Flare watch with all three LYRA units 29 Mar - 05 Apr 2017

IED 06 Jul 2017

Abstract

Lyman-alpha signatures were observed in the two M5 flares covered by unit 1 (02 Apr 20:33 UTC, and 03 Apr 14:29 UTC). There are significant signals in the Lyman-alpha channel, and again there are no significant signals in the Herzberg channel.

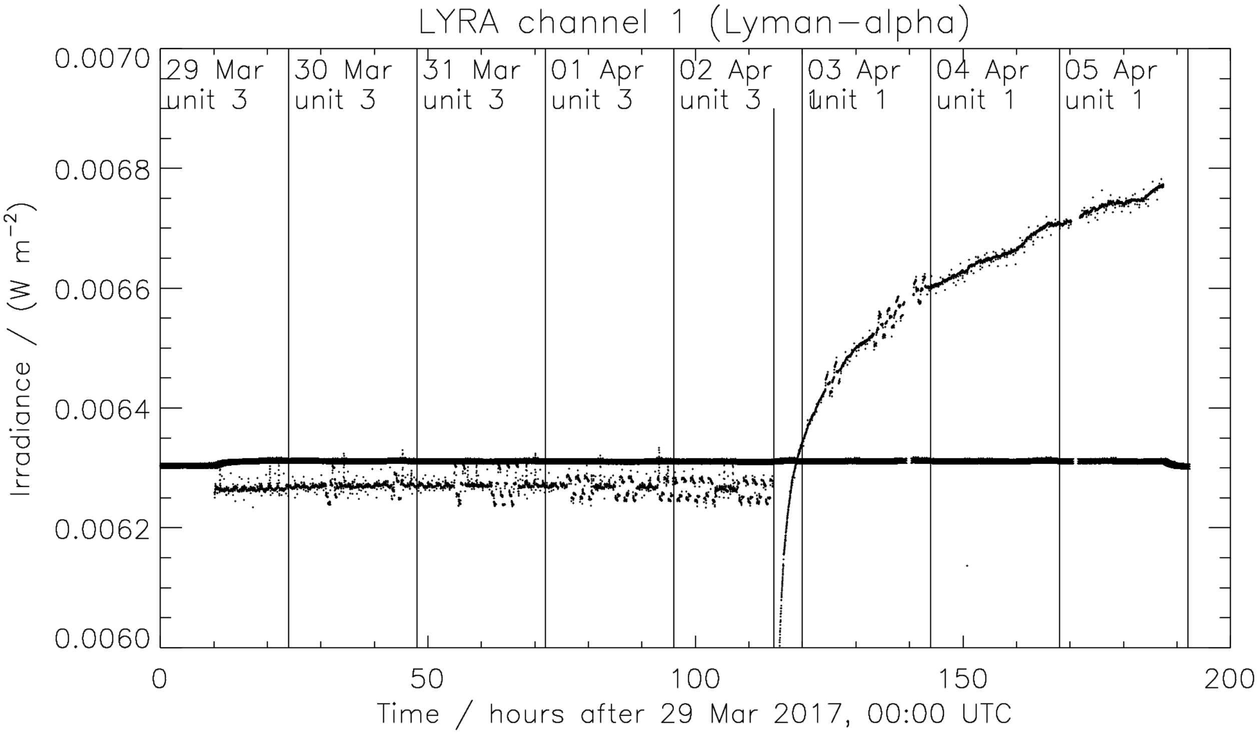
The flare strengths in Lyman-alpha (delta signal caused by flare) correspond to around 0.07 mW/m2, which is lower than to be expected from an earlier report:
http://solwww.oma.be/users/dammasch/IED_20130607_SpeculationsFlareSignatures.pdf

The flare watch campaign can also be used to confirm the calibration of the three LYRA units, and to estimate their individual spectral degradation.

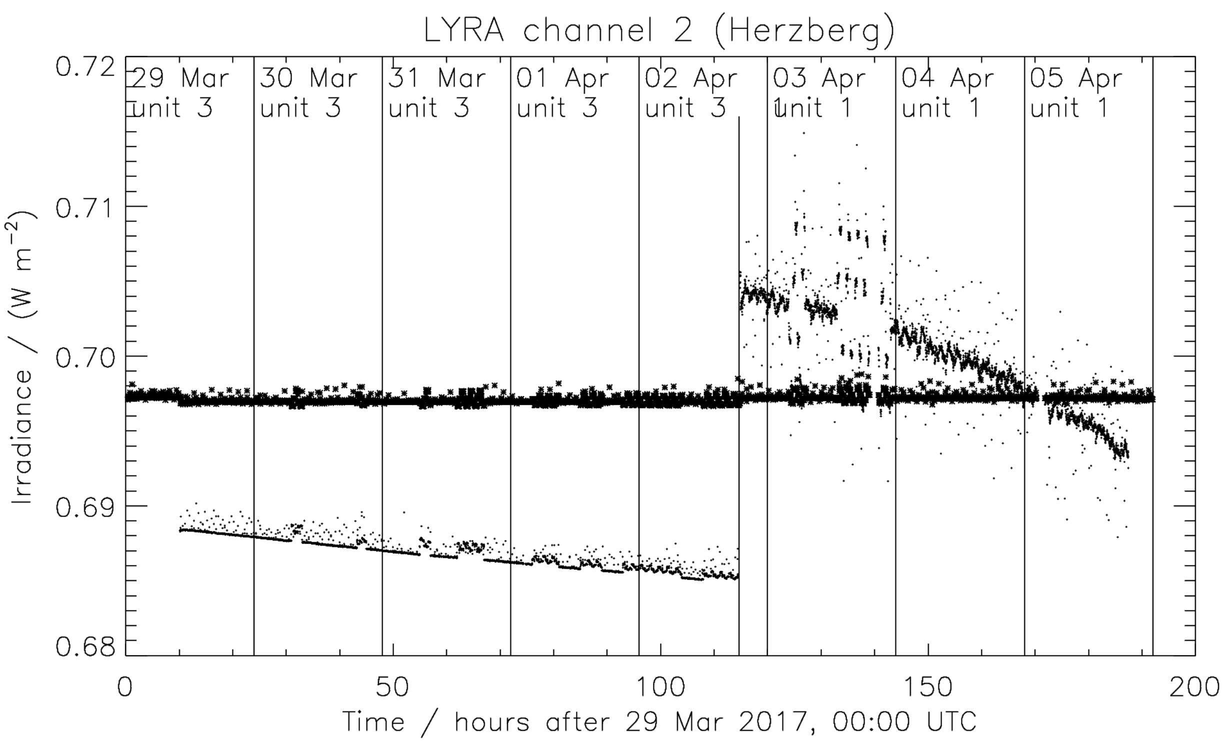
Campaign overview

The following two pages show the irradiance development during the flare watch for LYRA channels 1, 2, 3, 4.

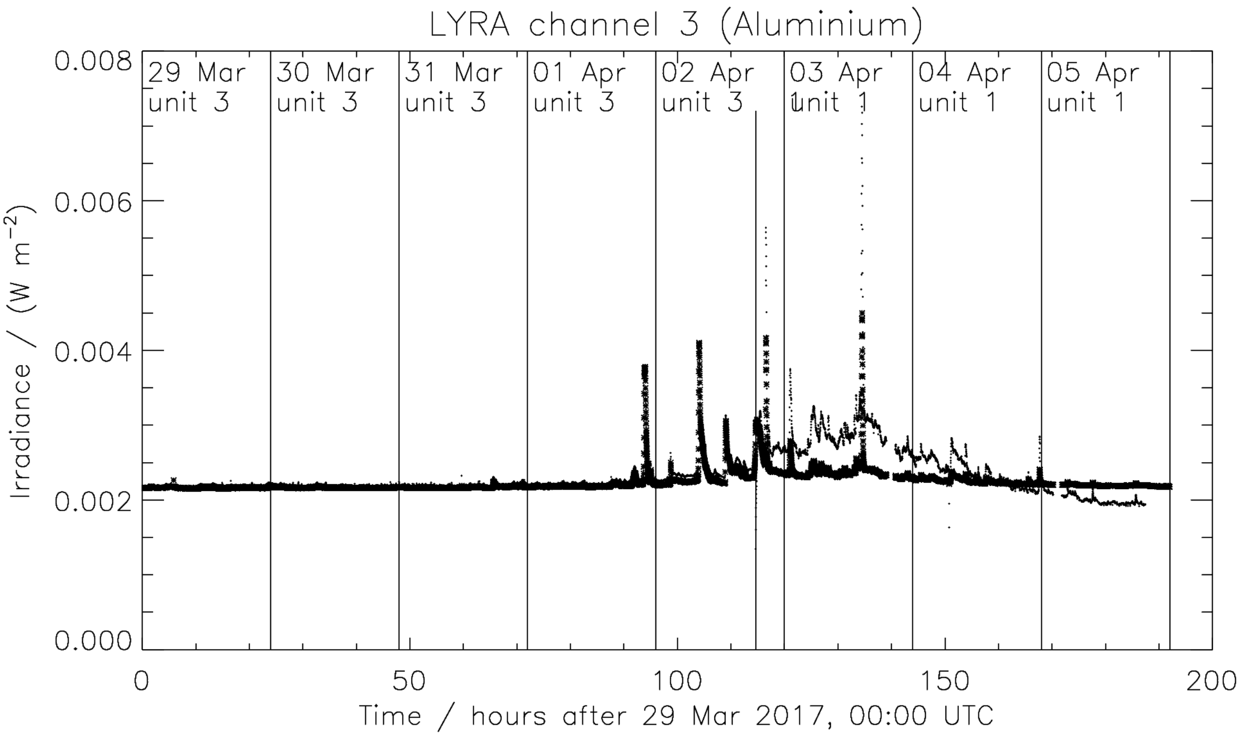
Dots are values from unit 3 (29 Mar - 02 Apr) and unit 1 (02 Apr - 05 Apr), asterisks are from unit 2.

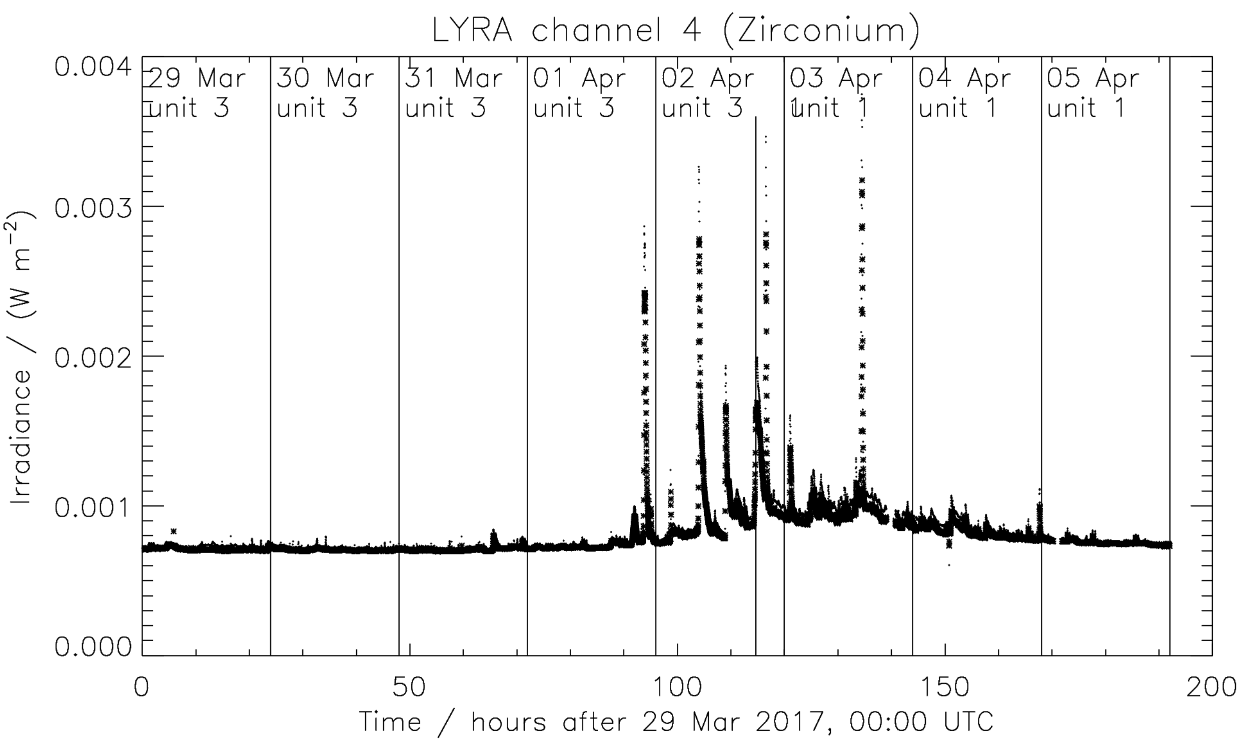


LYRA channel 1 (Lyman−alpha)
29 Mar unit 3
30 Mar unit 3
31 Mar unit 3
01 Apr unit 3
02 Apr unit 3
03 Apr unit 1
04 Apr unit 1
05 Apr unit 1
Irradiance / (W m−2)
0.0070
0.0068
0.0066
0.0064
0.0062
0.0060
0
50
100
150
200
Time / hours after 29 Mar 2017, 00:00 UTC



LYRA channel 2 (Herzberg)
29 Mar unit 3
30 Mar unit 3
31 Mar unit 3
01 Apr unit 3
02 Apr unit 3
03 Apr unit 1
04 Apr unit 1
05 Apr unit 1
Irradiance / (W m−2)
0.72
0.71
0.70
0.69
0.68
0
50
100
150
200
Time / hours after 29 Mar 2017, 00:00 UTC


LYRA channel 3 (Aluminium)
29 Mar unit 3
30 Mar unit 3
31 Mar unit 3
01 Apr unit 3
02 Apr unit 3
03 Apr unit 1
04 Apr unit 1
05 Apr unit 1
0.008
0.006
0.004
0.002
0.000
Irradiance / (W m^-2)
0
50
100
150
200
Time / hours after 29 Mar 2017, 00:00 UTC


LYRA channel 4 (Zirconium)
29 Mar unit 3
30 Mar unit 3
31 Mar unit 3
01 Apr unit 3
02 Apr unit 3
03 Apr unit 1
04 Apr unit 1
05 Apr unit 1
0.004
0.003
0.002
0.001
0.000
Irradiance / (W m^-2)
0
50
100
150
200
Time / hours after 29 Mar 2017, 00:00 UTC

For calibration purposes, it is generally assumed that LYRA's observations started in January 2010 in a quiet phase after the minimum, and have now returned to this level again. It is also assumed that ch1-3 and ch1-4 have not degraded. Degradation of the other channels is calculated such that in the current quiet phase the levels should be approx the same as in 2010. A channel is called "flat" when its calibrated output consists more than 99% of the assumed degradation, which is added to the remaining signal.

Channel 1: Start value was 0.0063 W/m2. Unit 2 (flat) and unit 3 are almost exactly on this value. Unit 1 increases without reaching saturation. After first light, it increased up to the technical ceiling (~1200 counts/ms). It was assumed that it would saturate around 1300. This assumption was probably wrong, and thus the absolute calibration of ch1-1 has to be taken with caution. Unit 1 and unit 3 are significantly reacting to off-pointing, unit 2 is not. Unit 3 is not reacting to flares any more, due to degradation of its Lyman-alpha spectral input, while the M5 flares are observable in unit 1. Ch3-1 (Si) reacts strongly to noise in the auroral oval.

Channel 2: Start value was 0.698 W/m2. Unit 2 is now flat. Unit 3 is about 1% below this value, Unit 1 about 1% above this value. Both are still strongly degrading. Unit 1 and unit 3 are significantly reacting to off-pointing, unit 2 is not. Neither unit 1 nor unit 3 appear to react to flares.

Channel 3: Start value was 0.0023 W/m2. Unit 2 and unit 3 are almost exactly on this value. Even their reaction to flares are almost exactly the same. Unit 2 and unit 3 react only a little to the appearance of active regions, due to degradation of their EUV spectral input. Unit 1 reacts significantly to AR, as did unit 2 around first light. It also reacts stronger to flares. Unit 1 shows a relatively short phase (several hours, other than ch1-1) until it saturates. It starts higher than unit 2 and unit 3, and ends lower. This could be due to calibration difficulties (slow MSM detector, short campaigns), or due to heavy degradation within this campaign (three days of open covers).

Channel 4: Start value was 0.0078 W/m2. All three units are close to this value. Unit 2 and unit 3 still react to AR (due to slower degradation), unit 1 reacts even slightly more. Unit 1 and unit 3 react stronger to flares than unit 2. Ch1-4 (Si detector) reacts strongly to noise in the auroral oval, ch1-3 (MSM) does not react. Ch3-3 (Si) and ch3-4 (Si) both react strongly to this noise. Ch2-3 (MSM) and ch2-4 (MSM) also react to this noise, but probably due to degradation, i.e., the noise has become relatively stronger, compared to the signal.

Degradation status

unit 1
ch1-1: from 1300(?) to 813(?) => 63 % remaining
ch1-2: from 613.4 to 502 => 82 % remaining
ch1-3: from 17.2 to 14.7 => 85 % remaining
ch1-4: from 30.3 to 29.2 => 96 % remaining

unit2
ch2-1: from 492 to 1.8 => 0.4% remaining
ch2-2: from 703.5 to 0.8 => 0.1% remaining
ch2-3: from 16.6 to 0.6 => 3.6% remaining
ch2-4: from 37.5 to 11.0 => 29 % remaining

unit3
ch3-1: from 920 to 562 => 61 % remaining
ch3-2: from 545.5 to 37 => 6.8% remaining
ch3-3: from 273.6 to 42 => 15 % remaining
ch3-4: from 30.0 to 20.9 => 70 % remaining

Values are irradiances, corrected for dark currents and 1AU, in counts/ms.

"from" values are first light observations.
"to" values are observations of 05 Apr 2017 for units 1 and 2, observations of 29 Mar 2017 for unit 3.

Dark current estimation was crucial in this campaign, because temperatures - and thus dark currents - were quite high, sometimes higher than the solar signal.

ch1-1 climbed from 800 to 813 in several hours, so even after three days it was not in saturation. Nevertheless the estimate was not much different from earlier estimates, because of the anticipated MSM behaviour.

ch1-2 dropped from 506 to 502 in several hours, so it is indeed degrading fast. But it appears to have recovered from lower observations (2012-2016), with a minimum of 467 in 2014.

ch1-3 probably has to be considered as degrading now.

ch1-4 can still be considered as non-degrading, at least until the beginning of this campaign.

ch2-1 and ch2-2 are flat and do not change any more. But they are still valuable for occultation or eclipse profiles.

ch2-3 is still valuable, but maybe its remaining value was estimated too optimistic (1.2 instead of 0.6) at the last unit-2 calibration software update (TBC).

ch2-4 is going well and its degradation evolution was estimated correctly.

ch3-1 appears to remain constantly at 61%, but this probably originates from visible or infrared spectral intervals. The Lyman-alpha nominal input region is probably flat.

ch3-2 and ch3-3 suffer from heavy degradation due to the short daily campaigns.

ch3-4 is doing better, as all Zirconium channels.

The values are still quite similar to the status as reported in Marie's presentation (ESWW13). One can still call it a "slow evolution".
http://solwww.oma.be/users/dammasch/Dominique_LyraStatus.pdf

Flare analysis

In the following eight pages, the four strongest flares of this campaign are shown in detail:
- the M4.4 flare of 01 Apr, observed by units 2 and 3,
- the M5.3 flare of 02 Apr, observed by units 2 and 3,
- the M5.7 flare of 02 Apr, observed by units 2 and 1,
- the M5.8 flare of 03 Apr, observed by units 2 and 1.
The latter two contain Lyman-alpha flare signatures.

The thick curve on top of each figure shows the LYRA channel, pre-flare background subtracted. Under this curve, there are up to three smaller ones:
- with dash-dotted line, the GOES curve, scaled such that it touches the LYRA curve in the rising phase, where the SXR contribution is assumed to dominate the LYRA response;
- with straight line, the remainder when the scaled GOES contribution is subtracted from the LYRA curve. This is assumed to be the EUV contribution of the LYRA response. It has a small part before the SXR phase (maybe from the heating-up of cooler material?) and a bigger part after the SXR phase (maybe from cooling-down material, post-flare loops?); the idea behind this method is described in some more detail, here:
  http://solwww.oma.be/users/dammasch/IED_20110809_SeparateContributions.pdf
- with asterisks, in the case of unit-1 observations, the Lyman-alpha signal, scaled because it is much weaker. This signal is pre-processed - the curve of the saturating MSM detector had to be removed, and in one case some minutes during a satellite roll.

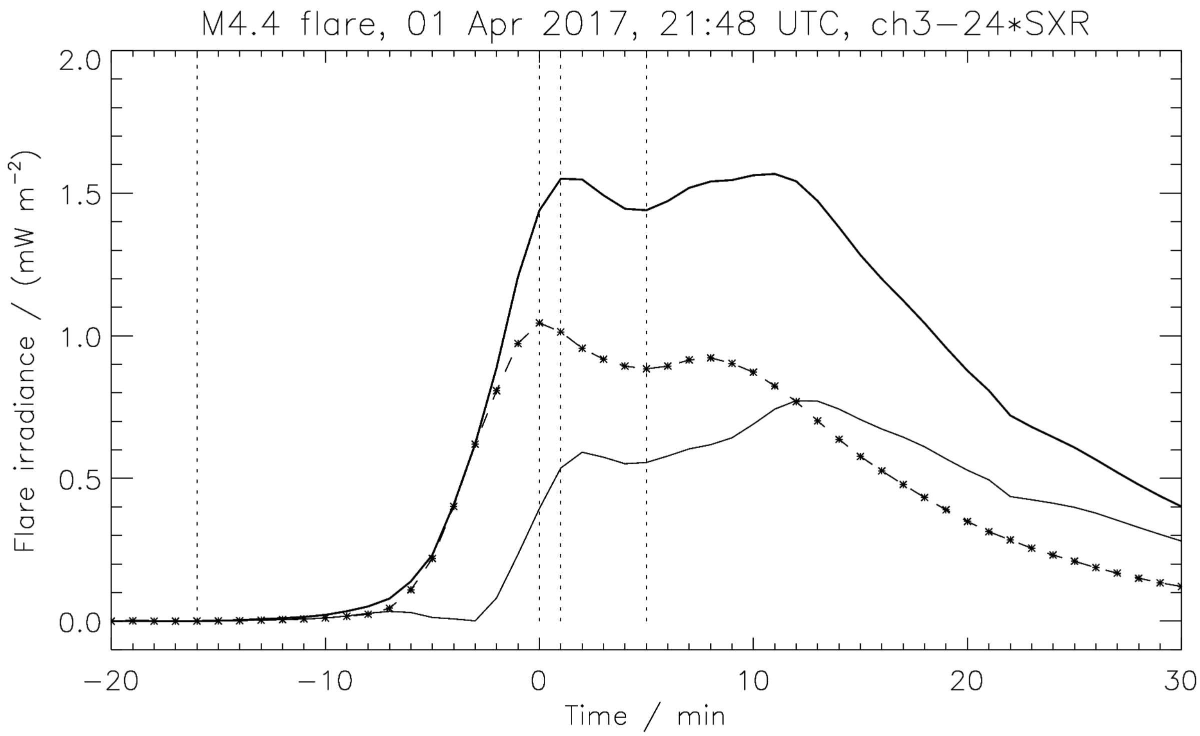
The information could be interesting for understanding spectral degradation. One can easily see the flare maxima in the figures; the integrals of the SXR and EUV flare components over time ("fluence") are written under the figures.

It is assumed that there is a strong degradation between, say, 20nm and 500nm, worst around LYRA's Lyman-alpha and Herzberg channels. Infrared and soft X-ray are less affected. Compare slide 7 here:
  http://solwww.oma.be/users/dammasch/Dammasch_Brussels_Apr2013.ppt
The degradation curves of channels 1, 2, and 3 start with a steep (exponential) decline, immediately after first light. Channel 4 gets its spectral input from below 20nm and shows a slower, non-exponential, decline. Compare unit-2 development, page 3, here:
  http://solwww.oma.be/users/dammasch/IED_20141006_LyraStatusAfter1500Days.pdf
As for the reason, UV-induced polymerization of certain molecules is assumed.

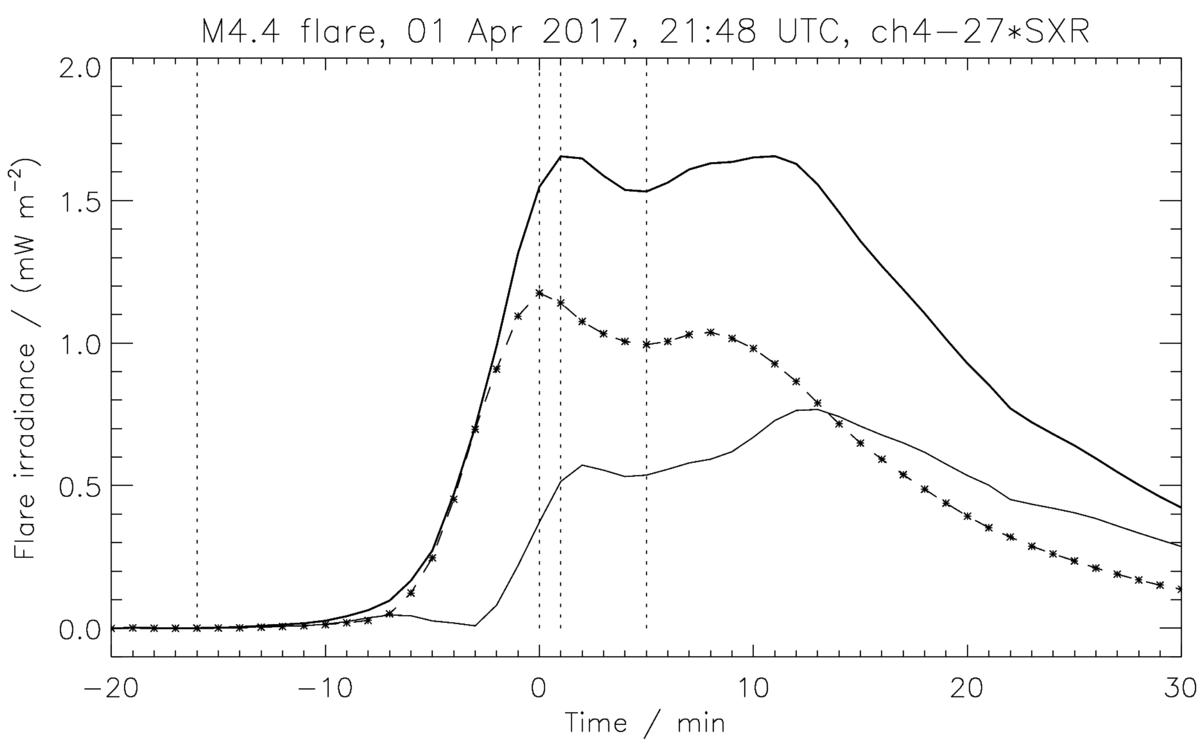
The degradation correction is calculated for the *quiet-Sun* levels, and it is *added*, because so far there is no model for what happens to the observed flare strengths. Until now, it was assumed that these are not affected, as SXR irradiance passes the “dirt film” on the filters. With the additional information of this flare campaign, it appears that the flare strengths are also degrading, only slower. Whether this is also due to a polymerization film, or due to the detectors, can not be said at this moment.

The figures in the next pages are “pure” flare curves, i.e., the pre-flare levels have been subtracted. LYRA's usual additive degradation correction has no influence here. As mentioned above, to calculate the SXR and EUV flare components, the SXR curve is a scaled GOES curve; the Lyman-alpha signature is also scaled.

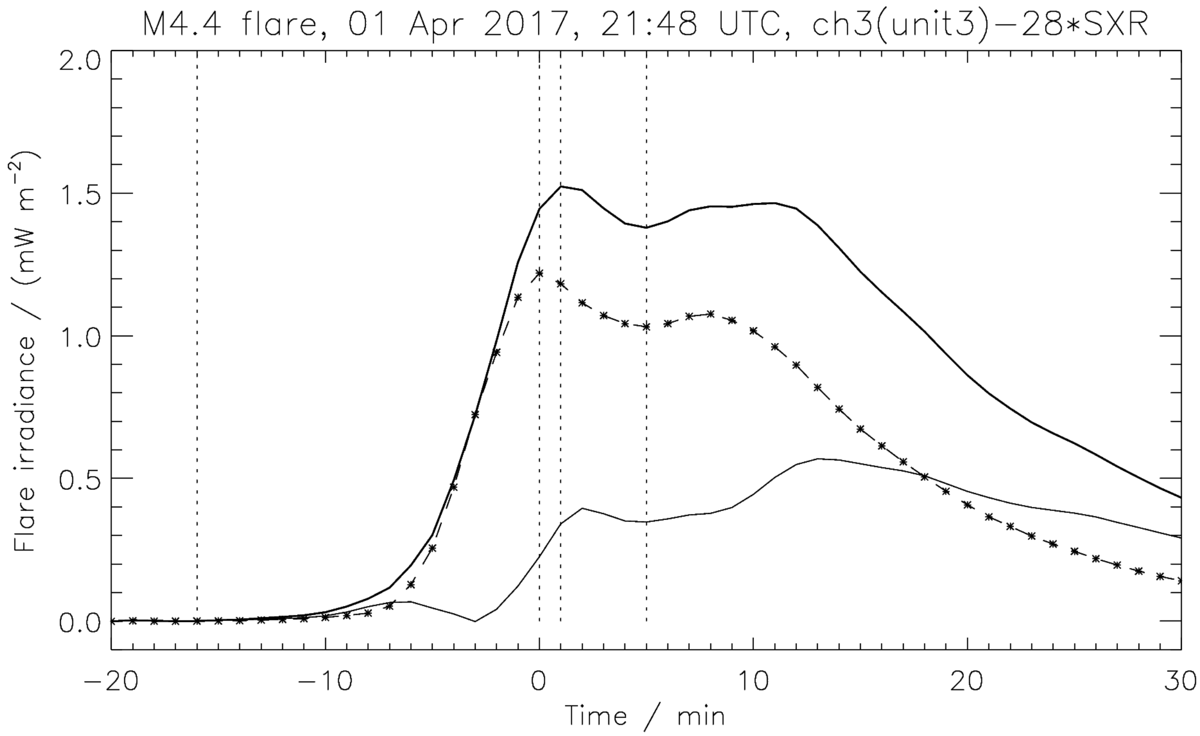
The vertical dotted lines are the assumed flare begin, the GOES peak, the LYRA peak (usually one or two minutes later), and the assumed flare end.



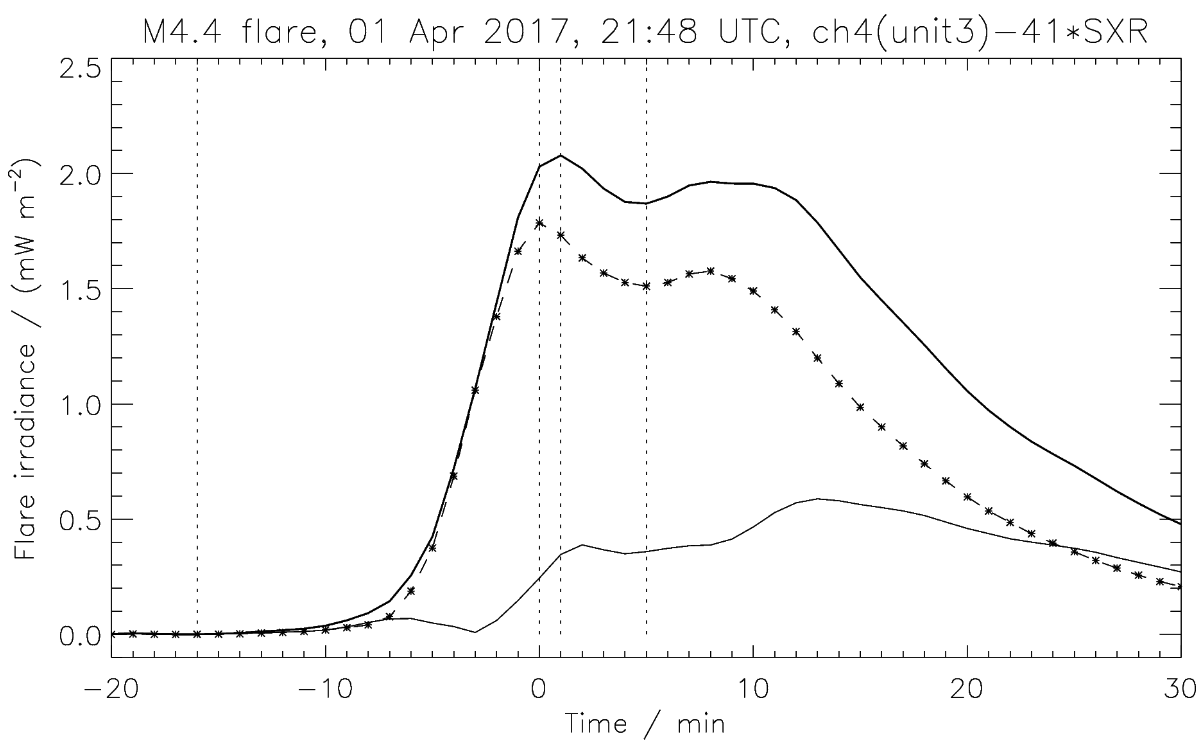
ch2-3 fluence = 12.6 mW/m2 * dt = 9.0 (71%) SXR + 3.7 (29%) EUV



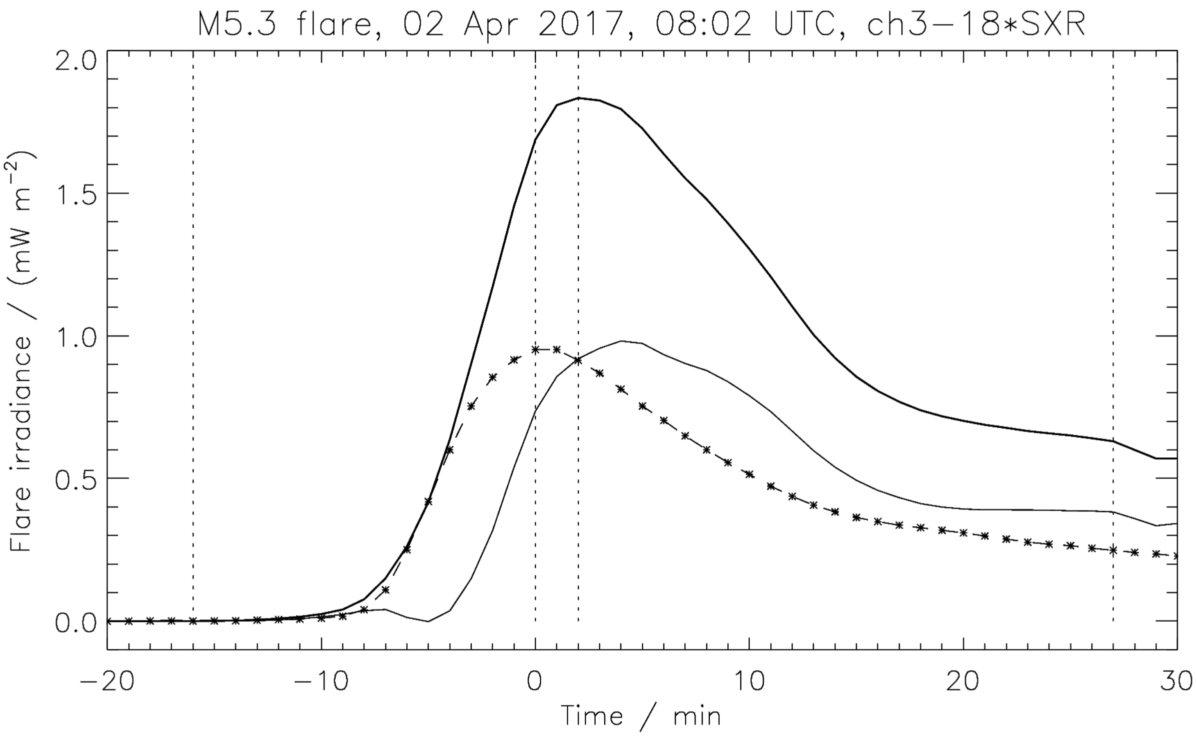
ch2-4 fluence = 13.7 mW/m2 * dt = 10.1 (74%) SXR + 3.6 (26%) EUV



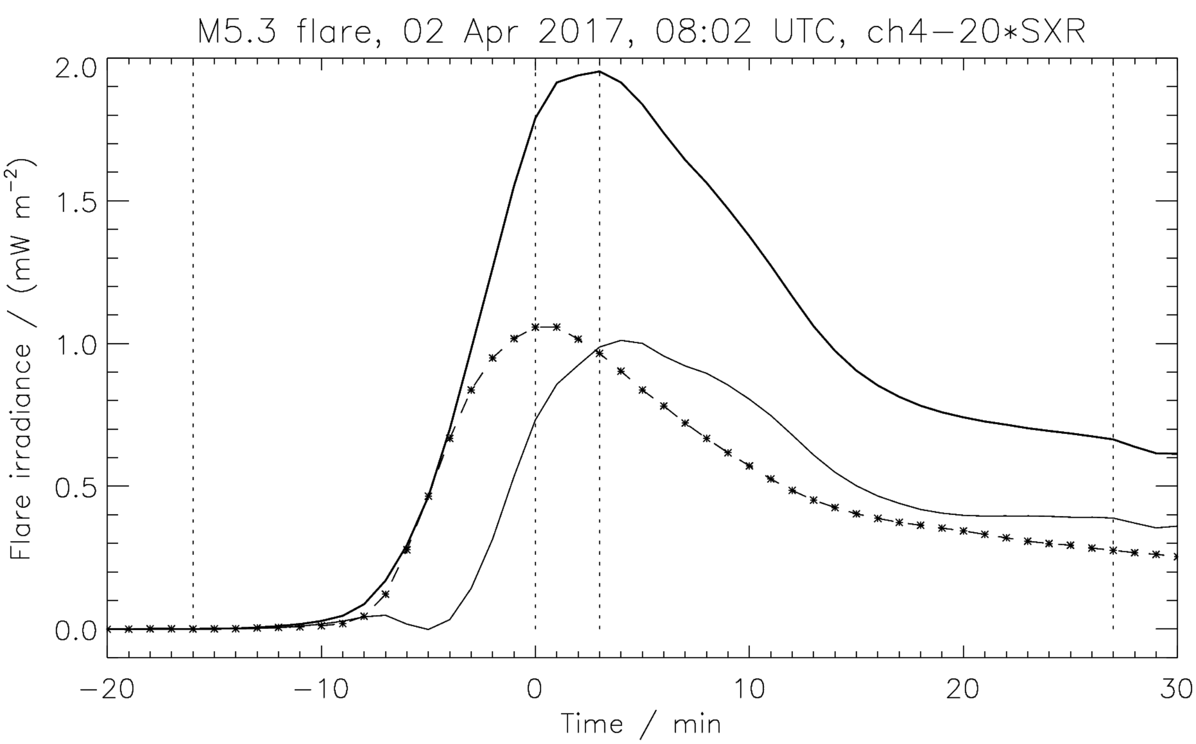
ch3-3 fluence = 13.0 mW/m2 * dt = 10.4 (80%) SXR + 2.5 (20%) EUV



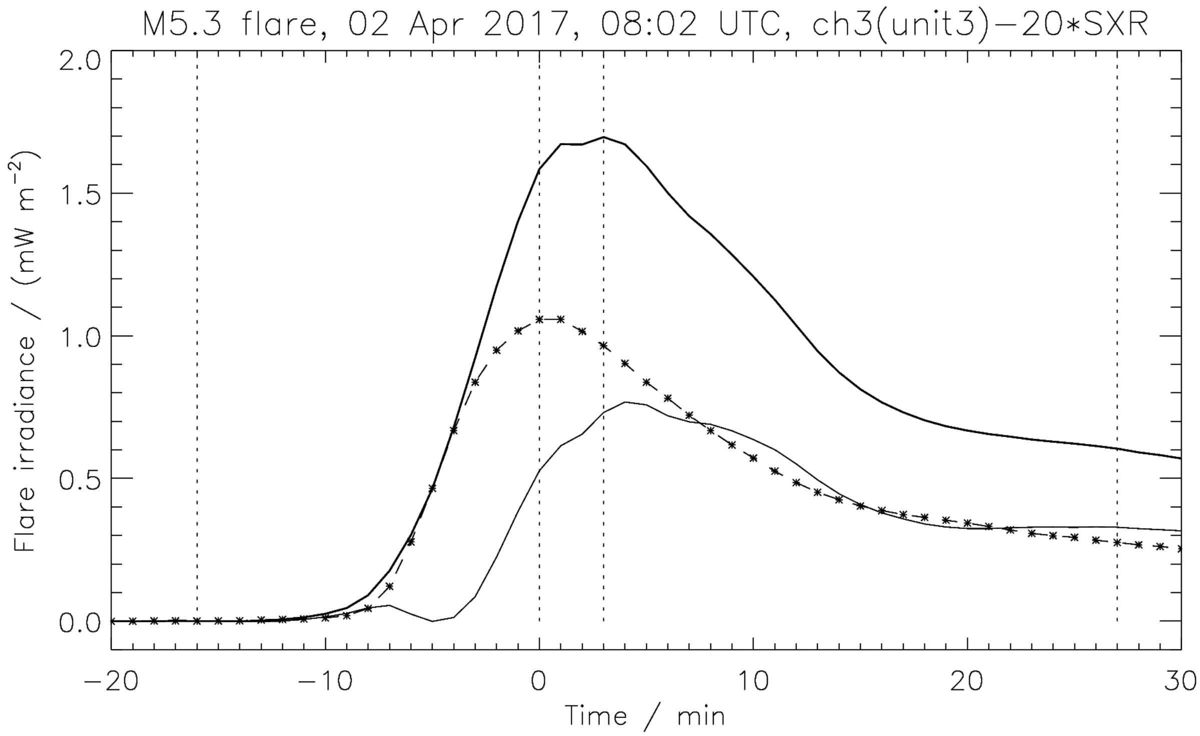
ch3-4 fluence = 17.9 mW/m2 * dt = 15.3 (85%) SXR + 2.6 (15%) EUV



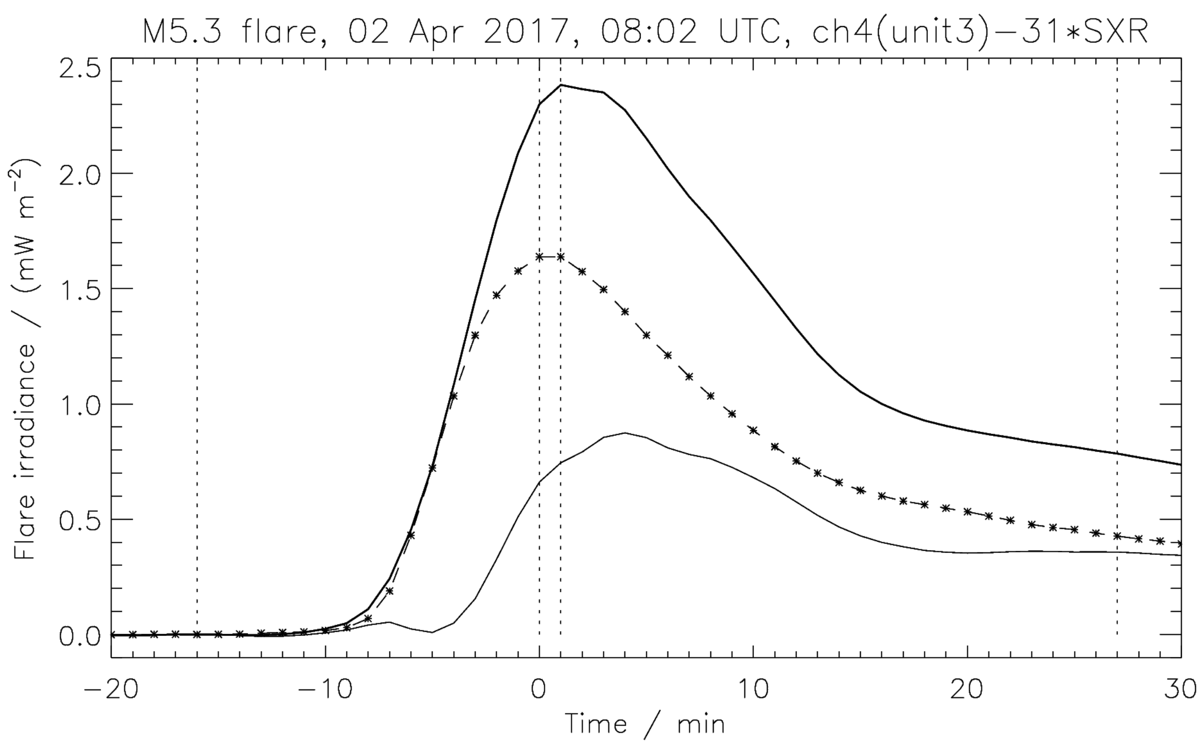
ch2-3 fluence = 36.6 mW/m2 * dt = 17.9 (49%) SXR + 18.8 (51%) EUV



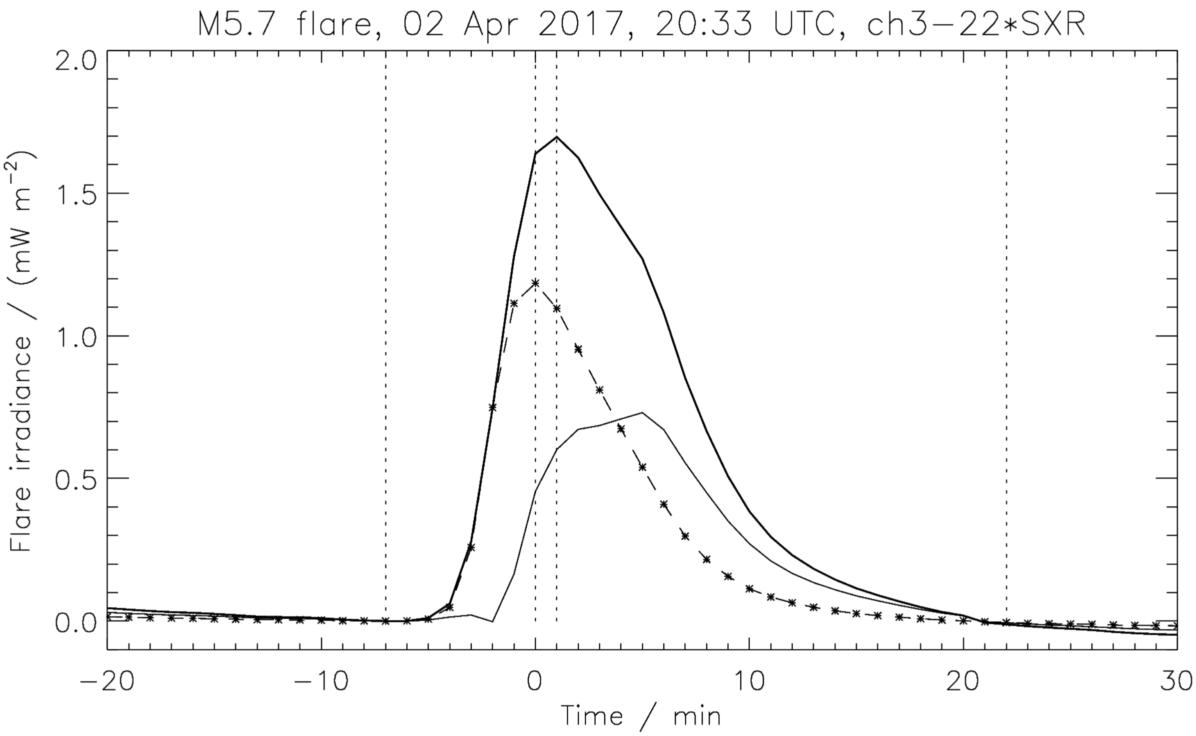
ch2-4 fluence = 39.0 mW/m2 * dt = 19.8 (51%) SXR + 19.1 (49%) EUV



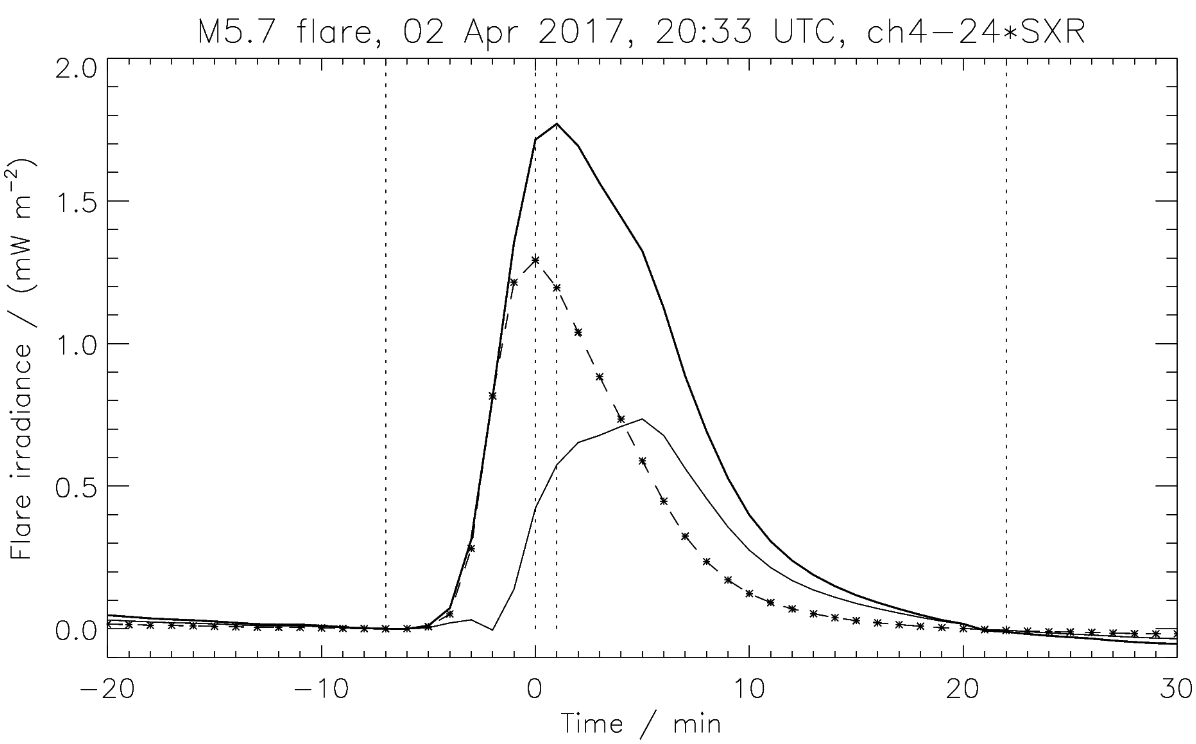
ch3-3 fluence = 34.7 mW/m2 * dt = 19.8 (57%) SXR + 14.9 (43%) EUV



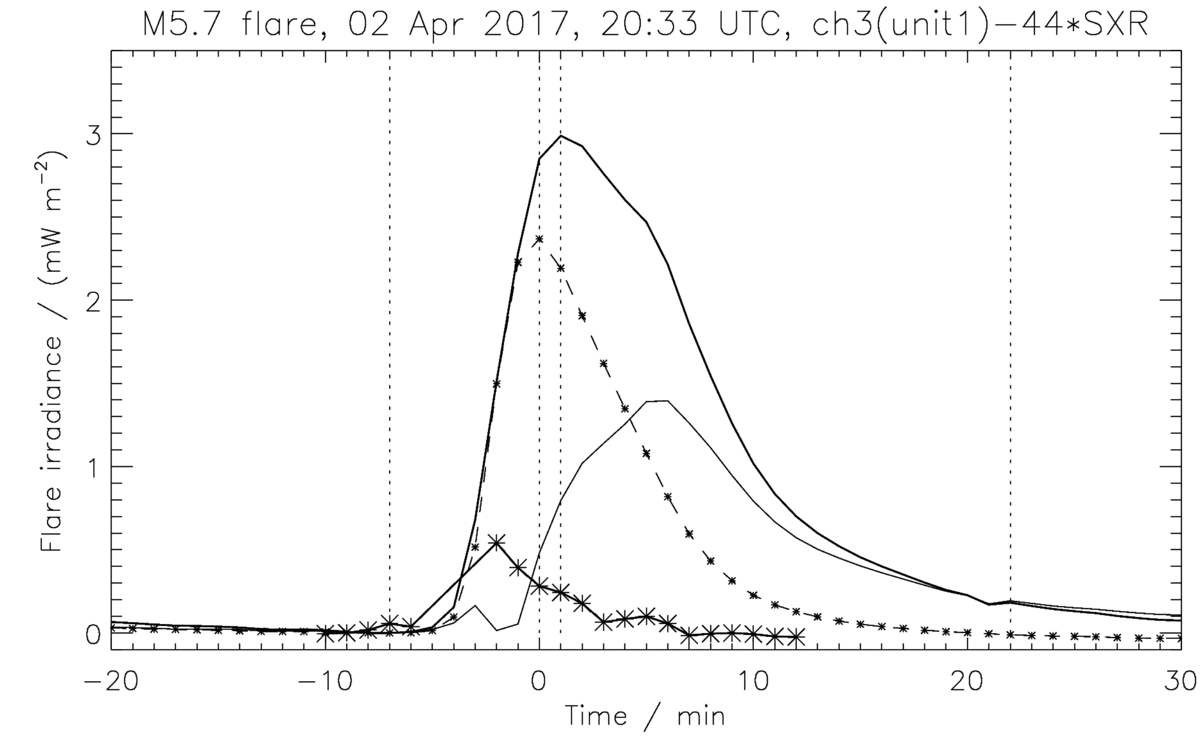
ch3-4 fluence = 47.5 mW/m2 * dt = 30.8 (65%) SXR + 16.7 (35%) EUV



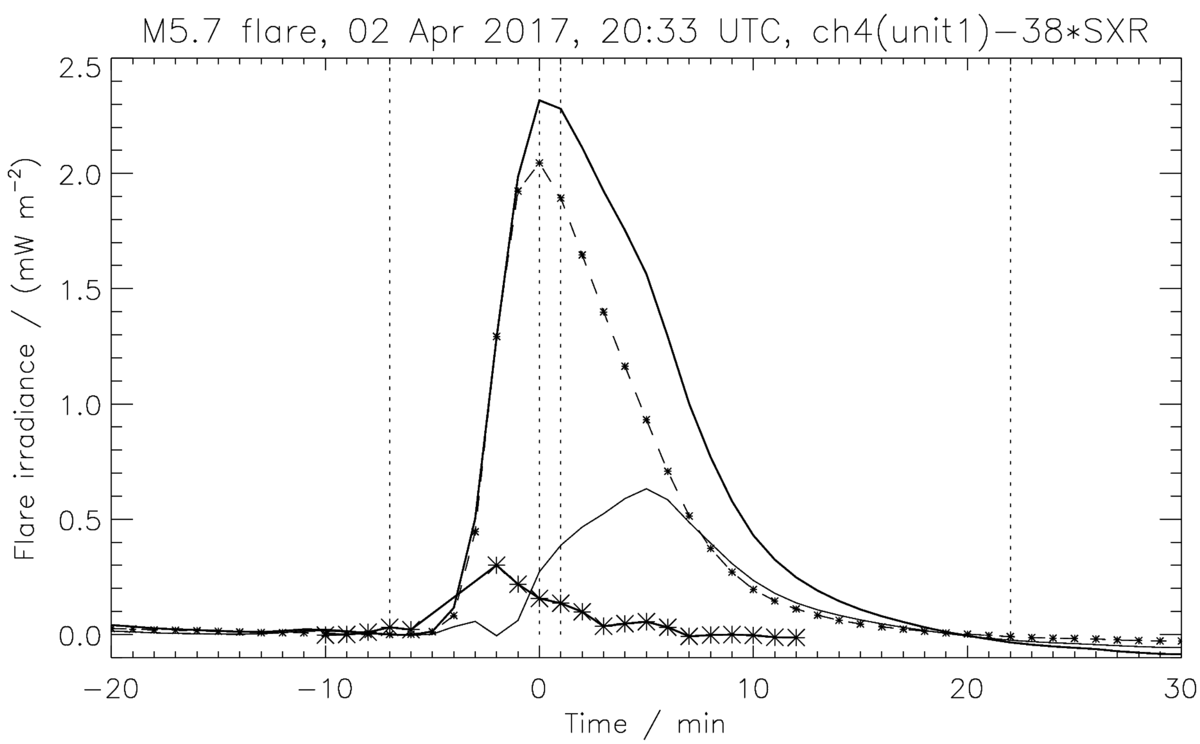
ch2-3 fluence = 16.2 mW/m2 * dt = 8.9 (55%) SXR + 7.3 (45%) EUV



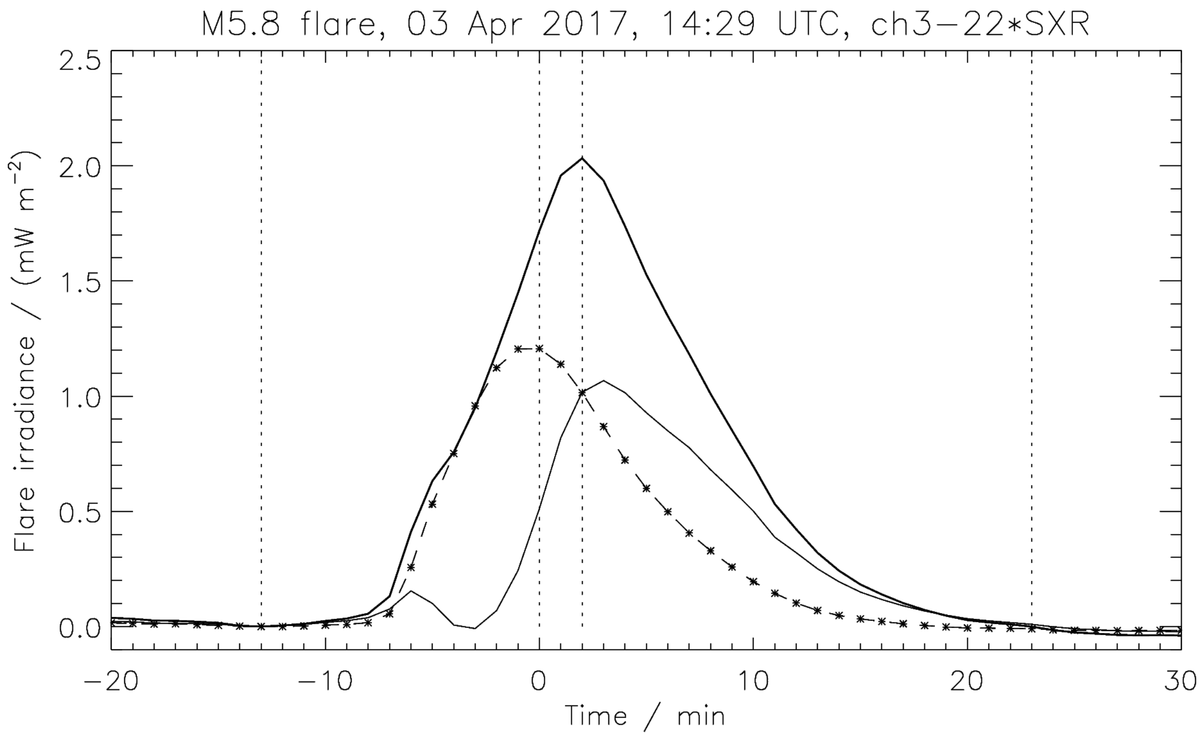
ch2-4 fluence = 16.9 mW/m2 * dt = 9.7 (57%) SXR + 7.2 (43%) EUV



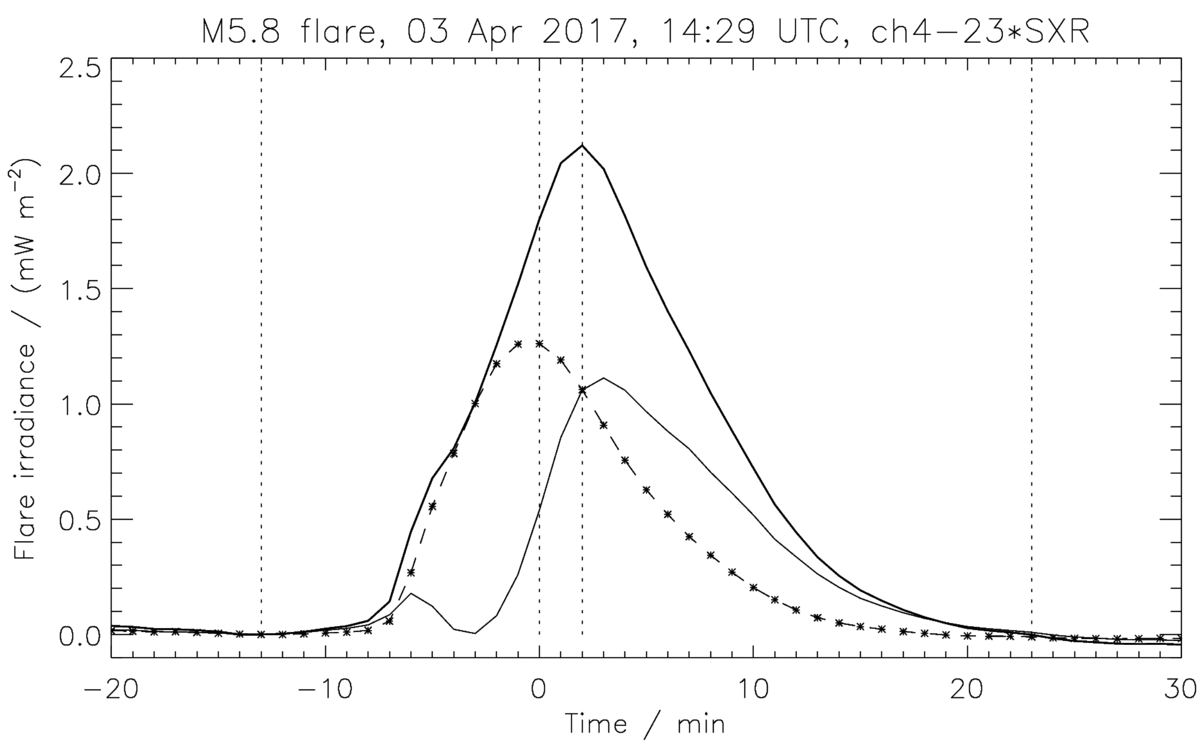
ch1-3 fluence = 34.2 mW/m2 * dt = 17.8 (52%) SXR + 16.3 (48%) EUV



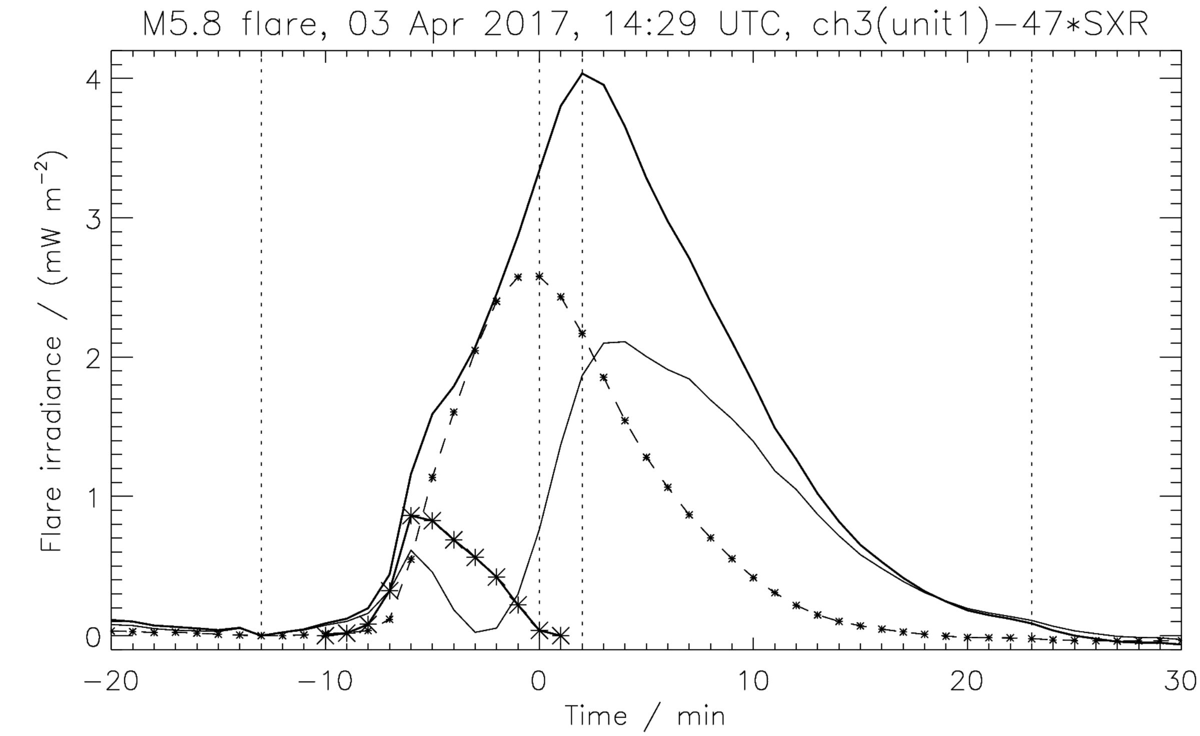
ch1-4 fluence = 21.0 mW/m2 * dt = 15.4 (73%) SXR + 5.6 (27%) EUV



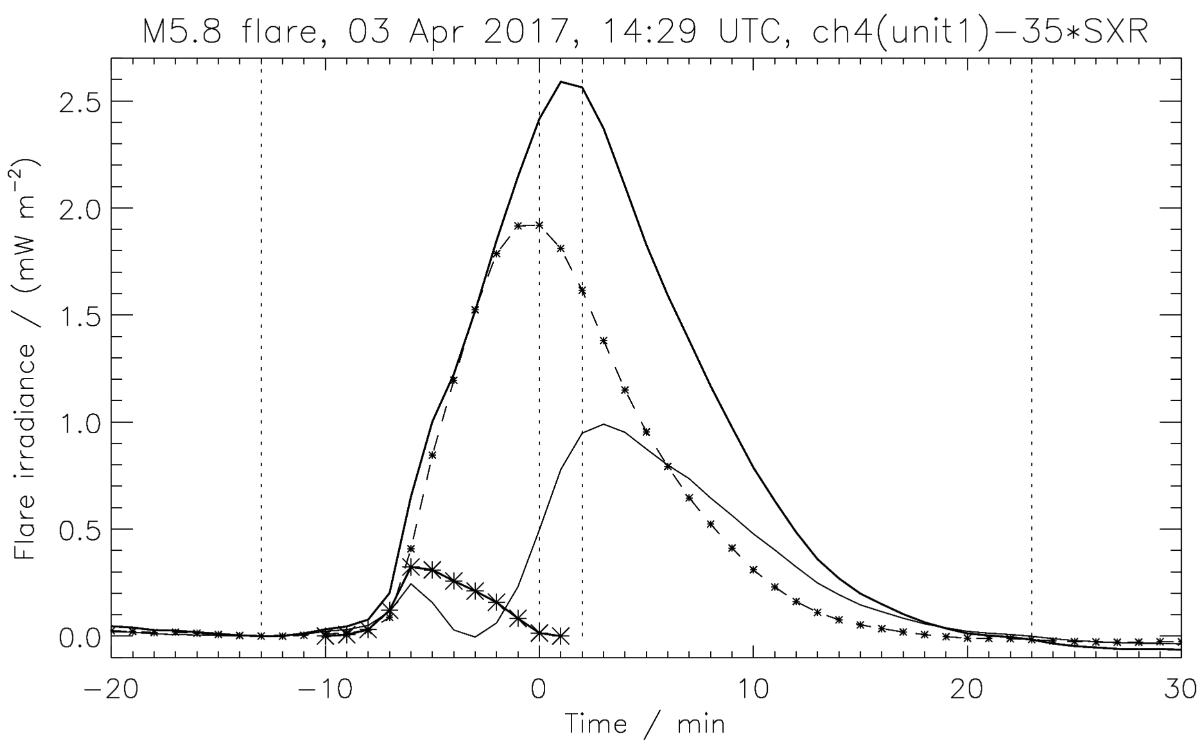
ch2-3 fluence = 23.8 mW/m2 * dt = 12.6 (53%) SXR + 11.2 (47%) EUV



ch2-4 fluence = 24.9 mW/m2 * dt = 13.1 (53%) SXR + 11.8 (47%) EUV



ch1-3 fluence = 54.2 mW/m2 * dt = 26.8 (49%) SXR + 27.4 (51%) EUV



ch1-4 fluence = 30.8 mW/m2 * dt = 20.0 (65%) SXR + 10.9 (35%) EUV

Spectral degradation

When putting the flare "fluences" (integral of irradiance in mW/m2 * dt) in one table, with emphasis on the SXR and EUV components, the following picture emerges:

M4.4	ch2-3 (3% left)	9.0 SXR +	3.7 EUV
	ch2-4 (30% left)	10.1 SXR +	3.6 EUV
	ch3-3 (19% left)	10.4 SXR +	2.5 EUV
	ch3-4 (71% left)	**15.3 SXR** +	2.6 EUV
M5.3	ch2-3 (3% left)	17.9 SXR +	18.8 EUV
	ch2-4 (30% left)	19.8 SXR +	19.1 EUV
	ch3-3 (19% left)	19.8 SXR +	14.9 EUV
	ch3-4 (71% left)	**30.8 SXR** +	16.7 EUV
M5.7	ch2-3 (3% left)	8.9 SXR +	7.3 EUV
	ch2-4 (30% left)	9.7 SXR +	7.2 EUV
	ch1-3 (100% left)	**17.8 SXR** +	**16.3 EUV**
	ch1-4 (100% left)	**15.4 SXR** +	5.6 EUV
M5.8	ch2-3 (3% left)	12.6 SXR +	11.2 EUV
	ch2-4 (30% left)	13.1 SXR +	11.8 EUV
	ch1-3 (100% left)	**26.8 SXR** +	**27.4 EUV**
	ch1-4 (100% left)	**20.0 SXR** +	10.9 EUV

The flares themselves cannot be compared - they have different lengths, sometimes there are multiple flares. But within the flares, there are some values that are exceptional (while the rest shows more or less similar values):
- the SXR components of ch3-4
- the SXR components of ch1-4
- the SXR components of ch1-3
- the EUV components of ch1-3

A possible explanation:
ch2-3 has a nominal spectral range 0-5nm + 17-80nm. Only 3% of that is left, as measured in the campaigns (no flares). Probably the 17-80nm range is gone (a fast, exponential loss within a couple of months), and the 0-5nm range remained to some extent. This can also be seen in the smaller reaction to active regions after the first months. The 0-5nm range must therefore be responsible for both the SXR and the EUV component.
ch3-3 has the same nominal range. 19% of that is left, obviously also mainly in the 0-5nm range, the reaction is comparable to ch2-3.
ch1-3 has 100% left, maybe slightly less. This means, the range 0-5nm leads to a stronger SXR (and EUV?) signal, while the still existing range 17-80nm additionally leads to a stronger EUV signal.

ch2-4 has a nominal spectral range 0-2nm + 6-20nm. Only 30% of that is left, but the loss was gradual, not exponential, probably more degraded around 20nm than around 6nm. So, an unknown 0-2nm + 6-??nm range is responsible for both the SXR and the EUV component. Since the values are quite similar for ch2-3 and ch2-4 in all four flares, one can say that the spectral contents of 0-5nm on one side, and 0-2 + 6-??nm on the other side must be quite similar.
ch3-4 has the same nominal range. 71% of that is left, which leads to a significantly stronger reaction in the SXR component, but not in the EUV component.
ch1-4 has 100% left, which likewise leads to a stronger SXR component, but not a stronger EUV component. Why the EUV components of ch3-4 and ch1-4 are on the same level as in the (heavily degraded) ch2-3 and ch2-4, and where this response might spectrally originate, can not be said at the moment. The only obvious thing is that the additional EUV component in ch1-3 must originate from the 17-80nm range mainly.

In the end, it can be deduced that the flare response is also degrading, but in a different way than the quiet-Sun response. First, the degradation is not so strong. Second, it is not so fast. For the SXR component, it can be stated: Compared to ch3-4 (71% quiet-Sun signal left) the other channels show ~ 2/3 remaining flare response. Compared to ch1-3 and ch1-4 (about 100% QS left) the others show ~ 1/2 remaining flare response. For the EUV component, it can be stated: Compared to ch1-3 (about 100% QS left), the others show ~ 1/2 remaining flare response - and this with up to 7 years of exposure.

The Lyman-alpha flare signature

Lyman-alpha as observed by unit 1 follows the impulsive phase. On the next page, these signals are shown: the GOES flare curve (straight line), the GOES derivative from onset to peak (dotted line), and the pre-processed Lyman-alpha line (asterisks), for the 02 Apr and 03 Apr flares. In the first figure, some data points of Lyman-alpha are missing due to a satellite roll maneuver.

The values are not scaled, they show flare irradiance in mW/m2, pre-flare levels subtracted.

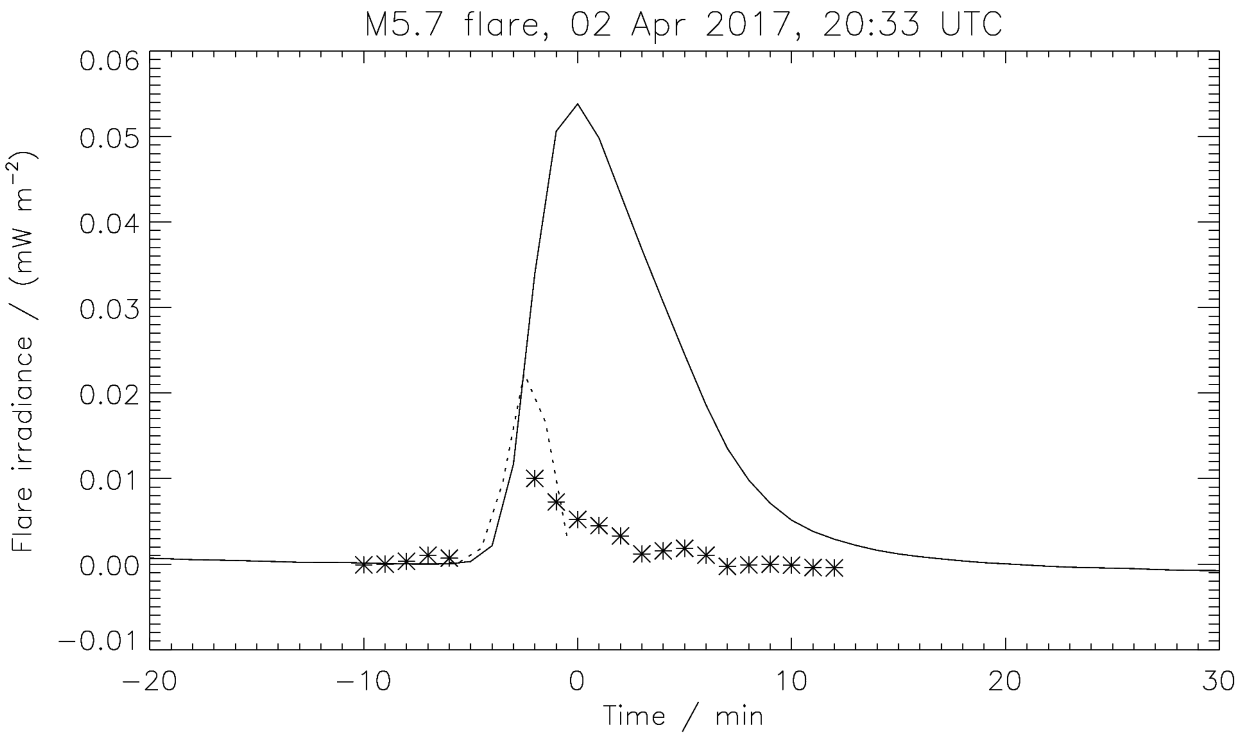
M5.7 flare, 02 Apr 2017:
max GOES = 0.0538 mW/m2
max Lyman-alpha = 0.0100 mW/m2
GOES fluence = 0.405 mW/m2 * dt, where dt = 1 minute
Lyman-alpha fluence = 0.0366 mW/m2 * dt

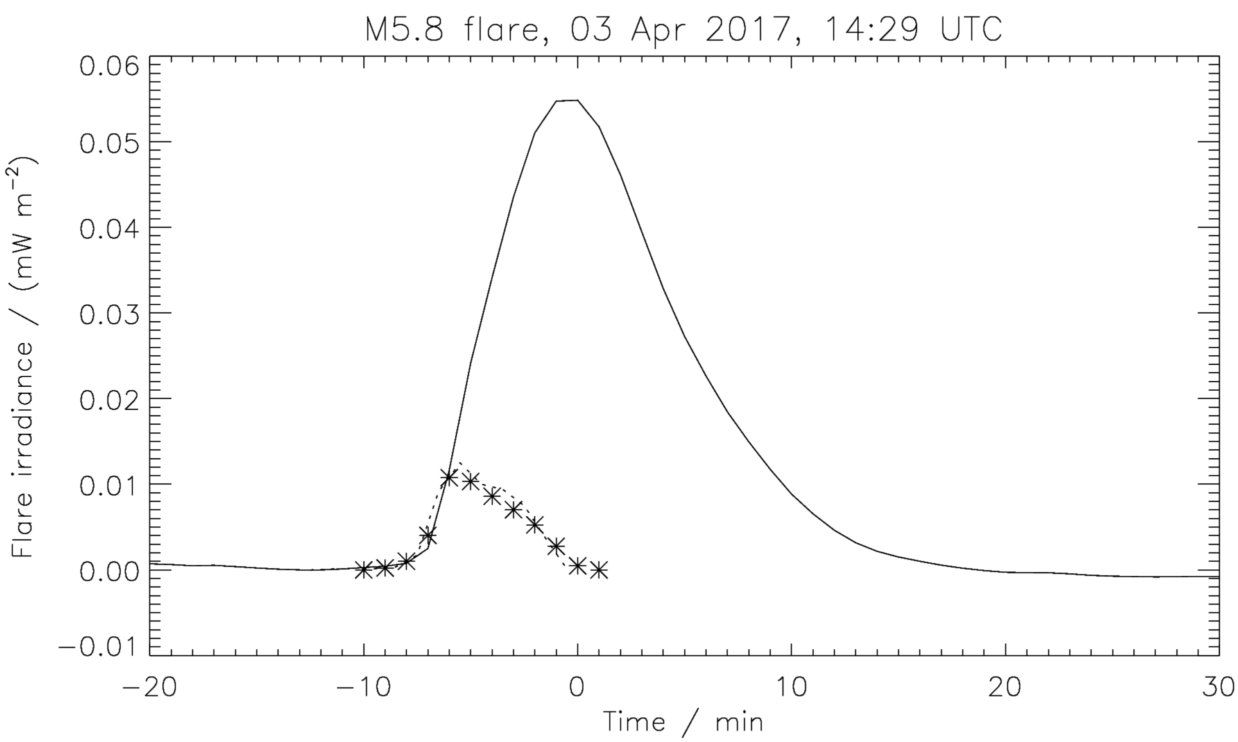
M5.8 flare, 03 Apr 2017:
max GOES = 0.0549 mW/m2
max Lyman-alpha = 0.0108 mW/m2
GOES fluence = 0.571 mW/m2 * dt, where dt = 1 minute
Lyman-alpha fluence = 0.0505 mW/m2 * dt

It is assumed that ch1-1 has lost around 50% of its response, and the "purity" (real Lyman-alpha contribution) was only around 30% anyway, so the Lyman-alpha values could in reality be 6 times higher. "30% purity" was the result of simulations with the LYRA radiometric model. After several modifications, the expected purity of the Lyman-alpha channels stabilized around 30%. In the case of ch1-1 and ch2-1, the "unwanted signal" originates from the area around 200nm, in the case of ch3-1 the response comes from a long tail stretching up to infrared. It is assumed that the infrared is not degrading a lot, while the spectral region around 200nm probably behaves like the Herzberg channel, i.e., strongly degrading like the Lyman-alpha channel. On the other hand, flare signature in a Herzberg channel were never observed. Therefore, maybe there is a Lyman-alpha flare signal of 0.06 mW/m2 instead of the observed 0.01 mW/m2 peak.

From earlier measurements with unit 2 (2010) and unit 3 (2011), one would expect a 3% increase, i.e. around 0.2 mW/m2, for flares like the observed. Thus, a factor 3 is still missing. On the other side, the LYRA radiometric model was not very helpful for predicting ch1-1 and ch2-1, in the sense that much higher values were received than originally expected. So maybe the Lyman-alpha purity values cannot really be trusted; all other channels were much more realistic.

For the position, AR2644 which produced both flares was at N16W68 on 02 Apr, and at N19W80 on 03 Apr. That is still on the disk, but with loops close to the limb. So maybe the difference can be explained by absorption of optically thick plasma.


M5.7 flare, 02 Apr 2017, 20:33 UTC
Flare irradiance / (mW m^{-2})
Time / min
0.06
0.05
0.04
0.03
0.02
0.01
0.00
−0.01
−20
−10
0
10
20
30


M5.8 flare, 03 Apr 2017, 14:29 UTC
Flare irradiance / (mW m^{-2})
Time / min
0.06
0.05
0.04
0.03
0.02
0.01
0.00
−0.01
−20
−10
0
10
20
30