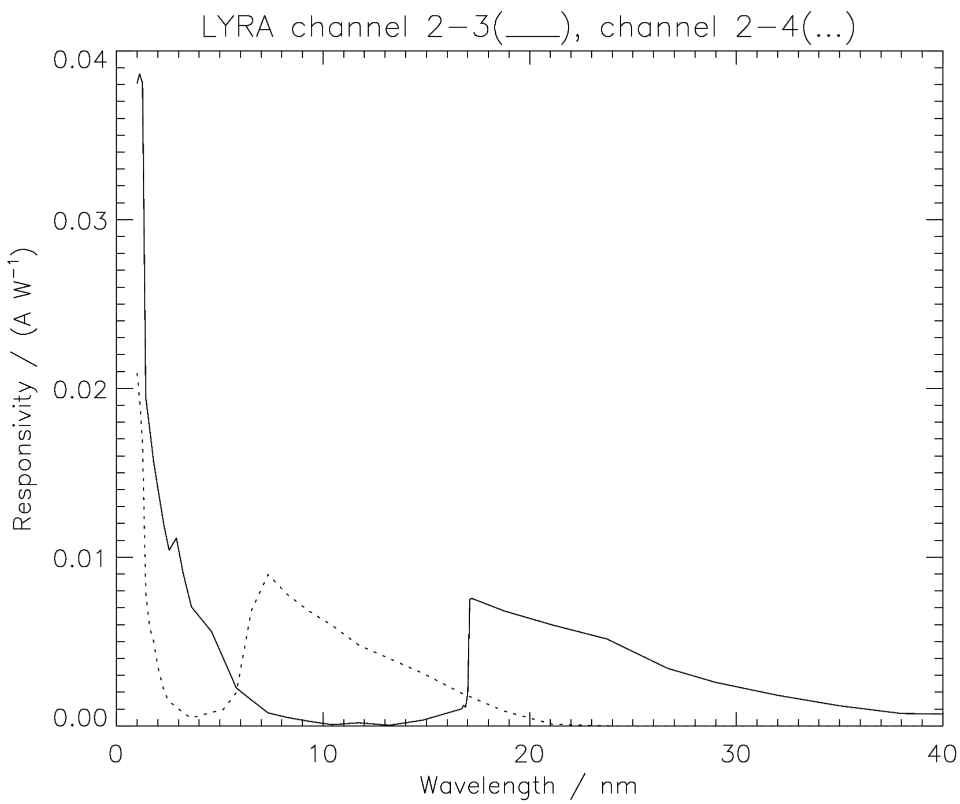
Trying to separate SXR and EUV contributions in LYRA channels 3 and 4

IED 09 Aug 2011, updated 10-11 Aug 2011, 18 Aug 2011

If one looks at typical examples from the LYRA flare list, like the M1.1 flare of 28 Feb 2011,
http://solwww.oma.be/users/dammasch/flares/flare20110228_0170.png
several features can be observed over and over again:

- The GOES curve and the LYRA curves practically start to rise in the same instance.
- The GOES curve peaks a bit earlier than the LYRA curves.
- The LYRA curves decrease significantly slower than the GOES curve, and thus take longer time to reach their pre-flare levels.
- In the impulsive phase, all curves practically rise in parallel for several minutes, then the GOES curve peaks, whereas the LYRA curves continue to rise – sometimes slower – to peak later.
- Comparing the calibrated pure flare irradiances (i.e., pre-flare levels subtracted from the LYRA flare curves), the LYRA peaks are an approx factor of 50 (relative to channel 2-4) or even 70 (relative to channel 2-3) higher than the GOES peaks.

It is has been known since the pre-launch BESSY campaigns that the LYRA Aluminium and Zirconium channels have a SXR contribution in their response, see following figure:



(Please note that the GOES nominal interval would be at the very left edge of this plot, between 0.1 and 0.8 nm.)

So it appears plausible that the impulsive phase of the LYRA flare curves is dominated by this SXR contribution, as observed by one of the GOES X-ray sensors. And the question immediately arising is: What would be left as a difference, were this SXR signal subtracted from the LYRA curves? Would it be a pure EUV signal? Would it be different for channels 3 and 4? Would the present EUV signal be different from signals observed at the begin of LYRA measurements, due to degradation, especially in channel 3?

On the following seven pages, some examples were tested:

- M2.9 flare, 06 Feb 2010, 18:59 UTC
- M1.1 flare, 28 Feb 2011, 12:52 UTC
- M9.3 flare, 30 Jul 2011, 02:09 UTC
- M1.4 flare, 02 Aug 2011, 06:19 UTC
- M9.3 flare, 04 Aug 2011, 03:57 UTC
- C2.2 flare, 08 Aug 2011, 16:36 UTC
- X6.9 flare, 09 Aug 2011, 08:05 UTC
- B3.8 flare, 17 Aug 2011, 00:11 UTC

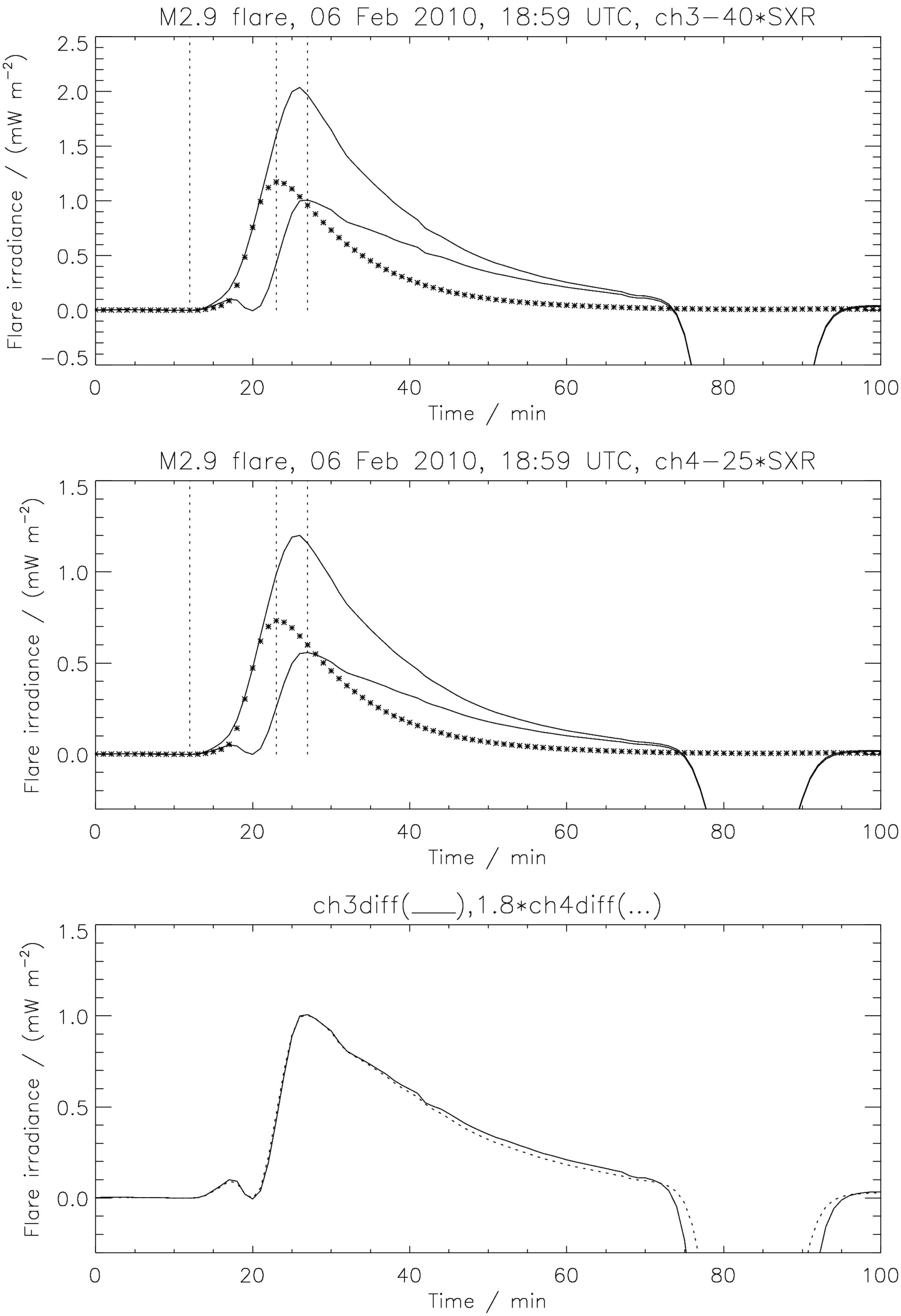
LYRA and GOES data were reduced to one-minute averages. The GOES curve was scaled, i.e. multiplied with a factor such that the values do not exceed the LYRA curve; this was then considered "the SXR contribution" and denoted with asterisks. The upper straight lines are the LYRA total signals, channel 2-3 (top) and 2-4 (middle), respectively. The lower straight lines (difference = total LYRA signal – factor * SXR signal) were then considered "the EUV contributions". In the bottom figure on each page, these two differences are compared; the channel-4 curve was scaled, i.e. multiplied with a factor such that the peaks of channel 3 and 4 match.

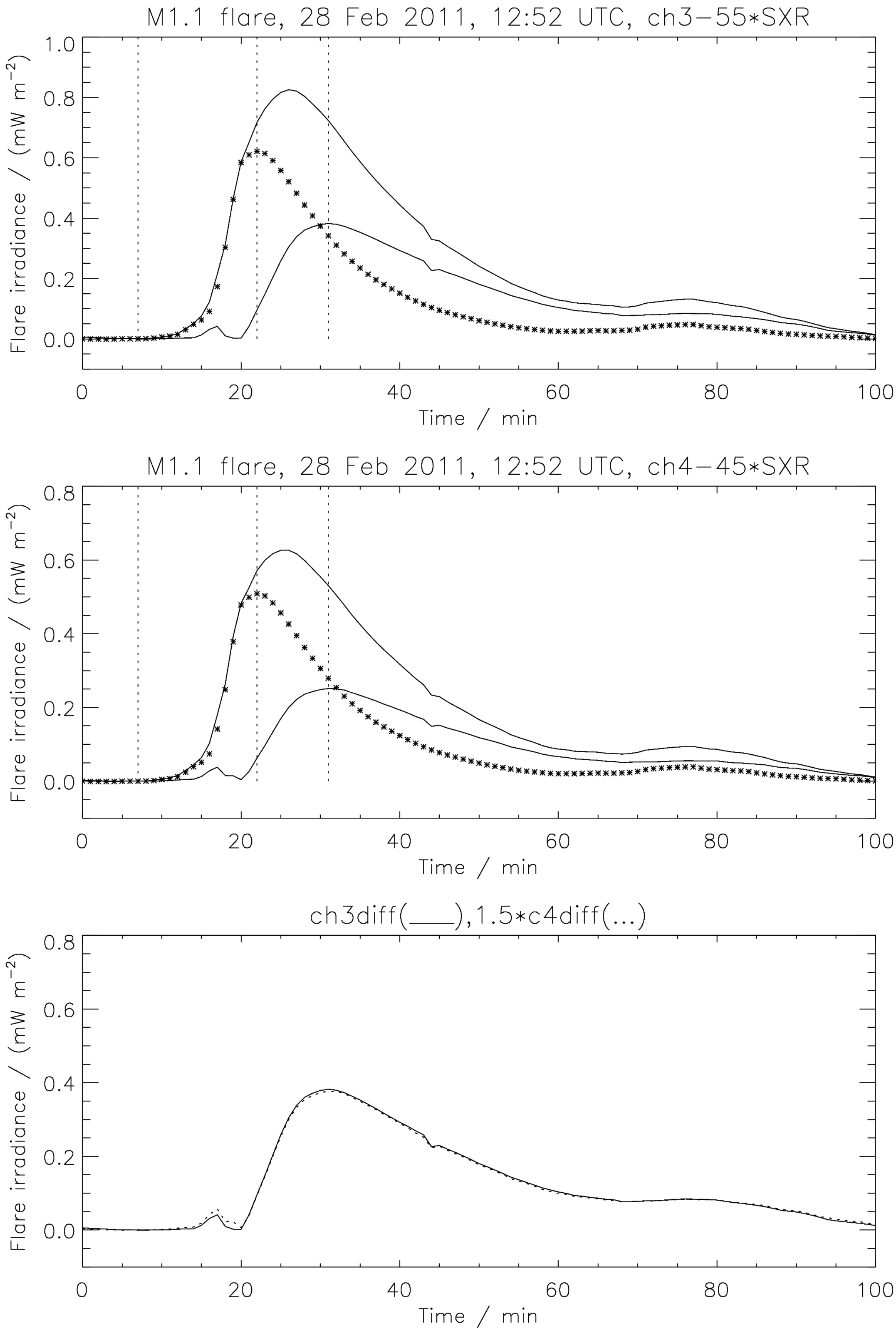
Making an analogy conclusion from the figure on the very last page, showing SUMER spectral intervals for lines of various temperatures during two hours of a flare (from *Feldman et al., ApJ 593, 1226-1241, 2003*), one might argue that the SXR contribution curve shows lines like Fe XIX, emitted at plasma temperatures of approx 8 million K, whereas the EUV contribution curve reflects lines like Ca XV (4 million K), Al XI (1.6 million K), and Ca X (800 000 K). In other words, the EUV curve represents the cooling down from SXR flare temperatures; the little bump before the rising phase might represent the heating of cooler plasma before it reaches SXR flare temperatures. (The bump cannot be seen in the example of 30 Jul 2011, probably because the flare rises too fast.)

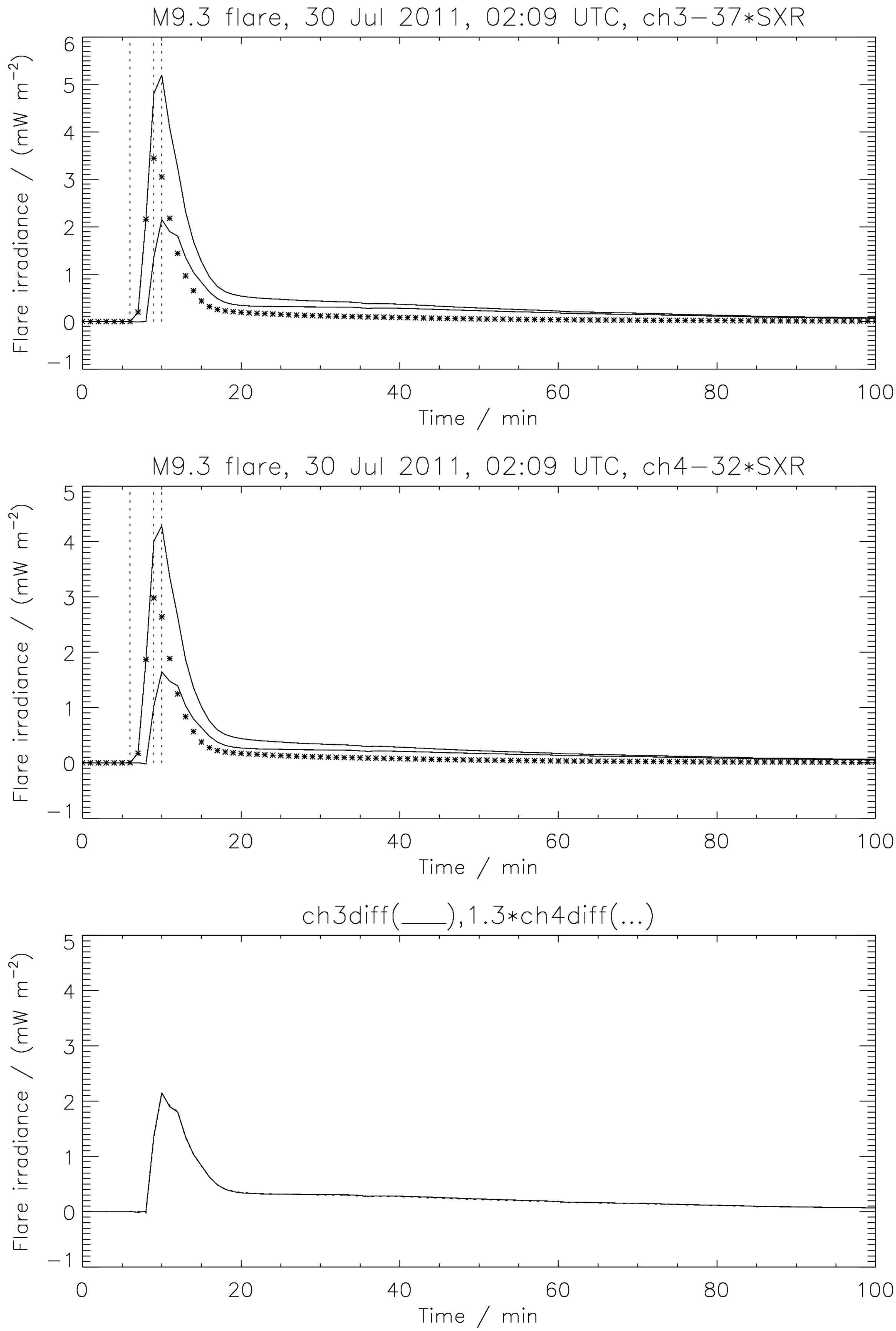
Some first results:

- Even if this may sound trivial, but each flare seems to be quite individual, i.e. different not only in strength, but also in temporal evolution, length of the rising phase, distance between SXR and EUV peaks, relative contribution of SXR and EUV, contributing plasma temperatures,...
- Basically, the approach works for B-, C-, M-, and X-flares, and for fast, impulsive flares as well as long and slow ones.
- The absolute values of the selected factors appear to vary quite arbitrary at first glance, their relation to flare strength or time of mission are not immediately obvious; the ratios between the channel-3 and channel-4 factors are very similar, though, and if not – as in the example of Feb 2010 – this can probably be explained by the different degradation of channels 3 and 4. The factors for the C flare had to be selected three times higher than the factors for the X flare; maybe this hints to a saturation in the LYRA count rates?
- The large difference between the original GOES SXR signal and the assumed LYRA SXR contribution has to be explained. It is mostly smaller than the previously mentioned factor 70 (or 50, resp.) in most cases, due to the signal separation, but it is still 40, 55, 37, 45, 46, 60, 20, 90 (or 25, 45, 32, 40, 39, 53, 17, 78, resp.). This can be either due to the fact that the LYRA responsivity is a factor 4 (or 2, resp.) higher below 5 nm (or 2 nm, resp.) in channel 2-3 (or 2-4, resp.). Or it could be due to the fact that GOES observes the Sun in a smaller spectral interval (0.1-0.8nm). A deeper knowledge about emission lines, their corresponding plasma temperatures, and their spectral position is needed to answer this question.
- Flares across more than three orders of magnitude have been selected and treated with the same processing scheme, compare below. The scaling factors were manually selected and their meaning is still not quite clear. But they may be related to flare strengths, as demonstrated in a series of four figures, shown below on the second to last page.
- The (scaled) difference curves, i.e. the EUV contributions of LYRA channel 2-3 and channel 2-4, are strikingly similar - independent from the flares observed, which just seem to change the temporal structure but not the similarity. Since, according to the responsivity figure above, these two LYRA channels have only small intersections (say, 0-2nm, 5-7nm, 17-19nm) the EUV flare contributions must either originate from these intervals, given that the signal is different elsewhere; or the flare signal must be quite similar everywhere in the spectral intervals observed by these two channels.

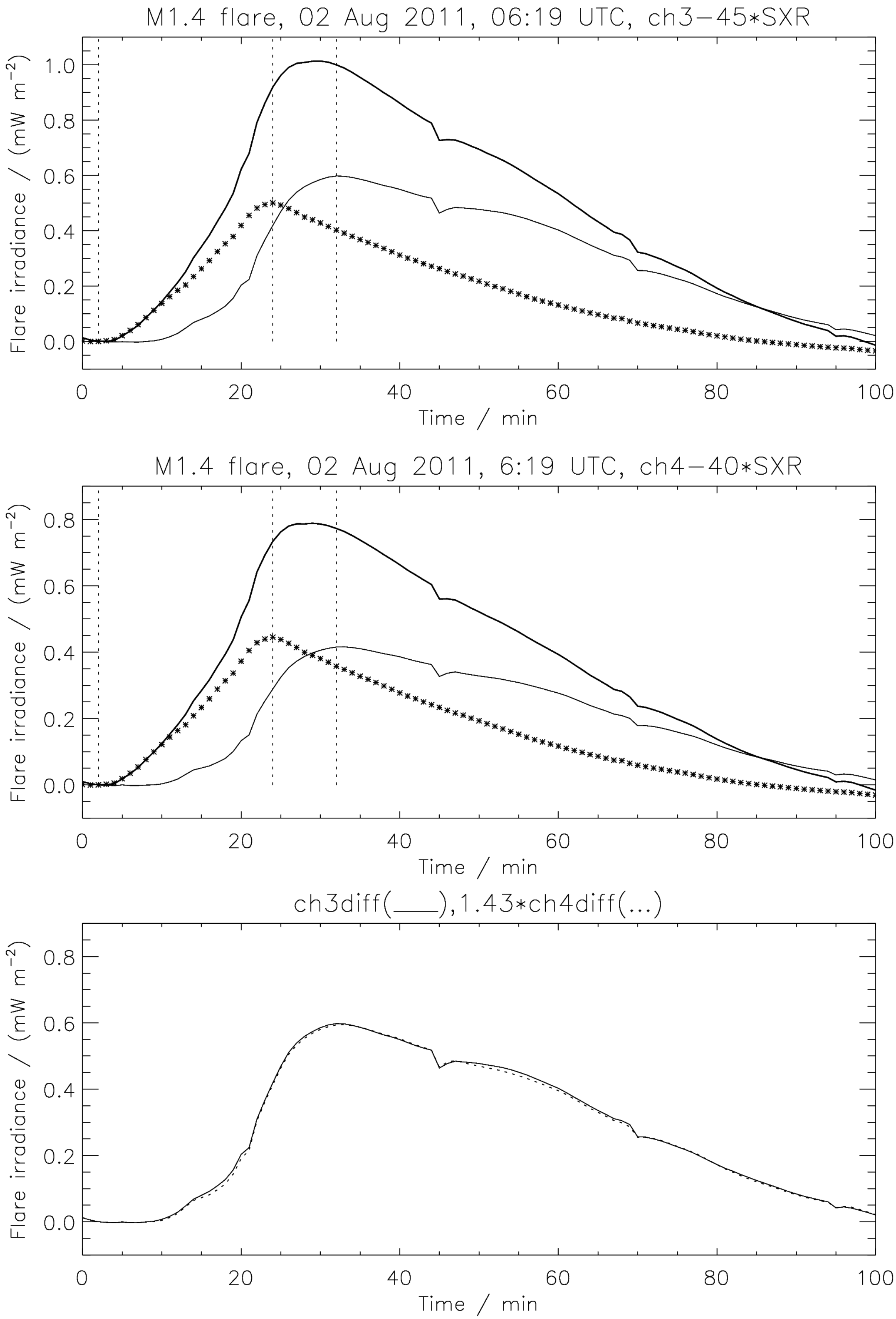
In the long range, this knowledge must be used to calibrate LYRA flares. Currently, it is assumed in the calibration software that there is a linear relationship between measured count rates (corrected for degradation) and solar irradiance. This may not be the case for flares, e.g. due to spectrally biased response strengths; flares might be overestimated, at least in their SXR components.


M2.9 flare, 06 Feb 2010, 18:59 UTC, ch3−40*SXR
Flare irradiance / (mW m−2)
Time / min
M2.9 flare, 06 Feb 2010, 18:59 UTC, ch4−25*SXR
Flare irradiance / (mW m−2)
Time / min
ch3diff(____),1.8*ch4diff(...)
Flare irradiance / (mW m−2)
Time / min

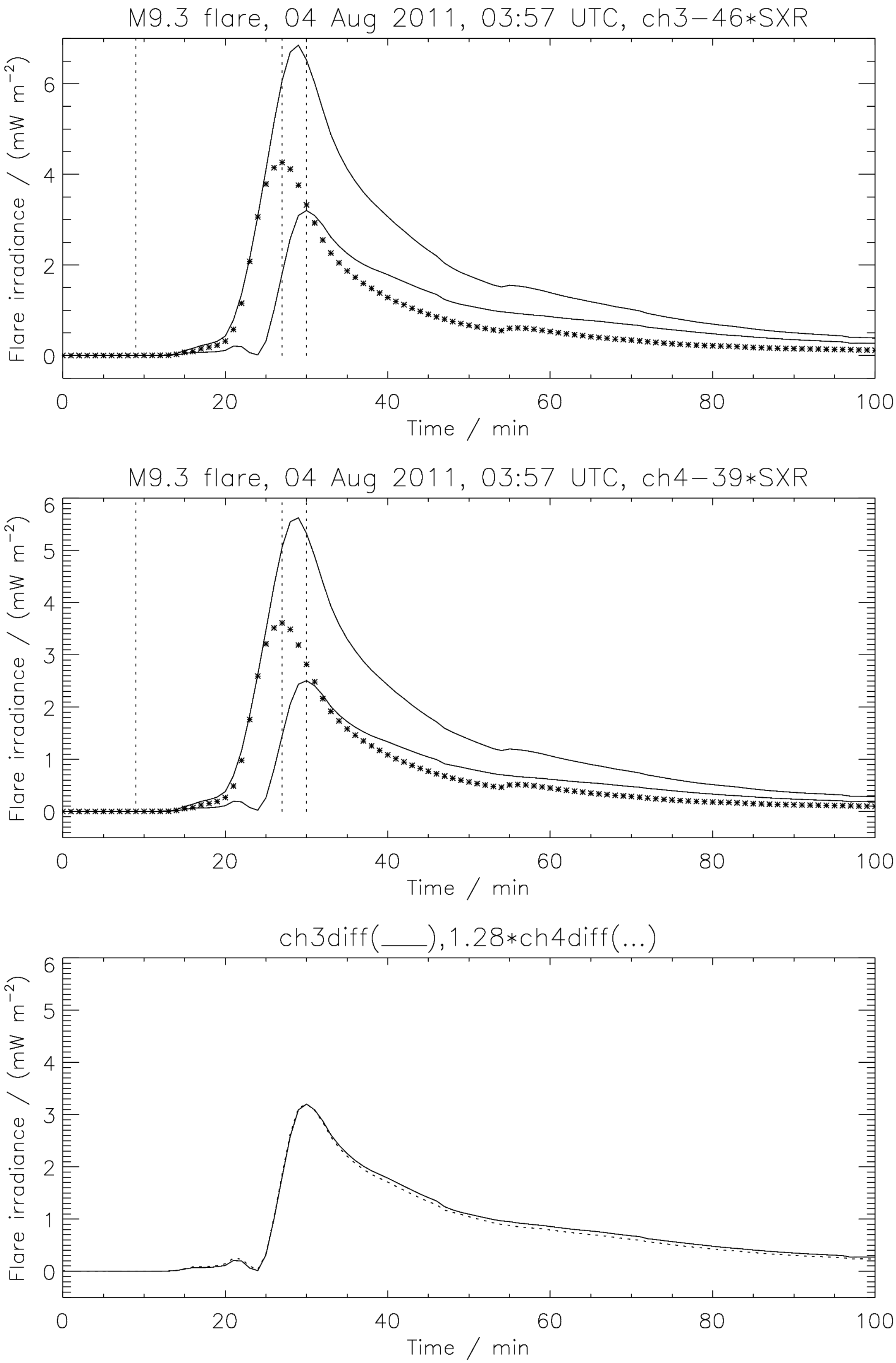

M1.1 flare, 28 Feb 2011, 12:52 UTC, ch3−55*SXR
Flare irradiance / (mW m−2)
Time / min
M1.1 flare, 28 Feb 2011, 12:52 UTC, ch4−45*SXR
Flare irradiance / (mW m−2)
Time / min
ch3diff(____),1.5*c4diff(...)
Flare irradiance / (mW m−2)
Time / min

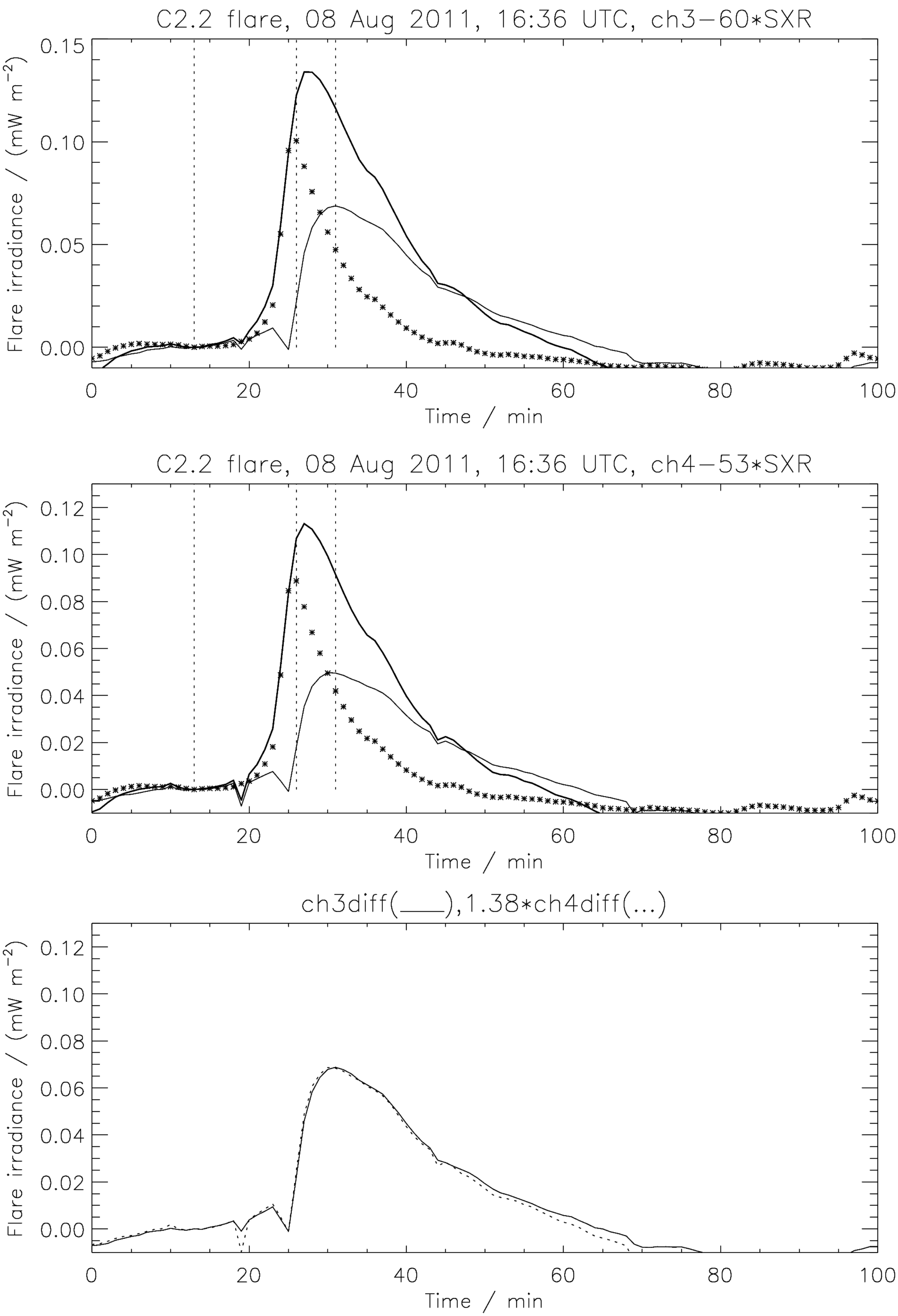


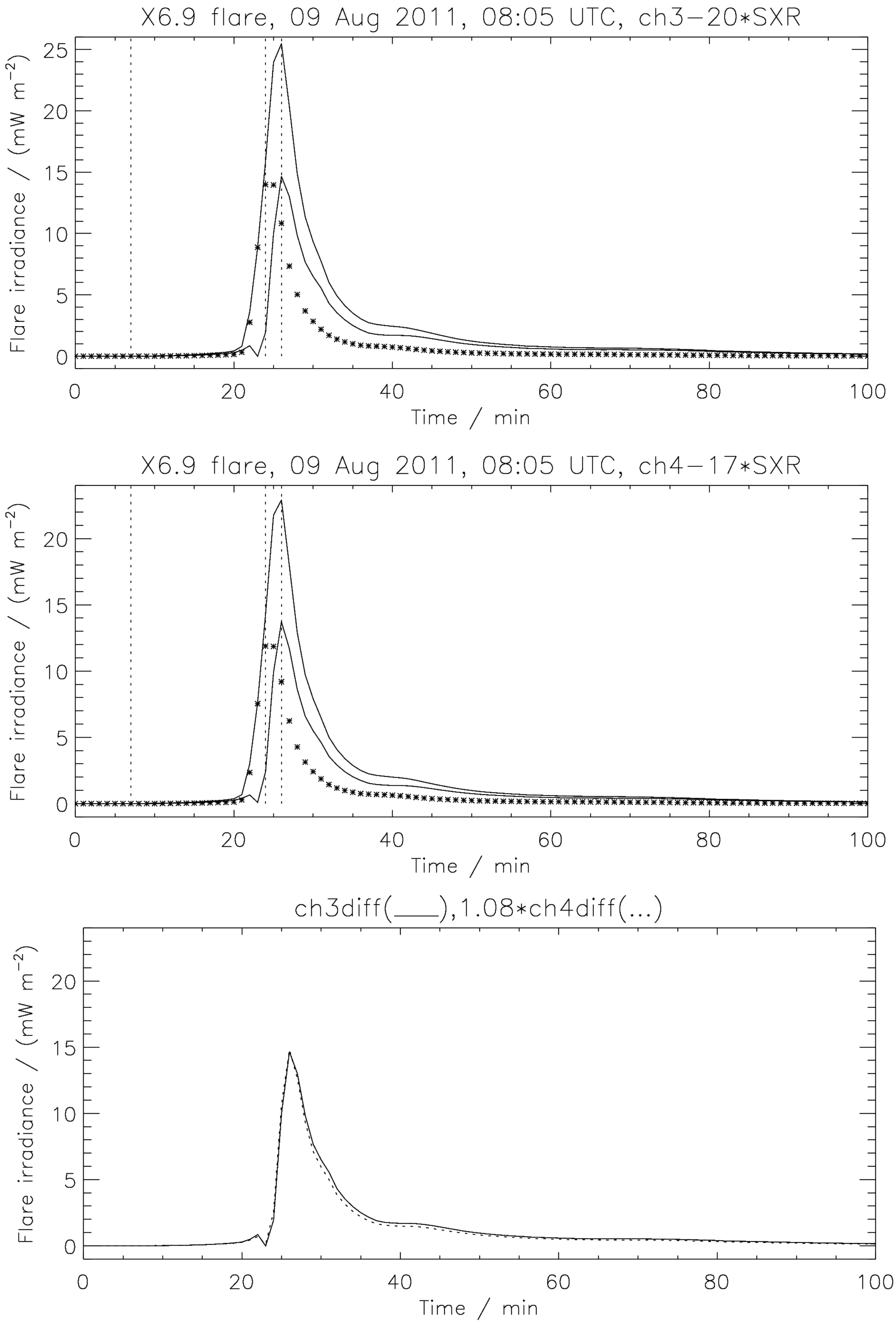
M9.3 flare, 30 Jul 2011, 02:09 UTC, ch3−37*SXR
Flare irradiance / (mW m^{-2})
Time / min
M9.3 flare, 30 Jul 2011, 02:09 UTC, ch4−32*SXR
Flare irradiance / (mW m^{-2})
Time / min
ch3diff(____),1.3*ch4diff(...)
Flare irradiance / (mW m^{-2})
Time / min

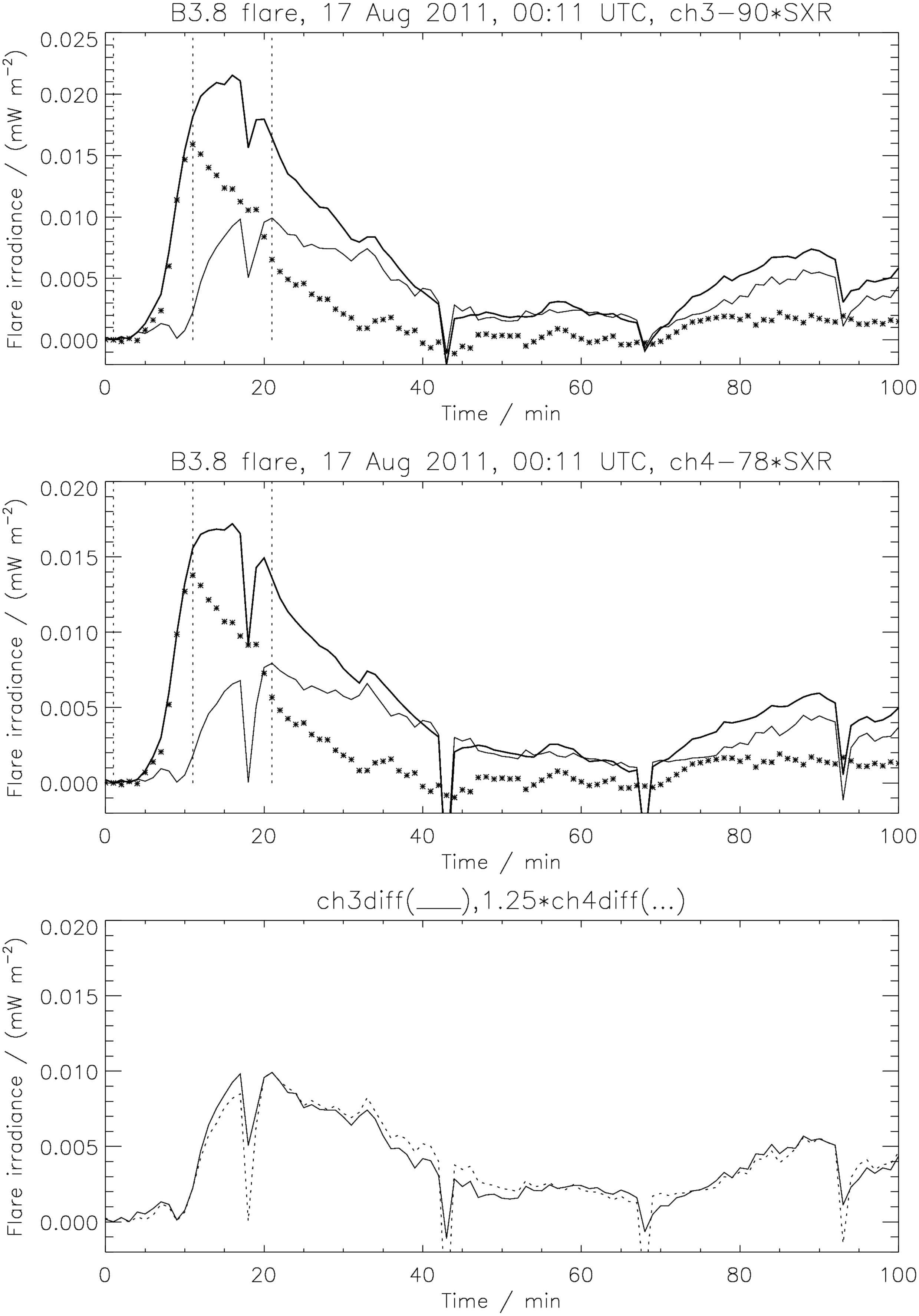


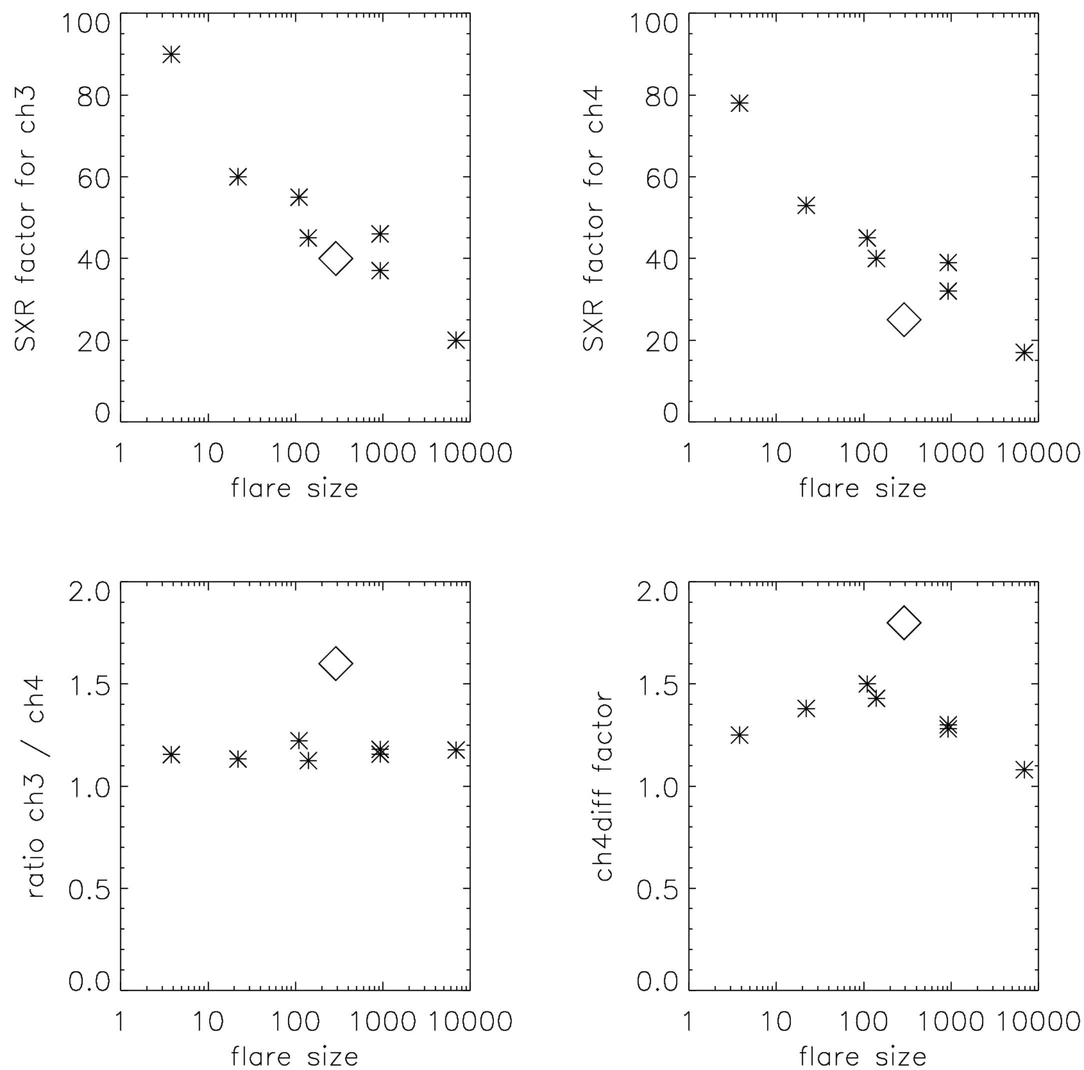
M1.4 flare, 02 Aug 2011, 06:19 UTC, ch3−45*SXR
Flare irradiance / (mW m^{-2})
Time / min
M1.4 flare, 02 Aug 2011, 6:19 UTC, ch4−40*SXR
Flare irradiance / (mW m^{-2})
Time / min
ch3diff(____),1.43*ch4diff(...)
Flare irradiance / (mW m^{-2})
Time / min


M9.3 flare, 04 Aug 2011, 03:57 UTC, ch3−46*SXR
Flare irradiance / (mW m^{-2})
Time / min
M9.3 flare, 04 Aug 2011, 03:57 UTC, ch4−39*SXR
Flare irradiance / (mW m^{-2})
Time / min
ch3diff(____),1.28*ch4diff(...)
Flare irradiance / (mW m^{-2})
Time / min


C2.2 flare, 08 Aug 2011, 16:36 UTC, ch3−60*SXR
Flare irradiance / (mW m^{-2})
0.15
0.10
0.05
0.00
0
20
40
60
80
100
Time / min
C2.2 flare, 08 Aug 2011, 16:36 UTC, ch4−53*SXR
Flare irradiance / (mW m^{-2})
0.12
0.10
0.08
0.06
0.04
0.02
0.00
0
20
40
60
80
100
Time / min
ch3diff(____),1.38*ch4diff(...)
Flare irradiance / (mW m^{-2})
0.12
0.10
0.08
0.06
0.04
0.02
0.00
0
20
40
60
80
100
Time / min


X6.9 flare, 09 Aug 2011, 08:05 UTC, ch3−20*SXR
Flare irradiance / (mW m^{-2})
Time / min
X6.9 flare, 09 Aug 2011, 08:05 UTC, ch4−17*SXR
Flare irradiance / (mW m^{-2})
Time / min
ch3diff(____),1.08*ch4diff(...)
Flare irradiance / (mW m^{-2})
Time / min


B3.8 flare, 17 Aug 2011, 00:11 UTC, ch3−90*SXR
Flare irradiance / (mW m^{-2})
Time / min
B3.8 flare, 17 Aug 2011, 00:11 UTC, ch4−78*SXR
Flare irradiance / (mW m^{-2})
Time / min
ch3diff(____),1.25*ch4diff(...)
Flare irradiance / (mW m^{-2})
Time / min



Please note that the asterisks denote flares from 2011 (mainly August), while the diamond denotes the flare from february 2010. The flare sizes are on a logarithmic scale; "1" corresponds to B1, "10" corresponds to C1, etc.

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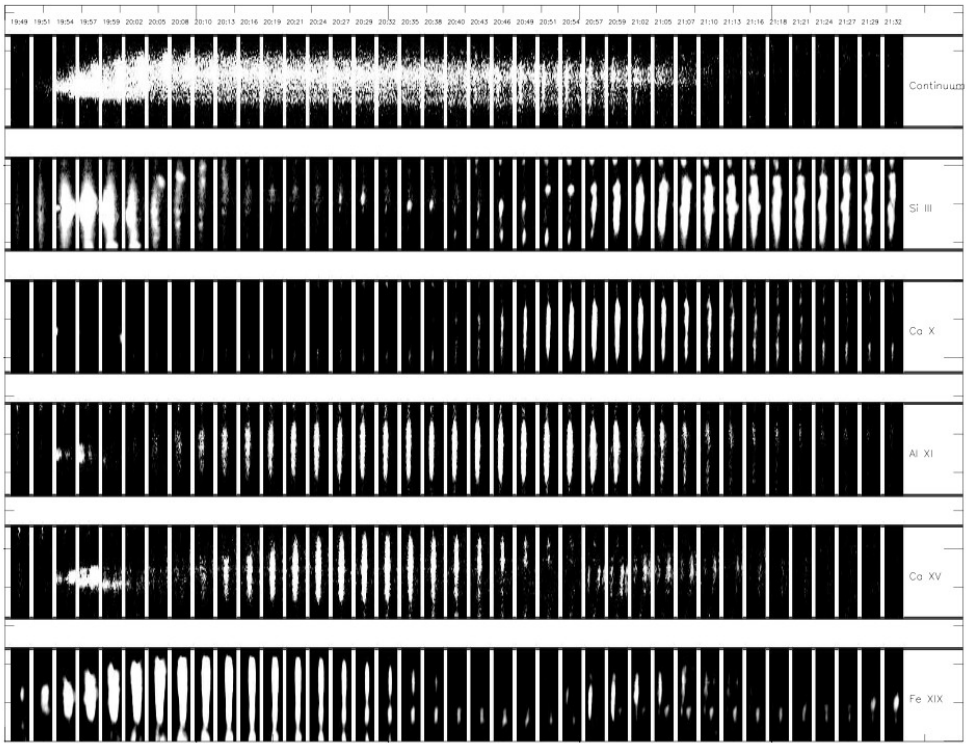

FIG. 8.—Background-subtracted spectra for the free-free continuum, for Si III, Ca X, Al XI, Ca XV, and Fe XIX, as a function of time. A Ne VI second-order line is present in the Fe XIX spectral window between 20:50 and 21:10 UT.

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Applications Places System Thu Jul 21, 17:07 Ingolf Dammasch