Adapted from Wei Liu's slides for the November 02, 2018, SDO Workshop

Presented by Paul Boerner

0. Overview

AIA Sensitivity Trending

AIA effective area calibration is implemented as follows:

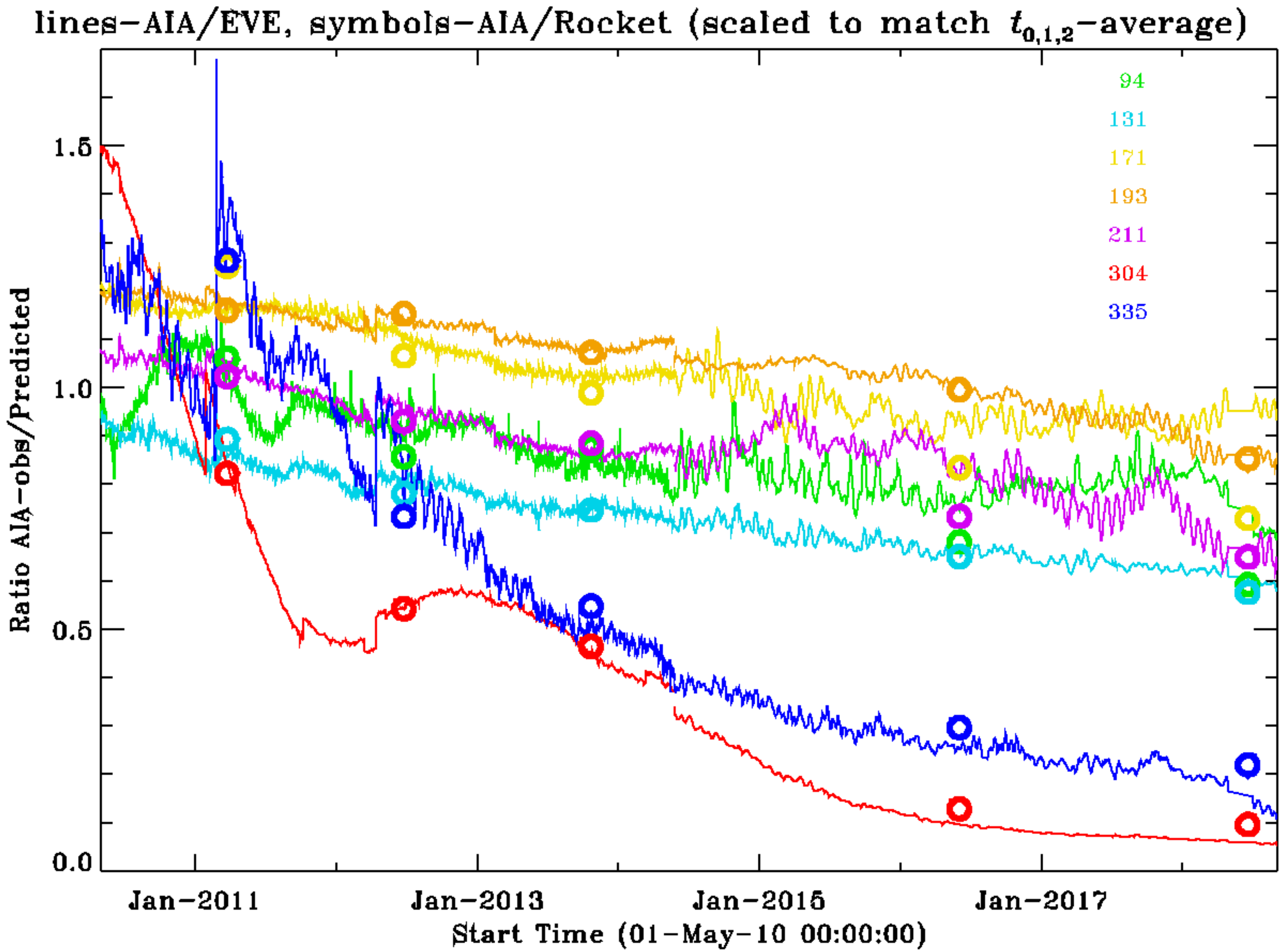
- The bandpass shape is based on pre-flight measurements of instrument components (mirrors, filters, CCD, etc.)
- A scalar correction factor calculated to ensure good agreement with a full disk irradiance spectrum (esp. from SDO-EVE, but can also use inputs from TIMED, SORCE, EVE rocket, or model spectra)

AIA thermal response calibration uses the effective area and contribution functions calculated with CHIANTI

In this presentation:

1) Review the status of AIA-EVE cross-calibration (this is mostly familiar material from the last SDO Workshop)
2) Ask some questions about how we could do things better (we have some ideas, but would like to get input from others this week)

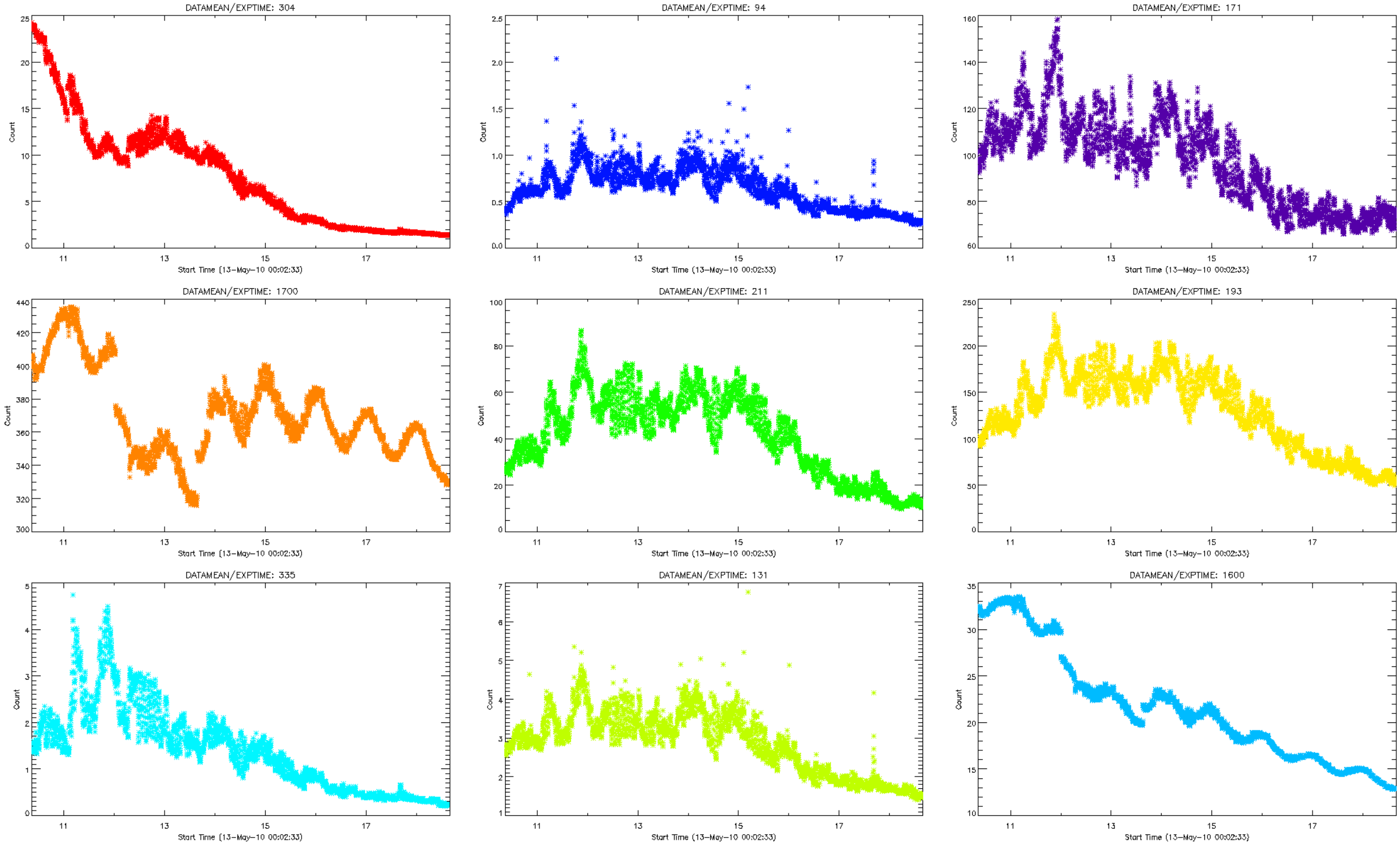
AIA Sensitivity Trending



1. Introduction

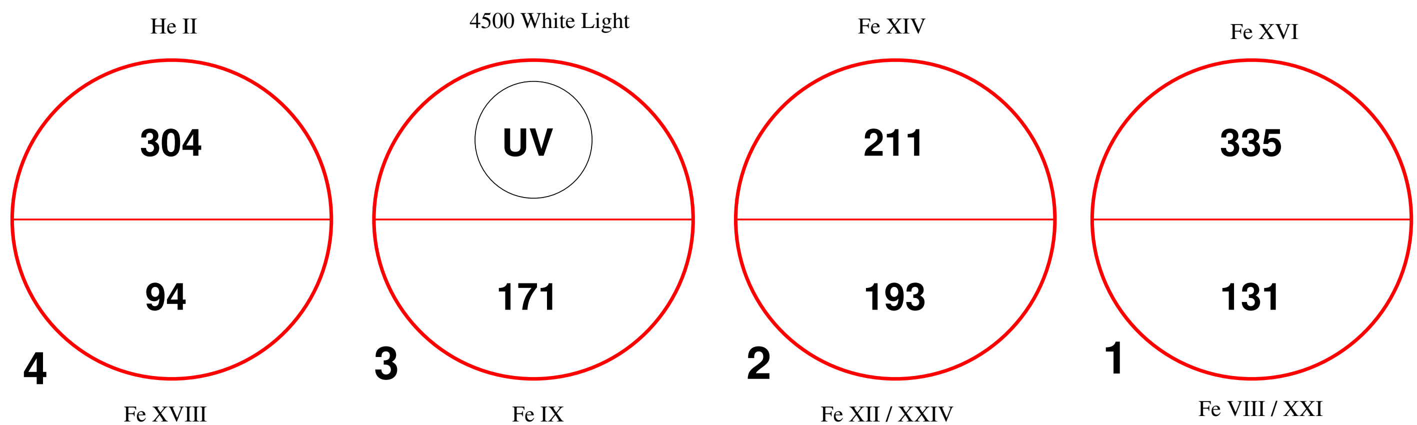
Sensitivity Trends (EUV+UV)

- Straight AIA average count rate (DATAMEAN/EXPTIME), degradation mixed with annual (Sun-Earth distance) and solar cycle variations.



Throughput Calibration: General Status

- **Possible Sources of degradation (in particular 304 & 335 Å):**
  - 1. Overcorrection of EVE degradation
  - 2. Removable Molecular Contamination (volatile, e.g., hydrocarbons) on the AIA CCD; bakeout can help with this.
  - 3. CCD burn-in by exposure to photons
  - 4. Non-removable contamination
  - 5. Degradation of other telescope components
- **Short Wavelength (EUV) Channels**
  - Previously relied on EVE/MEGS-A up to 2014-May-26
  - Now using FISM model irradiance as a proxy of MEGS-A measurements (*details below*)
- **Long Wavelength (UV) Channels**
  - Relied on TIMED/SEE and SORCE/SOLSTICE



2. Methodology

Sensitivity Trends: Basic Approach (EUV)

- AIA EUV channel full-disk band irradiance (B_{obs}) compared with band irradiance (B_{pred}) computed using EVE spectra (**EVL_L2_*** files, i.e. the band irradiance data product, not the spectral data) and AIA wavelength response functions.

$$B_{\mathrm{pred}} = \int_0^\infty E_{\mathrm{EVE}}(\lambda)\, R(\lambda)\, \mathrm{d}\lambda\,.$$

$$F_{\mathrm{norm}} = \frac{B_{\mathrm{obs}}}{B_{\mathrm{pred}}}\,.$$

Trending with FISM model since 2017-Nov-30

Summary: AIA team has been using FISM-1 to replace EVE spectra after 05-2014, with corrections to account for EVE/FISM-1 discrepancies

(This may not be the best long-term plan)

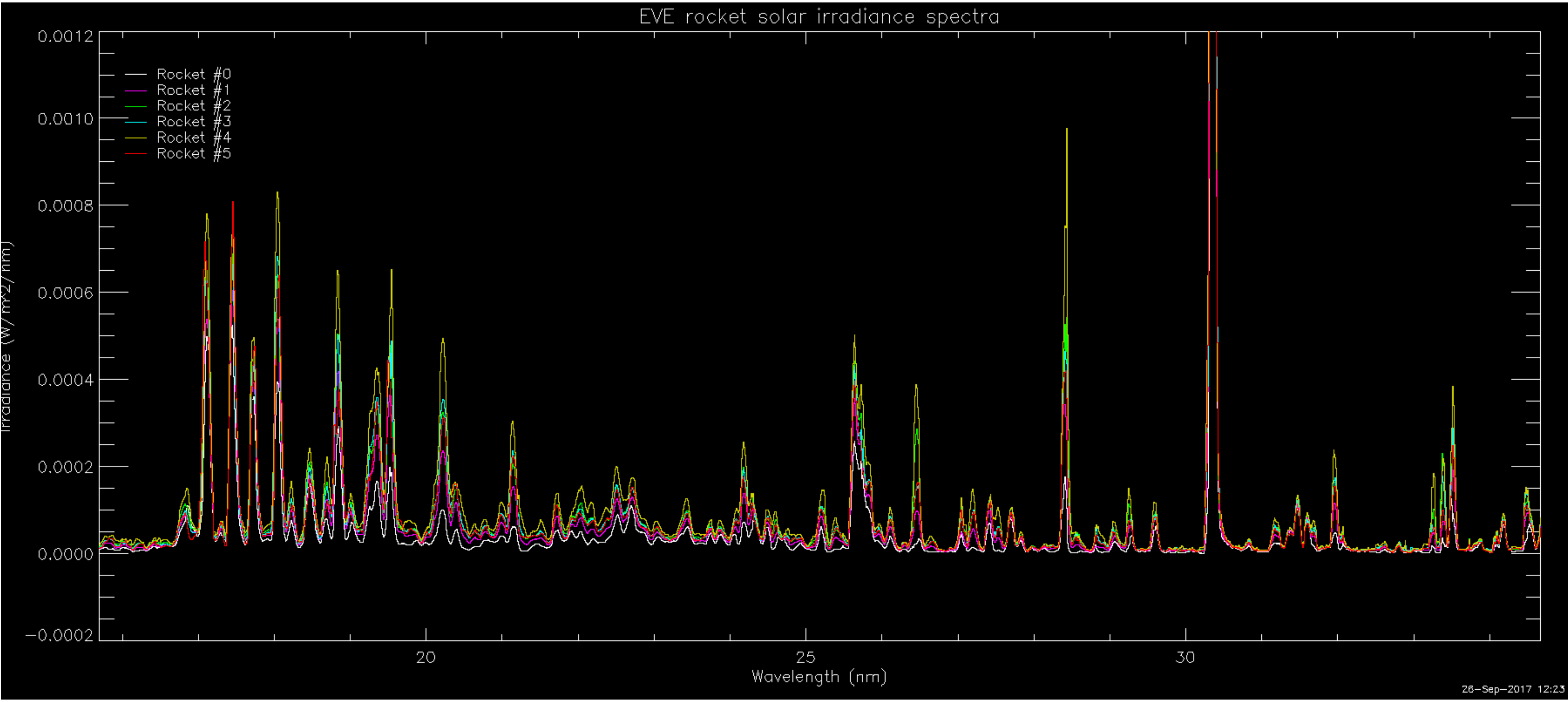
Reasons to account for differences between AIA/EVE and AIA/FISM ratios:

1. The FISM model spectra are modeled (with certain assumptions), not directly measured or observed.
2. The FISM model spectra have a coarse resolution of 1 Å (instead of 0.1 Å from EVE/MEGS-A or EVE sounding rockets). See next two pages for an example, where FISM model underestimate the solar irradiance, especially around the Fe IX 171 Å line.
3. In previous versions with AIA/EVE ratios, the data was sampled (the time window for obtaining the corresponding AIA data is [–100, 120] seconds around the time of the EVE data point), instead of daily average here, which includes varying solar conditions such as flares that can cause further undesired deviations.

Trending with FISM model since 2017-Nov-30

Reasons to account for differences between AIA/EVE and AIA/FISM ratios:

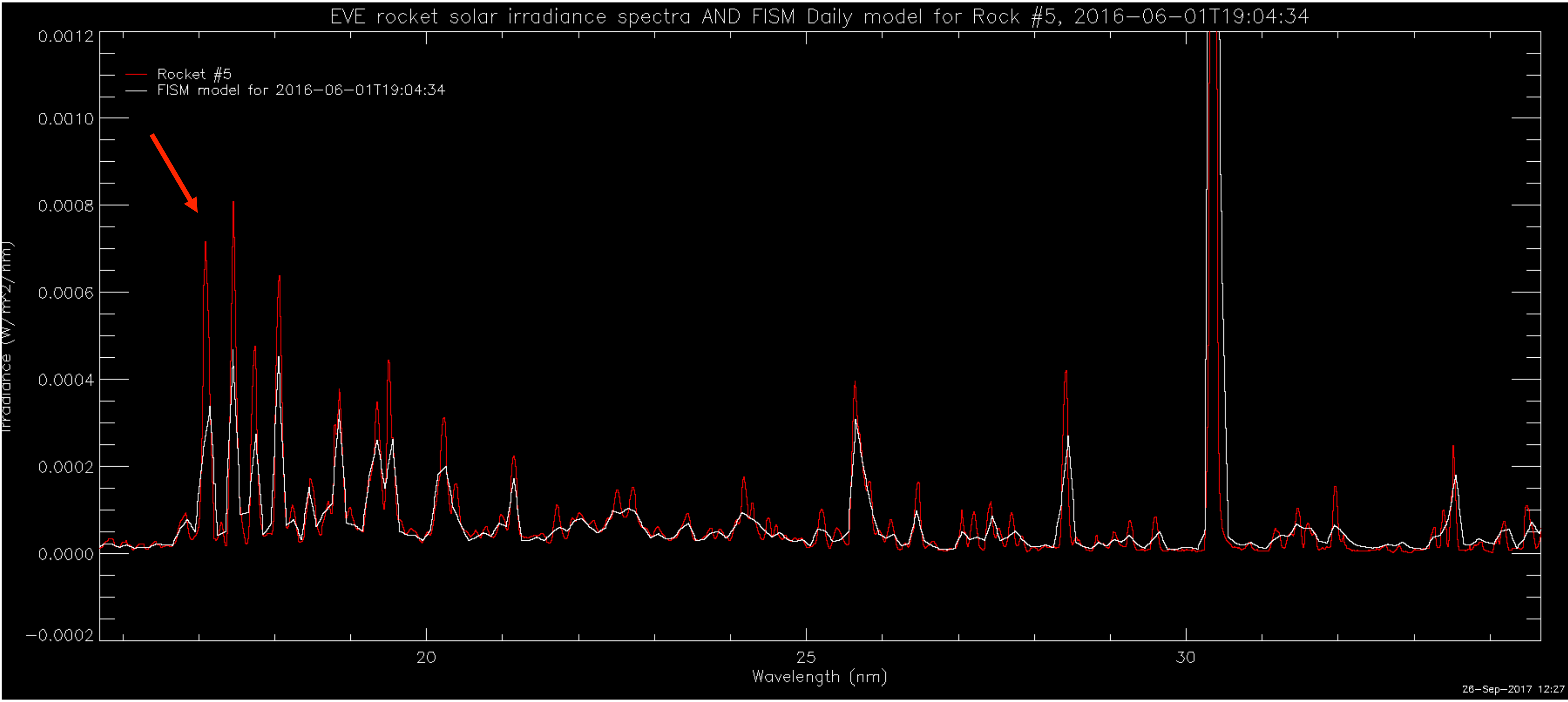
Example: The FISM model spectra have a coarse resolution of 1 nm (instead of 0.1 nm from EVE/MEGS-A or EVE sounding rockets). See next two pages for an example, where FISM model underestimate the solar irradiance, especially around the Fe IX 171 Å line.



Trending with FISM model since 2017-Nov-30

Reasons to account for differences between AIA/EVE and AIA/FISM ratios:

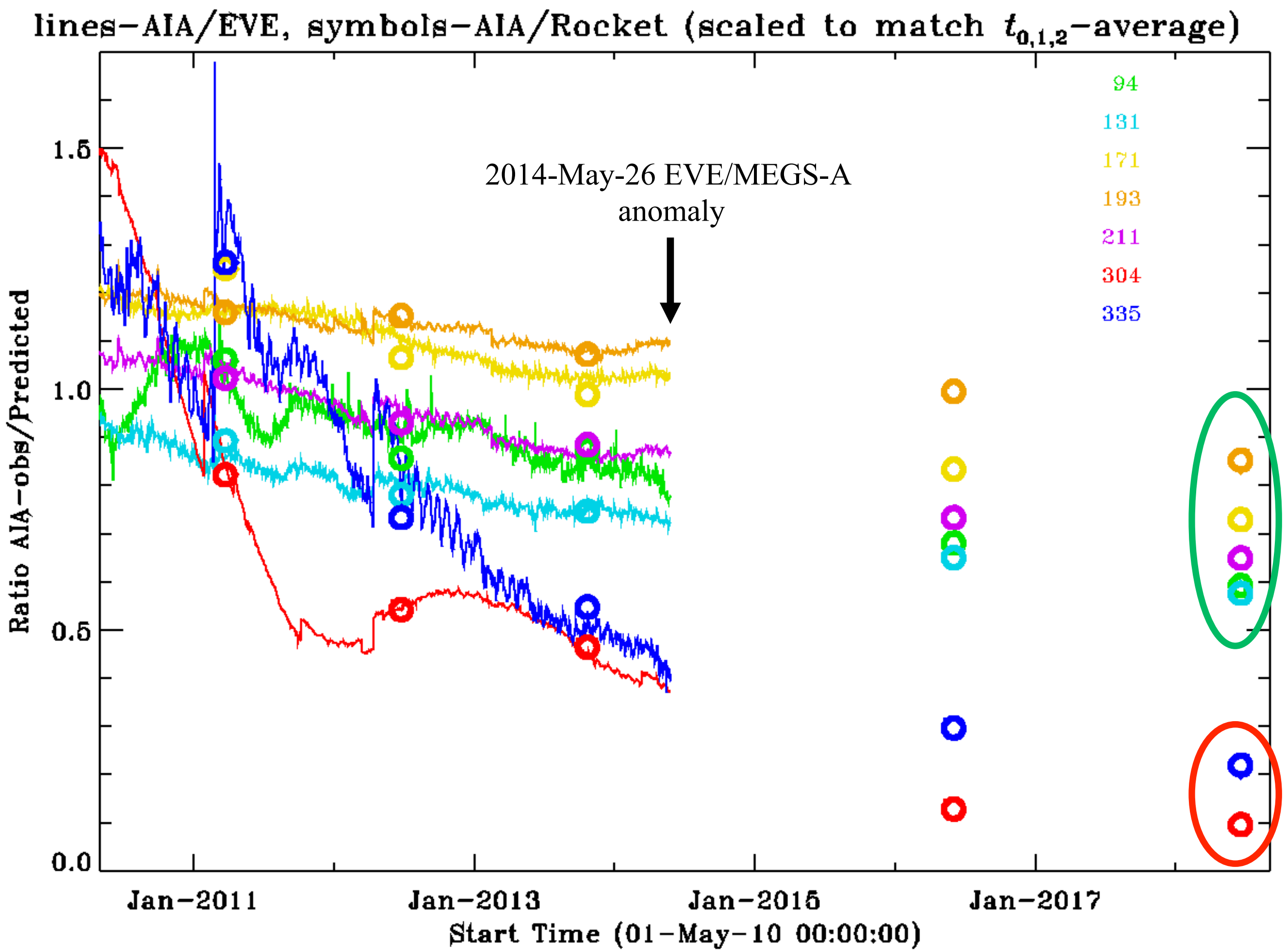
Example: The FISM model spectra have a coarse resolution of 1 nm (instead of 0.1 nm from EVE/MEGS-A or EVE sounding rockets). See next two pages for an example, where FISM model underestimate the solar irradiance, especially around the Fe IX 171 Å line.



3. Result

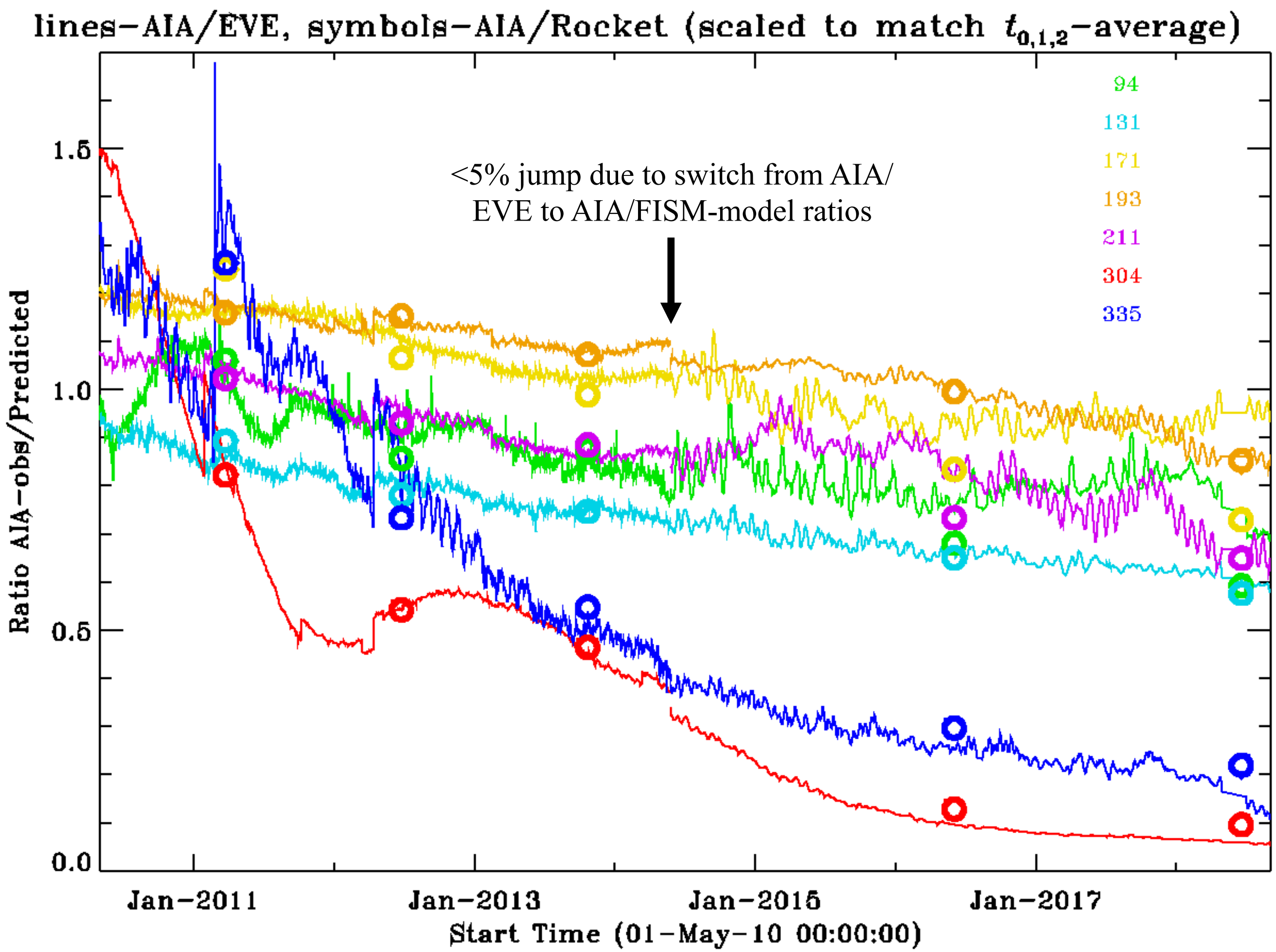
Sensitivity Trends: AIA/EVE and AIA/Rockets

- AIA EUV channel full-disk band irradiance compared with predicted values using EVE spectra convolved with AIA wavelength response functions (lines), and EVE calibration rockets (symbols).
- short wavelengths: 94 – 211 Å fairly slow sensitivity loss (<5%/year), 60-70% remaining.
- long wavelengths: 304 & 355 Å degraded fast early, has slowed down (now 1-3%/year), 10-20% remaining.



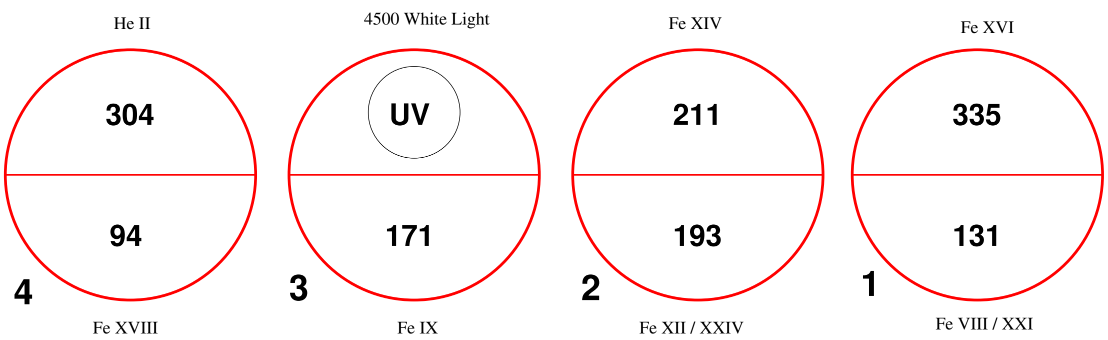
Sensitivity Trends: AIA/EVE and AIA/FISM-model

- Using the FISM-model (by Phil Chamberlin) predicted daily EUV flux, as a proxy of EVE-measured flux to estimate the AIA sensitivity loss beyond May 26, 2014.



Operations: Sensitivity Trends (EUV)

- Jumps due to AIA or EVE bakeouts, flat field updates



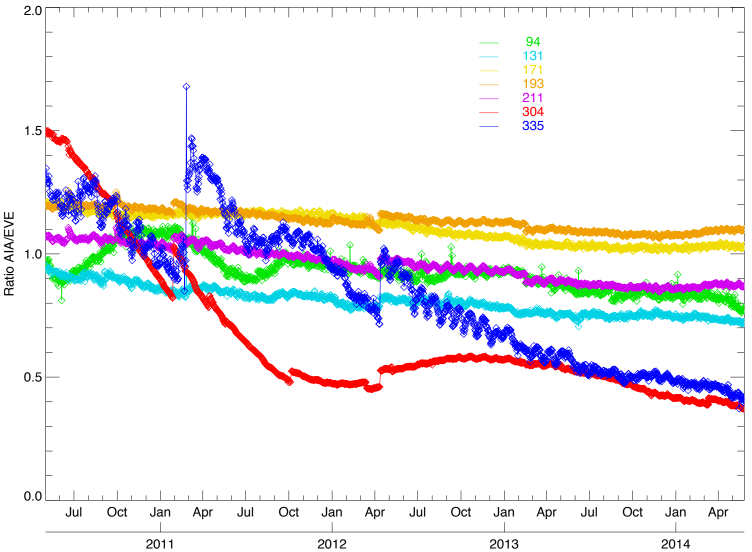


Table 1 History of bakeouts performed on AIA Telescope Assembly (ATA) and EVE/MEGS.

Date	Instrument affected	Approximate duration [h]	Temperature [°C]
18-Jun-2010	EVE/MEGS	240	
24-Sep-2010	EVE/MEGS	240	
28-Jan-2011	ATA2, 3, 4	2	10
25-Feb-2011	ATA1	2	10
14-Apr-2011	ATA4	24	10
19-May-2011	ATA4	8	20
4-Oct-2011	ATA4	36	20[a]
12-Mar-2012	EVE/MEGS	72	
12-Apr-2012	ATA1, 2, 3, 4	2	10

[a]Heated entire telescope, not just CCD.

AIA Sensitivity Trends

- AIA Degradation Correction factor every two years at selected times.

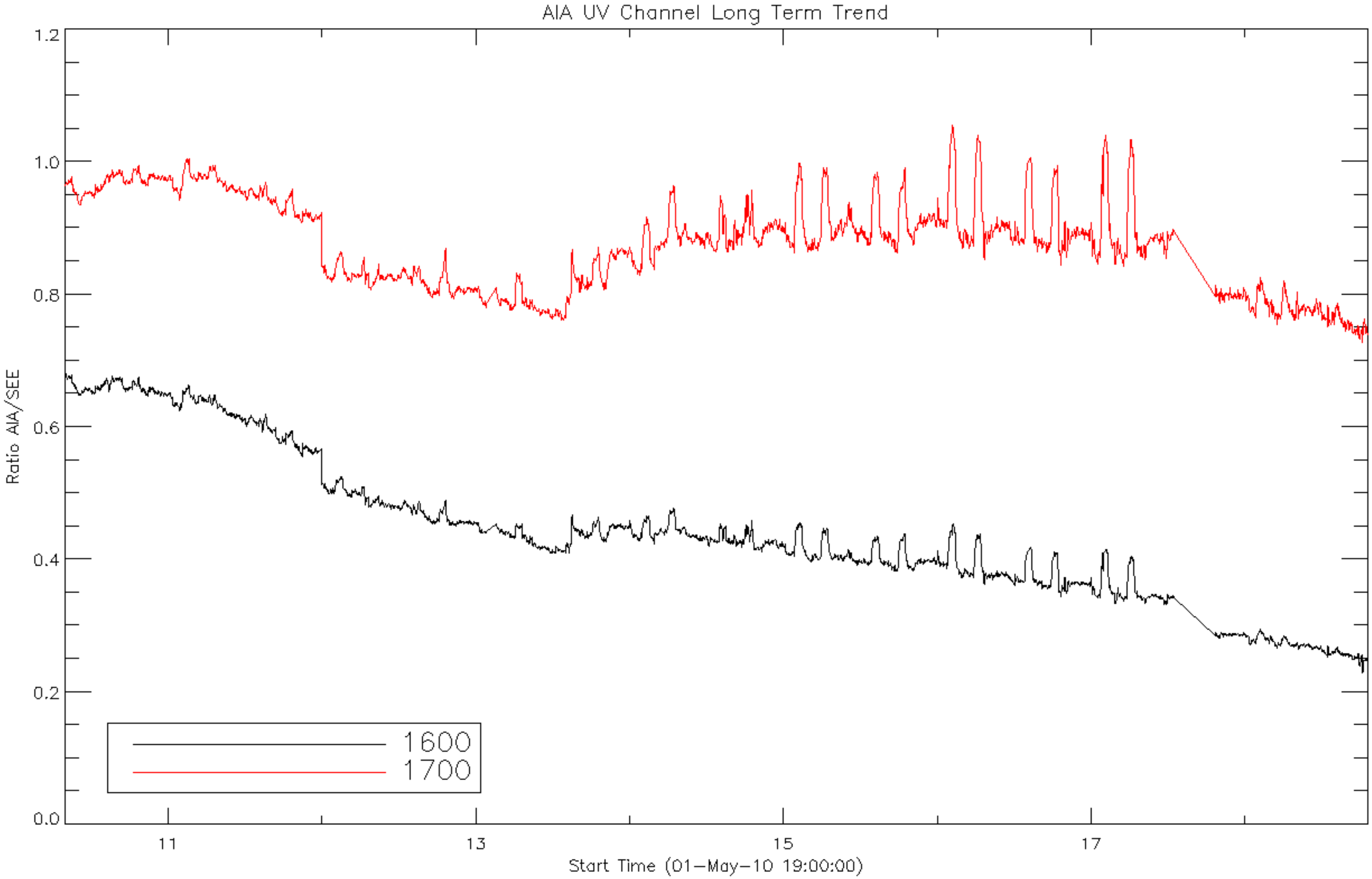
Channels (Å)	94	131	171	193	211	304	335	1600	1700
2012-01-01	0.93	0.85	0.96	0.95	0.91	0.29	0.70	0.76	0.86
2014-01-01	0.82	0.79	0.85	0.90	0.81	0.25	0.36	0.66	0.89
2016-01-01	0.74	0.69	0.79	0.84	0.74	0.078	0.21	0.59	0.94
2017-12-13 (last update)	**0.74**	**0.63**	**0.76**	**0.81**	**0.70**	**0.040**	**0.18**	**0.50**	**0.92**

Going forward:

Pending final/more accurate FISM update (with minor problems fixed) by Phil Chamberlin, later in 2018.

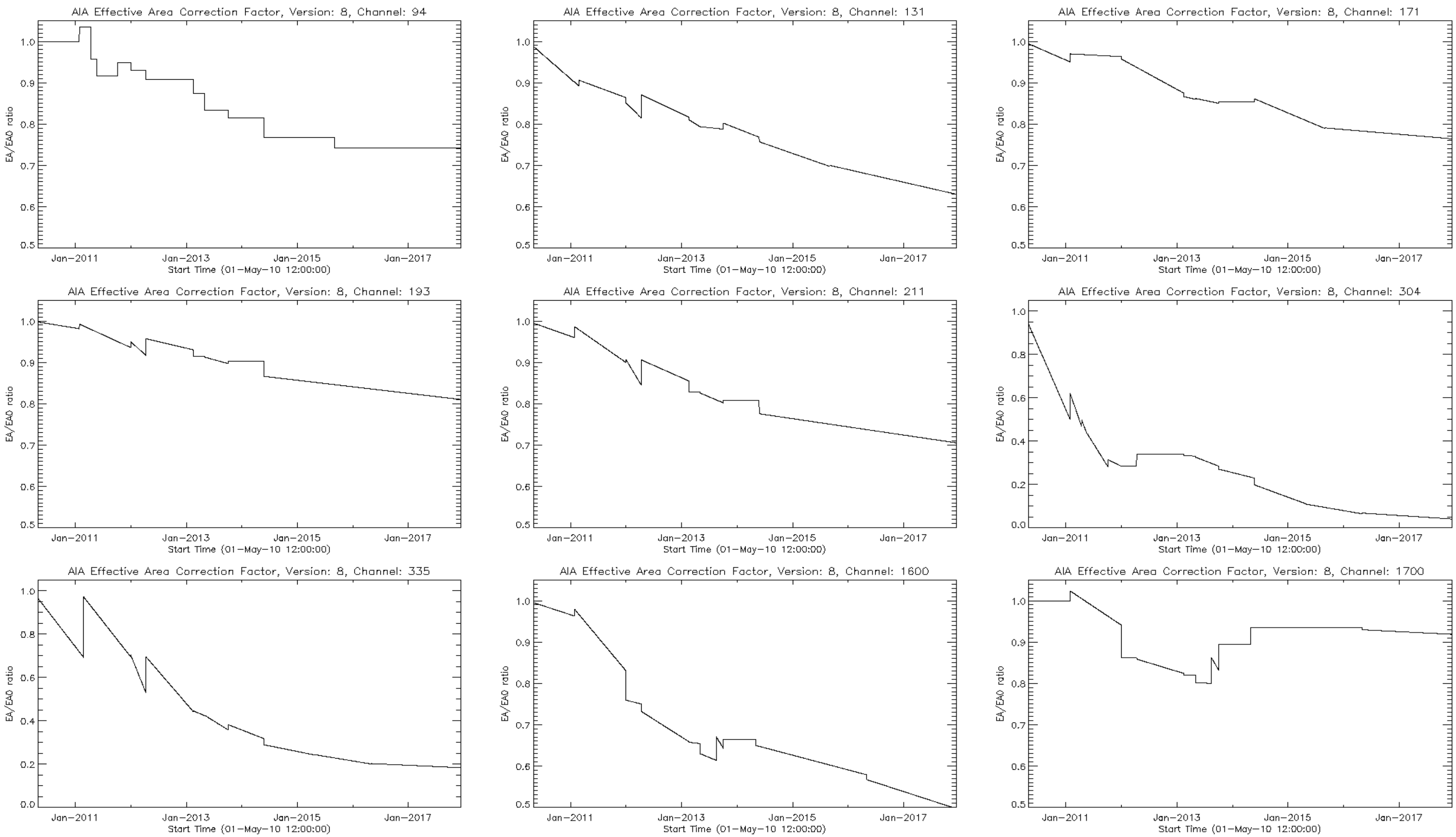
Sensitivity Trends (UV)

- AIA UV channel (1600, 1700 Å) full-disk band irradiance compared with band irradiance computed using TIMED/SEE. Disregard short spikes caused by SEE artifacts.



Sensitivity Trends (EUV+UV)

AIA Degradation Correction factor as a function of time, from Version 8 of AIA response table released to SSW on 2017-Dec-11. Piecewise linear fits to AIA/EVE and AIA/FISM ratios. Disallow positive slopes



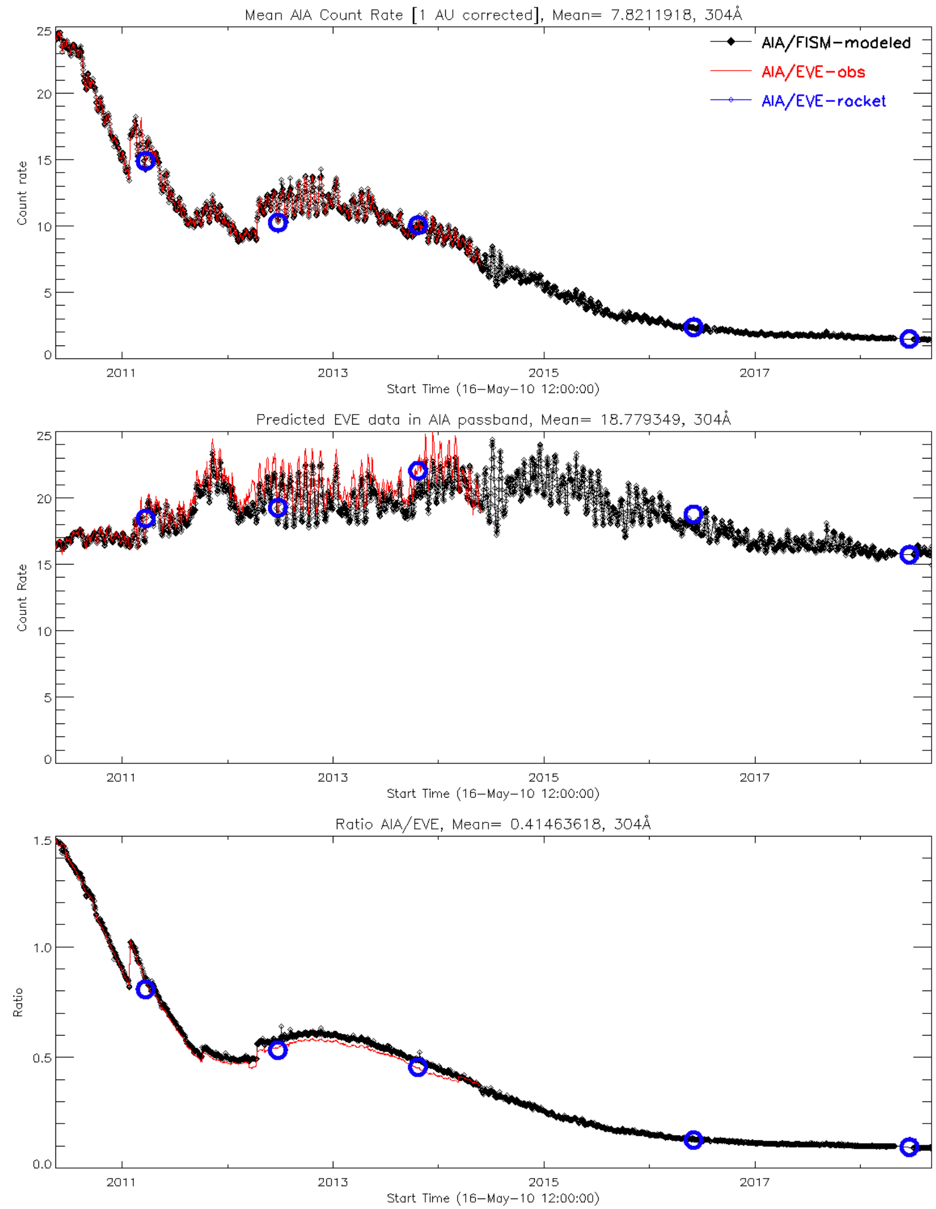
4. Technical Details

Sensitivity Trends (EUV): Best Example 304

AIA EUV channel full-disk band irradiance compared with band irradiance computed using EVE spectra.

Observed AIA 304 Å full-image average count rate (top), its FISM-model predicted counterpart (middle; folded through the AIA instrument response function), and then the ratio of the two (bottom).

This is the result of Data Processing Steps (1), (2), and (3) (see p. 7). The red curves are the corresponding quantity previously used for the AIA/EVE ratio, while the blue open circles for those using the EVE rocket data.



Sensitivity Trends (EUV): Best Example 304

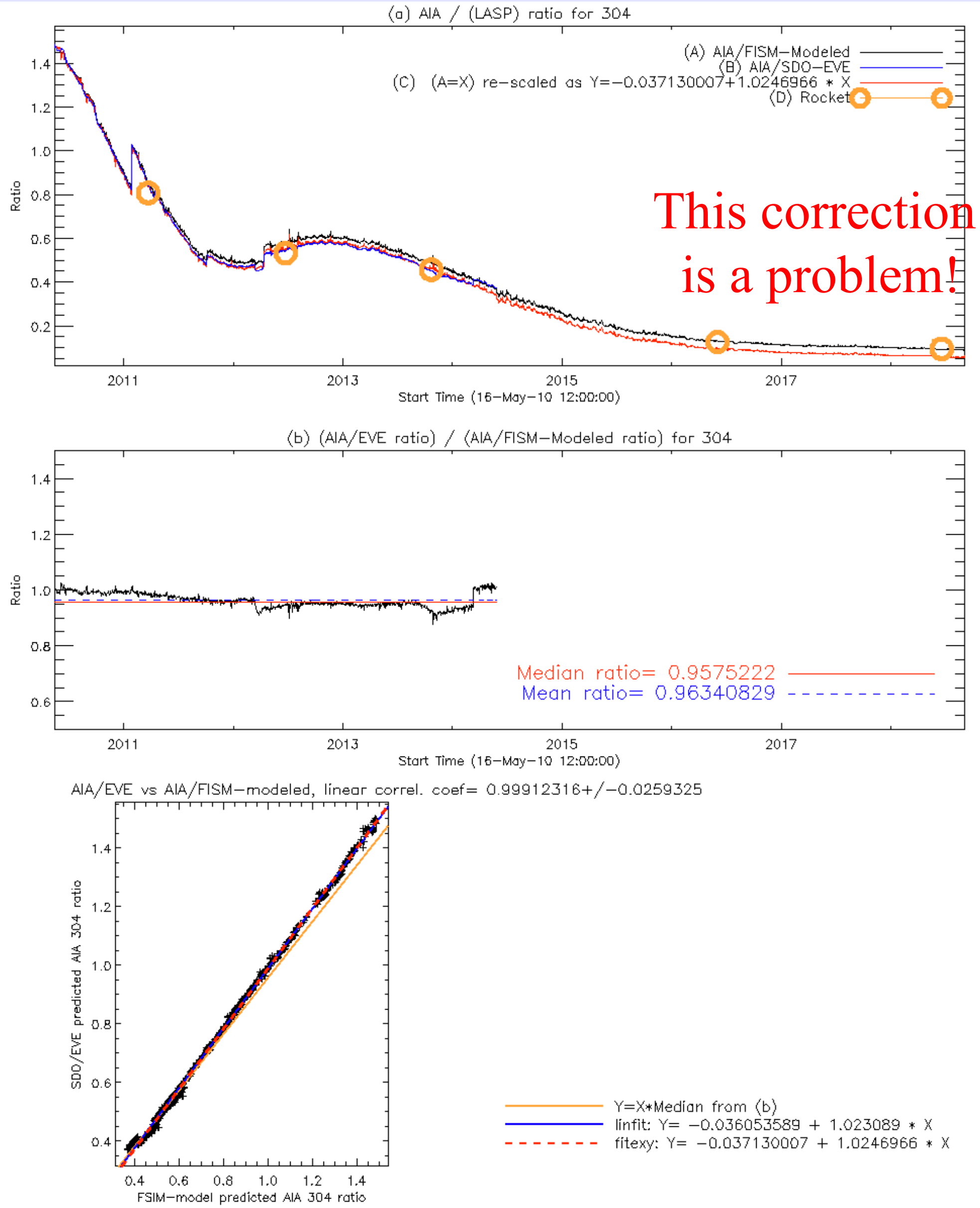
The basis of using FISM-model prediction is the decent linear correlation between the AIA/EVE and AIA/FISM ratios.

Best Example: Compare 304 Å AIA/EVE and AIA/FISM-model ratios.

Top: AIA/FISM-model ratio (black), overlaid with (i) the AIA/EVE ratio (blue), (ii) the rescaled AIA/FISM ratio (red) according to the linear fit/regression from the bottom panel (using IDL fitexy.pro), and (iii) the AIA/EVE-rocket ratio (orange open circles).

Middle: Ratio between AIA/EVE and AIA/FISM ratios. The horizontal red line marks the median value, and blue line the mean value.

Bottom: AIA/EVE ratio vs. AIA/FISM ratio when they overlap in time. The blue solid and red dashed lines are linear fits to the data using IDL linfit.pro and fitexy.pro, respectively (the latter is better as it accepts uncertainties in both X and Y data). The orange solid line is a linear function with zero intercept and a slope at the median Y/X ratio found in the middle panel.

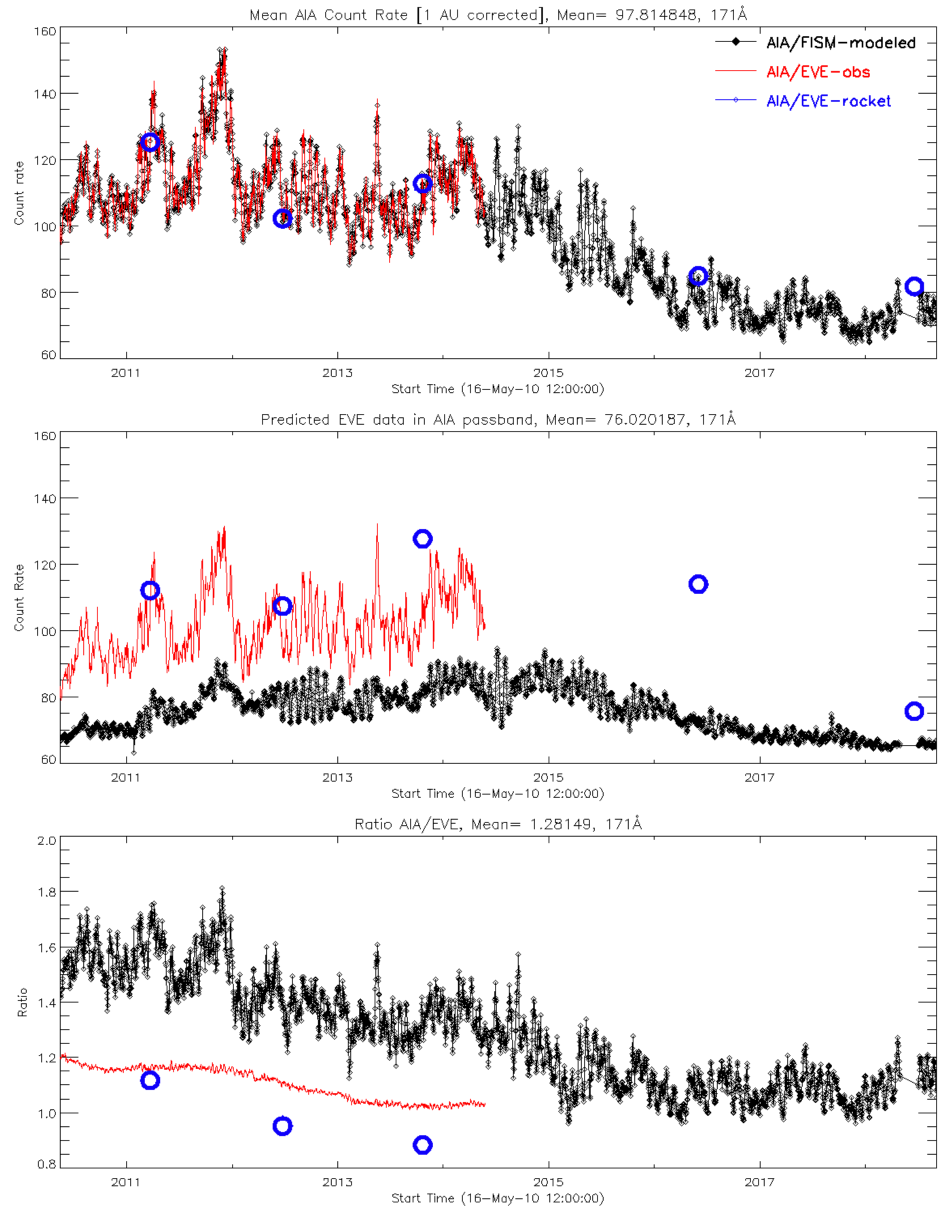


Sensitivity Trends (EUV): Bad Example 171

AIA EUV channel full-disk band irradiance compared with band irradiance computed using EVE spectra.

Observed AIA 171 Å full-image average count rate (top), its FISM-model predicted counterpart (middle; folded through the AIA instrument response function), and then the ratio of the two (bottom).

This is the result of Data Processing Steps (1), (2), and (3) (see p. 7). The red curves are the corresponding quantity previously used for the AIA/EVE ratio, while the blue open circles for those using the EVE rocket data.

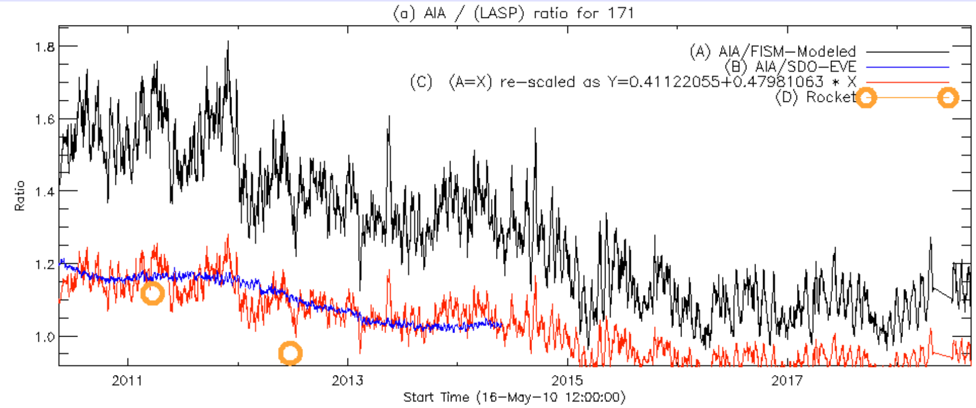


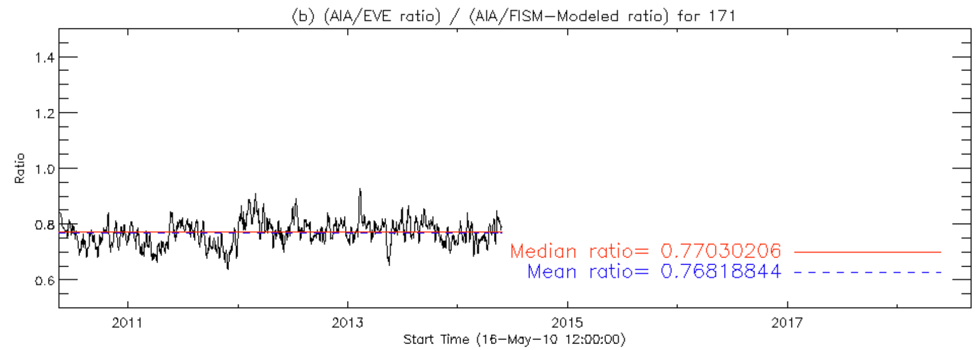
Sensitivity Trends (EUV): Bad Example 171

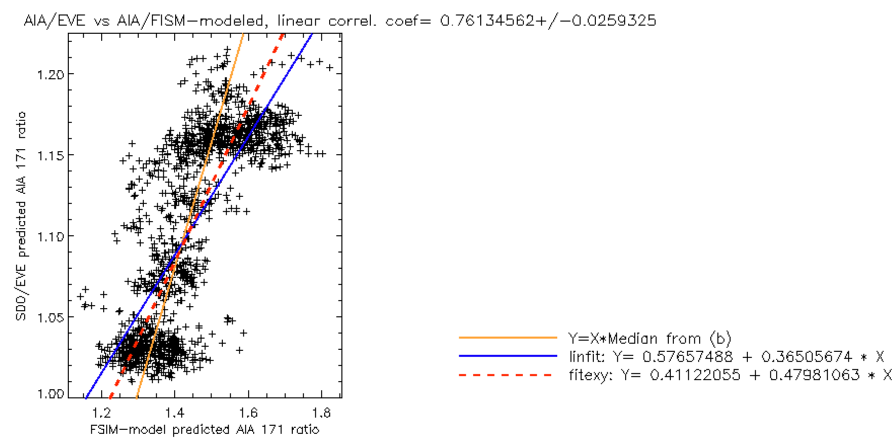
The basis of using FISM-model prediction is the decent linear correlation between the AIA/EVE and AIA/FISM ratios.

(Not so) Bad Example: Compare 171 Å AIA/EVE and AIA/FISM-model ratios.

AIA/FISM ratio is systematically higher than AIA/EVE ratio, yet with a decent linear correlation with a C.C.=0.76.





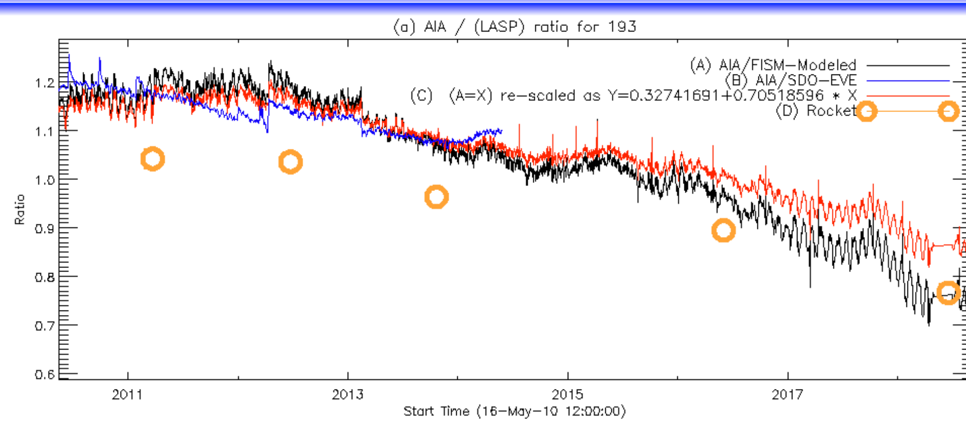


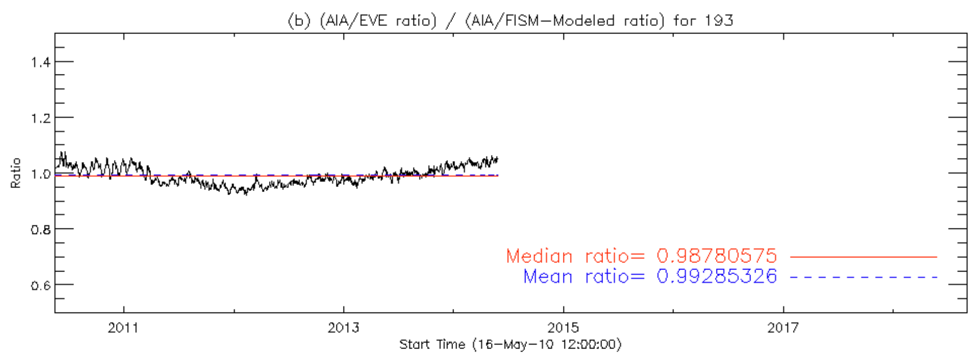
Sensitivity Trends (EUV): Bad Example 193

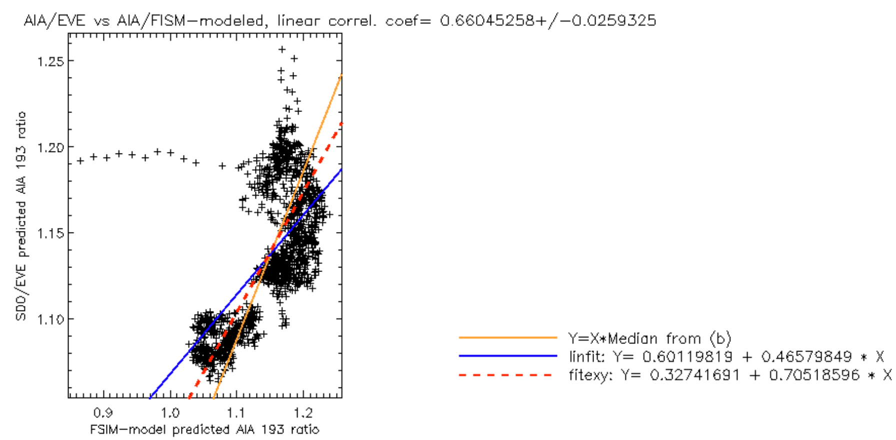
The basis of using FISM-model prediction is the decent linear correlation between the AIA/EVE and AIA/FISM ratios.

(Not so) Bad Example: Compare 193 Å AIA/EVE and AIA/FISM-model ratios.

AIA/FISM ratio is very close to AIA/EVE ratio, with a median ratio between the two at 0.988 (~1), but with the lowest linear correlation at a C.C.=0.66 among all 7 EUV channels.







Correlating AIA/EVE and AIA/FISM (2017/01 Version)

- The basis of using FISM-model prediction is the decent linear correlation between the AIA/EVE and AIA/FISM ratios.
- Correlation between AIA/FISM and AIA/EVE ratios. The linear regression result is used to rescale the former to approximate the latter. Outliers are in **bold face.**
- - 171 has the lowest median or mean ratio
- - 193 has the lowest correlation coefficient

Channels (Å)	Linear Correlation Coefficient (+/- 0.026 of 1σ error)	Median Ratio: (AIA/EVE) / (AIA/FISM)	Mean Ratio: (AIA/EVE) / (AIA/FISM)	Linear Fit (by IDL fitexy.pro) Y=AIA/EVE , X= AIA/FISM
94	0.616	1.056	1.056	Y = 0.190 + 0.833 X
131	0.843	1.039	1.038	Y = 0.131 + 0.867 X
171	0.741	**0.782**	**0.780**	Y = 0.447 + 0.462 X
193	**0.337**	1.000	1.007	Y = 0.507 + 0.555 X
211	0.585	1.001	1.015	Y = 0.168 + 0.832 X
304	0.998	0.991	0.995	Y = - 0.0228 + 1.033 X
335	0.971	1.105	1.113	Y = - 0.0455 + 1.178 X

Correlating AIA/EVE and AIA/FISM (2018/09 Prelim. Update) – **Improved C.C.** for all channels

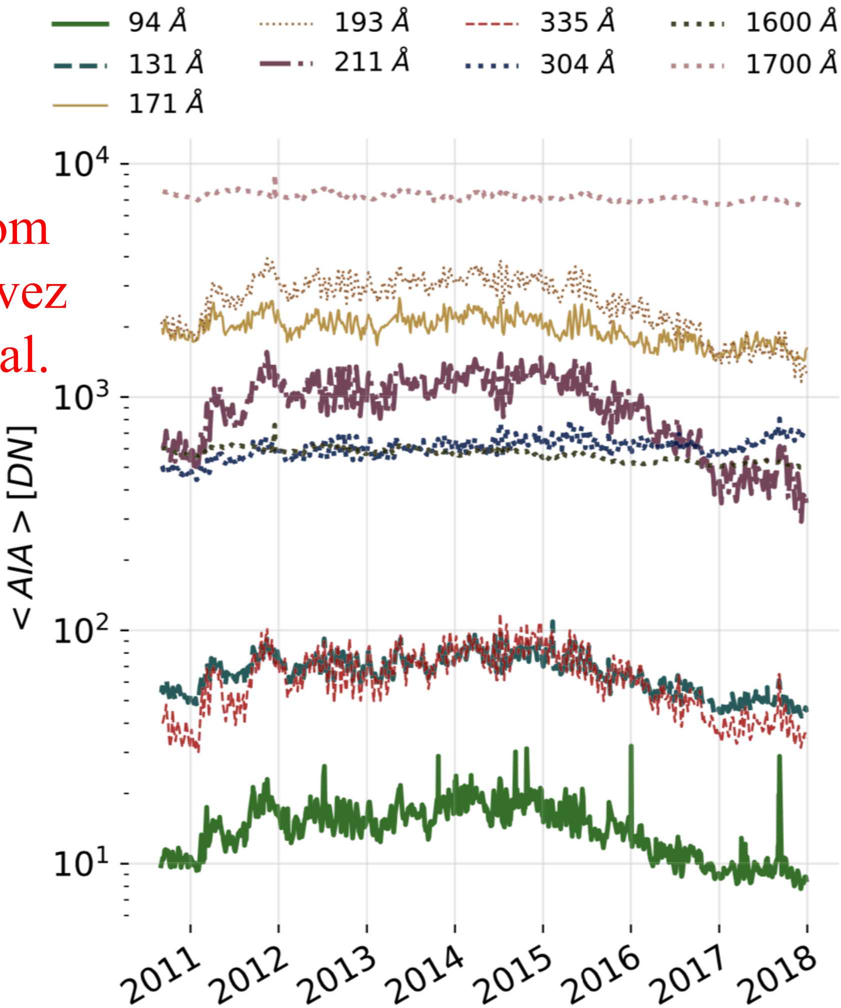
- The basis of using FISM-model prediction is the decent linear correlation between the AIA/EVE and AIA/FISM ratios.
- Correlation between AIA/FISM and AIA/EVE ratios. The linear regression result is used to rescale the former to approximate the latter. Outliers are in **bold face.**
- - 171 has the lowest median or mean ratio
- - 193 has the lowest correlation coefficient

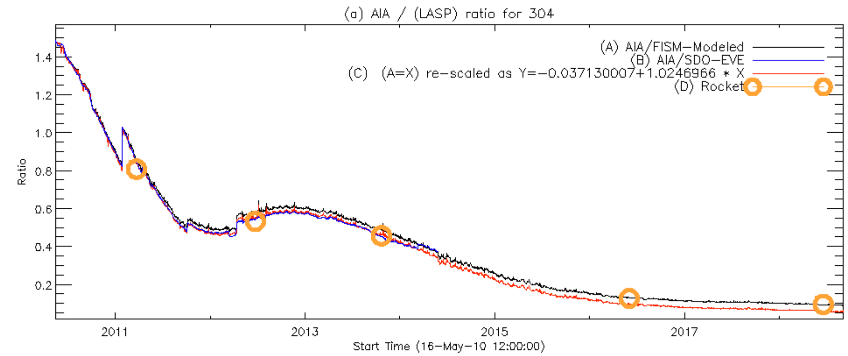
Channels (Å)	Linear Correlation Coefficient (+/- 0.026 of 1σ error)	Median Ratio: (AIA/EVE) / (AIA/FISM)	Mean Ratio: (AIA/EVE) / (AIA/FISM)	Linear Fit (by IDL fitexy.pro) Y=AIA/EVE , X= AIA/FISM
94	0.740	1.019	1.014	Y = 0.141 + 0.855 X
131	0.916	0.976	0.974	Y = 0.172 + 0.764 X
171	0.761	**0.770**	**0.768**	Y = 0.411 + 0.480 X
193	**0.660**	0.988	0.993	Y = 0.327 + 0.705 X
211	0.771	0.983	0.983	Y = 0.155 + 0.821 X
304	0.999	0.958	0.963	Y = - 0.0371 + 1.025 X
335	0.968	0.849	0.857	Y = - 0.0699 + 0.935 X

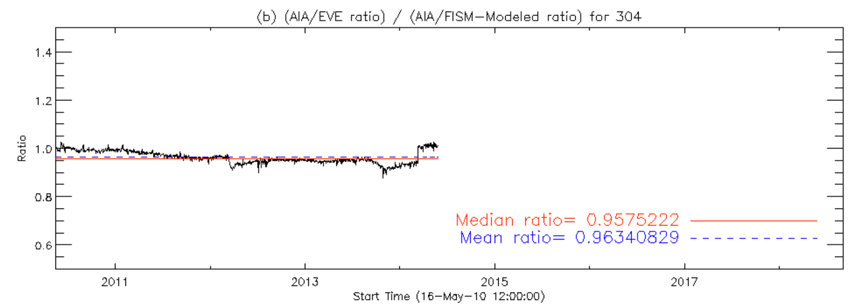
5. Questions: 2019-10-15

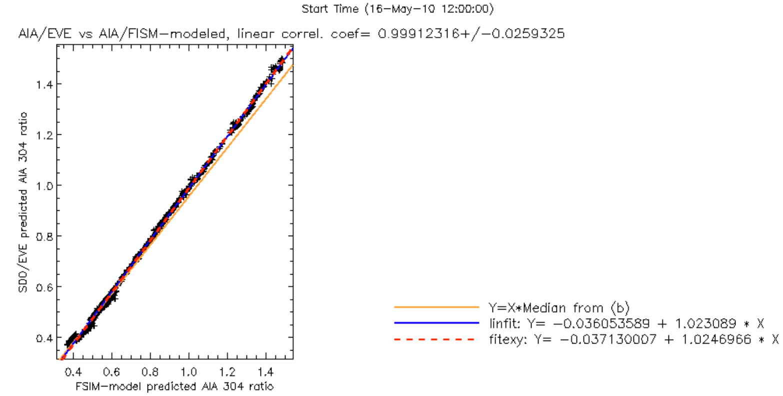
Issues with AIA 304

From Galvez et al.

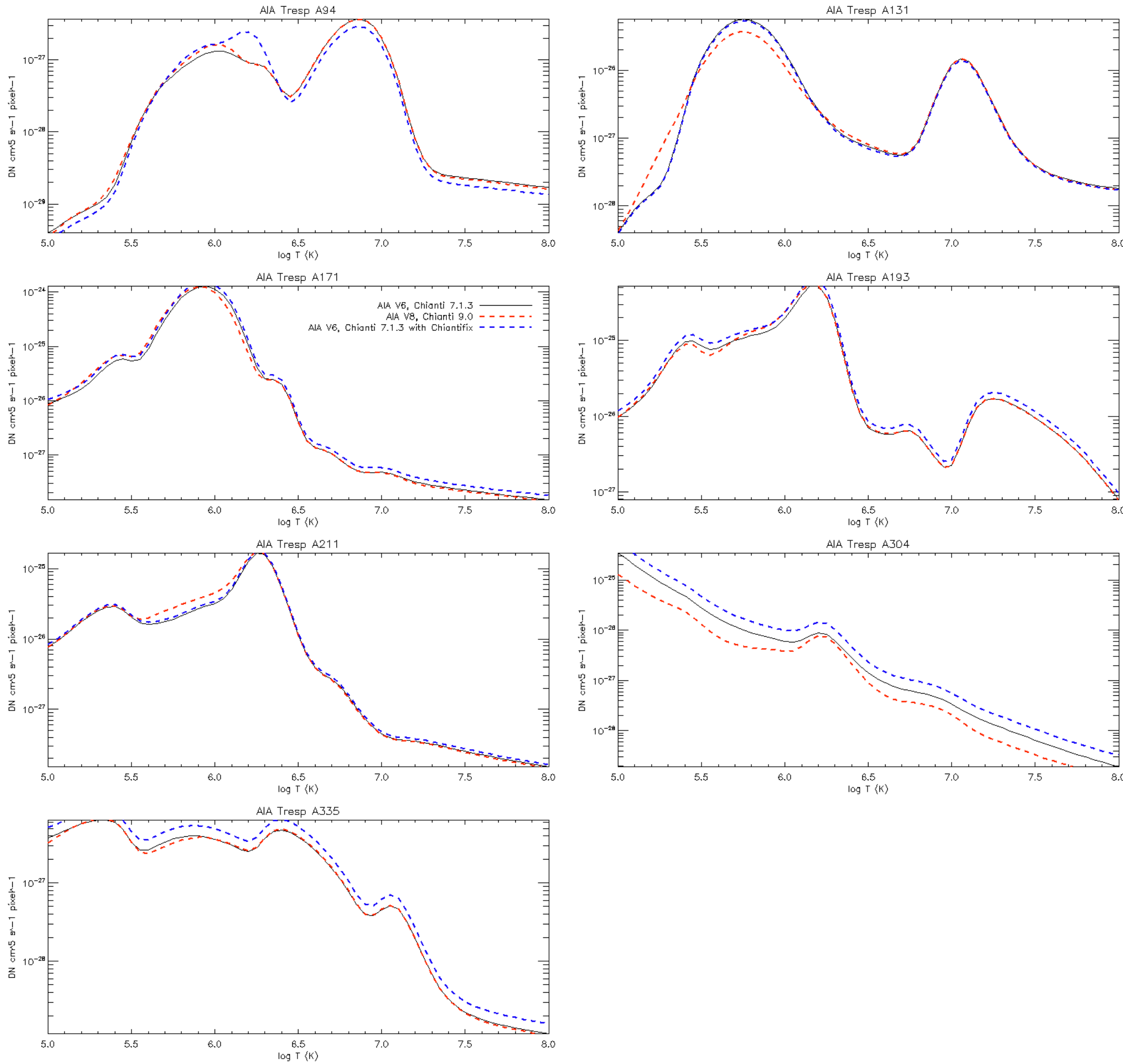








Temperature response functions from CHIANTI



Possible Next Steps

What goes into the EVE spectra that we have been using to correct AIA responses?

Instead of using FISM after 2014, should we:

- Fit a simple (exponential) function using only the (latest) EVE rocket measurements?
- Use revised FISM instead of rocket measurements?
- Or use empirical proxies, e.g. unsigned magnetic flux, ML scaling relationships
- Use TIMED/SEE for UV (160/170 nm) channels?
- Model degradation of all channels using a common mechanism (e.g. hydrocarbon absorption, oxide growth)?

For Thermal response functions, should we:

- Continue to use empirical corrections for missing CHIANTI lines?

7. Appendixes

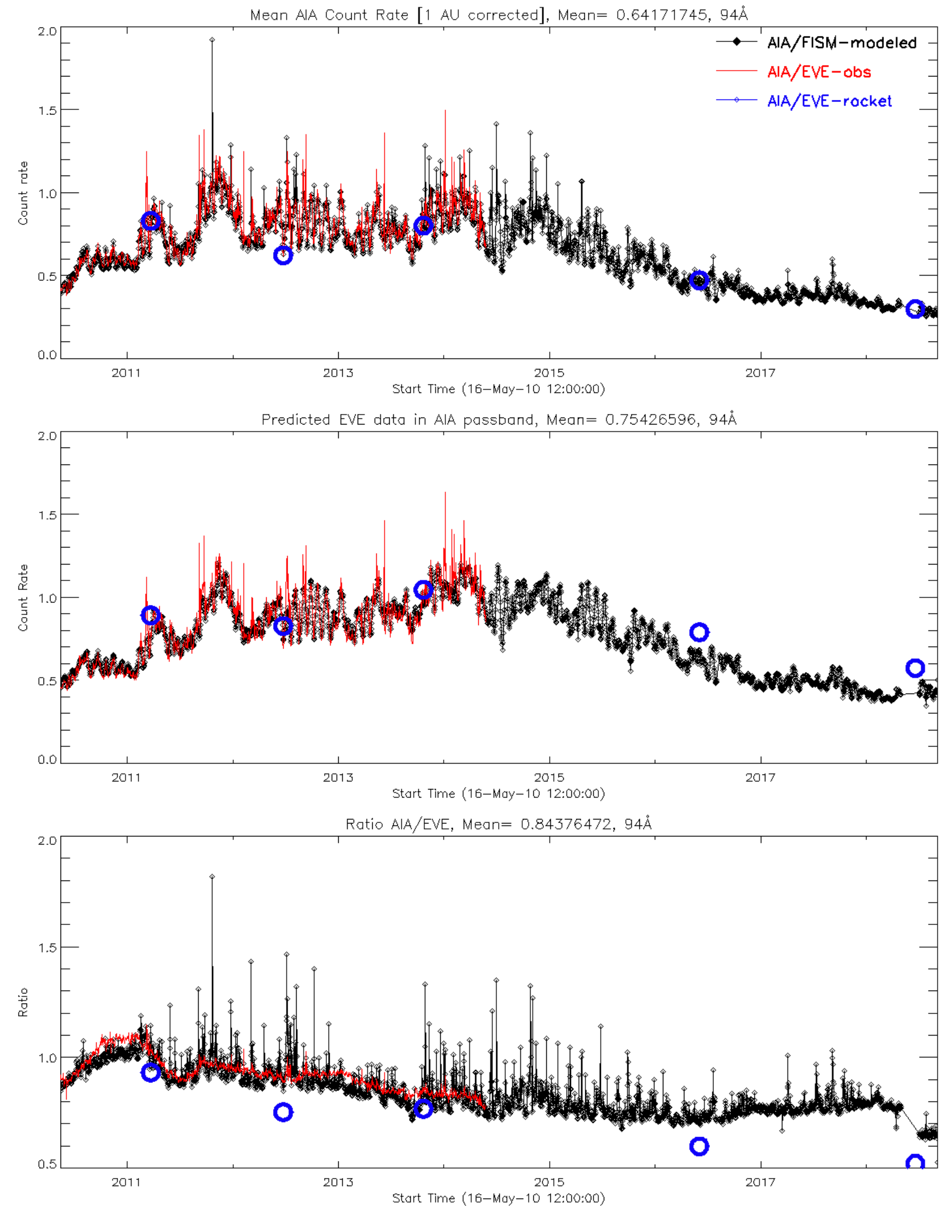
Figures for All AIA EUV channels
(Same layout as those shown above)

Appendix A. Observed to Predicted Ratios

AIA EUV channel full-disk band irradiance compared with band irradiance computed using EVE spectra.

Observed AIA 94 Å full-image average count rate (top), its FISM-model predicted counterpart (middle; folded through the AIA instrument response function), and then the ratio of the two (bottom).

This is the result of Data Processing Steps (1), (2), and (3) (see p. 7). The red curves are the corresponding quantity previously used for the AIA/EVE ratio, while the blue open circles for those using the EVE rocket data.



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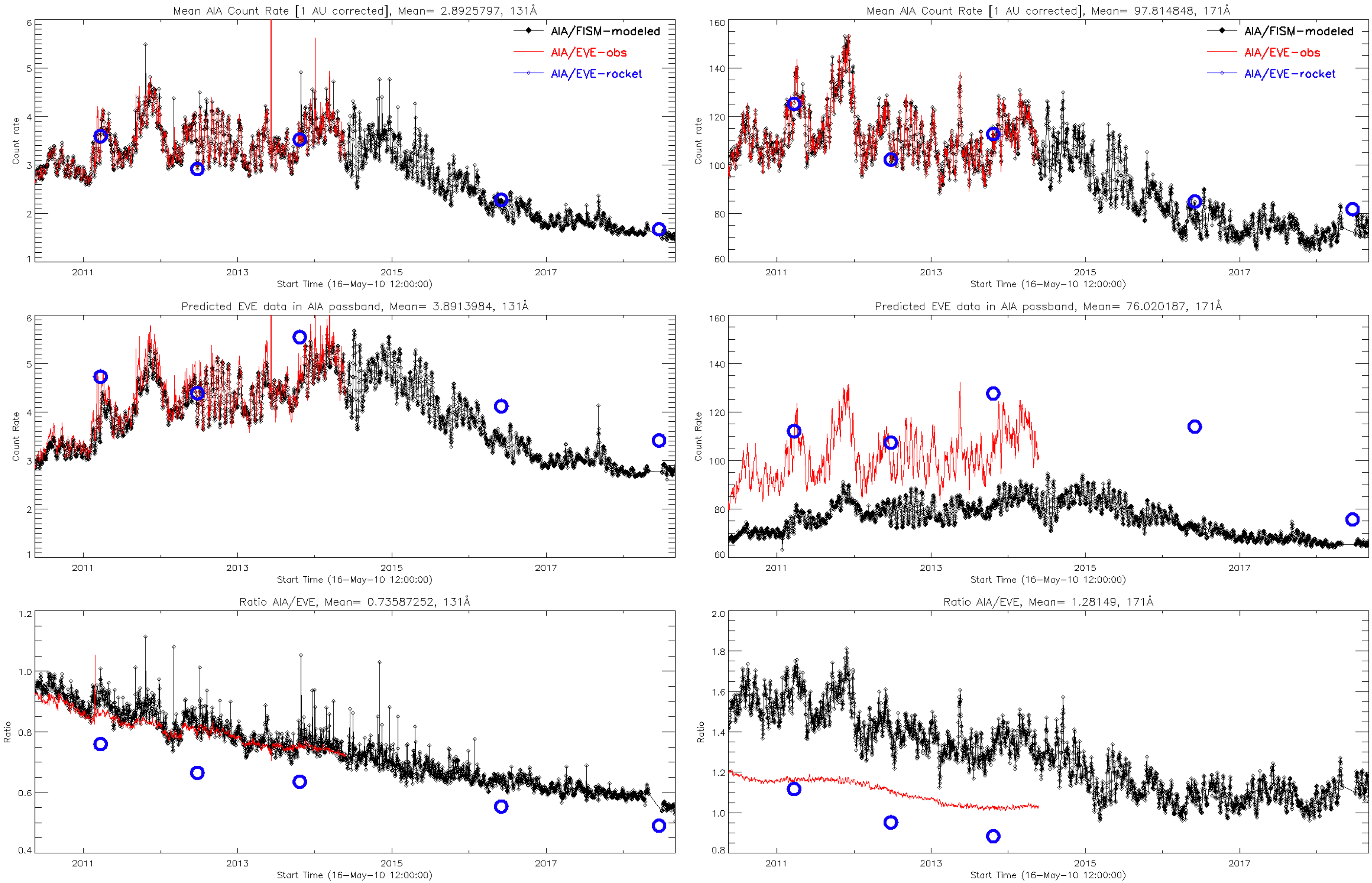

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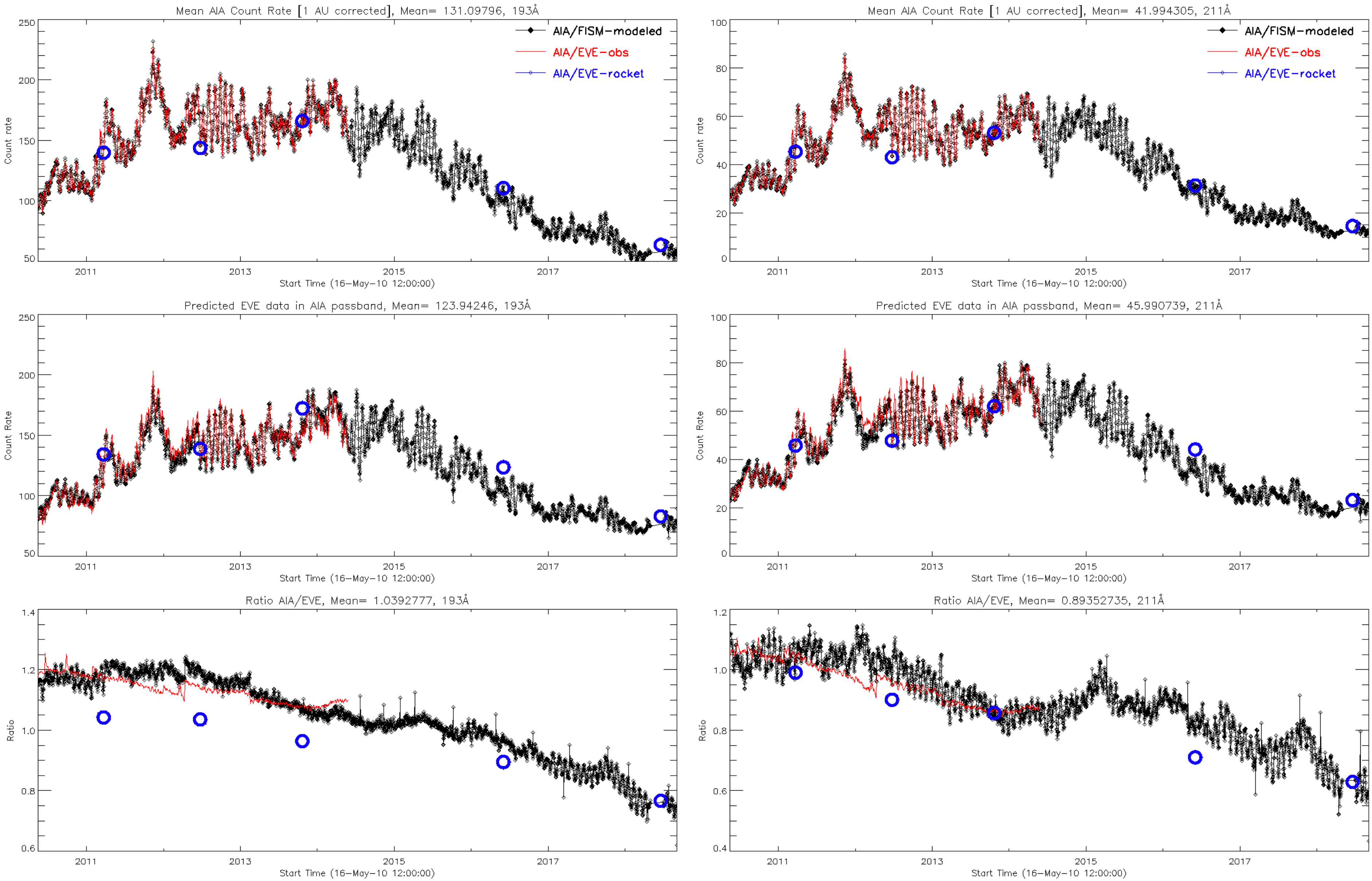

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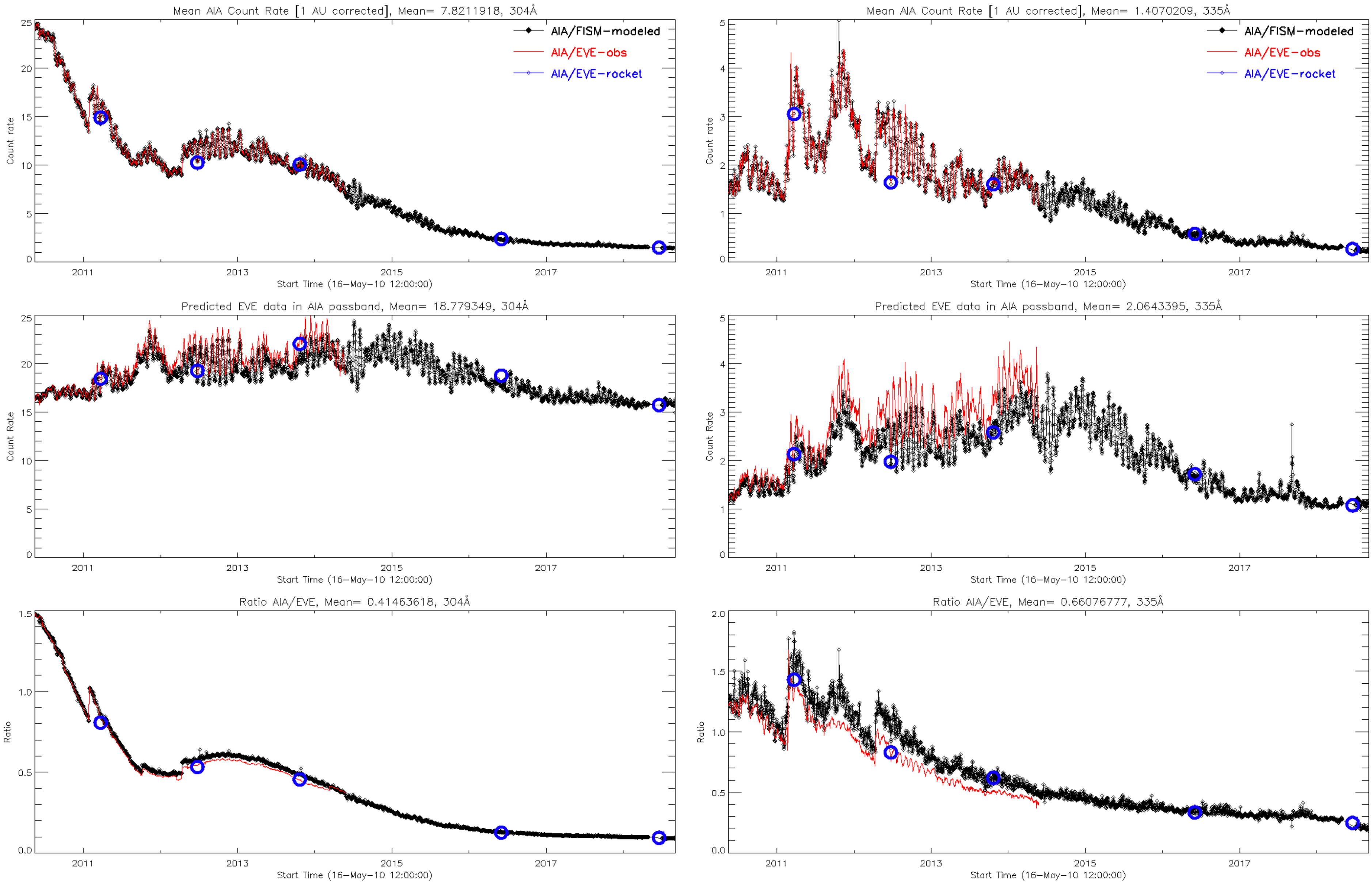

Appendix B. AIA/EVE and AIA/FISM correlation

The basis of using FISM-model prediction is the decent linear correlation between the AIA/EVE and AIA/FISM ratios.

Example: Compare 94 Å AIA/EVE and AIA/FISM-model ratios.

Top: AIA/FISM-model ratio (black), overlaid with (i) the AIA/EVE ratio (blue), (ii) the rescaled AIA/FISM ratio (red) according to the linear fit/regression from the bottom panel (using IDL fitexy.pro), and (iii) the AIA/EVE-rocket ratio (orange open circles).

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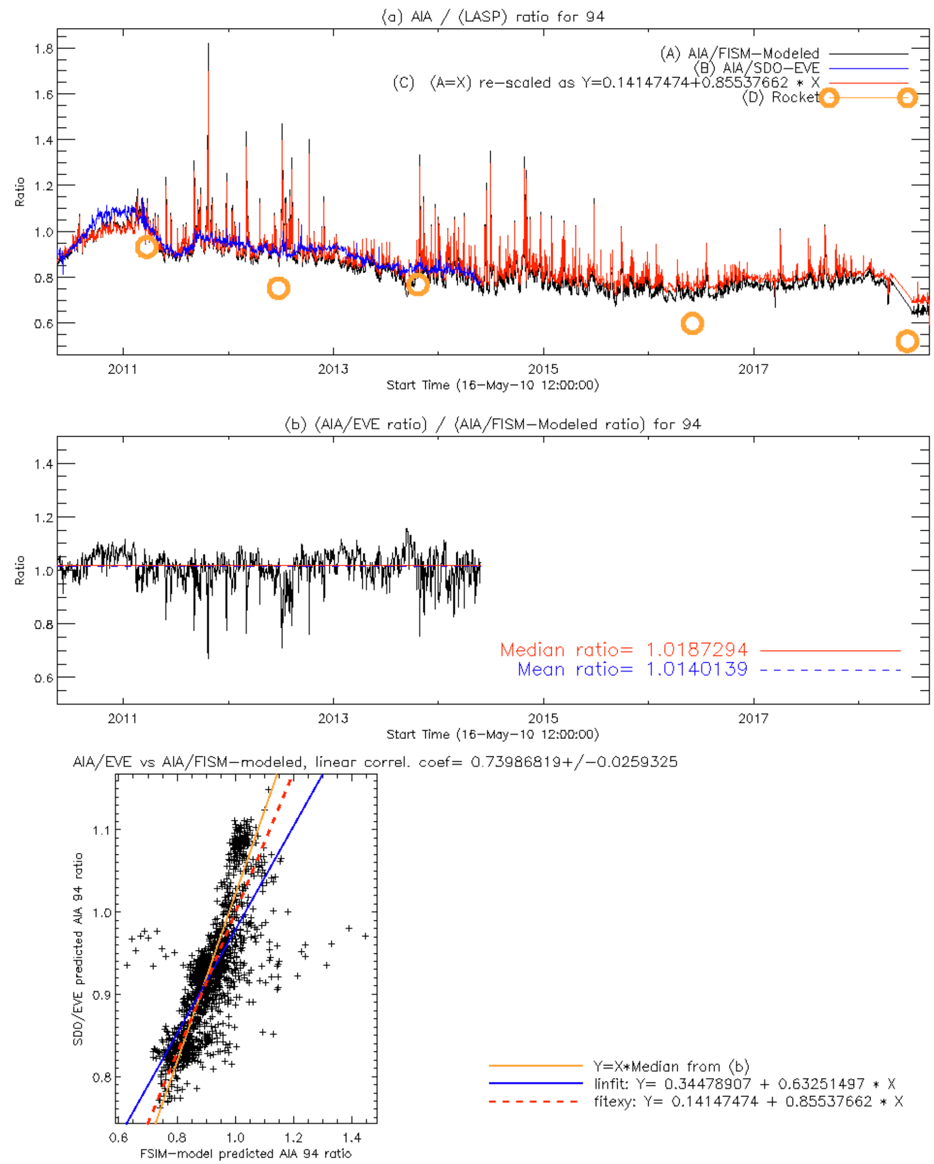

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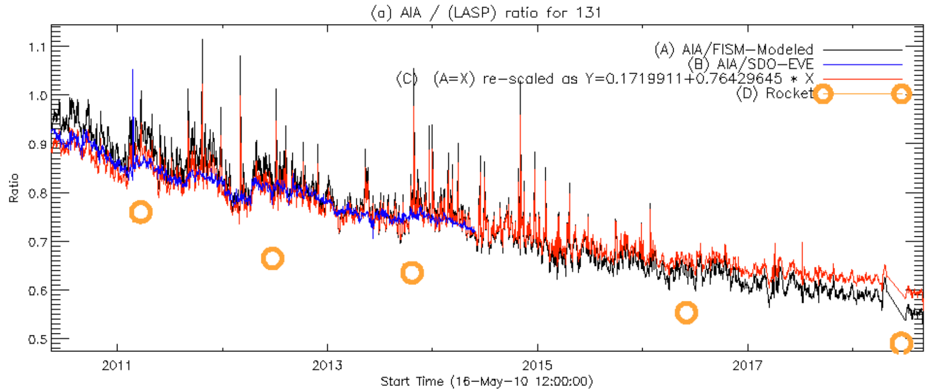

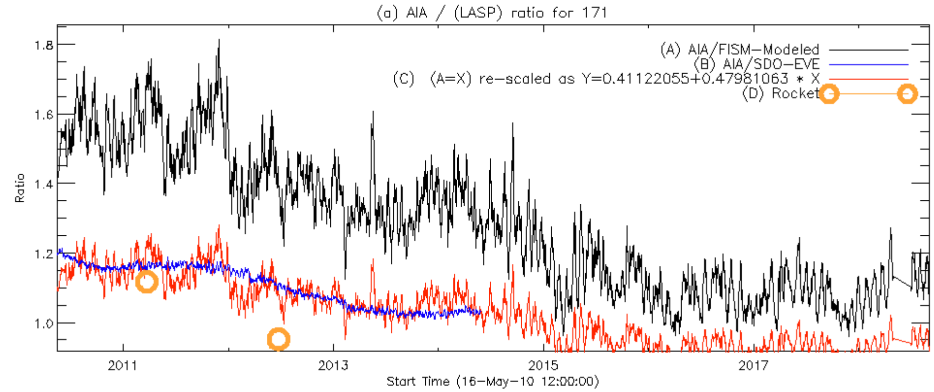

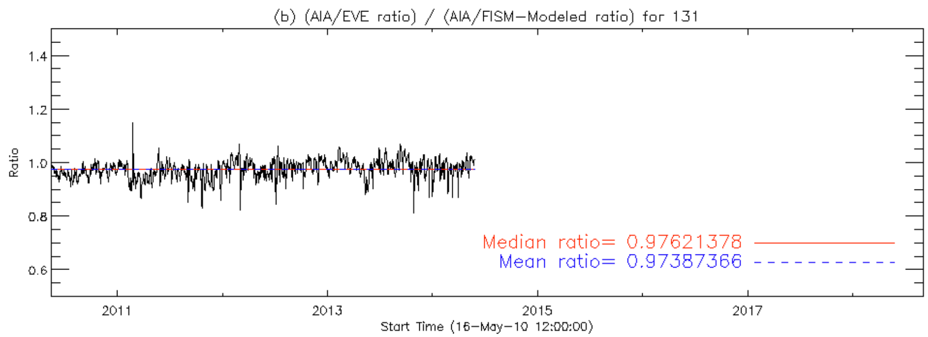

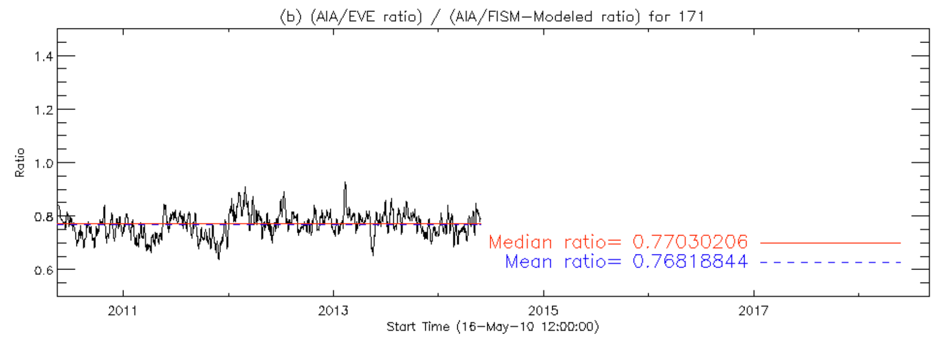

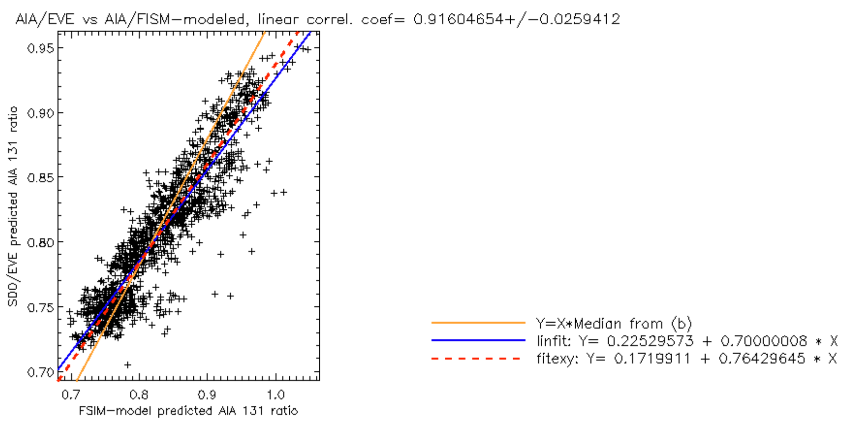

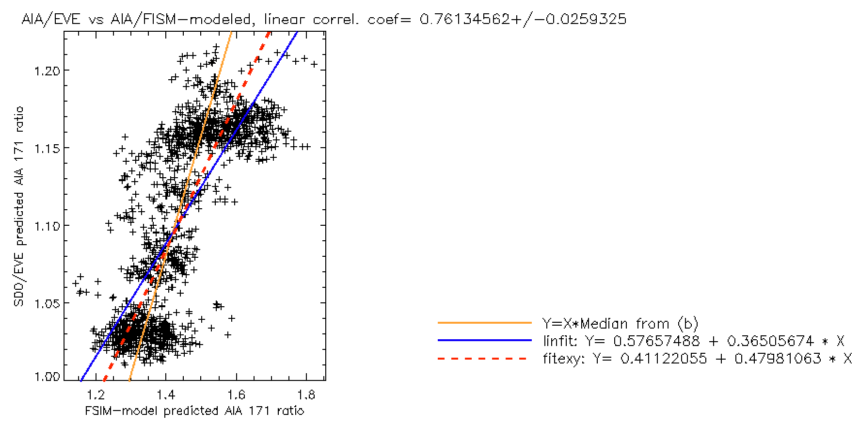

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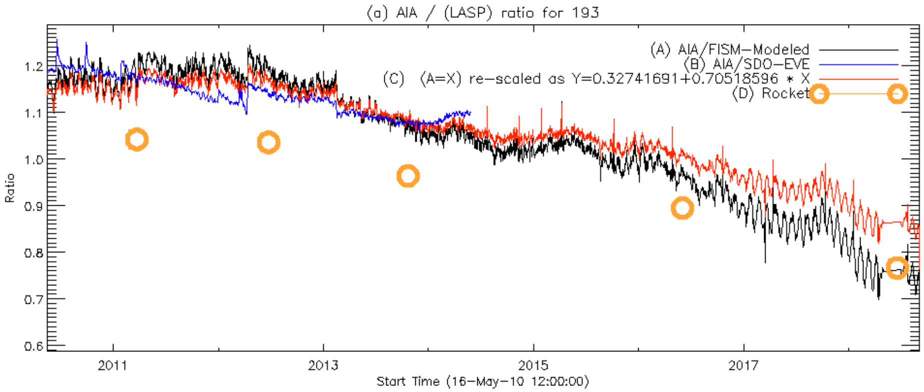
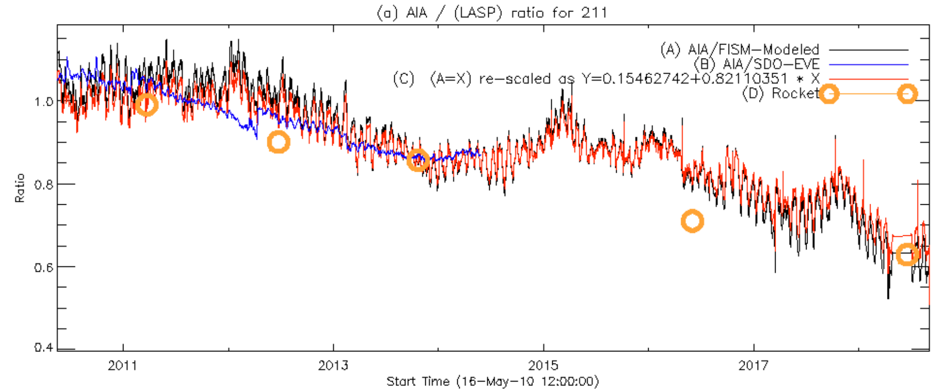
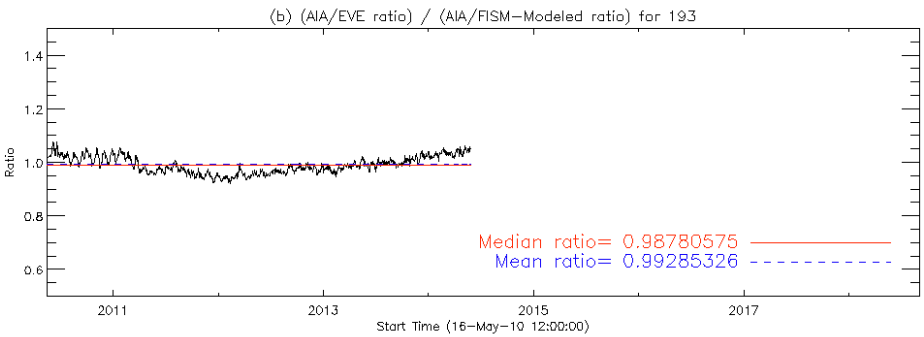
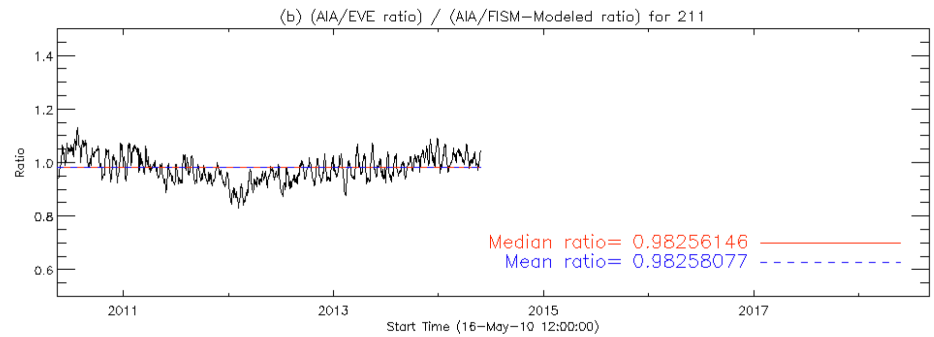
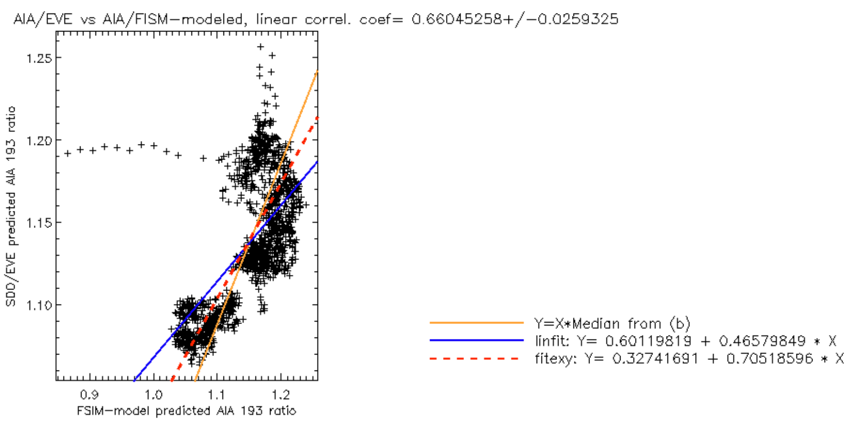
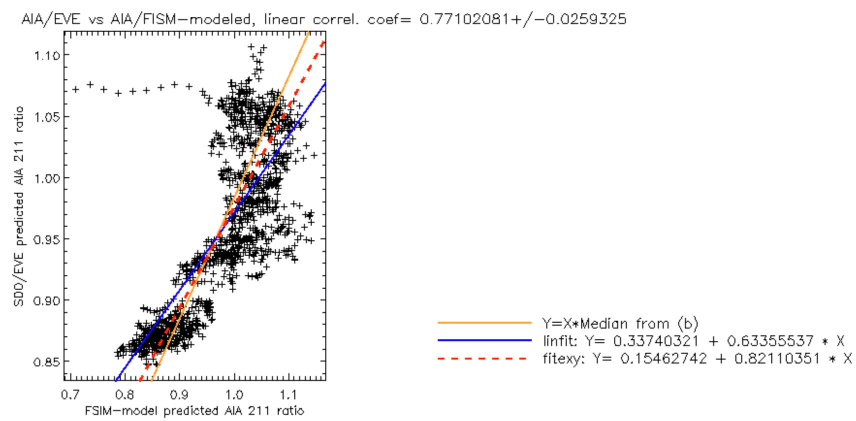




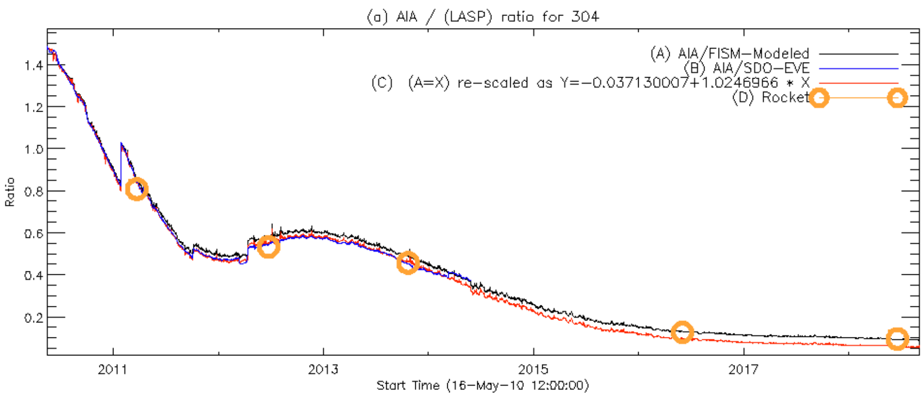


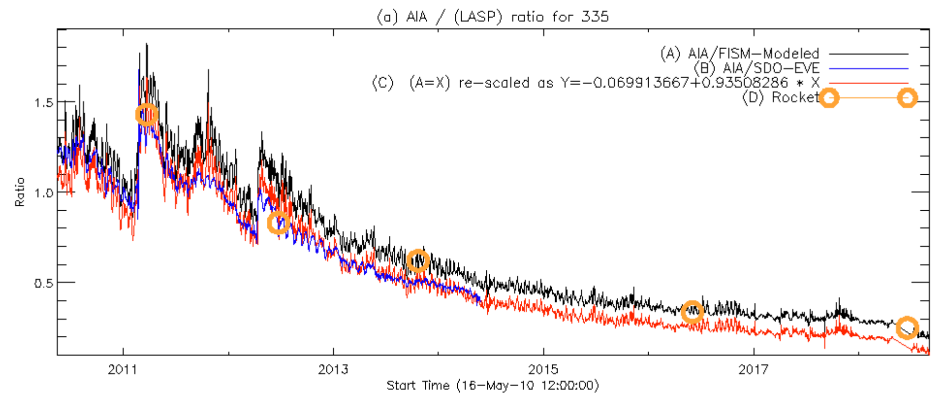


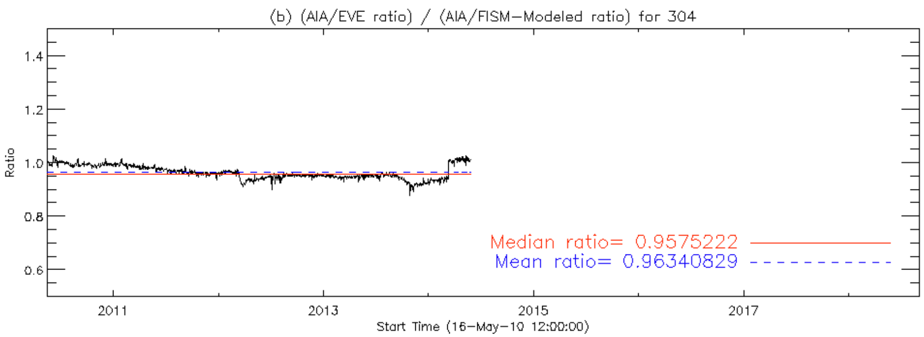


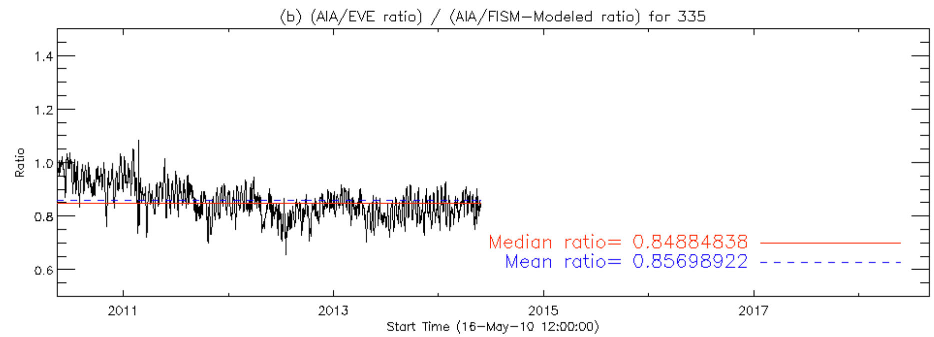


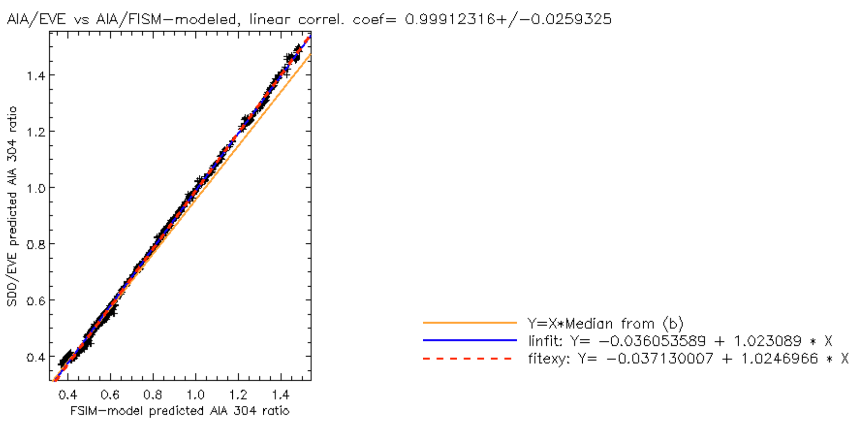
Appendix A. AIA/EVE and AIA/FISM correlation

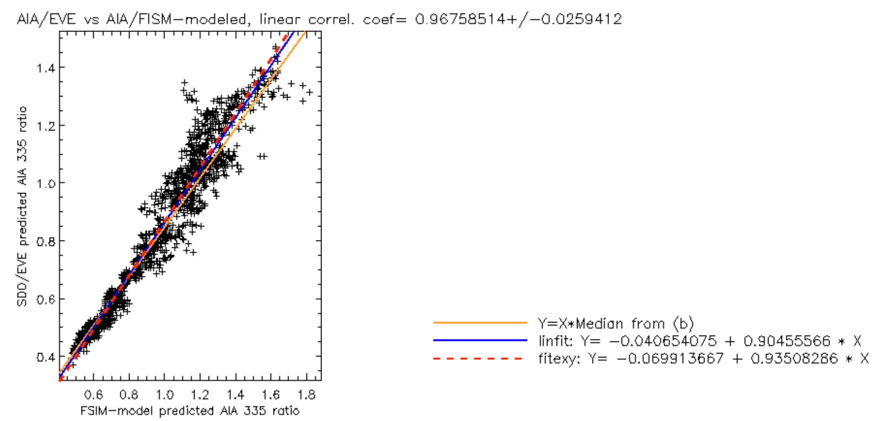












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