LYRA

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

Rescaled PROBA2/LYRA data used as GOES X-ray flux proxy

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Contents

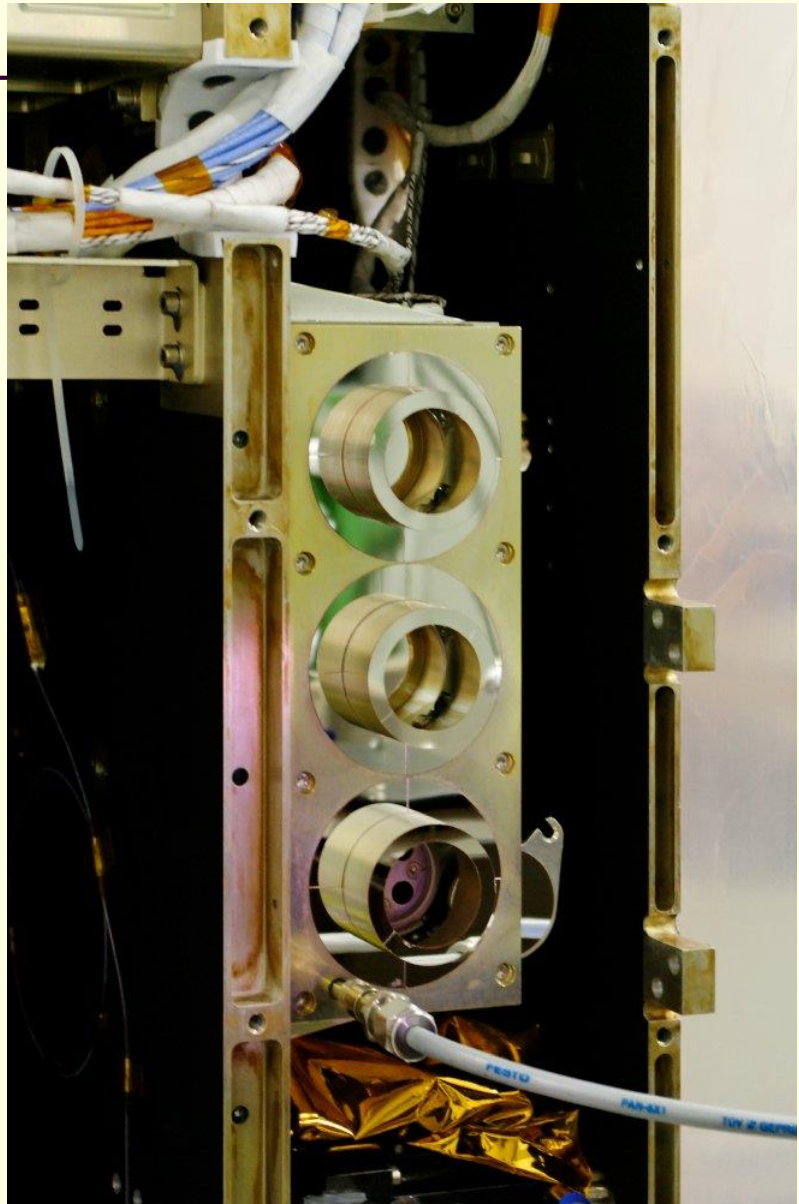
- LYRA: description, spectral response, data
- GOES X-ray flux
- Scaling and correlation
- Why proxy ?

PROBA2: PRoject for On-Board Autonomy

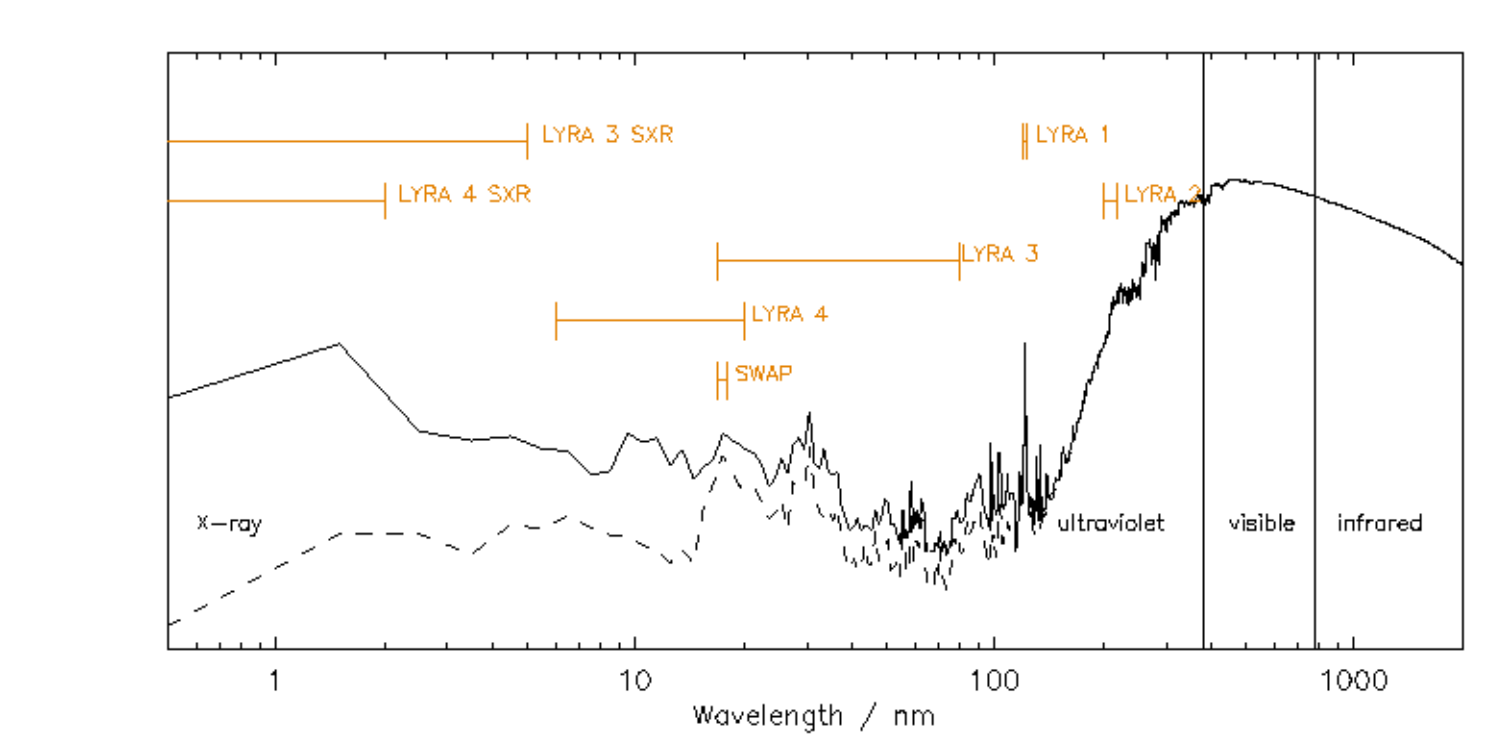
- ESA microsatellite in Sun-synchronous orbit, 725 km altitude
- Built in Belgium, commanded from ROB, launched 02 Nov 2009
- 17 technological experiments, 4 innovative instruments, for in-orbit demonstration (combined technology and science mission)
- LYRA and SWAP have been observing the Sun in EUV,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

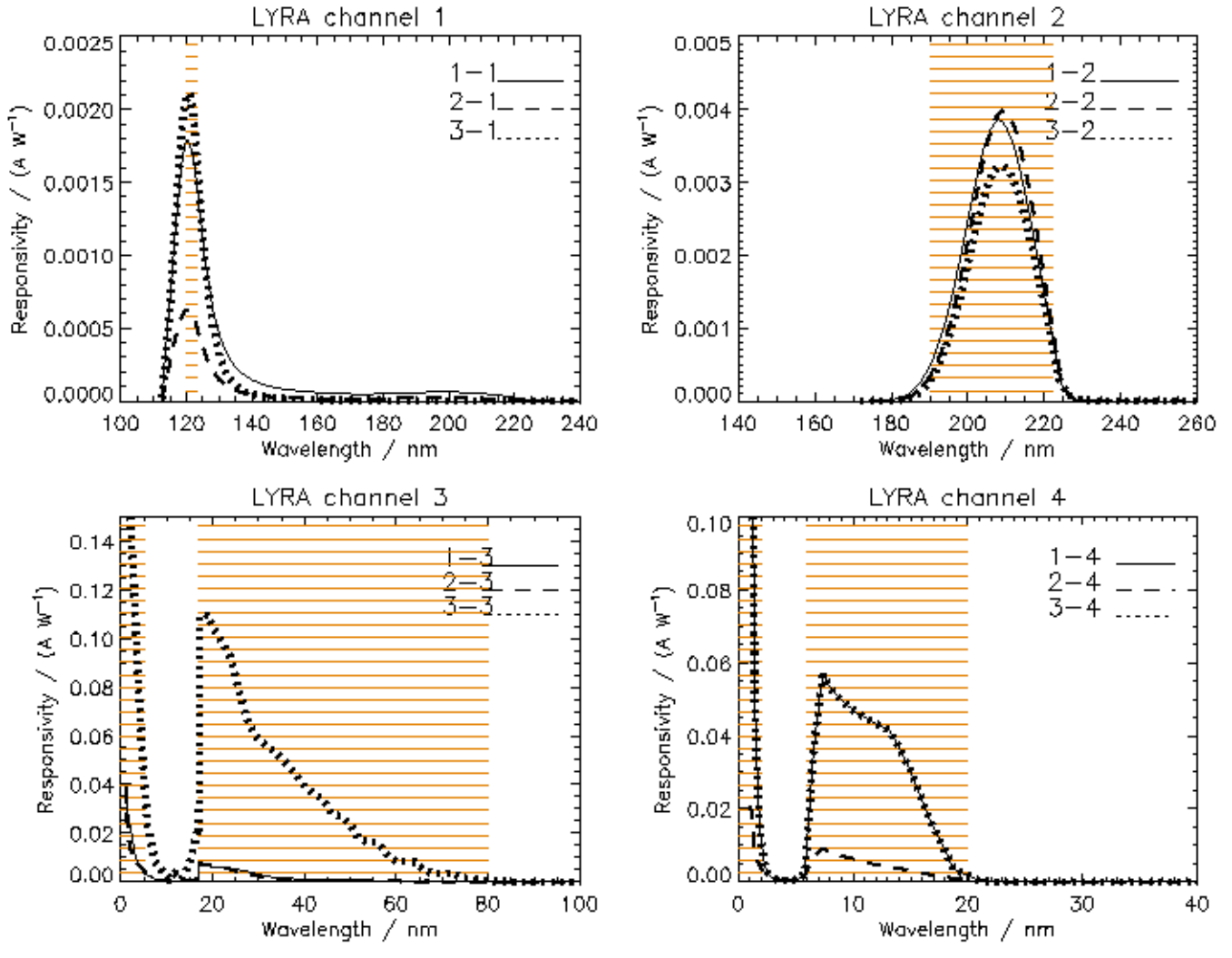


SWAP and LYRA spectral intervals for solar flares, space weather, and aeronomy



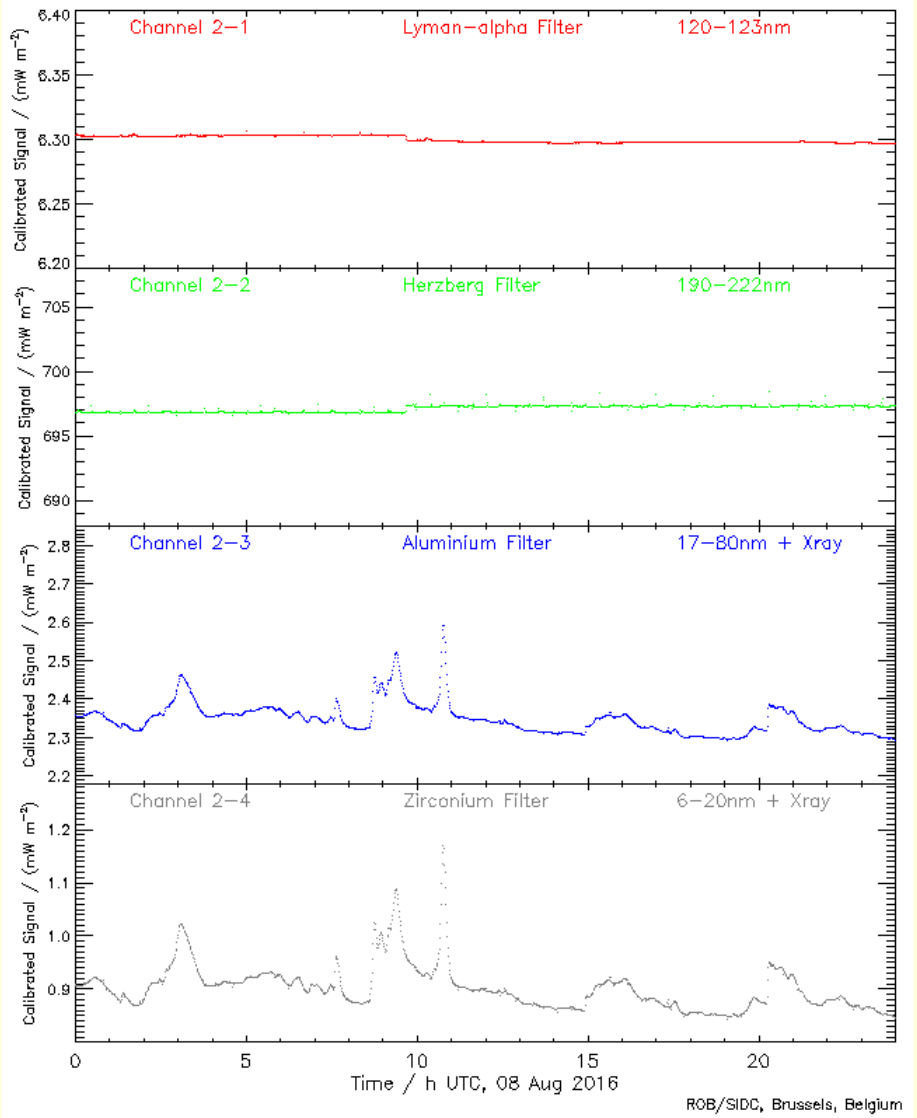
LYRA channel 1: the H I 121.6 nm Lyman-alpha line (120-123 nm)
LYRA channel 2: the 200-220 nm Herzberg continuum range (now 190-222 nm)
LYRA channel 3: the 17-80 nm Aluminium filter range incl the He II 30.4 nm line (+ <5nm X-ray)
LYRA channel 4: the 6-20 nm Zirconium filter range with highest solar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

LYRA spectral response

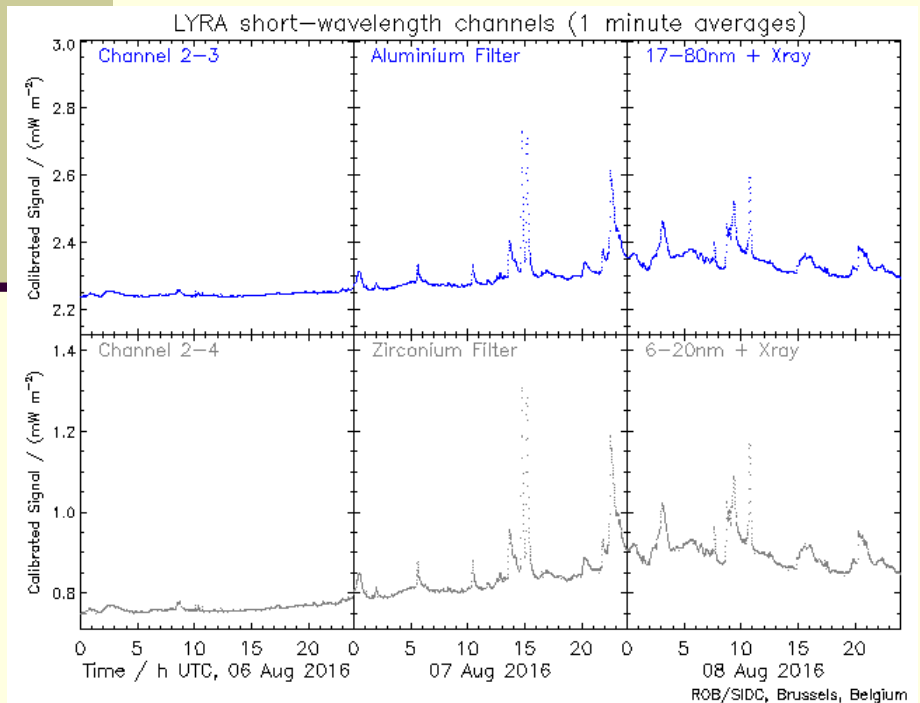


LYRA data products: Example 08 Aug 2016

One-day overview with all four channels



Three-day overview with just two channels



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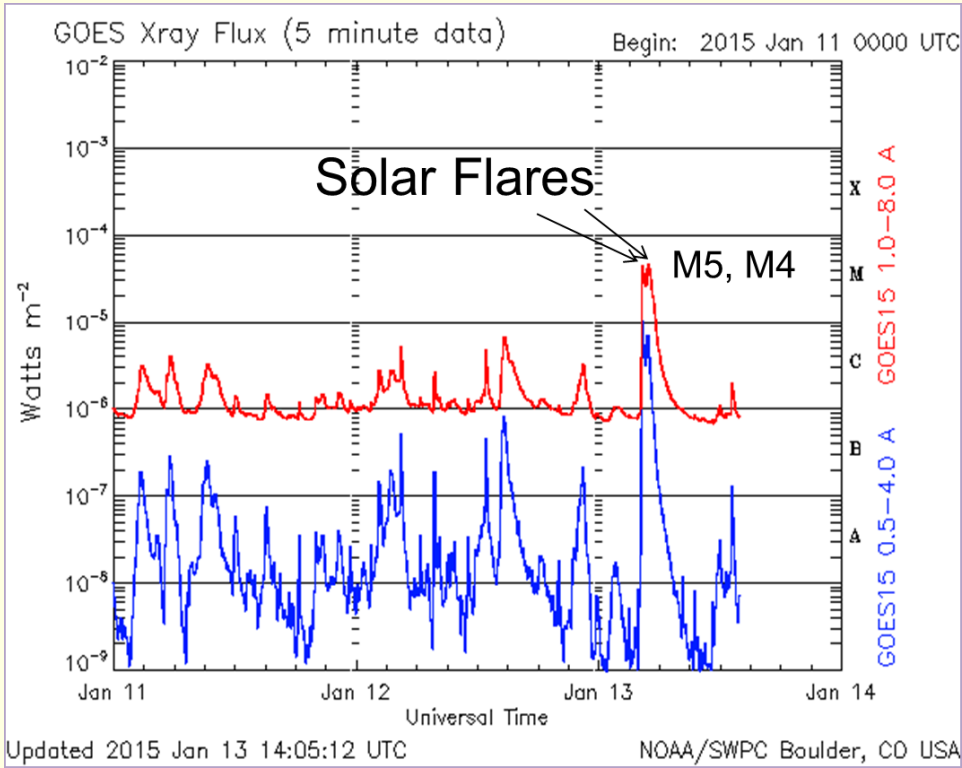
Why do we care …

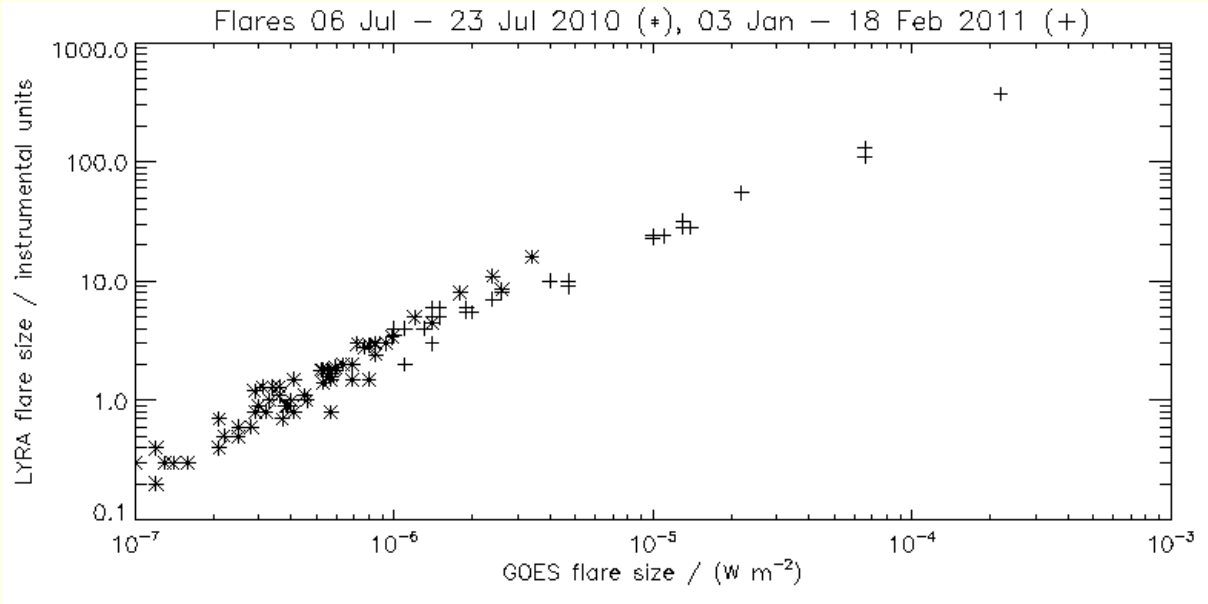
- **… about solar X-ray and EUV emissions?**
- Extreme ultraviolet (EUV; 30-120 nm) and X-ray ultraviolet (XUV; 1-30 nm) irradiance heat the thermosphere and create the ionosphere.
- EUV/XUV irradiance has the highest variability
- EUV/XUV is <0.01% of total solar irradiance (TSI) …
- … however TSI varies by 0.1% while EUV/XUV varies by >200%
- Variability is on many time scales.
- seconds – hours: solar flares
- days – months: solar rotation
- months – years: solar cycle (dynamo)
- Since variations in the EUV flux drive the dynamics of the thermosphere and ionosphere, EUV spectra are inputs for thermospheric/ ionospheric models.
- X-ray measurements are needed for warnings of radio blackouts and other communication hazards.

Solar X-ray measurements

- GOES = Geostationary Operational Environmental Satellite (at 36 km)
- XRS = X-Ray Sensor
- NOAA has measured solar X-ray fluxes continuously since 1974
- The GOES/XRS instrument measures X-ray irradiance in two channels, A (0.05-0.4 nm) and B (0.1-0.8 nm)
- Channel B (red) has become standard to classify flare strengths
- Example: Two M-class flares on 13 Jan 2015



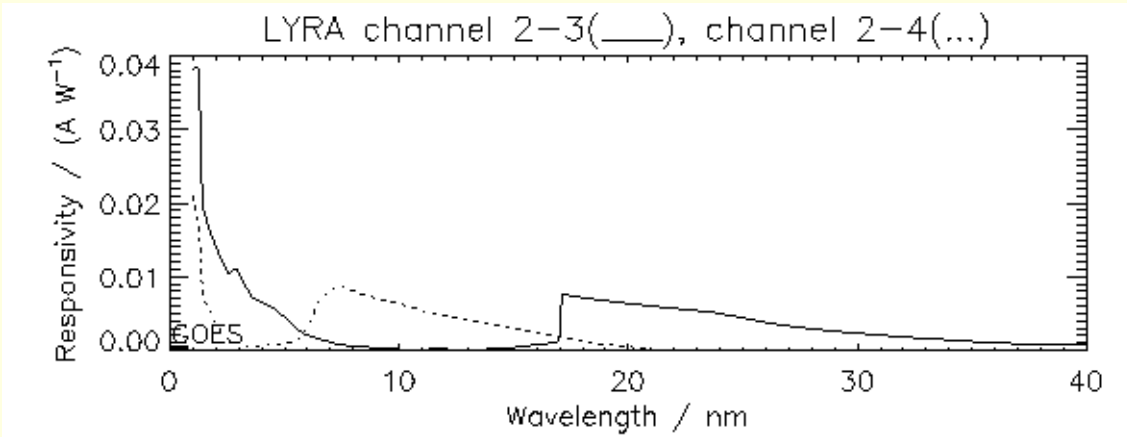
What do we see ?



- GOES flares are also observed by LYRA
- Good correlation across four orders of magnitude
- No degradation problems
- LYRA pre-flare background must be subtracted

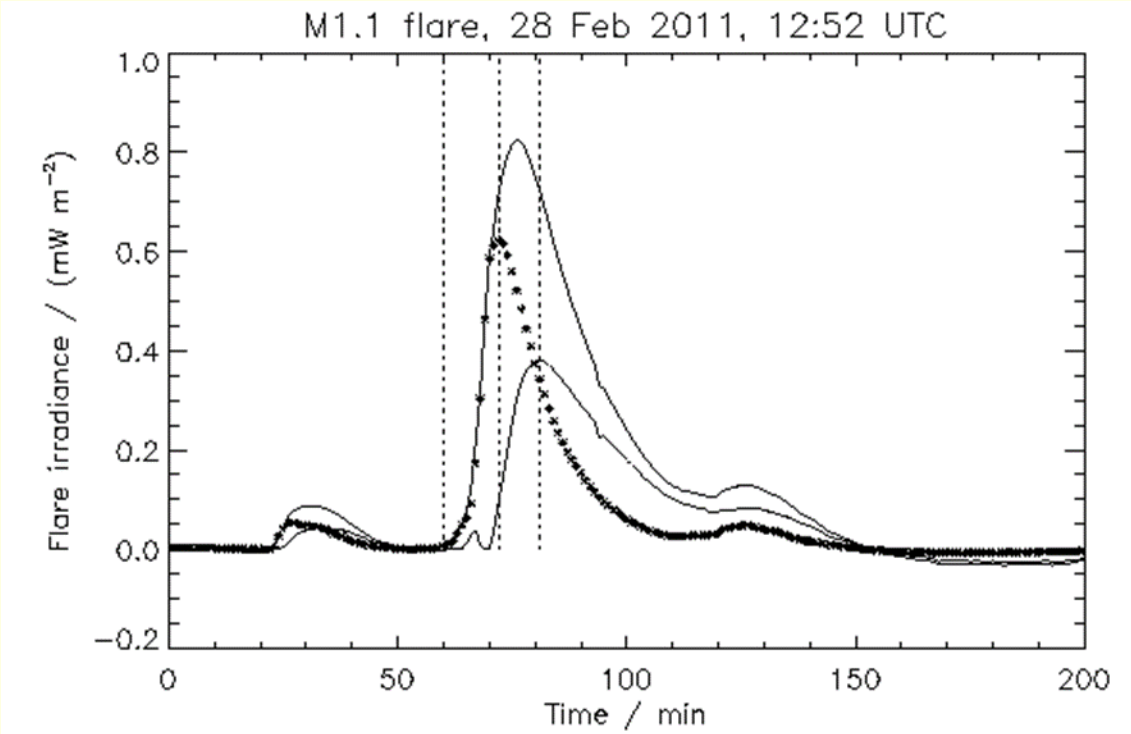
Why ?

Spectral response of GOES and LYRA channels



Flares are similar but not identical

- Example for flare components:
- LYRA ch2-3 (SXR + EUV) *vs.* GOES chB (SXR)
- “SXR”: emission with log(T)>7
- “EUV residual”: emission with 6<log(T)<7
- “little bump”: emission with log(T)<6



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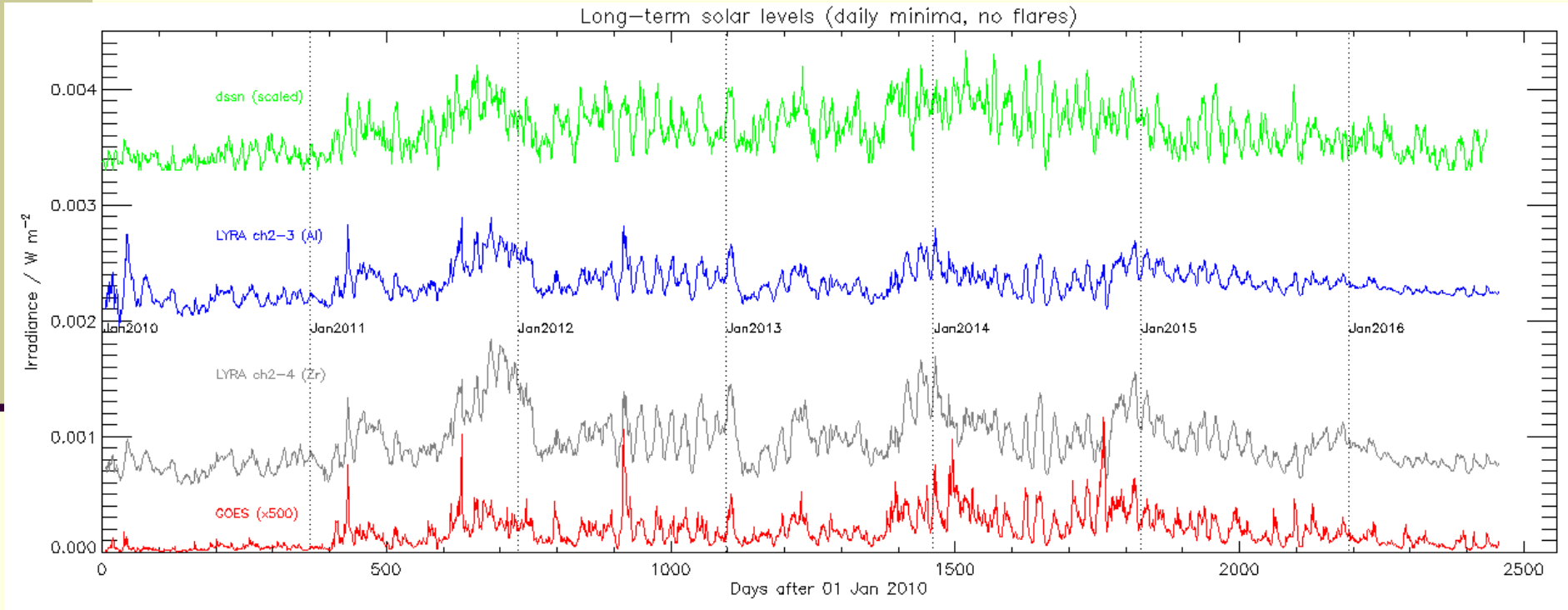
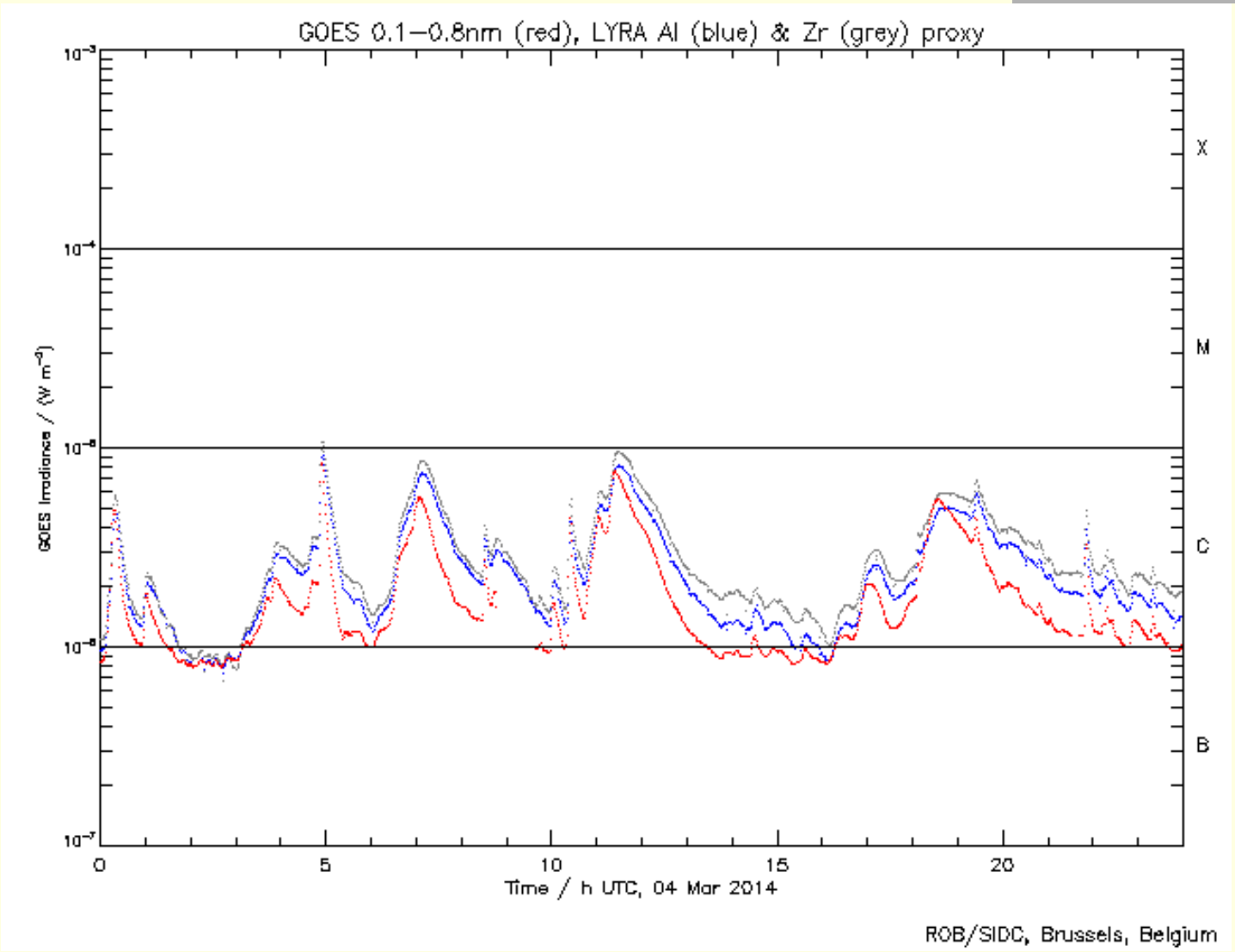
Proxy calculation

- GOES : LYRA flare strengths follow power law
- Exponent close to 1, thus almost perfect linear relationship
- But cooler LYRA background (EUV) has to be subtracted
- Simple approach: Find daily significant minimum
- Then:
- GOES proxy = 0.015 * (LYRA ch2-3 – min(LYRA ch2-3)) + min(GOES)
- GOES proxy = 0.018 * (LYRA ch2-4 – min(LYRA ch2-4)) + min(GOES)
- 0.015 and 0.018 are the linear factors from the power law estimation

LYRA data product: Long-term solar levels



LYRA data product: GOES vs. LYRA proxies



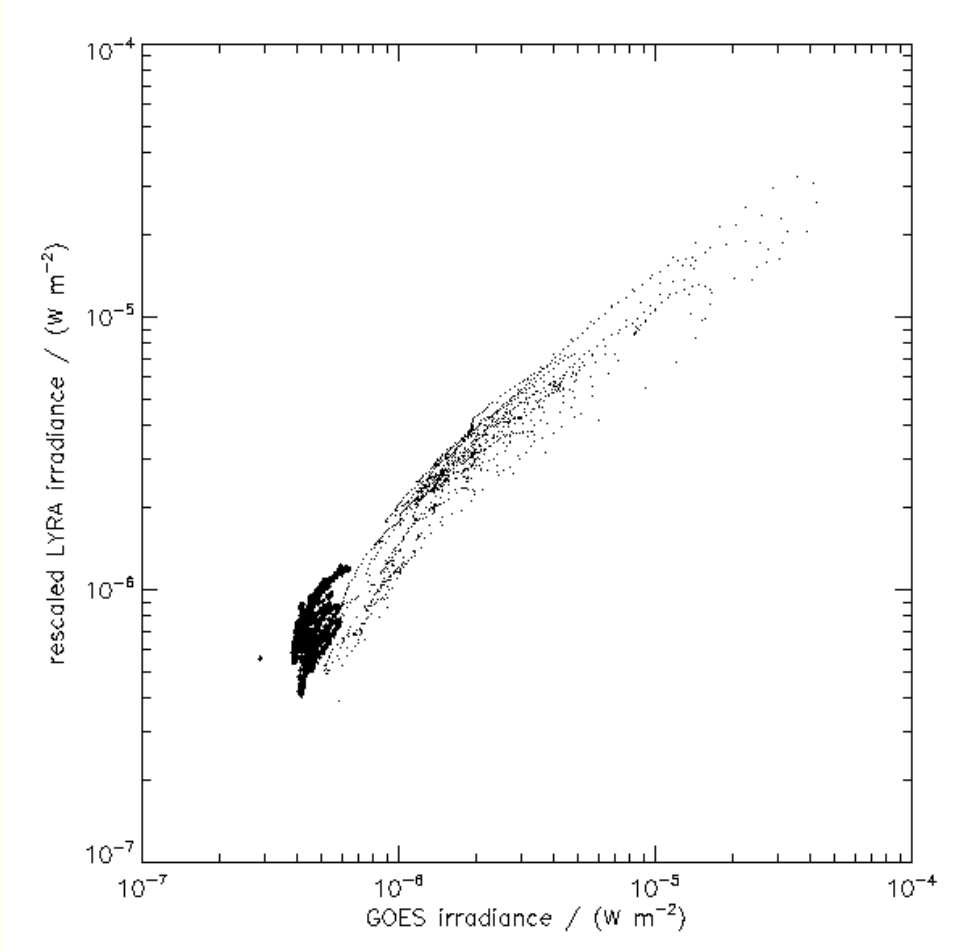
Correlation

Example:

“Active” day 12 Mar 2015
(mainly C-level with some M flares)

“Quiet” day 01 Apr 2015
(mainly B-level)

Proxy based on LYRA ch2-4 (Zr)
vs. original GOES values



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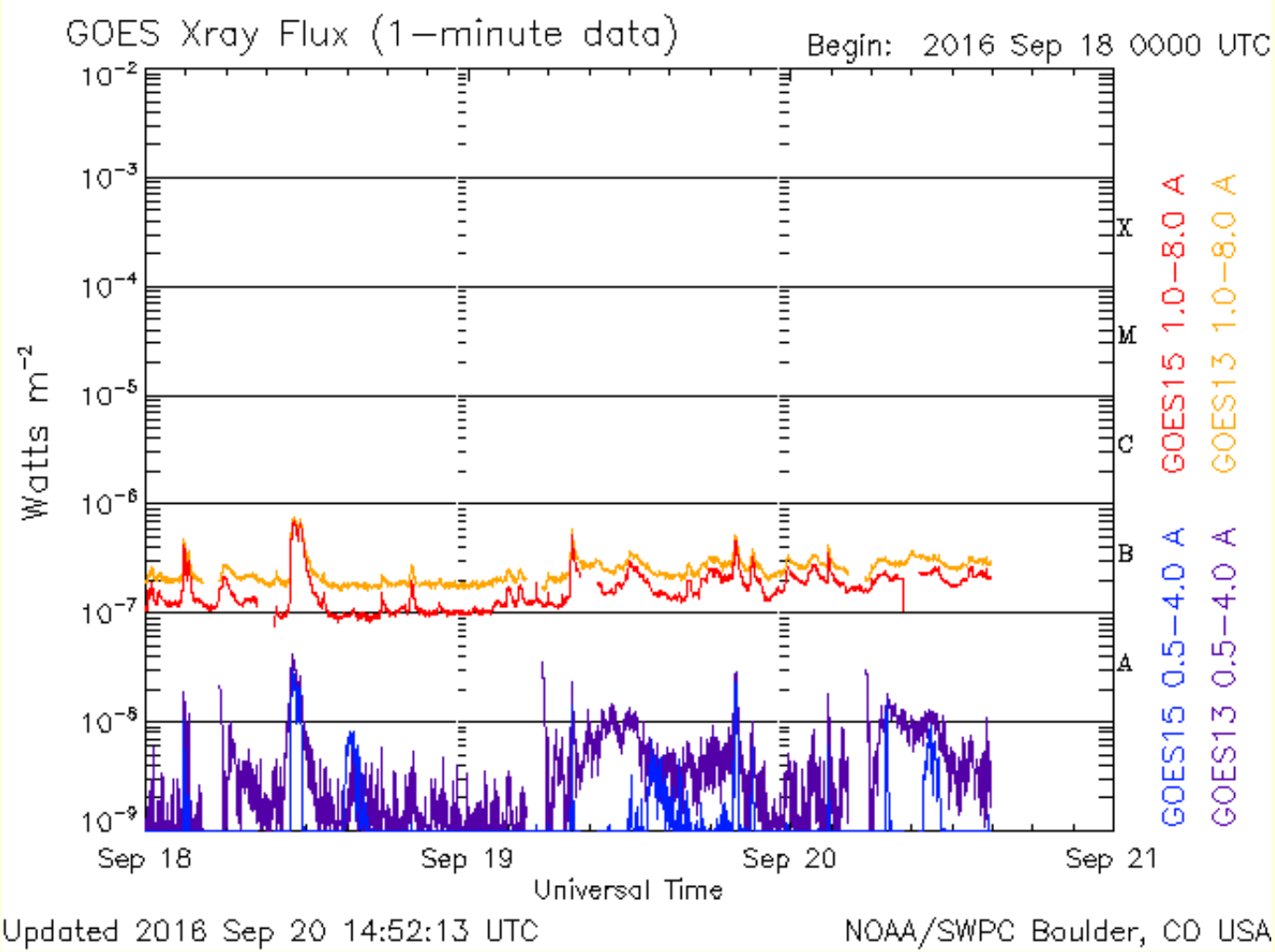
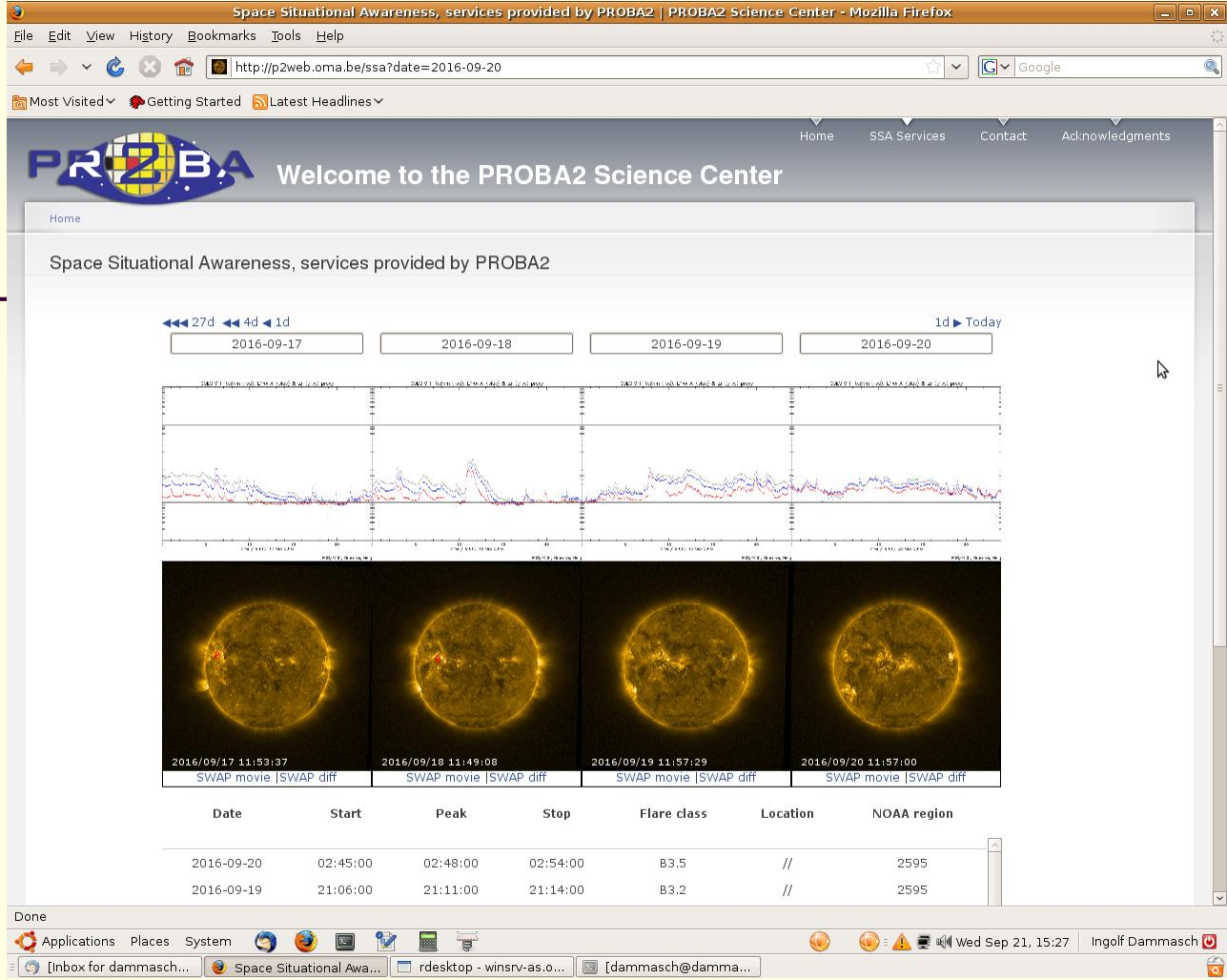
Sometimes there are gaps



So …

- GOES is the standard for flare levels
- GOES has eclipses sometimes (but so does LYRA)
- LYRA has a high temporal resolution (e.g. 50 ms)
- LYRA data update may be slower (orbit time)
- LYRA gives extra information (different bandpass, cooler material)
- LYRA will soon start its own flare detection (new algorithm by D. Ryan)
- EVE/SDO also developed a proxy (Hock, Woodraska & Woods, 2013)
- LYRA data can be used to estimate flare probability (forecast)
- Hope to improve Space Weather service

Please visit:



- http://proba2.oma.be/ssa
- and of course the official PROBA2 website
- http://proba2.oma.be/

- ***Thank you for your interest !***