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

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Abstract: LYRA is an EUV radiometer on ESA's PROBA2 spacecraft. Two of its detectors can be exploited to image the SXR flux. It will be demonstrated how the original LYRA data have to be scaled, what the similarities and the differences of the resulting curves are, and what causes them. It will also be shown where to find these and other LYRA data products.

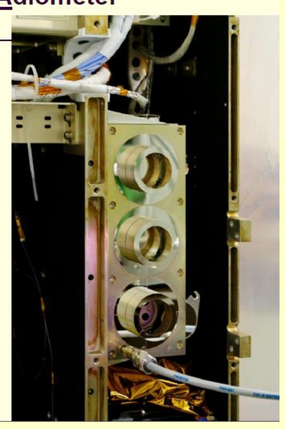
LYRA: description, spectral response

PROBA2: PRoject for On-Board Autonomy

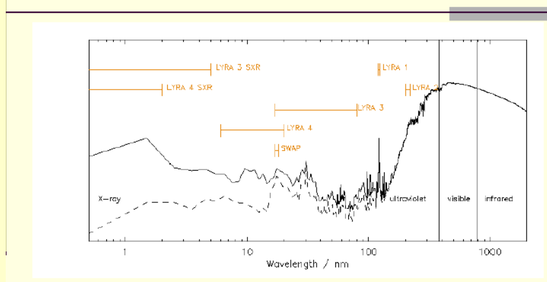
- ESA microsatellite in Sun-synchronous orbit, 725 km altitude
- Built in Belgium, commanded from ROB, launched 02 Nov 2009
- 17 technological experiments, 4 innovative instruments, for in-orbit demonstration (combined technology and science mission)
- LYRA and SWAP have been observing the Sun in EUV,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

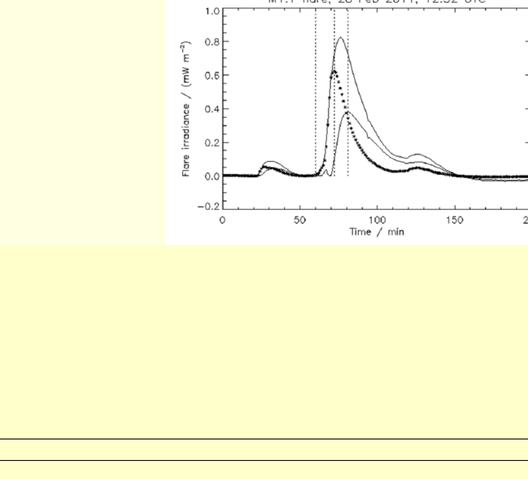


SWAP and LYRA spectral intervals for solar flares, space weather, and aeronomy



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 variability (+ <2nm X-ray)
SWAP: the range around 17.4 nm including coronal lines like Fe IX and Fe X

LYRA spectral response



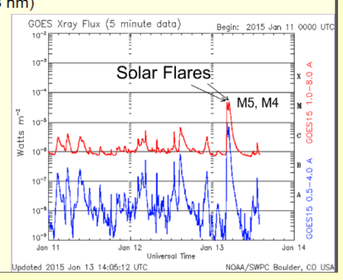
GOES X-ray flux

Why do we care …

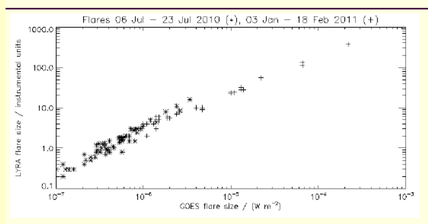
- **… about solar X-ray and EUV emissions?**
- Extreme ultraviolet (EUV; 30-120 nm) and X-ray ultraviolet (XUV; 1-30 nm) irradiance heat the thermosphere and create the ionosphere.
- EUV/XUV irradiance has the highest variability
- EUV/XUV is <0.01% of total solar irradiance (TSI) …
- … however TSI varies 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



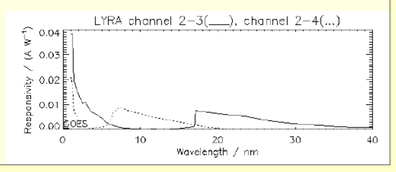
What do we see ?



- 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

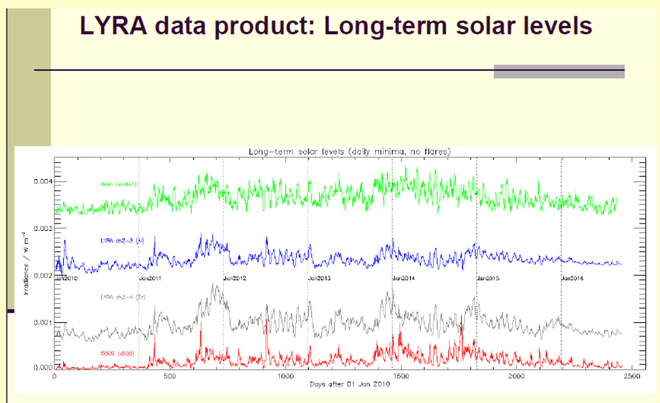
- Example for flare components:
- LYRA ch2-3 (SXR + EUV) *vs.* GOES chB (SXR)
- "SXR": emission with log(T)>7
- "EUV residual": emission with 6<log(T)<7
- "little bump": emission with log(T)<6

Scaling and correlation

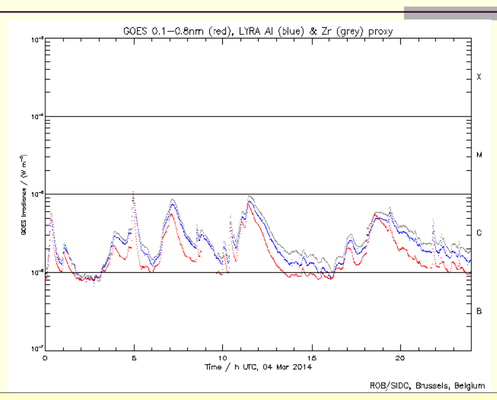
Proxy calculation

- 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



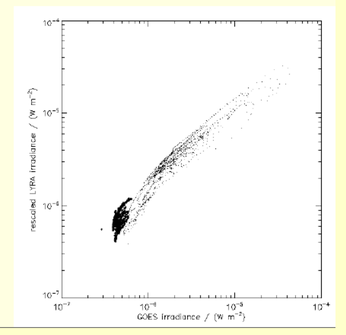
Correlation

Example:

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

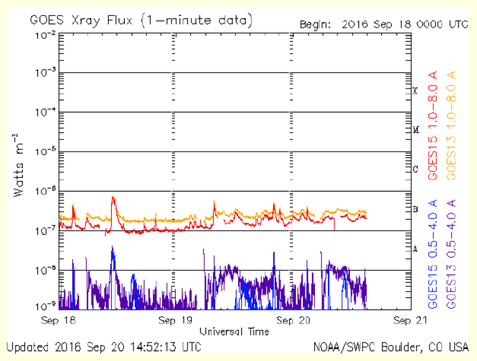
"Quiet" day 01 Apr 2015
(mainly B-level)

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



Other data products, and: why a proxy?

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 data can be used to estimate flare probability (forecast)
- 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)
- Hope to improve Space Weather service
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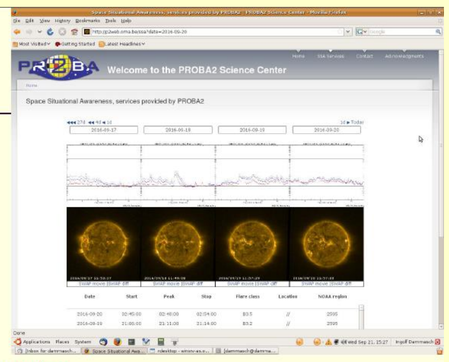
Please visit:



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

LYRA data products: Example 08 Aug 2016

One-day overview with all four channels

Three-day overview with just two channels