

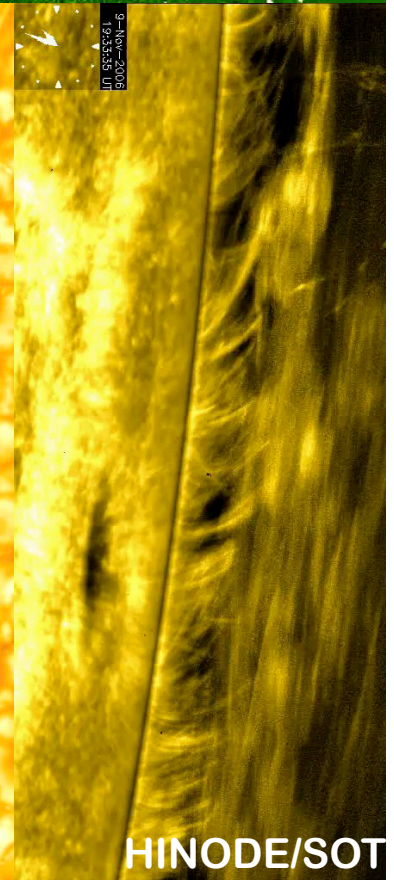
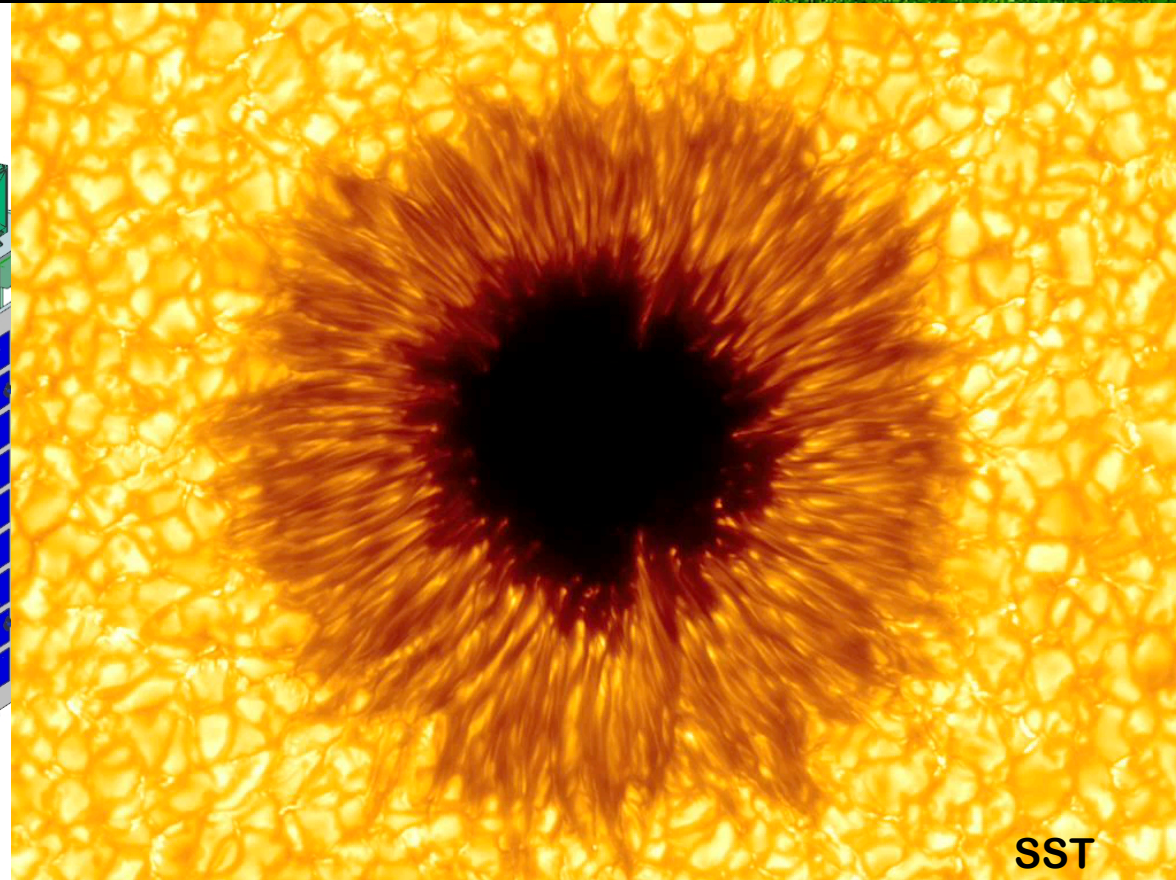
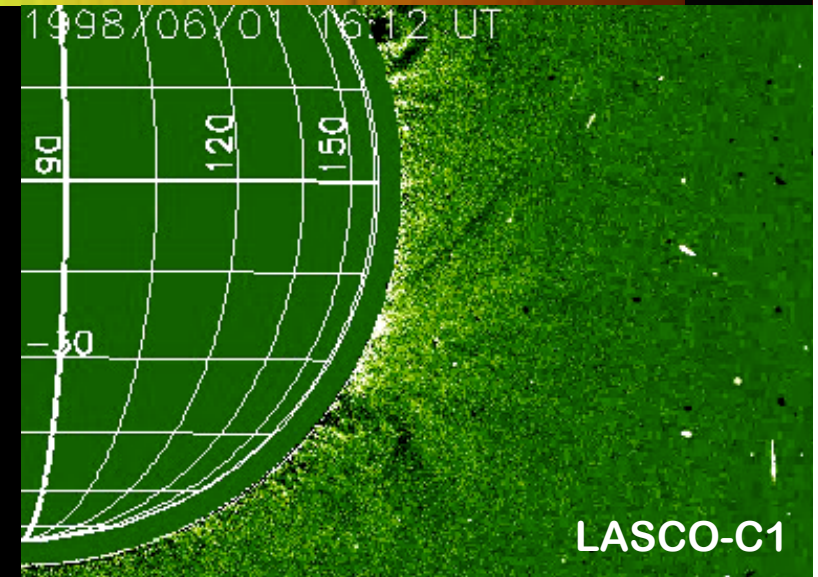
CUME 450: Introduction

- * CUME 450 is based on colloquia given by Prof. Durgesh Tripathi on Aditya-L1 Mission. However, the contents of the Cume 450, are based on basic knowledge of solar physics with some emphasis given to spectroscopy and astronomy instrumentation.
- * There are 22 slides to guide you, and you get 30 mins to go through the slides, so ~ 1 min per slide.
 - * Pay more attention to slides with graphs.
- * Additional background materials such as graphs and diagrams, are provided within the question. Take a few minutes to understand those figures, before answering the related questions.



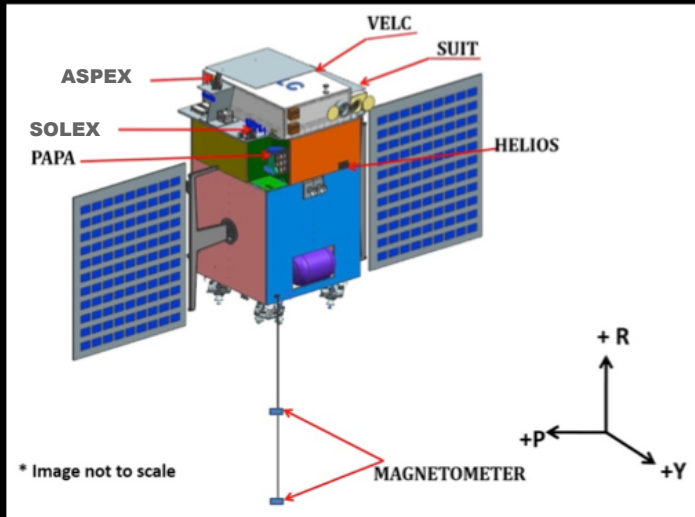
Aditya-L1 Mission

Durgesh Tripathi
with Aditya-L1 Team



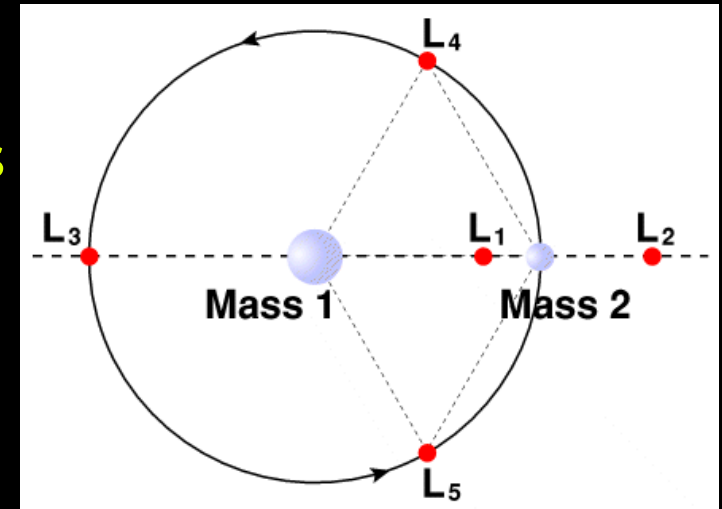


Aditya-L1 in a nutshell



Earth to L1 $\rightarrow$ 1.5 Mkms

Aditya-L1 will be launched in early 2022



- ★ Coupling and Dynamics of the Solar Atmosphere
 - ★ Space weather – better prediction
 - ★ CMEs, Flares
- ★ Heating of the upper atmosphere
- ★ Spatially resolved solar spectral irradiance
- ★ Solar Wind particle distribution and composition



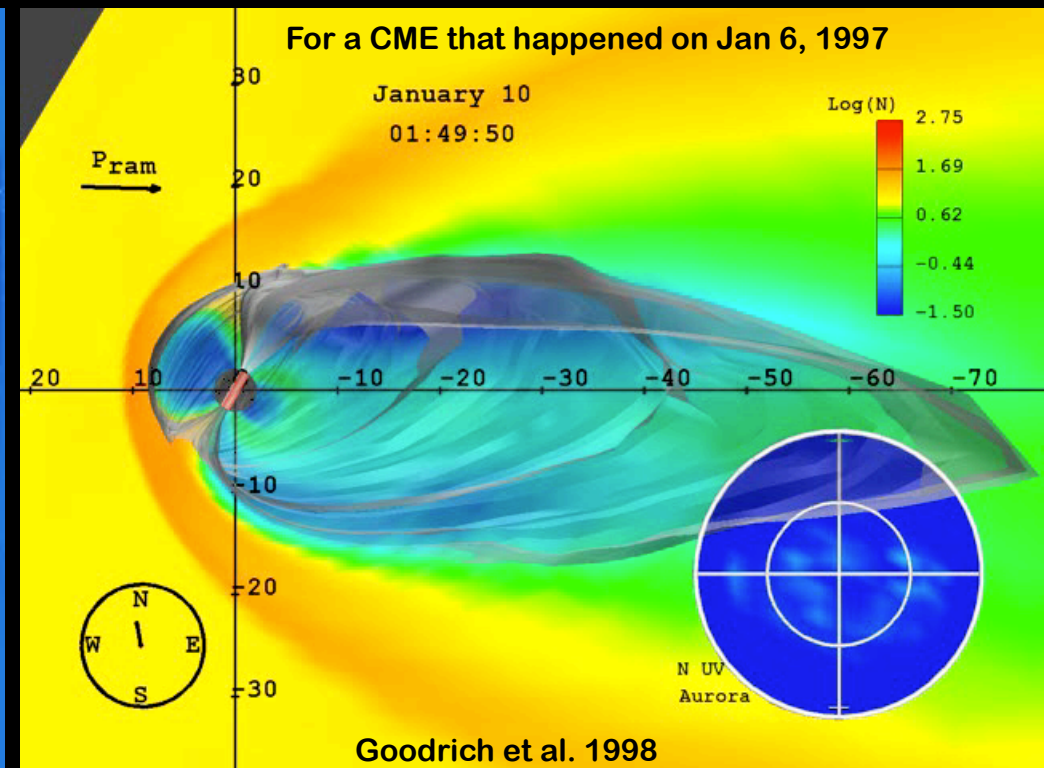
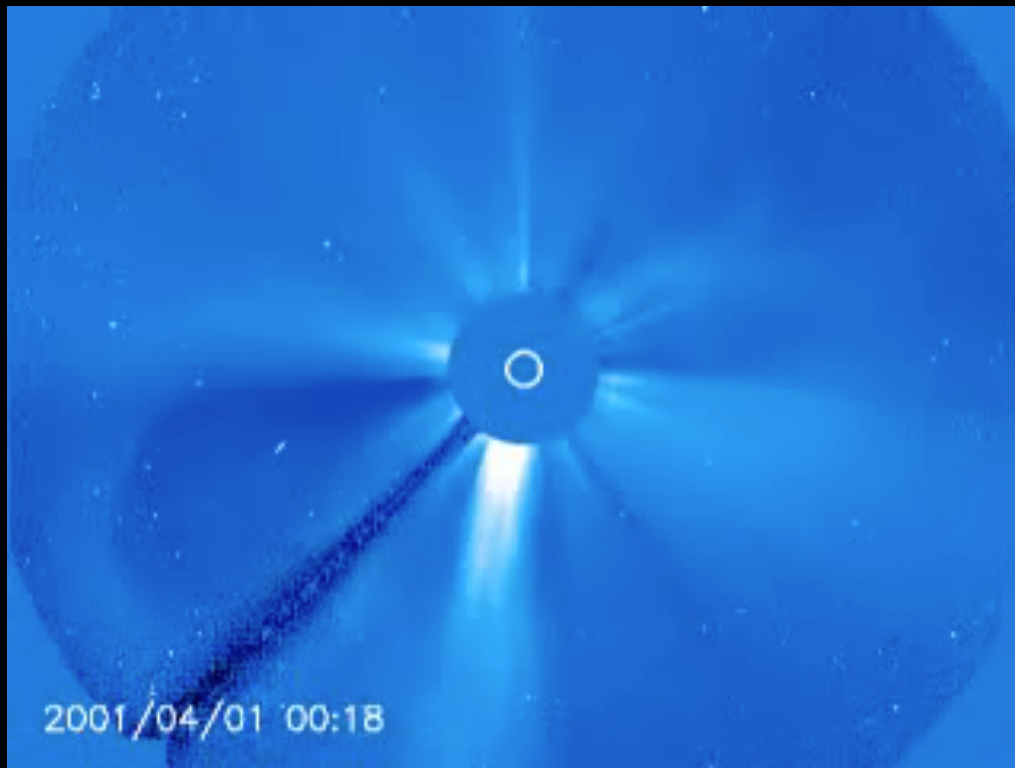
Space Weather



- * Environmental conditions in the Earth's atmosphere [magnetosphere, ionosphere and thermosphere] due to the Sun and Solar Wind that can influence the functioning and reliability of space borne and ground based system and services or endanger property or human health (Ref: ESA).

Short Term → CMEs with Bz
Radiation from Flares

Long Term → Solar Radiation
variation over cycle
→ Climate pattern

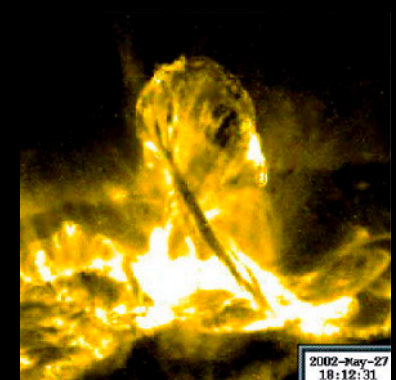
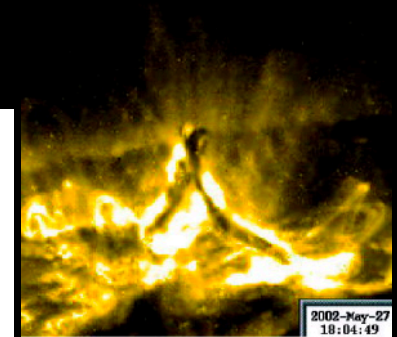
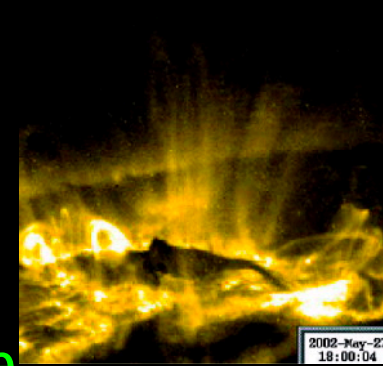




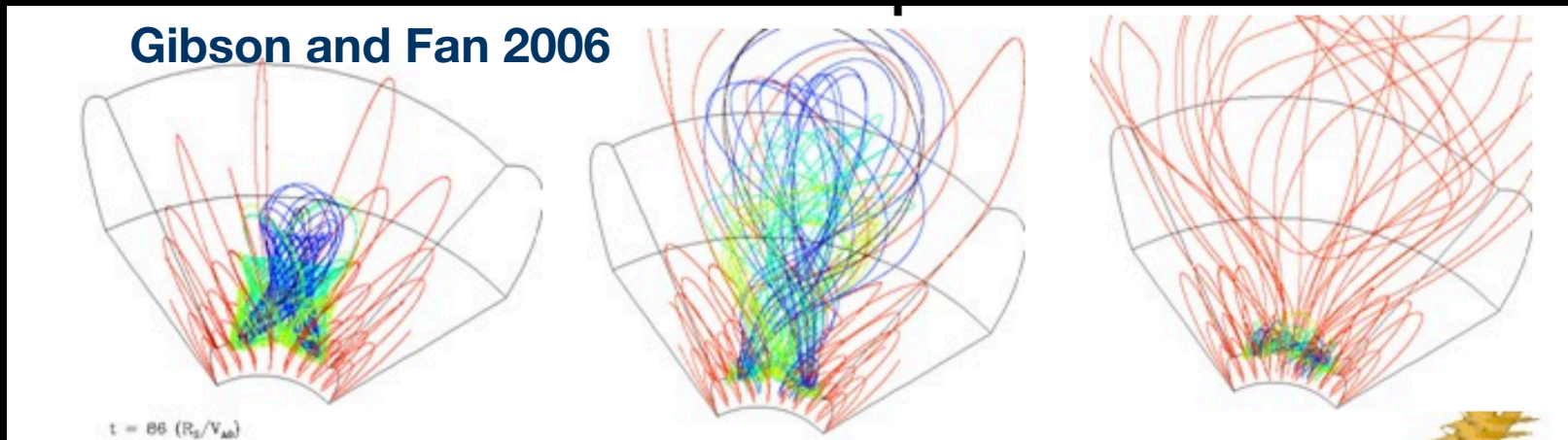
Coronal Mass Ejections



- For CMEs to be geo-effective:
 - Bz component – where? – at 1AU
 - does it change during propagation?
 - Gosling, Schwenn, Bothmer ...
 - Can we measure field topology at the launch of CMEs?



Toeroek and Kliem 2005



Partial eruptions – lead to homologous eruptions
(Tripathi et al. 2009)

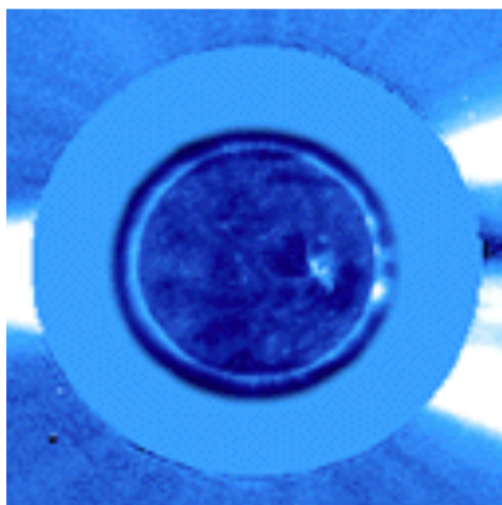
- In-situ measurements for composition – for the arrival of CMEs
- In-situ measurement of B-field



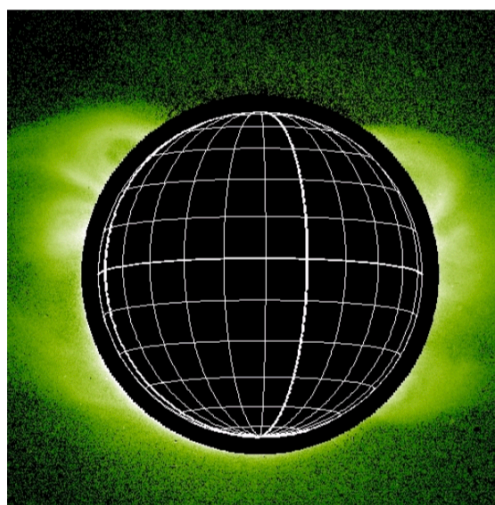
Coronal Mass Ejections



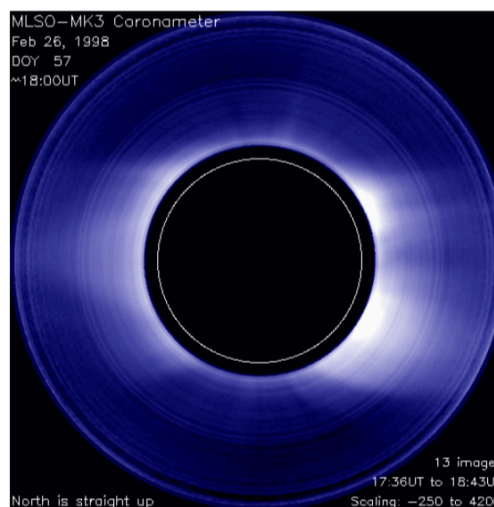
- Predicting the arrival time: good handle on the kinematics
- Lower coronal dynamics plays an important role, which remains un-probed
- More than 90% acceleration in CMEs occurs below $2R_s$ [Bein et al. 2011]



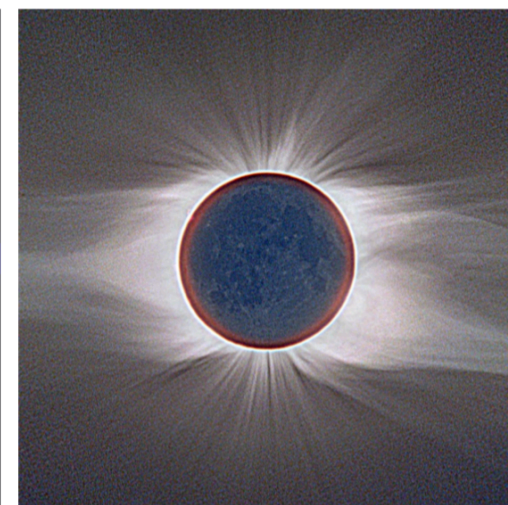
SoHO/LASCO-C2
 $R > 2.5 R_s$



SoHO/LASCO-C1
1.1 to 3 R_s
Operated for 2 years
at solar min

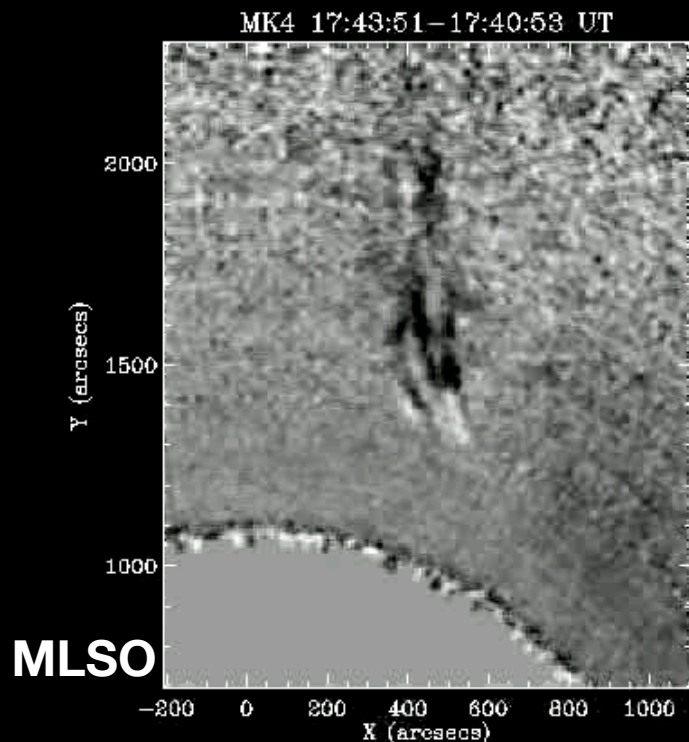
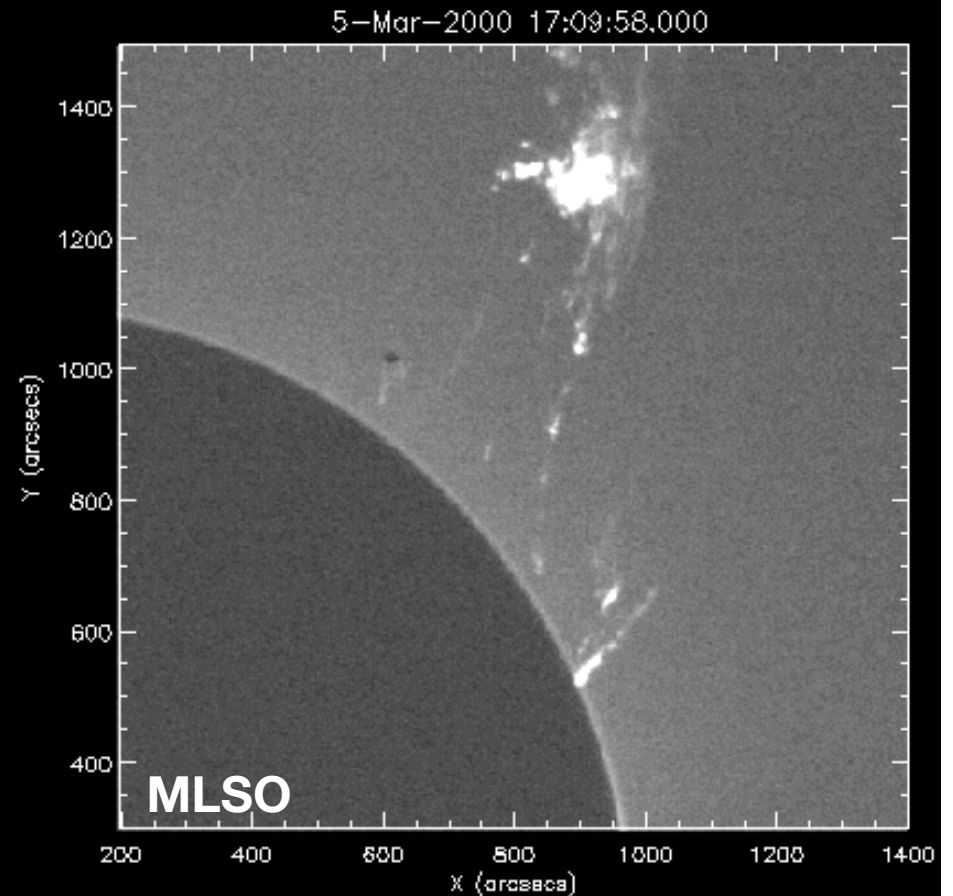
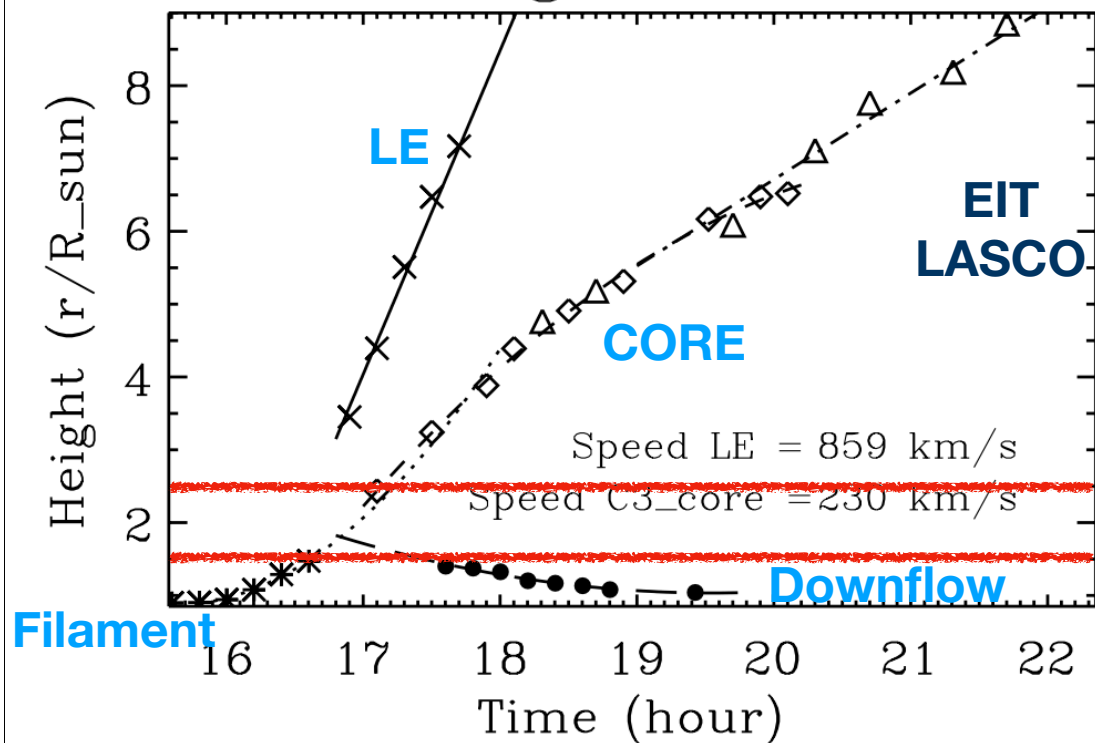


HAO/MLSO
Ground based
coronagraph



Eclipse
Limited
Observations

Height–Time

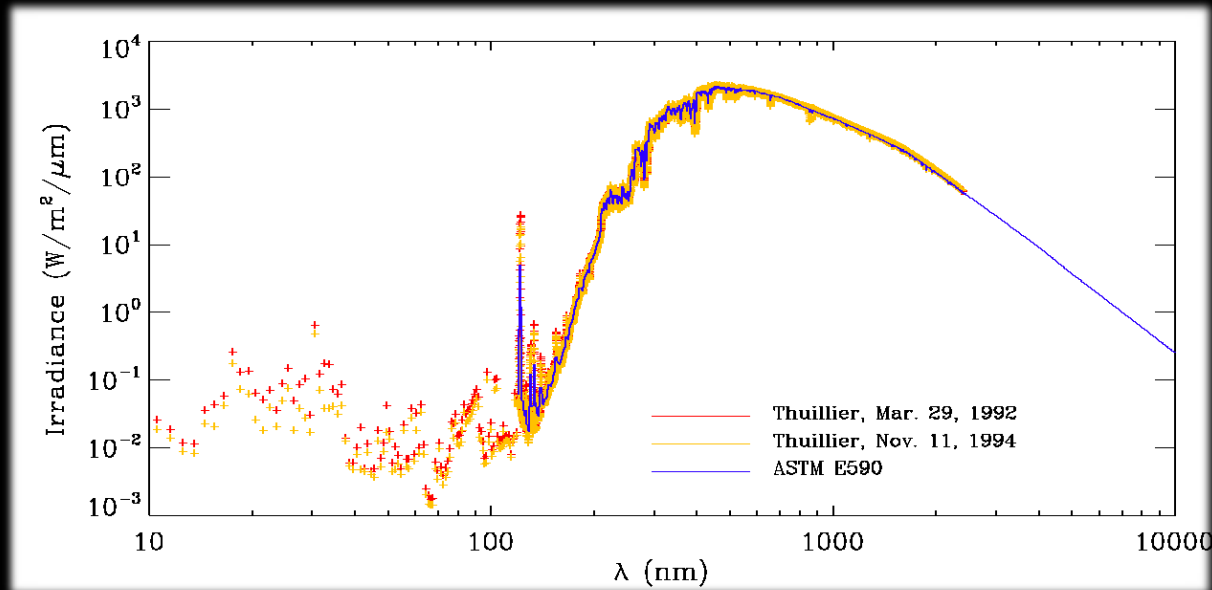


Magnetic reconnection within the flux rope was the probable cause that led to the bifurcation.

Note that this happens right at the height where we do not have continuous observation.



Solar Radiation Spectrum



The spectral irradiance changes by almost a million while the wavelength changes by 1000!

- The X-ray and UV irradiance is absorbed by the Earth's atmosphere
- Changes in the X-ray and EUV irradiance affect the thermosphere, ionosphere, and near-Earth space.



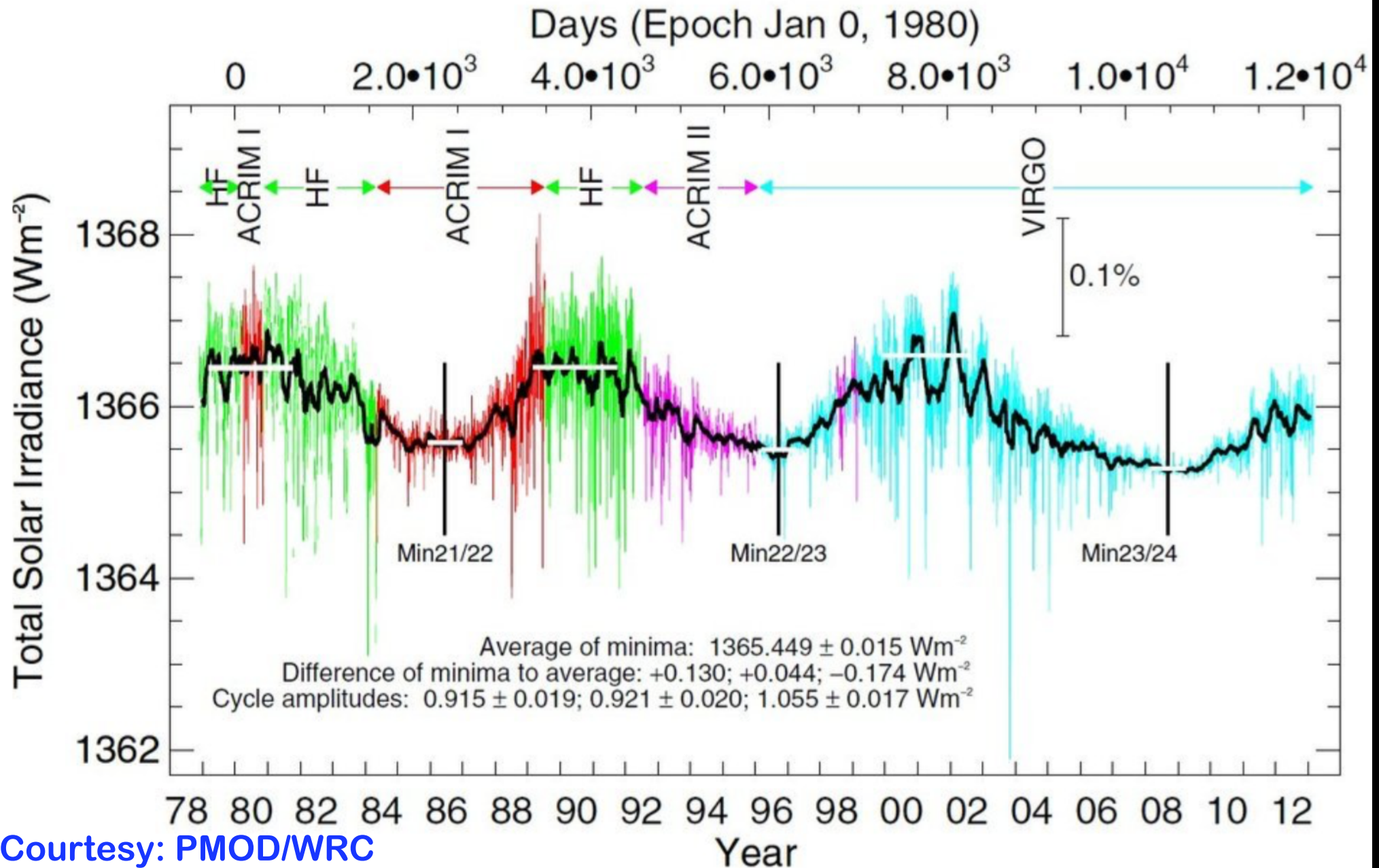
Solar Irradiance Variation – long term



- Total solar irradiance varies slowly on decadal and longer time scales
- The variation during recent solar magnetic cycles has been about 0.1%
- Most reconstructions of total solar irradiance point to an only small increase of about 0.05% to 0.1% between Maunder minimum and present



Total Solar Irradiance (TSI) over solar cycle



Courtesy: PMOD/WRC



Solar Irradiance Variation



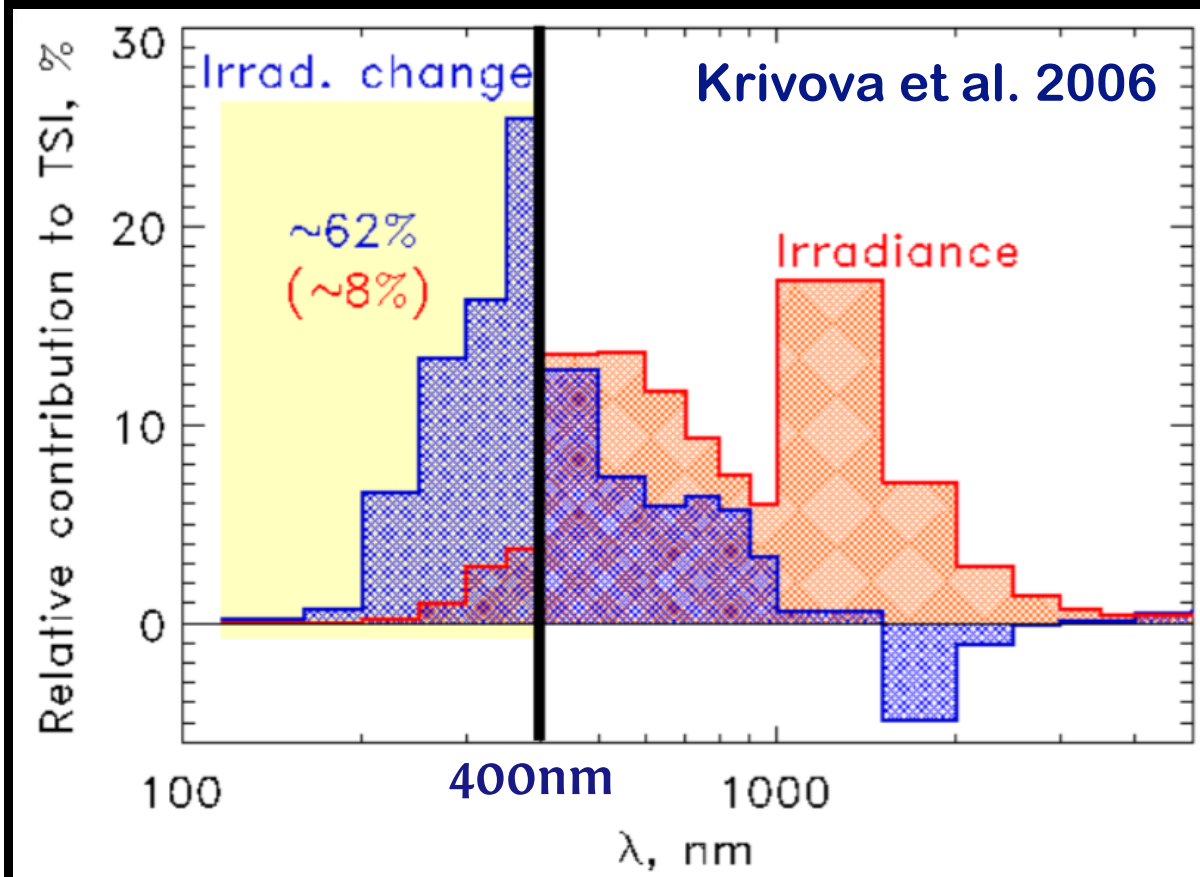
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BUT

- Solar irradiance variation show a strong wavelength dependence
- On the whole, up to 60% of the total irradiance variations are produced at wavelength below 400nm



Relative Contribution to TSI

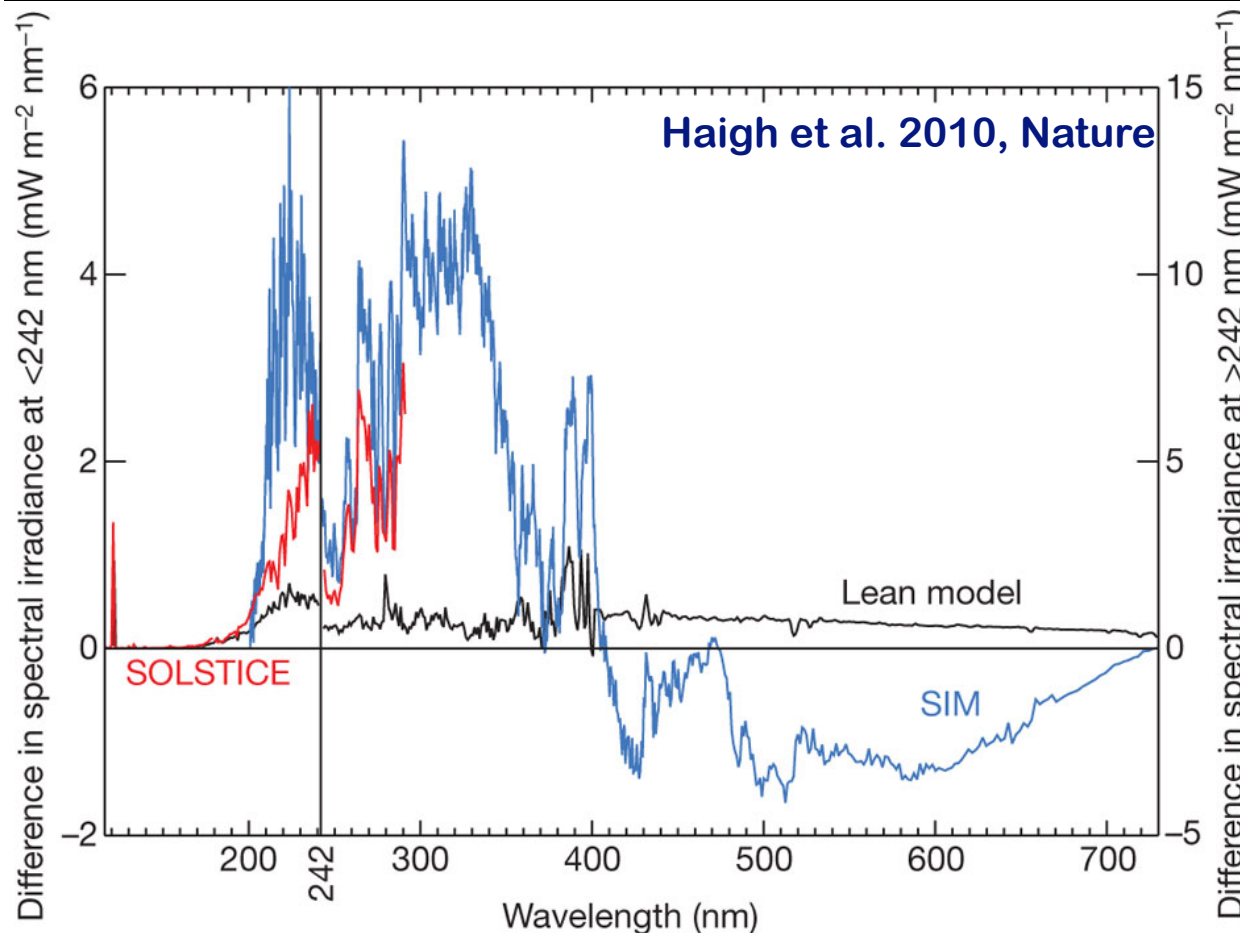


The relative contribution of different wavelength ranges to the total solar irradiance (red histogram) and its solar cycle variations (blue histograms)

Different bin sizes in the histogram: 40 nm below 200 nm, 50 nm between 200 and 400 nm, 100 nm between 400 and 1000 nm and 500 nm at yet longer wavelengths.



Solar Spectral Irradiance



- Solar Max occurred between 2000-2004
- Difference between 2004-2007 solar spectral irradiance
- A decline in UV form 2004-2007 that is a factor of 4-6 larger than predicted by models.

Clearly, we don't understand some crucial physics.

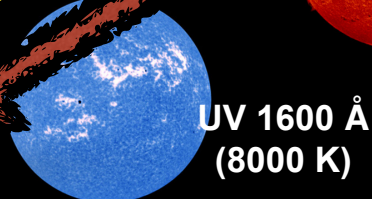
- All measurements are done using Sun-as-a-star!
- Proxies in the modelling not complete!



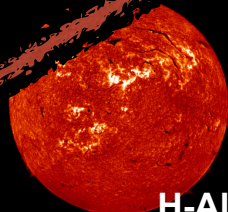
Solar Atmospheric Observations



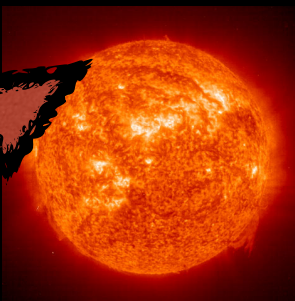
Not so well studied



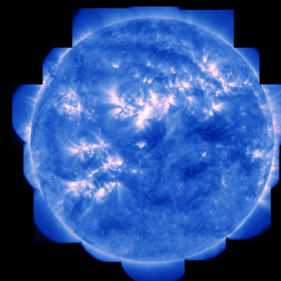
UV 1600 Å
(8000 K)



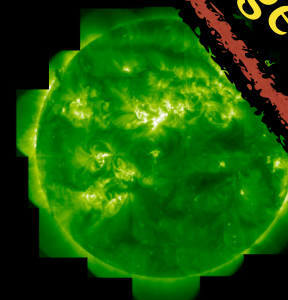
H-Alpha
(15000 K)



He II 304 Å
EUV (50000 K)

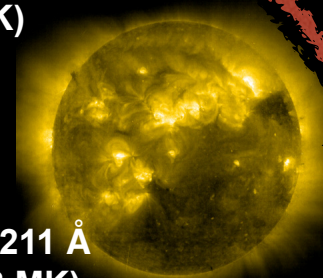


Fe IX/Fe X 171 Å
EUV (1 MK)

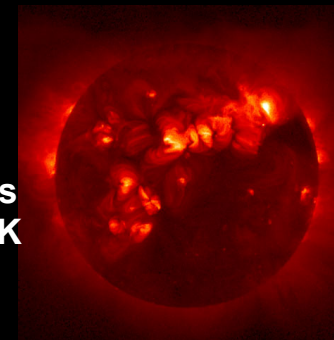


Fe XII 193 Å
EUV (2 MK)

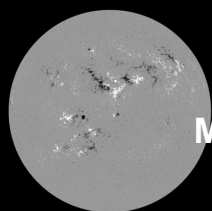
Huge emphasis is given



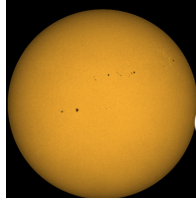
Fe XIV 211 Å
EUV (3 MK)



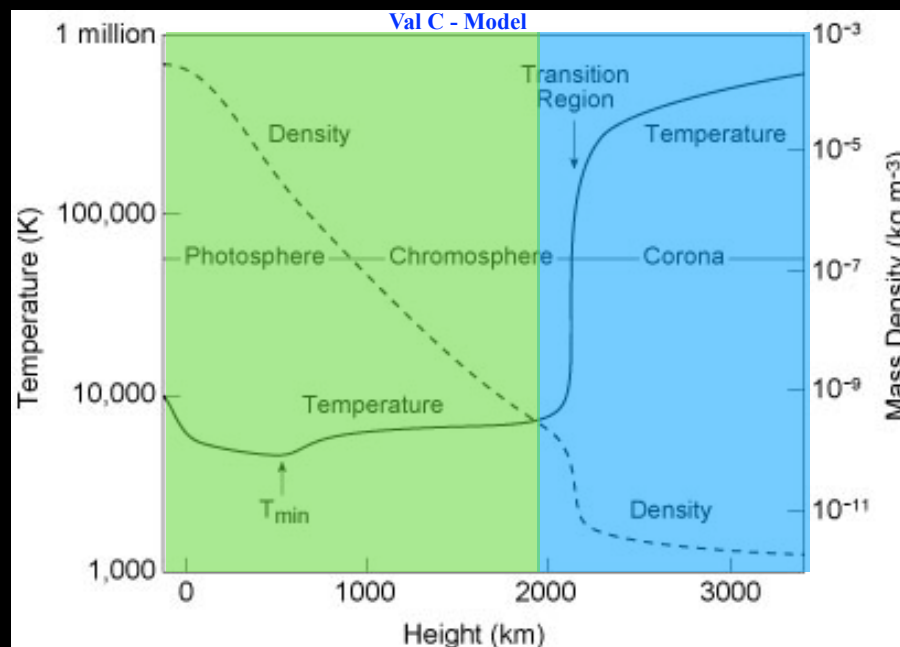
X-rays
4-6 MK



Magnetic Field
(5000 K)



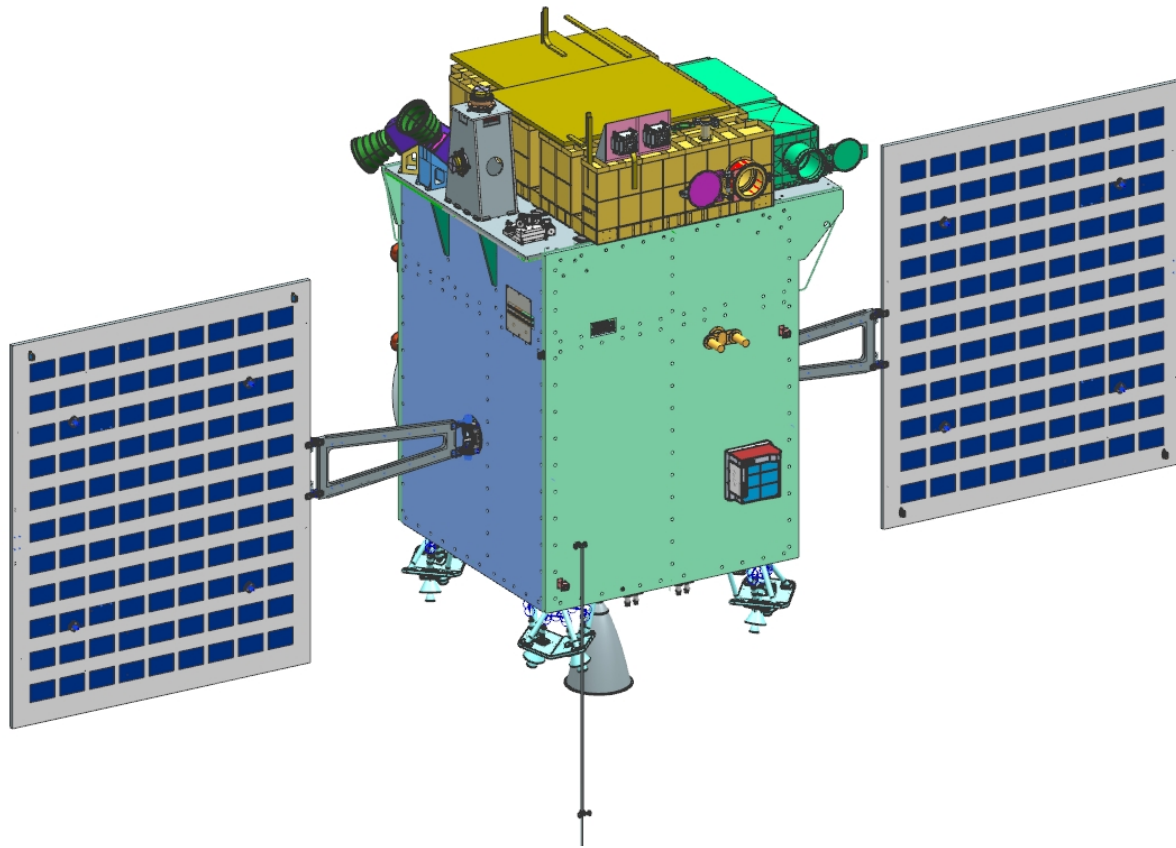
Visible
(5000 K)



Slide courtesy:
Robertus Erdelyi

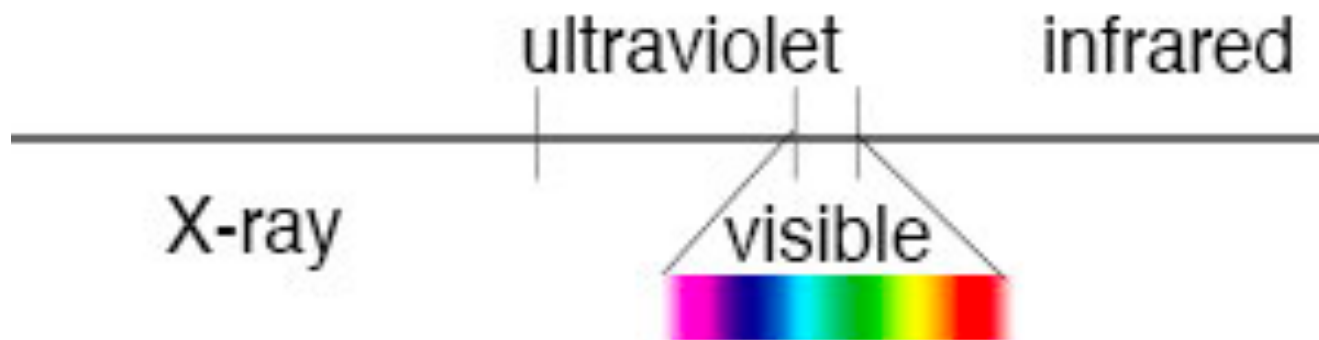
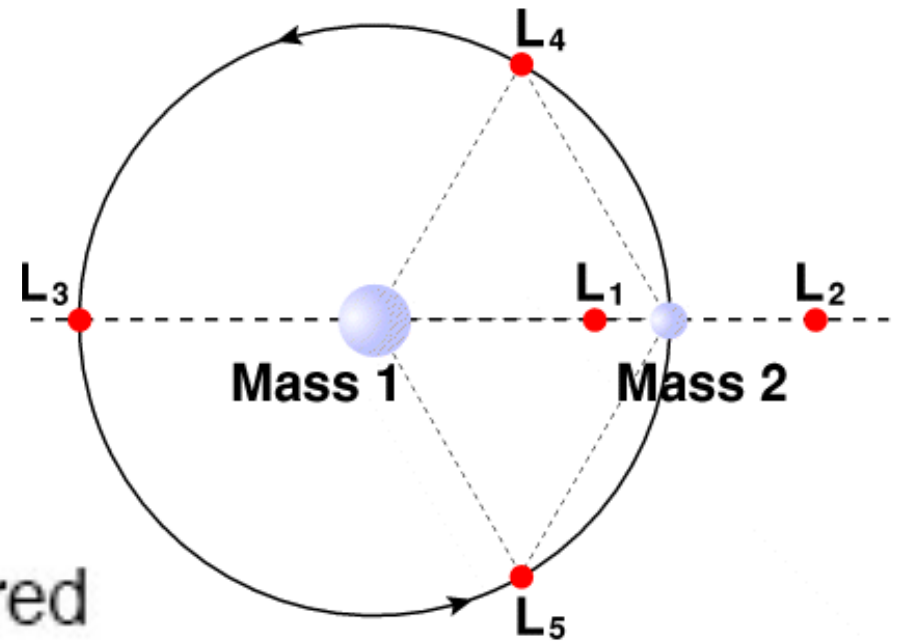
Images courtesy SDO/AIA, XRT/Hinode
and Kanzelhoehe

Aditya-L1 mission of ISRO



Aditya-L1 with 7 payloads onboard is scheduled to be launched in 2022.

Earth to L1 – 1.5×10^6 km





- Diagnostics of the large and small scale structure in the solar corona
- Magnetic topology and field measurement in the solar corona
- Origin and dynamics of solar flares and CMEs
- Spatially resolved Solar Spectral Irradiance
- Formation and Dynamics of solar prominences
- Coronal Abundances and FIP effects
- Solar Wind Composition & ICMs



The payloads on Aditya-L1



For the Cume 450, we are focussing on SUIT

Remote Sensing

- ❖ Visible Emission Line Coronagraph (VELC)
 - ❖ Lead: IIA, Bangalore
- ❖ Solar Ultraviolet Imaging Telescope (SUIT)
 - ❖ Lead: IUCAA, Pune
- ❖ Solar Low Energy X-ray spectrometer (SoLEXS)
 - ❖ Lead: ISAC, ISRO
- ❖ High Energy L1 Orbiting Spectrometer (HEL1OS)
 - ❖ Lead: ISAC, ISRO

In-situ Measurements

- ❖ Advance Solar-wind Particle Experiment (ASPEX)
 - ❖ Lead: PRL, Ahmedabad
- ❖ Plasma Analyser Package for Aditya-L1 (PAPA)
 - ❖ Lead: VSSC, ISRO
- ❖ Magnetometer
 - ❖ Lead: LEOS, ISRO



Solar Ultraviolet Imaging Telescope



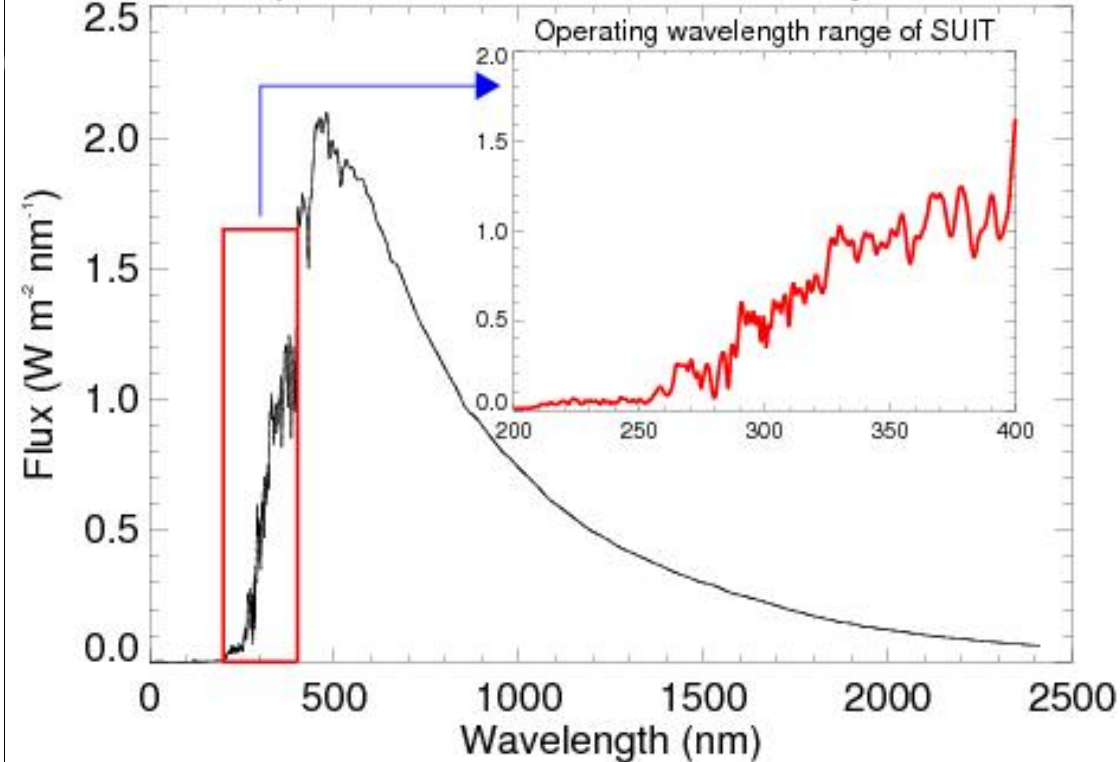
- Combined medium and narrow-band filter imager between 200-400 nm, with low stray light and high contrast to measure and monitor brightness contrast of the solar magnetic features.

Why is this important?

- Provides 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.
- Has not been done from space before – except Sunrise I and Sunrise II

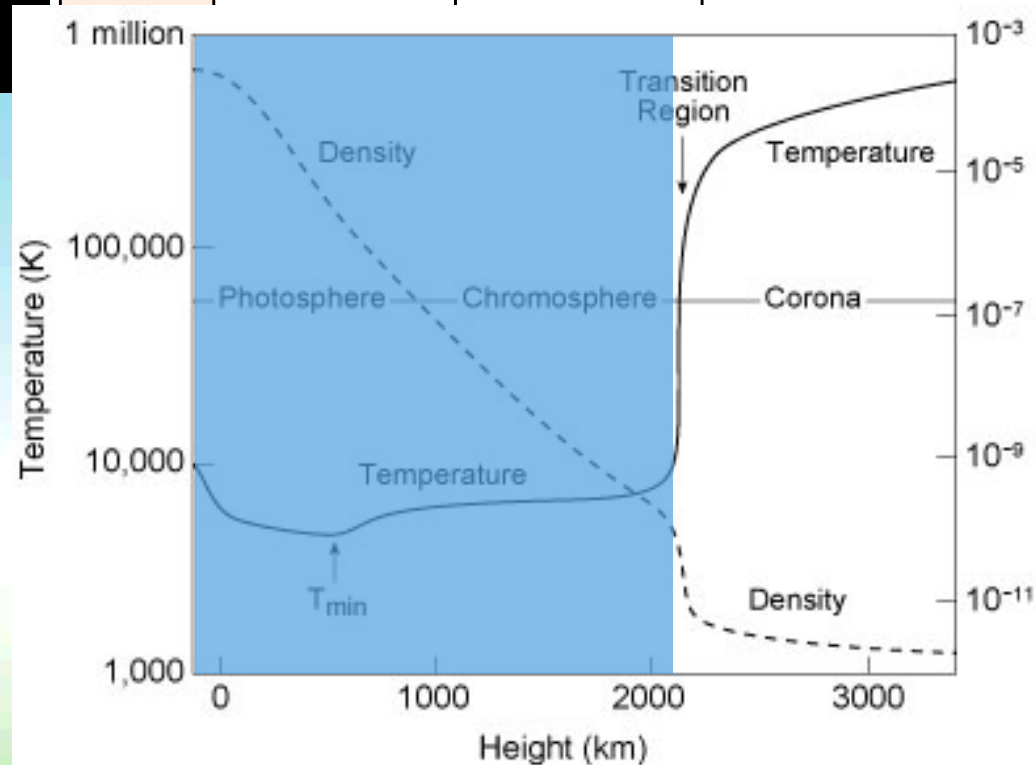
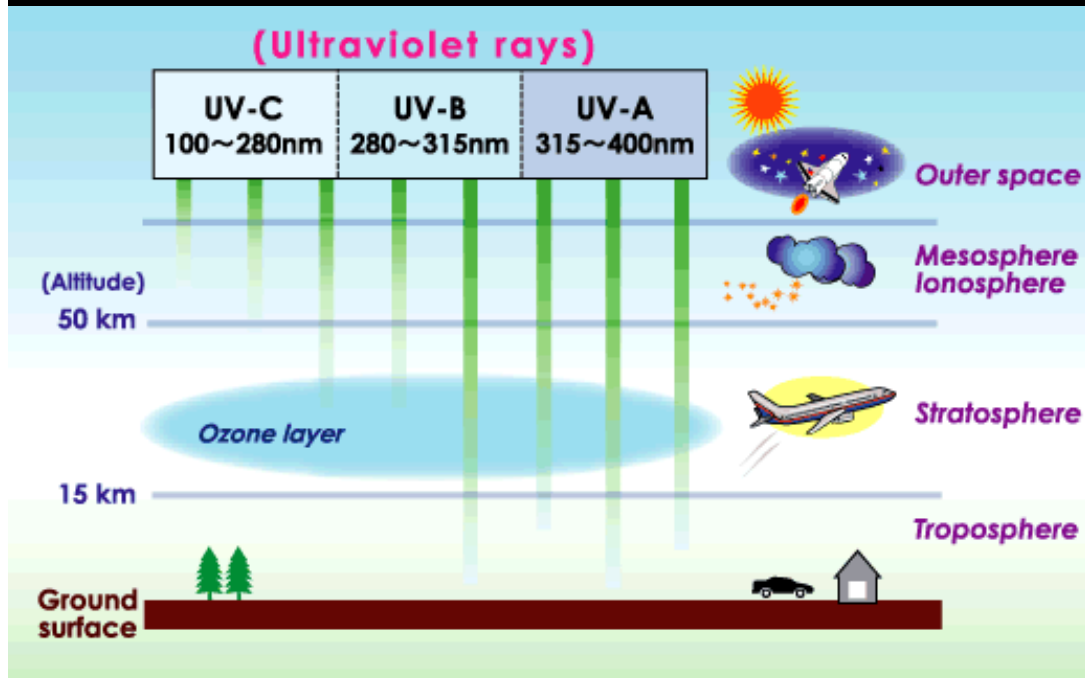


- ✦ **Coupling and Dynamics of the Solar Atmosphere:** What are the processes through which the energy is channelized and transferred from the photosphere to the chromosphere and to the transition region?
- ✦ **Sun Climate Studies:** Why and how strongly does the solar irradiance of relevance for the Earth's climate vary?
- ✦ **Solar Flare Studies:** At what wavelength do flares radiate most of their energy?
- ✦ **Prominence Studies:** What are the mechanisms responsible for formation, stability, dynamics and eruption of solar prominences?



1	214	5	Photosphere
2	276.7	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	Lower Photosphere
8	396.85	0.1	Ca II
9	200-242	42	Continuum
10	242-300	58	Continuum
11	320-360	40	Continuum

Credit: National Institute for Environmental Science, Japan

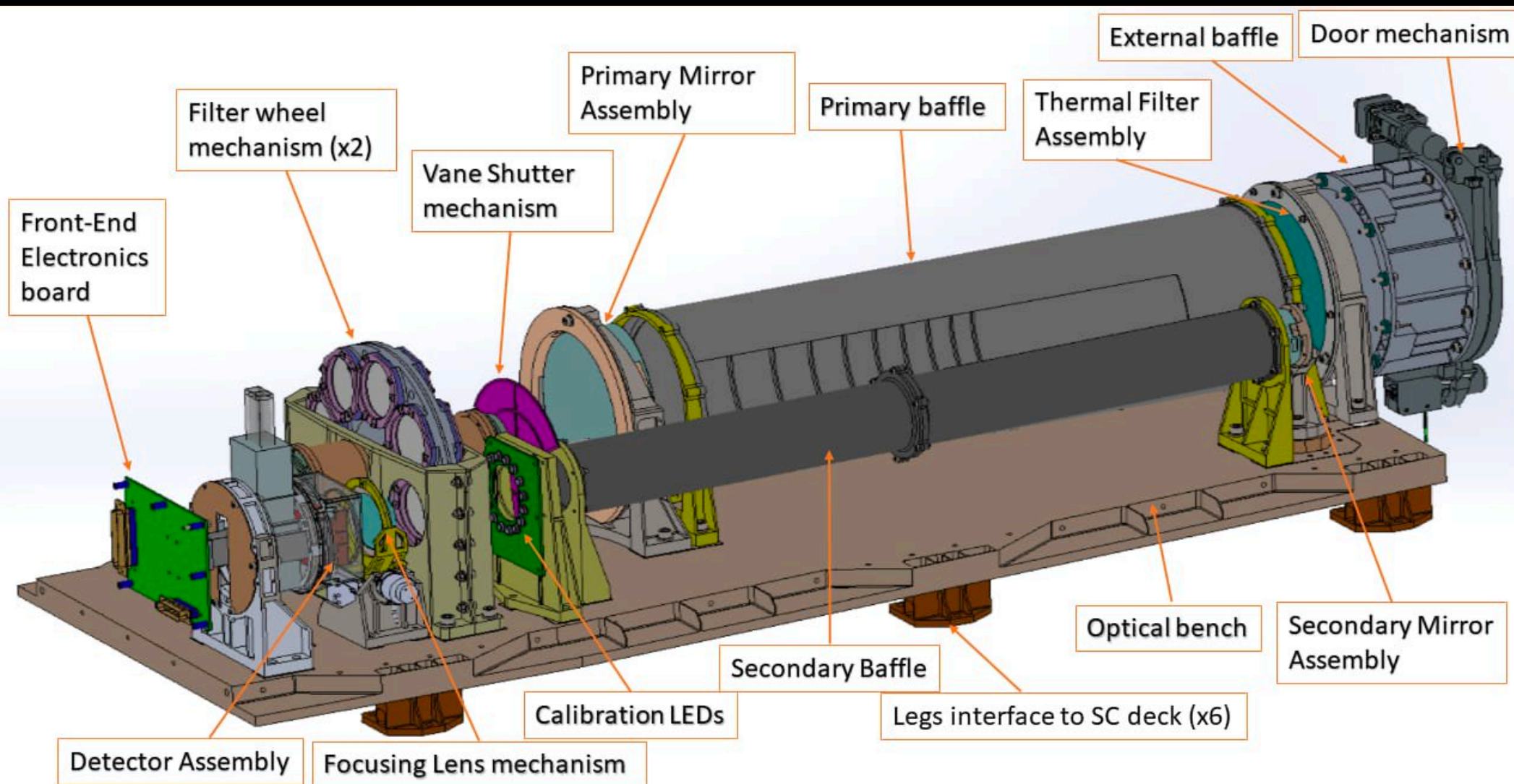




- **Detector - 4096 x 4096 - 48'**
- **FOV - 33'** - enough margin for alignment with VELC
- **Pixel size – 0.7"**
 - effective angular resolution – 1.4"
- **11 science filter**
 - 8 narrow-band - solar atmospheric dynamics
 - 3 broad-band - Sun-climate relationship
- **Synoptic as well as PI driven observational sequence possible**
- joint observing programs with others observatories
- **Cadence from 4 sec to 40 sec**
 - (depending on number of filters and FOV being used)



SUIT Internal Subassembly View





McAteer et al 2003

- Near simultaneous images slicing through the photosphere and chromosphere

- Full disk 4kx4k in all 11 filters – every 30 mins

- Full disk Mg II – 2kx2k – every min

- Partial disk – 700 x 700 – 4 to 40 s

- Automated flare mode

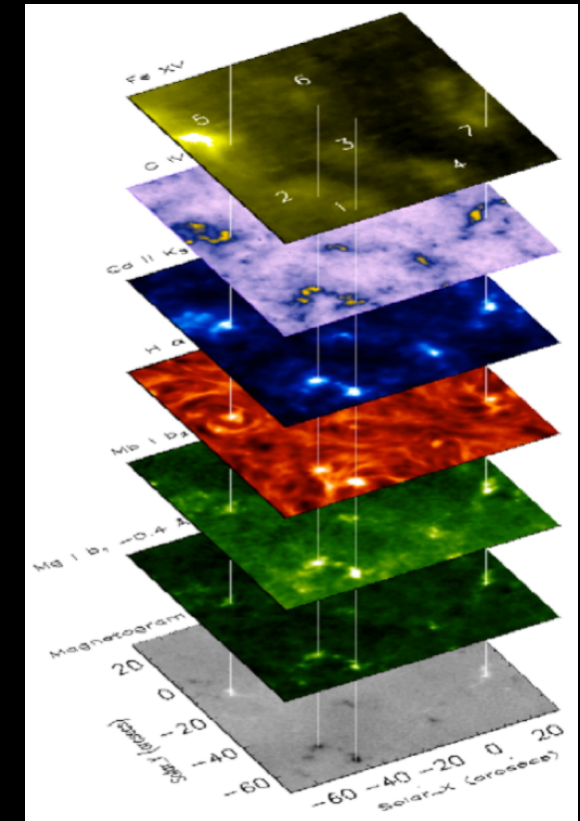
- Full disk 4kx4k

- spatially resolved solar spectral irradiance

- Partial Disk

- Solar Atmospheric dynamics

- Flare energy distribution in NUV



Combining SUIT observations with AIA and HMI on SDO, we shall have unique opportunities to learn about the magnetic coupling of the solar atmosphere.



Summary



- Aditya mission, to be launched in 2021, will provide a multi-wavelength [hard X-ray to infrared] comprehensive view of the Sun from photosphere to corona and in-situ measurements
- Firsts:
 - Measurements of coronal magnetic field from space using spectropolarimetry
 - Spatially resolved solar spectral irradiance in NUV
 - Remote sensing from HXR to Infrared and in-situ particle and magnetic field measurements from the same platform
- Combining Aditya-L1 observations with those from SDO (AIA & HMI) IRIS, SO, DKIST, SOS, PROBA-3 and possibly PUNCH [?] will provide unique opportunities to study the Sun as never before
- Current MAST and upcoming NLST in India shall provide ground based observational support