ESP In-Flight and Rocket Calibration

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ESP Calibration: Current and Planned

- ESP public products (e.g. Level 1) are absolute Solar Spectral Irradiance (SSI) in the ESP pass-bands;
- For accurate determination of the SSI we update the Level 1 equations for the following parameters based on ESP in-flight daily and weekly calibrations:
  – dark counts,
  – filters transmission, e.g. degradation,
  – electronics gain: stable,
  – energetic particle contamination: small,
  – visible light: small,
  – spectral variability: use MEGS-A spectra for the first-order channels,
  – angular offsets: SDO guiding is stable,
  – a distance from s/c to the Sun: regularly updated.
- Use Sounding Rocket under-flight and inter-comparison data
- Plan ESPR zeroth-order calibration at the Berlin Electron Storage Ring Society for Synchrotron Radiation (BESSY II) in Germany.
- Plan to upgrade the EVE/SAM instrument to measure solar spectra during EVE underflights

The Largest Uncertainties that Affect ESP In-Flight Calibration

1. Unexpected changes of the dark currents. There is some source of large change of the dark currents which was detected in the middle of 2012. Requires some better statistics for understanding the nature of such change and the way to calculate it.
2. The edges of the spectral bands, mostly for the zeroth-order channel due to strong spectral variability in the soft X-ray;
3. Zeroth-order channel responsivity in about 0.1 – 7.0 nm is currently modeled, not measured

Measurements and Calculation of the Darks

By the summer of 2012:

- Use daily calibration runs to measure dark counts and the temperature with the dark filter in place.
- Determine the equation (for each channel) to fit the measured dark counts with the dark proxy as a function of temperature.
- Use the dark thermal proxy to calculate darks for any instant temperature.

Measurements and Calculation of the Darks

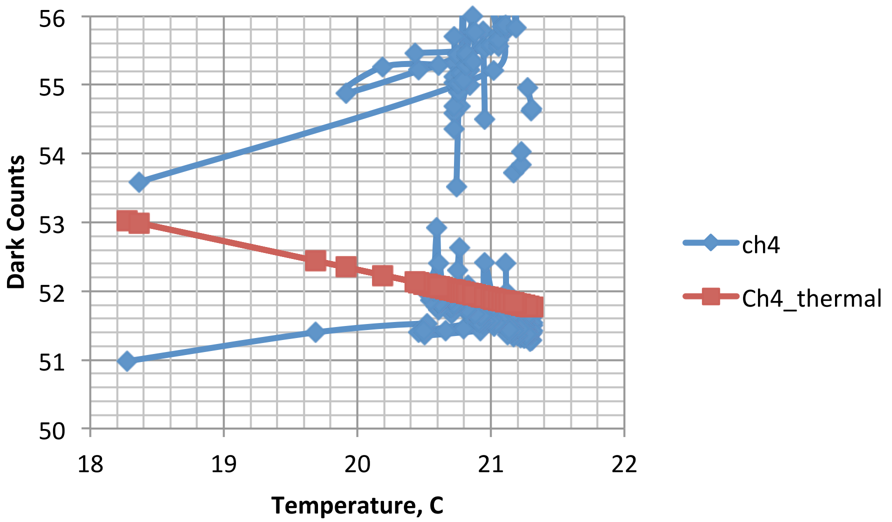
After the summer of 2012:

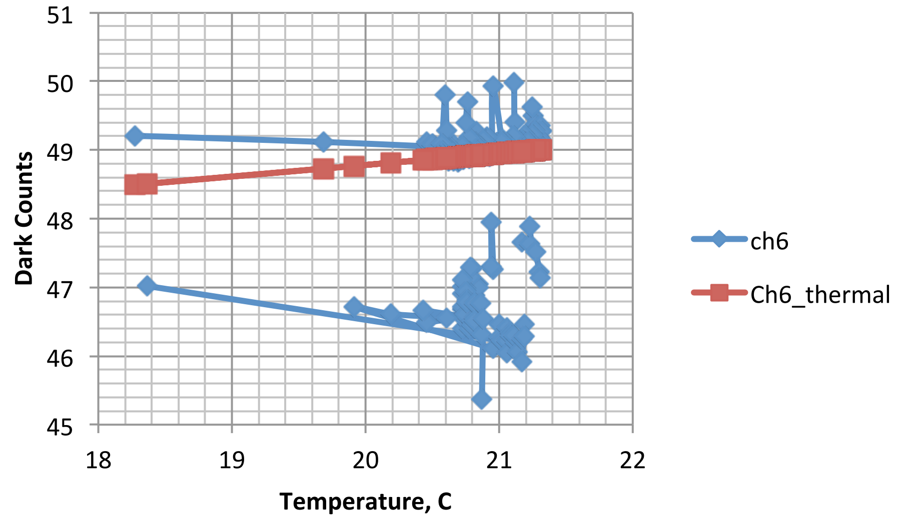
- Use daily calibration runs to measure dark counts and the temperature with the dark filter in place.
- Determine the equation (for each channel) to fit the measured dark counts with the dark proxy as a function of temperature and time.
- Use the dark thermal and temporal proxy to calculate darks for any instant temperature and/or time (see Equations in the EVE Sept Monthly Report).

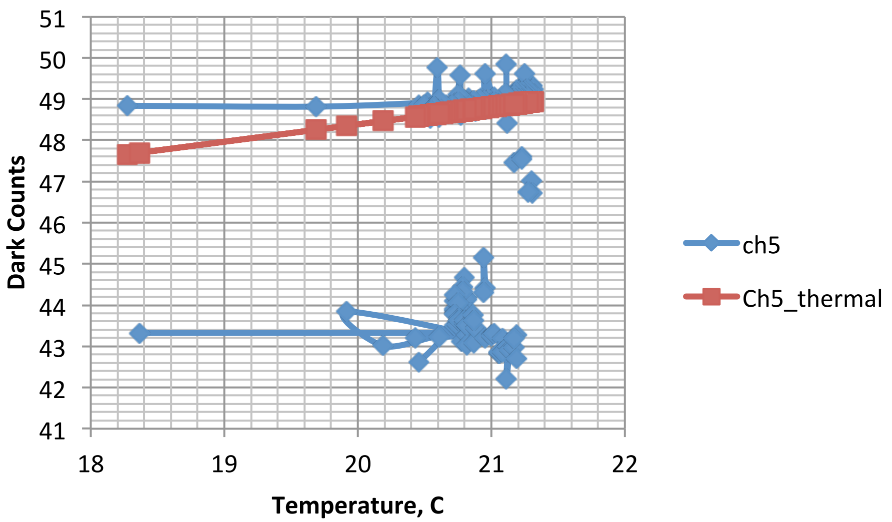
What Do We Know About Changes Detected in the ESP Darks

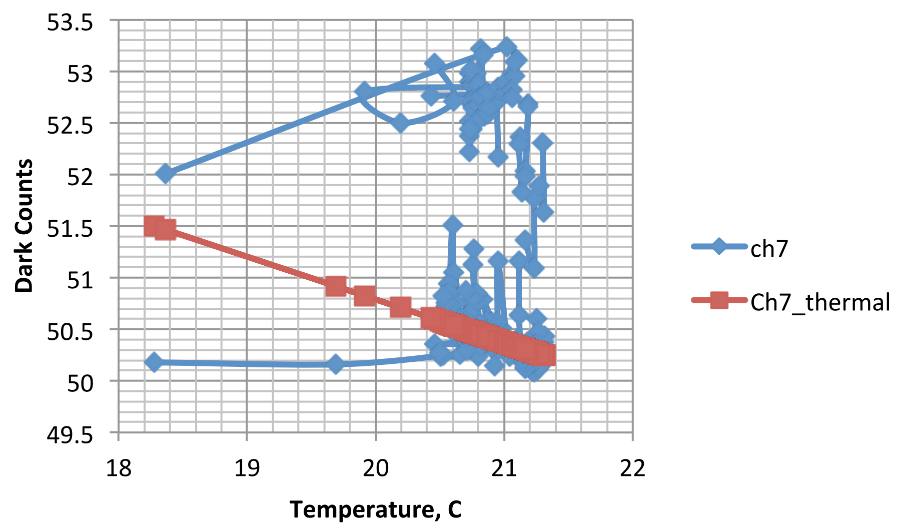
- The changes occurred during 2012 are significantly larger for the zeroth-order (QD) channels than for the first-order channels, up to 6 cnt/0.25 sec in Ch5.
- The changes in QD channels (Ch4-Ch7) are in opposite directions: increased for Ch4 and Ch7 and decreased for Ch5 and Ch6. This results in a small change for the QD as one zeroth-order channel.

Changes of the Thermal Darks









Factors that Could Affect the Darks

$$DN_d=[I_d\,(°C,S,t)+I_{offset}]*k1_{OPA}(t,TID)*k2_{VFC}(t, TID)$$

$$DNL=[(I_L+I_d)\,(°C,S,t)+I_{offset}]*k1_{OPA}(t,TID)*k2_{VFC}(t, TID)$$

- The change of the internal structure of the photodiode, e.g. its shunt resistance due to the space environment. Cannot be tested inflight.
- The changes of the Vref (VFC) gain (*k2*). Analysis of the Vref counts does not confirm this version.
- The change of the electronics offset for the darks (*Ioffset*). Cannot be tested inflight.
- The change of the electronics sensitivity *(k1):* Do the changes of the dark and light counts correlate to each other?

Do the Changes of Effective Counts Follow the Changes of the Darks?

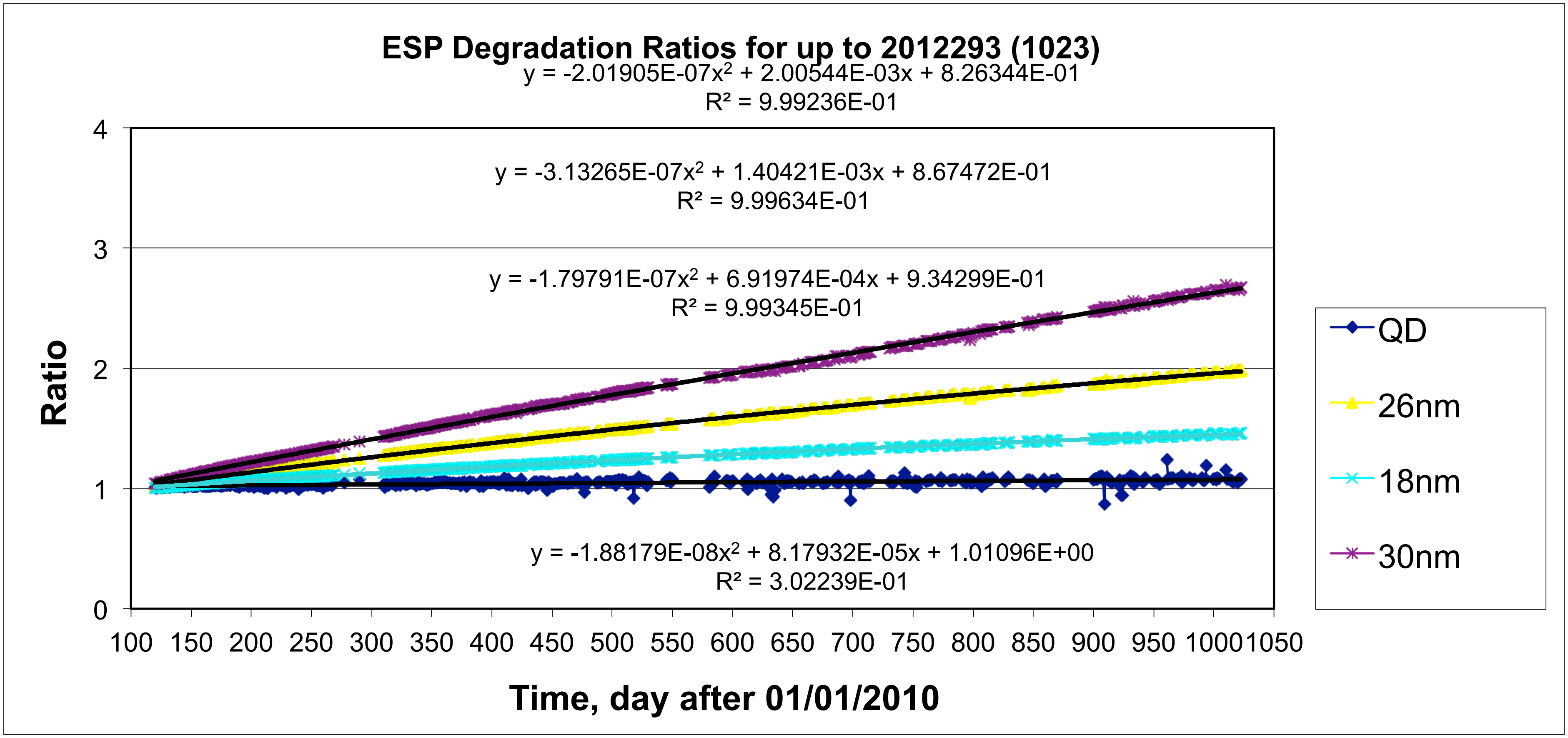
Ch Date	5 (Q0) dark	5 (Q0) eff	6 (Q1) dark	6 (Q1) eff	4 (Q2) dark	4 (Q2) eff	7 (Q3) dark	7 (Q3) eff
2010133	49.61	20.19	49.65	20.15	51.16	20.79	50.16	20.50
2012175	43.86 ↓	60.63 ↑	47.01 ↓	37.09 ↓	54.58 ↑	63.53 ↑	52.91 ↑	39.71 ↓
2012260	43.12 ↓	81.70 ↑	46.67 ↓	54.11 ↓	55.45 ↑	73.00 ↑	52.80 ↑	47.92 ↓

The only one explanation fits all known features: if the temperature of the diodes is significantly lower than the one registered as the ESP temperature. Deposition of hydrocarbons directly on QD that prevents the heat from longer WLs stray light?

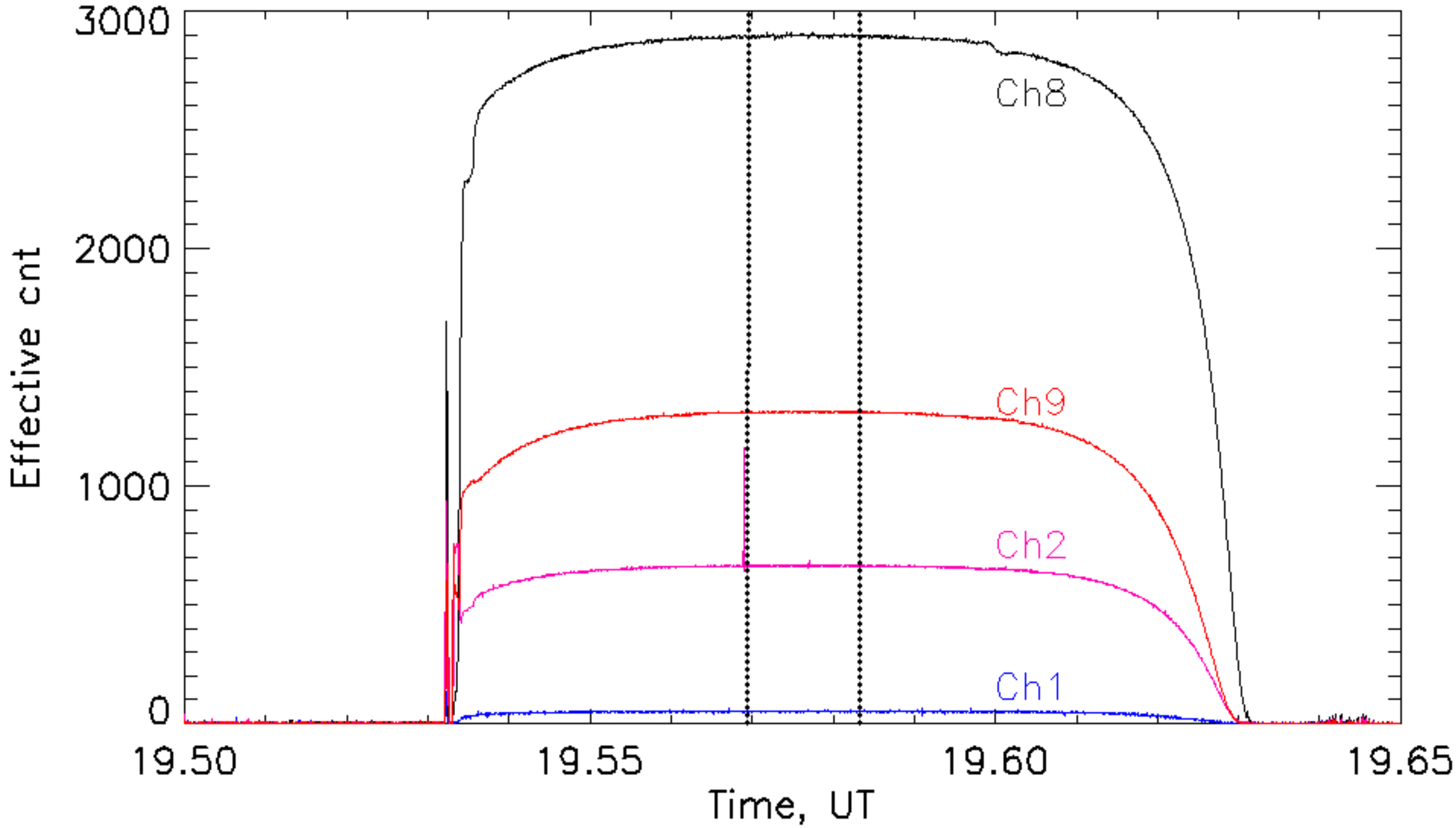
How Degradation of the Thin-Film Al Filter is Determined

- Use daily calibration runs and compare counts for the primery Al filter (F3) with the counts from one of spare Al filters (F4).
- Most of the mission time F4 is outside of the solar light and it is significantly less degraded than F3.
- The ratio F4/F3 shows F3 degradation (decreased transmission through the filter due to deposition of hydro-carbons).

Degradation Ratios for up to 2012293 (Oct 19)



ESP Data Analysis From EVE Rocket Underflight (NASA 36.286) on June 23, 2012



Apogee portion used for the analysis is marked with dotted vertical lines

Dark and **Effective Count-Rates**: Rocket (top) and Flight (bottom)

ESP channel (WL)	Dark, cnt/sec [1000:1200] and [2750:2800]	Effective, cnt/sec [1800:2000]
Ch1 (36 nm)	42.5155	51.072
Ch2 (25 nm)	23.6522	663.54
Ch8 (17 nm)	44.0967	2895.53
Ch9 (30 nm)	31.8807	1310.726
QD Ch4 (3.5 nm)	38.9208	246.088
QD Ch5 (3.5 nm)	31.6965	210.807
QD Ch6 (3.5 nm)	41.9102	181.036
QD Ch7 (3.5 nm)	37.0351	228.317
QD sum		866.25

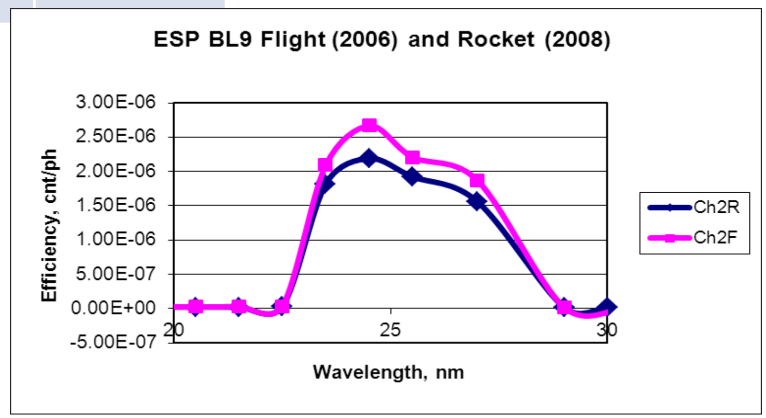
ESP channel (WL)	Dark, cnt/sec [daily calibration]	Effective, cnt/sec [19:34:30 – 19:34:50]
Ch1 (36 nm)	5.9	32.3433
Ch2 (25 nm)	53.7664	452.707
Ch8 (17 nm)	45.1711	2079.66
Ch9 (30 nm)	57.3684	499.803
QD Ch4 (3.5 nm)	54.5855	254.396
QD Ch5 (3.5 nm)	43.8684	243.136
QD Ch6 (3.5 nm)	47.0066	148.371
QD Ch7 (3.5 nm)	52.8947	158.974
QD sum		804.88

$$E(\lambda, t) = \frac{C_{eff}(A, f_{degrad}(t), G_{SM})}{A * k\,(\lambda, R_M, F_W) * f_{degrad}(t) * f_{1AU}(t)}$$

$$k(\lambda, R_M, F_W) = \frac{\sum_{\lambda 1}^{\lambda 2} R_M(\lambda) * F_i(\lambda) * \Delta\lambda}{\sum_{\lambda 1}^{\lambda 2} F_i(\lambda) * \Delta\lambda}$$

Comparison of (R) and (F) Eff. Counts Corrected for Degradation and Response Functions

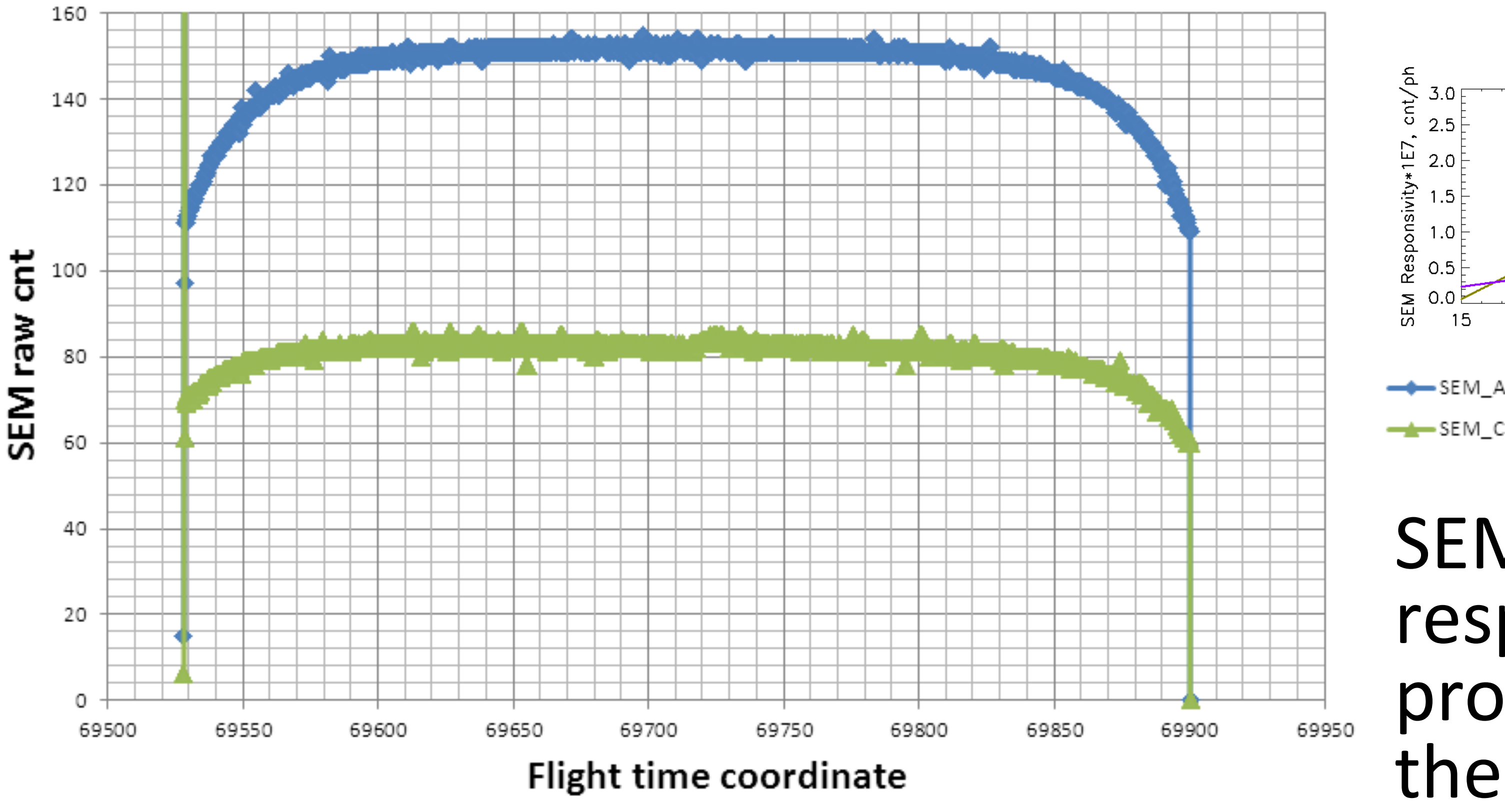
ESP Ch	Rocket Eff cnt/sec	Flight Eff cnt/sec (not corr for degrad)	Degrad Ratio @ 2012175	Flight Eff cnt/sec (corr for degrad)	Ratio R/F
Ch1	51.072	32.3433	noisy	-	
Ch2	663.54* 809.5	452.707	1.87	846.56* 693.90	0.96
Ch8	2895.53	2079.66	1.41	2932.32	0.99
Ch9	1310.726	499.803	2.54	1269.50	1.03
QD	866.3	804.9	1.08	869.3	0.99

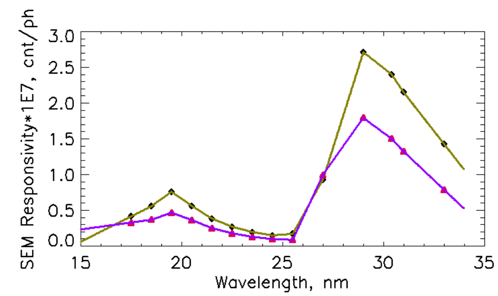


Angular Offsets and Atmosphere Transmissions are Corrected

ESP Ch	Ratio R/F (Initial)	Ratio R/F (R Ang. Offset)	Ratio R/F (R and F Ang. Offset)	Ratio R/F (Atm. Transmiss.)	Final R/F Ratio
1					
2	0.96	0.97	1.02	1.03	**1.03**
8	0.99	0.99	0.99	1.00	**1.00**
9	1.03	1.03	1.03	1.05	**1.05**
QD	0.99	0.99	0.99	0.99	**0.99**

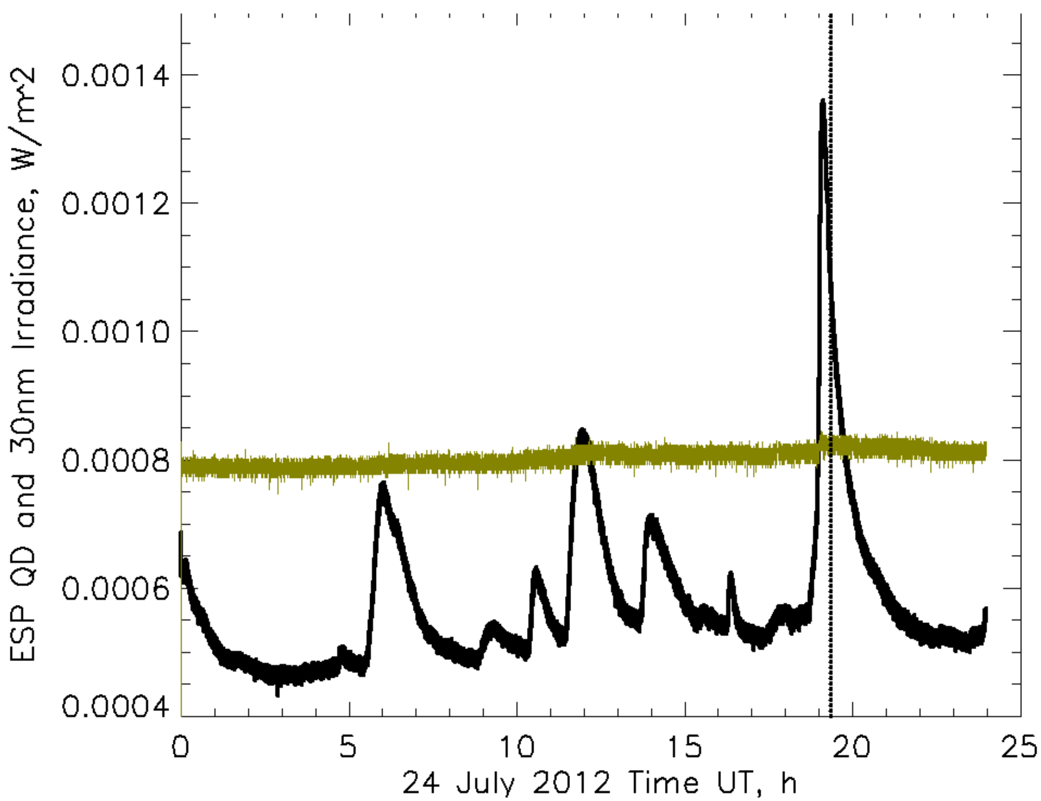
SEM 36.263 (24 July 2012 / 2012206) Rocket Profiles





SEM responsivity profiles with the cover-ON calibration

ESP Irradiance Profiles for 2012206



ESP Ch9 (27.16 – 33.8 nm) irradiance for the 36.263 flight apogee time (dotted line) is **8.2E-4 W/m^2**.

SEMR apogee irradiances are: 7.90E-4 (SEM-C) and 8.85E-4 (SEM-A) W/m^2. SEM mean apogee irradiance is **8.54E-4 W/m^2** (4% higher than ESP)

SEMF apogee time irradiances are: **9.7E-4 W/m^2** (No cover-ON efficiencies, SOLERS22);

8.1E-4 W/m^2 (cover-ON efficiencies, MEGS v2 refer. Spectrum)

ESP Bandpass Edges and v3 Status

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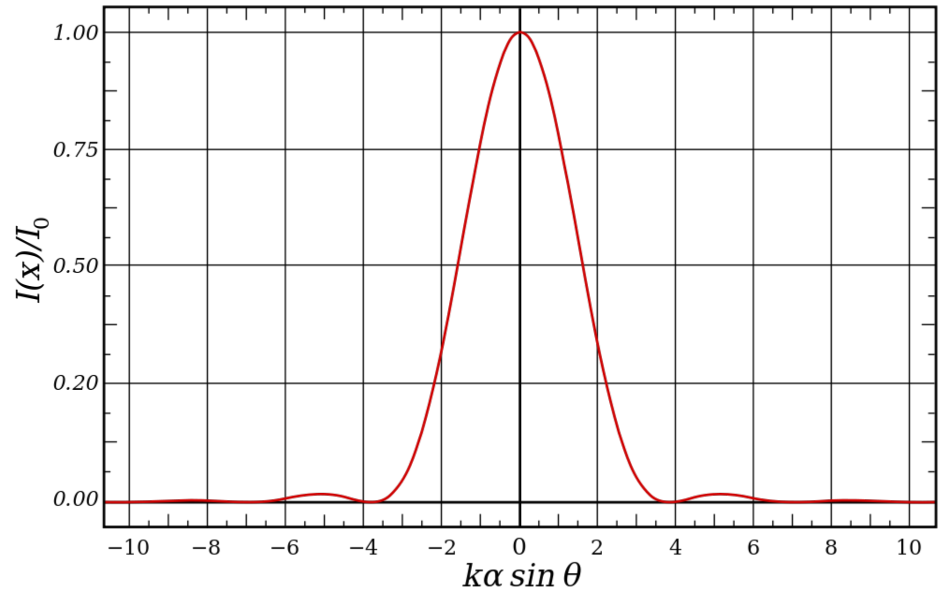
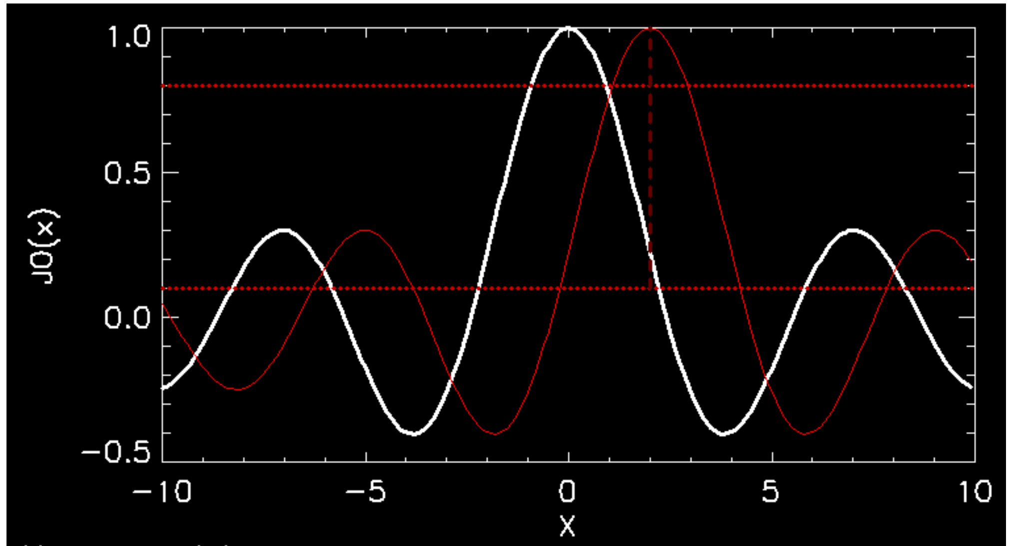
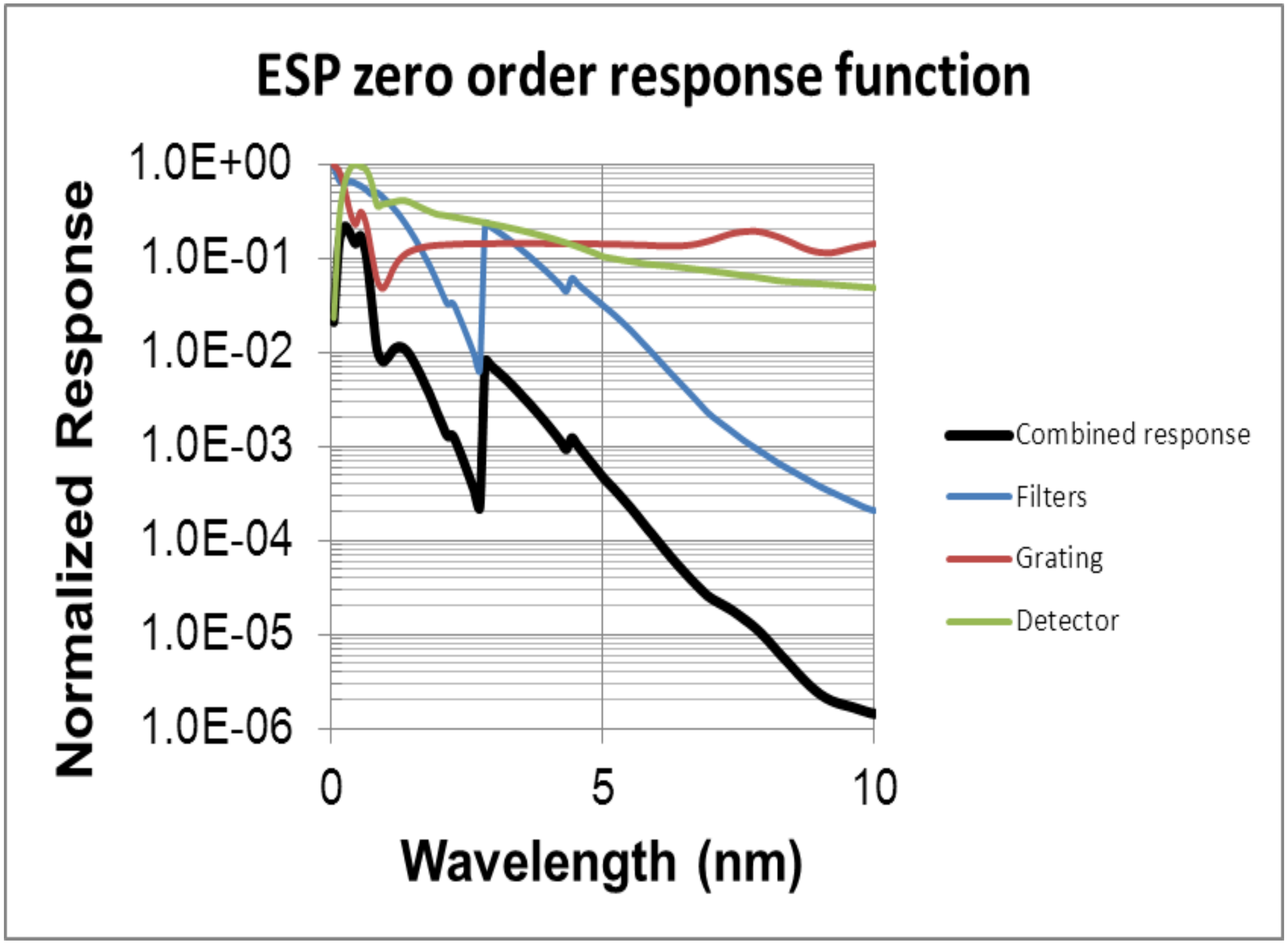
Spectral Resolution and Bandpass

- **Spectral resolution** in optics may be represented by the Airy disk pattern (top right). Spectral resolution is a measure of the ability of an instrument to differentiate between two adjacent wavelengths. Two peaks usually are considered resolved if the minimum of the absorption between the two peaks is lower than 80% of the peak maxima (bottom right). A 10% level of the maximum may be used as the level to determine the bandpass. However, this method does not work for the zeroth-order channel.





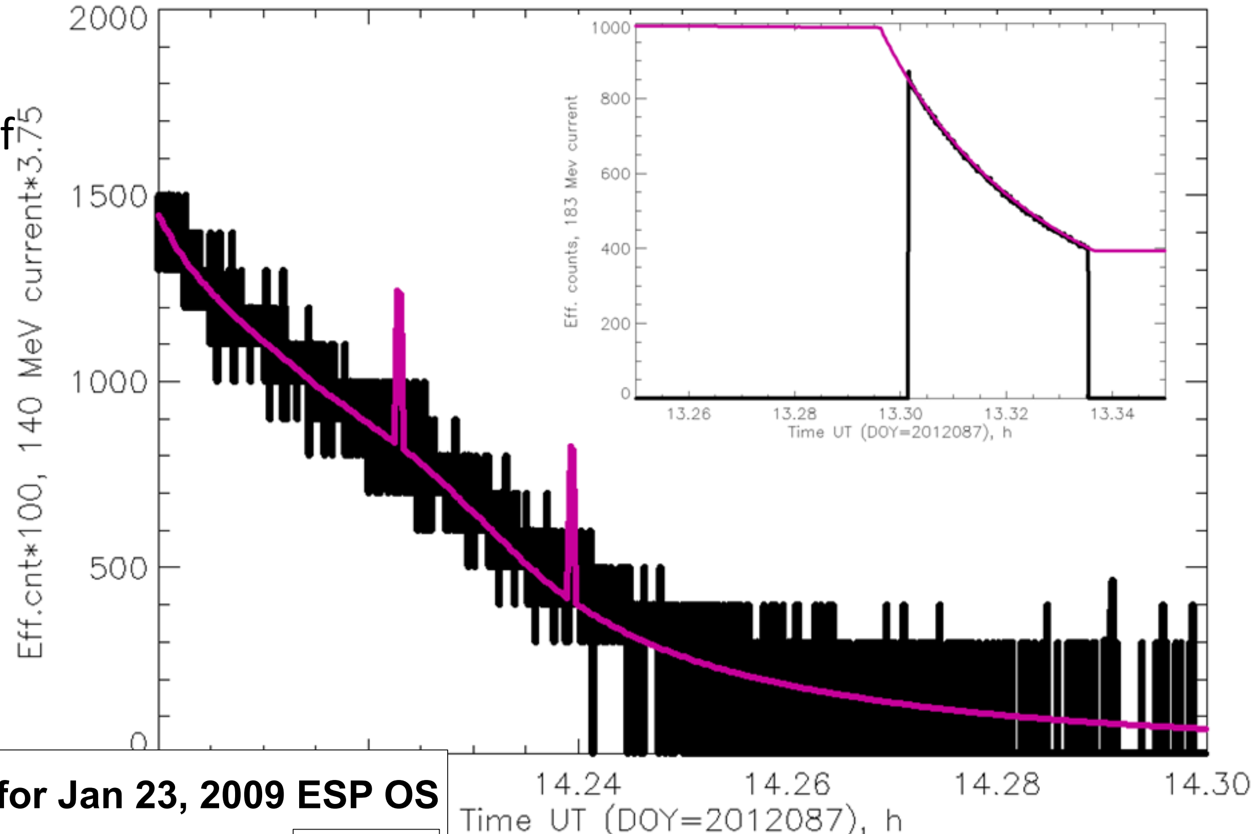
ESP/QD Calculated Response Function

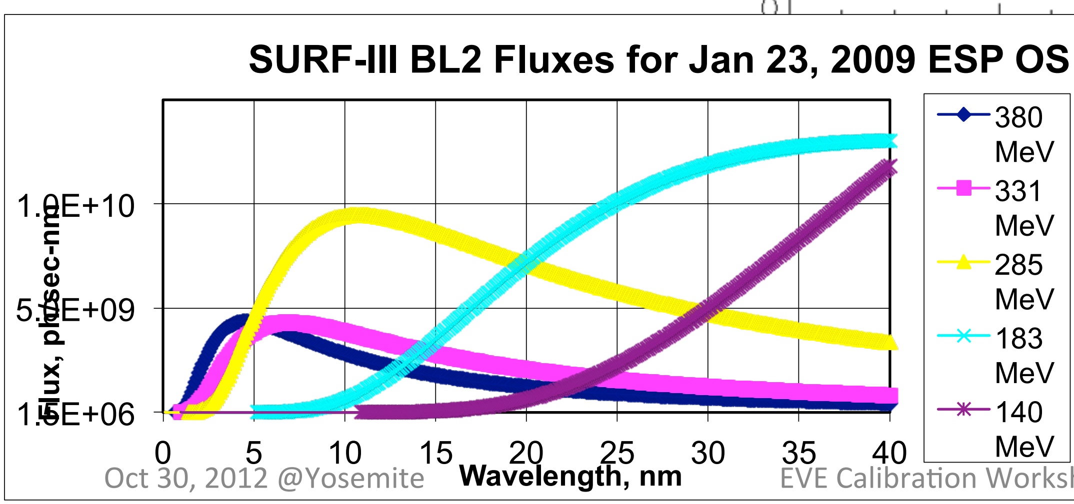


- Note, response at the right edge (7 nm) is about 4 orders of magnitude smaller than at the left edge.

ESP QD BL Calibration: Why It Is Not Sufficient

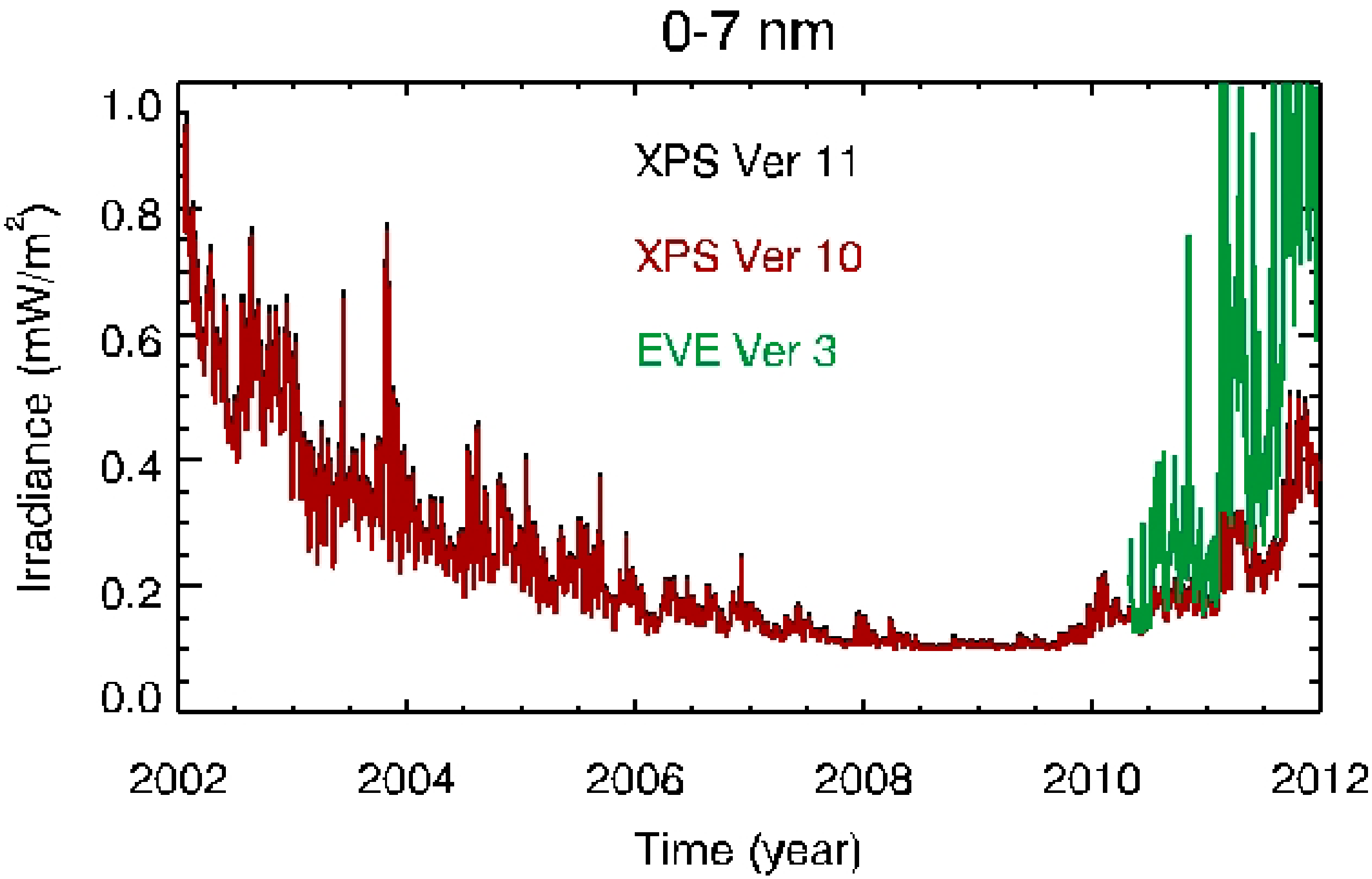
Linearity of the ESP QD SXR channel from March 2012 SURF radiometric calibration of the EVE rocket instrument. Effective counts (black lines) are compared to the beam intensity (beam current is shown as magenta curves). The insert on the top right shows the result for 183 MeV. Two spikes on the beam current line (140 MeV) do not represent real changes of the current, only its scale changes





A comparison of BL-2 fluxes

ESP Zeroth-Order Band: A Problem



A comparison ***(Tom Woods)*** *of XPS (Ver 10 and Ver 11, black (buried in the red) and red, accordingly) irradiance from TIMED/SEE and SORCE with SDO/EVE/ESP Quad Diode (zeroth-order) channel data (green).*

What Else Would Affect the QD Irradiance for a Higher Solar Activity

$$E(\lambda, t) = \frac{C_{eff}(A, f_{degrad}(t), G_{SM})}{A * k(\lambda, R_M, F_W) * f_{degrad}(t) * f_{1AU}(t)}$$

Where C_{eff} are effective counts as a function of the SXR flux through the entrance aperture *A*, degradation of the channel, and the electronics Gain G_{SM}, where

$$k(\lambda, R_M, F_W) = \frac{\sum_{\lambda 1}^{\lambda 2} R_M(\lambda) * F_i(\lambda) * \Delta\lambda}{\sum_{\lambda 1}^{\lambda 2} F_i(\lambda) * \Delta\lambda}$$

The reference spectrum $F_i(\lambda)$ **is currently a fixed composite spectrum**, the same for any periods of solar activity and the response function R_M is **currently modeled** for soft X-ray bands, e.g. for ESP zeroth-order.

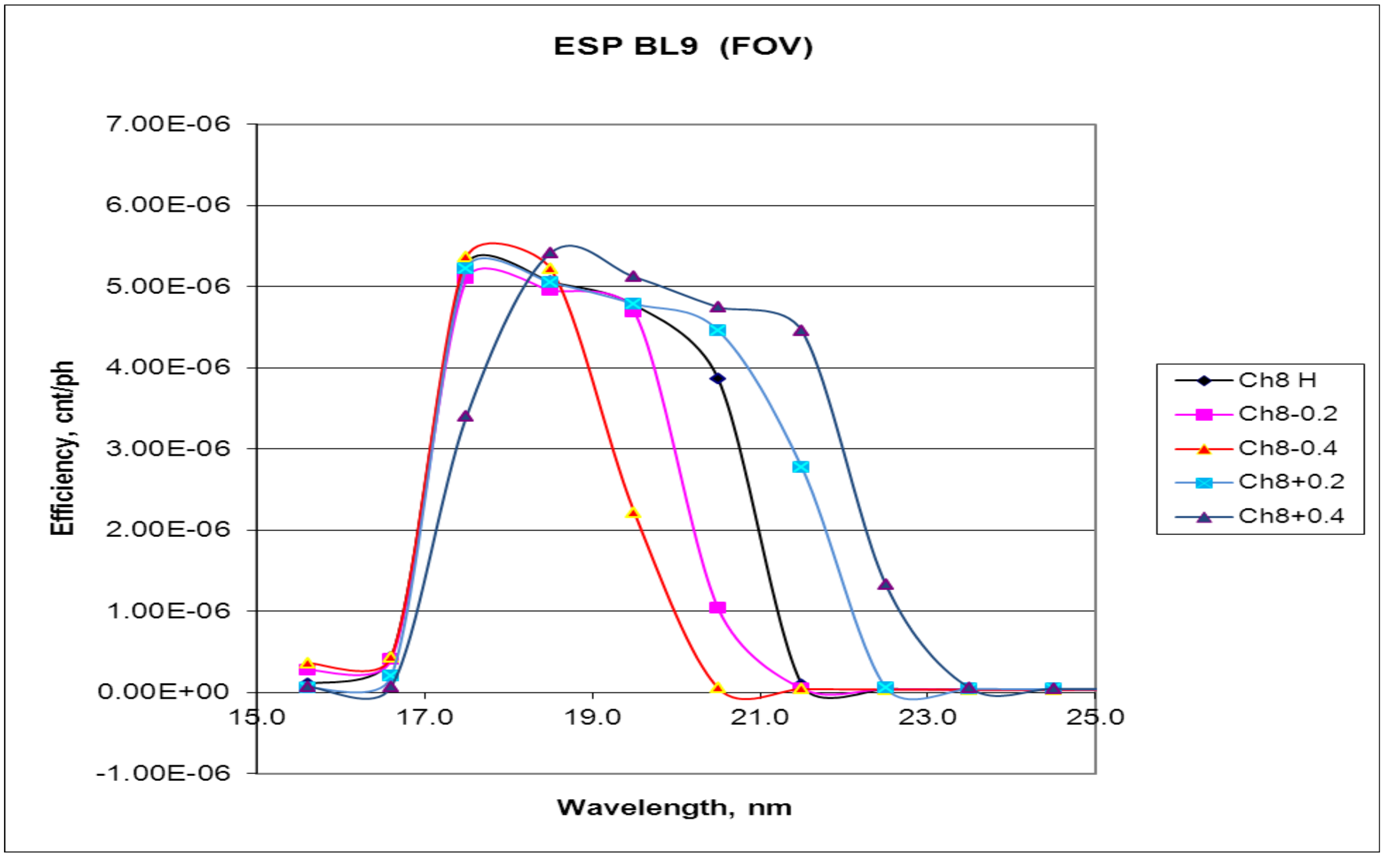
First-Order Bandpass Edges

$$\mathrm{Eff}_{\odot}(\lambda) = \sum_{\alpha} (W_{\alpha} * E_{\lambda,\alpha})$$

Where Eff for the disk is a sum over 535 areas (from -0.267 to +0.267 deg with Δα =0.001 deg) of the weight W_{α} of the area multiplied by the interpolated efficiency $E_{\lambda,\alpha}$ for the area.

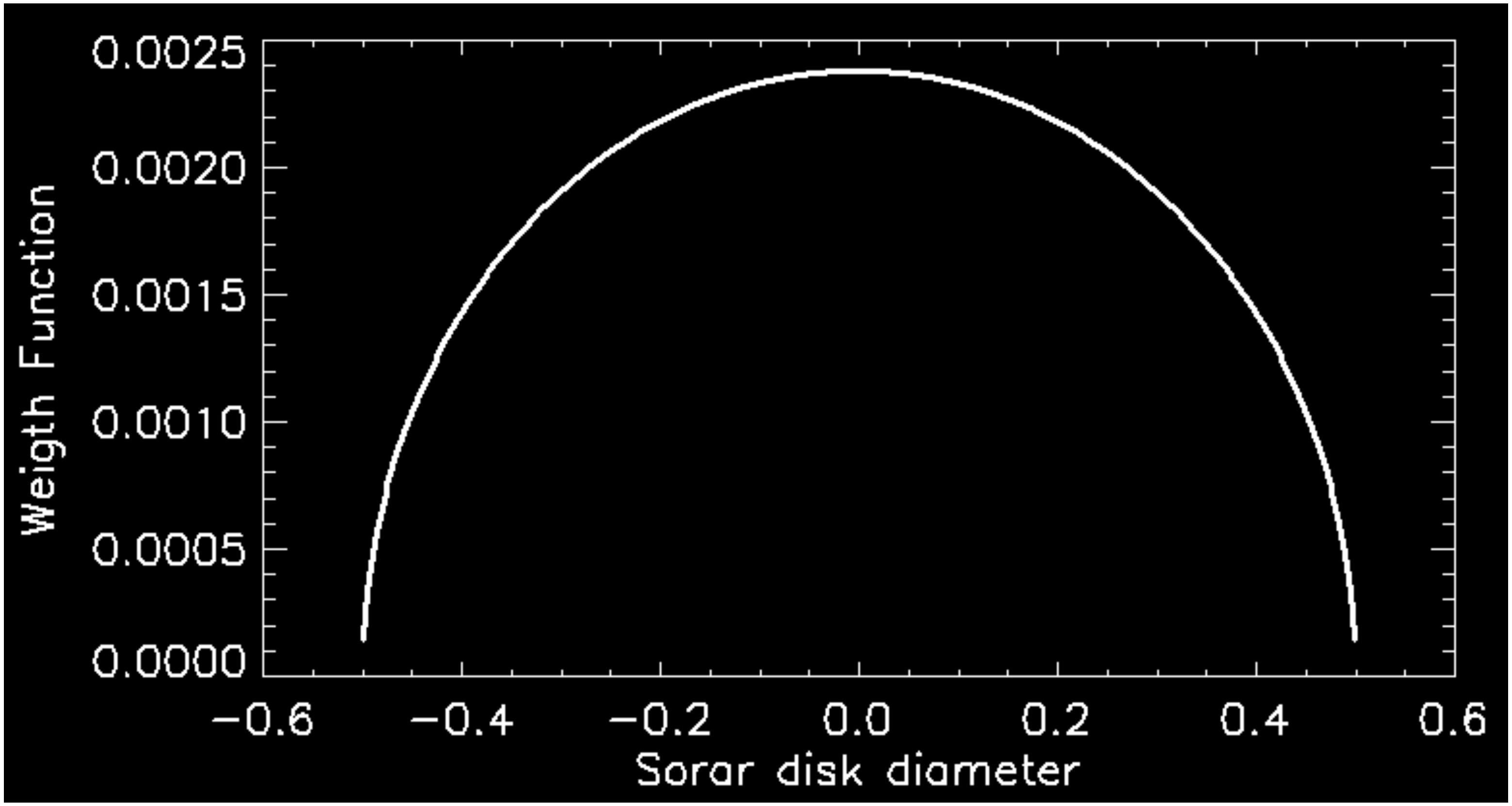
The edges for the first order channels were determined at the level of 10% from the maximum value of the calculated efficiency profile.

Efficiency Profiles for the Centered and Off-Axis Positions



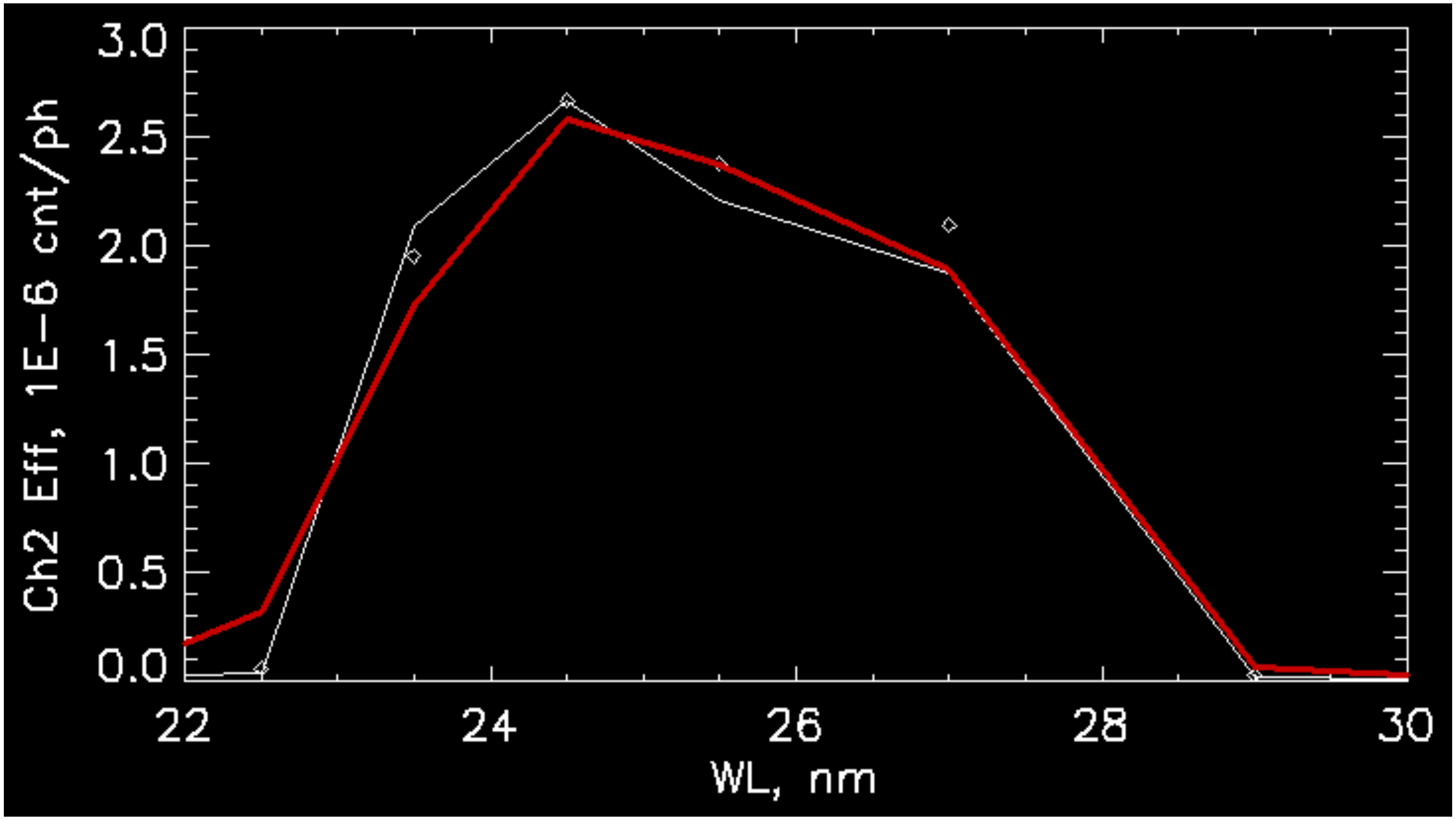
The edges (Dec 2011 – Jan 2012) were determined using SURF BL-9 Flight efficiency profiles (Ch8 shown) for both centered and tilted (± 0.4 and (± 0.2 deg) ESP positions.

Weight Function



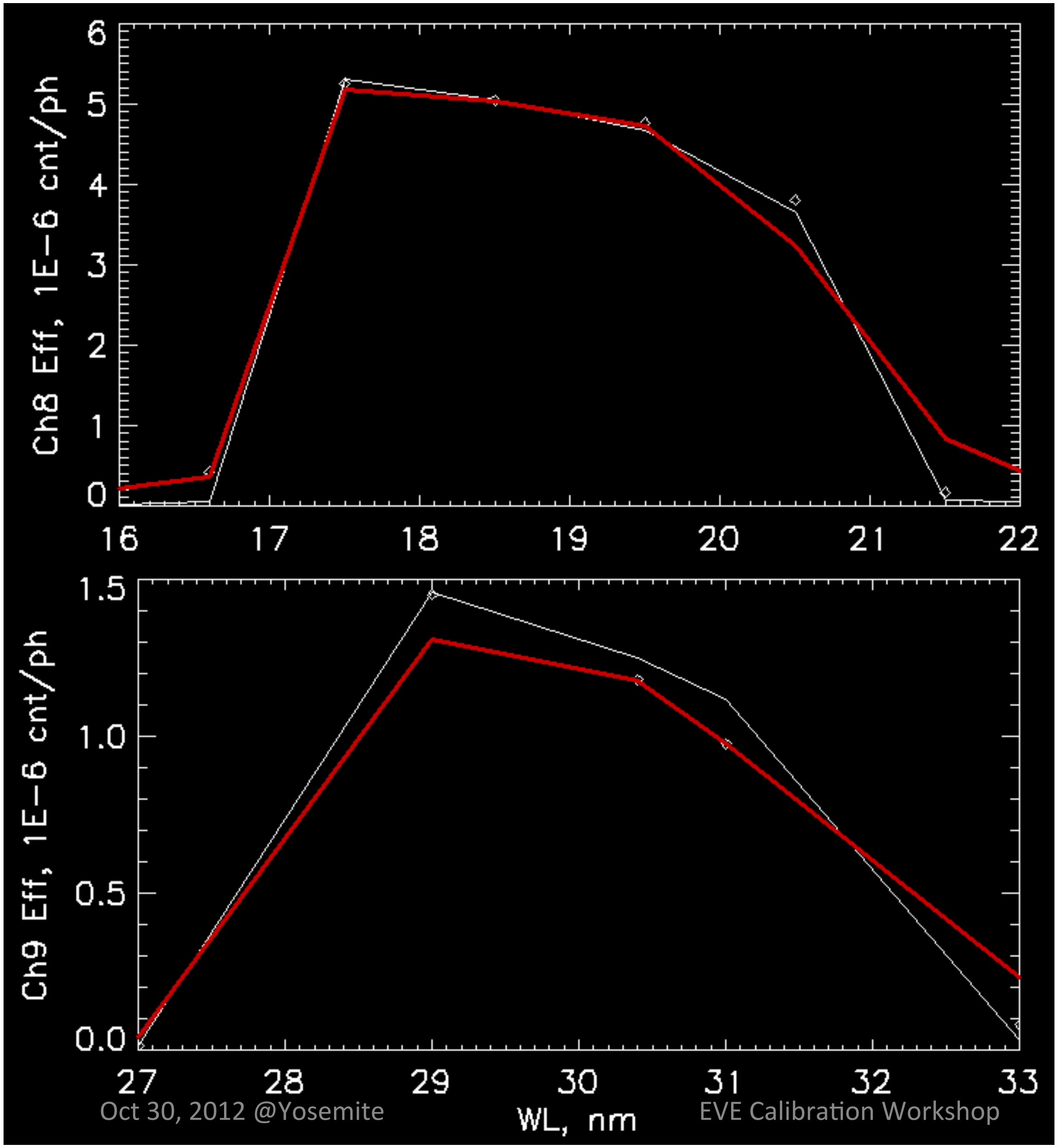
The whole disc area (-0.267 to +0.267 deg) was divided on 535 slices ($\Delta\alpha$ =0.001 deg) along the dispersion direction. Weight of each slice (*W*) and interpolated efficiency (*Eff*) were determined.

A Comparison of Efficiency Profiles



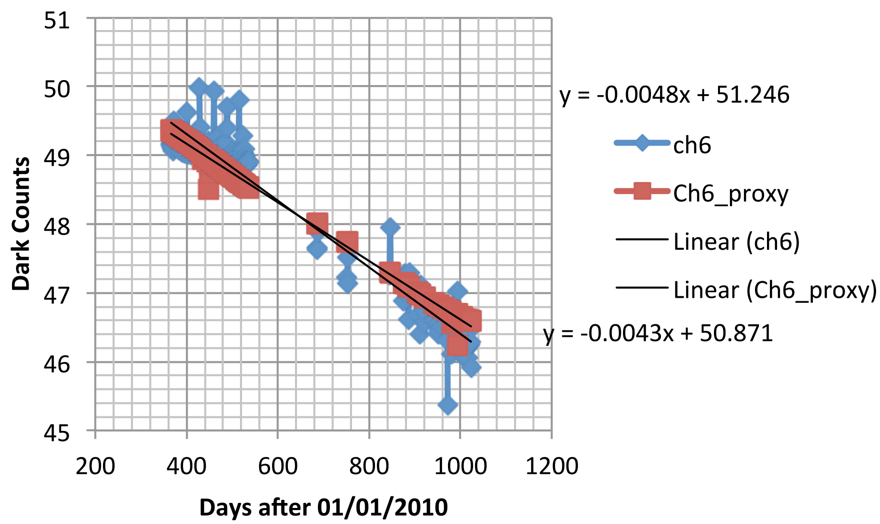
Calculated profiles (red) are compared to the original ESP flight efficiency profiles (thin white line) previously used as inputs for convolution with the slit function. Diamonds are based on TW suggestion to use three area model (central with the weight of 0.94 and two edge areas with the weight 0.03 each).

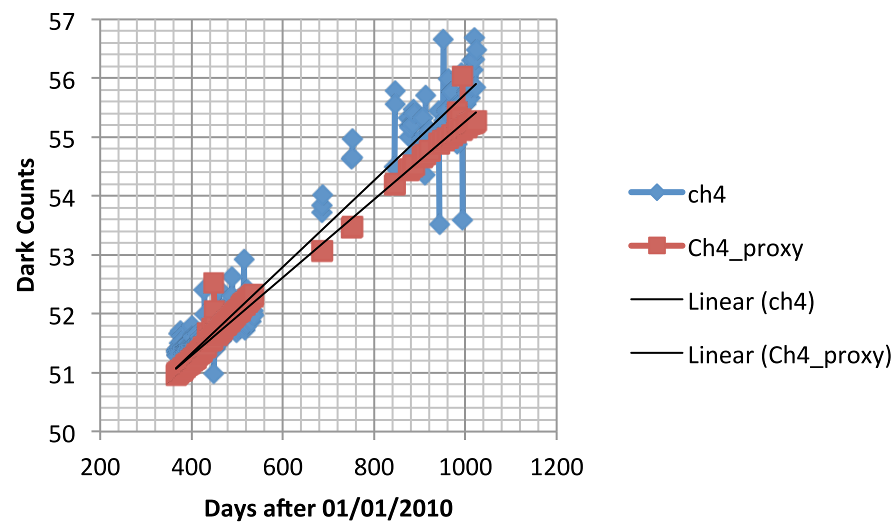
Same for Ch8 and Ch9

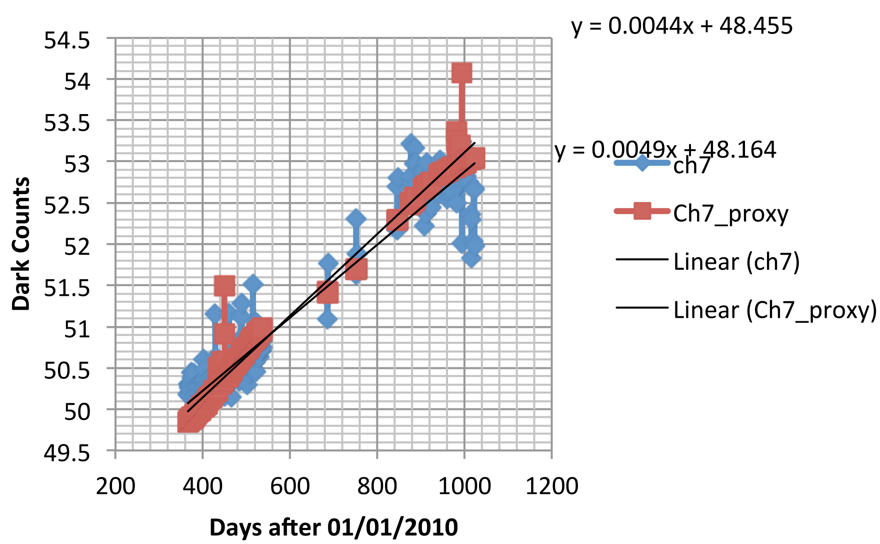


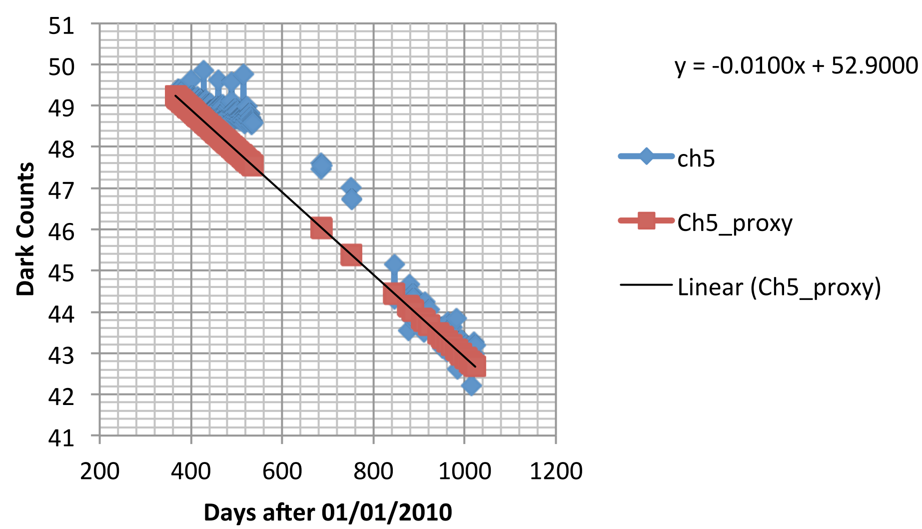
Detailed information about the change of the first-order bandpasses was provided in the EVE monthly report for Dec 2011.

V3 Status

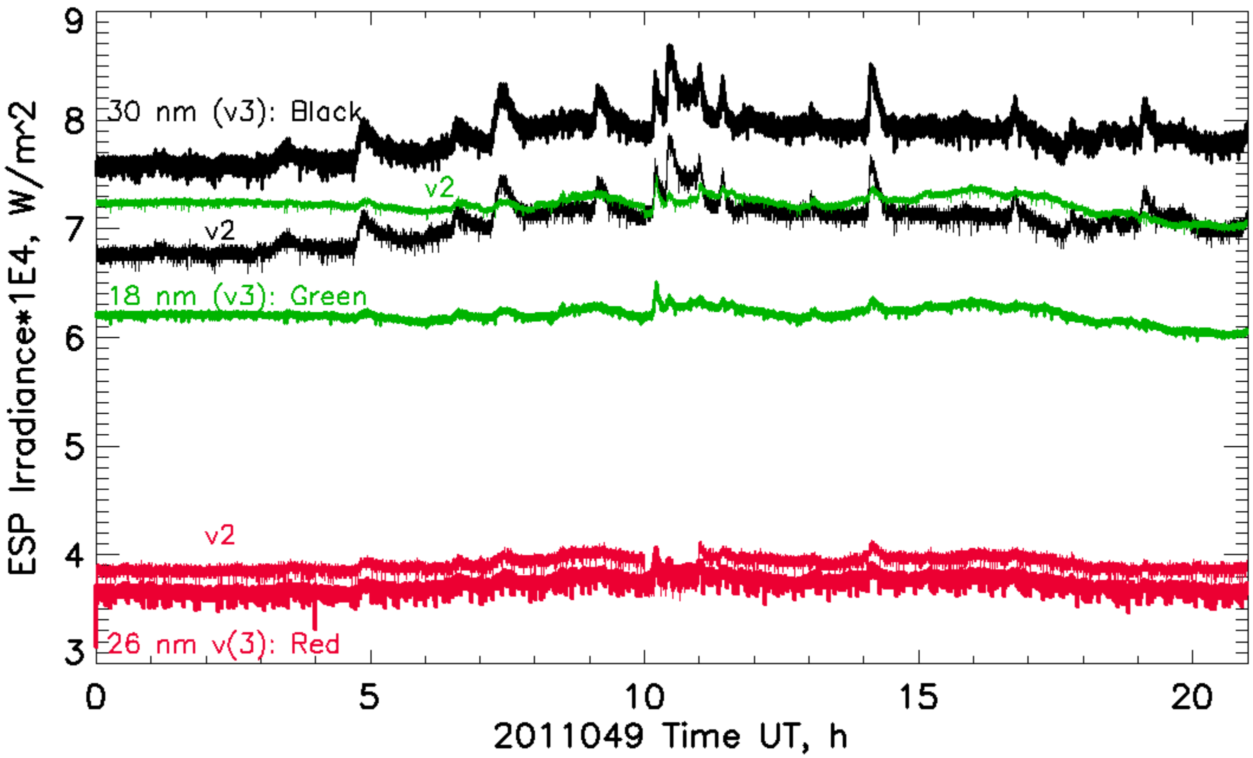

y = -0.0048x + 51.246
ch6
Ch6_proxy
Linear (ch6)
Linear (Ch6_proxy)
y = -0.0043x + 50.871
Dark Counts
Days after 01/01/2010
51
50
49
48
47
46
45
200
400
600
800
1000
1200


ch4
Ch4_proxy
Linear (ch4)
Linear (Ch4_proxy)
Dark Counts
Days after 01/01/2010
57
56
55
54
53
52
51
50
200
400
600
800
1000
1200


y = 0.0044x + 48.455
y = 0.0049x + 48.164
ch7
Ch7_proxy
Linear (ch7)
Linear (Ch7_proxy)
Dark Counts
Days after 01/01/2010
54.5
54
53.5
53
52.5
52
51.5
51
50.5
50
49.5
200
400
600
800
1000
1200


y = -0.0100x + 52.9000
ch5
Ch5_proxy
Linear (Ch5_proxy)
Dark Counts
Days after 01/01/2010
51
50
49
48
47
46
45
44
43
42
41
200
400
600
800
1000
1200

ESP v3 vs v2

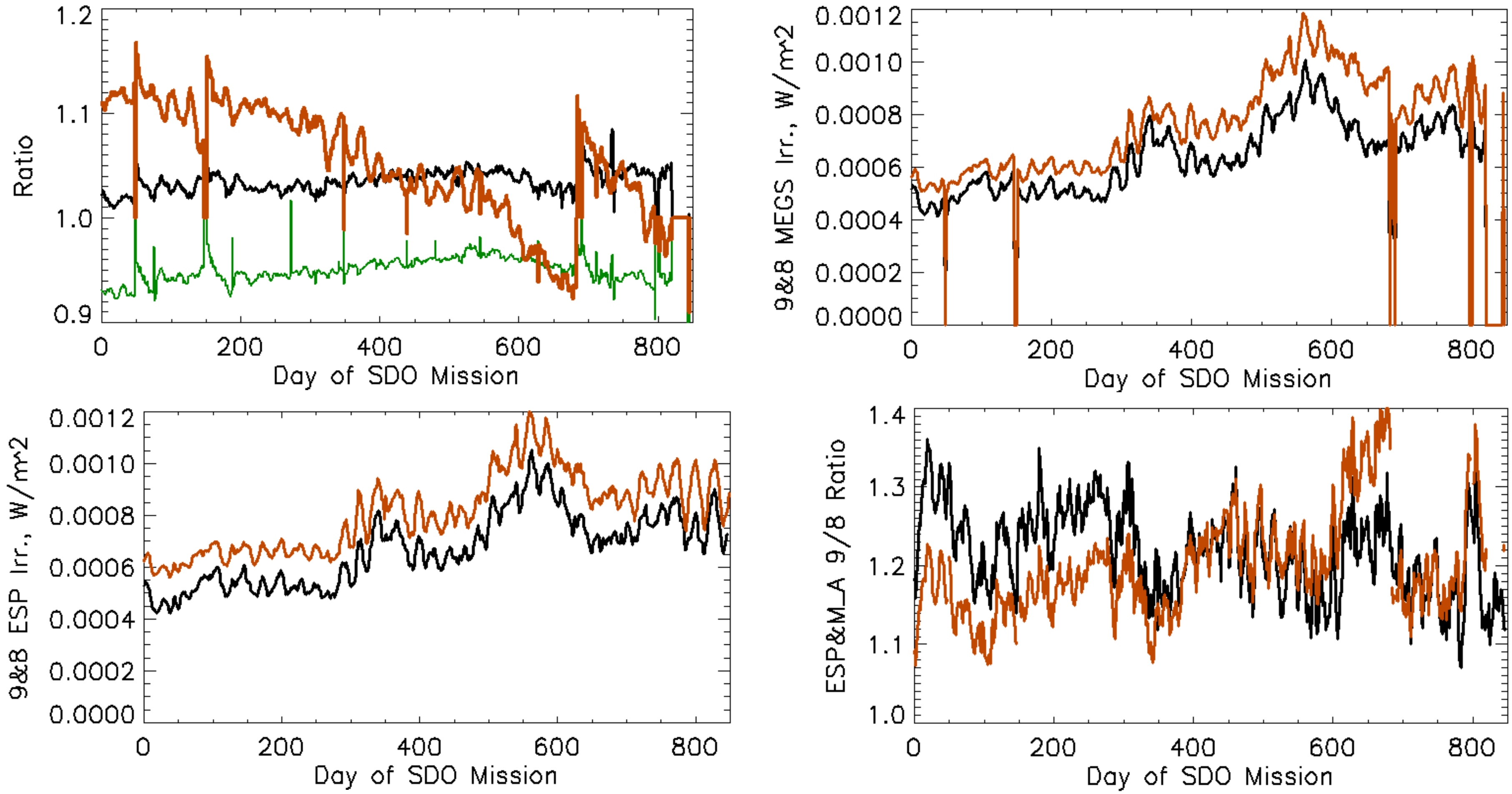


R_2 = ∑𝜆↑▒[𝑀↓𝐴_1 (𝜆)∗𝐸𝑓𝑓_1/

𝑘↓2 =𝑅↓2 /𝑅↓2 +∑𝜆2↑▒𝑀

v3 (thick) vs v2 (thin) difference is related to **a)** corrected MA and MB tables, **b)** updated bandpass edges, and **c)** updated 2nd order coefficients (k_2) as a result of EVE SR flight

ESP_MEGS Comparison for v3



- (top): ESP/MEGS ratios (L; Ch8-black; Ch9-red; Ch2-green); Ch9(red) and Ch8 (black) MEGS Irr (R);
- (bottom): Ch9(red) and Ch8(black) ESP Irr (L); Ch9/Ch8 ratios for ESP (black) and MEGS (red).