ADITYA – L1

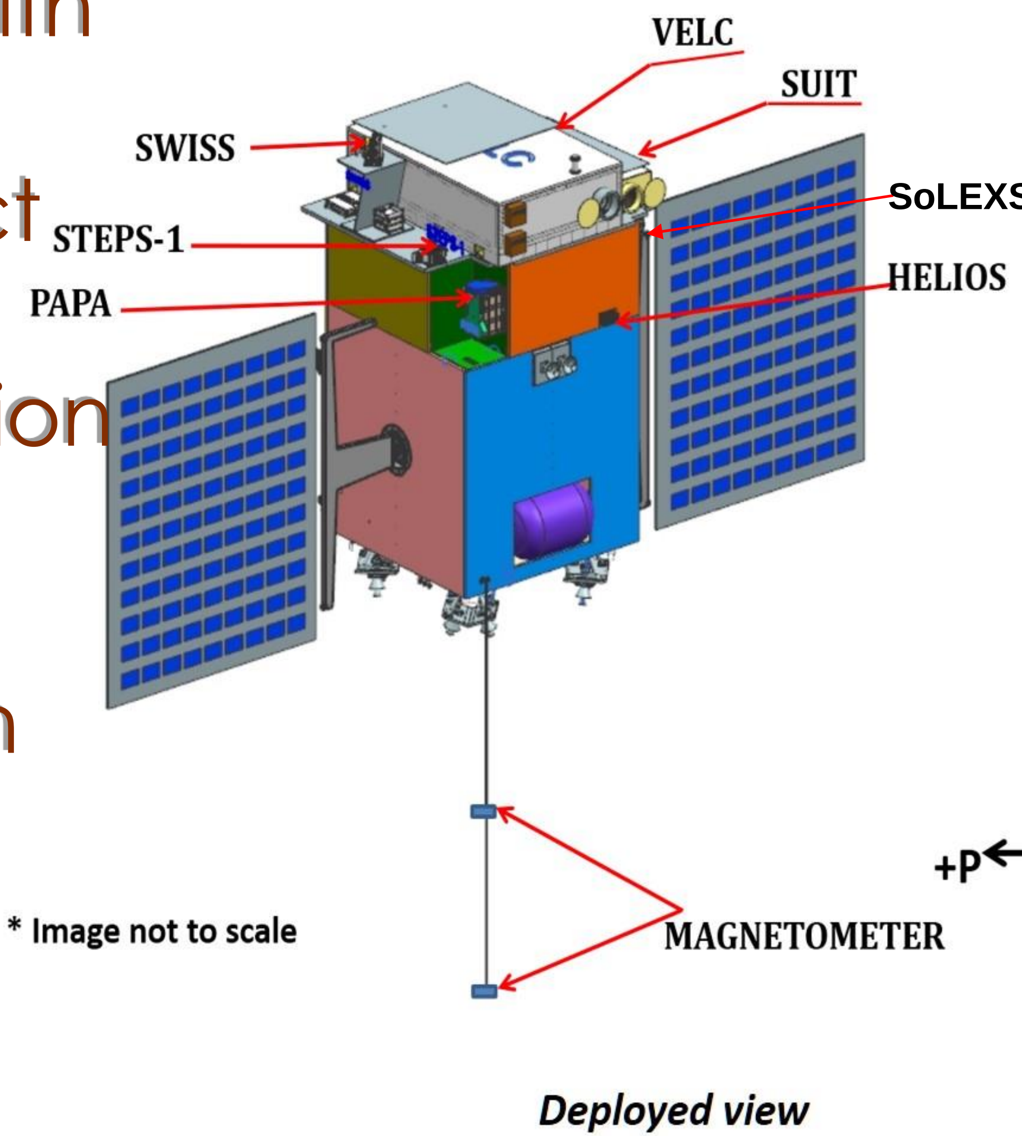
India's first dedicated satellite to study the Sun.

Sreejith Padinhatteeri,
SUIT Project Scientist,
IUCAA, Pune

(On Behalf of entire ADITYA-L1 team)

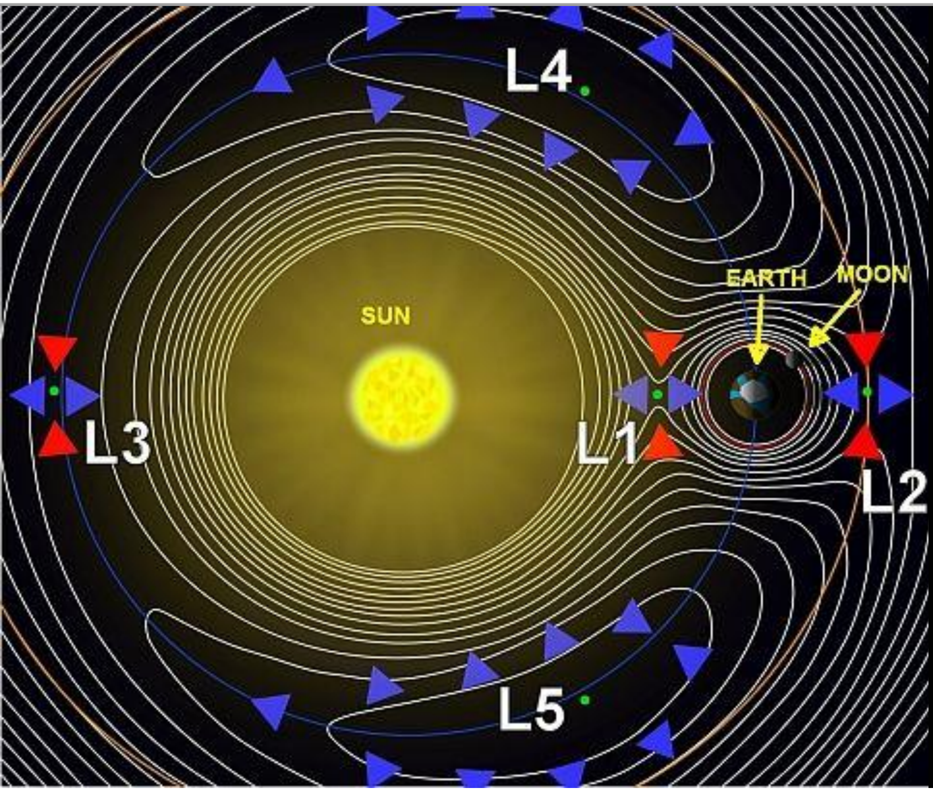
Aditya –L1

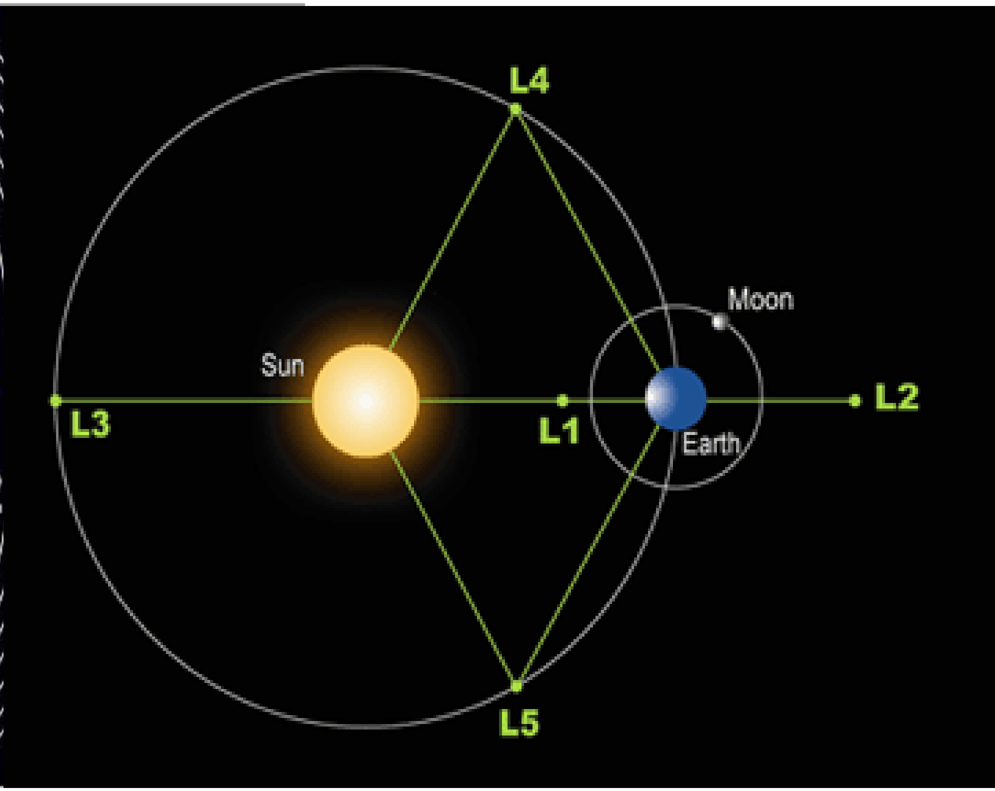
- Solar Observatory with 7 payloads - A collaborative project of Indian Space Research Organization (ISRO) along with multiple academic/ Research institutes in India.
- To be launched in 2020
- 5 years life time.



Satellite to be placed at halo orbit around Lagrangian point - L1

- Golden-aged, Veteran SOHO to have a younger companion soon.





Aditya – L1 Payloads.

1. Visible Emission Line Coronagraph (VELC)
2. Solar Ultraviolet Imaging Telescope (SUIT)
3. Solar Low Energy X-ray Spectrometer (SoLEXS)
4. High Energy L1 Orbiting X-ray Spectrometer (HEL1OS)
5. Aditya Solar wind Particle Experiment (ASPEx)
6. Plasma Analyser Package for Aditya (PAPA)
7. Magnetometer

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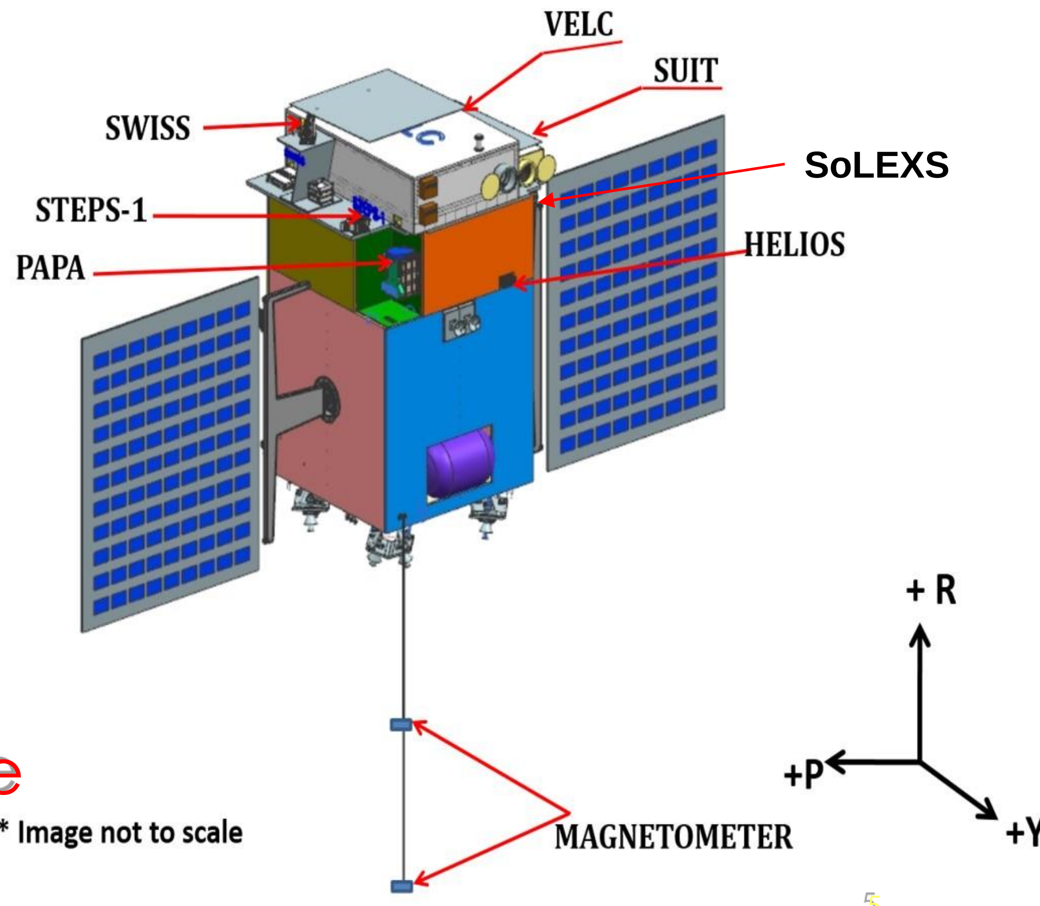
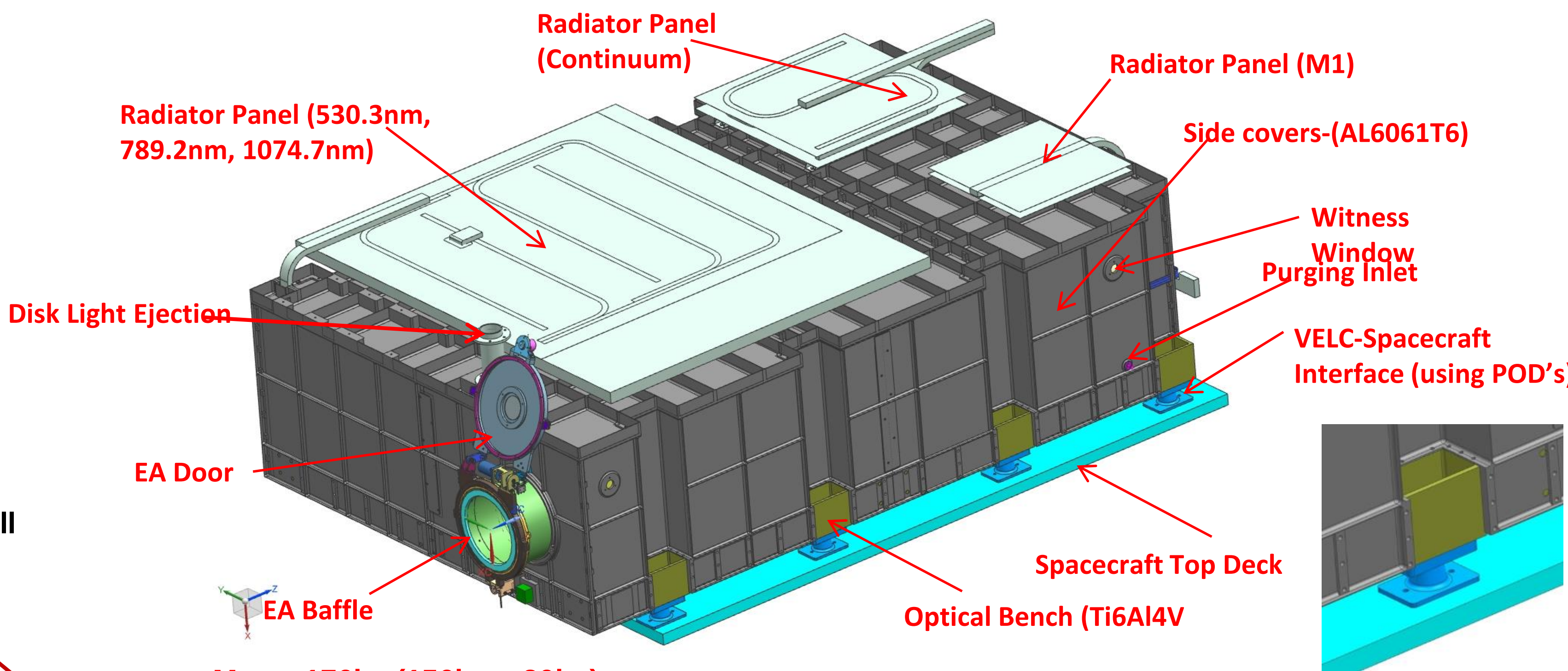
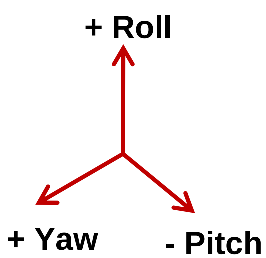


* Image not to scale

Deployed view

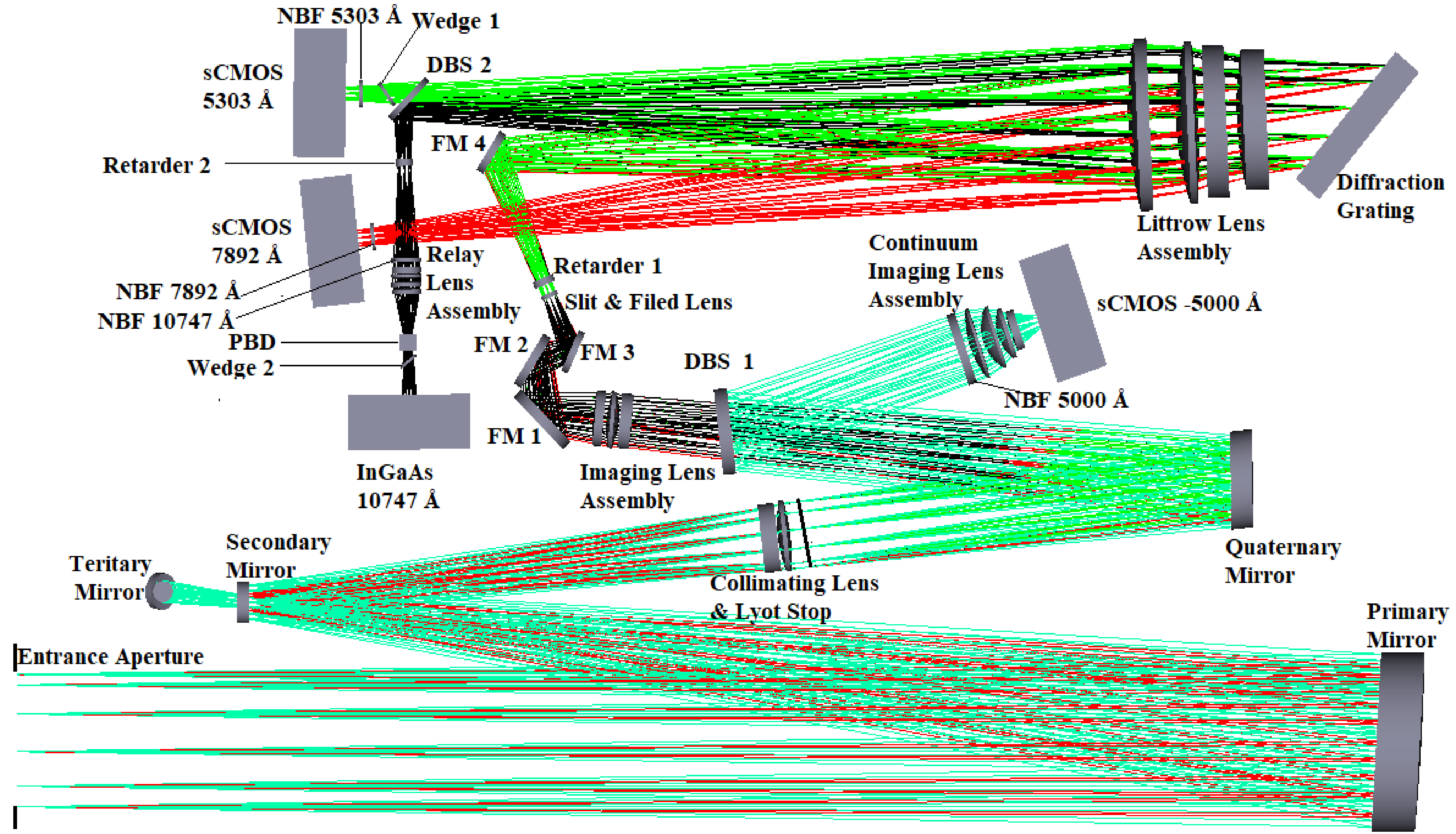
Visible Emission Line Coronagraph (VELC)



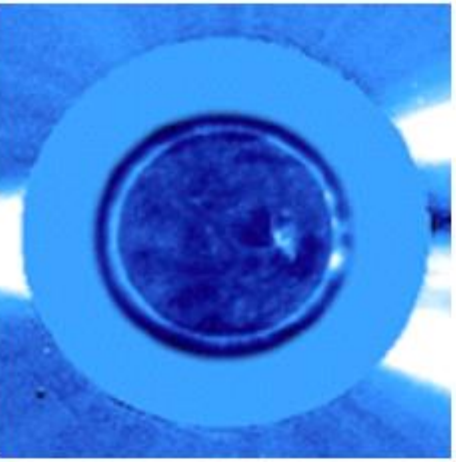


Mass: 176kg (156kg + 20kg)
Resonant Frequencies: 117Hz, 125Hz, 128Hz

VELC Optical Layout

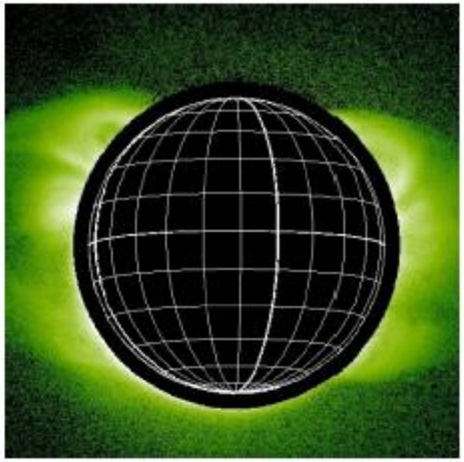


VELC Science Motivation



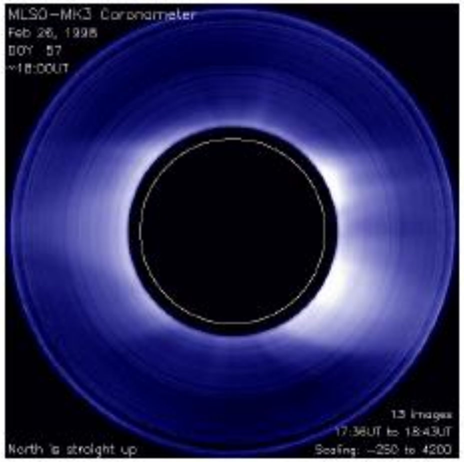
SOHO/LASCO-C2

R > 2.5 Rsol



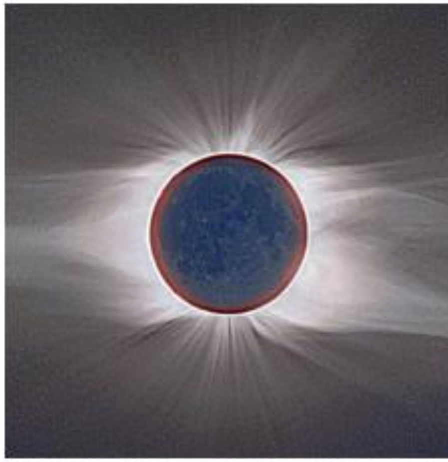
SOHO/LASCO-C1

Operated at solar minimum only for 2 yrs



Ground-based coronagraph:

Low spatial resolution and atmospheric noise

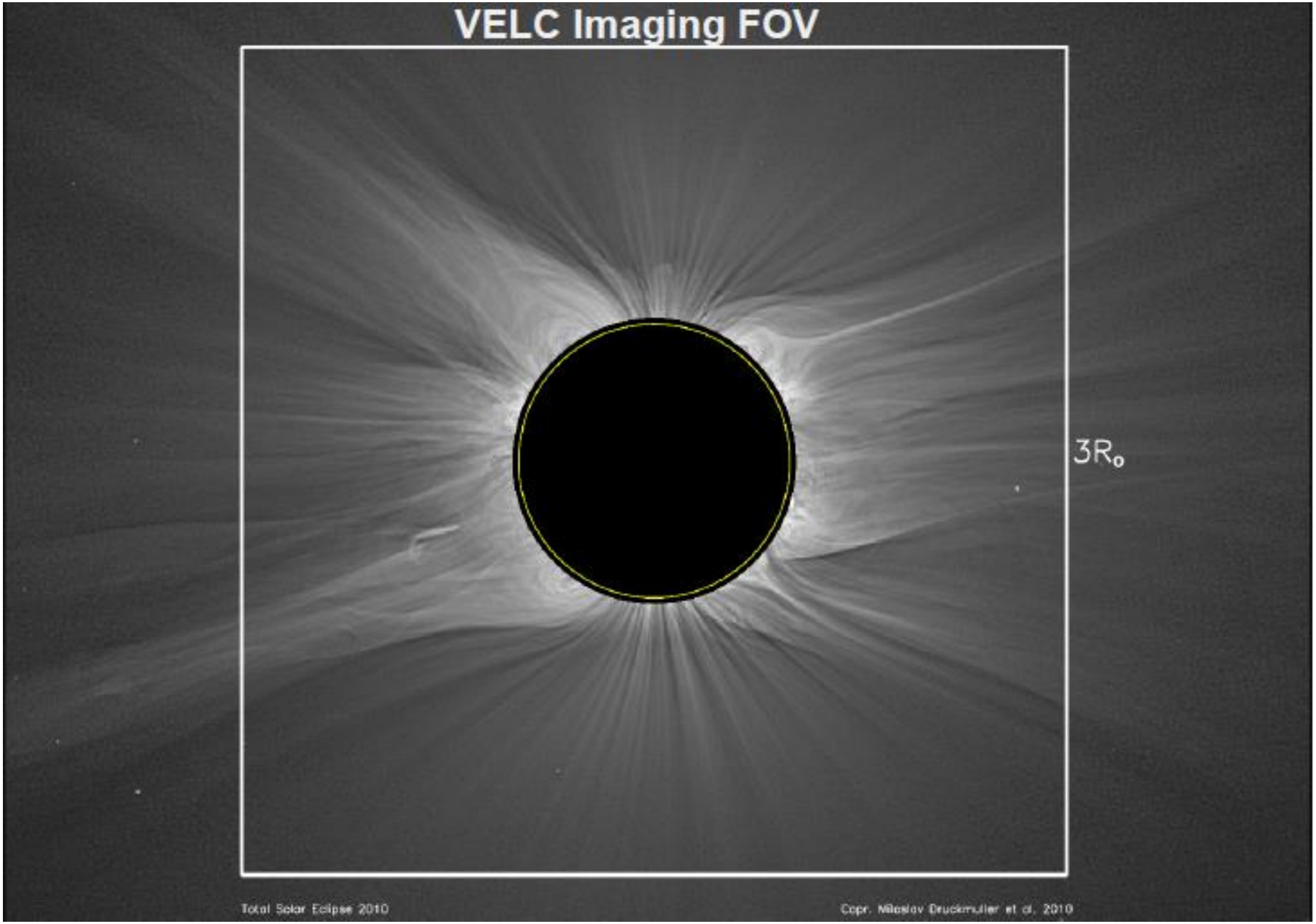


Total solar Eclipses:

Ideal but very rare and only a snapshot!

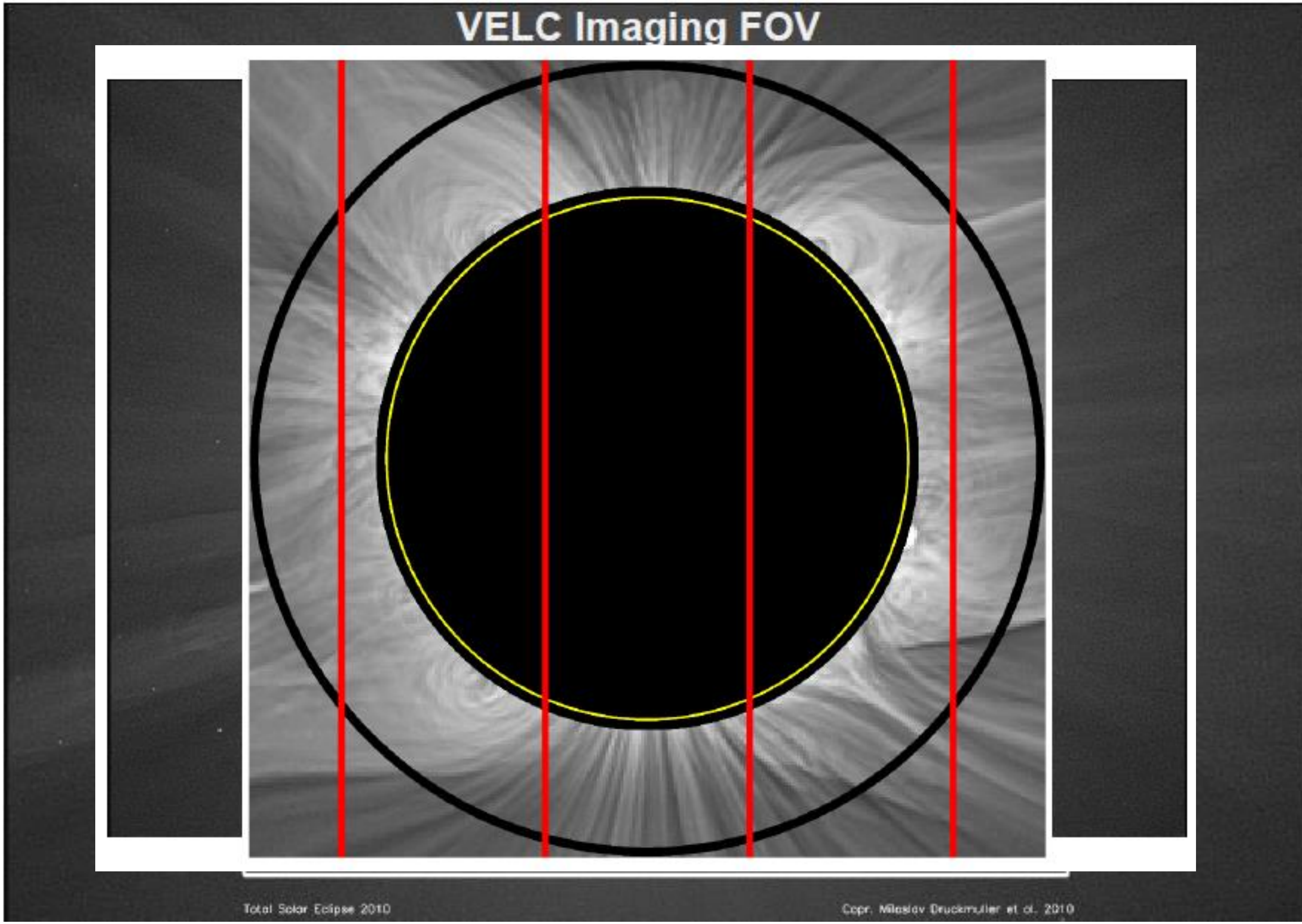
- 1Ro – 2Ro Corona is very little observed, especially in Visible and Infra Red.
- VELC will cover inner corona from 1.05 – 3.0 Rsun

Slide Courtesy : Dipankar Banerjee



- 1.05 R_{sun} – 3.0 R_{sun}

Slide Courtesy : Dipankar Banerjee



- 1.05 R_{sun} – 1.5 R_{sun} – Spectroscopic FOV

Slide Courtesy : Dipankar Banerjee

VELC – Science Goals

1. **Diagnostics of the corona and coronal structures (Temperature, Velocity, & Density)**
2. **Dynamics of small- and large-scale structures in the corona using difference imaging techniques & spectroscopy**
3. **Development, dynamics and origin of CME's, drivers for space weather**
4. **Magnetic topology & Field measurements**

Uniqueness

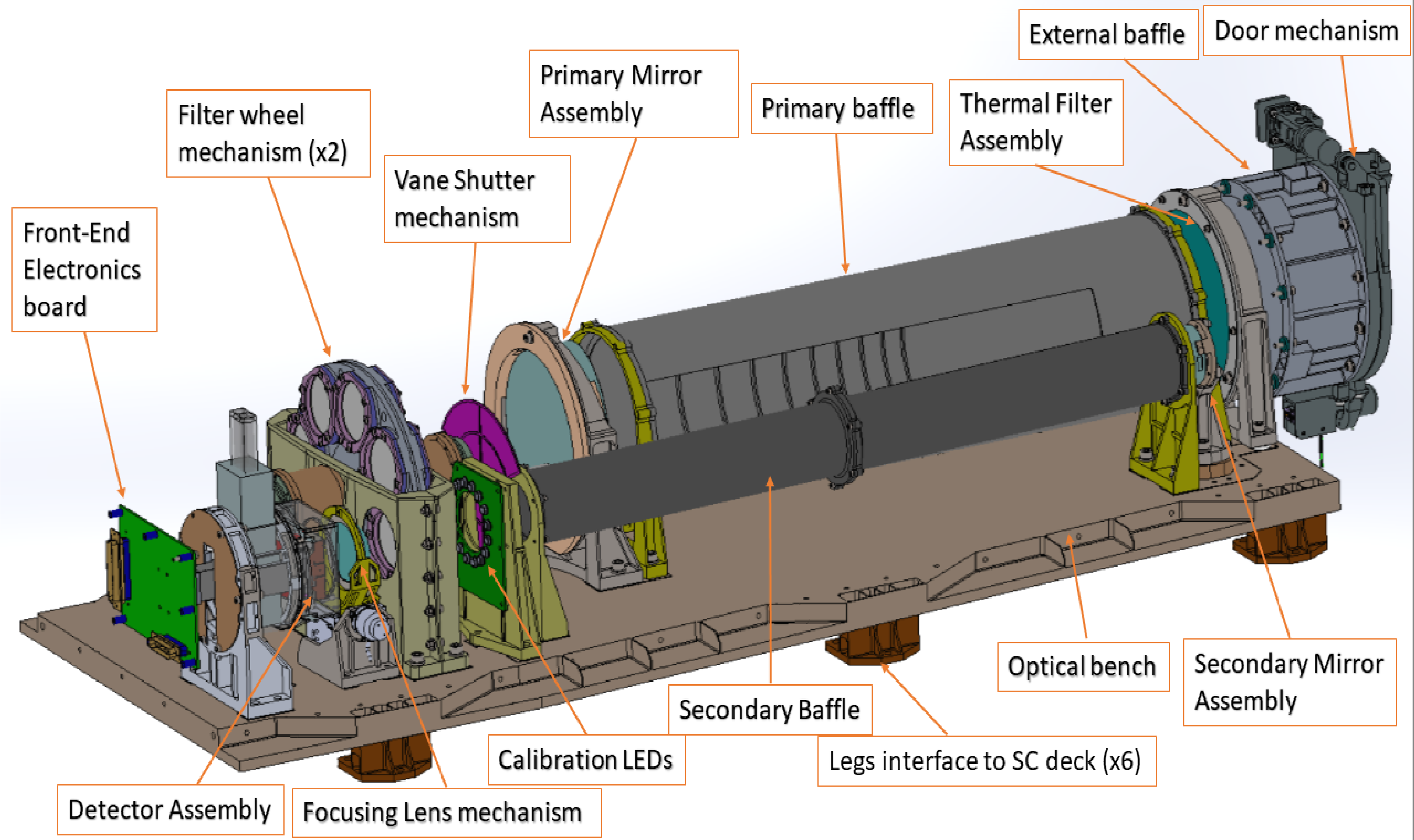
Close to solar limb (1.05 Ro)
High spatial & Spectroscopic resolution
High cadence

VELC – Important Specs

Channel Name	FOV (Ro)	Wavelength (nm)	Plate Scale (\pixel)	Science Goal
Imaging channel	1.05-3	500	2.5 arcsec	1. Development, dynamics, and origin CMEs 2. Studies on the drivers for space weather
530.3 nm	1.05-1.5	530.3	1.2” X 28 mÅ	Diagnostics of coronal plasma and coronal loop plasma
789.2 nm	1.05-1.5	789.2	1.2” X 31 mÅ	
1074.7 nm	1.05-1.5	1074.7	5” X 202 mÅ	Diagnostics of coronal and coronal loops plasma Measurement of coronal magnetic fields.

Solar Ultra-Violet Imaging Telescope (SUIT)

SUIT Internal subassembly view.



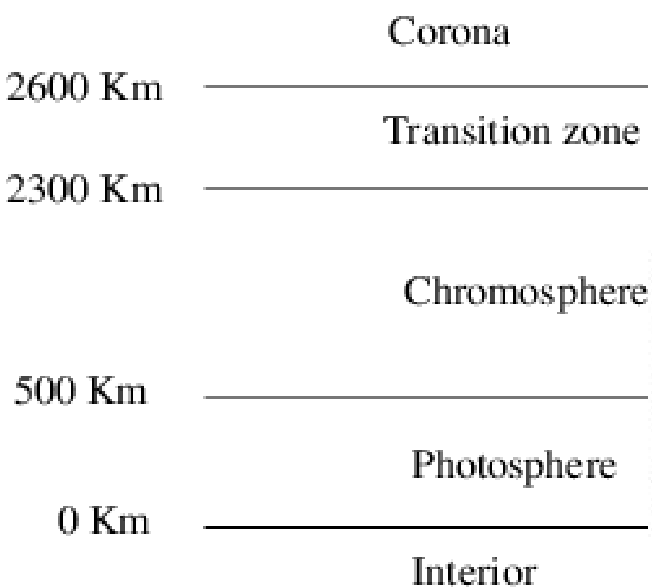
What is SUIT? Why is it important?

- A UV telescope to image the solar disk using narrow-band and broad-band spectral filters in the range of 200-400 nm, with low stray light and high contrast.

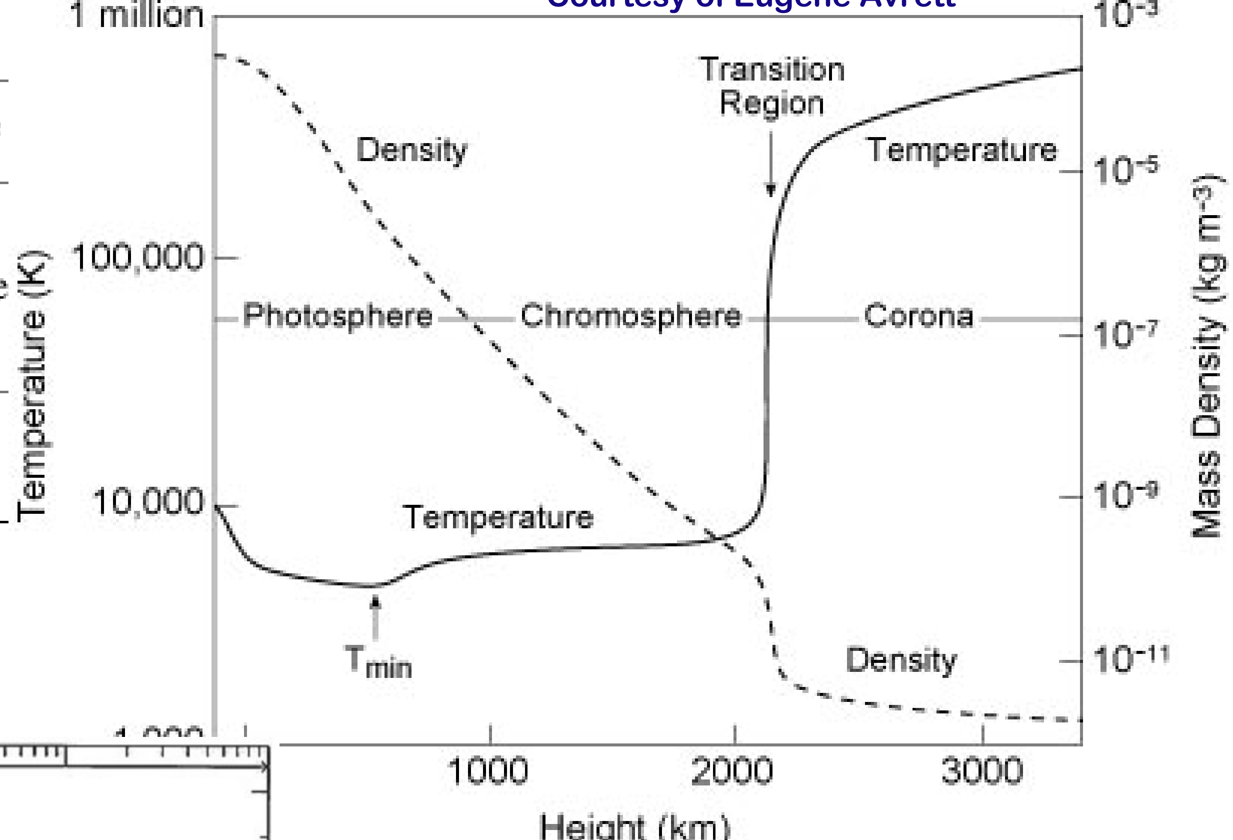
- Provides near-simultaneous coverage of the solar atmosphere from lower photosphere to the upper chromosphere and lower transition regions — important for coupling and dynamics of the atmosphere

- Provides unique opportunity to study the spatially resolved solar spectral irradiance in near ultra-violet wavelength range — relevant for Sun Climate relations — atmospheric dynamics of the Earth.

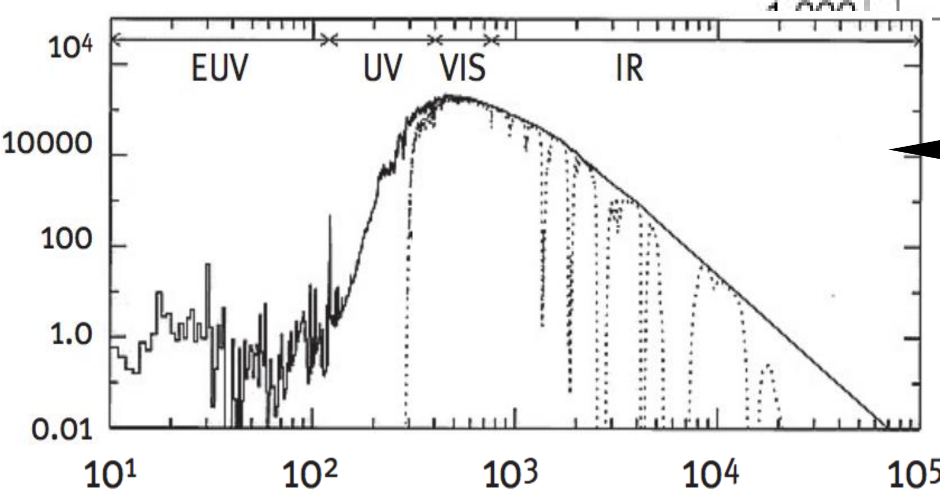
SUIT Overview: Science Goals



Courtesy of Eugene Avrett



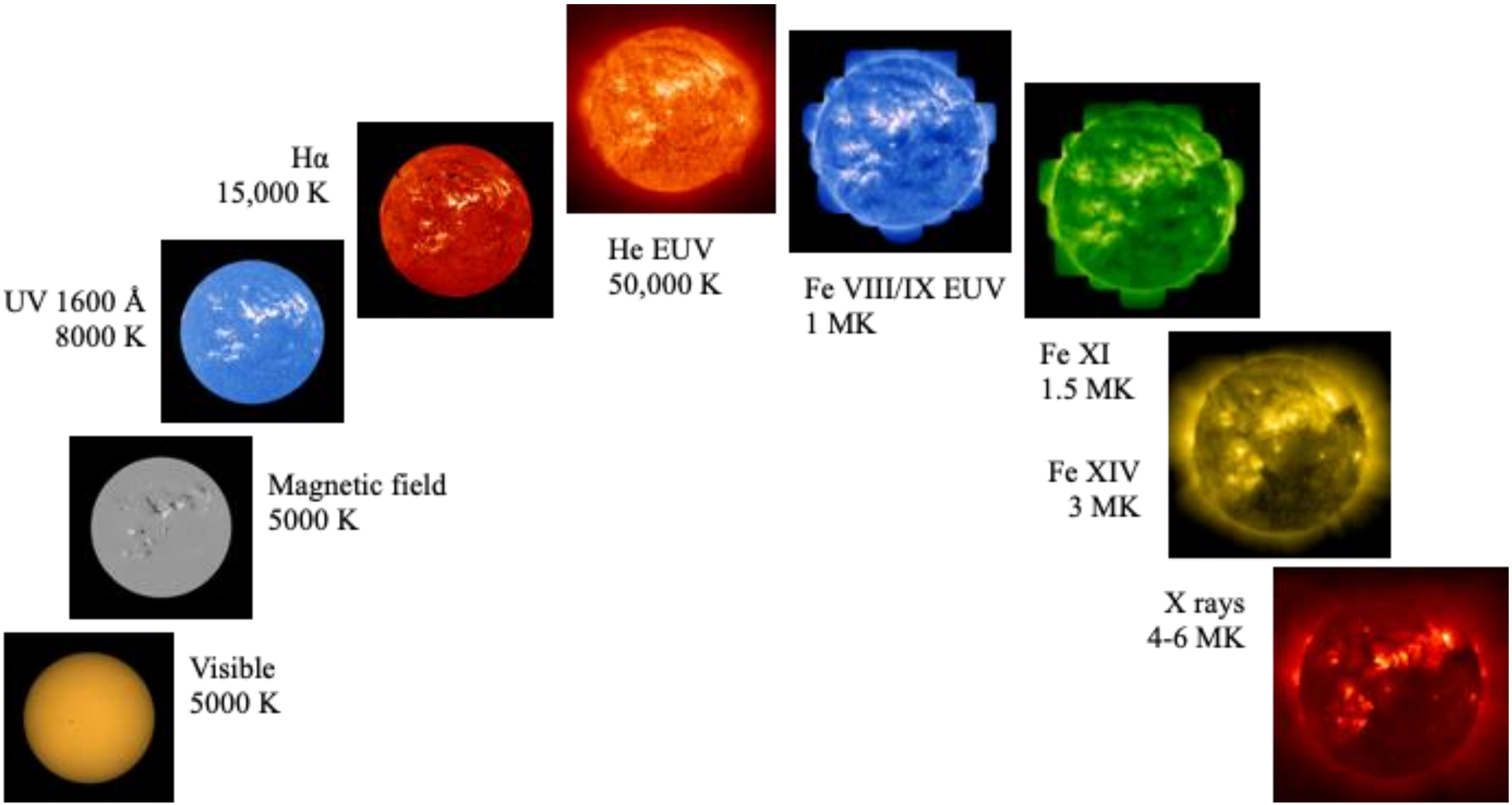
Lean and Rind 1998



Visible and UV

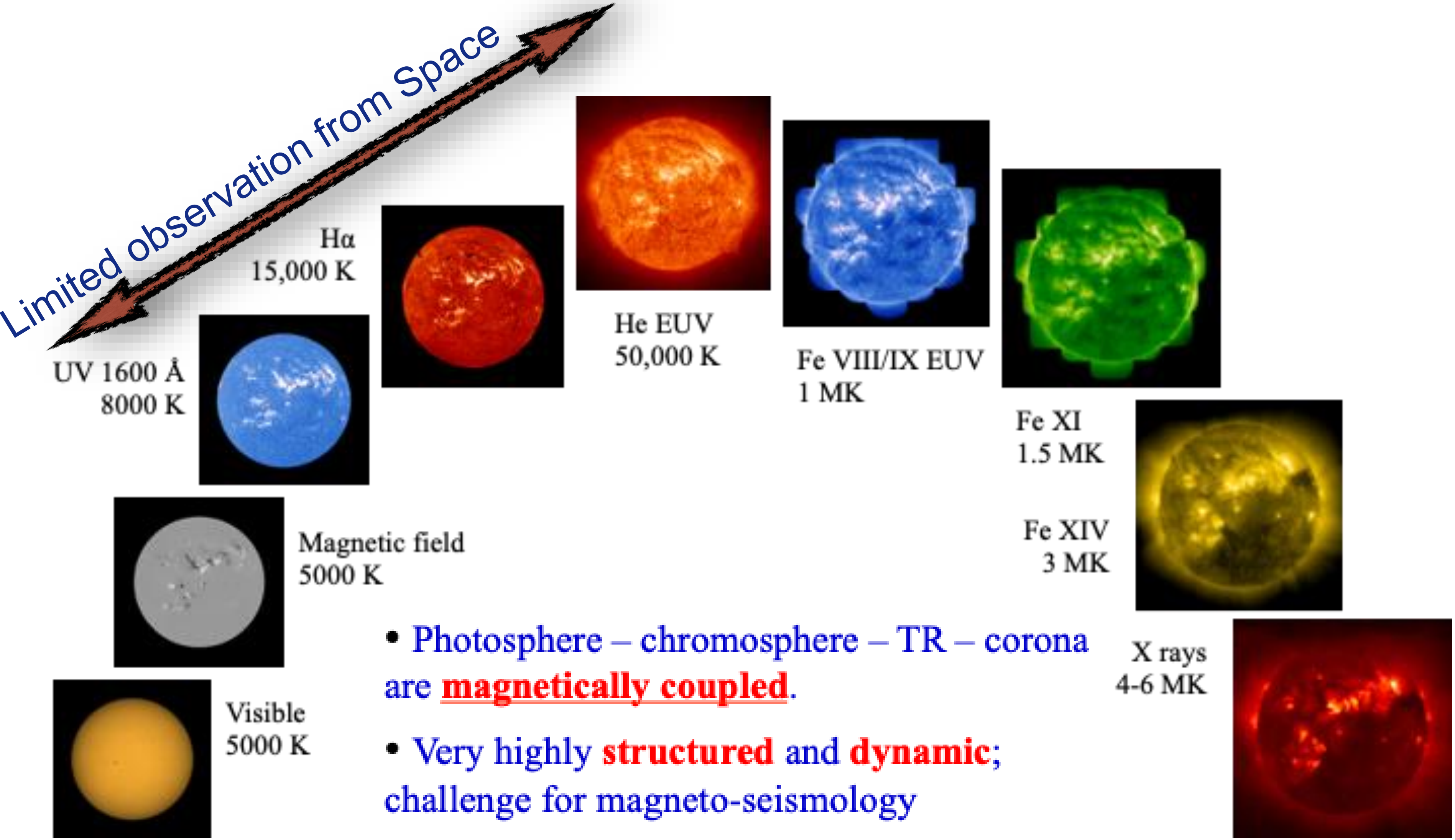
EUV and X-rays

SUIT : Motivation



Slide courtesy: Robertus Erdelyi

SUIT : Motivation

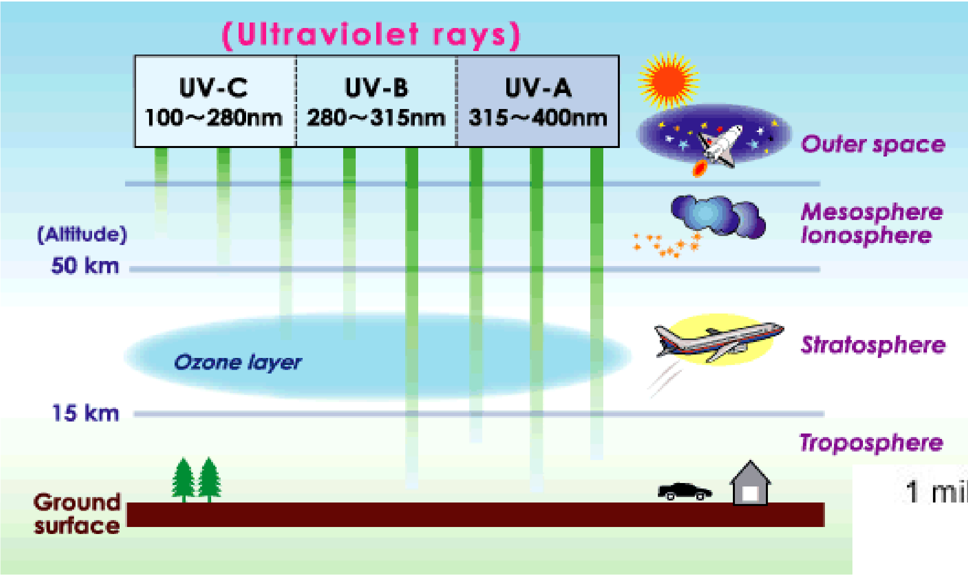


- Photosphere – chromosphere – TR – corona are **magnetically coupled**.
- Very highly **structured** and **dynamic**; challenge for magneto-seismology

Slide courtesy: Robertus Erdelyi

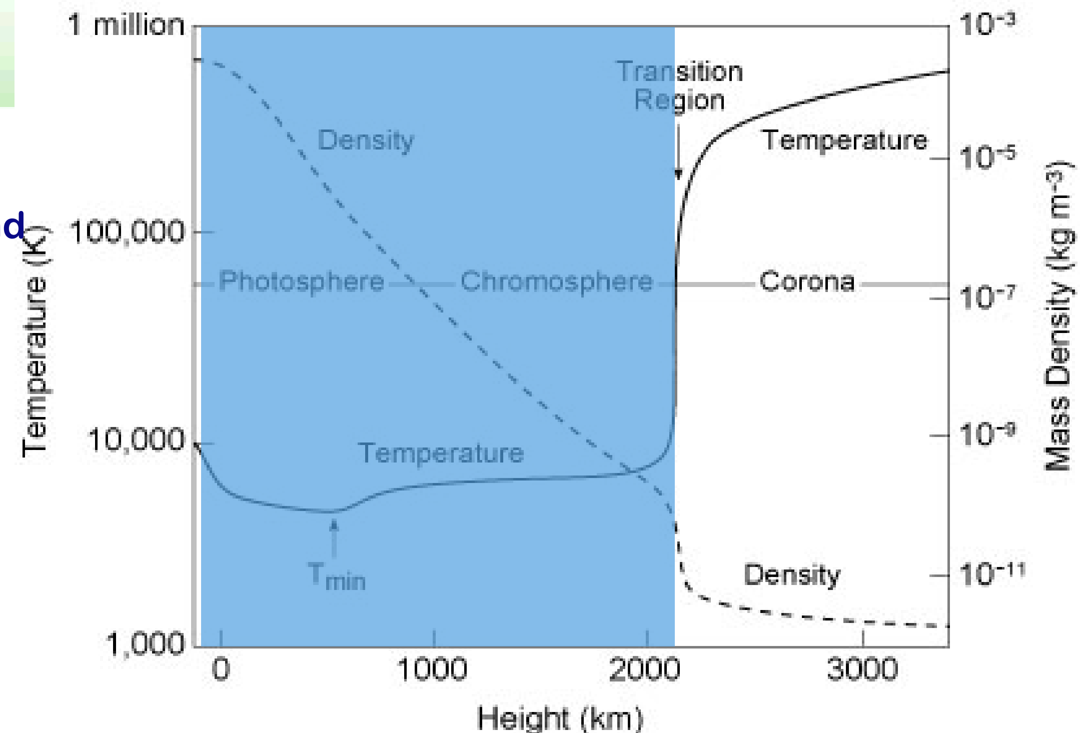
SUIT : Motivation

Credit: National Institute for Environmental Science, Japan



NUV important for the chemistry of Oxygen and Ozone in the Stratosphere

Radiation from Photosphere and chromosphere in NUV



Instrument Overview

Spectral Coverage: *200-400 nm with 11 different Science filters*

Field of view: *~0.8 degrees of arc (Field extending upto ~1.6 Solar Radius)*

Image Quality-Angular Resolution: *0.7 arcsecond/pixel (pixel size of 12 µm @ 280 nm)*

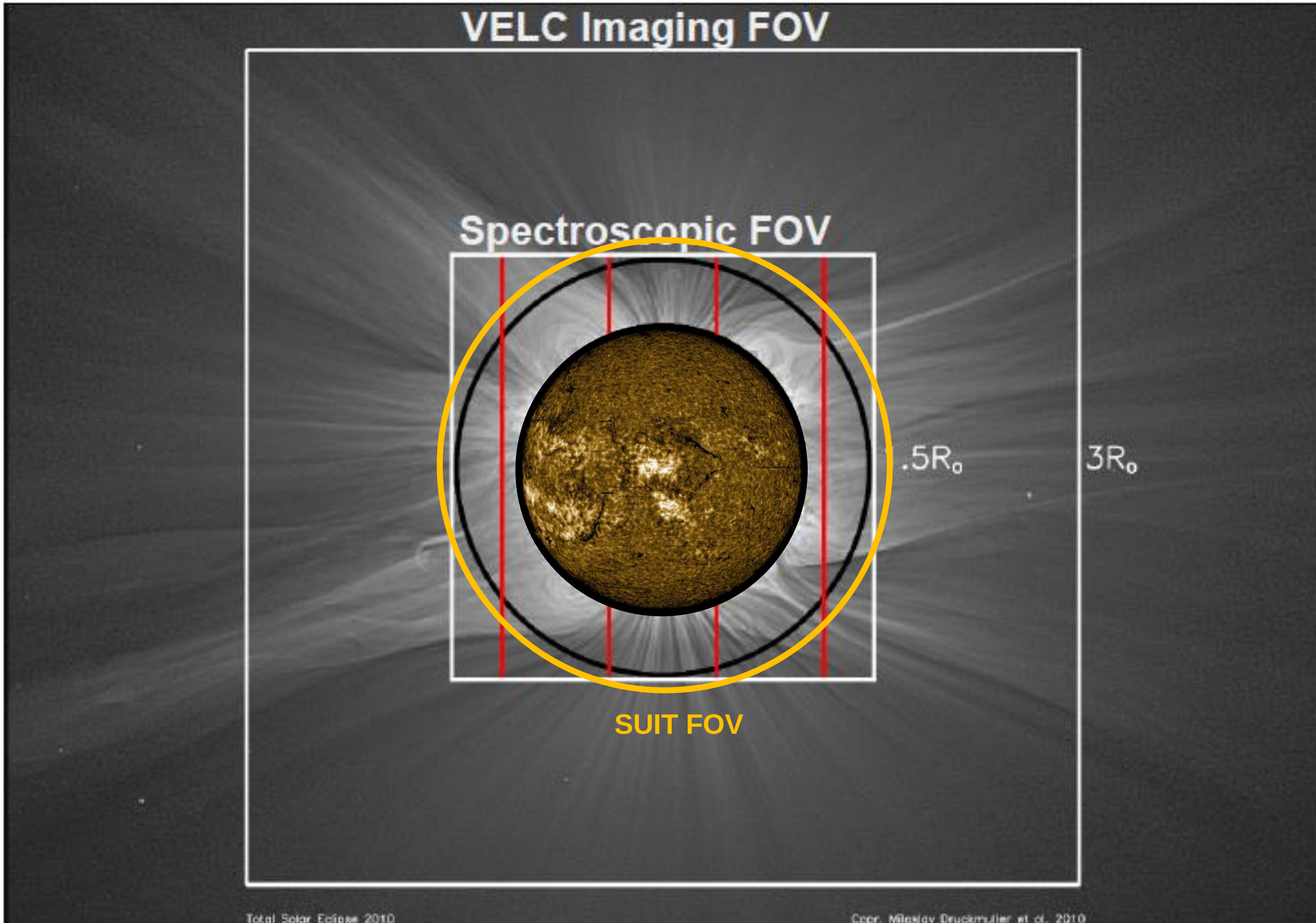
Image Quality- Encircled Energy (EE): *80 % EE to fall within 1 pixel*

Primary aperture: 140.8 mm ($2.44\lambda/\Delta\theta$, @280nm *for* $\Delta\theta = 1$ arcsecond*)*

Effective Focal Length: 3500 mm

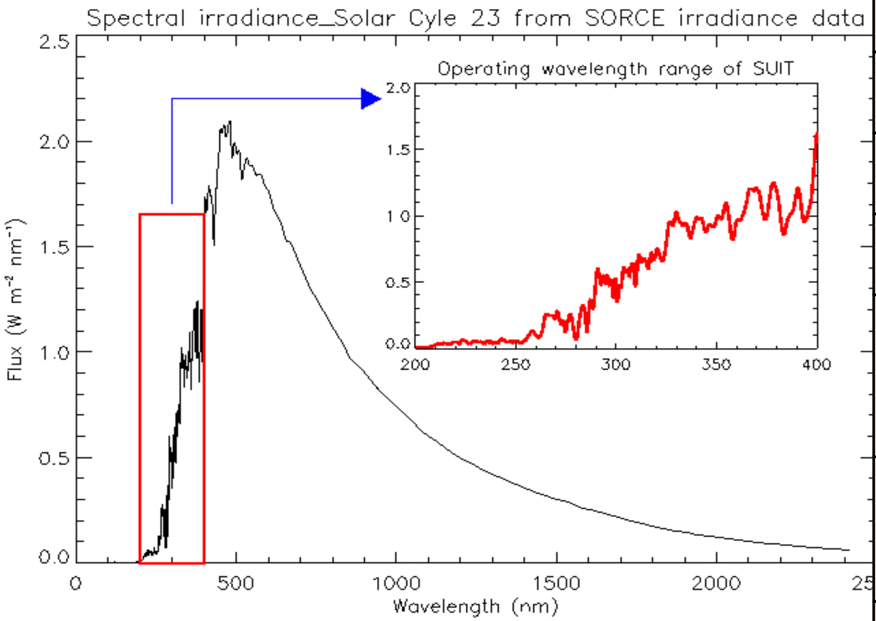
Image Size: *4kx4k (Detector)*

SUIT-VELC combined FOV



SUIT- Important Specs

Spectral Coverage: 200-400 nm
Spectral Channels: 11 (3 Broadband & 8 Narrowband)



- Automatic Flare Detection, and high cadence observation mode

S. No.	Name	Centre (nm)	Band pass (nm)	Description
1	NB1	214	5	Photosphere
2	NB2	274.7	0.4	Wing of Mg II k
3	NB3	279.6	0.4	Mg II k
4	NB4	280.3	0.4	Mg II h
5	NB5	283.2	0.4	Wing of Mg II h
6	NB6	300	1	Sunspots
7	NB7	388	1	Lower Photosphere
8	NB8	396.85	0.1	Ca II
9	BB1	200-242	42	Continuum
10	BB2	242-300	58	Continuum
11	BB3	320-360	40	Continuum

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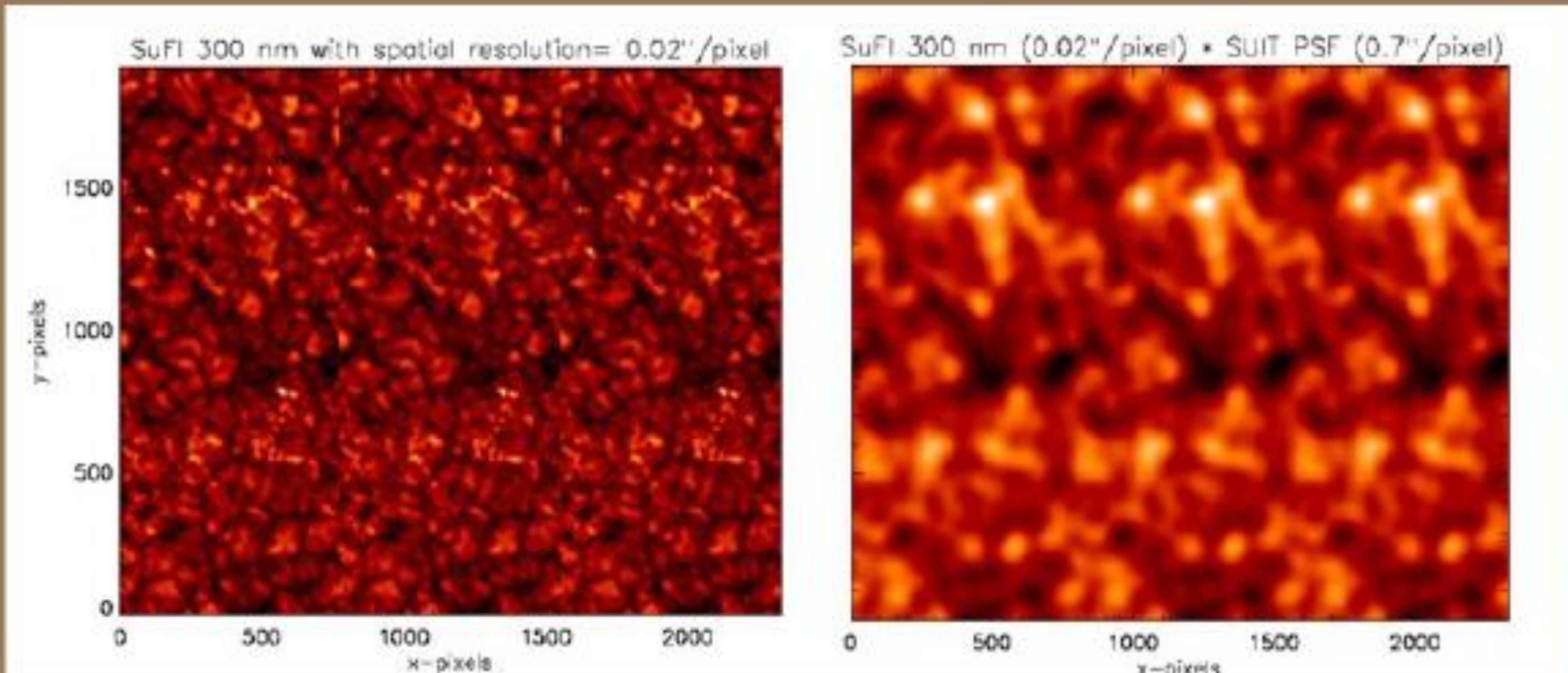


Figure: 300 nm SuFI (0.02 arcsec/pixel) Image (Left) convolved with SUIT's model PSF (spatial scale 0.7 arcsec/pixel)

SUIT – Science Goals

Coupling and Dynamics of the Solar Atmosphere:

What are the processes through which the energy is channelized and transferred from the photosphere to the chromosphere and to the transition region?

Solar Flare studies :

At what wavelength do flares radiate most of it’s energy, how does different phases of the flare appear in lower heights of solar atmosphere?

Prominence Studies:

What are the mechanisms responsible for stability, dynamics and eruption of solar prominences?

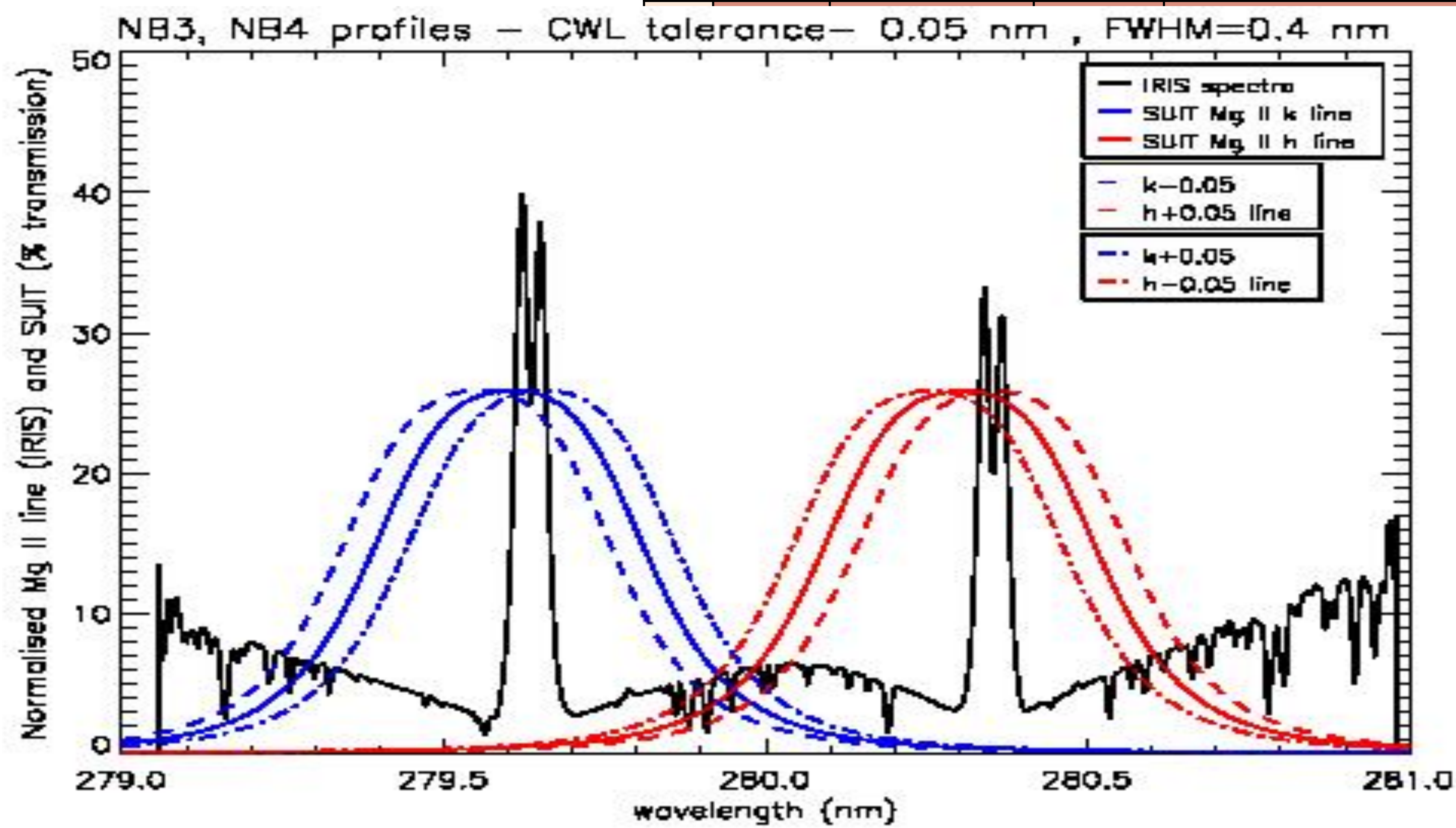
Sun-Climate studies:

How relevant is the variability of solar UV irradiance for the Earth's climate?

SUIT- IRIS Overlap

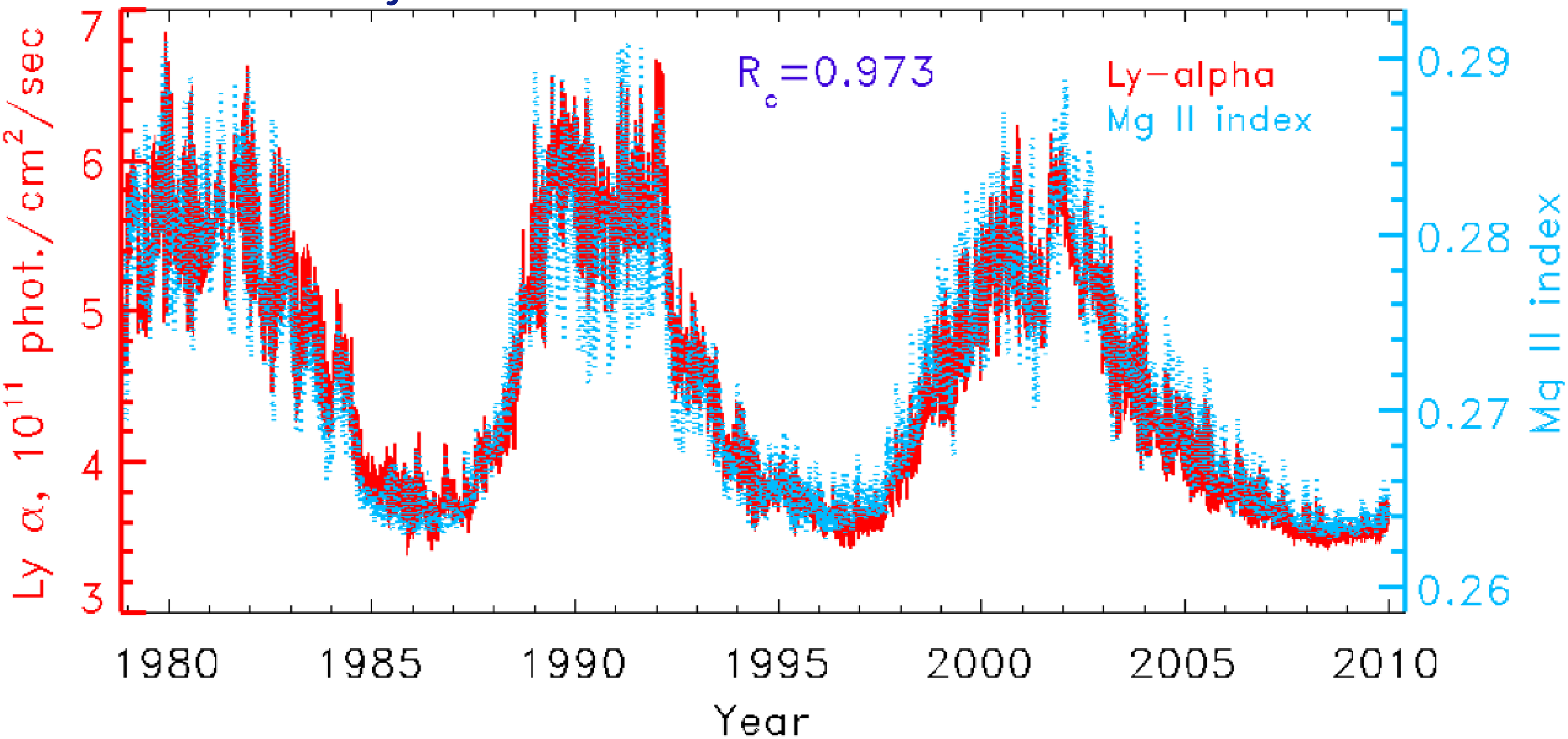
CWL tolerance = 0.05 nm
FWHM = 0.4 nm

No.	Name	(nm)	pass (nm)	Description
1	NB1	214	5	Photosphere
2	NB2	274.7	0.4	Wing of Mg II k
3	NB3	279.6	0.4	Mg II k
4	NB4	280.3	0.4	Mg II h



Mg II as a proxy for Ly-alpha

Plot courtesy Sami Solanki



SUIT, by measuring the Mg II index (Spatially Resolved), will allow to monitor Ly-alpha variability — the most strongly varying radiation from the Sun's surface

Coutesy : Durgesh Tripathi

X-ray Payloads on ADITYA-L1

* Solar Low Energy X-ray spectrometer (SoLEXS)

* Hard X-ray L1 Orbiting Spectrometer (HEL1OS)

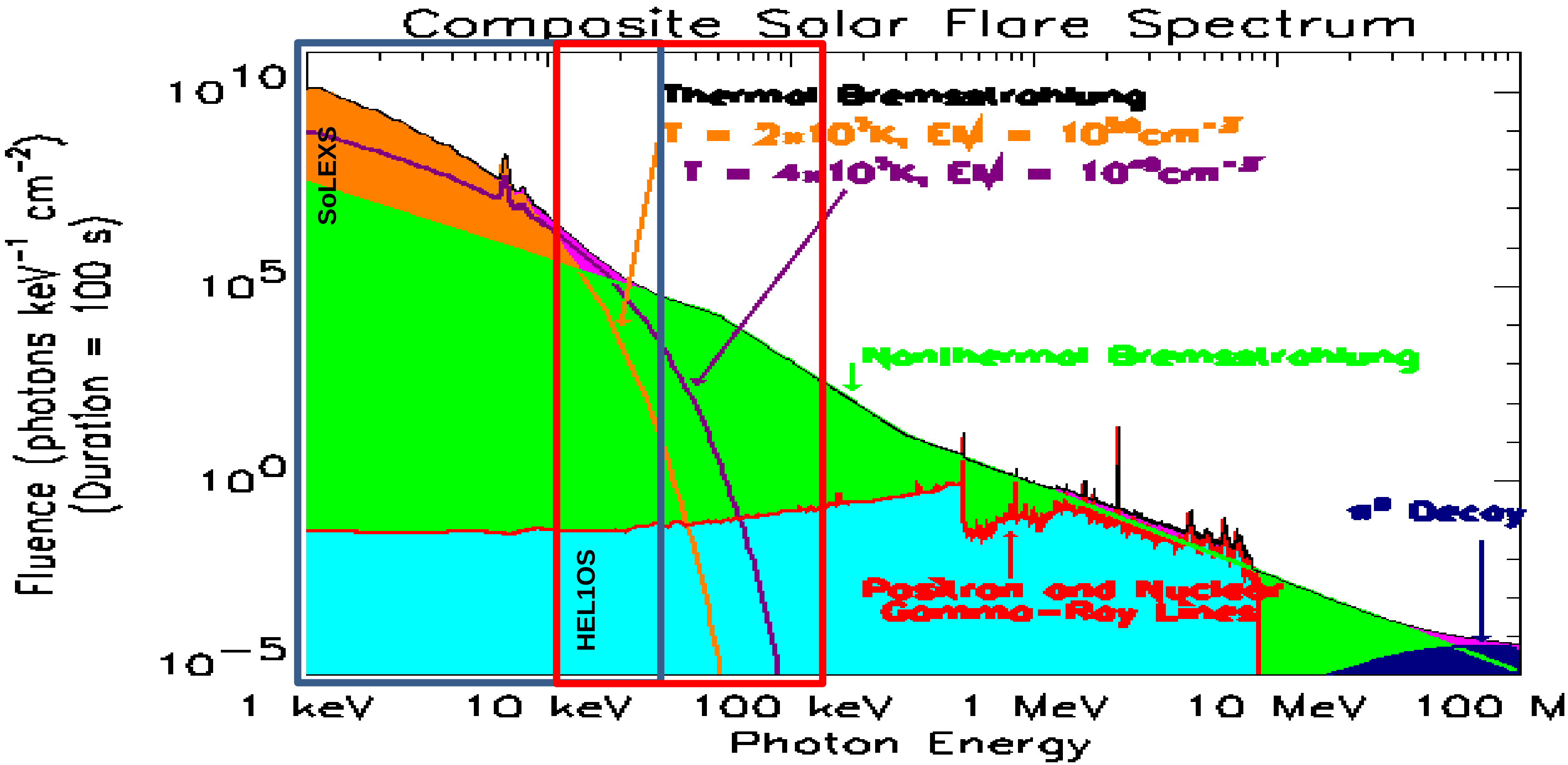


Image Courtesy: NASA Modified to include Energy Ranges of Aditya-L1

SoLEXS

- ❑Energy Range: 1 – 30 keV with > 5% efficiency
- ❑Energy Resolution: 250eV at 6keV
- ❑Flare coverage: A-class to X-class
- ❑Aperture Area used: 0.1mm^2 for > C-class; 30mm^2 for < C-class; Identical detector behind each aperture
- ❑Temporal Resolution ~ few seconds for C-class (large aperture) & X-class (small aperture)
- ❑FOV of the payload (< 4 deg. - limited by collimation)
- ❑Non-imaging (sun as a star)
- ❑Sun – pointing within about 0.5 deg

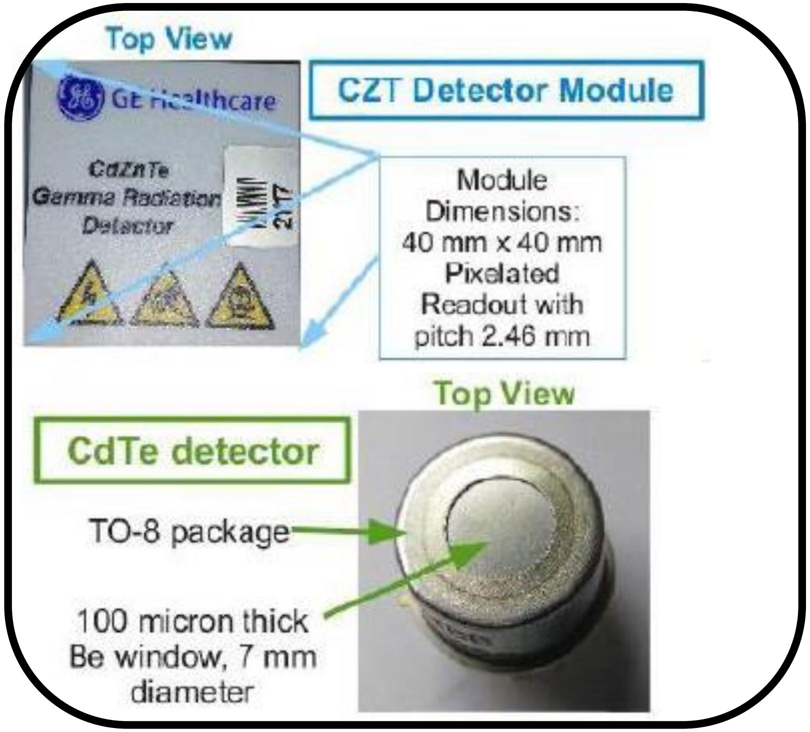
HEL1OS

FOV	6^0 x 6^0 (SS Collimator)
Energy Resolution & Range	≤ 1.2 keV @ 14 keV (- 35 ^{0}C) in **CdTe (10 – 40 keV)** ~ 6 keV @ 60 keV (+ 10 ^{0}C) in **CZT (20 – 150 keV)**

Operational Mode(s):

- **Event Mode – continuously ON at L1 phase**

Detectors:

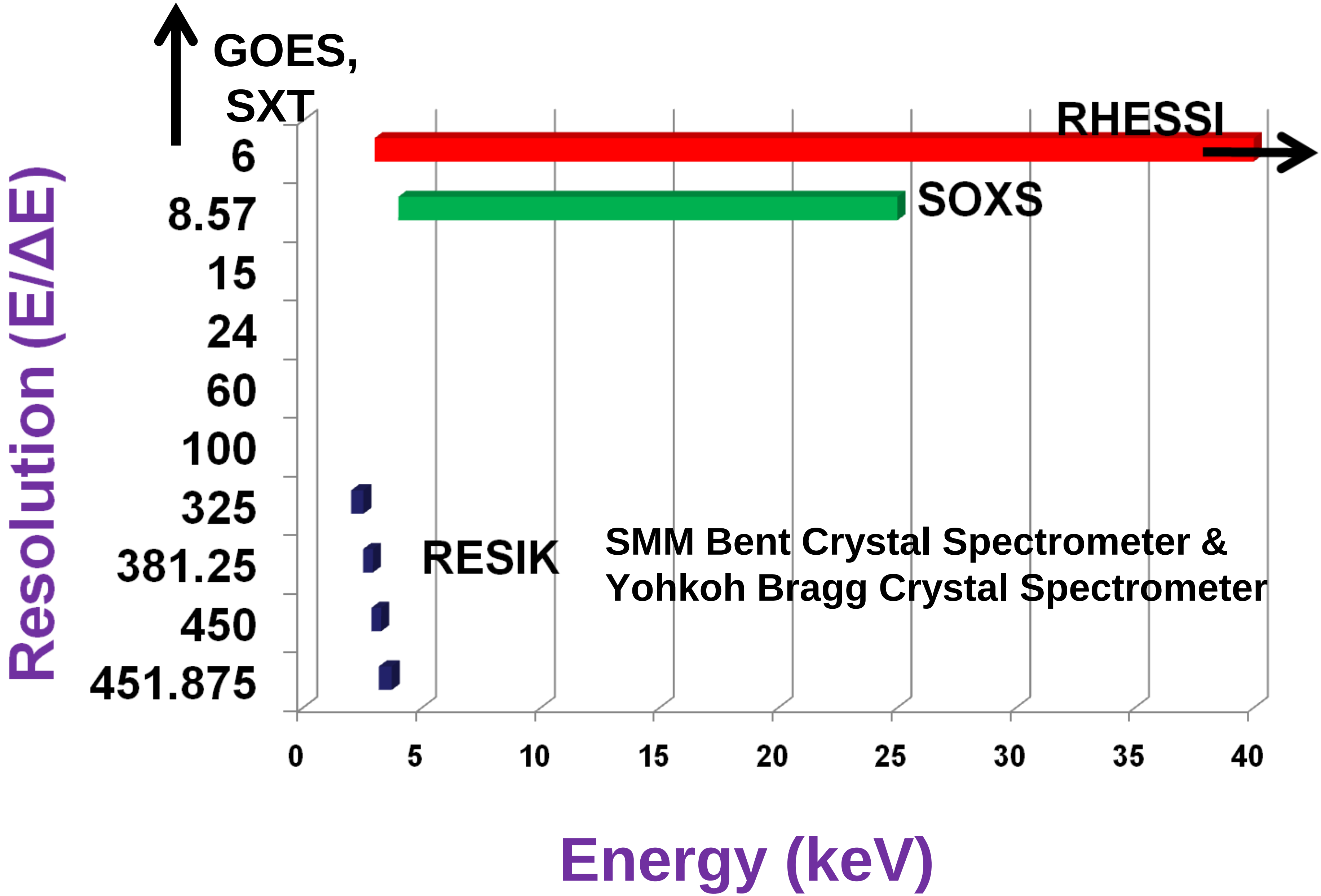


X-ray payloads – Major Science Goals.

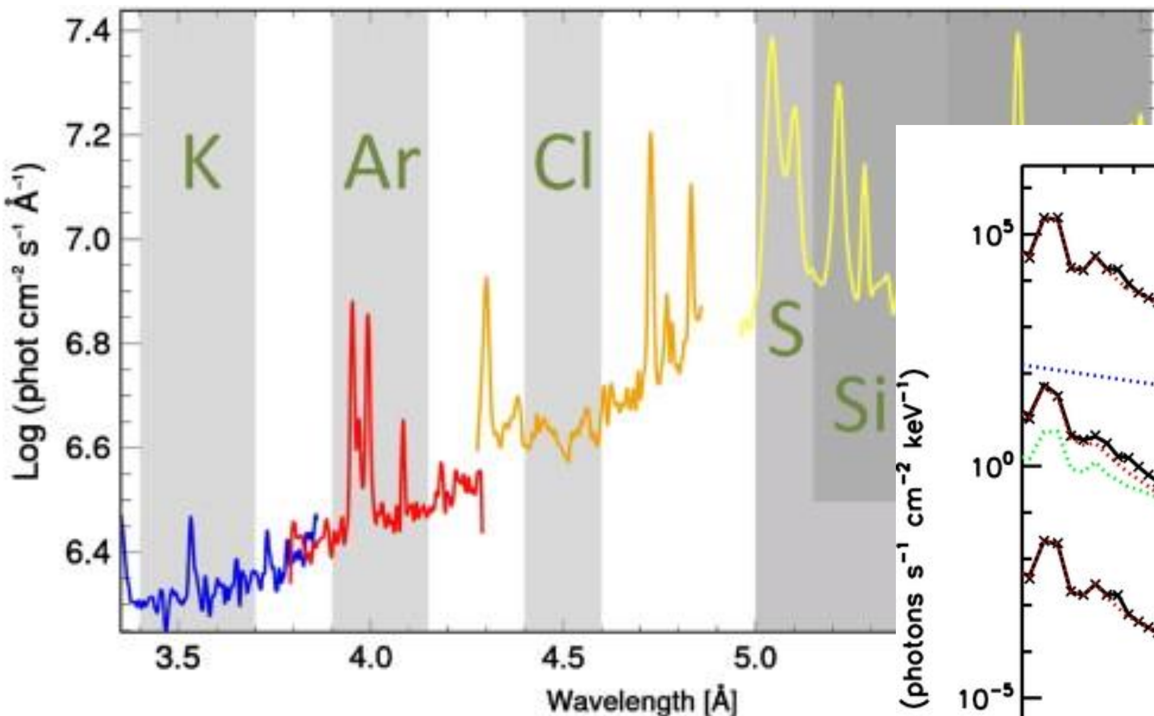
- Flare & Abundance Studies
  - Heating Mechanism
  - Coronal Abundance & FIP Effect
  - Pre-flare activities
  - Particle acceleration during Impulsive phase

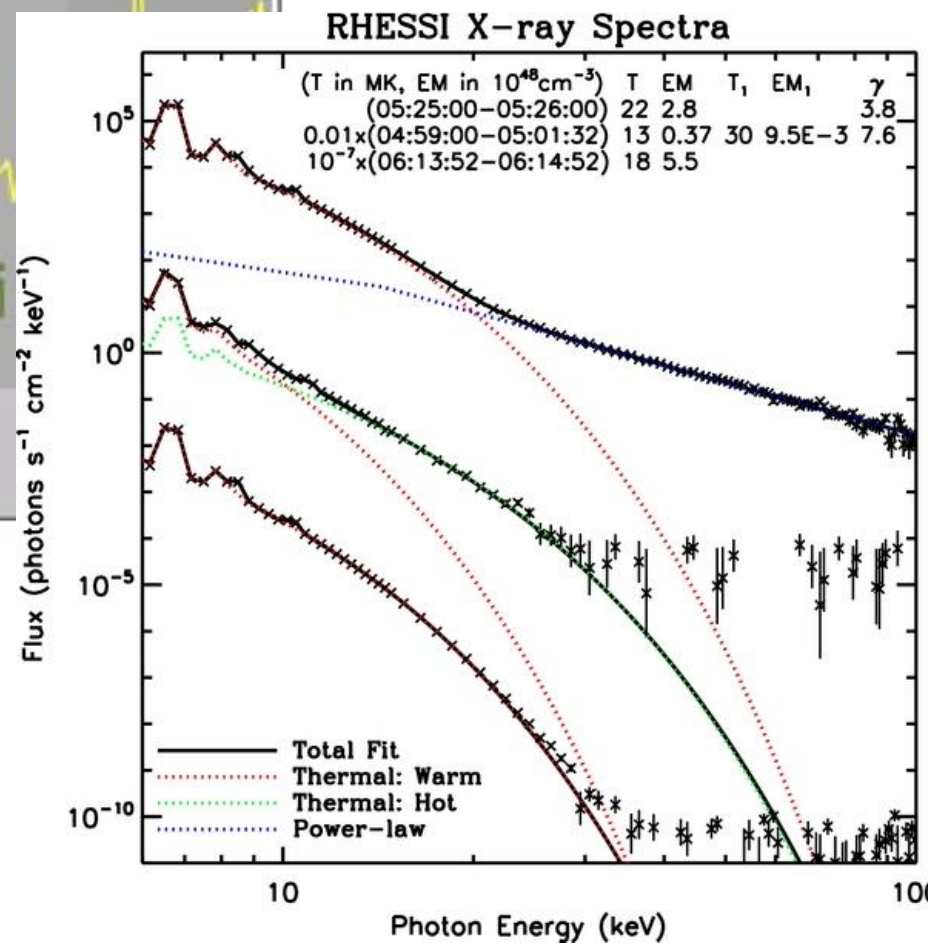
- Coronal Studies with other payloads
  - Flare - CME Association
  - Flare – Prominence Eruption

Solar X-ray Spectrometers

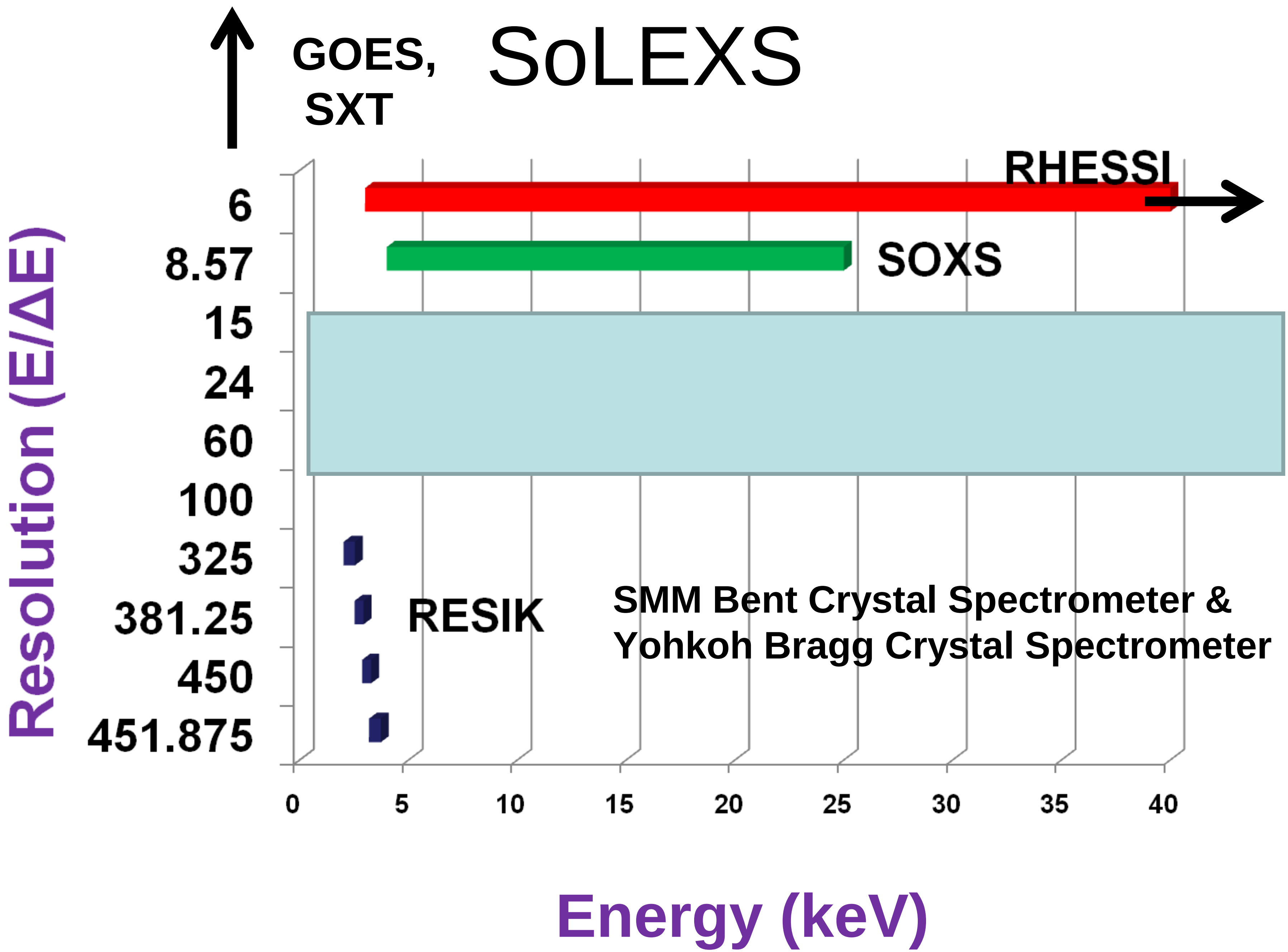


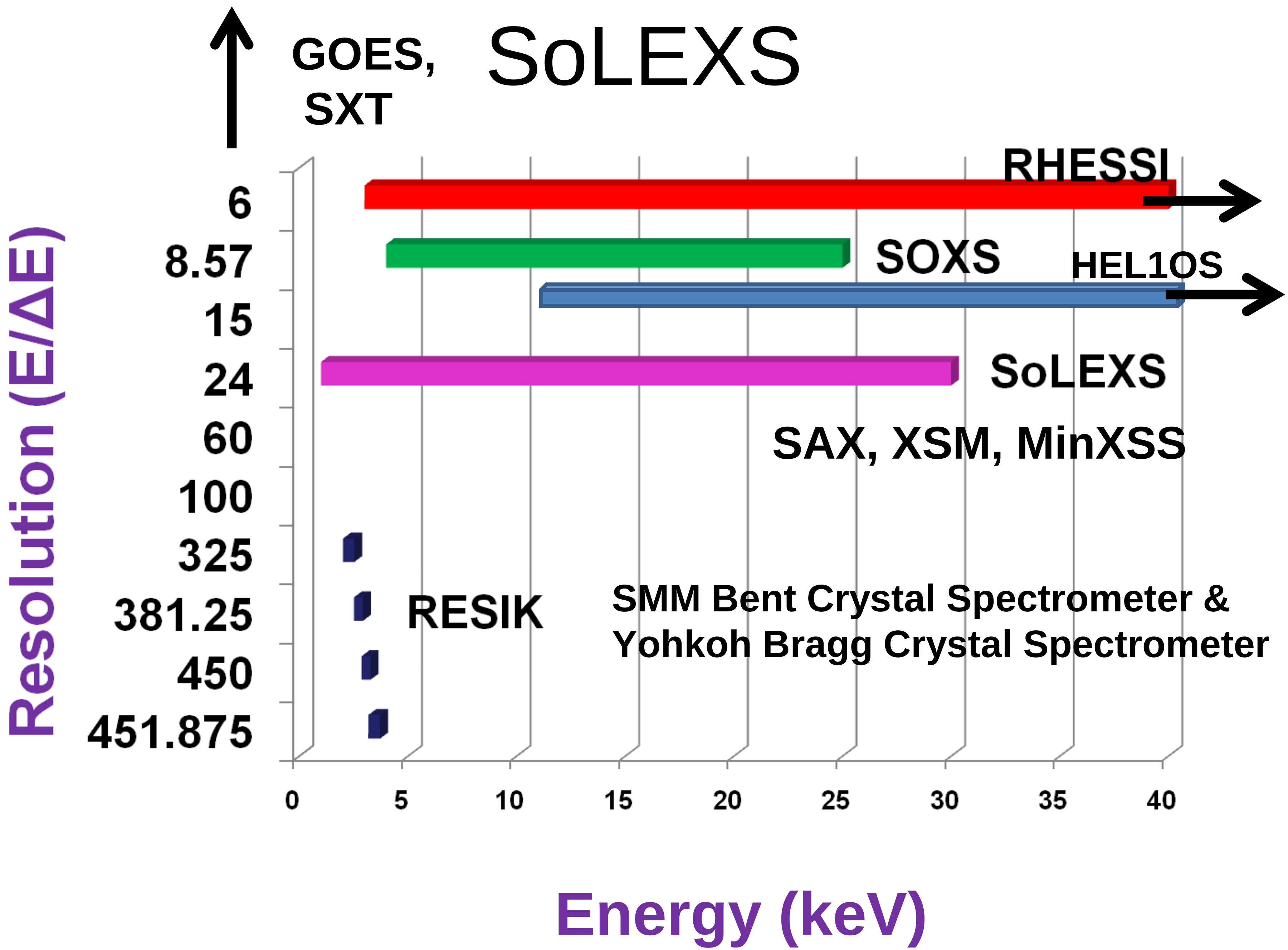
RESIK vs RHESSI





Liu et al., 2013


SoLEXS
GOES, SXT
RHESSI
SOXS
RESIK
SMM Bent Crystal Spectrometer &
Yohkoh Bragg Crystal Spectrometer
Resolution (E/ΔE)
6
8.57
15
24
60
100
325
381.25
450
451.875
0
5
10
15
20
25
30
35
40
Energy (keV)



GOES,
SXT
SoLEXS
RHESSI
SOXS
HEL1OS
SoLEXS
SAX, XSM, MinXSS
RESIK
SMM Bent Crystal Spectrometer &
Yohkoh Bragg Crystal Spectrometer
Resolution (E/ΔE)
6
8.57
15
24
60
100
325
381.25
450
451.875
0
5
10
15
20
25
30
35
40
Energy (keV)

Synergetic Science with other instruments on ADITYA-L1

VELC (Visible Emission Line Coronagraph)	SUIT (Solar Ultra-violet Imaging Telescope)	SoLEXS (Solar Low Energy X-ray Spectrometer)	HEL1OS (High Energy L1 Orbiting X-ray Spectrometer)
Diagnostics of corona and coronal structure – quantitative measurements of temperature, density and velocity.	Coupling and dynamics of Solar Atmosphere.	Flare plasma diagnostic studies (density, temperature etc) for all flare classes from A to X.	Particle acceleration physics during the impulsive phase of solar flare from C to X.
Origin and dynamics of CME.	Prominence studies.	Variation of coronal abundance with flare evolution.	Evolution of the parameters of the accelerated electron energy distribution.
CME Drivers	Initiation of CME and Space Weather.	Flare precursor activity.	Flare precursor study.
Measurement of Coronal Magnetic Fields	Sun-Climate Studies.	Relationship between flare and CME.	Relationship between flare and CME.

Global Energetics (pink)

CME-Flare Relation (green)

Courtesy : Manju Sudhakar

In-Situ Instruments

* Aditya Solar Particle Experiment (ASPEX)

* Plasma Analyser Package for Aditya (PAPA)

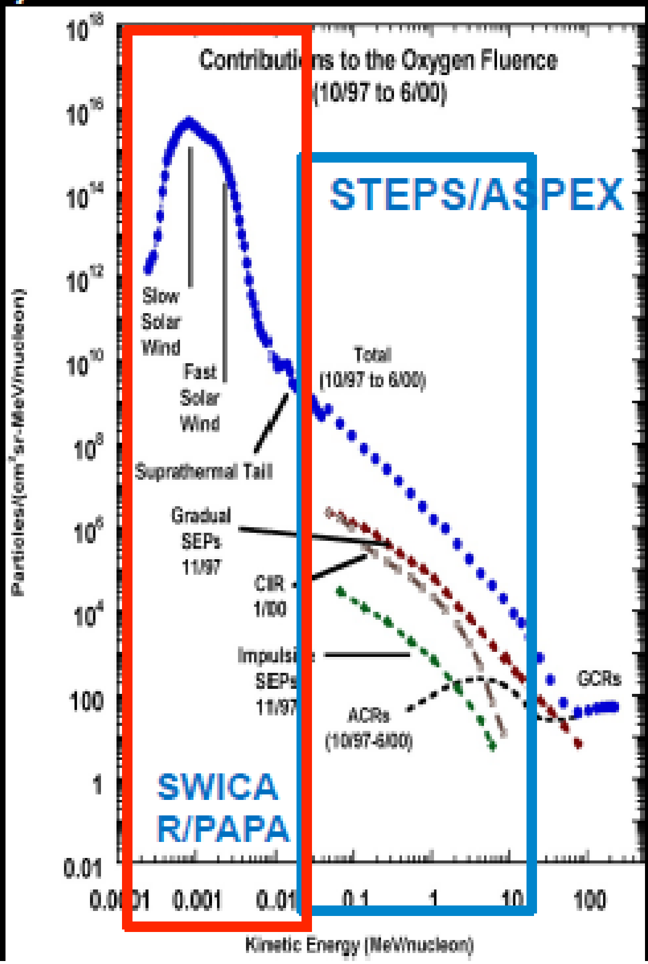


Image Courtesy: California Institute of Technology

Magnetometer (Mag)

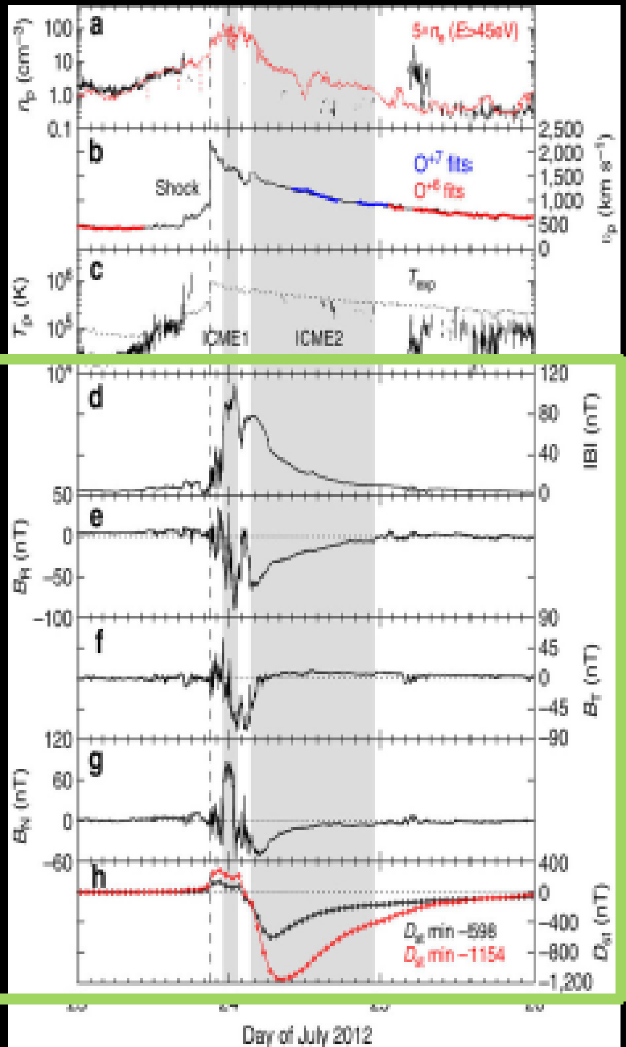
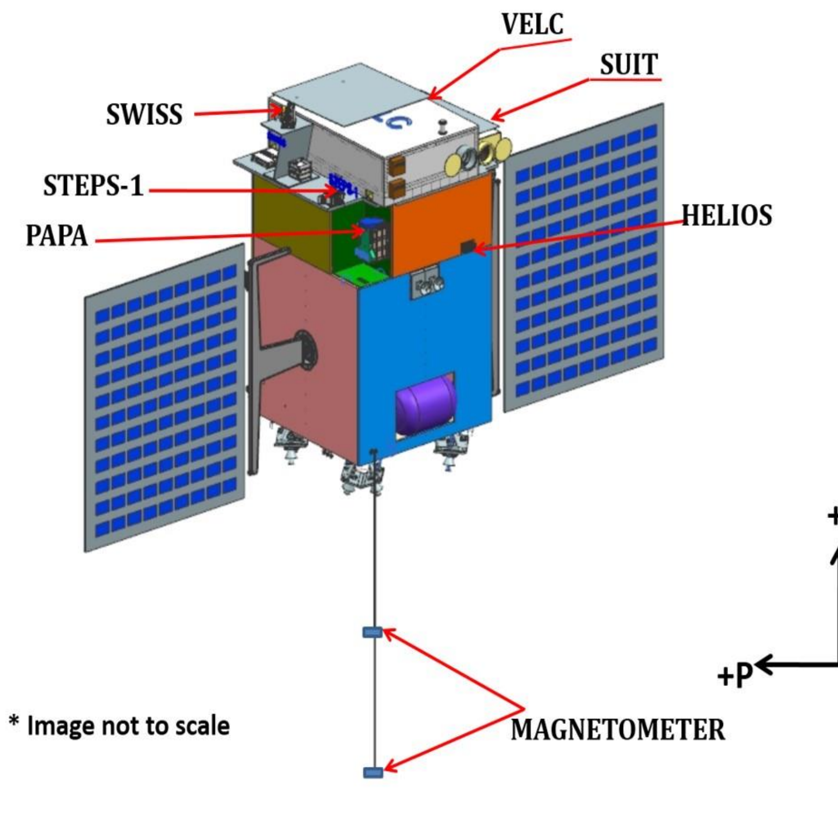


Image Courtesy: Nature Communications

Slide Courtesy : Sankarasubramanian

Summary

- ADITYA-L1, solar observatory with four remote-sensing payloads and 3 in-situ instruments, to reach L1 next year.
- Will be complementing other Solar observatories on space as well as on ground.



Deployed view

Thanks.