Monitoring space weather with PROBA2/LYRA after 12 years in space

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Abstract: The radiometer LYRA on board of the satellite PROBA2 consists of three similar units; one observes the Sun permanently, while the other two are spare units only used for limited campaigns. Each unit consists of four different UV-EUV sensors, of which two also respond to soft X-ray signals. While the nominal unit has heavily suffered from degradation concerning quiet-Sun signals, the monitoring of solar activity is still possible, because active-regions and flares mainly emit in the shortest wavelengths, which are less affected. This holds even more for the spare units. In this presentation, we quantify the impact of degradation on the performances of each unit of LYRA, considering separately the response to quiet-Sun, active regions and flares.

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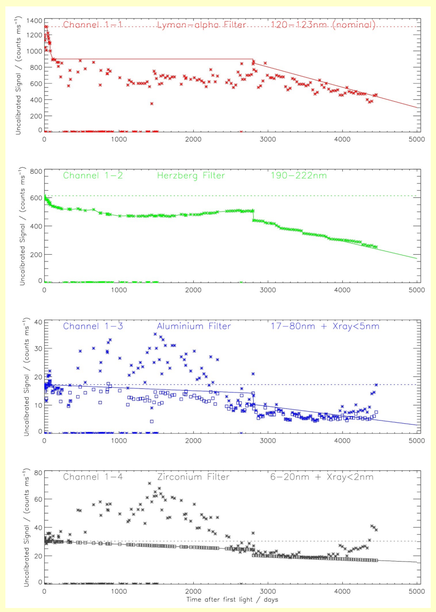
Degradation of LYRA, quiet-Sun signal

In general, degradation is probably caused by a mix of C and Si (e.g. 100 nm and 5 nm, resp., for unit 2) and maybe oxidation.

UV-polymerization, molecular contamination on first optical surface, worst between spectral range [20nm,500nm].

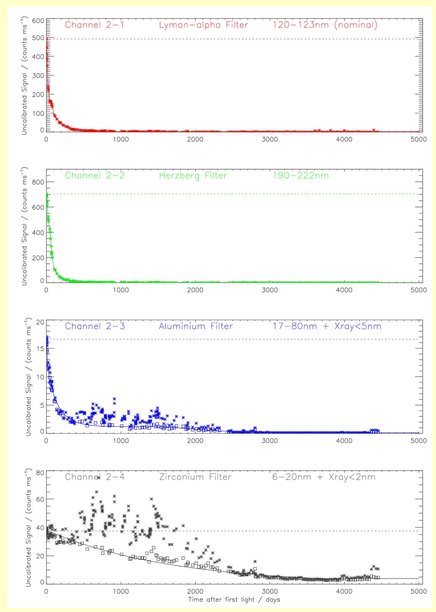


LYRA unit1
"calibration unit"
rarely used (*)
(~ weeks)

Remaining quiet-Sun signal:

ch1-1: 34%
ch1-2: 39%
ch1-3: 28%
ch1-4: 55%

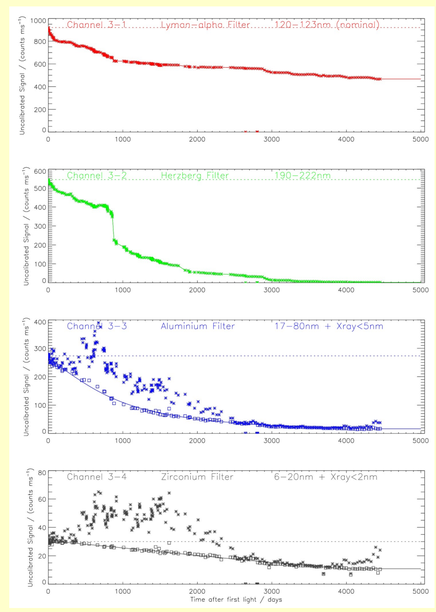
(*) several campaigns only after 2017



LYRA unit 2
"nominal unit"
permanently used
(~ years)

Remaining quiet-Sun signal:

ch2-1: < 1%
ch2-2: < 1%
ch2-3: < 1%
ch2-4: 11%



LYRA unit 3
"campaign unit"
temporarily used
(~ months)

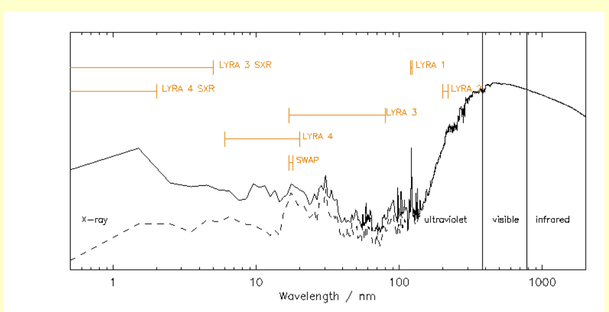
Remaining quiet-Sun signal:

ch3-1: 51% (*)
ch3-2: < 1%
ch3-3: 6%
ch3-4: 36%

(*) from outside nominal spectral interval

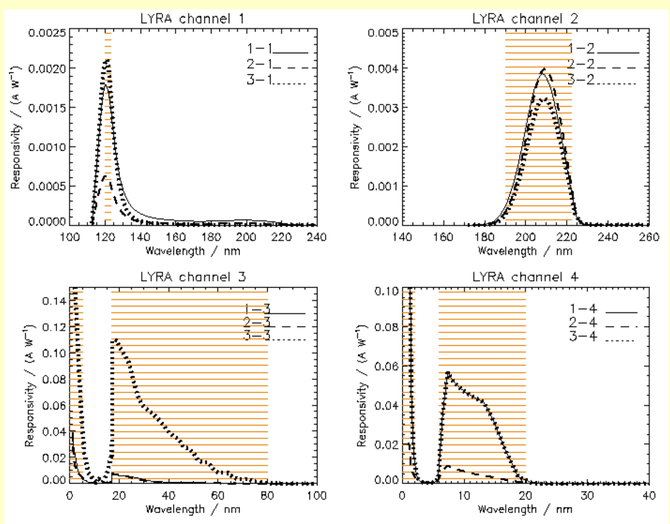
For channels 3 and 4, raw data (asterisks) are corrected for solar activity. Resulting data (squares) are used for the fit.

SWAP and LYRA spectral intervals

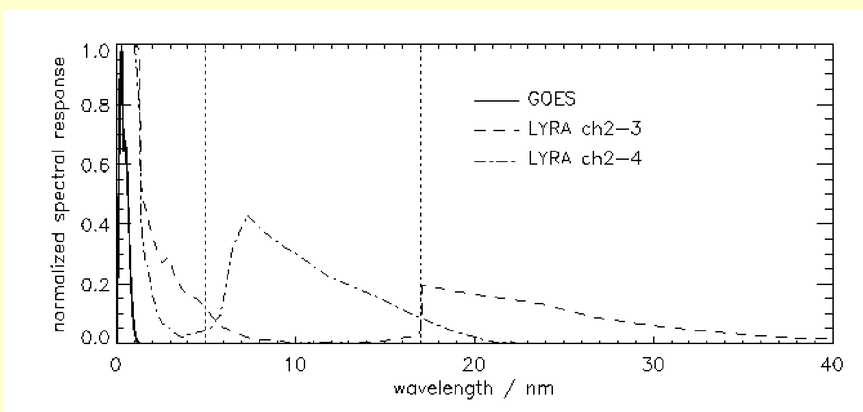


LYRA channel 1: the H I 121.6 nm Lyman-alpha line (120-123 nm)
LYRA channel 2: the 200-220 nm Herzberg continuum range (now 190-222 nm)
LYRA channel 3: the 17-80 nm Aluminium filter range incl the He II 30.4 nm line plus <5 nm X-ray
LYRA channel 4: the 6-20 nm Zirconium filter range with highest solar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

LYRA spectral response



What is left of channels 3 and 4 ?



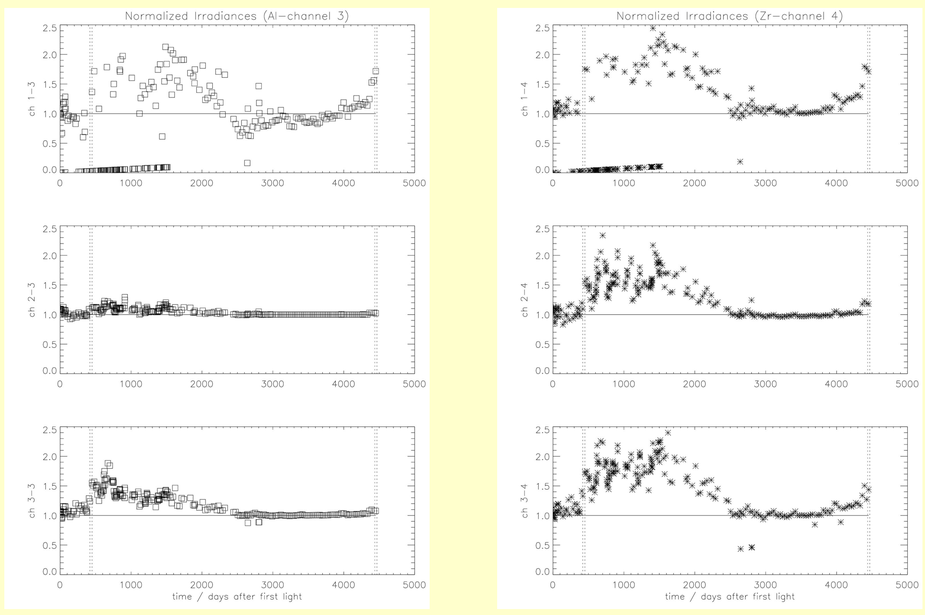
Assumption:
Spectral range [17nm, 80nm]: rest still existing for unit 1, vanished for unit 2 and unit 3
Spectral range [5nm, 17nm]: rest still existing for unit 2, more for unit 1 and unit 3
Spectral range [0.1nm, 5nm]: still existing for all units, somewhat degraded for unit 2

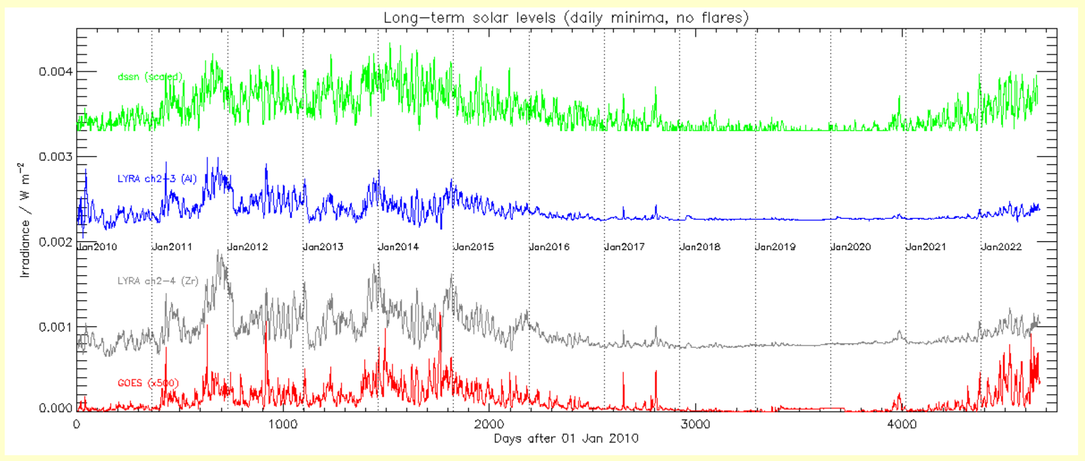
Degradation of LYRA, active-region signal

Compared are results from March 2011 and March 2022 (intervals marked), both 27 months after the previous solar minimum. First-light level is set to 1.0, the difference above this level (unit1, March 2011) is set to 100%.

Remaining active-region signal:

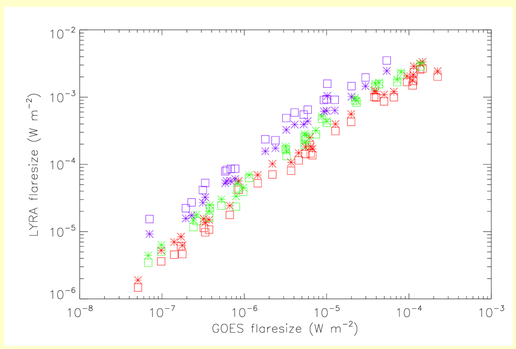
ch1-3: 100% ch1-4: 99%
ch2-3: 3% ch2-4: 24%
ch3-3: 11% ch3-4: 59%





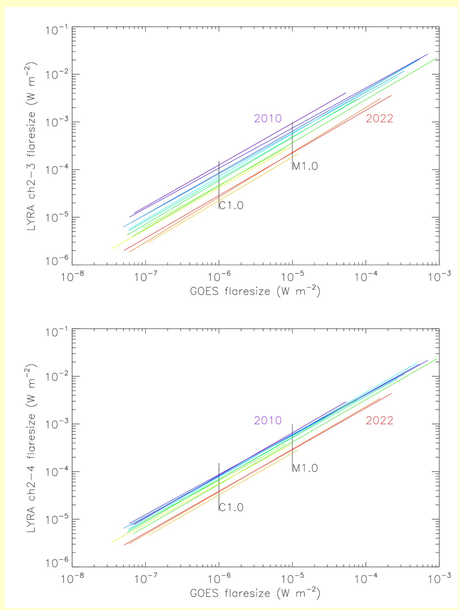
While GOES values and sunspot numbers have returned to the level of the previous cycle, LYRA unit 2 values are lower, but still detecting active regions. Unit 3 values would be higher than unit 2 in 2022, unit 1 values would be even as high as in 2011.

Degradation of LYRA, flare signal



[above] LYRA unit 2 flare sizes (peak level - onset level) as a function of GOES flare sizes, from B to X class: squares = ch2-3, asterisks = ch2-4; purple = 2010, green = 2017, red = 2022.

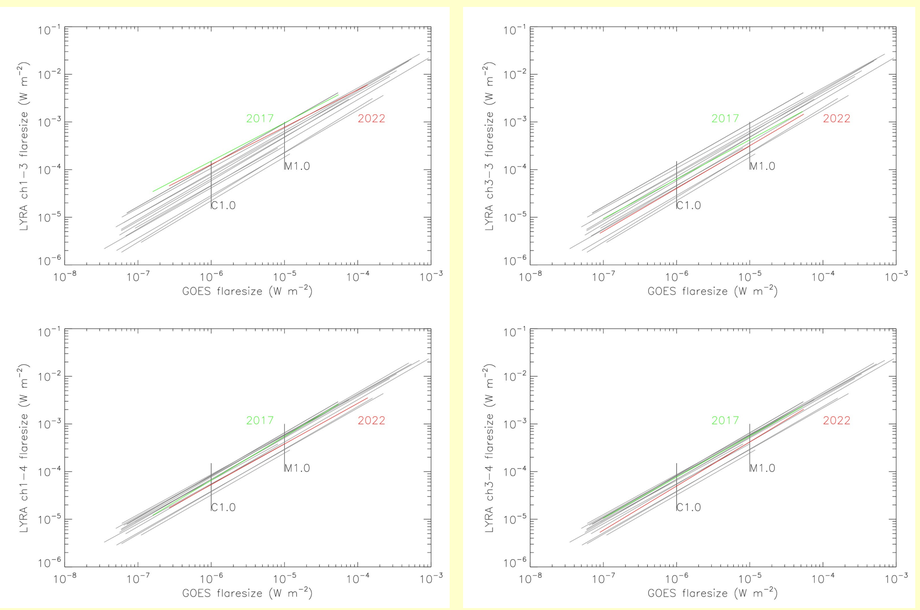
[right] Linear fits for all years 2010 - 2022 show a continuous degradation that is faster for ch2-3. In the end, the response of ch2-4 is relatively stronger.

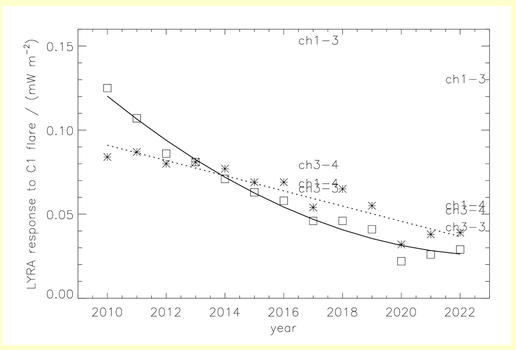


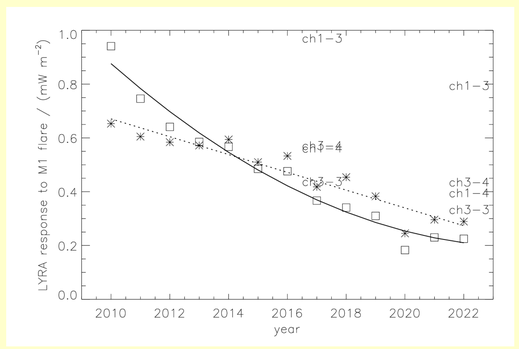
[right] Similar linear fits for unit 1 and unit 3, with flare sizes taken from campaigns in 2017 and 2022, (gray = unit 2 fits). Obviously, unit 3 flare responses remain stronger than unit 2, and unit 1 flare responses remain equal or stronger than unit 3.

Remaining flare signal:

ch1-3: 89-106% ch1-4: 57-58%
ch2-3: 22-24% ch2-4: 40-41%
ch3-3: 33-36% ch3-4: 55-63%
(Please note that there were no flare campaigns with units 1 and 3 in 2010, so their initial strengths were assumed to be like unit 2)







As marked in the previous figures, to make the drop in flare response comparable, the yearly fitted responses for two medium flare sizes were taken: the vertical cuts at GOES C1.0 and M1.0 responses. These were again fitted with a second degree polynomial for ch2-3 (squares, fitted by straight line) and with a first degree polynomial for ch2-4 (asterisks, fitted by dotted line). The 2017 and 2022 values for unit 1 and unit 3 are inserted as text.

Results: Impact of degradation on the performance of LYRA units

(calibration) unit 1 remaining signals

ch1-1: QS 34%
ch1-2: QS 39%
ch1-3: QS 28%
AR 100%
flare 89-106%
ch1-4: QS 55%
AR 99%
flare 57-58%

(nominal) unit 2 remaining signals

ch2-1: QS < 1%
ch2-2: QS < 1%
ch2-3: QS < 1%
AR 3%
flare 22-24%
ch2-4: QS 11%
AR 24%
flare 40-41%

(campaign) unit 3 remaining signals

ch3-1: QS 51%
ch3-2: QS < 1%
ch3-3: QS 6%
AR 11%
flare 33-35%
ch3-4: QS 36%
AR 59%
flare 55-63%

After twelve years in space, monitoring of solar activity is still possible !