LYRA

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

15-year EUV dataset to monitor solar activity

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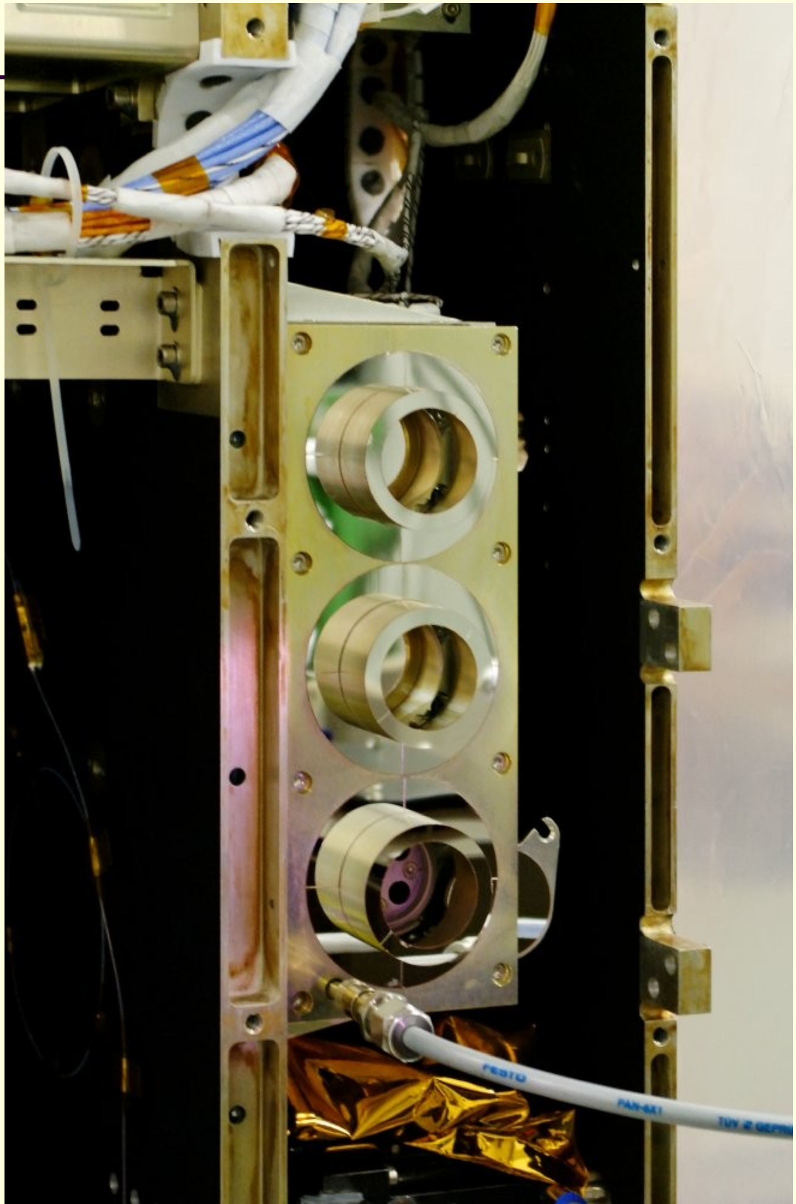
XVIII Hvar Astrophysical Colloquium (HAC2025)
Hvar/Croatia, 18 Sep 2025

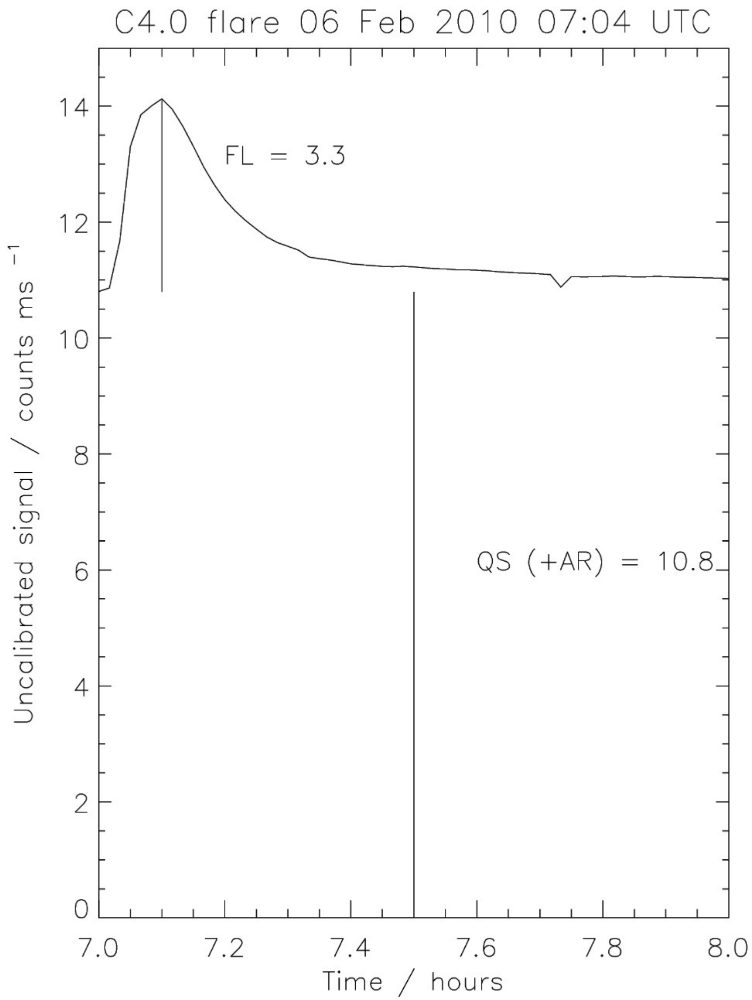
Contents

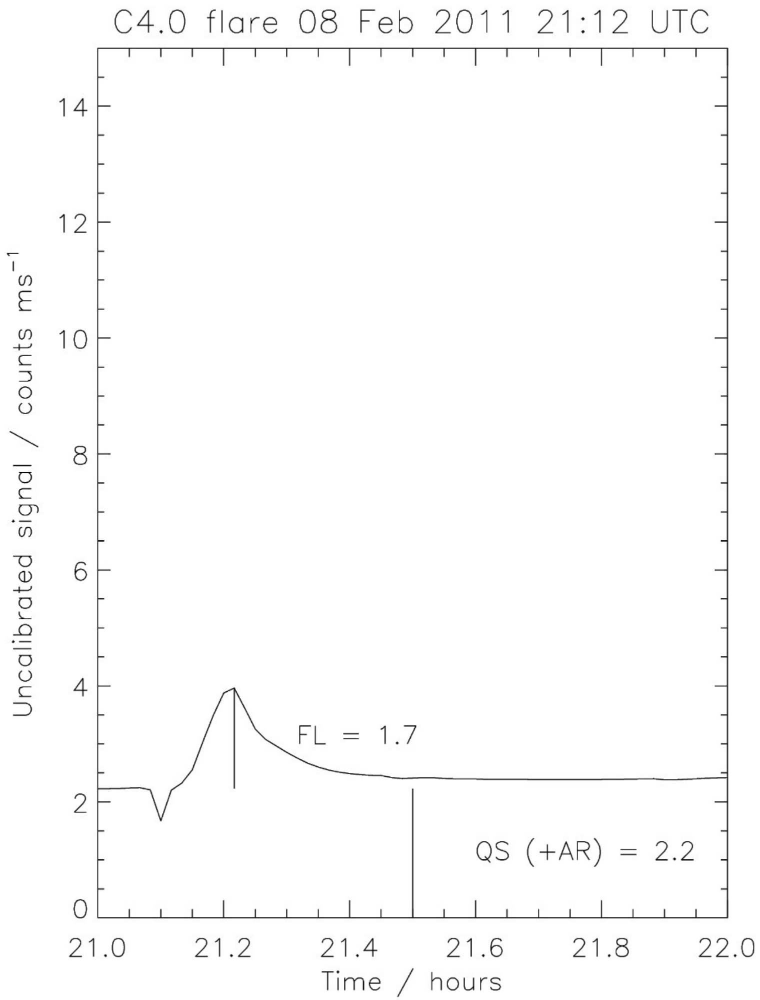
LYRA: the Large-Yield RAdiometer

- On-board PROBA2 satellite
- 3 instrument units (redundancy)
- 4 spectral channels per head
- Testing 3 types of detectors
- High cadence up to 100 Hz
- ESA technology project, then science, then space weather
- 15 years in space and observing

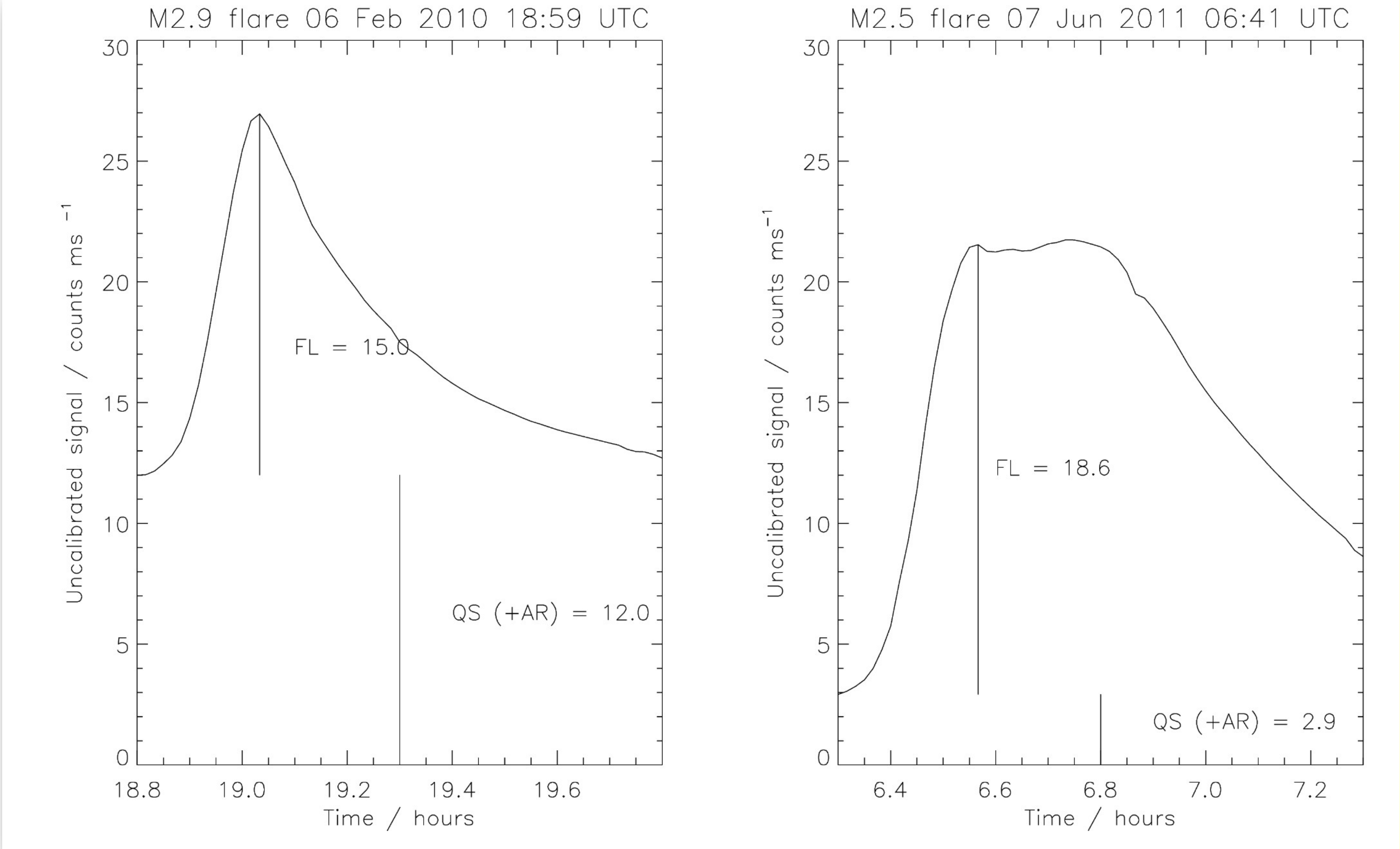


How to detect / correct degradation ? (Al channel 2-3, first example)





How to detect / correct degradation ? (Al channel 2-3, second example)



What did we learn from this?

- Within one year, the quiet-Sun signal drops by a factor 4 or 5.
- Flare-signal development is ambiguous.
- Multiplicative method would blow flare strength out of proportion.
- Solution: Additive method.
- Estimated degradation is added to quiet-Sun signal.
- But what to do for active-region or flare signal?

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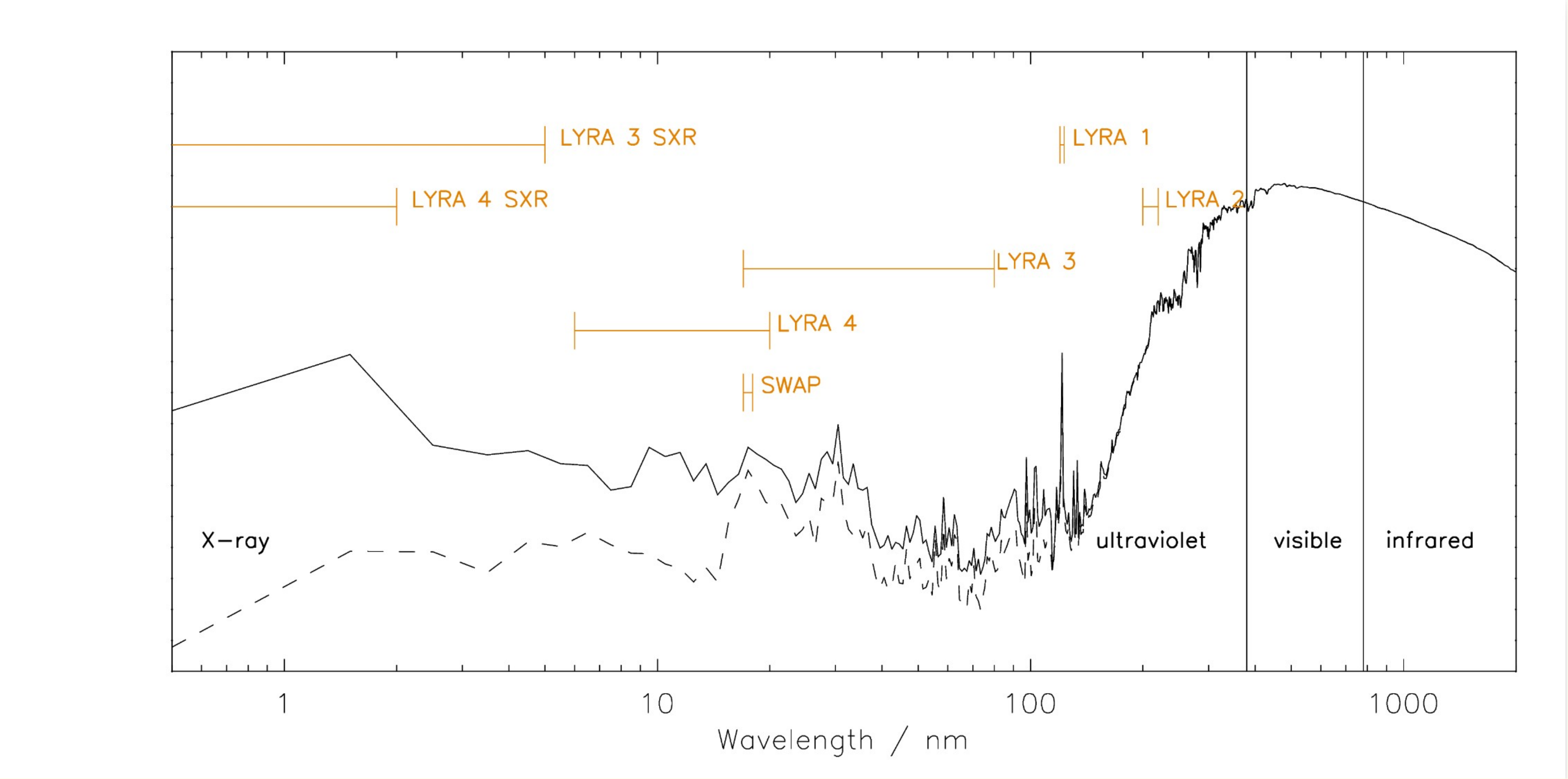
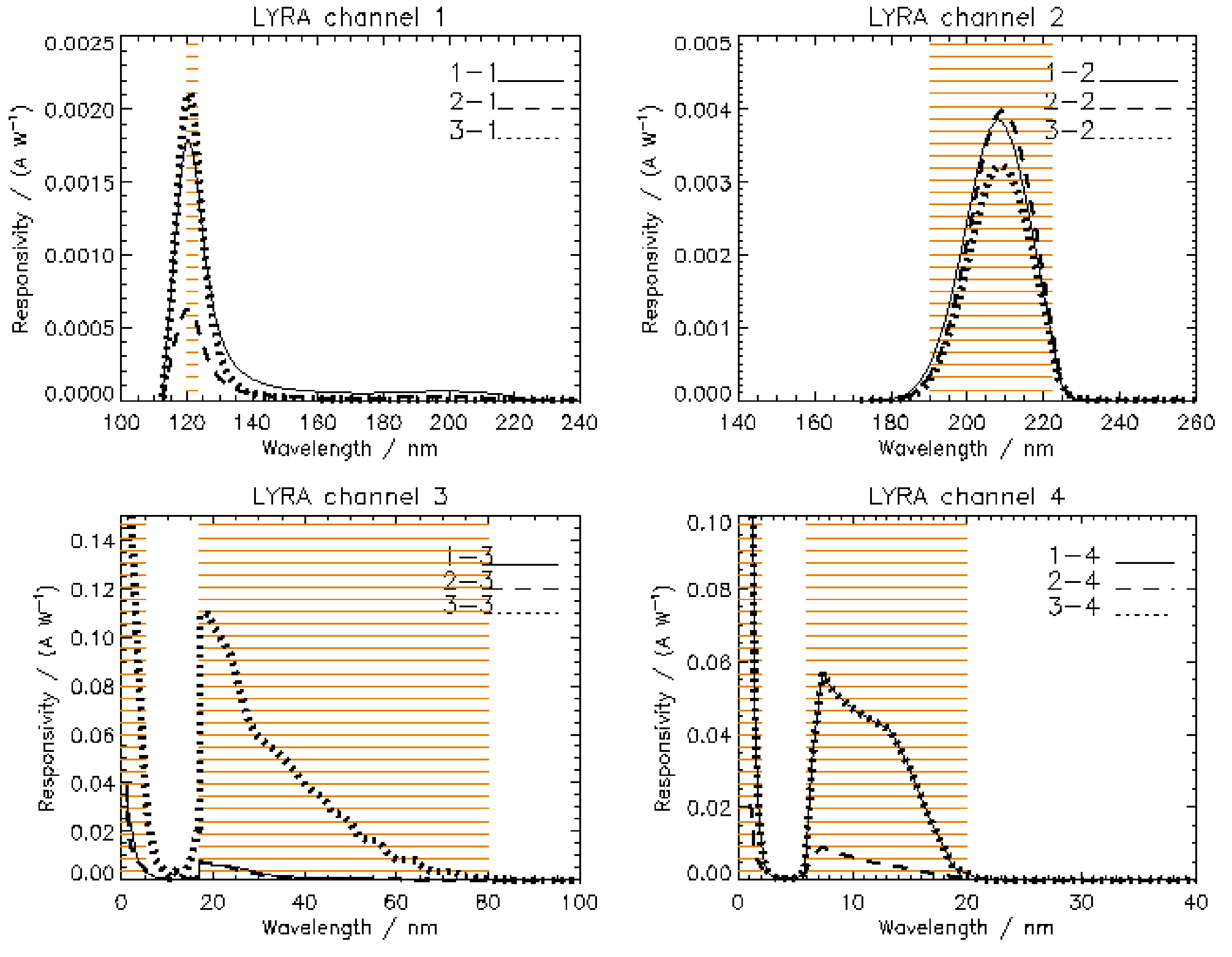
SWAP and LYRA spectral intervals for solar flares, space weather, and aeronomy

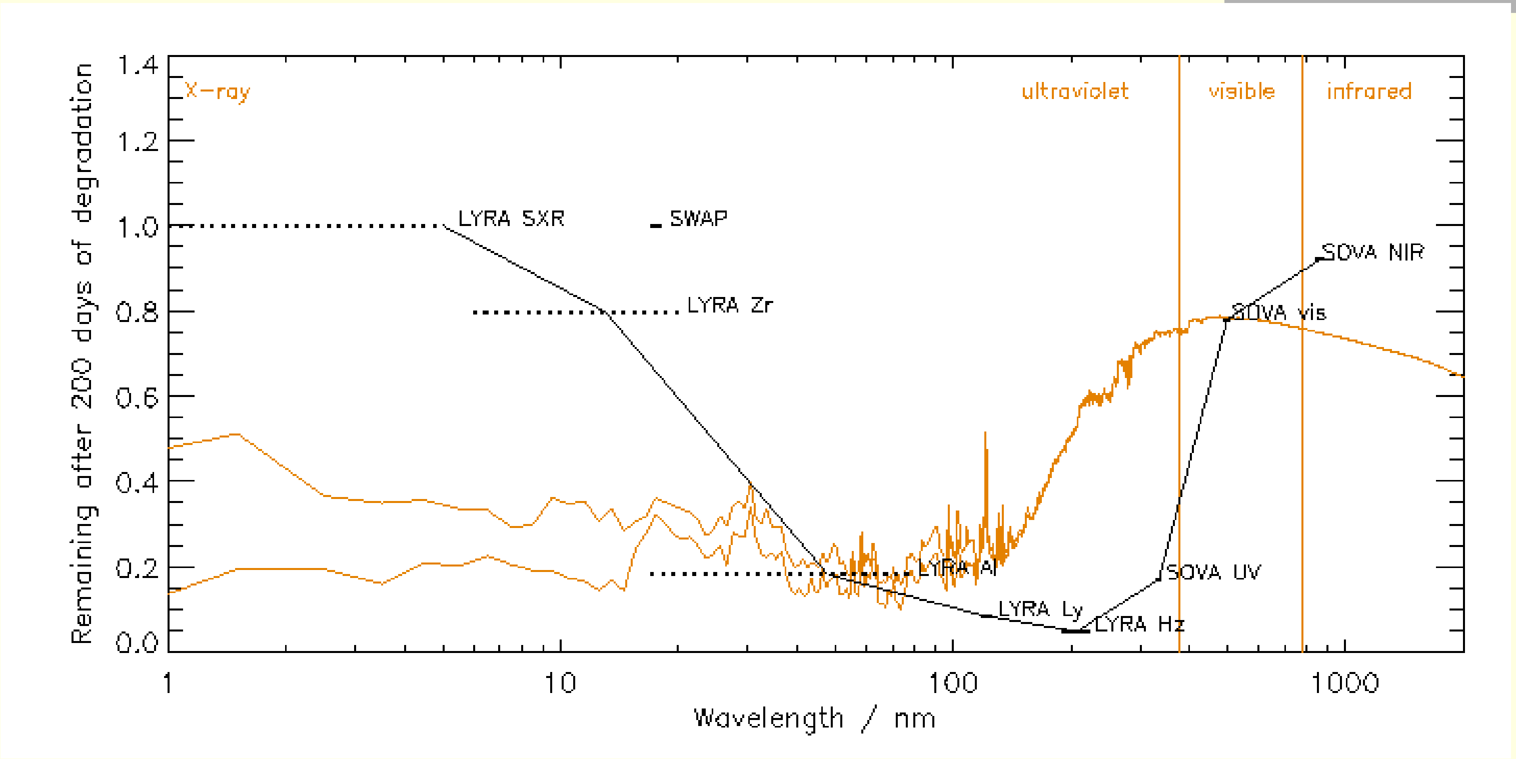


LYRA channel 1: the H I 121.6 nm Lyman-alpha line (120-123 nm)
LYRA channel 2: the 200-220 nm Herzberg continuum range (now 190-222 nm)
LYRA channel 3: the 17-80 nm Aluminium filter range incl the He II 30.4 nm line (+ <5nm X-ray)
LYRA channel 4: the 6-20 nm Zirconium filter range with highest solar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

LYRA spectral response (before launch)

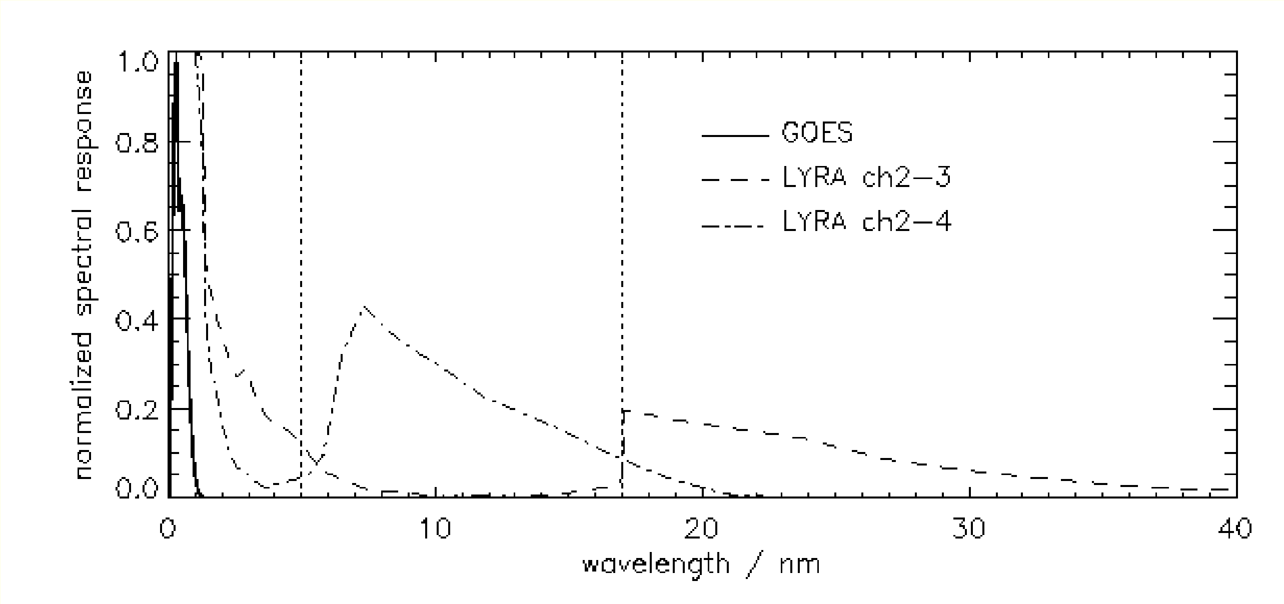


Spectral degradation in space



EURECA / SOVA 1992-1993 (retrieved by Space Shuttle)
PROBA2 / LYRA 2010-2012 (nominal unit 2)
UV-polymerization -> molecular contamination on first optical surface
mix of 100nm C, 5nm Si, and maybe oxidation; worst effect in [20nm,500nm] range

What is left for LYRA's active-region or flare signals?



Assumption:

Spectral range [17nm , 80nm]: rest still existing for unit 1, vanished for unit 2 and unit 3.

Spectral range [5nm , 17nm]: rest still existing for unit 2, more for unit 1 and unit 3.

Spectral range [0.1nm , 5nm]: still existing for all units, somewhat degraded for unit 2.

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1. Description of instrument and problem
2. LYRA's spectral degradation
3. Estimating QS-signal degradation
4. Estimating AR-signal degradation
5. Correction and conclusion

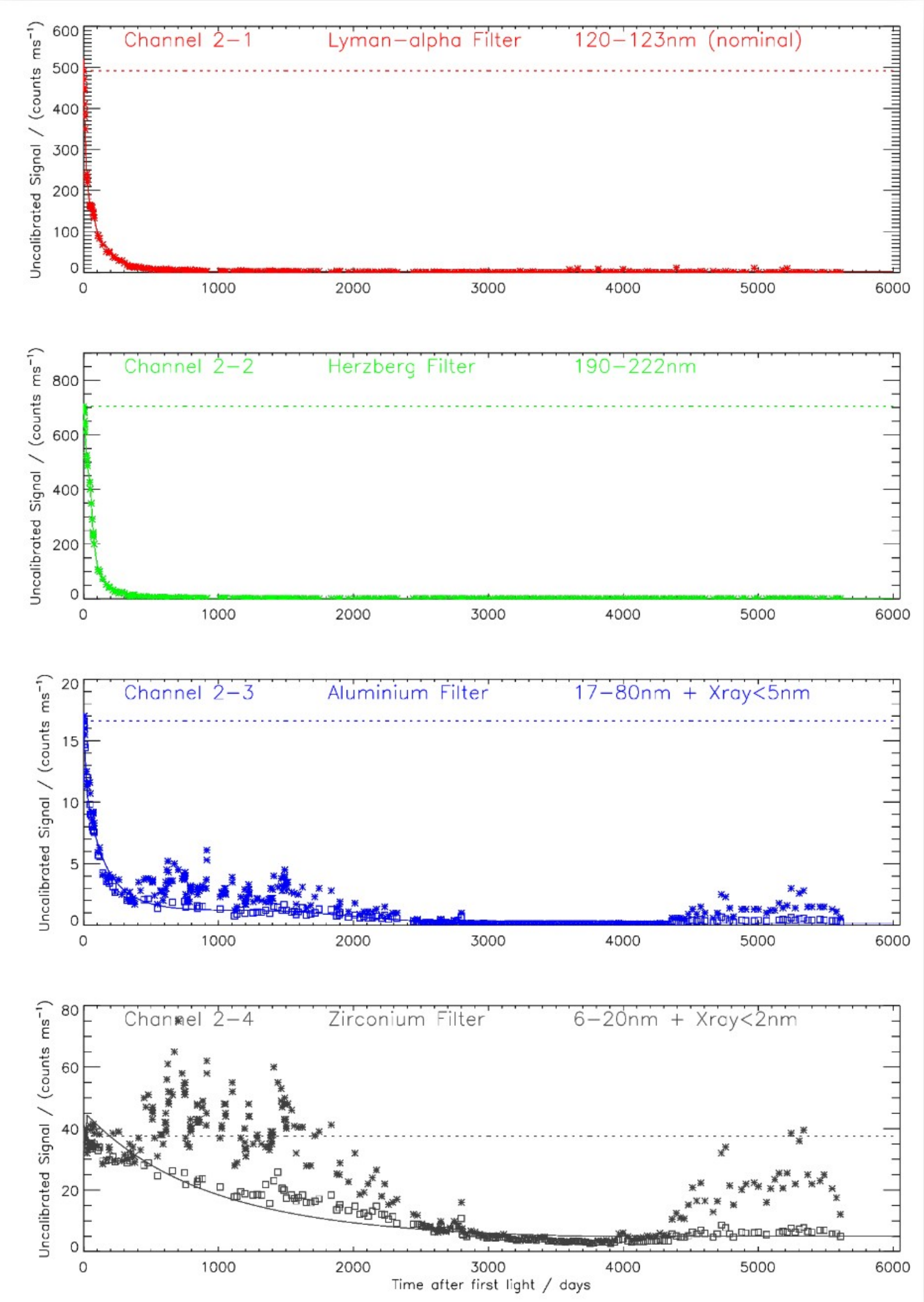
Degradation of quiet-Sun signal: ”nominal” unit 2, permanently used (~years)

Status: June 2025.
Data from short, regular campaigns.
Data of ch3 and ch4 corrected for solar variability before fit.

Remaining QS response:

ch2-1 (Ly)	<1%
ch2-2 (Hz)	<1%
ch2-3 (Al)	<1%
ch2-4 (Zr)	13%

Not significantly changing any more.



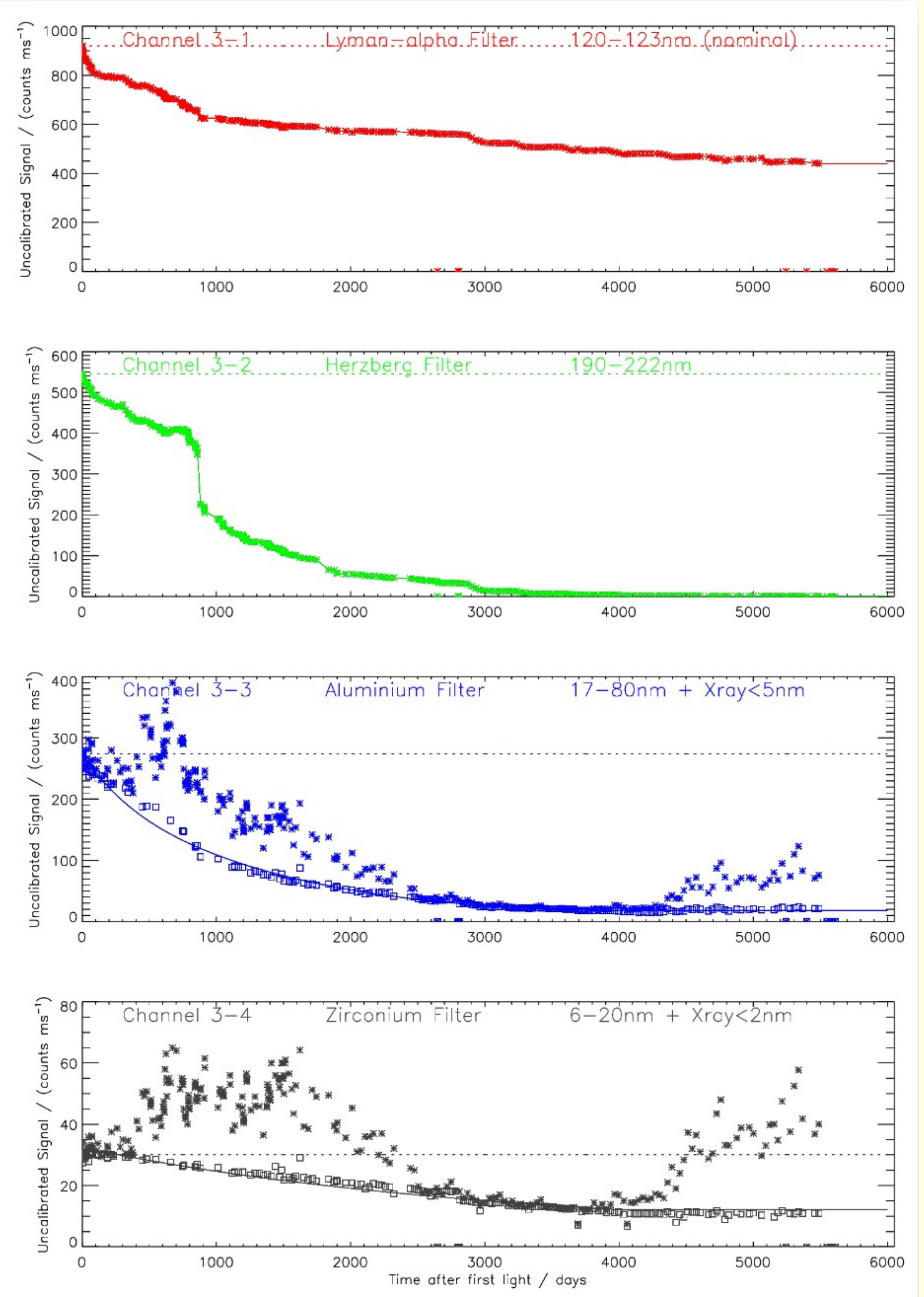
Degradation of quiet-Sun signal: ”campaign” unit 3, temporarily used (~months)

Remaining QS response:

ch3-1 (Ly)	48%
ch3-2 (Hz)	<1%
ch3-3 (Al)	7%
ch3-4 (Zr)	40%

Not significantly changing any more.

ch3-1 remaining portion due to visual light.



Degradation of quiet-Sun signal: ”calibration” unit 1, rarely used (~weeks)

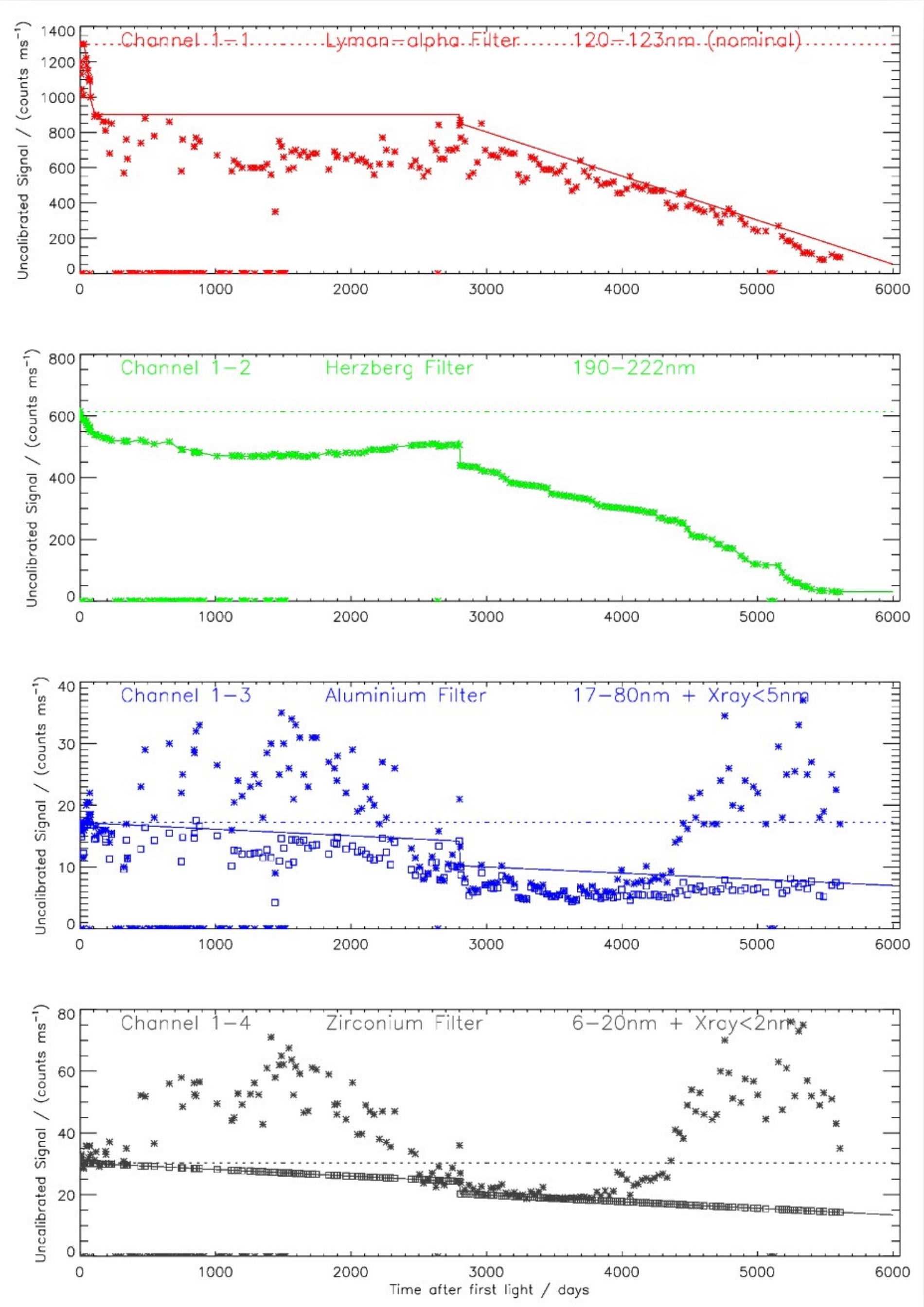
Remaining QS response:

ch1-1 (Ly)	12%
ch1-2 (Hz)	5%
ch1-3 (Al)	43%
ch1-4 (Zr)	47%

Still changing at individual rates.

ch1-1 and ch1-3 difficult to estimate due to long saturation time.

Please note:
ch1-4 is used to correct for “solar variability” before fit.



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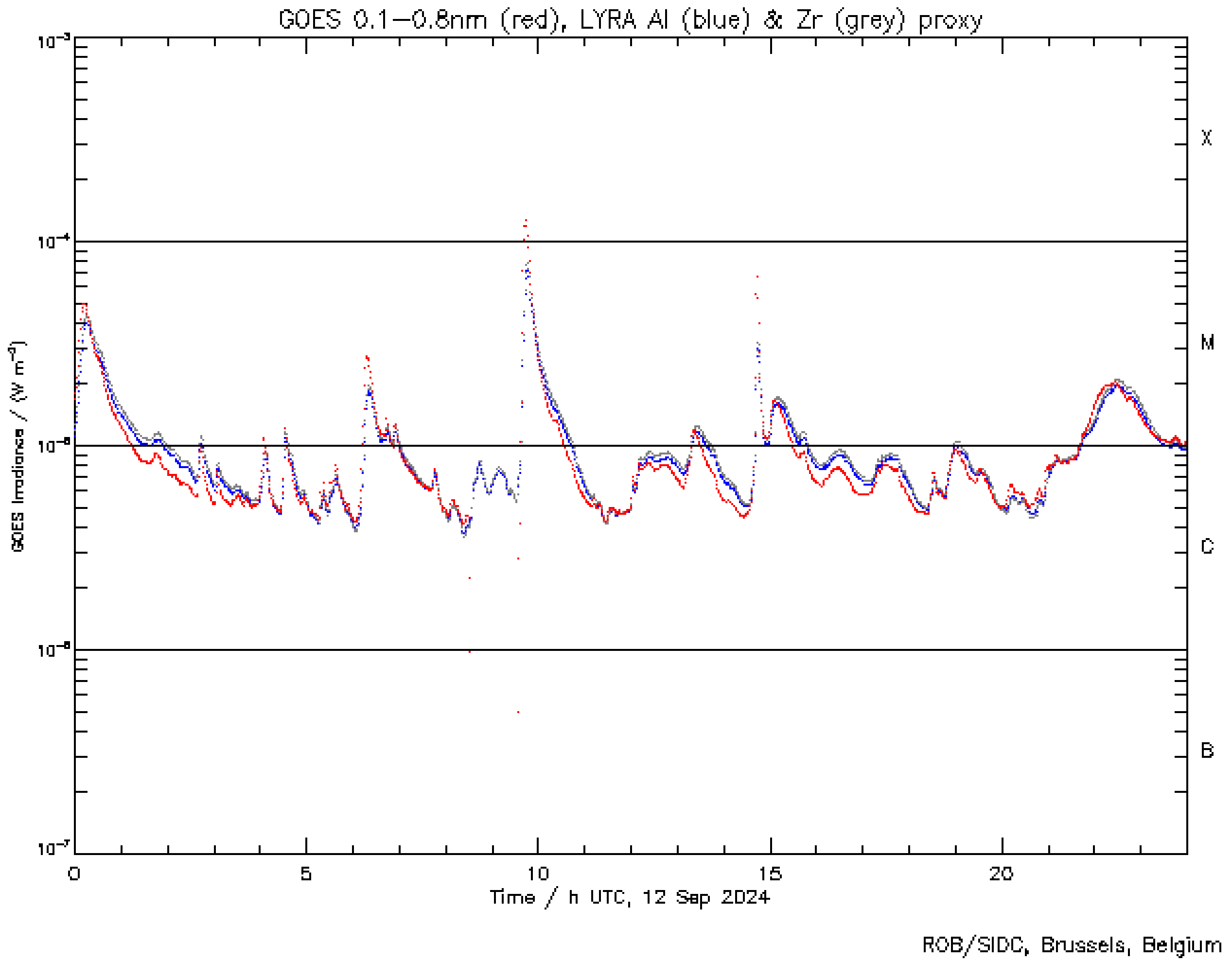
GOES-LYRA proxy

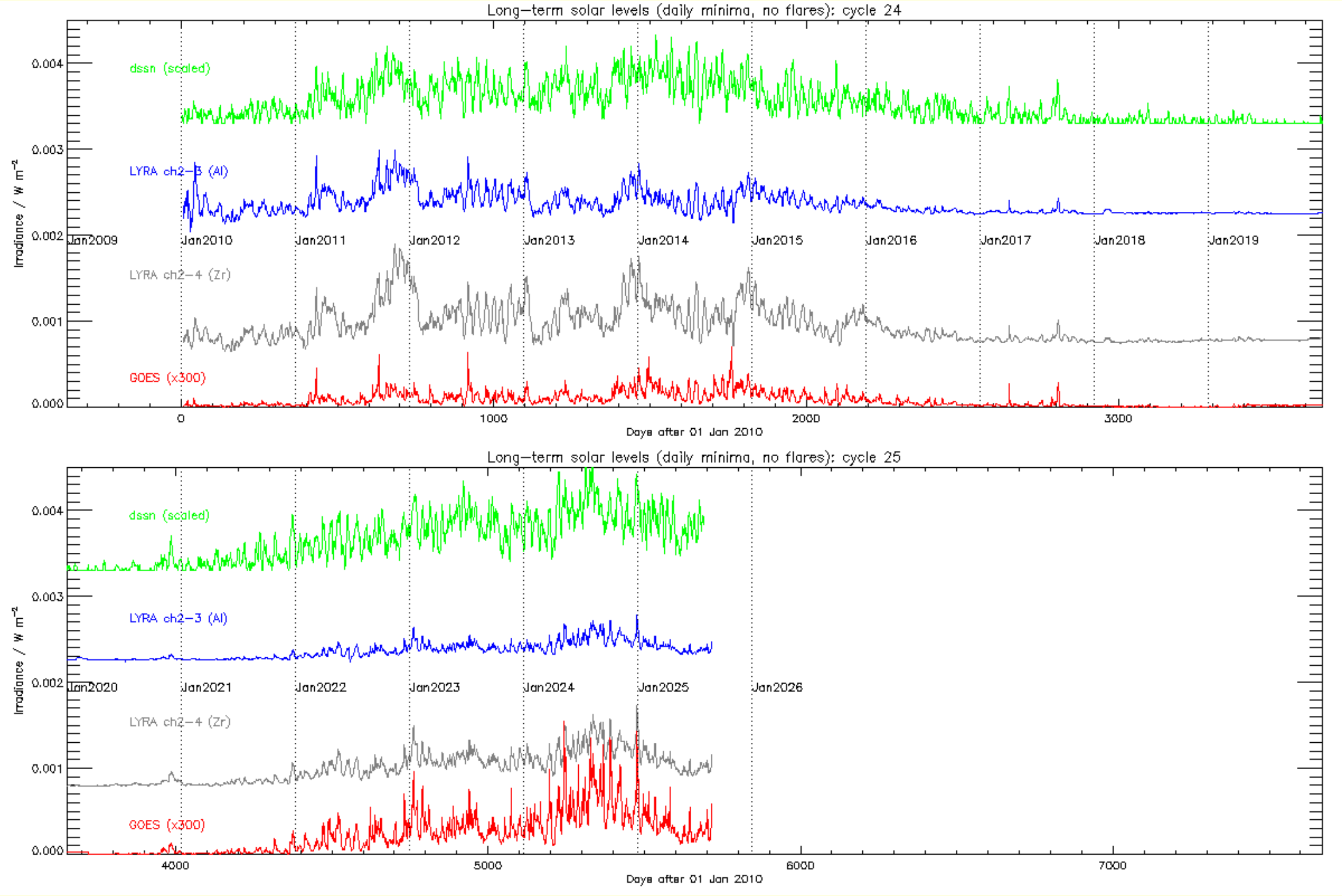
GOES=f1*LYRA ch2-3
GOES=f2*LYRA ch2-4

Necessary:
Find daily significant minimum for all three curves.

This value is called
“long-term solar level”
or
“active-region signal”.



Active-region signal of unit 2

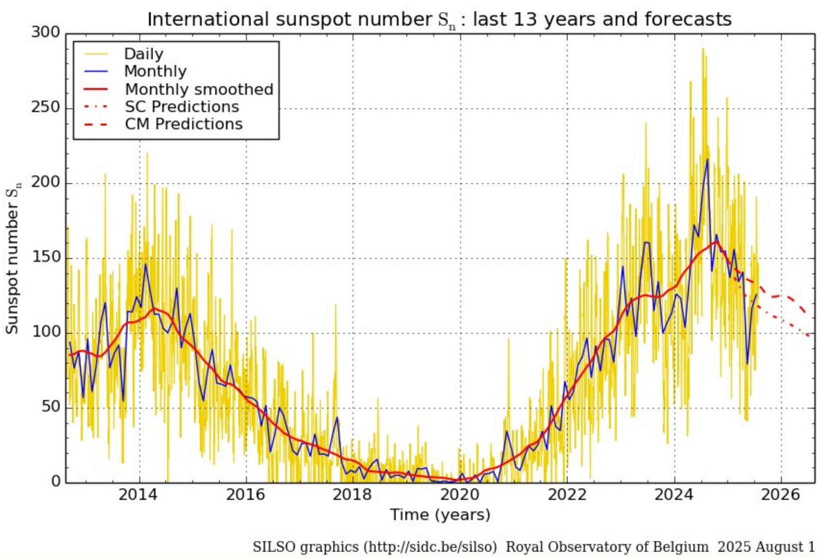


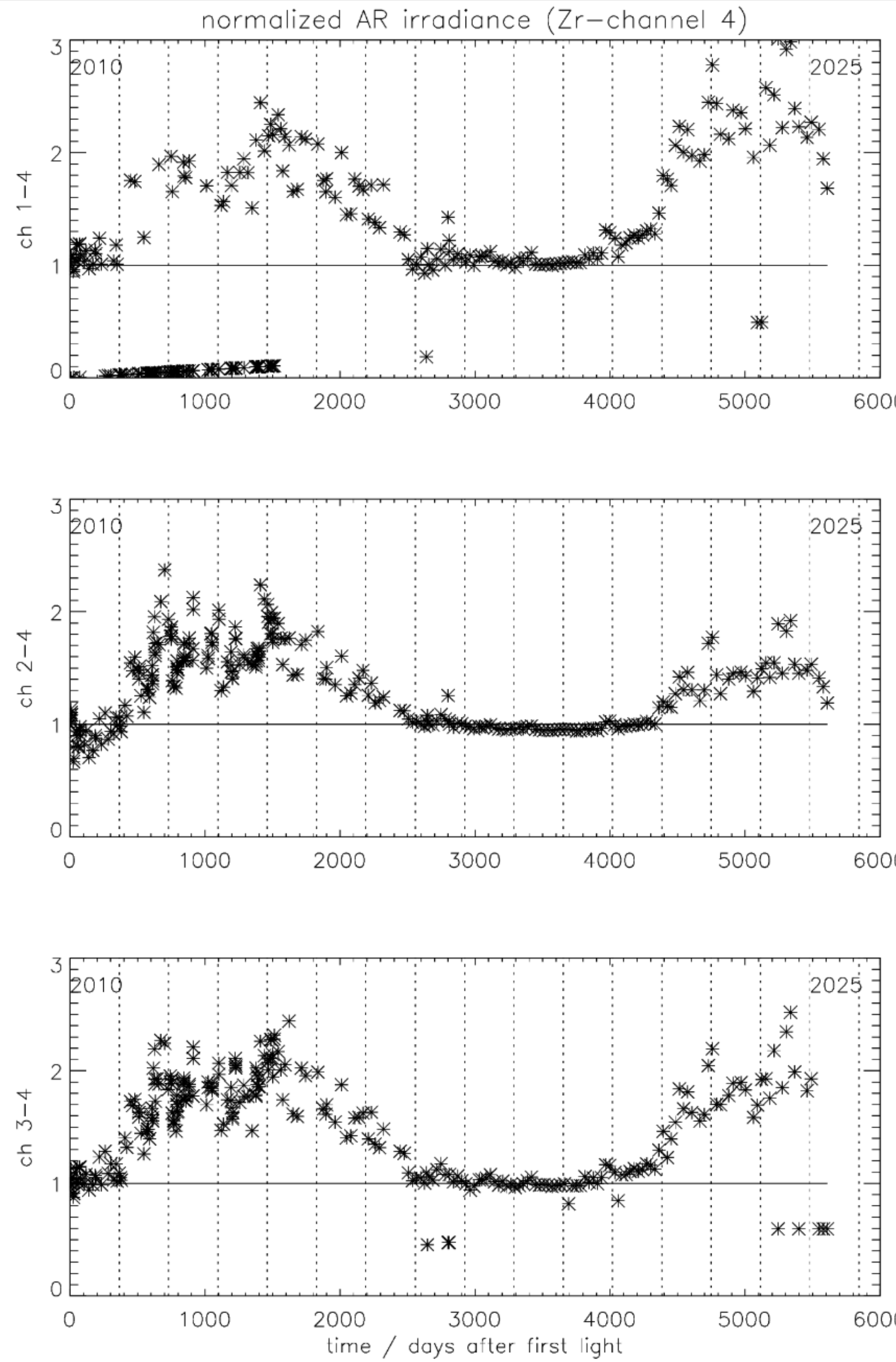
<u>Observations:</u>

- GOES values and sunspot numbers reach or exceed previous cycle
- LYRA active-region signal degraded, but less so than quiet-Sun signal
- ch2-4 less degraded than ch2-3
- problem: no daily measurements for unit 1 and unit 3, only (~monthly) campaigns

Comparison of all three LYRA units (Zr-channel 4)

Development similar
to sunspot number:

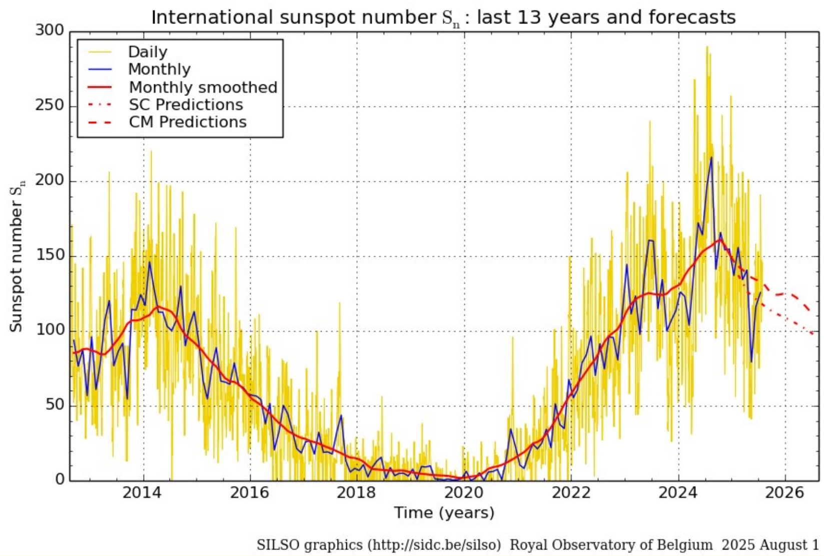


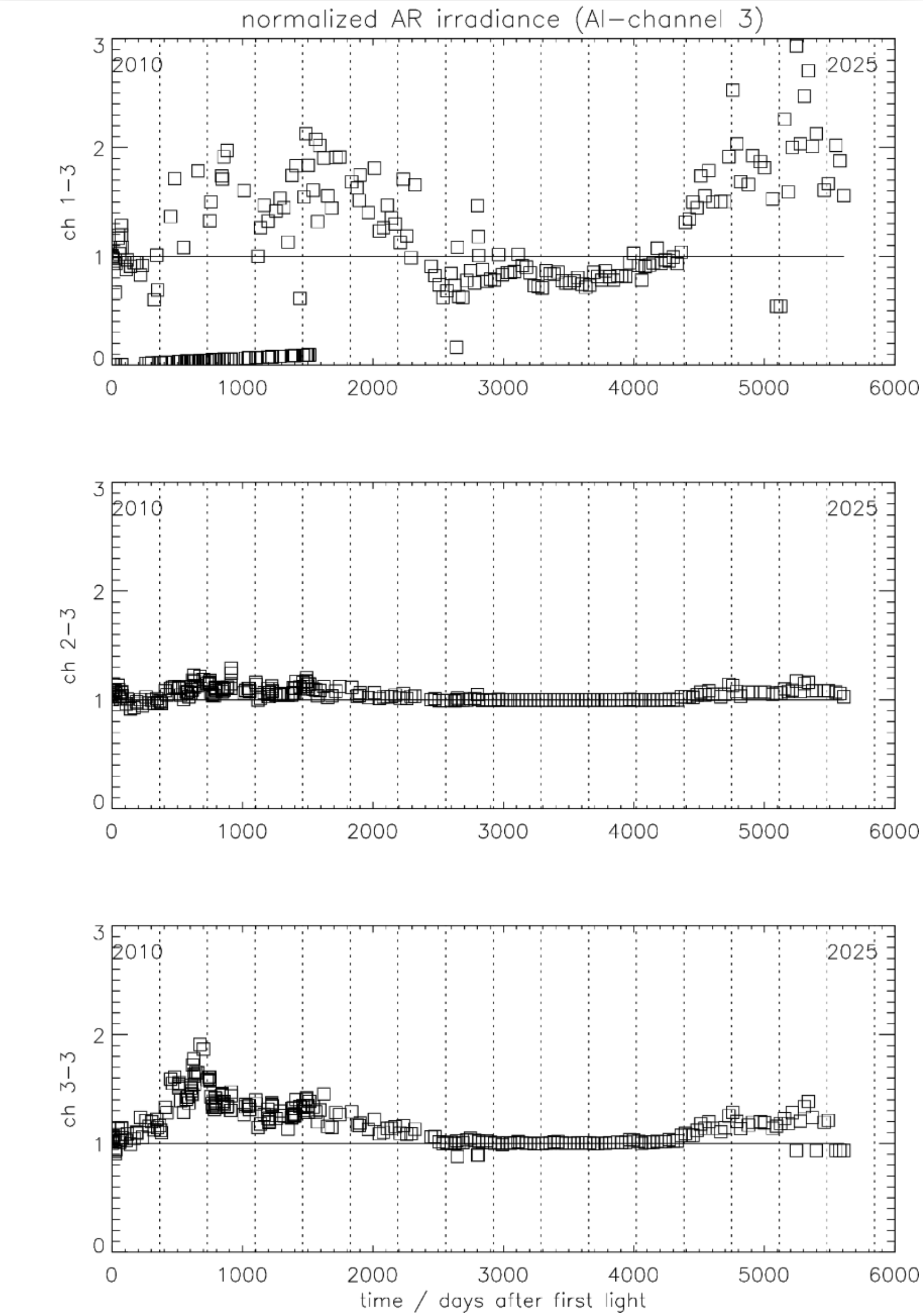


"Normalized" to QS signal level - assuming that the QS level is properly corrected.

Comparison of all three LYRA units (Al-channel 3)

Again, development similar to sunspot number:





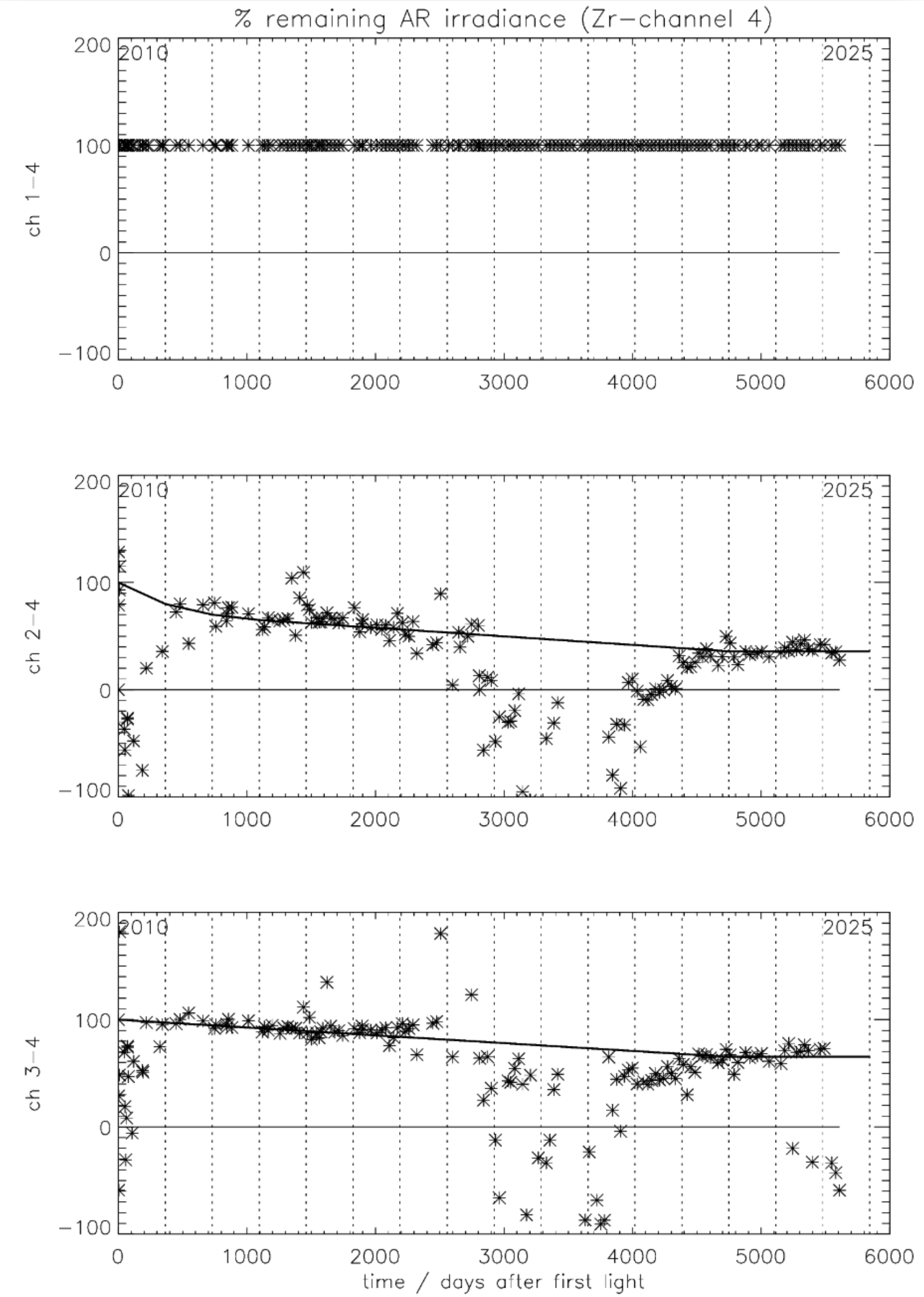
problems:
- less campaigns with unit1
- slow saturation of unit 1
- low signal for unit 2

Development of AR signal (Zr-channel 4)

- Assumption: No AR-signal degradation in unit 1.
- Normalized AR-signal of unit 2 and unit 3 divided by unit 1.
- Values in solar minimum less significant.
- Development fitted manually, first light value set to 100%.

Remaining AR response:

ch1-4 (Zr)	100%
ch2-4 (Zr)	36%
ch3-4 (Zr)	65%

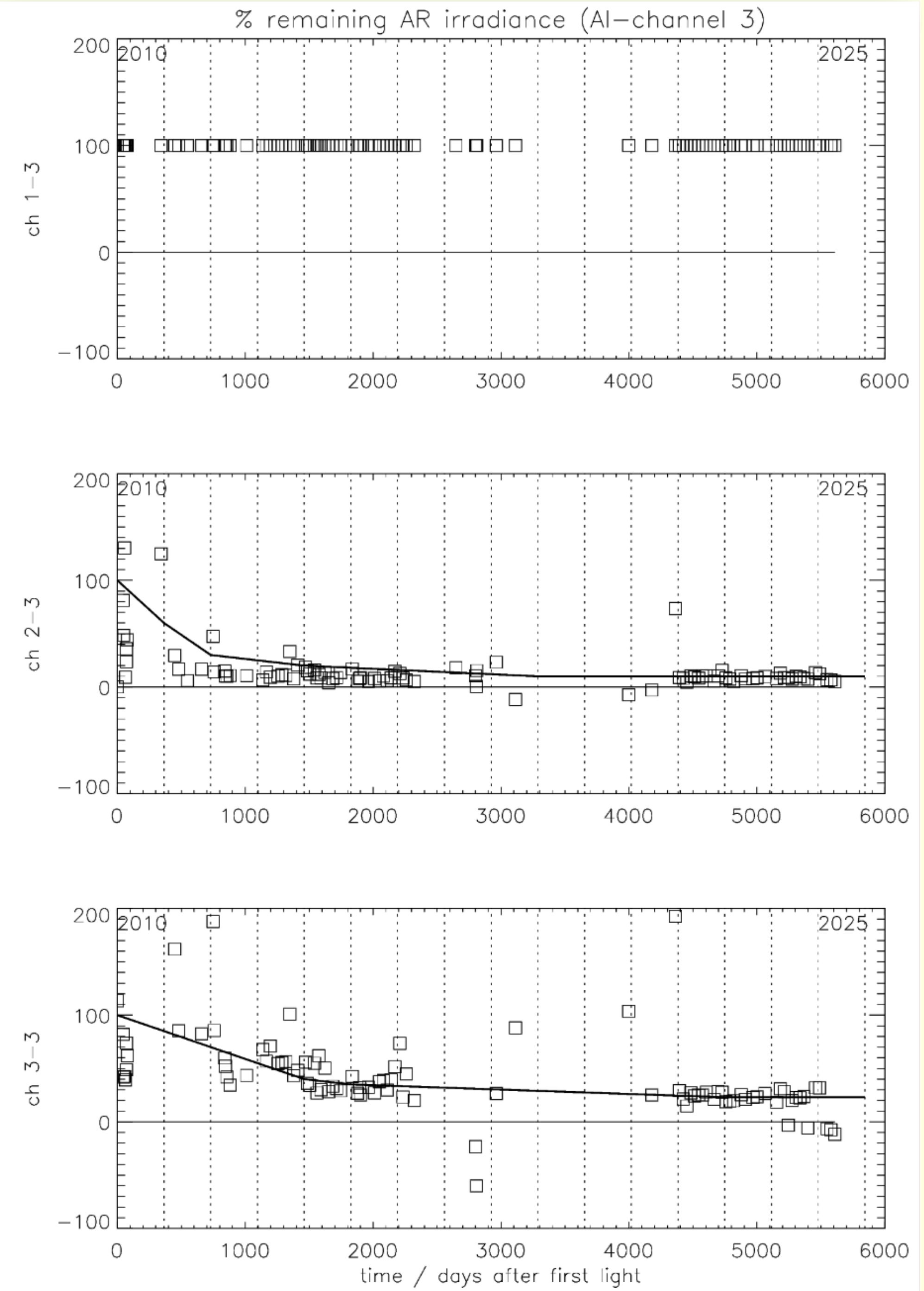


Development of AR signal (Al-channel 3)

(Same procedure)

Remaining AR response:

ch1-3 (Al)	100%
ch2-3 (Al)	10%
ch3-3 (Al)	23%



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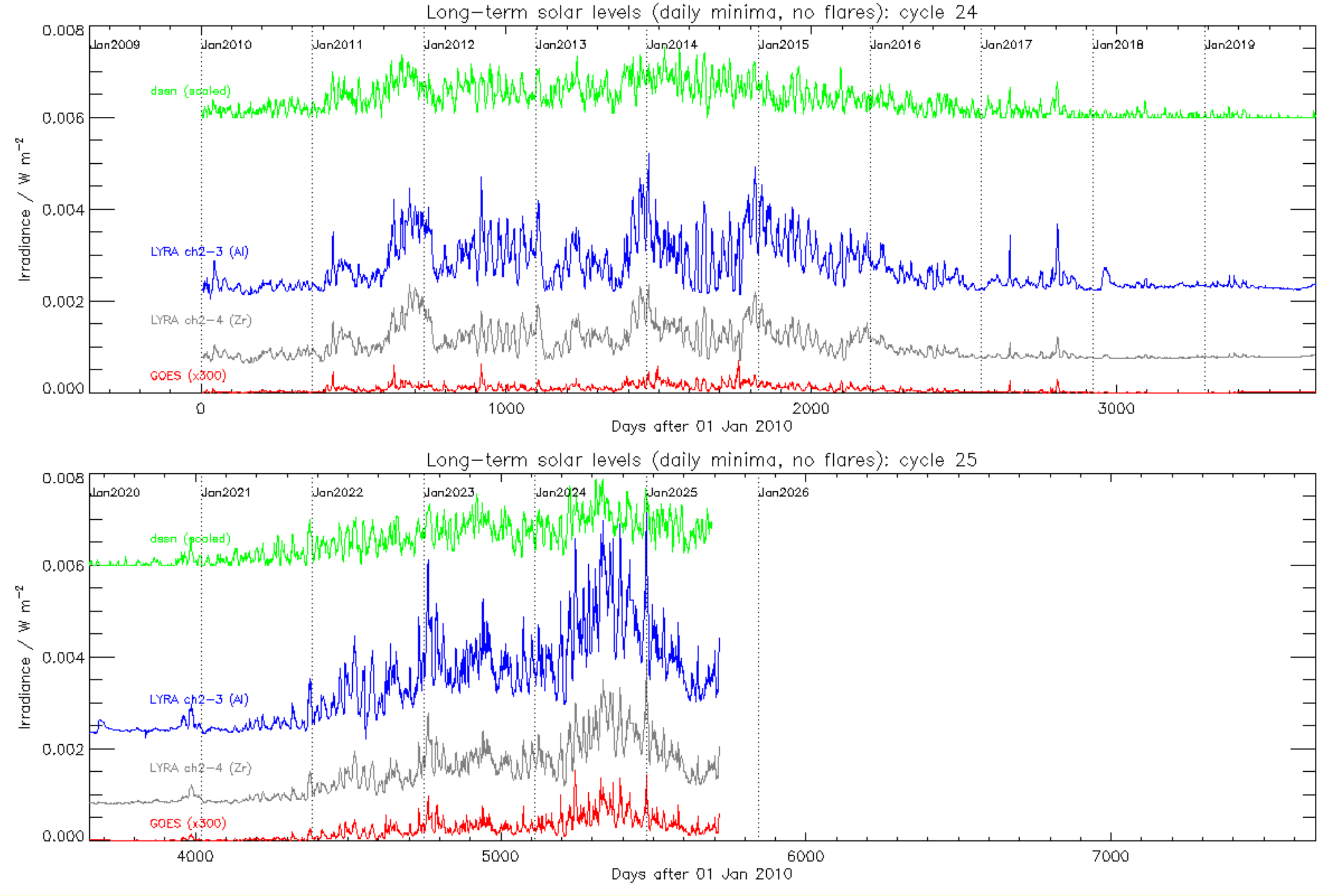
Correction of active-region signal



The AR signal of LYRA ch2-3 is multiplied by a factor between 1 (initially) and 10 (currently).
The AR signal of LYRA ch2-4 is multiplied by a factor between 1 (initially) and 2.8 (currently).
A link to the data set can be found on *https://www.sidc.be/users/dammasch/GoesVsLyra.html*

Correction of active-region signal: Consequences

Additive correction (according to QS-signal degradation)
plus multiplicative correction (according to AR-signal degradation)
makes LYRA's estimation of long-term solar levels more realistic.

The correlations confirm this (status: end-July 2025):

		before	after correction
c (LYRA ch2-3, GOES)	=	0.67	0.94
c (LYRA ch2-3, SUNSPOT)	=	0.75	0.82
c (LYRA ch2-4, GOES)	=	0.72	0.90
c (LYRA ch2-4, SUNSPOT)	=	0.82	0.86
c (LYRA ch2-3, LYRA ch2-4)	=	0.94	0.97
c (GOES, SUNSPOT)	=	0.78	0.78

Questions ?

- LYRA spectral degradation
- quiet-Sun signal correction
- active-region signal correction
- resulting data set