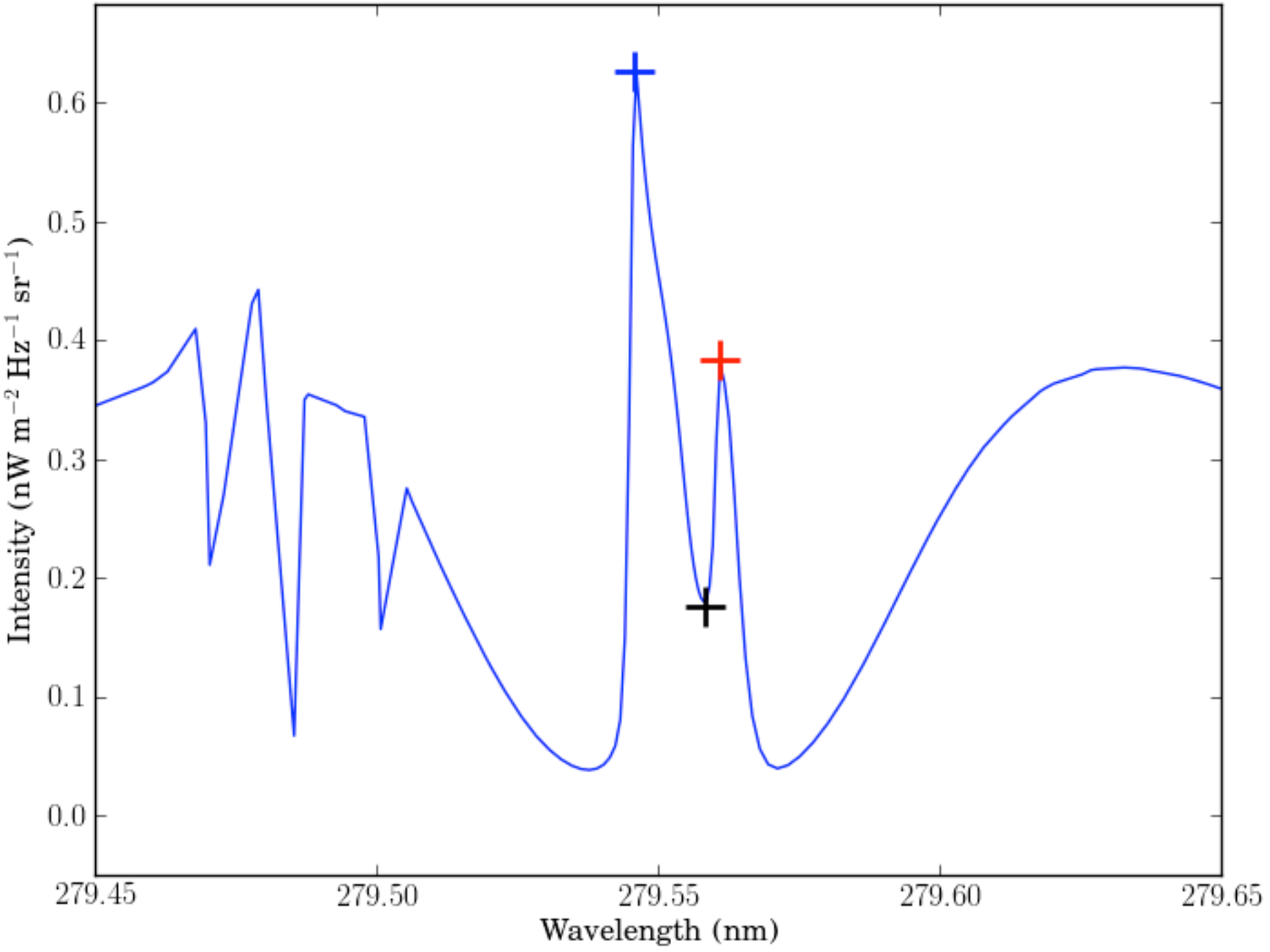
Tutorial

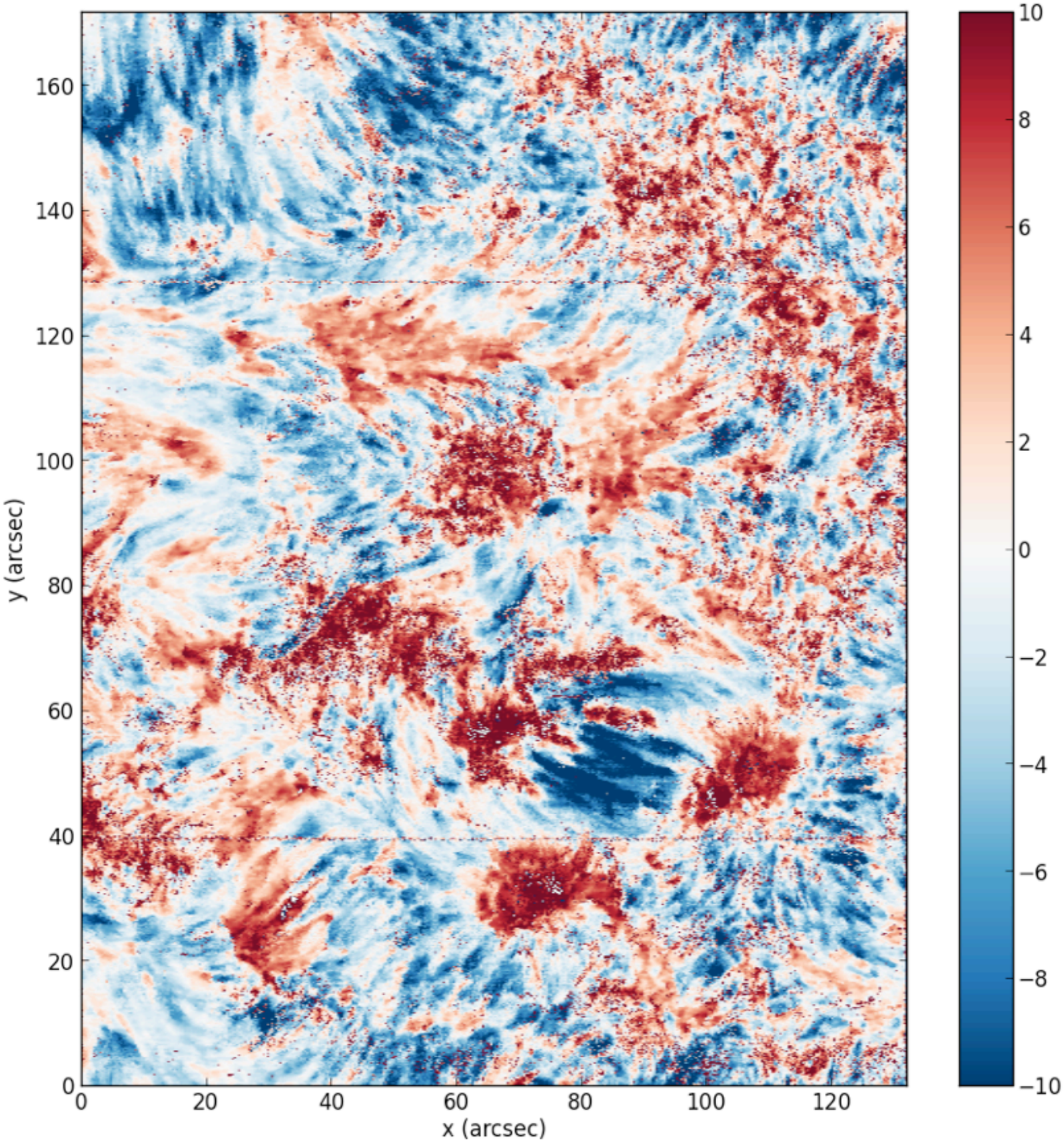
- Exercise questions
- Hands-on tutorials

# Algorithm to automatically measure Mg II line properties available on solarsoft:

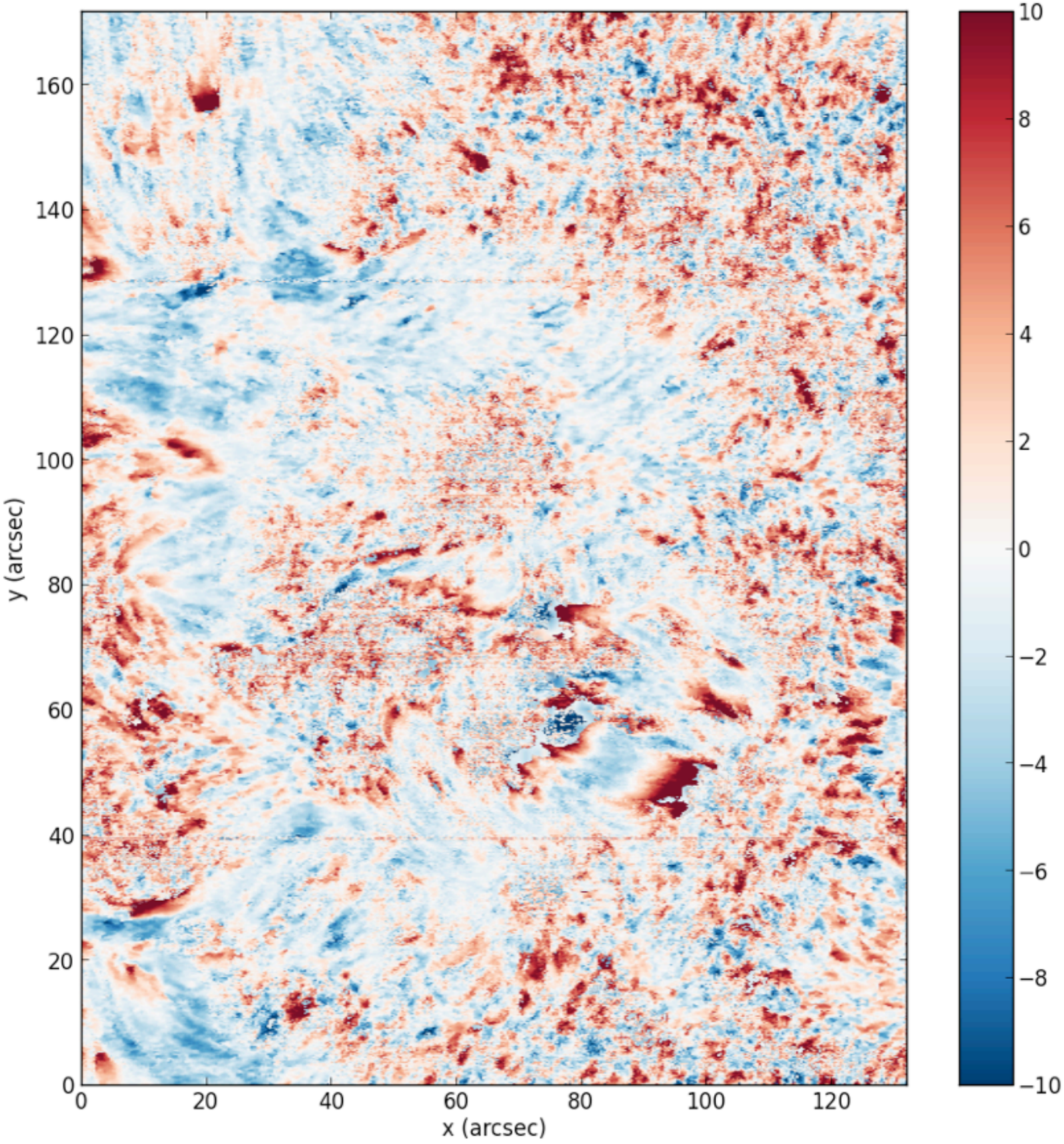
`iris_get_mg_features_lev2, file, mg_id, vr, lc, rp, bp`

Based on the algorithm described in Pereira et al. (2013)


0.6
0.5
0.4
0.3
0.2
0.1
0.0
Intensity (nW m$^{-2}$ Hz$^{-1}$ sr$^{-1}$)
279.45
279.50
279.55
279.60
279.65
Wavelength (nm)




k2v velocity (km/s)

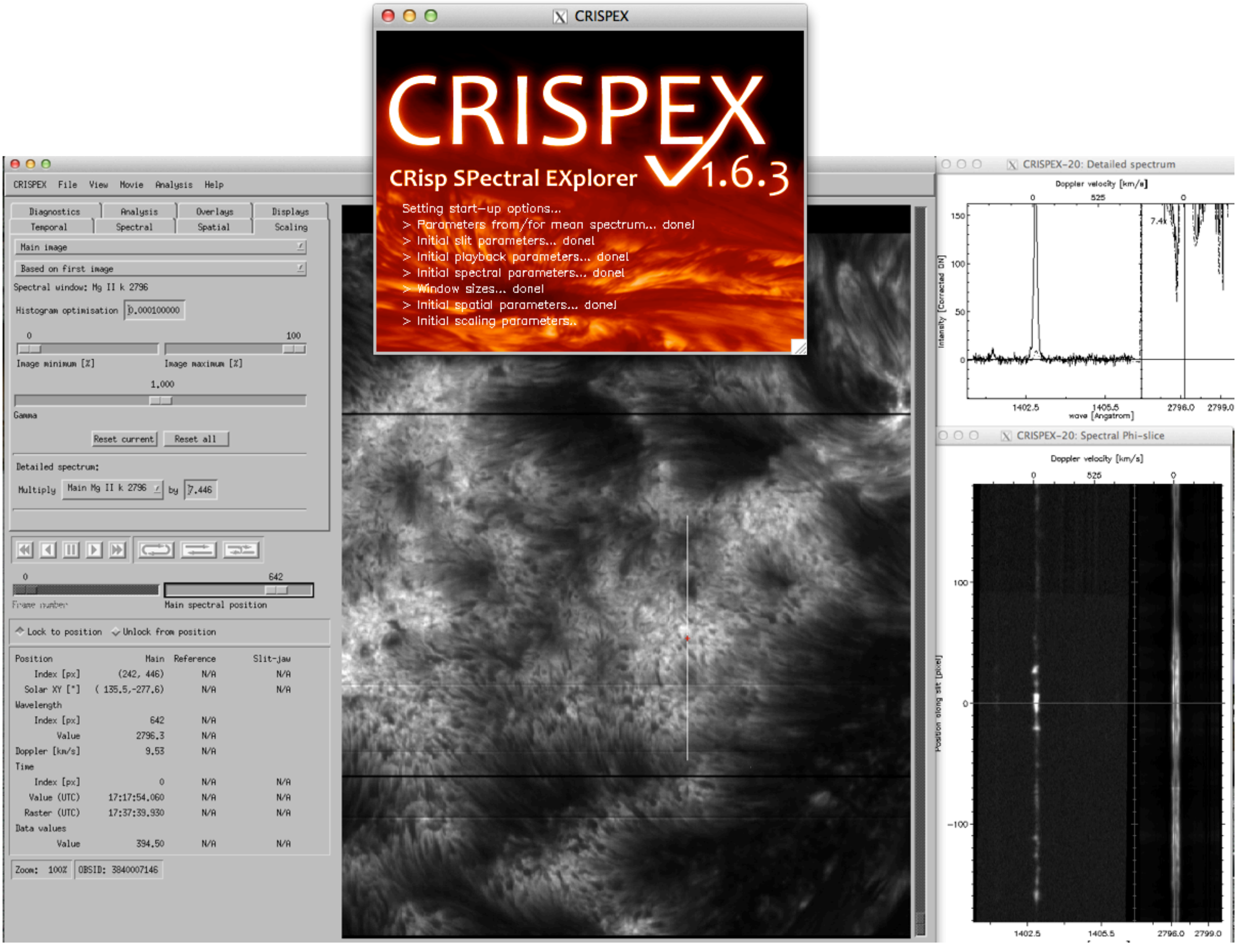



k3 velocity (km/s)

# Lecture overview

- Overview of IRIS, capabilities and resources
- Getting the data, quicklook tools
- Working with IRIS data
- Additional Data Calibration
- Utility functions for Mg II lines
- CRISPEX
- Time to work on questions

- Exercise questions
- Hands-on tutorials


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
0
100
Image minimum [%]
Image maximum [%]
1.000
Gamma
Reset current
Reset all
Detailed spectrum:
Multiply
Main Mg II k 2796
by
7.446
0
642
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]
0
525
0
7.4x
150
100
50
0
Intensity [Corrected DN]
1402.5
1405.5
2796.0
2799.0
wave [Angatrom]
CRISPEX-20: Spectral Phi-slice
Doppler velocity [km/s]
0
525
0
100
0
-100
Position along slit [pixel]
1402.5
1405.5
2796.0
2799.0

# 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

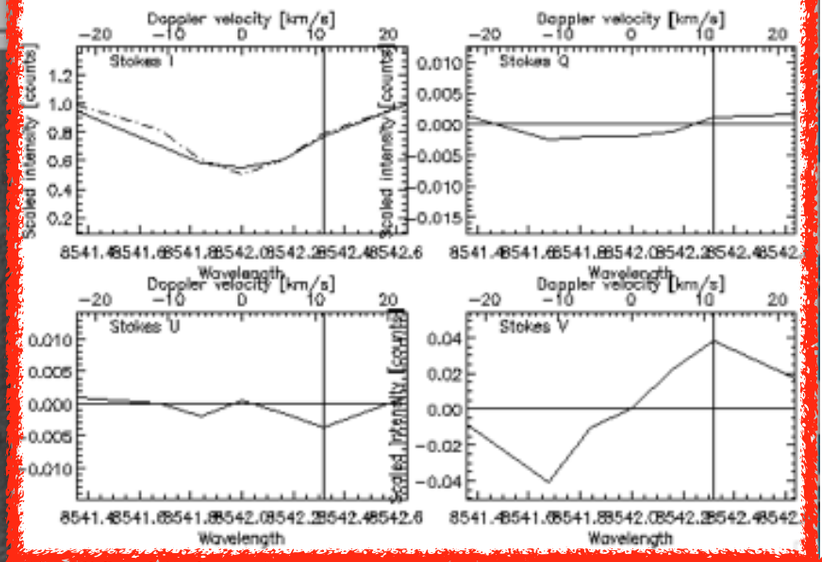
0 5

Frame number Main spectral position

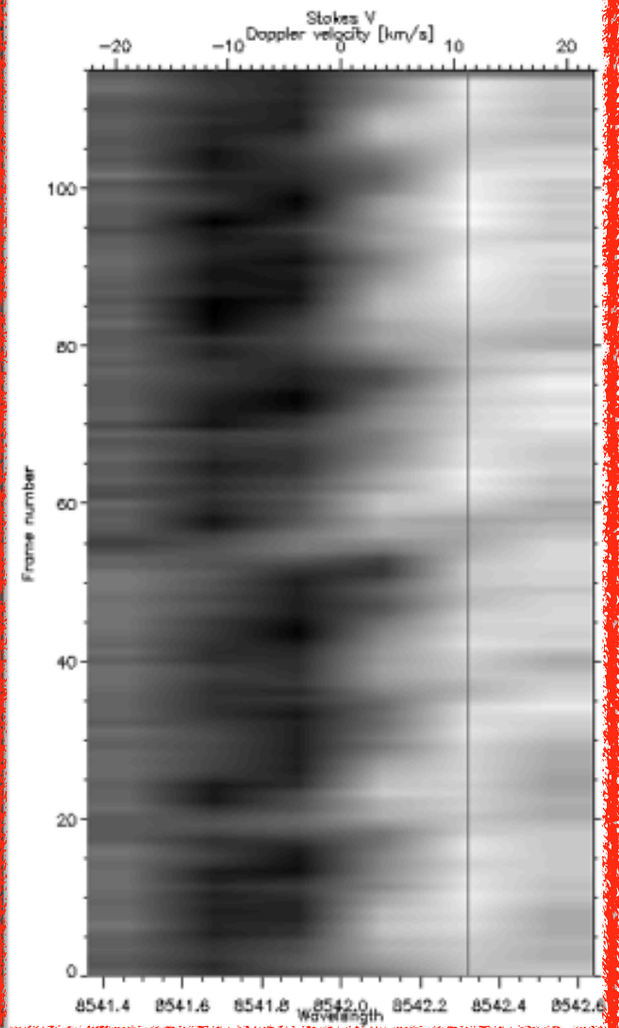
| Position | Main | Reference | Slit-jaw |
|---|---|---|---|
| Index [px] | (381,400) | N/A | N/A |
| Value ["] | (22.6,23.7) | N/A | N/A |
| Wavelength | | | |
| Index [px] | 5 | N/A | |
| Value | 8542.3 | N/A | |
| Doppler [km/s] | 11.23 | N/A | |
| Time | | | |
| Index [px] | 0 | N/A | N/A |
| Data values | | | |
| Value | 573.00 | N/A | N/A |

Zoom: 100% Date: N/A OBSID: N/A

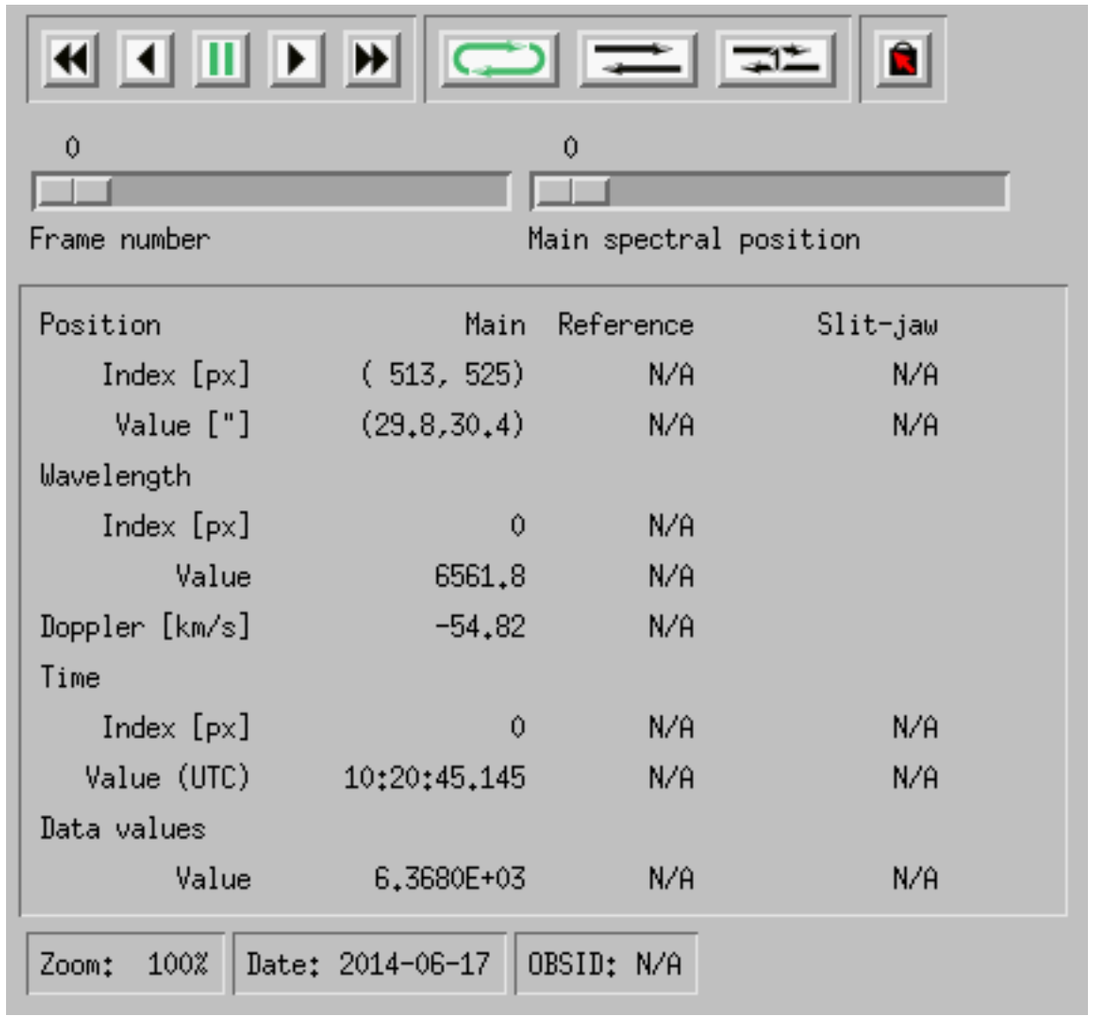
CRISPEX-26: Detailed spectrum



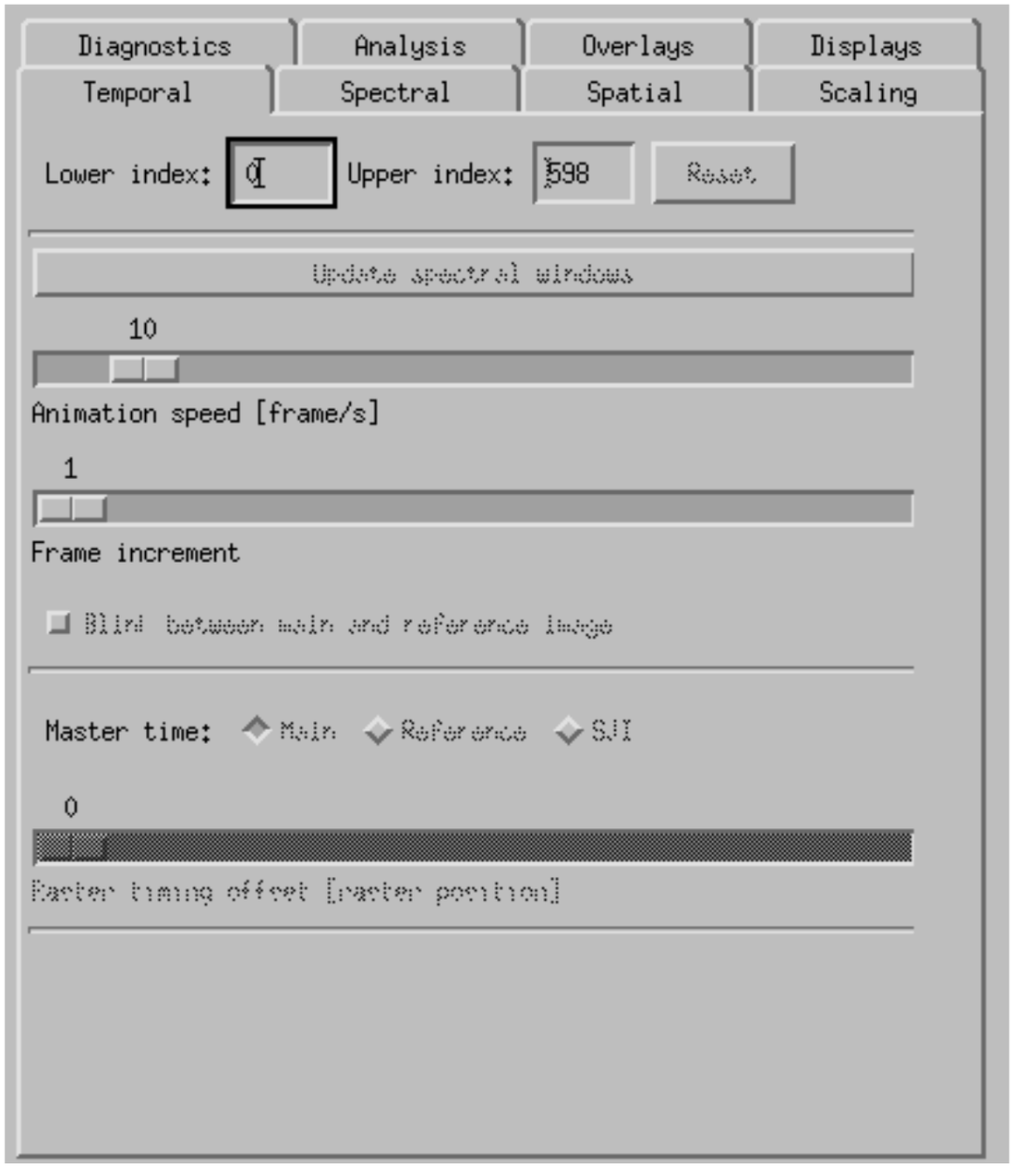

CRISPEX-26: Spectral T-slice

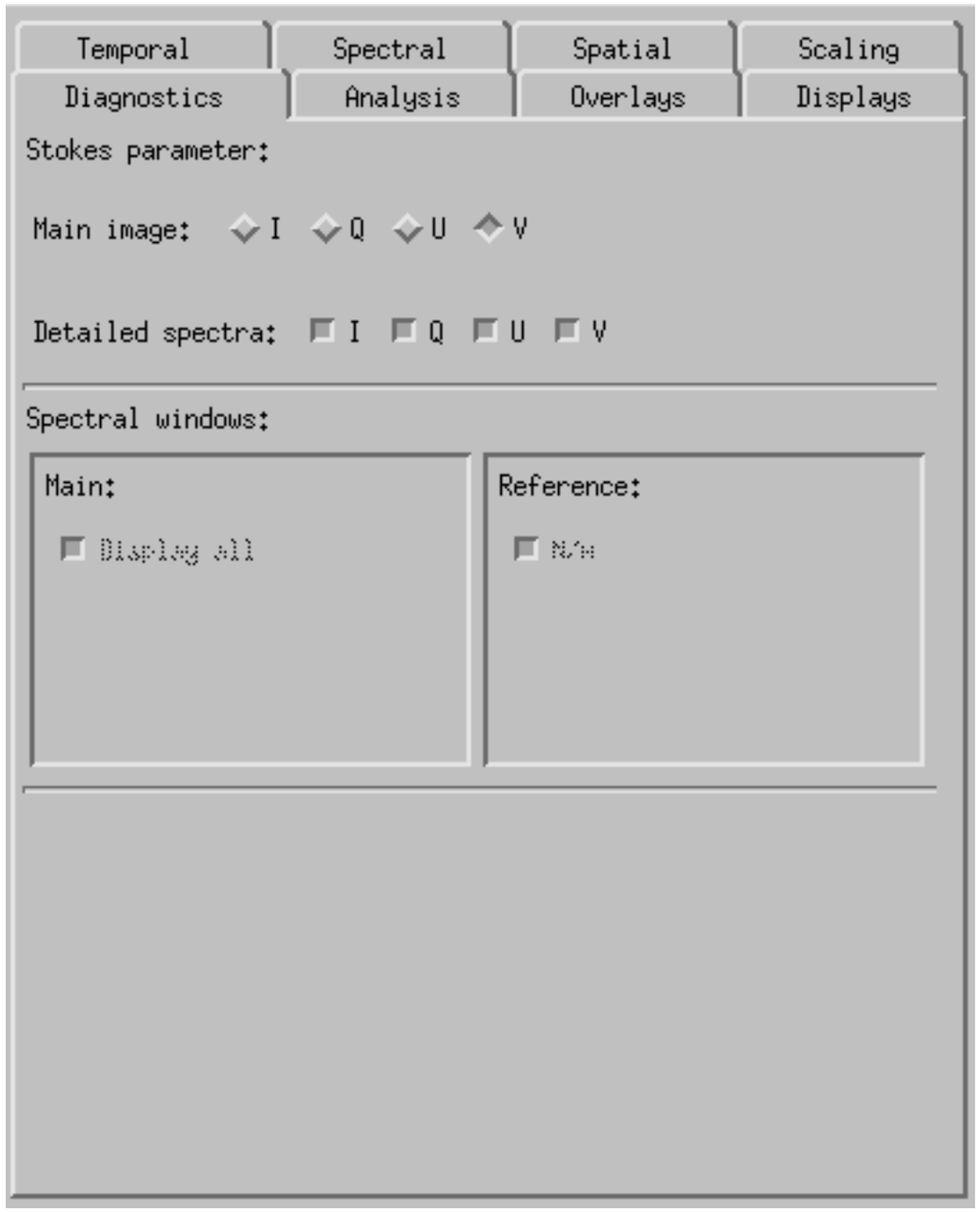


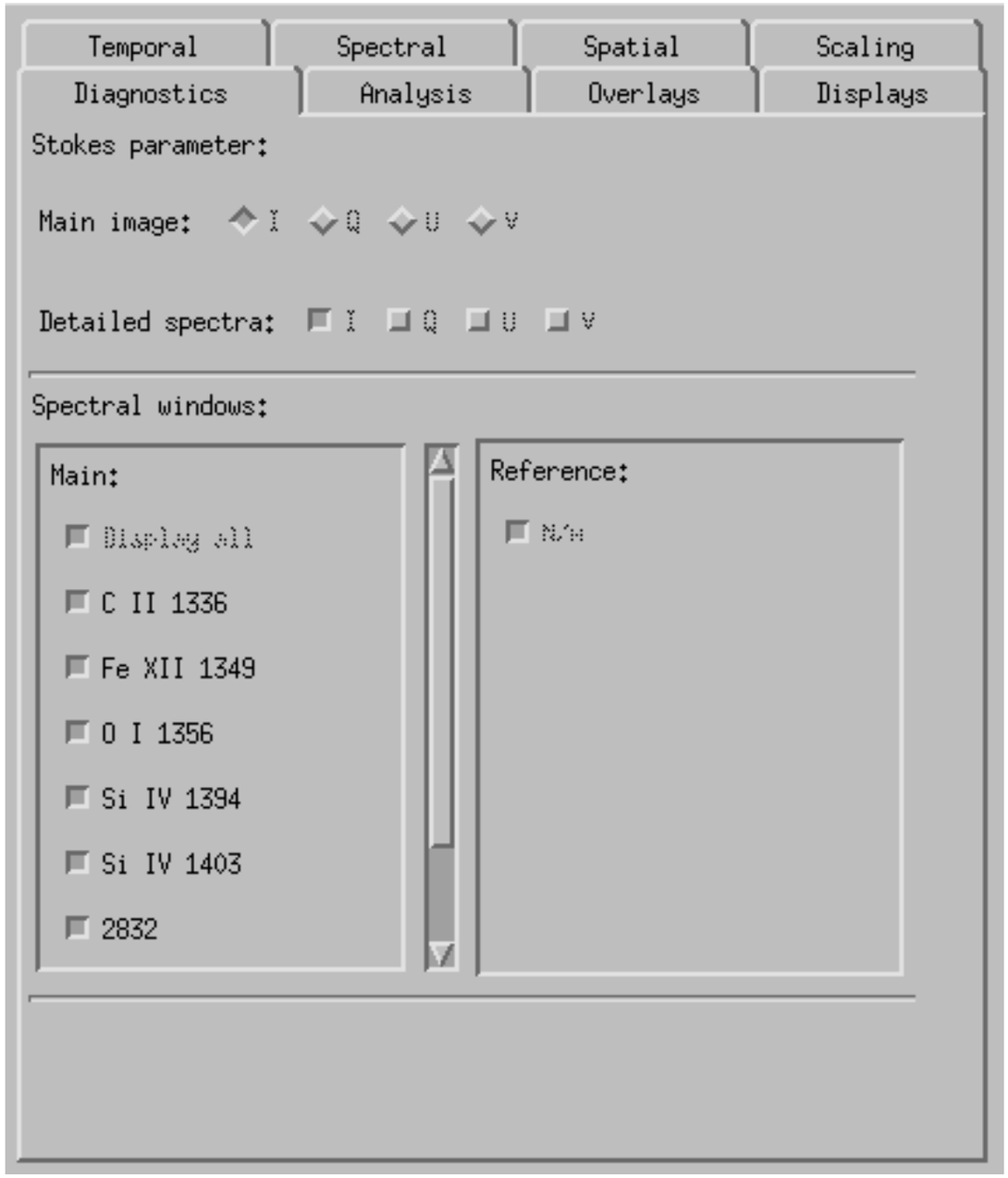
# Bottom control panel

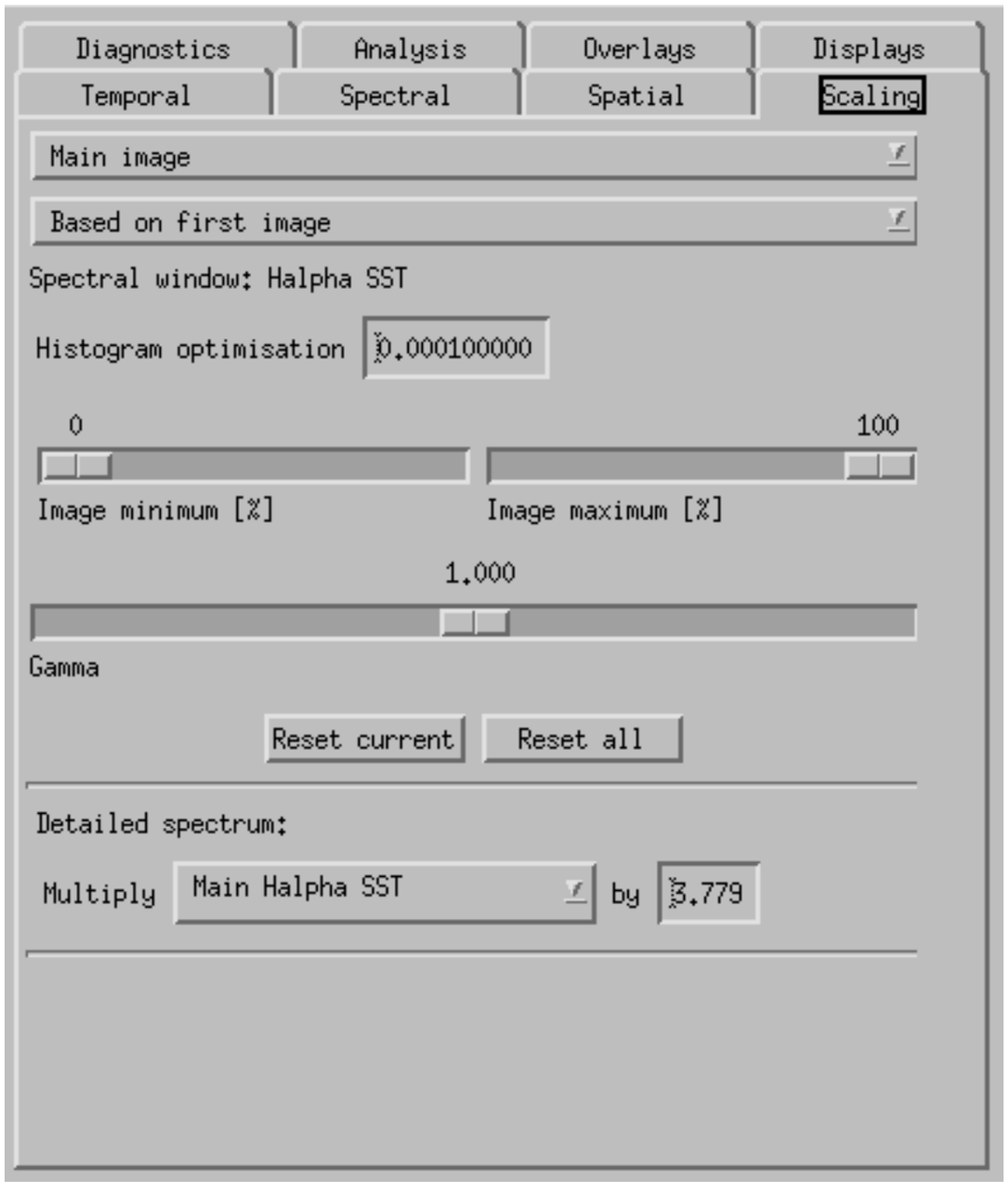


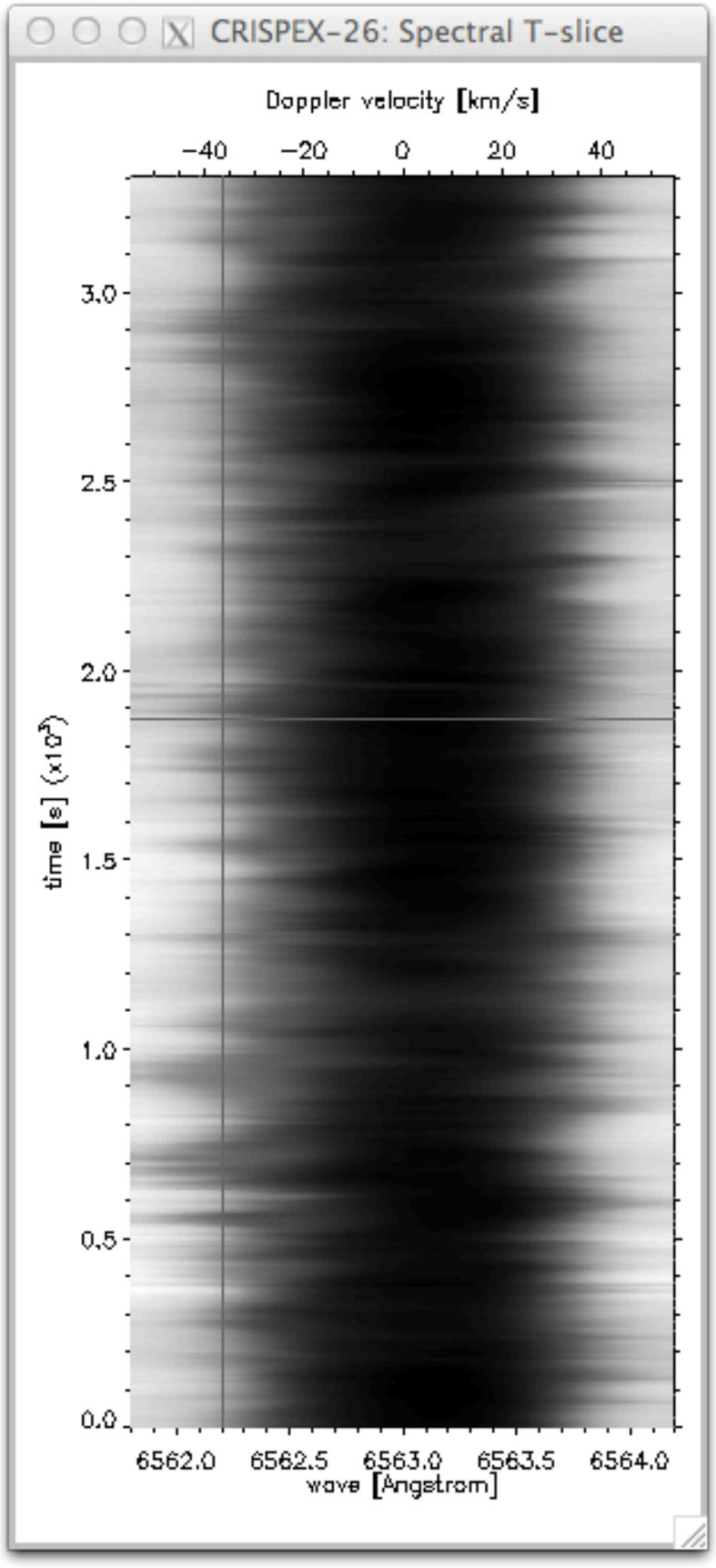
# Tabs


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
3.0
2.5
2.0
1.5
1.0
0.5
0.0
time [s] (x10³)
6562.0
6562.5
6563.0
6563.5
6564.0
wave [Angstrom]

# Live demo:

# CRISPEX

# Lecture overview

- Overview of IRIS, capabilities and resources
- Getting the data, quicklook tools
- Working with IRIS data
- Additional Data Calibration
- Utility functions for Mg II lines
- CRISPEX
- Time to work on questions

- Exercise questions
- Hands-on tutorials

# Lecture overview

- Overview of IRIS, capabilities and resources
- Getting the data, quicklook tools
- Working with IRIS data
- Additional Data Calibration
- Utility functions for Mg II lines
- CRISPEX
- Time to work on questions

- Exercise questions
- Hands-on tutorials

http://pollev.com/iris7

# Lecture overview

- Overview of IRIS, capabilities and resources
- Getting the data, quicklook tools
- Working with IRIS data

- Additional Data Calibration
- Utility functions for Mg II lines
- CRISPEX
- Time to work on questions

- Exercise questions
- Hands-on tutorials