Speculations about the “real” strength of Lyman-alpha flare signatures

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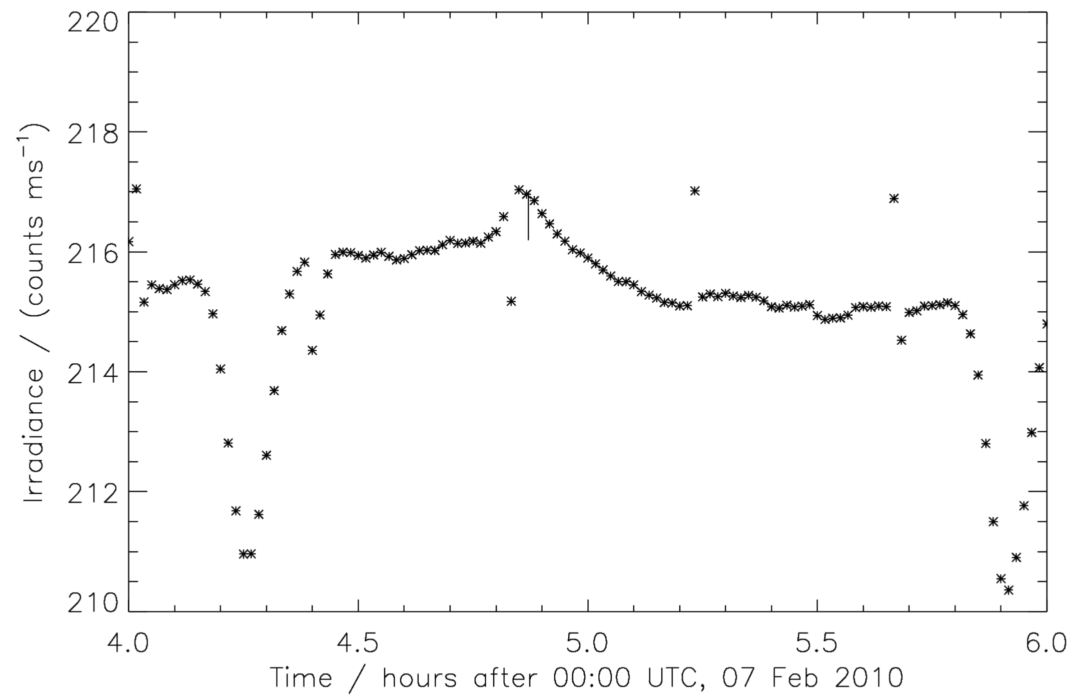
Several flares were analyzed that show a reaction in the LYRA Lyman-alpha channel. Some of these happened in February 2010 before the massive degradation of (nominal) unit 2; some were observed in 2011 with (campaign) unit 3. To determine the absolute radiometric strength of these signatures is a bit tricky due to the “additive” character that was generally chosen for the degradation correction within the LYRA calibration routines. The longer-wavelength channels 2-1 and 2-2 lost more than 90% in the first couple of months. A multiplicative correction with a factor 10, e.g., would have blown every little instrumental artifact out of proportion. In addition, especially for channel 2-3, the flare strength did not degrade like the UV and EUV levels; the flares rather stayed constant over time, because the SXR was not absorbed by the growing “dirt” layer of polymerized molecules on the filter surface. Here, too, adding the estimated degradation makes more sense than a multiplicative correction.

But what is appropriate for the shorter-wavelength channels 2-3 and 2-4 may lead to a misconception when calculating the flare signatures in the Lyman-alpha channel directly from LYRA standard level-2 FITS files. In Kretzschmar et al (2013), see here:
http://arxiv.org/abs/1210.2169
in Figure 4 on p.227 and the text around it, it is demonstrated how to avoid the problem: The LYRA count rates - instrumental dark currents subtracted - were directly converted to the SORCE irradiance level of the day. It is also mentioned that this may still lead to an underestimation due to the unclear spectral band of the Lyman-alpha channel.

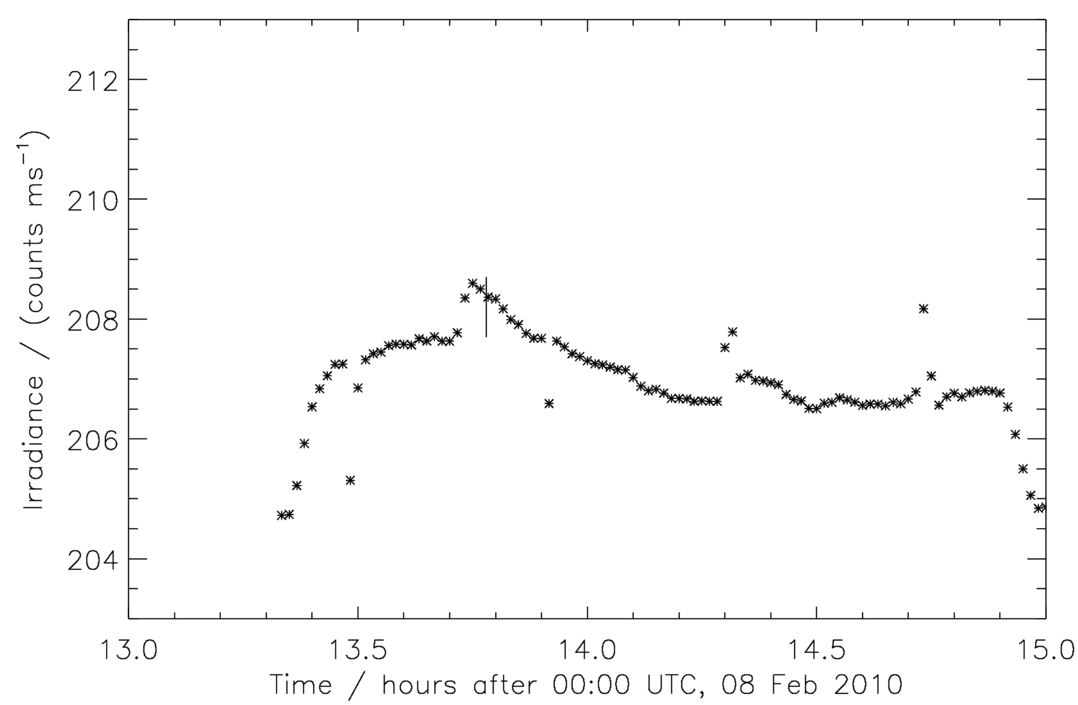
Let me assume the following:

- In contrast to the SXR flare signatures in LYRA channels 3 and 4, the Lyman-alpha flare signature does not stay constant over time, but degrades together with its spectral band; this is plausible since, due to the filters, SXR input cannot be seen in the LYRA longer-wavelength channels, and flare signatures indeed cannot be observed after the degradation of the Lyman-alpha channel, e.g. in unit 2 after February 2010.
- The Lyman-alpha flare signature actually only appears within the Lyman-alpha range, and not in the additional spectral interval around 200-220nm (unit 2) or anywhere else (unit 3). For the spectral bands of the Lyman-alpha channels, please see Kretzschmar et al (2013), Figure 1 on p.223. This is plausible as long as there are no flare signatures detected in the Herzberg channel.
- Spectral degradation is witnessed with LYRA, according to Figure 21 as published in the LYRA section of BenMoussa et al (2013), see here:
  http://arxiv.org/abs/1304.5488
  In detail, degradation is worst in the Lyman-alpha and Herzberg channels' spectral range, but less heavy in the visual and infrared range. In other words, the Lyman-alpha channels of units 1 and 2 (diamond detectors) degrade everywhere, whereas the Lyman-alpha channel of unit 3 basically degrades only in the UV range; this is plausible if one considers the first 1000 hours of open covers, see Figures 1, 2, and 3 in the following report:
  http://solwww.oma.be/users/dammasch/IED_20121218_DegradationUpdate.pdf
  Here, unit 3 seems to stabilize on a higher level.
- The “pure” contribution of the Lyman-alpha line is in all cases (unit 2 or 3) around one third of the total contribution of the channel.
- The absolute irradiance of the Lyman-alpha line is around 0.0065 W/m2.

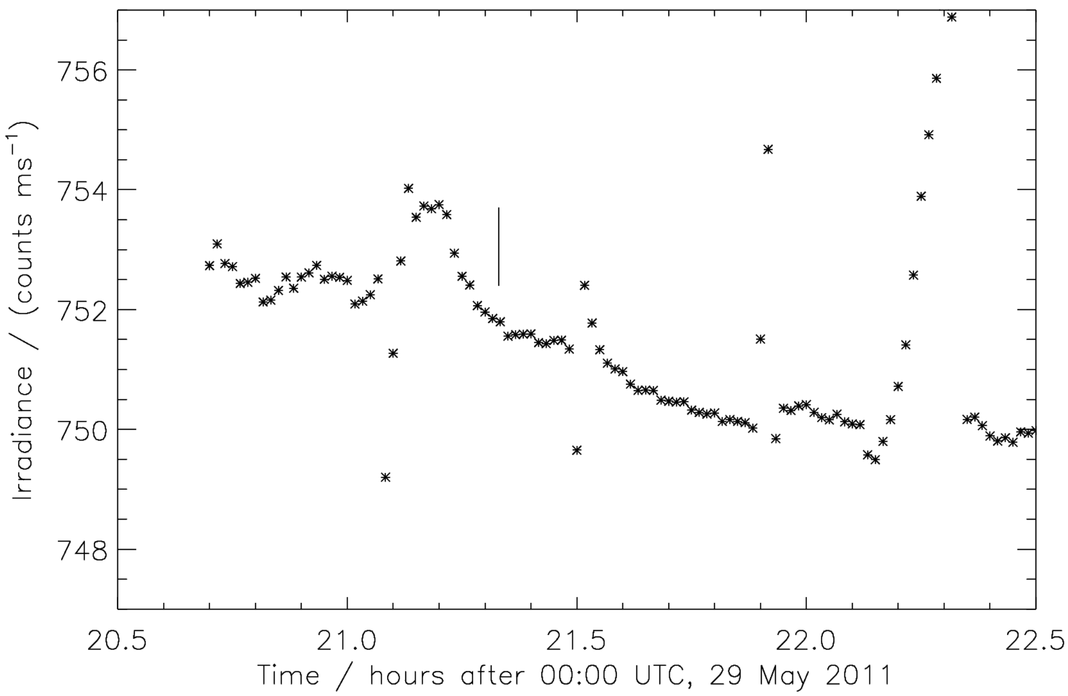
Under these circumstances, the relative and absolute Lyman-alpha flare signatures can be estimated as follows (considering - very roughly - the peak value increase, not the integral). The figures show irradiance vs. time around the flare; irradiances are not fully calibrated, only the dark currents are subtracted and the 1-AU-correction performed. The assumed signatures are plotted as a vertical line at the time of the GOES flare maximum.



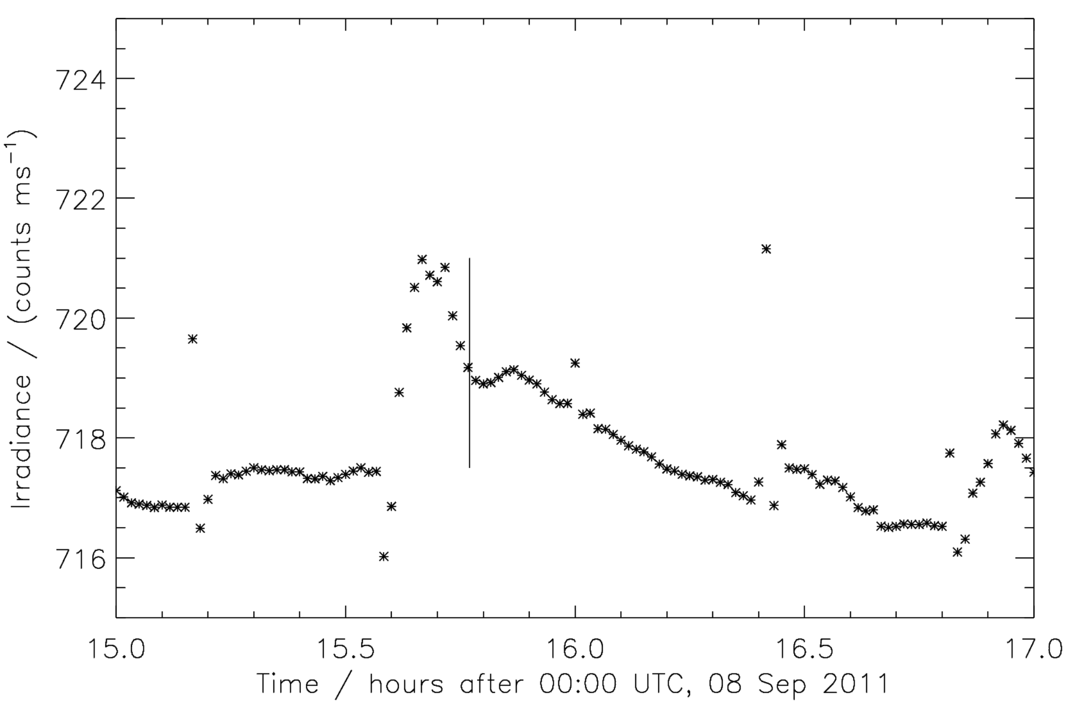
C9.9, 07 Feb 2010, 04:52 UTC, unit 2: The increase is a little less than one count/ms, say, 0.8. At that time, slightly over 200 of the initial 492 counts/ms are left in channel 2-1; 0.8 in relation to 200 counts/ms would be 0.4%. But if only one third (~ 70) is actually originating from the Lyman-alpha line, the flare signature is 0.8/70 or 1.1% or 0.00007 W/m2.



M2.0, 08 Feb 2010, 13:47 UTC, unit 2: The increase is approx one count/ms; in relation to 200 counts/ms this would be 0.5%. But in relation to 70 counts/ms it is 1.4% or 0.00009 W/m2.

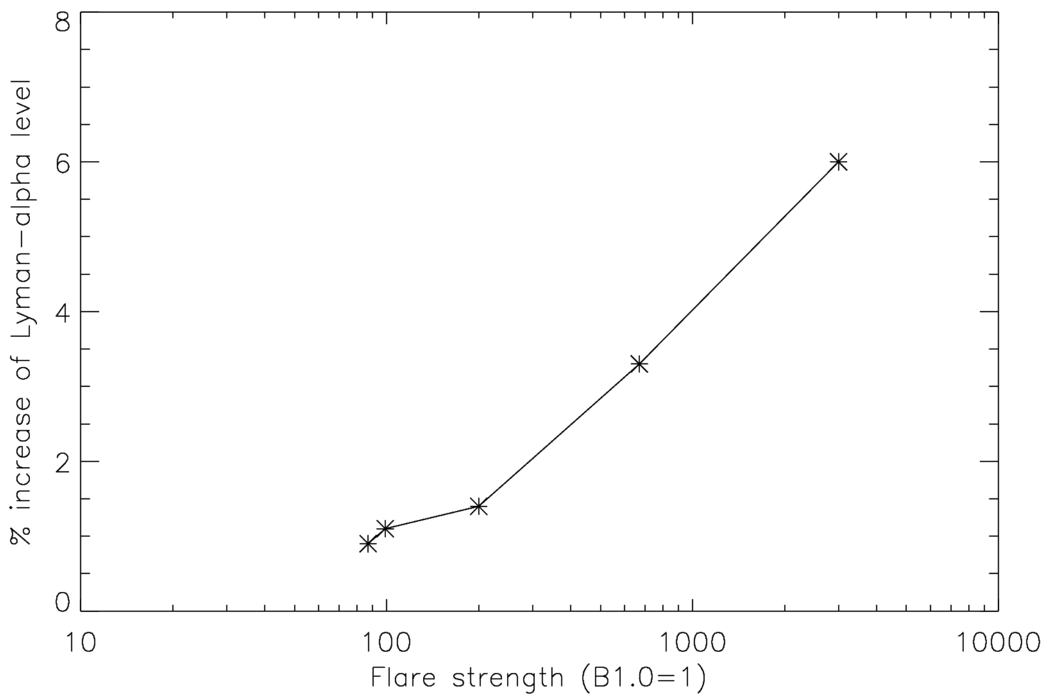


C8.7, 29 May 2011, 21:20 UTC, unit 3: The increase is approx 1.3 counts/ms. Until that day, the level of channel 3-1 has degraded from 920 to 750 counts/ms; 1.3 in relation to 750 would be 0.2%. But assuming that this loss (170 counts/ms) has only happened in the Lyman-alpha part and nowhere else (one third of 920 ~ 310 counts/ms), then only 140 counts/s are left there; 1.3 in relation to 140 are 0.9% or 0.00006 W/m2.



M6.7, 08 Sep 2011, 15:46 UTC, unit 3: The increase is approx 3.5 counts/ms. Until that day, the level of channel 3-1 has degraded to 715 counts/ms; 3.5 in relation to 715 would be 0.5%. But considering the loss (205 counts/ms) has only happened in the Lyman-alpha part (310 counts/s), then only 105 counts/ms are left there; 3.5 in relation to 105 are 3.3% or 0.00021 W/m2.

Together with the remark in Kretzschmar et al (2013) about a 6% increase due to an X3 flare found by Brekke et al, this does not exactly lead to a linear relationship, but - with the flare strength plotted on a logarithmic scale - it looks reasonable.



To make things even more complicated, the Lyman-alpha flare signatures happen on a different time scale than the flares observed by GOES or the LYRA short-wavelength channels. For example, the Lyman-alpha flare signature of 08 Sep 2011 actually consists of two strikes; the first one leads to an X-ray flare that builds up to approx GOES class M5, only the second one, three minutes later, makes the flare rise up to M6.7. Due to the cooling periods, it appears as one long flare.

With respect to the cross-calibration with SDO/EVE - see slides #17 and #20, here:
http://solwww.oma.be/users/dammasch/Dammasch_CosparC12000612.ppt
- the brown lines correspond to temperatures log(T)=4.9 and resemble the LYRA Lyman-alpha-channel curves. Whether they actually are from the Lyman-alpha line is TBC. If yes, a factor 2 to 5 difference has to be explained, since Phil Chamberlin's model gives a flare signature of 0.000012 W/m2 (29 May 2011) and 0.00009 W/m2 (08 Sep 2011), while 0.00006 W/m2 and 0.00021 W/m2 were calculated above.