LYRA Degradation Report: Update Dec 2012

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This is the first part of an effort to update the LYRA calibration software with respect to degradation. Later on, the second part will consist of a new estimation curve that will substitute the current one which ends at day 1200 after First Light. In other words, the current BSDG software has to be updated before 19 Apr 2013. The LYRA data will have to be reprocessed afterwards, but major changes are not expected. - In addition, BSDG-like software will be written for data observed by units 1 and 3.

This update is based on 105 calibration campaigns between Jan 2010 and Nov 2012 in which the performance of unit 2 was compared to unit 3, or unit 1, or both. Unit 2 ("nominal") has been used quasi-continuously since First Light on 06 Jan 2010. Unit 3 has basically been used for campaigns, altogether leading to 964 hours with open cover. Unit 1 is still considered the spare unit and has only been opened and used for 90 hours.

One has to keep in mind that the time horizons of the three units are quite different. While unit 2 has been observing the Sun for approx three years by now, and thus the degradation is more or less a function of mission days, the degradation of units 3 and 1 is a function of time with open cover, i.e. ***hours*** instead of ***days***. This makes it sometimes difficult to compare the curves, and one has to pay attention especially when the degradation of units 3 and 1 is plotted versus mission days (see Fig.4 and following).

In the previous reports, channels 3-4 and 1-4 were considered as being constant (i.e., non-degrading), in order to form the foundation to remove the solar variability trend from channels 2-3 and 2-4, as well as from 3-3 and 1-3. This was justified by (a) the fact that units 3 and 1 were rarely opened for longer time in the beginning of the mission, and (b) it could be observed that the short-wavelength Zirconium channel 4 was less influenced by degradation. Degradation was observed to be depending on wavelength – also taking into account the experience of other space-born instruments – and being strongest between, say, 20 and 500 nm. Channel 4, on the other hand, is influenced by wavelengths within the 6-20nm range, and from below 2nm.

Now, due to several day-long flare-hunting campaigns, and due to an additional period without observations in which the cover was accidentally left open, even the shortest-wavelength channel of unit 3 has started to degrade. While the trends have not been fitted mathematically yet, the manually selected numbers appear consistent (see table below). Thus, channel 3-4 cannot be assumed to be non-degrading any longer, instead channel 1-4 is now used as a "standard"; it is assumed by comparison with the first 90 hours of channels 2-4 and 3-4 that it has not significantly degraded yet and can safely be used to remove the solar variability.

In Fig.1 to Fig.3, channel 3 is shown with solar variability removed based on channel 4. Channel 4, on the other hand, is shown with the original variability – otherwise it would simply be a flat line on the level of the First Light day. - In the following figures, both channels are shown *with* solar variability (small asterisks) and *without* solar variability (squares). Fig.7 is an exception as it only shows both channels without solar variability, but with the previous fit based on these.

Channels 2-1 and 2-2 are almost lost, but they can still be used to observe the Earth atmospheric profile during the occultation phase (Oct-Feb), or the solar disk inhomogeneity during eclipses. Otherwise channel 2-1 rests now at a level around 1 to 2 counts/ms, and channel 2-2 rests around 2 to 3 counts/ms. These levels can best be determined by the absolute difference as seen before and after an occultation. The dark current of channel 2-1, meanwhile, can be much larger than the solar signal (e.g., by a factor of 10), so a small over-estimation of the dark current may lead to senseless results; in addition, both these channels have shown erratic jumps for more than a year now. The remaining levels of channels 2-1 and 2-2 (below 0.5% compared to First Light levels) may be caused by the possibility that the polymerized "dirt" films on the filters are still letting a small portion of radiation from the nominal spectral intervals pass - or by possible influences from outside the nominal intervals which may have been small originally, but are in the end less affected by degradation, e.g. above 500nm or – less probably – below 20nm.

The figures concerning the degradation in the first 964 hours show that the Herzberg channels 2-2 and 3-2 appear to degrade in two phases, with a plateau phase after the first steep decrease. Whether this can be explained by polymerization of different molecules is still a matter of speculation.

The relatively high remaining level of channel 3-1 can be explained by its response function: a big part of the spectral input originates from relatively long wavelengths (visible, infrared) that are not inhibited by the usual degradation around the Lyman-alpha line and the Herzberg continuum, where the input for channels 1-1 and 2-1 originates (ch3-1 uses a silicon detector, the others are MSM).

Although the behaviour of channels 1-1 and 1-3 cannot easily be determined in short campaigns, due to their long stabilization phase (due to MSM detectors), it appears that channel 1-1 declines twice; it seems to recover to original strength (which is actually above the possible count rate, limited by VFC technology, so 1300 counts/ms is a just guess) after the end of January 2010 which coincides with a bake-out. Channel 1-1 seems to be the only channel to display such a behaviour (best seen in Fig. 4).

Fig. 7 shows the previous estimate which was calculated a year ago - i.e. based on data up to day 701 (07 Dec 2011) - together with the actual data realized meanwhile. While the estimate is reasonably good, it may have been slightly too pessimistic, since the decline may have gone slower. This is balanced by the fact that the estimate was based on unit 3 and not on unit 1, so the future estimate might again be quite close to the last one.

LYRA Performance

ch1-1	53% (1300 → 690)		
ch1-2	77% (613.4 → 470)		
ch1-3	100% (17.2 → 17 based on ch1-4)		
ch1-4	100% (30.3 → 30.3 based on ch1-4)		

... after 90 hours of exposure

ch2-1	<0.5% (492 → 1.5)		
ch2-2	<0.5% (703.5 → 2.5)		
ch2-3	13% (16.6 → 2.2 based on ch2-4)	9% (16.6 → 1.5 on ch3-4)	7% (16.6 → 1.2 on ch1-4)
ch2-4	100% (37.5 → 37.5 based on ch2-4)	67% (37.5 → 25 on ch3-4)	56% (37.5 → 21 on ch1-4)

... after 1053 days of exposure

ch3-1	67% (920 → 620)	
ch3-2	31% (545.5 → 170)	
ch3-3	44% (273.6 → 120 based on 3-4)	38% (273.6 → 104 on ch1-4)
ch3-4	100% (30.0 → 30 based on 3-4)	83% (30.0 → 25 on ch1-4)

... after 964 hours of exposure

All values are in counts/ms. Short-wavelength channels are corrected for solar variability according to channels 2-4, 3-4, or 1-4, respectively. Percentages are given as "remaining signal" [please note that on other occasions, percentages were given as "loss"]. With the notation used here, percentages are multiplicative, and consistency can be checked easily. For example, unit 2 has retained 67% relative to unit 3, but now it was found that unit 3 was not constant but has in turn retained only 83% relative to unit 1 (which can still be considered non-degrading in both its short-wavelength channels). Thus, unit 2 has retained 67%*83%~56% relative to unit 1. Likewise, 44%*83%~38%, 67%*13%~9%, 83%*9%~7%.

Figure Captions

Figure 1: Performance of unit 1 vs its 90 hours of exposure
Figure 2: Performance of unit 2 vs its first 964 hours of exposure
Figure 3: Performance of unit 3 vs its 964 hours of exposure
Figure 4: Performance of unit 1, selected daily values vs mission time, ch1-3 and ch1-4 corrected by ch1-4
Figure 5: Performance of unit 2, selected daily values vs mission time, ch2-3 and ch2-4 corrected by ch2-4
Figure 6: Performance of unit 3, selected daily values vs mission time, ch3-3 and ch3-4 corrected by ch3-4
Figure 7: Performance of unit 2, selected daily values vs mission time, ch2-3 and ch2-4 corrected by ch3-4, incl. fit
Figure 8: Performance of unit 3, selected daily values vs mission time, ch3-3 and ch3-4 corrected by ch1-4
Figure 9: Performance of unit 2, selected daily values vs mission time, ch2-3 and ch2-4 corrected by ch1-4
(All values have the dark currents removed, and are corrected to 1AU. Some are corrected for solar variability. None were corrected for degradation or transformed into physical units, thus they are all still called "Uncalibrated Signal").

Figure 1

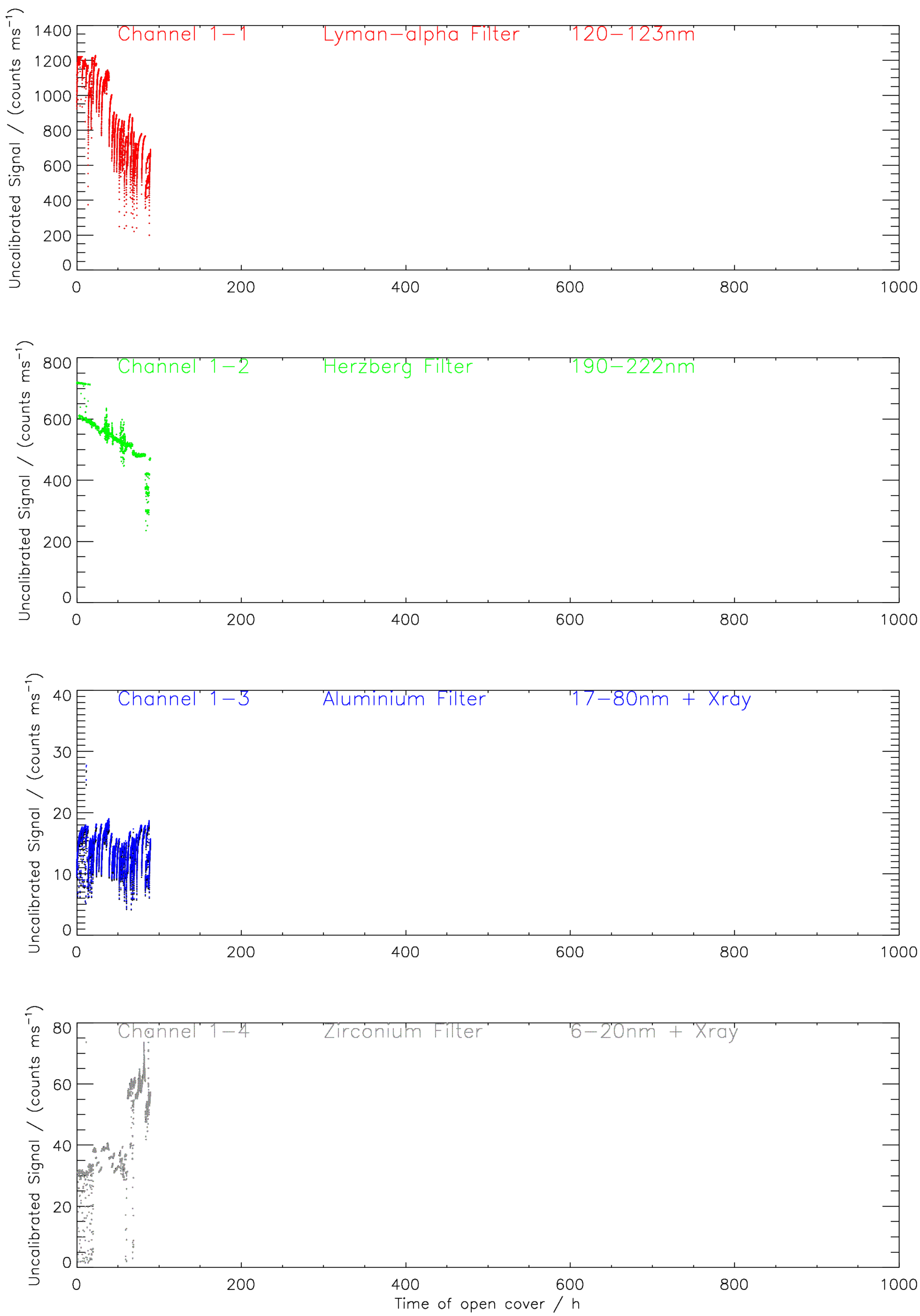
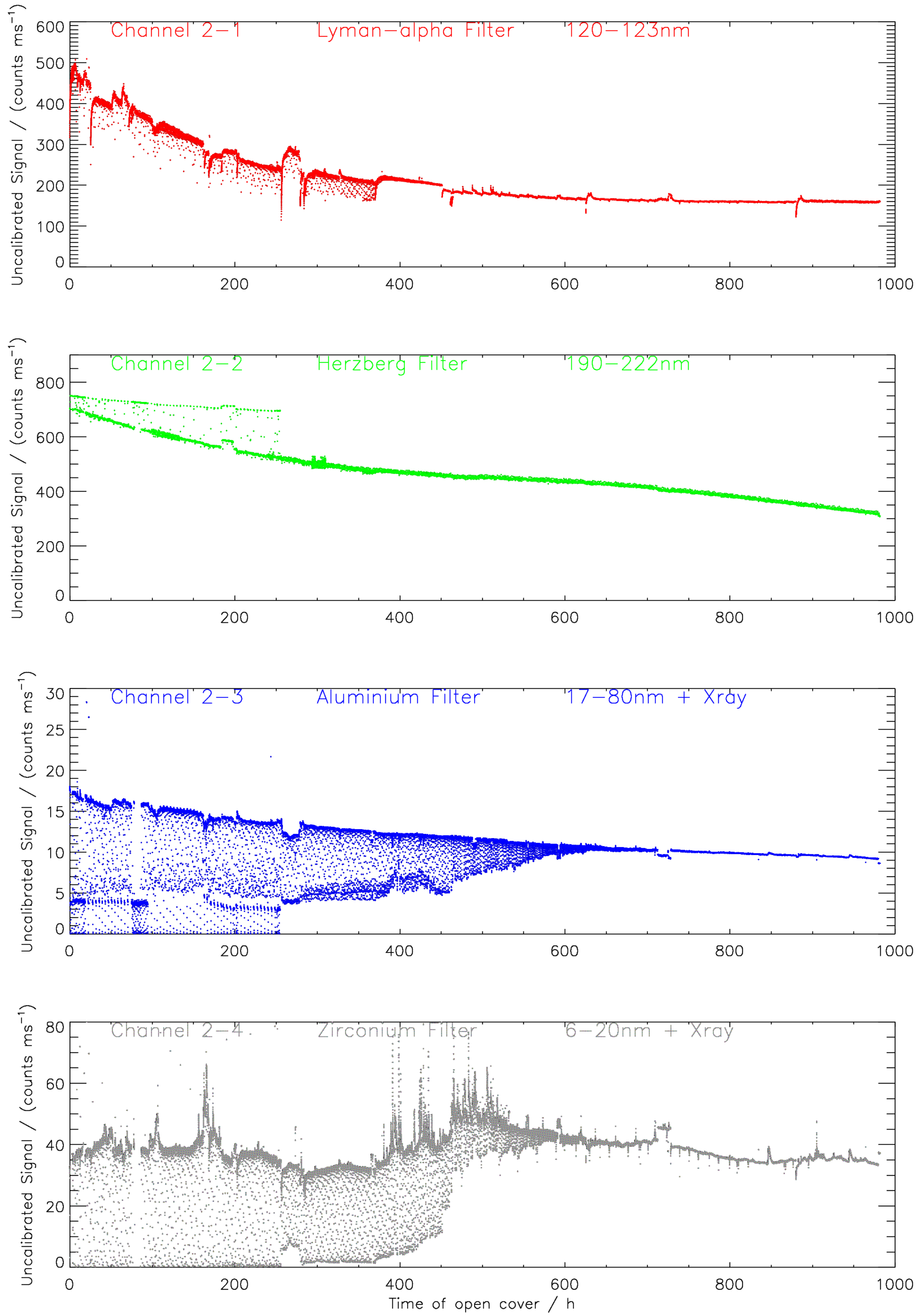

Channel 1–1
Lyman–alpha Filter
120–123nm
Uncalibrated Signal / (counts ms^{-1})
Channel 1–2
Herzberg Filter
190–222nm
Uncalibrated Signal / (counts ms^{-1})
Channel 1–3
Aluminium Filter
17–80nm + Xray
Uncalibrated Signal / (counts ms^{-1})
Channel 1–4
Zirconium Filter
6–20nm + Xray
Uncalibrated Signal / (counts ms^{-1})
Time of open cover / h

Figure 2



Channel 2−1
Lyman−alpha Filter
120−123nm
Uncalibrated Signal / (counts ms^{-1})
0
100
200
300
400
500
600
0
200
400
600
800
1000
Channel 2−2
Herzberg Filter
190−222nm
Uncalibrated Signal / (counts ms^{-1})
0
200
400
600
800
0
200
400
600
800
1000
Channel 2−3
Aluminium Filter
17−80nm + Xray
Uncalibrated Signal / (counts ms^{-1})
0
5
10
15
20
25
30
0
200
400
600
800
1000
Channel 2−4
Zirconium Filter
6−20nm + Xray
Uncalibrated Signal / (counts ms^{-1})
0
20
40
60
80
0
200
400
600
800
1000
Time of open cover / h

Figure 3

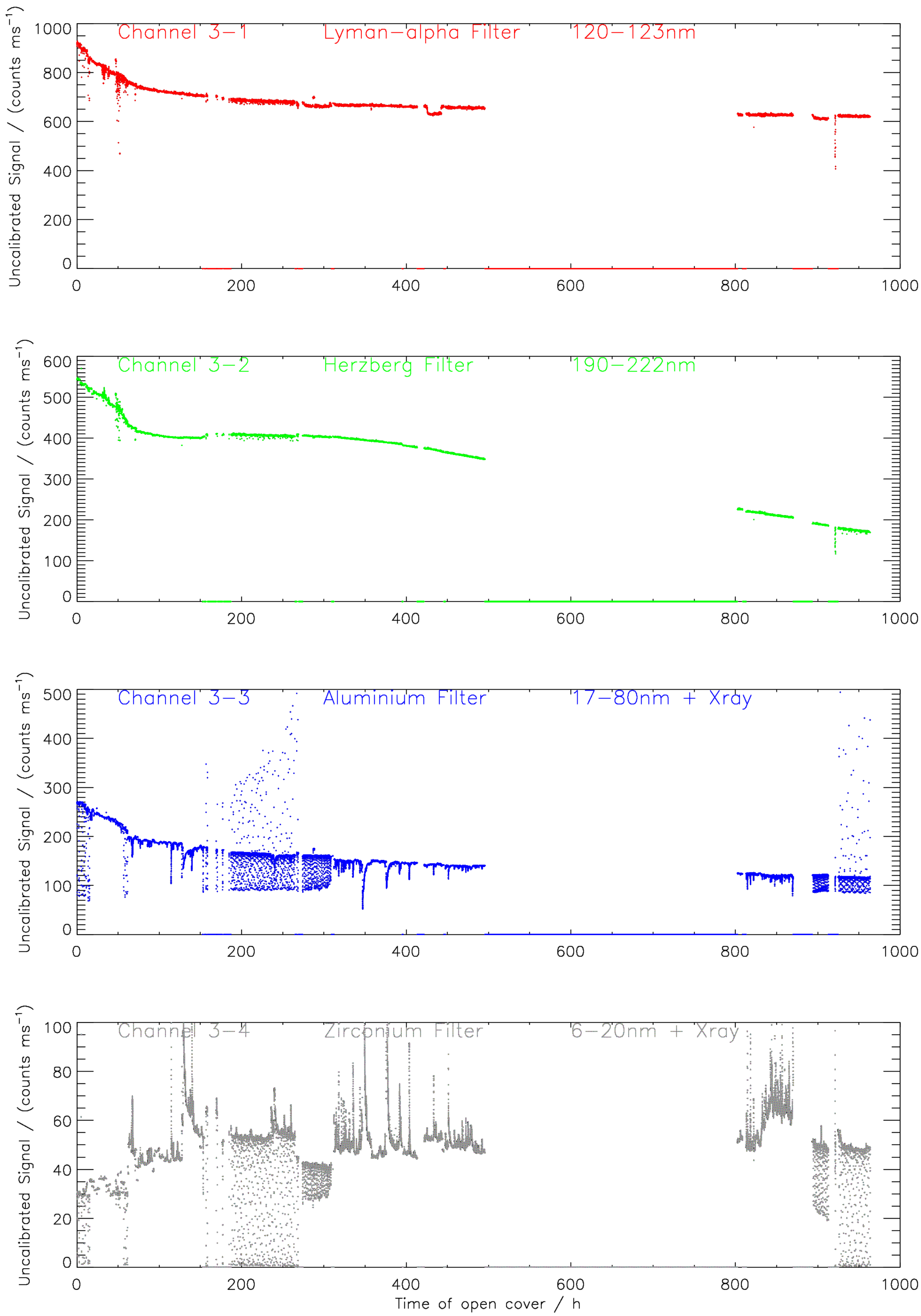
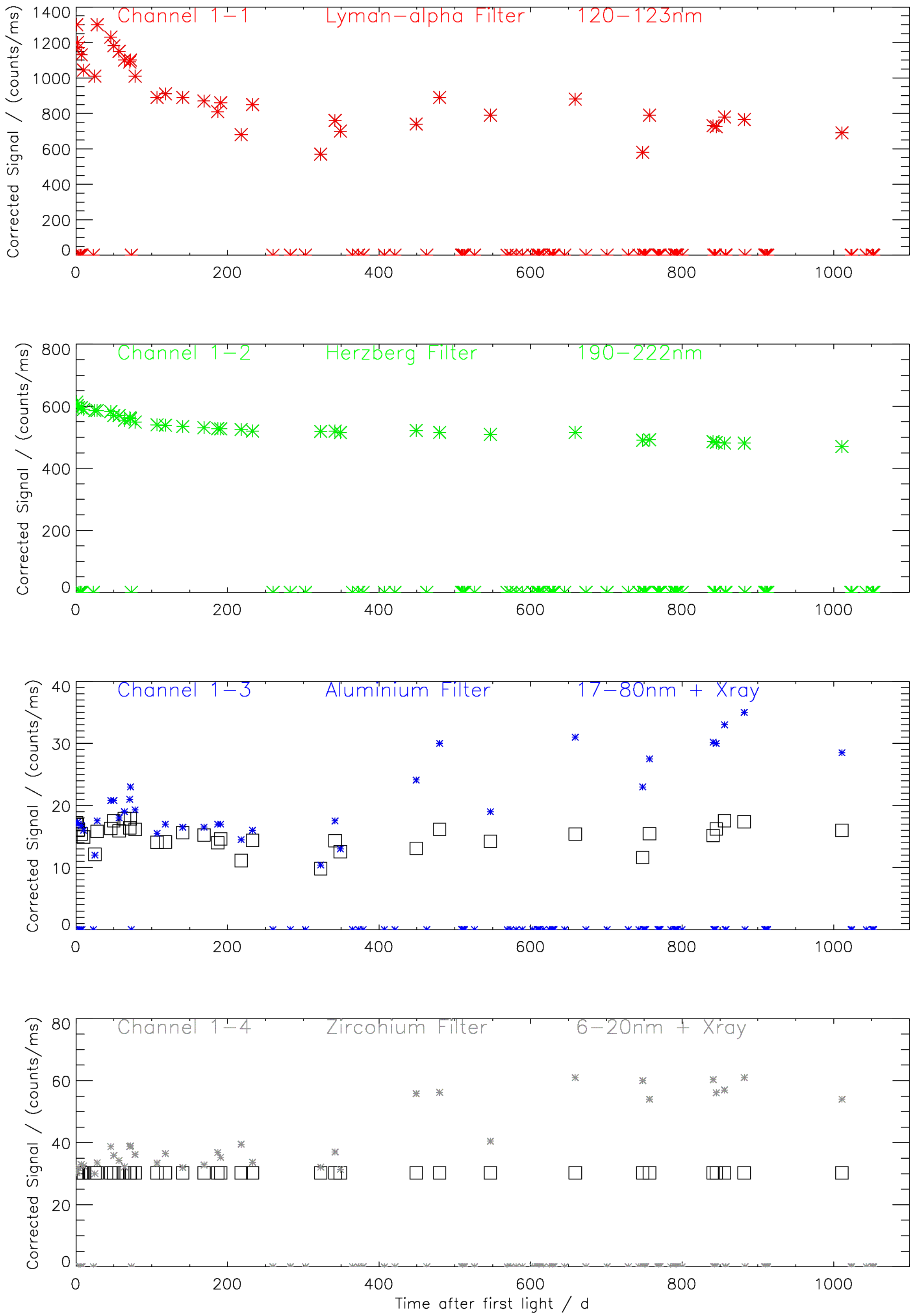
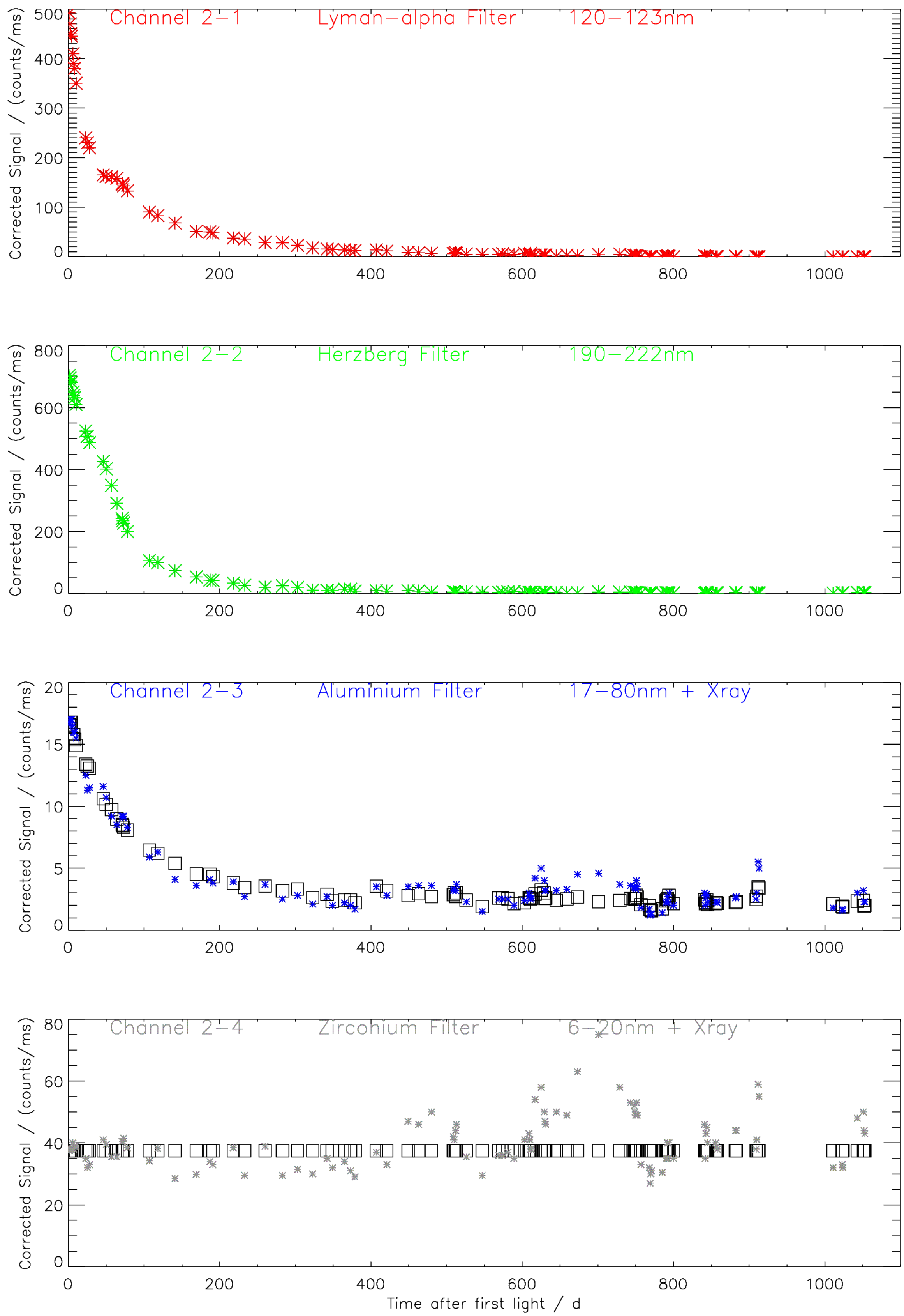

Channel 3−1
Lyman−alpha Filter
120−123nm
Uncalibrated Signal / (counts ms^{-1})
1000
800
600
400
200
0
0
200
400
600
800
1000
Channel 3−2
Herzberg Filter
190−222nm
Uncalibrated Signal / (counts ms^{-1})
600
500
400
300
200
100
0
Channel 3−3
Aluminium Filter
17−80nm + Xray
Uncalibrated Signal / (counts ms^{-1})
500
400
300
200
100
0
Channel 3−4
Zirconium Filter
6−20nm + Xray
Uncalibrated Signal / (counts ms^{-1})
100
80
60
40
20
0
Time of open cover / h

Figure 4



Channel 1–1
Lyman–alpha Filter
120–123nm
Channel 1–2
Herzberg Filter
190–222nm
Channel 1–3
Aluminium Filter
17–80nm + Xray
Channel 1–4
Zirconium Filter
6–20nm + Xray
Corrected Signal / (counts/ms)
Time after first light / d

Figure 5



Channel 2-1 Lyman-alpha Filter 120-123nm
Channel 2-2 Herzberg Filter 190-222nm
Channel 2-3 Aluminium Filter 17-80nm + Xray
Channel 2-4 Zirconium Filter 6-20nm + Xray
Corrected Signal / (counts/ms)
Time after first light / d

Figure 6

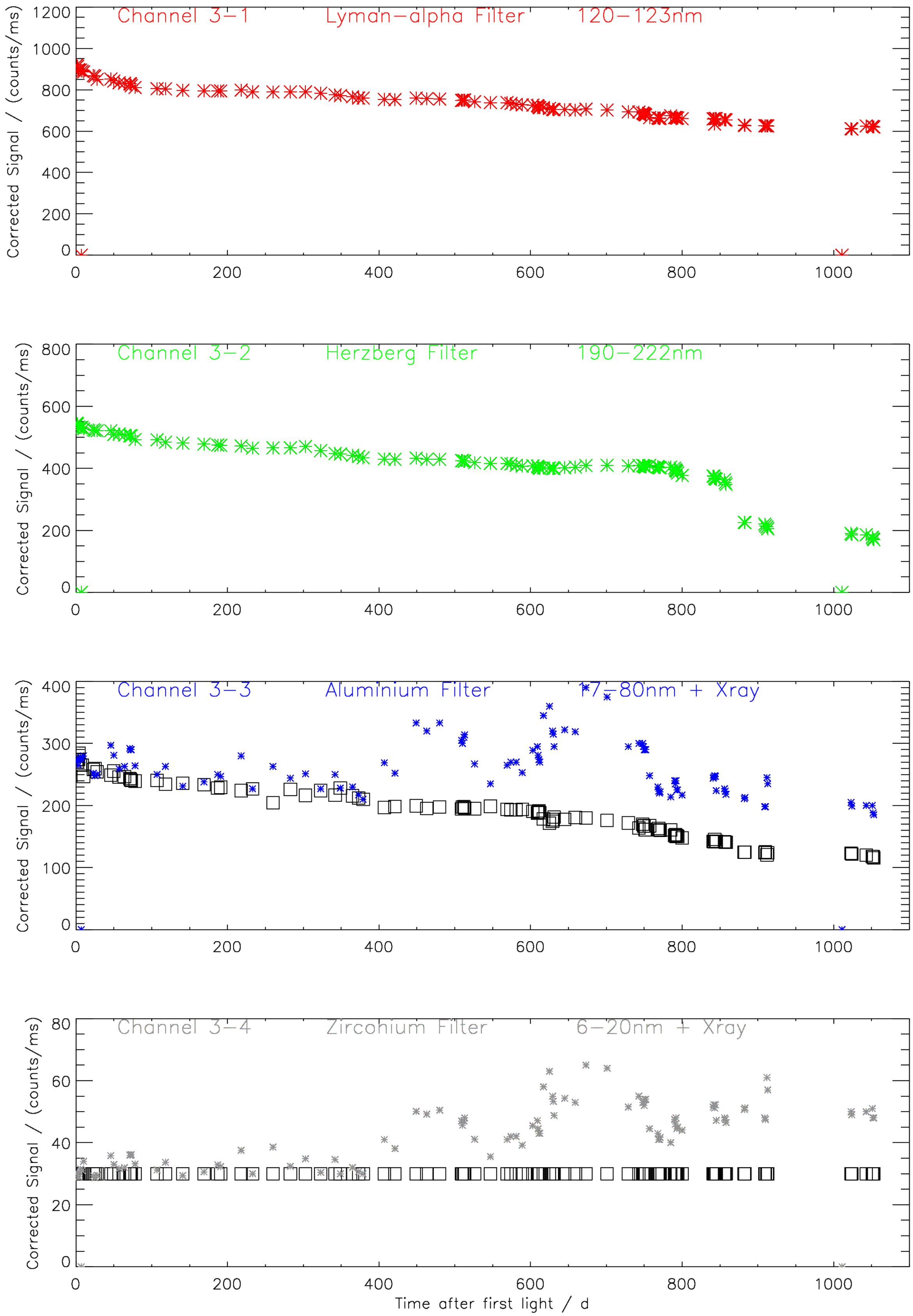
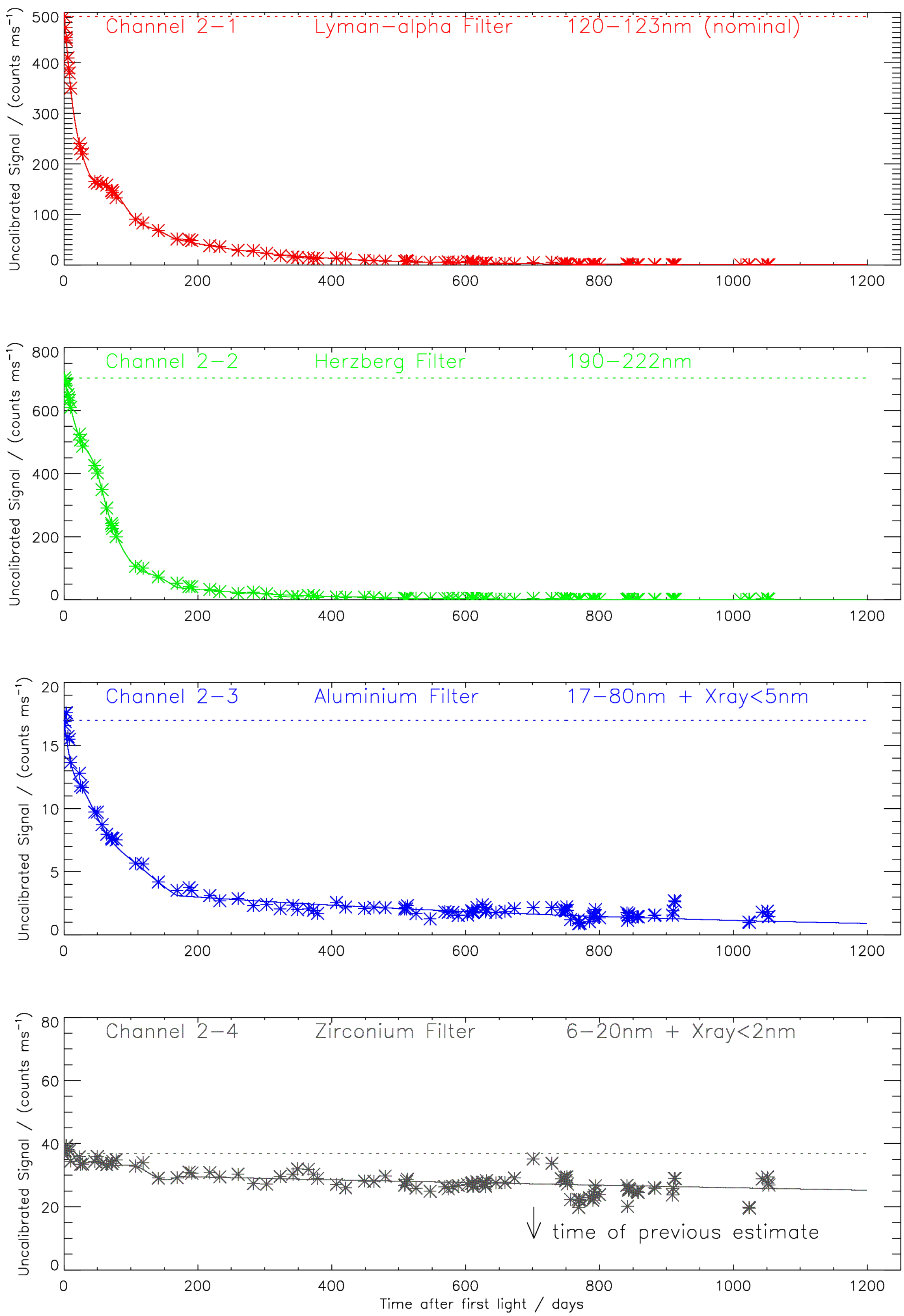
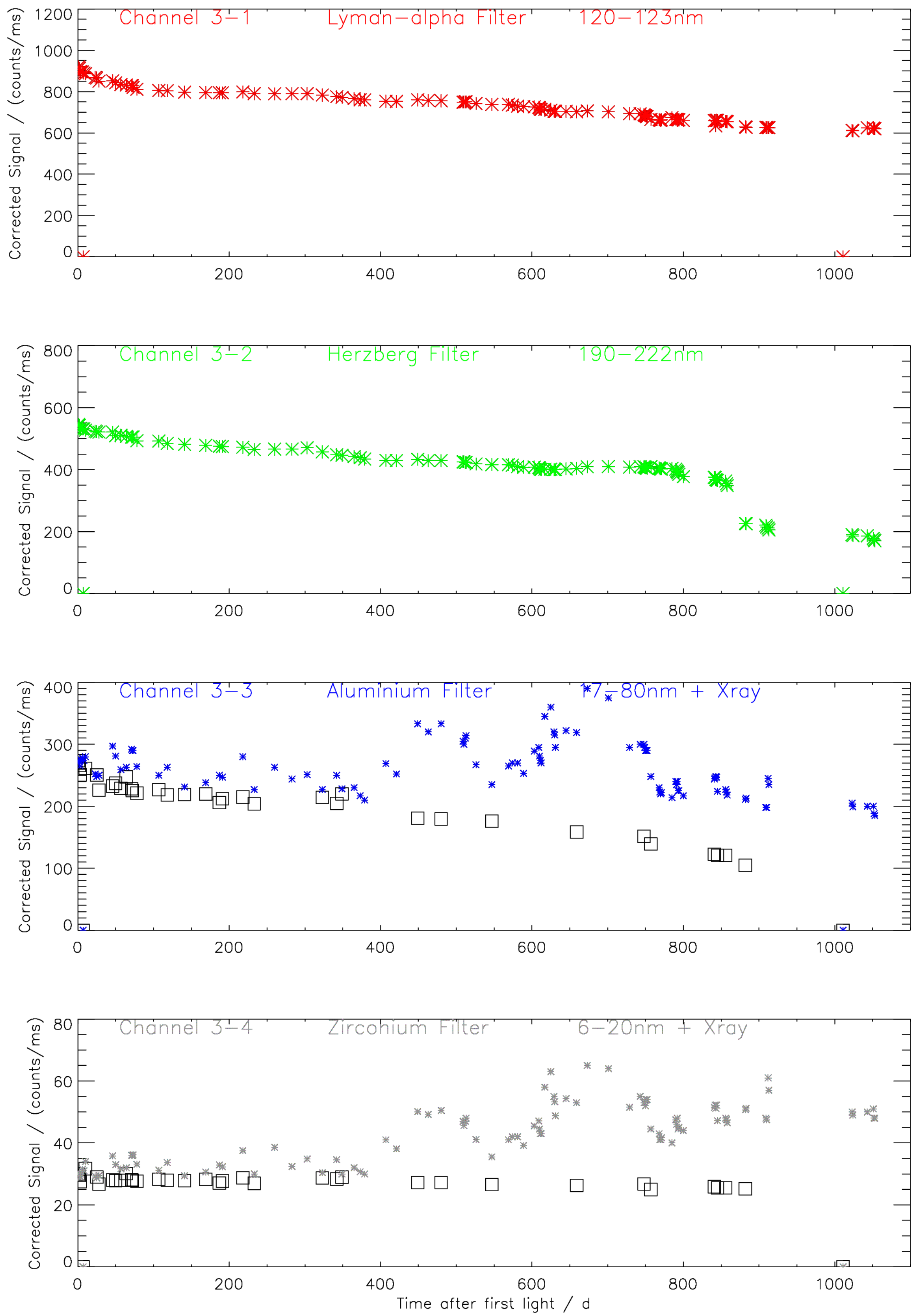

Channel 3−1
Lyman−alpha Filter
120−123nm
Corrected Signal / (counts/ms)
Channel 3−2
Herzberg Filter
190−222nm
Corrected Signal / (counts/ms)
Channel 3−3
Aluminium Filter
17−80nm + Xray
Corrected Signal / (counts/ms)
Channel 3−4
Zirconium Filter
6−20nm + Xray
Corrected Signal / (counts/ms)
Time after first light / d

Figure 7



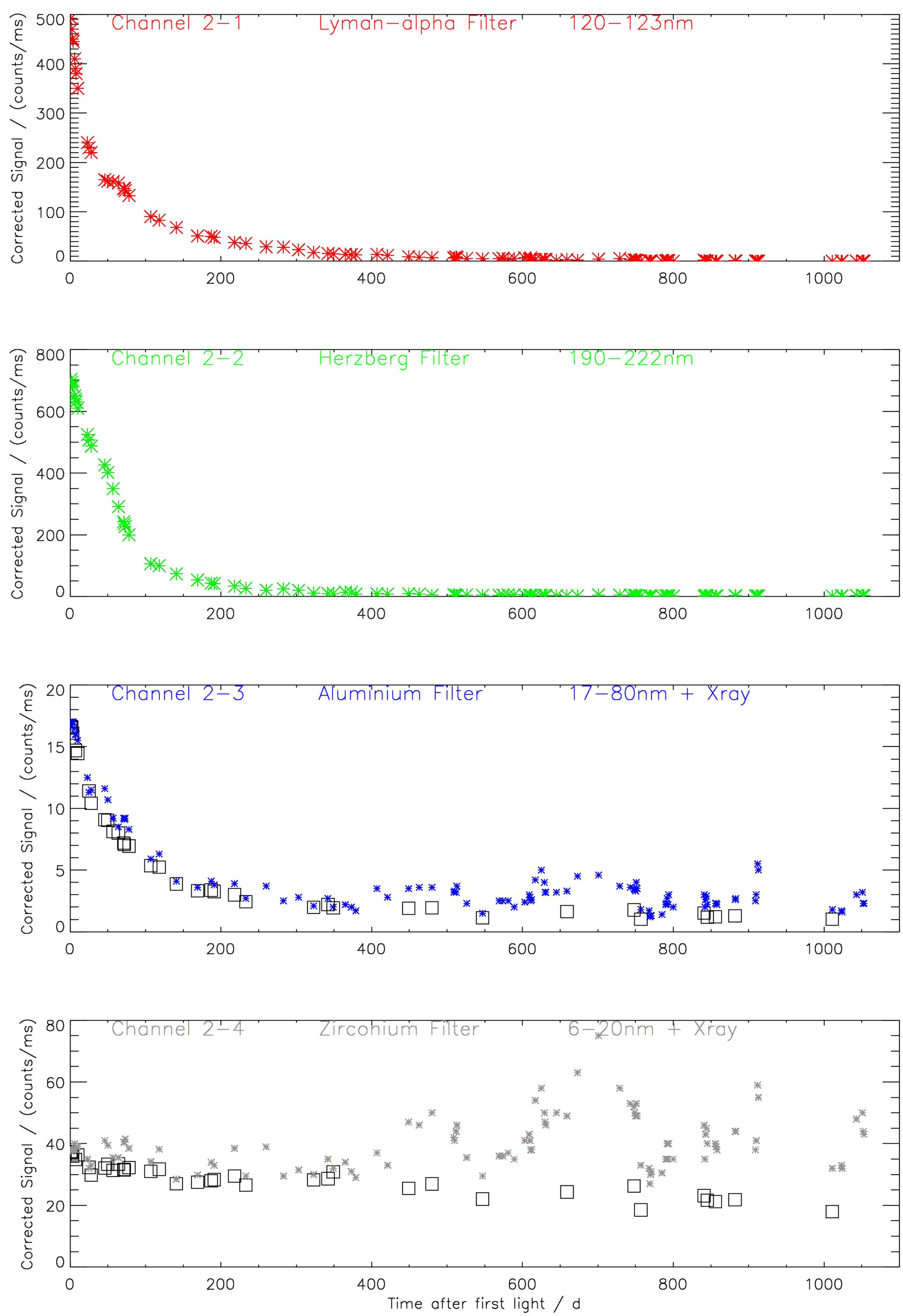
Channel 2−1 Lyman−alpha Filter 120−123nm (nominal)
Channel 2−2 Herzberg Filter 190−222nm
Channel 2−3 Aluminium Filter 17−80nm + Xray<5nm
Channel 2−4 Zirconium Filter 6−20nm + Xray<2nm
time of previous estimate
Uncalibrated Signal / (counts ms⁻¹)
Time after first light / days

Figure 8



Channel 3-1
Lyman-alpha Filter
120-123nm
Corrected Signal / (counts/ms)
1200
1000
800
600
400
200
0
0
200
400
600
800
1000
Channel 3-2
Herzberg Filter
190-222nm
Corrected Signal / (counts/ms)
800
600
400
200
0
0
200
400
600
800
1000
Channel 3-3
Aluminium Filter
17-80nm + Xray
Corrected Signal / (counts/ms)
400
300
200
100
0
0
200
400
600
800
1000
Channel 3-4
Zirconium Filter
6-20nm + Xray
Corrected Signal / (counts/ms)
80
60
40
20
0
0
200
400
600
800
1000
Time after first light / d

Figure 9


Channel 2–1
Lyman–alpha Filter
120–123nm
Corrected Signal / (counts/ms)
Channel 2–2
Herzberg Filter
190–222nm
Corrected Signal / (counts/ms)
Channel 2–3
Aluminium Filter
17–80nm + Xray
Corrected Signal / (counts/ms)
Channel 2–4
Zirconium Filter
6–20nm + Xray
Corrected Signal / (counts/ms)
Time after first light / d