# The EUV and X-ray Irradiance Sensors (EXIS): GOES-R and Beyond!

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# Outline

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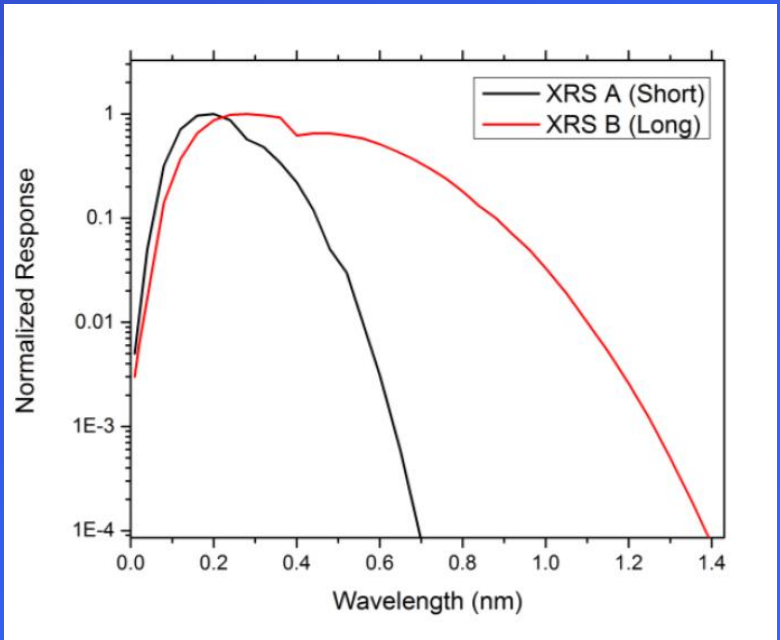
GEOSTATIONARY OPERATIONAL ENVIRONMENTAL SATELLITE R-SERIES
GOES R
NOAA ~ NASA

# GOES Irradiance History

- X-ray measurements began in 1974
  - Primary goal is to provide real-time warning for solar flares
  - Measures in two bands:
    - 0.05 – 0.4 nm (short)
    - 0.1 – 0.8 nm (long)



# XRS Calibration

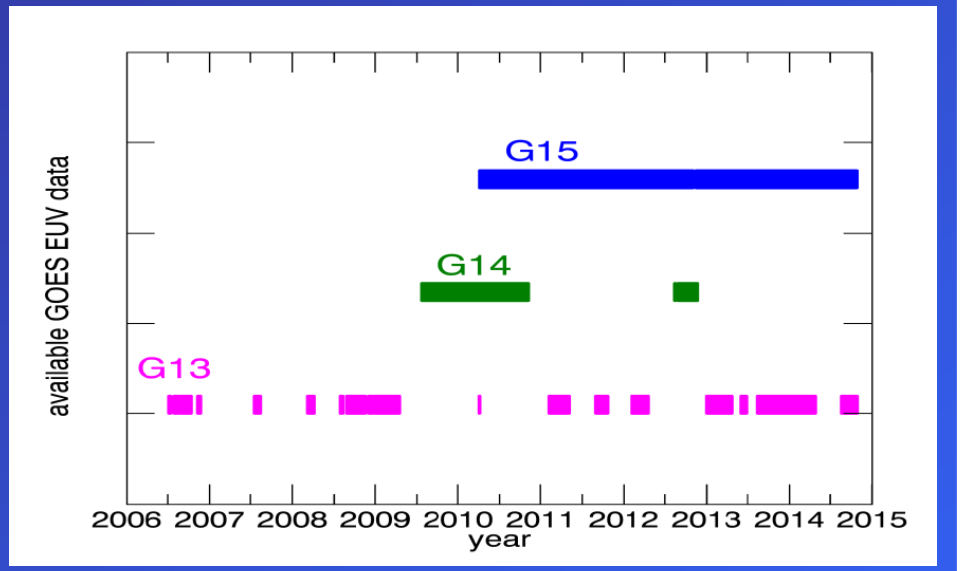
- GOES-8 and all later XRS measurements include a scaling factor to bring them into agreement with earlier measurements.
  - Short: 0.85
  - Long: 0.7

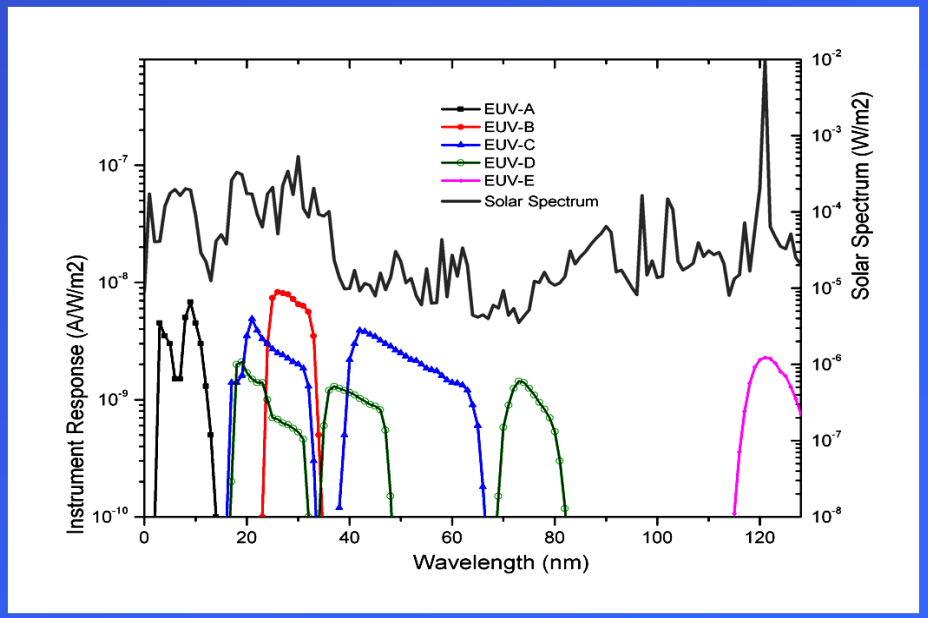
- Modern calibration shows that it was the earlier measurements that should have been re-scaled. Oops.

NOAA intends to create an archive without this scaling factor in the near future.

# GOES Irradiance History (2)

- Extreme Ultraviolet (N-O-P):
  - GOES 13 2006+ (Operational East)
  - GOES 14 2009+ (On-Orbit Storage)
  - GOES 15 2010+ (Operational West)



# Current GOES Data Products

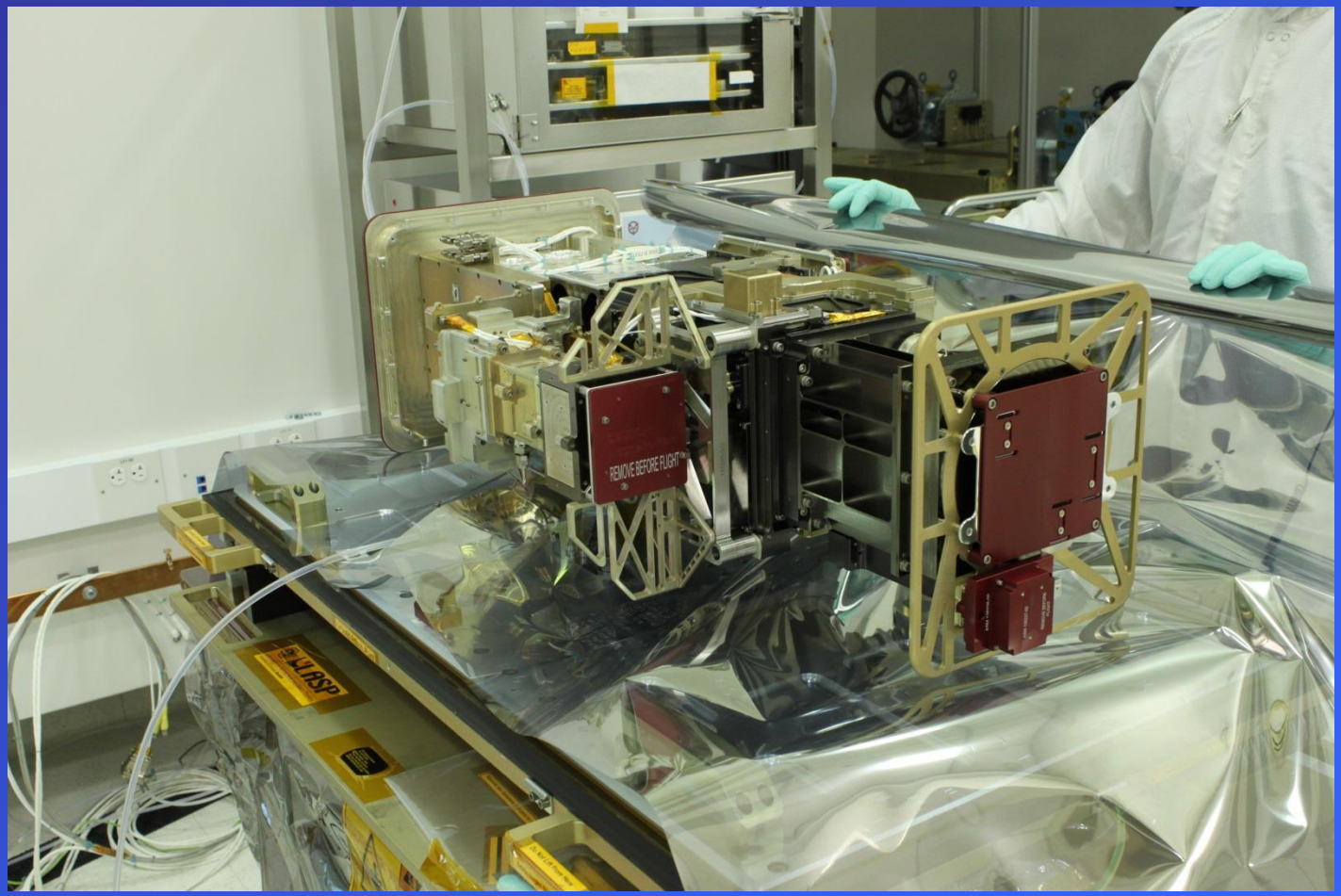
- XRS (GOES13 onwards)
  - 1 minute average
  - Raw data is 2 s cadence
- EUV
  - 1 minute average
  - Daily average
  - Raw data is 10 s cadence

Raw data for (2 or 3 s cadence) is available for all satellites back to 1976.

# EXIS

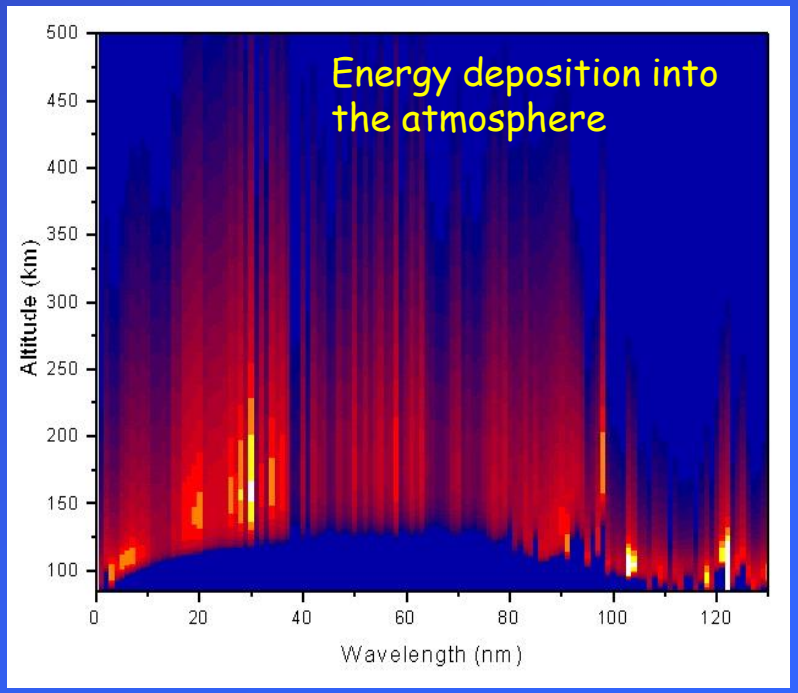
- Instruments for GOES-R series (RSTU)
- Designed and built by LASP
- XRS
  - Short and Long channels with improvements
- EUVS
  - Replaces 5 broadbands with 3 spectral regions

# Flight Model 1



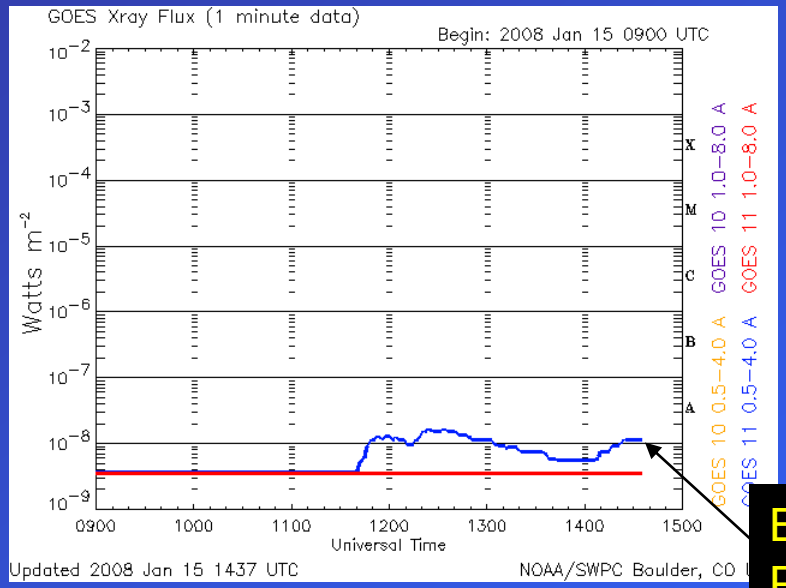
# XRS Improvements

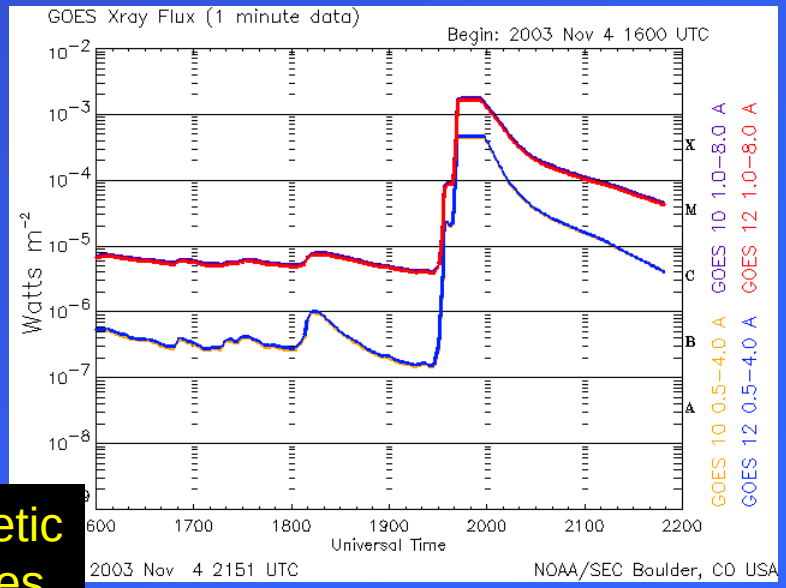
- Better dynamic range
  - No signal at solar min
  - Saturated by flares
- Flare location



# XRS Dynamic Range

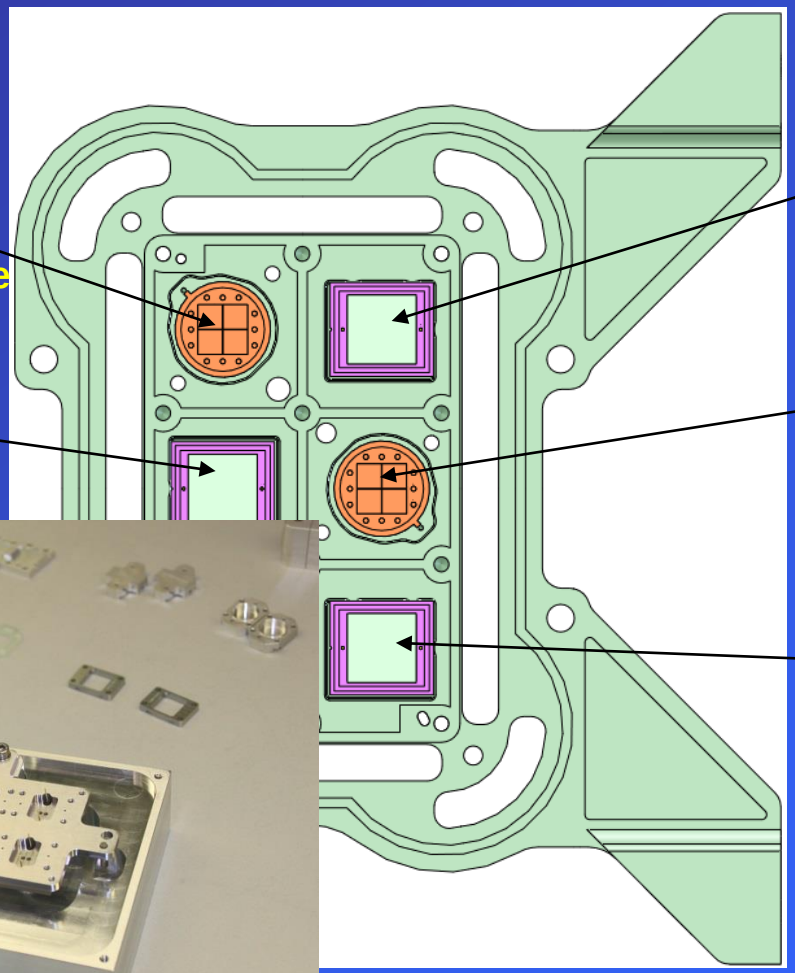
- Pre-GOES-R XRS: Ionization chamber instruments with limited dynamic range (solar min unresolved in noise and bright flares clipped)
- XRS for GOES-R: Solid state detectors that capture full dynamic range of solar variability




Energetic Particles

# XRS Bands: A=0.05-0.4 nm and B=0.1-0.8 nm



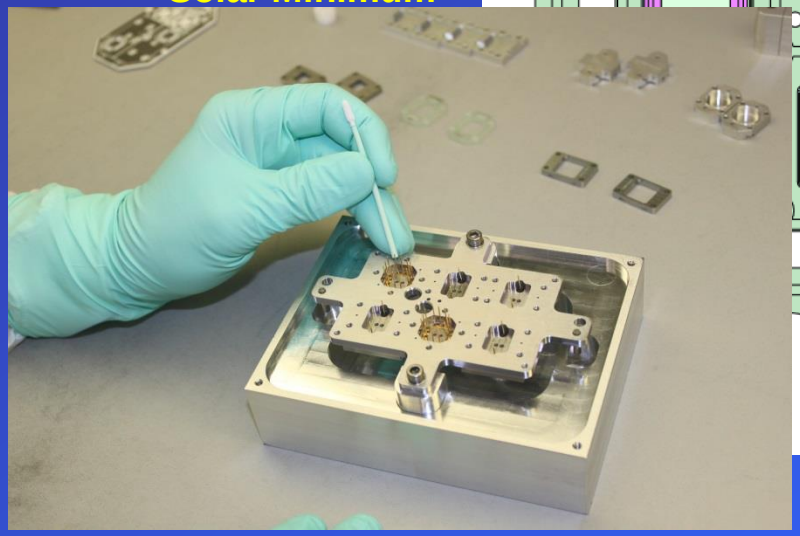
**A2:**
**PS6**
**Solar Maximum/Flare**
**λ = 0.05 to 0.4nm**

**A1:**
**AXUV50**
**Solar Minimum**
**λ = 0.05 to 0.4 nm**

**B1:**
**AXUV50**
**Solar Minimum**

**B2:**
**PS6**
**Solar Maximum/Flare**
**λ = 0.1 to 0.8nm**

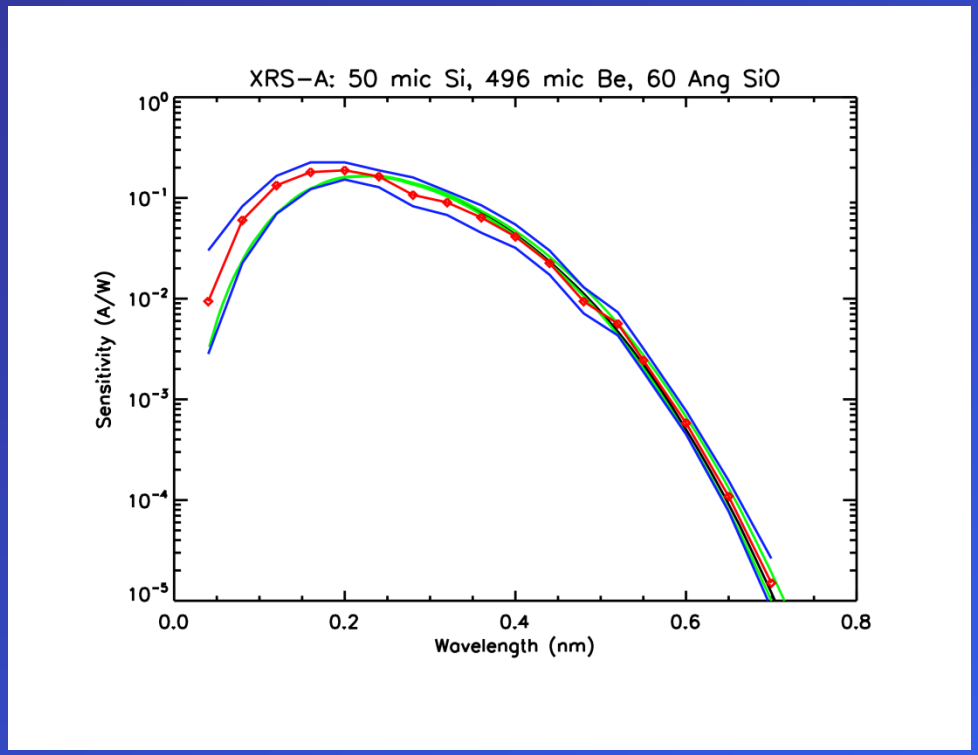
**Dark:**
**AXUV50**

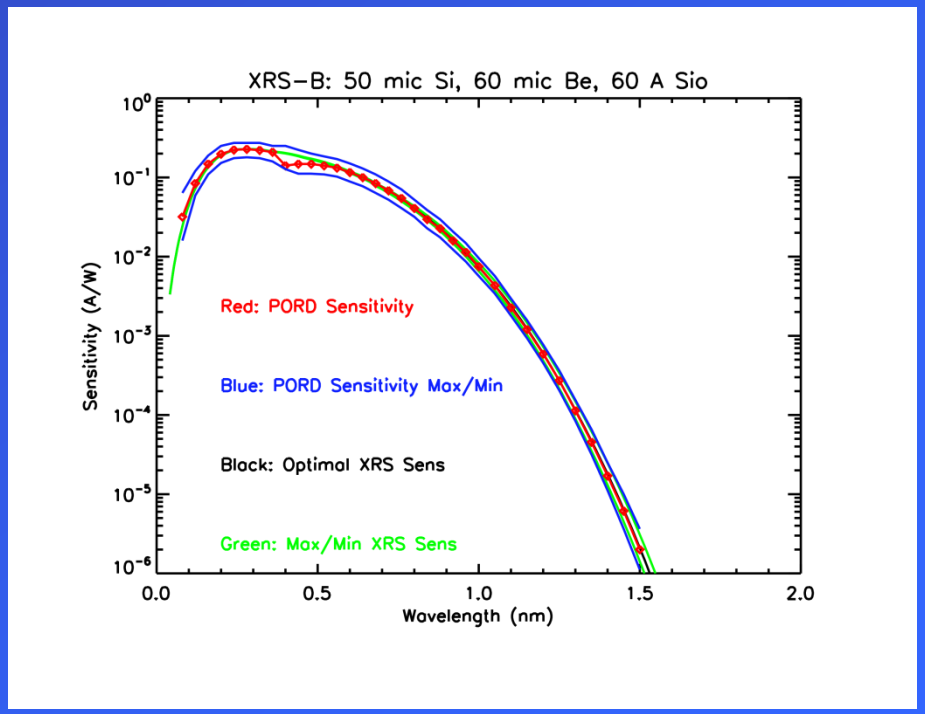


The two quad diodes will provide information on flare location.

# XRS Wavelength Response

Matching the spectral responsivity of the previous XRS instruments is one of the driving design requirements (called PORD requirements).

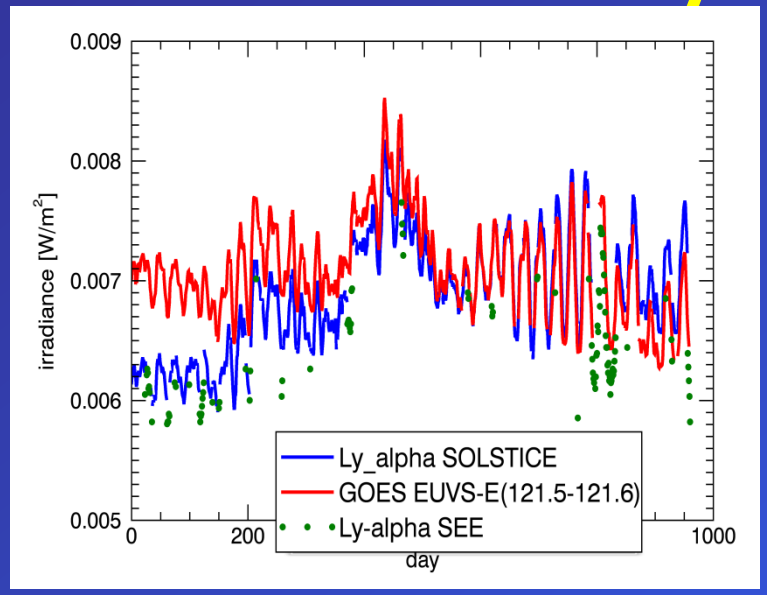


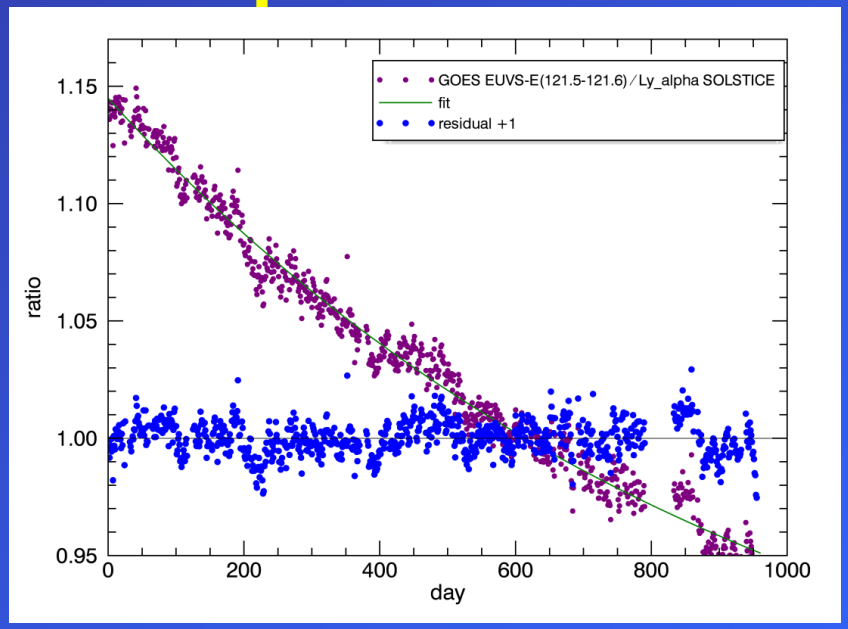



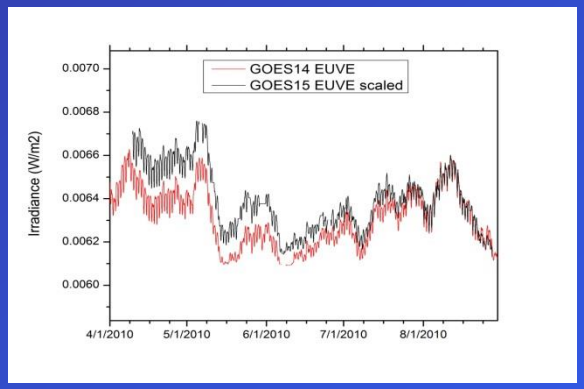
# EUVS Concept

- GOES N-O-P measured five broadbands, but did not include adequate degradation tracking.
- Measuring full spectrum would tax spacecraft resources.
- If best EUV proxies could be measured operationally, then a model spectrum could meet NOAA requirements.

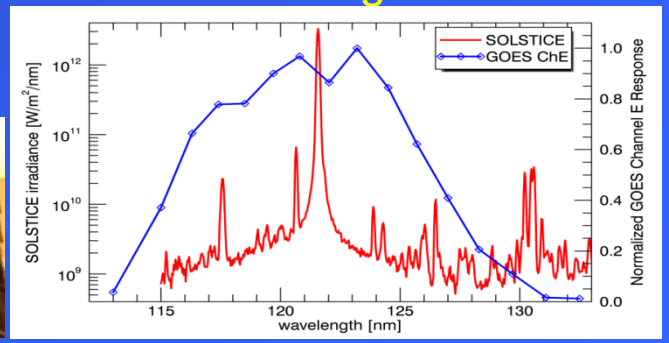
# GOES-15 Lyman alpha trends




Current NOAA analysis of EUV-E relies on SORCE SOLSTICE for long term trending.

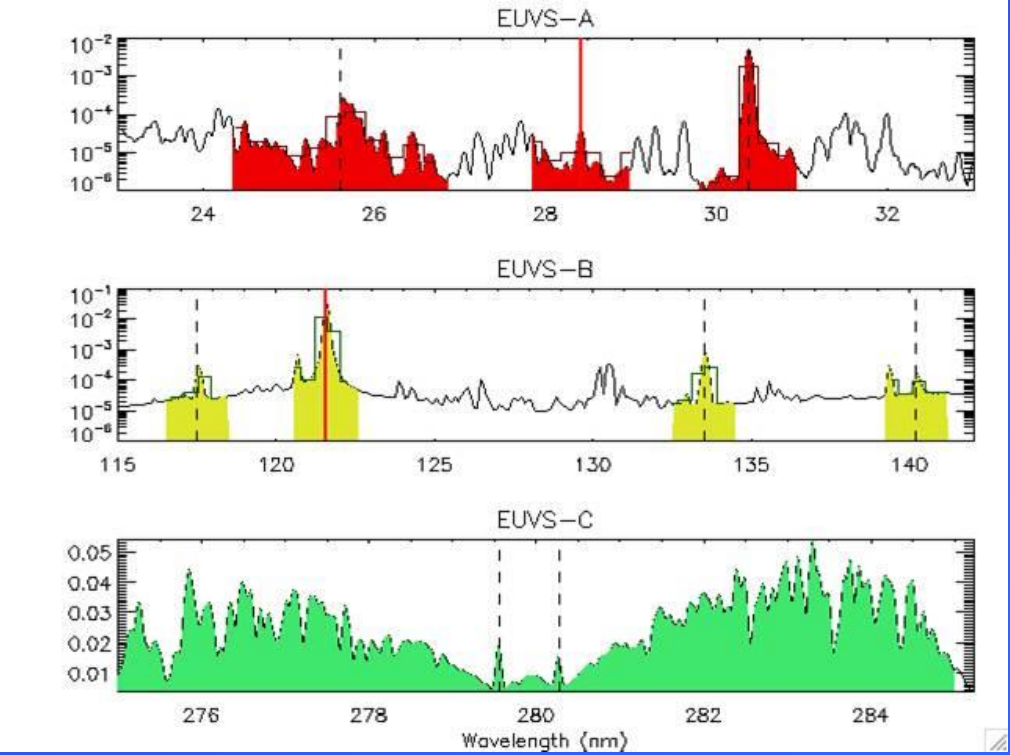


# EUVS Data Product

- Measure proxies that are used to describe the full EUV range (5-125 nm)
- Three EUVS channels will provide accurate proxies for the emissions from the chromosphere (CH), transition region (TR), and corona (COR)
  - XRS provides a fourth proxy for hot coronal continuum emissions during flares
  - EUVS Irradiance Model:
    - 5-125 nm spectral irradiance in 5-nm bins
    - 27-second cadence (measurements on 9-sec cadence)
    - <20% accuracy through mission

# EUVS Measurements

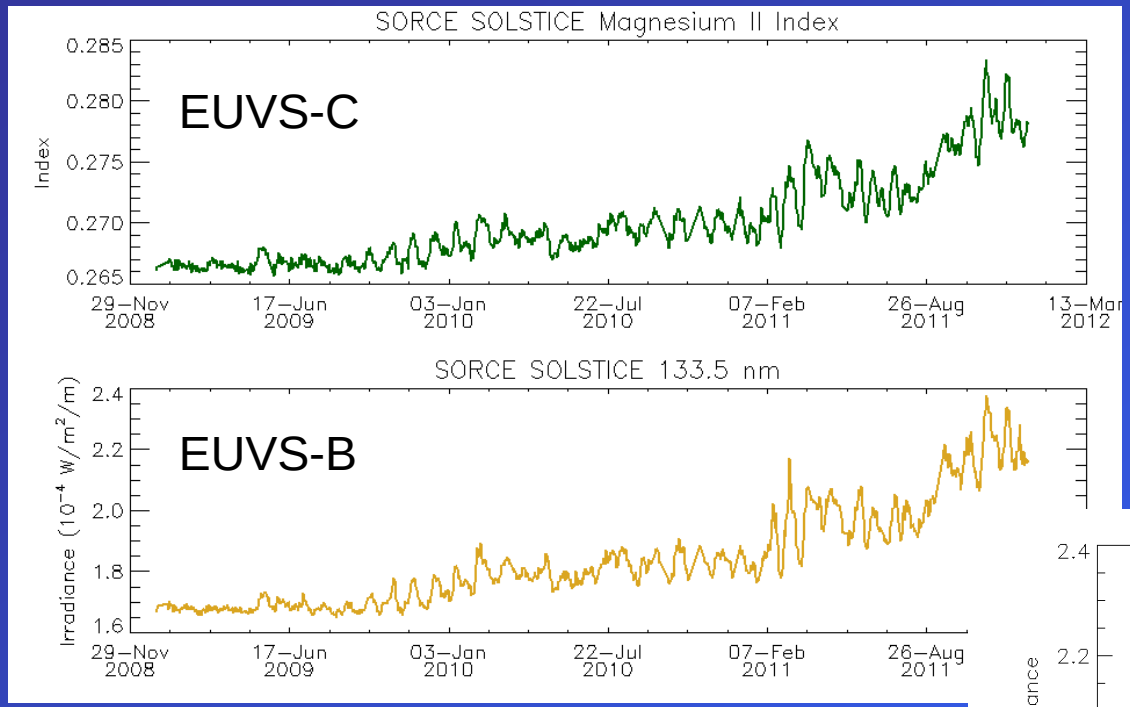
- **Primary Measurements Used in Spectral Model:**
  - **Chromospheric:** MgII C/W **(EUVS-C)**
  - **Transition Region:** Ly-alpha 121.6 nm **(EUVS-B)**
  - **Corona:** FeXV 28.4 nm **(EUVS-A)**
  - **Hot Coronal:** 0.1-0.8 nm **(XRS)**
- **Secondary Measurements Used for Degradation Tracking and Backup:**
  - **Chromospheric:** CIII 117.5 nm and CII 133.5 nm **(EUVS-B)**
  - **Transition Region:** SiIV/OIV 140.5 nm **(EUVS-B)**, HeII 30.4 nm and HeII 25.6 nm **(EUVS-A)**
  - **Hot Corona:** 0.05-0.4 nm **(XRS)**

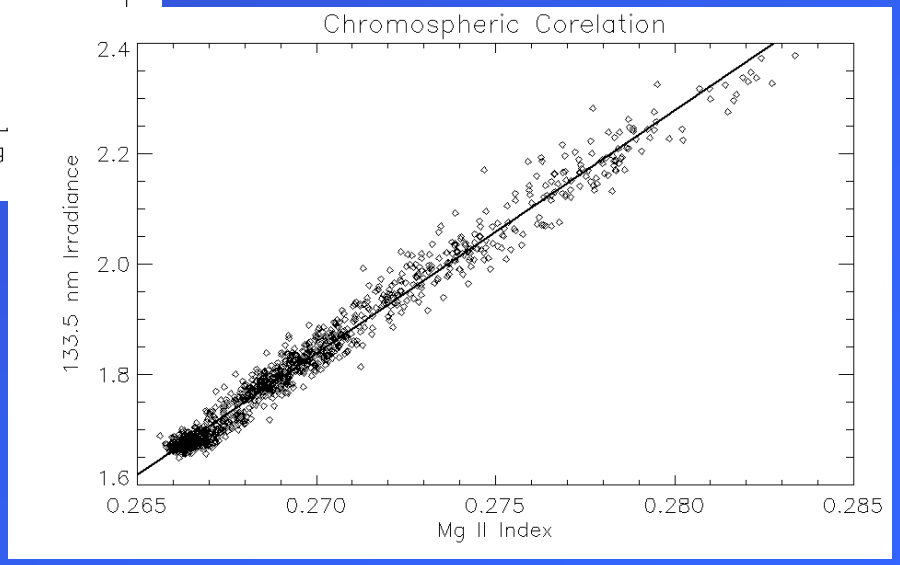


# EUVS Degradation Tracking

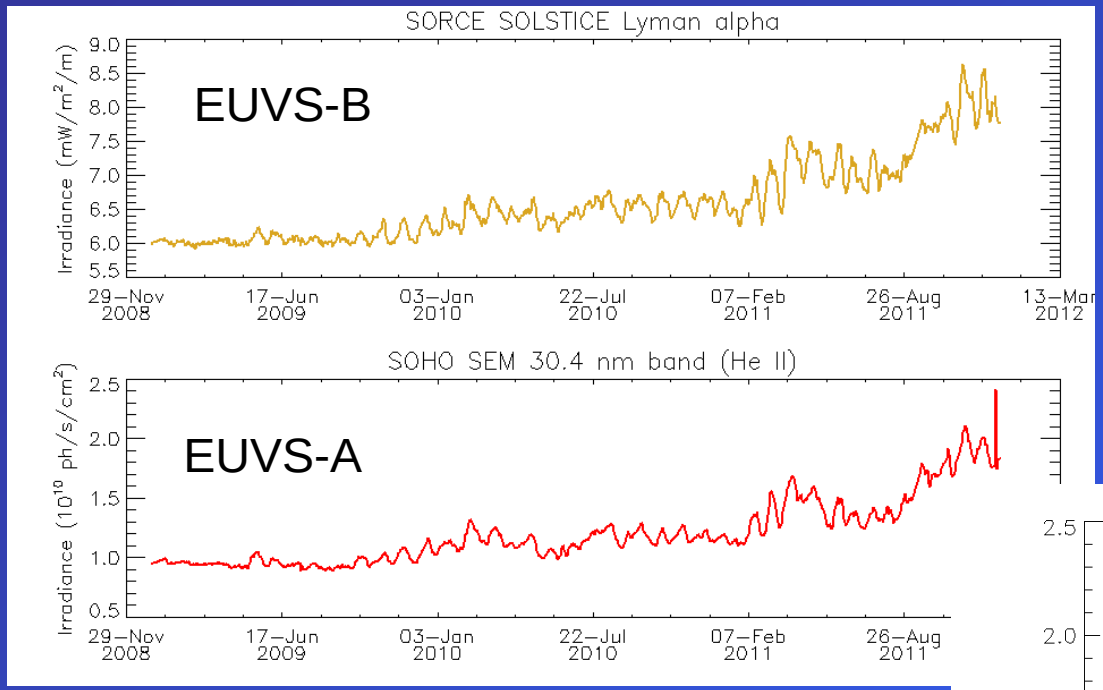
- Utilizes same modeling techniques as irradiance data product
- **First:** measure something degradation independent:
  - Measure (EUVS-C):
    - Mg II Index
- **Second:** measure things that vary like Mg II C/W with the same instrument that measures TR emissions.
  - Measure (EUVS-B):
    - C II (133.5 nm), C III (117 nm): Chromosphere
    - Si IV (141.5 nm) and H I (121.6 nm): Transition Region
  - Degradation tracked by comparing to Mg II C/W (EUVS-C) ove
- **Third:** measure things that vary like TR with the same instrument t
Coronal emission.
  - Measure (EUVS-A):
    - He II (30.4 nm), He II (25.6 nm): Transition Region
    - Fe XV (28.4 nm): Corona
  - Degradation tracked by comparing to HI and Si IV (EUVS-B) o
- Note: All channels have flatfield lamps to track pixel-to-pixel changes

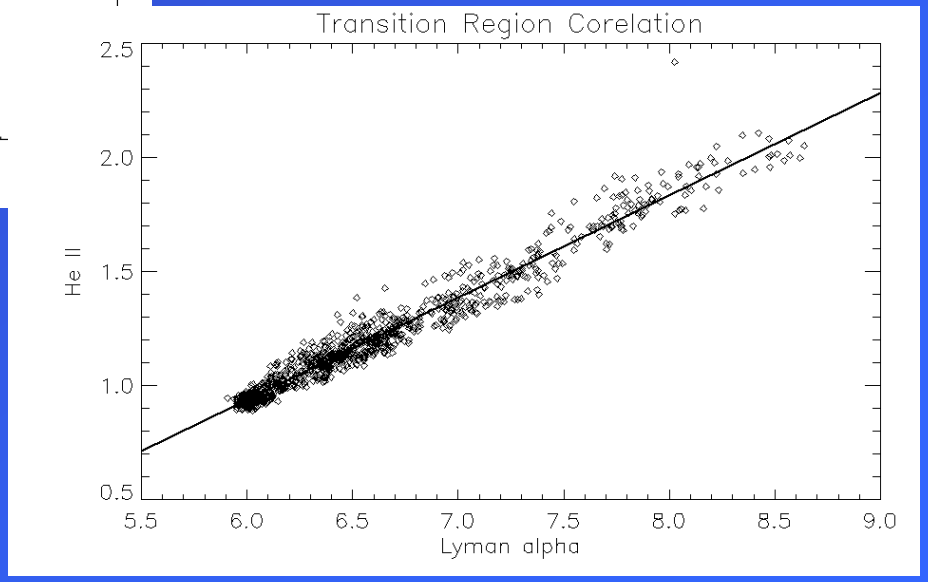
# Step One…


SORCE SOLSTICE Magnesium II Index
EUVS-C
Index
0.285
0.280
0.275
0.270
0.265
29–Nov 2008
17–Jun 2009
03–Jan 2010
22–Jul 2010
07–Feb 2011
26–Aug 2011
13–Mar 2012
SORCE SOLSTICE 133.5 nm
EUVS-B
Irradiance ($10^{-4}$ W/m$^2$/m)
2.4
2.2
2.0
1.8
1.6
29–Nov 2008
17–Jun 2009
03–Jan 2010
22–Jul 2010
07–Feb 2011
26–Aug 2011

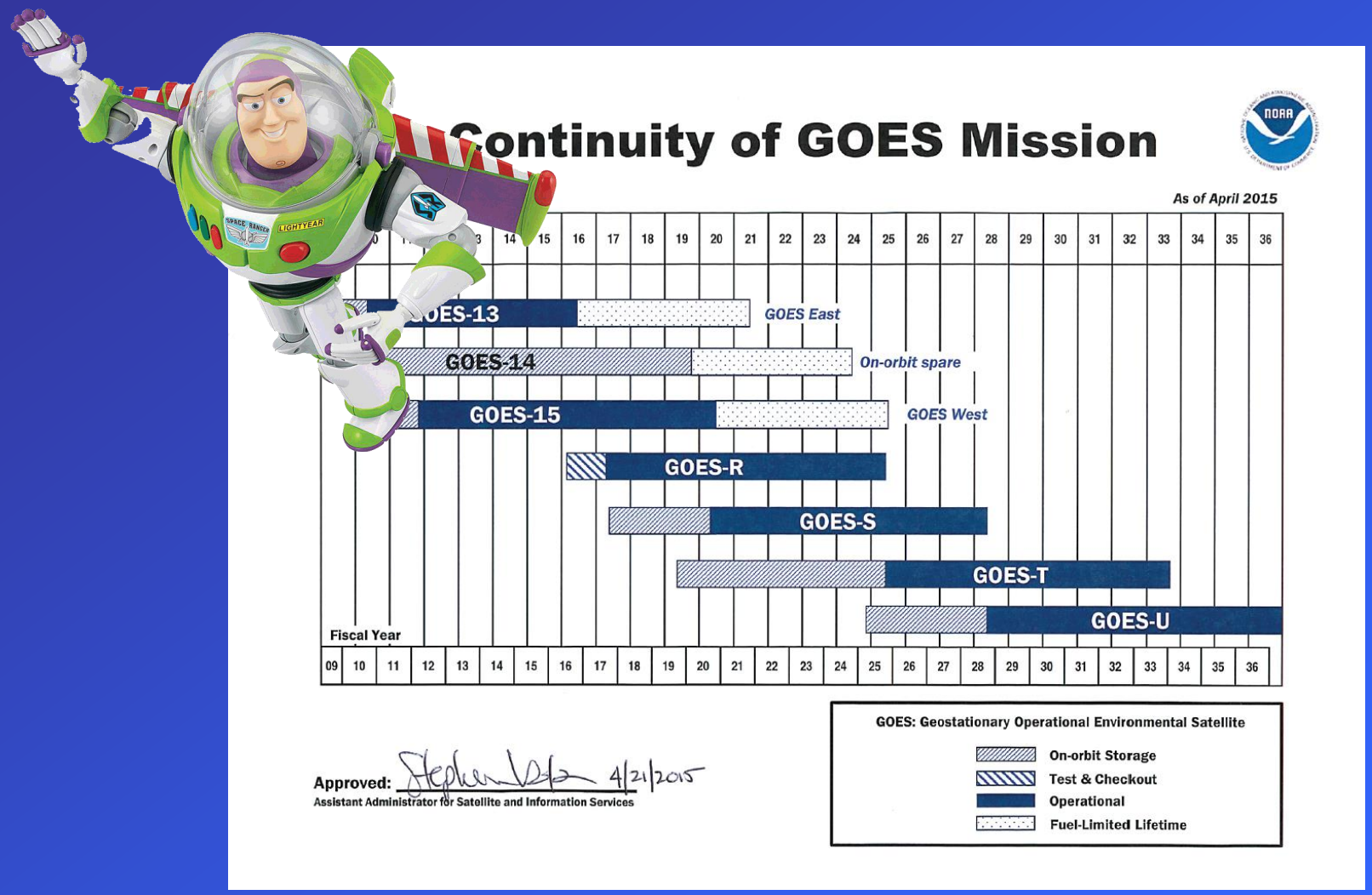

Chromospheric Corelation
133.5 nm Irradiance
2.4
2.2
2.0
1.8
1.6
0.265
0.270
0.275
0.280
0.285
Mg II Index

# Step Two


SORCE SOLSTICE Lyman alpha
EUVS-B
Irradiance (mW/m²/m)
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
29–Nov 2008
17–Jun 2009
03–Jan 2010
22–Jul 2010
07–Feb 2011
26–Aug 2011
13–Mar 2012
SOHO SEM 30.4 nm band (He II)
EUVS-A
Irradiance (10¹⁰ ph/s/cm²)
2.5
2.0
1.5
1.0
0.5
29–Nov 2008
17–Jun 2009
03–Jan 2010
22–Jul 2010
07–Feb 2011
26–Aug 2011


Transition Region Corelation
He II
2.5
2.0
1.5
1.0
0.5
5.5
6.0
6.5
7.0
7.5
8.0
8.5
9.0
Lyman alpha

# Current Schedule



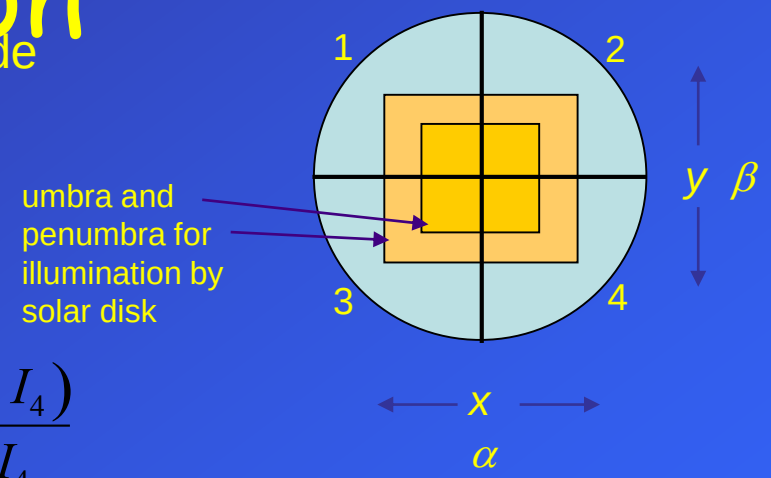
# The EXIS Nursery

## Any questions?

# Backup Slides

# How a quad diode senses position

- Quad position sensor consists of a quad diode with a square aperture in front.
- Ratios of illumination on each quadrant give the position of the light source in the FOV.
- Standard quad diode position equations:




$$x = \frac{(I_2 + I_4) - (I_1 + I_3)}{I_1 + I_2 + I_3 + I_4} \qquad y = \frac{(I_1 + I_2) - (I_3 + I_4)}{I_1 + I_2 + I_3 + I_4}$$

Where $I_i$ is the dark-corrected current in quadrant *i* of the diode, and *x* and *y* are the relative (normalized) position of the source (-1 to +1) in the FOV.

- The angular position in the FOV is given as:

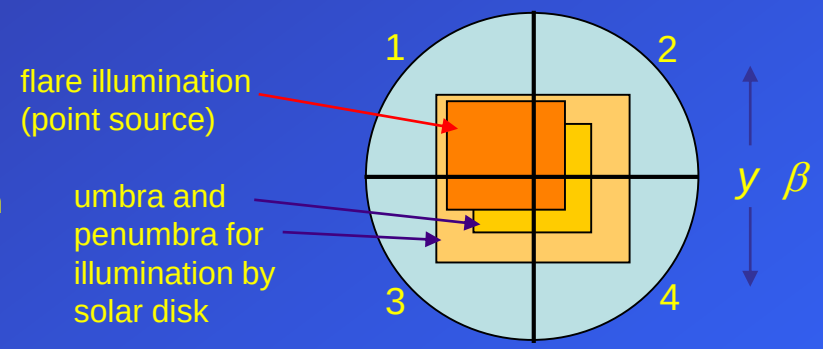
$$\tan\alpha = \frac{x \cdot W}{L} \qquad \tan\beta = \frac{y \cdot H}{L}$$

Where *L* is the distance from the aperture to the diode and W,H are the width and height of the aperture, respectively.

- **Note that the full irradiance measurement is preserved as the sum of the currents in all four quadrants: $I_{tot}=I_1+I_2+I_3+I_4$**

# XRS Flare Location

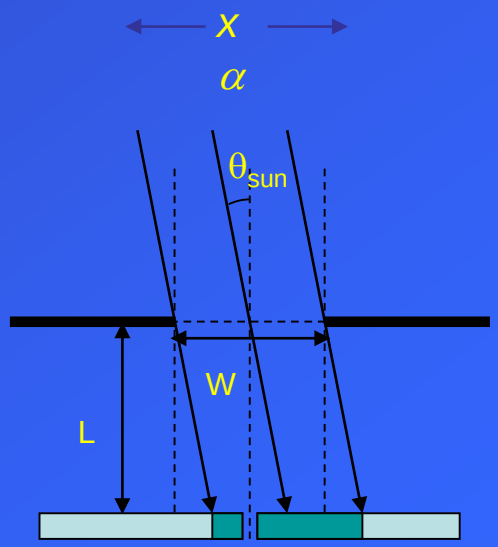
- Illumination on quad is from the background Sun plus the flare.
  - **We assume that the background Sun can be represented by the pre-flare measurement, which can be subtracted off.**
- Flare position equations become:




$$x_{Flare} = \frac{\left(\left(I_2 - I_{2,P}\right) + \left(I_4 - I_{4P}\right)\right) - \left(\left(I_1 - I_{1P}\right) + \left(I_3 - I_{3P}\right)\right)}{\left(I_1 + I_2 + I_3 + I_4\right) - \left(I_{1P} + I_{2P} + I_{3P} + I_{4P}\right)}$$

$$y_{Flare} = \frac{\left(\left(I_1 - I_{1,P}\right) + \left(I_2 - I_{2P}\right)\right) - \left(\left(I_3 - I_{3P}\right) + \left(I_4 - I_{4P}\right)\right)}{\left(I_1 + I_2 + I_3 + I_4\right) - \left(I_{1P} + I_{2P} + I_{3P} + I_{4P}\right)}$$

Where the subscript *P* denotes the quad diode measurements for the pre-flare Sun.




- The angular position of the flare in the FOV is given as:

$$\tan\alpha_{Flare} = \frac{x_{Flare} \cdot W}{L} \qquad \tan\beta_{Flare} = \frac{y_{Flare} \cdot H}{L}$$

# XRS Flare Location Performance

**Estimated FPS performance for single flare on disk of Sun:**

| Single Flare Magnitude | M1 Flare | X1 Flare | X10 Flare |
|---|---|---|---|
| **XRS-A2** | 5.7 arc-min | 0.57 arc-min | 0.06 arc-min |
| **XRS-B2** | 7.1 arc-min | 0.71 arc-min | 0.07 arc-min |

**Simple enhancement of converting XRS solar max diodes into quads meets new flare location requirement.**