



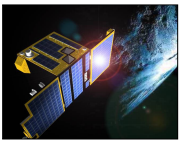
Space Weather with PROBA-2, SWAP

ESA's IHY Mission



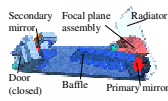
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SPACECRAFT



- **Mission duration:** 2 Years, launch early '07 via Eurockot (N. Russia), with SMOS mission
- **Orbit:** dawn-dust sun sync. orbit at 760 km
- **Visibility:** eclipsed up to max. of 18 min/day

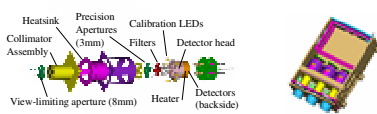
INNOVATIVE DETECTORS BEHIND HERITAGE OPTICS



Both SWAP (above) and LYRA (below) have optical layouts with SOHO heritage

SWAP is an off-axis Richey-Chretien shutterless design based on EIT, with one-time door, two mirrors and fixed filter.

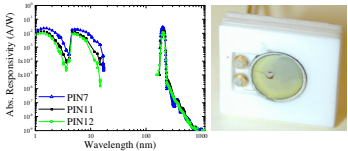
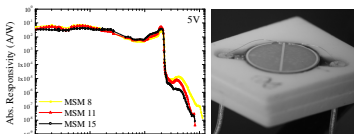
LYRA's optical layout is based on the VIRGO photometers, triply redundant.



SWAP will use a HAS complementary metal oxide semiconductor - CMOS - detector (left) from FillFactory (Belgium). This will be the first orbital solar mission using a CMOS device and may yet be the very first solar application. It is coated with a P43 scintillator (AST, UK) to respond to EUV, not visible, light.

Compared to a CCD a CMOS detector benefits from: low power consumption and heat output; integrated design allowing, e.g., random pixel access, windowing, faster image cadence; low input noise and high signal/noise; correlated double sampling reduces artifacts, smearing and blooming. The disadvantage of lower quantum efficiency is compensated by integration time in SWAP's case. The SWAP detector and coating have been tested satisfactorily w.r.t. the specified operational and non-op. thermal ranges. Extensive testing of several flight model detector/coating units at the PTB-BESSY synchrotron facility in Berlin indicate that full-well level (100,000 e⁻) will be reached in 20s for active regions and ~200s for the quiet sun. Thus a 10s exposure time will resolve an AR well while providing adequate signal/noise and contrast for the QS. These values are fully compatible with the baseline 1-minute image cadence, and provide ample flexibility for special campaign modes.

LYRA will benefit from wide bandgap diamond detectors which makes the sensors radiation hard and solar-blind. The number of filters is reduced and serious attenuation of the desired UV radiation avoided. Radiometrically calibrated to synchrotron source standards (PTB & NIST), stability will be monitored by on-board UV LEDs to distinguish detector drift vs. filter degradation. LYRA's diamond detectors are designed and fabricated at IMOMEC, Belgium in collaboration with NIMS, Japan and IEMN, France. The single pixel devices are MSM structures, or a PIN junctions for the Herzberg channel. The collaboration between ROB and IMOMEC originates with the BOLD program submitted to ESA.

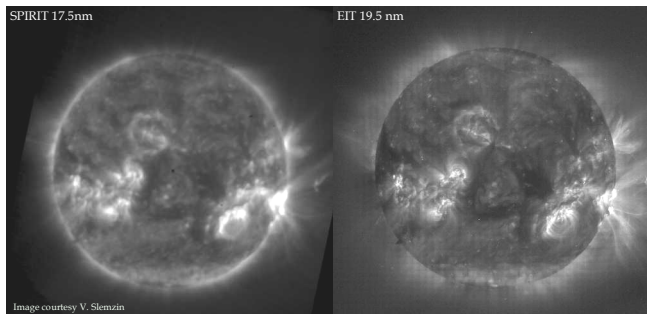


Absolute spectral responsivity (in A/W) of MSMs 8, 11 and 15 at 5V bias (top) and PIN 7, 11 and 12 (bottom) between 1 nm and 1000 nm, with sample detectors.

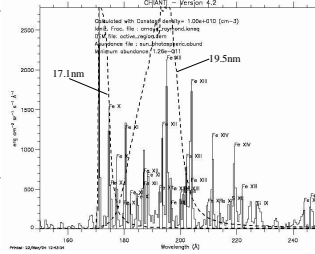
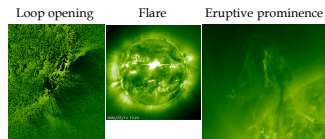
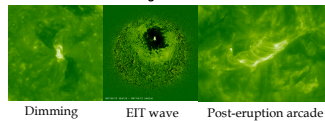
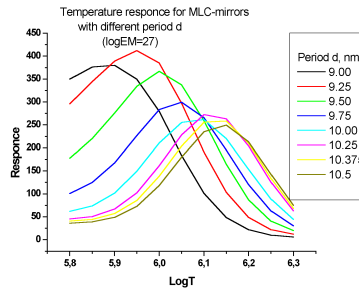
ABSTRACT

The European Space Agency's PROBA2 mission, due for launch in September 2007, will carry onboard two instruments which will greatly enhance ESA's space weather capabilities. The Sun Watcher with APS Detector and Processing - SWAP - is a full disk imager that will monitor the Sun at high temporal cadence and spatial resolution in a single extreme UV passband, while the Large Yield Radiometer - LYRA - will measure irradiance in four carefully selected UV passbands: all five were selected for their relevance to aeronomy, space weather and solar physics. SWAP can be viewed as ESA's replacement for the ageing EIT instrument onboard the joint ESA/NASA SOHO mission. LYRA's higher-energy channels will augment the soft X-ray time series observed by NOAA's GOES satellites while the lower energy channels will monitor the local response to steady and transient solar drivers. Together they will monitor solar output, eruptive events and atmospheric response in real-time. ESA's Project for On-board Autonomy - PROBA - mission line is primarily intended to test new technologies for satellites and systems, and the instruments onboard these launches tend to follow a similar design philosophy. SWAP and LYRA will both use advanced technology detectors behind heritage optics, and will be able - in fact, required - to perform a wide variety of autonomous operations. The scientific objectives, instrumental capabilities, technological advances, anticipated return and expected operational modes are described here.

SCIENCE OBJECTIVES AND RATIONALE

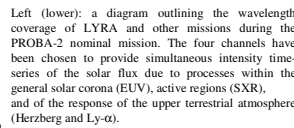


Above: 17.5 nm (left) has been chosen for SWAP's passband since it closely resembles 19.5 nm (right) - the passband normally used for EUV synoptic observations - but with the added advantage of more photons (below, left). We therefore expect SWAP to capture all features and processes important to solar physics (below, right) and space weather events (bottom). In addition, SWAP's 1-minute image cadence will resolve such processes to a greater extent than has hitherto been possible.



Left (upper): examples of on-disk signatures of coronal mass ejections (CMEs) as observed in SOHO-EIT's 195 nm synoptic CME watch program, running normally at 12-min image cadence (a maximum cadence of 7-min is possible).

All the events pictured here typically occur and evolve on timescales too fast to be fully captured by EIT. SWAP's 1-min cadence will resolve for the first time the onset, local evolution and global response to events like these, which are known to be drivers of excited space weather conditions.



Left (lower): a diagram outlining the wavelength coverage of LYRA and other missions during the PROBA-2 nominal mission. The four channels have been chosen to provide simultaneous intensity time-series of the solar flux due to processes within the general solar corona (EUV), active regions (SXR), and of the response of the upper terrestrial atmosphere (Herzberg and Ly- α).

LYRA's sampling frequency of >50 Hz is better than an order of magnitude faster than has previously been achieved. This will be especially important to understand the physics of solar flares via the SXR channel, while the EUV channel in particular will complement the high-cadence imaging provided by SWAP. Atmospheric response will also be studied in unprecedented detail via the selected passbands.

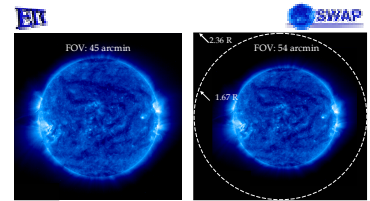
PAYLOAD



Images: courtesy Verhaert

- **Dimensions:** 60 cm x 70 cm x 85 cm
- **Mass:** 120 kg
- **Payload:** Technology demonstrators, plus LYRA and SWAP

OPERATIONAL CAPABILITIES

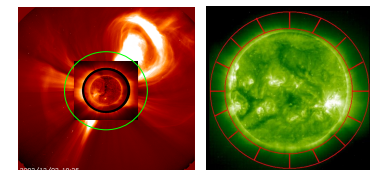


- 1024x1024 back-illuminated CCD
- 17.1nm, 19.5nm, 28.4nm, 30.4 nm
- Fixed sun-centering
- +EIT
- 12 min cadence
- 1024x1024 coated CMOS APS
- 17.5nm
- Flexible off-pointing
- Protected by magnetosphere
- 1 min cadence

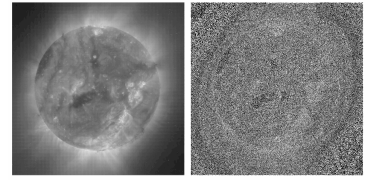
Above: although SWAP's optics are based on those of EIT its focal length is shorter so the solar image appears smaller on the roughly-equally sized detector (also very small contributions from detector and pixel sizes).

SWAP will thus image far more of the off-limb region than EIT; coupled with flexible pointing/exposure time and higher cadence it is anticipated that some CMEs should be detectable well into the off-limb area, even into the regions of the corona usually sampled by occulting instruments like SOHO-LASCO (below left, with the SWAP field of view superimposed). Sampling this region is fundamental to understanding CME acceleration.

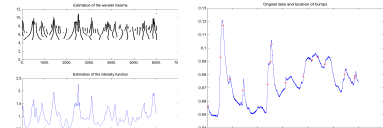
Since such events tend to occur rapidly and full data coverage is needed, SWAP will run a CME detection algorithm based on total brightness enhancement in a set of annular segments (below right). Subsequently, autonomous off-pointing to the relevant region of the sky and modification of exposure time are utilised. The 1-minute cadence may also be altered. A flare detector, based on total brightness enhancement, will also operate.



Since at present only one ground station is baselined (at Redu, Belgium though efforts are underway to augment this) SWAP will be somewhat telemetry-limited. Various measures to optimise the TM stream are being incorporated, including: near-lossless compression up to factor 50 (below, see Nicula et al. for details); onboard image prioritisation and subsequent preferential downlink of high-priority images; onboard over-writing of low-priority images in a circular buffer.

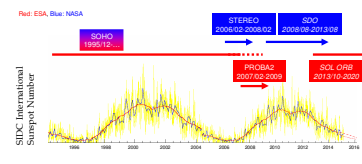


EIT image, recorded & compression at a total compression factor 50 (original-compressed)/sqrt(original) Only 100 pixels are above 1 sigma of photon shot noise



Above: LYRA will also have autonomous detection capability - shown is a sample output from a wavelet-based flare detection routine applied to a GOES soft X-ray time series (see Delouille et al.)

OVERLAP WITH RELEVANT MISSIONS



- **Space weather with ESA's PROBA2 mission**, G. Lawrence et al, *Solar Wind 11/SOHO-16 Workshop (Whistler, June 2005)*, ESA-SP 2005, in press
- **SWAP onboard PROBA 2, a new EUV imager for solar monitoring**, D. Berghmans et al., 35th COSPAR Scientific Assembly (Paris, July 2004), Adv. Space Res. 2005, in press
- **LYRA: the Solar UV radiometer aboard the ESA Proba 2**, J.-F. Hochedez, et al., 35th COSPAR Scientific Assembly (Paris, July 2004), Adv. Space Res. 2005, in press
- **Poisson recoding of solar images for enhanced compression**, B. Nicula et al., *Topical Issue: Solar Image Processing II Workshop (Annapolis, November 2004)*, Sol. Phys. 228, 2005.
- **PROBA2/SWAP as**
 - 5th wavelength (alternative) for SOHO/EIT
 - high cadence (and full disk) extension for SOHO/EIT
 - third eye for STEREO/EUVI
 - as instrument studying the EUV counterpart in the STEREO inner coronagraph domain
 - as technology demonstration for Solar Orbiter

REFERENCES/INFO

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- <http://www.esa.int>