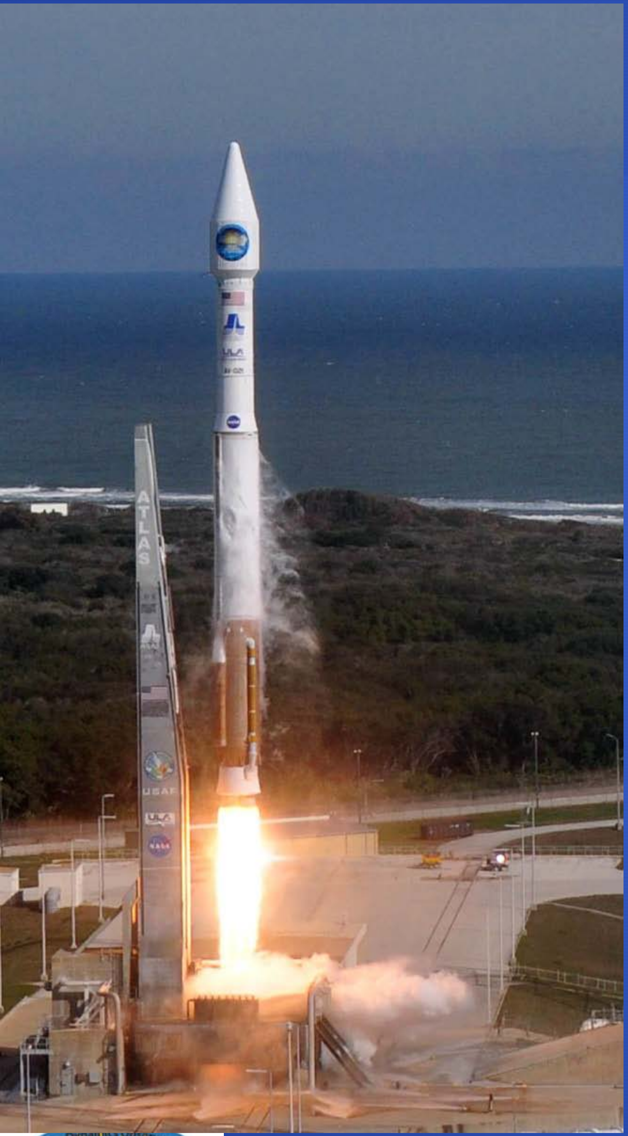
# EUV Variability Experiment
# Introduction, First Results

Tom Woods
Frank Eparvier
Rachel Hock

LASP

# Public Lecture – October 6, 7:30 PM - LASP

# 4 Things to Know about SDO

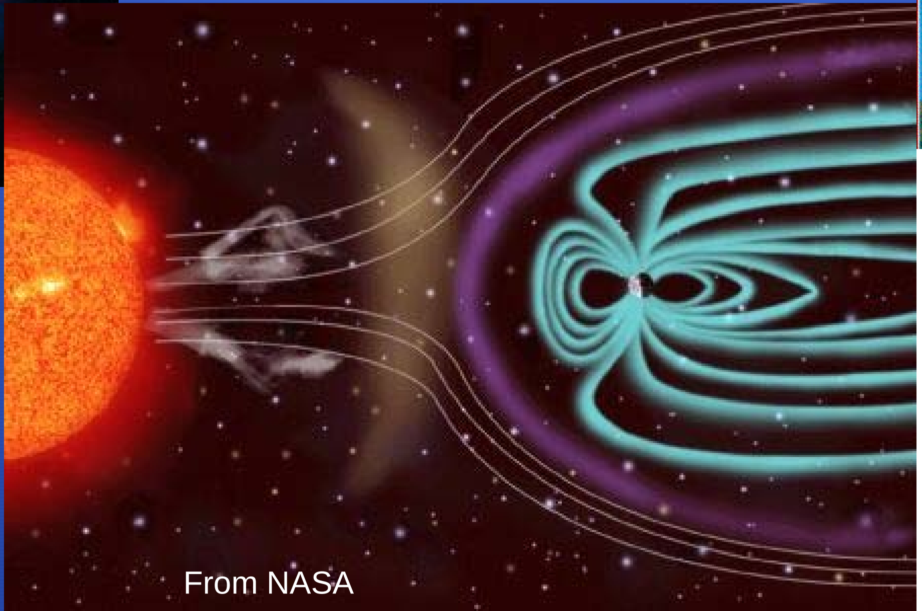


1. SDO is first mission for NASA's Living With a Star (LWS) program
   - Launched February 11, 2010
   - Normal operations began May 1, 2010

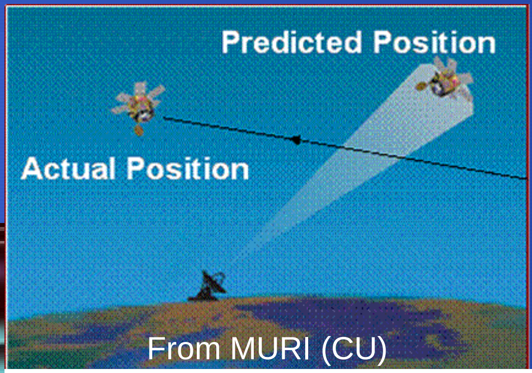
From Andrew Jones

# 4 Things to Know about SDO

2. Key objective for mission is understanding how and why the Sun varies
   - Determine how the magnetic field is generated and structured
   - Determine how the stored magnetic energy is released
   - Predict the solar variations that influence life on Earth and humanity's technological systems



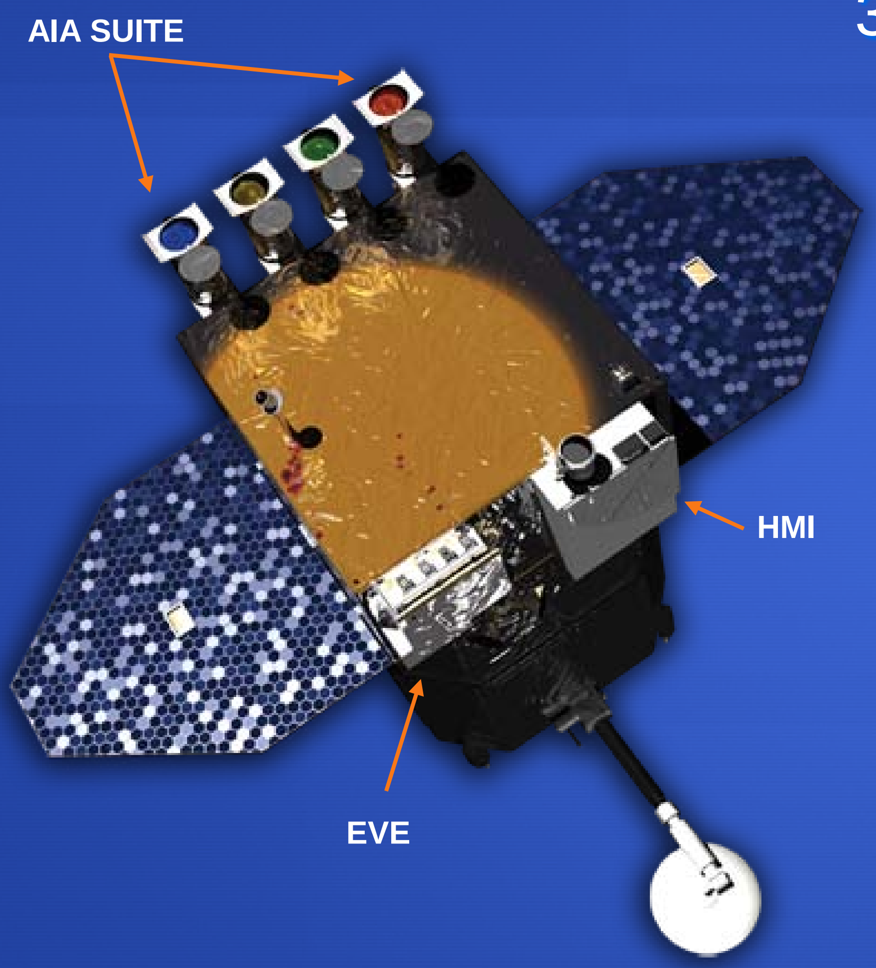
From NASA




From MURI (CU)

GPS Navigation

# 4 Things to Know about SDO




3. SDO has 3 instruments

- HMI : Helioseismic & Magnetic Imager (PI: Phil Scherrer, Stanford Univ.)
  - Measures the solar magnetic fields and local oscillations that provide a view into the Sun (helioseismology)
- AIA : Atmospheric Imaging Assembly (PI: Alan Title, LMSAL)
  - Measures solar images at multi-temperatures
- EVE : Extreme ultraviolet Variability Experiment (PI: Tom Woods, LASP/CU)
  - Measures the solar EUV irradiance from 0.1 to 121 nm

# 4 Things to Know about SDO

4. SDO's data rate is 150 Mbits per sec (Mbps) or 2 TB per day
- The Sun Today: browse: http://sdo.gsfc.nasa.gov/data/
- iSolSearch: events: http://www.lmsal.com/isolsearch
- JSOC HMI + AIA: http://jsoc.stanford.edu/
- LASP EVE: http://lasp.colorado.edu/eve/data/

SDO has 8 times better resolution than HD TV

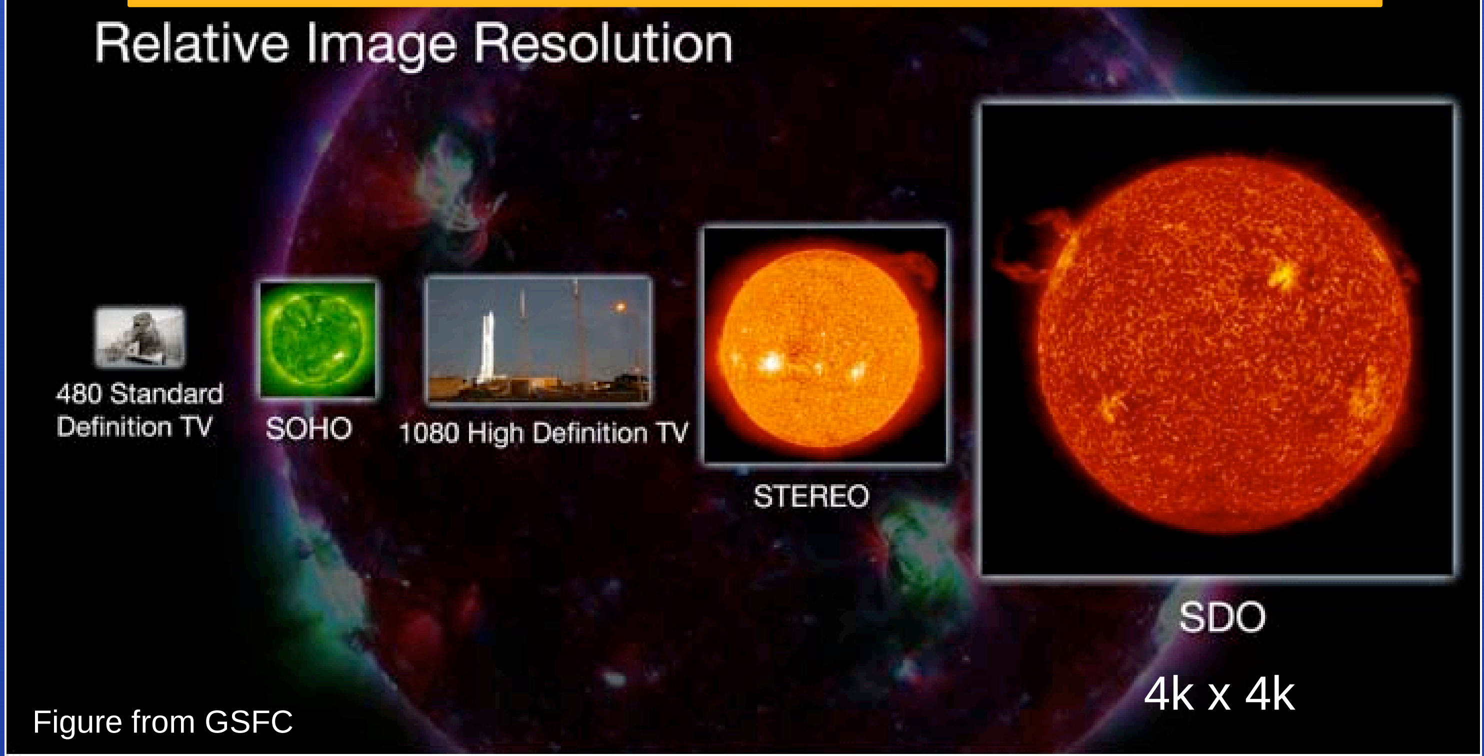


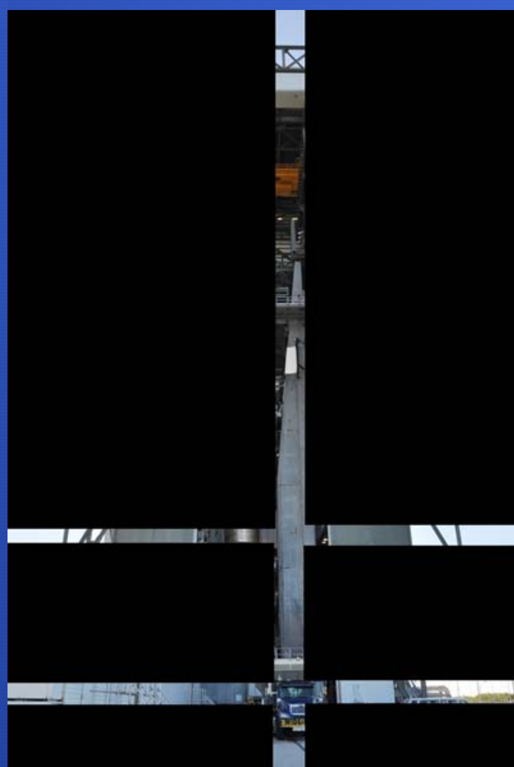

Figure from GSFC

# 4 Things to Know about EVE

1. LASP / MIT-LL / USC / SI built excellent solar EUV irradiance instrument with significant improvements in spectral resolution and time coverage

Analogy with Photograph

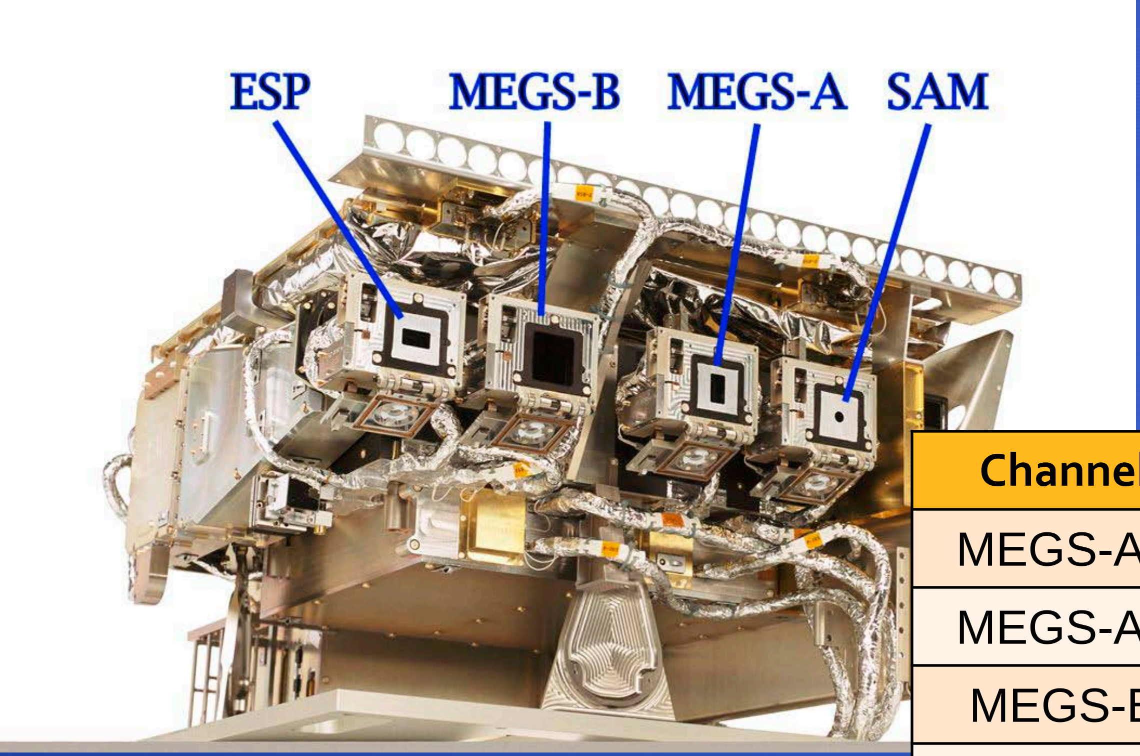
Prior to SDO



With SDO

# 4 Things to Know about EVE

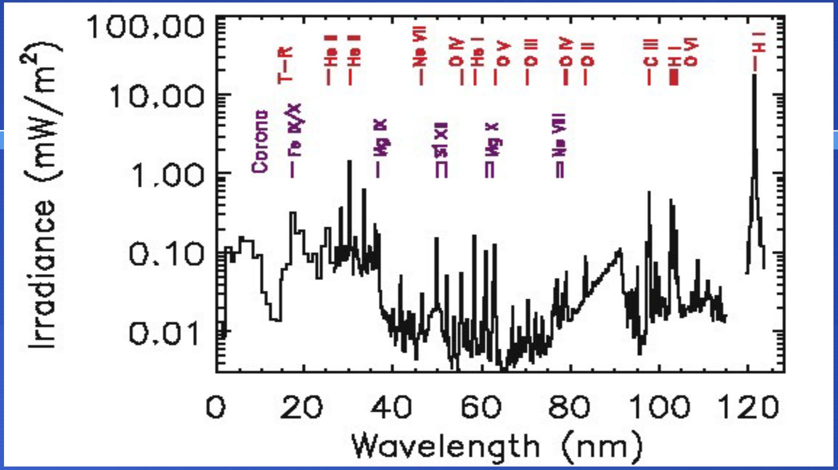
1. LASP / MIT-LL / USC / SI built excellent solar EUV irradiance instrument with significant improvements in spectral resolution and time coverage



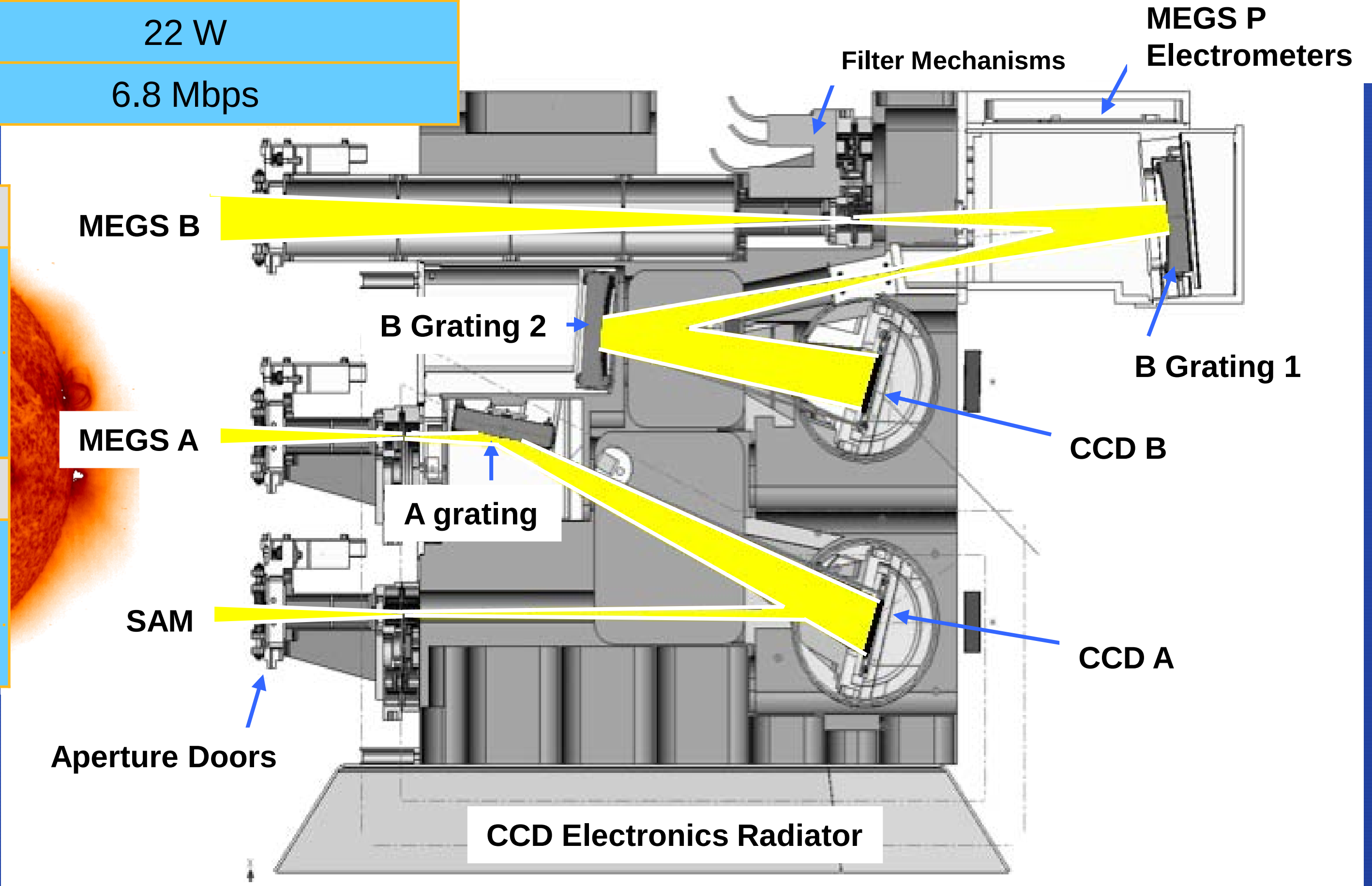

| Channel | λ Range | Δλ | Δt |
|---|---|---|---|
| MEGS-A1 | 6-18 nm | 0.1 nm | 10 sec |
| MEGS-A2 | 18-37 nm | 0.1 nm | 10 sec |
| MEGS-B | 37-106 nm | 0.1 nm | 10 sec |
| MEGS-SAM | 0.1-7 nm | (1 nm) | 10 sec |
| MEGS-P | 121.6 nm | 1 nm | 0.25 s |
| ESP | 0.1-38 nm | 4 nm | 0.25 s |

# Multiple EUV Grating Spectrograph (MEGS) Optical Overview

| | |
|---|---|
| λ Range | A: 5-37 nm, B: 34-105 nm, SAM: 0.1-7 nm, P: 121.6 nm |
| Δλ Resolution | A & B: 0.1 nm, SAM & P: 1 nm |
| Time Cadence | A,B,SAM: 10 sec, P: 0.25 sec |
| Field of View | ±2° |
| Power | 22 W |
| Data | 6.8 Mbps |




| Mechanisms |
|---|
| One-shot Aperture Door (3) |
| Five-position Filter Wheel (3) |
| **Detectors** |
| 1024 x 2048 CCDs (2) |
| Si Photodiodes (2) |

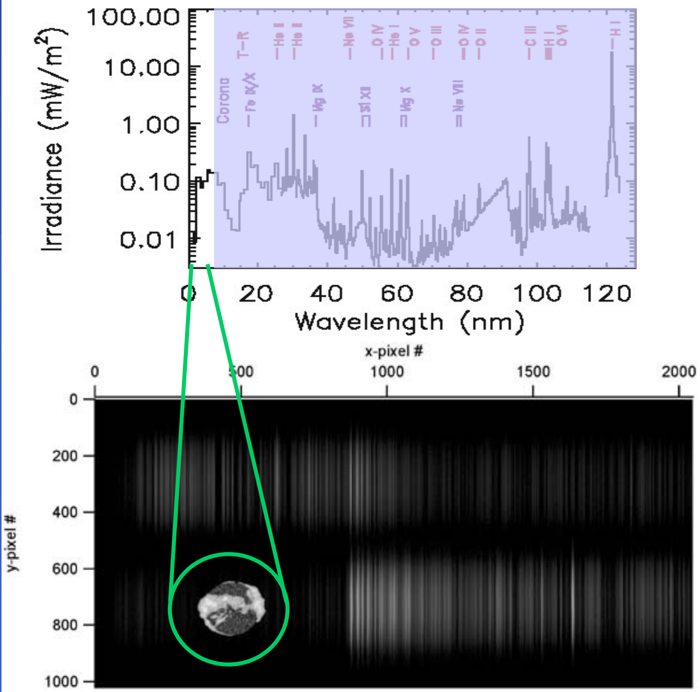


# Solar Aspect Monitor (SAM)

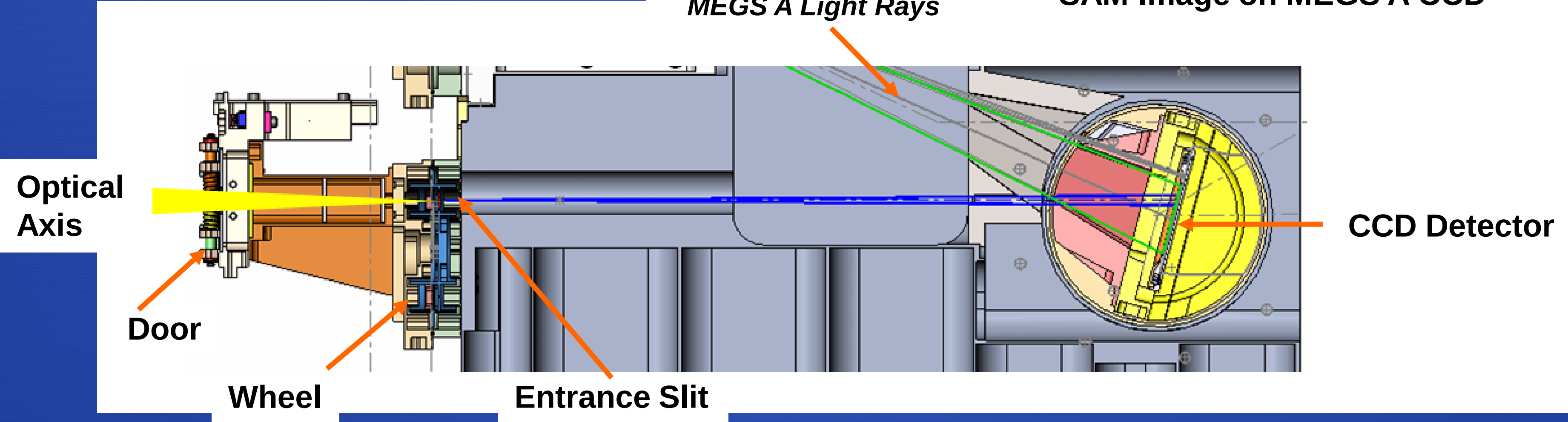
| | |
|---|---|
| λ Range | 0.1 - 7 nm |
| Δλ Resolution | 0.01 - 1 nm |
| Time Cadence | 10 sec |
| Field of View | ± 2° |
| Aperture Door | One-shot |
| Filter Wheel | 5 positions |
| CCD Detector | * |
| Average Power | * |
| Data | * |

SAM is a pinhole camera with photon-counting technique for X-rays: SPECTRA and IMAGES

** Power, CCD, and detector are accounted for in the MEGS A budgets*



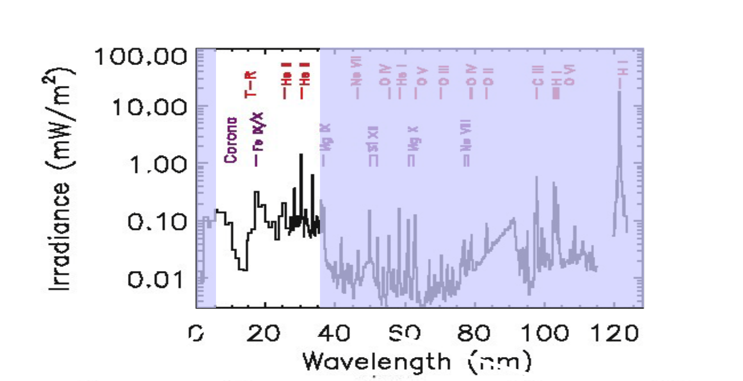

SAM Image on MEGS A CCD



# MEGS A Overview

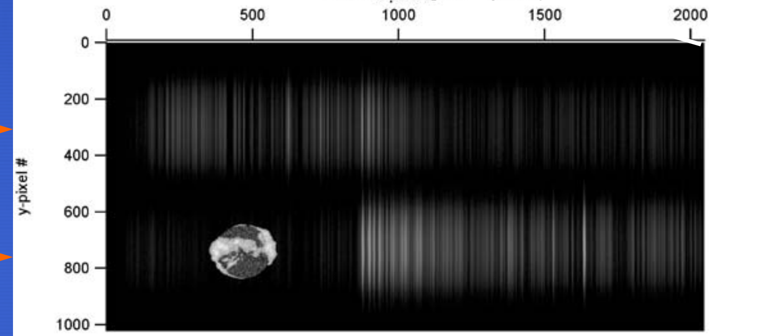
| | |
|---|---|
| λ Range | 5 - 37 nm |
| Δλ Resolution | 0.1 nm |
| Time Cadence | 10 sec |
| Field of View | ±2° |
| Aperture Door | One-shot |
| Filter Wheel | 5 positions |
| CCD Detector | 1024 x 2048 |
| Power | 11 W |
| Data | 3.4 Mbps |

SAM images have 10 arc-sec pixels

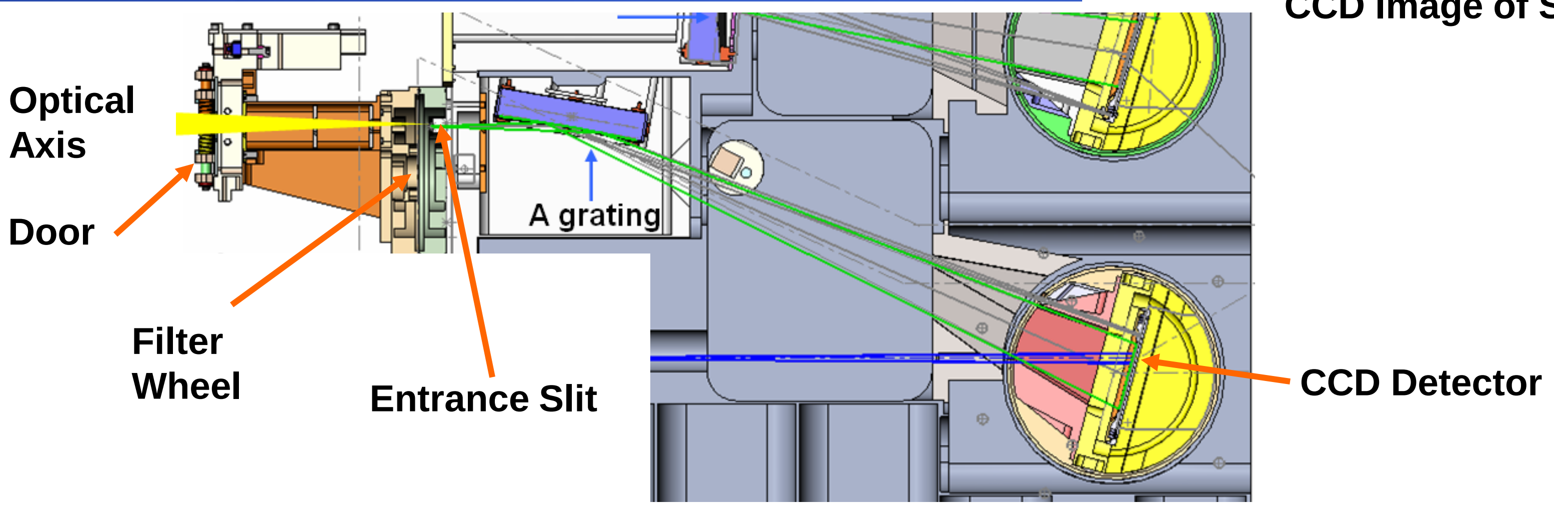



Slit 1
5-20 nm

Slit 2
17-37 nm

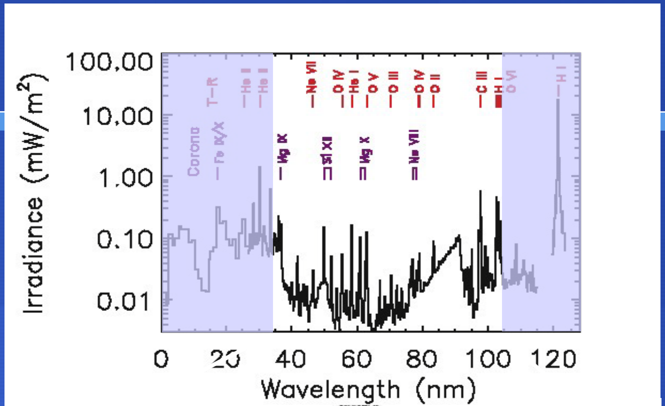


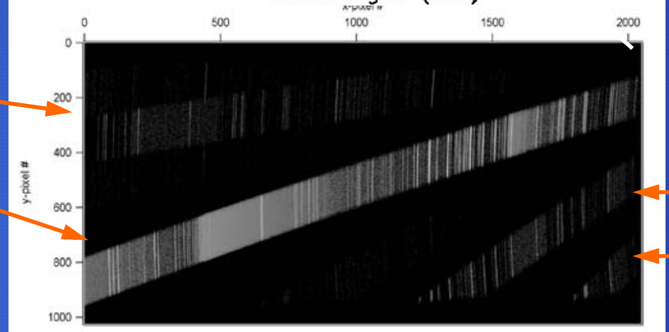

CCD Image of Solar Spectrum

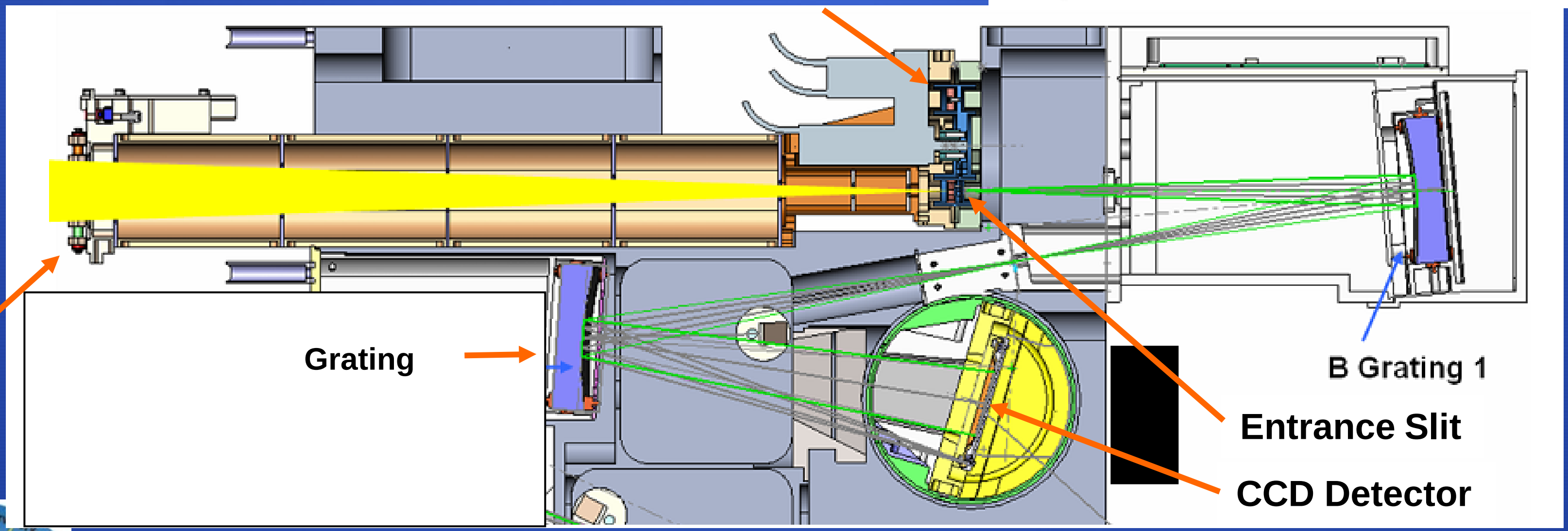


# MEGS B Overview

| | |
|---|---|
| λ Range | 34 - 105 nm |
| Δλ Resolution | 0.1 nm |
| Time Cadence | 10 sec |
| Field of View | ±2° |
| Aperture Door | One-shot |
| Filter Wheel | 5 positions |
| CCD Detector | 1024 x 2048 |
| Power | 11 W |
| Data | 3.4 Mbps |



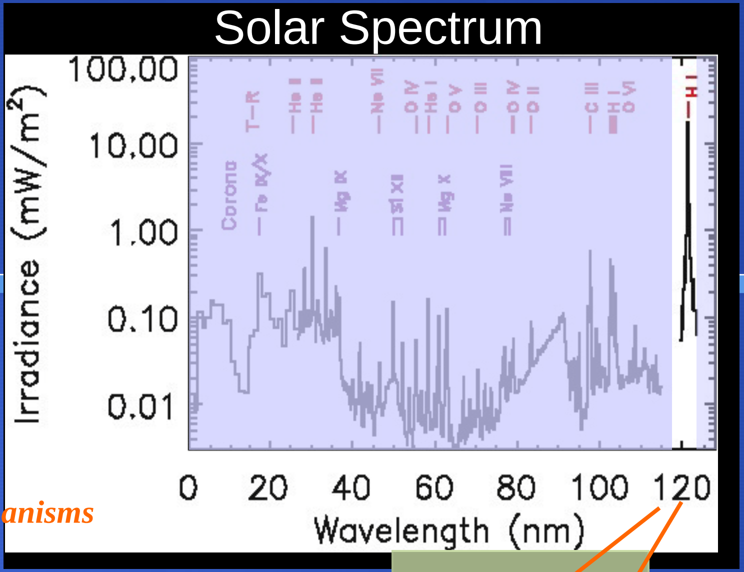



# MEGS P Overview

| | |
|---|---|
| λ Range | 121.6 nm |
| Δλ Resolution | 1 nm |
| Time Cadence | 0.25 sec |
| Field of View | ±2° |
| Aperture Door | * |
| Filter Wheel | * |
| Si Photodiode | 1 cm x 1 cm |
| Power | 0.2 W |
| Data | 0.001 Mbps |

** Behind MEGS B mechanisms*



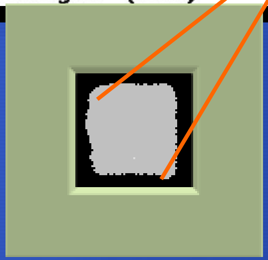
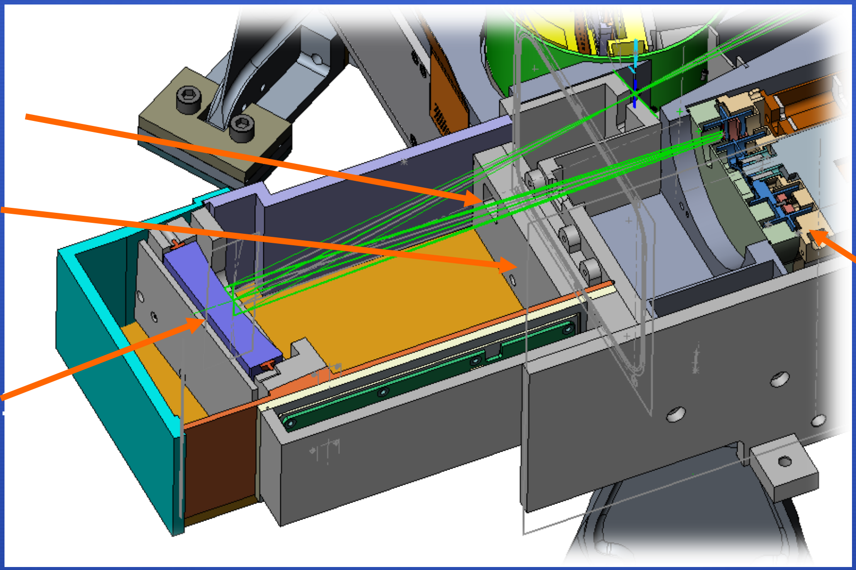



Image on MEGS P Detector

121 nm Filter& Detector

Dark Detector

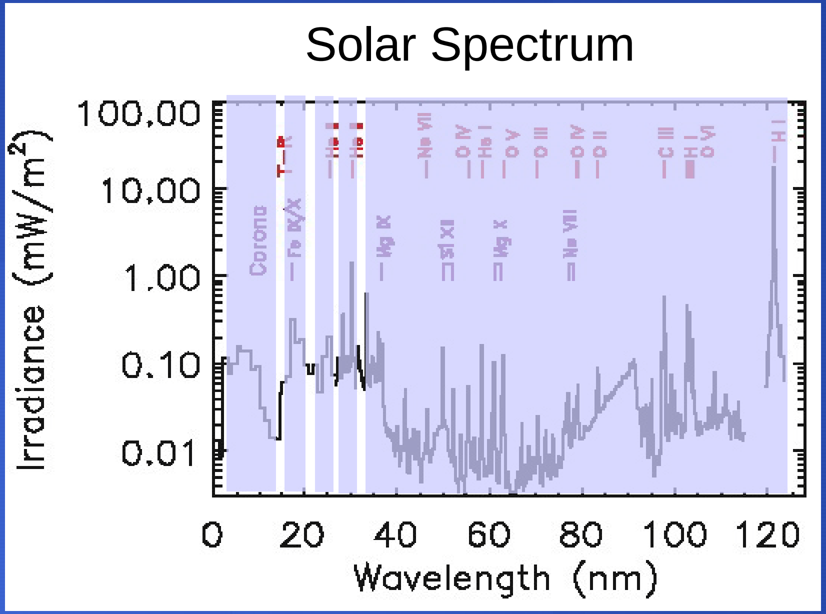
MEGS B Grating



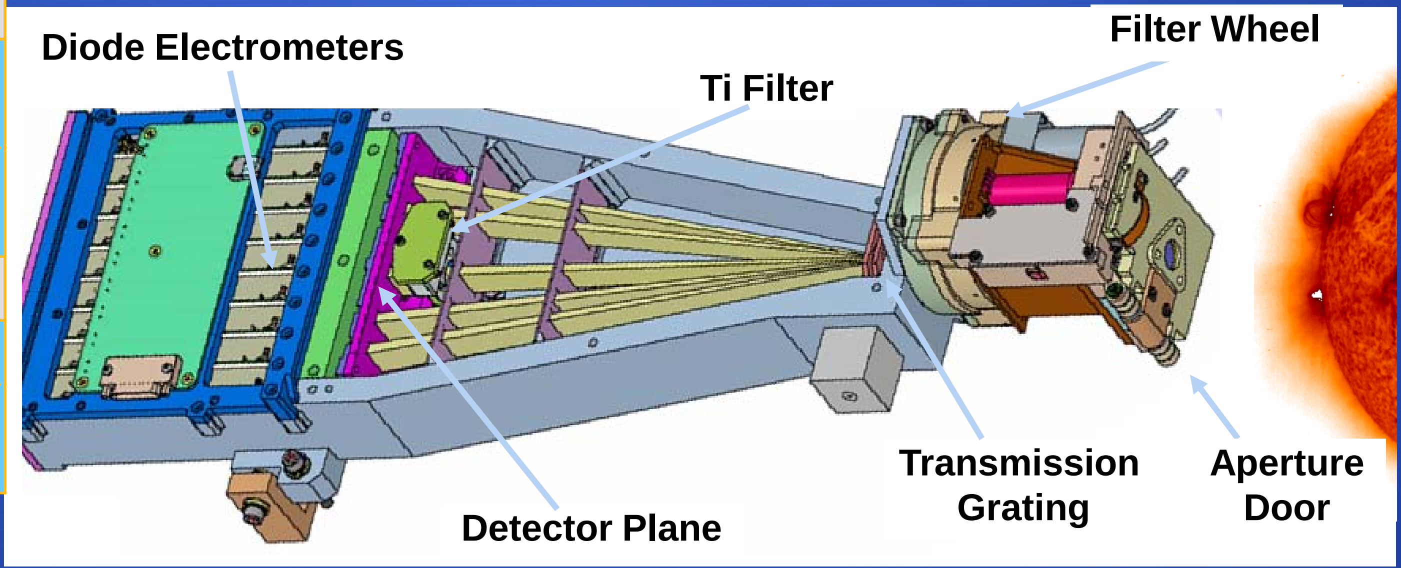
MEGS B
Filter Wheel

# EUV SpectroPhotometer (ESP) Optical Overview

| | |
|---|---|
| λ Range | 1st: 18.4, 25.5, 30.4, 35.5 nm<br>0th order: 0.1-7 nm |
| Δλ Resolution | 1st: 4 nm 0th: 7 nm |
| Time Cadence | 0.25 sec |
| Field of View | ±2° |
| Power | 1.9 W |
| Data | 0.007 Mbps |



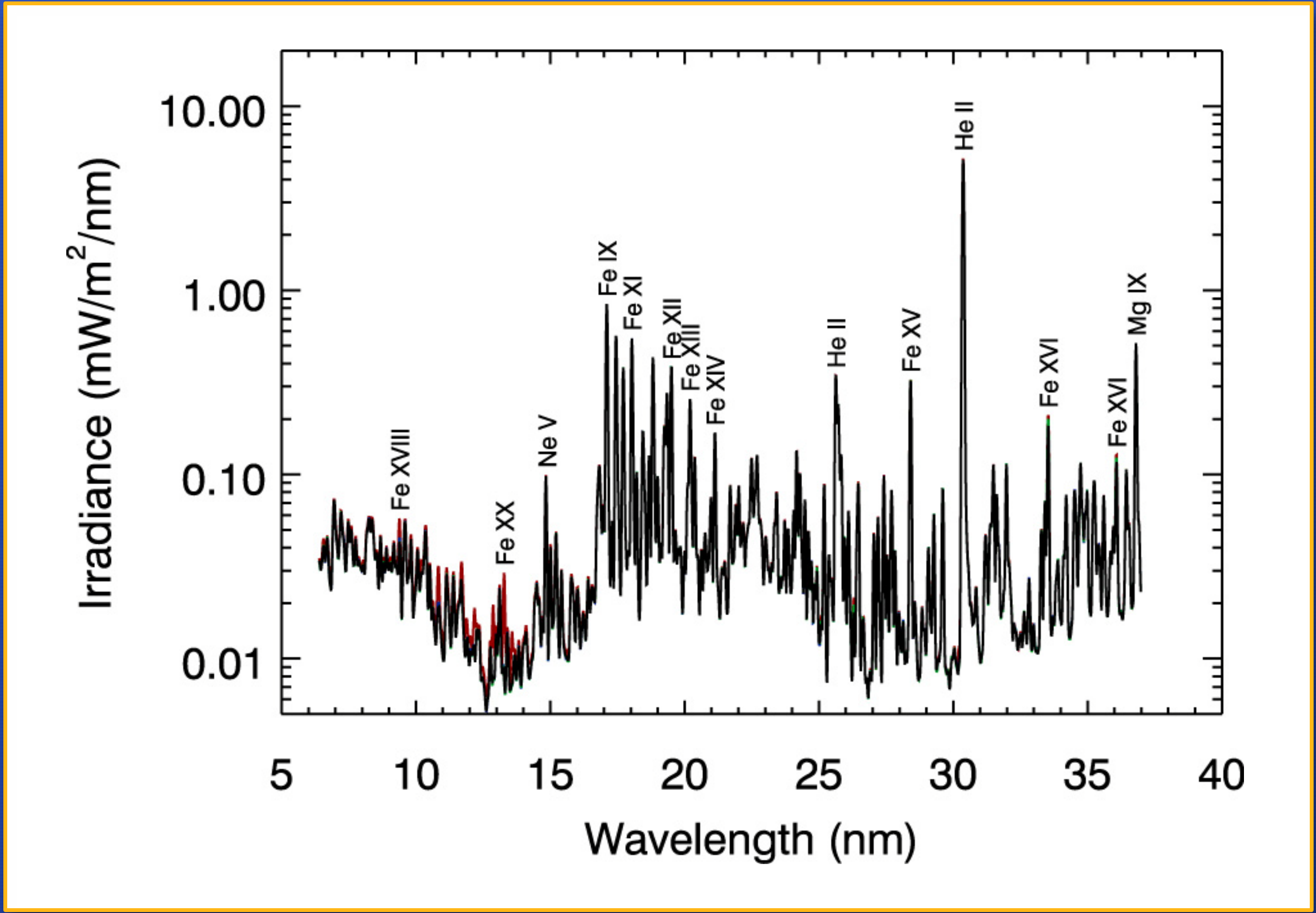

| Mechanisms |
|---|
| One-shot Aperture Door (1) |
| Five-position Filter Wheel (1) |
| **Detectors** |
| Si Photodiodes (5) |
| Quad Si Photodiode (1 - 0th order) |




**USC's ESP instrument is similar to SOHO SEM**

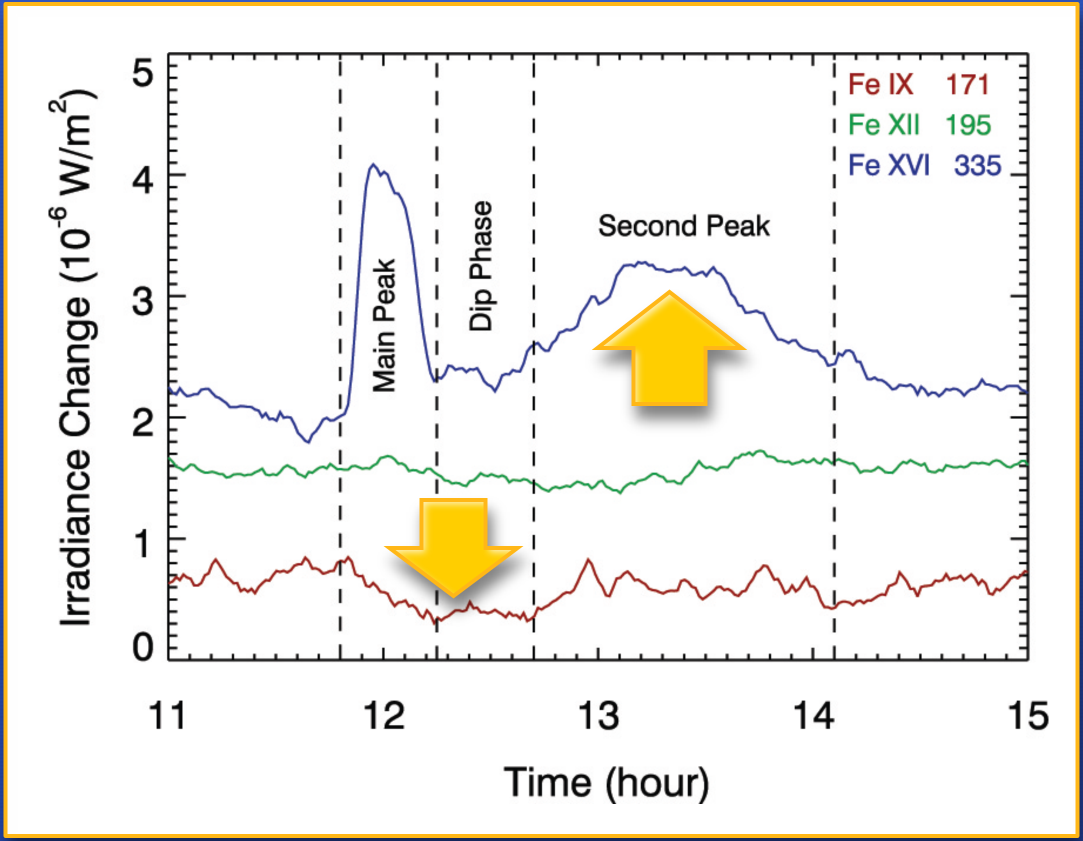
# 4 Things to Know about EVE

2. EVE MEGS provides spectrum every 10 seconds of dozens of bright coronal emissions in the extreme ultraviolet range (EUV: 5-110 nm)



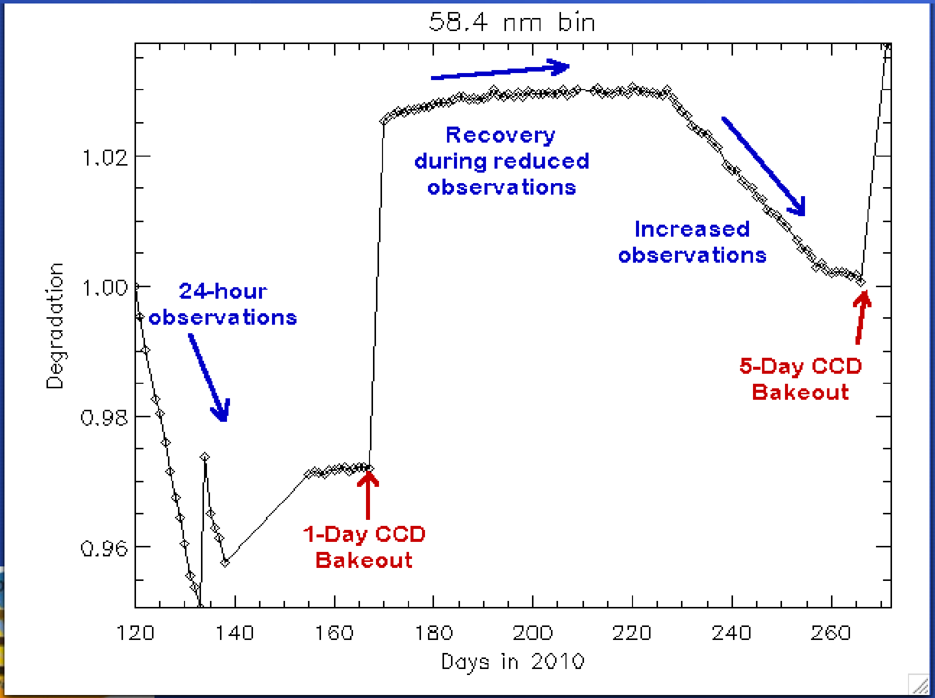
# 4 Things to Know about EVE

3. EVE observations are providing new insights on short-term solar variability
   - Some coronal emissions dim during solar flare
   - Some coronal emissions have large, delayed second peak



# 4 Things to Know about EVE

4. EVE has some degradation
   - CCD charging of its SiOx top layer – on MEGS-B
   - External contamination on Al foil filter – on MEGS-A2 & ESP
- Daily calibrations and annual calibration rocket flight are working well to provide corrections for EVE degradation
   - First calibration rocket flight was on May 3, 2010

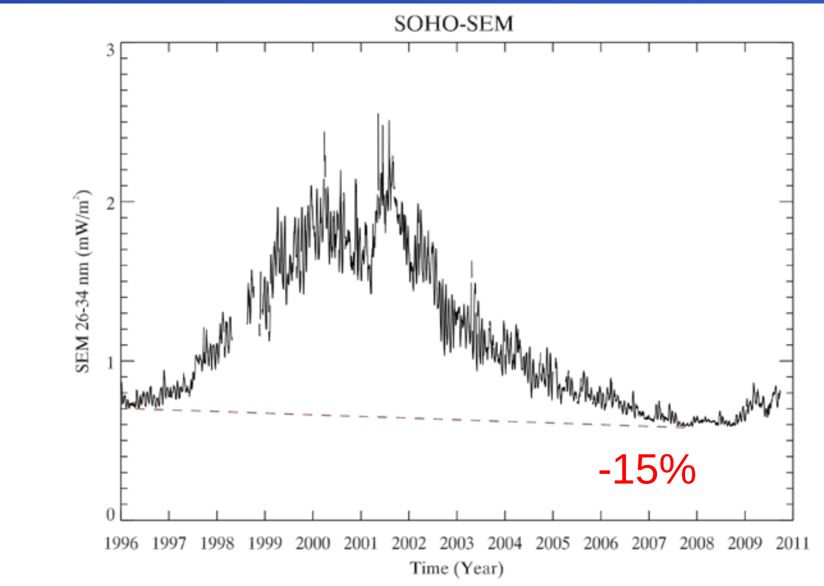



Exposure to solar EUV radiation is causing charging on CCD; this creates extra Si dead-layer that absorps the EUV photons more.

CCD bakeout and less exposure provides recovery from the CCD charging effect.

# 4 Things to Know about the Sun

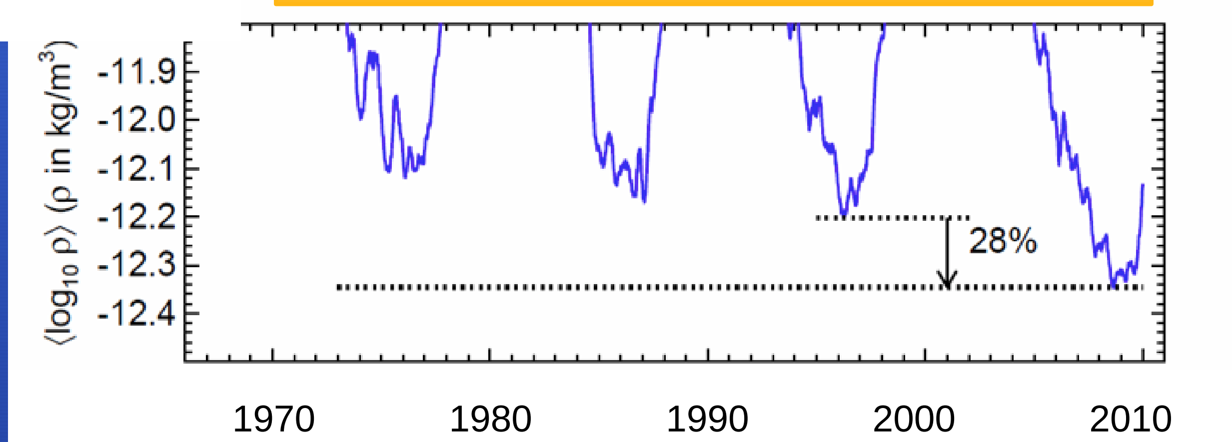
1. The Sun started its new 11-year solar cycle (# 24) in 2009 and is coming out of its lowest minimum since about 1900




Solomon *et al*., *GRL*, 2010

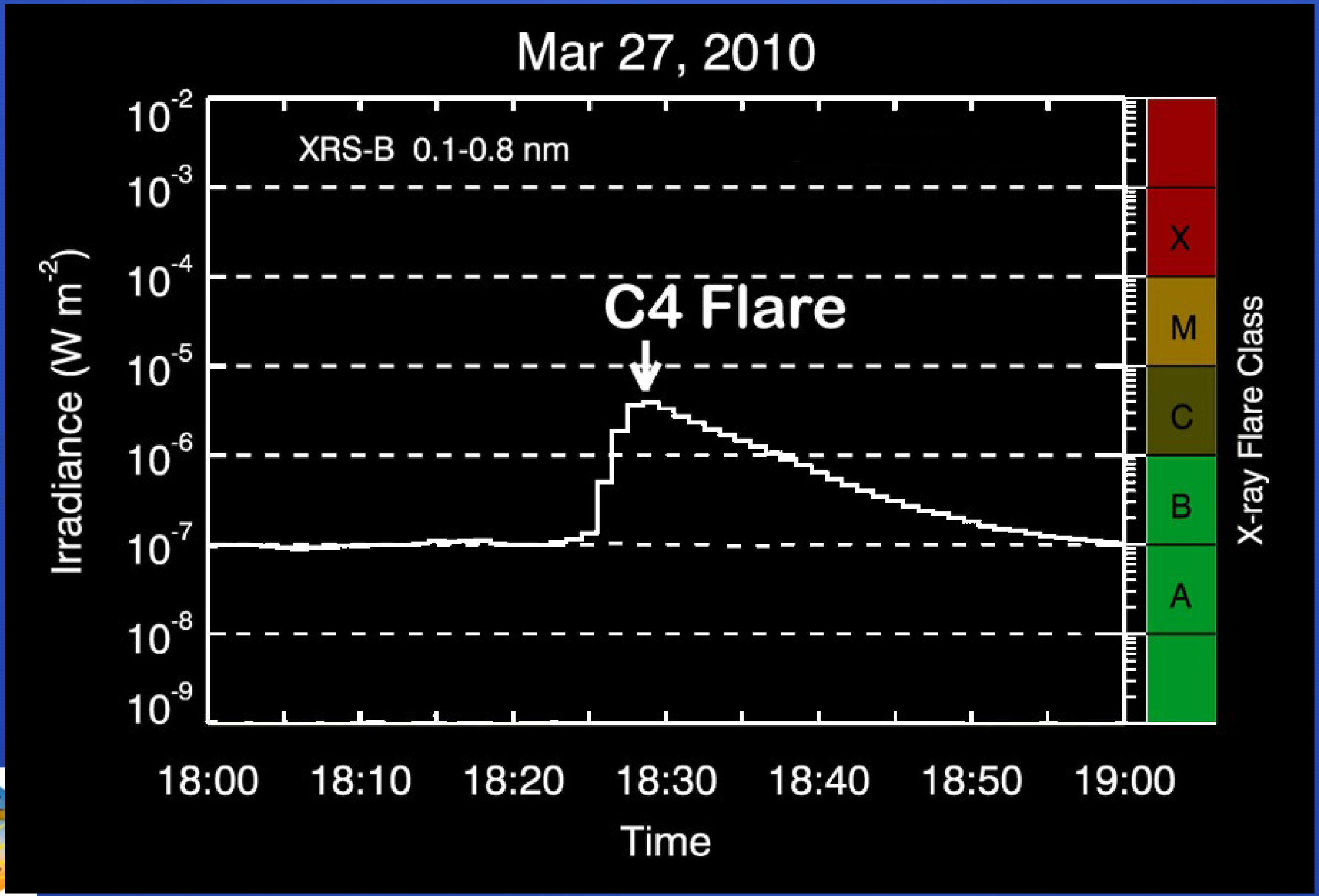
Solar EUV Irradiance lower in 2008 relative to 1996

Reduction of Earth's Atmospheric Density at 400 km



# 4 Things to Know about the Sun

2. Flares occur frequently on the Sun.
   - More than 30 solar flares have been observed by SDO / EVE
     - These are small C-class and M-class flares
     - No X-class flares yet.  Last X-class flare was on 9/14/2005.

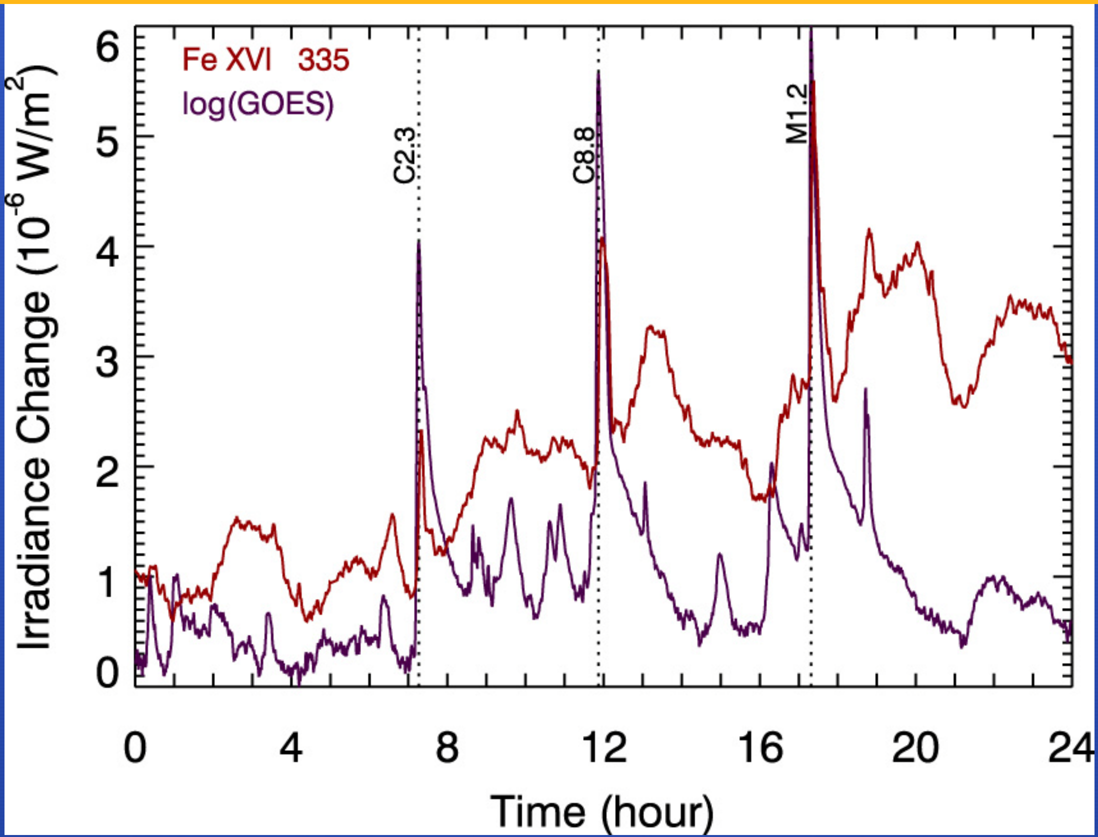



GOES XRS-B irradiance defines X-ray flare class.

# 4 Things to Know about the Sun

3. GOES X-ray monitor does not capture all of the activity of the coronal emissions.

Empirical irradiance models FISM and SIP that use GOES as proxy for flare variations require major revision based on SDO EVE new results.



# 4 Things to Know about the Sun

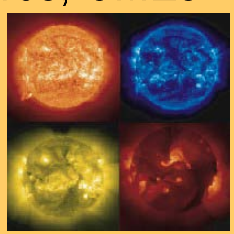
4. Solar EUV radiation directly affect Earth’s ionosphere and thermosphere.
   - Thermosphere:  neutral density impacts satellite drag
   - Ionosphere: charged plasma can affect some of our communication and GPS navigation systems
   - Space weather research and operations need solar EUV observations.

Solar Dynamics Observatory
(NASA-GSFC)

Solar Images -> Flares, CMEs

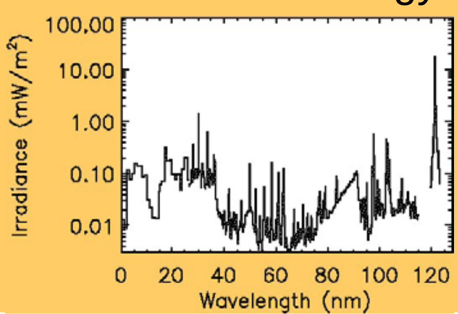
HMI

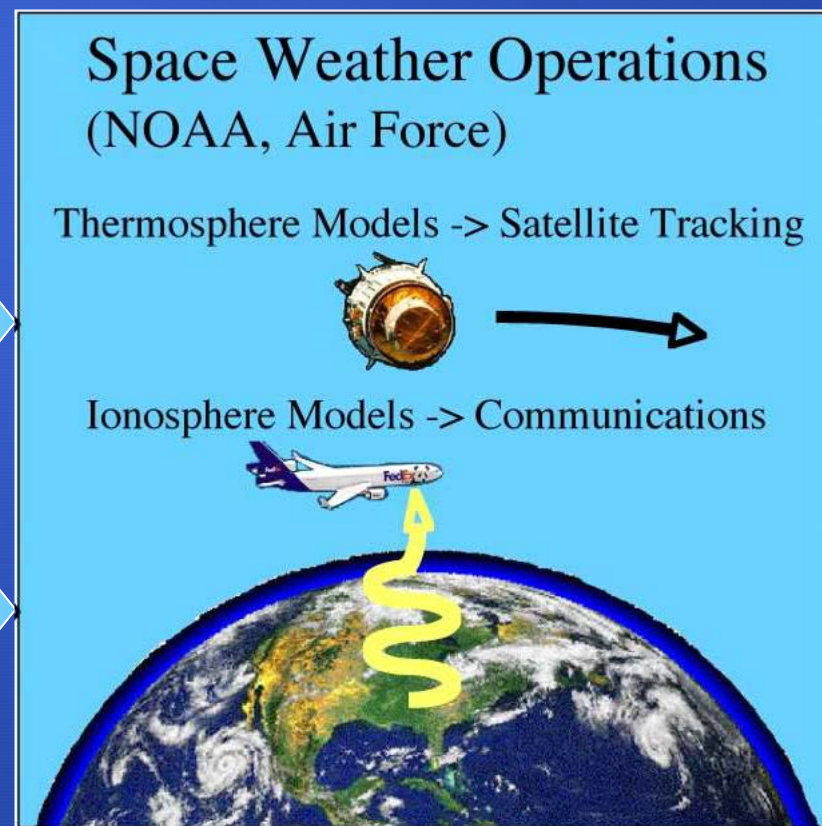
AIA



Solar Irradiance -> Energy Input

EVE



# Some EVE First Results

## May 5, 2010

Focus day for Flares & Fluctuations

**The Flares**
Rachel Hock

**The Fluctuations**
Frank Eparvier

- **Cool corona lines (Fe IX) decrease right after flare**
  - **EUV dimming is related to having eruption / CME**
- **Hot corona lines (Fe XVI) have delayed second peak that is hours after flare**