“Cleaning” the early Lyman-alpha channel 2-1 from artefacts

IED 11 May 2015

Does the Lyman-alpha channel (ch2-1) of LYRA's nominal unit 2 display long-term solar changes, and not only short-term solar signatures like in the rising phase of flares? In order to answer this question, possible artefacts must be eliminated to better understand the degradation in the early phase, the first months of 2010. (Afterwards, the degradation has probably already advanced too far.)

One possible source of artefacts is the dark current, which has to be subtracted to calculate the real solar signal. For a while, it was assumed that the dark currents - as measured in several calibration campaigns in 2010/2011 - were constant, though smaller than measured in the laboratory before launch. In 2014, it was realized that the dark currents are actually not only a function of temperature, but also a function of the exposure of the channels to the Sun; see *Figure 1*. In other words, the dark current of, say, ch2-1 decreases over time, and thus this channel's dark currents after first light actually started out as before launch (diamonds = lab measurements); they were underestimated in early 2010 (top curves), and overestimated in later years (bottom curves).

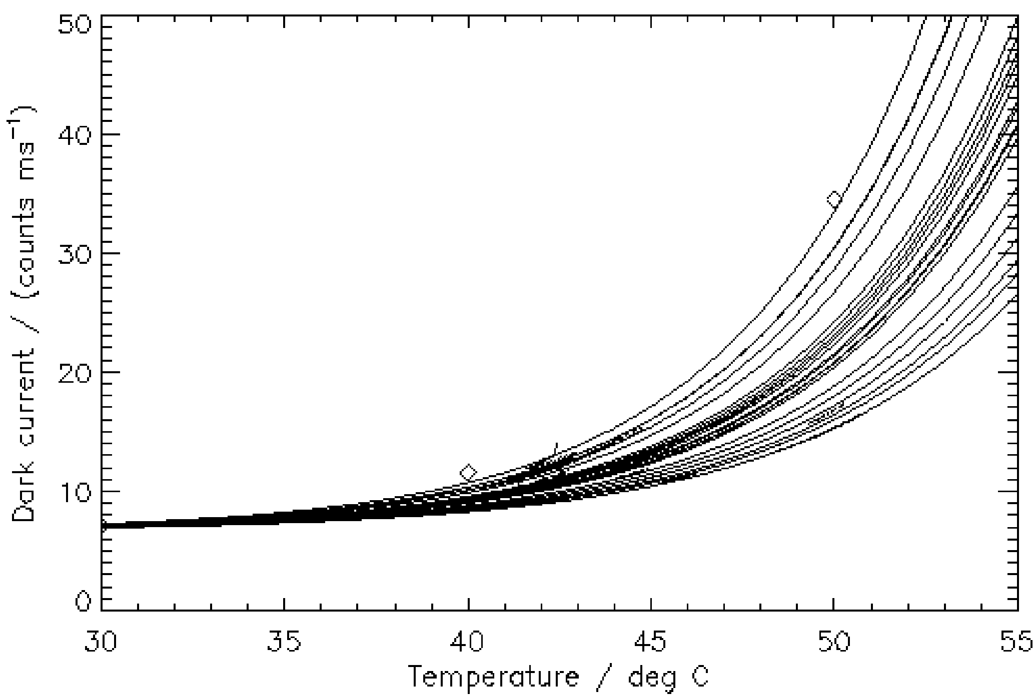

Figure 1.

Meanwhile, the calibration software has been modified accordingly, and some problems were therefore solved. Two examples are shown in *Figure 2*: the Lyman-alpha channel and the Zirconium channel of unit 2 during 10 Feb 2013. This is a relatively late day of the mission, and thus the calibration software initially overestimated the dark currents, shown as a dotted line. This leads to an overcompensation of the temperature-induced bump around 11:00 UTC in both channels, and in the case of ch2-1 even to a negative result due to subtraction (left part).

After the software update, the results are more realistic (right part): the calibrated curves are positive, and relatively straight.

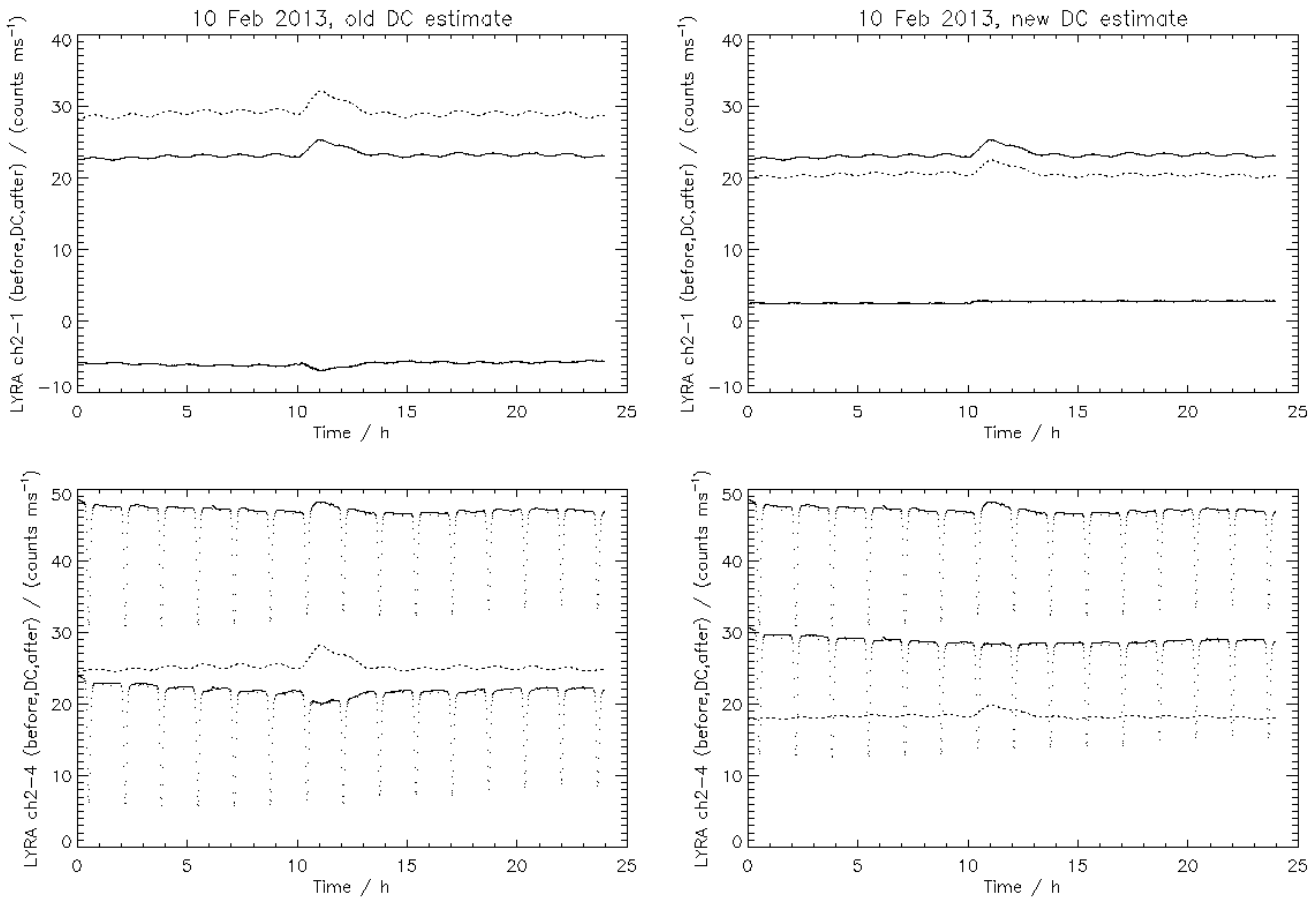

Figure 2.

Figure 3 shows the development of all four channels of the nominal unit during the first 1500 hours of exposure, Jan-Mar 2010. The Aluminium-filter channel 2-3 is “normalized” by ch2-4 in order to eliminate solar variations and display more clearly the course of degradation. An artefact is clearly visible after 250 h: The dark current of ch2-4 is underestimated, the solar signal is thus overestimated, and as a secondary effect, the development of ch2-3, as divided by ch2-4, shows a dip.

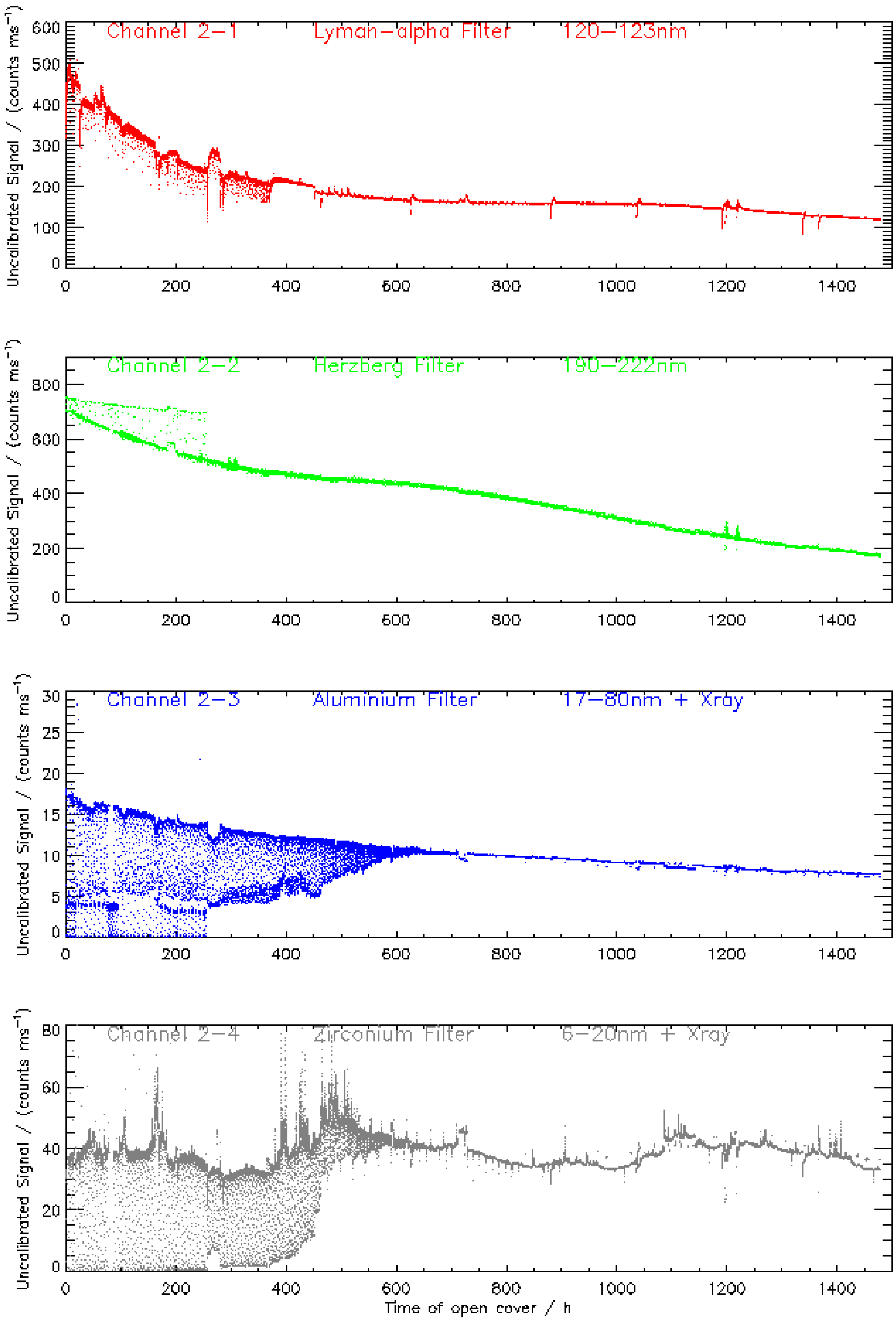

Figure 3.

To distinguish between real solar signal and artefact, one can use information from other instruments. As an example, in *Figure 4* the development of the nominal-unit channels in January 2010 is presented, i.e., in commissioning phase, immediately after the opening of the covers on 06 Jan 2010. Despite the data gaps (ch2-1 on 29-30 Jan does not have a gap, it is simply so high that it is outside the frame; the other gaps are real), one can ask: Which of the curves, after a first calibration attempt, are real?

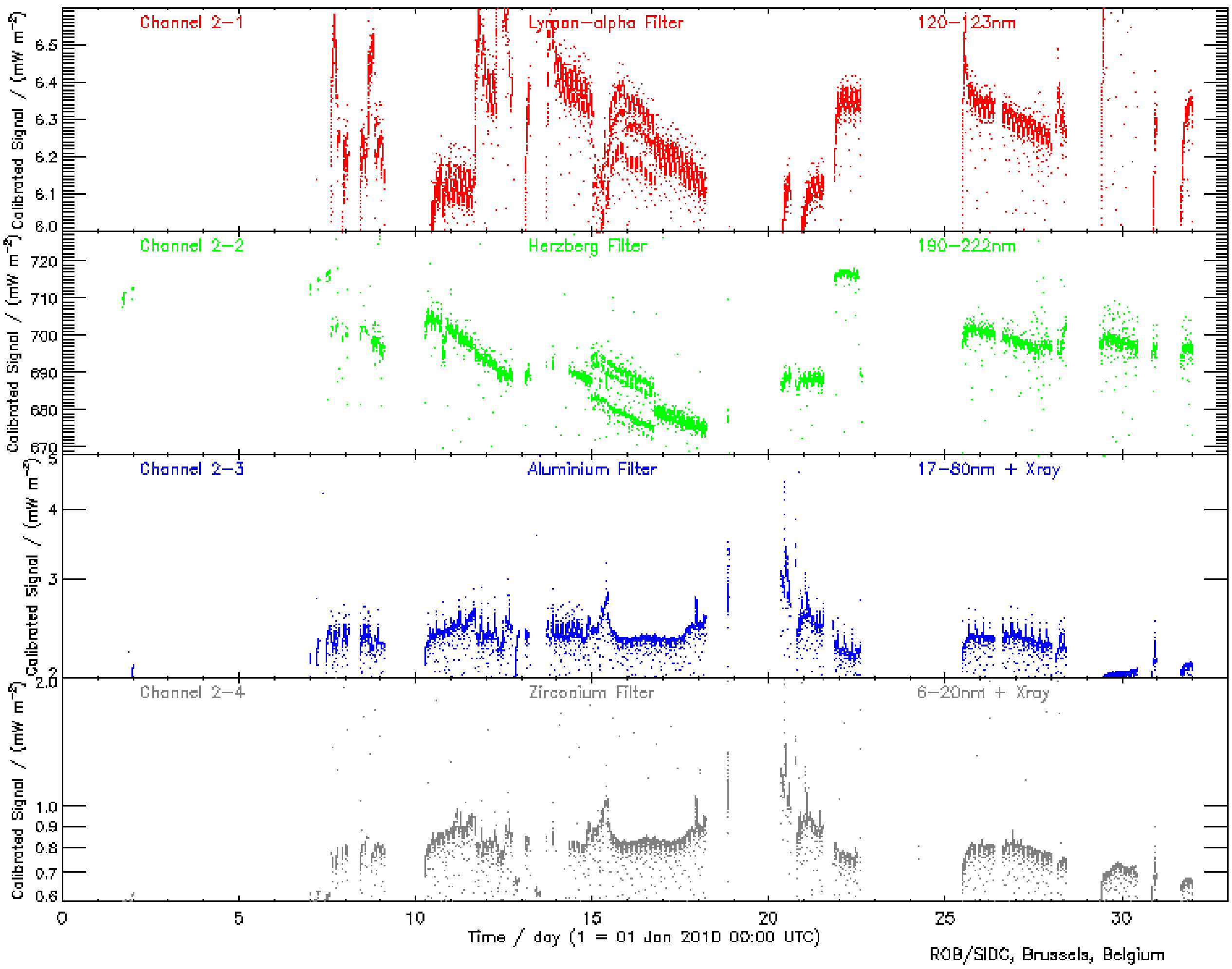

Figure 4.

Figure 5 shows the same month as observed by SORCE around 10.5 nm. LYRA ch2-4 follows this curve more or less during 07-17 Jan and 20-23 Jan; during the SORCE peak (18-20 Jan) LYRA has a data gap; 25-28 Jan it slowly declines, like SORCE; 28-29 Jan it has a data gap; 29-30 Jan SORCE shows a sharp decline, while ch2-4 stays on the same level and ch2-3 also displays a sharp decline. The reason is, 29-30 Jan was a bake-out phase with unusually high temperatures; thus the more temperature-sensitive ch2-4 was overestimated, because its dark current was still underestimated with this early version of the calibration software. Meanwhile ch2-3 is approximately realistic.

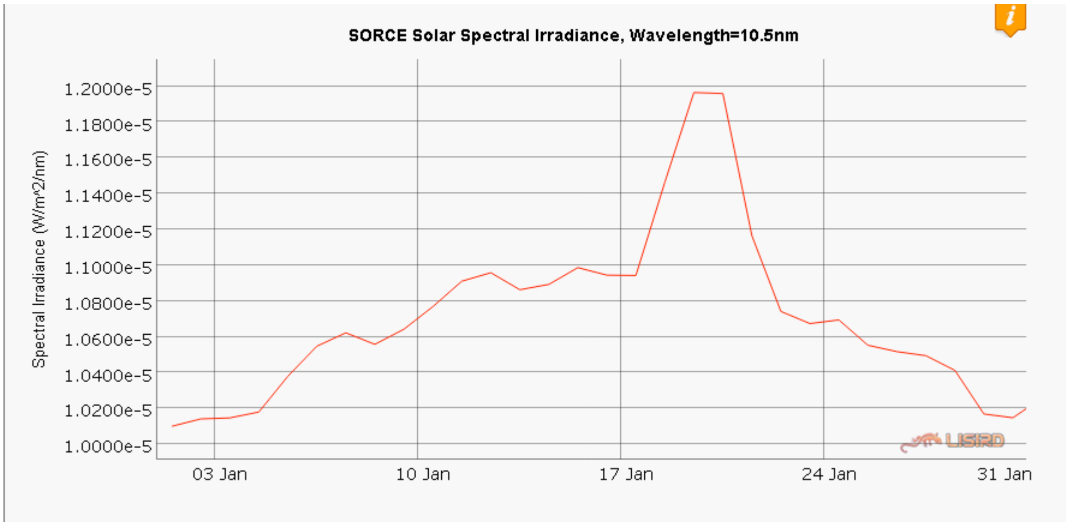

Figure 5.

Figure 6 shows the same month as observed by SORCE around 121.5 nm. LYRA ch2-1 follows this curve to a certain extent; the peak 11-17 Jan might actually be caused by the Sun. After the data gap 23-25 Jan, it should stay more or less constant, but during the bake-out phase the LYRA curve makes a great leap upwards, which is definitely an artefact. Will this be eliminated by the calibration software update?

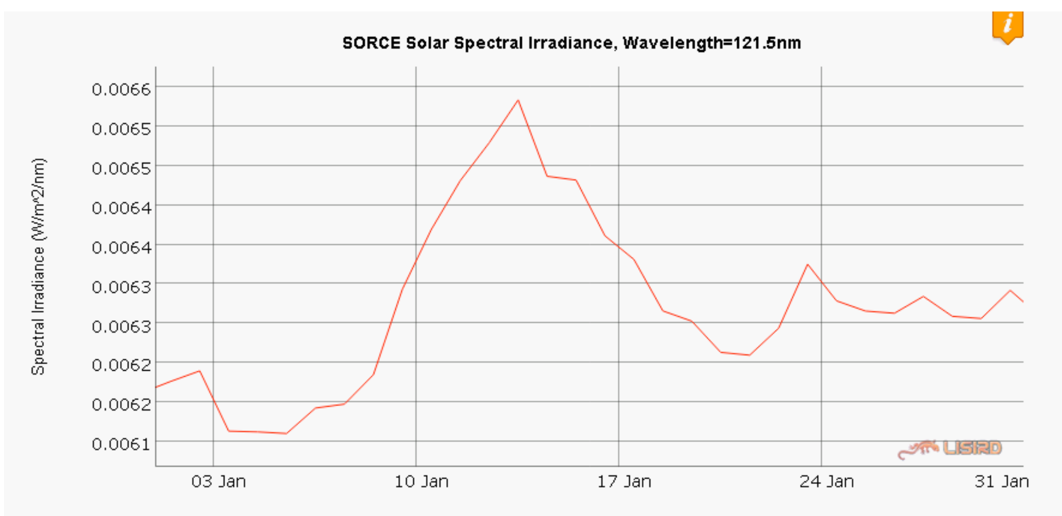

Figure 6.

Figure 7 again shows the four channels of unit 2, after the mentioned update. After the data gap around 250 h (28-29 Jan), ch2-4 drops to a lower level in the bake-out phase, i.e. the dark current is no longer underestimated; consequently, the normalized ch2-3 curve is smoother now. But the artefact in ch2-1 is still where it was. Something must be different for the Lyman-alpha channel.

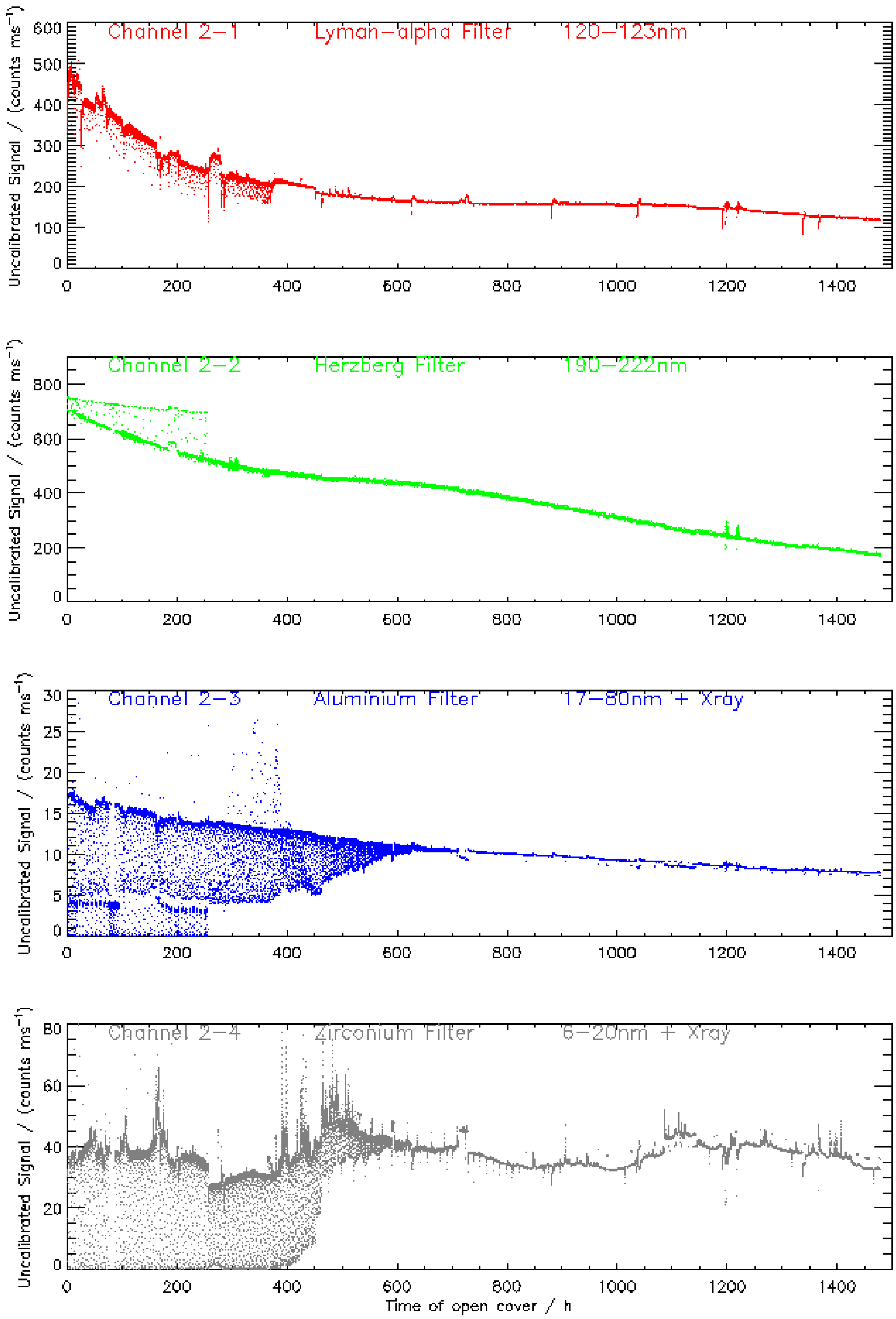

Figure 7.

Figure 8 shows the relationship between temperature and dark current as assumed for ch2-1. The temperature (upper curve) rises from an initial approx. 35 degree C to approx 45 degree C at the end of the month. But the assumed jump of the dark current from 10 to 18 does not eliminate the artifacts. The relationship must be more extreme, more like in the right side of *Figure 1*, i.e., rather a jump from 40 to 50 degree C is needed to explain the dark current artifacts. In other words, higher temperatures than actually measured must be assumed.

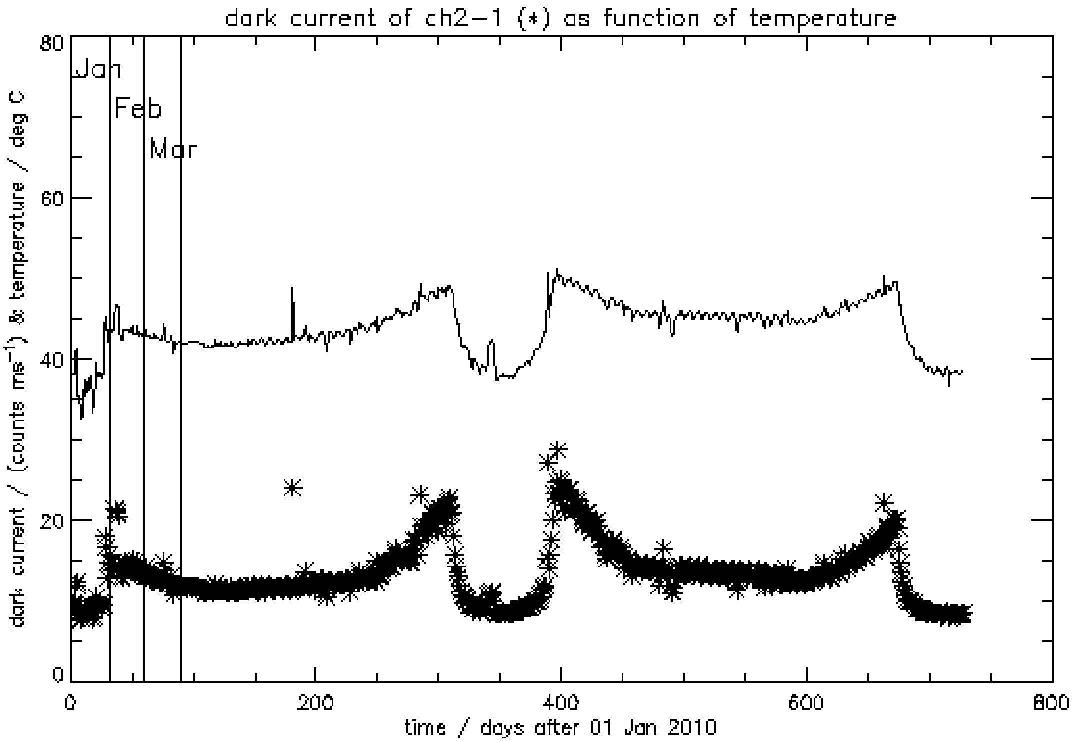

Figure 8.

This can be demonstrated in *Figure 9*. In the upper part, the temperatures to estimate the dark current are taken as observed. The middle curve shows the raw data, the curve above 250 shows the estimated dark currents (they are really around 20 counts/ms). The lower curve shows the result after subtraction of dark currents: the bump after 8 h UTC - caused by the temperature increase - is still there; all orbital cycles have different shapes. - In the lower part, the observed temperatures are increased by 6 degree C in order to estimate the dark current once more. Again, the middle curve shows the raw data, the curve above 250 shows the newly estimated dark current (now around 40 counts/ms). The lower curve now displays a different behaviour: the temperature bump is practically gone, the curve shows an almost continuous decline as seen over the course of the day (this decline is caused by degradation), and the orbital cycles are more similar, like inverse U-shapes (which are also known from other channels during occultation phase). - Although it can only be speculated about the reason why ch2-1 should have a higher temperature than the other channels of unit 2: the assumed +6 degree C do help to eliminate the artifact of the bake-out phase, as well as periodic daily artifacts like the one described here.

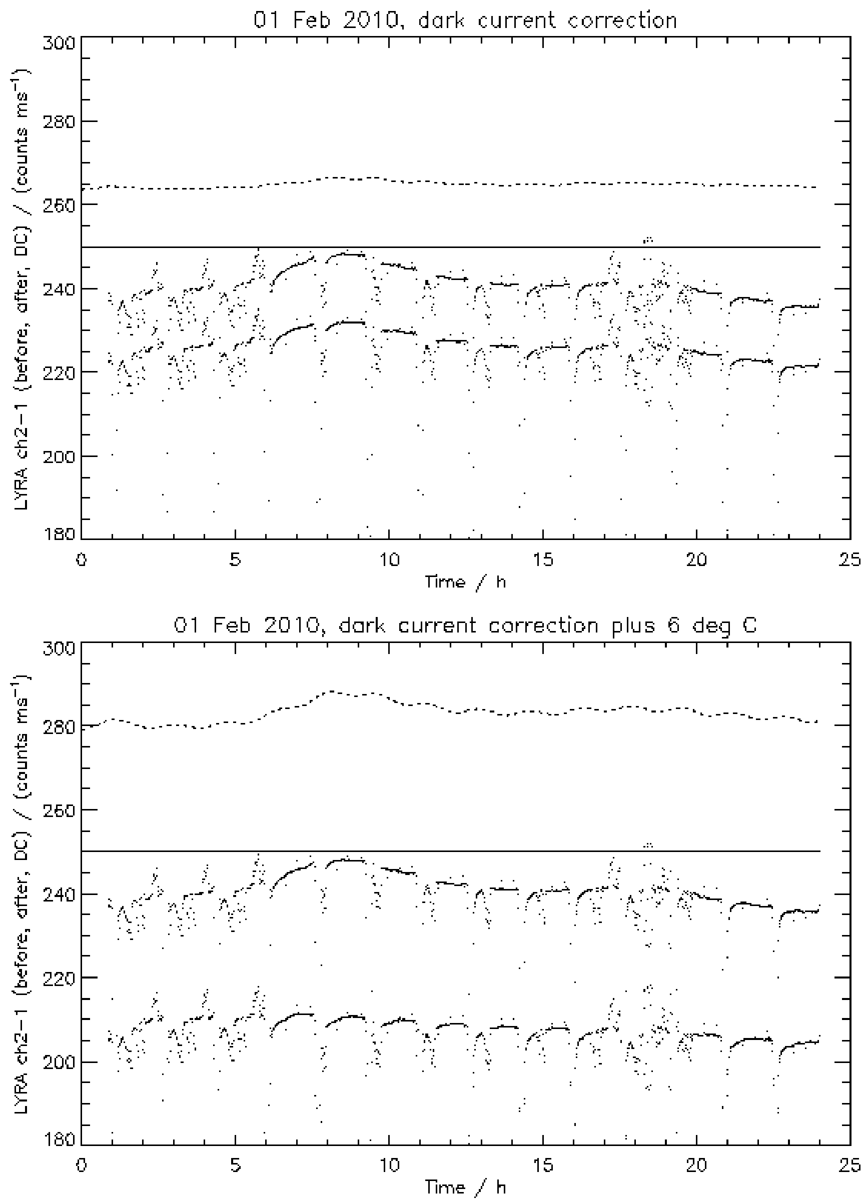

Figure 9.

Figure 10 demonstrates the possible consequences of these additional 6 degree C. For low measured temperatures (35-40 C), there is hardly a difference to be recognized. For middle measured temperatures around 40 C , the assumed additional 6 C double the dark currents. For measured temperatures above 45 C, an additional 6 C triples the dark currents. - But again, things are not as simple as that.

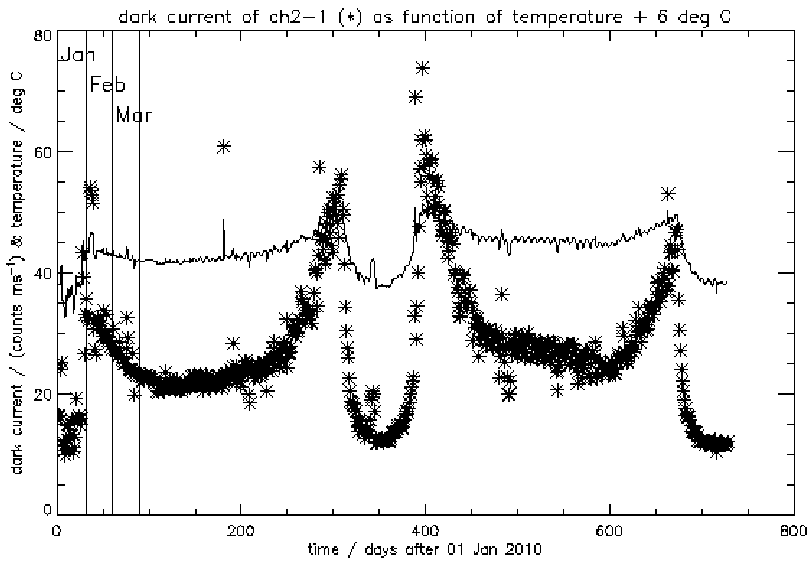

Figure 10.

The additional temperature that is necessary to compensate for the artefacts was tested for all days in Jan-Mar 2010, and for one day per week in Apr 2010 - Dec 2011. The result is shown in *Figure 11*: The necessary corrections have almost vanished after two years. In other words, not only do we have to explain why ch2-1 appears to be hotter than the other channels of unit 2, but also why this is only the case during the commissioning phase and then gradually diminishes.

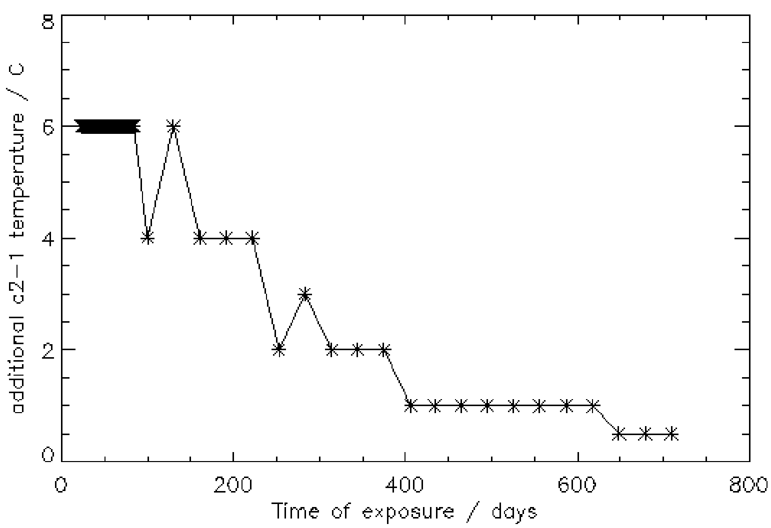

Figure 11.

Figure 12 shows how the assumed additional temperature works to make ch2-1 smoother within the first three months, and that this modification *only* works for ch2-1; when applied to the other channels, ch2-3 and ch2-4 display erratic results; ch2-2, like all Herzberg channels, is rather insensitive to temperature changes, in other words, their dark currents are almost constant.

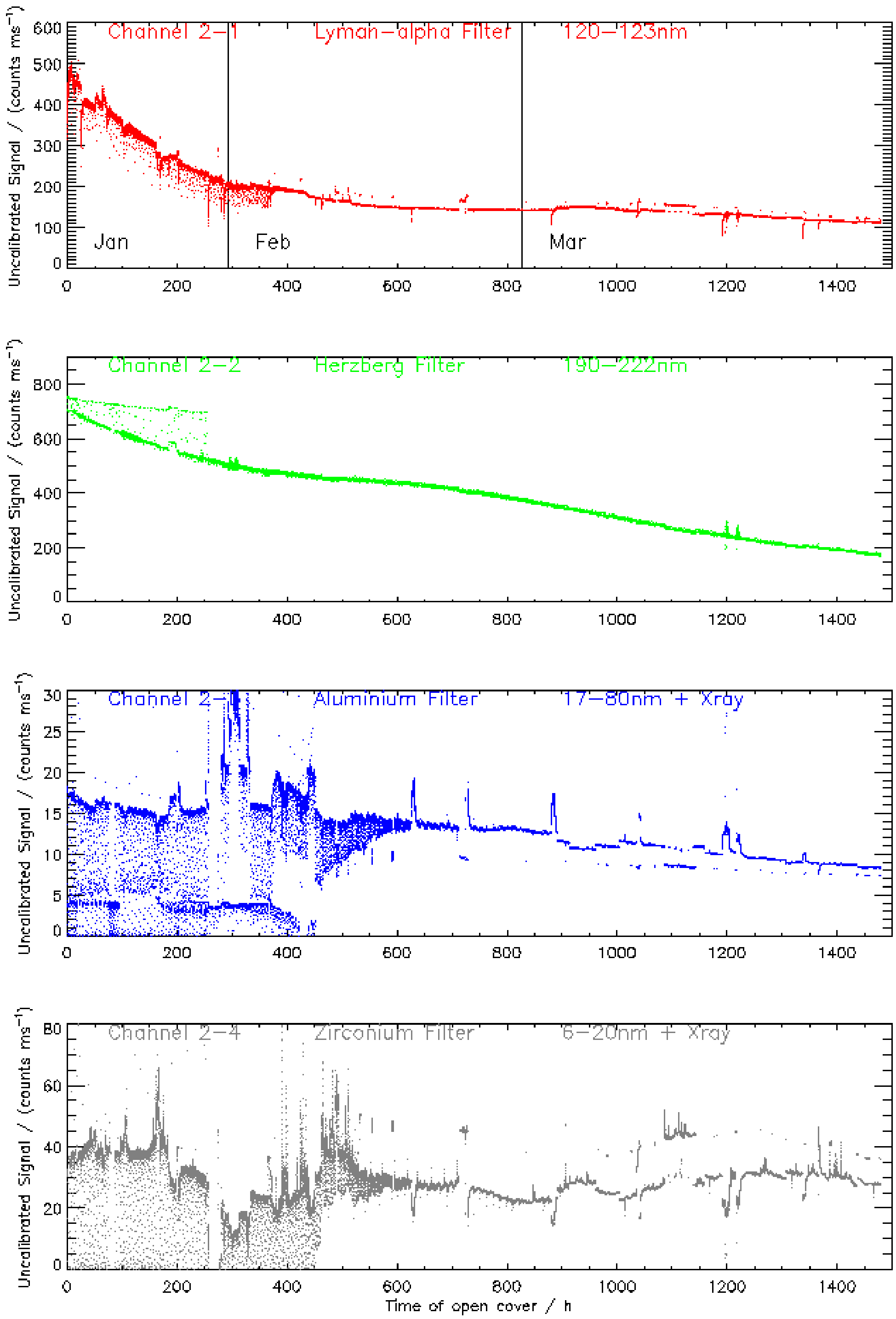

Figure 12.

Due to observation gaps in the commissioning phase, the first three months of 2010 come down to 61 full days. These were manually checked for the daily significant minimum in ch2-1; afterwards, it was checked once a week. This leads to a more or less "clean" curve for the remaining ch2-1 irradiance during the first two years, shown in *Figure 13*. It appears quite smooth, except for a bump around the beginning of Mar 2010. This could theoretically be caused by increased solar activity, except that other instruments do not observe this. Another explanation is that the degradation consists of several phases and can thus not be fitted with only one (exponential) decay curve.

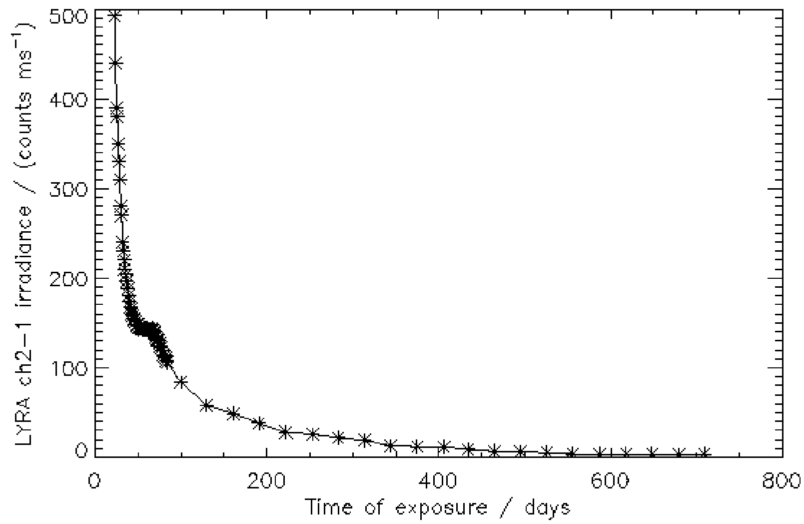

Figure 13.

Figure 14 demonstrates that this behaviour is not restricted to Lyman-alpha ch2-1. Herzberg ch2-2 similarly shows two degradation phases, in this case with a bump around mid-Feb 2010. So, more explanations have to be found. - It remains uncertain whether the degradation, even with smooth "cleaned" curves like these, can be fitted in such a way that a long-term solar variability becomes visible.

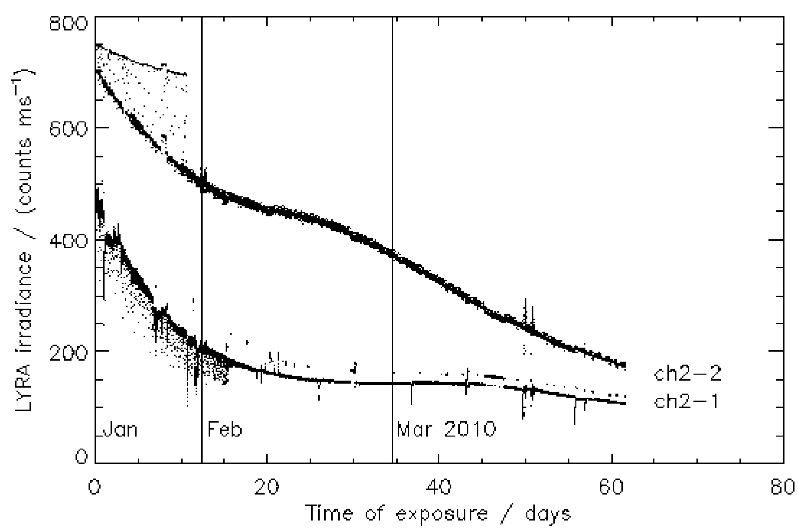

Figure 14.