More PROBA2 Science Data Products

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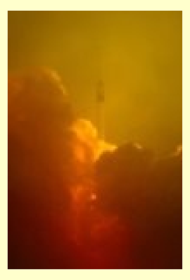
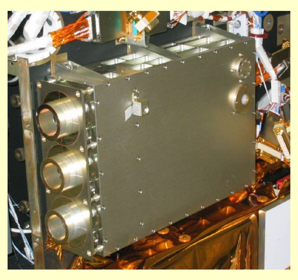
Introduction

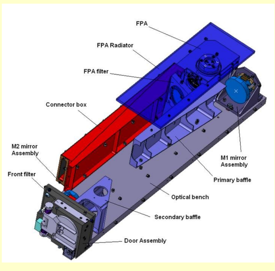
LYRA (Large Yield RAdiometer) and SWAP (Sun Watcher using APS detector and image Processing) are instruments on ESA's satellite PROBA2 (Project for On-Board Autonomy) which was launched 02 Nov 2009. LYRA will deliver solar irradiances with high temporal resolution (10 ms - 10 s) in four nominal UV intervals: 120-123 nm, 200-220 nm, 17-80 nm, 6-20 nm. SWAP will be able to deliver one image per minute of the solar corona in the 17-18 nm range. Due to the spectral responsivity of the LYRA detectors, it appears possible to split the LYRA total signal of the two short-wavelength channels such that also time series of SXR radiation can be produced. In addition, the overlap of LYRA's short-wavelength channels - both covering the SWAP spectral interval - offers two ways to estimate a "coronal" time series that can be cross-calibrated with SWAP's integrated output. - Radiometric model simulations are presented and expected results described.

PROBA2 is a micro-satellite developed under the ESA General Support Technology Program (GSTP) demonstrating new technology in flight. It was recently launched from Plesetsk (Russia) and hosts several new developments and scientific instruments, among them LYRA and SWAP.

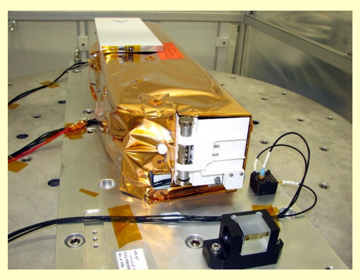


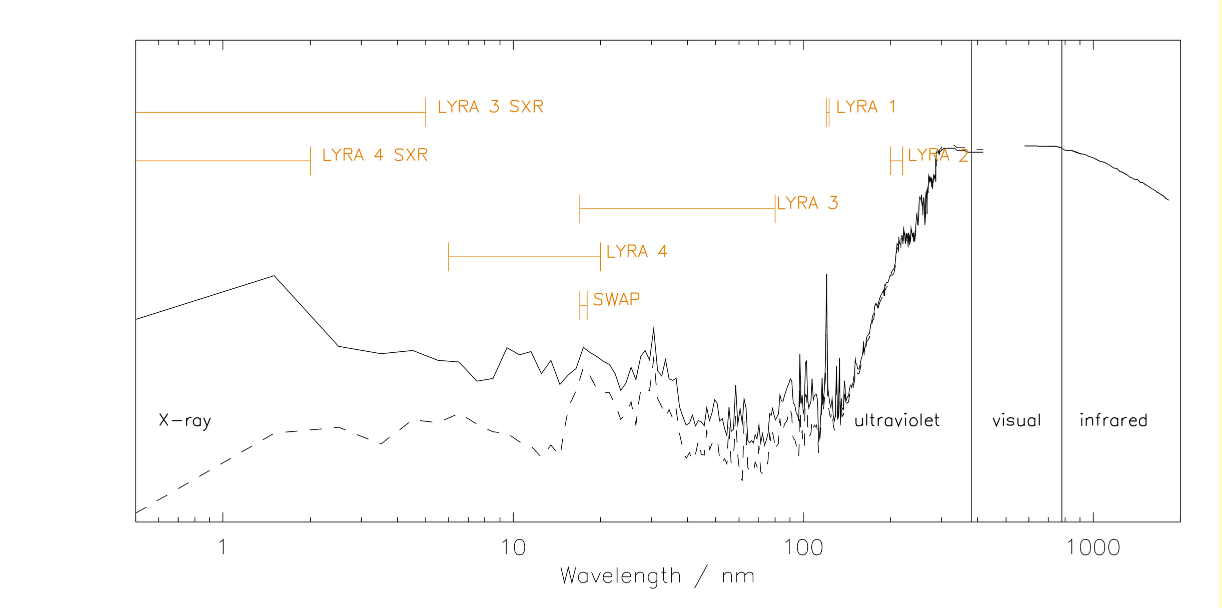
LYRA is an ultraviolet irradiance radiometer that will observe the Sun in four passbands, chosen for their relevance to solar physics, aeronomy and space weather. The instrument will detect flares and help to analyze the atmospheric composition of the Earth (Hochedez et al., 2006)





SWAP is a small EUV telescope that will image the solar corona at a temperature of 1 million degrees K. SWAP will continue the systematic CME watch program of SOHO/EIT at an improved cadence and monitor events in the lower solar corona that might be relevant for space weather (Berghmans et al., 2006)



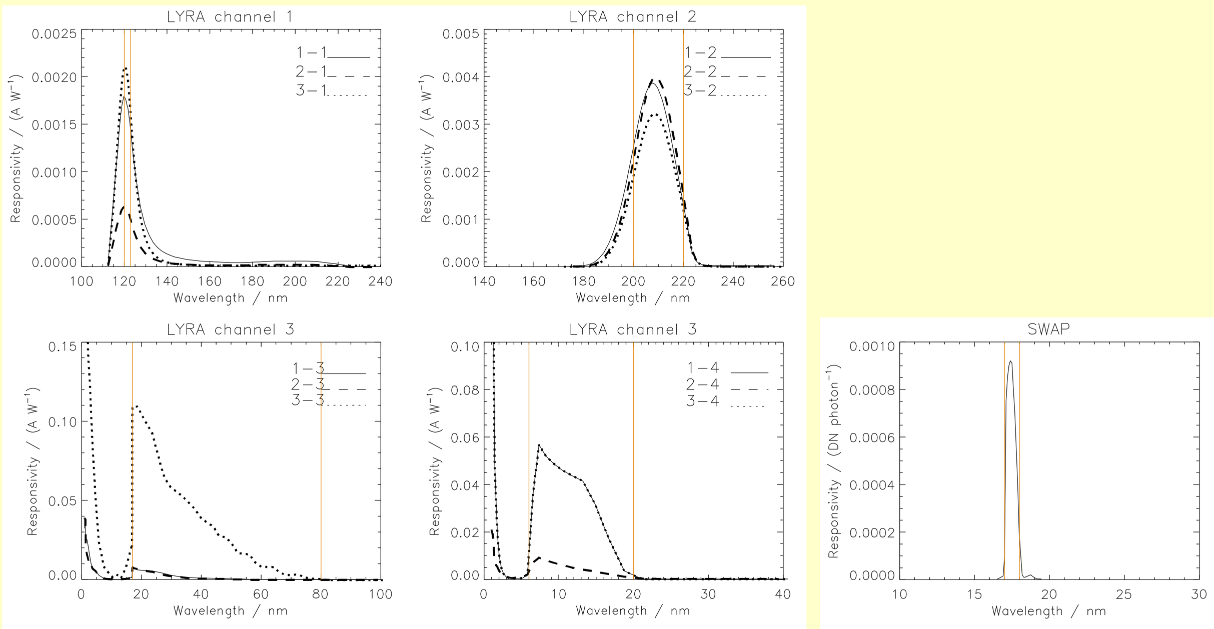


LYRA and SWAP are built to observe the Sun in various ultraviolet wavelength intervals.

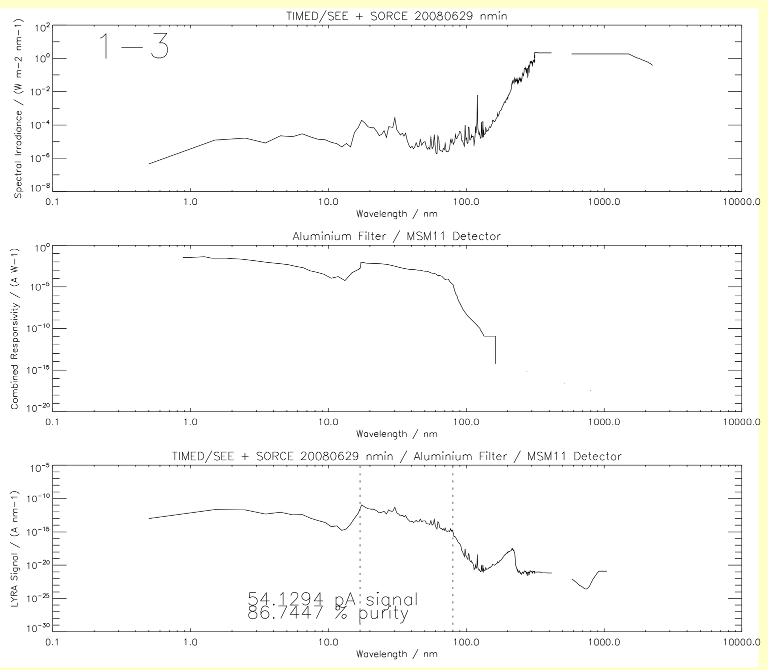
LYRA channel 1: the H I 121.6 nm Lyman-alpha line
LYRA channel 2: the 200-220 nm Herzberg continuum range
LYRA channel 3: the 17-80 nm aluminium filter range including the He II 30.4 nm line
LYRA channel 4: the 6-20 nm zirconium filter range, where solar variability is highest

SWAP: the range around 17.4 nm including coronal lines like Fe IX and Fe X.

But in addition to its nominal bandpasses, LYRA is also highly responsive for soft X-ray radiation in intervals below 2 or 5 nm.



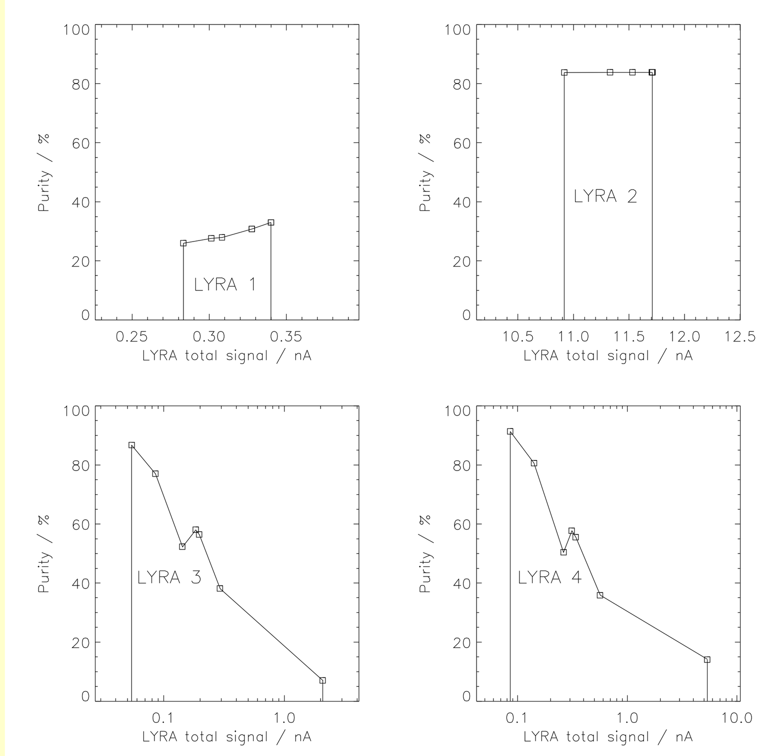
LYRA consists of three redundant units, each with the four channels as defined above. These units are built with different technical components (silicon detectors, diamond detectors, filters of varying thickness, etc.) leading to different responsivities. While SWAP's response is concentrated around its nominal spectral interval (coloured lines), LYRA's filter-detector-combinations lead to responses which are not always ideal but may include contaminations. In order to calibrate the instrument, the "purity" of its response had to be estimated under various solar conditions, which were simulated.



This is an example how the response of channel 3 in LYRA unit 1 was simulated: We selected a solar spectrum which was observed by TIMED/SEE - an instrument already in space since several years - during the current solar minimum (29 Jun 2008). The spectrum was multiplied with the responsivity curve of this particular filter-detector combination as measured in the laboratory tests (BenMoussa et al. 2009).

Purity is then defined as the response within the nominal interval (17-80 nm, dotted lines) relative to the overall response. Simulations show that this channel can be expected to have a high purity for silent solar conditions because there is not much contamination from the short-wavelength interval. Simulations with flare spectra lead to significantly different results.

The four channels in each of the three LYRA units were thus tested with seven spectra representing various solar conditions: from the 2008 solar minimum spectrum mentioned above, a relatively low spectrum of 2005, a relatively high-flux spectrum of 2003, two pre-flare examples of Oct/Nov 2003, to the subsequent X3.9 and X17 flares. The simulated LYRA total output varies over approx. two orders of magnitude in the short-wavelength channels 3 and 4, but far less in the long-wavelength channels 1 and 2.



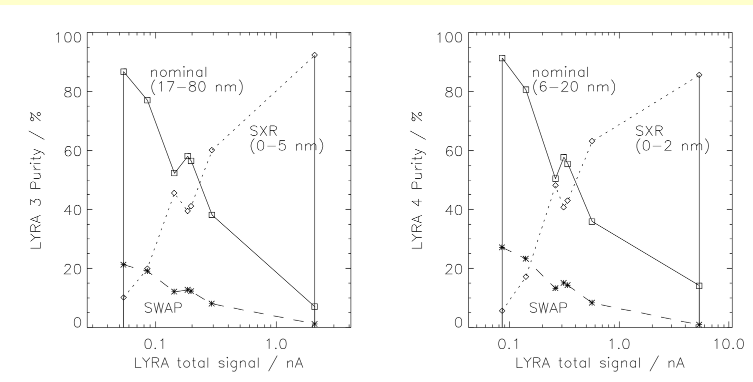
Purity = nominal signal / total signal

As an example, simulations with the LYRA radiometric model described before are shown here for the four channels of unit 1. The figures also demonstrate the estimated total signal variation going from quiet Sun to flares.

Purity for channel 1 is generally only around 30%, due to contaminations from longer wavelengths (up to 220 nm, see responsivity curve, above). It slightly increases in flare situations.

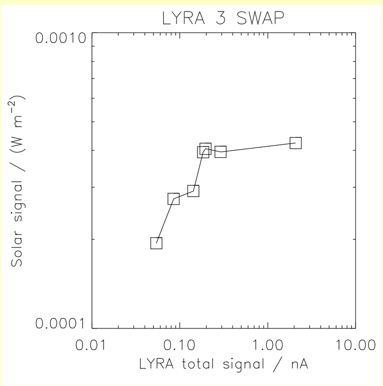
Purity for channel 2 is largely independent from high or low flux. It remains around 85%, due to the definition of the nominal interval.

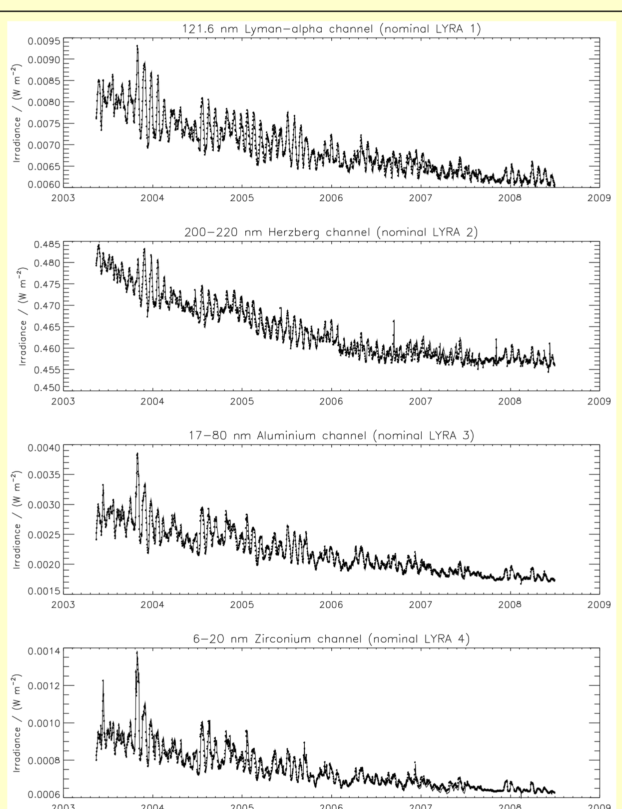
Purities for channels 3 and 4 are high for low flux, but low in flare situations. This is due to the short-wavelength contaminations which become predominant in flare situations. On the other hand, this opens the chance to estimate the SXR contribution as the remainder of the nominal signal.



From LYRA's short-wavelength channels 3 and 4, the SWAP signal can be estimated as a subset of both the nominal signals; the SXR signals (0-5 nm and 0-2 nm) can be estimated as the complement of the nominal signals.

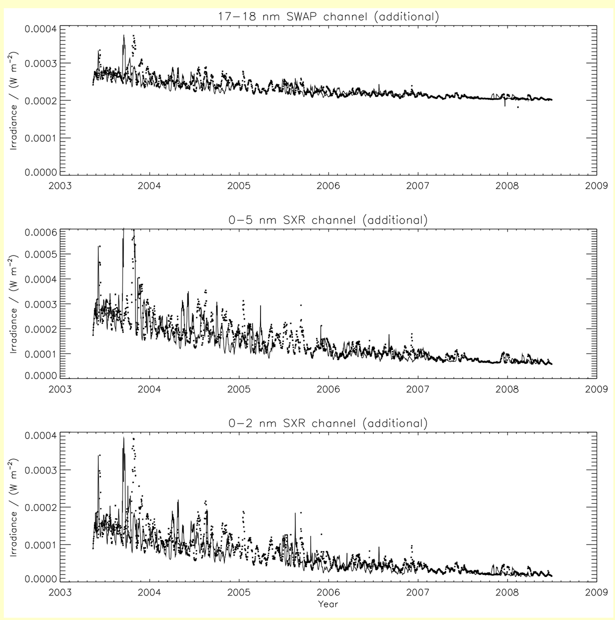
For example, according to the TIMED/SEE observations, the model predicts that SWAP will hardly react to flares. Irradiances in the interval around 17.4 nm do rise from solar-minimum to pre-flare spectra, but the one-million-degree corona in its entirety hardly reacts to the flare itself. While the LYRA total signal can be expected to rise significantly, this is mainly due to the SXR irradiance - reflected by the rising purity of the SXR subset. Meanwhile, the nominal (EUV) purity and especially the purity of the SWAP subset decline.





The LYRA team plans to deliver - among other data products - a daily overview of its four bandpasses in one-minute resolution, as FITS files ("Level 3") and as graphics ("Level 4"). What these figures may look like is demonstrated here: Instead of averaged minutes over a day, averaged days over five years between solar maximum and minimum are used as an example.

Actually, the original temporal resolution of LYRA observations will be in the order of seconds or below (data product "Level 2") and will thus give new insights, especially in flare development.



With a clever signal partitioning, the teams may be able to present more time series; in the SXR range (to be cross-calibrated with, e.g., GOES data), and in the 17.4 nm range (to be cross-calibrated with SWAP integrated images at 1-minute resolution).

With the higher temporal resolution, a much greater irradiance variability, particularly in short wavelengths, can be expected.

We anticipate that a SWAP image can produce several interesting scalar values, in addition to mere integration. Likewise, in addition to just averaging LYRA data points, one can compute higher moments; this is just the entry point to more complex mathematical schemes.

We expect LYRA and other radiometers to contribute to SWAP's and other imagers' inflight absolute calibration. We further hope to reconstruct the line spectrum from integrated observations and statistical models based on imagers' ability to partition the solar atmosphere into AR, CH, and QS regions.

Please monitor our website for data products, especially after the beginning of 2010:

http://proba2.sidc.be

References

A. BenMoussa et al. (2009): Pre-flight calibration of LYRA, the solar VUV radiometer on board PROBA2. *Astronomy and Astrophysics, in press*

D. Berghmans et al. (2006): SWAP onboard PROBA2, a new EUV imager for solar monitoring. *Advances in Space Research 38, Issue 8, 1807-1811*

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