LYRA

the **L**arge-**Y**ield **Ra**diometer onboard PROBA2

LYRA Calibration, Data Products, Cross-Calibration

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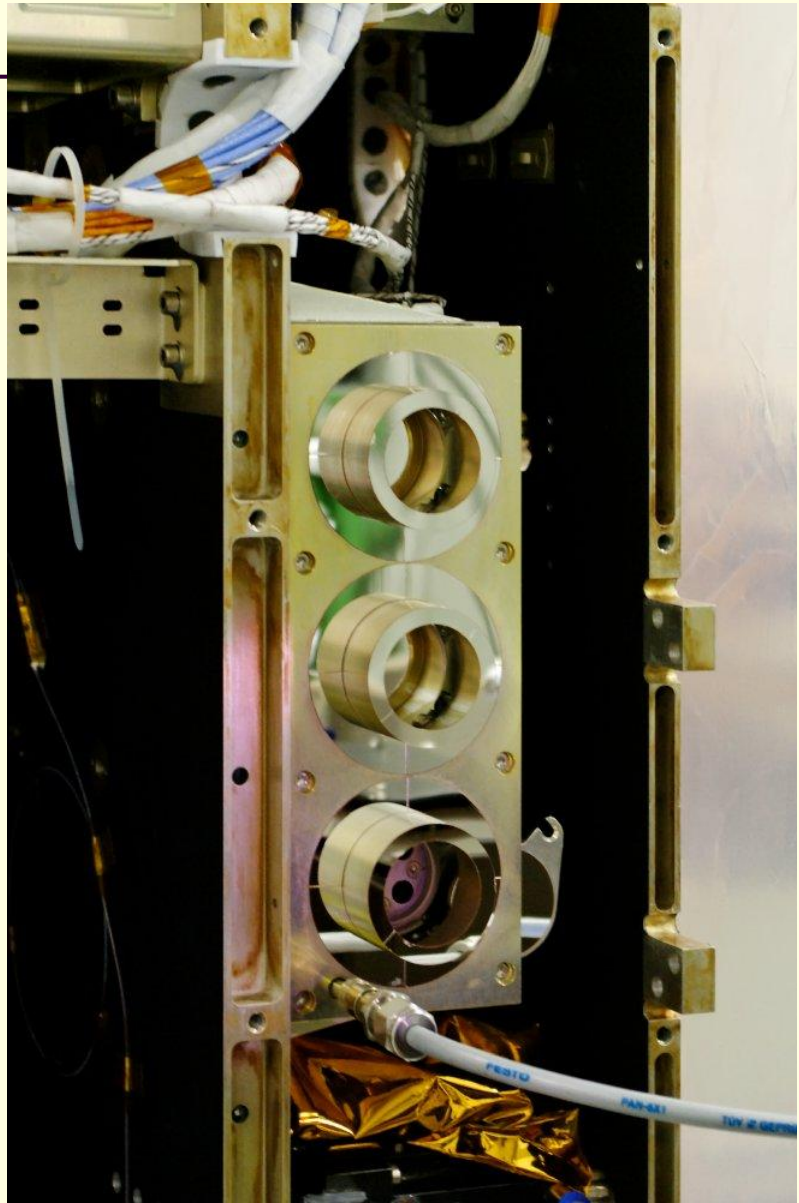
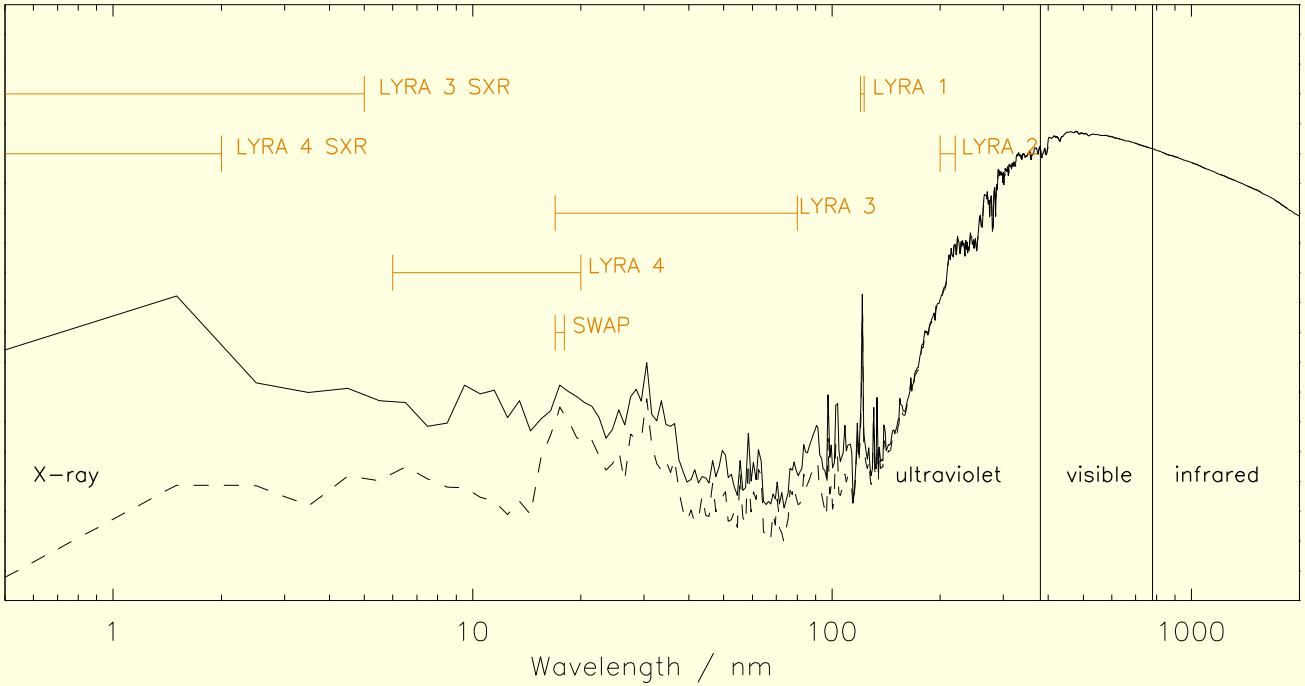
EUV Irradiance Workshop, LASP
Boulder, Colorado, 25-27 Oct 2011

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

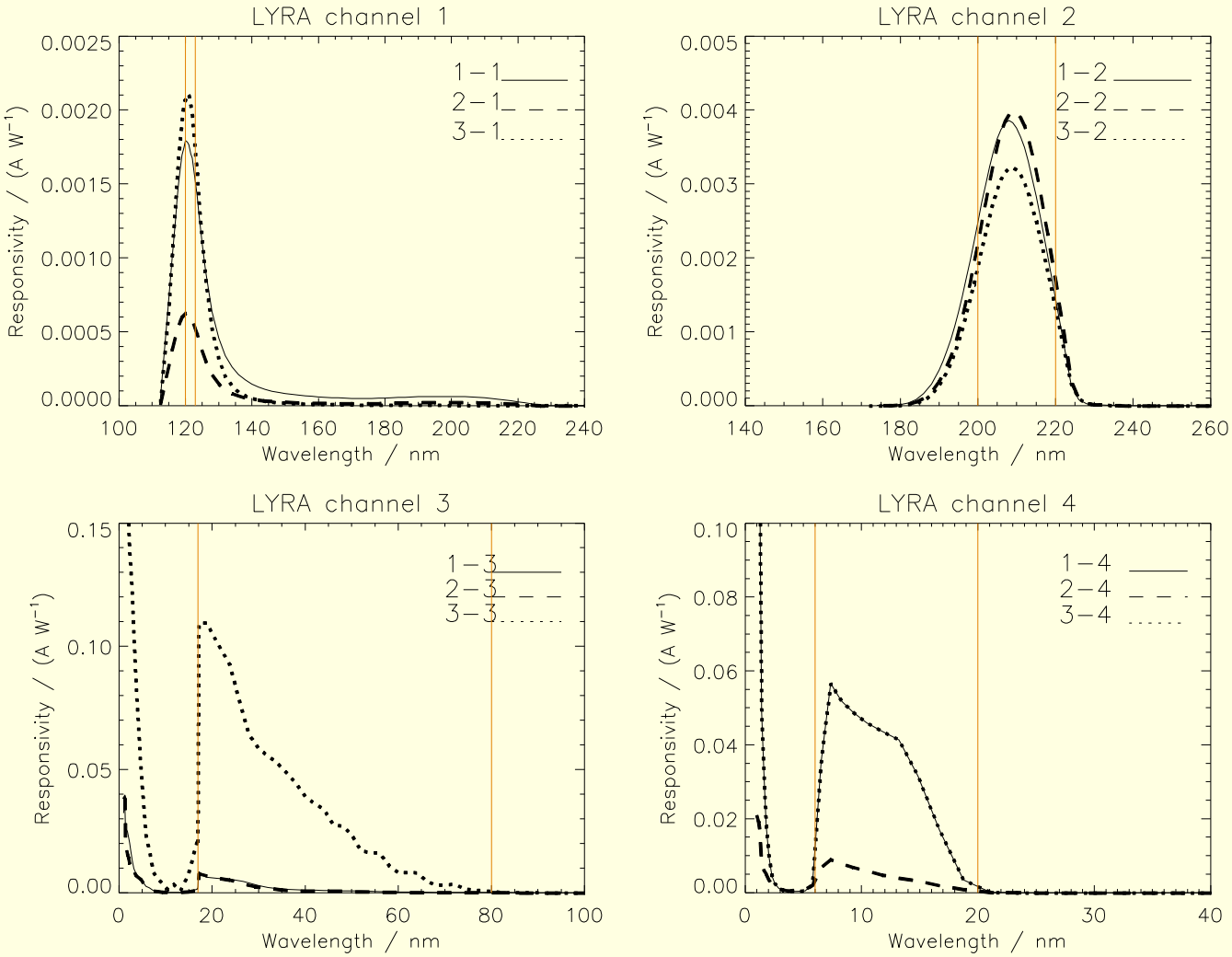


SWAP and LYRA spectral intervals for solar flares, space weather, and aeronomy



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)



LYRA calibration …

… was not as easy as anticipated (surprise!)

Problems:

1. Unrealistic nominal intervals
2. Fast degradation
3. Periodically varying dark currents

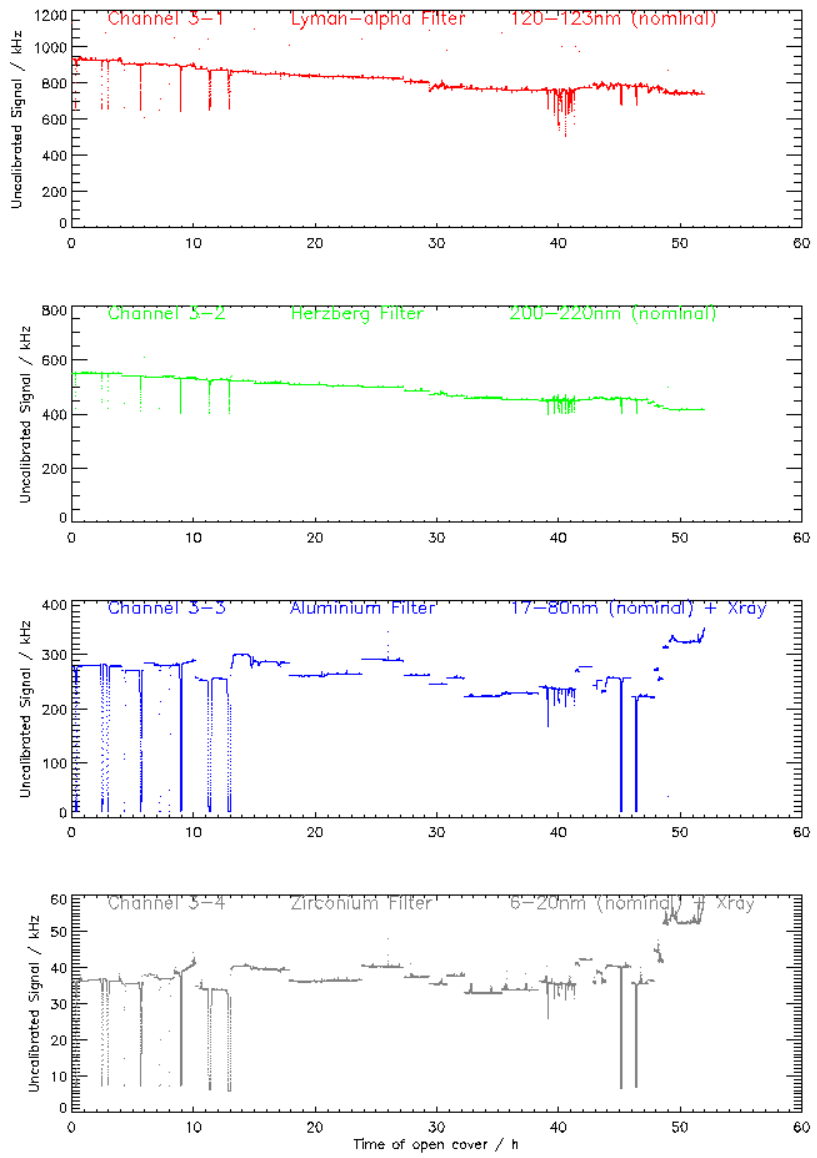
Possible solutions

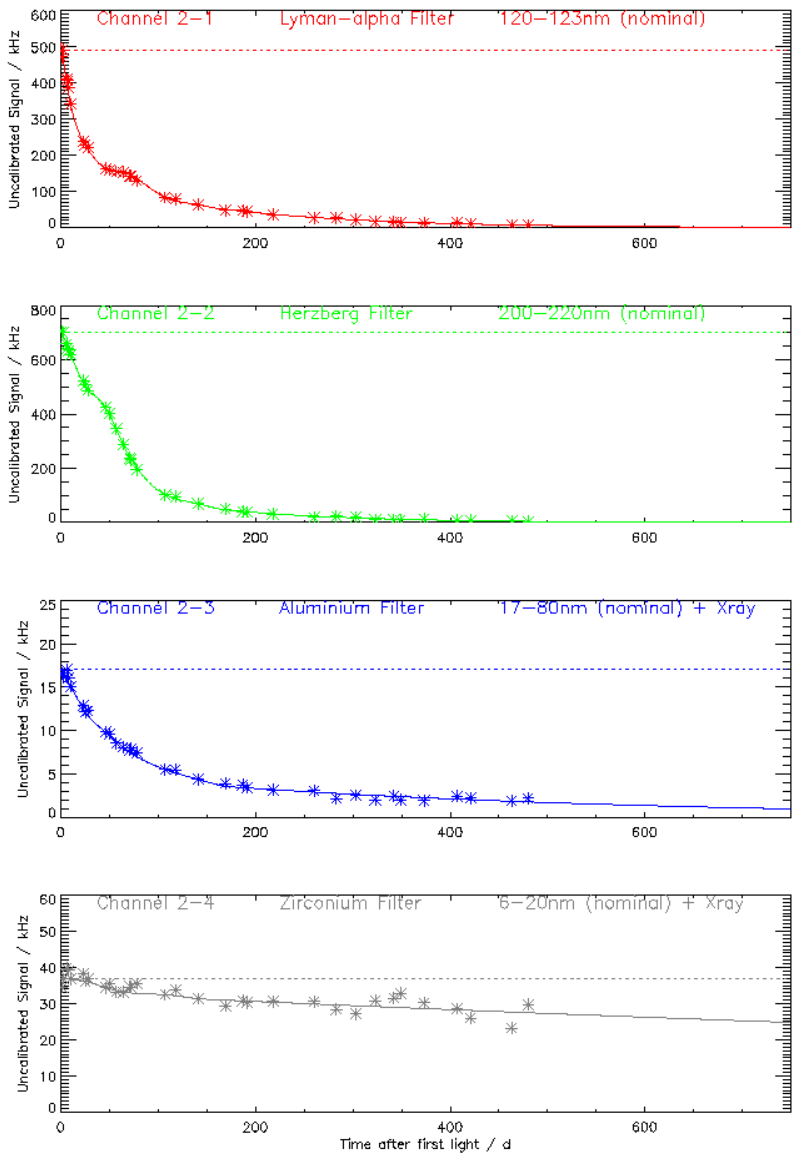
1. Re-define realistic nominal intervals, at least for a start
2. Estimate and correct degradation by internal means (LYRA Head 2 vs. Head 3)
3. Estimate and correct dark currents by using detector temperatures

Then calibrate according to First Light Day

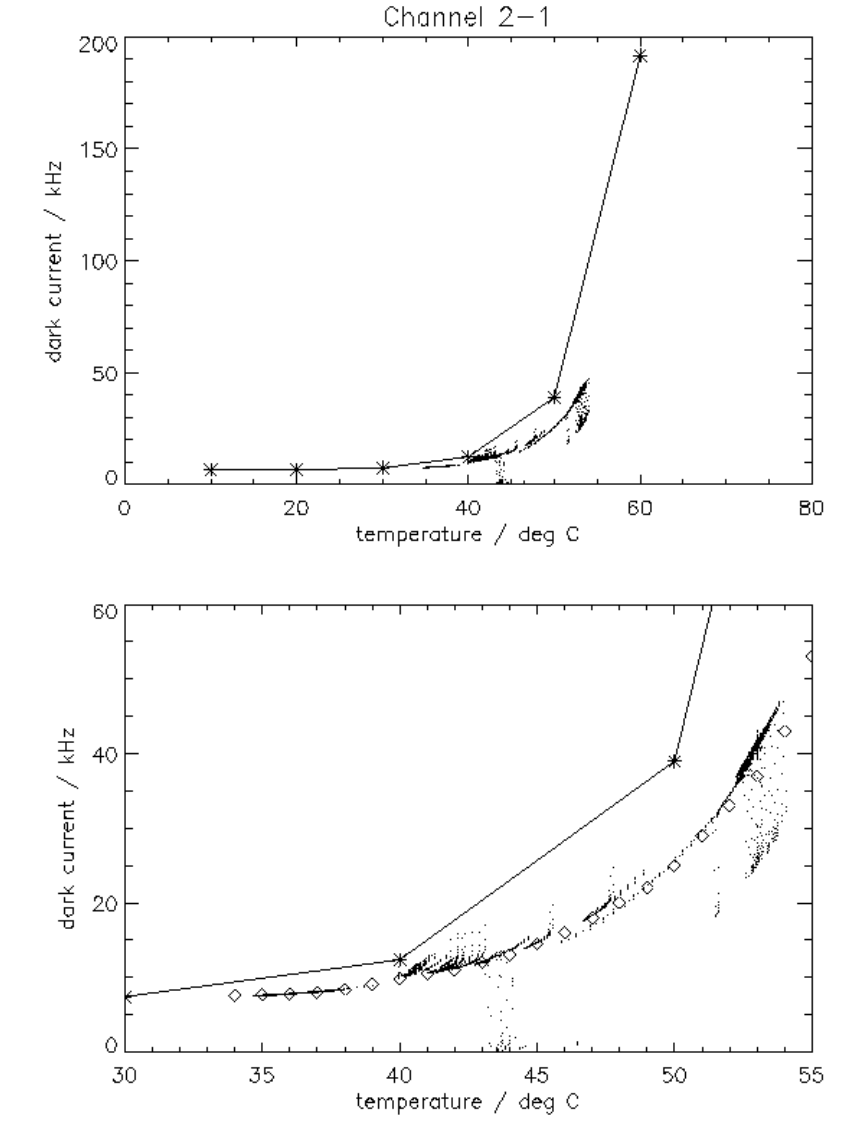
(i.e. before degradation begins)

Most recent degradation fit





Most recent dark current fit



Observed vs. LRM-simulated values

(Example: Head 2 count rates, TIMED/SEE, SORCE/SOLSTICE spectra of 06 Jan 2010)

	ch2-1	ch2-2	ch2-3	ch2-4
sim	0.1030 nA	12.07 nA	0.05765 nA	0.1542 nA
obs	500 kHz	710 kHz	23.0 kHz	45.0 kHz
dc	-8.0 kHz	-6.5 kHz	-6.4 kHz	-7.5 kHz
VFC,resis. =>	0.1969 nA	14.81 nA	0.06780 nA	0.1539 nA
	+91.2%	+22.8%	+17.6%	-2.0%

Resulting conversion to physical units

+81.3%	+13.3%	+11.2%	+14.3% (1)
+91.2%	+22.8%	+17.6%	-2.0% (2)
+3.3%	+18.0%	+11.2%	+15.4% (3)
=> ? (0.0%)	=> +18.0%	=> +13.3%	=> +9.2%

ch*-1	ch*-2	ch*-3	ch*-4
(120-123nm)	(190-222nm)	(17-80&0-5nm)	(6-20&0-2nm)
0.006320 W/m²	0.5914 W/m²	0.002008 W/m²	0.0007187 W/m²
? (0.0%)	+18.0%	+13.3%	+9.2%
=>			
0.006320 W/m²	0.6979 W/m²	0.002275 W/m²	0.0007848 W/m²
which corresponds to ...			
492 kHz	703.5 kHz	16.6 kHz	37.5 kHz

(Example: Head 2, dark currents subtracted, degradation added.
Simple linear conversion!)

Data product definition

- Level 1 = full raw data (LY-EDG output)
- Level 2 = calibrated physical data (LY-BSDG output)
  Caution: preliminary status. Require versioning.
- Level 3 = processed products (e.g. averages)
- Level 4 = plots of products
- Level 5 = event lists (optionally with plots)

New (well, more or less new) LYRA products

… resulting from calibration attempts:

- Level 2 FITS files
- Level 3 FITS files
- (Level 4) One-day overviews
- (Level 4) Three-day overviews
- (Level 5) Flare lists
- (Level 5) GOES vs. LYRA proxies (preliminary)

… available here at the P2SC website:

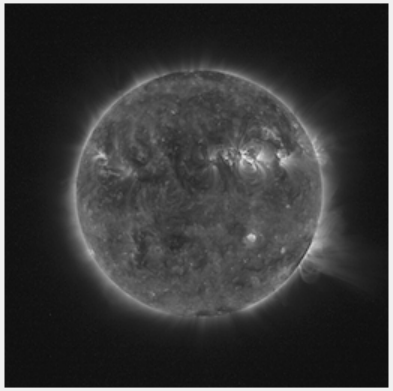
http://proba2.sidc.be/

PROBA2 SCIENCE CENTER

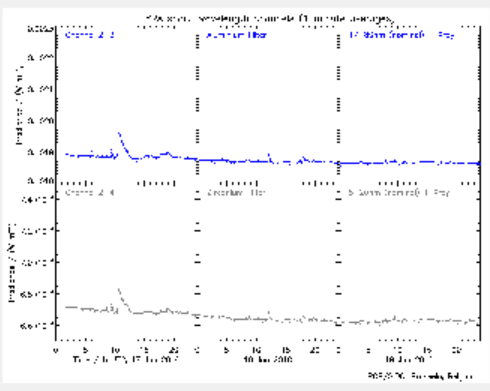
Last update: 18th of July 2011

Welcome to the PROBA2 science center.

Check out the news on the July 1st solar eclipse and the June 7 M-flare!



Watch the latest SWAP image or movie



Go to the latest 3-day LYRA curve and quicklook daily image

Direct link to the scientific data:

- SWAP calibrated FITS - SWAP movies
- LYRA calibrated FITS - LYRA quicklook PNGs over a day and over 3 days - LYRA flare list

More info on all available data here. Consult the tutorial on SWAP analysis software.

Data gaps or unusual data? Please consult the Google Calendars for SWAP and LYRA to find out about special campaigns and off-pointing sequences (commanded via SWAP but also affecting LYRA signals).

NEW : LYRA calibrated data available on-line + an interactive Quicklook Viewer.

Contact us via swap_lyra *at* sidc.be.

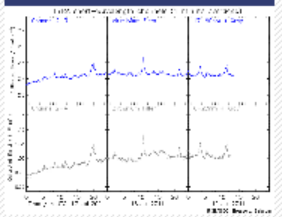
Latest news

2 July 2011
Partial solar eclipse of July 1, 2011

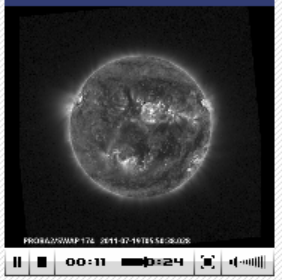
7 June 2011
Extra-ordinary M-flare observations

2 June 2011
June 1st partial solar eclipse

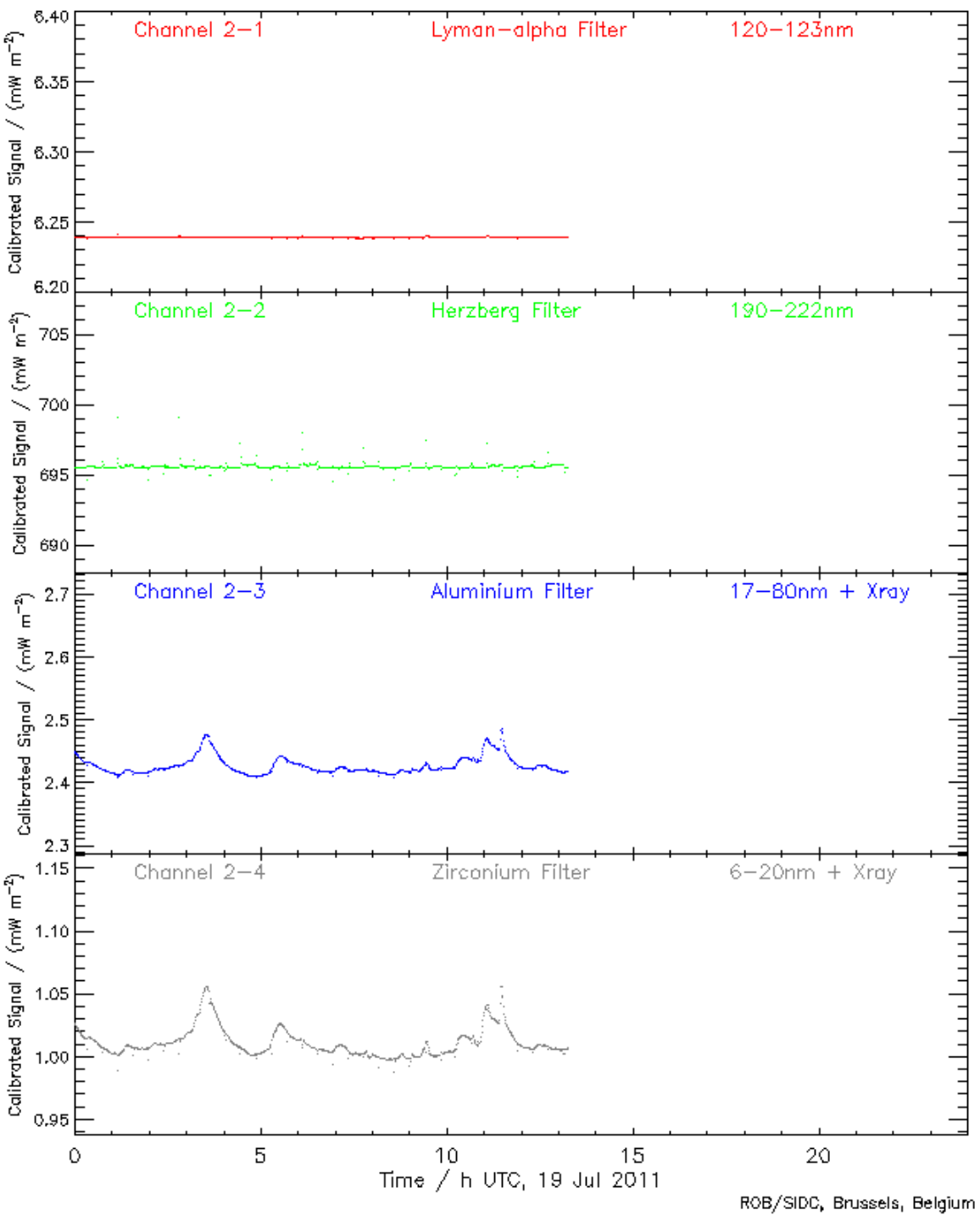
Latest LYRA curve



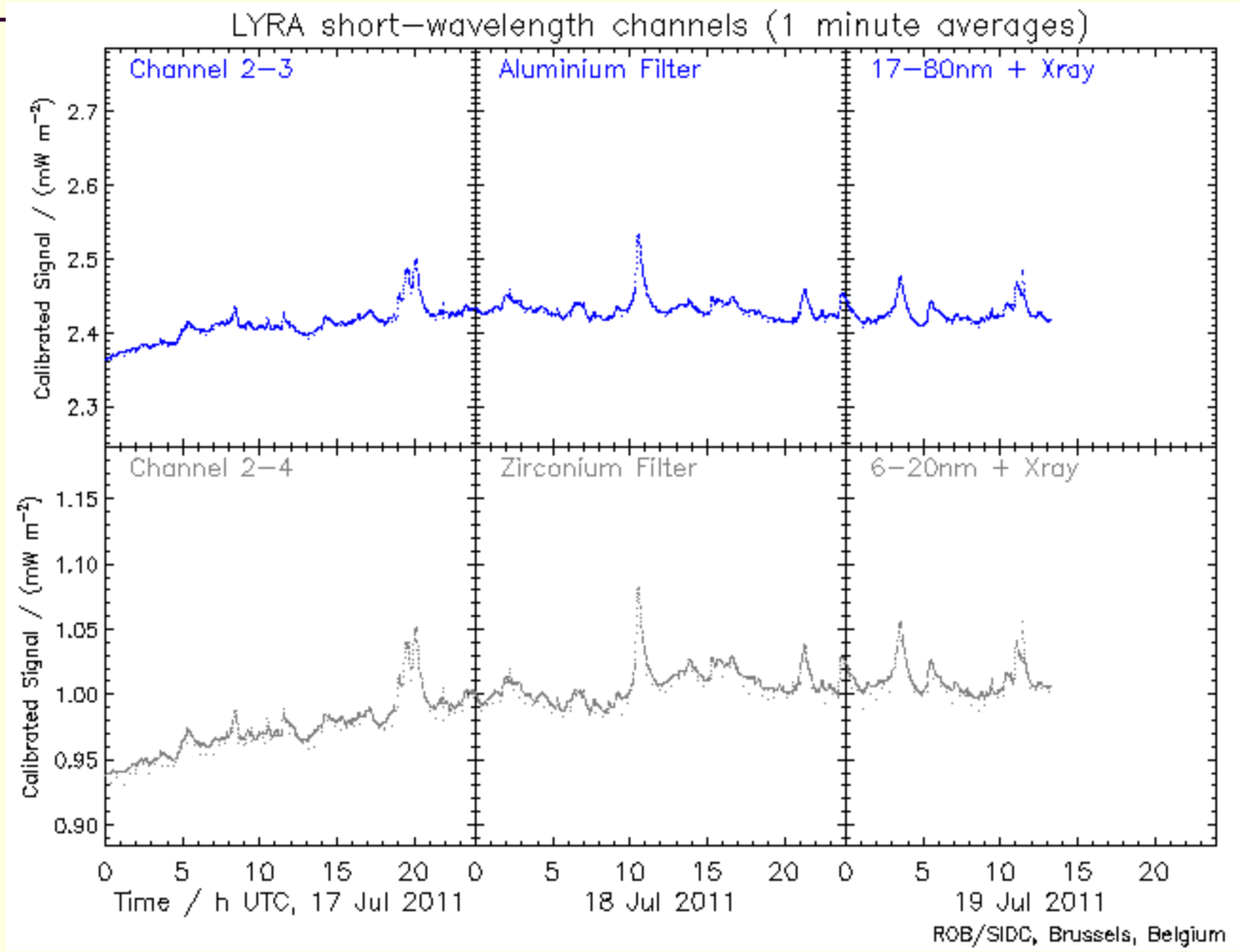
Latest SWAP movie



one-day
overview



three-day overview



2011 LYRA Flare List

Please note:

- This list uses the "G14" and "G15" X-ray entries from the "Edited Events" lists of the NOAA Space Weather Prediction Center.
- The purpose of the list is to get an overview of the flares that LYRA observes and relate them to class, begin, max, etc. according to GOES.
- In the daily images (follow links below), the flares are marked at the top of the LYRA Zr-channel curve, with event number and class corresponding to their temporal "begin".
- Images of intervals around each flare (1h before, 2h after) are linked to a list below this curve (follow event links), given that LYRA was observing during this interval.
- In the flare images, event number and class are again marked at the top, corresponding to their "begin", while the GOES maximum is marked with a short vertical line. These images contain all four LYRA channels, plus one GOES channel.
- From November to January, PROBA2 experiences "eclipse season". For several minutes during each orbit, the solar disk is occulted by the Earth, and the observed irradiances decrease to dark-current levels - thus LYRA flares may be (partially) hidden.
- Additional information can be found at the PROBA2 website on the LYRA daily quicklook page or on the LYRA 3day quicklook page.

2010 page

July 2011

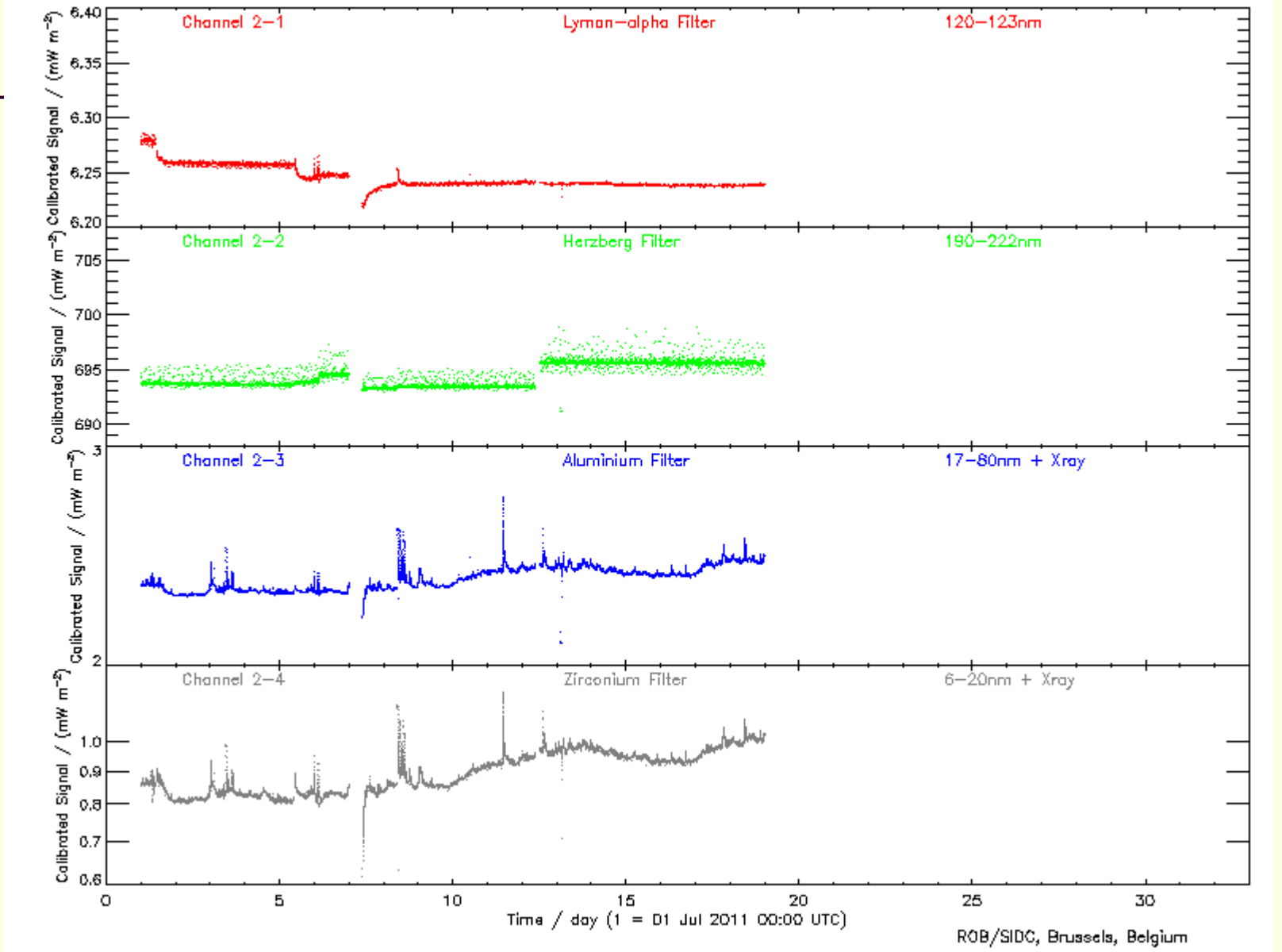
				Fri 01	Sat 02	Sun 03
Mon 04	Tue 05	Wed 06	Thu 07	Fri 08	Sat 09	Sun 10
Mon 11	Tue 12	Wed 13	Thu 14	Fri 15	Sat 16	Sun 17
Mon 18	Tue 19	Wed 20	Thu 21	Fri 22	Sat 23	Sun 24
Mon 25	Tue 26	Wed 27	Thu 28	Fri 29	Sat 30	Sun 31

June 2011

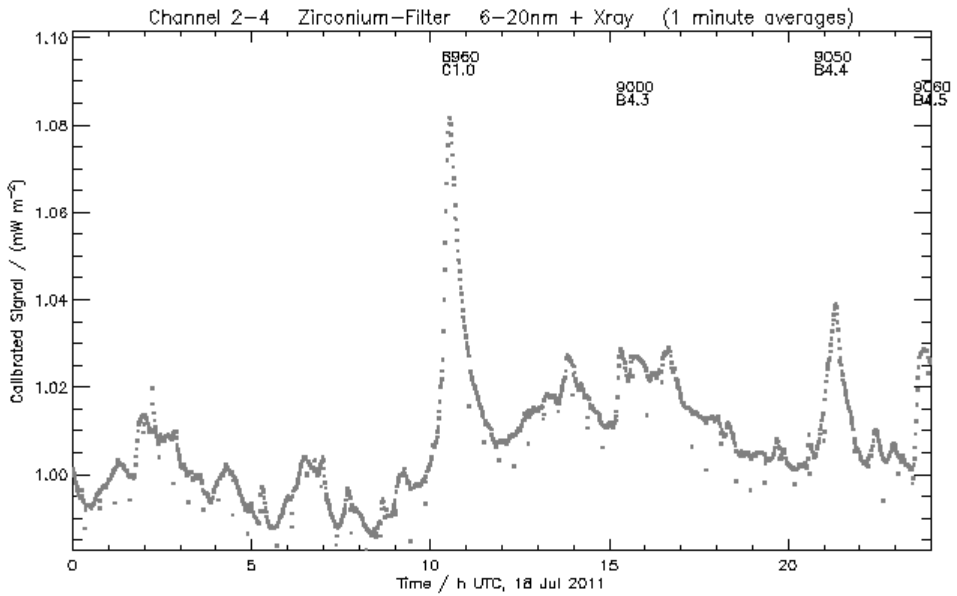
		Wed 01	Thu 02	Fri 03	Sat 04	Sun 05
Mon 06	Tue 07	Wed 08	Thu 09	Fri 10	Sat 11	Sun 12
Mon 13	Tue 14	Wed 15	Thu 16	Fri 17	Sat 18	Sun 19
Mon 20	Tue 21	Wed 22	Thu 23	Fri 24	Sat 25	Sun 26
Mon 27	Tue 28	Wed 29	Thu 30			

May 2011

monthly overview

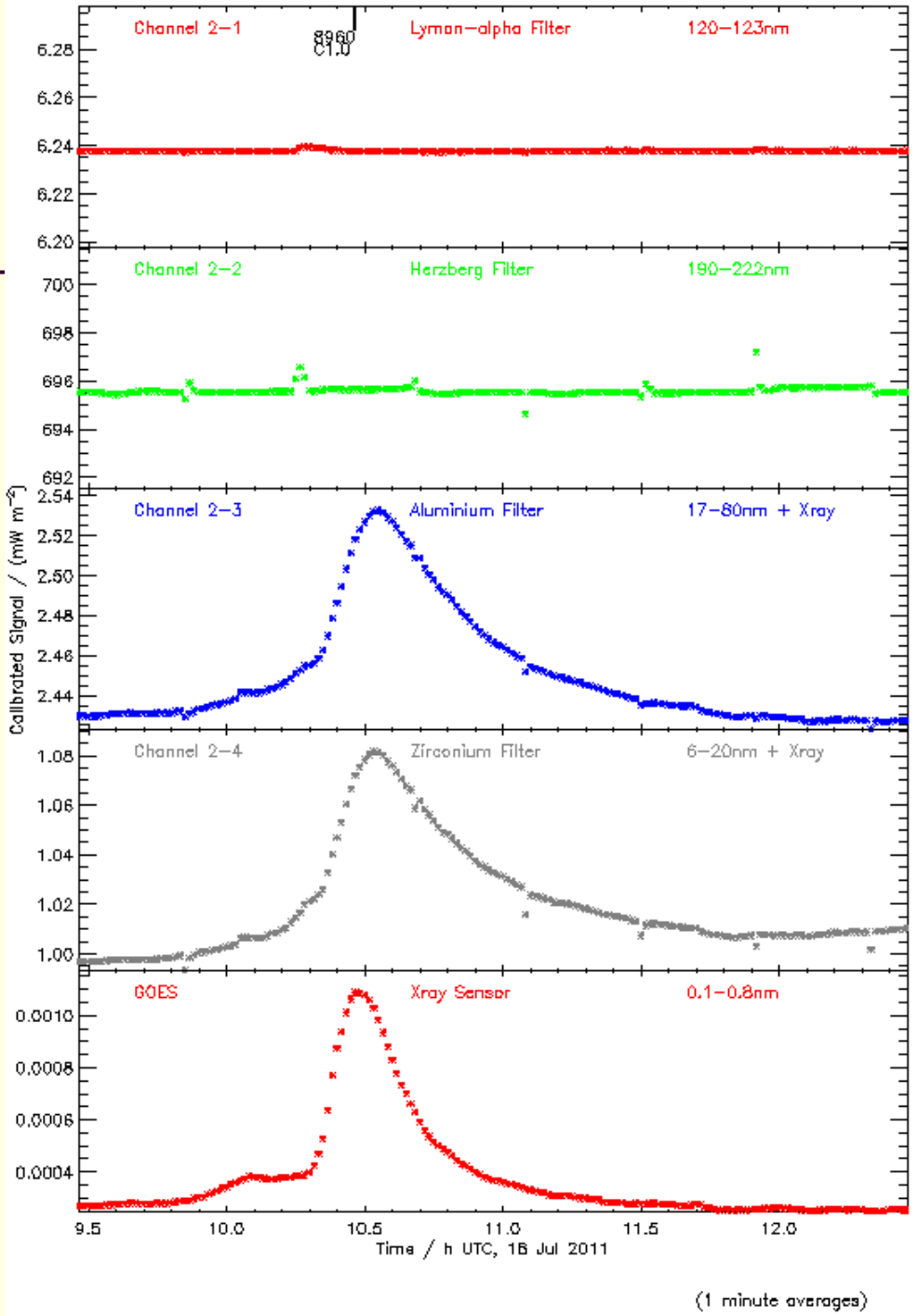


18 Jul 2011 Flare List

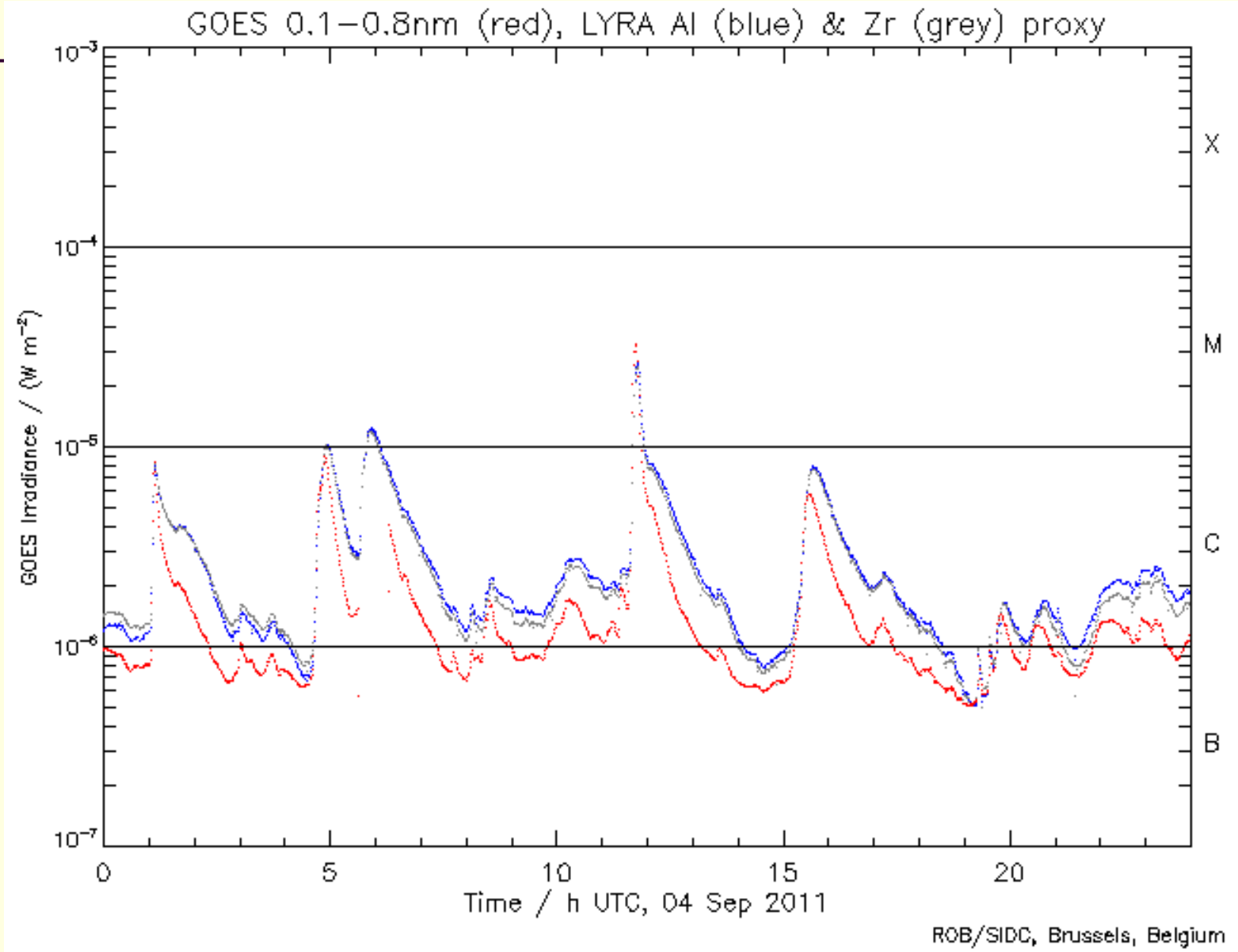


event	begin	max	end	class	region
8960	10:19	10:28	10:38	C1.0	1254
9000	15:12	15:17	15:24	B4.3	1254
9050	20:44	21:14	21:29	B4.4	
9060	23:31	23:40	23:58	B4.5	1255

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



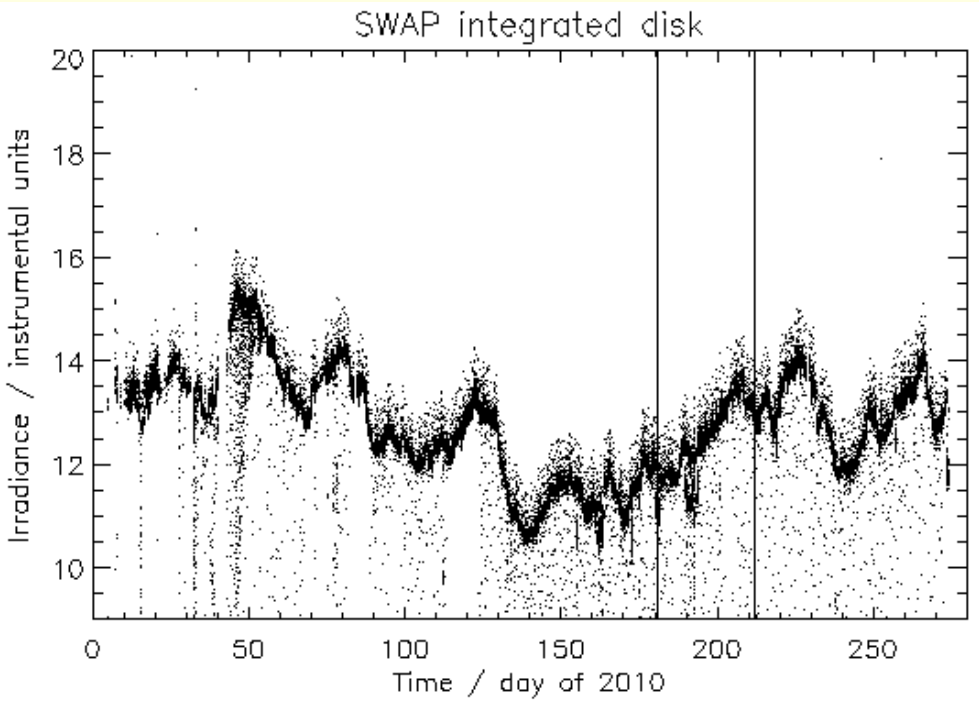
GOES vs. LYRA proxies

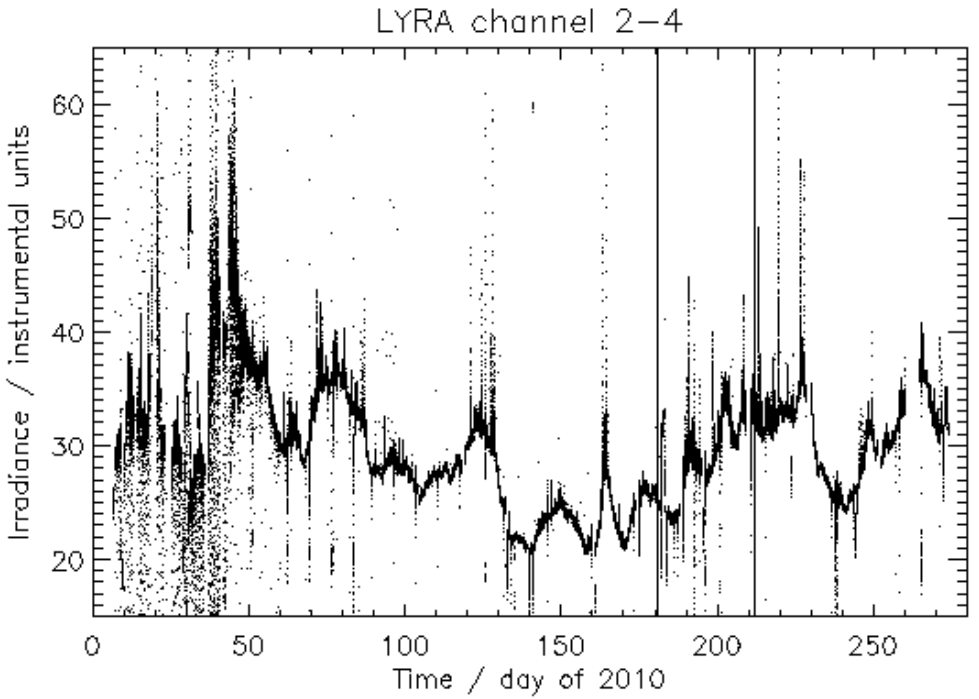


Jan - Sep 2010

SWAVINT and LYRA
look quite similar

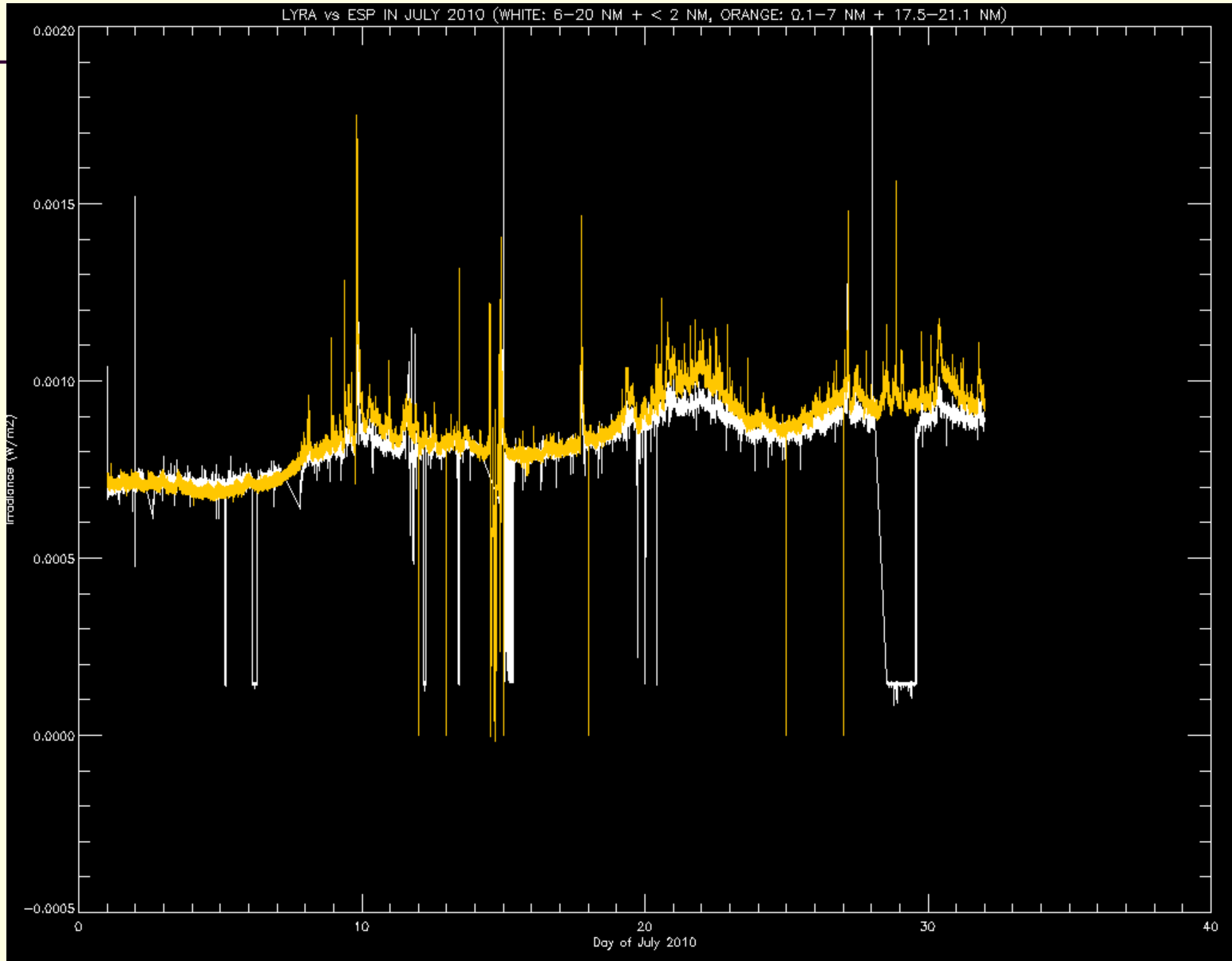
LYRA shows flares
in addition to EUV





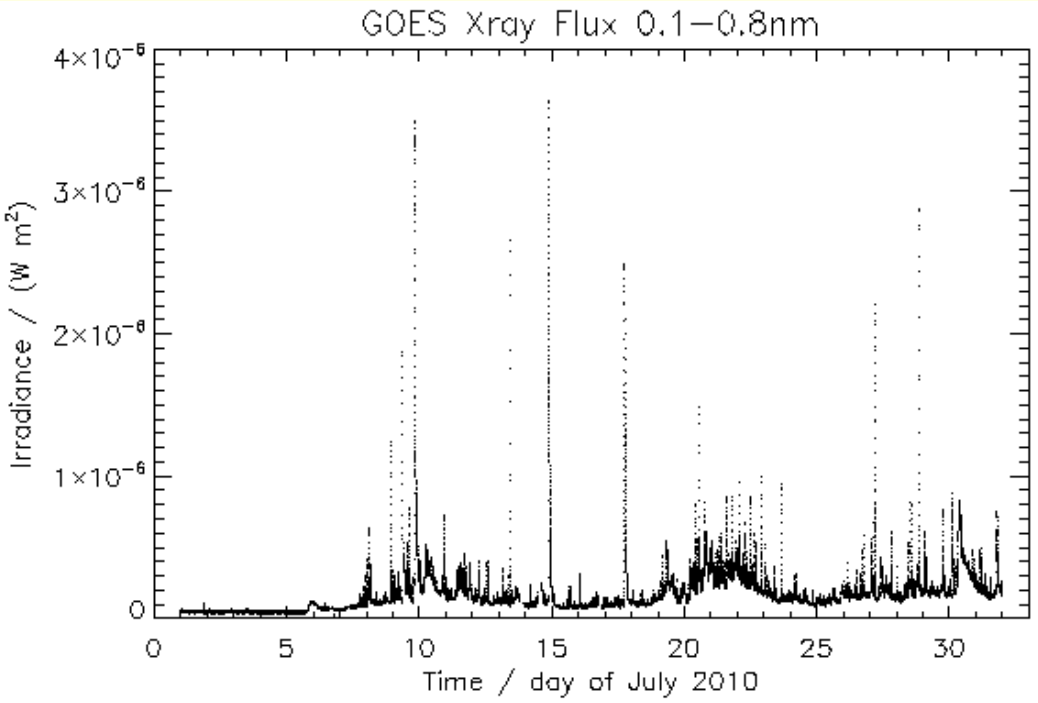
July 2010

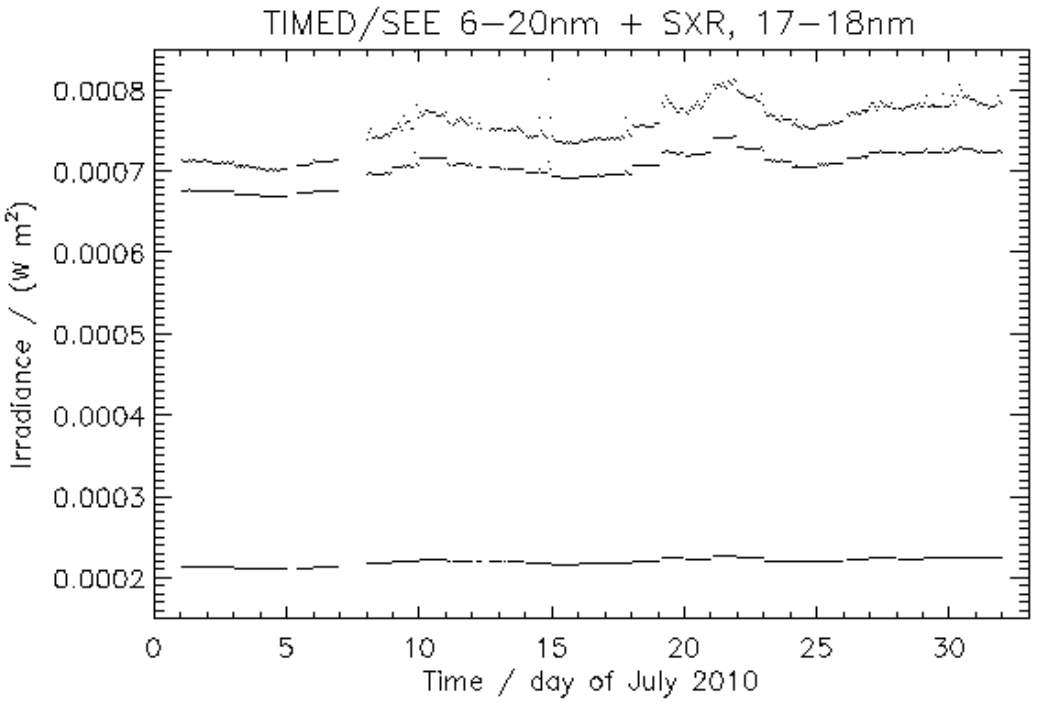
LYRA vs. EVE



July 2010

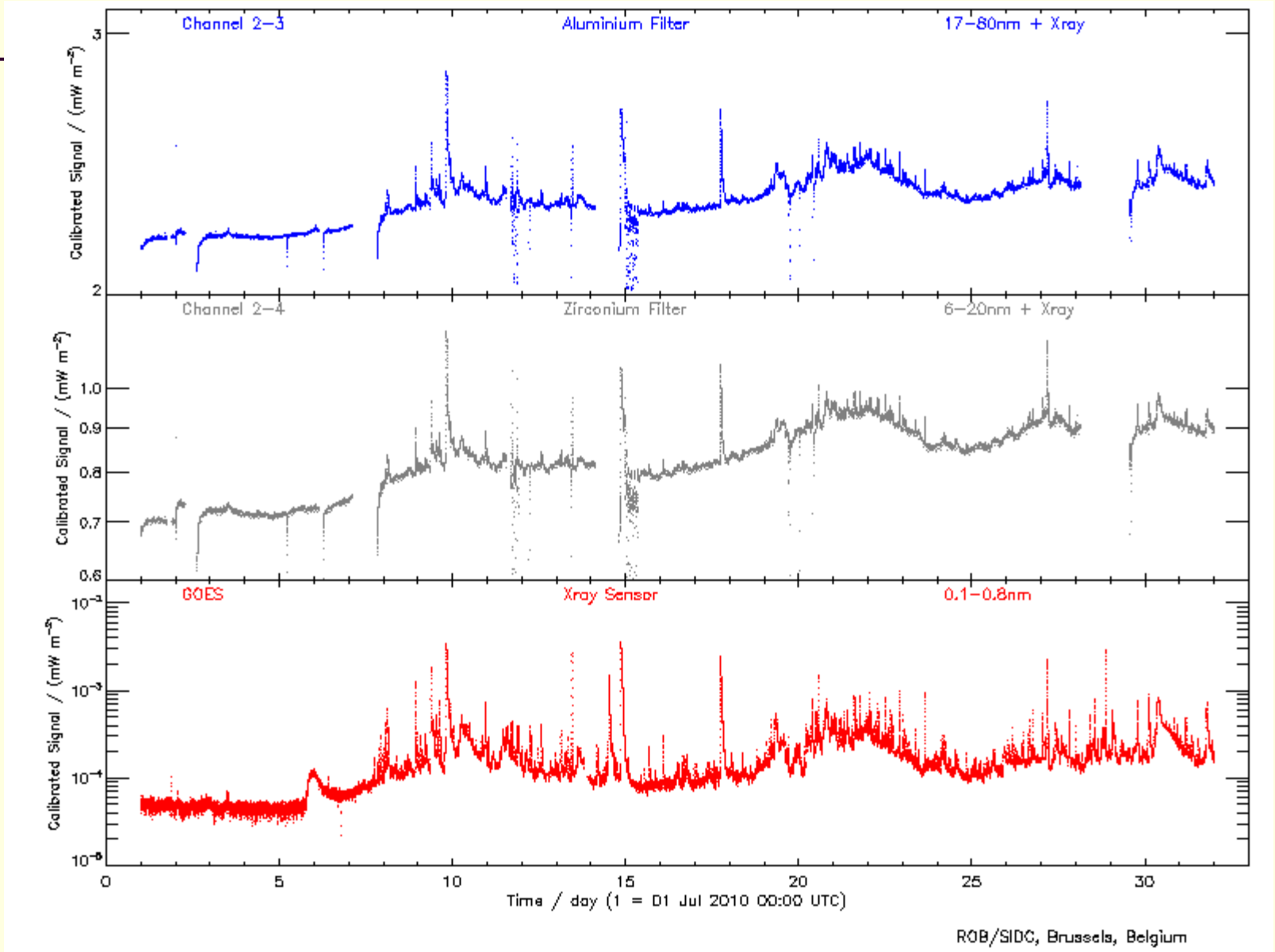
GOES vs.
TIMED/SEE



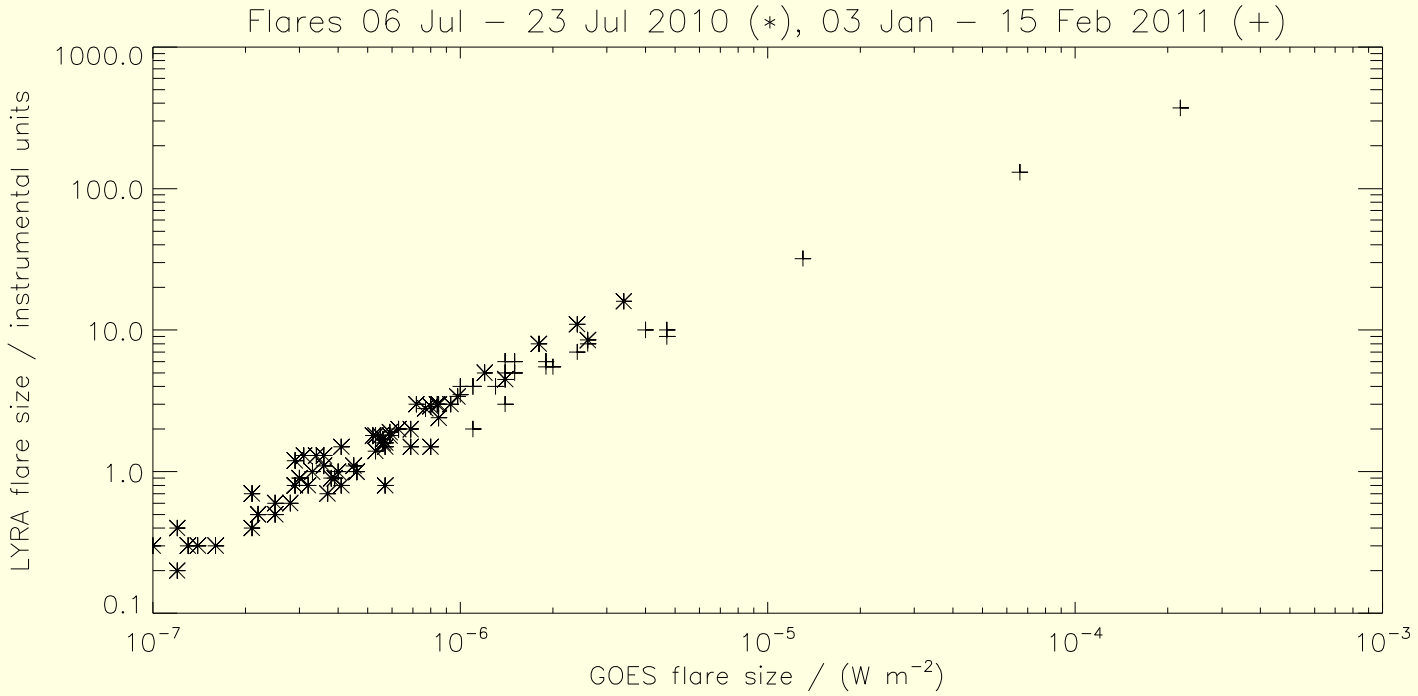


July 2010

LYRA vs. GOES



LYRA flare size

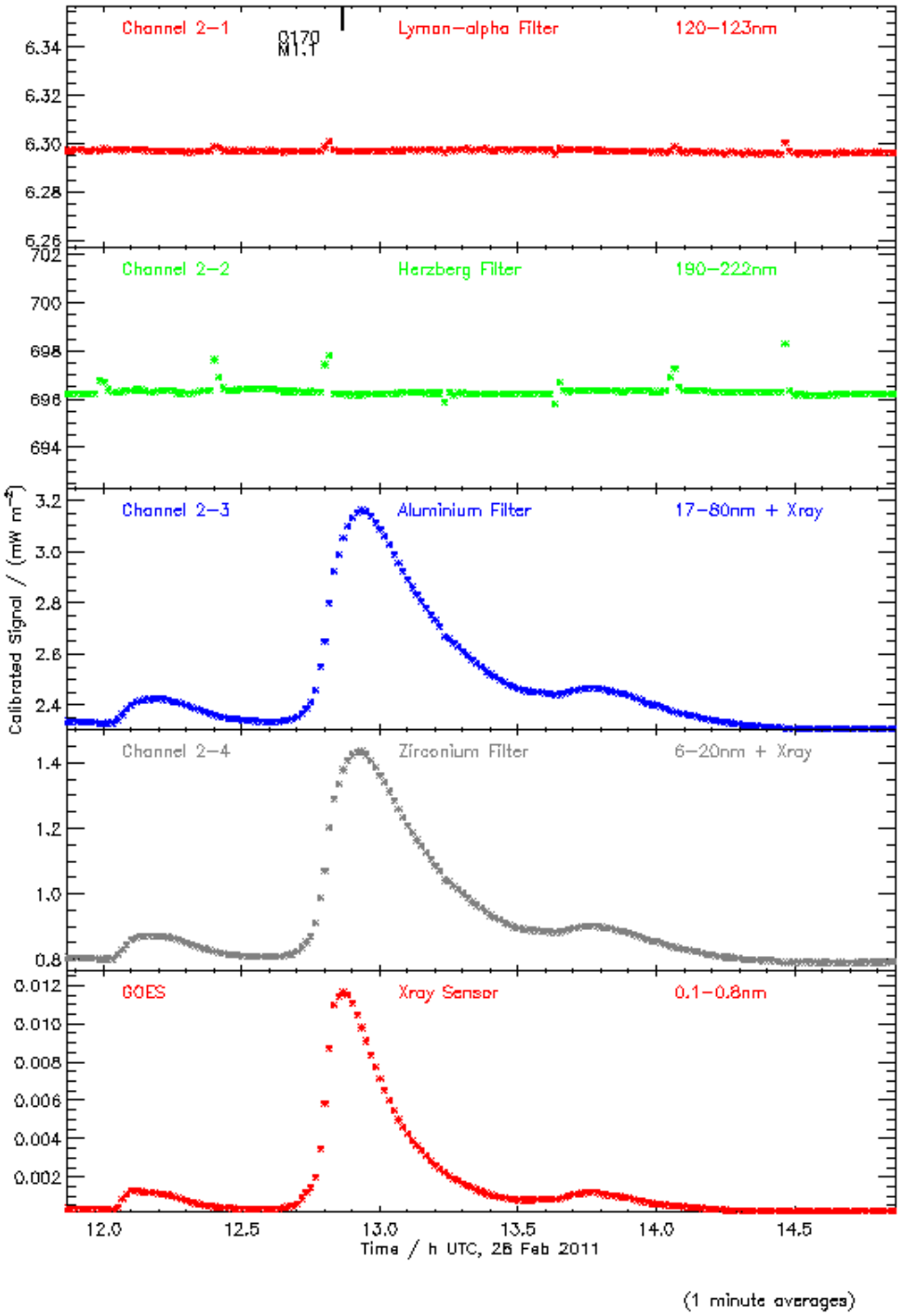


LYRA background-subtracted flux in Zr (channel 2-4)

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

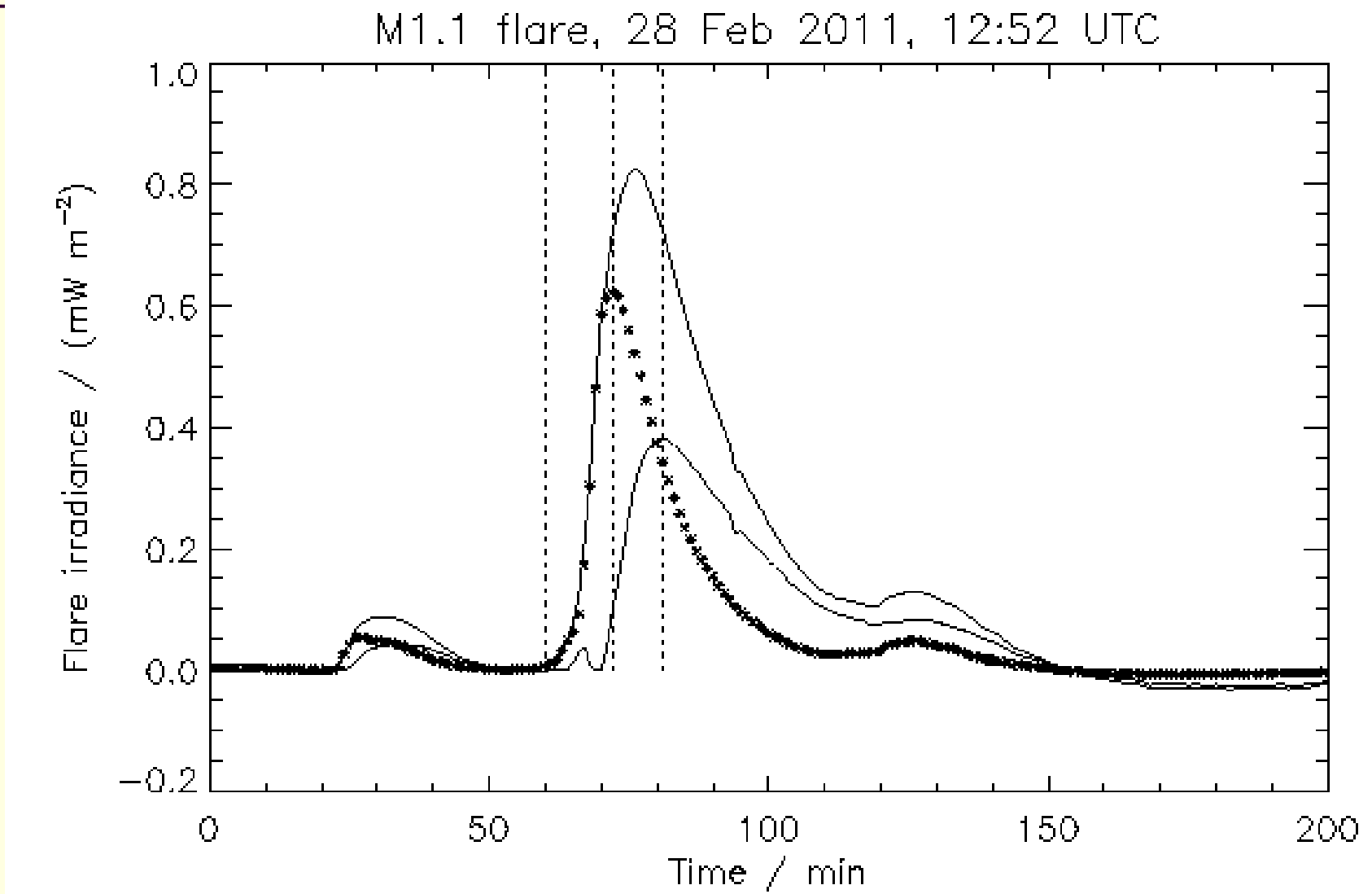
Example

M1.1 flare
28 Feb 2011



Flare components

ch2-3 = SXR+EUV



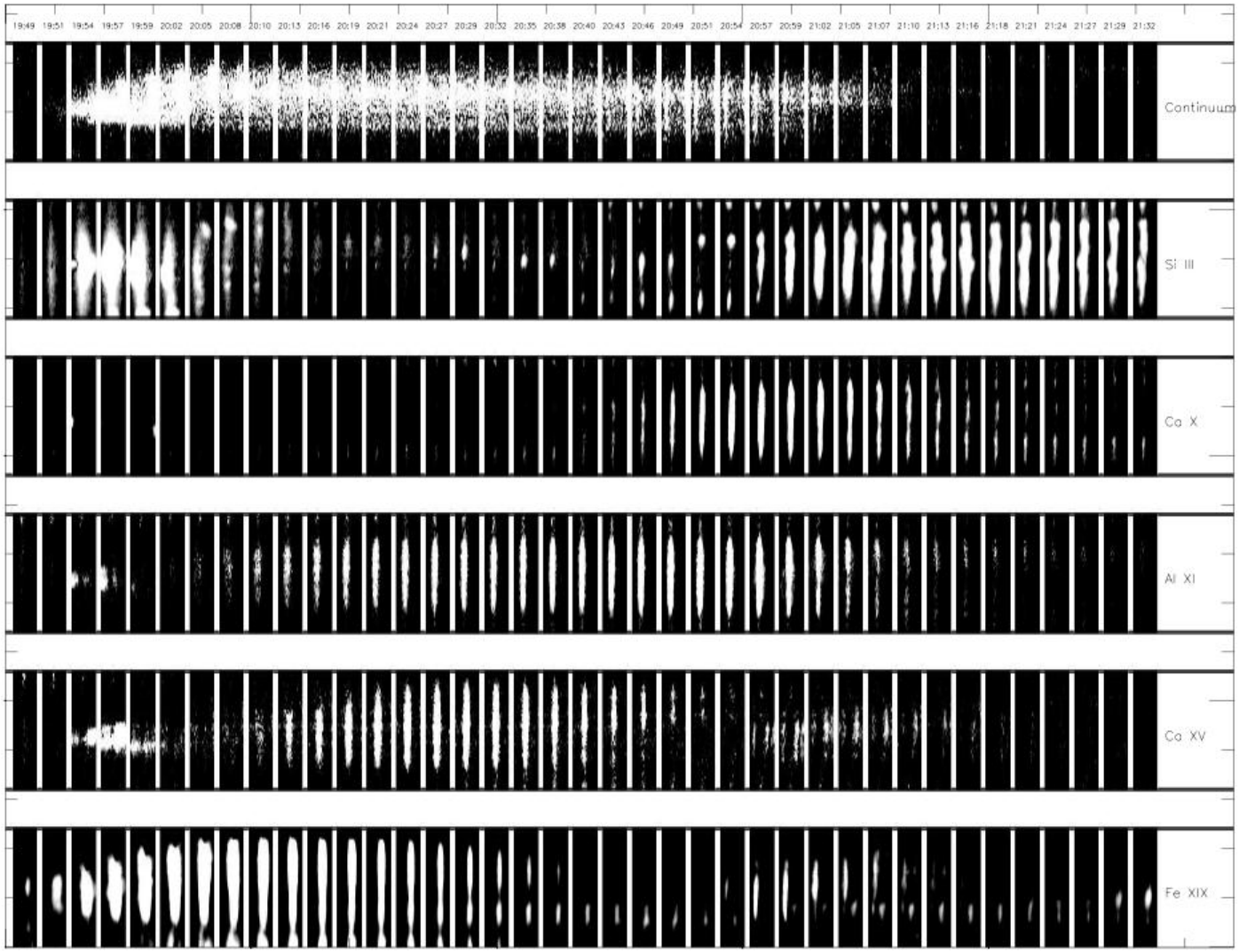
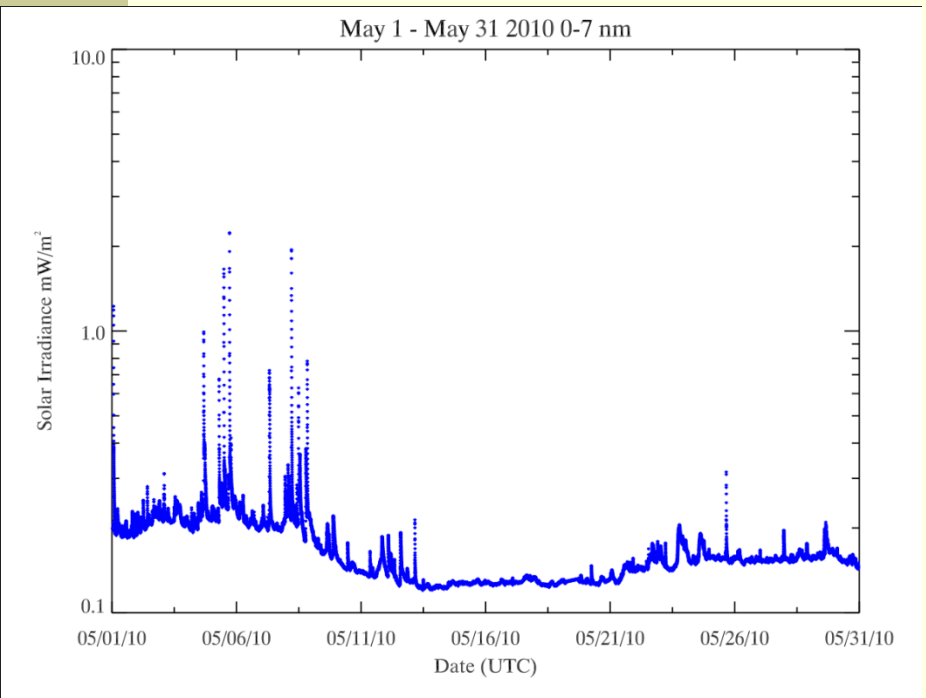
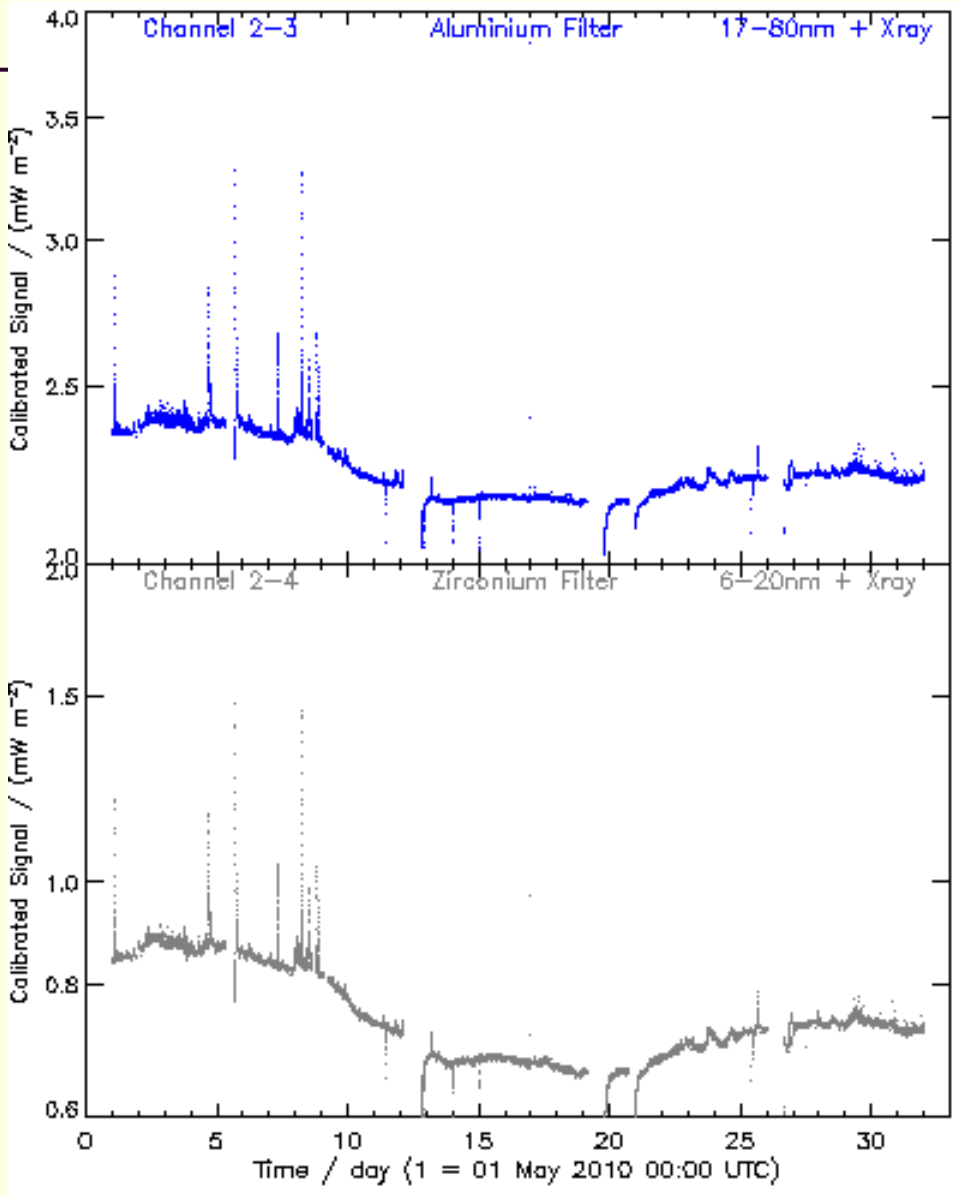


FIG. 8.—Background-subtracted spectra for the free-free continuum, for Si III, Ca X, Al XI, Ca XV, and Fe XIX, as a function of time. A Ne VI second-order line is present in the Fe XIX spectral window between 20:50 and 21:10 UT.

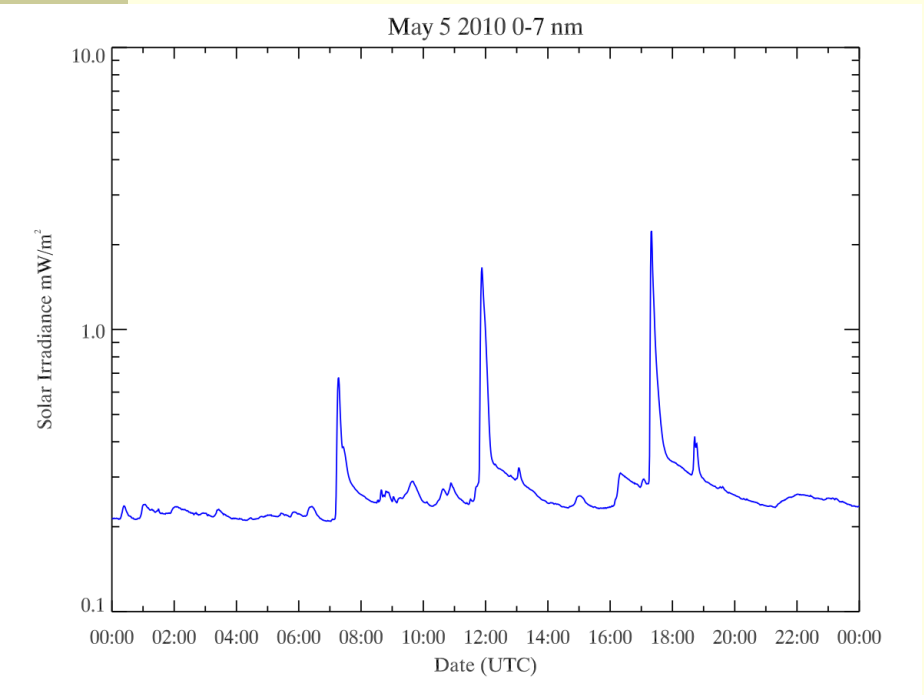
May 2010 EVE vs. LYRA

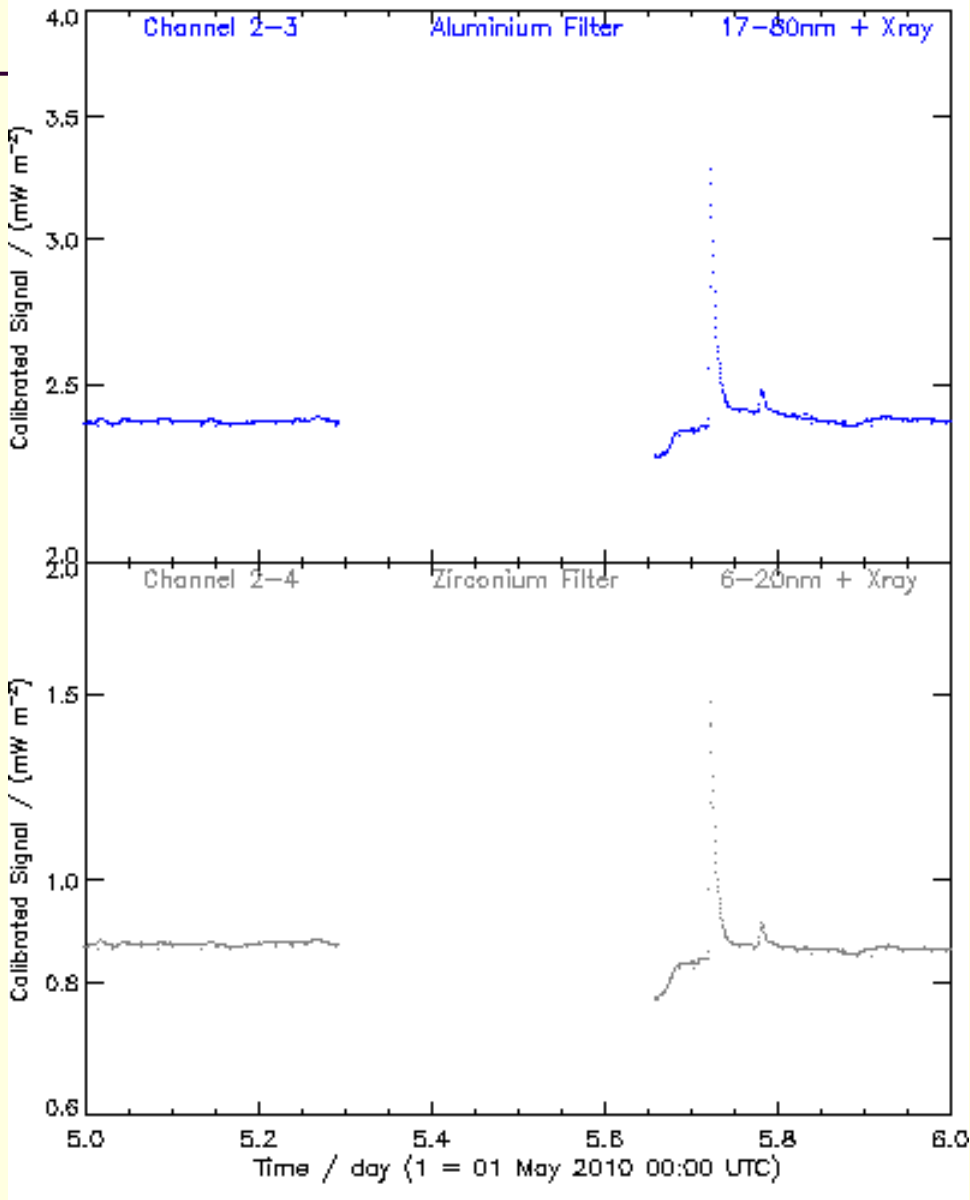




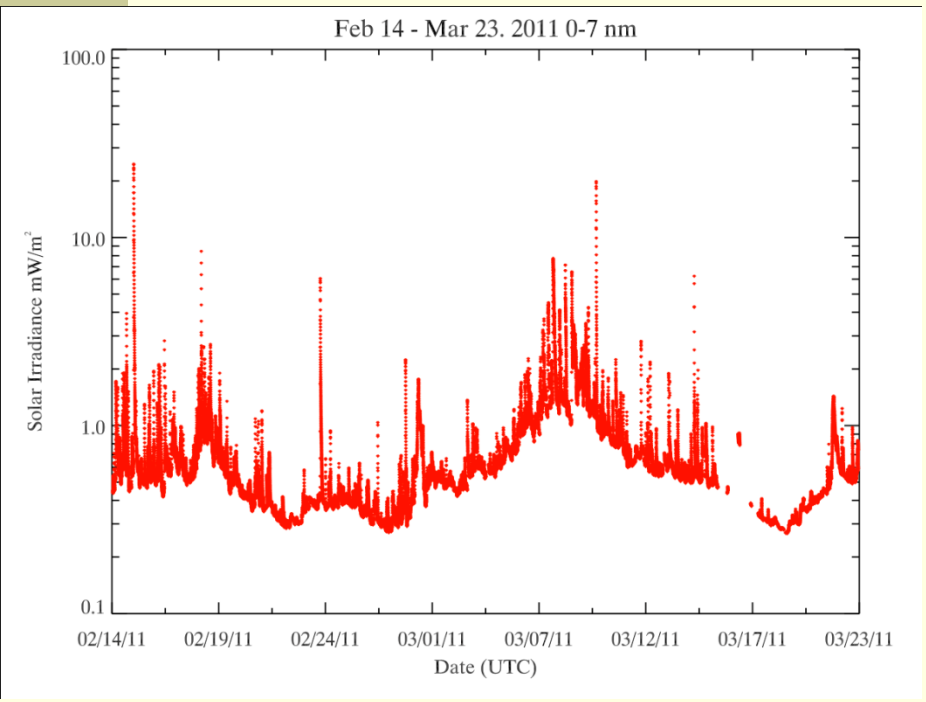
M1.2 flare 05 May 2010 17:19 UTC

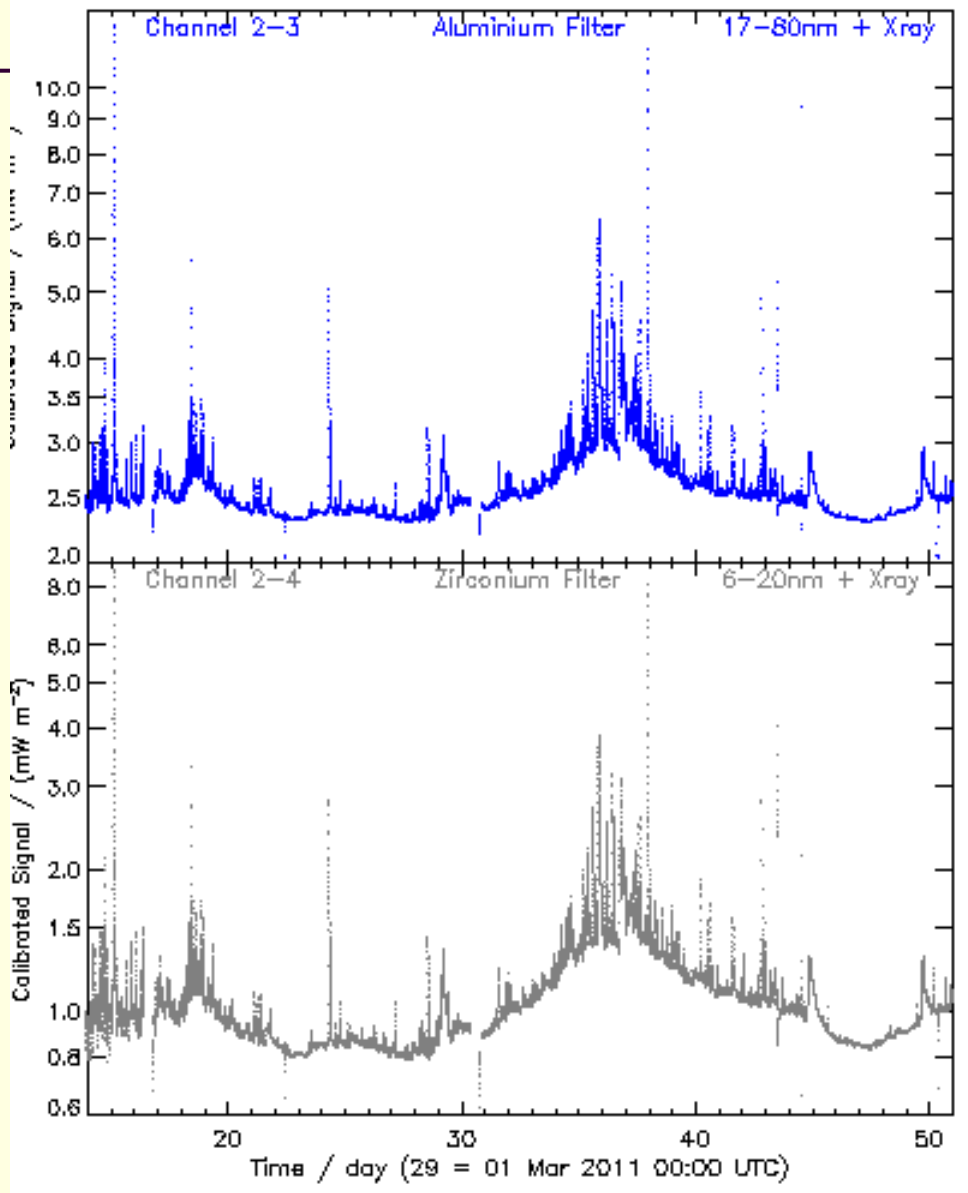
GOES (0.1 - 0.8 nm) ~0.012 mW/m^2
LYRA (0 - 2 nm) ~0.7 mW/m^2
LYRA (0 - 5 nm) ~1.0 mW/m^2
EVE (0 - 7 nm) ~2.0 mW/m^2





Feb/Mar 2011 EVE vs. LYRA



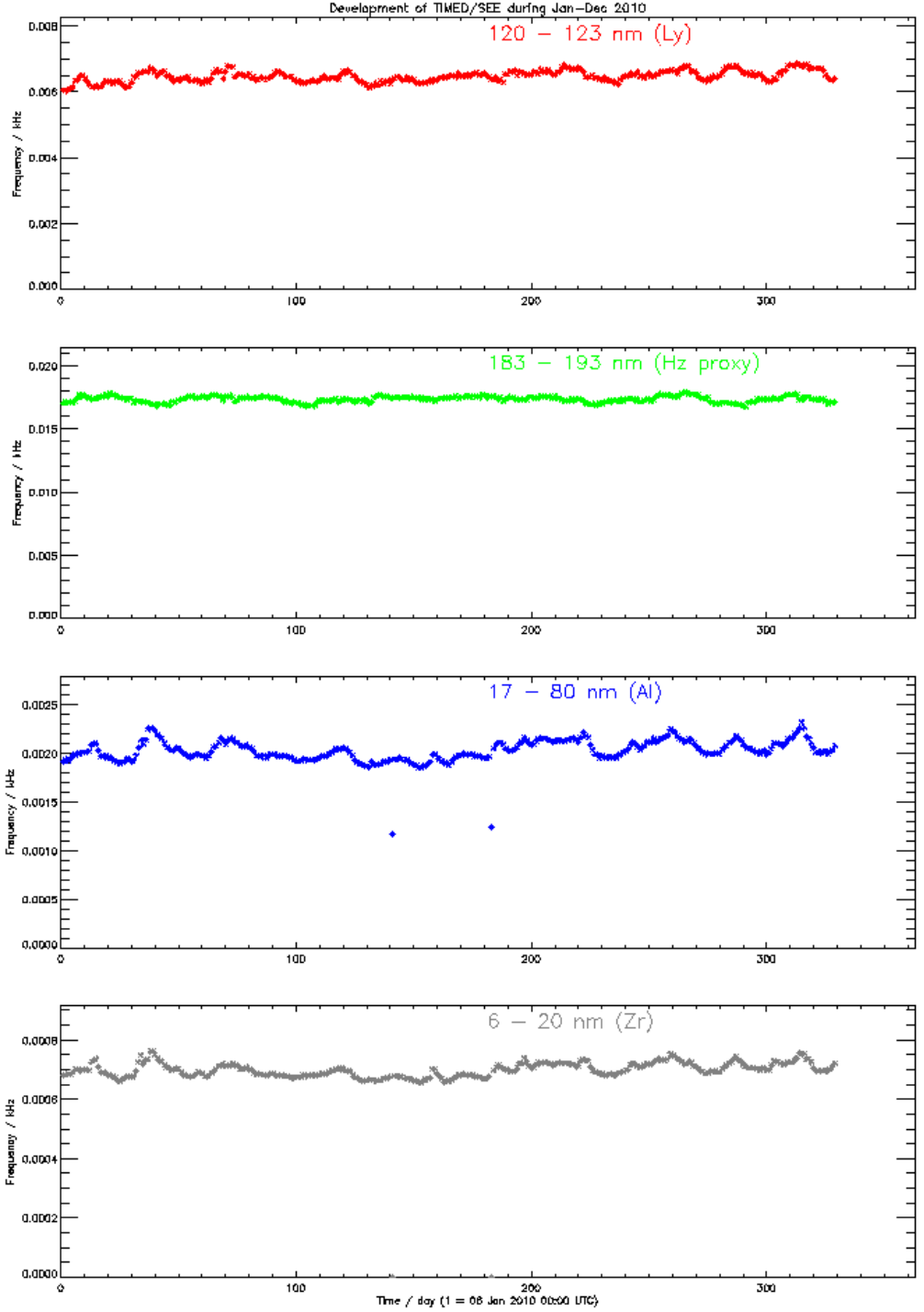


Appendix

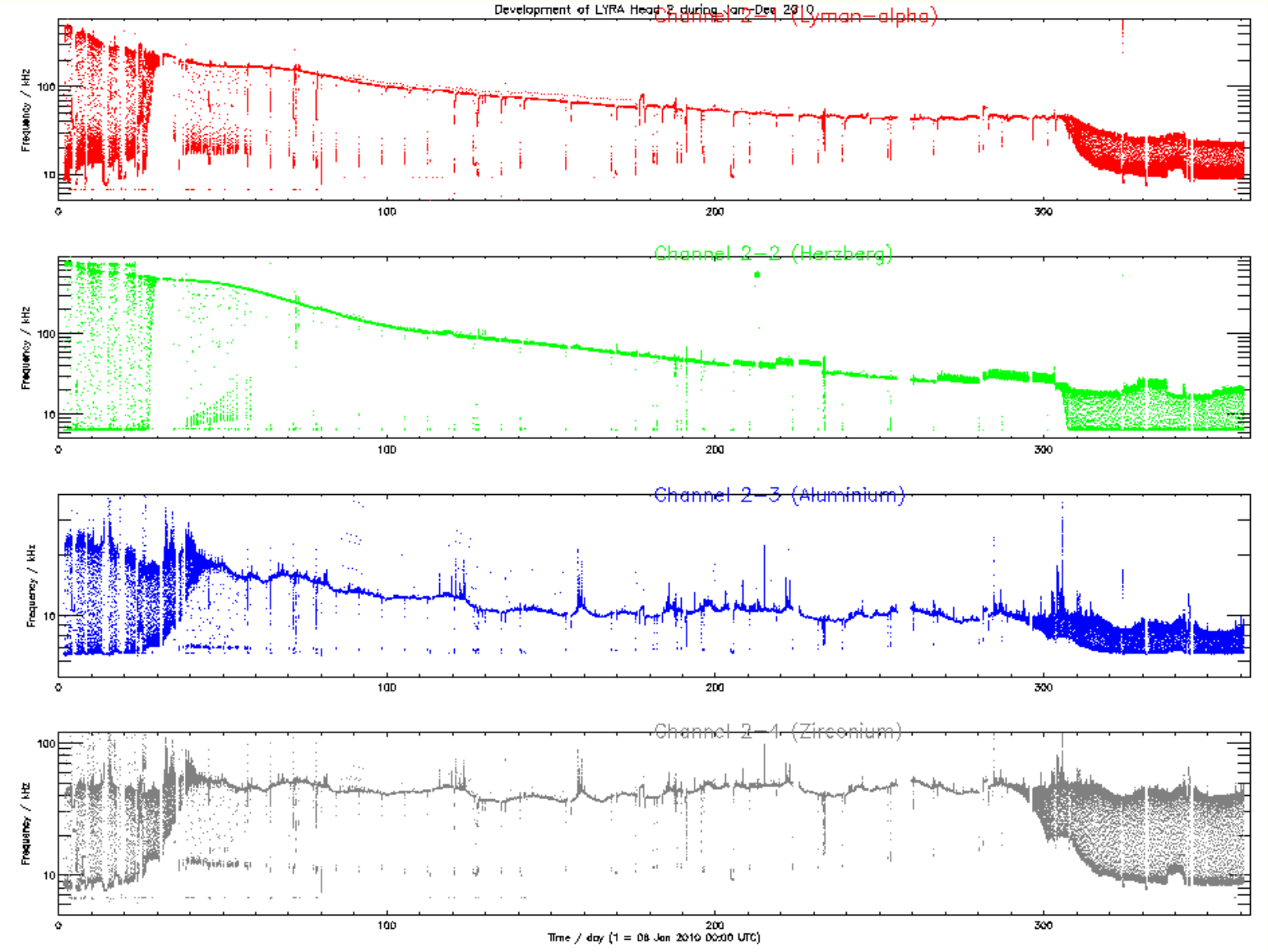
LYRA calibration details

Calibration

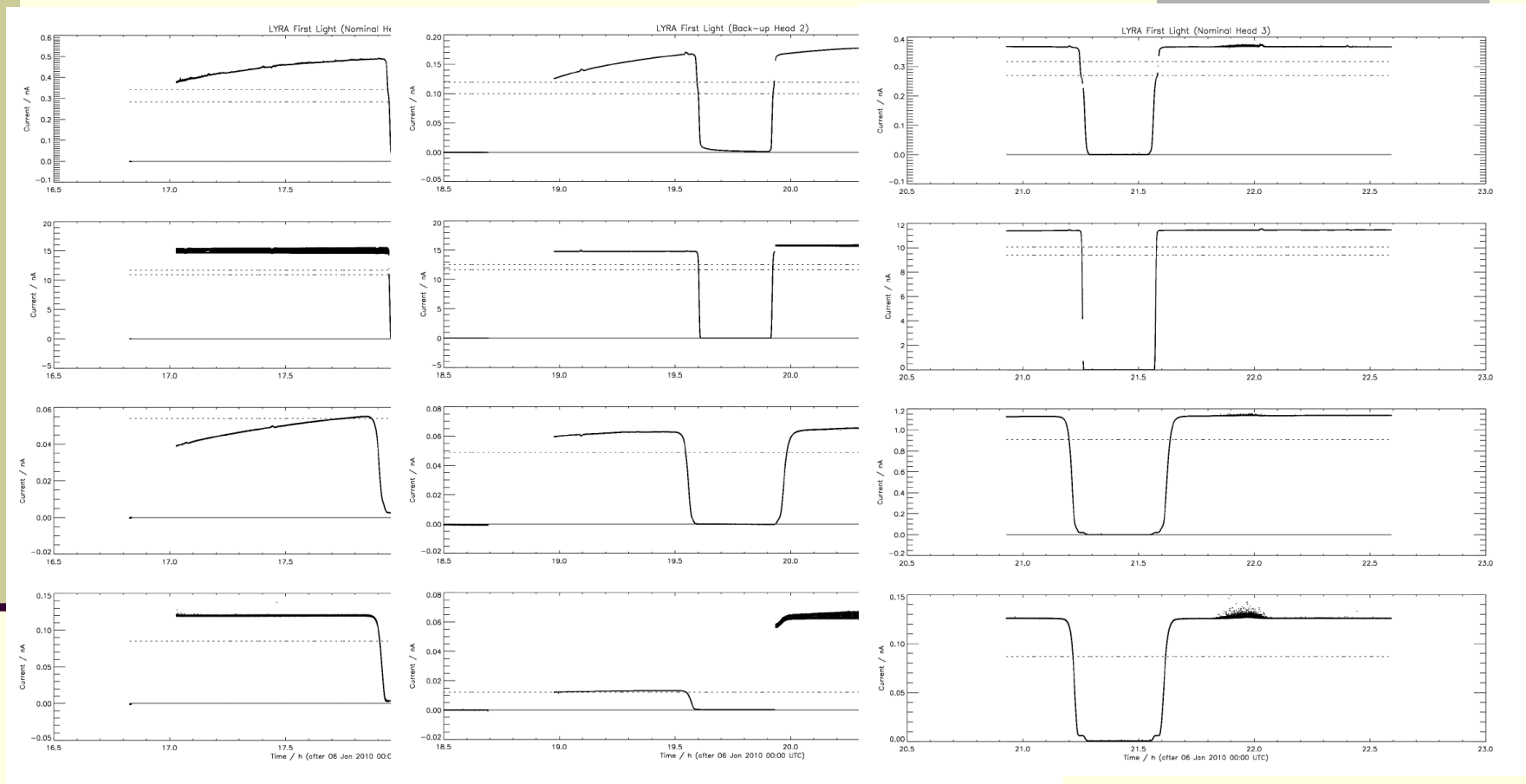
2010 according to TIMED/SEE



Calibration – Problem: 2010 according to LYRA

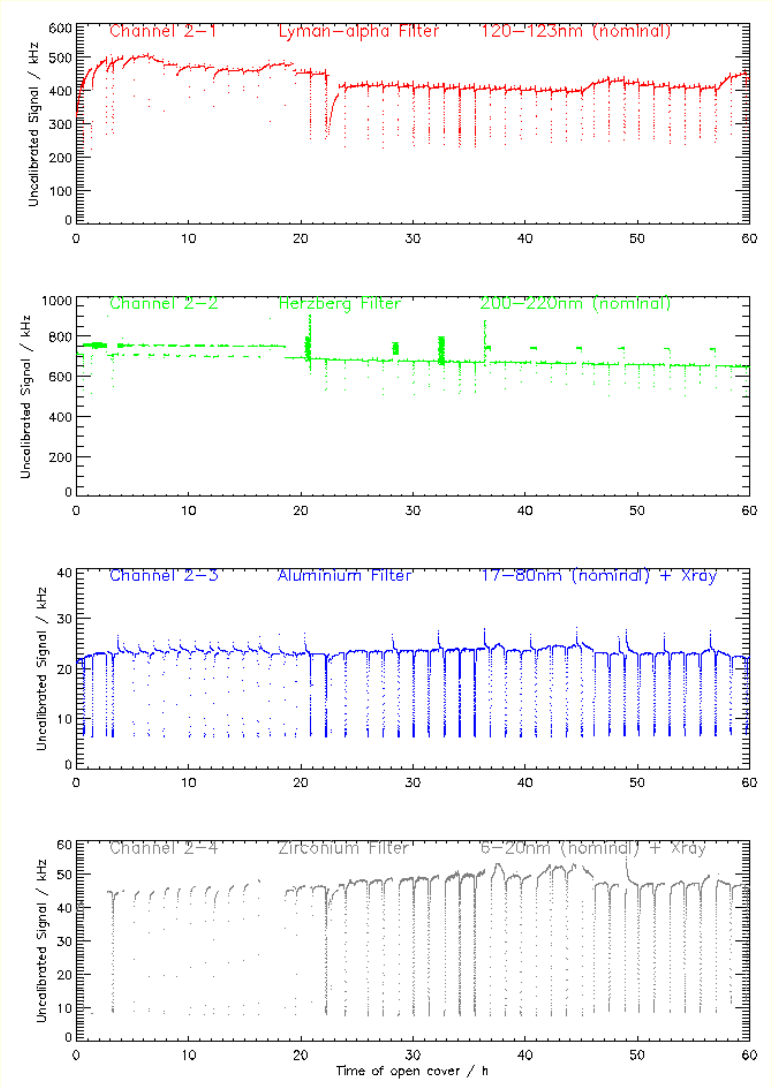


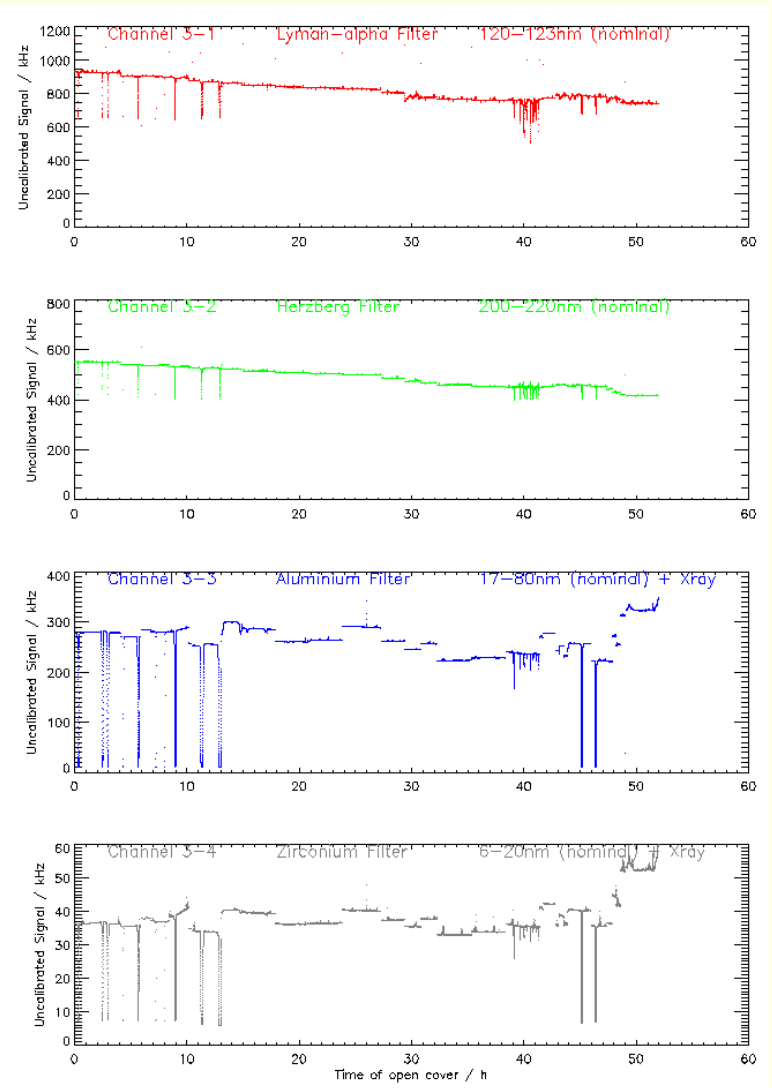
First Light acquisition (06 Jan 2010)



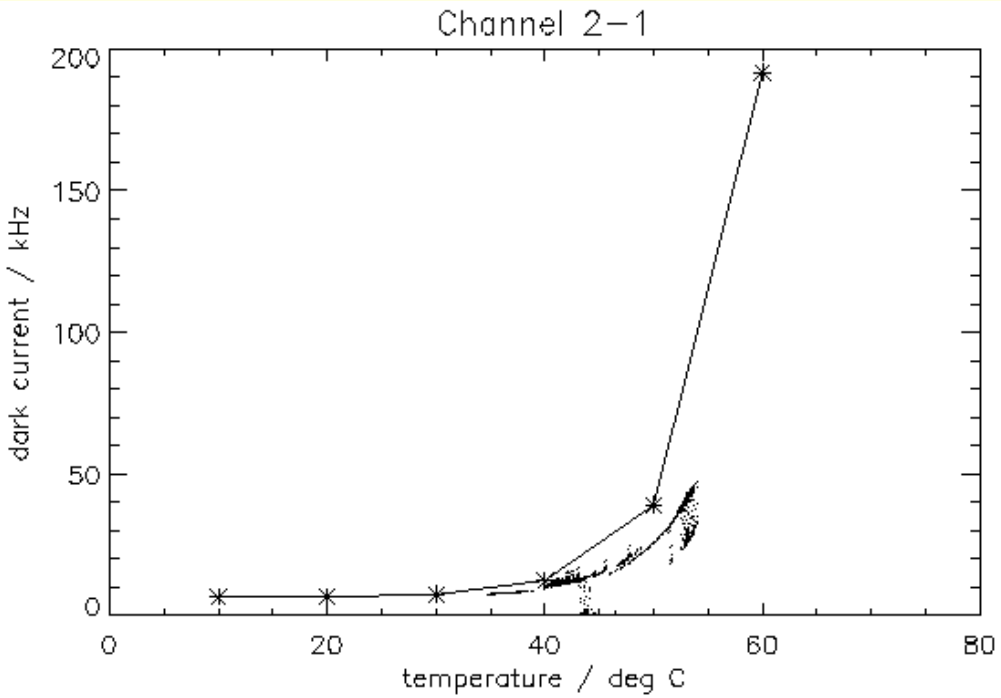
… no degradation so far …

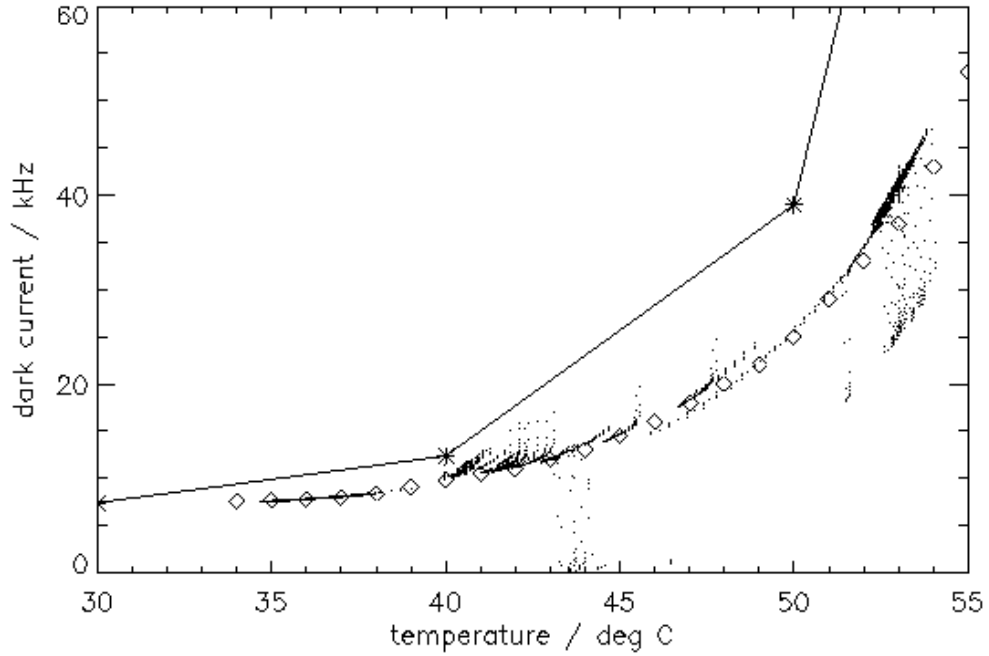
Start with “First Light”…



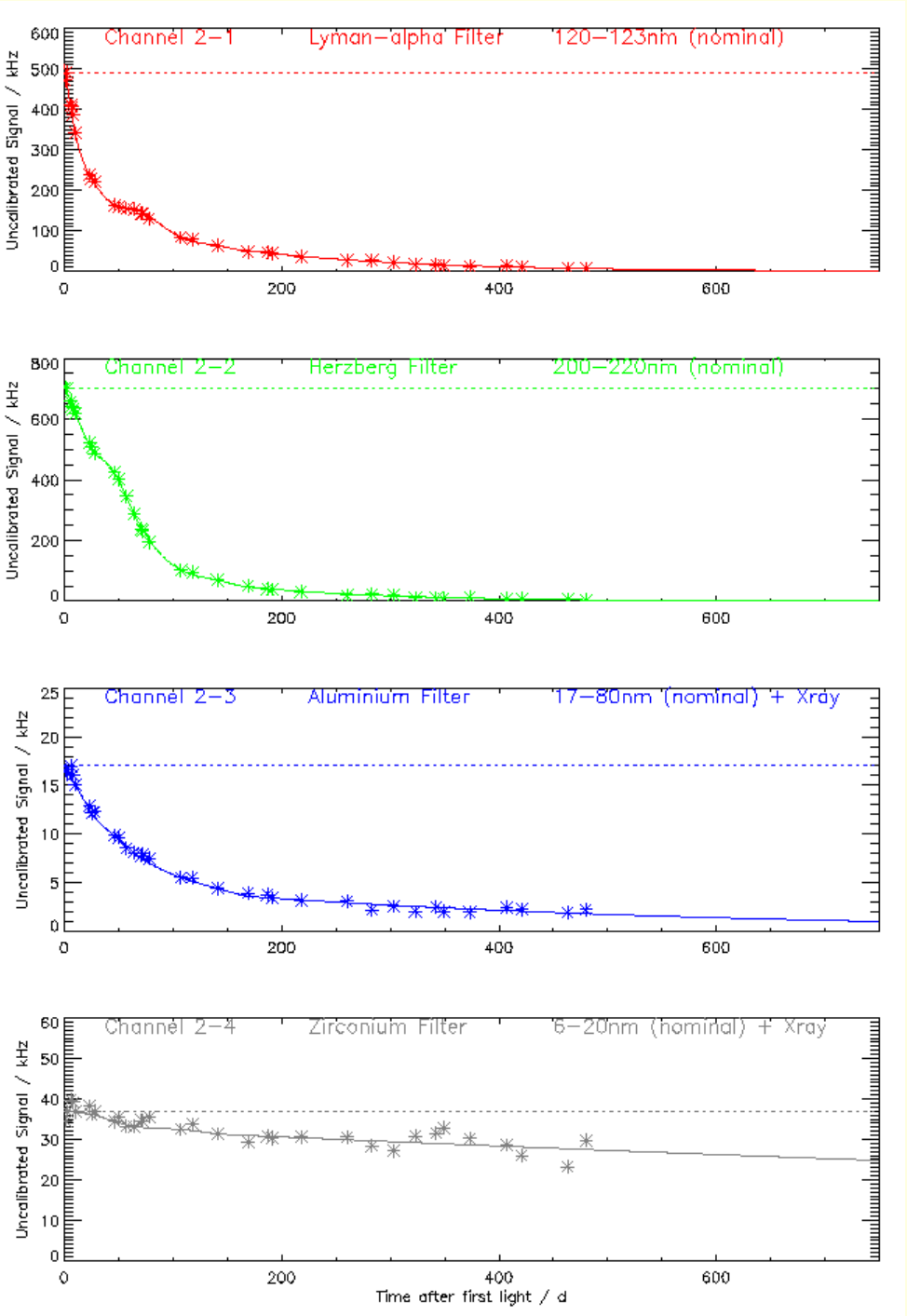


…estimate and subtract dark currents…





… fit the degradation …



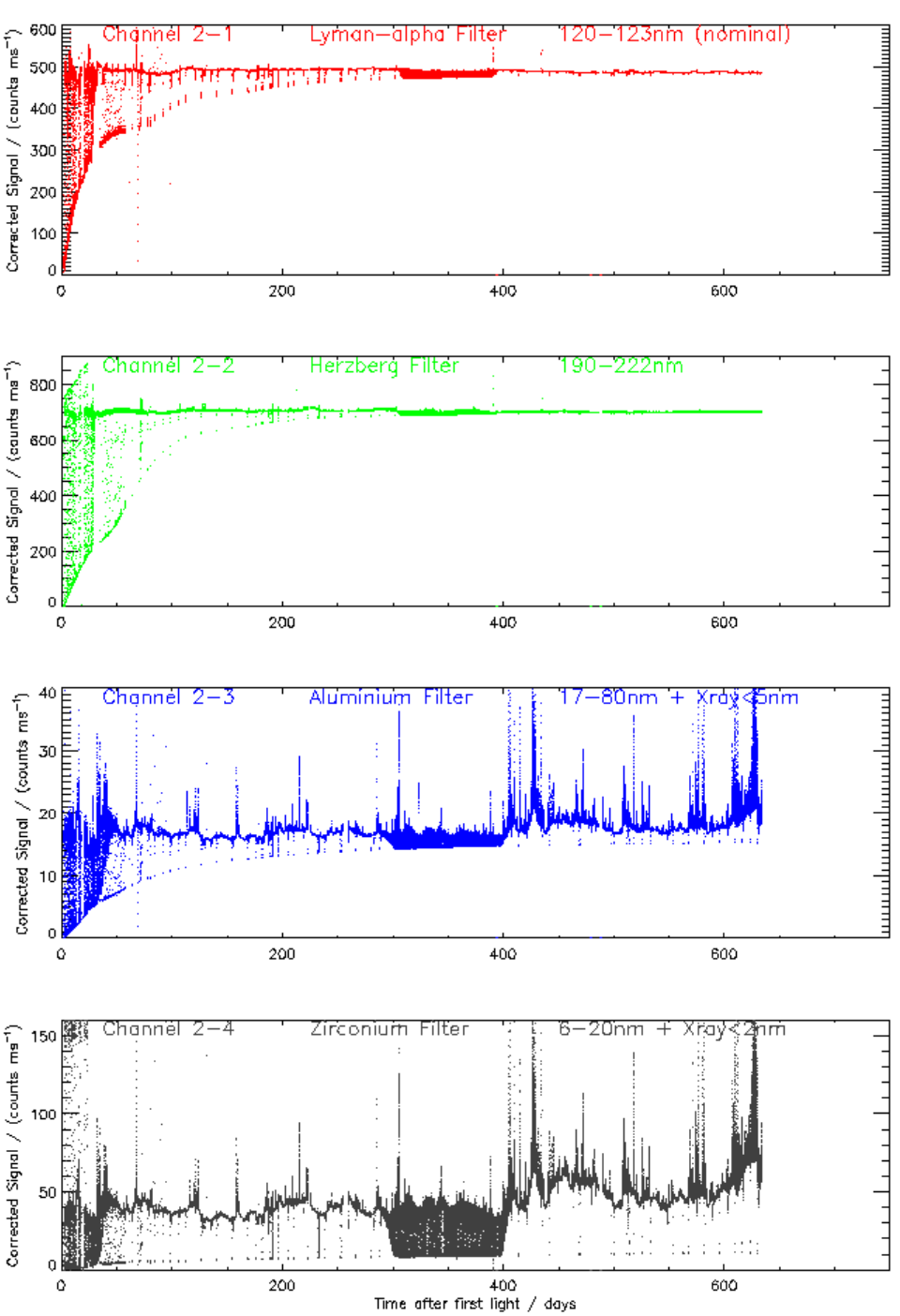
… and add it

Plausibility:

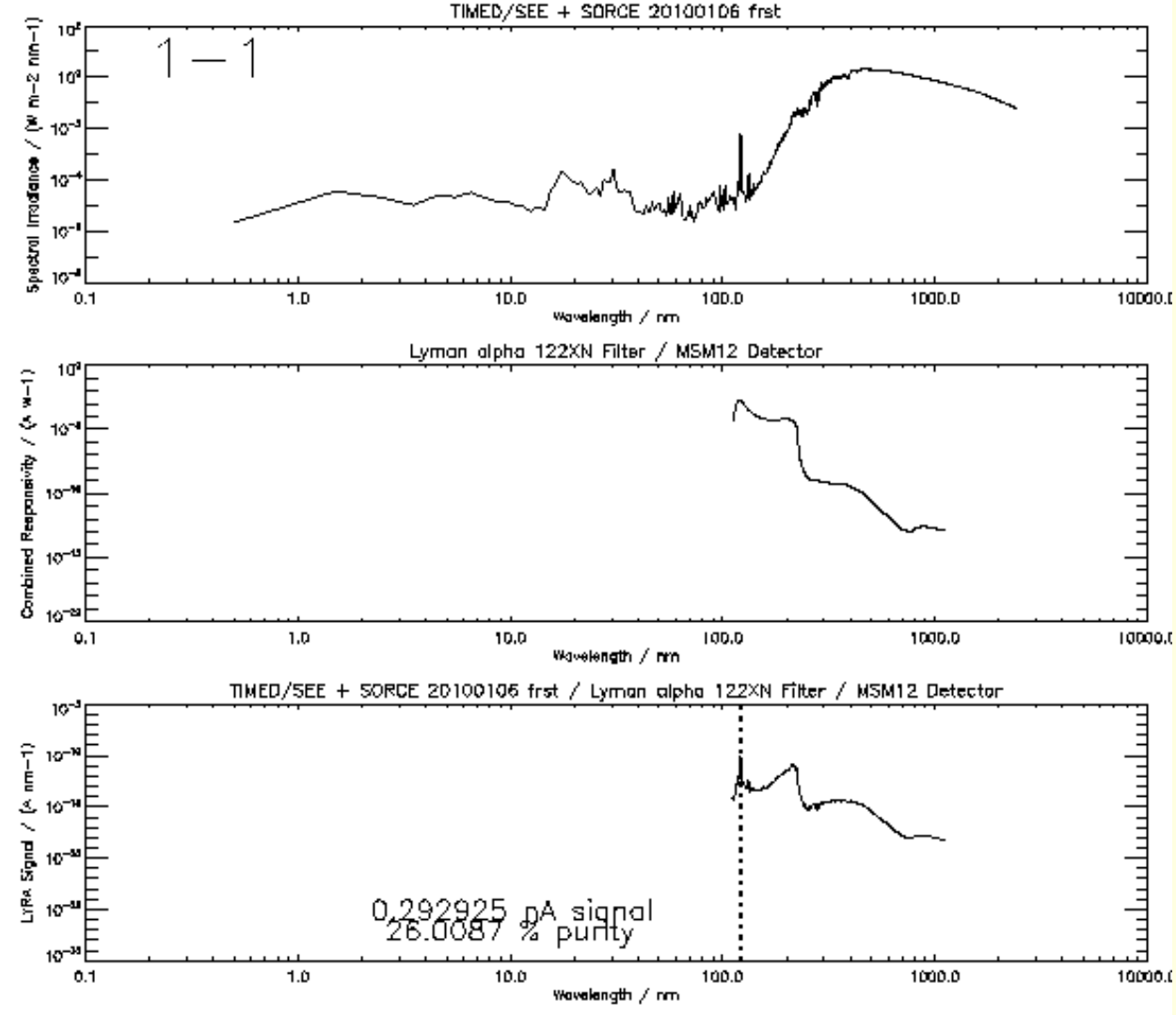
- Artifacts in channels 1 and 2
- Non-degraded SXR in channels 3 and 4

Disadvantages:

- Underestimate EUV in channels 3 (and 4)
- Distortion of occultations



LYRA Radiometric Model, ch1-1 simulated

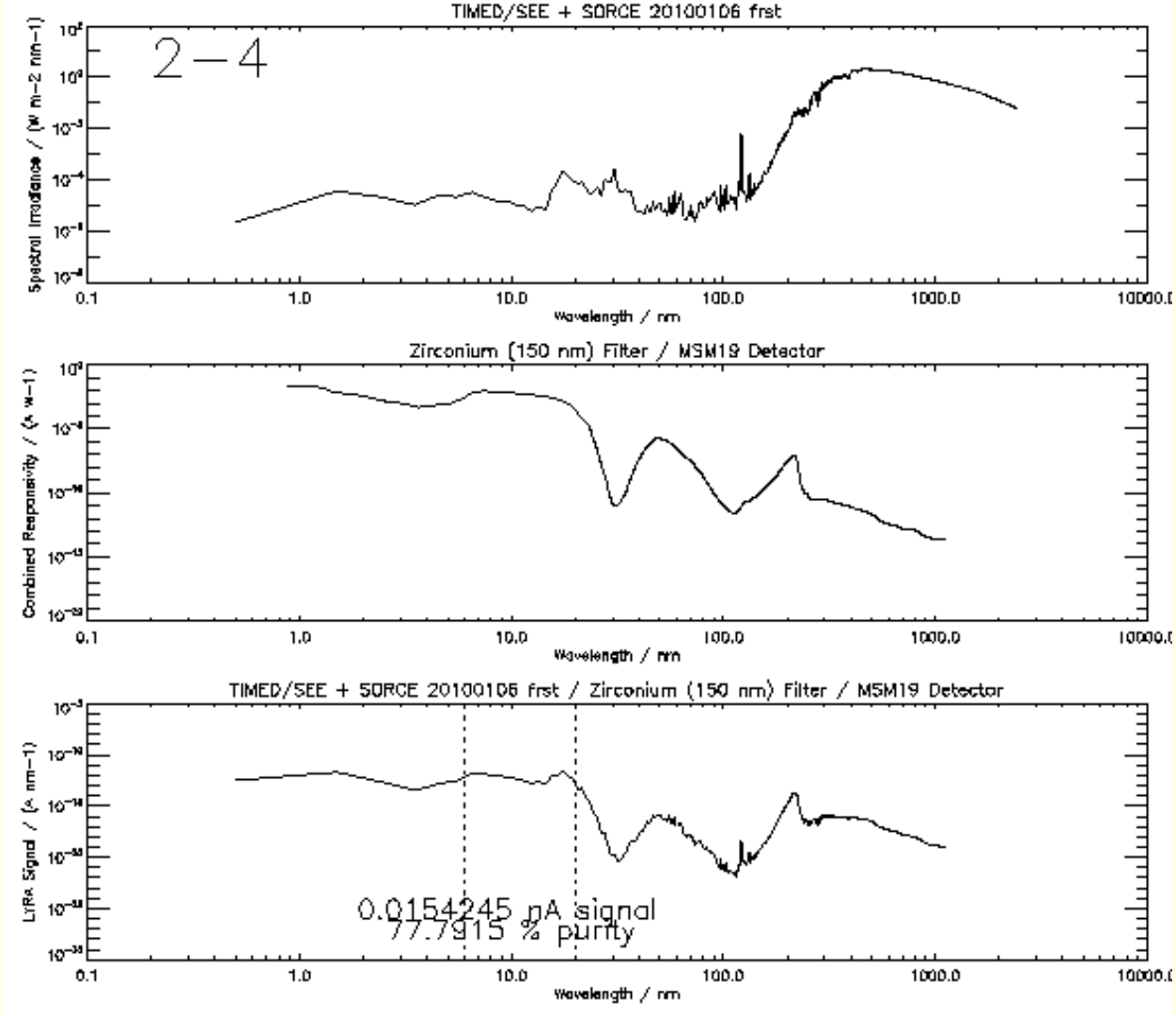


Observed vs. LRM-simulated values (head 1)

	ch1-1	ch1-2	ch1-3	ch1-4
sim	0.2929 nA	11.28 nA	0.06399 nA	0.1064 nA
obs	~1300 kHz	620 kHz	24.0 kHz	37.5 kHz
dc	-9.0 kHz	-6.6 kHz	-6.8 kHz	-7.2 kHz
VFC,resis.	=>	=>	=>	=>
	0.5311 nA	12.78 nA	0.07116 nA	0.1216 nA
	+81.3%	+13.3%	+11.2%	+14.3%

(kHz = counts/ms)

LYRA Radiometric Model, ch2-4 simulated



Observed vs. LRM-simulated values (head 2)

	ch2-1	ch2-2	ch2-3	ch2-4
sim	0.1030 nA	12.07 nA	0.05765 nA	0.1542 nA
obs	500 kHz	710 kHz	23.0 kHz	45.0 kHz
dc	-8.0 kHz	-6.5 kHz	-6.4 kHz	-7.5 kHz
VFC,resis. =>	0.1969 nA	=> 14.81 nA	=> 0.06780 nA	=> 0.1539 nA
	+91.2%	+22.8%	+17.6%	-2.0%

Observed vs. LRM-simulated values (head 3)

	ch3-1	ch3-2	ch3-3	ch3-4
sim	0.3686 nA	9.693 nA	1.0250 nA	0.1082 nA
obs	930 kHz	552 kHz	280 kHz	36.2 kHz
dc	-10.0 kHz	-6.5 kHz	-6.4 kHz	-6.2 kHz
VFC,resis.	=>	=>	=>	=>
	0.3807 nA	11.44 nA	1.1400 nA	0.1249 nA
	+3.3%	+18.0%	+11.2%	+15.4%

Resulting conversion to physical units

+81.3%	+13.3%	+11.2%	+14.3% (1)
+91.2%	+22.8%	+17.6%	-2.0% (2)
+3.3%	+18.0%	+11.2%	+15.4% (3)
=> ? (0.0%)	=> +18.0%	=> +13.3%	=> +9.2%

ch*-1	ch*-2	ch*-3	ch*-4
(120-123nm)	(190-222nm)	(17-80&0-5nm)	(6-20&0-2nm)
0.006320 W/m²	0.5914 W/m²	0.002008 W/m²	0.0007187 W/m²
? (0.0%)	+18.0%	+13.3%	+9.2%
=>			
0.006320 W/m²	0.6979 W/m²	0.002275 W/m²	0.0007848 W/m²
which corresponds to ...			
492 kHz	703.5 kHz	16.6 kHz	37.5 kHz

(Example: Head 2, dark currents subtracted, degradation added.
Simple linear conversion!)

Formal:

$$i = is + id$$

i=measured photocurrent

is=solar photocurrent

id=dark current

$$is = A/T \int_t \int_\lambda E(\lambda,t)\ F(\lambda)\ D(\lambda)\ d\lambda\ dt$$

λ=wavelength

A=detector surface

T=total exposure time

E(λ,t)=solar spectral irradiance

F(λ)=filter transmittance

D(λ)=detector spectral responsivity

Formal:

$$Ecal = \frac{iuncal - id + corr}{iuncal(FL) - id(FL)} \; Ecal(FL)$$

Ecal,Ecal(FL) = LYRA-channel spectral irradiance in W/m2 (FL=First Light)

iuncal,iuncal(FL)= unprocessed solar irradiance in counts/ms (proportional to solar photocurrent)

$$Ecal(FL) = \frac{iuncal(FL) - id(FL)}{is(FL)} \int Es(FL)\, d\lambda$$

Es(FL) = solar spectral irradiance from SEE&SOLSTICE

is(FL) = simulated photocurrent