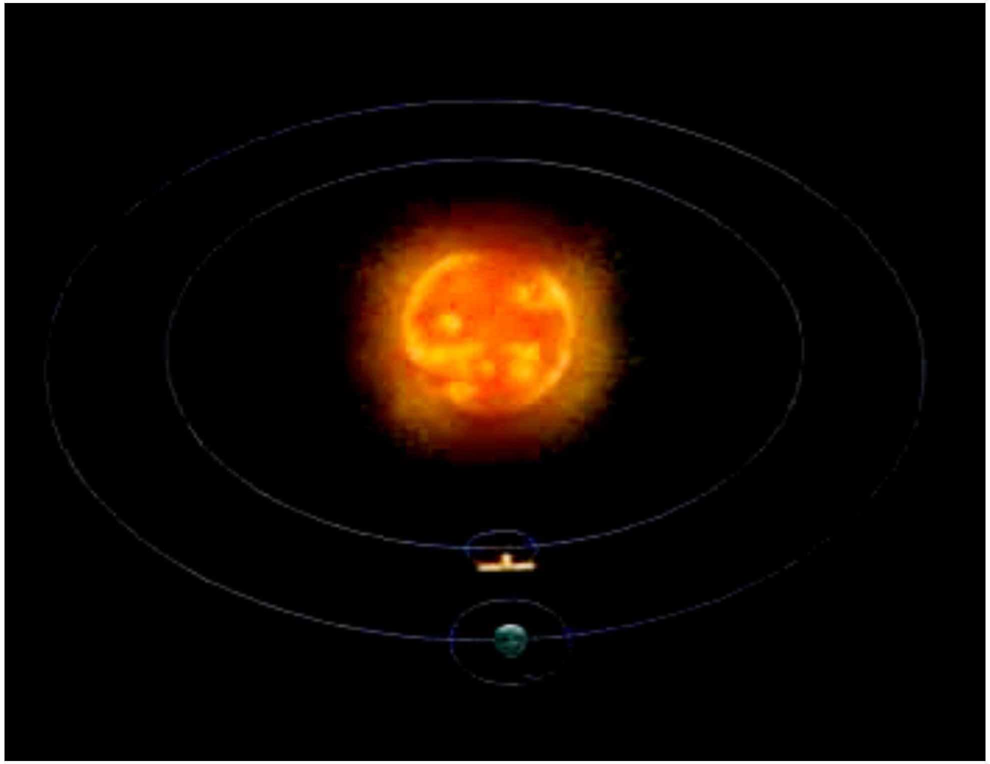
Study of waves from India's solar mission Aditya L1



Dipankar Banerjee (On Behalf of the SWG)
Indian Institute of Astrophysics
dipu@iiap.res.in

The complete list of payloads: (ISRO website)

Visible Emission Line Coronagraph (VELC): To study the diagnostic parameters of solar corona and dynamics and origin of Coronal Mass Ejections (3 visible and 1 Infra-Red channels); magnetic field measurement of solar corona down to tens of Gauss – Indian Institute of Astrophysics (IIA)

Solar Ultraviolet Imaging Telescope (SUIT): To image the spatially resolved Solar Photosphere and Chromosphere in near Ultraviolet (200-400 nm) and measure solar irradiance variations - Inter-University Centre for Astronomy & Astrophysics (IUCAA)

Aditya Solar wind Particle Experiment (ASPEX) : To study the variation of solar wind properties as well as its distribution and spectral characteristics – Physical Research Laboratory (PRL)

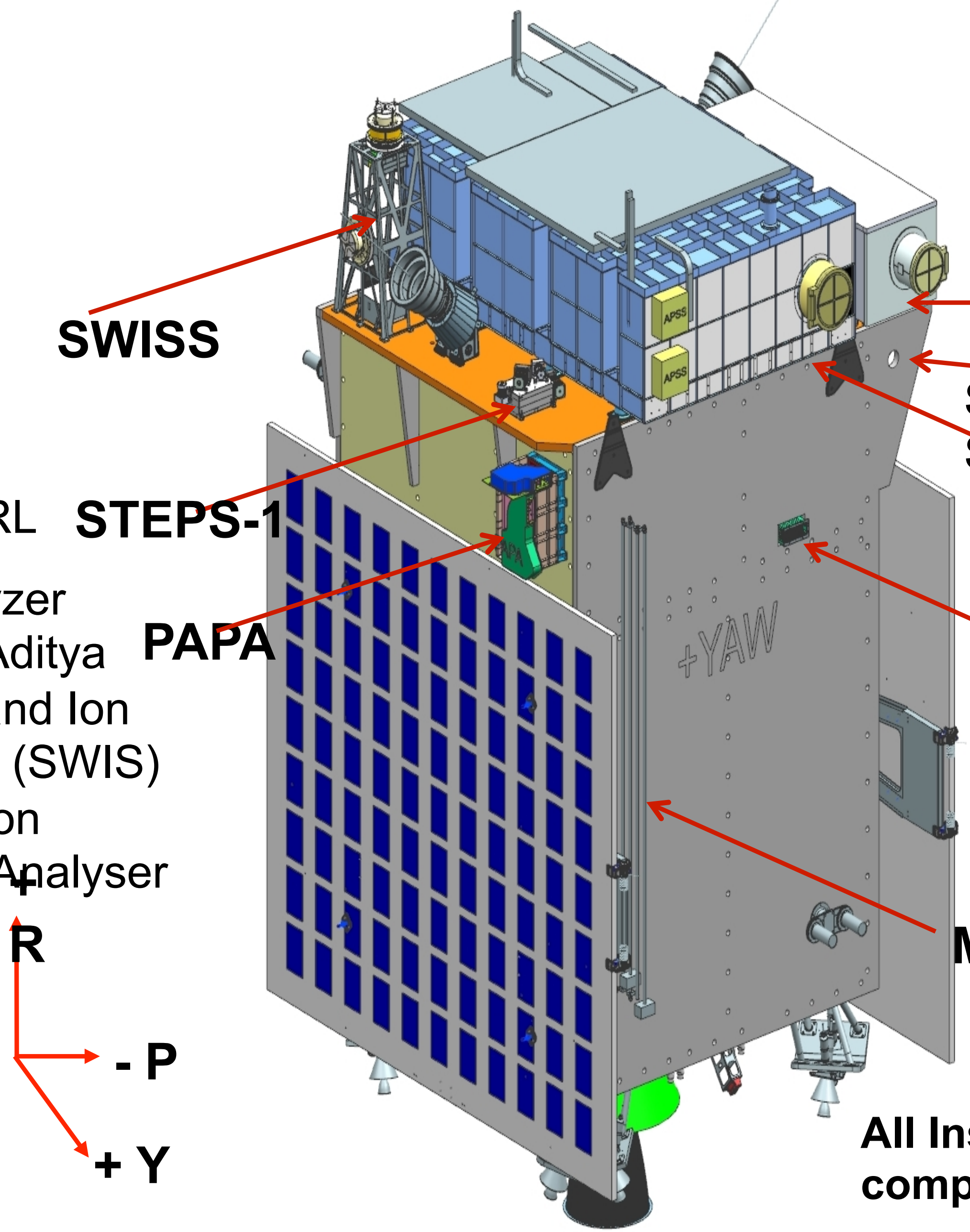
Plasma Analyser Package for Aditya (PAPA) : To understand the composition of solar wind and its energy distribution – Space Physics Laboratory (SPL), VSSC

Solar Low Energy X-ray Spectrometer (SoLEXS) : To monitor the X-ray flares for studying the heating mechanism of the solar corona – ISRO Satellite Centre (ISAC)

High Energy L1 Orbiting X-ray Spectrometer (HEL1OS): To observe the dynamic events in the solar corona and provide an estimate of the energy used to accelerate the particles during the eruptive events - ISRO Satellite Centre (ISAC) and Udaipur Solar Observatory (USO), PRL

Magnetometer: To measure the magnitude and nature of the Interplanetary Magnetic Field – Laboratory for Electro-optic Systems (LEOS) and ISAC.

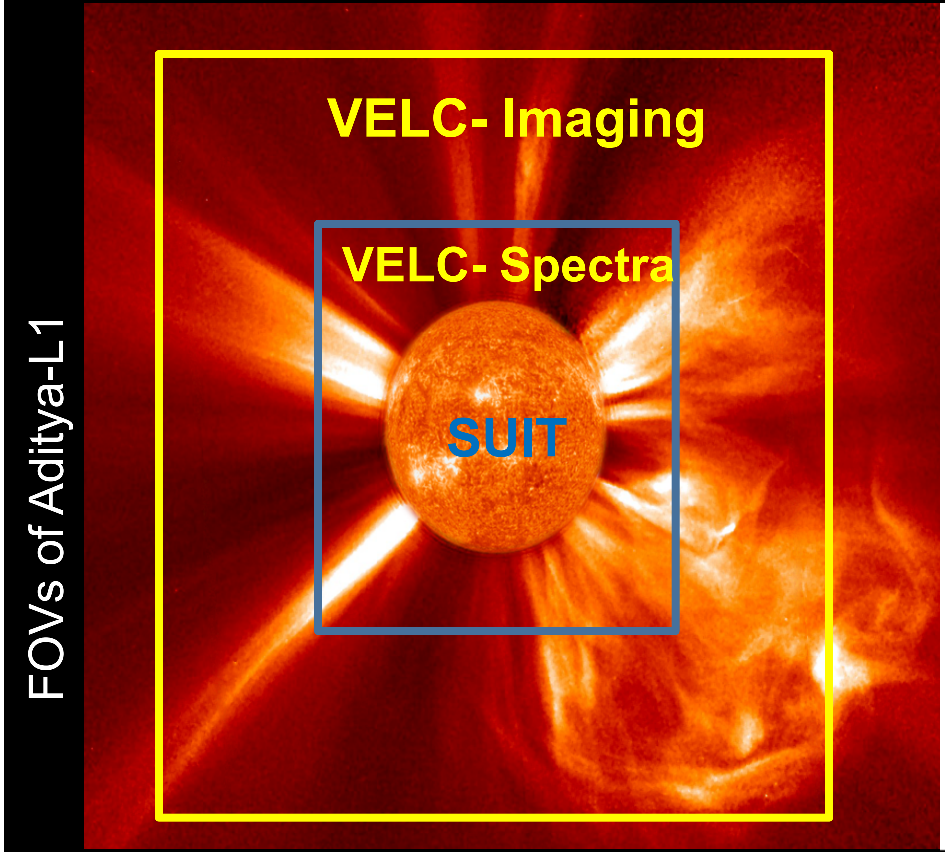
Payload STOWED VIEW OF ADITYA-L1

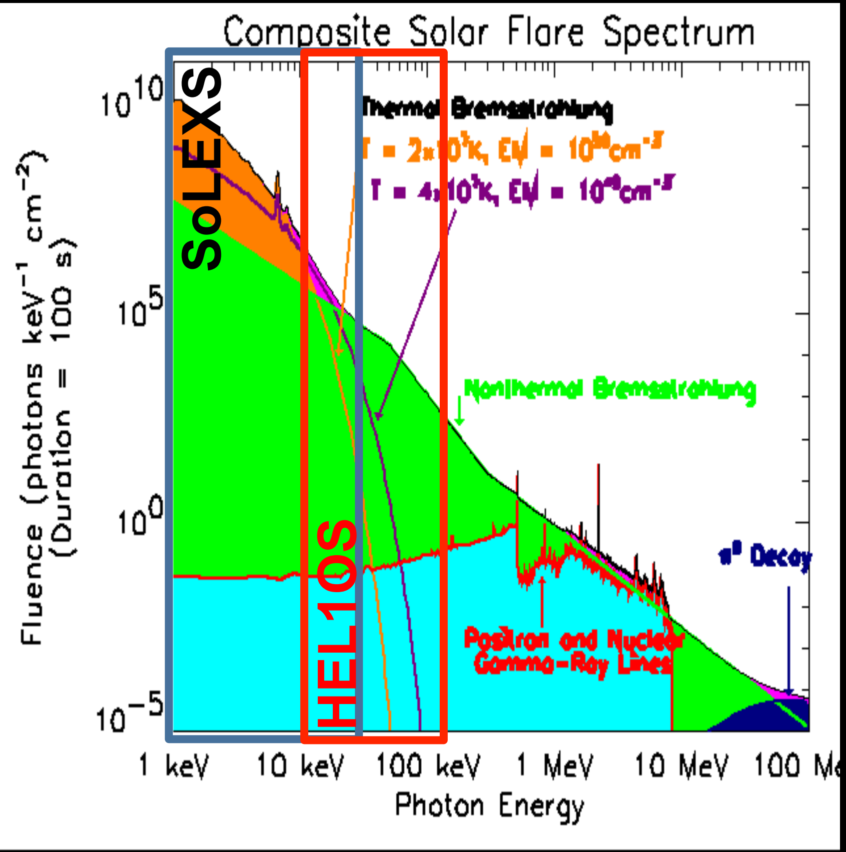


All Instruments are close to completion of EM development

PAYLOADS: Remote Sensing (4) & In-situ (3) Instruments

* Visible Emission Line Coronagraph (VELC)
* Solar Ultra-violet Imaging Telescope (SUIT)
* Solar Low Energy X-ray spectrometer (SoLEXS)
* Hard X-ray L1 Orbiting Spectrometer (HEL1OS)





PAYLOADS: Remote Sensing (4) & In-situ (3) Instruments

IN-SITU INSTRUMENTS

* Aditya Solar Particle Experiment (ASPEX)

* Plasma Analyser Package for Aditya (PAPA)

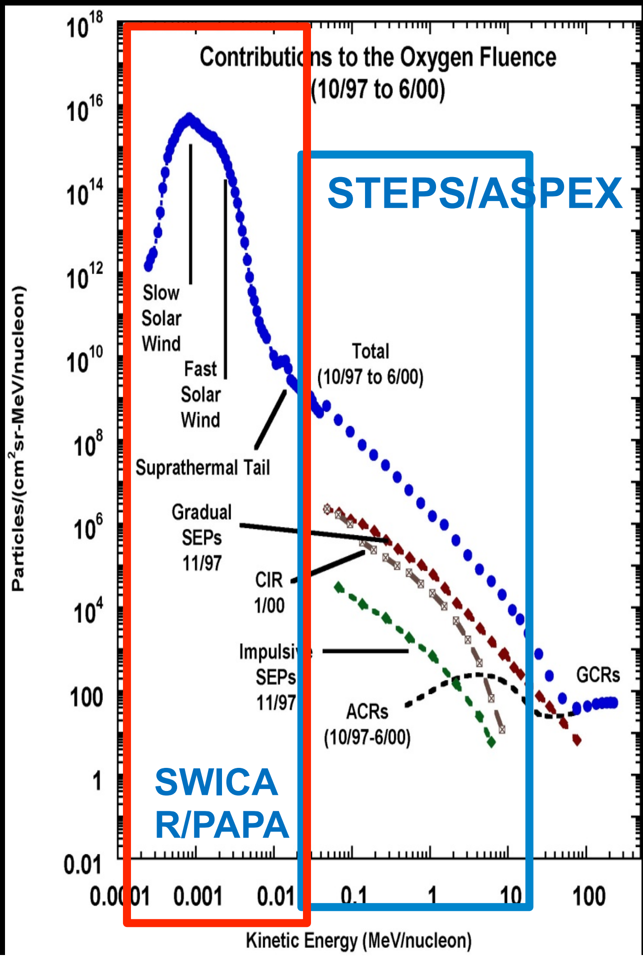


Image Courtesy: California Institute of Technology

Magnetometer (Mag)

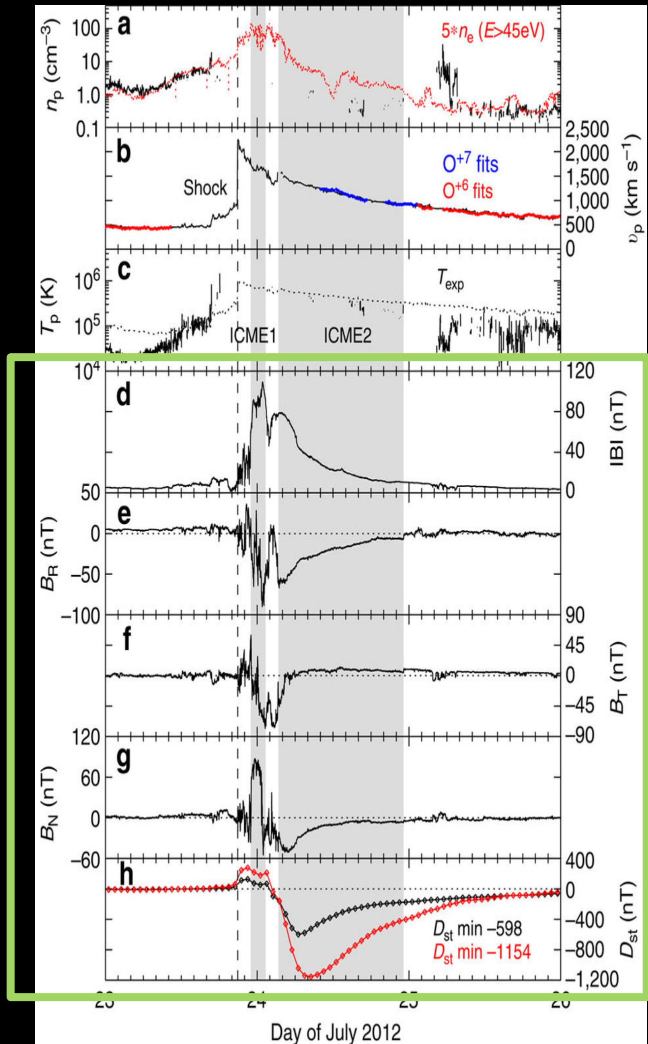
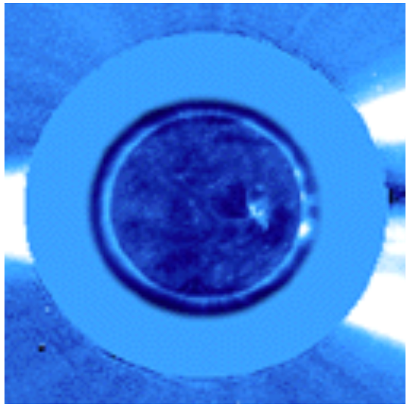


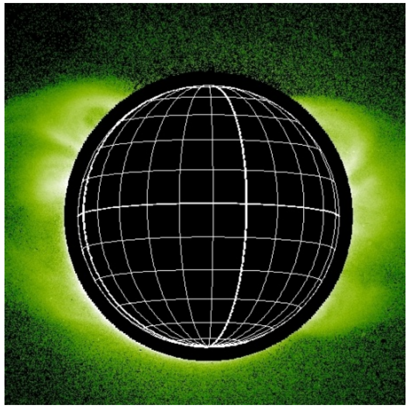
Image Courtesy: Nature Communications

Importance – Inner Corona



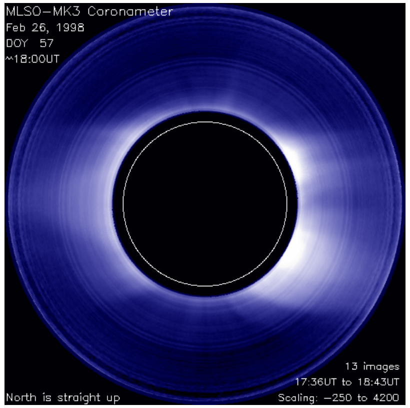
SOHO/LASCO-C2

R > 2.5 Rsol



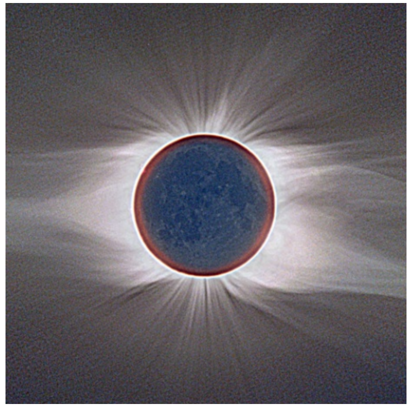
SOHO/LASCO-C1

Operated at solar minimum only for 2 yrs



Ground-based coronagraph:

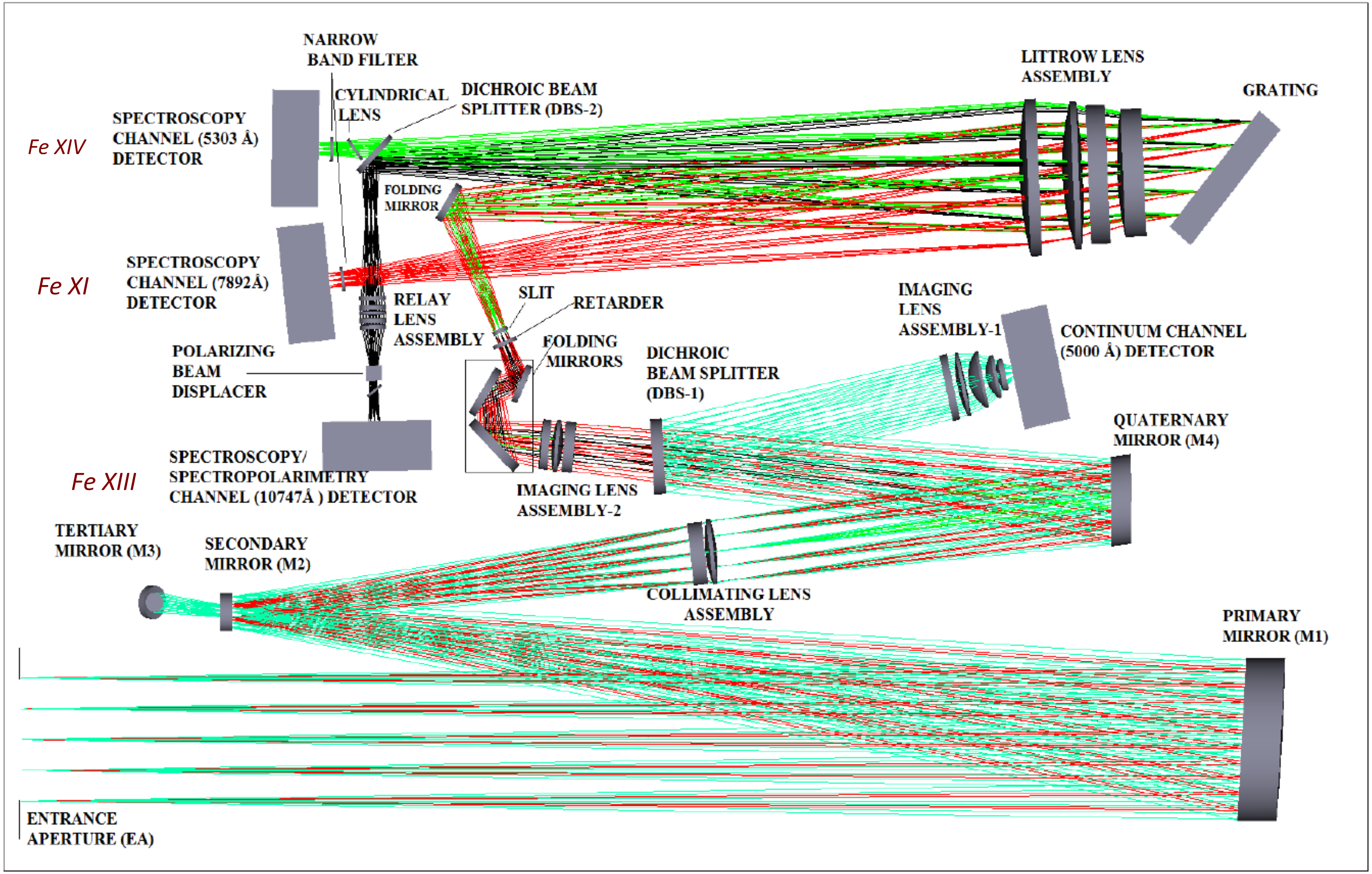
Low spatial resolution and atmospheric noise



Total solar Eclipses:

Ideal but very rare and only a snapshot!

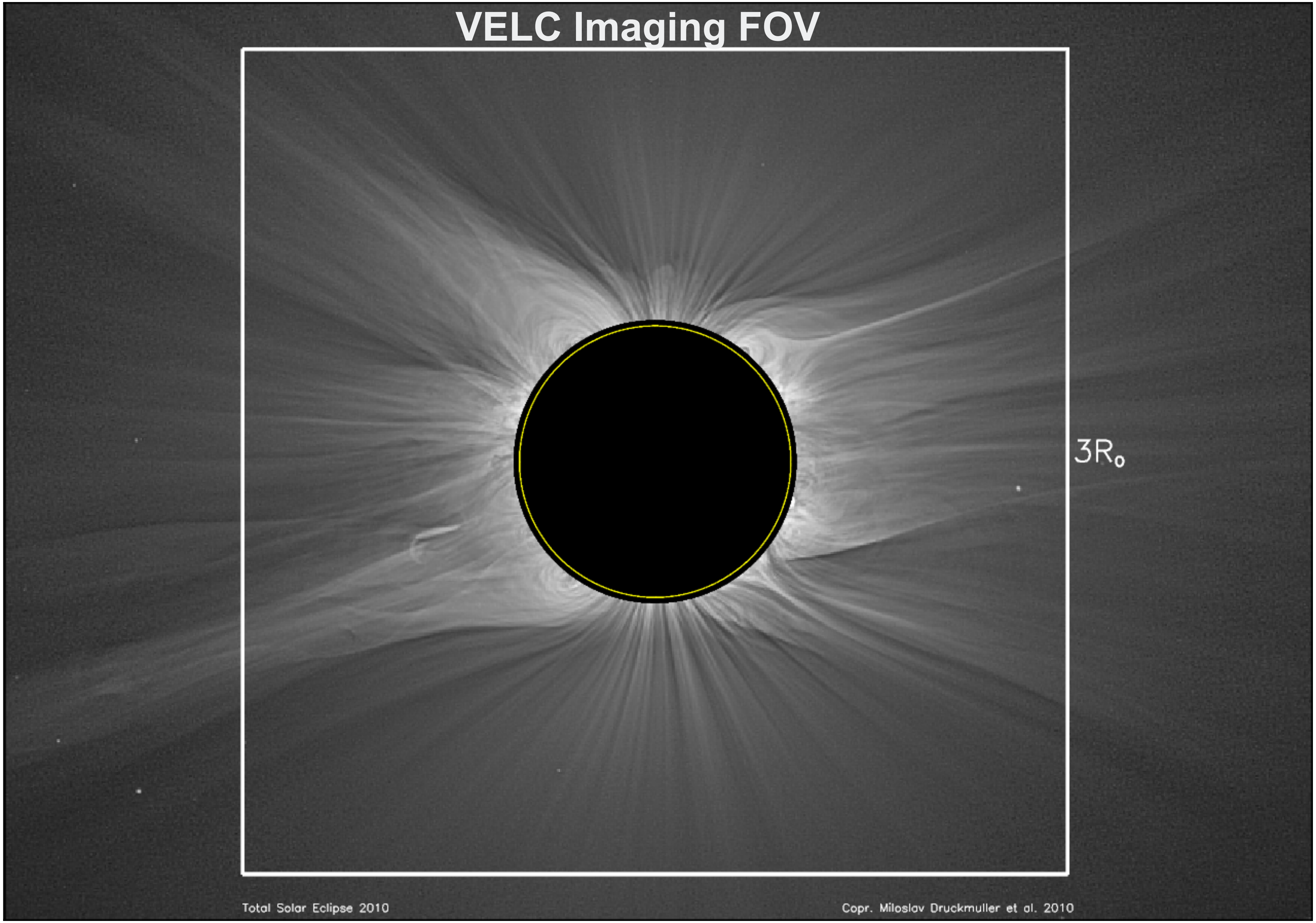
- After 40 years of space coronagraphy the lower corona (<2Rsun) remains practically unobserved especially in the visible and IR wavelength band
- Aditya Mission will cover inner corona from 1.05 – 3.0 R_{sun}
- Larger coronagraph (~ 20 cm dia primary mirror) providing higher cadence data

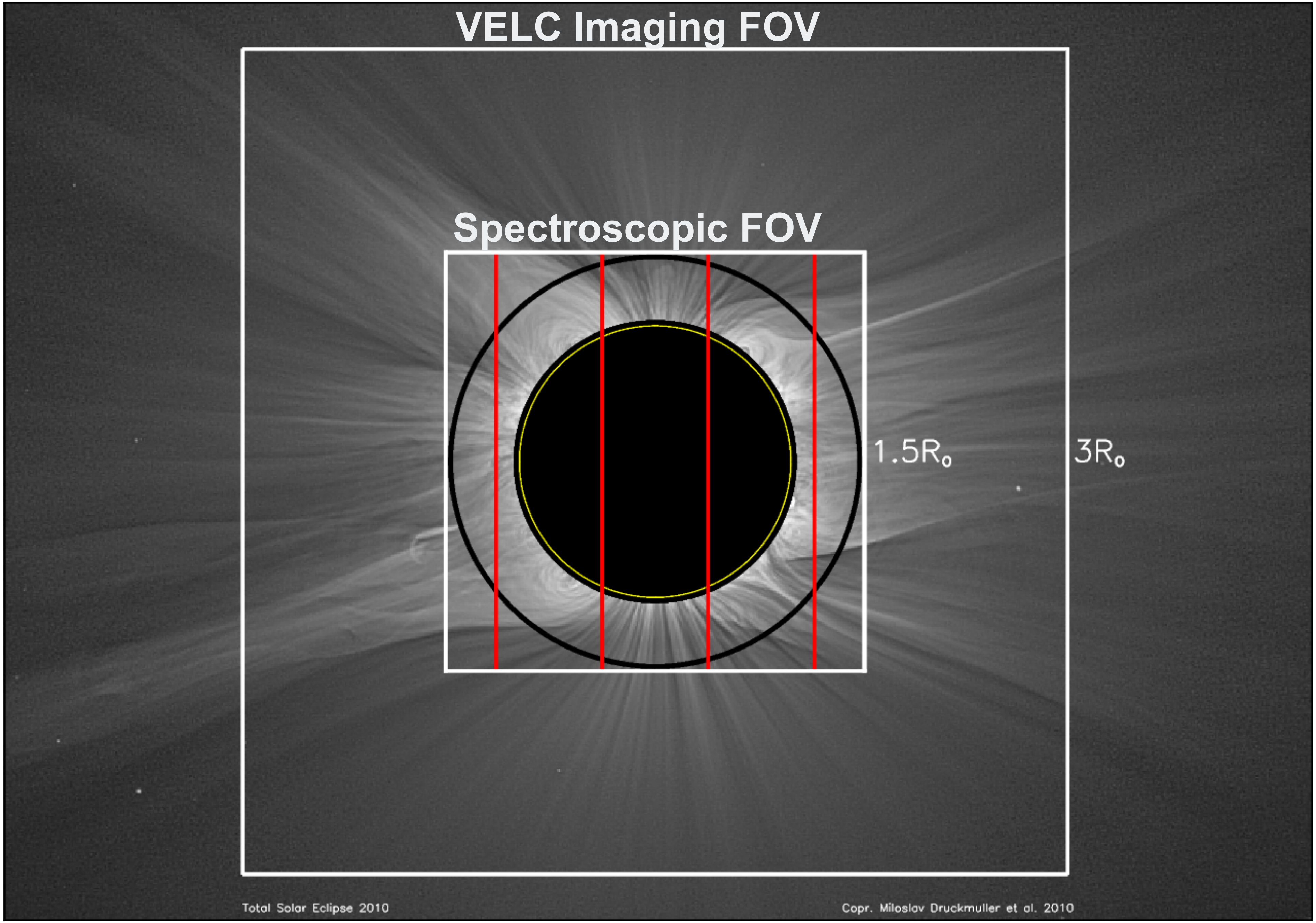


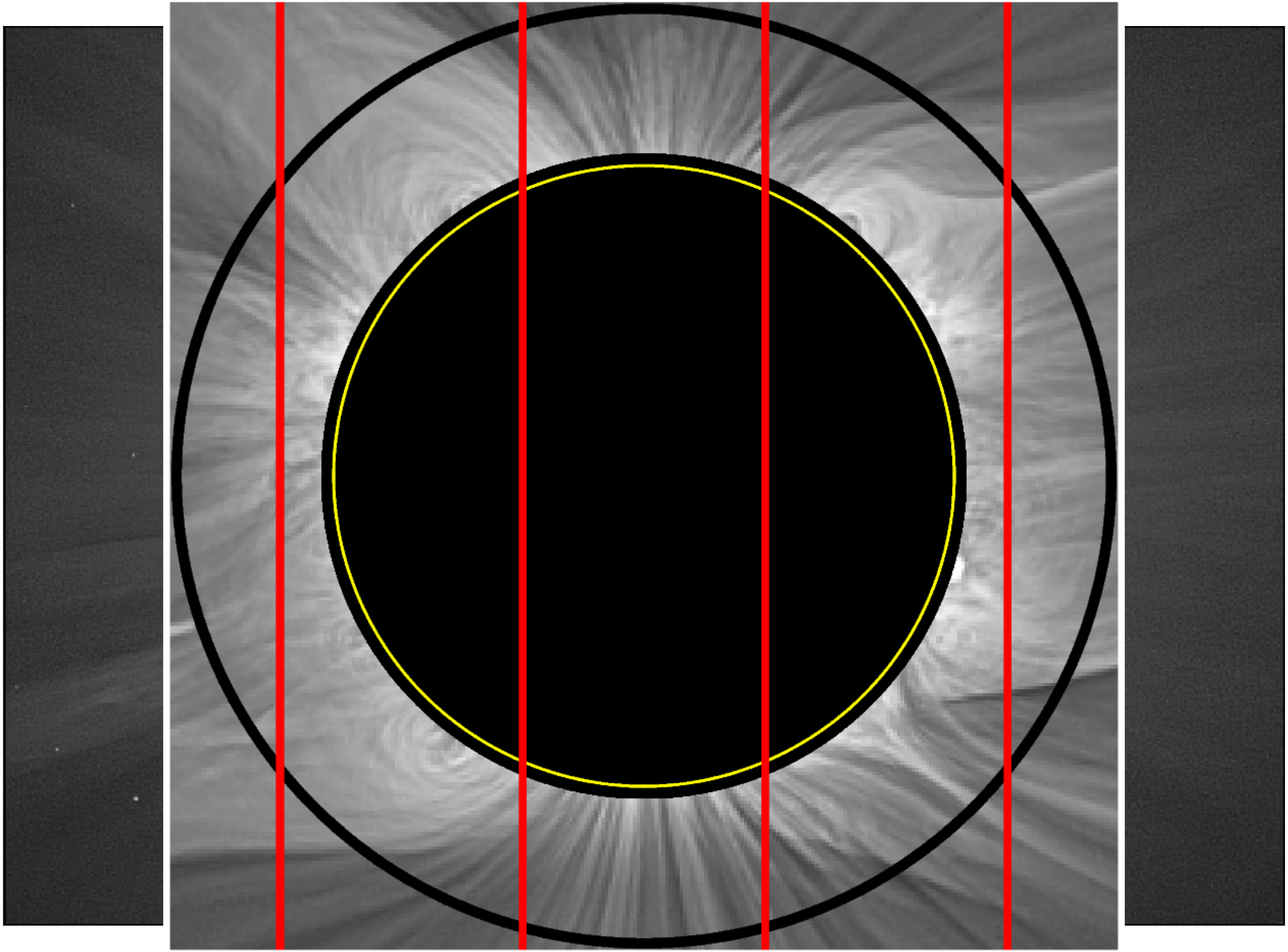
Optical Layout of VELC

Instrument capabilities

Instrument specifications	Visible	Infrared
Spectral lines (A)	5303 A and 7892 A	10747 A
Continuum (A)	5000 A & 10 A bandwidth	----
Detector size (pixels)	2160 x 2560 pixels	512 x 640
Field of view (R_{sun})	1.05 – 3.0 continuum; 1.05 – 1.5 emission lines	1.05 – 1.5
Spatial resolution	1.25 arcsec / pixel in emission; twice in cont.	4.0 arcsec / pixel
Spectral resolution	0.065 and 0.095 A	0.200 A
Velocity resolution	3.6 km/s; 1 pixel	5 km/s; 1 pixel
Exposure times	1 – 5 sec	1-5 sec for spectroscopy Multiples of 10sec for polarimetry
Observing cadence	1 – 60 sec or slower	1- 60 sec or slower
Polarimetric accuracy		Better than 10^{-4}
Observables	Emission line profiles Images in continuum	Emission line profiles


VELC Imaging FOV
3R₀
Total Solar Eclipse 2010
Copr. Miloslav Druckmuller et al. 2010


VELC Imaging FOV
Spectroscopic FOV
1.5R$_\odot$
3R$_\odot$
Total Solar Eclipse 2010
Copr. Miloslav Druckmuller et al. 2010



VELC

VELC Scientific objectives (Spectroscopy)

Diagnostics of the corona (Temperature, Velocity, & Density!).

Heating of the corona and solar wind acceleration.

Dynamics of the large scale transients (CMEs, Jets).

Uniqueness of the payload

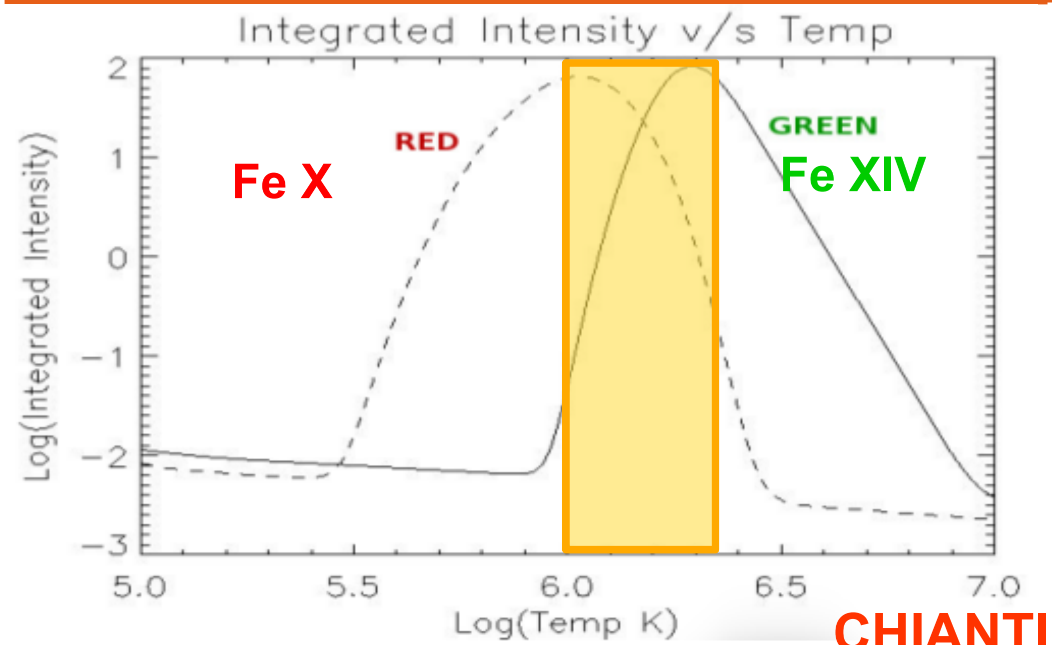
High-cadence, high- spatial and spectral resolution

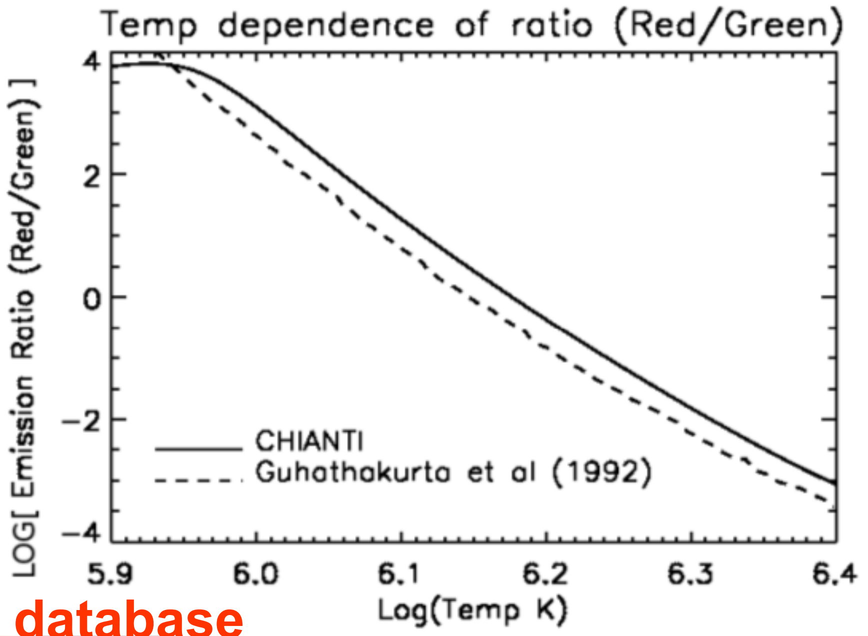
Simultaneous spectroscopic and imaging.

Observations very close to solar limb (1.05 R).

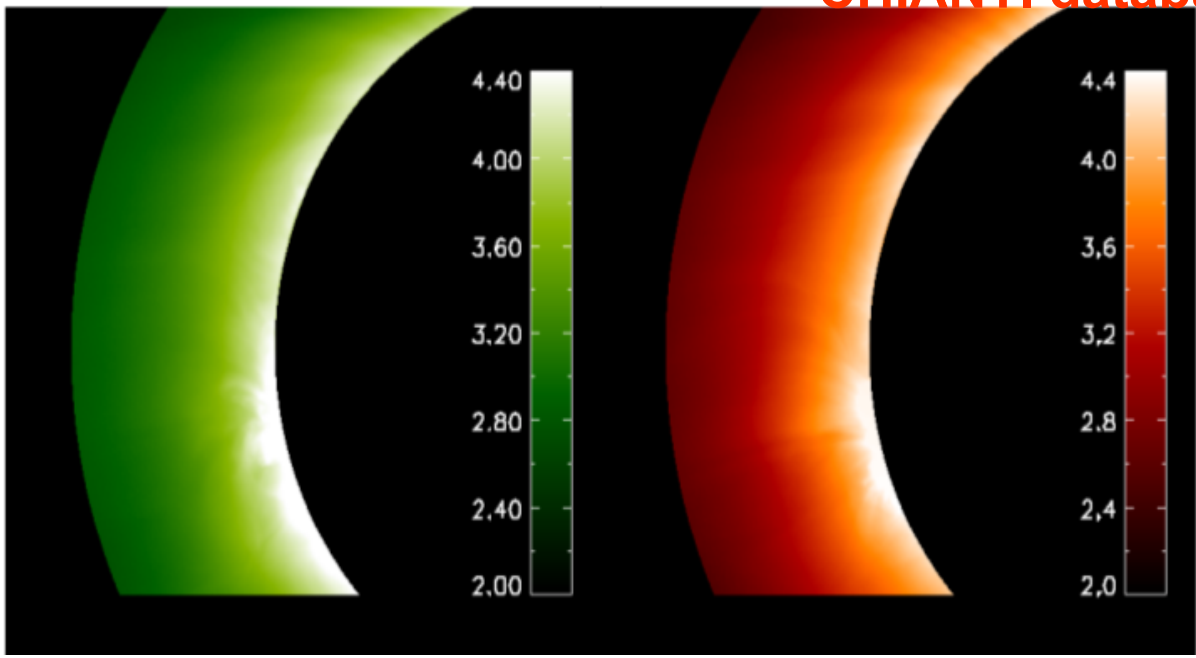
Magnetic field measurements.

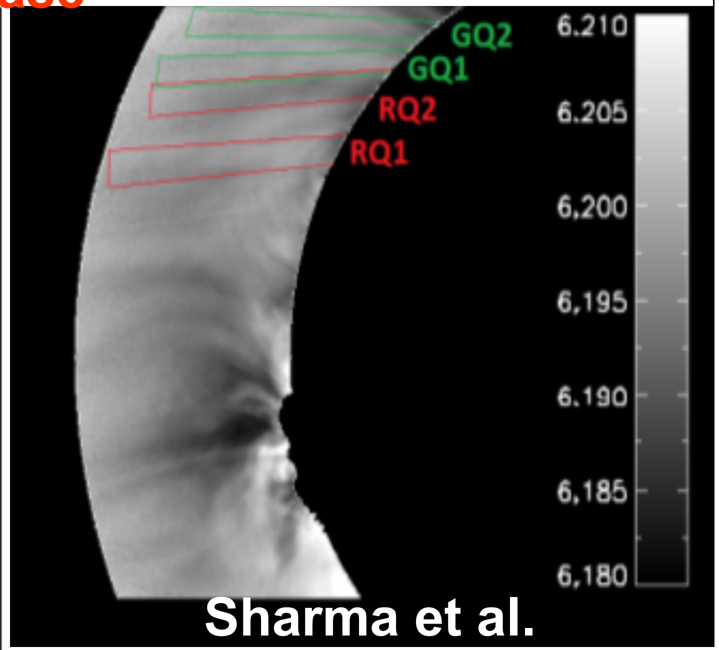
Temperature



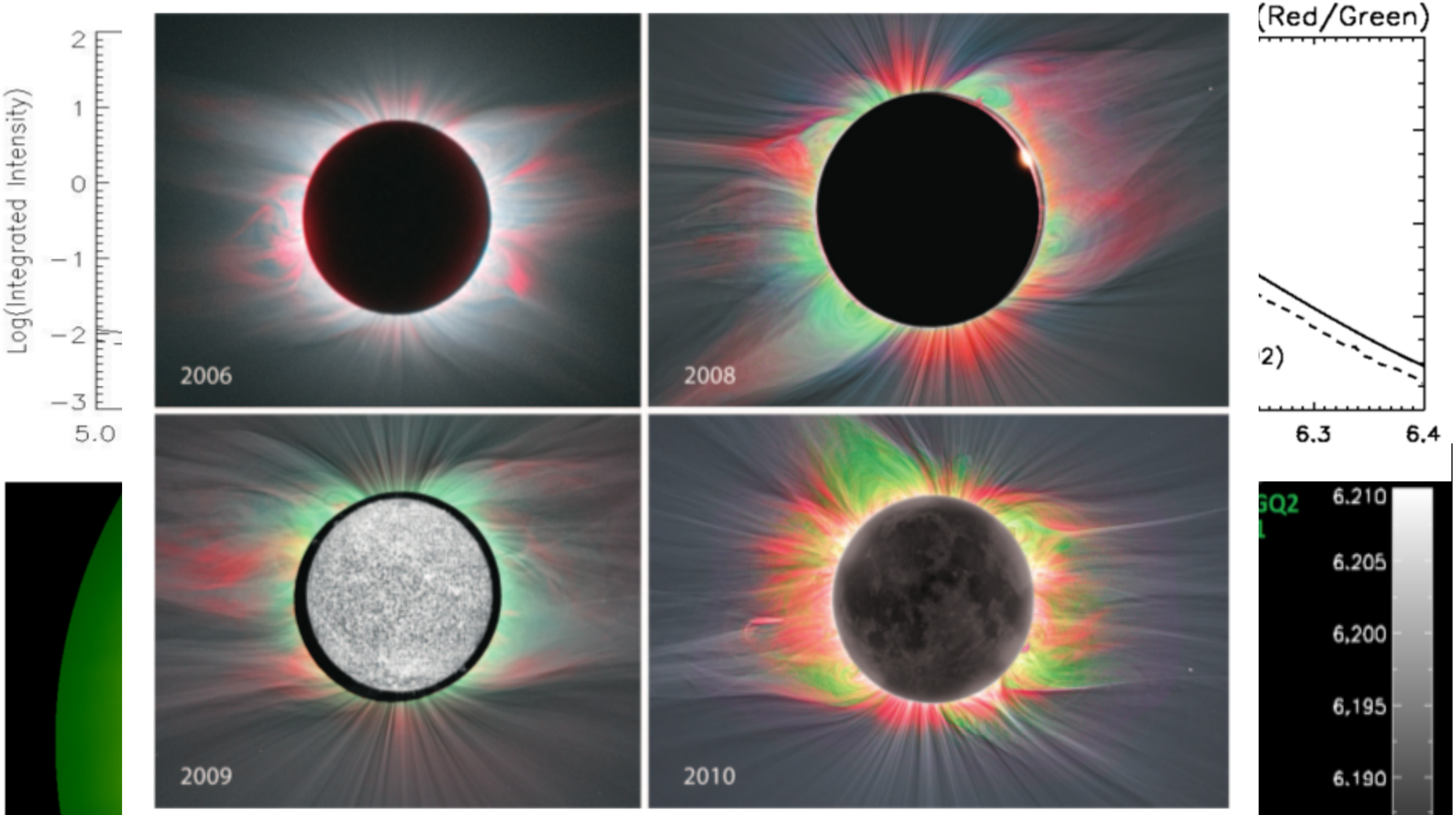


CHIANTI database





Temperature

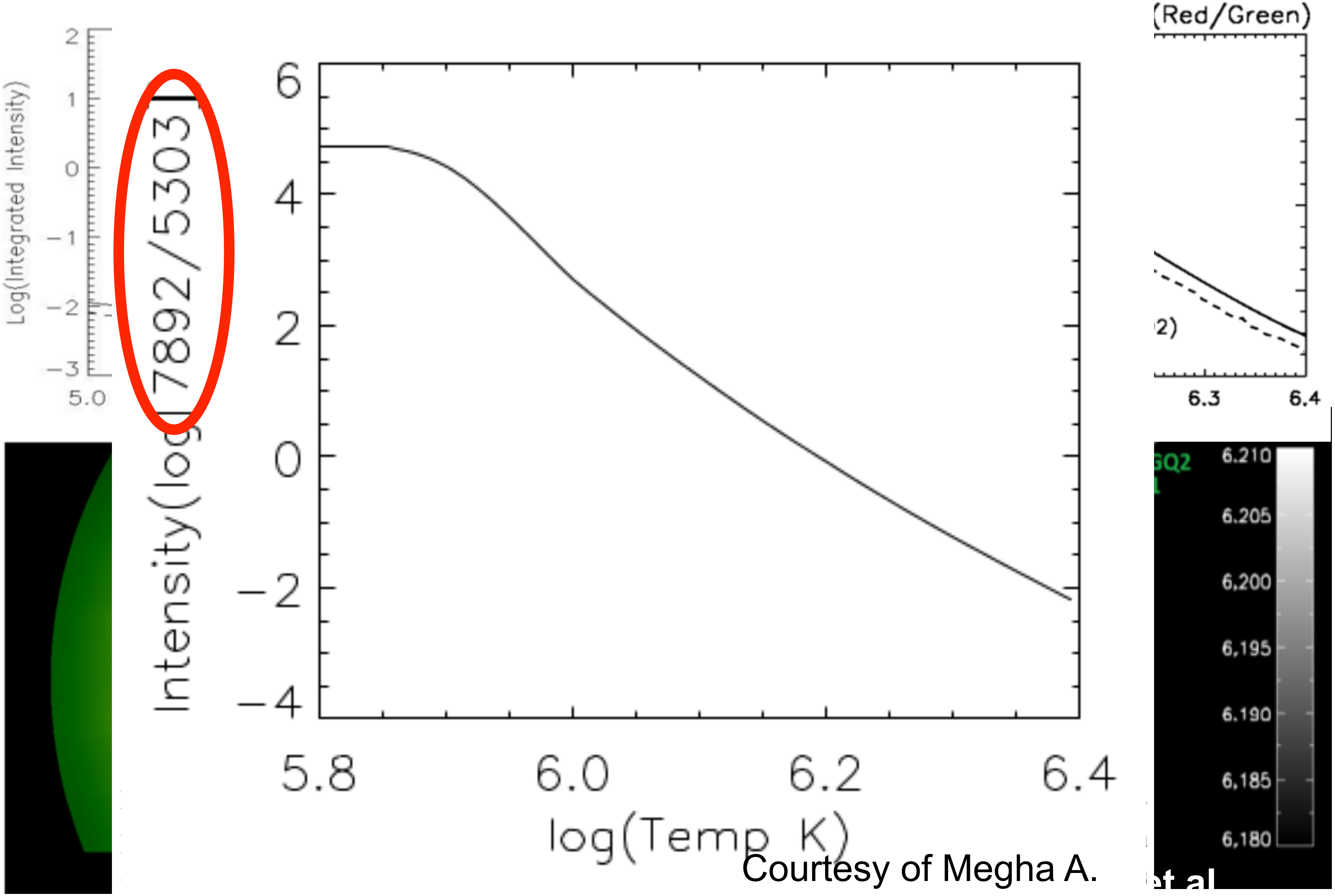


Habbal et al. 2011

Figure 2. Overlay of white light Fe XI 789.2 nm (red) and Fe XIV 530.3 nm (green) ACHF-processed images, from the 2008, 2009 and 2010 eclipses eclipse observations. He II 30.4 nm SOHO/EIT disk emission is shown for 2009 only. In 2006, only Fe XI with white light was

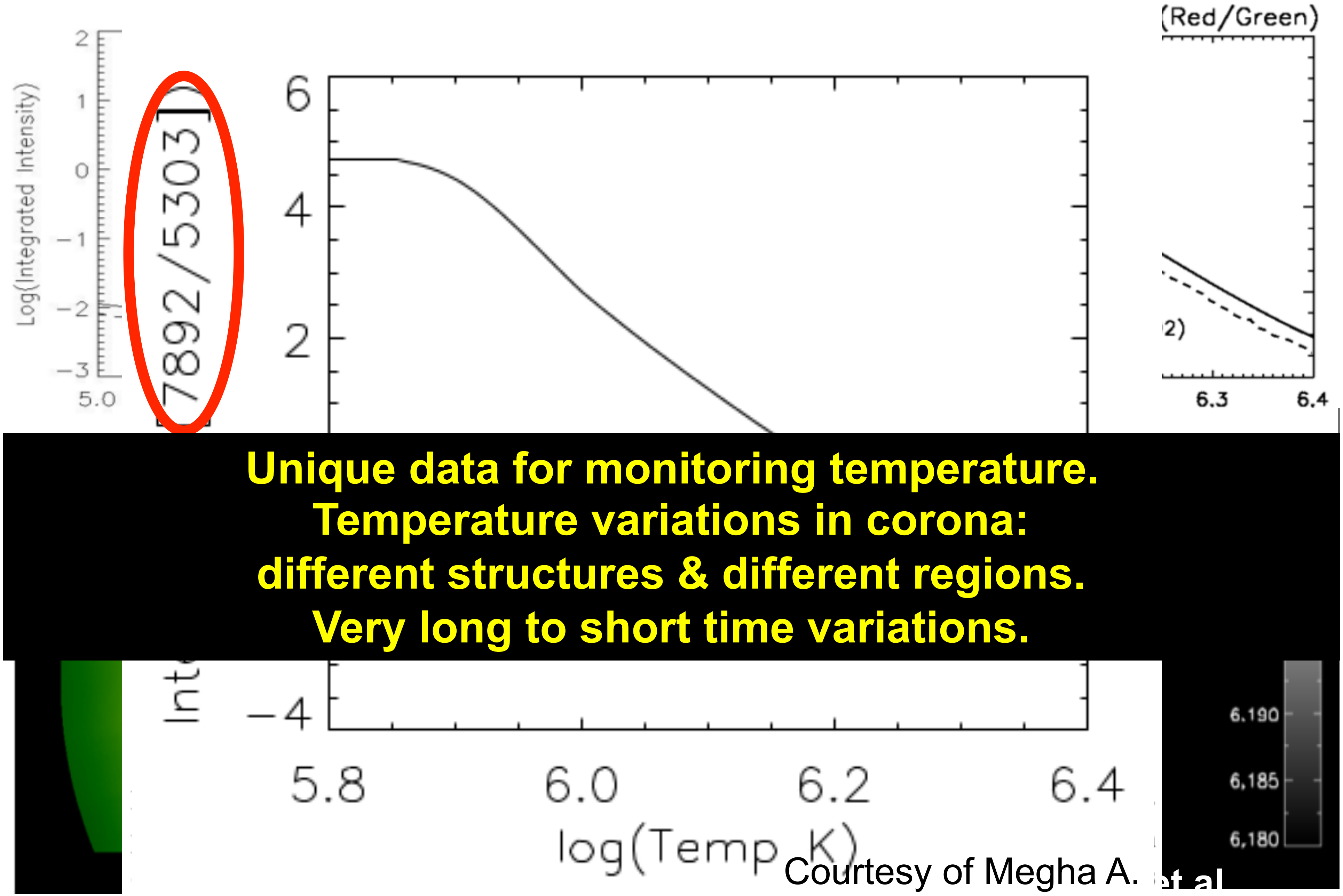
et al

Temperature



Courtesy of Megha A.

Temperature



Unique data for monitoring temperature.
Temperature variations in corona:
different structures & different regions.
Very long to short time variations.

Courtesy of Megha A. et al

Total Solar Eclipse Observations

- **High-resolution multi-slit spectroscopic observations of corona during the total solar eclipse of 11th July, 2010 at Easter Island, Chile.**
- **Observation of the solar corona in the green emission line (5303 Å due to Fe XIV) and the red line (6374 Å due to Fe X).**
- **Cadence ~ 1 sec.**

Total Solar Eclipse Observations

Multi-slit Spectroscopic Observations

Spectral resolution = 0.33 Å
Pixel resolution = 2.64”
Cadence = 1 s

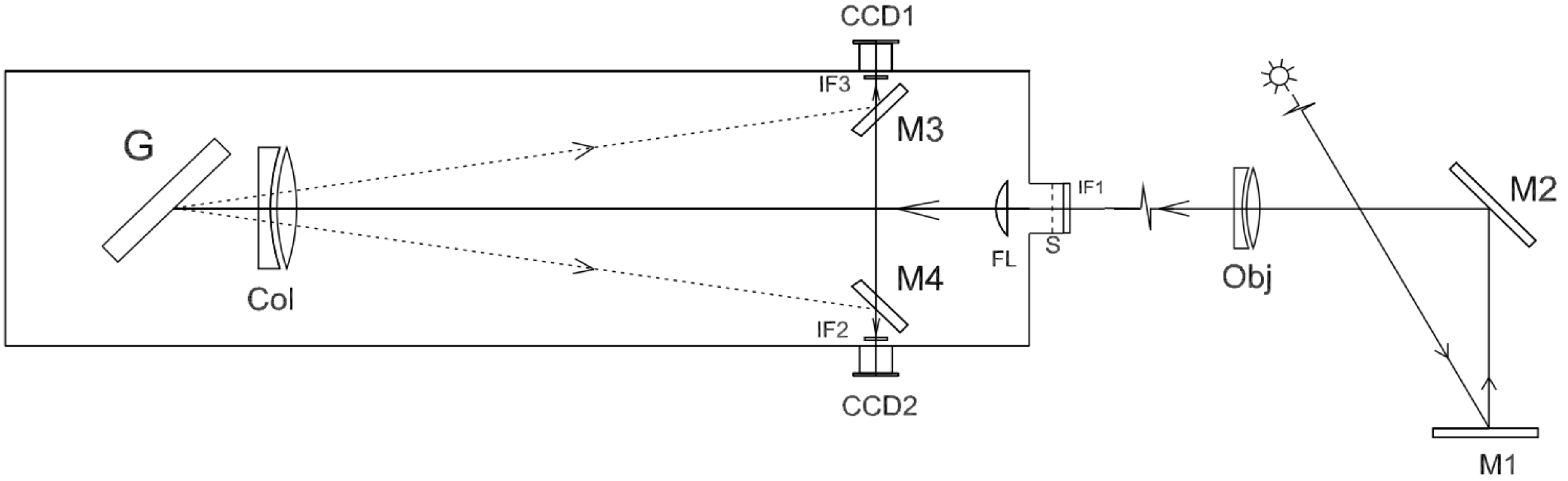
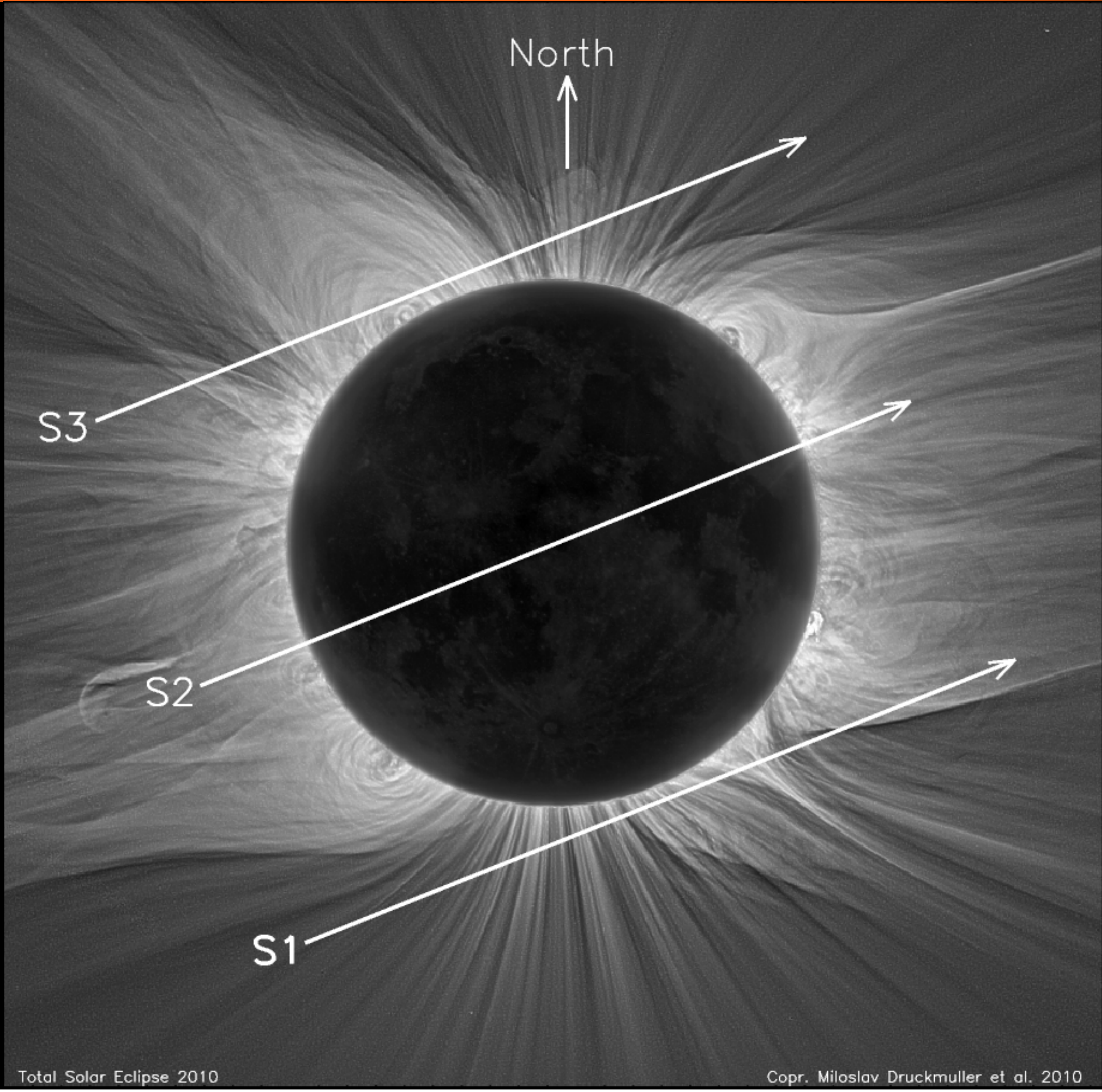


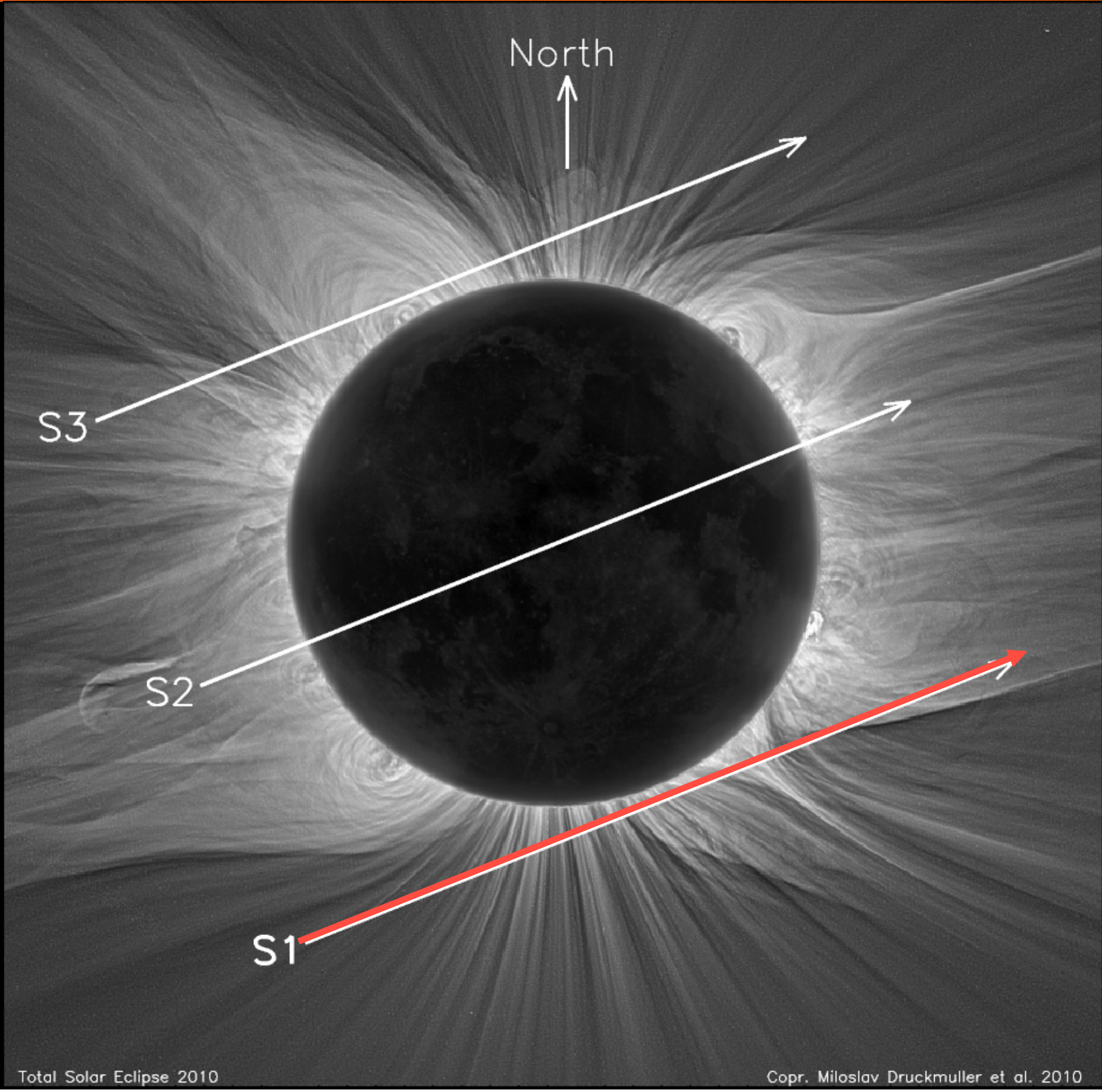
Figure 1 Schematic diagram of the optical layout used to obtain spectra around the red and green emission lines of the solar corona. M1 and M2 = flat mirrors of the coelostat system. Obj = objective lens of 10 cm diameter and of 100 cm focal length. IF1 = interference filter with transmission in the wavelength between 5000 – 7000 Å, S = four slits separated by 5 mm each, FL = field lens to focus the beam on the collimator, Col = collimator and camera lens of the spectrograph, G = grating with 600 lines mm^{-1} blazed at 2.2 µm, M3 and M4 = flat mirrors to divert the spectral beams, IF2 and IF3 = narrow-band interference filters with a FWHM of 4 Å, CCD1 and CCD2 = detectors to record the spectra.

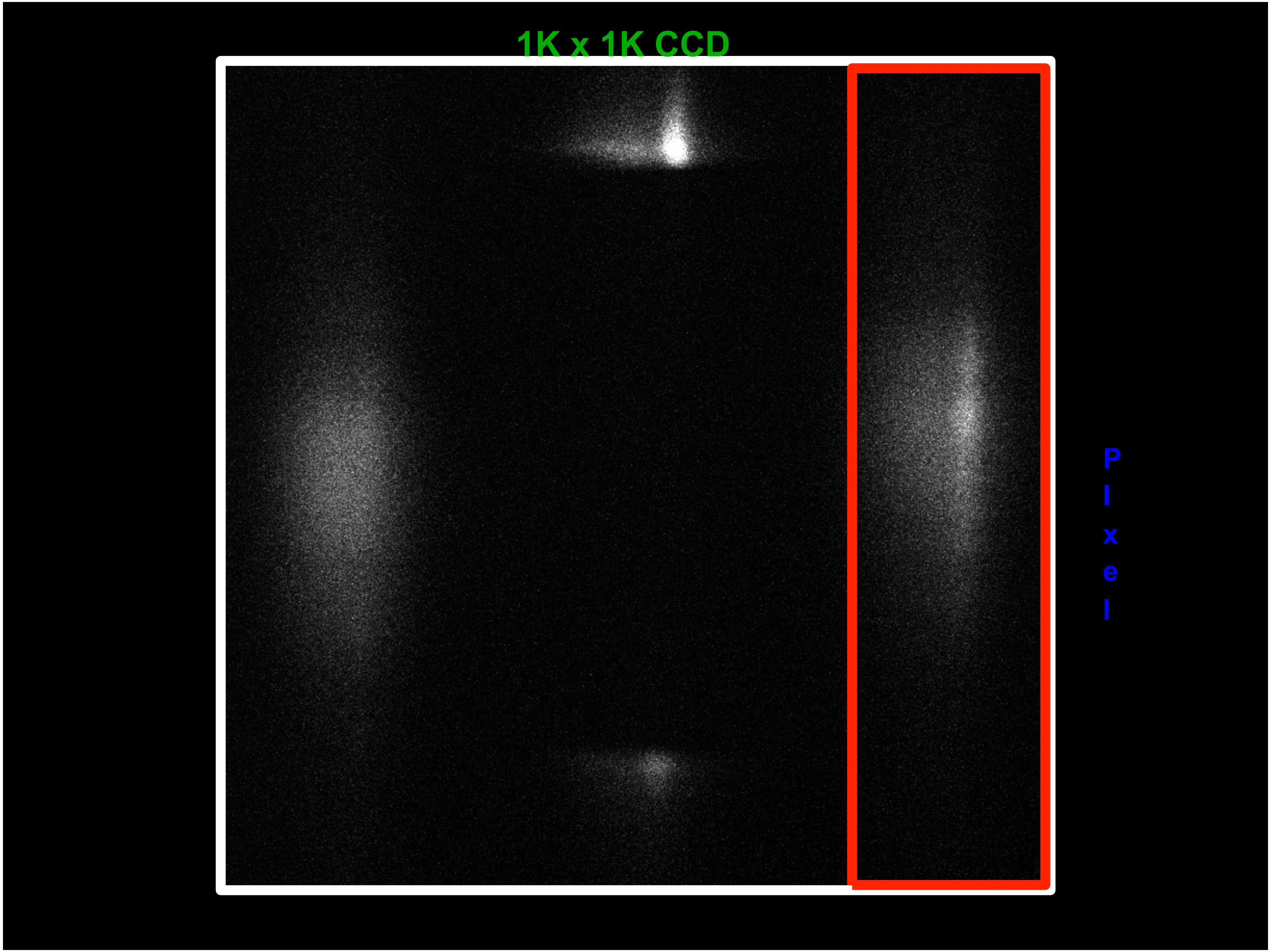
Slit-Position

Slit-Position



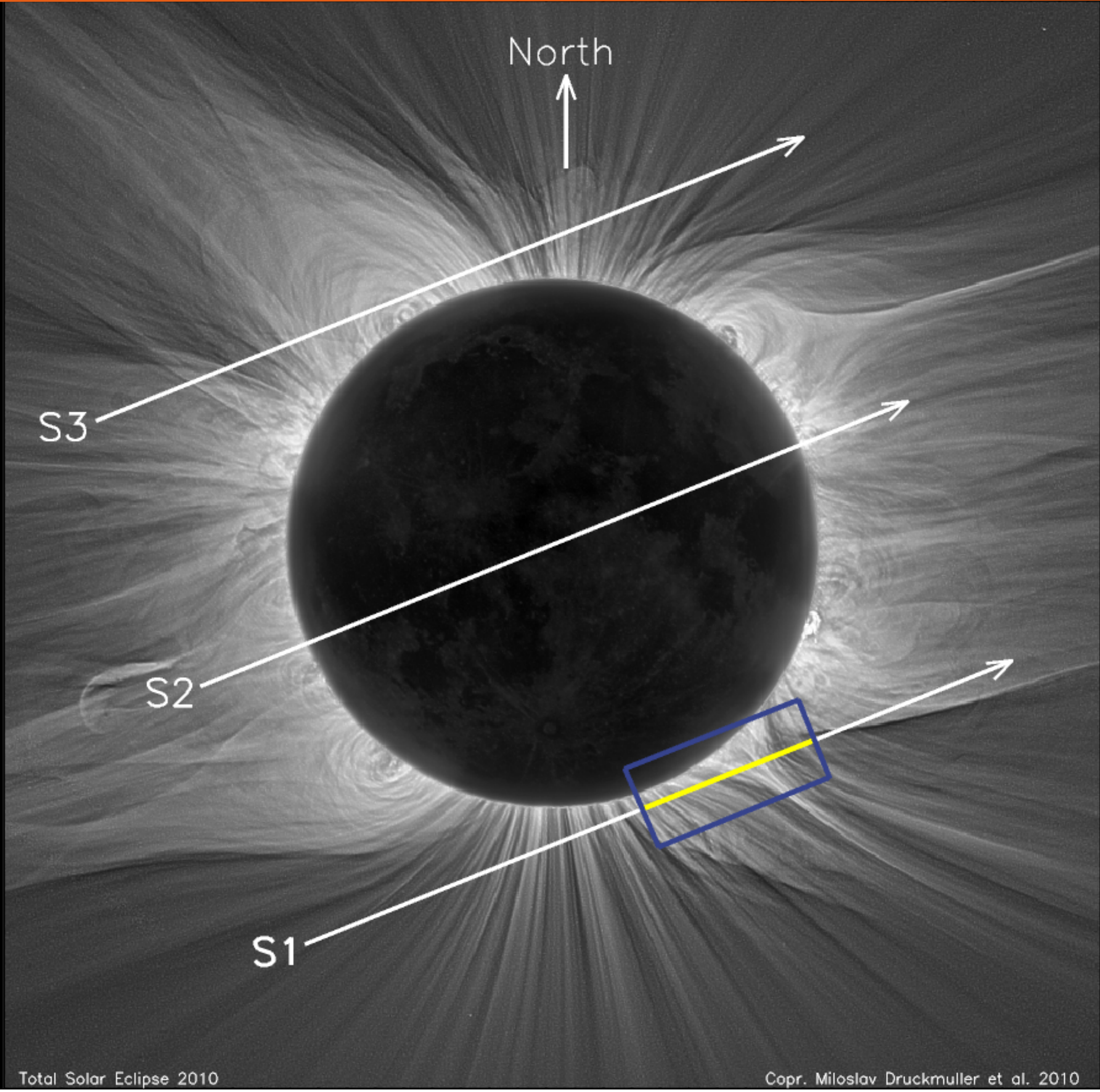
Slit-Position



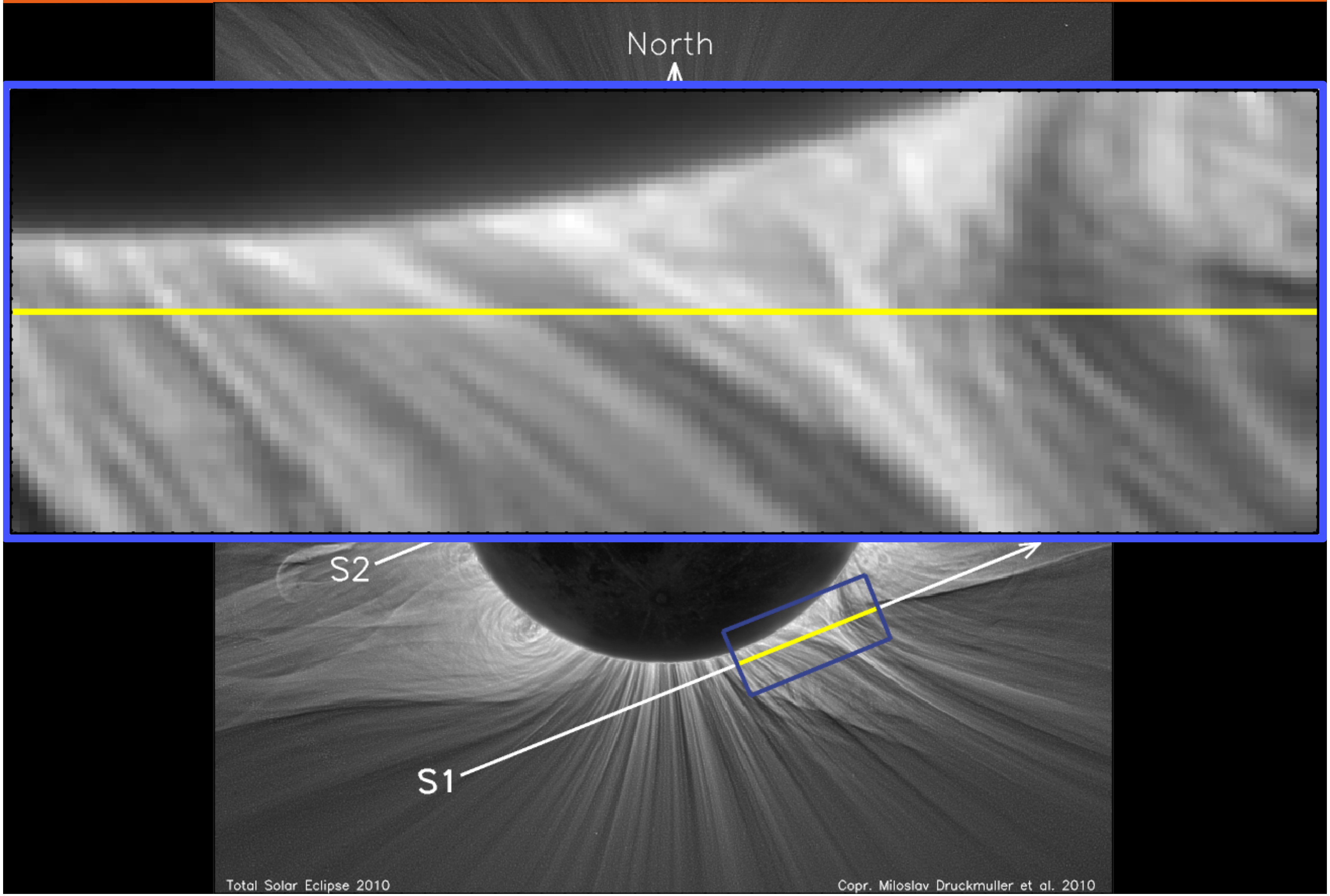


1K x 1K CCD
Pixel

ROI

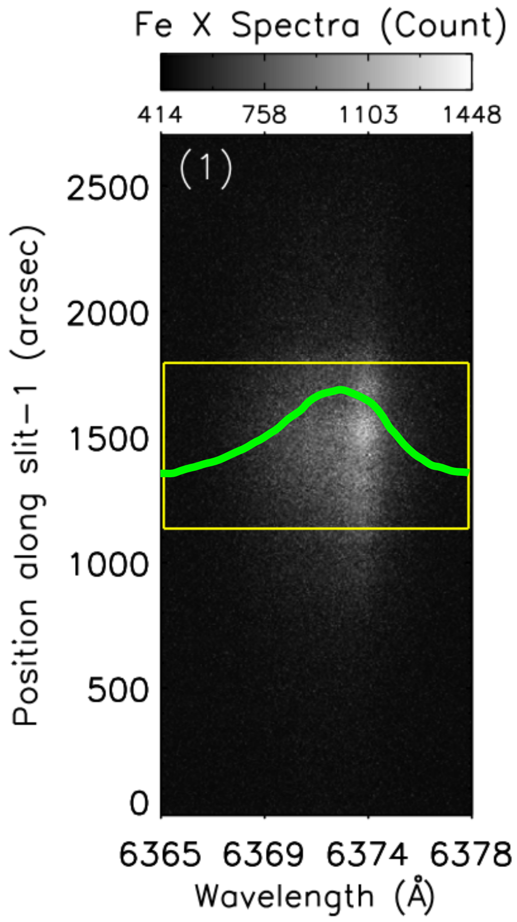

North
S3
S2
S1
Total Solar Eclipse 2010
Copr. Miloslav Druckmuller et al. 2010

ROI


North
S2
S1
Total Solar Eclipse 2010
Copr. Miloslav Druckmuller et al. 2010

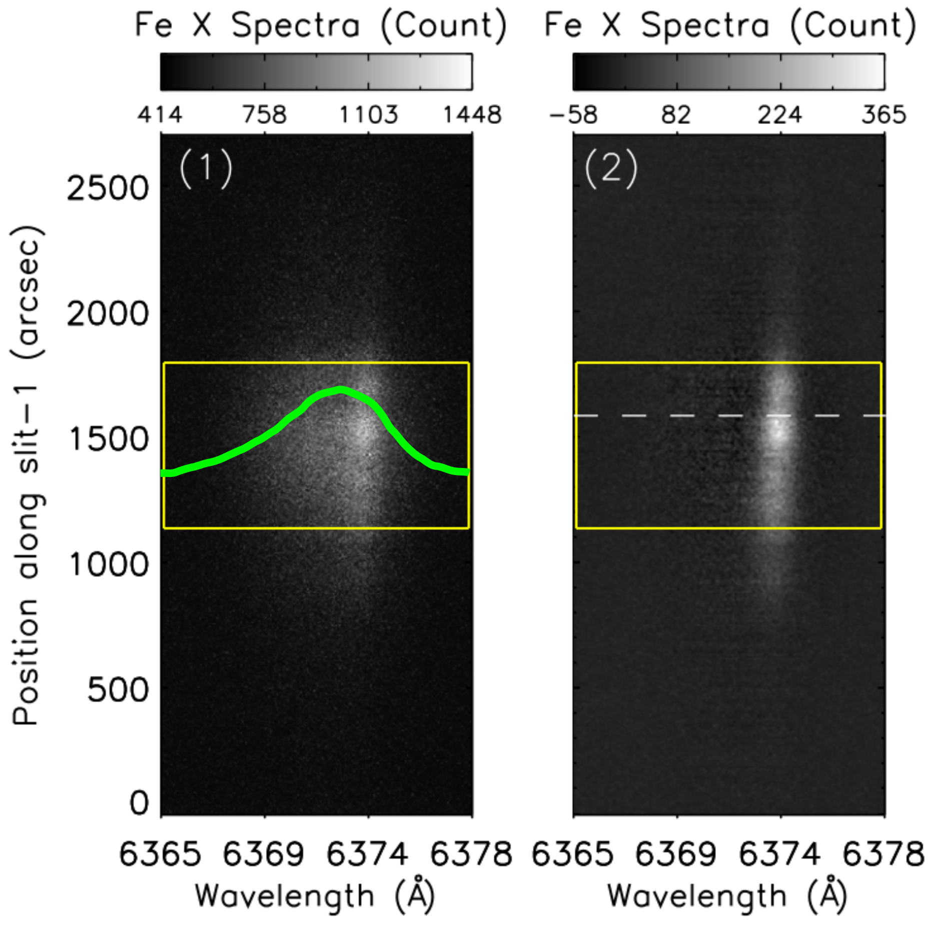
Spectral Processing

Raw Spectra

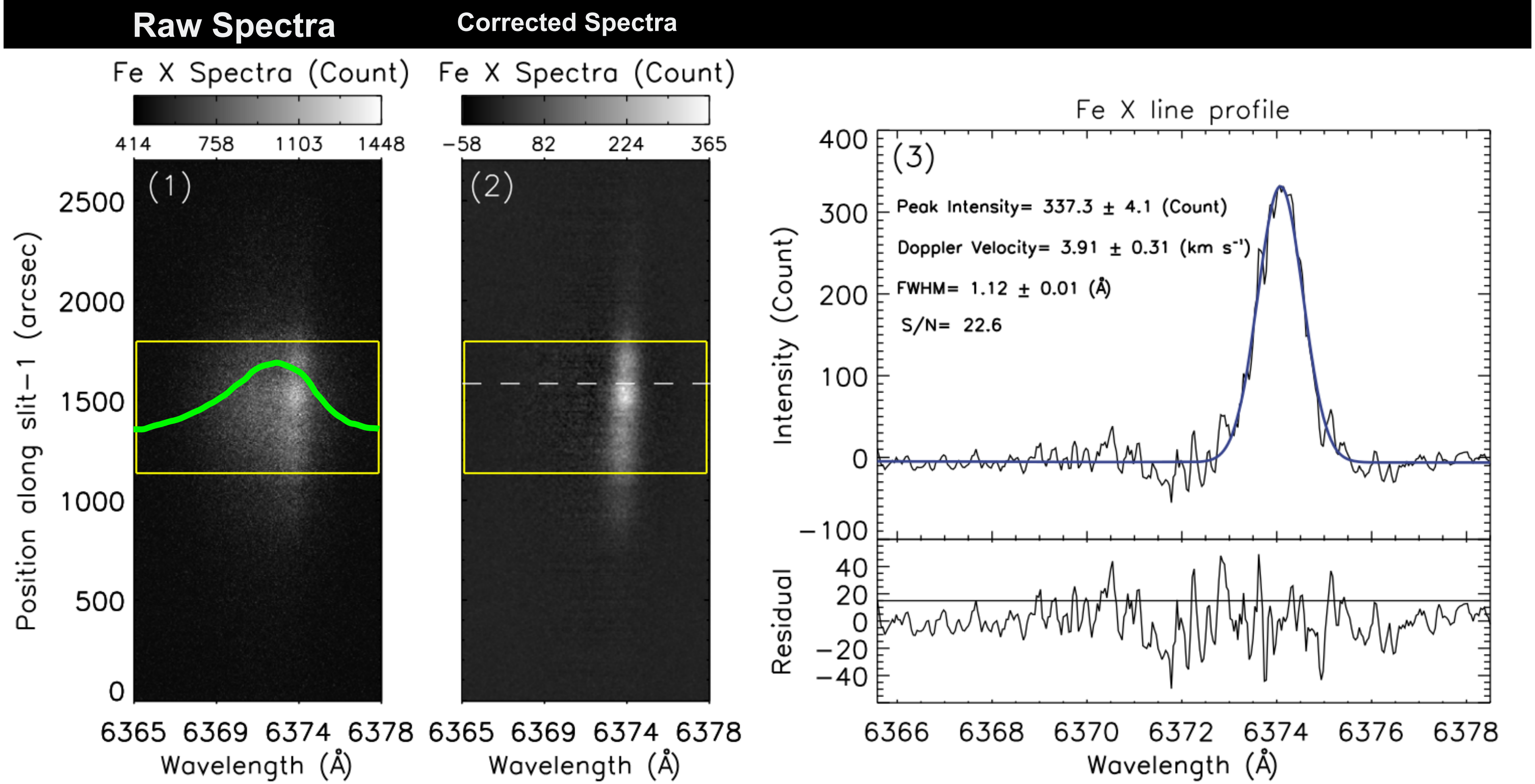


Spectral Processing

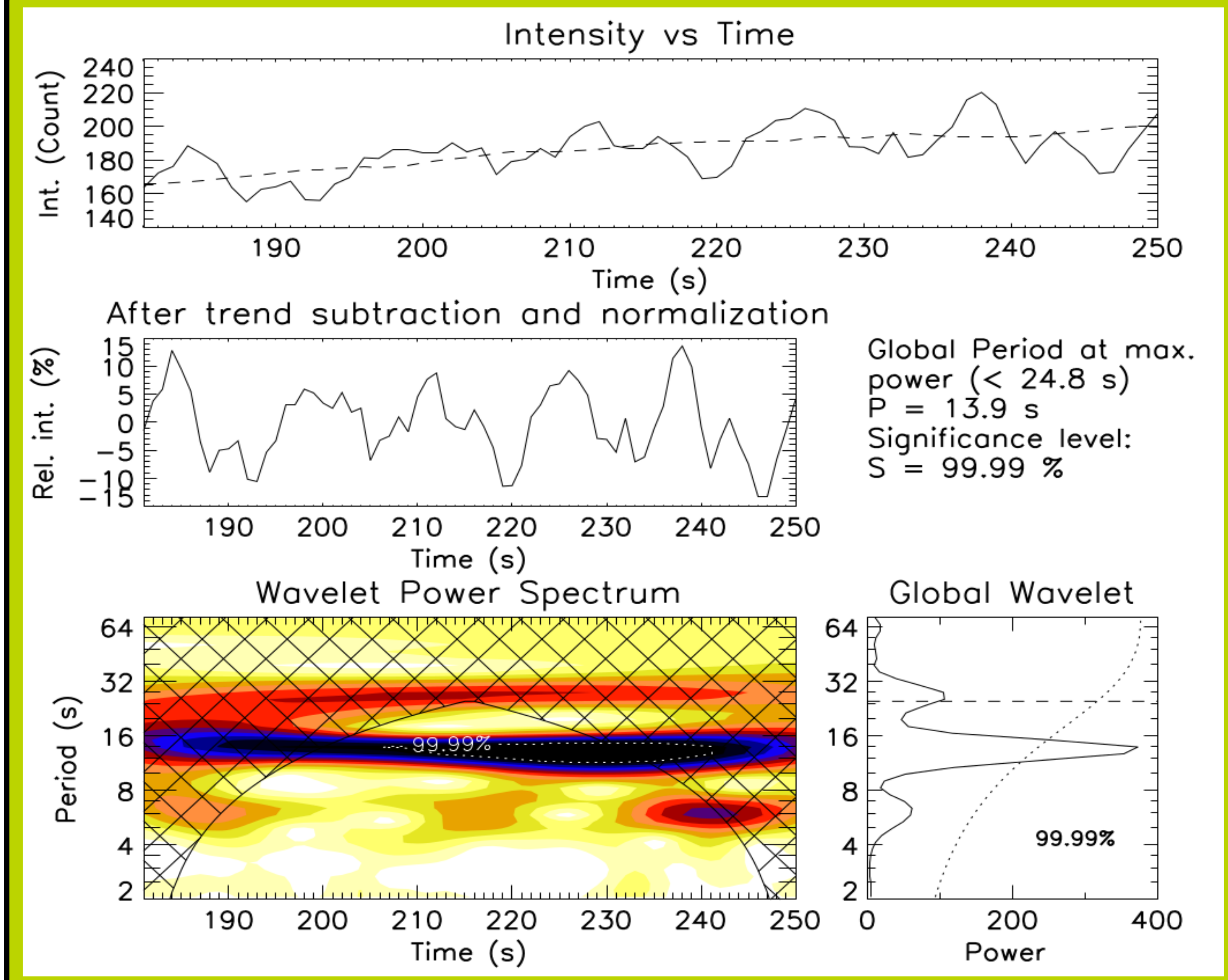
Raw Spectra **Corrected Spectra**



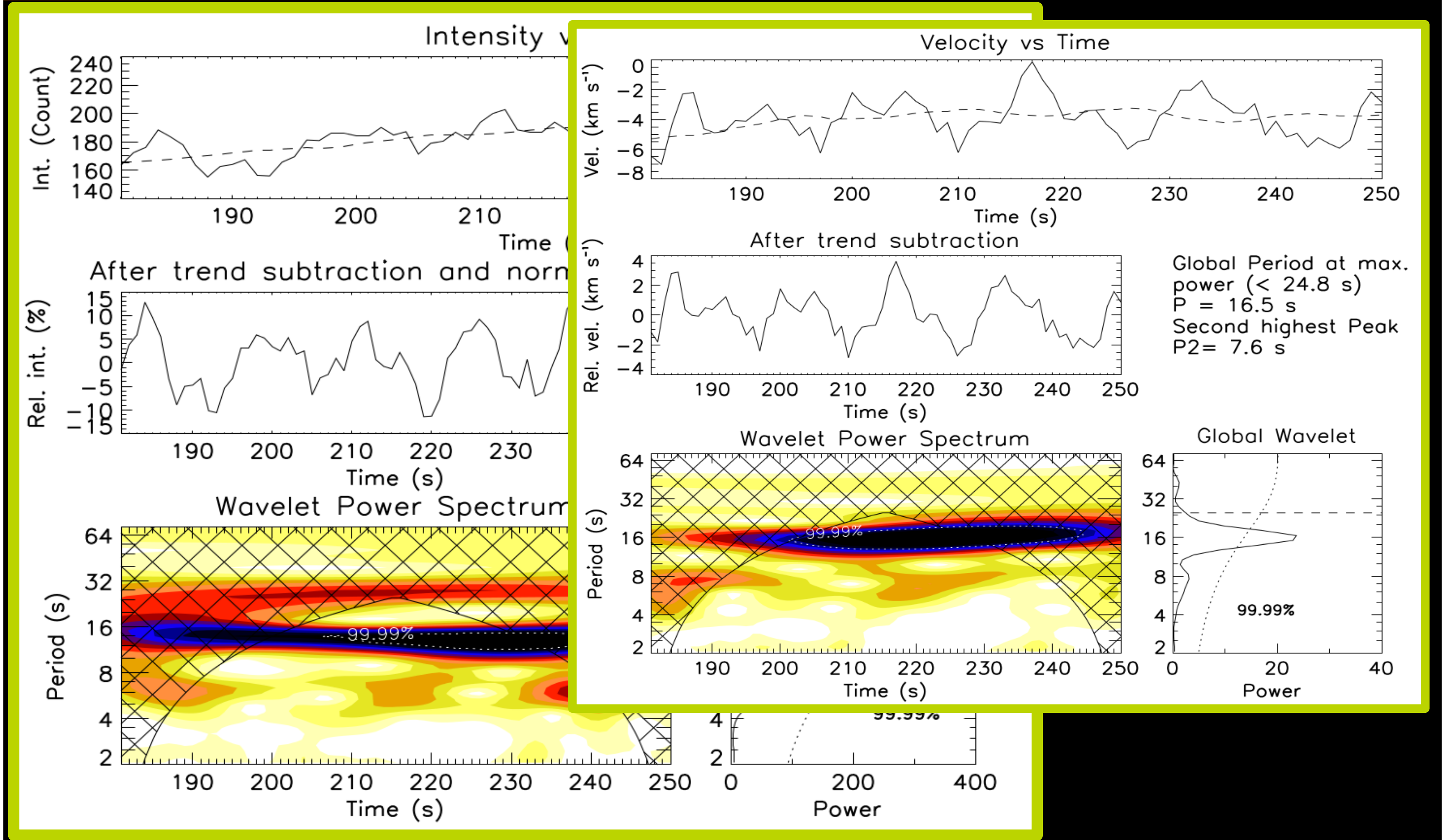
Spectral Processing



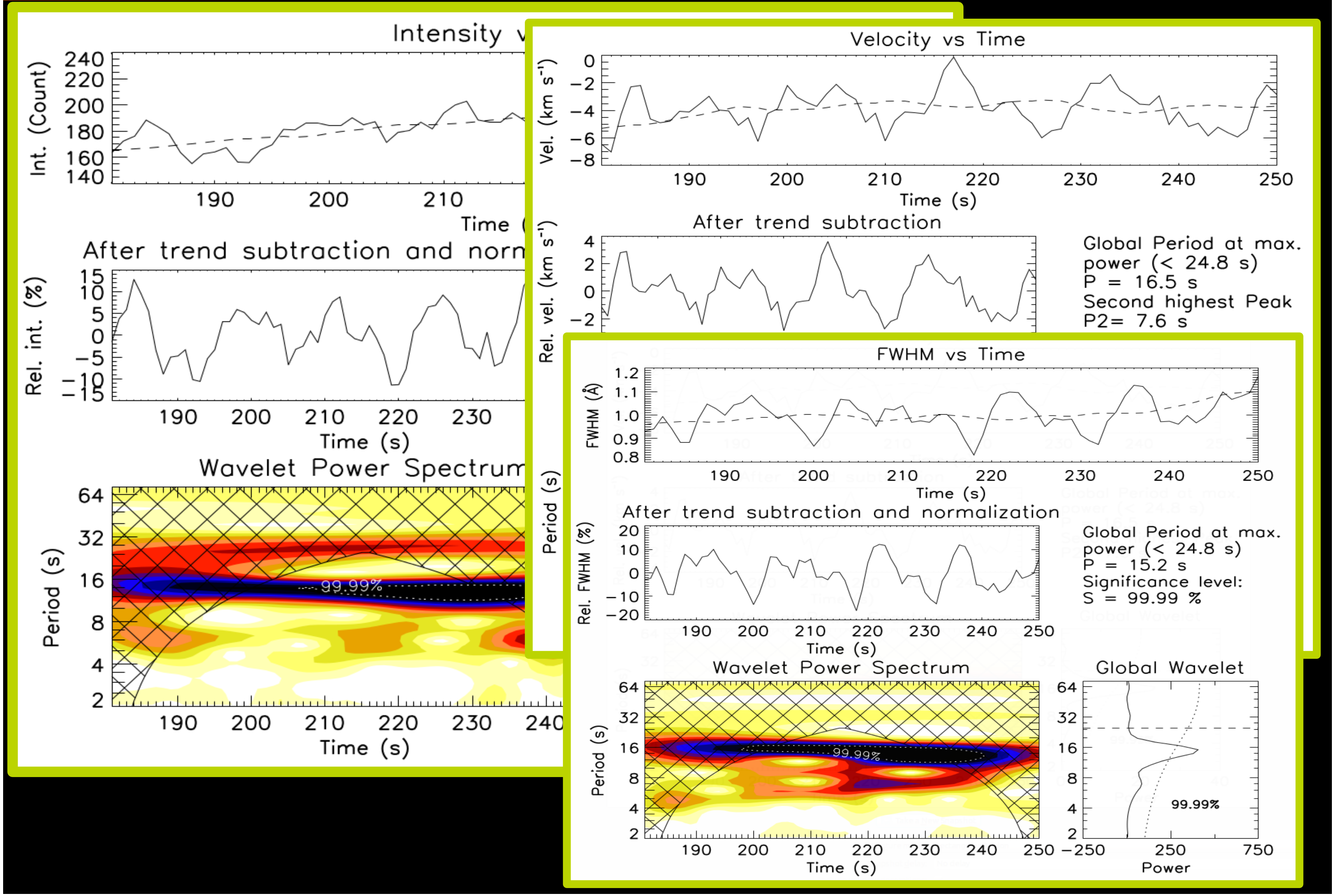
Detection of Oscillations



Detection of Oscillations



Detection of Oscillations



Detection of Oscillations

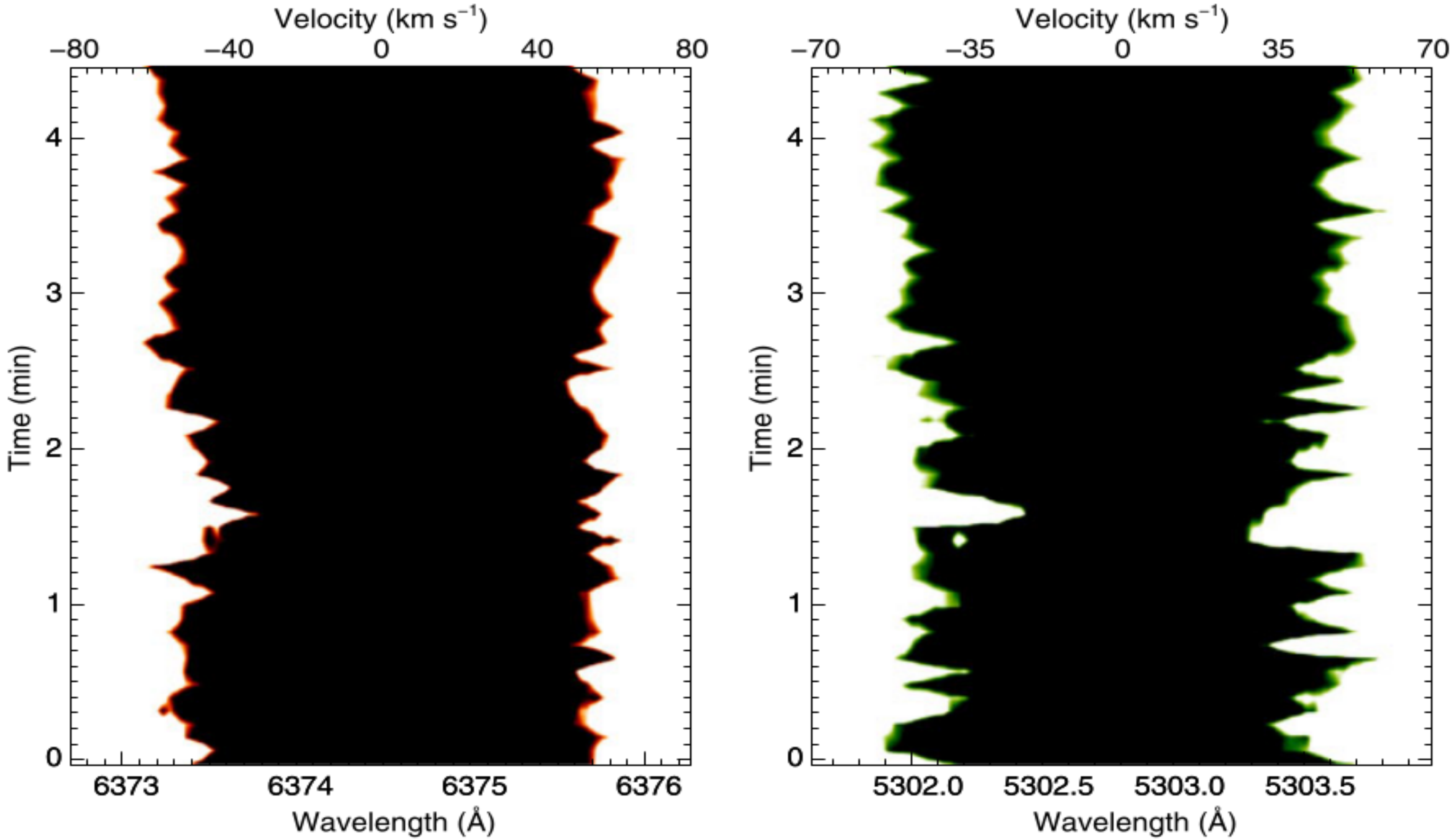
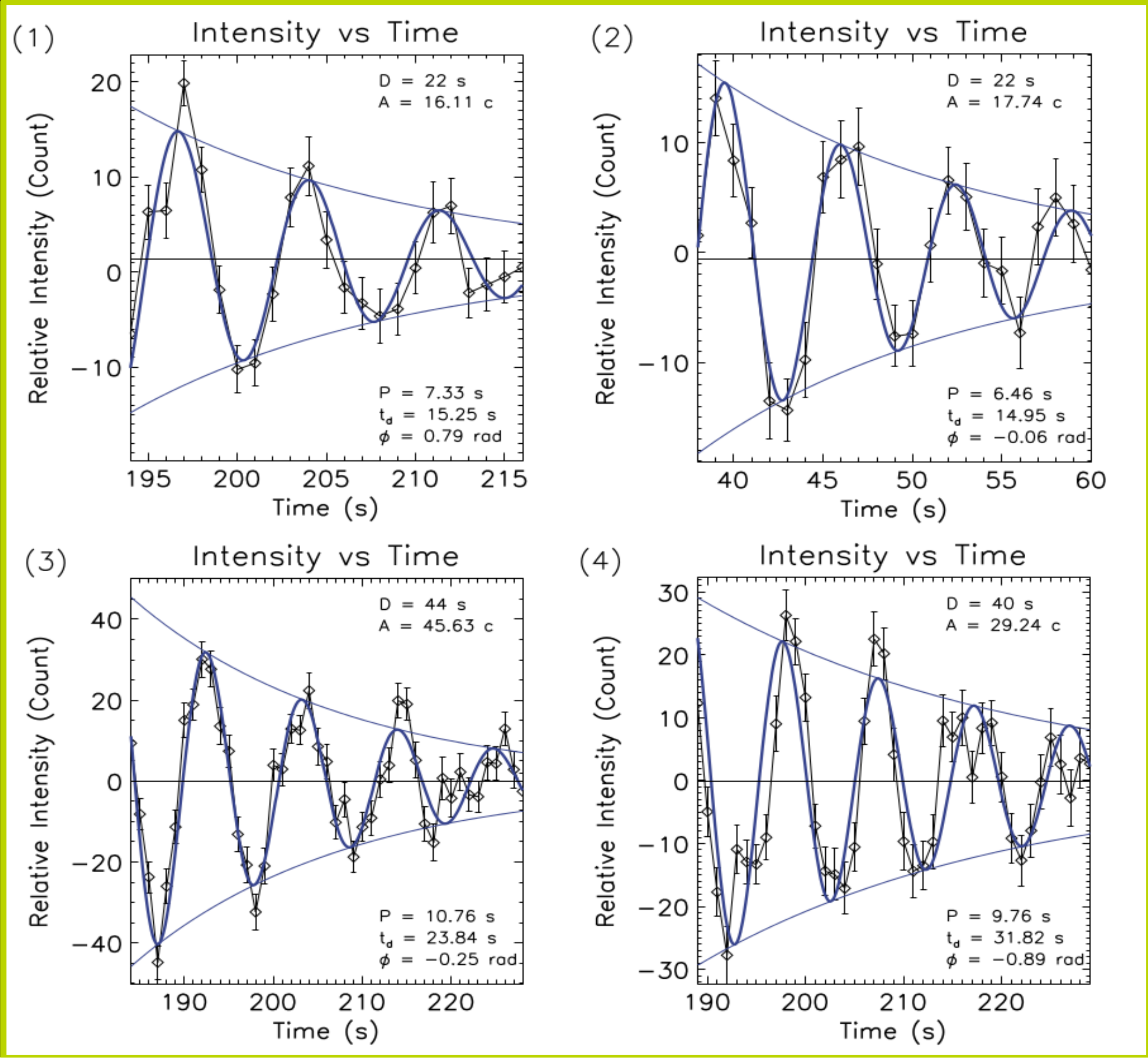
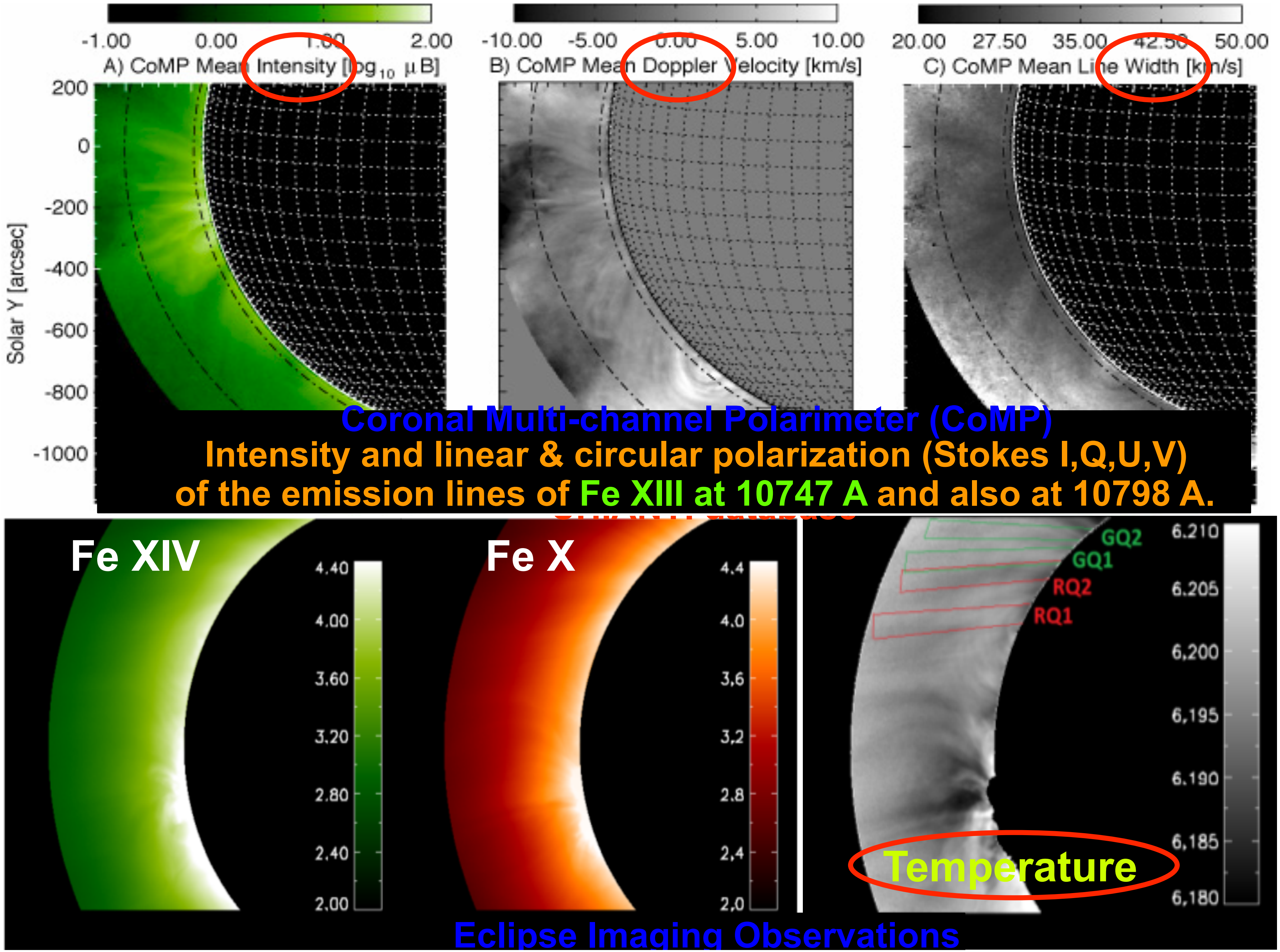


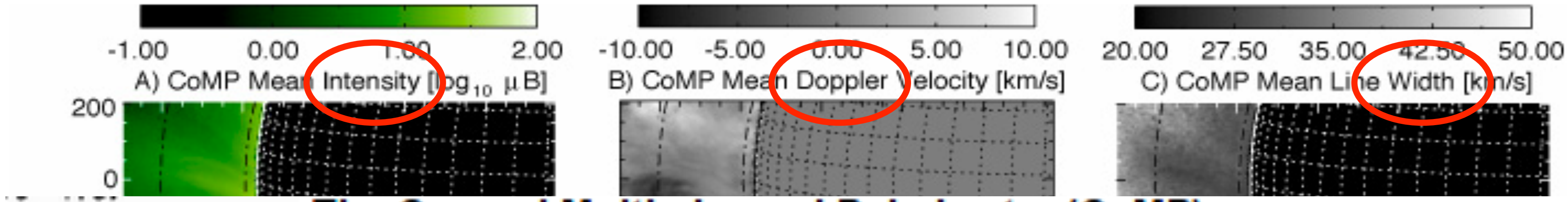
Figure 11 A wavelength-versus-time plot of the red (left panel) and green (right panel) line profiles showing the variation of line width at FWHM as a function of time during the eclipse at the locations marked with asterisks in Figure 4. These figures clearly show the variation of red and blue shifts and line broadening

Damping Signature of the Oscillations

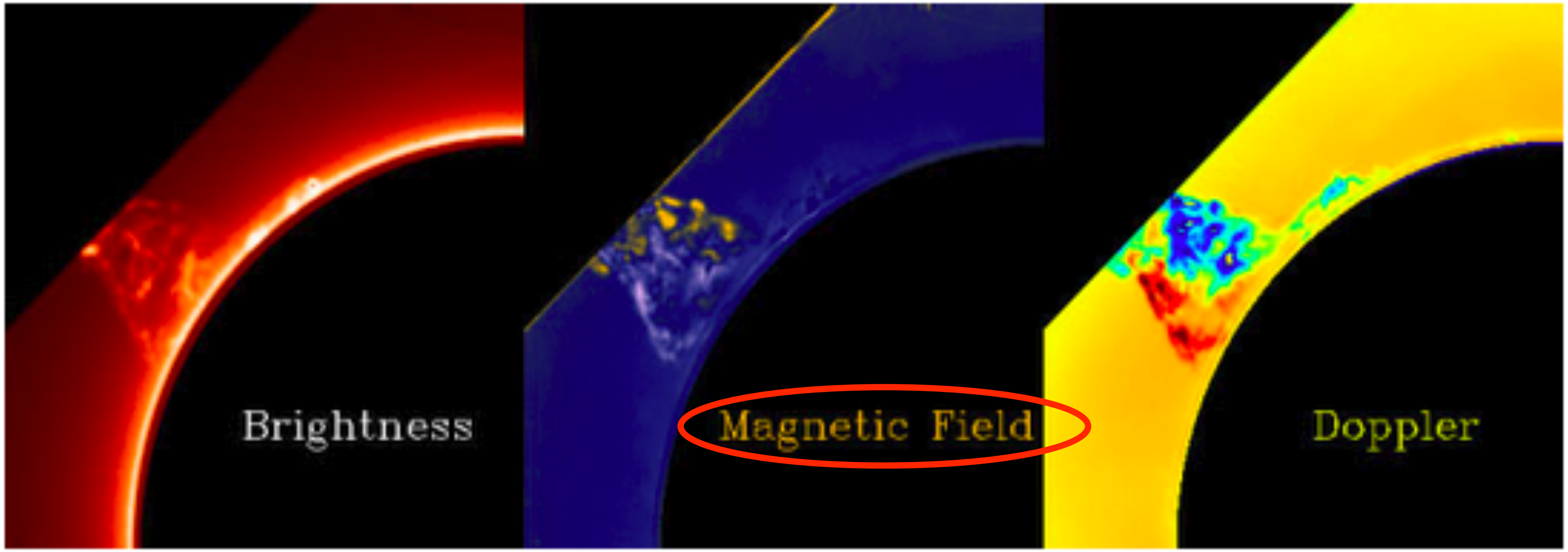


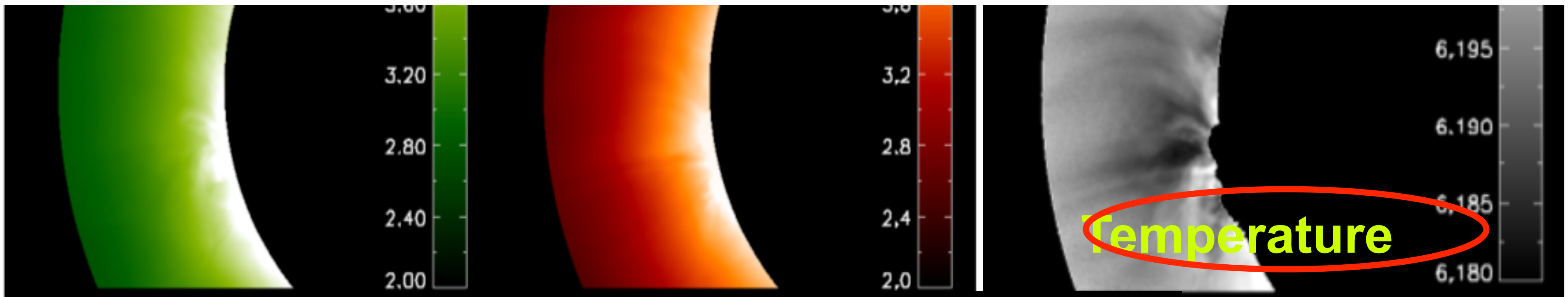


-1.00 0.00 1.00 2.00
A) CoMP Mean Intensity [log10 μB]
-10.00 -5.00 0.00 5.00 10.00
B) CoMP Mean Doppler Velocity [km/s]
20.00 27.50 35.00 42.50 50.00
C) CoMP Mean Line Width [km/s]
Solar Y [arcsec]
200
0
-200
-400
-600
-800
-1000
Coronal Multi-channel Polarimeter (CoMP)
Intensity and linear & circular polarization (Stokes I,Q,U,V)
of the emission lines of Fe XIII at 10747 A and also at 10798 A.
Fe XIV
4.40 4.00 3.60 3.20 2.80 2.40 2.00
Fe X
4.4 4.0 3.6 3.2 2.8 2.4 2.0
GQ2
GQ1
RQ2
RQ1
6.210 6.205 6.200 6.195 6.190 6.185 6.180
Temperature
Eclipse Imaging Observations



The Coronal Multi-channel Polarimeter (CoMP)

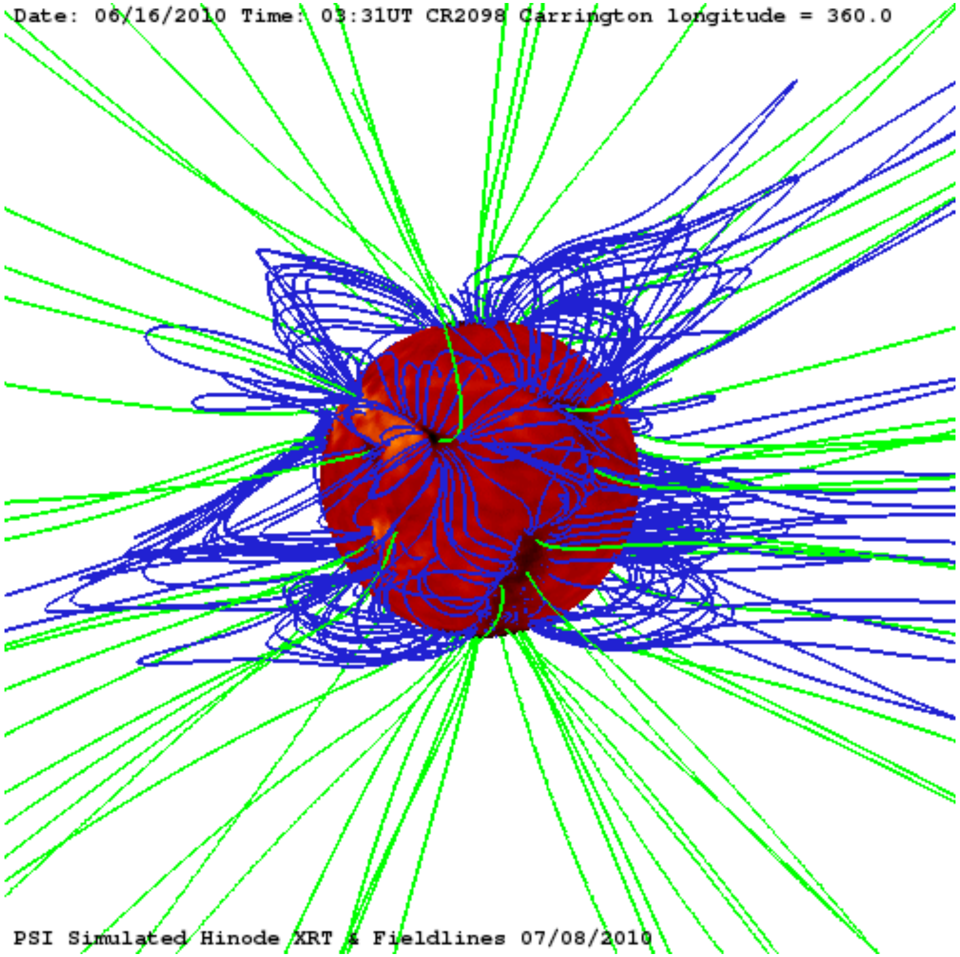




Eclipse Imaging Observations

Global field

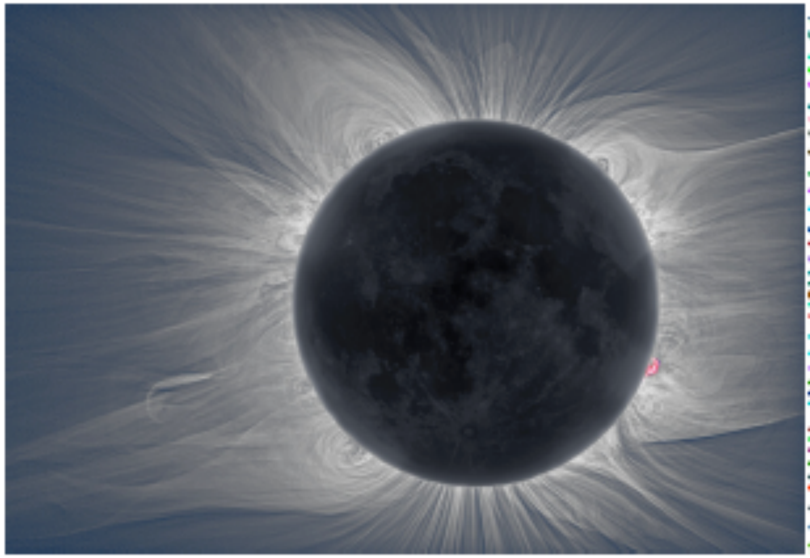
http://www.predsci.com/hmi/home.php



- What is the magnetic structure of the corona on large scales?
- How does the magnetic field change on a global scale? **With different time scales.**

Coronal Structures

Eclipse Image (July 11, 2010)



MHD Simulated Magnetic Conf

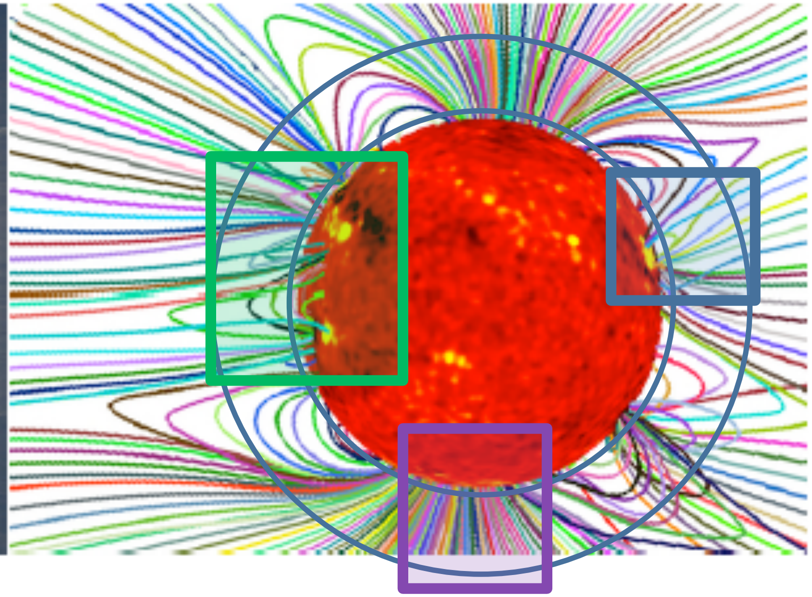
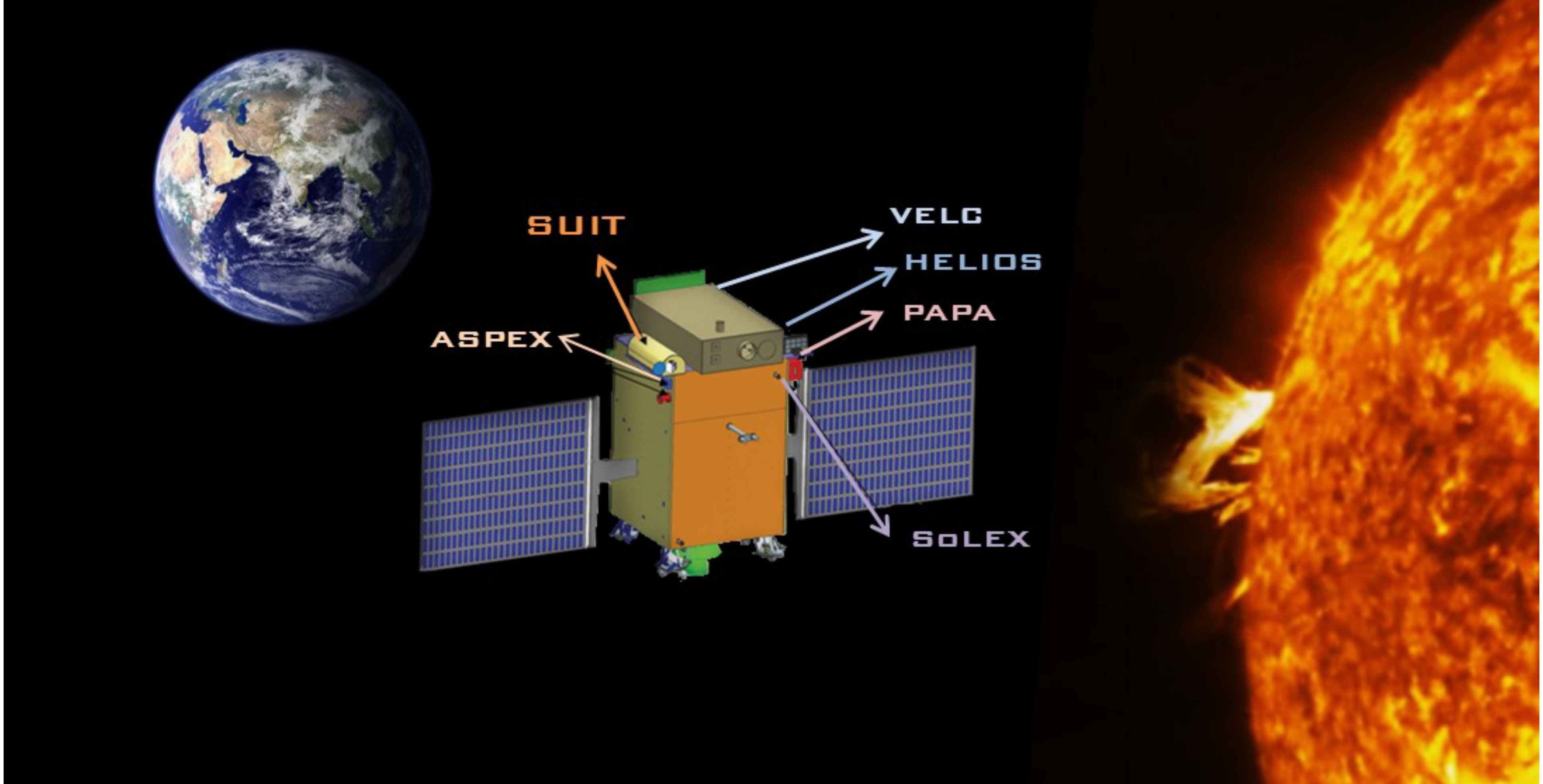


Image Courtesy: http: //www.zam.fme.vutbr.cz/~druck/eclipse

Model image: Linker http://www.predsci.com/corona/jul10eclipse/july10eclipse.html

SOLAR ULTRAVIOLET IMAGING TELESCOPE (SUIT)

Onboard ISRO ADITYA-L1

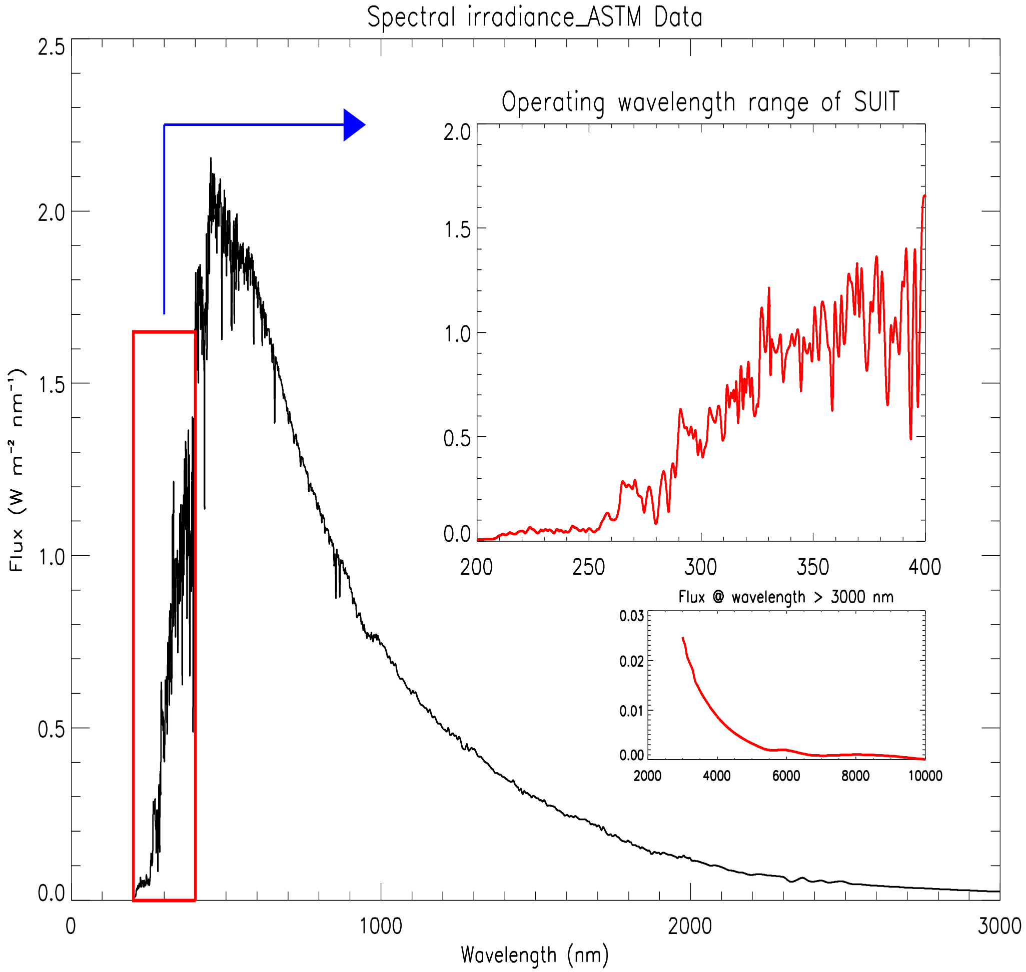


IUCAA

Inter-University Centre for Astronomy and Astrophysics
Pune, India

SUIT instrument concept

- **Combined full disk medium- and narrow-band filter imager between 200nm and 400nm – covering different heights**
- low straylight, high constrast imager in the important, but neglected near UV portion of solar spectrum - Prominences
- FOV ~ 1.2 R to overlap the FOV of VELC – CME initiation studies
- Important for the lower solar atmosphere: source regions
- Irradiance science: Sun-EARTH



SUIT Filters

S. No.	Centre (nm)	Bandpass (nm)	Description
1	214	1	Photosphere
2	274.7	0.4	Wing of Mg II k
3	279.6	0.4	Mg II k
4	280.3	0.4	Mg II h
5	283.2	0.4	Wing of Mg II h
6	300	1	Sunspots
7	388	1	Low[illegible]
8	397.8	0.1	
9	200-242	42	
10	242-300	58	
11	320-360	40	

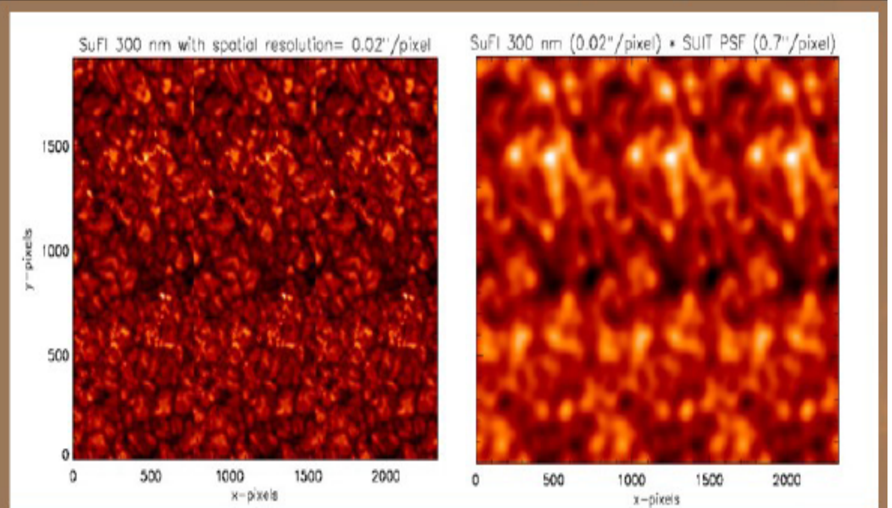
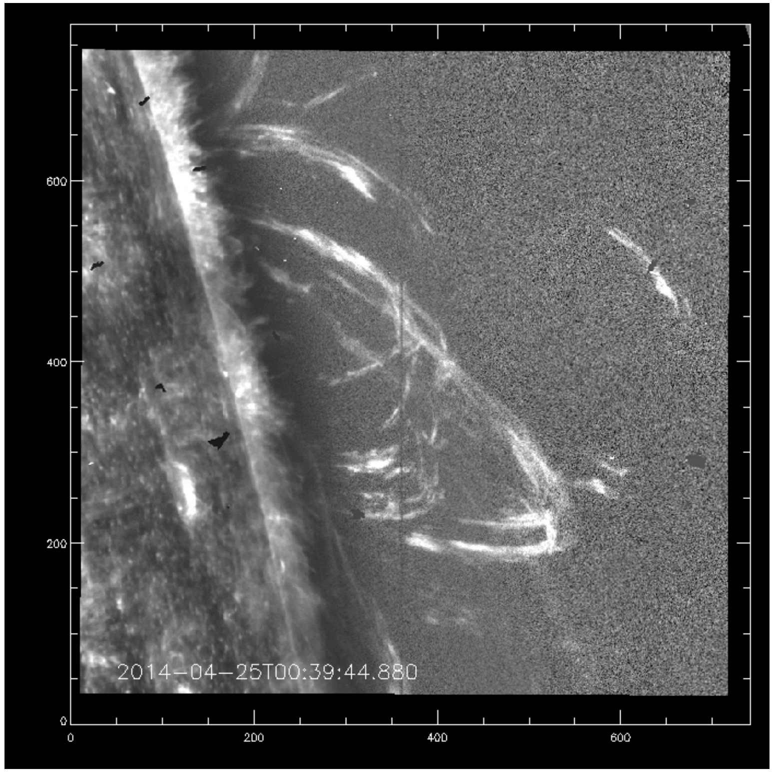


Figure: 300 nm SuFI (0.02 arcsec/pixel) Image (Left) convolved with SUIT's model PSF (spatial scale 0.7 arcsec/pixel)

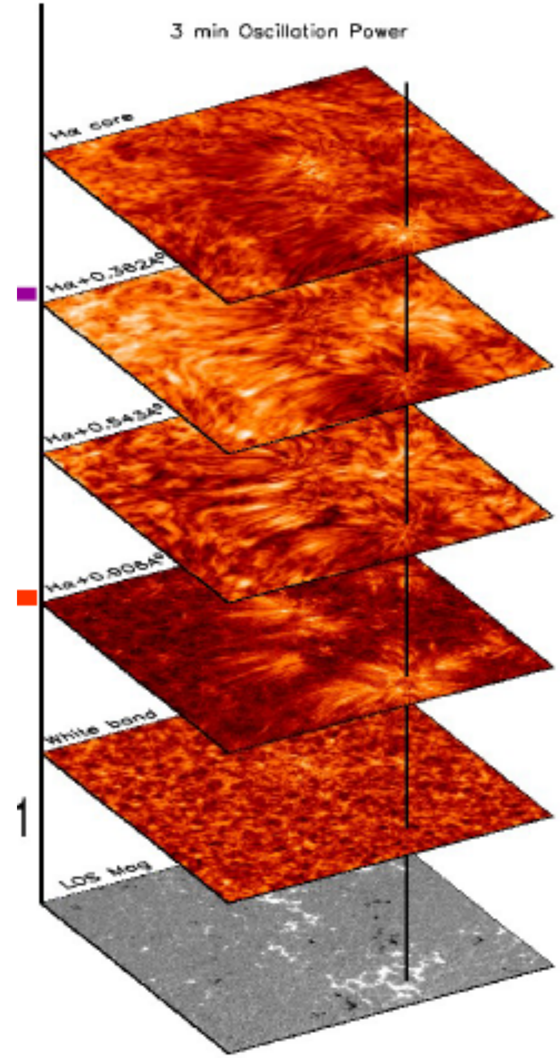
SUIT (NUV): Science Goals

- Evolution and Dynamics of Solar Prominences
- Sun-Climate Relationship



IRIS 1400 A
Slit jaw images
Radial gradient
Filtered

Coronal Rain: Pant et al. 2018



Power maps in the different layers at the 3 minutes period band with the magnetogram

Samanta et al (2015)

VELC for wave studies

High-Frequency Waves

- What are the sources of high-frequecy oscillation at high-corona?
- What are these wave modes and what is the damping mechanism?
- Are they significant/contribute to coronal heating?

Alfv´en waves

- Role of Alfv´en wave in heating the solar corona
- Damping of Alfv´en waves with Temperature (Gupta 2017)

Slow-Waves

- Slow wave properties/ Flows
- Damping length with Temperature

Kink Waves

- Horizontally and Vertically Polarized Kink waves
- Damping mechanism of the Kink waves

Watch out for Aditya (the sun God from India) @Lagrangian1

Importance of coordinated observations between ground
And space from multiple vantage points

Thank you for your attention