Using a Reference Spectrum Model to Account for Bandpass Differences During Cross-Calibration of Solar EUV Instruments

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- If we standardize the method for the assumed solar spectrum, then cross-calibrating broadband irradiance measurements is a straightforward scaling exercise.
- The XPS Irradiance Model is a good option for spectral determination given its long heritage, thorough validation and intended reliance on broadband EUV inputs.

The XPS L4 Model aka SynRef

- The XPS L4 model is a synthetic reference spectrum model. Hereafter, called “SynRef” to avoid implied dependence on XPS.

- Solar spectrum is decomposed into Quiet Sun, Active Region and sub-daily (flare) components.

$$I_{measure} = I_{day\_min} + I_{SubDaily} \tag{1}$$

$$I_{day\_min} = f_{QS} \int_0^\infty R(\lambda) E_{QS}(\lambda) d\lambda + f_{AR} \int_0^\infty R(\lambda) E_{AR}(\lambda) d\lambda \tag{2}$$

$$I_{SubDaily} = f_{SD} \int_0^\infty R(\lambda) E_{SD}(\lambda, T) d\lambda \tag{3}$$

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Will Only Focus On Daily Time-Scale Variability Here

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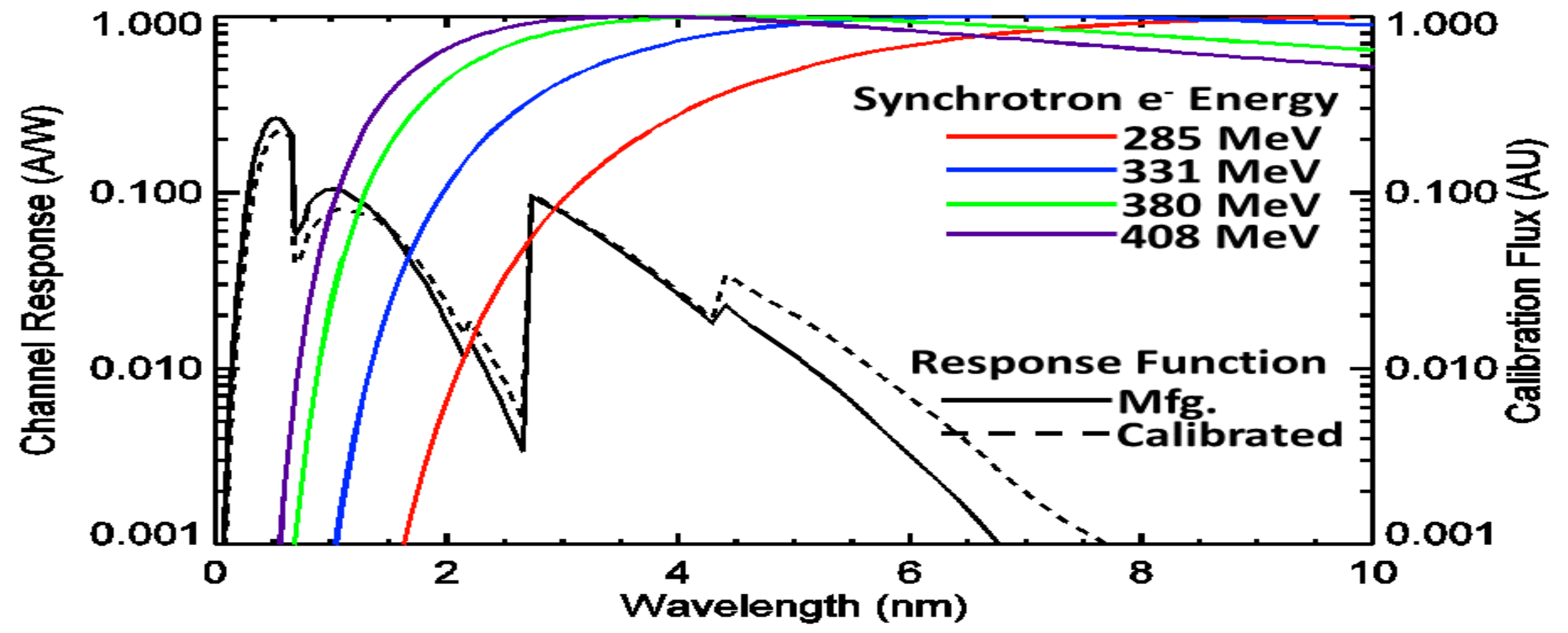
The Instrument Response Function, R(λ)

- The instrument response function is calibrated during pre-flight testing.
- Synchrotron radiation generally used in two ways:
  - Coupled with grating to isolate wavelengths over region of interest
    - Assumes grating calibration is known
  - Using multiple beam energies to constrain response function model
    - Assumes response function model is known.

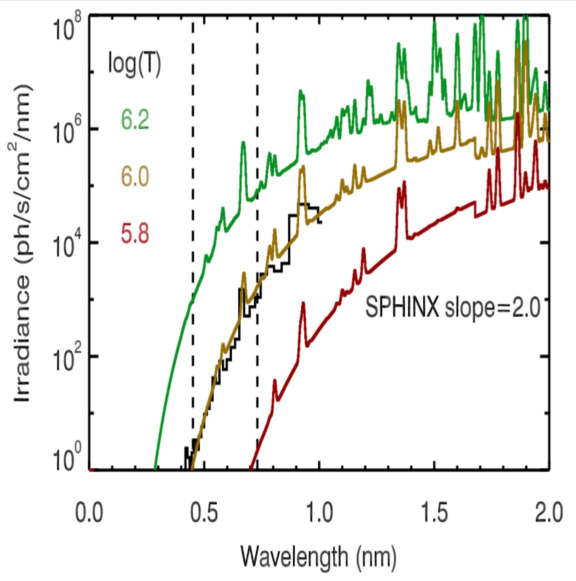


The Model Reference Spectra, $E_{QS}(\lambda)$ and $E_{AR}(\lambda)$

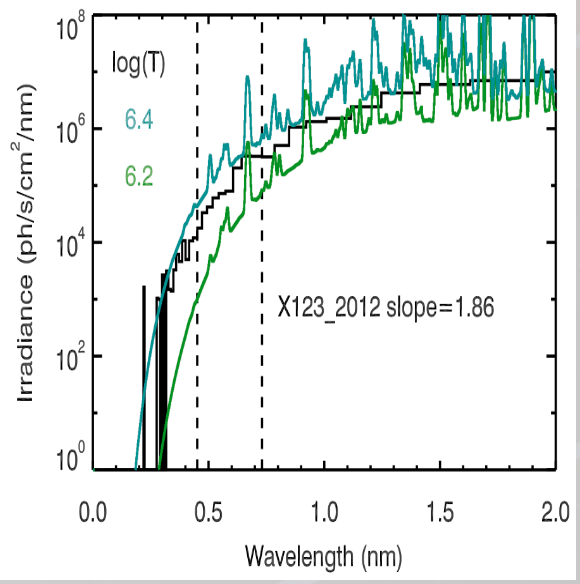
- Reference spectra derived from CHIANTI model, constrained by spectral measurements.
  - <6.5 nm: SPHINX and X123 rocket measurements
  - >6.5 nm: EVE rocket measurements

Soft X-Ray Constraints

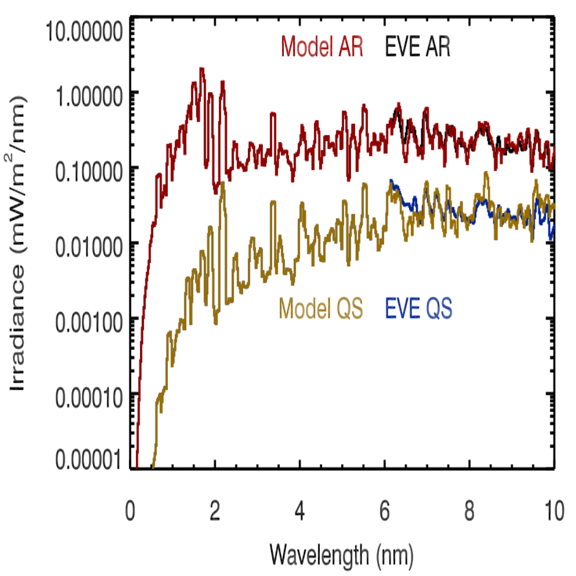
QS Model, T=10^6 K



AR Model, T=$10^{6.4}$ K



EUV Constraints



SynRef Model Implementation

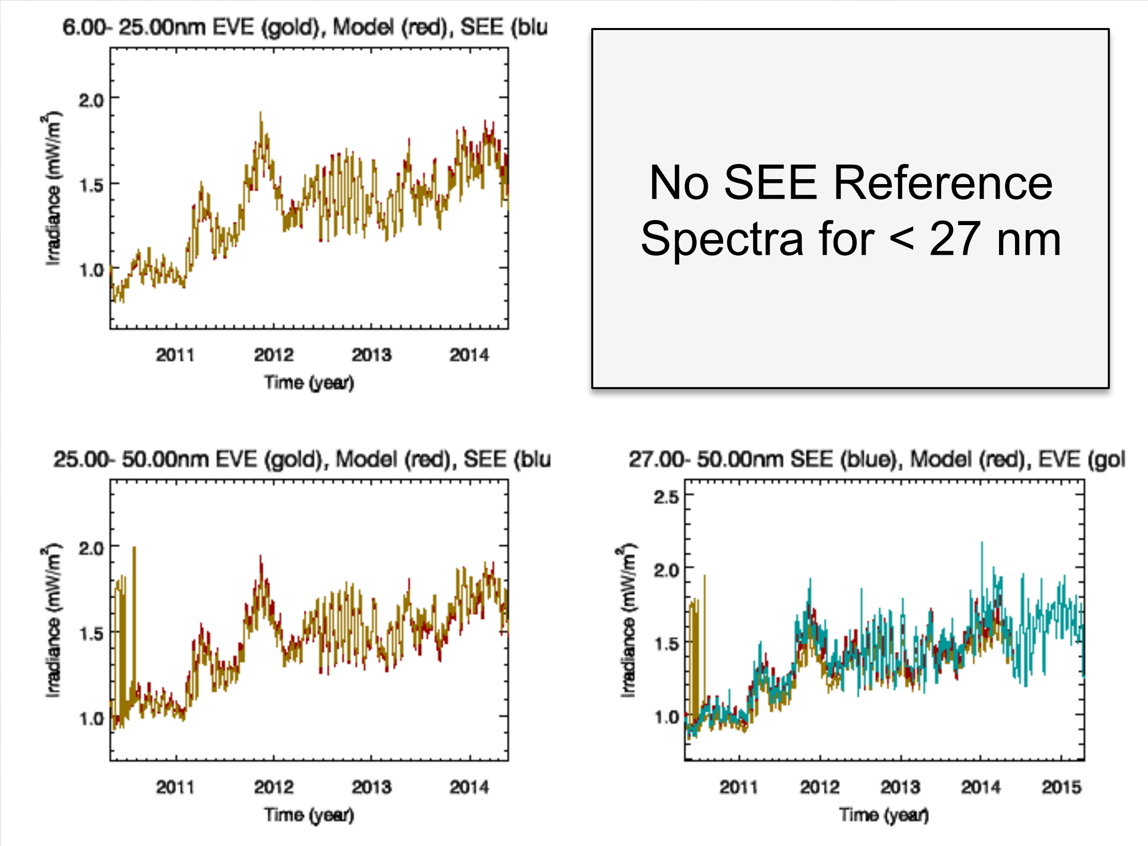
$$I_{day\_min} = f_{QS} \int_0^\infty R(\lambda) E_{QS}(\lambda) d\lambda + f_{AR} \int_0^\infty R(\lambda) E_{AR}(\lambda) d\lambda$$

- Knowns
  - I_{day_min} is the measurement
  - $R(\lambda)$, $E_{QS}(\lambda)$, and $E_{AR}(\lambda)$ are predetermined/fixed
- Unknowns
  - f_{AR} and f_{QS}
- Algorithm
  - Assume $f_{QS}=1$
  - Solve for f_{AR}
  - Reconstruct spectrum

$$E_{day\_min} = f_{QS} E_{QS} + f_{AR} E_{AR}$$

SynRef Validation

- SEE/SORCE XPS Model validated with SEE measurements in Woods et al. Solar Physics 250 (2008)
- Model with updated reference spectrum agrees wells with EVE over broad bands.



No SEE Reference Spectra for < 27 nm

One more assumption...

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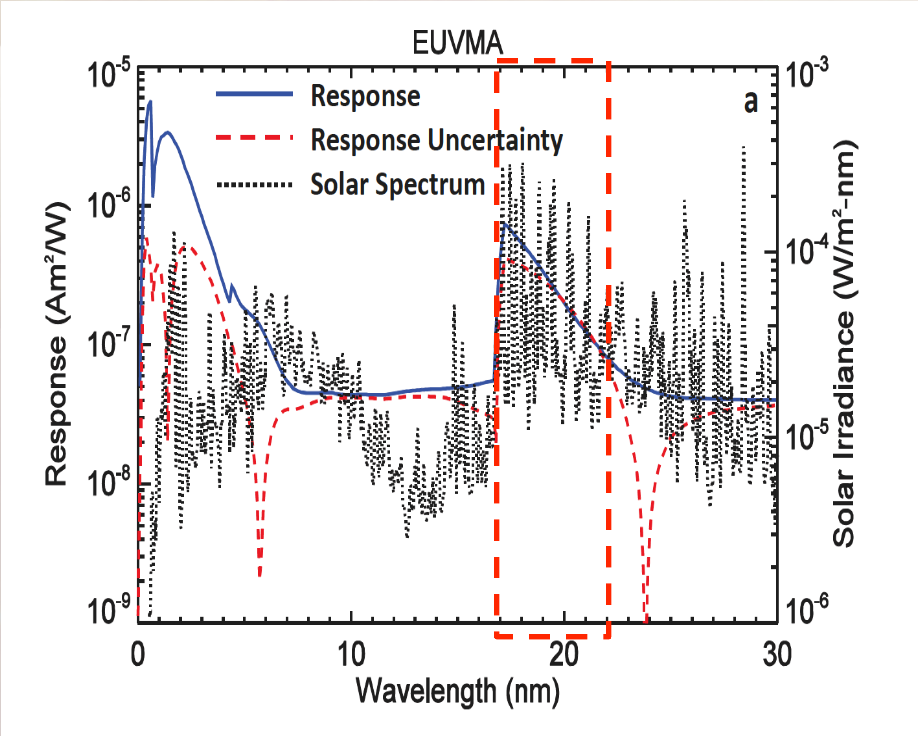
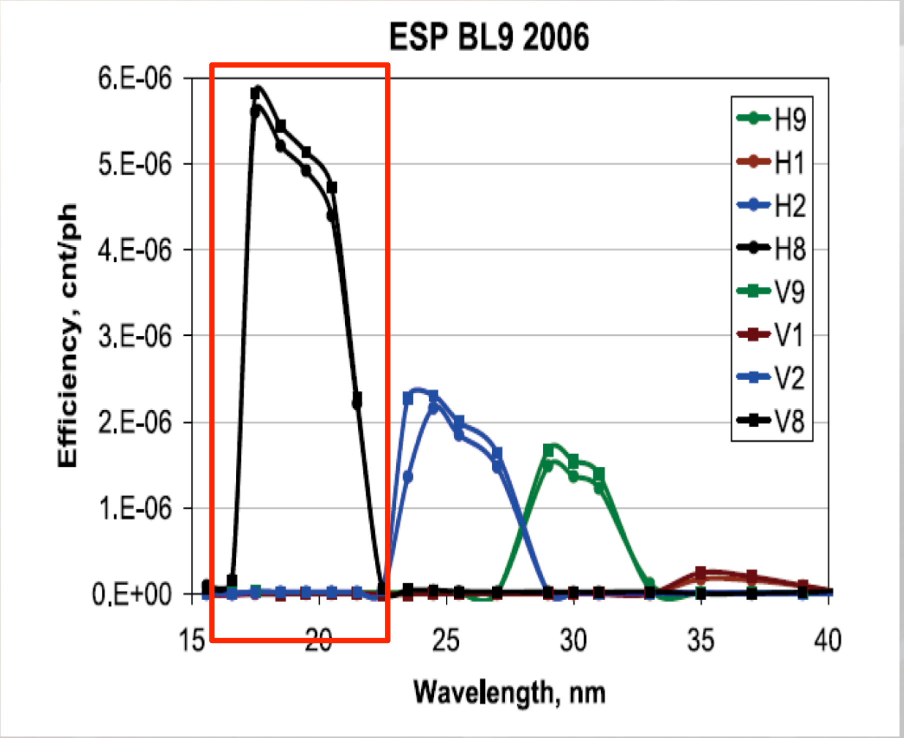
- Model inherently assumes that the reference spectra and response function is on the same absolute scale (in this case, that of SDO/EVE).

$$I_{day\_min} = f_{QS} \boxed{a_{cal}} \int_0^\infty R(\lambda) E_{QS}(\lambda) d\lambda + f_{AR} \int_0^\infty R(\lambda) E_{AR}(\lambda) d\lambda$$

- In the case where there are calibration differences, need to include a scaling factor to put the calibrations of R(λ) and E(λ) on the same scale.

Sample Application: EUVM vs ESP 17-22nm Bands



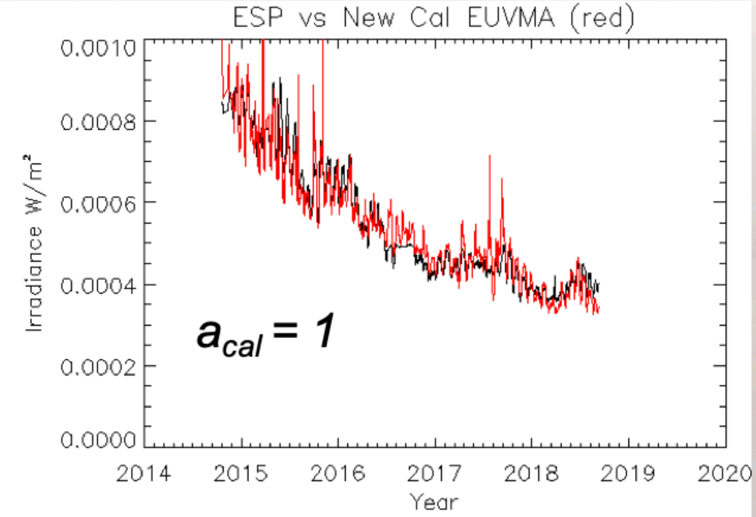


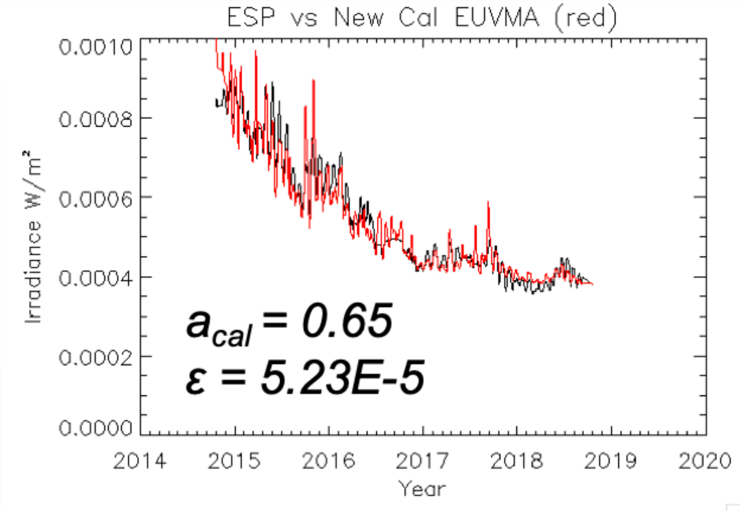
$$I_{day\_min} = f_{QS} a_{cal} \int_0^\infty R(\lambda) E_{QS}(\lambda) d\lambda + f_{AR} \int_0^\infty R(\lambda) E_{AR}(\lambda) d\lambda$$

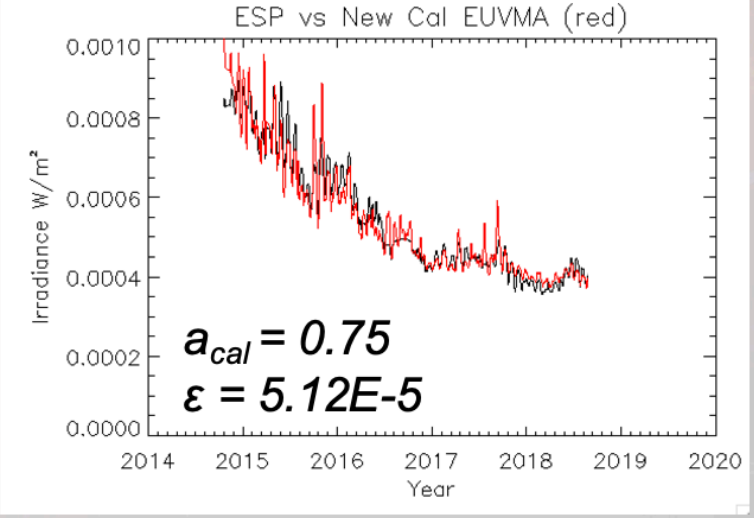
Methodology:

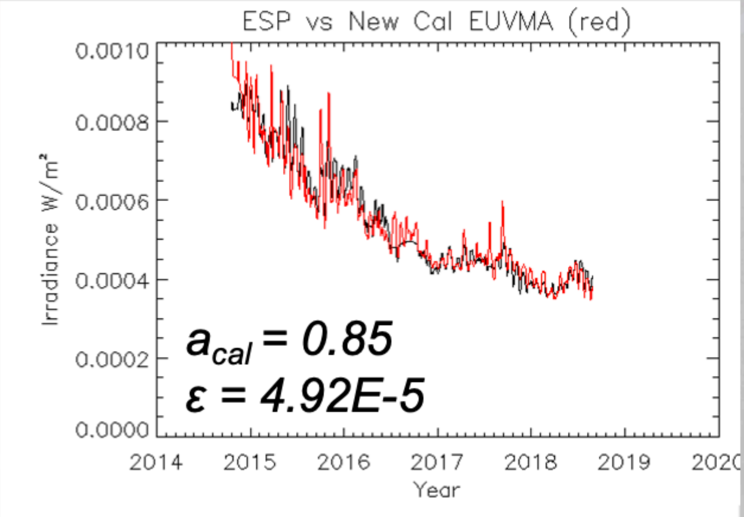
1. Compute SynRef spectrum from EUVM A.
2. Scale EUVM A counts by fraction of spectral irradiance from 17-22 nm.
3. Find fit between scaled counts and ESP 17-22 nm band.
4. Adjust a_{cal} to optimize EUVM A and ESP agreement.

15% Adjustment Yields Best Agreement









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