LYRA

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

Multi-instrument observations of an X9.3 flare

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- PROBA2 / LYRA: description
- Degradation problems
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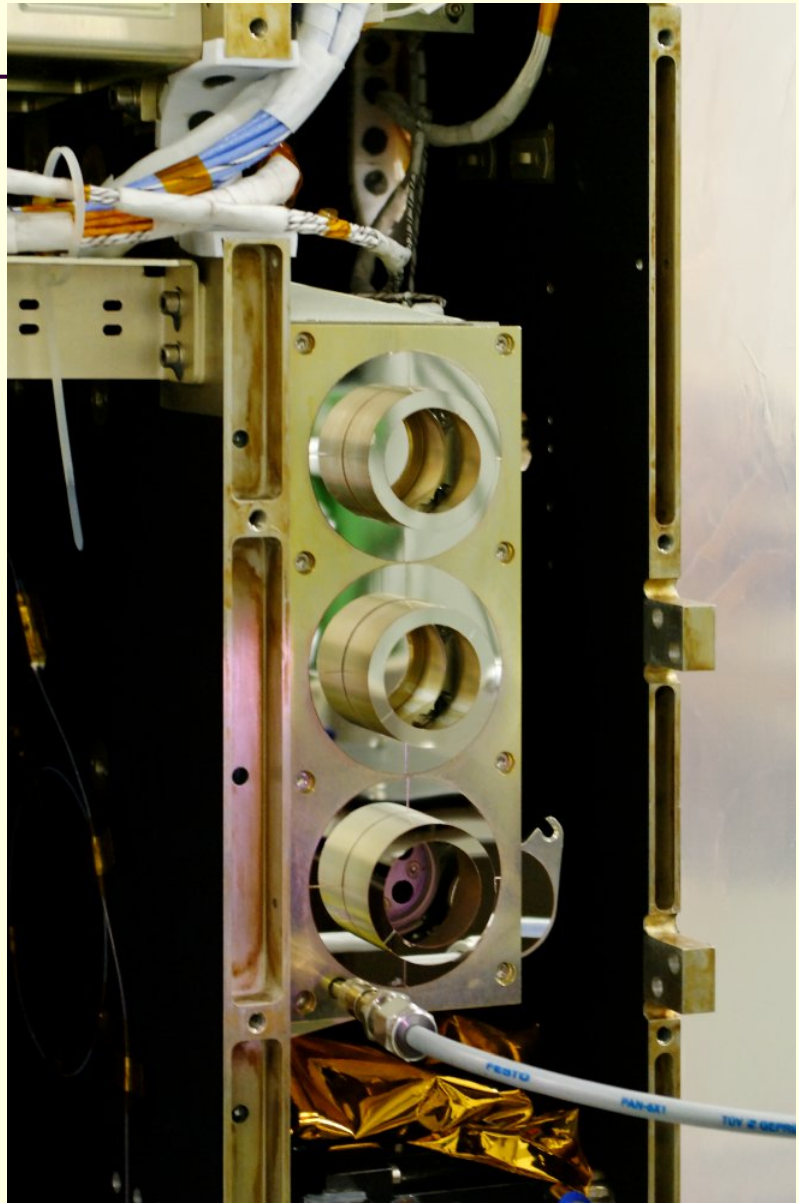
PROBA2: PRoject for On-Board Autonomy

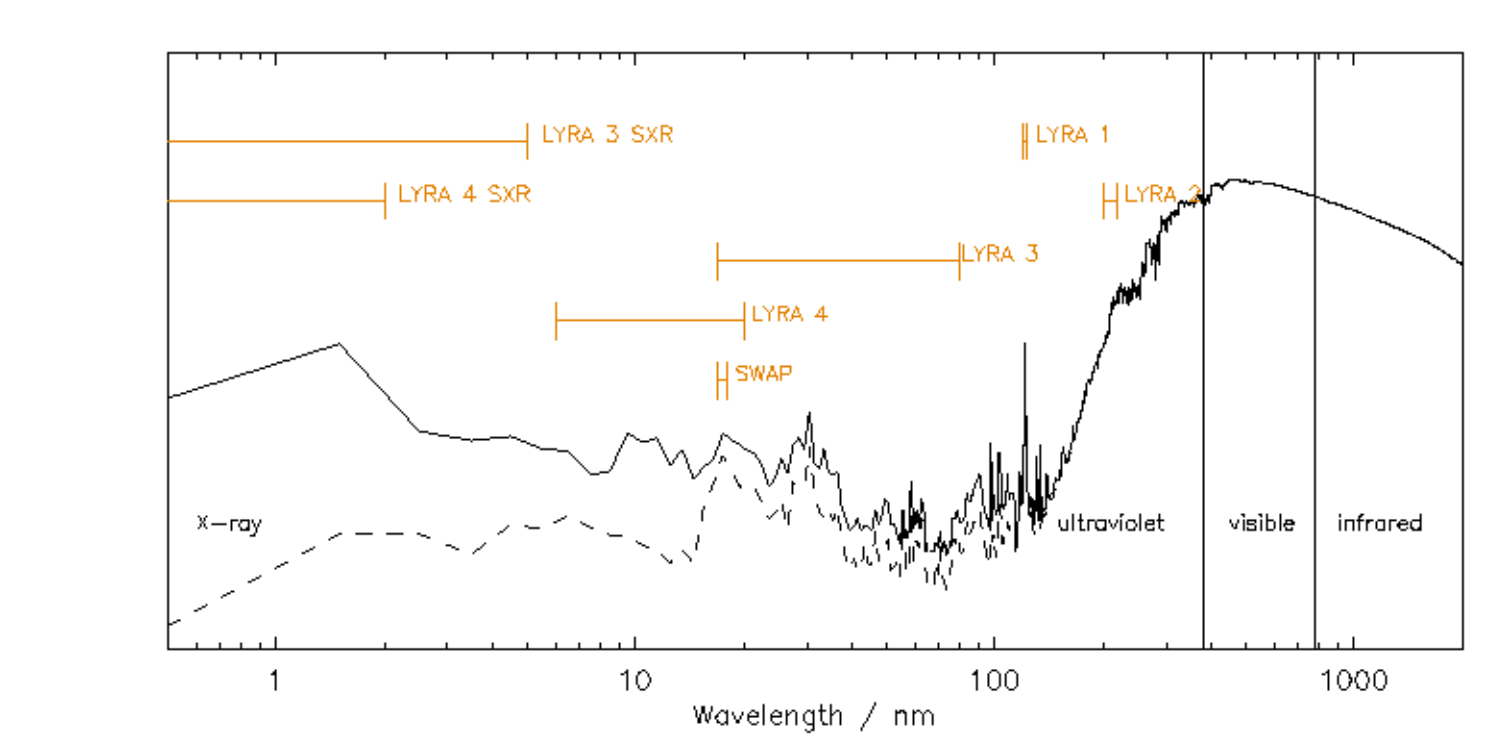
- ESA microsatellite in Sun-synchronous orbit, 725 km altitude
- Built in Belgium, commanded from ROB, launched 02 Nov 2009
- 17 technological experiments, 4 innovative instruments, for in-orbit demonstration (combined technology and science mission)
- LYRA and SWAP have been observing the Sun in EUV, continuously since Jan 2010

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

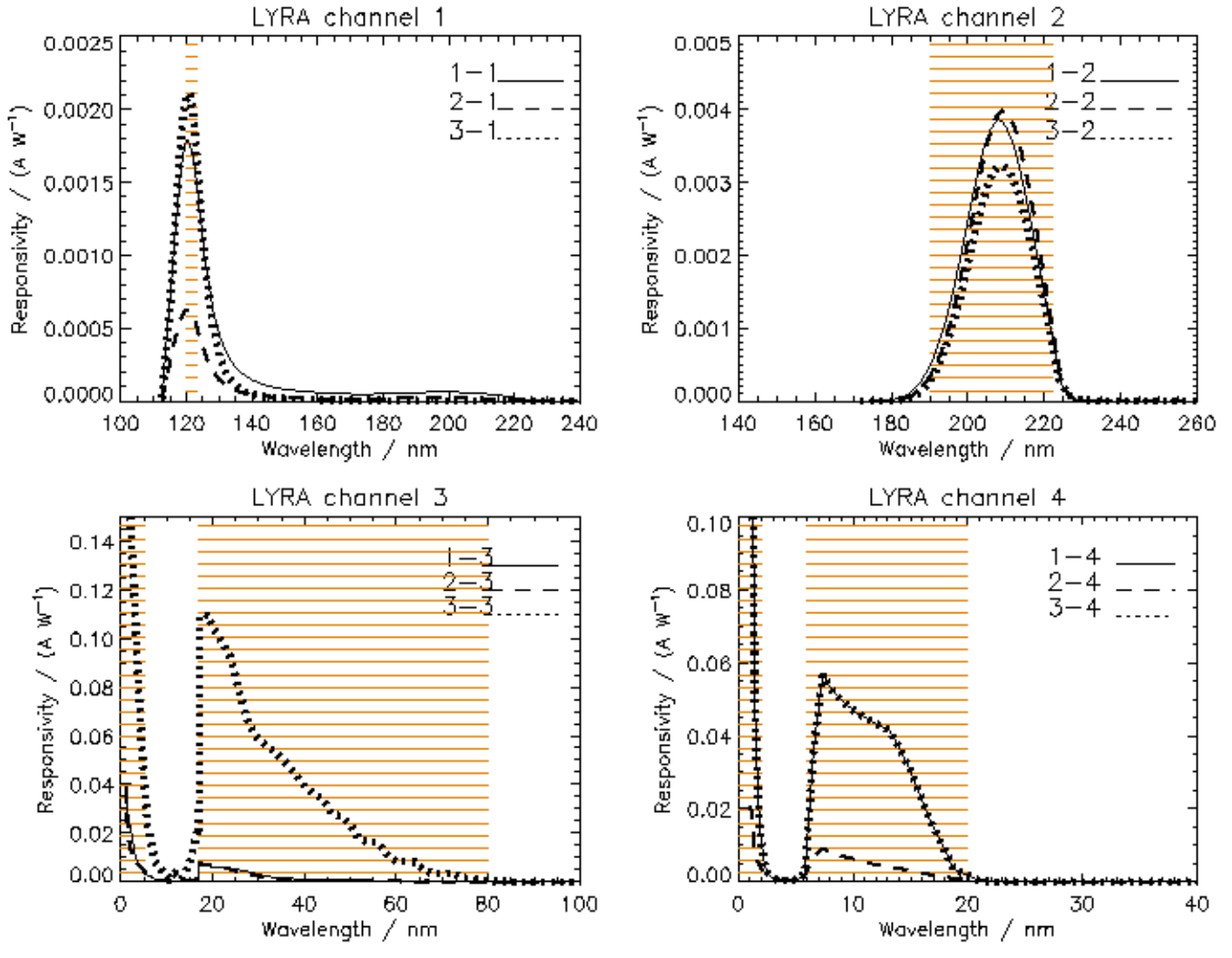


SWAP and LYRA spectral intervals for solar flares, space weather, and aeronomy



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

LYRA spectral response



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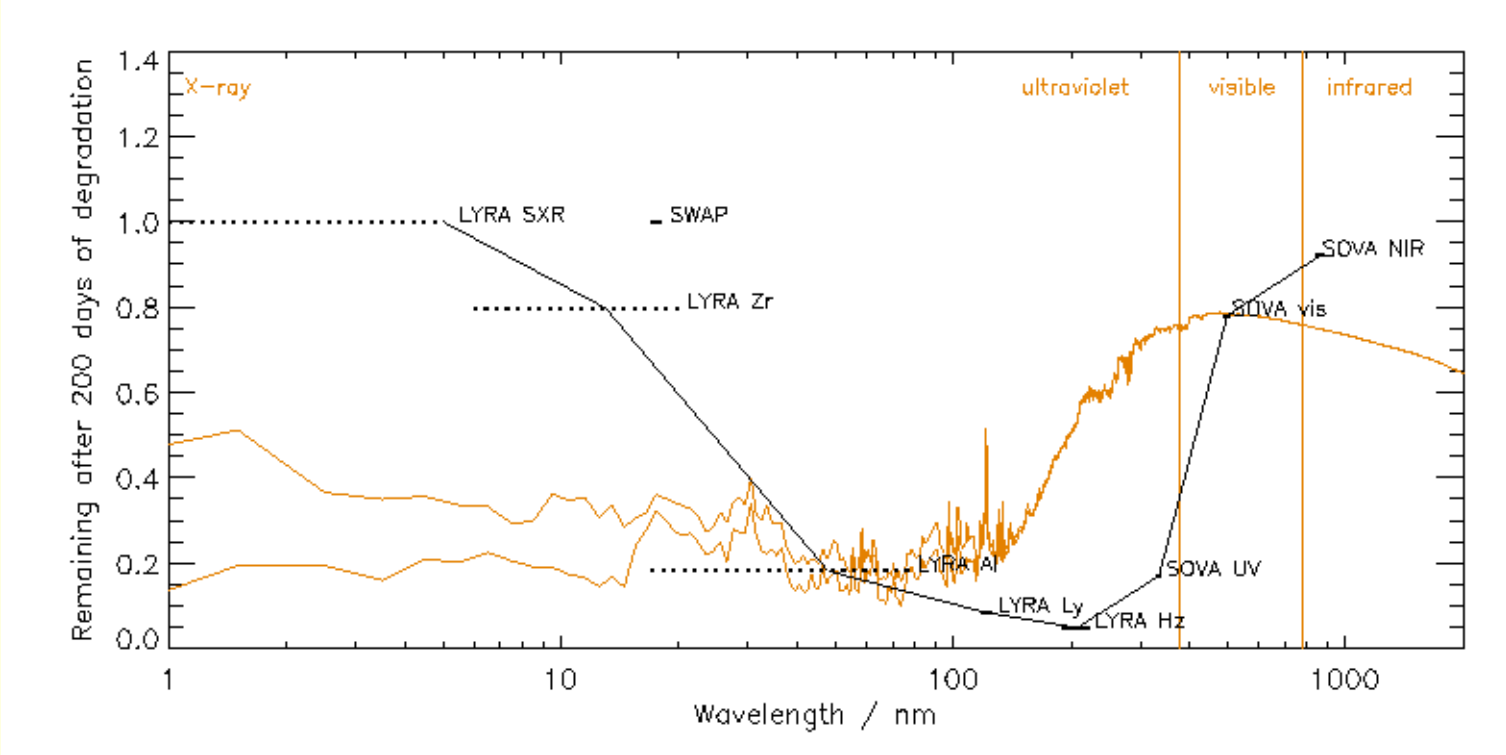
LYRA units and channels

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

Redundancy: LYRA has one nominal unit and two spare units.

Unit 1	“calibration unit”	open several days since 2010
Unit 2	“nominal unit”	open permanently since 2010
Unit 3	“campaign unit”	open several weeks since 2010

Spectral degradation in space



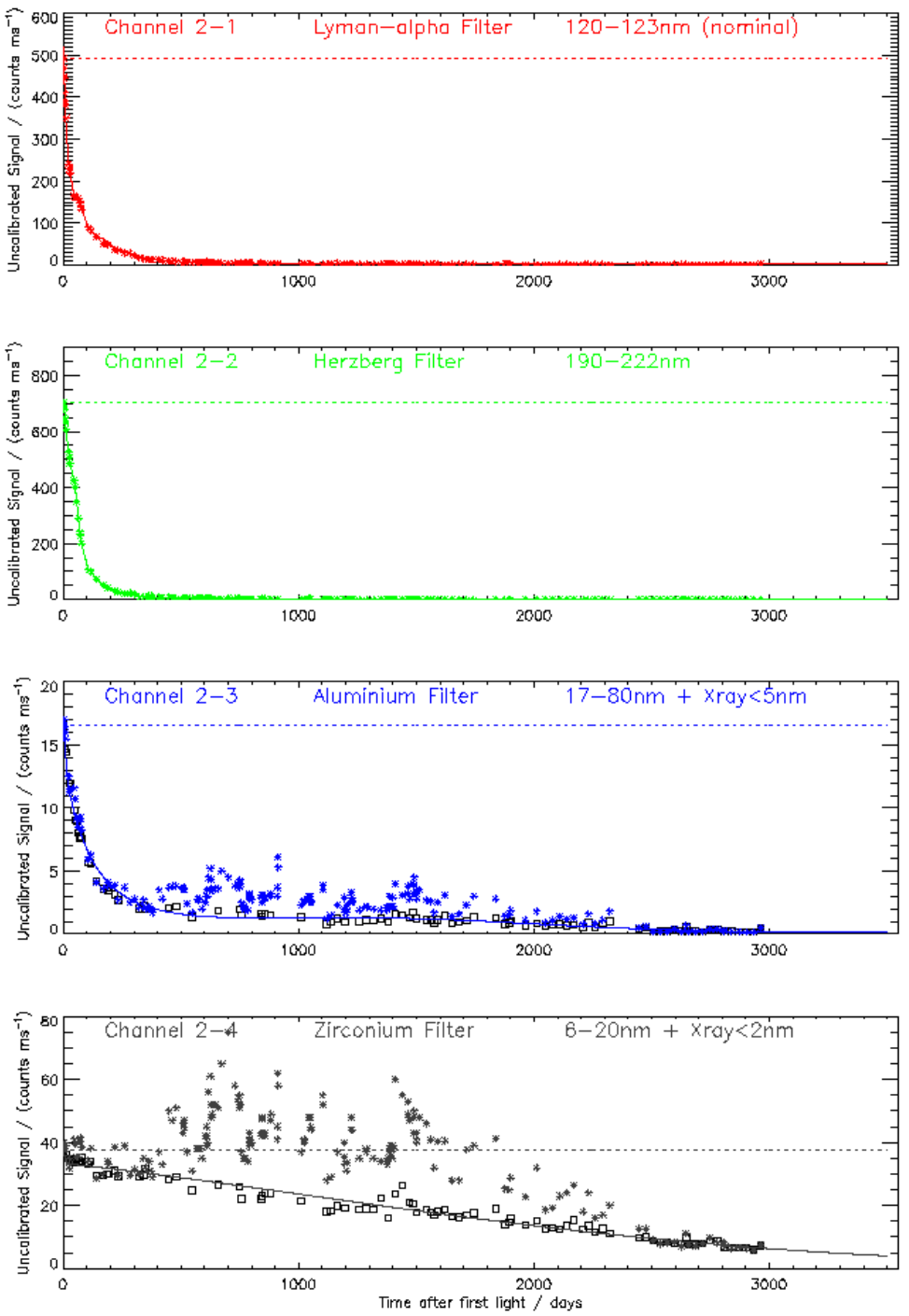
EURECA / SOVA 1992-1993 (retrieved by Space Shuttle)
PROBA2 / LYRA 2010-2012
UV-polymerization -> molecular contamination on first optical surface
LYRA: initially no detector degradation

Degradation unit 2 ("nominal unit")

Probably caused
by a mix of C and Si
(100 nm and 5 nm, resp.)
and maybe oxidation.

Remaining response:

ch2-1 (Ly)	<0.5%
ch2-2 (Hz)	<0.5%
ch2-3 (Al)	1%
ch2-4 (Zr)	12%

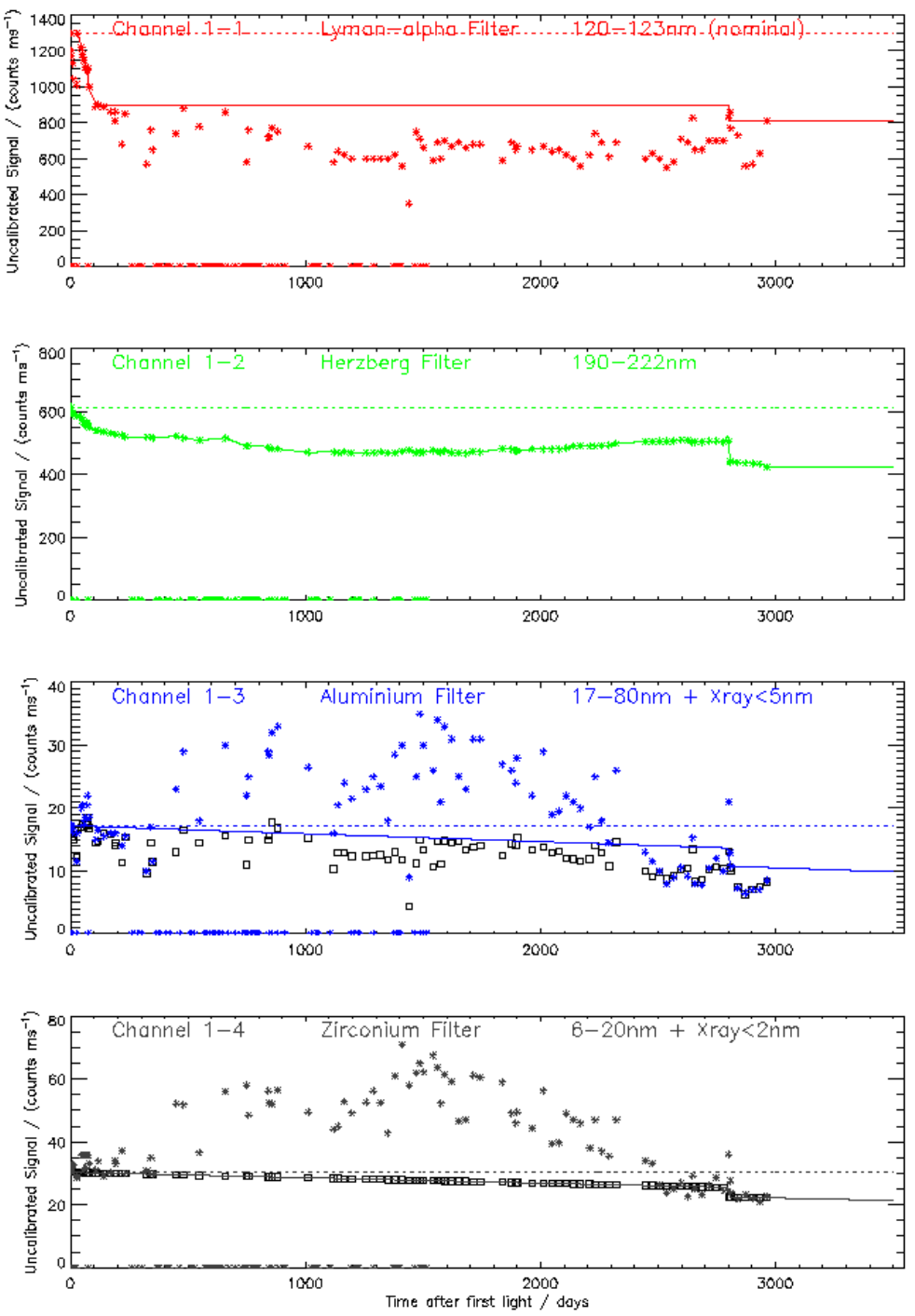


Degradation unit 1 ("calibration unit")

Probably caused
by 10 nm of C.

Remaining response:

ch1-1 (Ly)	65%
ch1-2 (Hz)	64%
ch1-3 (Al)	60%
ch1-4 (Zr)	72%



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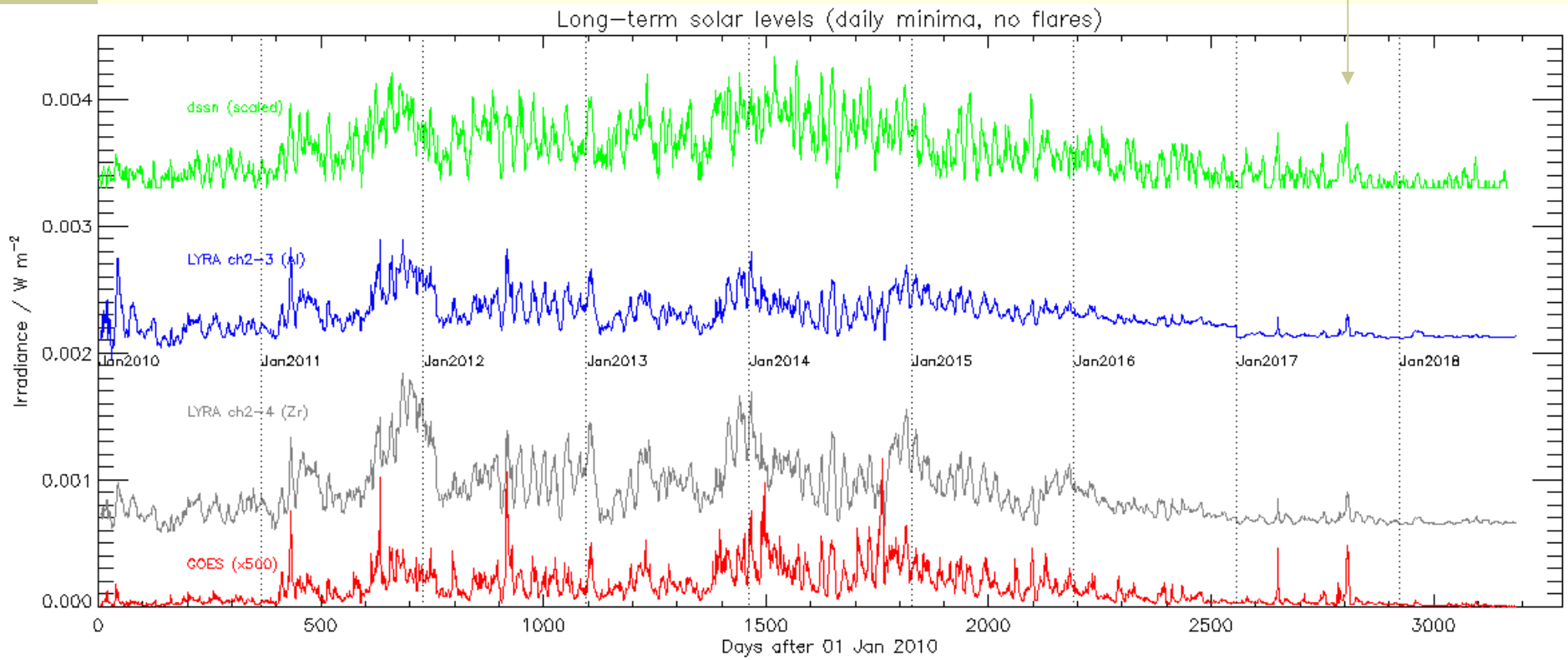
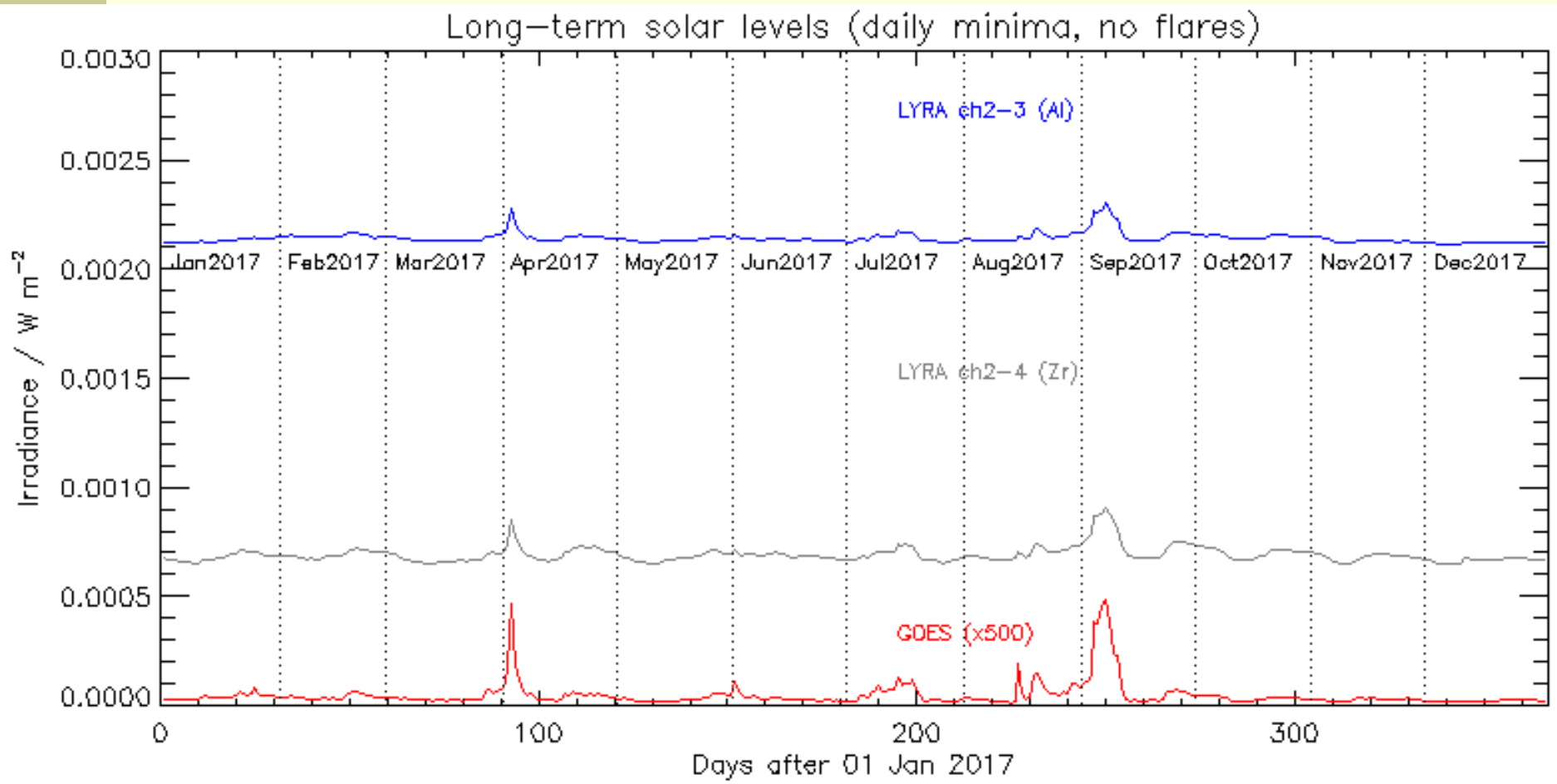
2010 - 2018

After several months of relative quiet …



2017

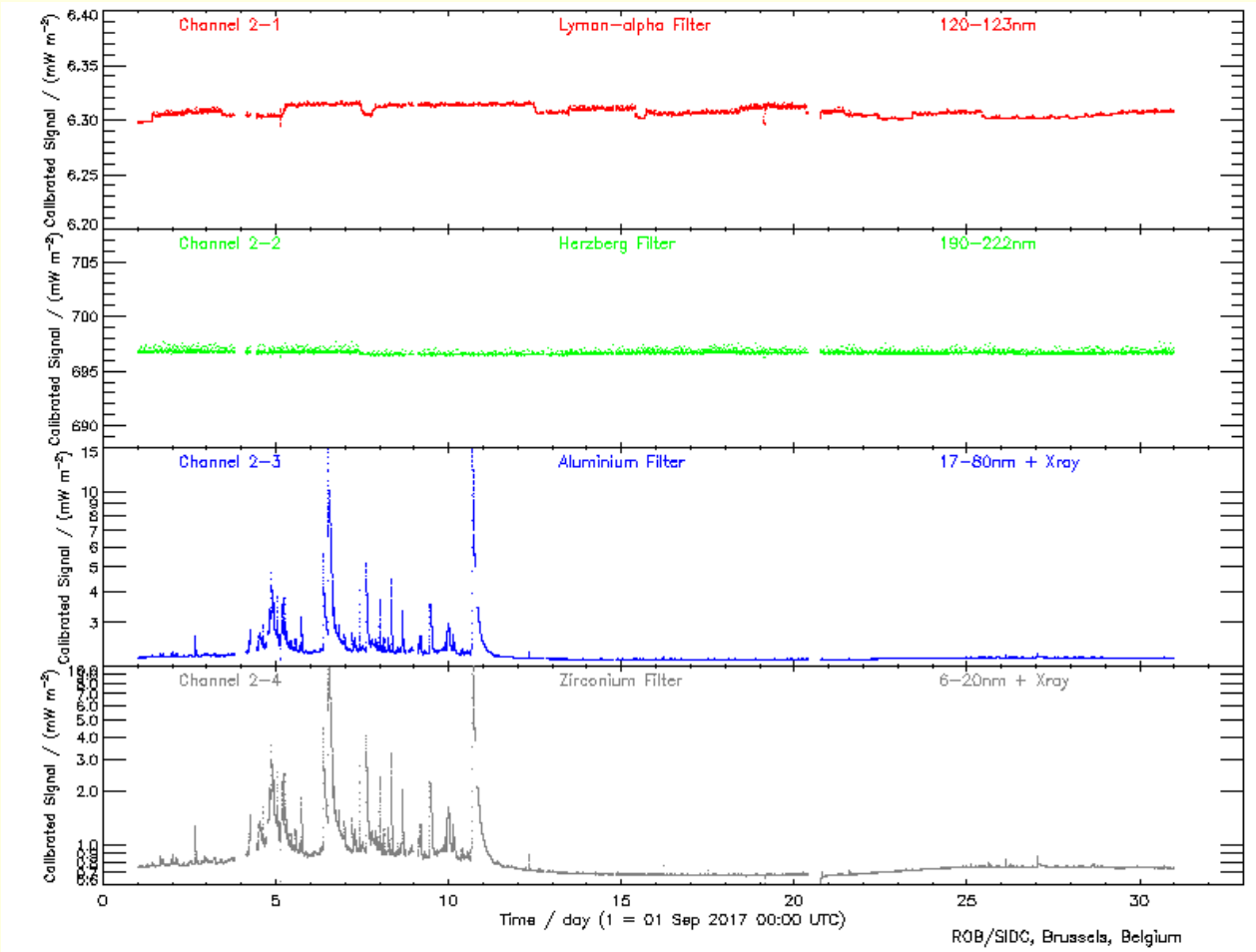
… a sudden increase of solar activity was observed …



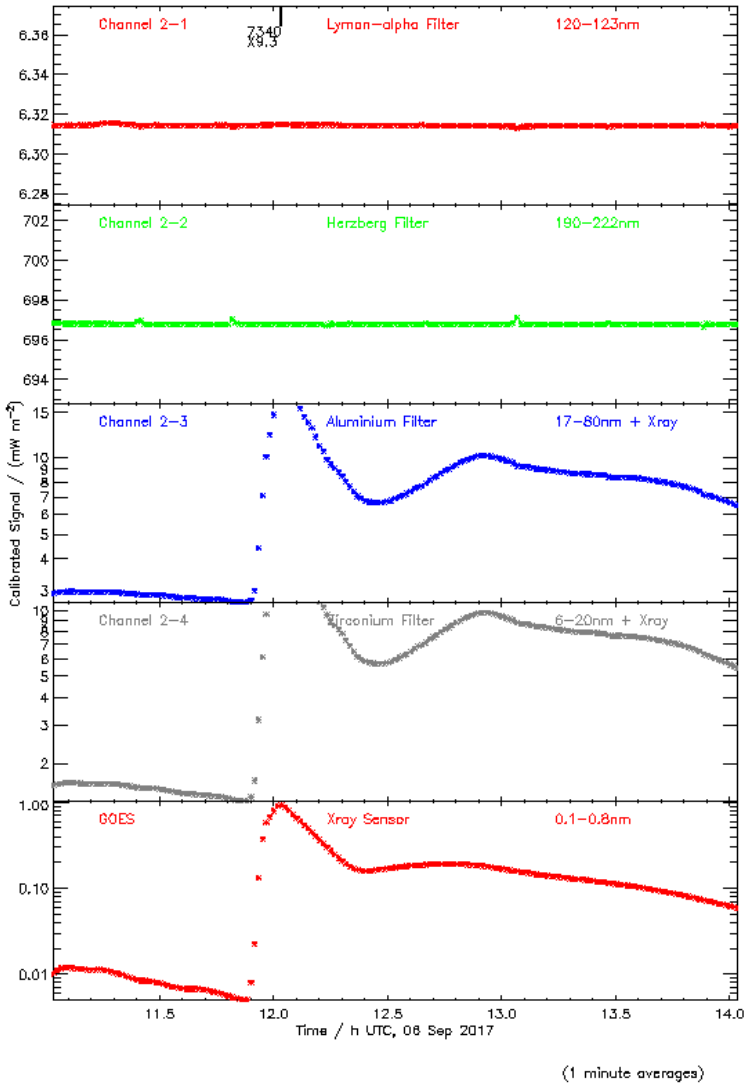
September 2017

… on 04 Sep 2017 when NOAA AR 12673 started to grow quickly …

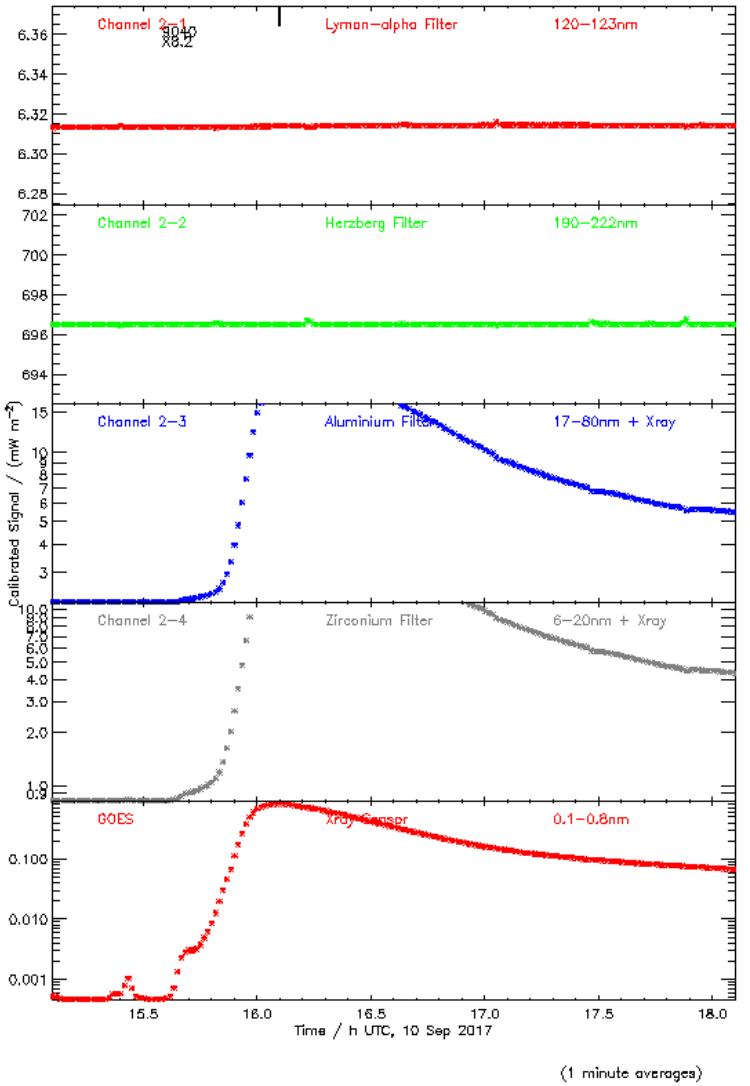
… producing
27 M-class and
4 X-class flares,
among them so far
the two strongest
of solar cycle 24.



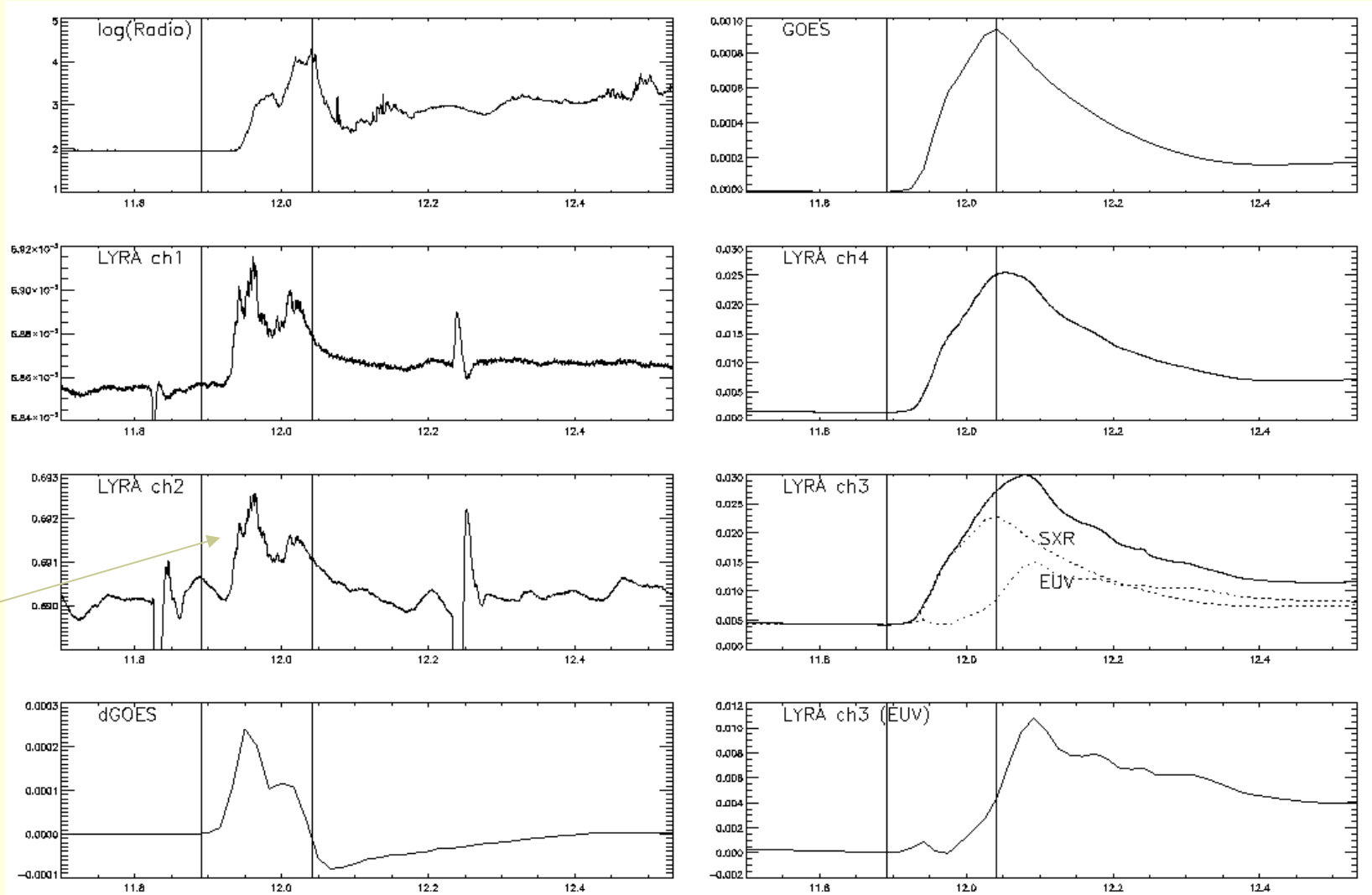
X9.3 on 06 Sep 2017, 12:02 UTC
X8.2 on 10 Sep 2017, 16:06 UTC



LYRA ch2-1, ch2-2: flat

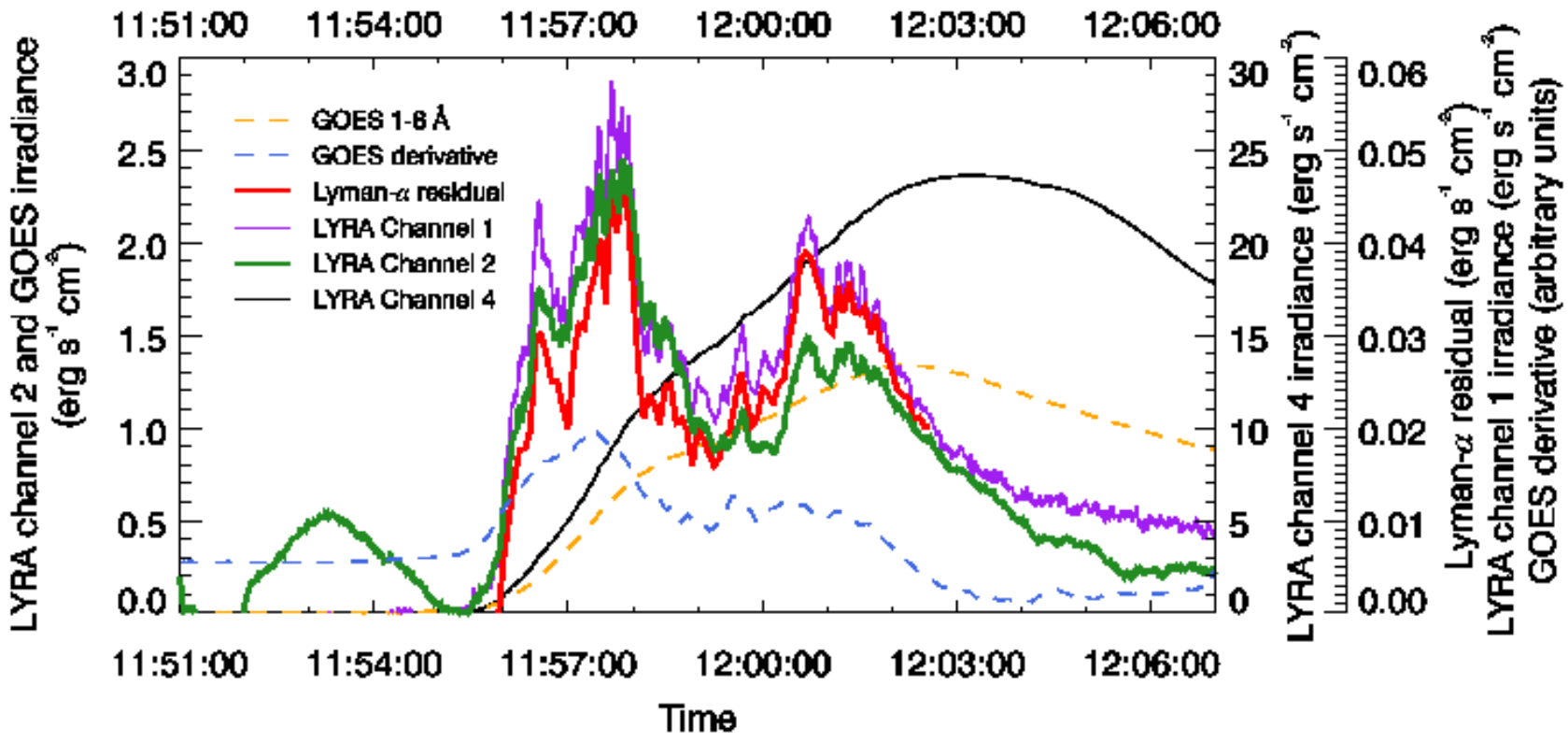


Multi-instrument observations of X9.3: Flare hunting campaign incl. LYRA unit 1



first and only signature so far

Solar irradiances during X9.3, pre-flare levels subtracted



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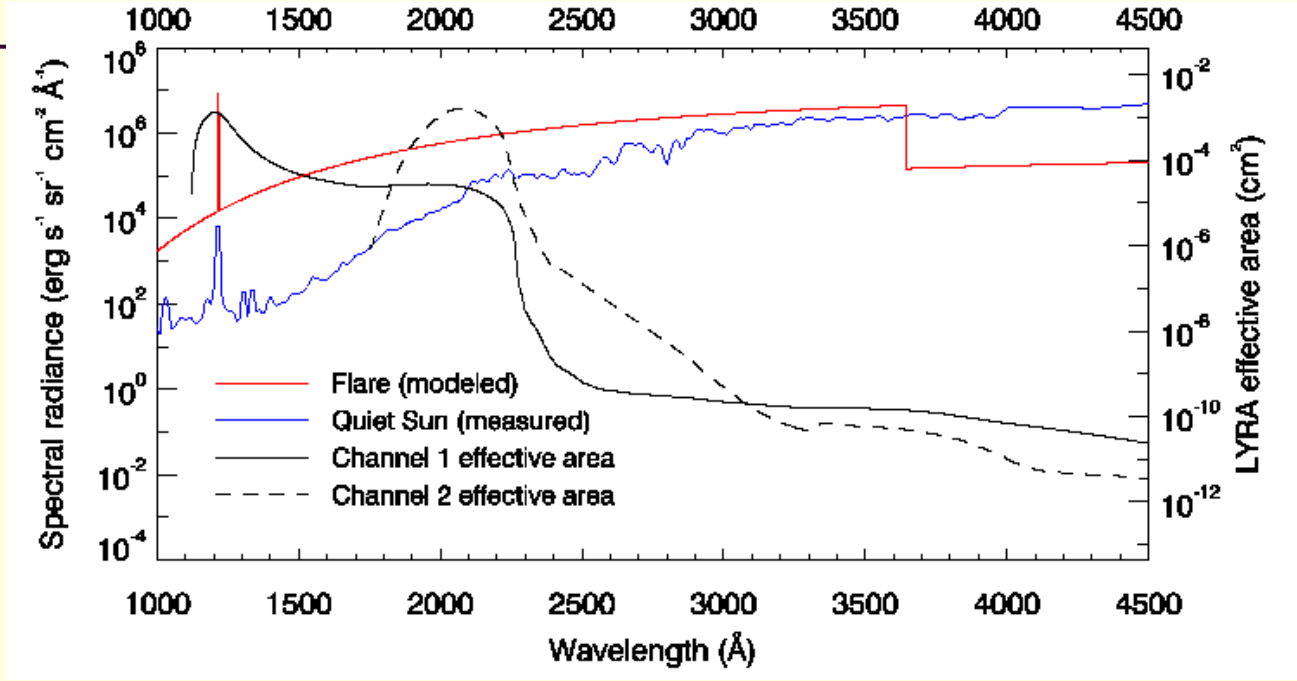
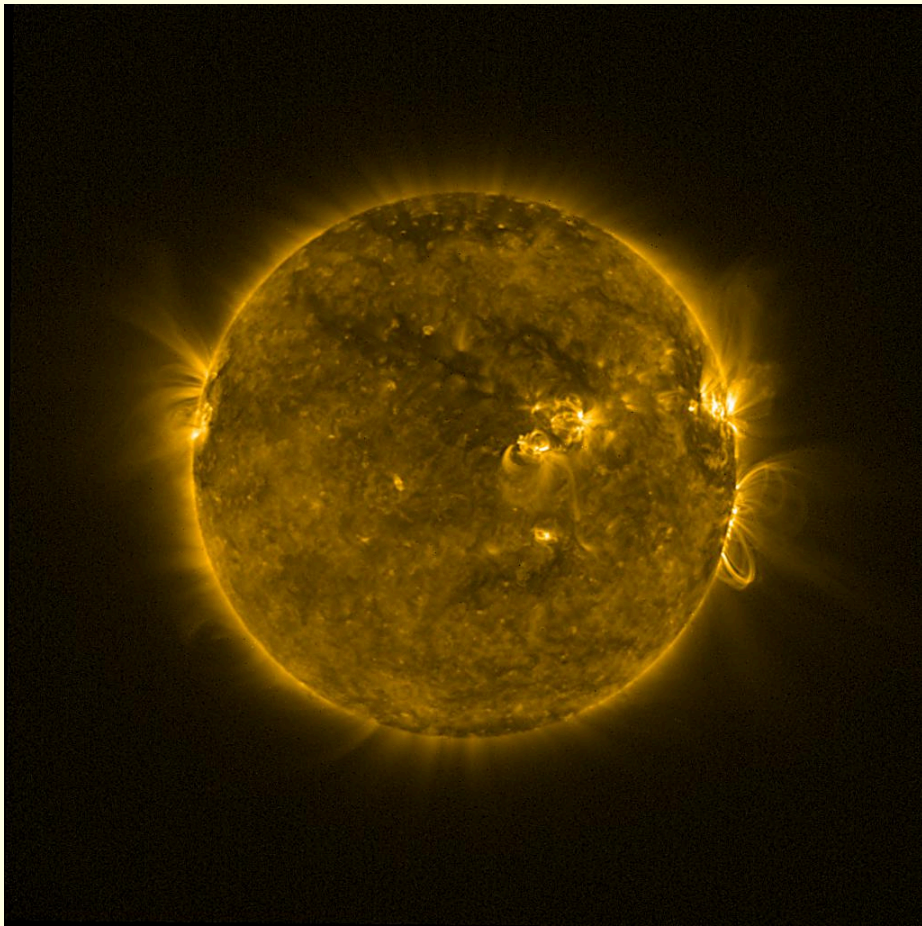
Spectral modeling



- Carbon contamination estimated (10 nm layer)
- Lyman-alpha channel corrected for out-of-band contributions
- i.e. ch1-1 (Ly) corrected by longer-wavelength ch1-2 (Hz)
- Flare spectrum estimated and multiplied by spectral response
- Resulting numbers (electron density at peak time) correspond to theoretical models and to similar studies

The other big flare (X8.2)

- Signatures in LYRA ch1-3 (Al), ch1-4 (Zr), and GOES
- No signatures in LYRA ch1-1 (Ly), ch1-2 (Hz)
- Flare behind limb
- Foot points occulted



Emission in LYRA channel 2

- The flare signal in LYRA channel 2 primarily comes from an increase of the H Balmer continuum.
- Emission is produced by an optically thin chromospheric layer of thickness L ~ 130 km.
- T = 10 000 K
- Emitting surface estimated on SDO/HMI observations
  = 400 Mm2
- Results will be published soon:

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FIRST DETECTION OF SOLAR FLARE EMISSION IN MIDDLE-ULTRAVIOLET BALMER CONTINUUM

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ABSTRACT

We present the first detection of solar flare emission at middle-ultraviolet wavelengths around 2000 Å by the channel 2 of the Large-Yield RAdiometer (LYRA) onboard the PROBA2 mission. The flare (SOL20170906) was also observed in the channel 1 of LYRA centered at the H I Lyman-α line at 1216 Å, showing a clear non-thermal profile in both channels. The flare radiation in channel 2 is consistent with the hydrogen Balmer continuum emission produced by an optically thin chromospheric slab heated up to 10000 K. Simultaneous observations in channels 1 and 2 allow the