SUITS: a Solar-Terrestrial Space Weather & Climate Investigation

A European-Chinese Microsatellite Mission in preparation for the ESA-CAS S2 Call

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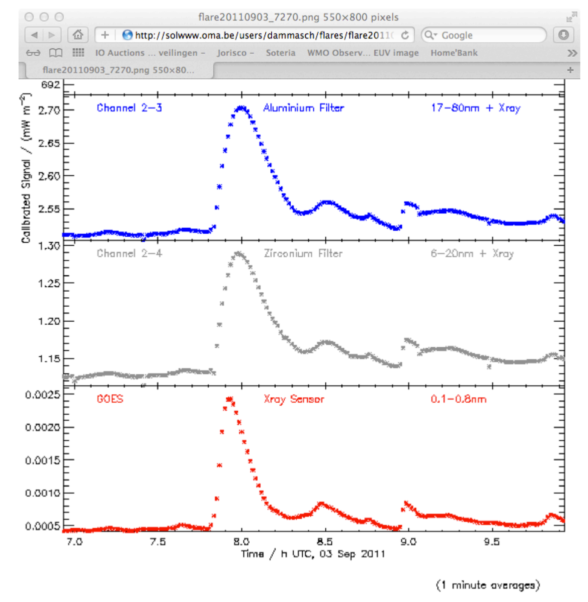
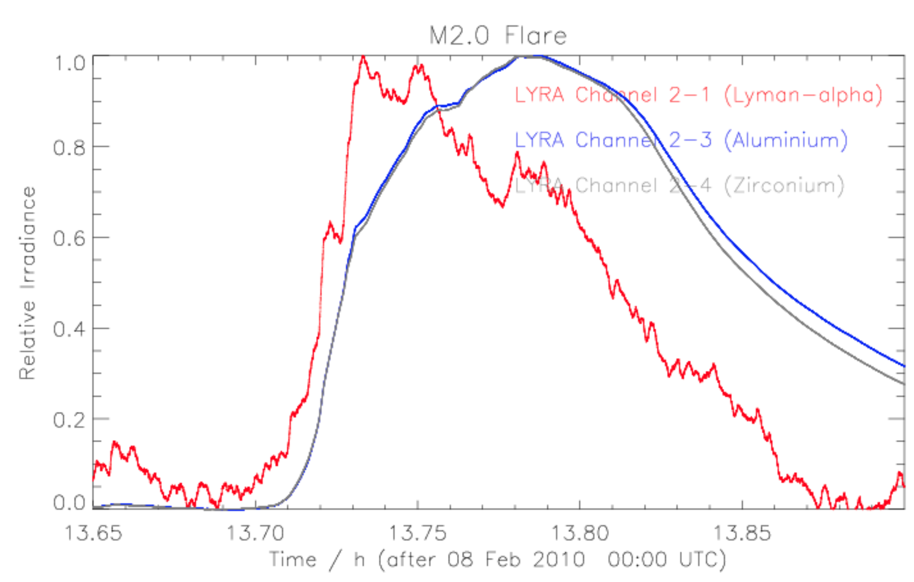
Introduction

Space Weather observations rely largely on solar missions that are not dedicated to them. With the SUITS (*Solar Ultraviolet Influence on Troposphere/Stratosphere*) microsatellite mission we propose to directly obtain essential observations for space weather: early forecasting of major flares and CMEs and the complete monitoring of the ultraviolet solar variability influence on climate. SUITS encompasses three major scientific objectives: (1) Space Weather including the prediction and detection of major eruptions and coronal mass ejections (using Lyman-Alpha and Herzberg continuum imaging and H-Alpha ground support); (2) solar forcing on the climate through radiation and their interactions with the local stratosphere (UV spectral irradiance from 170 to 340 nm, plus Lyman-Alpha and the CN bandhead); (3) simultaneous local radiative budget of the Earth, UV to IR, with an accuracy better than 1% in differential. The mission is on a sun-synchronous polar orbit and proposes 5 instruments to the model payload: SUAVE (*Solar Ultraviolet Advanced Variability Experiment*), an optimized telescope for FUV (Lyman-Alpha) and MUV (200–220 nm Herzberg continuum) imaging (sources of variability); UPR (*Ultraviolet Passband Radiometers*), with 36 UV filter radiometers; DSSIM (*Dual Solar Spectral Irradiance Monitor*) for solar and atmospheric variability measurements between 170 and 340 nm (0.2 nm resolution); HEBS (*High Energy Burst Spectrometers*) to reinforce Space Weather flares prediction objectives; and a total solar irradiance and Earth radiative budget ensemble (SERB, *Solar irradiance & Earth Radiative Budget*), a vector magnetometer, thermal plasma measurements and Langmuir probes. SUITS is considered for the next ESA Call for a Small-size mission with China (ESA-CAS, Chinese Academy of Sciences, Call expected early 2015 for a flight in 2021).

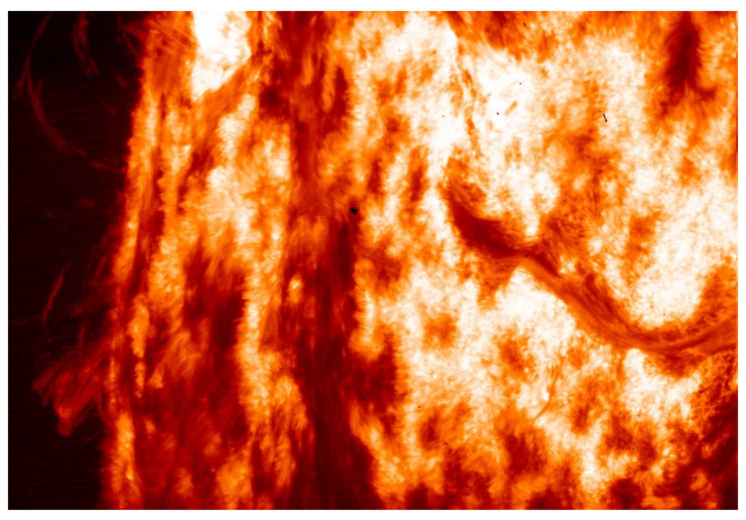
Predicting and monitoring large flares & CMEs: Lyman-Alpha imaging

- Objective is to monitor flares in Lyman-Alpha rather than X-ray or XUV but not only since Lyman-Alpha, much like H-Alpha, is an excellent flares/CMEs precursor indicators since of filaments and emerging bipolar region high visibility (space weather direct application). Furthermore, comparing sensitivity difference with H-Alpha formed slightly below in the chromosphere might lead hopefully to even better and robust flare/CME indicators.
- First, recall that Lyman-alpha is EXCELLENT at detecting flares (as shown by LYRA/PROBA-2) with raise in global integrated light curve even slightly before GOES X-ray (1–8 Å) or the LYRA channel 2-3, Aluminium 17–80 nm, or 2-4, Zirconium 6–20 nm.

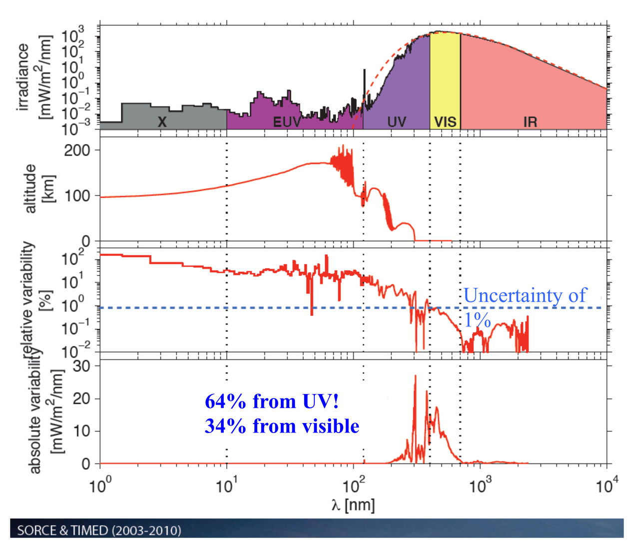




- But even better is that filaments and emerging bipolar region (the two major flare's precursors) are EXTREMELLY well seen in Lyman-Alpha allowing their detection and tracking for a more than easier prediction of large flares happening (the only ones leading to the Space Weather annoying Interplanetary Coronal Mass Ejections, ICMEs, the ones towards the Earth) that, for example, their delicate identification in He II 304 Å.

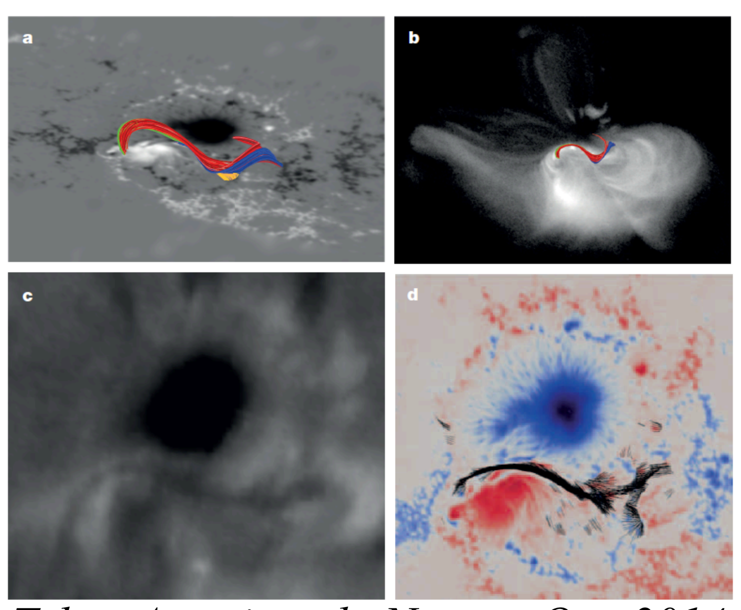


High resolution image of the Sun in Lyman-Alpha taken by the VAULT rocket program of NRL and nicely showing prominences and filaments (prominences seen in absorption on the disk).



Solar spectrum, its absorption altitude, relative (%) and absolute variability over solar cycle (data from SORCE & TIMED, 2003–2010).

Recent Modelling Evidence for Twisted Flux Rope/ Filament Rising before Major Eruptions and CMEs



Tahar Amari et al., Nature, Oct. 2014

Figure 2 | Twisted flux rope before the major eruption. Selected field lines of the reconstructed magnetic configuration of December 12, 20:30 UT (D−1), with the same colour code as in Fig. 1. **a**, A large rope consisting of several components sits between the two spots and is seen to have accumulated a large amount of twist (about 2.25π). The hyperbolic nature of the rope (field lines bifurcating with an X-type topology) is detailed in Extended Data Fig. 2. **b**, Good agreement of the shape of some computed field lines with X-ray data from Hinode/XRT. **c**, Hα data from the spectroheliograph at the Paris-Meudon Observatory reveals that a filament (darker) extends in the atmosphere between the two spots. **d**, The filament shown in **c** coincides with the locations of the dips in the computed magnetic field (shown as black segments and seen from the same vantage point as in **c**) where cool material can sit and be supported against gravity by the magnetic force.

Hα data from Paris-Meudon Observatory © showing filament twisted and rising; Lyman-Alpha from SUITS will complete the observations of filaments rising in the high chromosphere towards corona heights

- A further objective of Lyman-Alpha imaging is, when comparing sensitivity differences between **Lyman-Alpha and H-Alpha**, formed slightly below in the chromosphere, to develop better and **more robust flare/CME indicators** (early – several hours before – probability of major flares/CMEs) that may /allow to anticipate on the **CMEs' direction**.

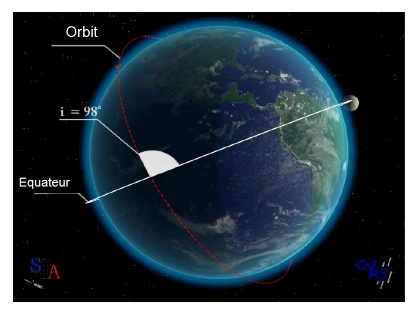
And MUV affects stratospheric dynamics and temperatures, altering weather patterns:

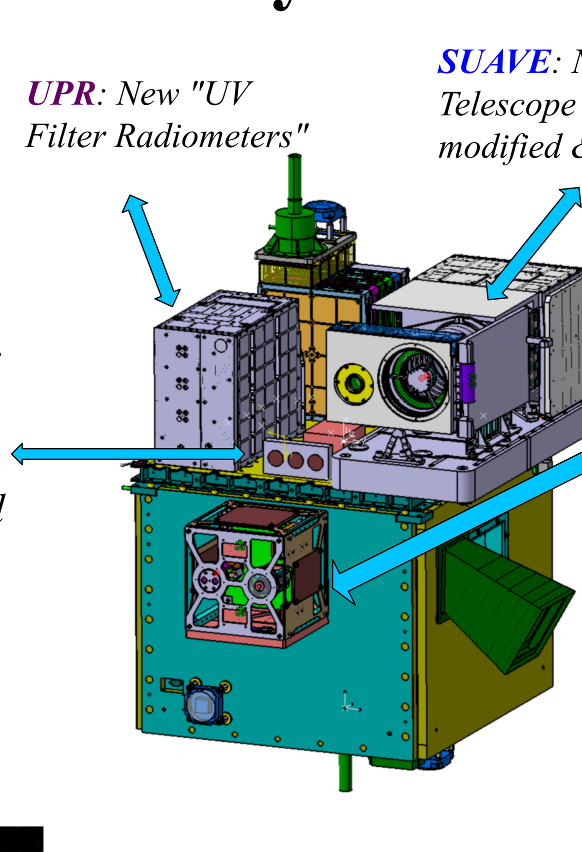
solar UV influence on Earth climate

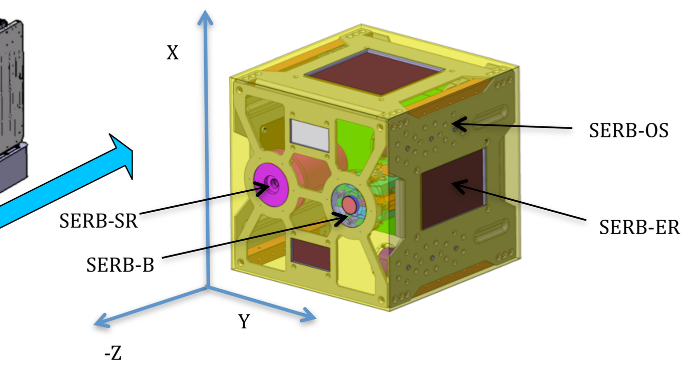
=> Spectral Irradiance Measurements (UPR; DSSIM)

SUITS: a Space Weather & Ultraviolet Solar Variability Microsatellite Mission

- **SUAVE** (*Solar Ultraviolet Advanced Variability Experiment*), optimized "SODISM" for FUV Lyman Alpha and 200-220 nm Herzberg continuum imaging (sources of variability) with 3 redundant set of filters (sensitivity comparison)
- **UPR** (*Ultraviolet Passband Radiometers*) based on PREMOS & LYRA with 36 UV filter radiometers (24 redundant) for Lyman-Alpha, CN bandhead (385-390 nm) and UV from 180 to 340 nm by 20 nm bandpasses
- Place for **HEBS** (*High Energy Burst Spectrometer*), **DSSIM** (*Dual Solar Spectral Irradiance Monitor*), Magnetometer Thermal Plasma Units & Particles (multiple heritage: SMESE, SOLSPEC, PROBA-2)
- **SERB** (Solar irradiance & Earth Radiative Budget): 4 instruments, 20 cm cube of 3 kg
- Orbit with "almost" permanent Sun viewing (alike PICARD but Earth center oriented):
  - Sun synchronous orbit
  - Ascending node: 06h00
  - Altitude: > 725 km
  - inclination: 98.29°
  - Eccentricity: 1.04x10^{-3}
  - Argument of periapsis: 90°





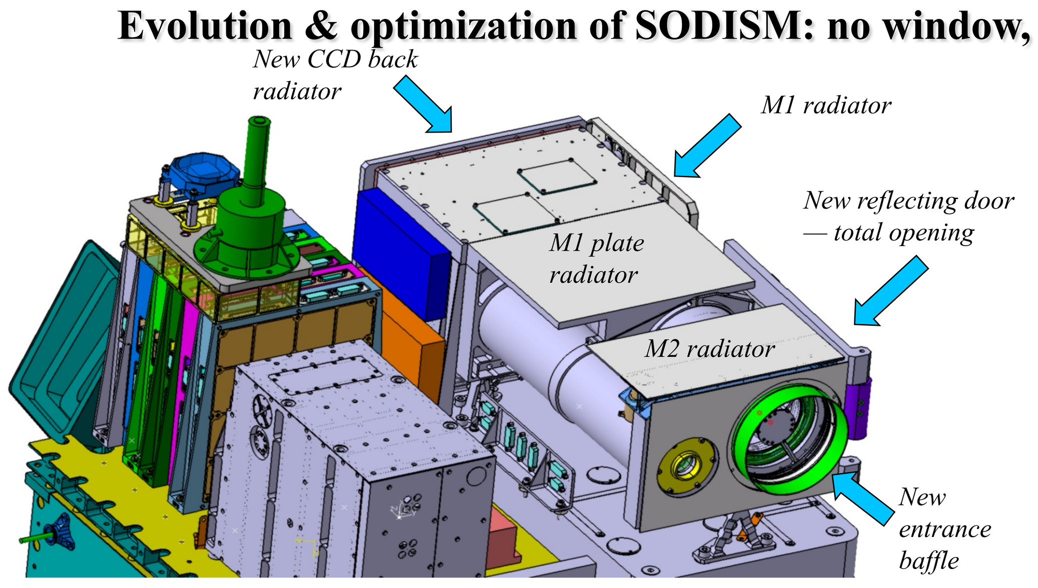


Instrument	Instrument Type	Channel
SERB-OS	Optical sensor	310 nm, Δ20 nm (measuring O3) 350 - 450 nm (polar albedo, particle size) 535 nm, Δ20 nm (ref. for differential measures) 760 nm, Δ20 nm (measuring altitude of cloud top) 880 nm, Δ50 nm (particle size) 940 nm, Δ20 nm (water vapor H20)
SERB-ER	Radiometer	2.5 µm - 40 µm
SERB-B	Bolometer	0.2 µm - 40 µm
SERB-SR	Radiometer	0.2 µm - 3 µm (TSI: PMO6 type)

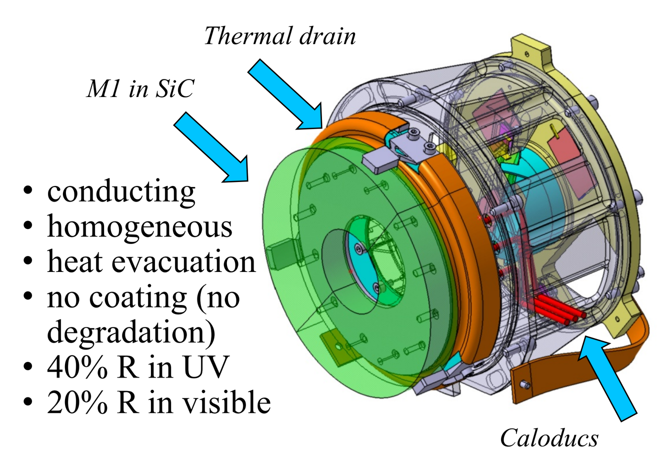
SUITS implemented on the same CNES/Myriade platform than PICARD; it could as well be implemented on the new ESA/ PROBA platform (ITAR free)

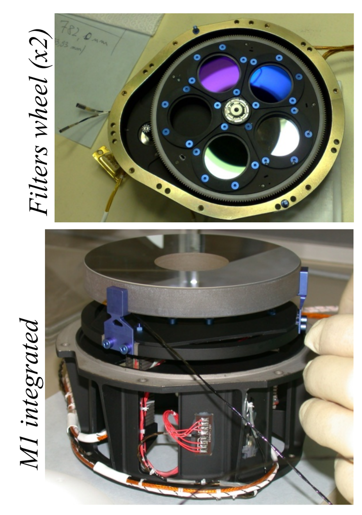
SUAVE: a FUV Imaging Telescope

Evolution & optimization of SODISM: no window, SiC mirrors & new "thermal" door and radiators



- conducting
- homogeneous
- heat evacuation
- no coating (no degradation)
- 40% R in UV
- 20% R in visible

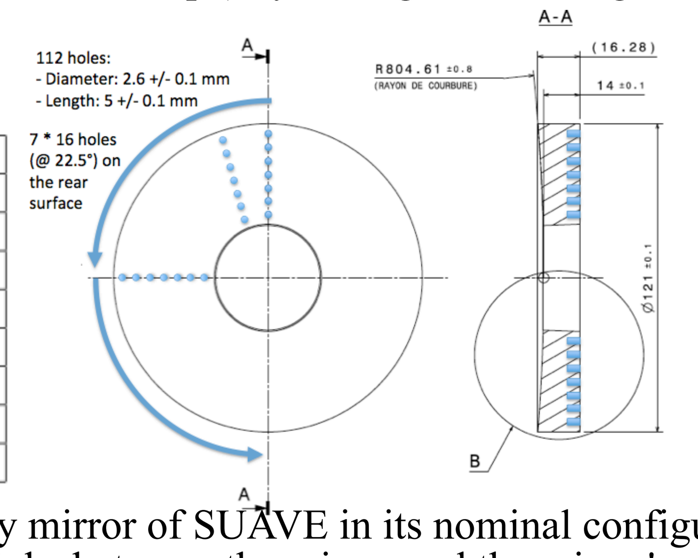


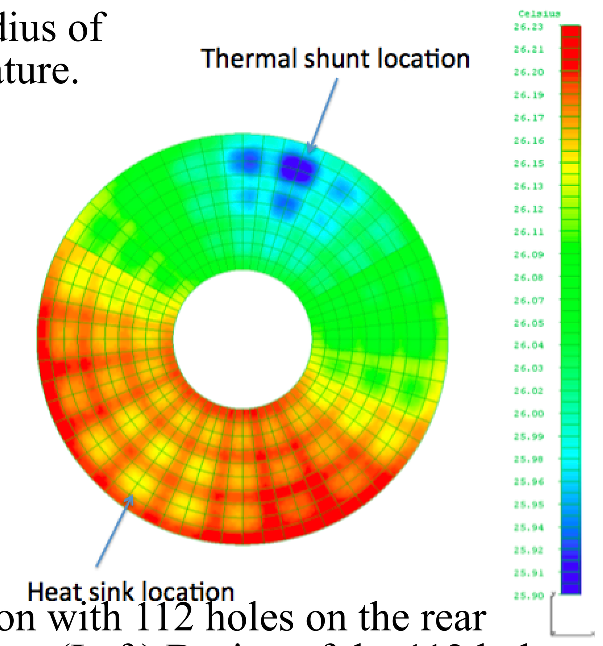


SUAVE is a FUV optimized version of SODISM with SiC mirrors for prolongated observations and ultimate thermal control (heat evacuation, focus control). SUAVE has no entrance window and hosts a main entrance baffle and a new implementation of the door to avoid Earth albedo returns. The radiator M2 has been increased to improve the cooling of the secondary mirror M2. Two radiators were added: for the CCD, and for the primary mirror M1. Using SiC (or CVD SiC) mirrors avoids the degradation of coatings (SiC "naked" reflects 40% in the FUV and 20% in the visible), limits the thermal load (SiC is homogeneous and conducting) and the flux on the filters (less than a solar constant: no or limited polymerization possibilities) to preserve their lifetime. SiC also has the advantage of being sensitive to temperature what allows to control the radius of curvature of the mirror (focal length of telescope) by setting the working temperature.

Main characteristics of SUAVE telescope

Telescope type	Ritchey-Chrétien
Focal length	2626 mm
Main entrance pupil	90 mm
Volume	670 (d) x 308 (w) x 300 (h) mm^3
Weight	28 kg
Field of view	35 arcminutes
Angular resolution	1.06 arcseconds/pixel
Power consumption	45 W nominal
Data rate	<2 Gbits per day





Thermal analysis of the SiC primary mirror of SUAVE in its nominal configuration with 112 holes on the rear surface of the mirror used as heat sinks between the mirror and the mirror's support. (Left) Design of the 112 holes in the SiC mirror; (right) the resulting temperature gradients appear acceptable (±0.16°C).

Conclusion:

The SUITS microsatellite program proposed is unique, answering the needs for early detection of Flares and CMEs, and for understanding the stratospheric dynamics influence on climate by providing the necessary tools to measure and quantify the FUV and MUV variability influence and its origins. The program benefit of the very recent technology developments and in-flight proven performances of CNES/PICARD and ESA/PROBA-2 microsatellite programmes. It builds on them and on our laboratories' expertise in FUV imaging and measurements. As such, a short development program can be envisaged, compatible with a Small-size Mission launch in 2020–2021, and able to rapidly provide the lacking inputs in harmfull CMEs predictions, and in FUV and MUV required for the modelling of the stratospheric dynamics and its influence on climate. Experiments address both FUV imaging (sources of variability), flux measurements from FUV to UV, Earth radiative budget and total irradiance, and Space Weather from a Sun synchronous orbit with almost no eclipses. Program is supported by a CNES R&T program and is to be proposed to the ESA-CAS Small-size Call early 2015.

Background illustration: Lyman-Alpha filtrogram obtained in 1979 during the first rocket flight of the Transition Region Camera (TRC) and yet having the best spatial resolution (1 arcsec) for a full disk Lyman-Alpha image of the Sun.