Degradation of LYRA on PROBA2 after two years in orbit

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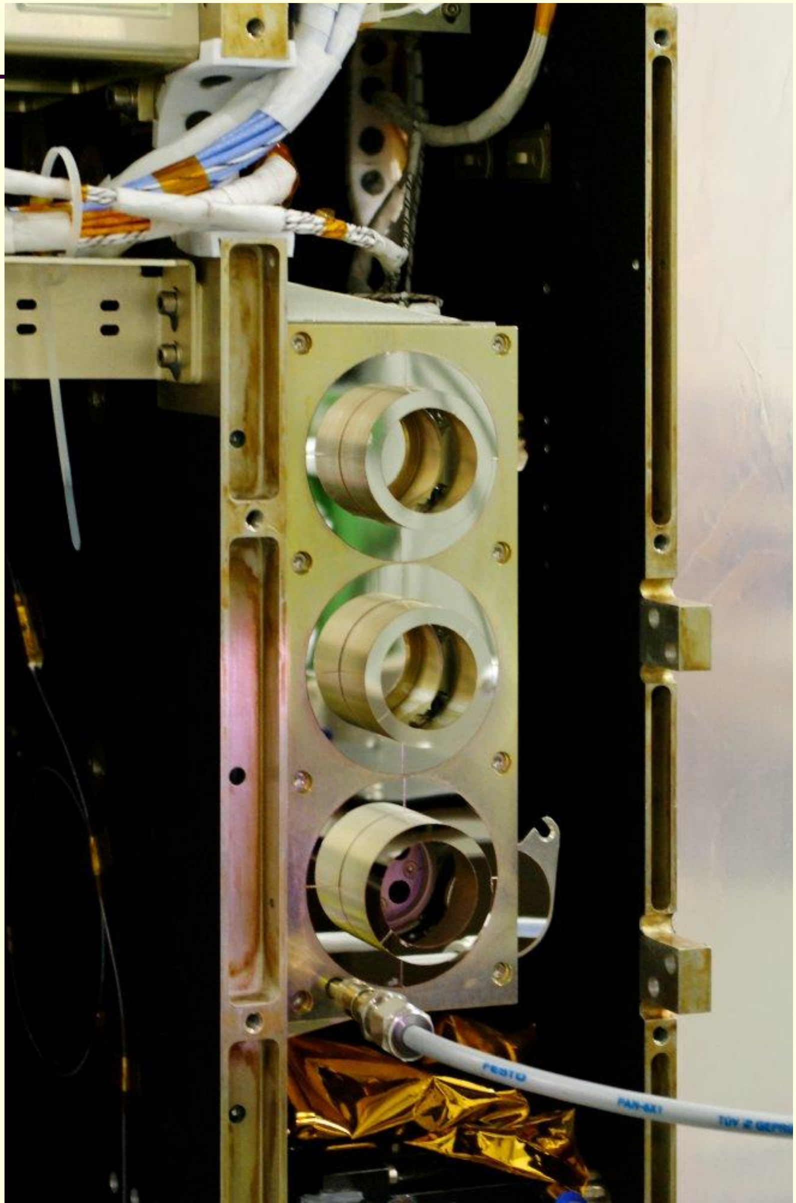
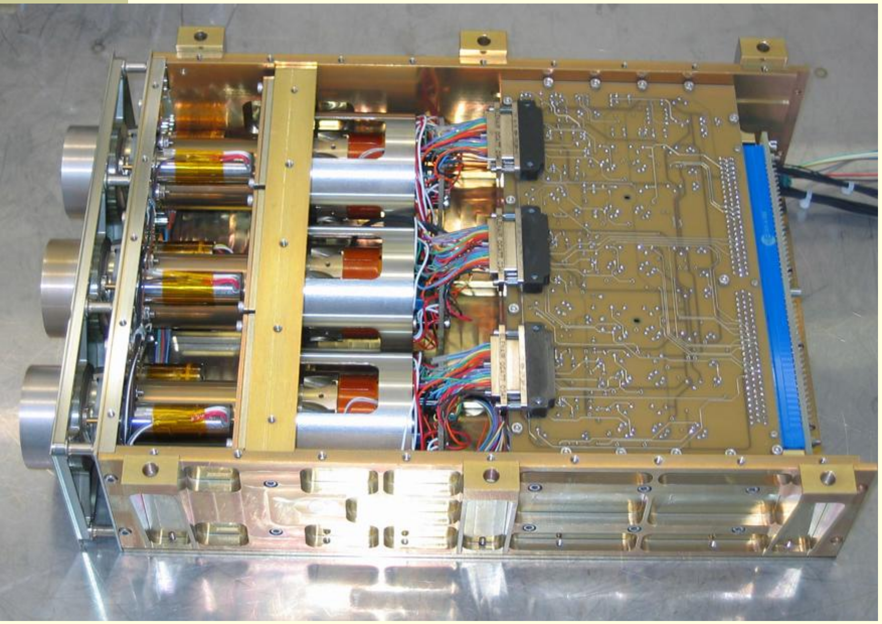
1. Some info on the instrument, spectral response, and data
2. Degradation and possible ways to cope with it in calibration
3. Degradation in detail
4. Spectral degradation

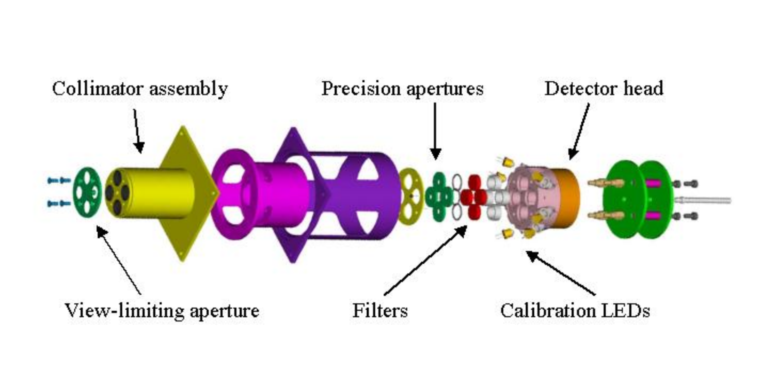
Part 1: LYRA: the Large-Yield RAdiometer

- 3 instrument units (redundancy)
- 4 spectral channels per head
- 3 types of detectors,
  Silicon + 2 types of
  diamond detectors (MSM, PIN):
  - radiation resistant
  - insensitive to visible light
    compared to Si detectors
- High cadence up to 100 Hz



LYRA highlights





- Royal Observatory of Belgium (Brussels, B)
  Principal Investigator, overall design, onboard software specification, science operations
- PMOD/WRC (Davos, CH)
  Lead Co-Investigator, overall design and manufacturing
- Centre Spatial de Liège (B)
  Lead institute, project management, filters
- IMOMEC (Hasselt, B)
  Diamond detectors
- Max-Planck-Institut für Sonnensystemforschung (Lindau, D)
  calibration
- science Co-Is: BISA (Brussels, B), LPC2E (Orléans, F)…

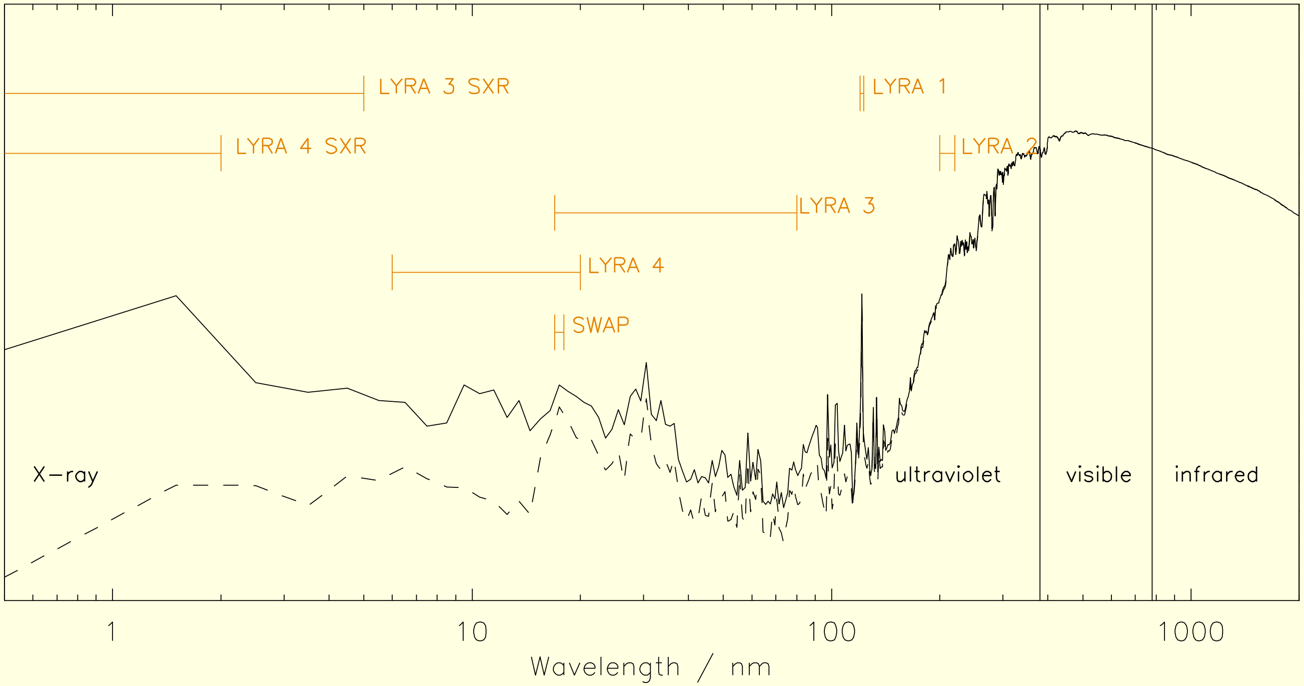
LYRA highlights

- 4 spectral channels covering a wide emission temperature range
- Redundancy (3 units) gathering three types of detectors
  - Rad-hard, solar-blind diamond UV sensors (PIN and MSM)
  - AXUV Si photodiodes

	Ly	Hz	Al	Zr
Unit1	MSM	PIN	MSM	Si
Unit2	MSM	PIN	MSM	MSM
Unit3	Si	PIN	Si	Si

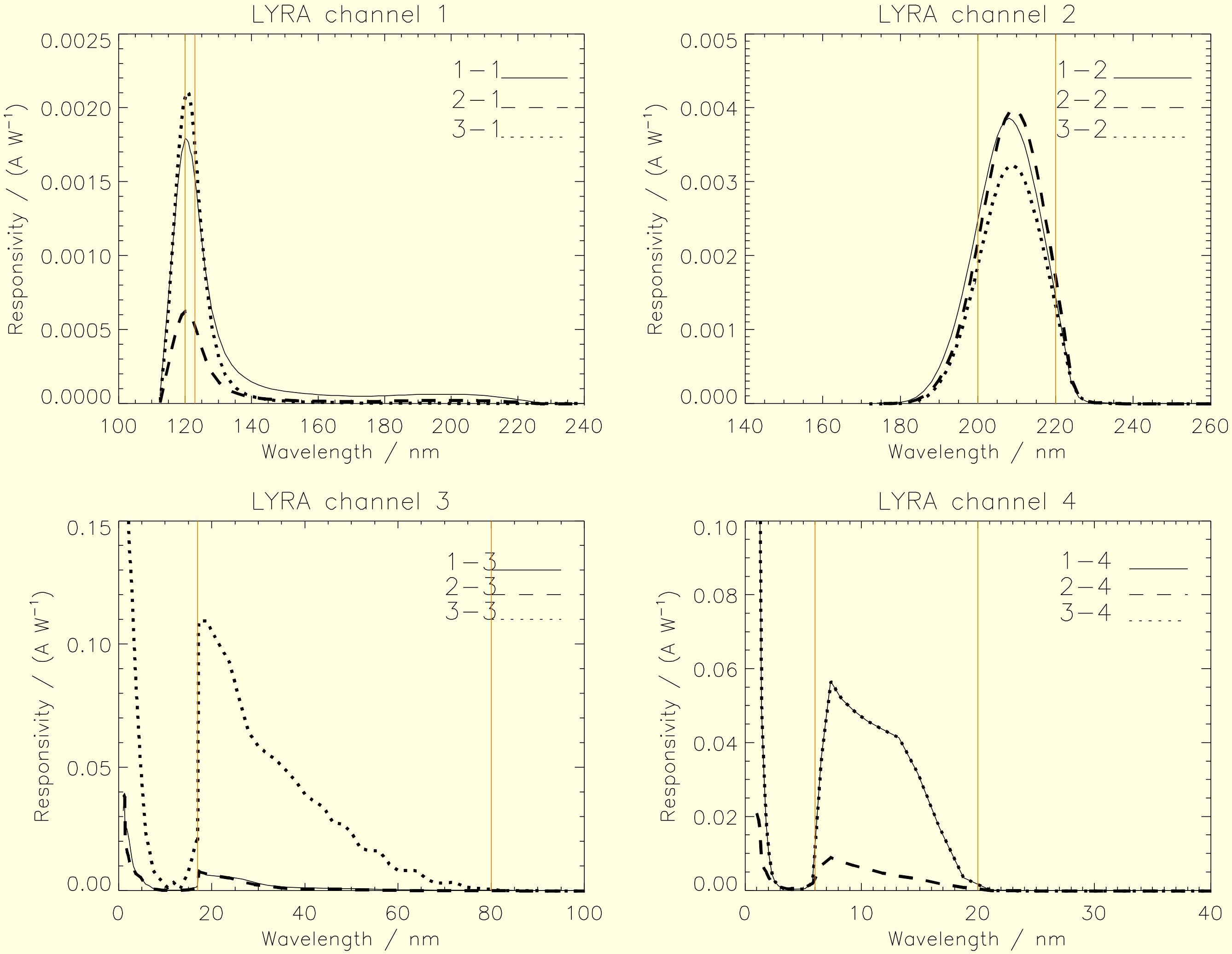
- 2 calibration LEDs per detector (λ = 465 nm and 390 nm)
- High cadence (up to 100Hz)
- Quasi-continuous acquisition during mission lifetime

SWAP and LYRA spectral intervals for solar flares, space weather, and aeronomy

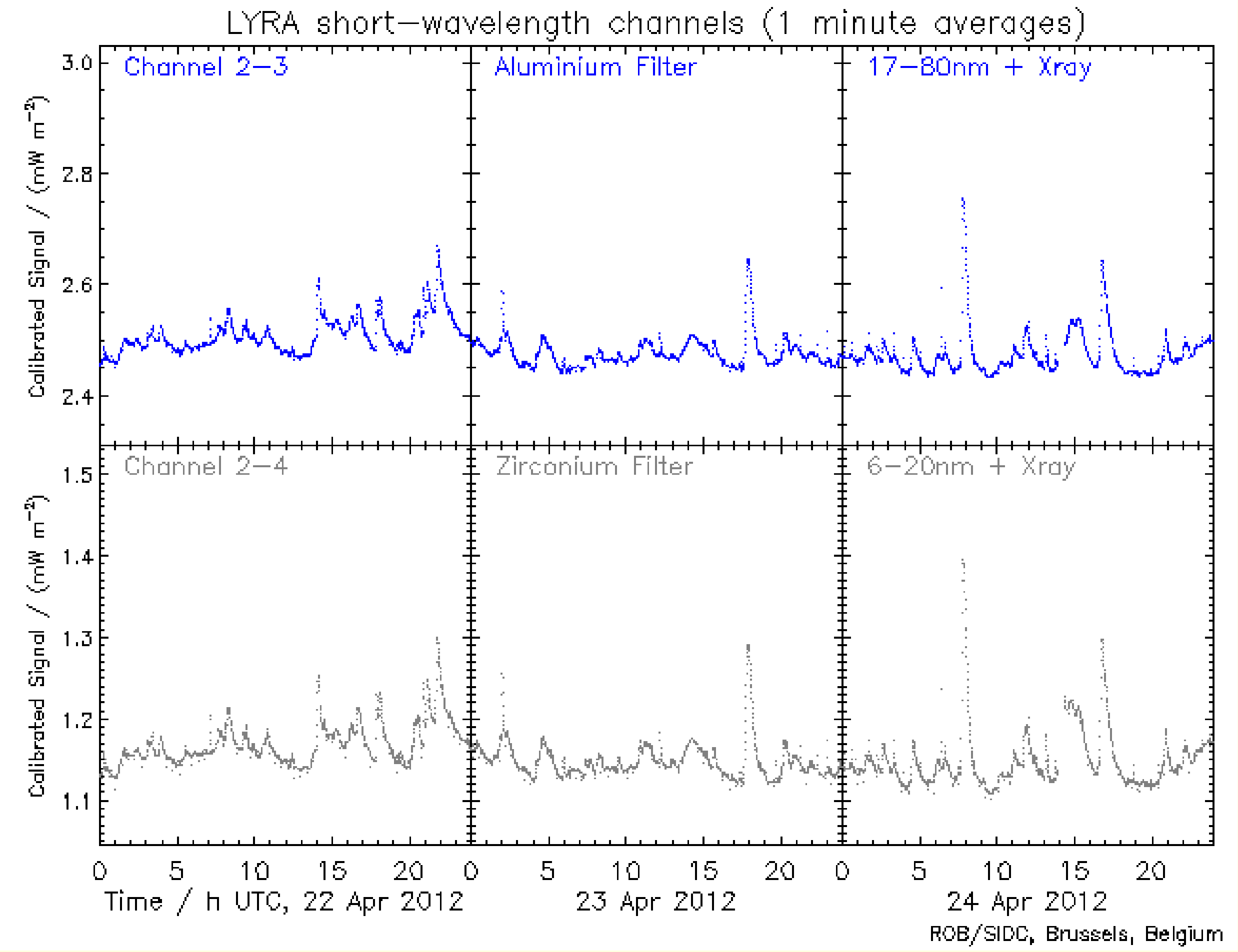


LYRA channel 1: the H I 121.6 nm Lyman-alpha line (120-123 nm)
LYRA channel 2: the 200-220 nm Herzberg continuum range (now 190-222 nm)
LYRA channel 3: the 17-80 nm Aluminium filter range incl the He II 30.4 nm line (+ <5nm X-ray)
LYRA channel 4: the 6-20 nm Zirconium filter range with highest solar variablility (+ <2nm X-ray)
SWAP: the range around 17.4 nm including coronal lines like Fe IX and Fe X

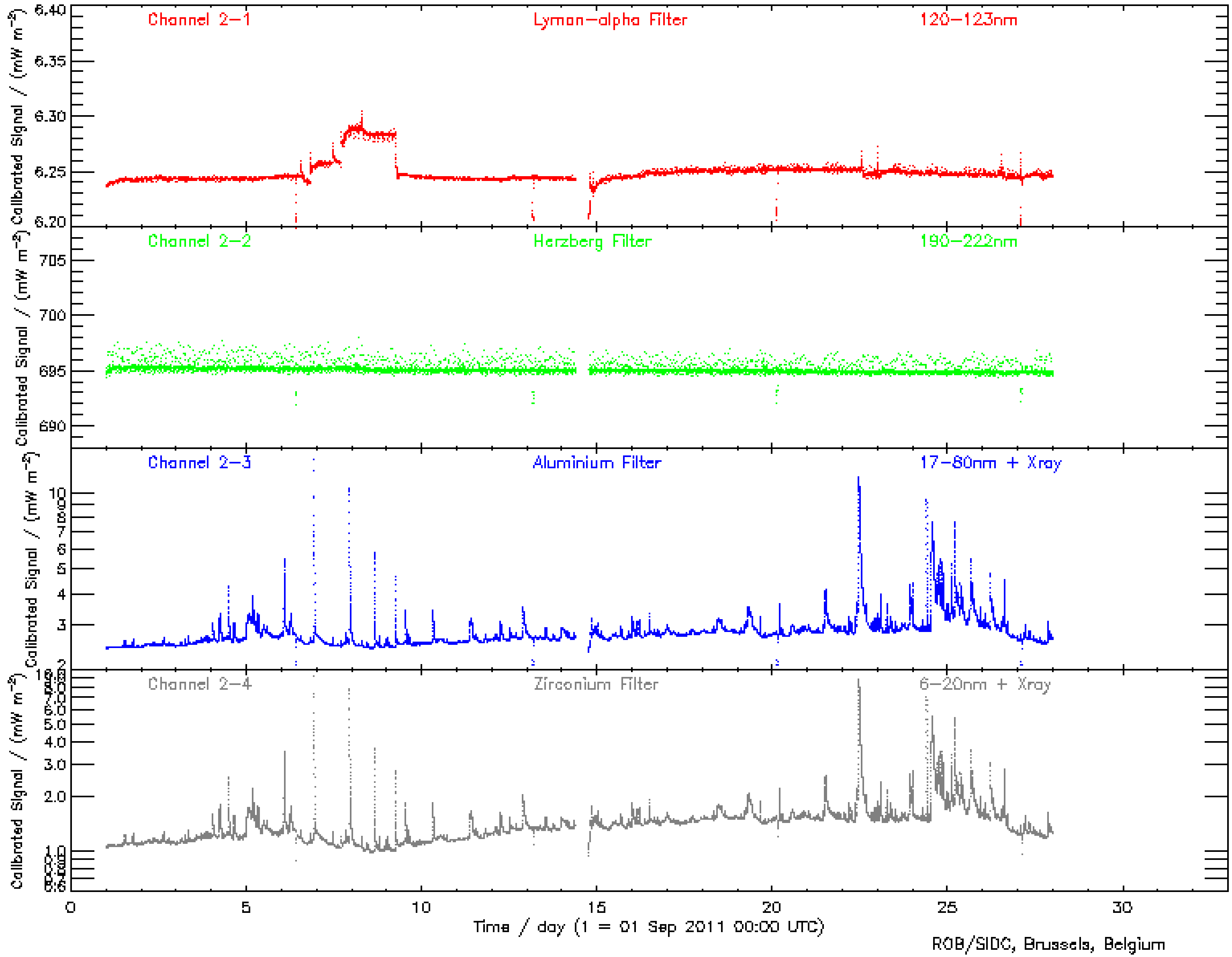
LYRA pre-flight spectral responsivity (filter + detector, twelve combinations)



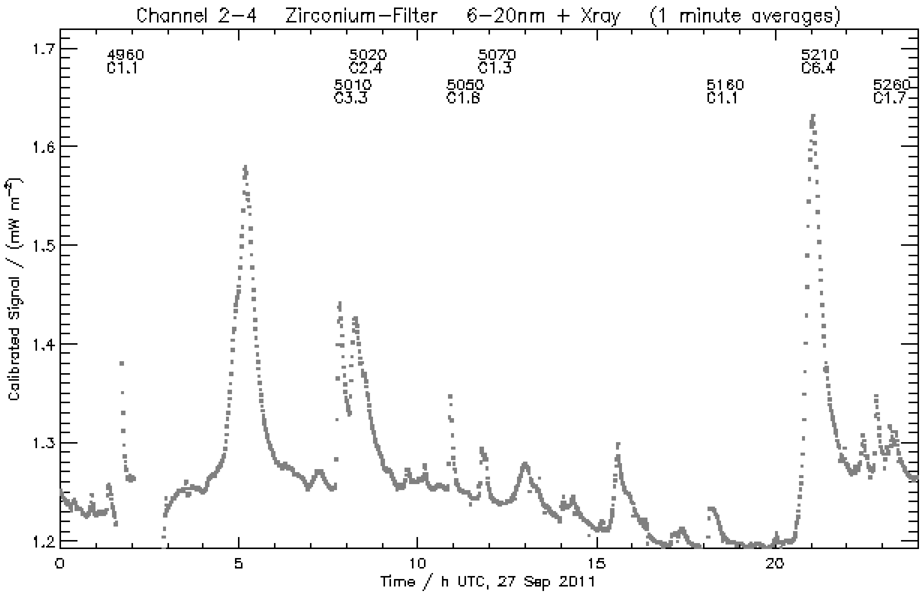
Data (examples): Daily plots



Monthly overviews

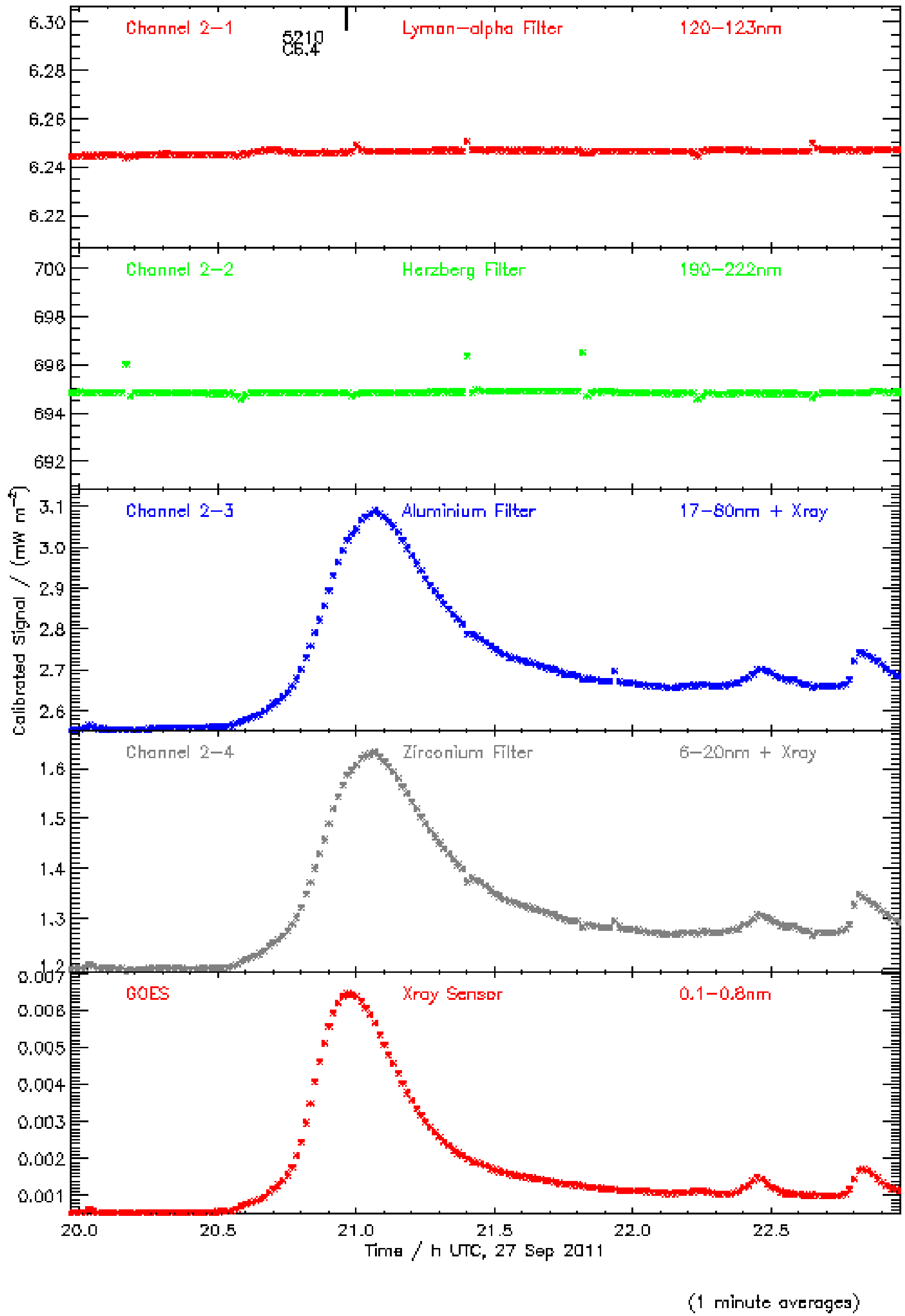


27 Sep 2011 Flare List

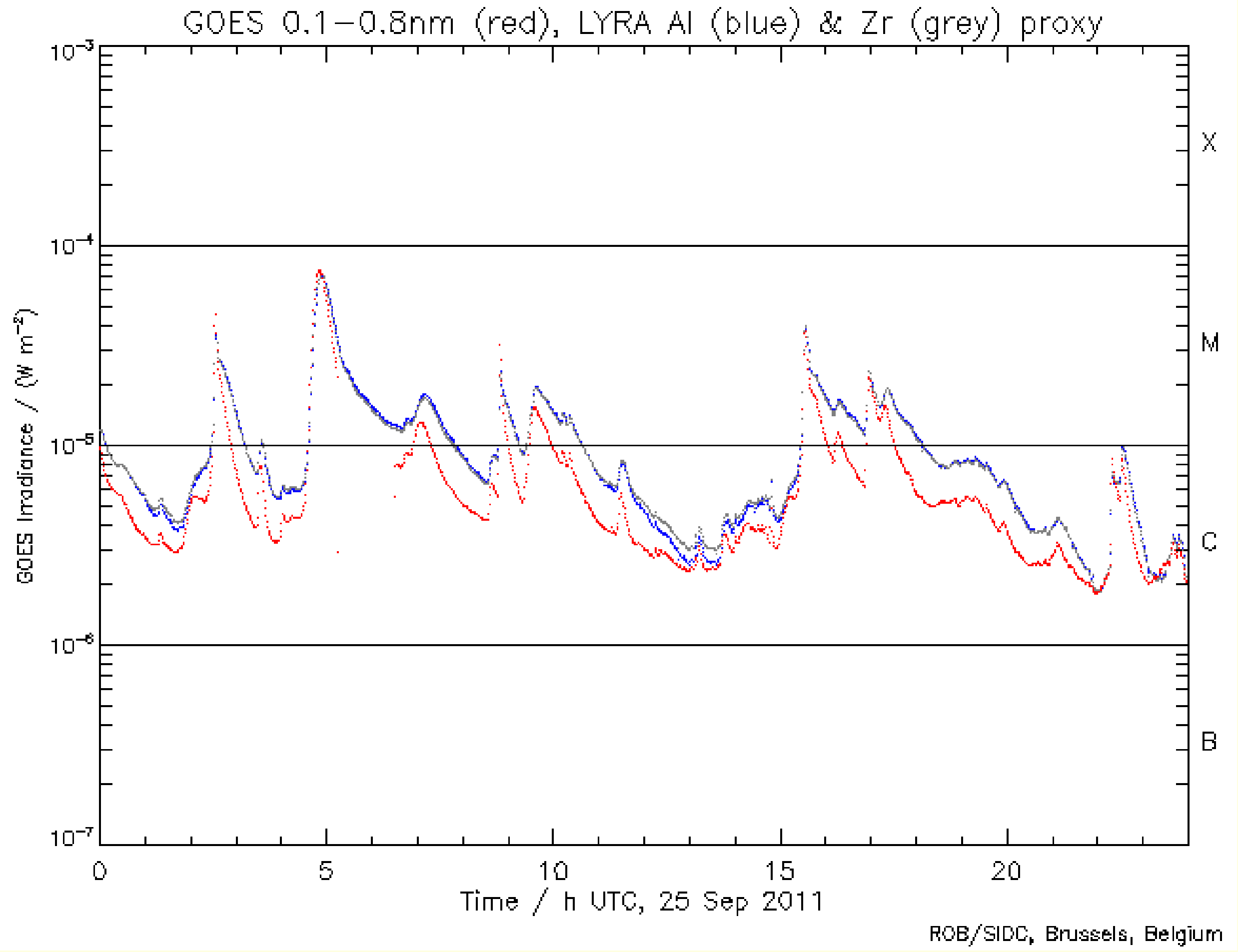


event	begin	max	end	class	region
4960	01:18	01:21	01:24	C1.1	
5010	07:40	07:47	07:54	C3.3	1302
5020	08:05	08:13	08:21	C2.4	1302
5050	10:49	10:54	10:57	C1.8	
5070	11:42	11:47	11:51	C1.3	
5160	18:05	18:10	18:22	C1.1	1302
5210	20:44	20:58	21:11	C6.4	1302
5260	22:45	22:50	22:54	C1.7	

interval
around a flare
(-1h,+2h)



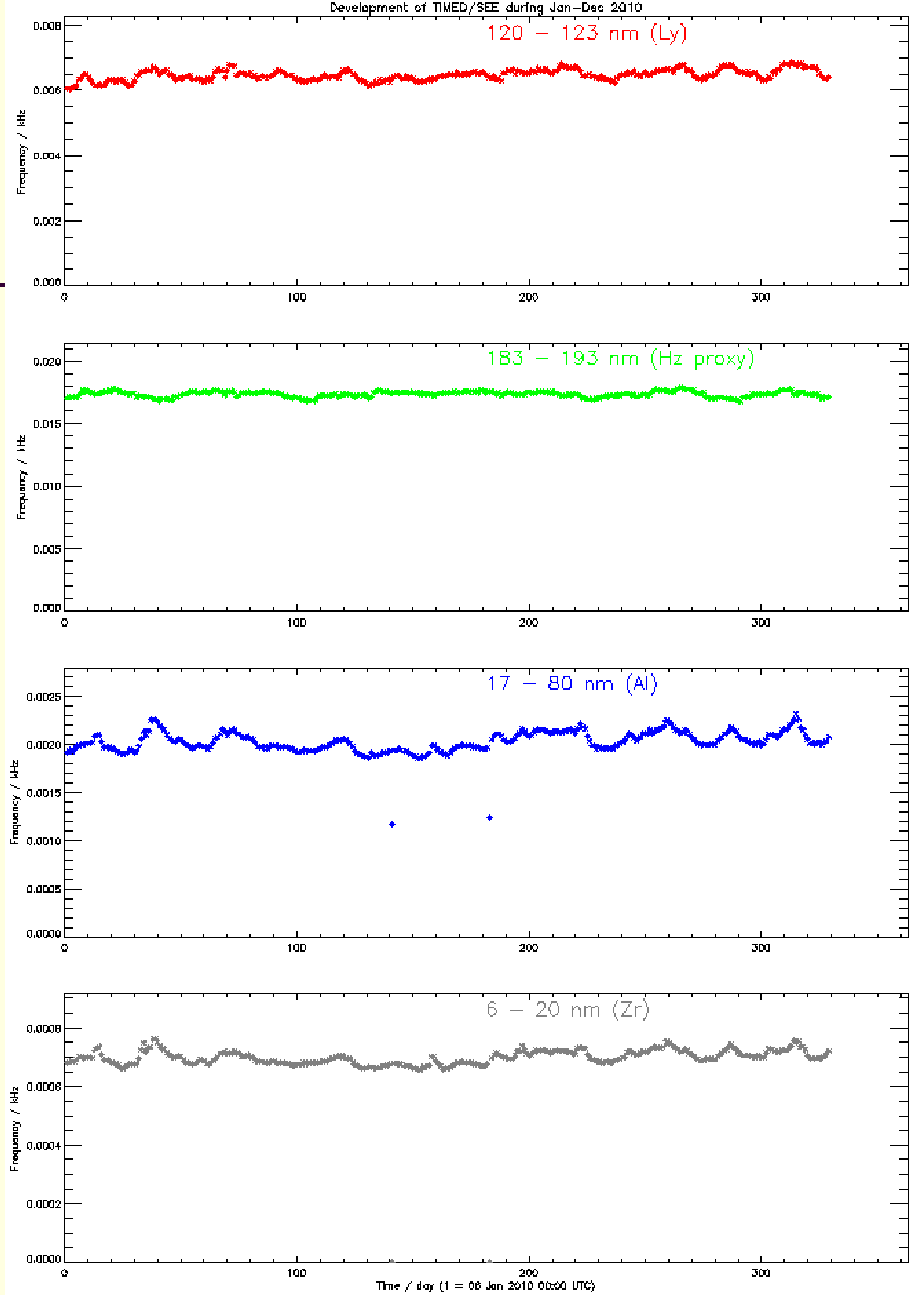
GOES vs. LYRA proxies



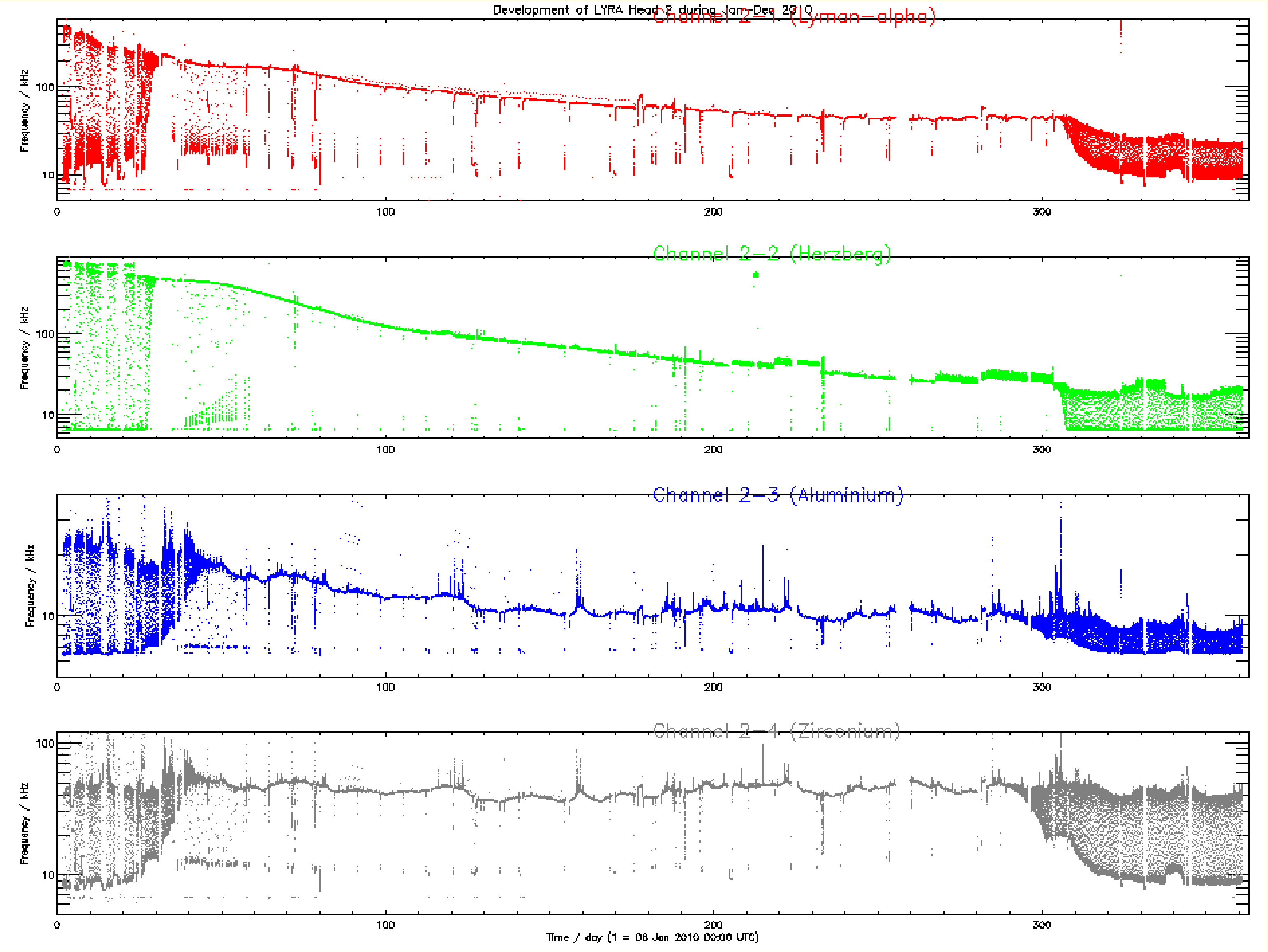
(new website under construction)

Part 2: Calibration

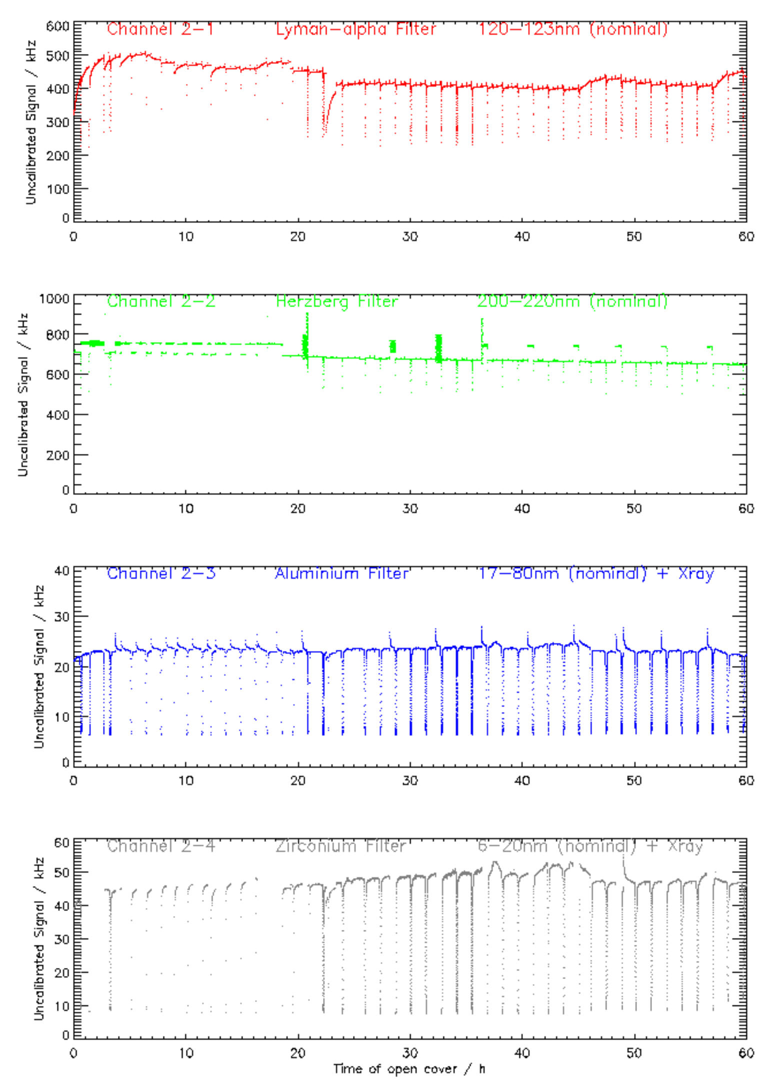
2010 according to TIMED/SEE

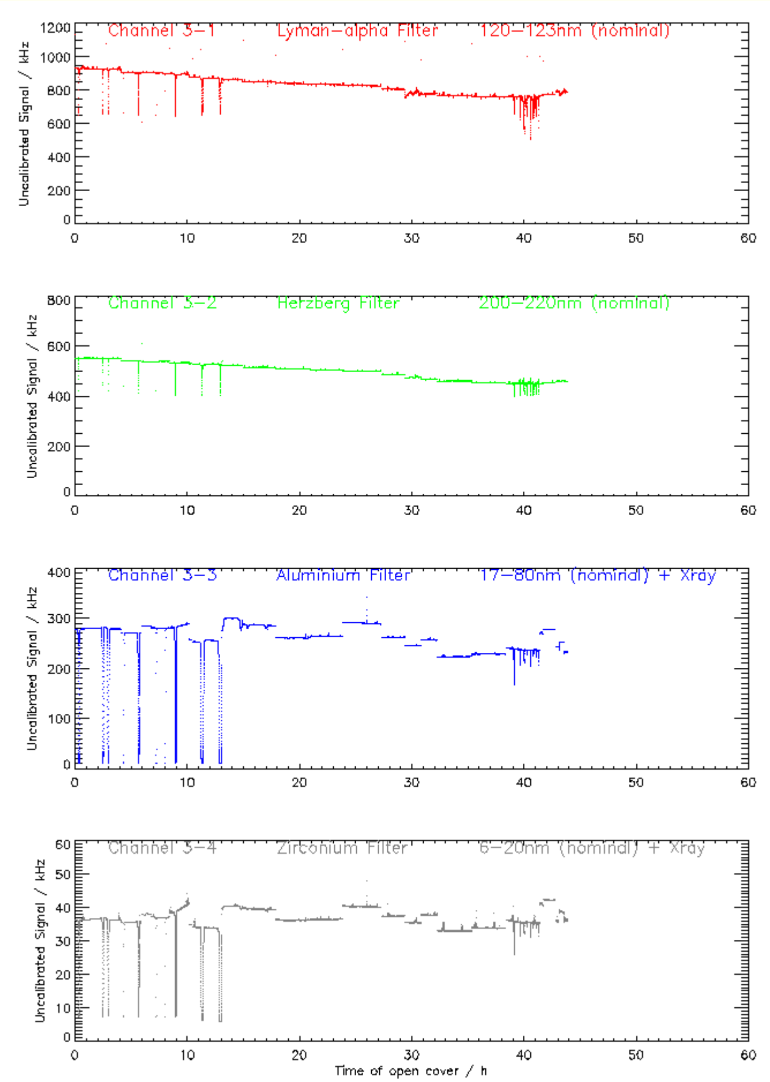


Calibration – Problem: 2010 according to LYRA

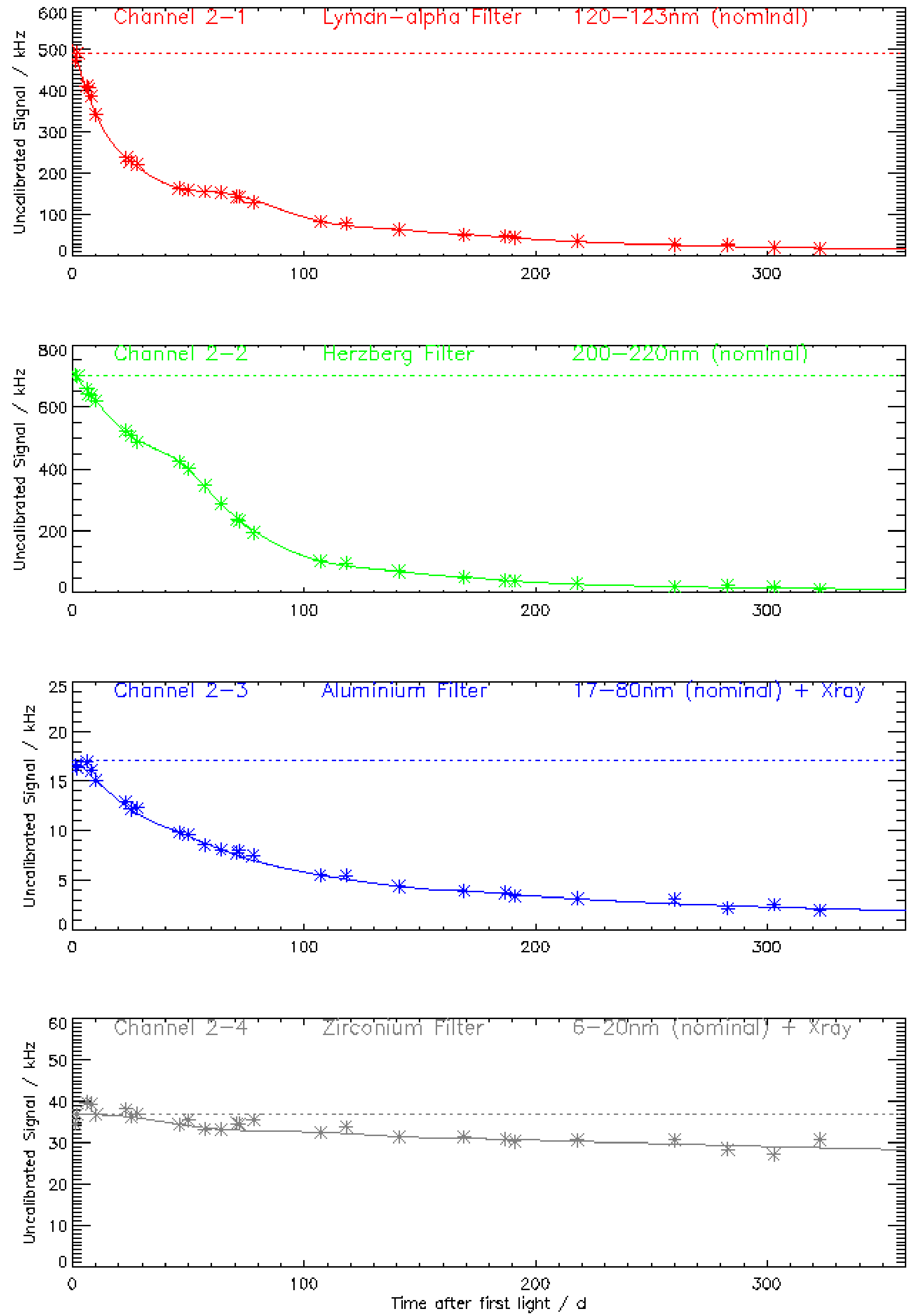


Solution – Start with “First Light”





… fit the degradation …

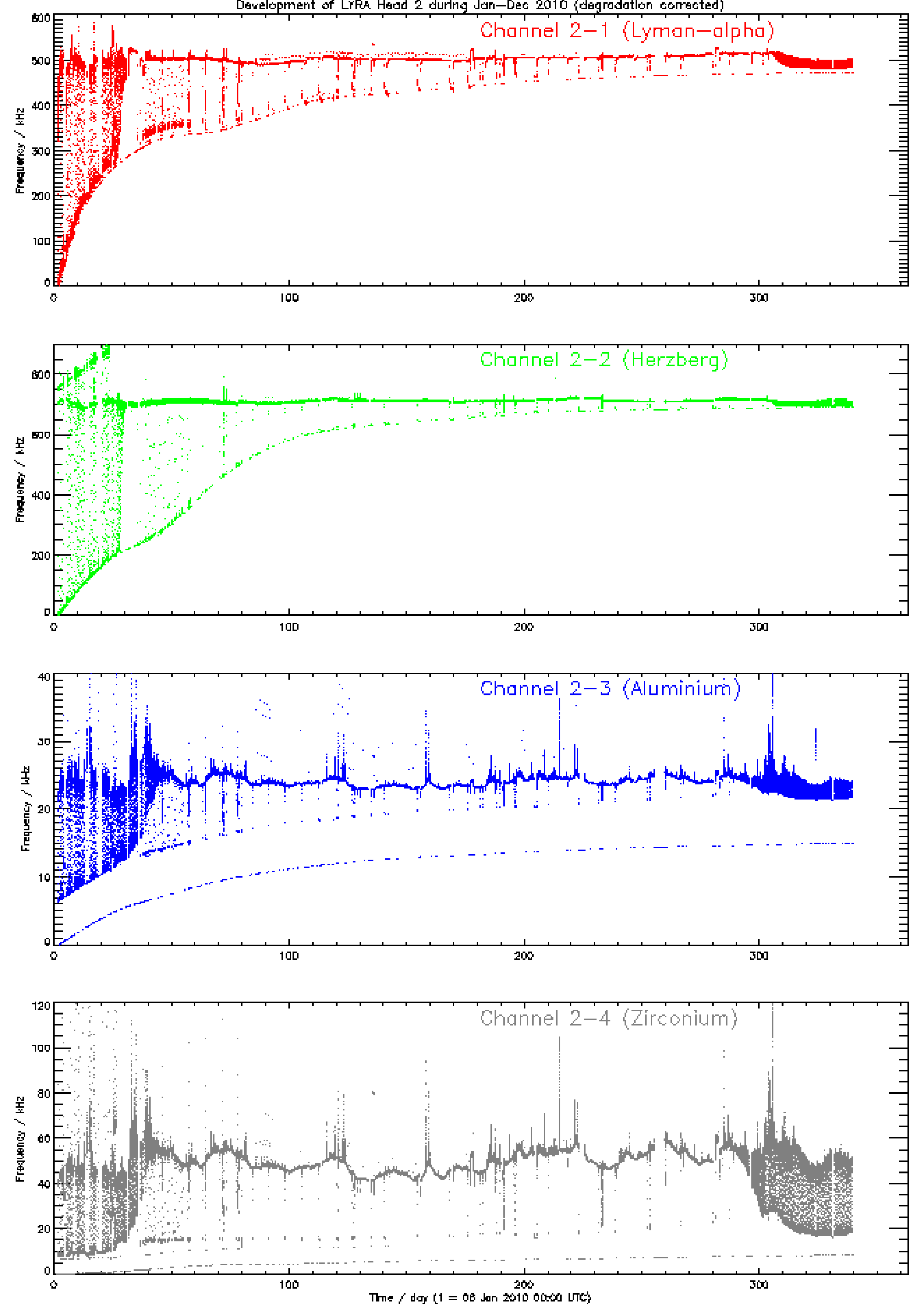


… and add it

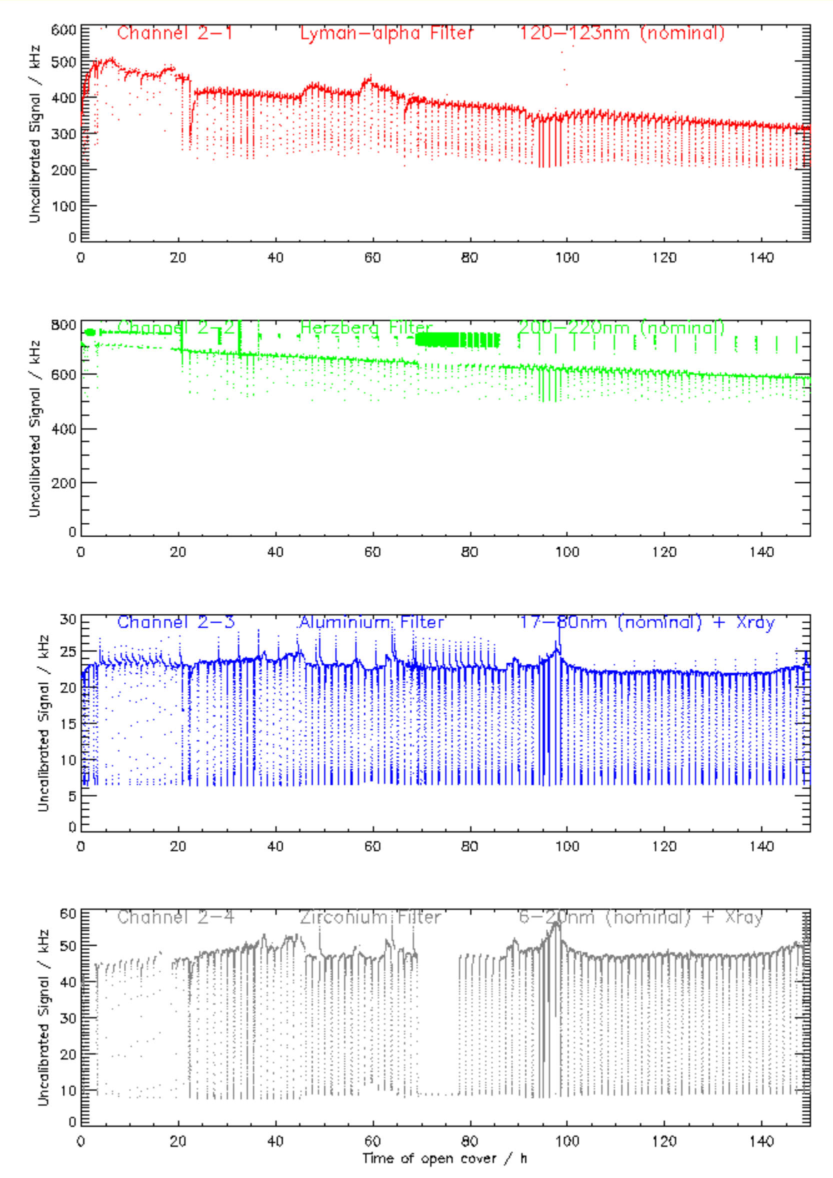
Plausibility:

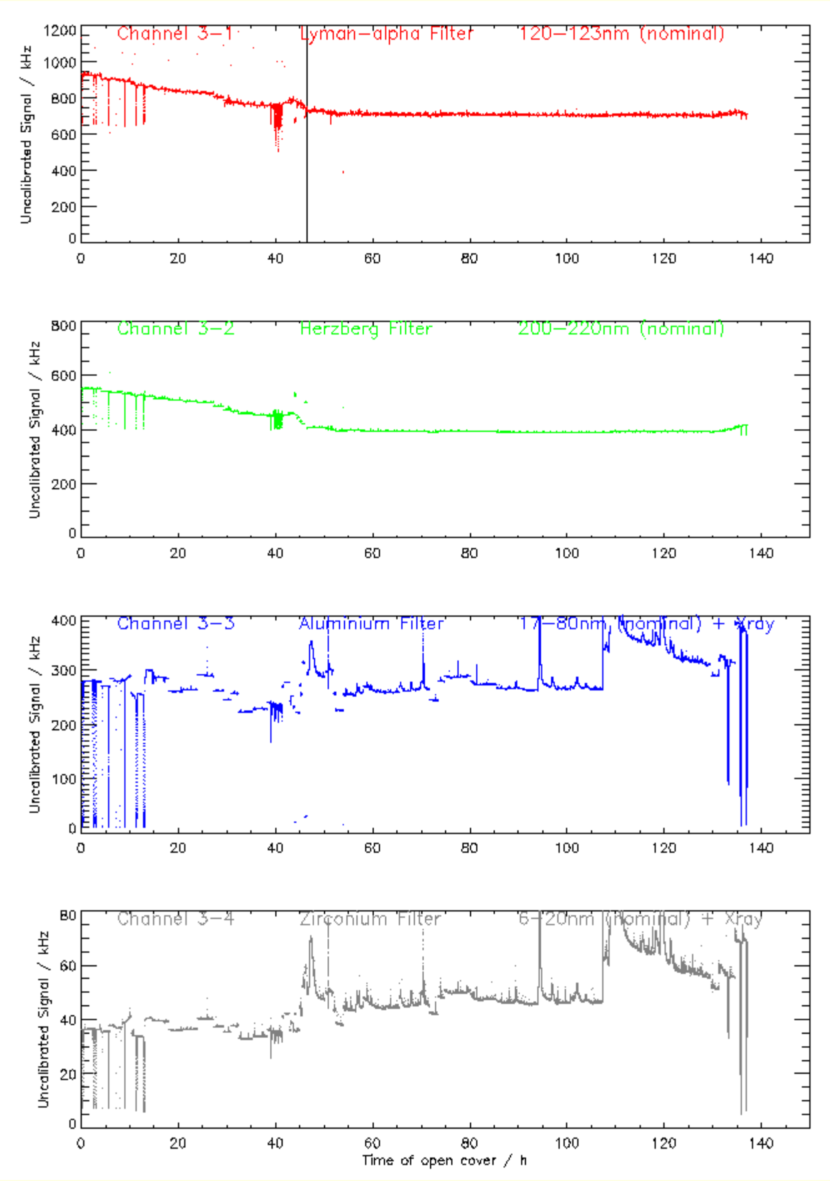
Artifacts in
channels 1 and 2

Non-degenerated
SXR in
channels 3 and 4



Part 3: Degradation in detail





Degradation after 320 hours

■	ch2-1: from 492.0 to 298.0	39.4% loss
■	ch2-2: from 703.5 to 584.0	17.0% loss
■	ch2-3: from 16.6 to 14.3	13.9% loss
■	ch2-4: from 37.5 to 36.6	2.4% loss

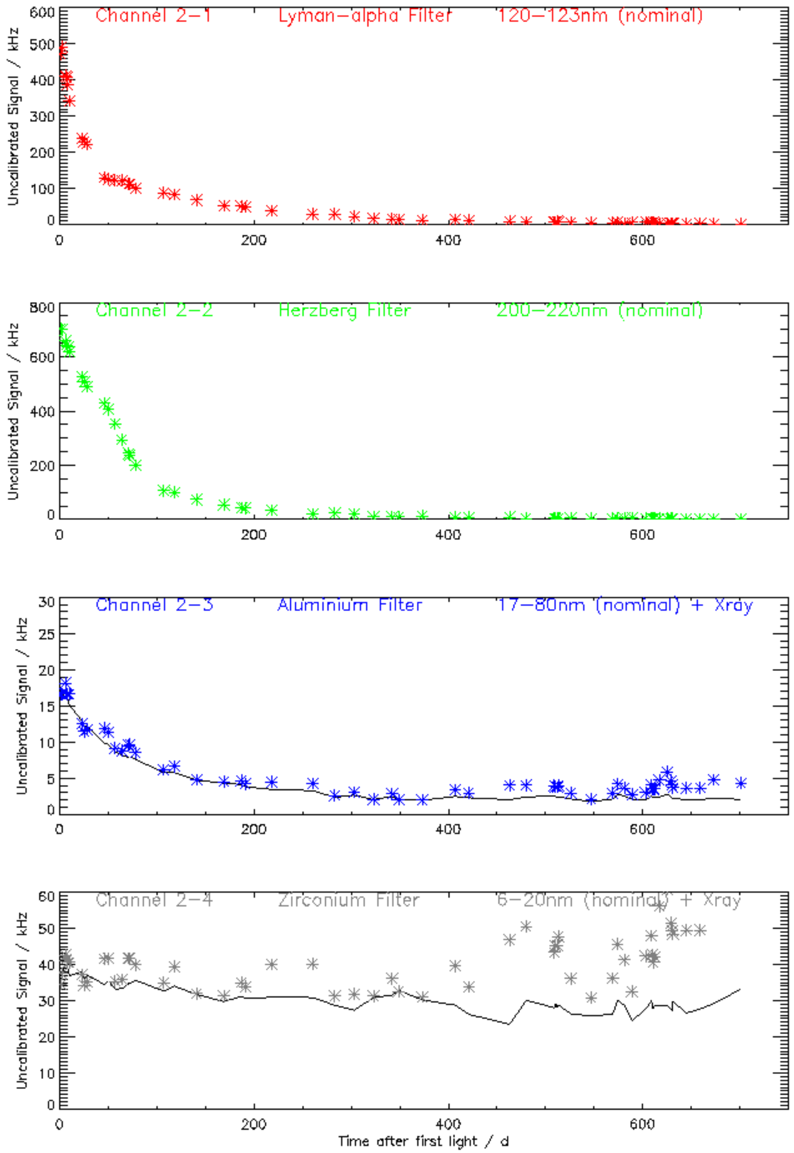
(Status 20 Jan 2010, “day 14”)

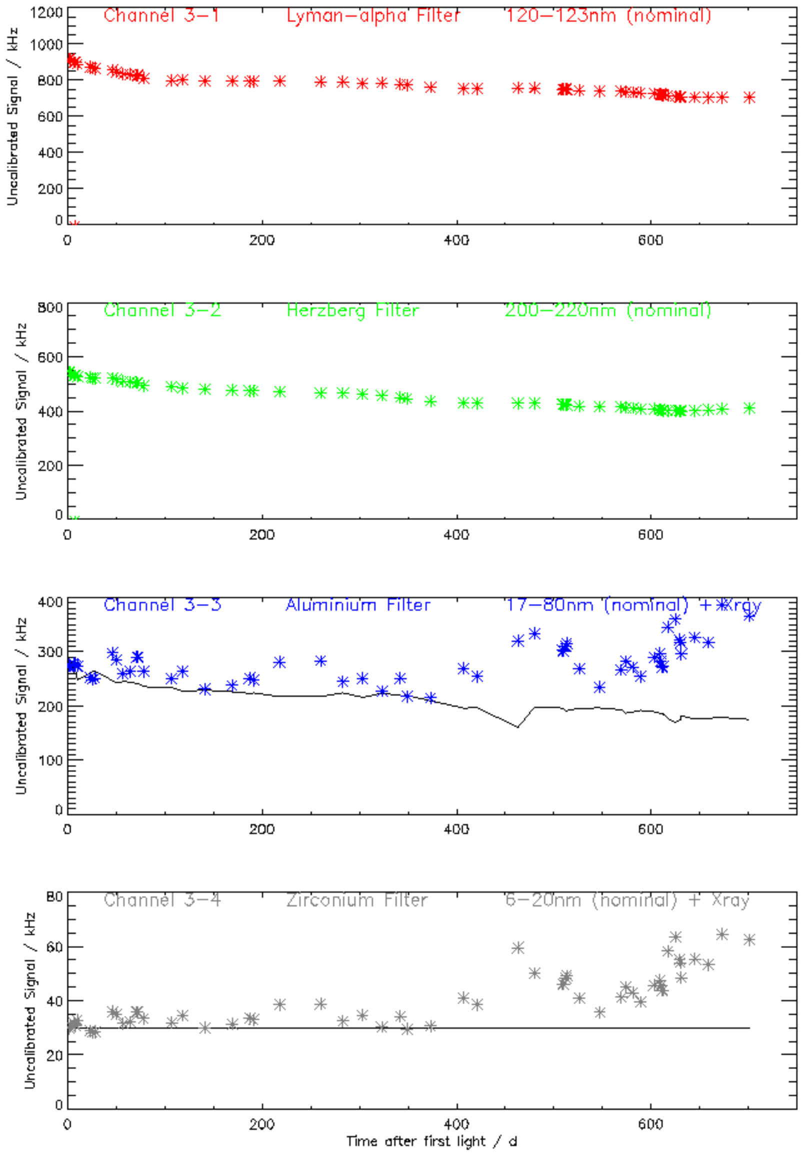
■	ch3-1: from 920.0 to 664.0	27.8% loss
■	ch3-2: from 545.5 to 377.0	30.9% loss
■	ch3-3: from 273.6 to 230.0	19.6% loss (estimated)
■	ch3-4: from 29.8 to 47.0	0.0% loss (estimated)

(Status 09 Mar 2012)

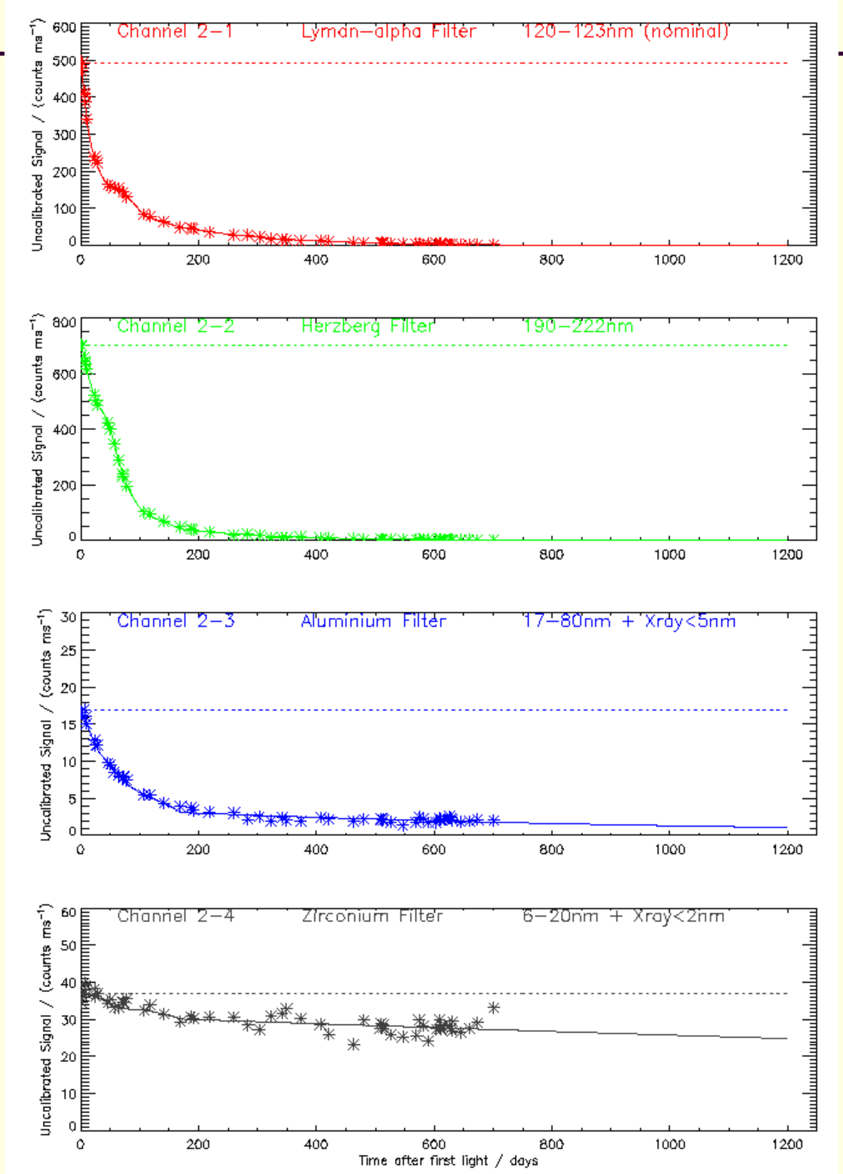
(values in counts/ms, dark current subtracted)

Degradation estimate (partially based on ch3-4)

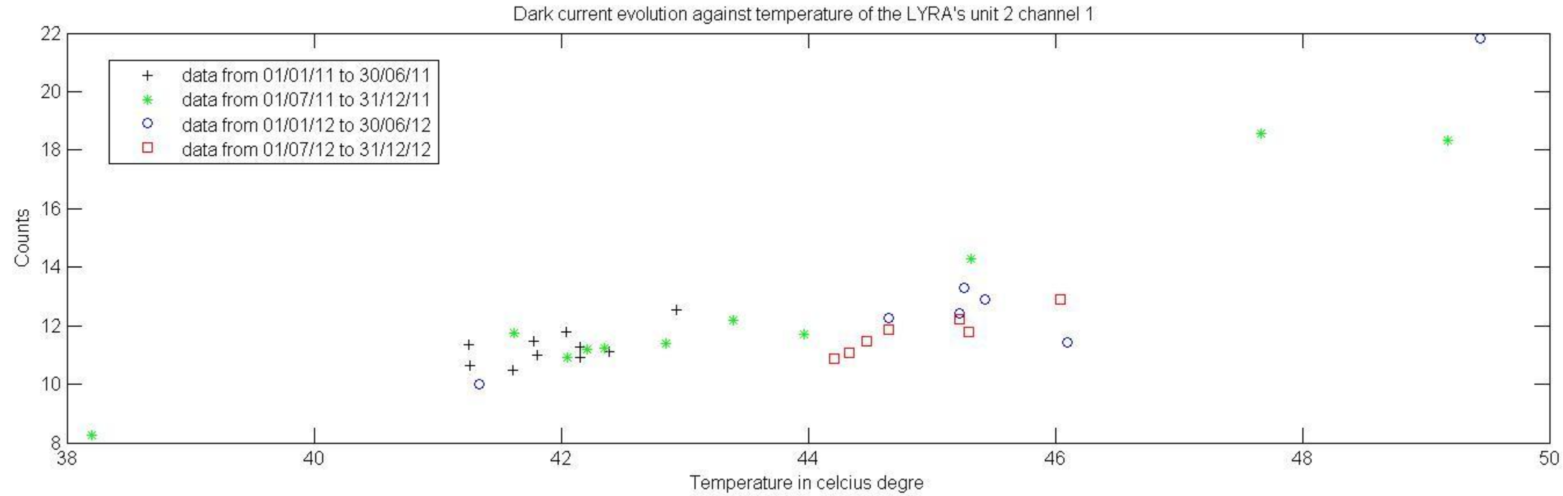


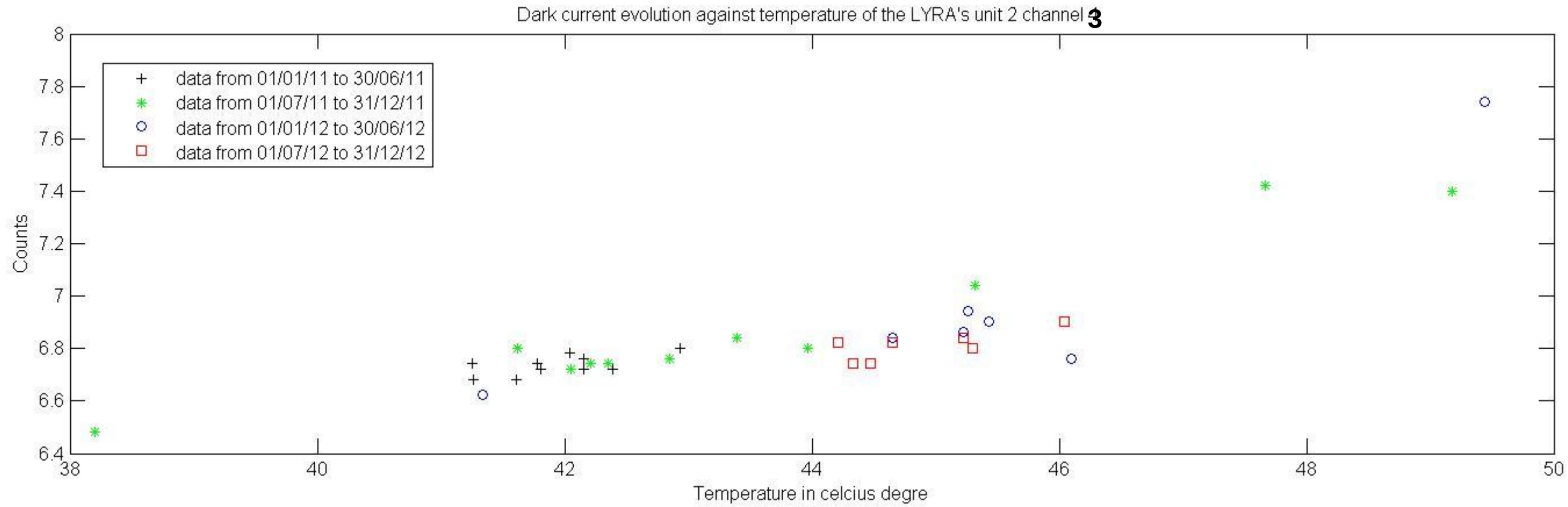


Long-range degradation estimate for unit 2

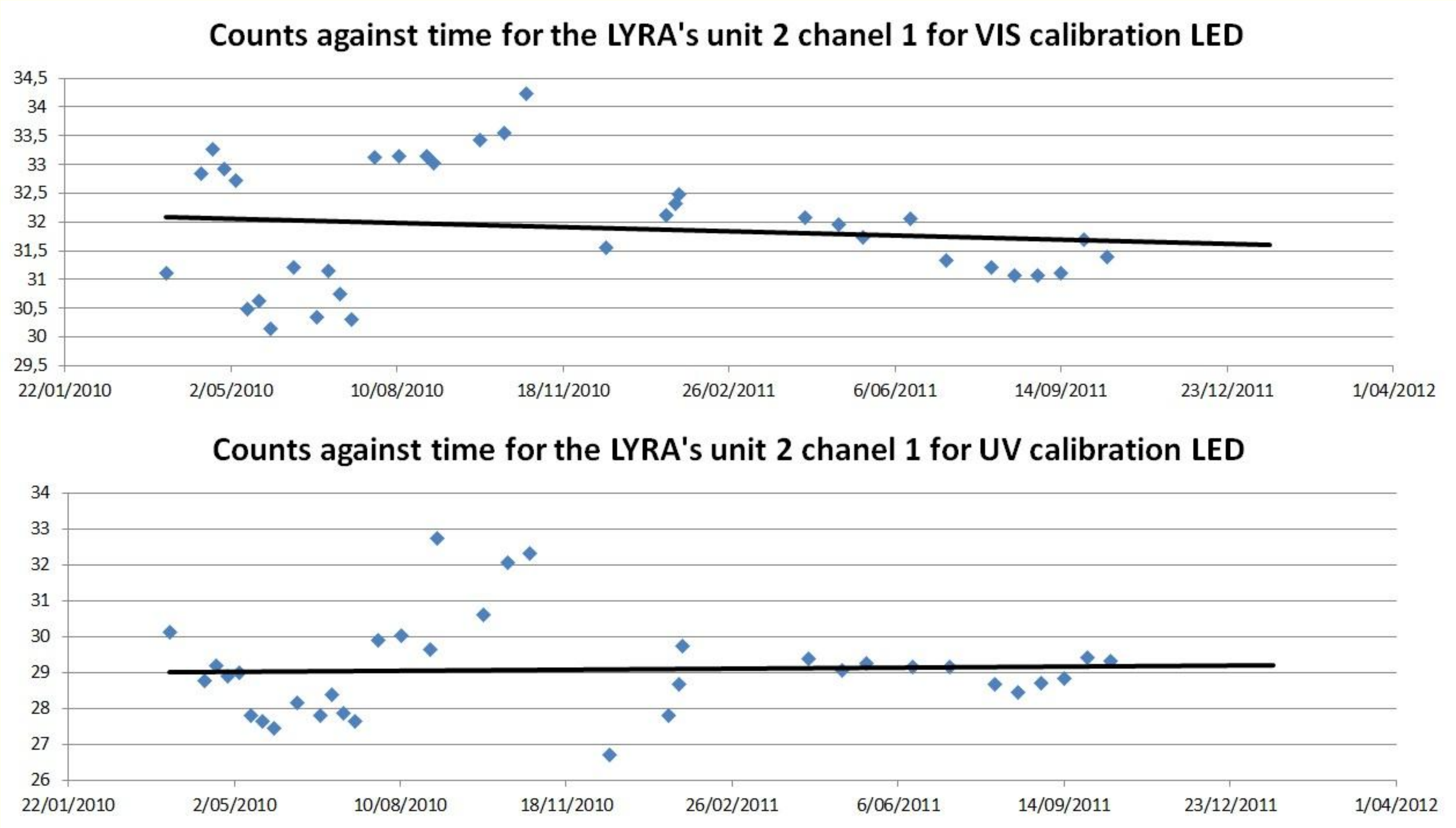


No degradation in dark-current signal



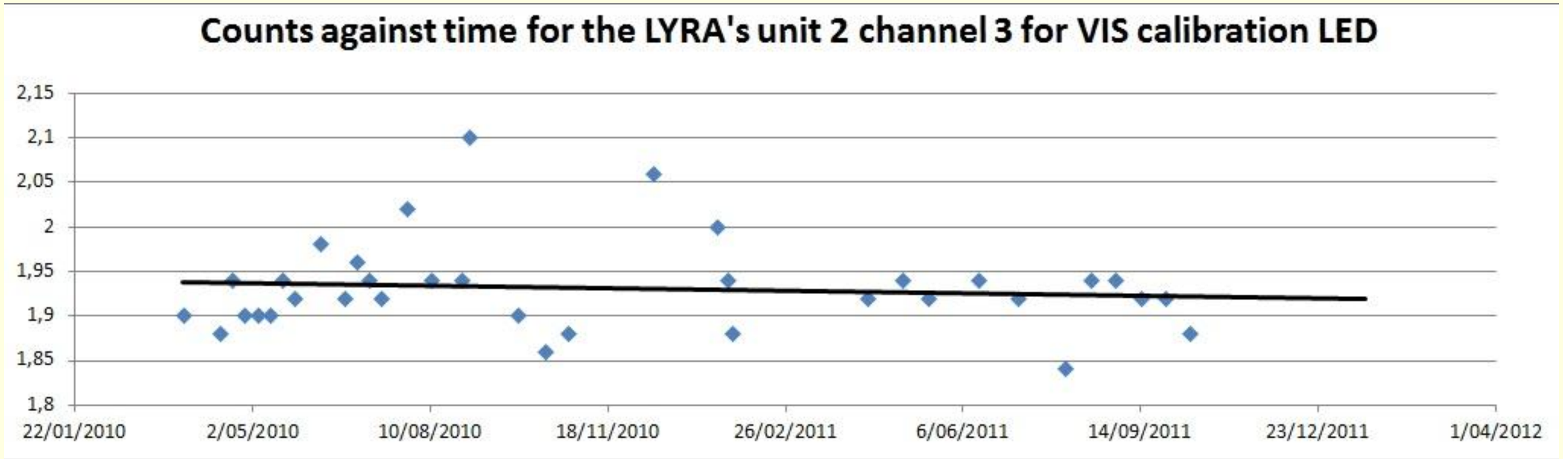


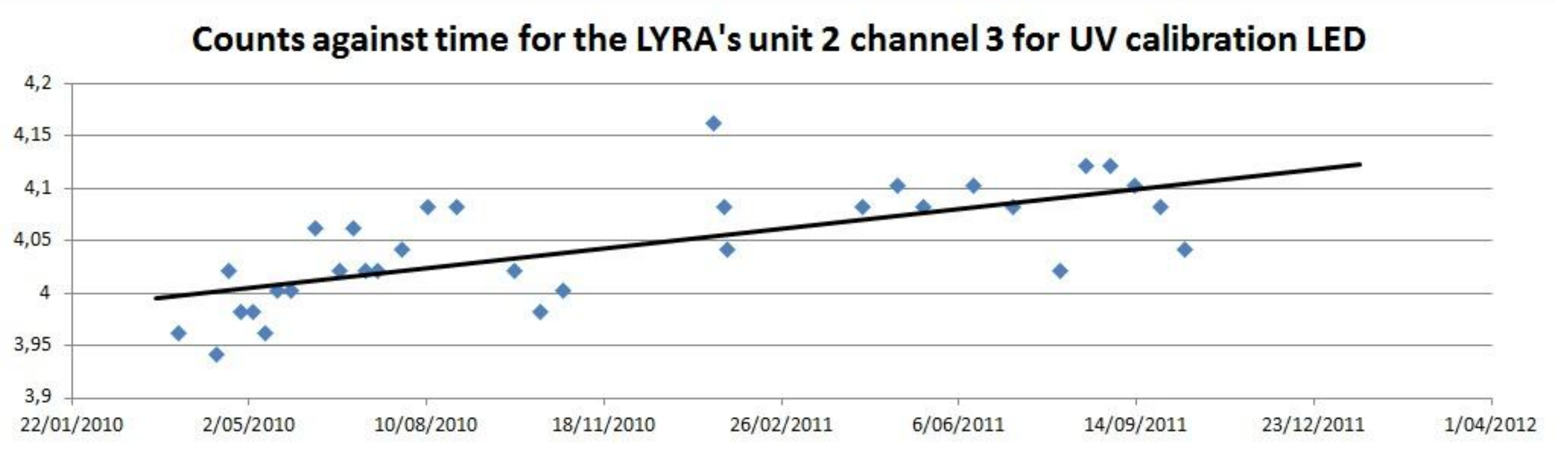
No degradation in vis- or uv-LED signal of ch2-1



Pre-launch measurements were 25.0-30.7 (vis) or 47.9-55.3 counts/ms.

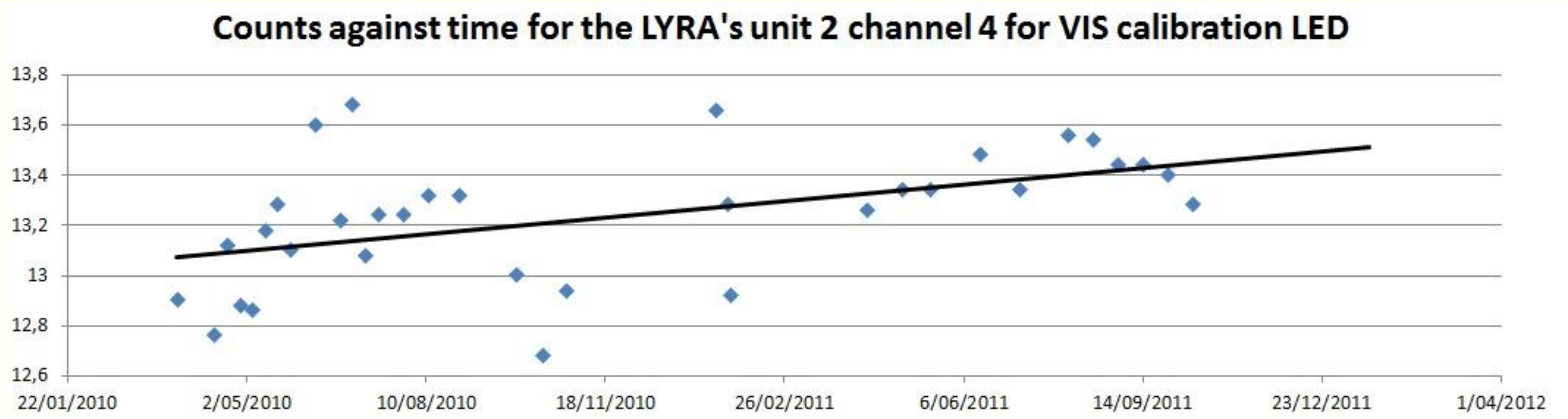
No degradation in vis- or uv-LED signal of ch2-3

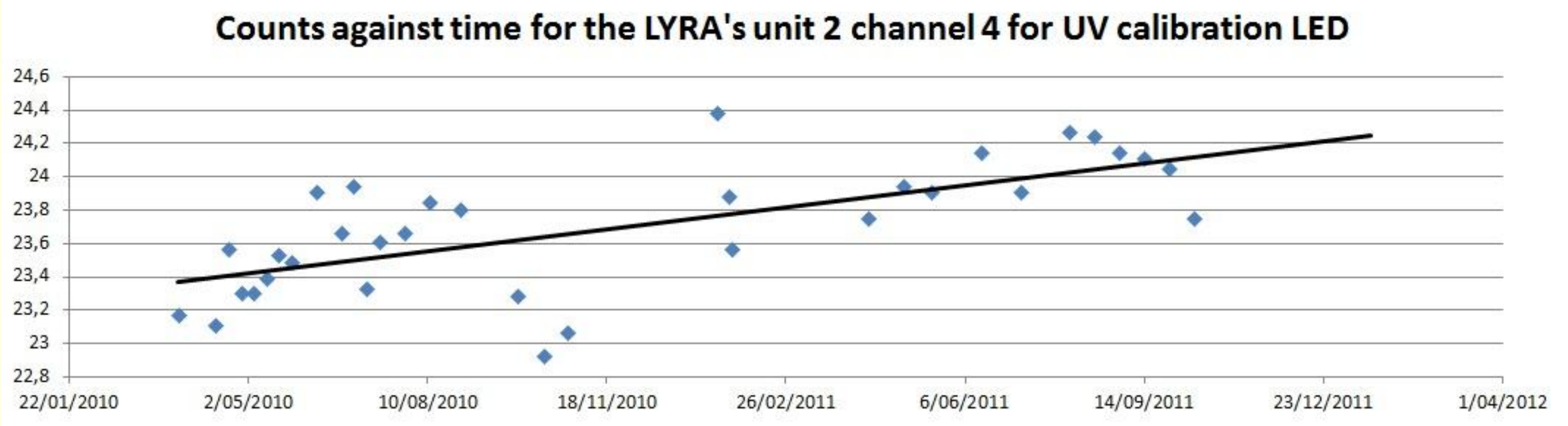




Pre-launch measurements were 1.97-3.81 (vis) or 9.4-10.1 counts/ms.

No degradation in vis- or uv-LED signal of ch2-4





Pre-launch measurements were 13.1-17.8 (vis) or 55.6-58.2 counts/ms.

Preliminary conclusions

- Degradation in LYRA is basically *not* due to long-range detector loss, but:
- Degradation in LYRA is due to molecular contamination on the first optical surface.
- Another instrument (SOVA, see below) experienced both kinds.
- Their UV detector degradation appeared to be caused by radiation, independent from open-cover duration: An immediate loss of ~70%.
- LYRA appears to have avoided detector degradation by a different technology.

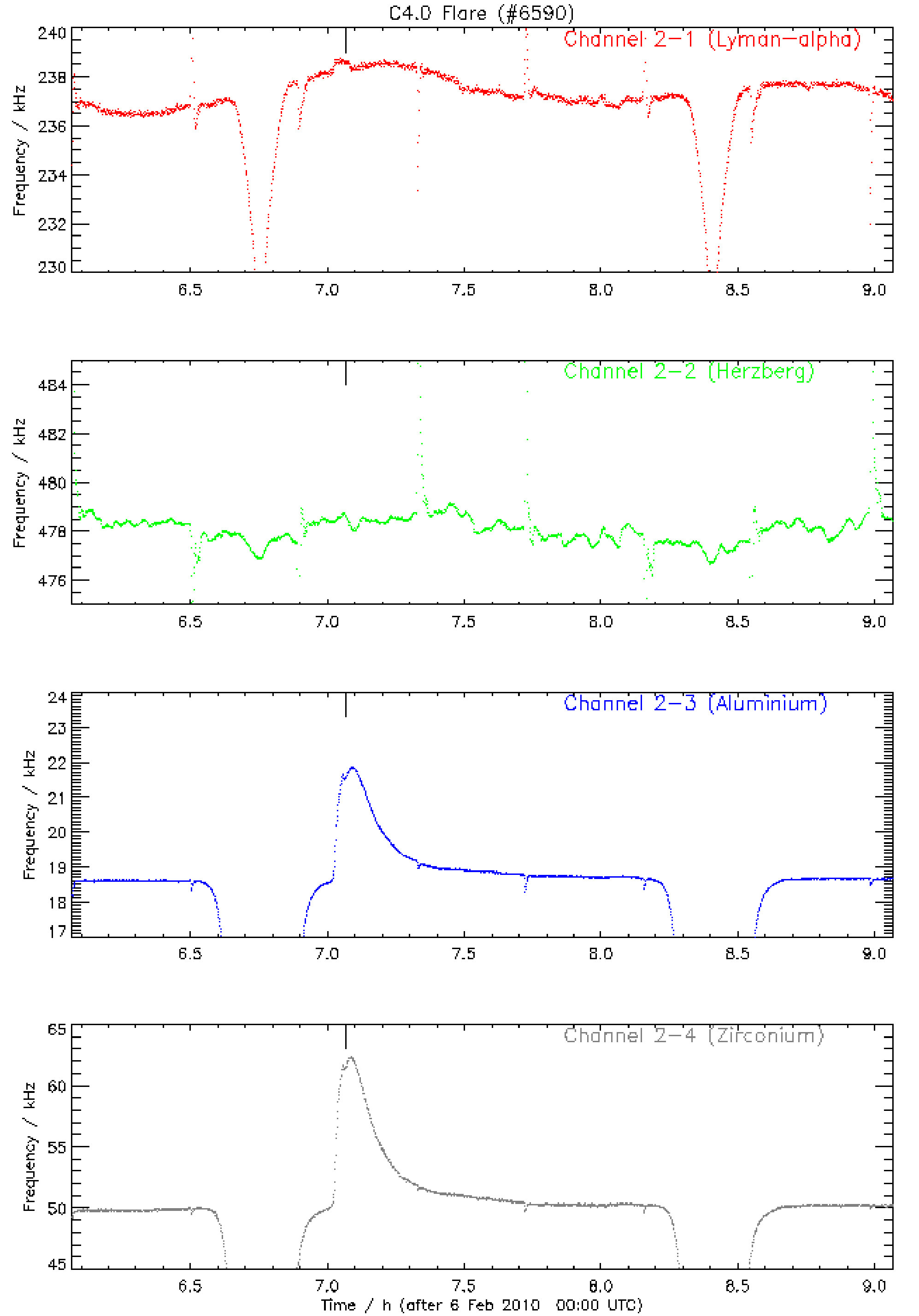
Part 4: Spectral degradation

ch2-1: from 492.0 to 2.0	>99% loss
ch2-2: from 703.5 to 1.7	>99% loss
ch2-3: from 16.6 to 1.8	89% loss
ch2-4: from 37.5 to 27.0	28% loss

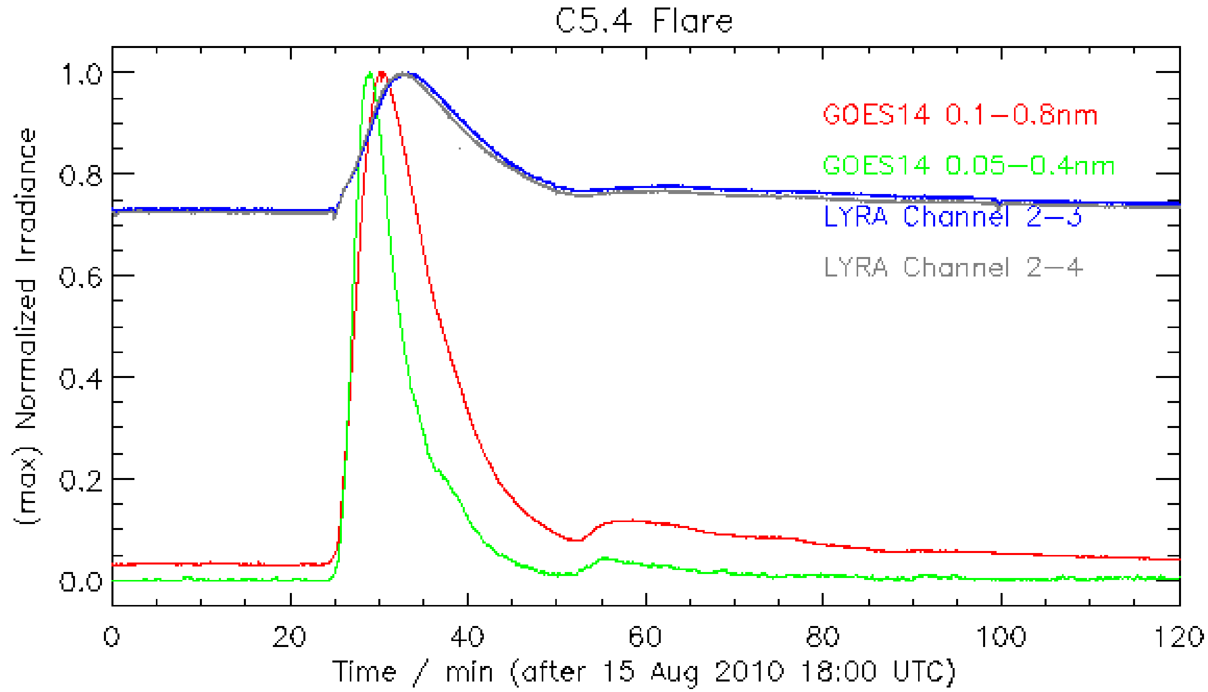
(values in counts/ms, dark current subtracted)

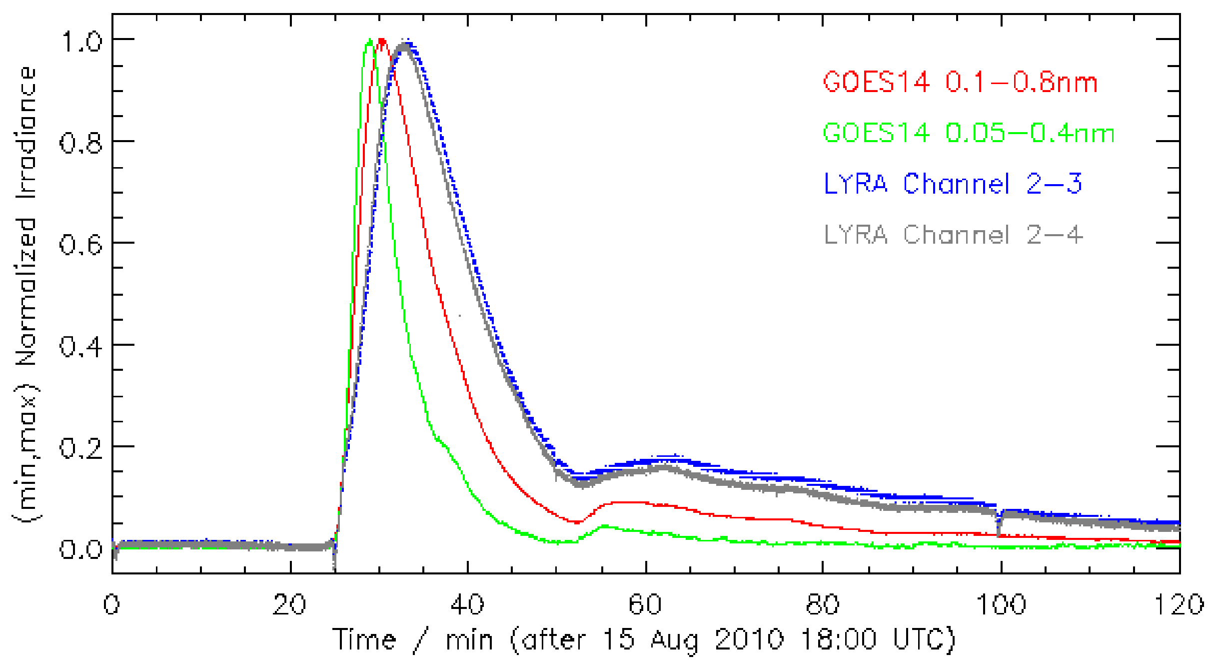
Flares

- LYRA observes flares down to B1.0
- LYRA flare list agrees with GOES14&15
- Flares are visible in the two short-wavelength channels
- Exceptionally strong and impulsive flares are also visible in the Lyman-alpha channel (precursor)
- Example: C4.0 flare, 06 Feb 2010, 07:04 UTC



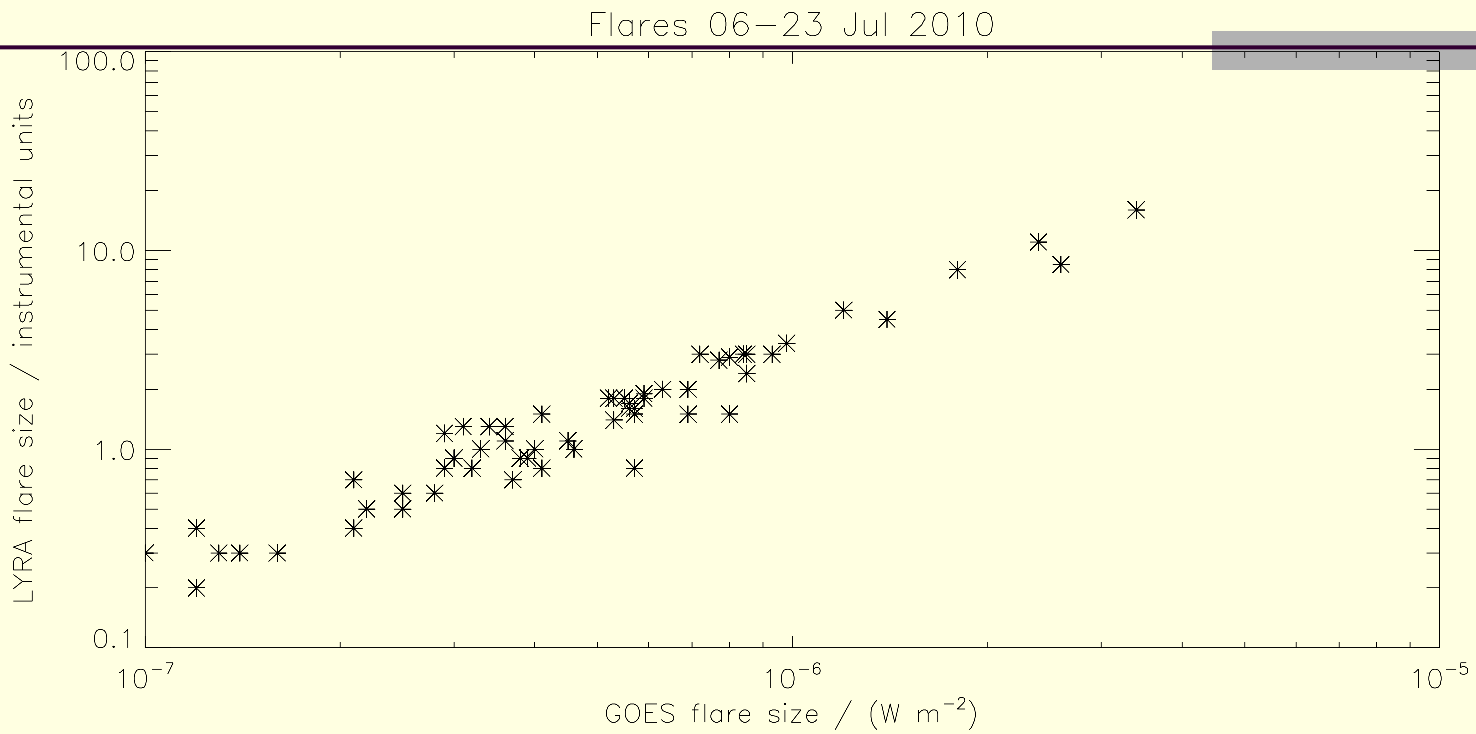
Comparison with GOES flare





Example:
C5.4 flare,
15 Aug 2010,
18:30 UTC

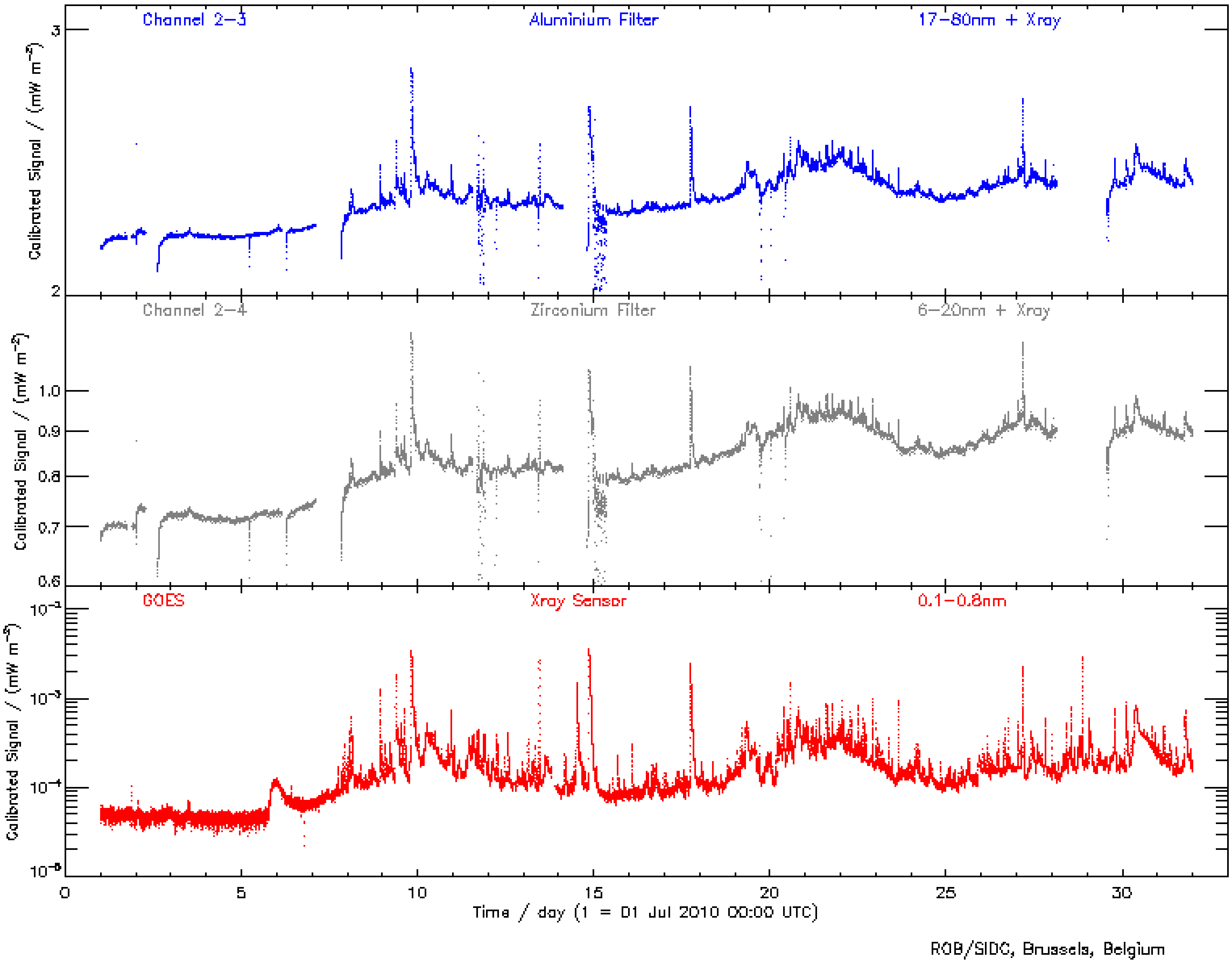
LYRA flare size



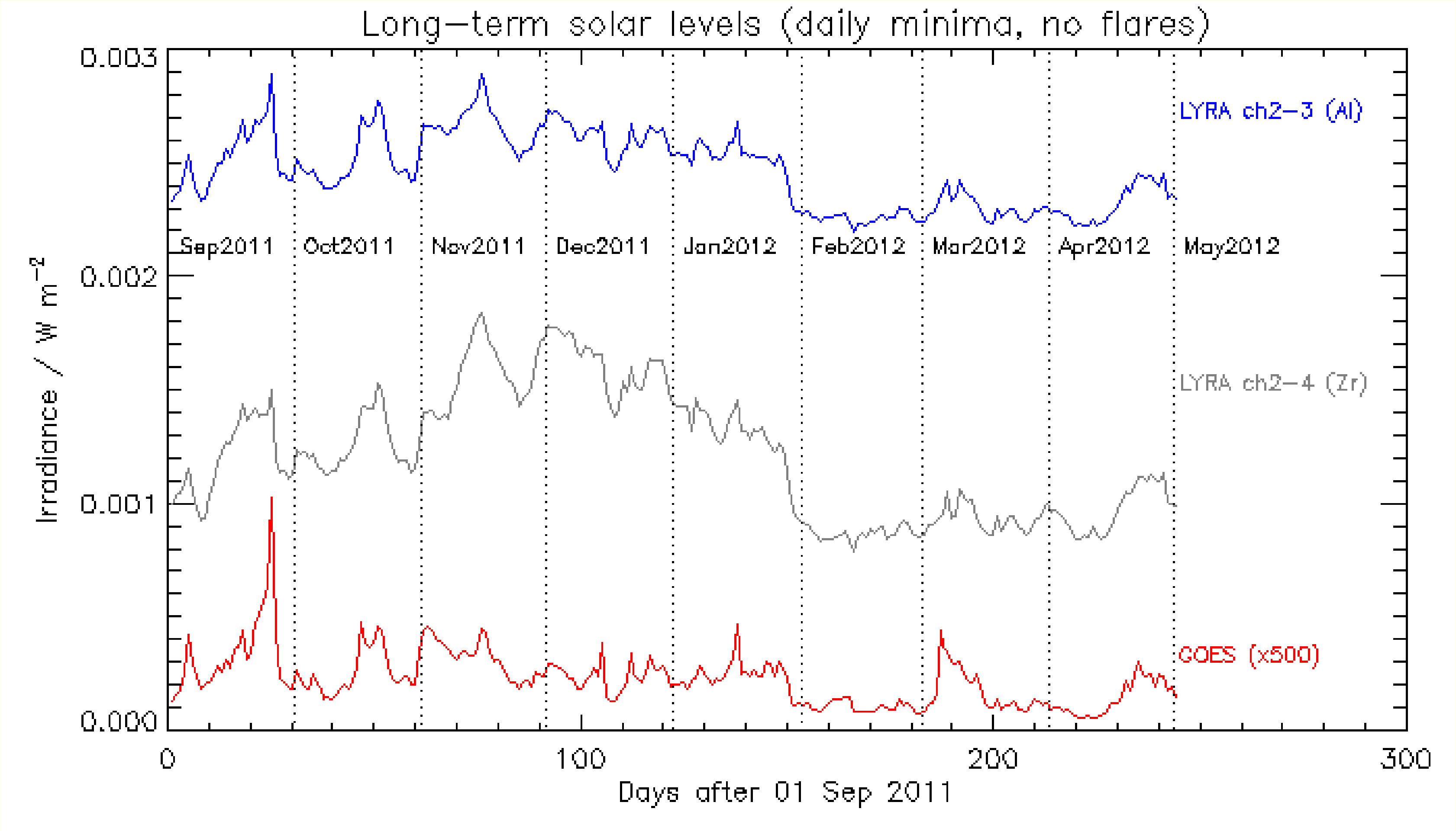
LYRA background-subtracted flux in Zr (channel 2-4)

- LYRA observes all GOES flares in both Al and Zr channels
- Initially also Lyman-alpha contribution for strong impulsive flares
- Similar onset, different peak times in different pass bands
- Good correlation to GOES, better temporal resolution

July 2010: LYRA vs. GOES



Sep 2011 – Apr 2012: LYRA vs. GOES

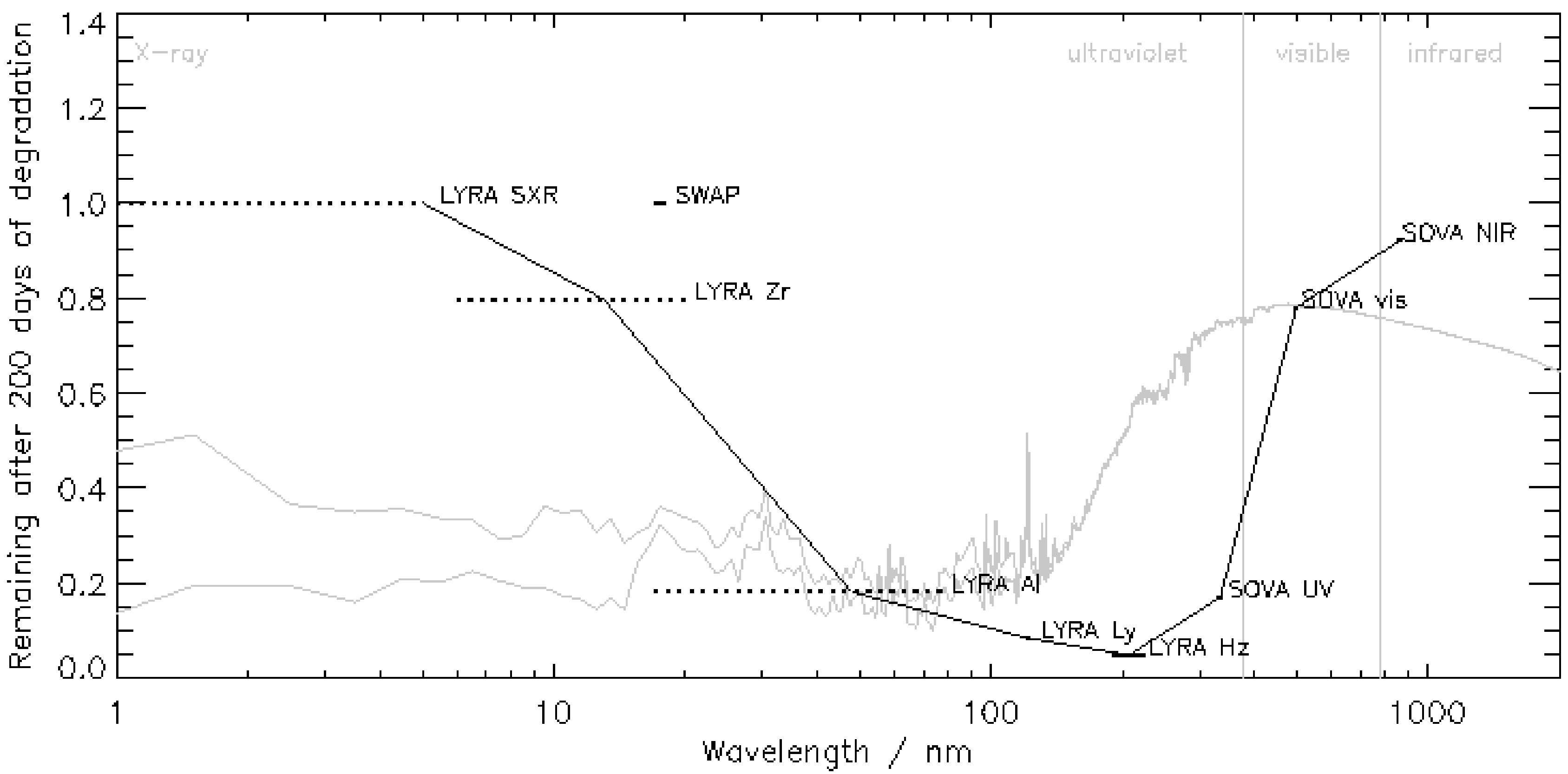


ch2-3 lost 89% between 17-80nm, but ch2-4 lost only 28% between 6-20nm

Example: SOVA on EURECA

- Sunphotometers (SPM) were operated in space for eleven months on board the *European Retrievable Carrier* (EURECA)
- Launched and retrieved with shuttles in 1992/1993.
- Inspected at PMOD (Davos) in 1994.
- Found “a yellow-brownish stain on the quartz windows and the apertures”, composition unknown.
- The *Solar Oscillations and Variability* (SOVA) experiment has three channels around 862 nm (NIR), 500 nm (vis), and 335 nm (UV).
- Compare “window” degradation of nominal unit SPM-A after 200 days of sunlight exposure with LYRA unit-2 degradation:

SOVA and LYRA results combined



Which molecules could be the cause? How can they be avoided? At what cost?