LYRA

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

LYRA Calibration using TIMED and SORCE

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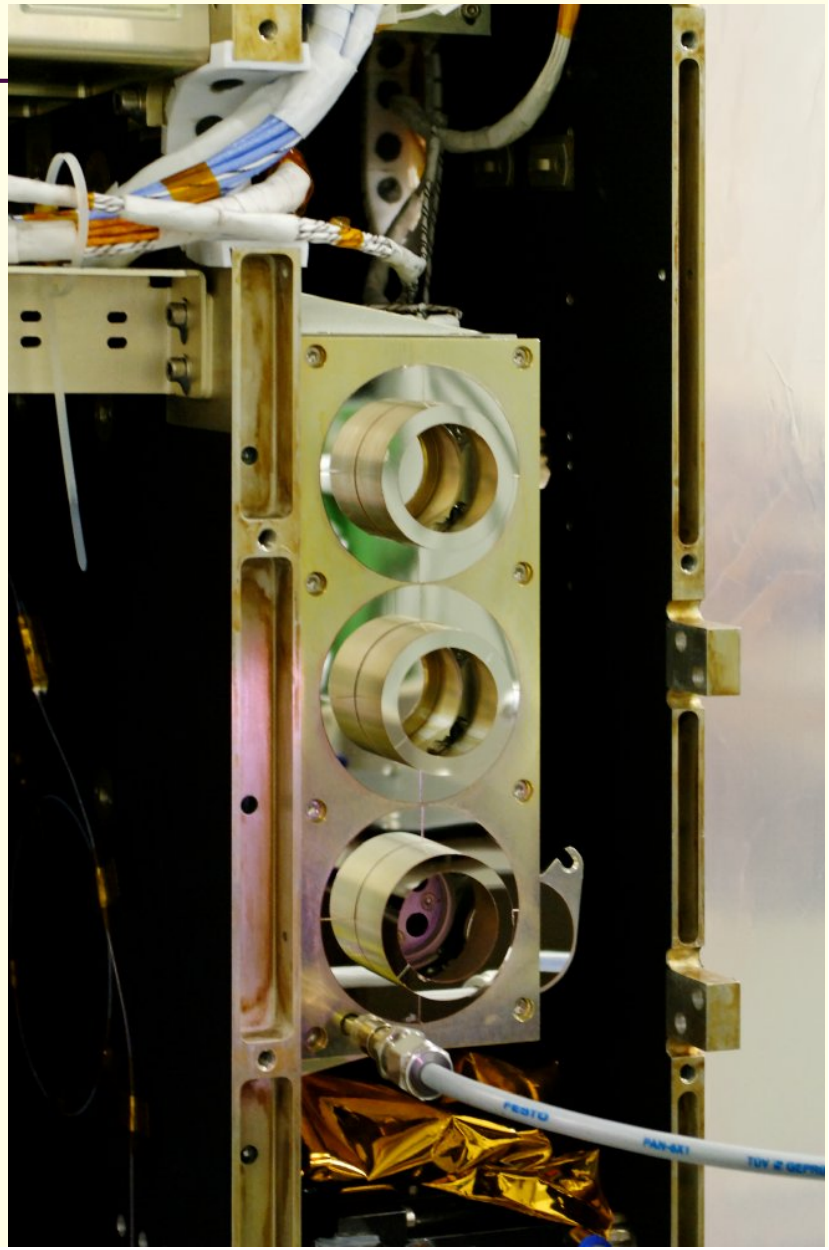
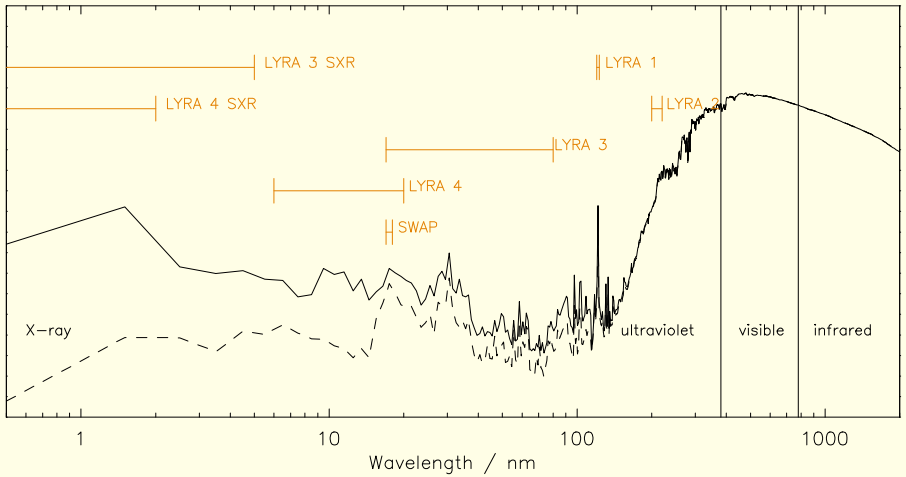
Solar EUV Irradiance Working Group
Inter-Calibration and Degradation of EUV Instruments
ROB, Brussels, Belgium, 15-18 Apr 2013

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

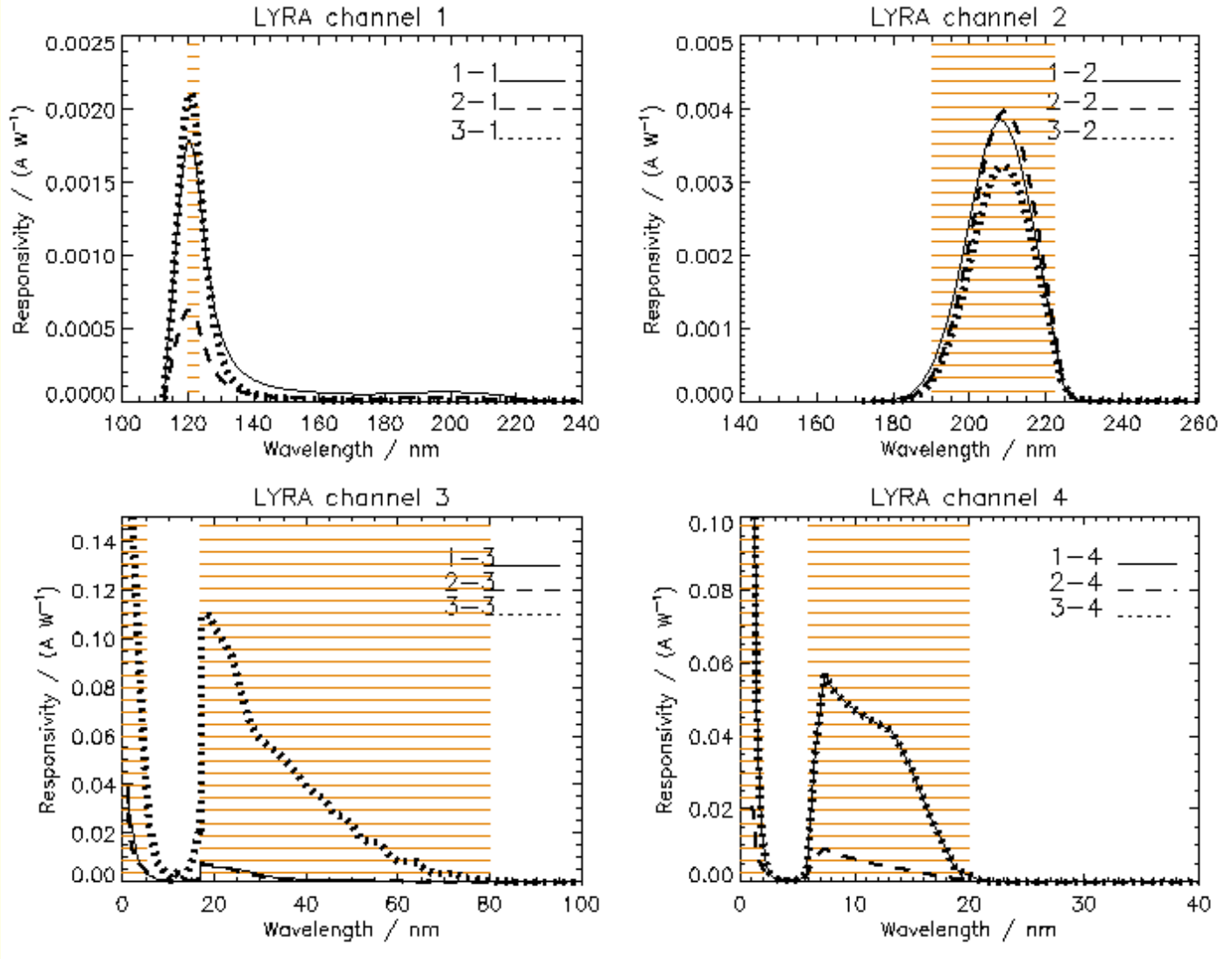


SWAP and LYRA spectral intervals for solar flares, space weather, and aeronomy



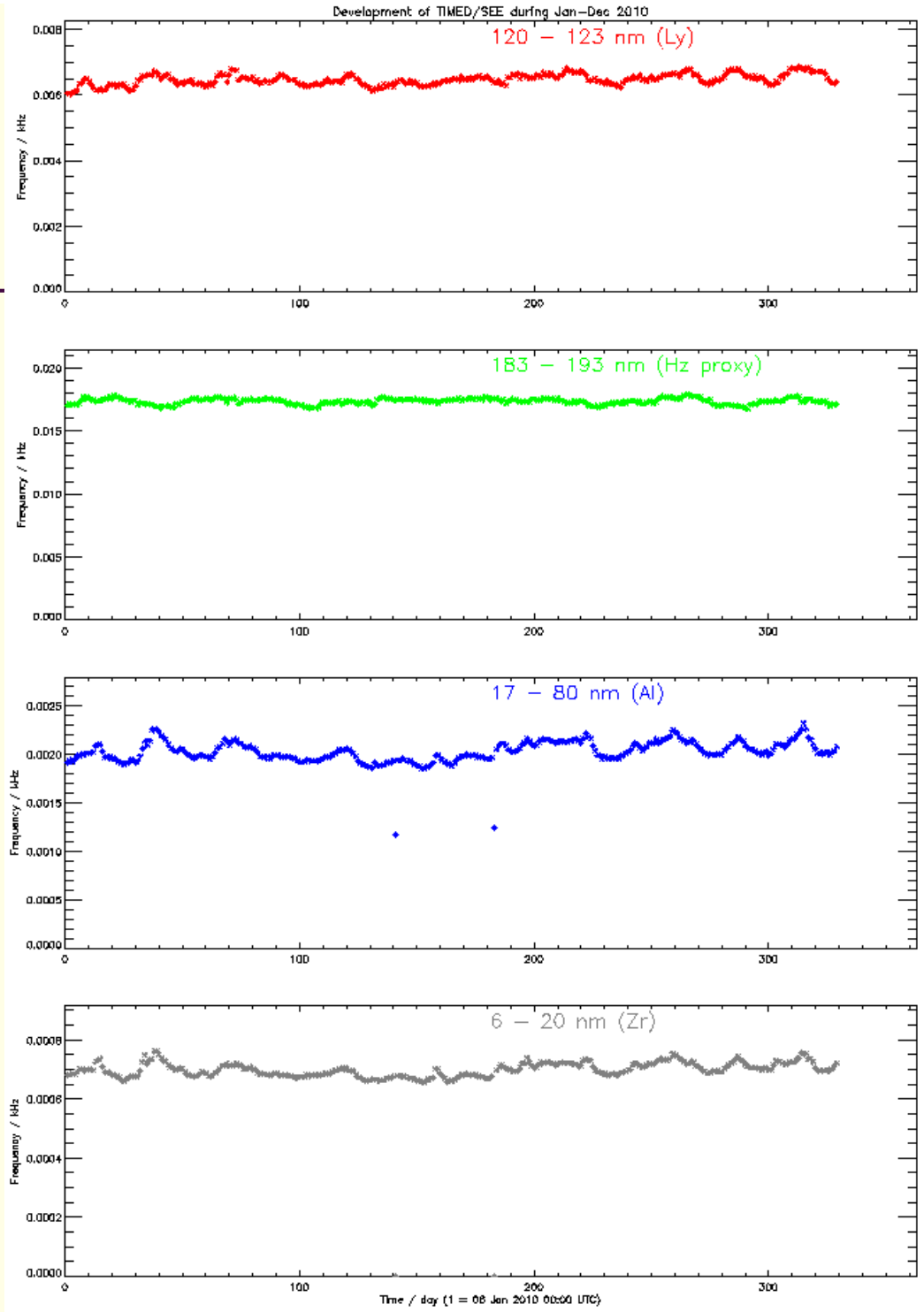
LYRA channel 1: the H I 121.6 nm Lyman-alpha line (120-123 nm)
LYRA channel 2: the 200-220 nm Herzberg continuum range (now 190-222 nm)
LYRA channel 3: the 17-80 nm Aluminium filter range incl the He II 30.4 nm line (+ <5nm X-ray)
LYRA channel 4: the 6-20 nm Zirconium filter range with highest solar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

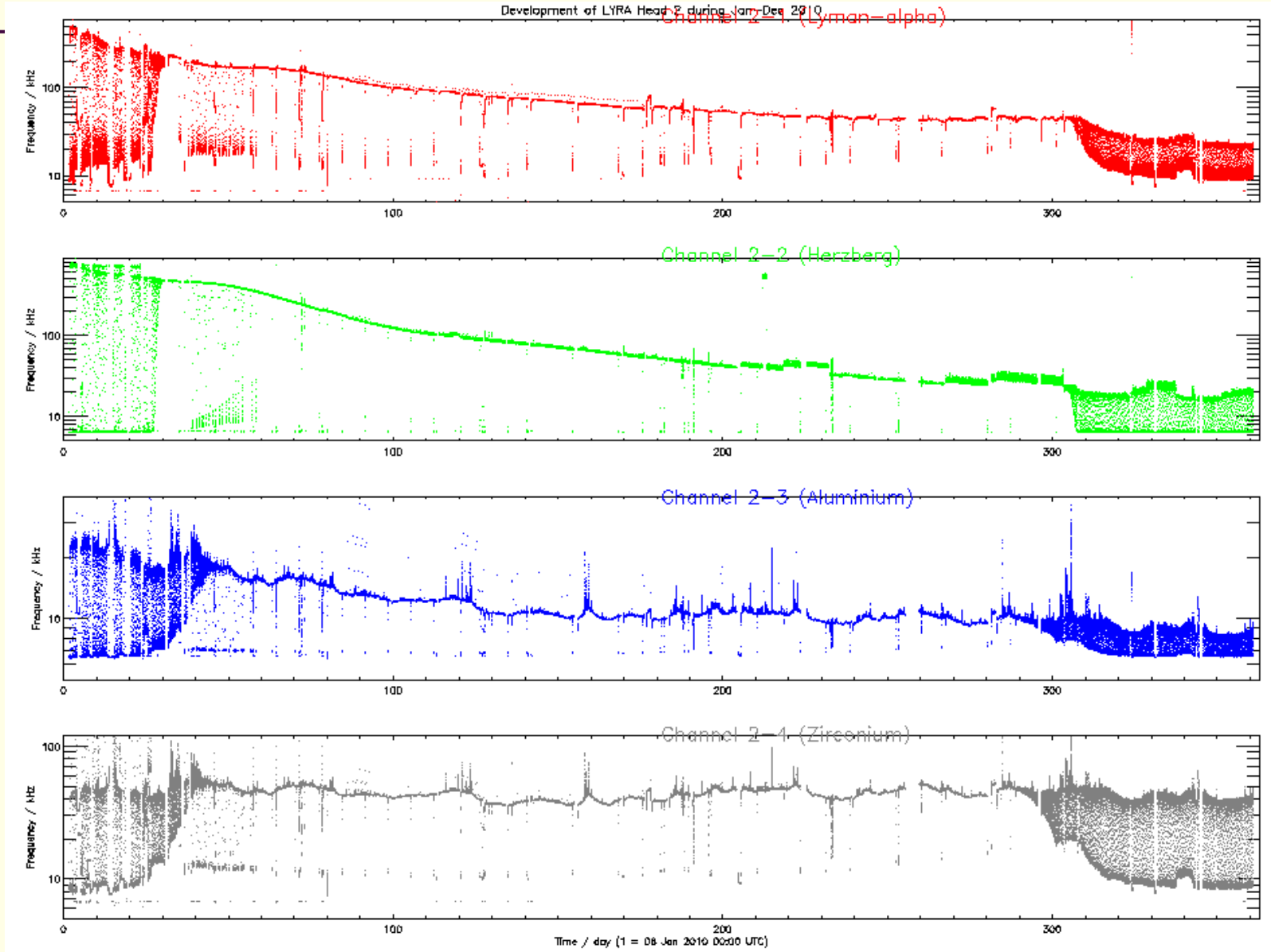


Calibration-Problem:

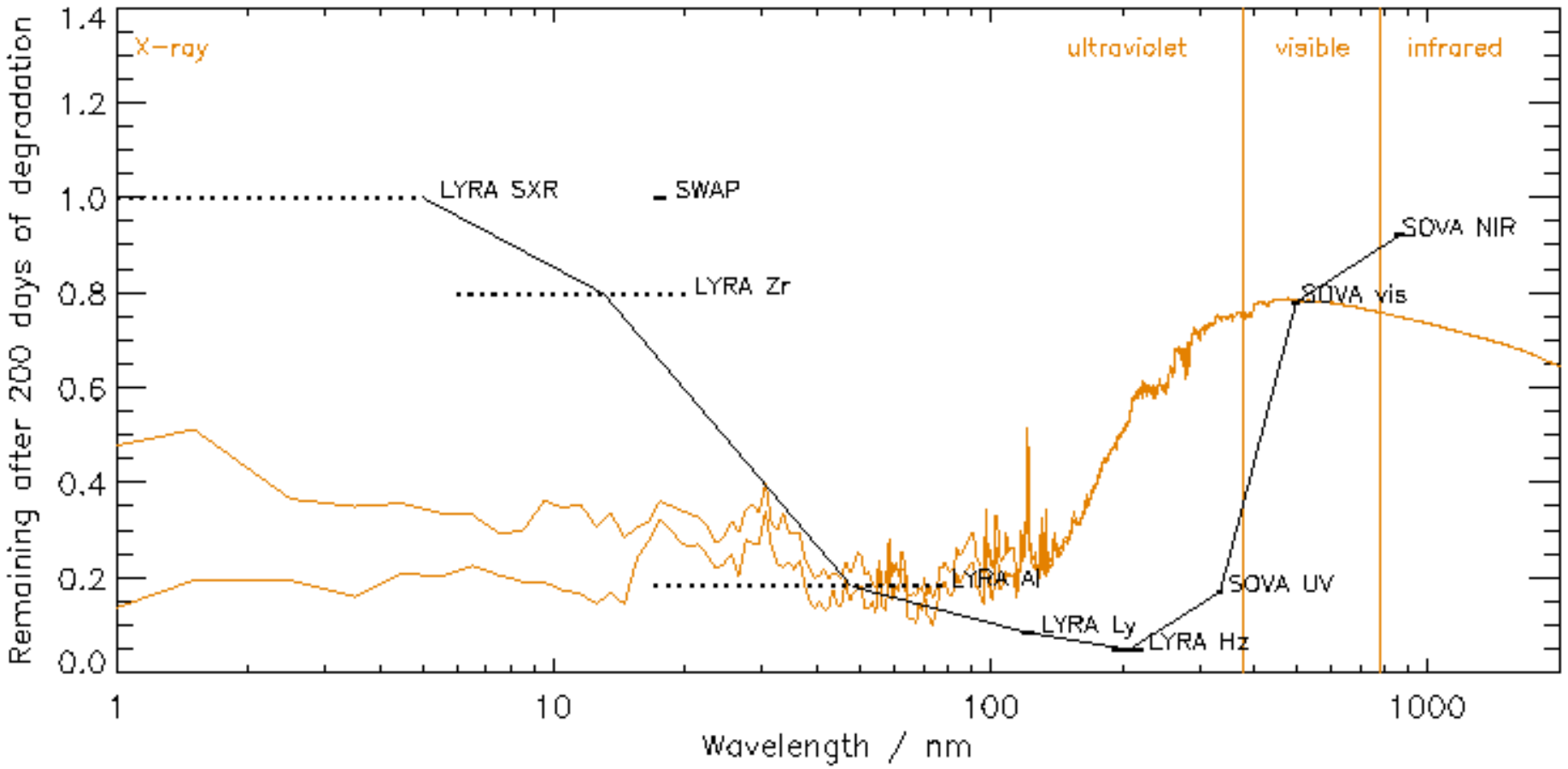
2010 according to TIMED/SEE



Calibration-Problem: 2010 according to LYRA

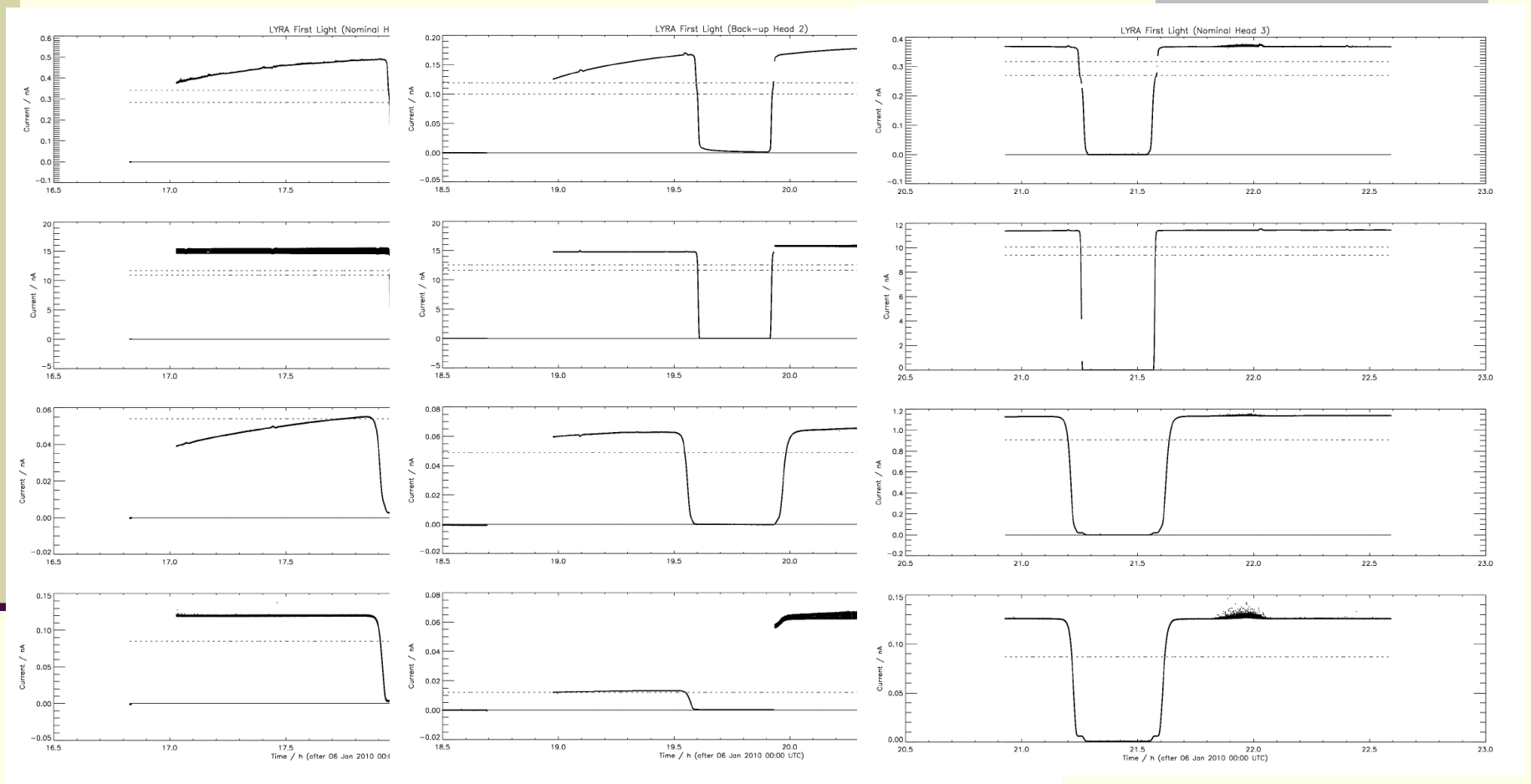


Speculation on spectral degradation



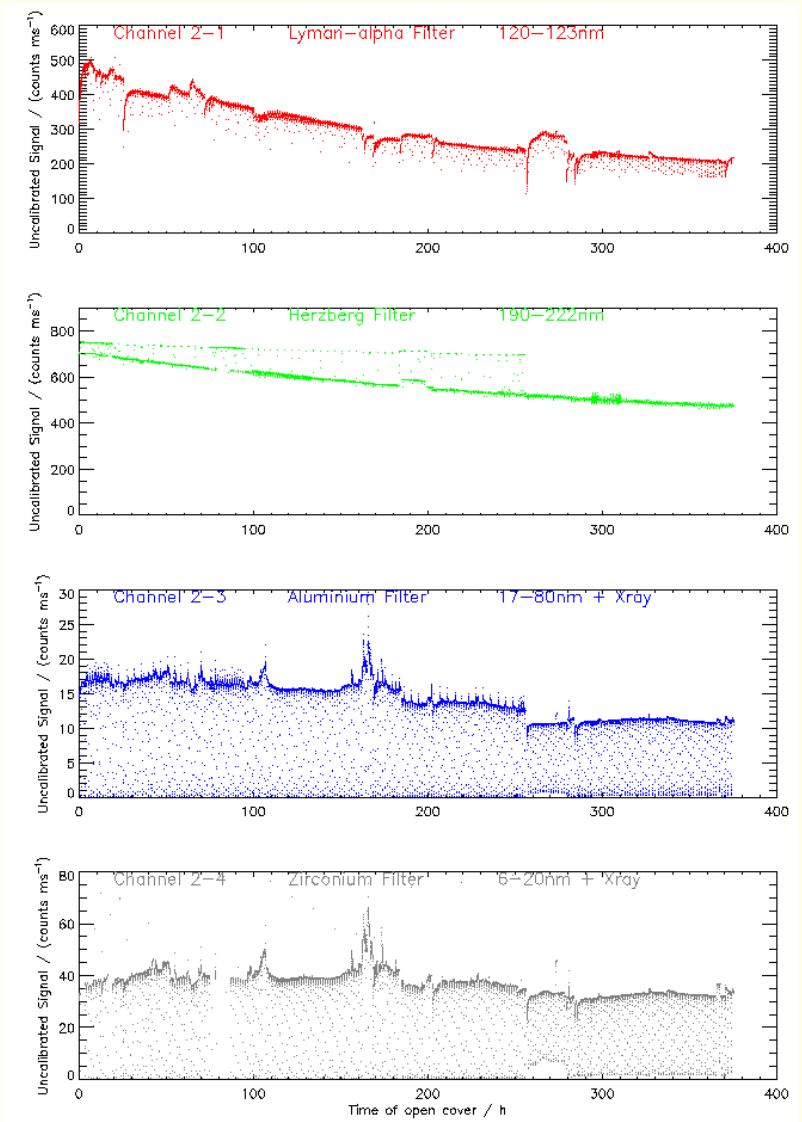
(Edge could actually be steeper between 17nm and 20nm)

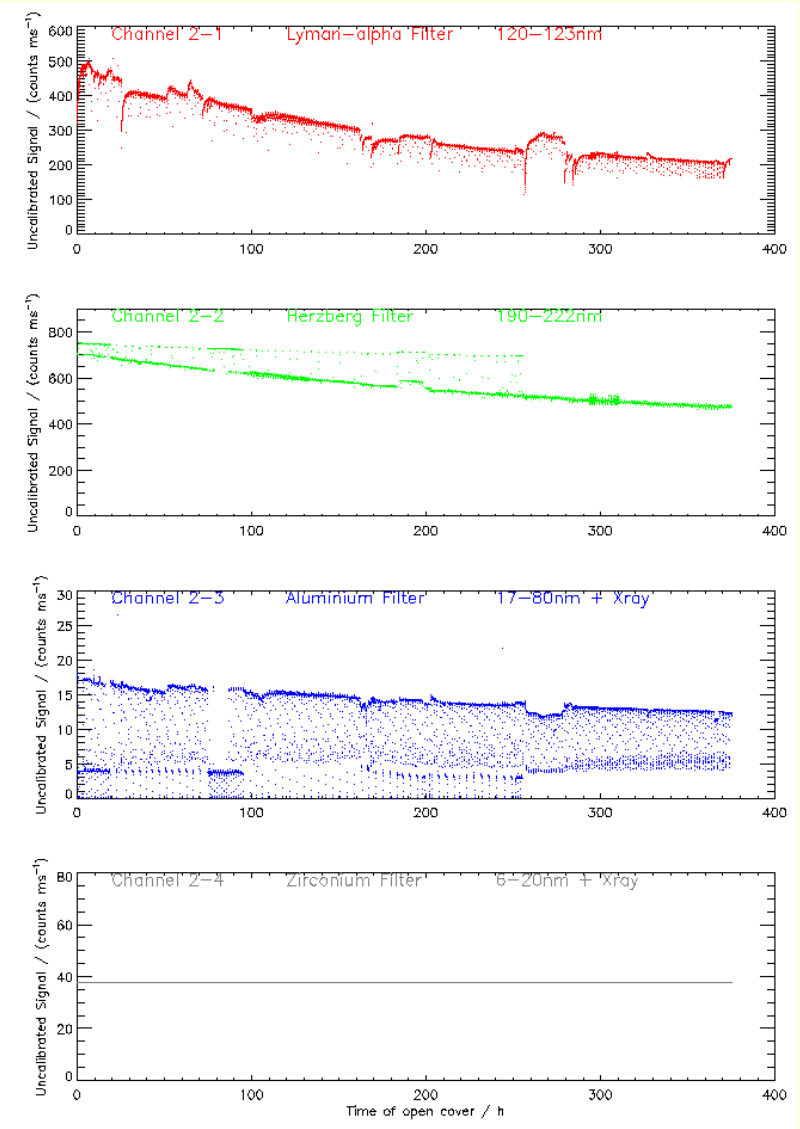
First Light acquisition (06 Jan 2010)



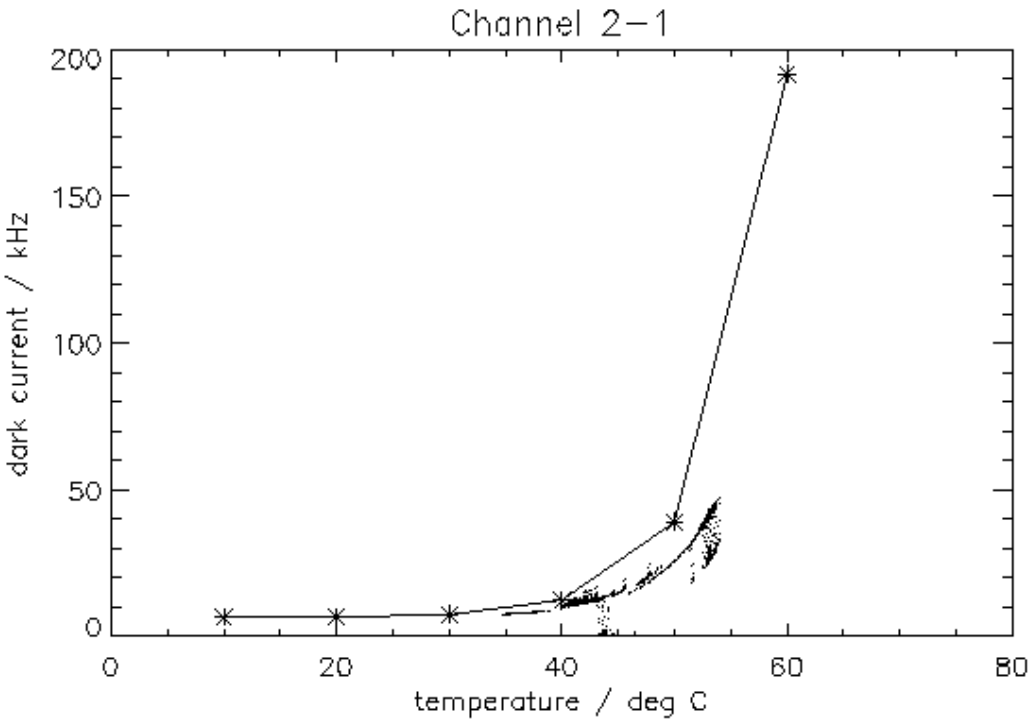
… no degradation so far …

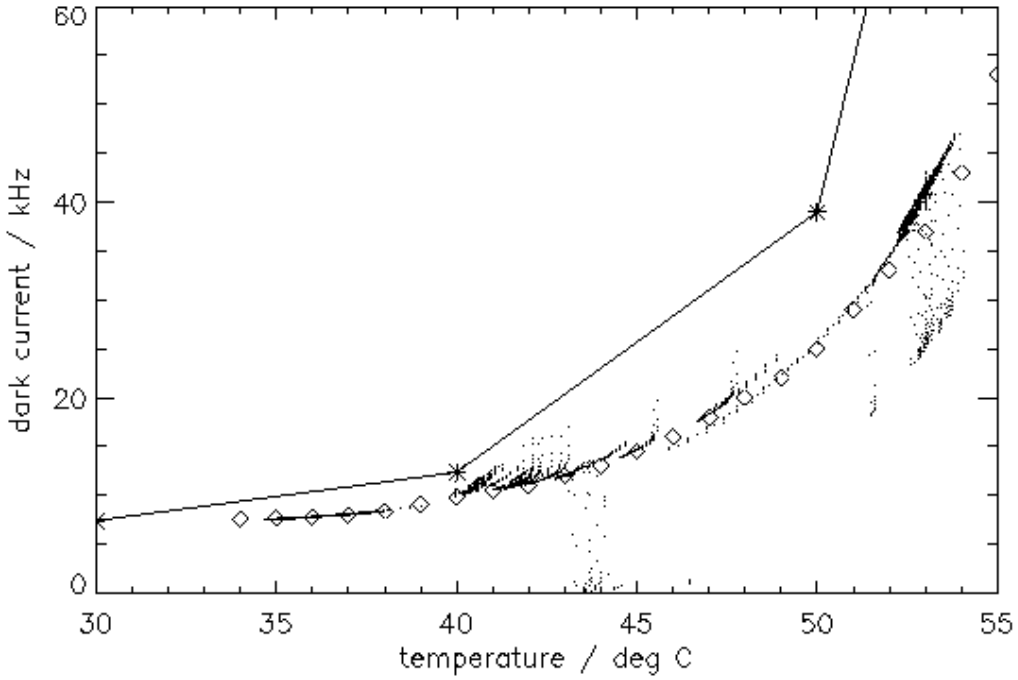
Start with “First Light”…



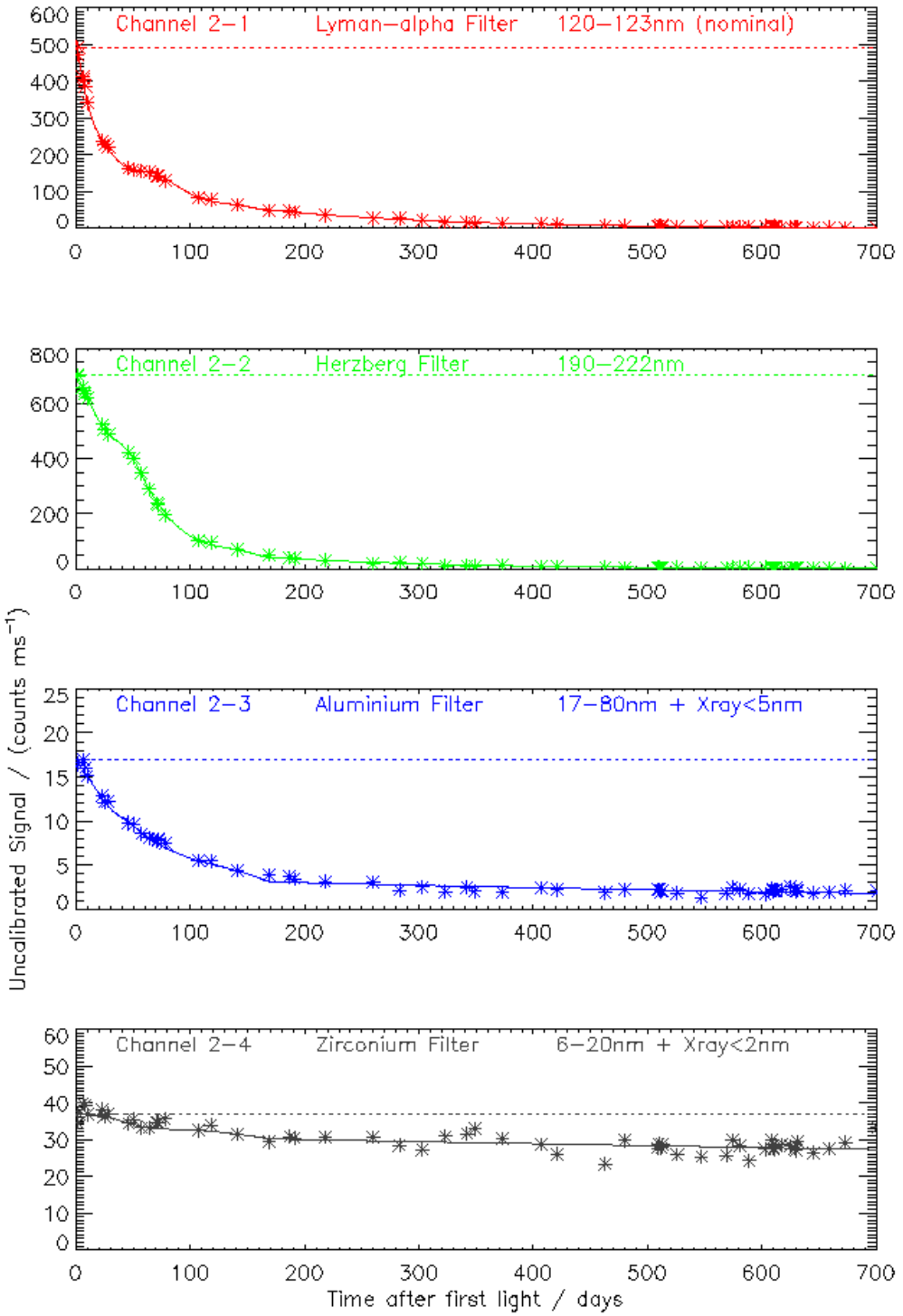


…estimate and subtract dark currents…





… fit the degradation …



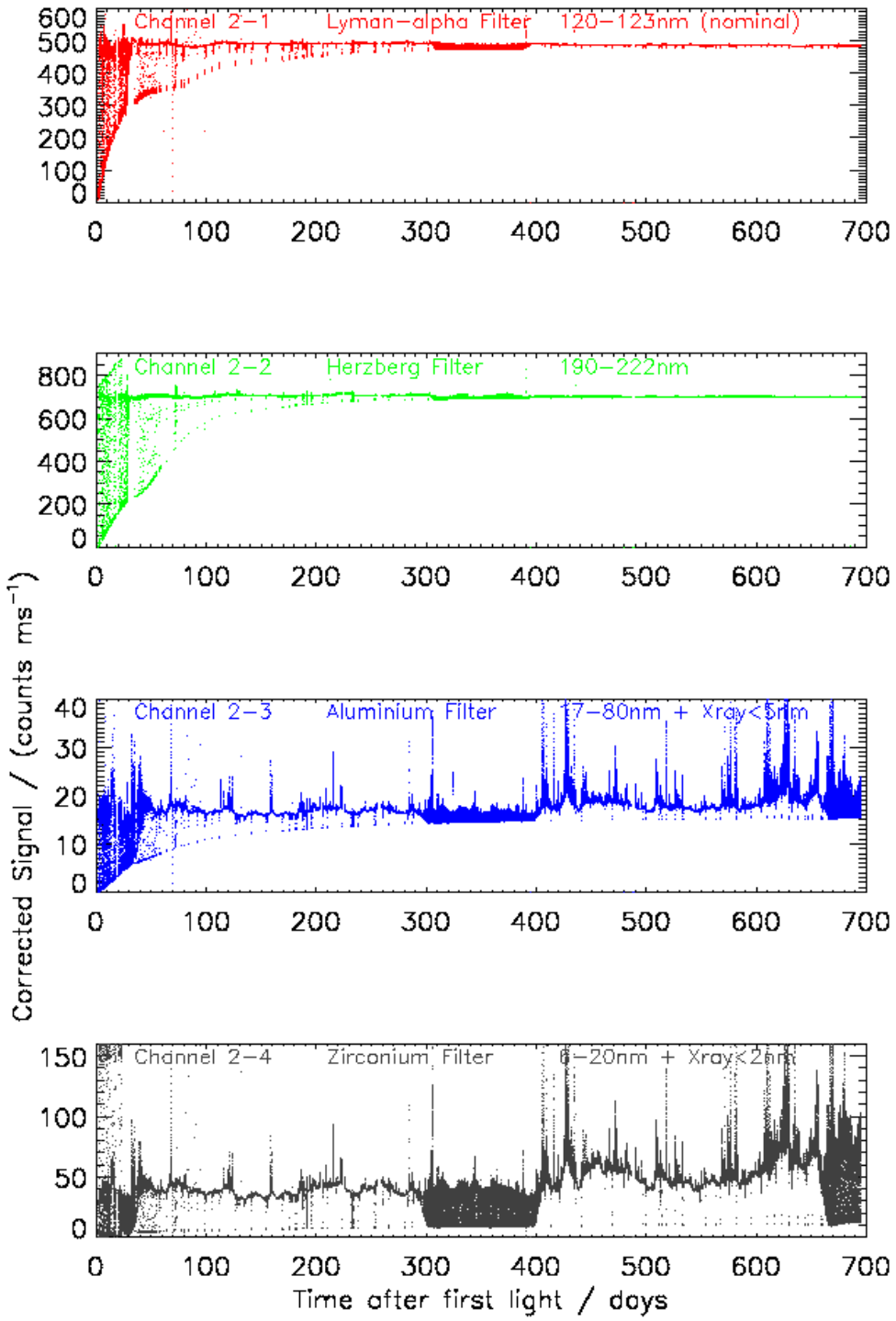
… and add it

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



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

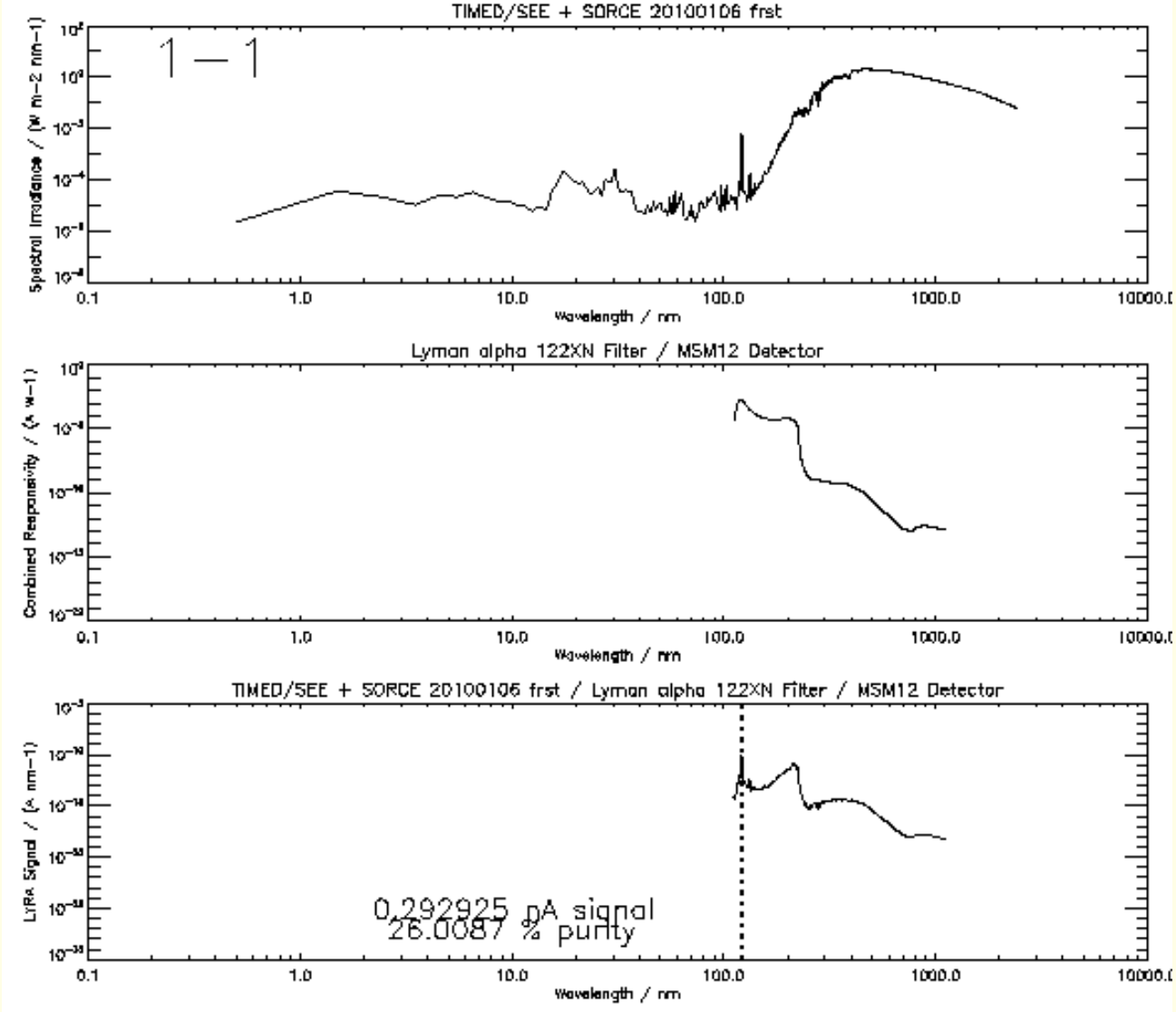
T=total exposure time

E(λ,t)=solar spectral irradiance

F(λ)=filter transmittance

D(λ)=detector spectral responsivity

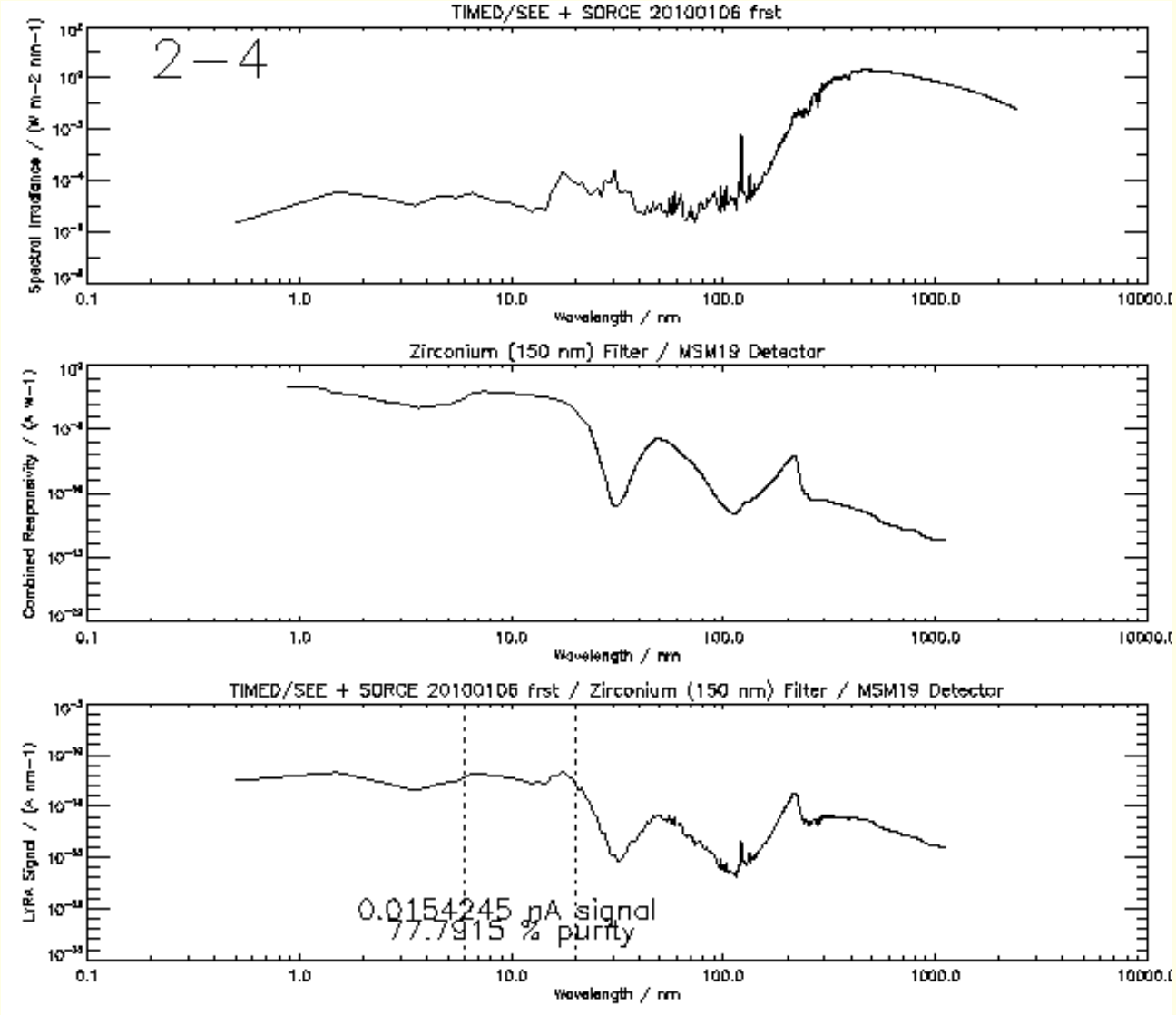
LYRA Radiometric Model, ch1-1 simulated



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	~1300.0counts/ms	620.0counts/ms	24.0counts/ms	37.5counts/ms
dc	-9.0counts/ms	-6.6counts/ms	-6.8counts/ms	-7.2counts/ms
VFC,resis.	=>	=>	=>	=>
	0.5311 nA	12.78 nA	0.07116 nA	0.1216 nA
	+81.3%	+13.3%	+11.2%	+14.3%

LYRA Radiometric Model, ch2-4 simulated



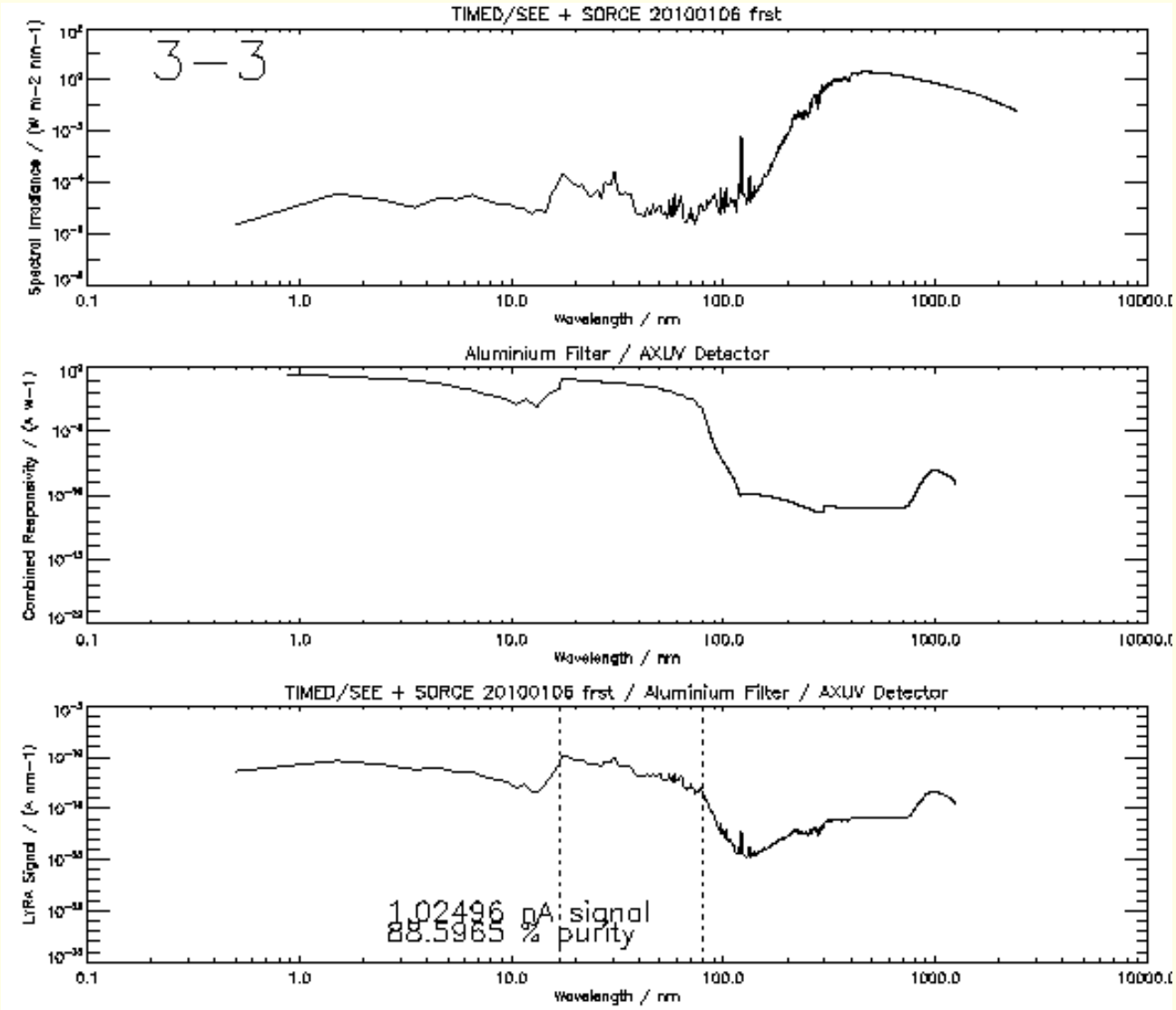
Observed vs. LRM-simulated values (head 2)

	ch2-1	ch2-2	ch2-3	ch2-4
sim	0.1030 nA	12.07 nA	0.05765 nA	0.01542 nA
obs	500.0counts/ms	710.0counts/ms	23.0counts/ms	45.0counts/ms
dc	-8.0counts/ms	-6.5counts/ms	-6.4counts/ms	-7.5counts/ms
	492.0counts/ms	703.5counts/ms	16.6counts/ms	37.5counts/ms

multiplied by VFC-parameter in V/(counts/ms),
divided by resistance in Giga-Ohm =>

*0.00415086	*0.00414635	*0.00414969	*0.00415007
/10.37	/0.1969	/1.016	/10.30
obs 0.1969 nA	14.81 nA	0.06780 nA	0.01511 nA
	+91.2%	+22.8%	+17.6%	-2.0%

LYRA Radiometric Model, ch3-3 simulated



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	930.0counts/ms	552.0counts/ms	280.0counts/ms	36.2counts/ms
dc	-10.0counts/ms	-6.5counts/ms	-6.4counts/ms	-6.2counts/ms
VFC,resis. =>	0.3807 nA	=> 11.44 nA	=> 1.1400 nA	=> 0.1249 nA
	+3.3%	+18.0%	+11.2%	+15.4%

Formal:

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

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

iuncal,iuncal(FL)= observed effect of solar irradiance in counts/ms (proportional to solar photocurrent in nA)

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

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

is(FL) = simulated photocurrent in nA (proportional to count rate)

Resulting conversion to physical units

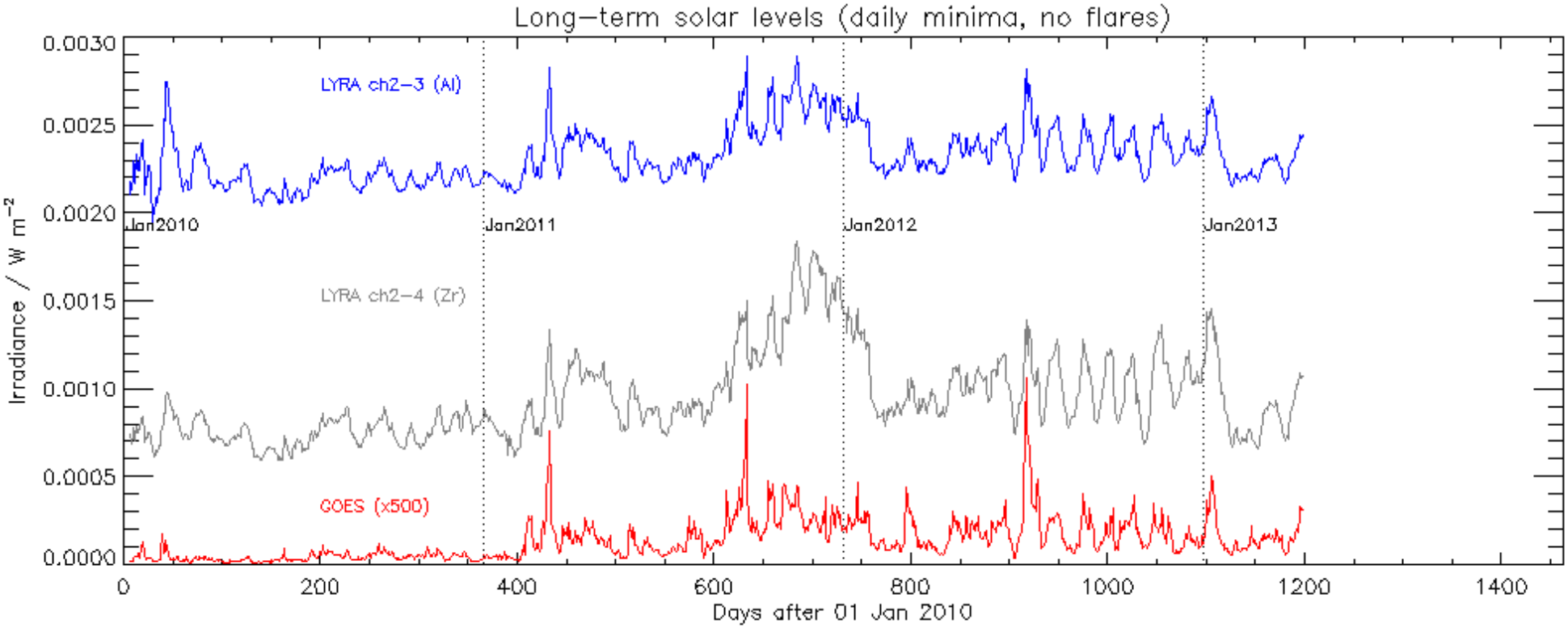
+81.3%	+13.3%	+11.2%	+14.3% (1)
+91.2%	+22.8%	+17.6%	-2.0% (2)
+3.3%	+18.0%	+11.2%	+15.4% (3)
=> ? (0.0%)	=> +18.0%	=> +13.3%	=> +9.2%

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 ...			
492.0counts/ms	703.5counts/ms	16.6counts/ms	37.5counts/ms

(Example: Head 2, dark currents subtracted)

Degradation added. Simple linear conversion.

Solar EUV irradiance according to LYRA



LYRA channel 2-3 (17-80nm degraded(?) plus <5nm)
LYRA channel 2-4 (6-20nm plus <2nm)
Jan 2010 – Apr 2013, versus GOES (scaled)

Possible error sources

- First-Light-Day calibration (selection of “significant” values, difference among LYRA units, measured/modeled channel response, difference among TIMED and SORCE, short wavelengths modeled, hardly info below 1nm)
- Degradation estimation
- Simple addition (spectral degradation in channels 3 and 4)
- Dark current estimation
- Simple linear conversion (different response in SXR and EUV)

Next steps

- Is the long-term development consistent ?
- Cross-calibration with LYRA units 1 and 3
- Cross-calibration with TIMED and SORCE
- Cross-calibration with SDO/EVE (others?)
- What do the flares consist of (spectral, thermal) ?