

The Solar Dynamics Observatory

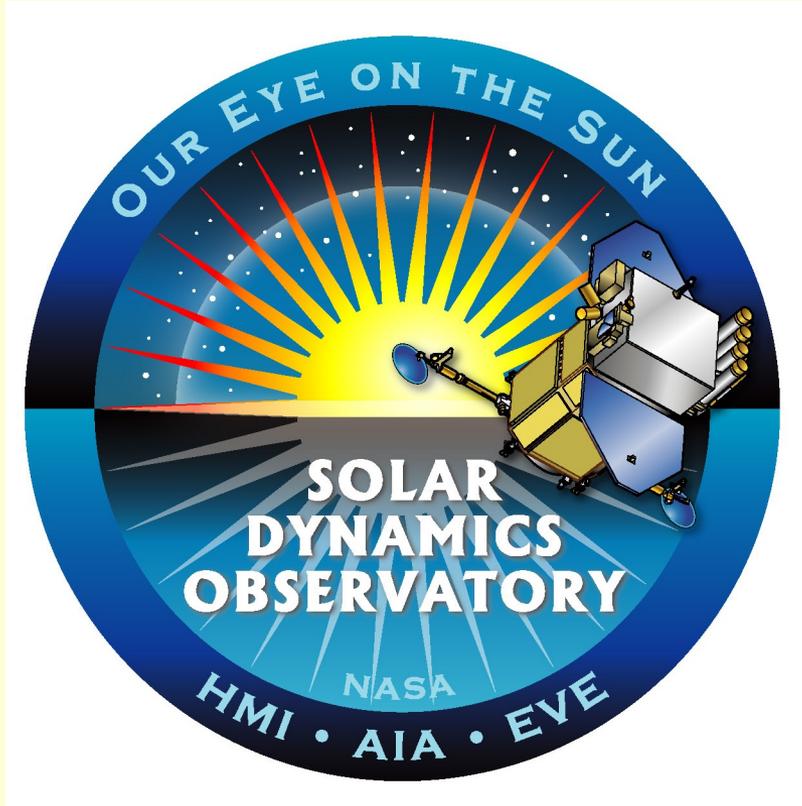


Frank Eparvier
Univ. Colorado

Alan Title
Lockheed-Martin

Outline

- **SDO Overview**
 - Frank Eparvier
- **EVE = EUV Variability Experiment**
 - Frank Eparvier
- **AIA = Atmospheric Imaging Assembly**
 - Alan Title
- **HMI = Helioseismic Magnetic Imager**
 - Alan Title



SDO Overview

Frank Eparvier

University of Colorado, LASP

What is SDO?

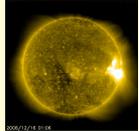
- The Solar Dynamics Observatory (SDO)
- NASA's first mission in the Living With a Star (LWS) line.
- Carries instruments to study:
 - The Sun's magnetic field
 - The Sun's interior
 - Changes in the Sun's activity
- Primary goal of the SDO mission: to understand, driving towards a predictive capability, the solar variations that influence life on Earth and humanity's technological systems by determining:
 - How the Sun's magnetic field is generated and structured
 - How this stored magnetic energy is converted and released into the heliosphere and geospace in the form of solar wind, energetic particles, and variations in the solar irradiance

SDO Investigations

- **Atmospheric Imaging Assembly (AIA) and Guide Telescopes (GT);**

PI: Alan Title – LMSAL;

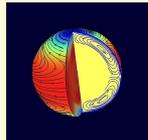
- Multiple simultaneous, high-resolution images of the corona over a wide range of temperatures.



- **Helioseismic Magnetic Imager (HMI);**

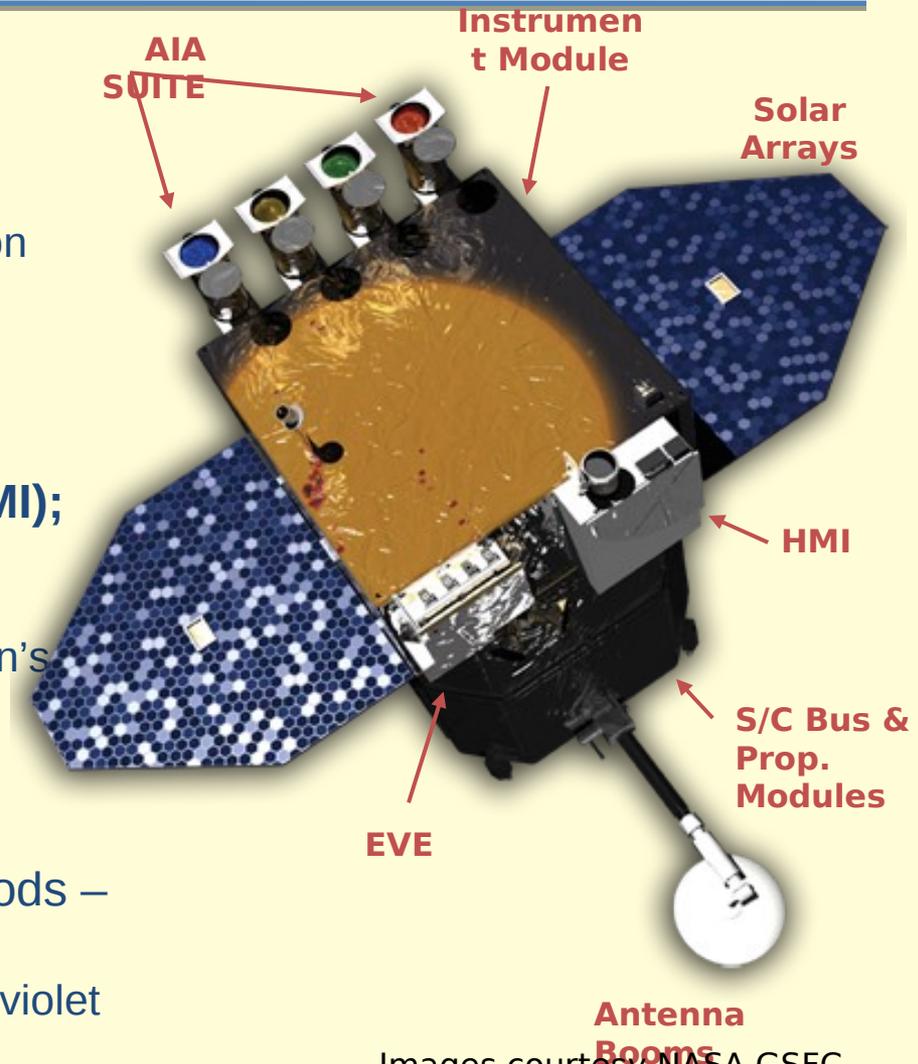
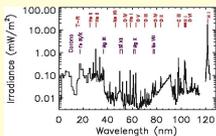
PI: Phil Scherrer – Stanford Univ.;

- Images the Sun's helioseismic and magnetic fields to understand the Sun's interior and magnetic activity.



- **Extreme ultraviolet Variability Experiment (EVE);** PI: Tom Woods – LASP, Univ. of Colorado

- Measures the solar extreme ultraviolet (EUV) irradiance to understand variations.



Images courtesy NASA GSFC

SDO Specs

- Size: 2.2m x 2.2m x 4.5m
- Mass: 3200 kg (270 payload)
- Launch: Feb 3, 2010 on Atlas V from Kennedy Space Center
- Orbit: Geosynchronous (over White Sands, New Mexico)
- Mission: 5-years nominal life
- Data Rate: 150 Mbps continuous (1.5 TeraBytes per day)
- Status: **In Florida, ready for ride to space**

<http://sdo.gsfc.nasa.gov>

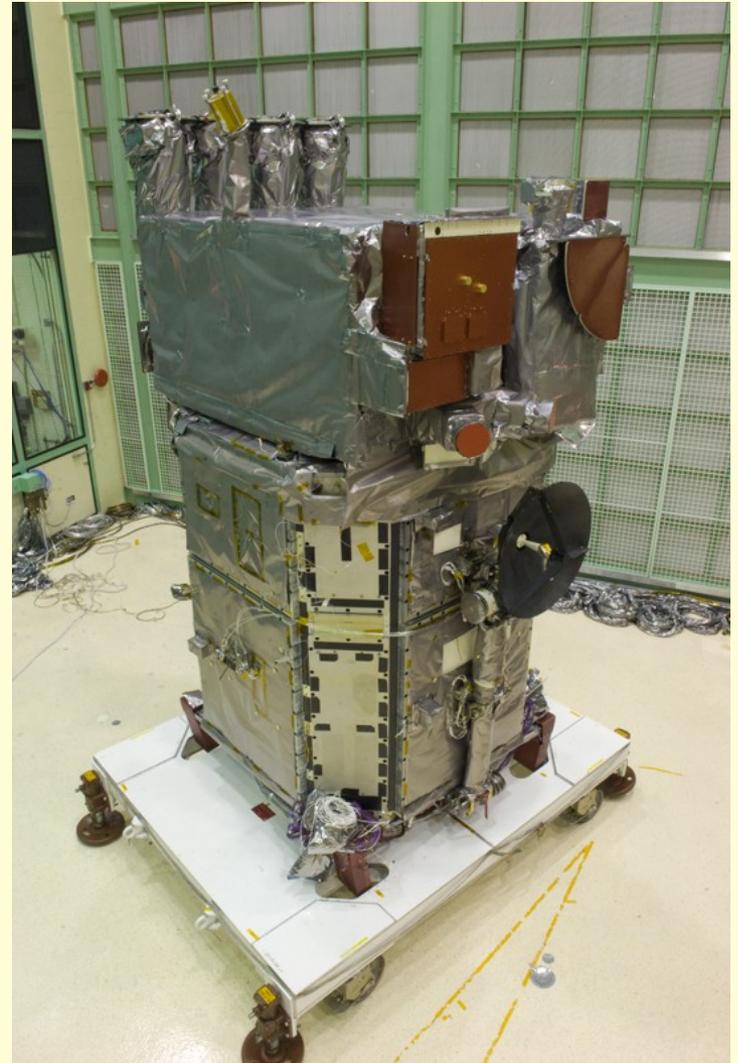


Image courtesy NASA GSFC

SDO Summary

- SDO improves gives higher temporal, spatial, and spectral resolution than previous missions.
- SDO data will be available to all via web.
- From SDO data we will be able to observe solar activity like never before:
 - Answer questions
 - Constrain models and theories
 - Improve predictive capabilities
 - Raise new questions

The Extreme ultraviolet Variability Experiment

Frank Eparvier
EVE Project Scientist
Univ. Colorado - LASP



What is Irradiance?

- **Irradiance** is the amount of light coming from the Sun that falls on a unit area per unit time at a specific distance (such as at 1 AU).
Irradiance is what we get from the Sun.
 - Irradiance treats the Sun like a point source (or like a star).
- **Spectral Solar Irradiance (SSI)** is how the light is distributed as a function of wavelength.
- **Total Solar Irradiance (TSI)** is spectral irradiance added up over all wavelengths. (Used to be called the Solar Constant, but it's not constant.)

The Solar Irradiance Spectrum

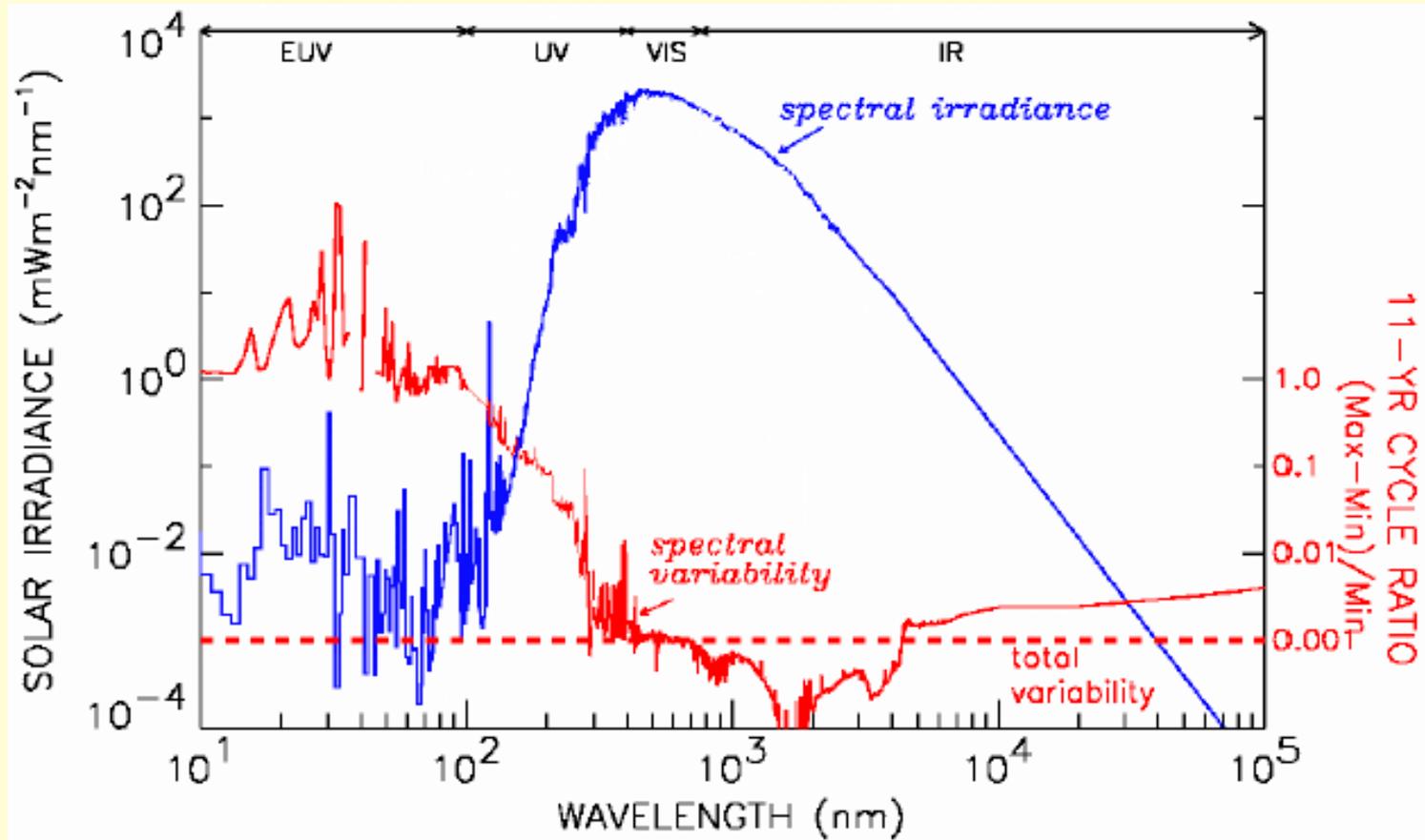
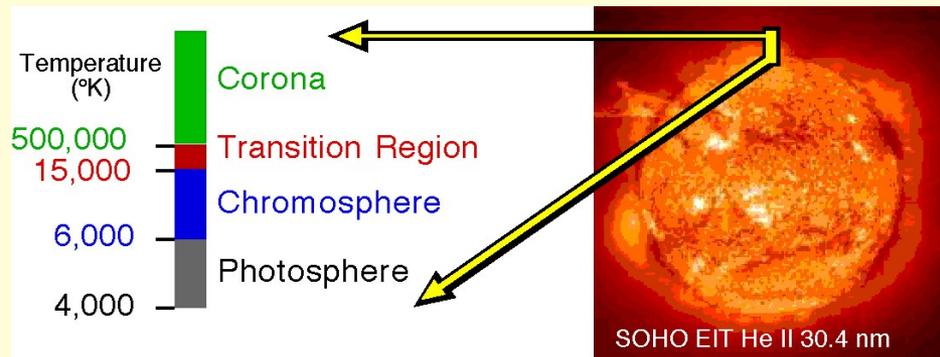
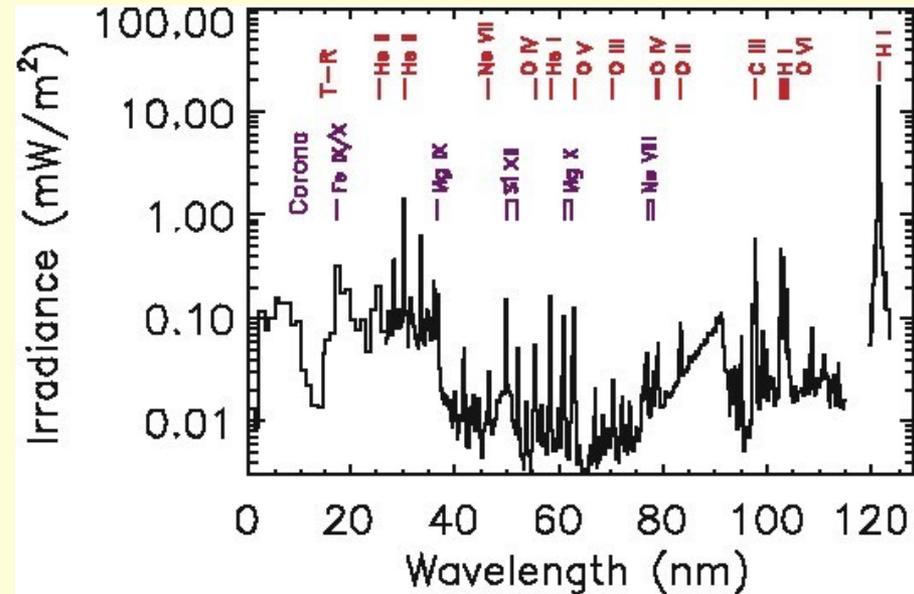


Image courtesy J. Lean

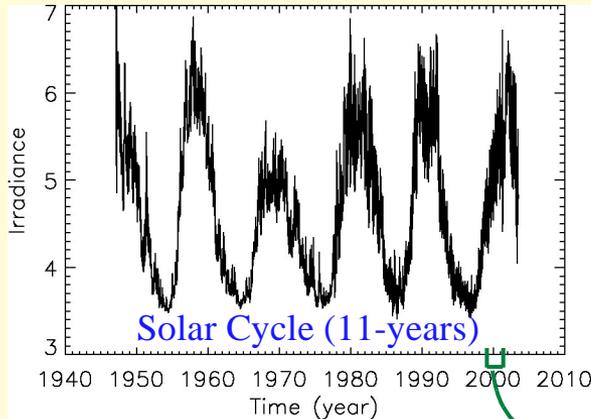
- Spectrum looks like blackbody ($\sim 5700\text{K}$) in visible
- TSI is integrated total ($\sim 1361 \text{ W/m}^2$, depending on whom you ask)

What is the Solar EUV?

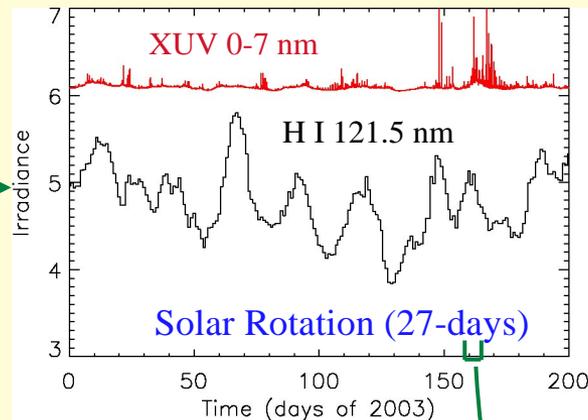
- The solar Extreme Ultra-Violet (EUV) radiation consists of emissions from the solar chromosphere, transition region, and corona
 - EUV is < 0.01% of the total solar irradiance (TSI: >99% from photosphere)
 - But the solar EUV varies by factors of 2 to 100 (wavelength dependent). (TSI only varies by 0.1% or less.)
 - And the EUV varies on timescales from minutes (flares) to days (solar rotation) to decades (solar cycle)



Timescales of Solar Spectral Variability

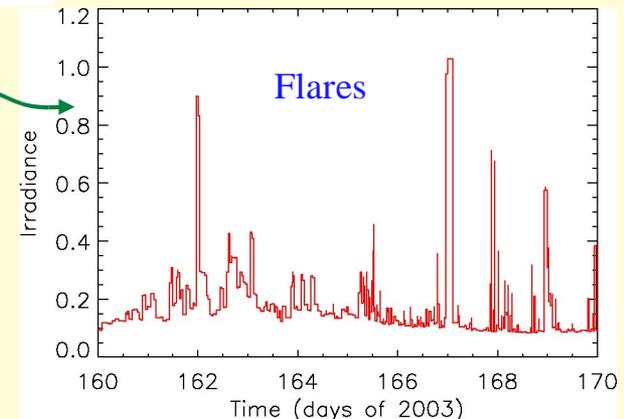


- Solar Cycle - months to years
 - Evolution of solar dynamo with 22-year magnetic cycle, 11-year intensity (sunspot) cycle



- Solar Rotation - days to months
 - Beacon effect of active regions rotating with the Sun (27-days)

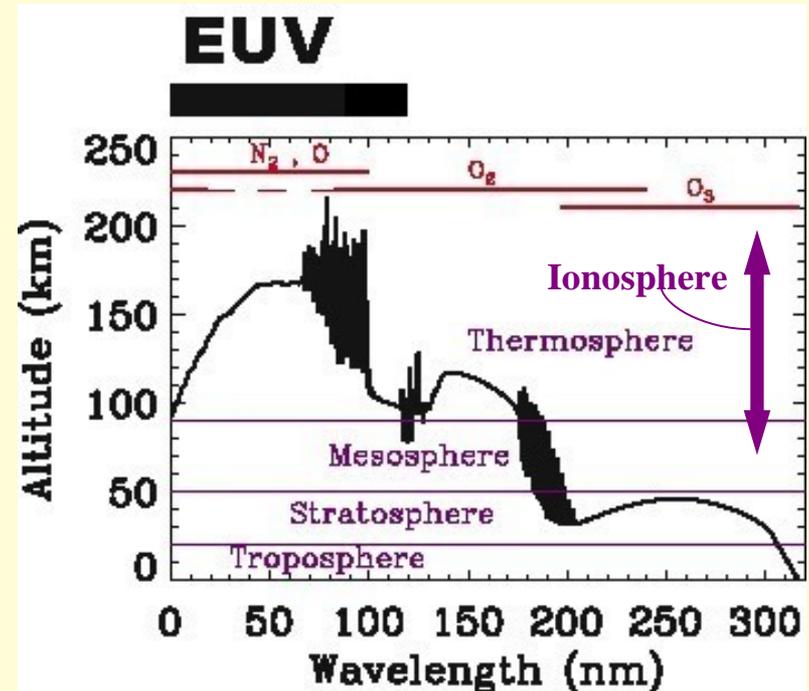
- Flares - seconds to hours
 - Related to solar solar eruptive events due to the interaction of magnetic fields on Sun



Why Do We Care About EUV?

- The solar EUV ($\lambda < 120$ nm) radiation is the primary energy input for the upper atmosphere (altitudes > 100 km)
- Absorption of EUV heats the thermosphere (where many satellites reside).
- Ionization by EUV creates the ionosphere (affecting communications).
- Dissociation by EUV initiates complex photochemistry in the atmosphere (changing composition of minor species).

Variability in solar EUV drives variability in the upper atmosphere.



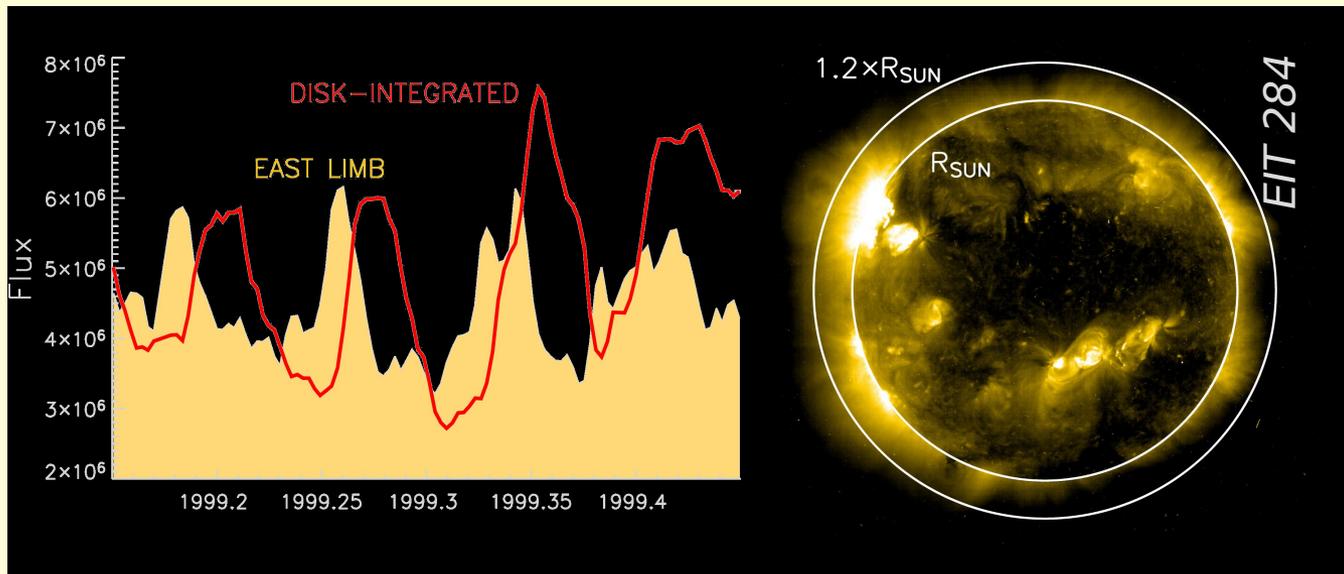
Plot shows where the solar radiation is deposited in the atmosphere. The primary atmospheric absorbers are N_2 , O , O_2 , and O_3 .

History of EUV Spectral Irradiance Measurements

- **Early Space Age:**
 - Spectral measurements with little or no absolute irradiance calibration
- **Late 1970s to early 1980s:**
 - Rockets and AE-E measurements (Hinteregger et al.)
 - Cadence sporadic (rockets) or daily
 - Good precision, but **dispute over accuracy**, especially at shorter wavelengths, by as much as **factor of 4**
- **Late 1980s to the Present:**
 - Rockets, SOHO-SEM, SNOE, TIMED-SEE (Woods et al., Judge et al.)
 - Cadence improved to sub-daily at some wavelengths
 - Improved calibrations
 - narrowing of disputed irradiances to < 50%
 - Precisions of 1-30% (mostly < 10%)
 - **Accuracies 15-30%** for bright EUV lines (daily averages), larger for XUV broad bands

What Else Is Missing from Our Current Knowledge of EUV?

- Spectral information shortward of 27 nm
- Adequate time cadence to capture details of flare phases at EUV wavelengths (e.g., precursor, impulsive phase, gradual phase)
- How important are EUV flares (versus X-ray flares) for space weather?
- Are there reliable precursors for forecasting EUV irradiance and flare events?
 - Concurrent solar EUV and magnetic field images with solar EUV spectral irradiance measurements from SDO at high cadence are expected to revolutionize our understanding of EUV radiation and especially flare events



Example from Judith Lean

Flux emerging on east limb can be used to predict daily EUV irradiance.

The EVE Science Team

EVE team spans solar and terrestrial physics:

- **Principal Investigator**
 - Tom Woods, Univ. Colorado – LASP
- **Co-Investigators:**
 - Univ. Colorado: Frank Eparvier, Andrew Jones
 - Univ. Southern California: Darrell Judge, Leonid Didkovsky
 - Naval Research Lab: Judith Lean, Harry Warren, John Mariska, Don McMullin
 - MIT-LL: Greg Berthiaume
 - Virginia Tech: Scott Bailey
 - NASA-GSFC: Phil Chamberlin
- **Collaborators:**
 - NOAA-SWPC: Tim Fuller-Rowell, Rodney Viereck
 - Utah State Univ.: Jan Sojka
 - Space Env. Tech.: Kent Tobiska

What is EVE all about?

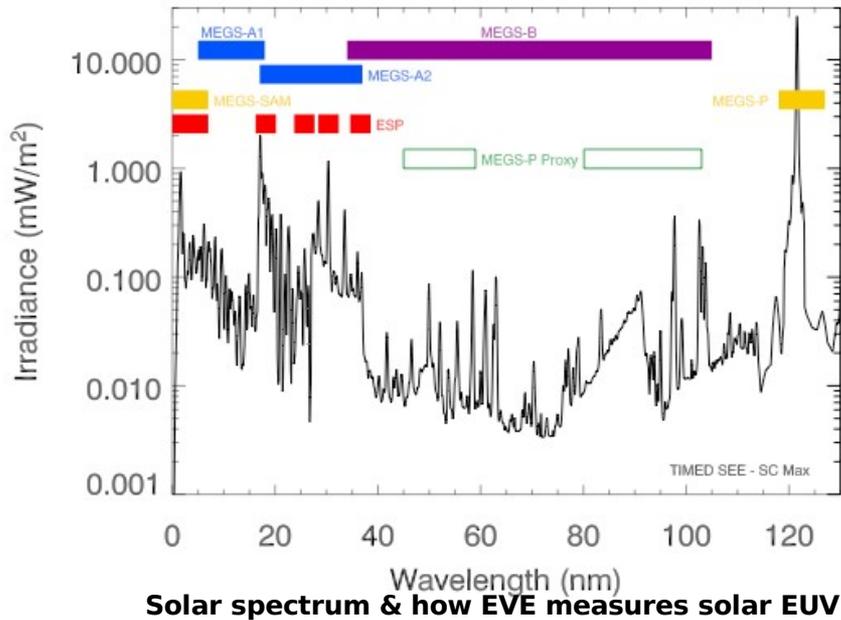
- **EVE Science Goal:**

- Specify and understand the highly variable solar extreme ultraviolet (EUV) electromagnetic radiation and its impacts on the geospace environment and the societal consequences

- **EVE Science Objectives:**

1. **Specify Irradiance:** *Specify the solar EUV irradiance and its variability on multiple time scales (seconds to years).*
2. **Understand Variability:** *Advance current understanding of how and why the solar EUV spectral irradiance varies.*
3. **Nowcast/Forecast:** *Improve the capability to predict (nowcast and forecast) the EUV spectral irradiance variability.*
4. **Geospace Impacts:** *Understand the response of the geospace environment to variations in the solar EUV spectral irradiance and the impact on human endeavors.*

EVE Instrument



- **The Key Components of EVE**
 - **EVE Optical Package (EOP)**
 - MEGS A + SAM (Solar Aspect Monitor)
 - MEGS B + P (Photometer Channel)
 - EUV Spectrophotometer (ESP)
 - **EVE Electrical Box (EEB)**
 - EVE processor spacecraft interface
 - CCD power converter/regulator
 - ESP power converters

EVE Metrics		
Power	Average (28V)	59.6 watts
Mass	Peak (28V)	136.9 watts 61.2 kg (132.4 lbs)
Data Rate	2 Kbps (engineering) 7 Mbps (science)	
Wavelength Range	0.1 nm – 105 nm	
Dimensions (EVE Envelope)	~39"L x 24"W x14"H	

How EVE Measures the EUV

- **Multiple EUV Grating Spectrograph (MEGS)**

- *at 0.1 nm resolution*

MEGS-A: 5-37 nm

MEGS-B: 35-105 nm

- *at 1 nm resolution*

MEGS-SAM: 0-7 nm

- *at 10 nm resolution*

MEGS-Photometers: @ 122 nm

- Ly- α Proxy for:

H I emissions at 80-102 nm

He I emissions at 45-58 nm

- **EUV Spectrophotometer (ESP)**

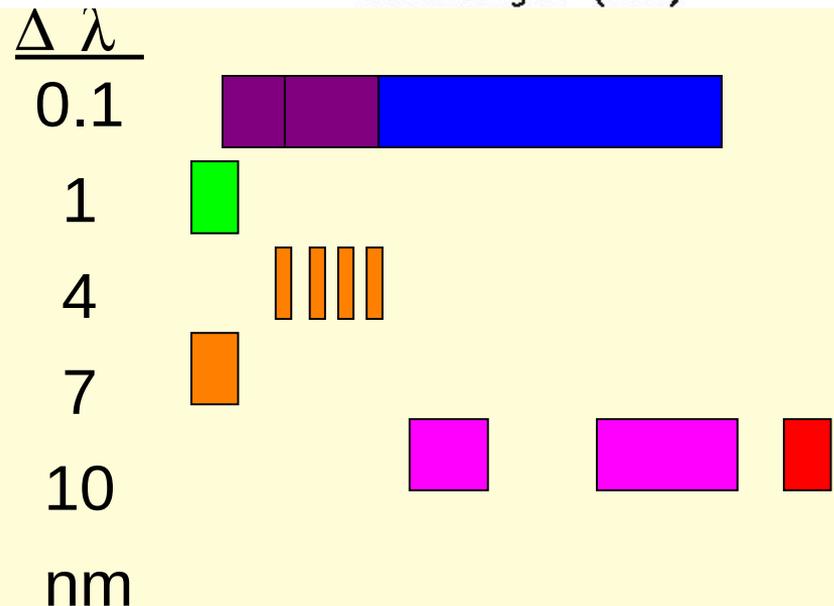
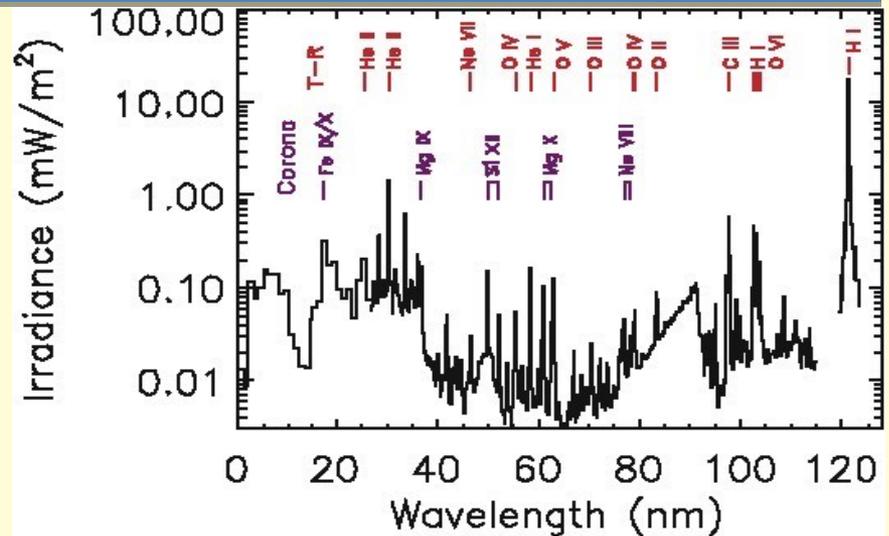
- *at 4 nm resolution*

17.5, 25.6, 30.4, 36 nm

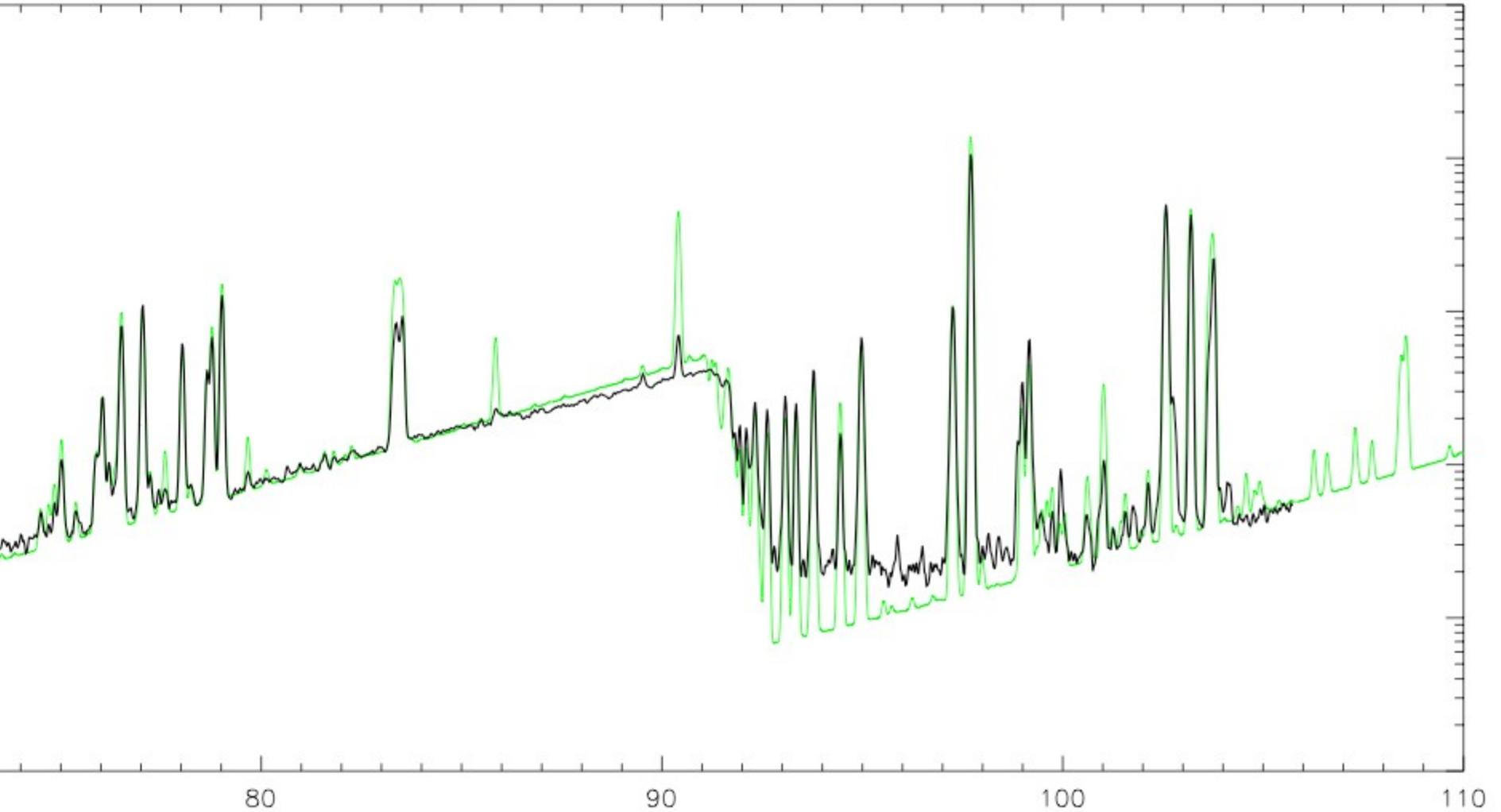
- *at 7 nm resolution*

0-7 nm (zeroth order)

- In-flight calibrations from ESP and MEGS-P on daily basis and also annual calibration rocket flights



Sample EVE Data



EVE Summary

- EVE will provide improved EUV observations:
 - Higher spectral resolution
 - Expanded wavelength range
 - Better accuracy and precision
 - Continuous, high time cadence
 - Fast turnaround of data for space weather uses
- EVE research:
 - Addresses sources of solar EUV variability
 - Improves models of solar irradiance for nowcasting and forecasting
 - Improves models of geospace response to EUV

<http://lasp.colorado.edu/eve>