Building on the heritage of PROBA2/LYRA for future small-sat missions

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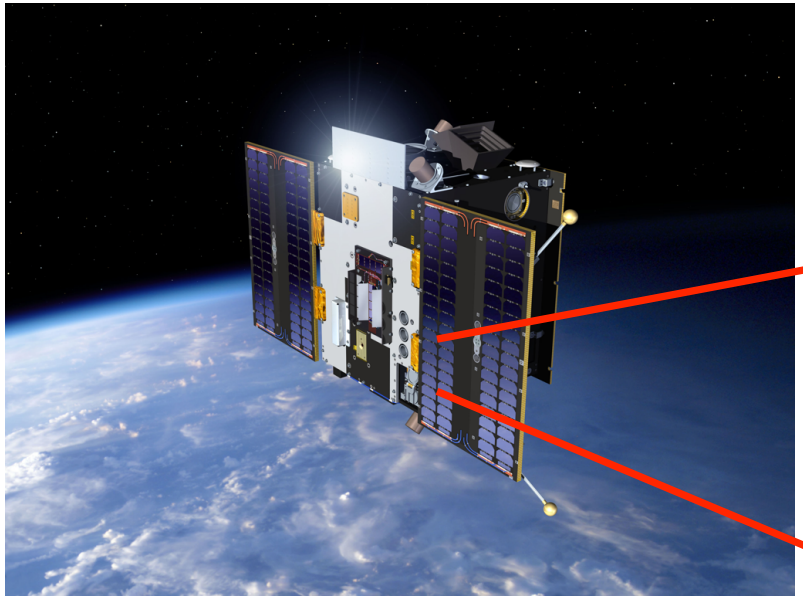
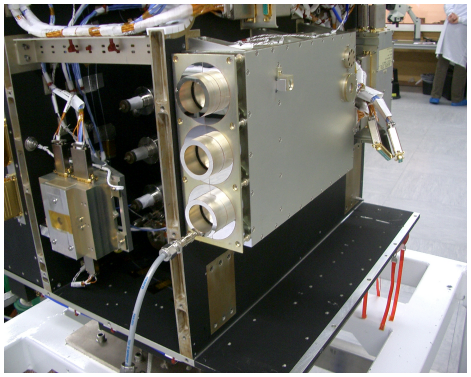
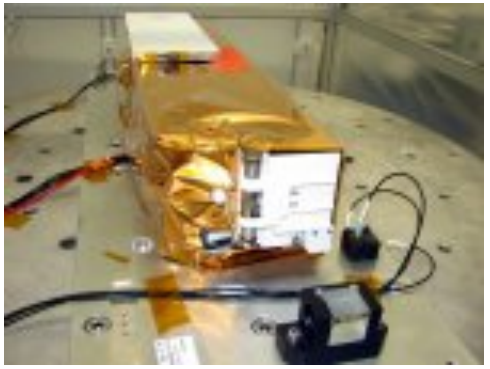
PROBA2: an ESA microsat



LYRA



SWAP



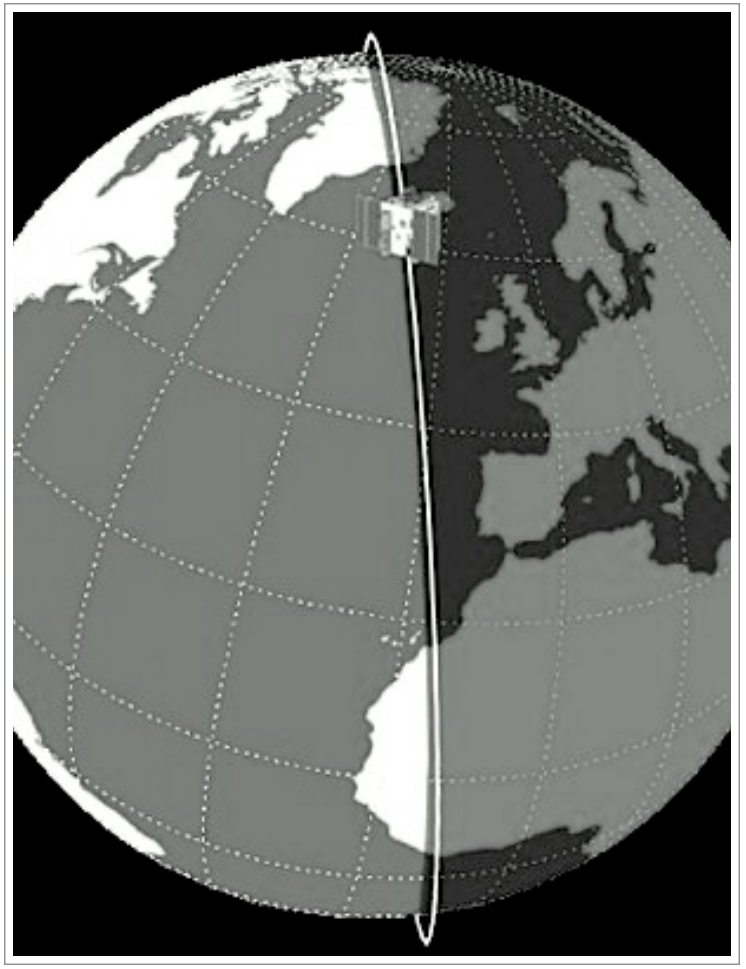
- An ESA micro-sat launched in November 2009
- Dimensions: 80x70x60cm
- Mass: 120kg
- 17 technological demonstrators
- 4 scientific instruments

PROBA2 orbit

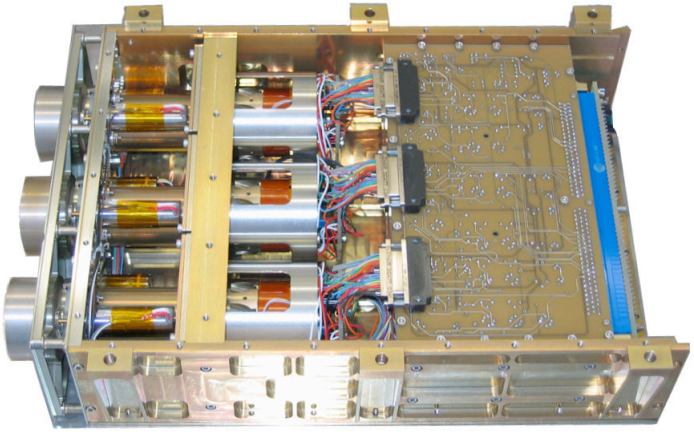
PROBA2 orbit:

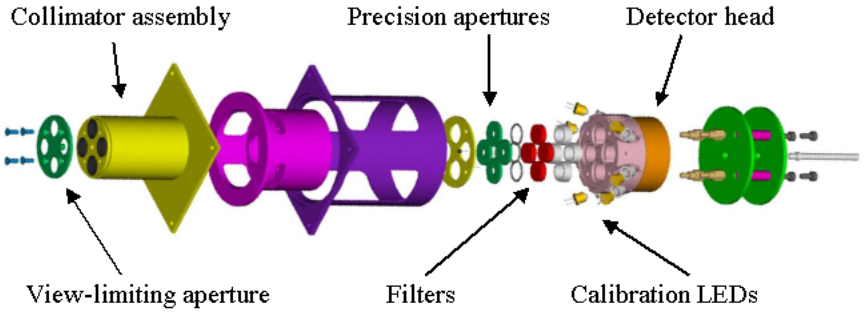
- Heliosynchronous
- Polar (inclination of 98°)
- Dawn-dusk
- 725 km altitude
- Duration of 100 min

- Occultation season:
  - Visible:October-February
  - Maximum duration 20 min per orbit

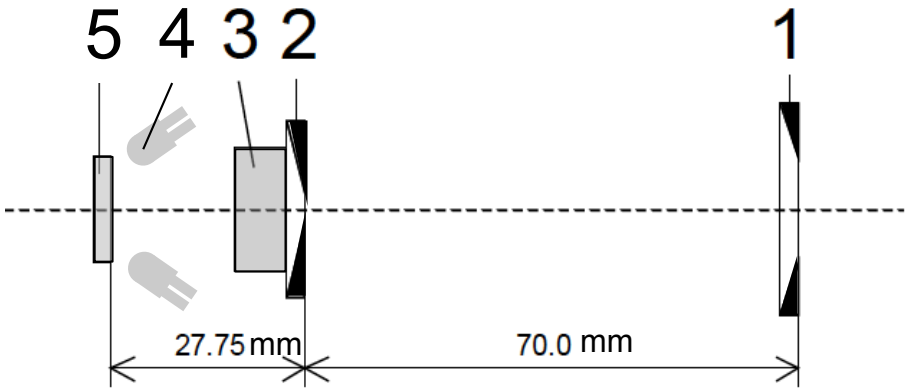


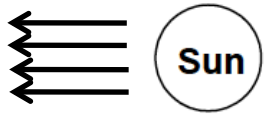
LYRA highlights

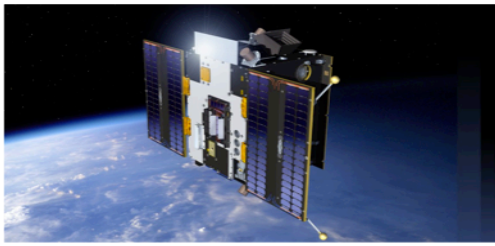




1: View-limiting aperture (Ø 8mm)
2: precision aperture (Ø 3mm)
3: filter
4: LEDs (λ 375 and 465 nm)
5: detector (Ø 4mm)





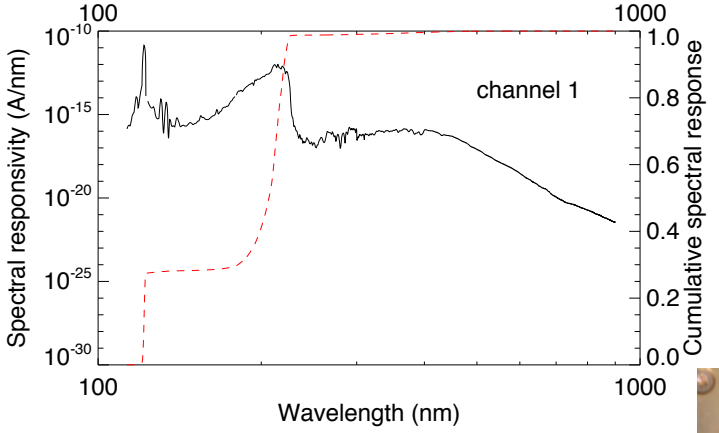


Characteristics of the instrument

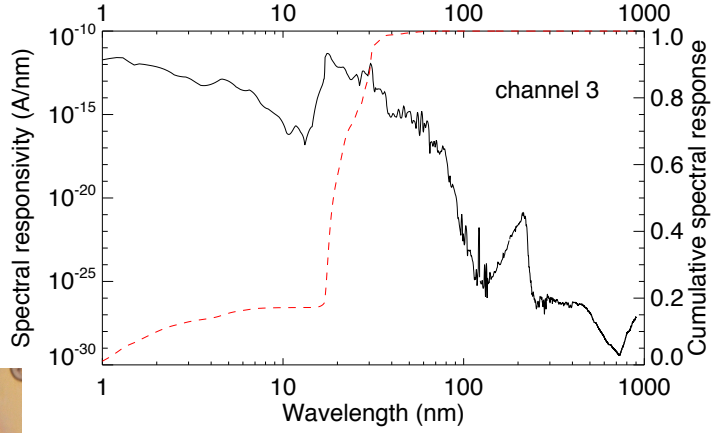
- Size: 315 x 92.5 x 222 mm
- Weight: 5 kg
- Power: ~4W in nominal operation
- Unobstructed half-FOV: 1.03°
- Pointing stability: 90’’
- Amount of data produced: ~15 MB/day of science data + ~1.5 MB/day of housekeepings
- Wide bandgap detectors
- Detector working temperature of ~50°, but no cooling needed
- Flexibility in the commanding
- Redundancy

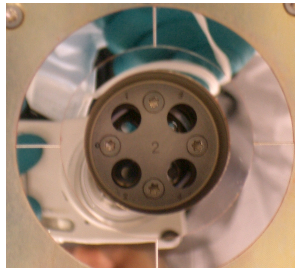
LYRA bandpasses

Channel 1 – Lyman alpha
120-123 nm

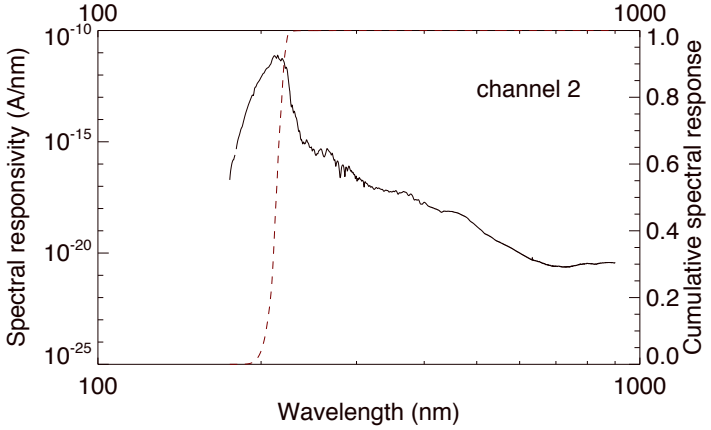


Channel 3 – Aluminum
17-80 nm + < 5nm

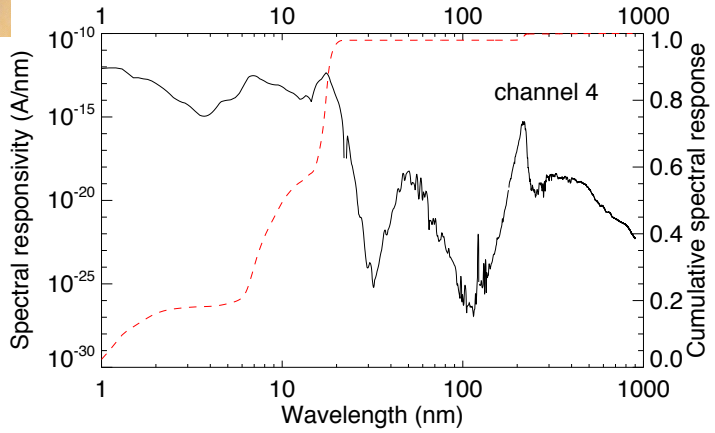




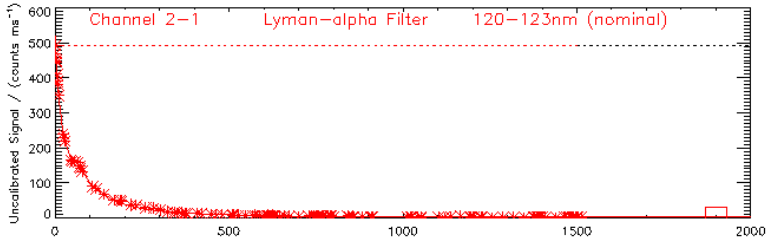
Channel 2 – Herzberg
190-222 nm

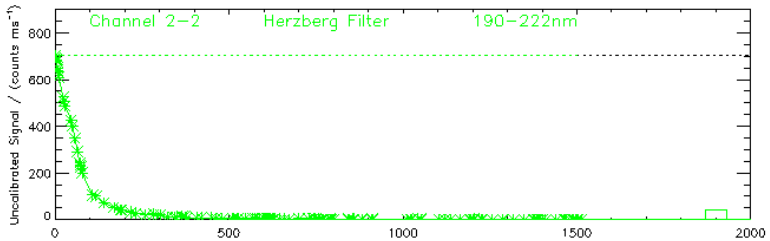


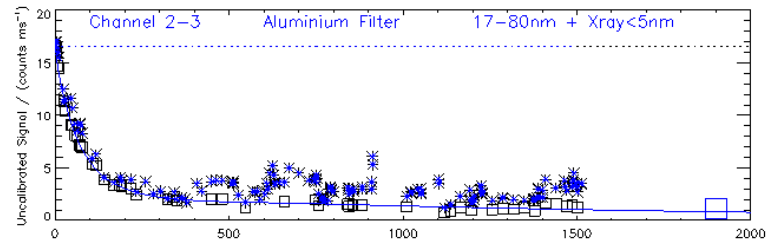
Channel 4 – Zirconium
6-20 nm + < 2nm

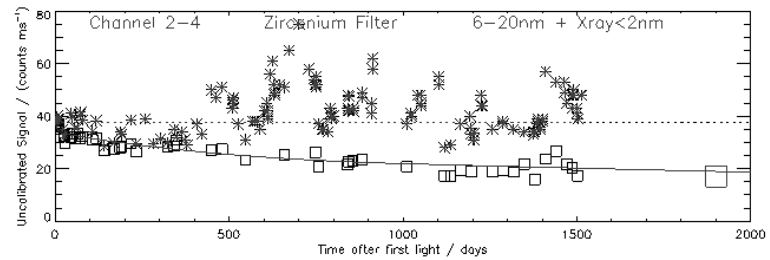


Degradation







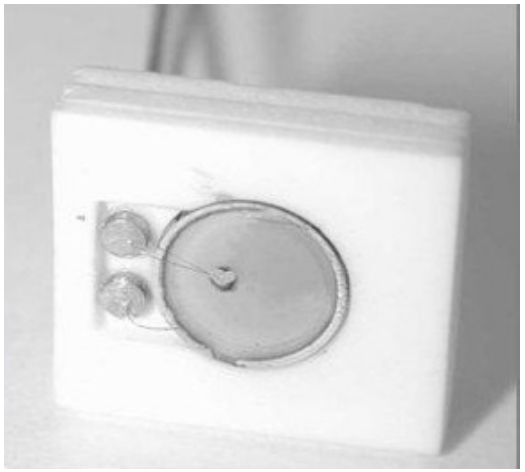


- Probable cause of degradation: contamination by Si+C
- Diagnosis:
  - Comparison of the four channels
  - LEDs and darks evolution

Main science objectives

- Characterization of new wide-bandgap detectors
- Flare monitoring and multi-spectral, high-cadence analysis
- Mid-term evolution of the solar irradiance and characteristics
- Analysis of the composition of the Earth atmosphere during occultations
- Impact of the solar activity on the Earth environment

Diamond detectors

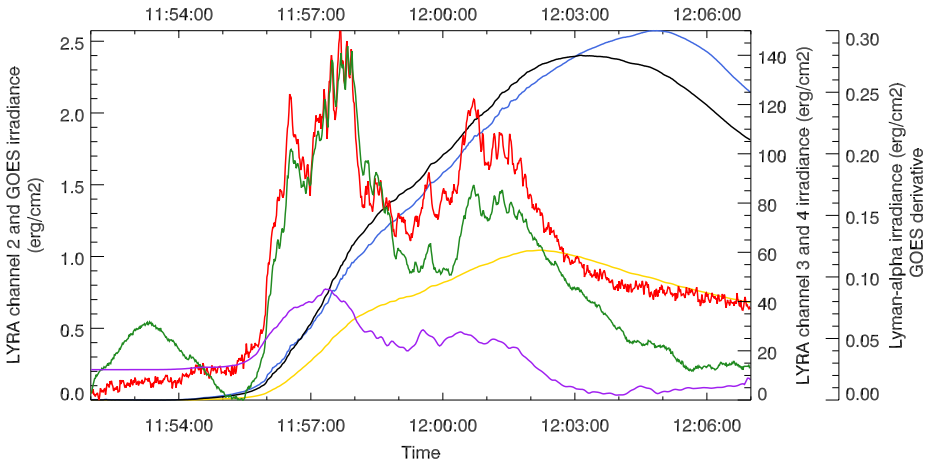


- Analysis of the detector performances and their evolution
  - BenMoussa et al. 2009 (A&A 508)
  - BenMoussa et al. 2013 (Sol Phys 288)
  - BenMoussa et al. 2015 (Exp. Astr. 39)

- Requirements:
  - Good pre-launch calibration
  - Off-pointing capabilities (analysis of the flat-field evolution)
  - Covers (dark current measurements)
  - LEDs (evolution of the detector response)
  - Redundancy (degradation)

High-cadence observation of flares

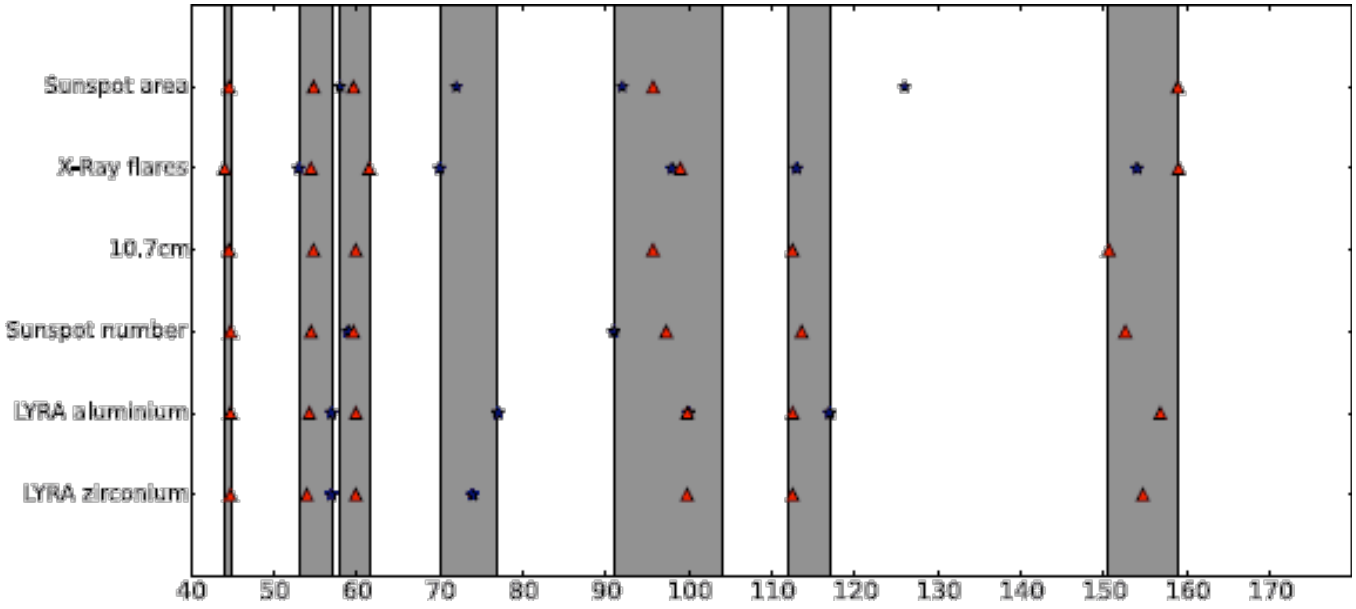
X9.3 flare of September 6, 2017



- Requirements:
  - Sub-second cadence
  - Favorable signal-to-noise => pointing stability
  - Flexibility in the commanding
  - Well-known spectral response
    - Good pre-launch calibration
    - Redundancy
    - LEDs and covers

- Construction of a flare catalogue
  - Ryan et al. 2016 (A&A 592)
- Observation of quasi-periodic pulsations in flares (QPP):
  - Van Doorsselaere et al. 2011 (ApJ 740:90),
  - Dolla et al. 2012 (ApJL 749:L16)
  - Inglis et al. 2015 (ApJL 798:108)
  - Dominique et al. 2018 (Sol. Phys. 293)
- Observation of flares signatures in Lyman-α or in the Balmer continuum around 200 nm:
  - Kretzschmar et al. 2013 (Sol. Phys. 286)
  - Dominique et al. 2018 (ApJL, submitted)

Analysis of the mid-term periodicities in solar time-series

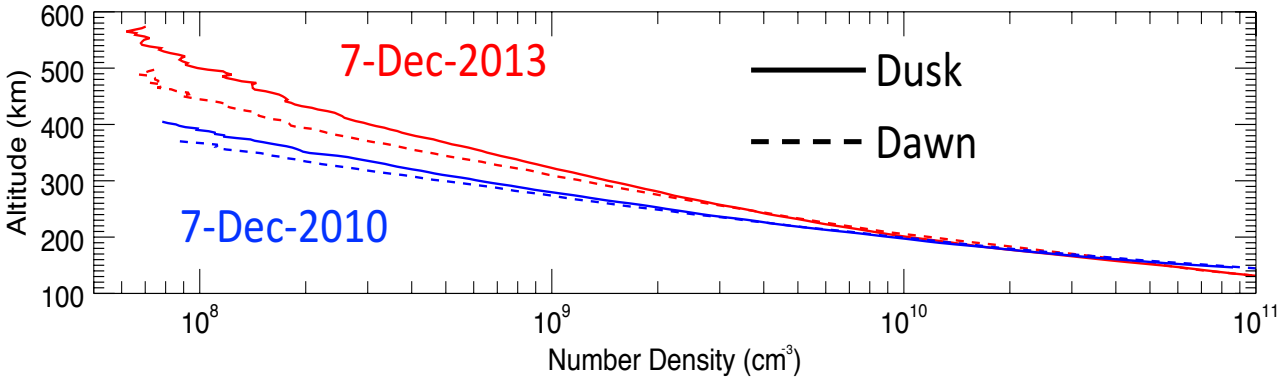


Periodicities (in days)

- Wauters et al. 2016 (Sol. Phys. 291)

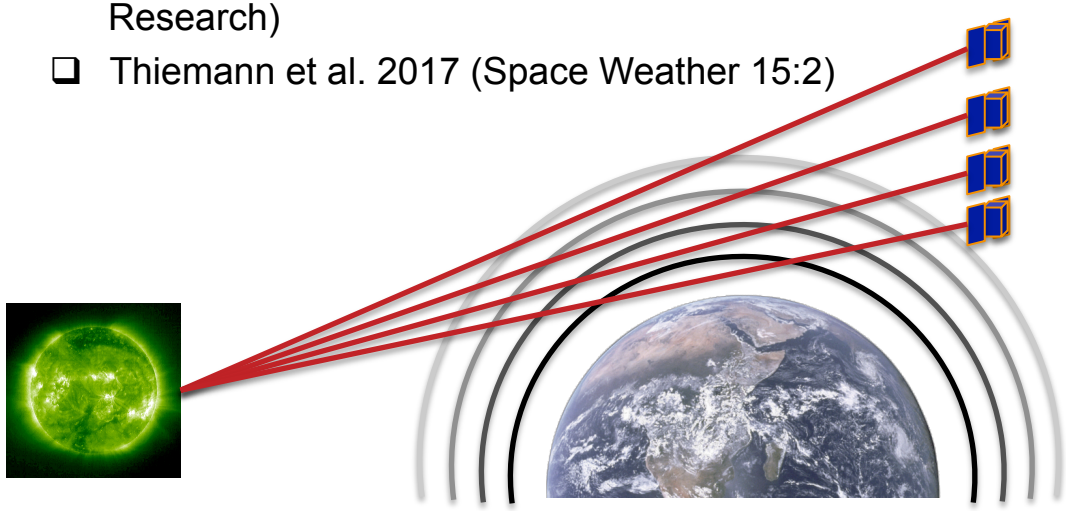
- Requirements:
  - Well-known spectral response
    - Good pre-launch calibration
    - Redundancy
    - LEDs and covers
  - Long life-time

Retrieval of O+N2 densities from LYRA occultation data



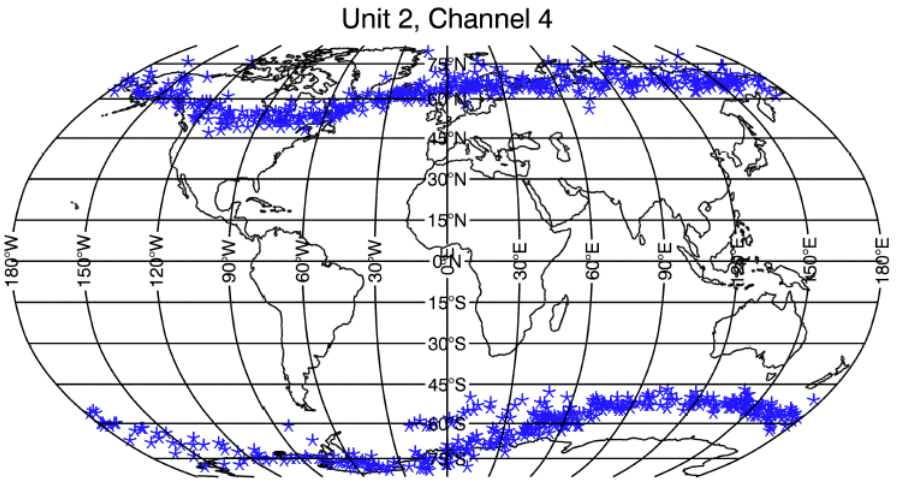
- Requirements:
  - Well-known spectral response
    - Good pre-launch calibration
    - Redundancy
    - LEDs and covers
  - Multiple channels

- Dominique et al. 2009 (Horizons in Occultation Research)
- Thiemann et al. 2017 (Space Weather 15:2)



Impact of solar activity on the Earth environment

Location of the detections of ultra-relativistic electrons



- Analysis of the impact of the flare emission on the Earth ionosphere
  - Raulin et al. 2013 (JGR 118)
- Detection of ultra-relativistic electrons after geomagnetic perturbations
  - Katsiyannis et al. 2018 (JSWSC 8)

- Requirements:
  - High acquisition cadence
  - Favorable signal-to-noise => pointing stability
  - Well-known spectral response
    - Good pre-launch calibration
    - Redundancy
    - LEDs and covers
  - Multiple channels
  - Flexibility in the commanding

Lessons learned

- Avoid frequent maneuvers
- Keep the commanding simple and flexible
- Careful pre-launch calibration needed
- Avoid too broad bandpasses
- Whenever possible, have some instrumental redundancy
- Ensure ways to perform in-flight calibration
- Even for small missions, the choice of the materials and the cleanliness are essential

Adaptable to cubesats?

- Reduction of size and weight
  - One unit instead of three
  - Loss of redundancy
- Reduction of the operational costs
  - Fewer contacts
  - Loss of flexibility in the commanding
- What about the pointing stability?

Collaborations

ORB – KSB

wrc pmod

esa

CSL

IMO

NIMS

THANK YOU!

More on http://proba2.oma.be

belspo

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LPC2E

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Max-Planck-Institut für Sonnensystemforschung