# The performance of PROBA2 / LYRA

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Dep4 Seminar
Royal Observatory of Belgium
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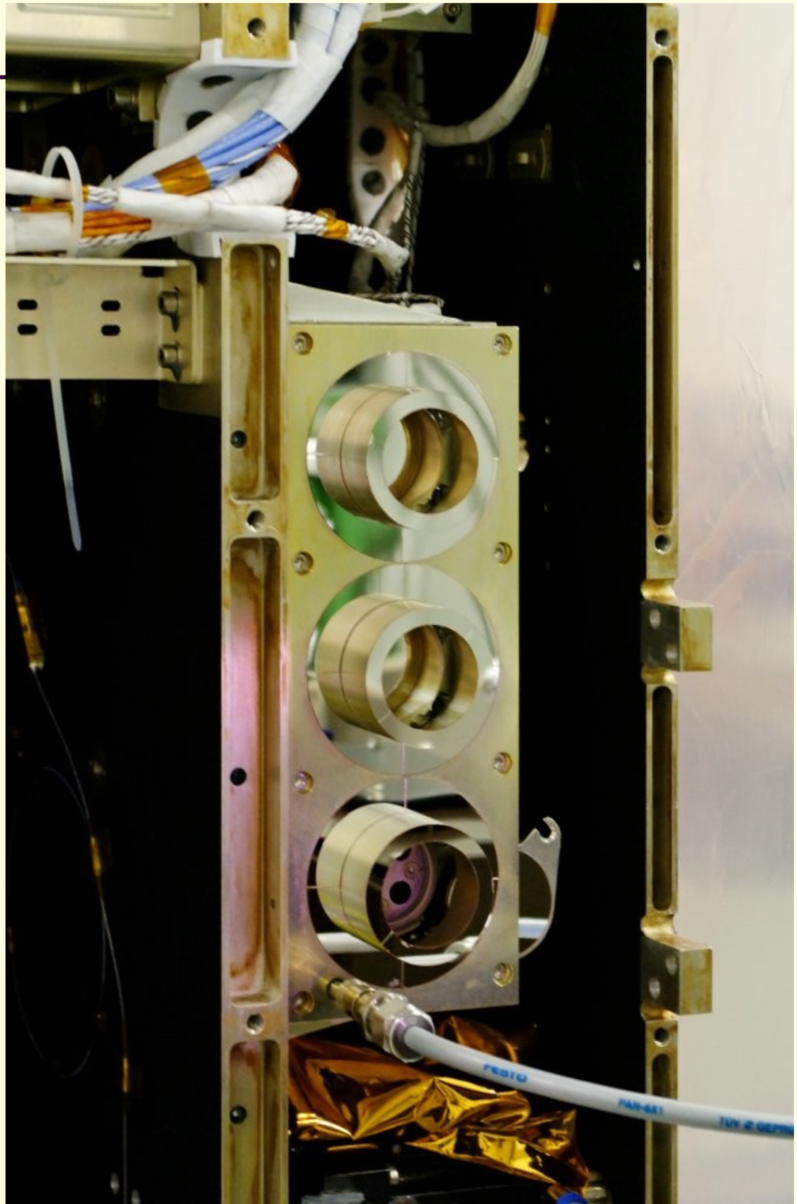
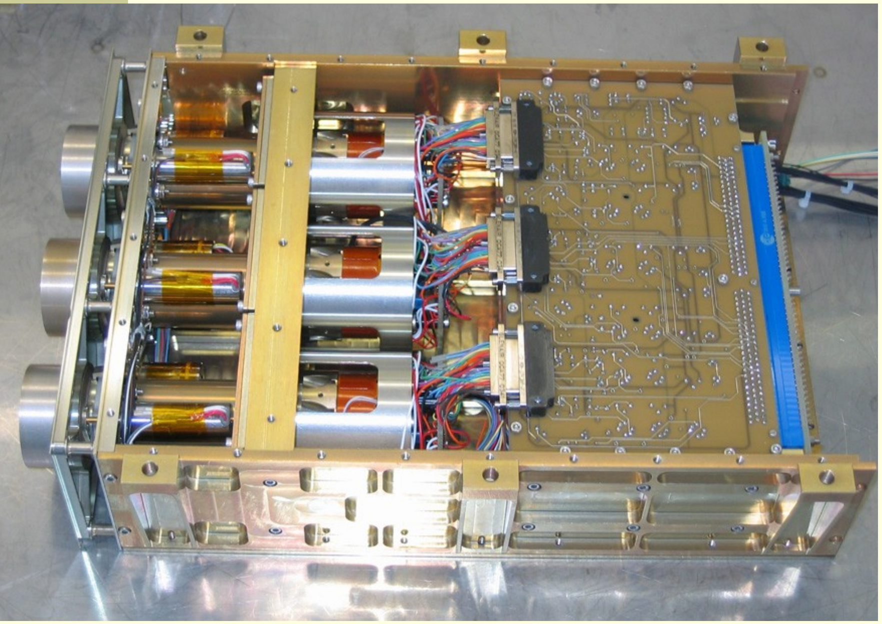
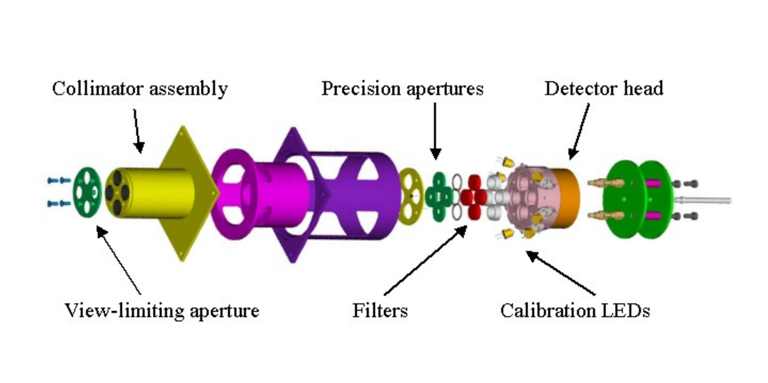
# LYRA: the Large-Yield RAdiometer

- 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 properties






- 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
- MPI für Sonnensystemforschung (Goettingen, D)
  calibration
- science Co-Is: BISA (Brussels, B), LPC2E (Orléans, F)

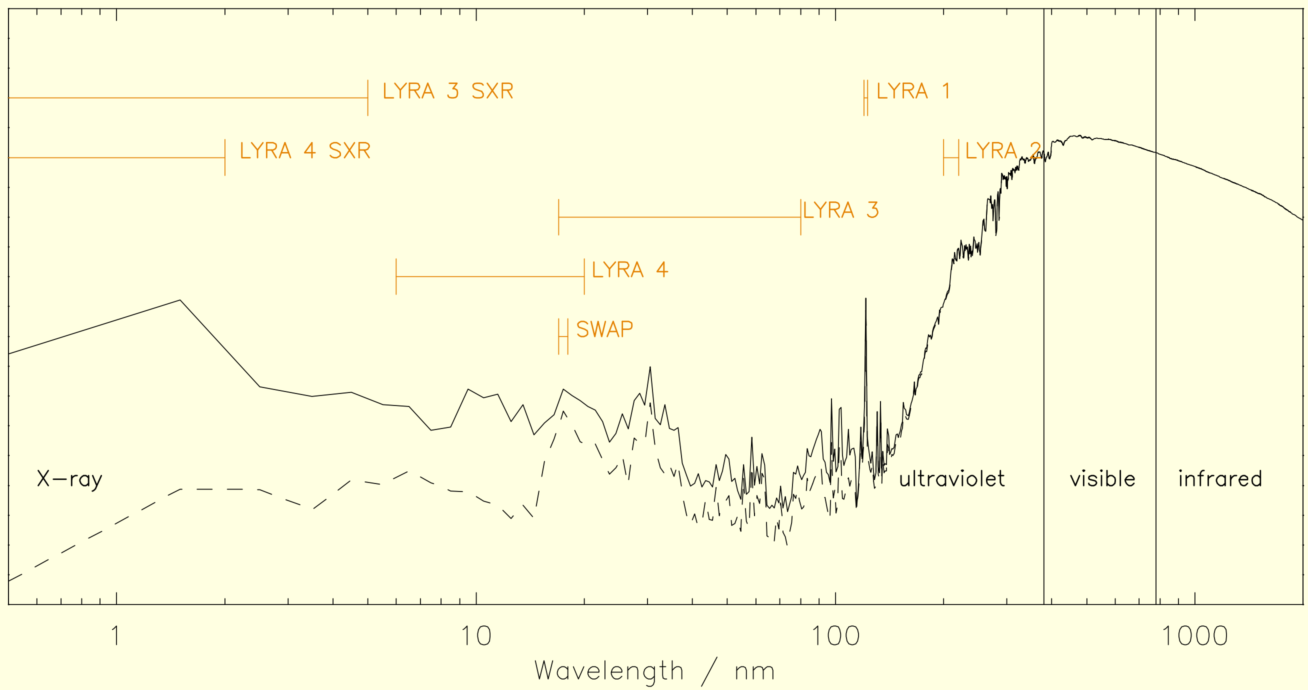
# LYRA properties

- 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 |

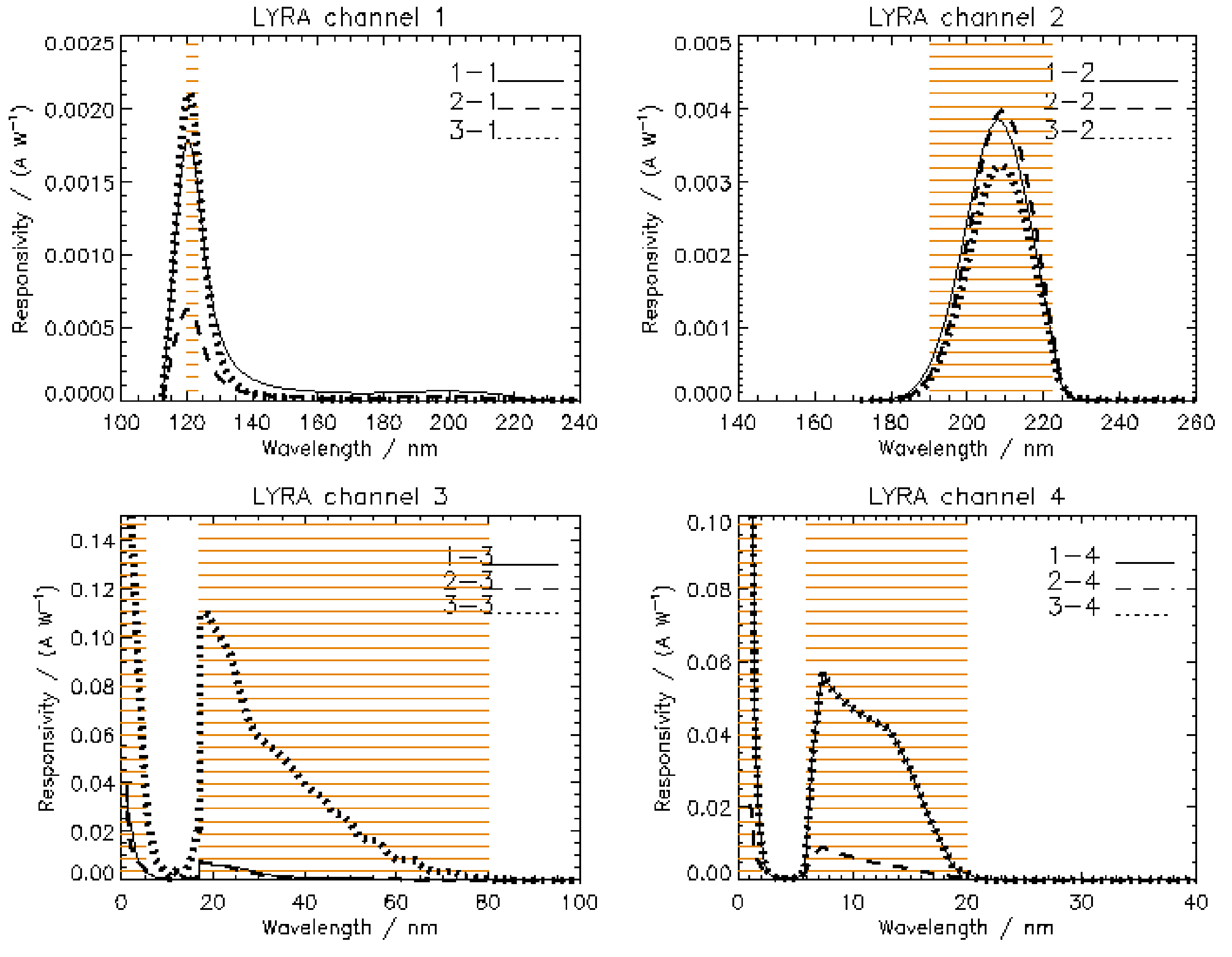
- 2 calibration LEDs per detector (λ = 465 nm and 390 nm)
- High cadence (up to 100Hz)
- Quasi-continuous acquisition during mission lifetime

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



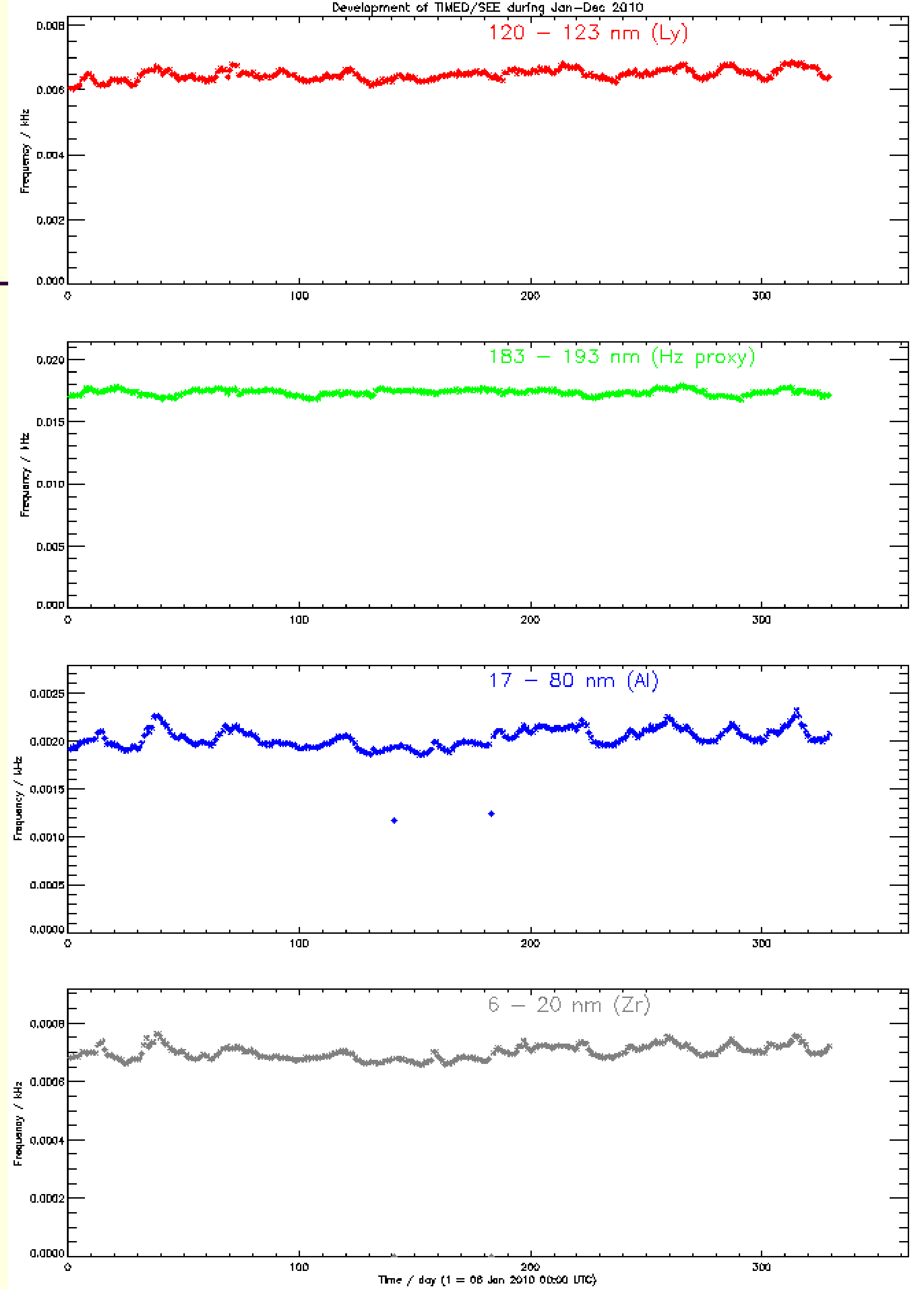

LYRA channel 1: the H I 121.6 nm Lyman-alpha line (120-123 nm)
LYRA channel 2: the 200-220 nm Herzberg continuum range (now 190-222 nm)
LYRA channel 3: the 17-80 nm Aluminium filter range incl the He II 30.4 nm line (+ <5nm X-ray)
LYRA channel 4: the 6-20 nm Zirconium filter range with highest solar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

# LYRA spectral response (before launch)

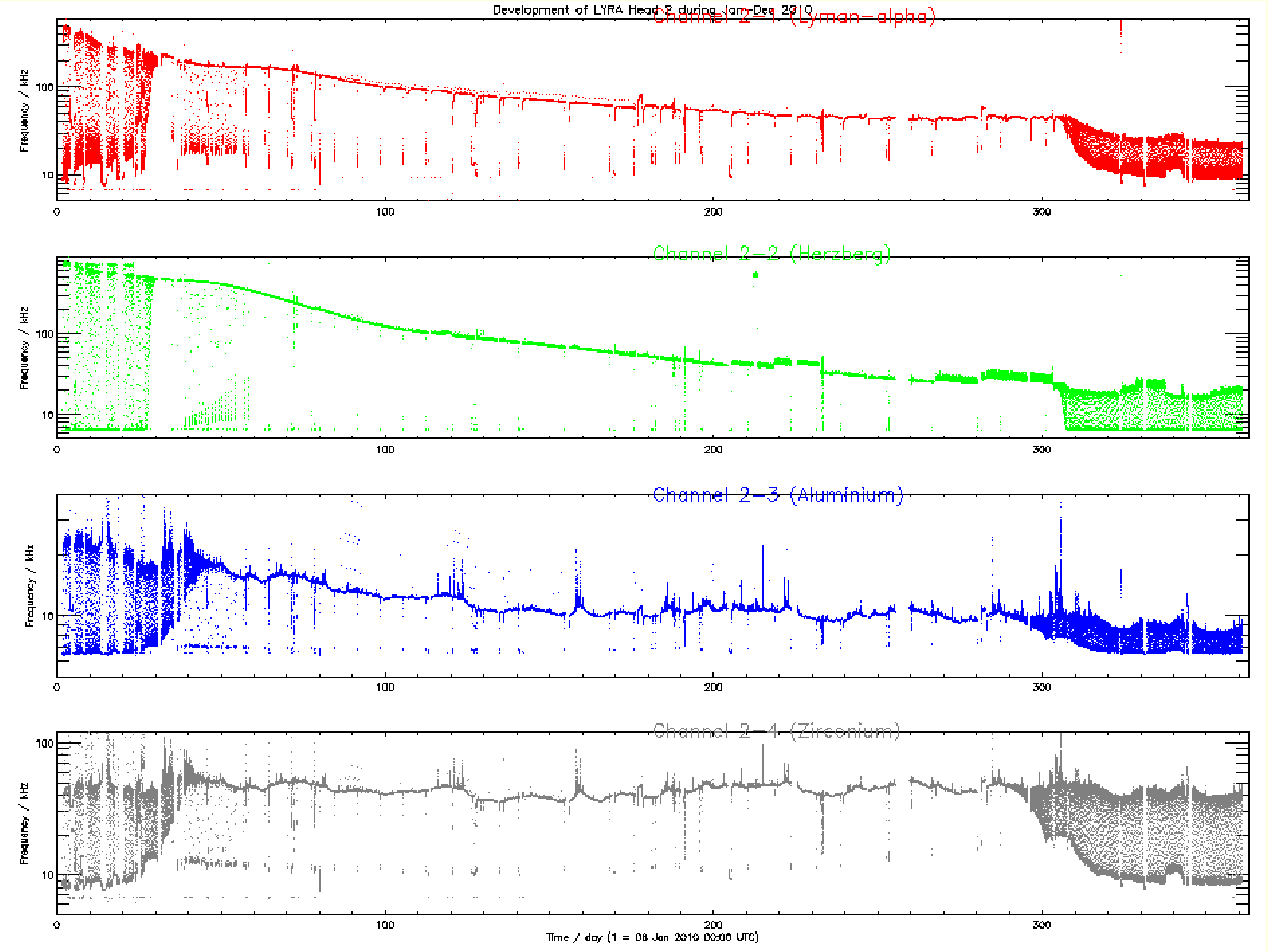


# Calibration - first problems

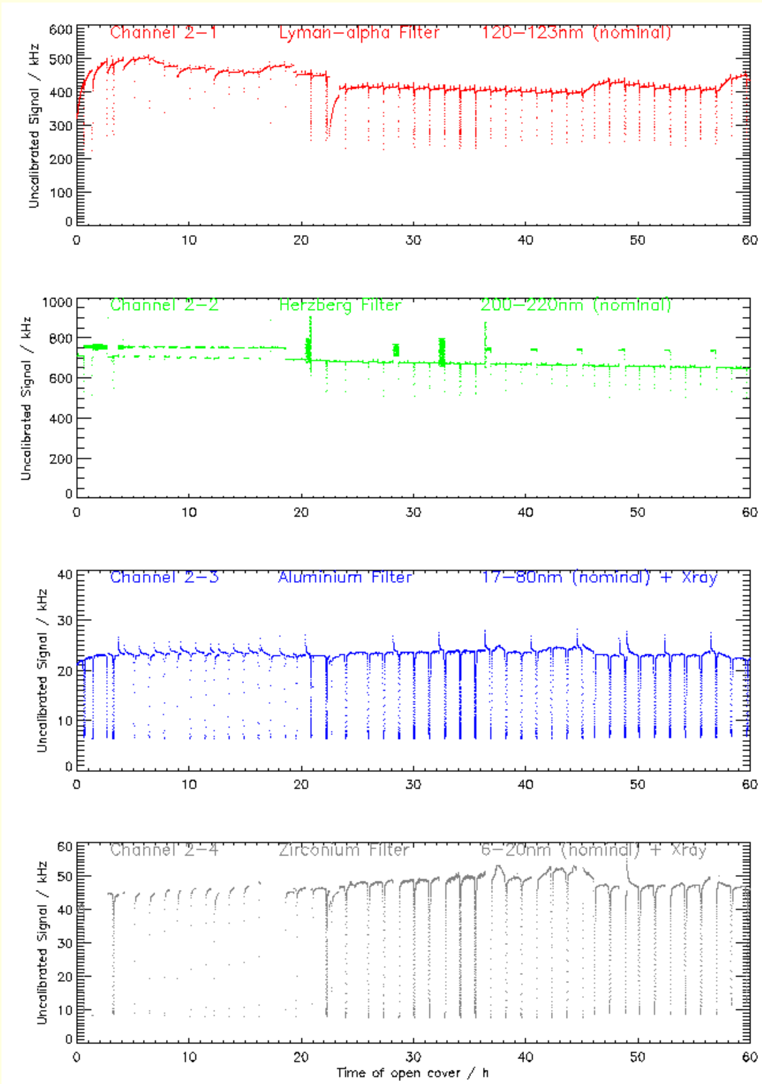
2010 according to TIMED/SEE

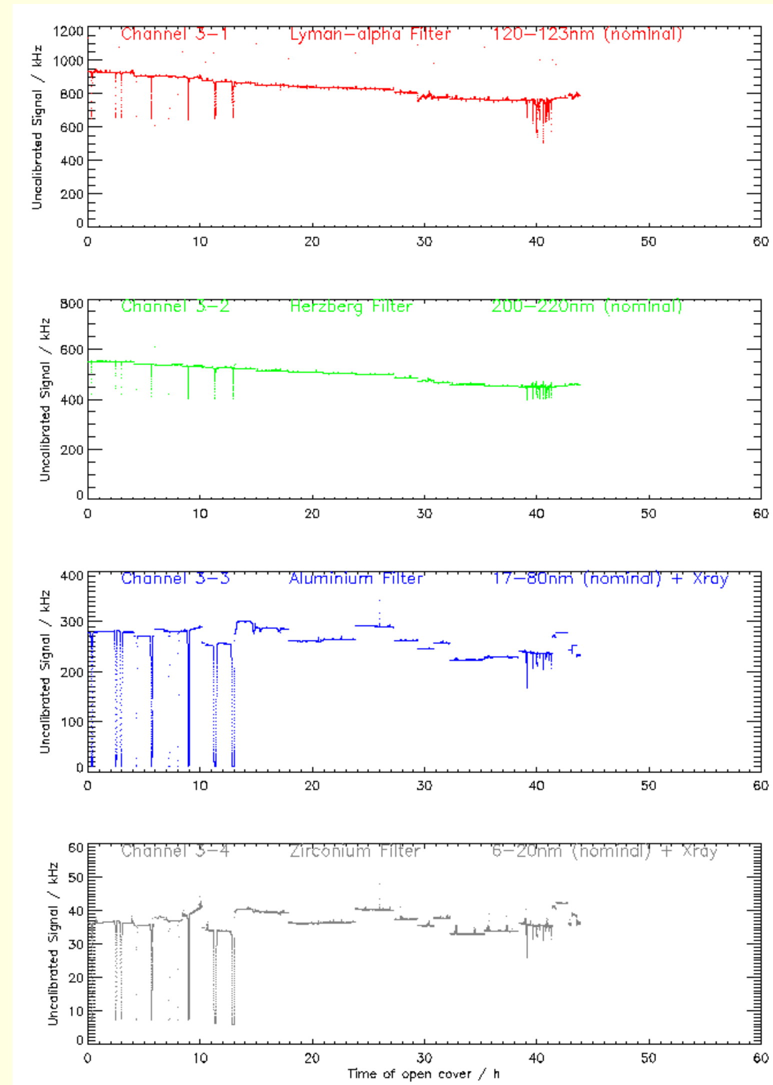


# Calibration – first problems: 2010 according to LYRA

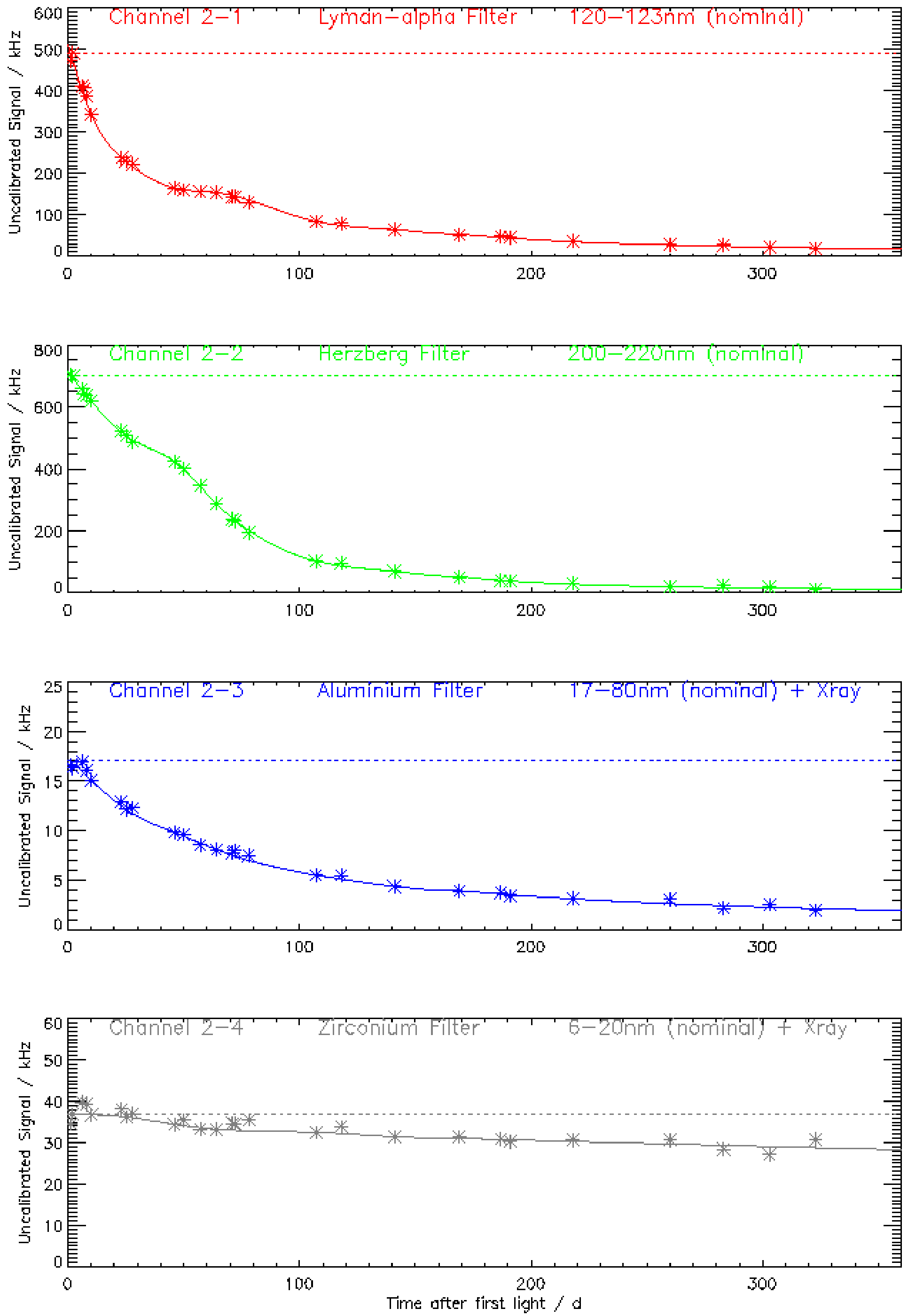


# Solution – Start with "First Light"



# … fit the degradation …

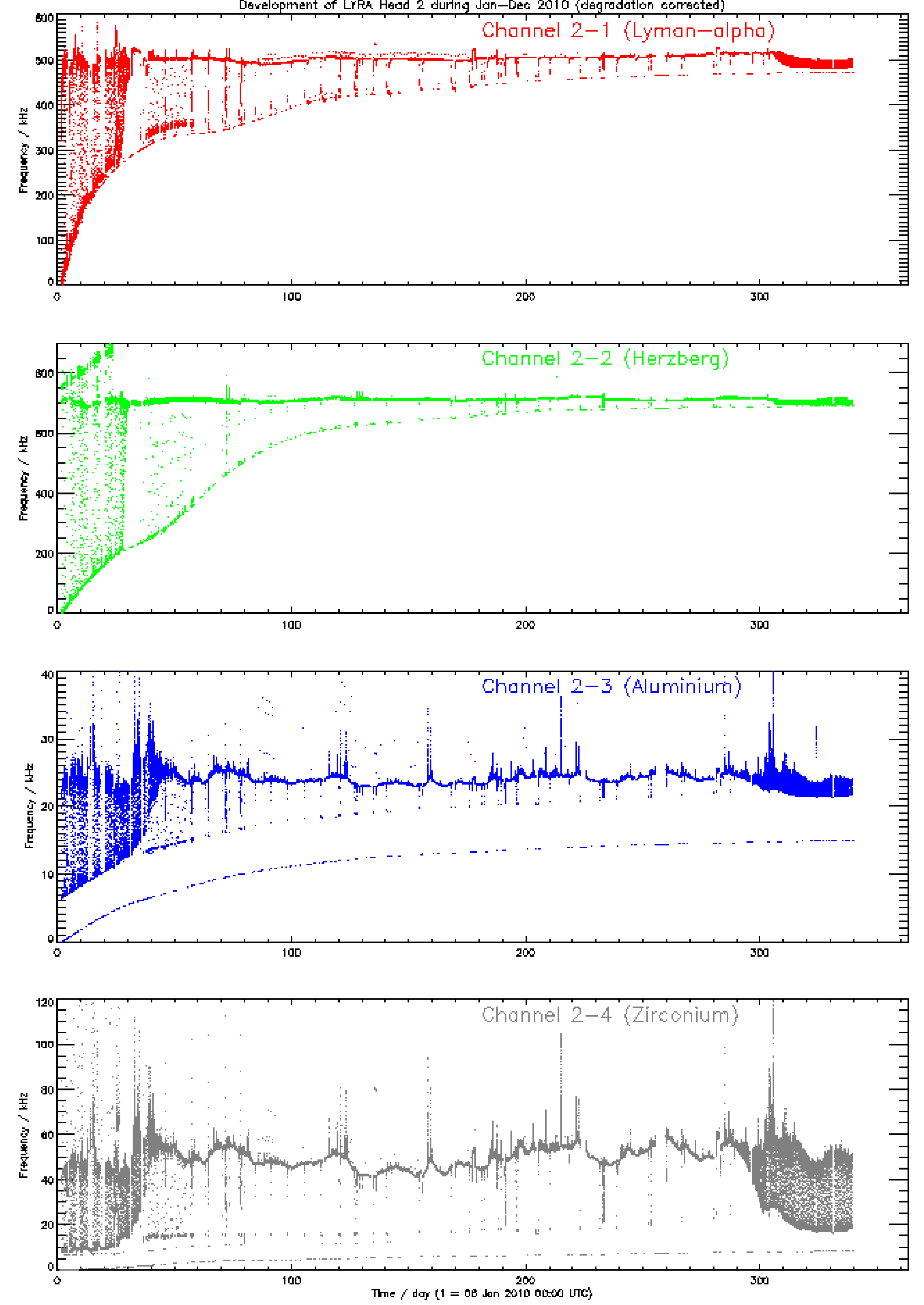


# … and add it

Plausibility:

Artifacts in channels 1 and 2

Non-degenerated SXR in channels 3 and 4

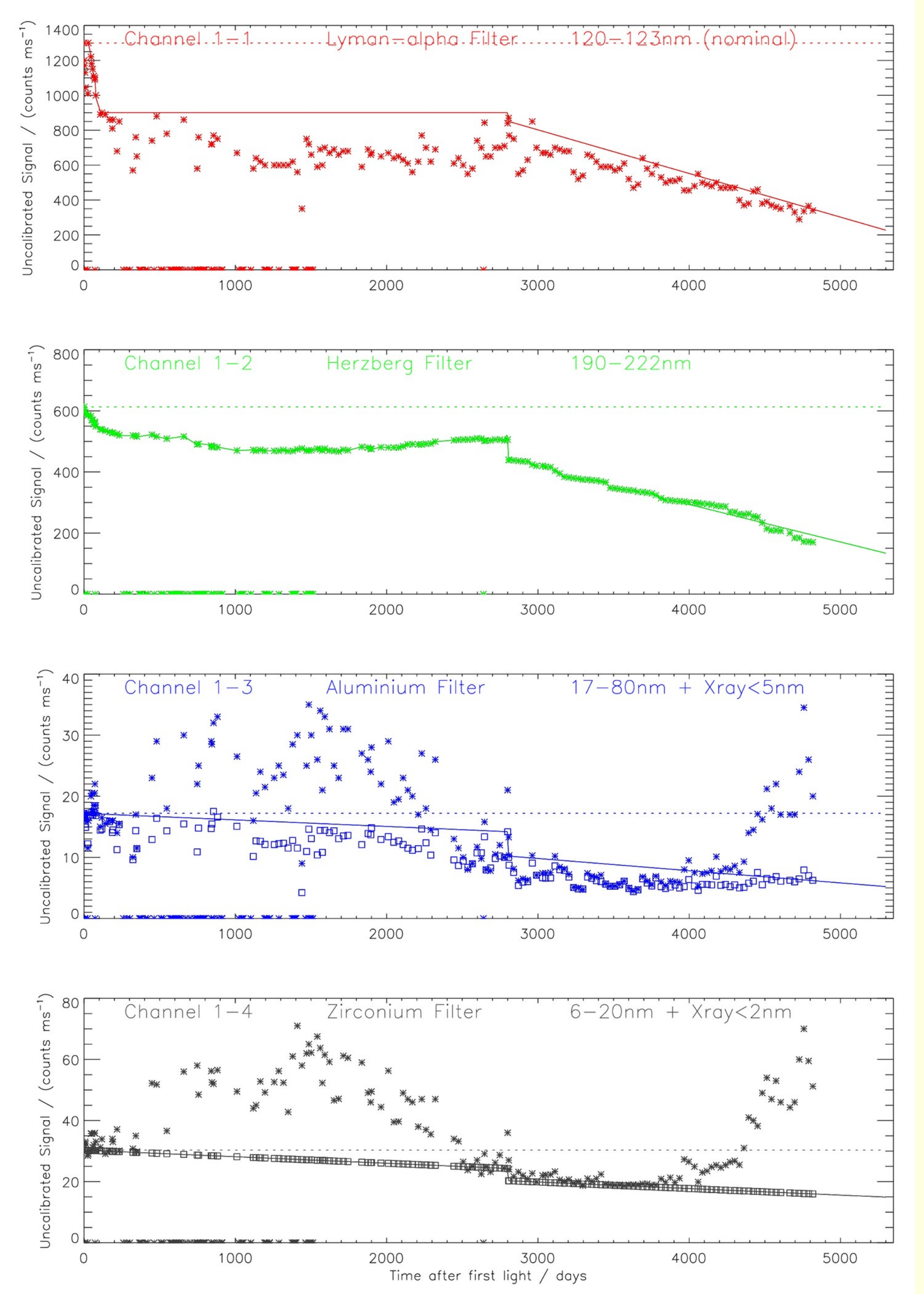


## Degradation of quiet-Sun signal: ”calibration” unit 1, rarely used (~weeks)

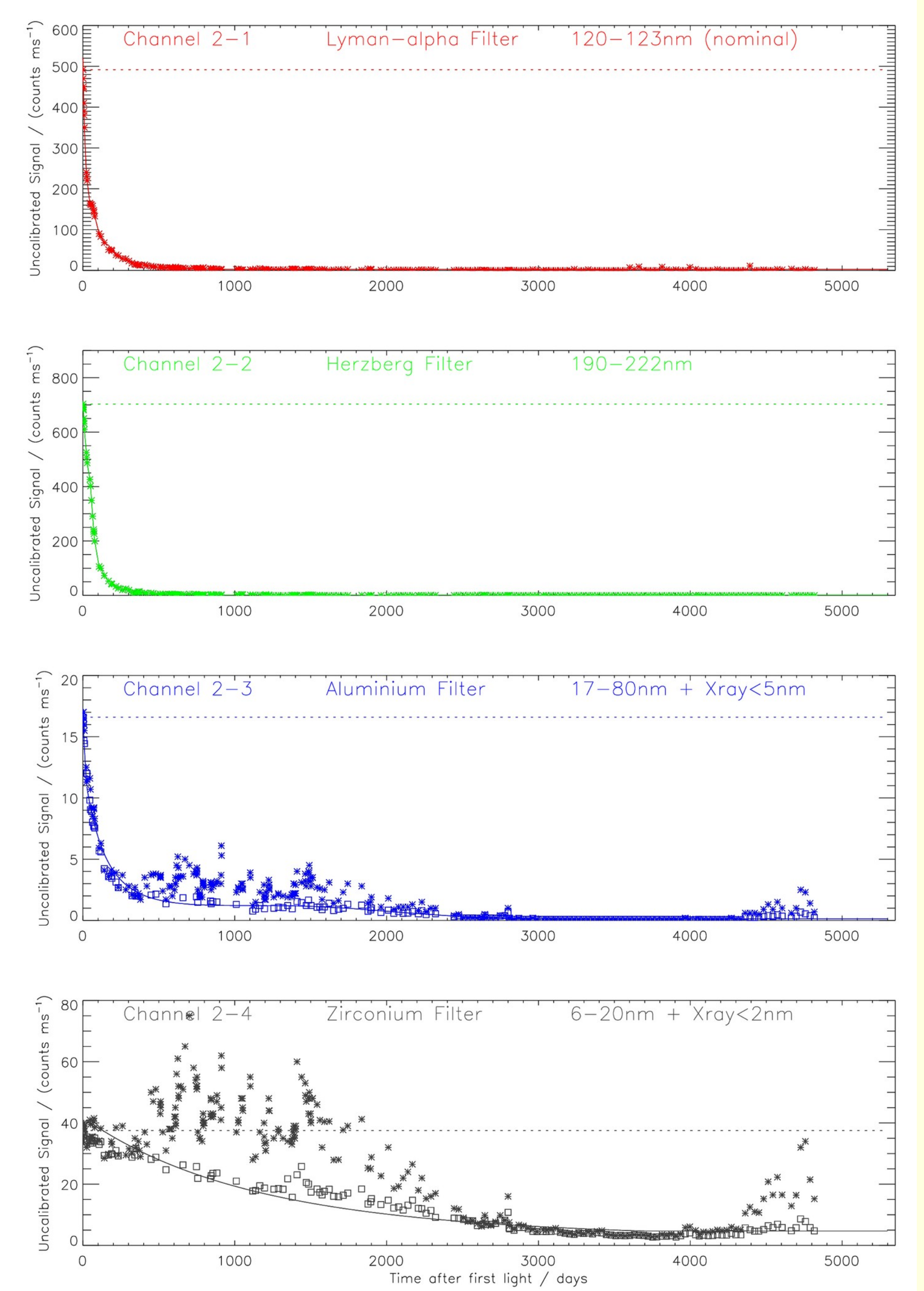
Remaining EUV response:

| | |
|---|---|
| ch1-1 (Ly) | 27% |
| ch1-2 (Hz) | 31% |
| ch1-3 (Al) | 36% |
| ch1-4 (Zr) | 53% |

status: March 2023,
data from short, regular (~monthly) campaigns,
solar variability in ch3 and ch4 corrected for fit



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



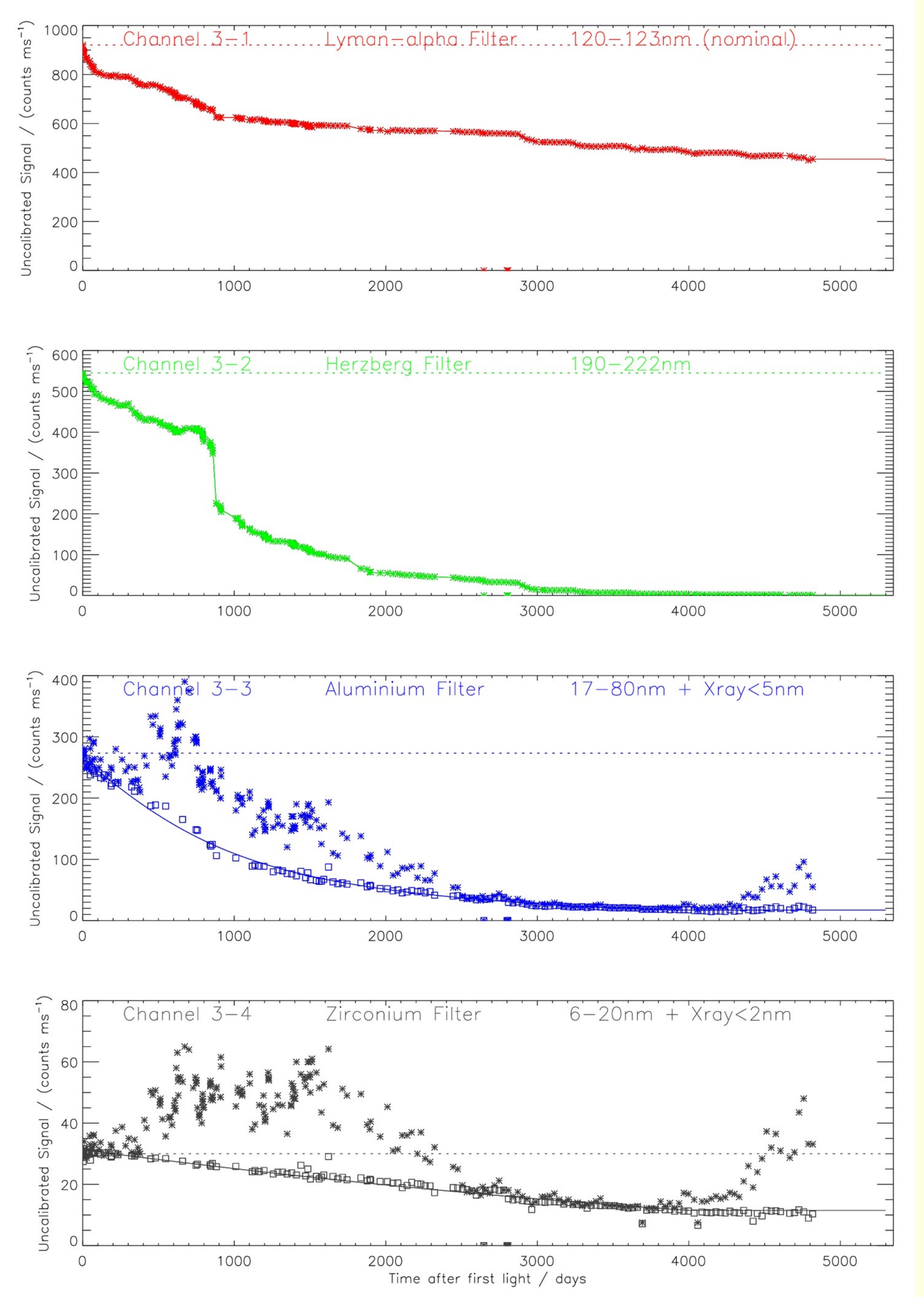

Remaining EUV response:

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

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

Remaining EUV response:

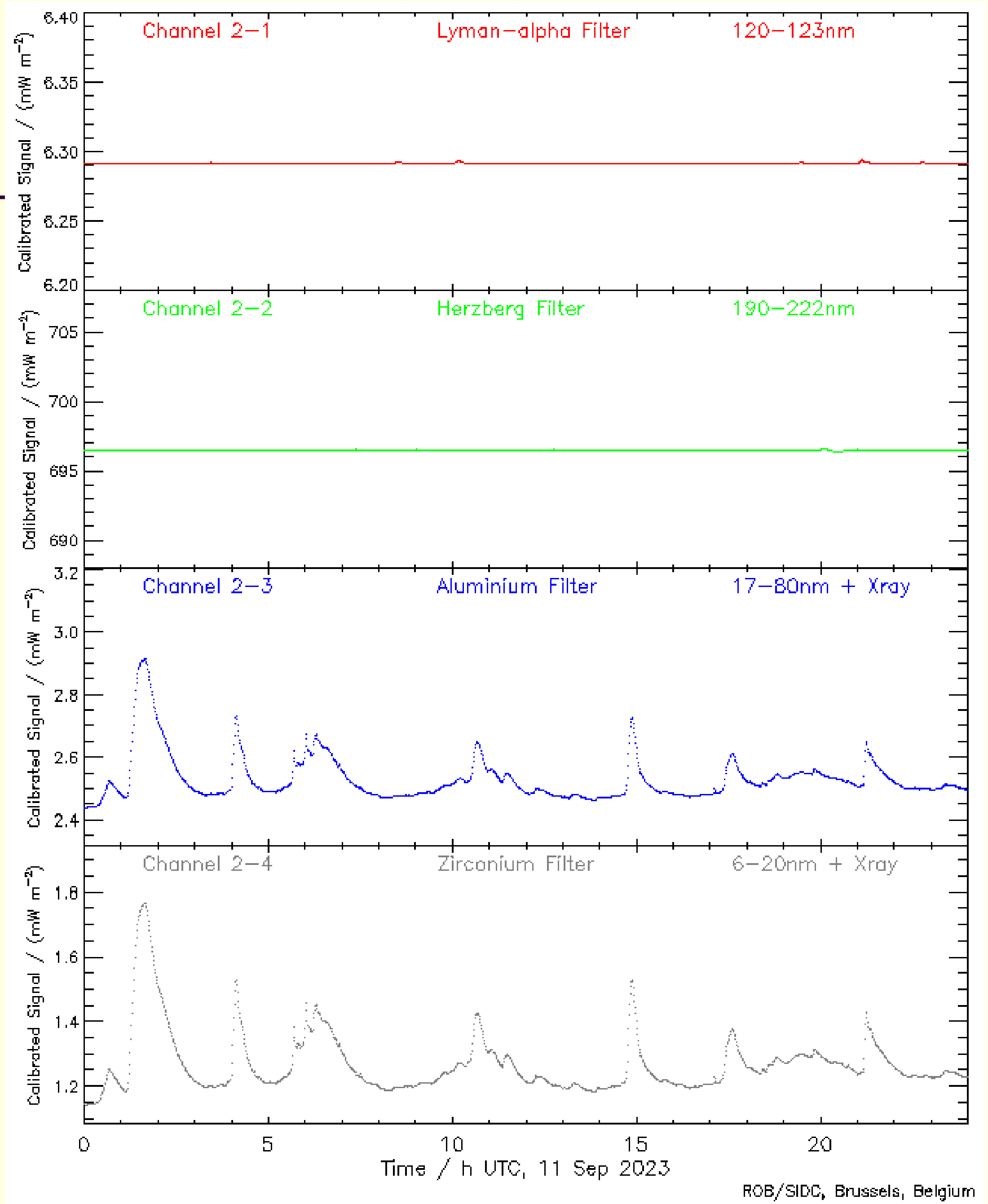
| | |
|---|---|
| ch3-1 (Ly) | 49% |
| ch3-2 (Hz) | <1% |
| ch3-3 (Al) | 6% |
| ch3-4 (Zr) | 38% |



# Status quo (unit 2 in September 2023)

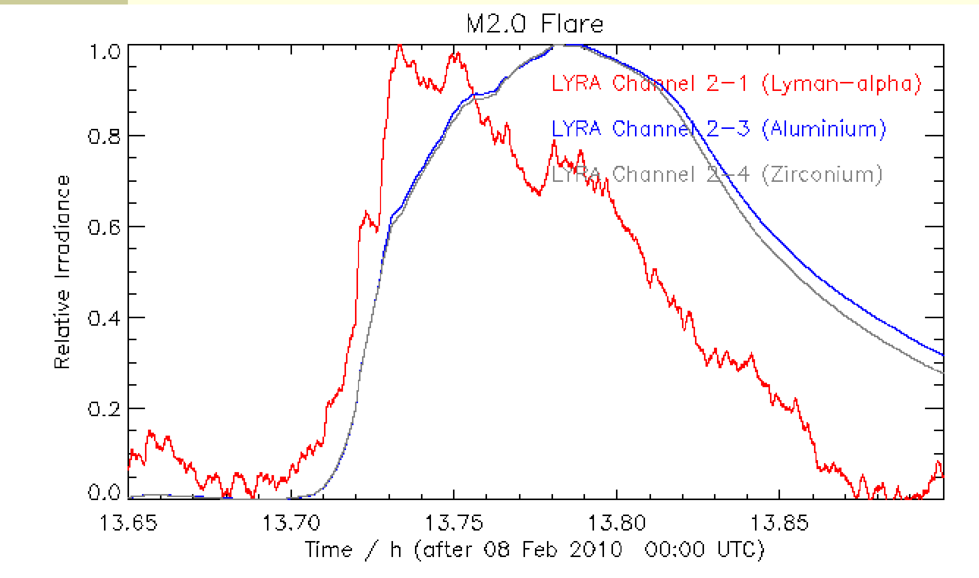
channels 1 and 2: flat

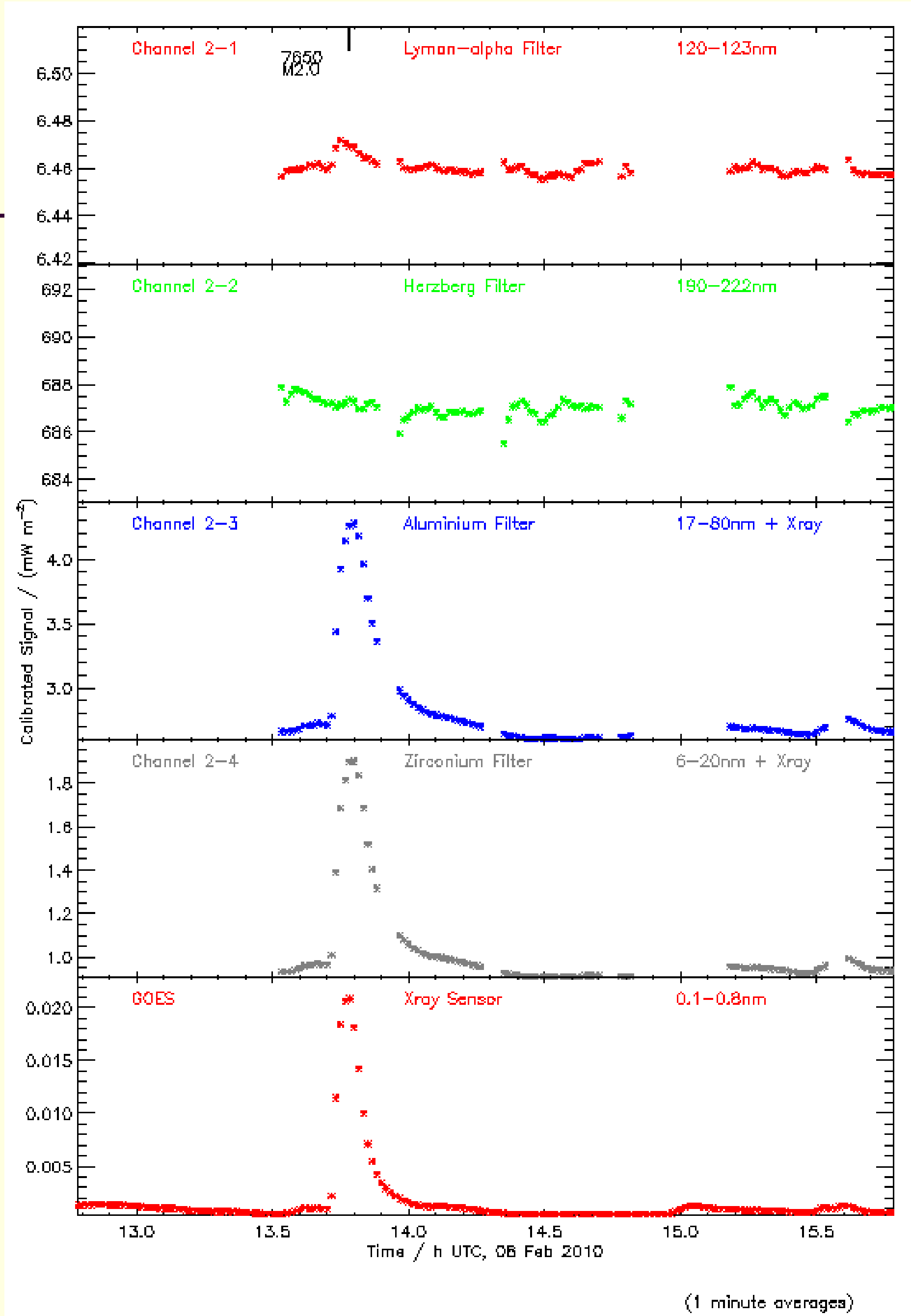
channels 3 and 4: flares



# M2.0 flare on 08 Feb 2010

But ch2-1 was not always flat...

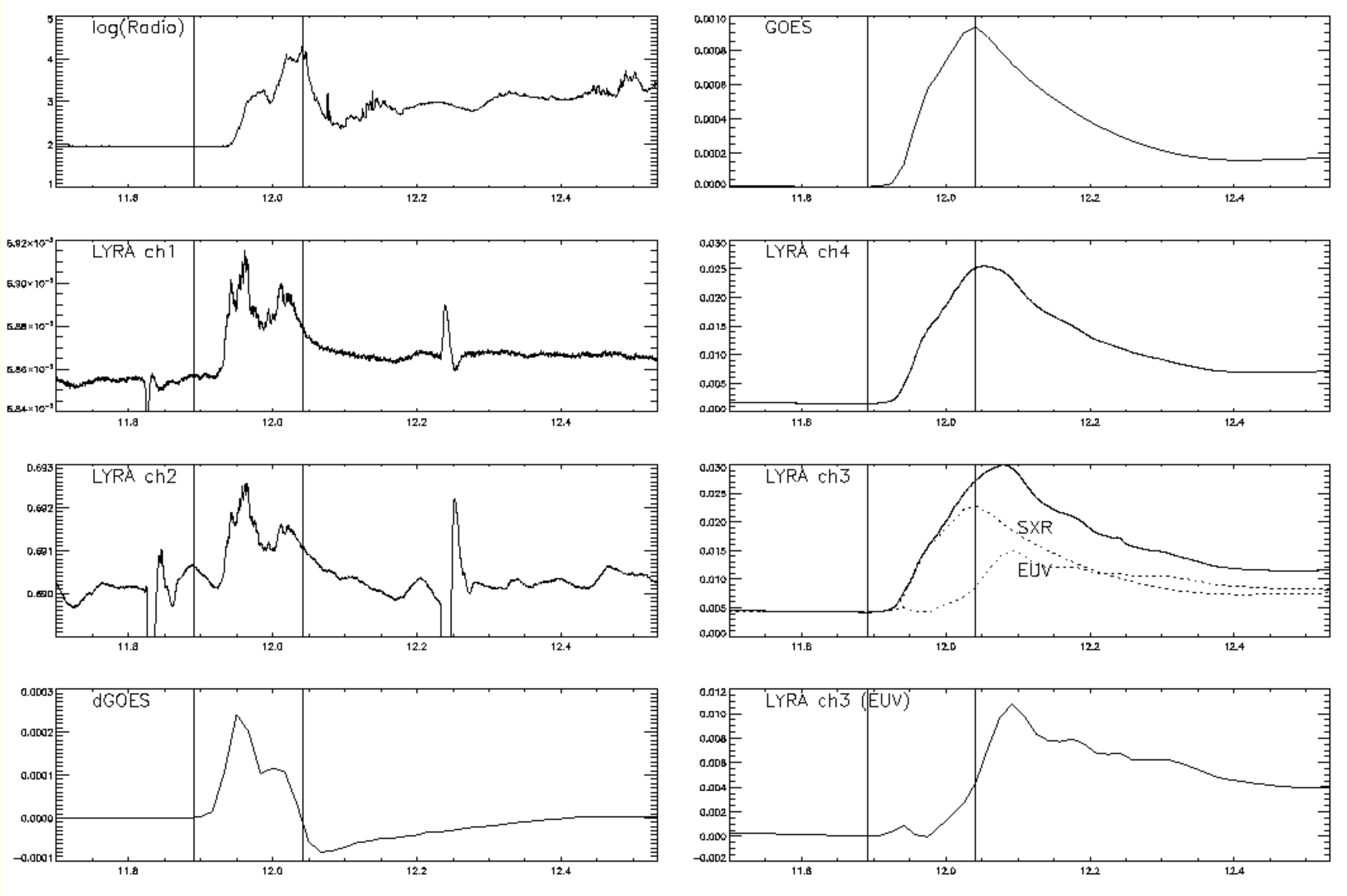


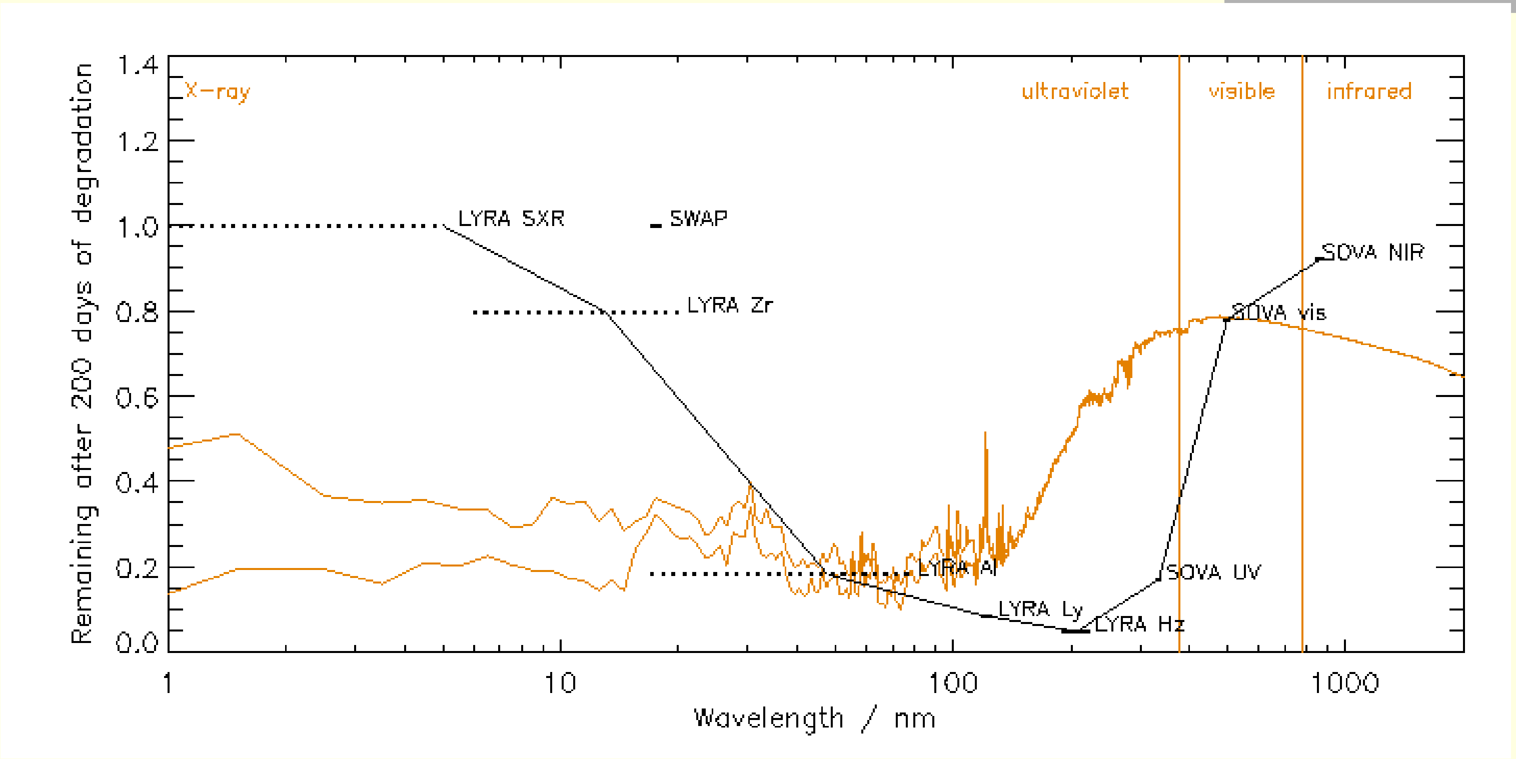
# X9.3 flare on 06 Sep 2017

The strongest flare of cycle24 - the only observation of a signal in a Hz channel...

...in ch1-2, here >>>

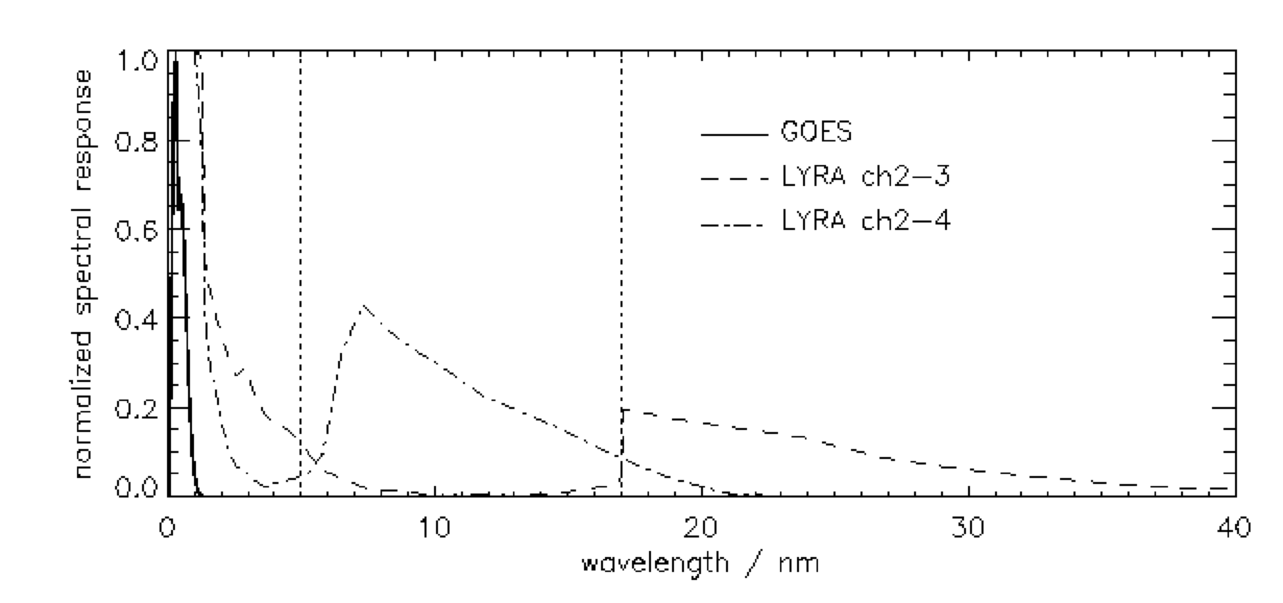


# Spectral degradation in space




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
LYRA: initially no detector degradation

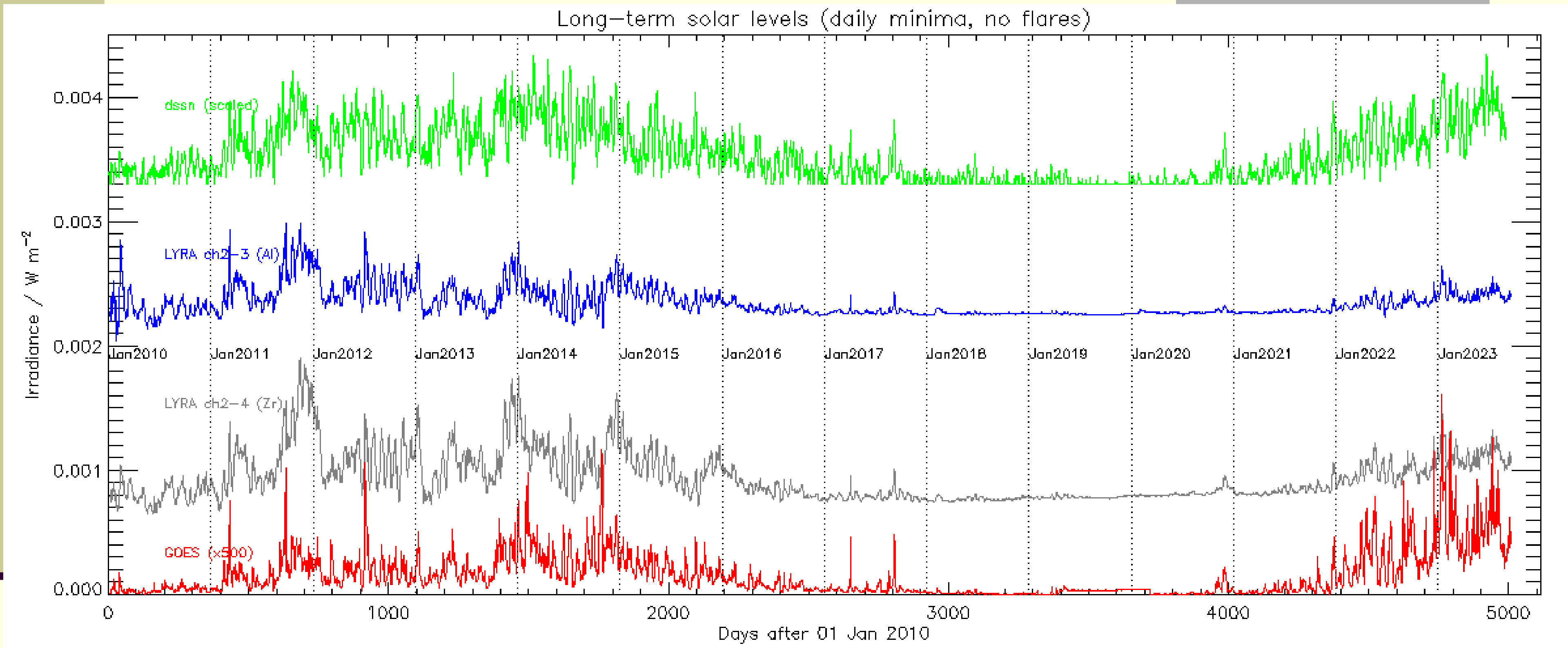
# What is left for LYRA's active-region or flare signals?




<u>Assumption:</u>

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.

# Active-region signal of unit 2

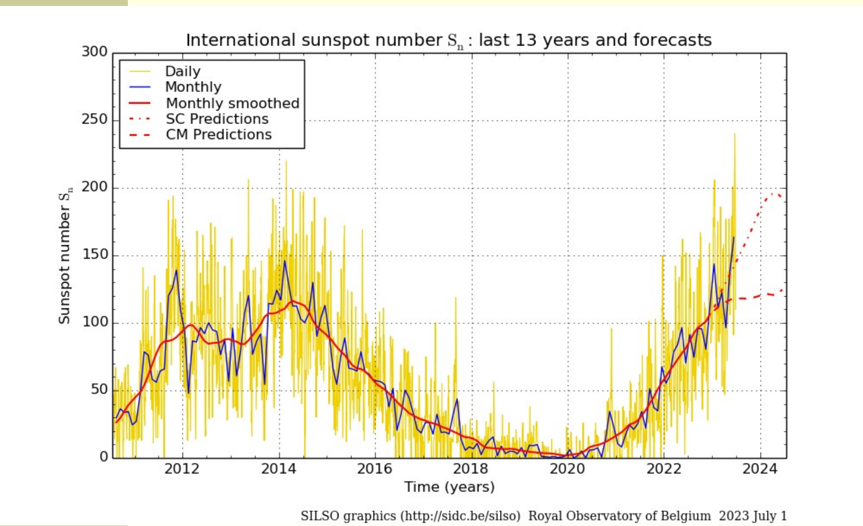



<u>Observations:</u>

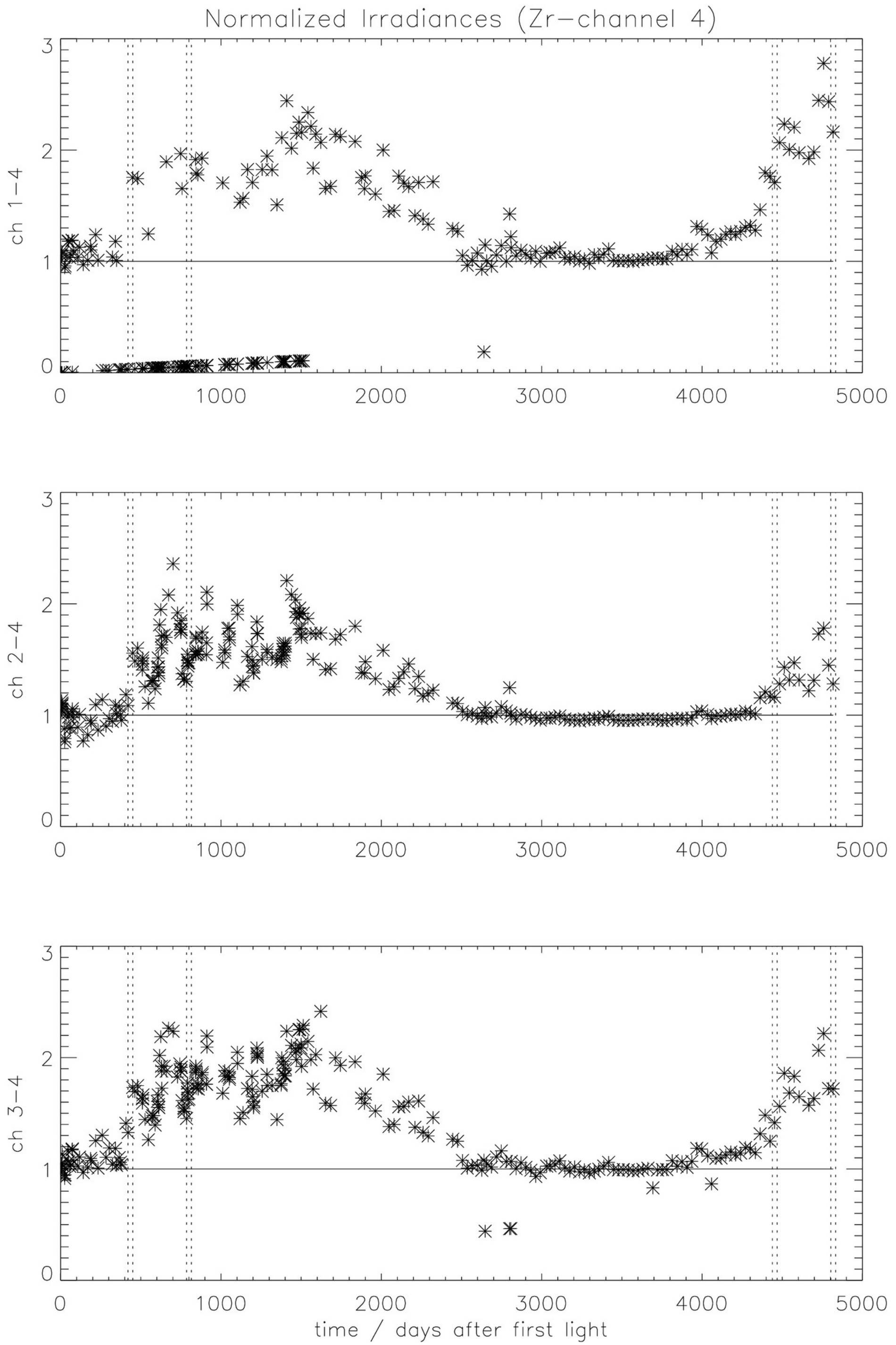
- GOES values and sunspot numbers reach or exceed previous cycle
- LYRA active-region signal degraded, but less so than quiet-Sun signal
- ch2-4 less degraded than ch2-3
- problem: no daily measurements for unit 1 and unit 3, only (~monthly) campaigns

# Comparison of all three LYRA units (Zr channel)

development similar to sunspot number:



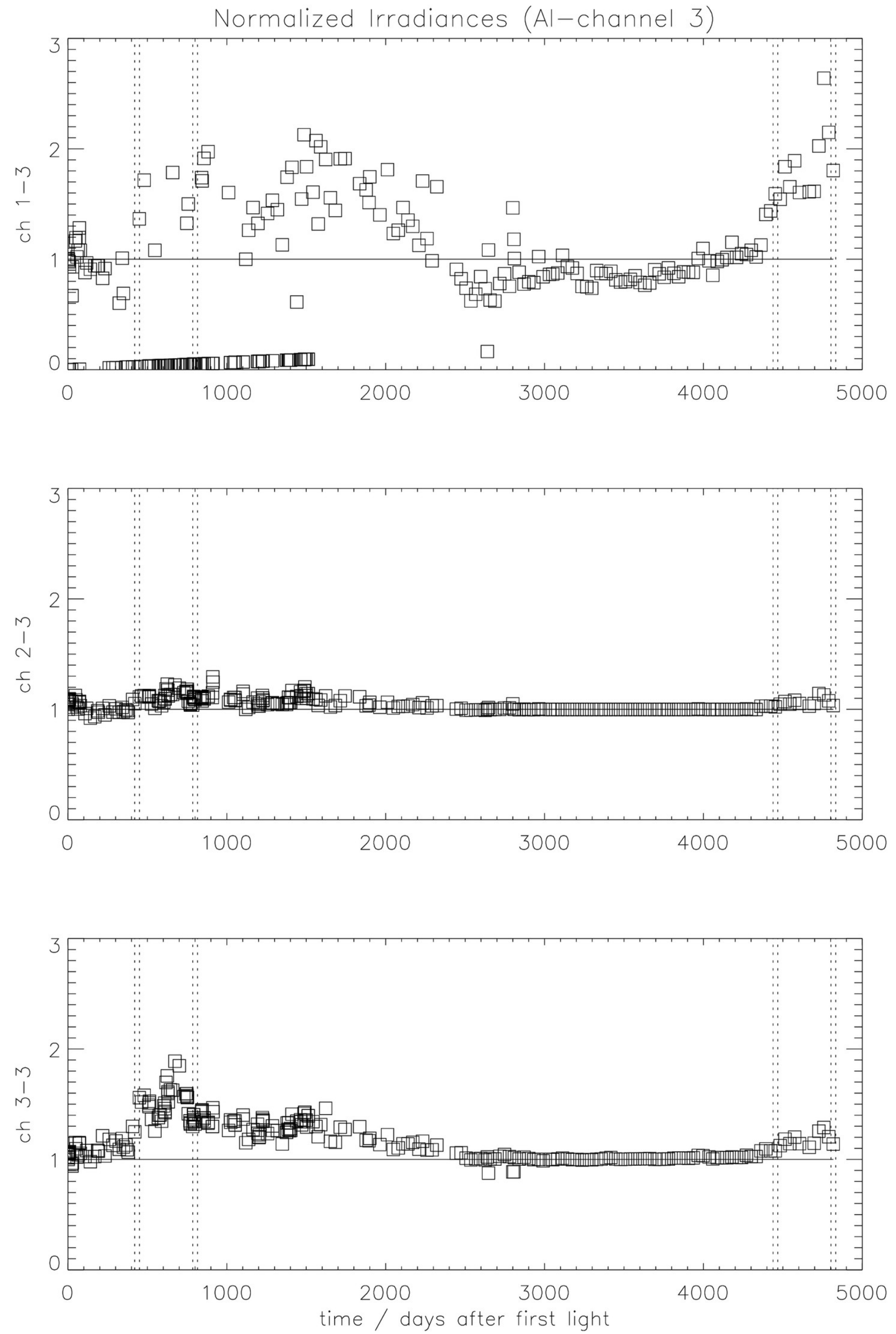

| | *cycle24* | | *cycle25* |
|---|---|---|---|
| ch1-4: | 100% | -> | 100% (assumed) |
| ch2-4: | 72% | -> | 45% |
| ch3-4: | 95% | -> | 77% |



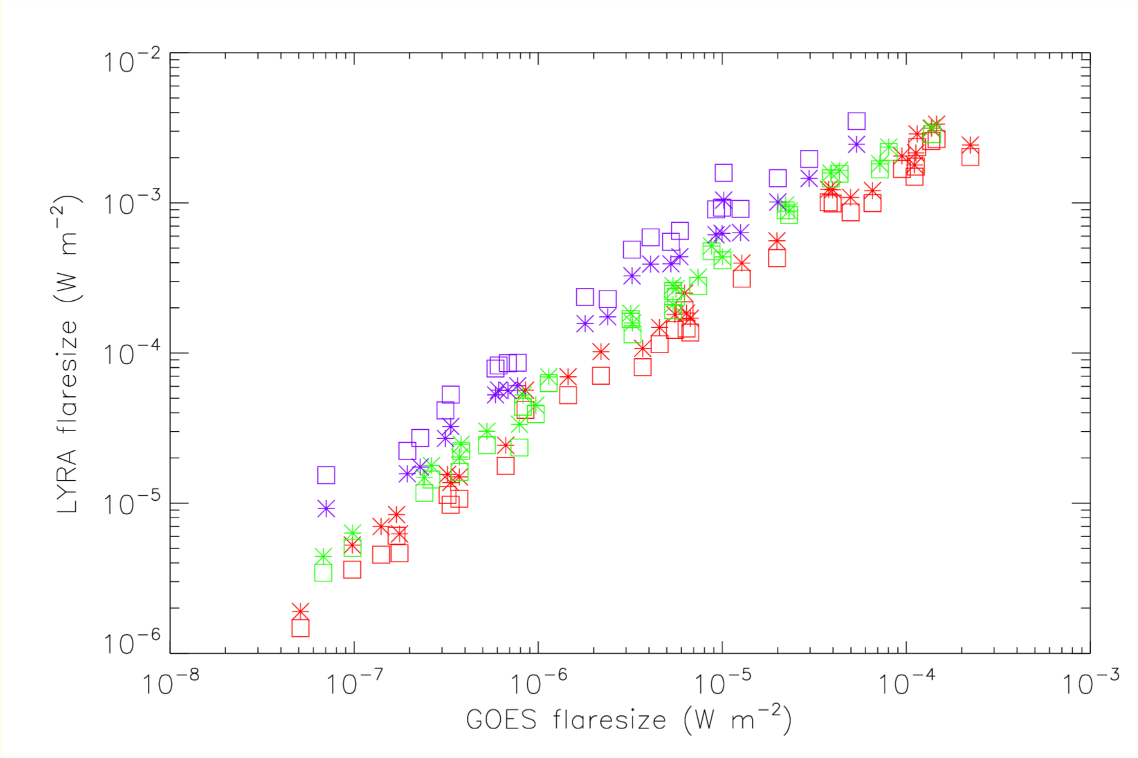
# Comparison of all three LYRA units (Al channel)

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

| | *cycle24* | | *cycle25* |
|---|---|---|---|
| ch1-3: | 100% | -> | 100% (assumed) |
| ch2-3: | 22% | -> | 13% |
| ch3-3: | 67% | -> | 22% |

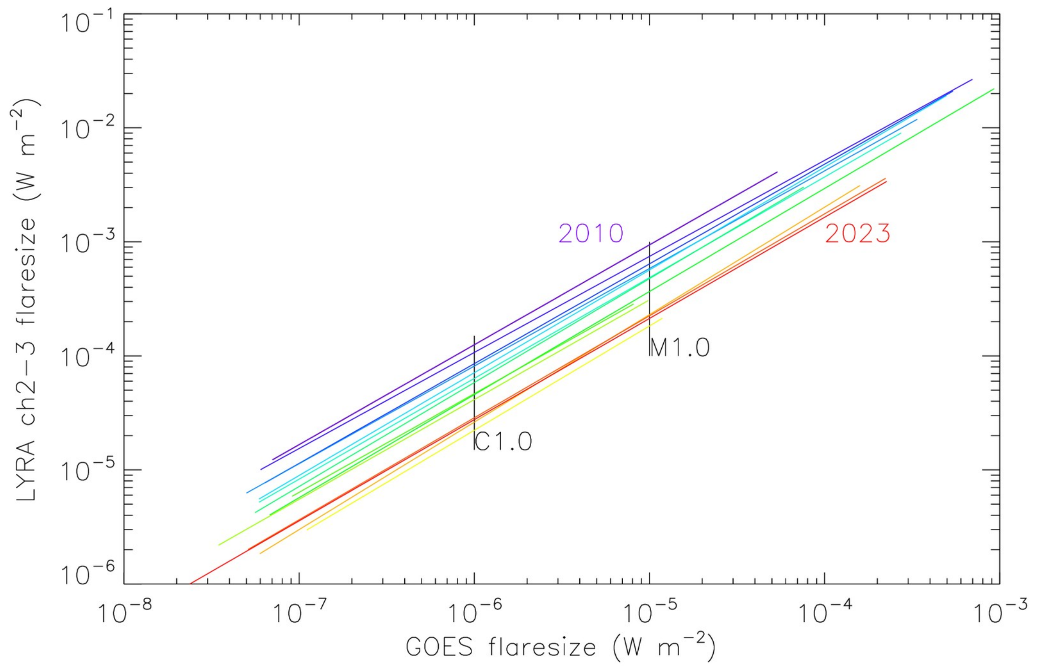


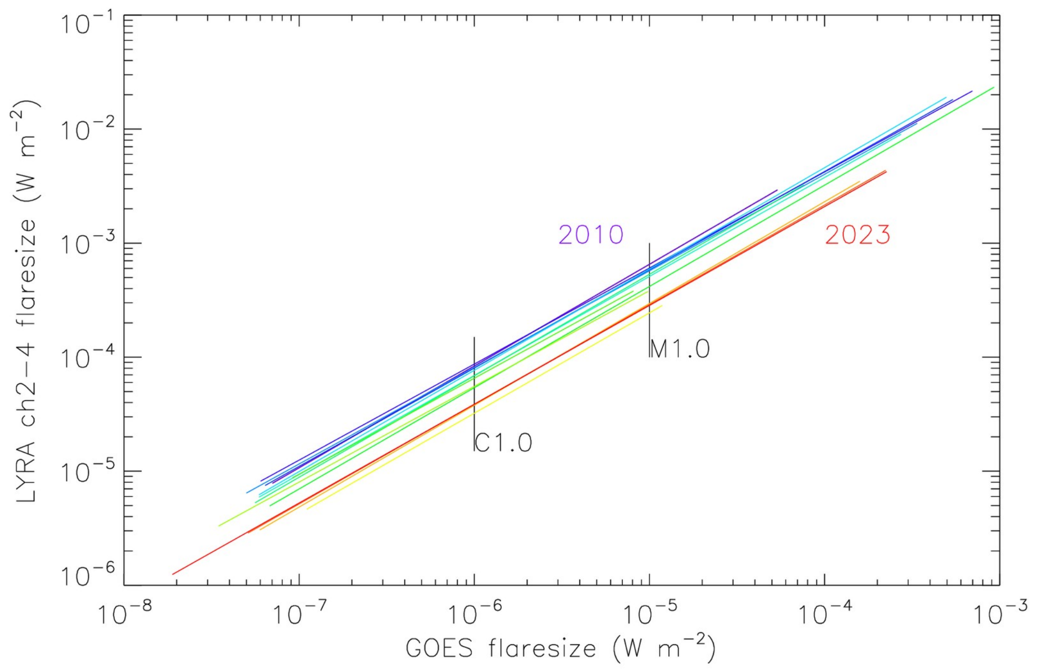
# Flare signal of unit 2




- hardly any flares during monthly campaigns => representative sample per year
- flare size = (peak level - onset level) for GOES and LYRA
- squares = ch2-3, asterisks = ch2-4
- purple = 2010, green = 2017, red = 2022

# Flare signal of unit 2 over time

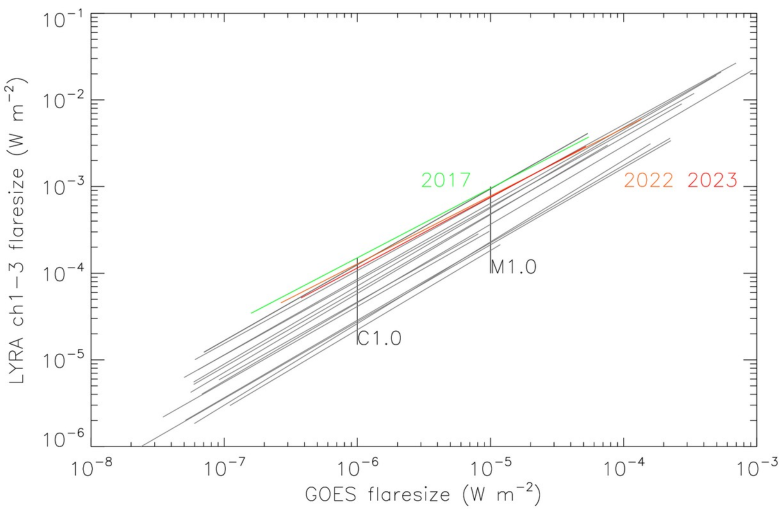


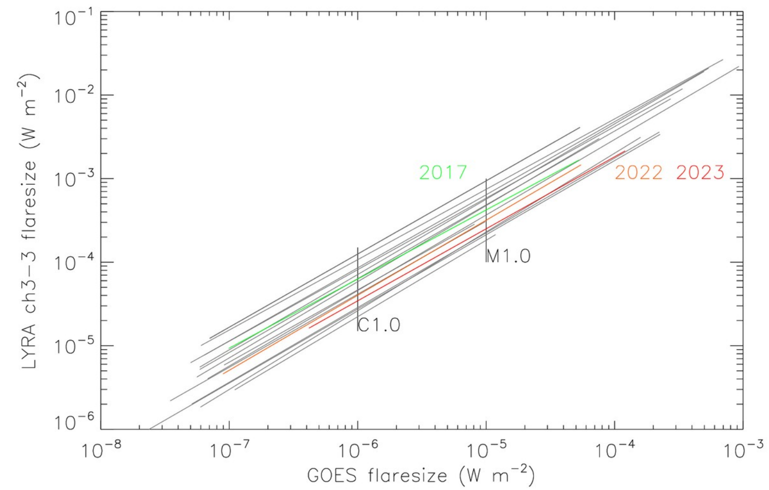



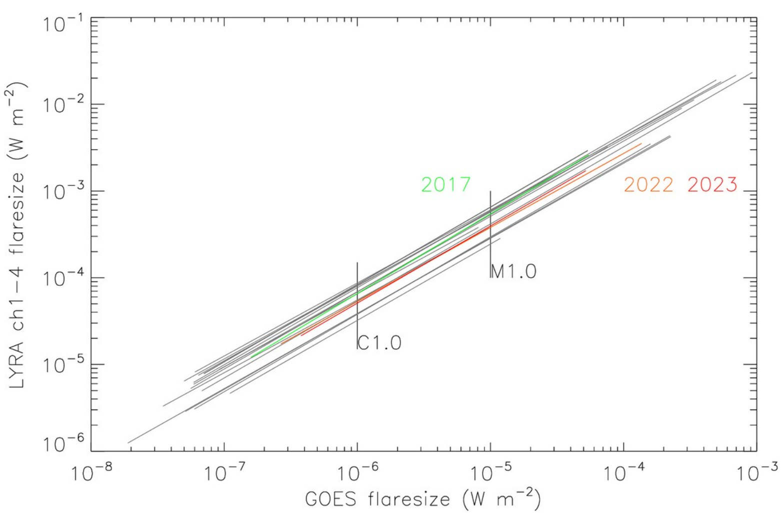

- linear fit per year 2010 - 2023
- LYRA flare signal degraded
- but less so than quiet-Sun signal
- ch2-4 less degraded than ch2-3

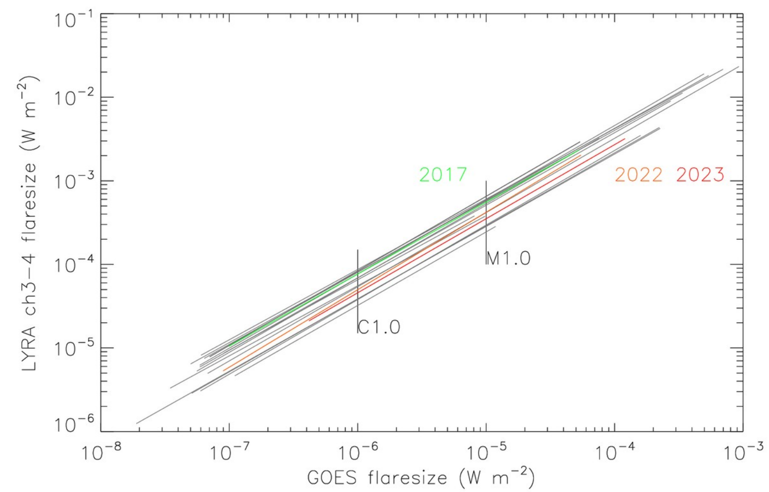
# Flare signal of unit 1 and unit 3 over time

## (hardly any campaigns before 2017; unit 2 = gray for comparison)



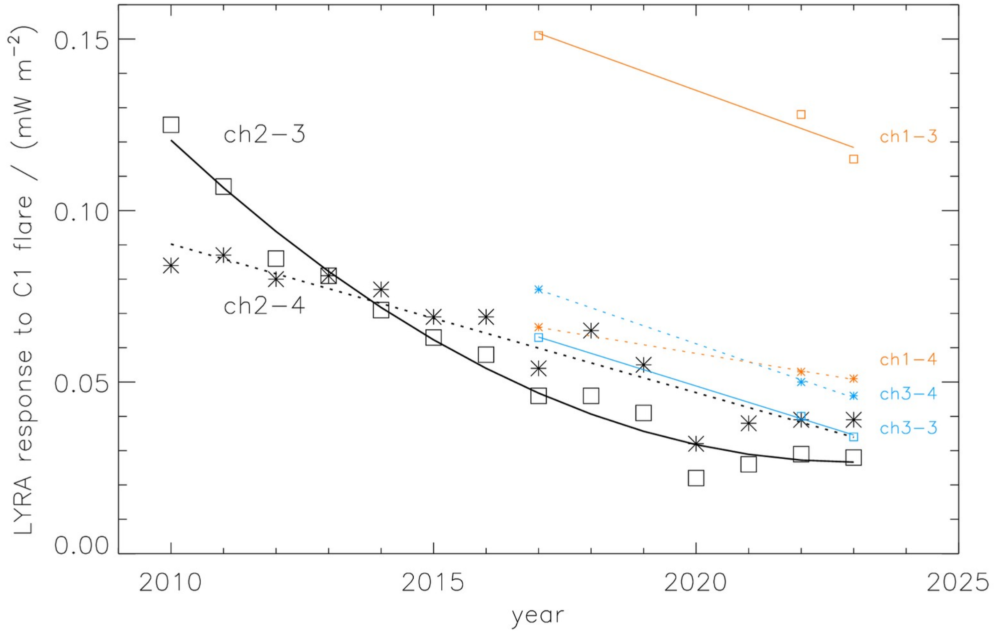



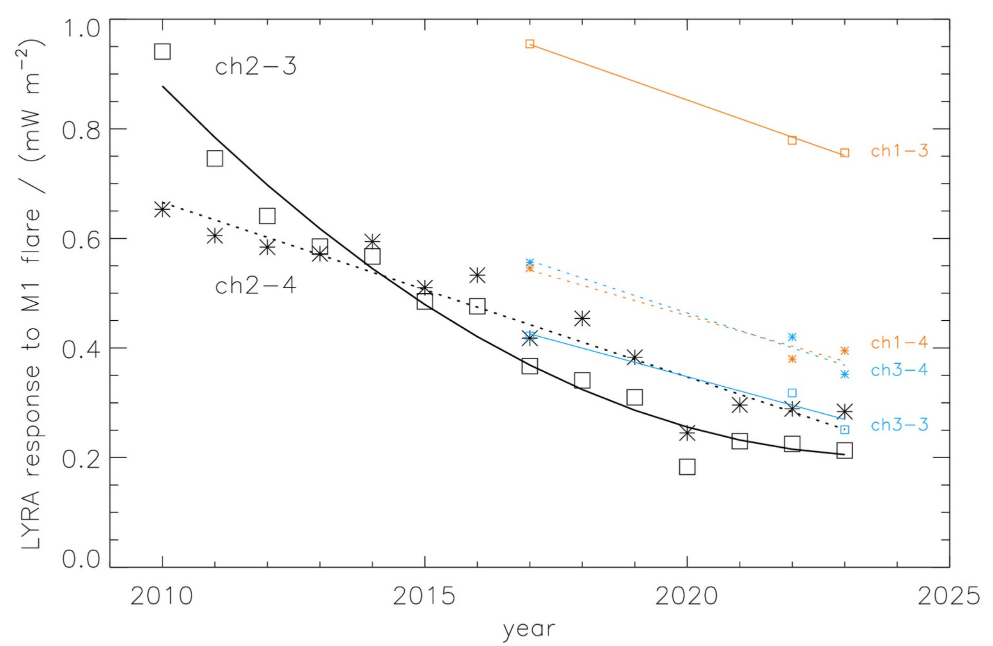
# C1.0 and M1.0 flares over time

remaining flare response

ch1-3: 79-80%
ch2-3: 21-22%
ch3-3: 25-28%

ch1-4: 64-77%
ch2-4: 38-39%
ch3-4: 56-64%



# Conclusions

- Active regions and flares mainly emit in the shortest wavelengths, which are less effected by degradation.

- This holds even more for the spare units.

- After more than 13 years in space, monitoring of solar activity is still possible with LYRA.