LYRA

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

PROBA2 / LYRA
soft x-ray response
after ten years in space

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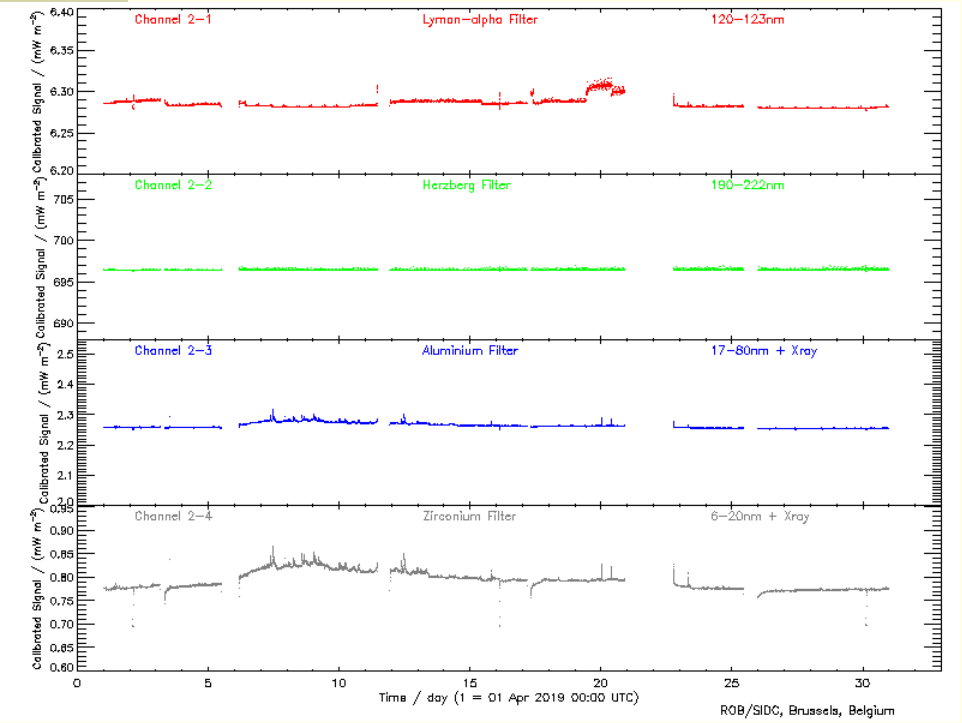
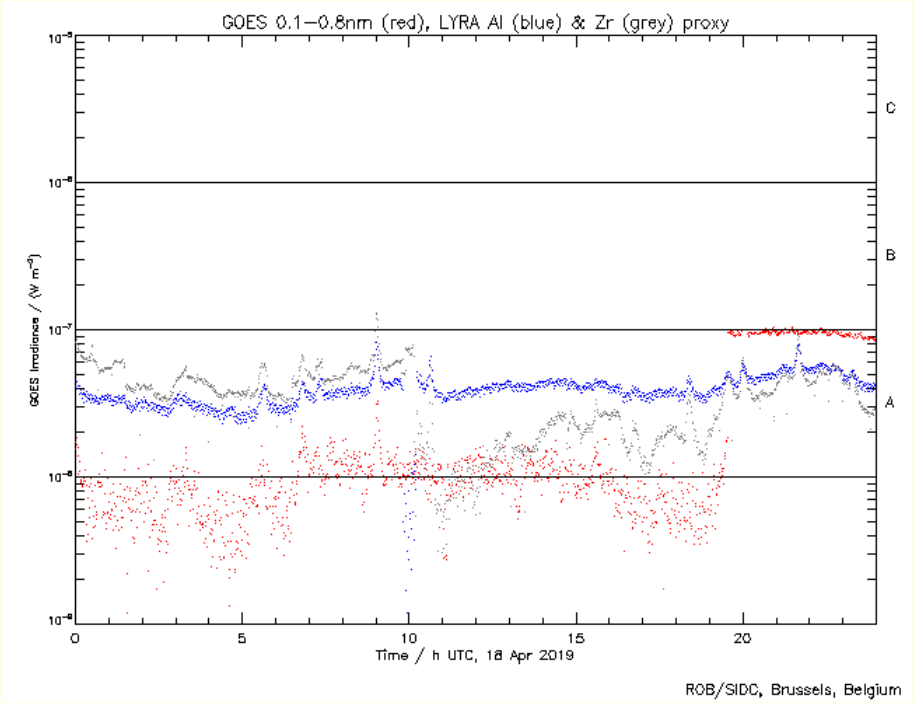
Solar EUV Irradiance Workshop
STCE, Royal Observatory of Belgium
Brussels, 14-18 Oct 2019

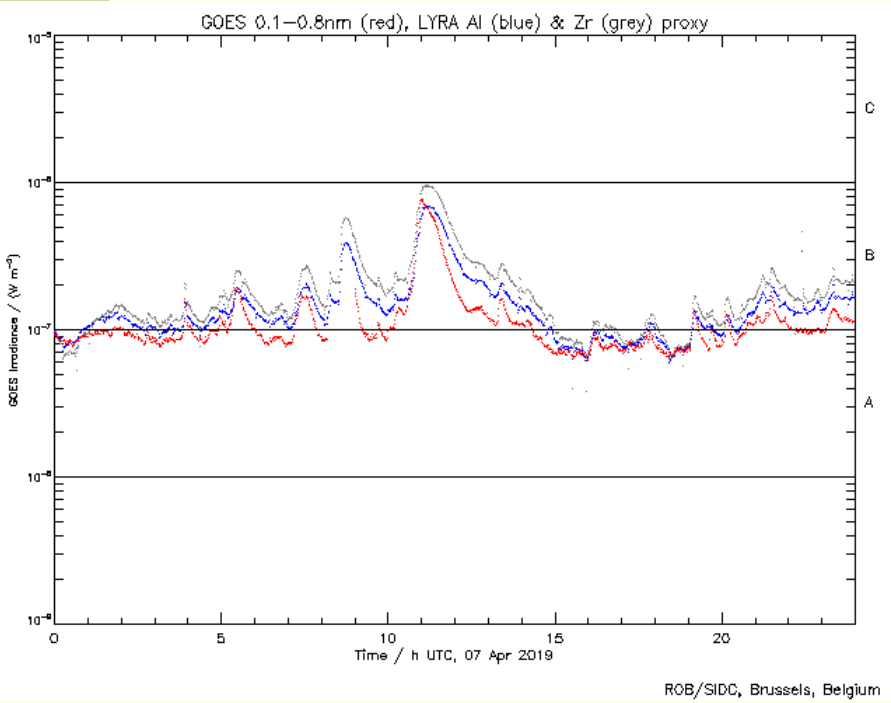
GOES re-calibration

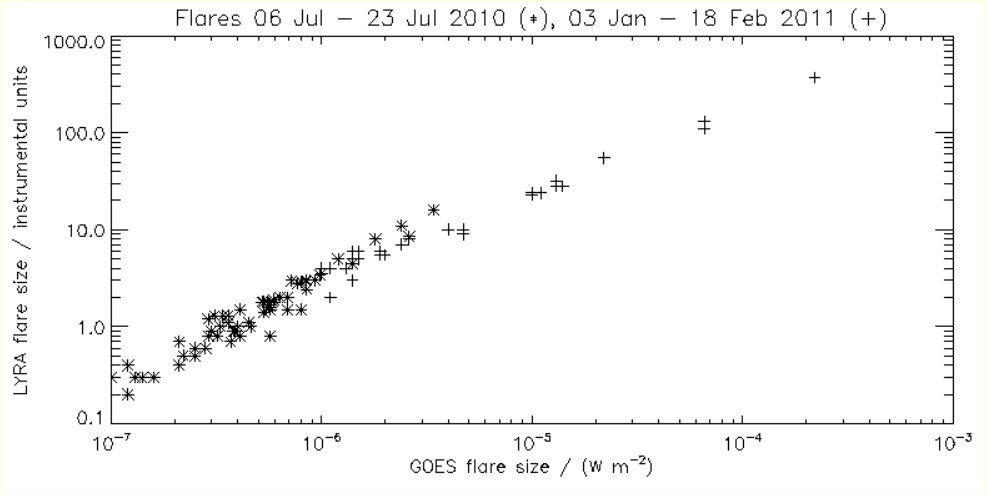




All April 2019, LYRA ch2-3 stayed around a baseline of about 2.25e-3 W/m², LYRA 2-4 stayed around 0.78e-3 W/m².
Meanwhile, GOES jumped from 1.86e-8 up to 9.66e-8 W/m² between 19:33 and 19:34 UTC on 18 Apr 2019.

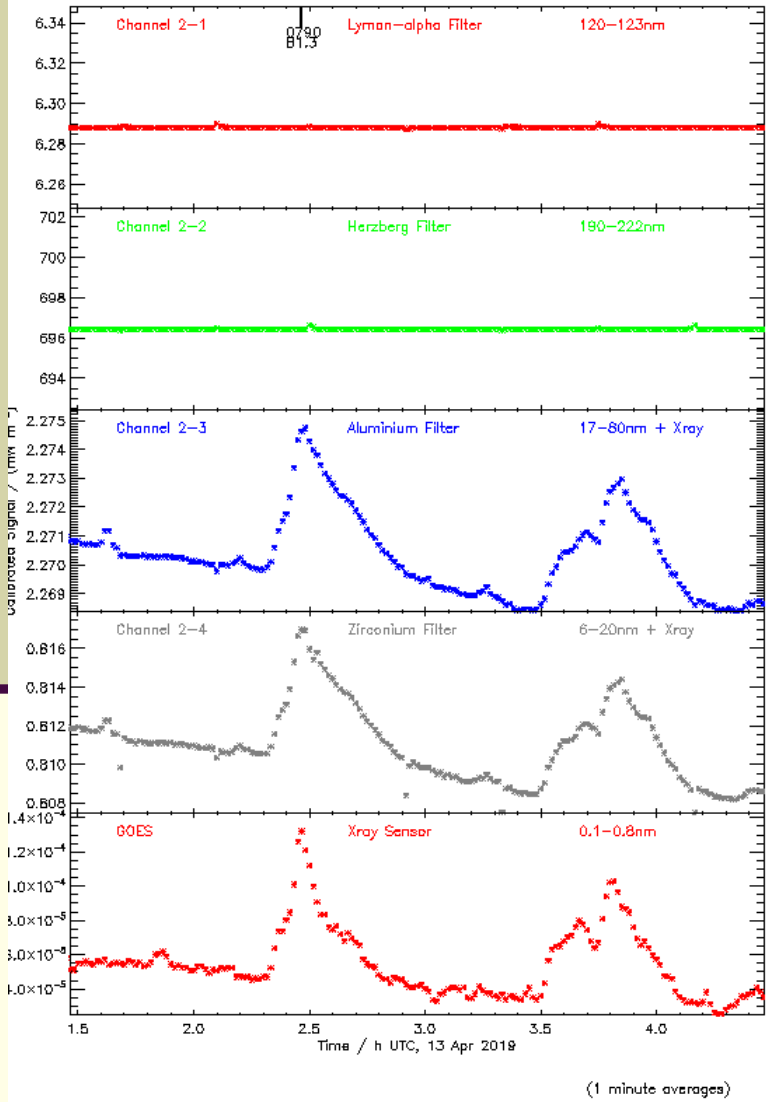
LYRA-GOES-proxy





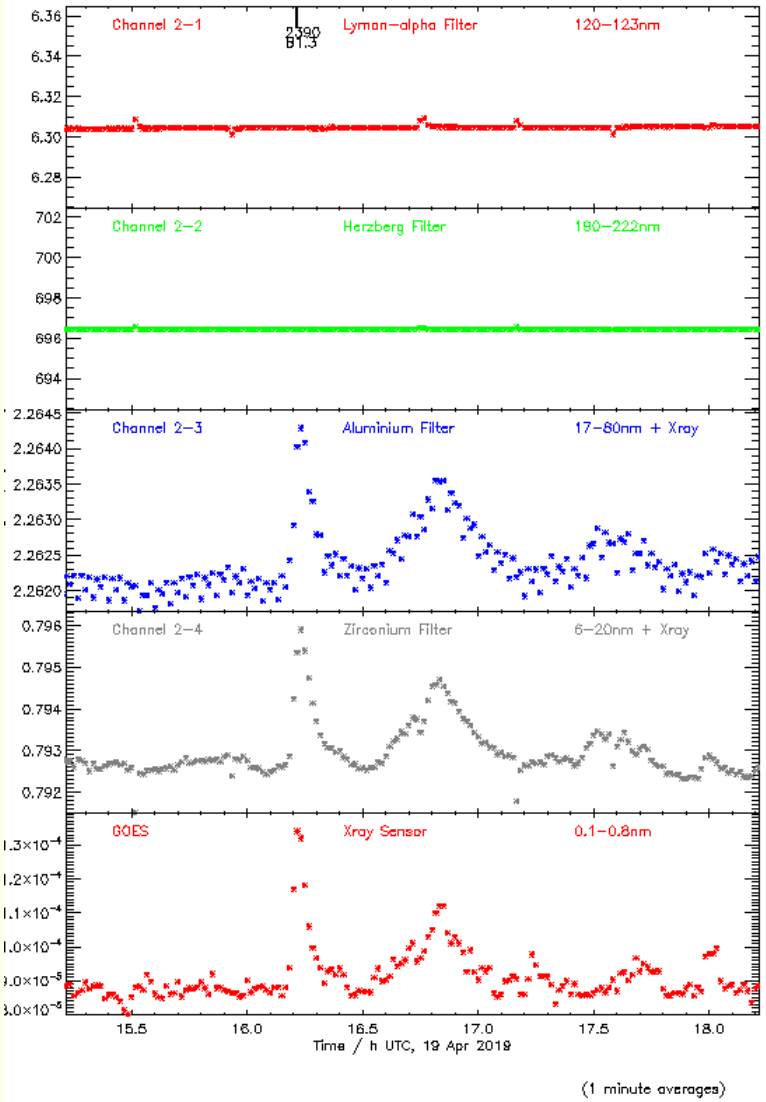
The linear relationship between GOES and LYRA (ch2-3 and ch2-4) flare strengths across several orders of magnitude is the foundation of the LYRA-GOES-proxy. Does this assumption still hold? (Note that LYRA3 < LYRA4, almost always.)

Two B1.3 flares, *before* and *after*

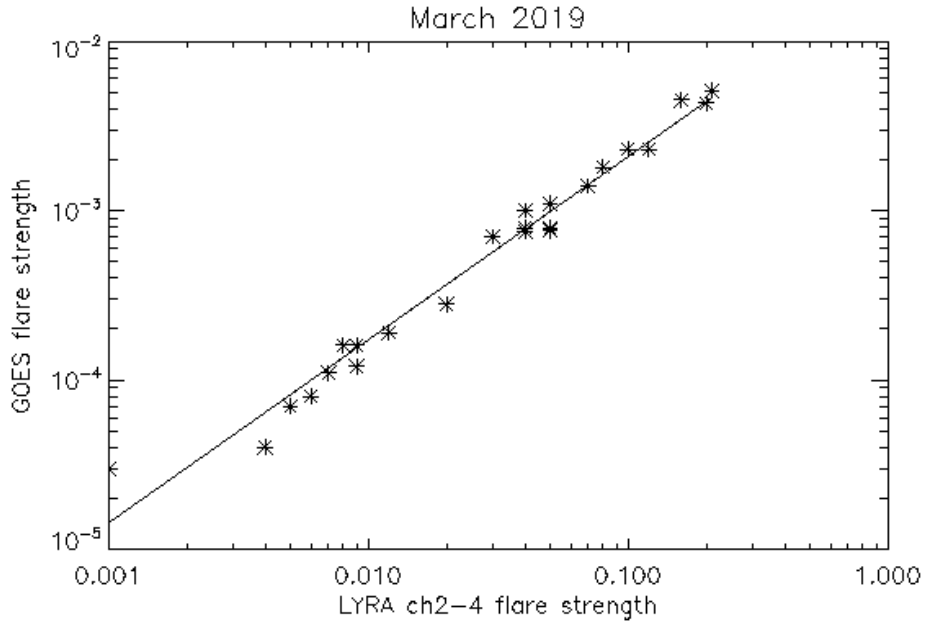


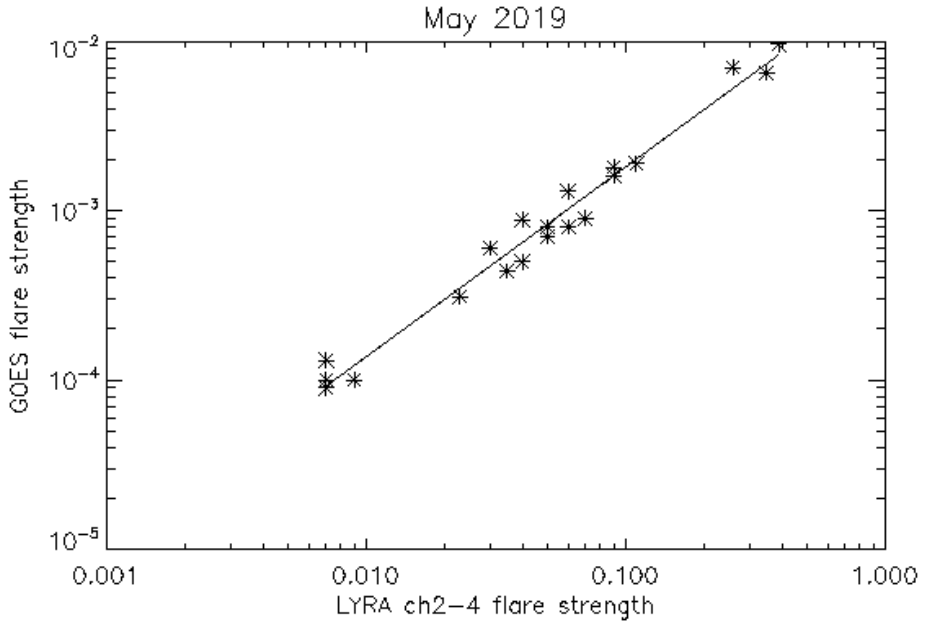
before:
GOES jump =
1.3e-7 - 5e-8
= 8e-8
LYRA3 jump =
2.275e-3 – 2.270e-3
= 5e-6
LYRA4 jump =
8.17e-4 – 8.11e-4
= 6e-6

after:
GOES jump =
1.3e-7 – 9e-8
= 4e-8
LYRA3 jump =
2.264e-3 - 2.262e-3
= 2e-6
LYRA4 jump =
7.96e-4 – 7.93e-4
= 3e-6



Two groups of flares, *before* and *after*





Active week 20–25 Mar 2019

Active week 03–10 May 2019

As an example, GOES vs. LYRA4 net flare strengths (i.e. pre-flare backgrounds subtracted), on a log scale, with fit. Similar results for LYRA3, for linear and logarithmic fits. Correlations generally ~ 99%.

Relation? still OK. - Factors? different.

Basic assumption for GOES-LYRA-proxy (2011):
The GOES curve can be estimated from the LYRA curves
via a simple linear factor:
GOES = 0.015*LYRA3 , GOES = 0.018*LYRA4

lin-fit: GOES = a + b*LYRA (a ~ 0)
log-fit (power law): GOES = c * LYRA^d (d ~ 1)

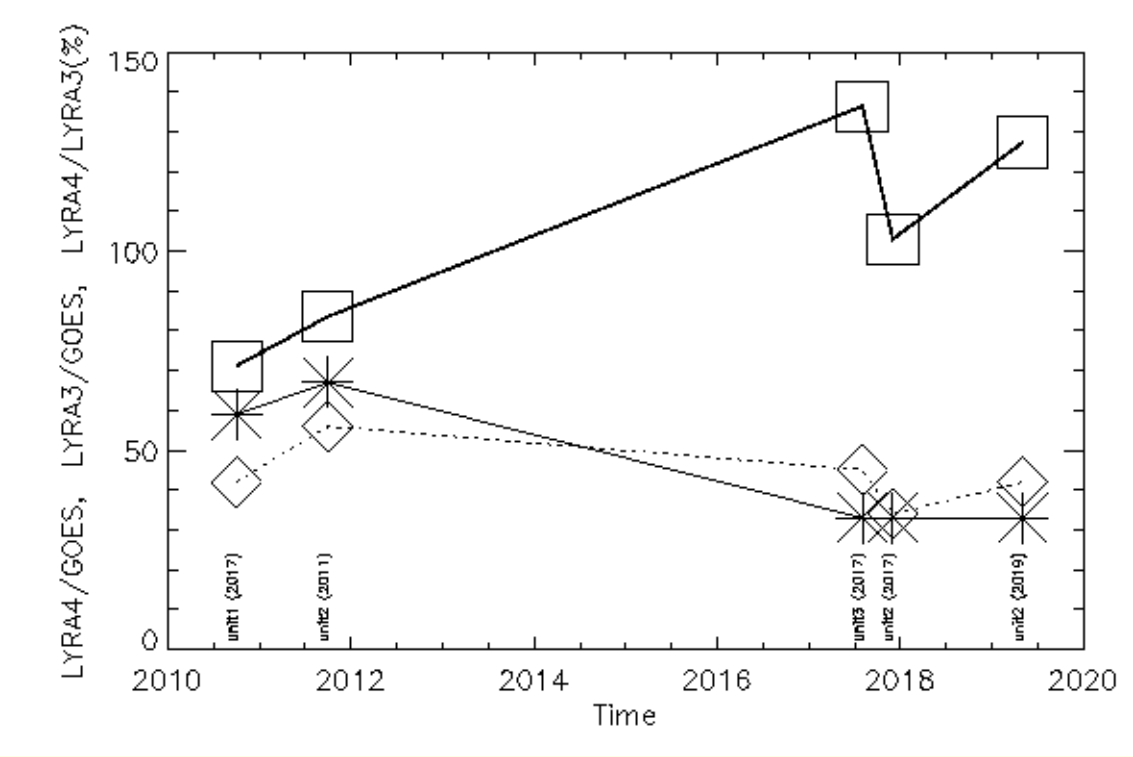
Sep 2011: LYRA3/GOES = 67
LYRA4/GOES = 56
LYRA4/LYRA3 ~ 80%

Mar 2019: LYRA3/GOES = 32, 34, 35 (lin-fit with, lin-fit w/o, log-fit w/o back)
LYRA4/GOES = 40, 42, 39
LYRA4/LYRA3 ~ 122%, 110% (lin-fit, log-fit)

May 2019: LYRA3/GOES = 33, 33, 29
LYRA4/GOES = 42, 43, 42
LYRA4/LYRA3 ~ 128%, 138%

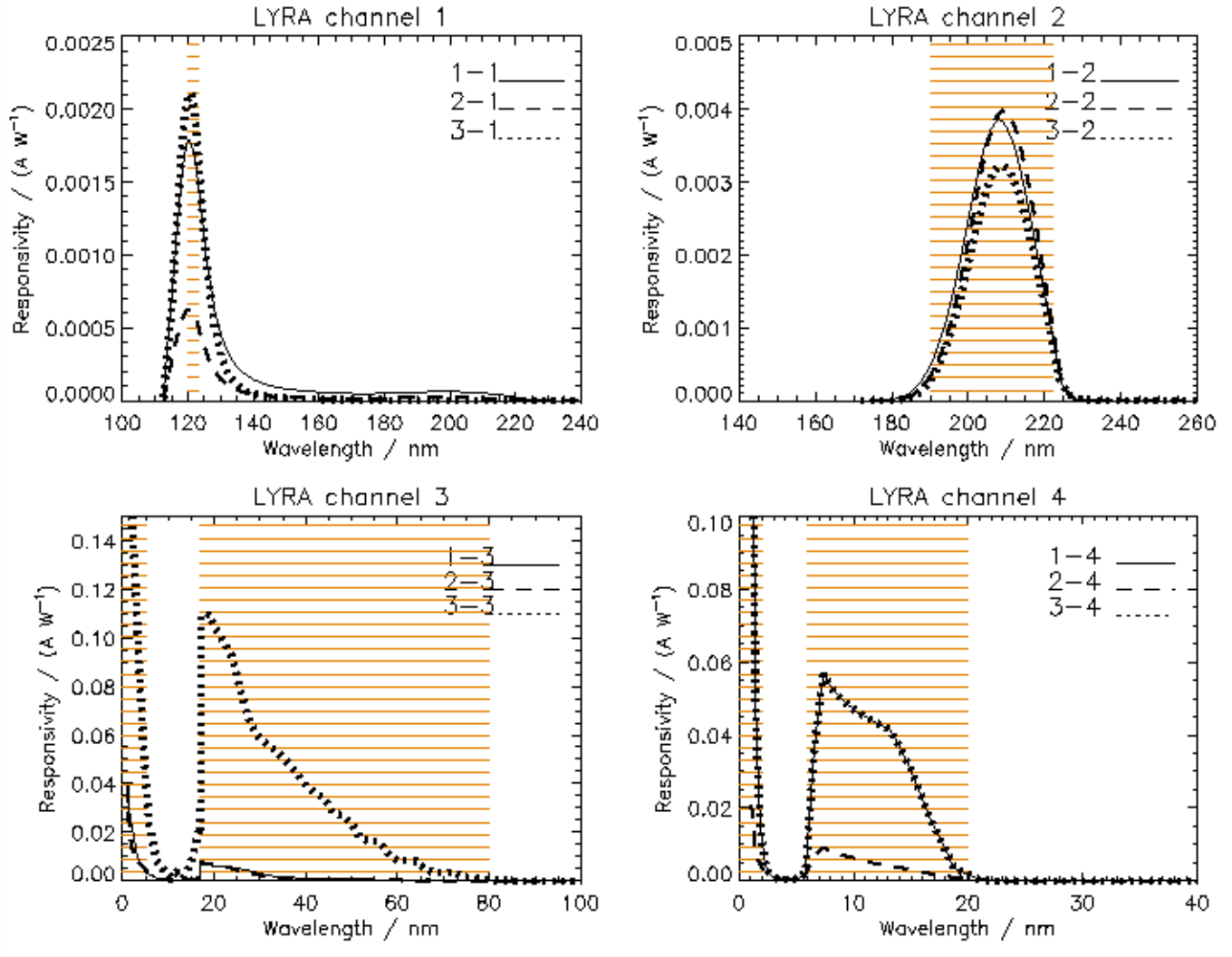
Development over time ?

In a flare campaign performed in September 2017, all three LYRA units were used.
LYRA unit 1 is less degraded than unit 3, which is less degraded than unit 2.
Flare SXR: ch3-4 and ch1-4 are less degraded than ch2-4.
Flare SXR and EUV: ch1-3 is less degraded than ch3-3 and ch2-3.

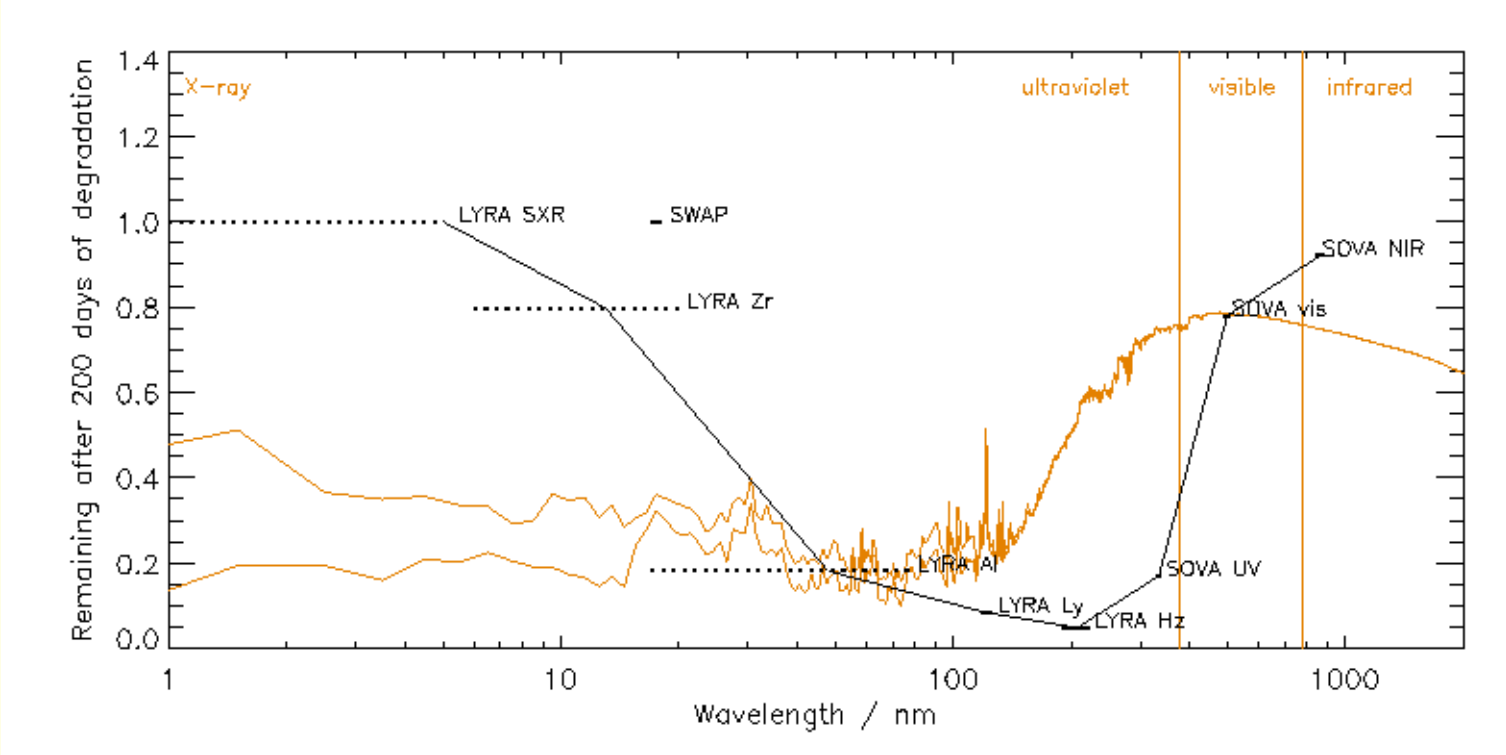


What happened?
Spectral degradation.

LYRA spectral response (before launch)



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

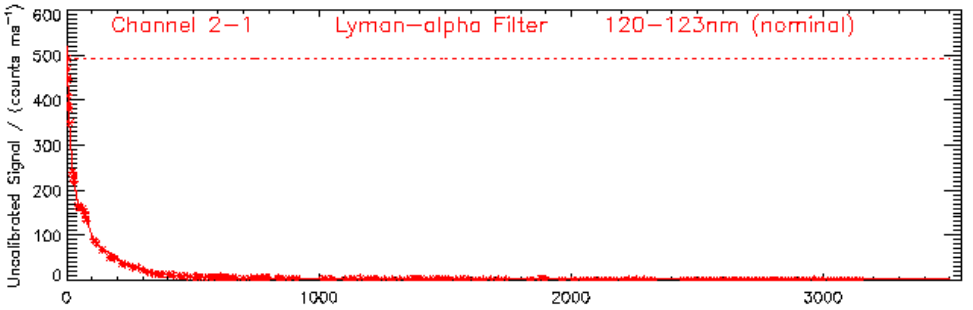
Degradation unit 2 ("nominal unit")

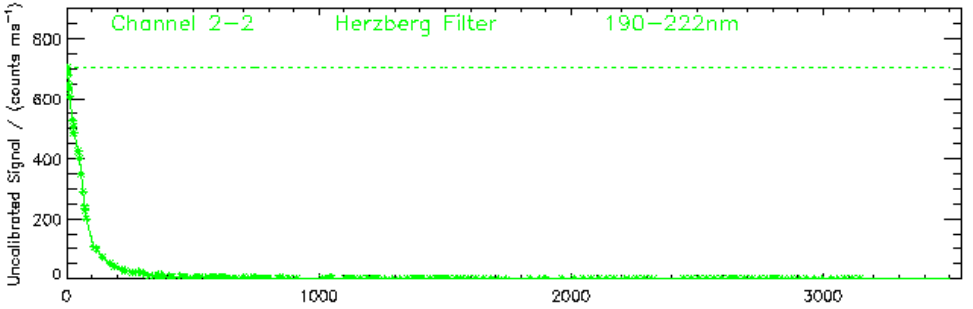
Probably caused
by a mix of C and Si
(100 nm and 5 nm, resp.)
and maybe oxidation.

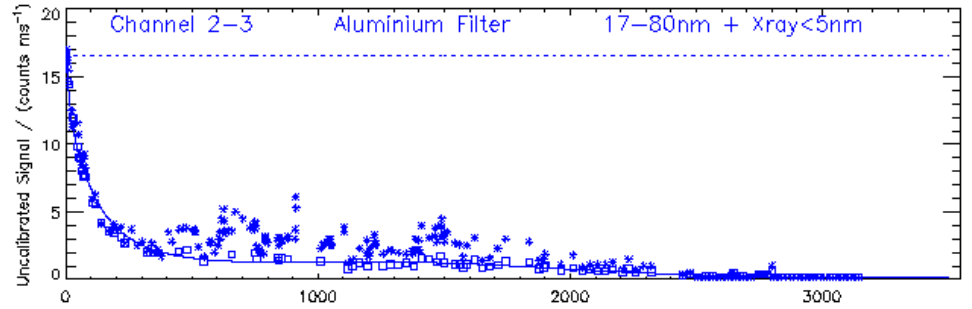
Remaining EUV response:

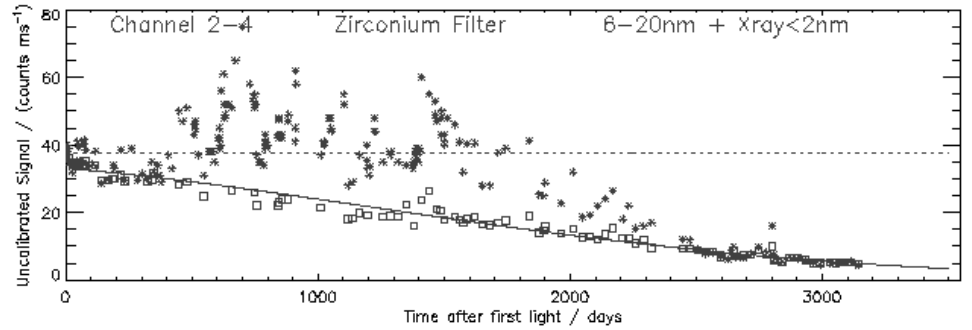
ch2-1 (Ly)	<0.5%
ch2-2 (Hz)	<0.5%
ch2-3 (Al)	1%
ch2-4 (Zr)	13%

(status: Sep 2018)

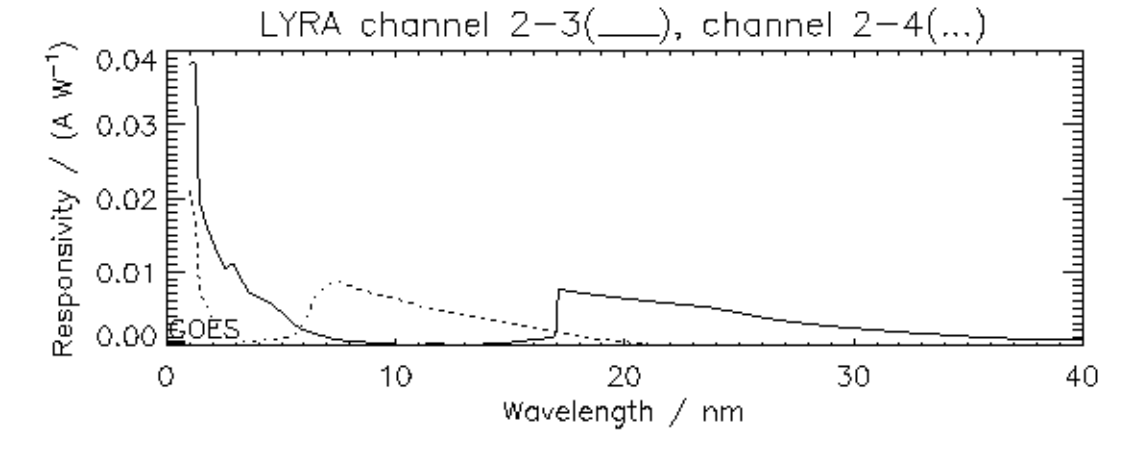








What is left for LYRA flares ?



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.

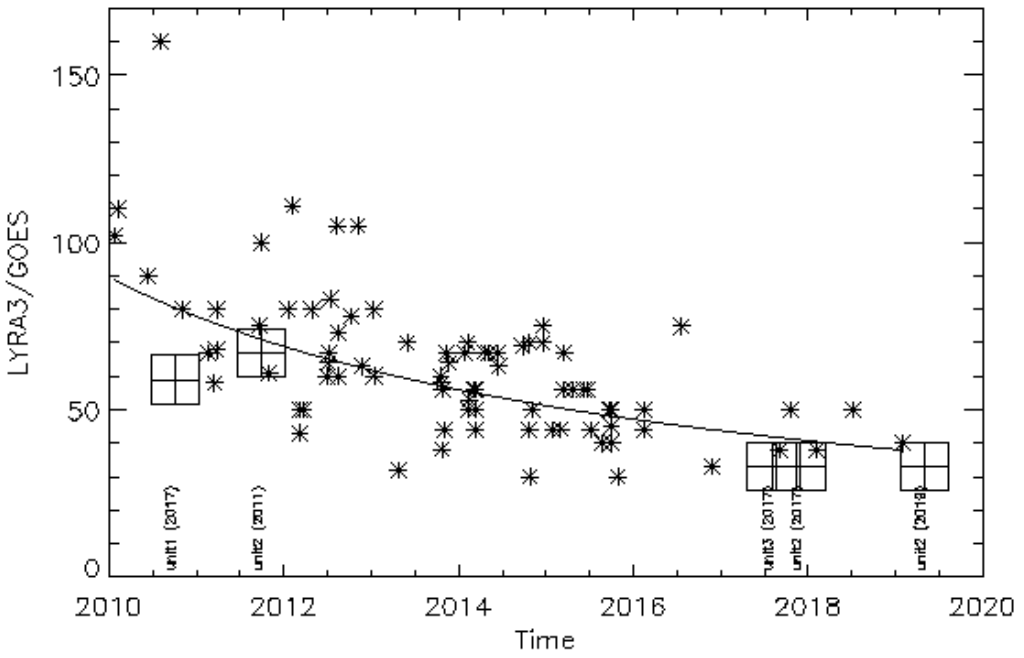
Spectral range [0.1nm , 5nm]: still existing for all units, somewhat degraded for unit 2.

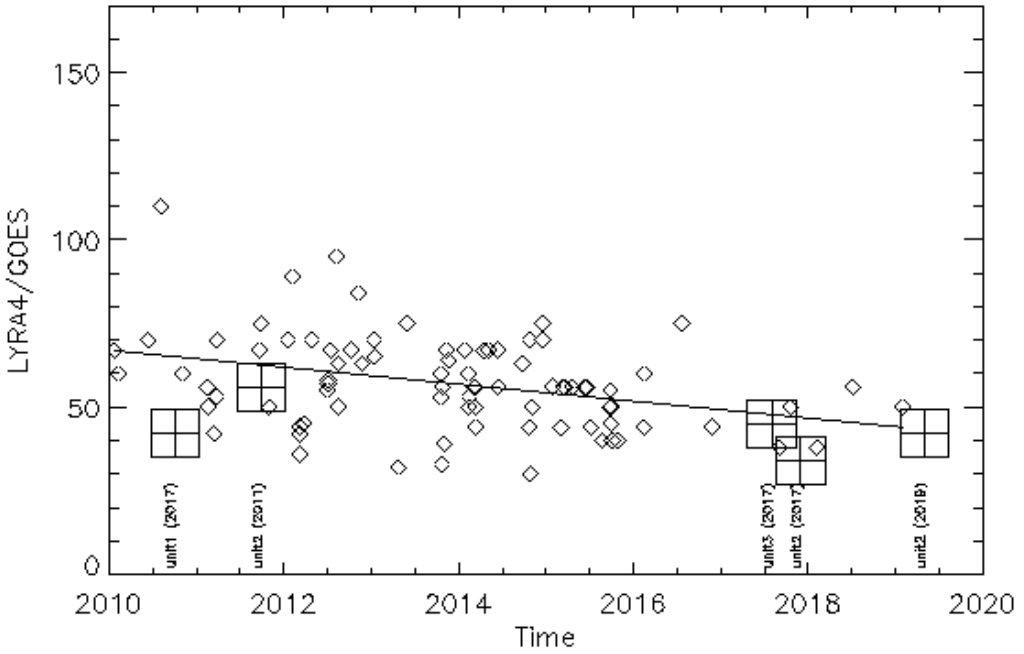
LYRA flare strengths over time in space

84 flares,
most of them M1.0,
2010-2019.
Single observations
(2011, 2017, 2019)
inserted.

Remaining SXR response:

ch2-3 (Al)	~ 40%
ch2-4 (Zr)	~ 60%





[Remark] Why are LYRA flares so different ?

Hypothesis: Due to different temperatures.
(Hotter flares, shorter wavelengths, less present in LYRA spectral range; cooler flares, longer wavelengths, more present in LYRA spectral range)

Test: Estimate flare temperatures.

Method (White et al. 2005, Thomas et al. 1985):

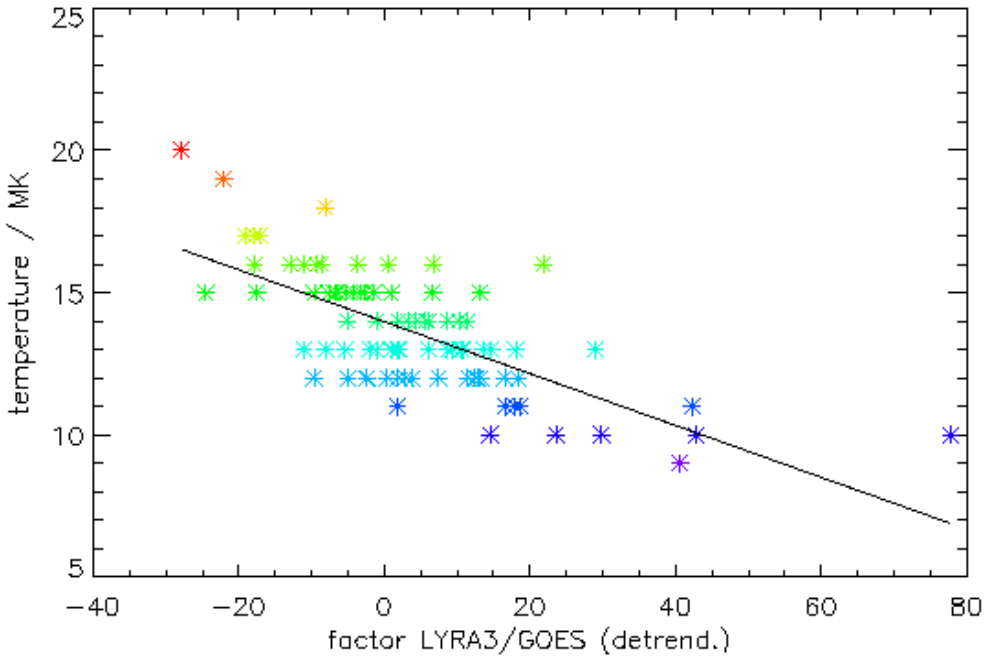
B4 (0.05-0.4nm) and B8 (0.1-0.8nm) : GOES x-ray flux channels

$R = B4/B8$: their ratio

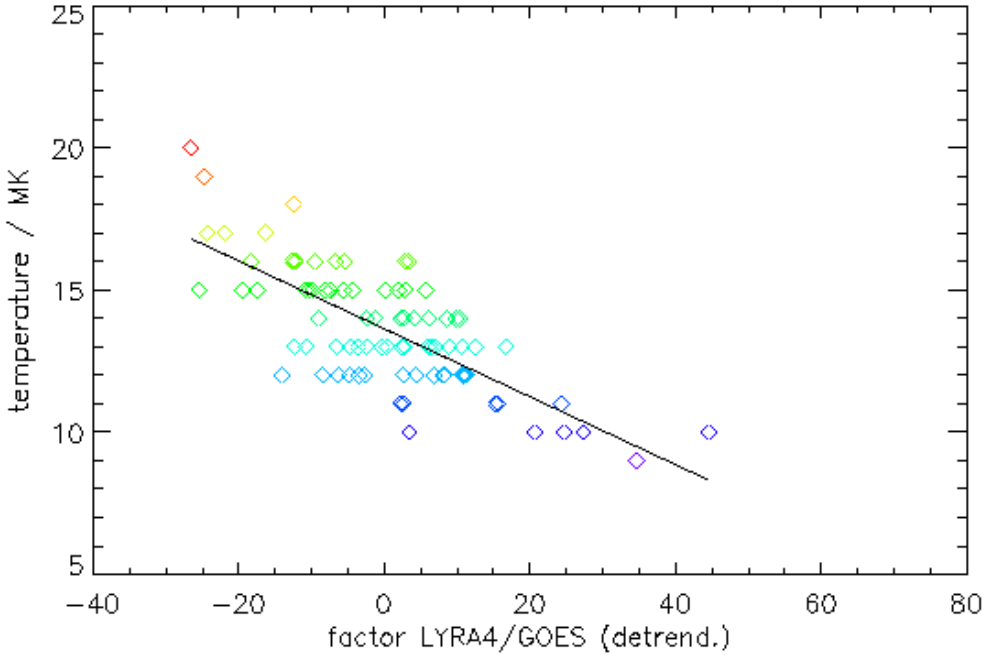
$T(R) = 3.15 + 77.2*R - 164.0*R^2 + 205.0*R^3$: temperature

Correlation

-70% for LYRA ch2-3



-74% for LYRA ch2-4

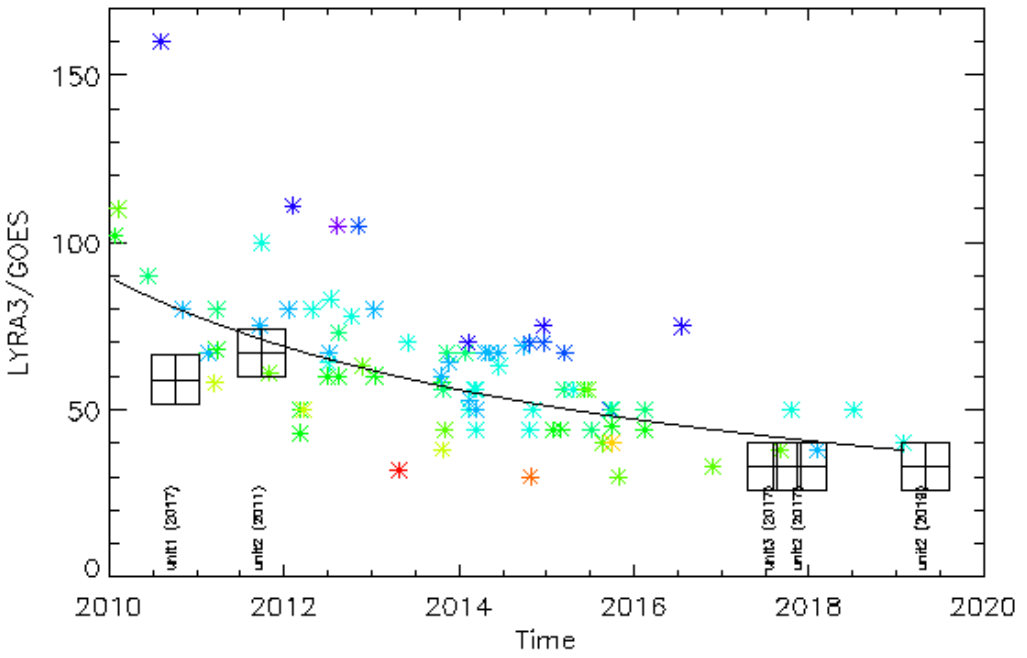


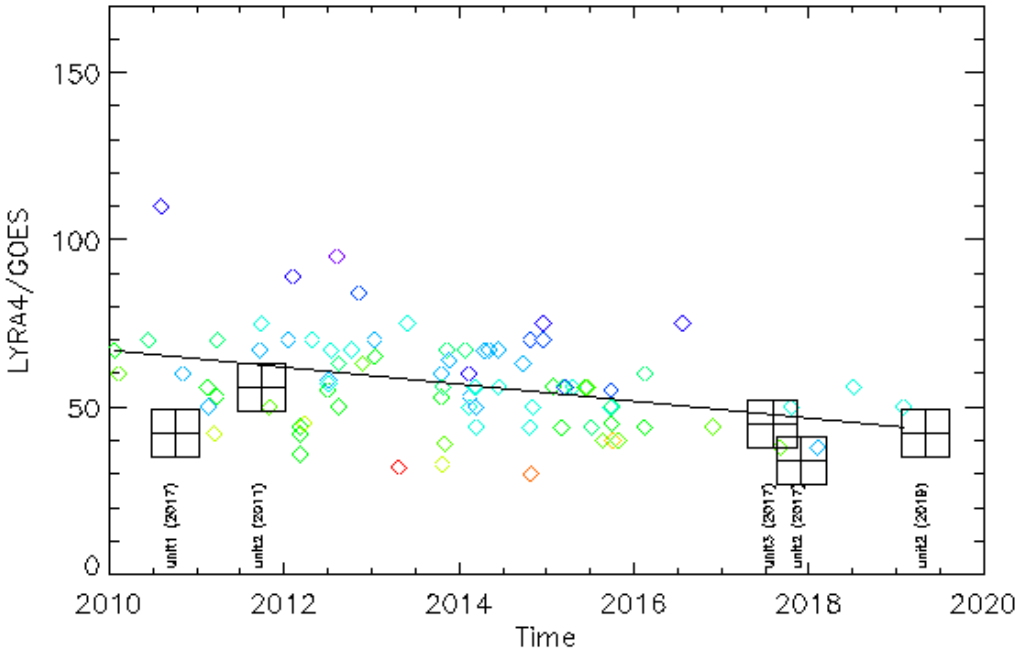
LYRA flare strengths over time in space

84 flares,
most of them M1.0,
2010-2019.
Single observations
(2011, 2017, 2019)
inserted.

Higher temperatures (red)
=> weaker LYRA flares

Lower temperatures (blue)
=> stronger LYRA flares





Factor update after (almost) ten years ?

GOES = 0.030 * LYRA3 , GOES = 0.025 * LYRA4

LYRA3 and LYRA4 would be back in sync.