The Space Weather & Ultraviolet Solar Variability (SWUSV) Microsatellite Mission

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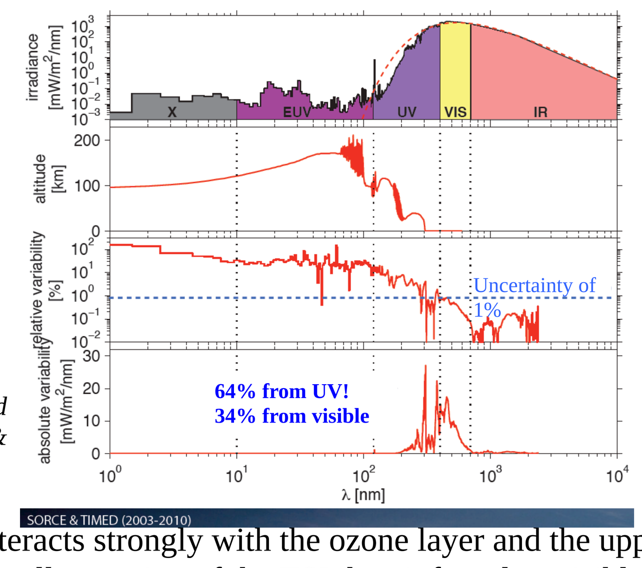
Introduction

The Sun is the primary source of energy responsible for governing both the weather and climate of Earth. Changes in the amount and type of energy Earth receives alter its weather and climate. The variability of the solar flux during the solar cycle occurs mainly in the ultraviolet and especially at wavelengths below 350 nm where it may exceed 3% and even 20 to 40% in the far UV (FUV). This spectrum does not reach the surface: it is completely absorbed by stratospheric ozone and oxygen, playing an important role in the stratosphere where it modifies the fields of temperature, pressure and wind and therefore the conditions of propagation of atmospheric waves that couple the lower and upper layers of the atmosphere. A *Space Weather and Ultraviolet Solar Variability microsatellite* (SWUSV), is proposed to monitor UV and FUV (Lyman-Alpha 121.6 nm, 200–220 nm Herzberg continuum) in imaging and irradiance (radiometers). This for early precursor Flares and CMEs detection in Lyman-Alpha for Space Weather awareness, and to have information on the physical causes of the changes of irradiance observed, to identify the causes of these changes and measure their parameters according to solar magnetism: what only an imaging instrument of the whole disc, with a fair spatial resolution and a good rate of observation, can do. The nature of the variations of Lyman-Alpha will help to directly interpret the variations of ozone, on short and long terms. An overview and the objectives of the SWUSV program is presented as well as the FUV imaging telescope (an evolution of SODISM/PICARD), and instrumentation for solar spectral irradiance (radiometers' ensemble: evolution of the LYRA/PROBA-2 experiment), thermal plasma measurements and magnetometer (evolution of PROBA-2 instruments), and Solar irradiance and Earth Radiative Budget (SERB) to complete stratospheric information. The program is supported by a CNES R&T "Far UV Telescopes Development" in 2013–2014, and is proposed to CNES and ESA (Small-size Mission). It could be envisaged as the CNES/France contribution to the ESA Space Situational Awareness (SSA) program.

UV affects stratospheric dynamics and temperatures, altering weather patterns

- The components of the Earth system that are most important to the radiation budget are the planet's surface, atmosphere and clouds. Understanding clouds, where they occur, their characteristics, is important but also what affects them: the stratospheric and tropospheric dynamics induced by the absorption of **UV below 350 nm** in the atmosphere (**direct solar input to atmosphere**).
- UV below 350 nm is essential to the understanding of climate changes since representing most of the relative variability below 300 nm (up to 20–40% in the FUV) and, even more important, ***more than 60 % of the absolute variability*** over the solar cycle
- Oxygen and ozone below 100 km absorb the major part of the UV below 350 nm



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

- UV radiation, on the contrary to visible and IR, interacts strongly with the ozone layer and the upper atmosphere. So, though UV solar radiation makes up a much smaller portion of the TSI than infrared or visible radiation, UV solar radiation tends to change much more dramatically over the course of solar cycles.
- The impacts of undulating UV solar radiation may be substantial. Since UV radiation creates ozone in the stratosphere, the oscillation in UV levels can affect the size of the ozone hole. Absorption of UV radiation by the ozone also heats up the stratosphere. Many studies suspect that changes in stratospheric temperatures may alter weather patterns in the troposphere.
- A "real" estimate of the UV interactions with the atmosphere requires a good temporal resolution since, to simulate the Physics of the interaction, THE FULL AMPLITUDE of PHENOMENA is to be taken in consideration since the chemical interactions of the UV with ozone and oxygen in the stratosphere and troposphere are not dealing with averages but the incoming, real and fast changing, UV variability.

Evidence for MUV influence on stratospheric dynamics

The Spectral Irradiance Monitor (SIM) instrument on SORCE (since April 2004), has revealed that over this declining phase of the solar cycle there was a **four to six** times **larger decline** in ultraviolet than would have been predicted on the basis of our previous understanding. This reduction was partially compensated in the total solar output by an increase in radiation at visible wavelengths. **Haigh *et al.* (2010)** showed that these spectral changes appear to have led to a significant *decline from 2004 to 2007 in stratospheric ozone below an altitude of 45 km, with an increase above this altitude*. Stratospheric dynamics of ozone and oxygen is definitively affected!

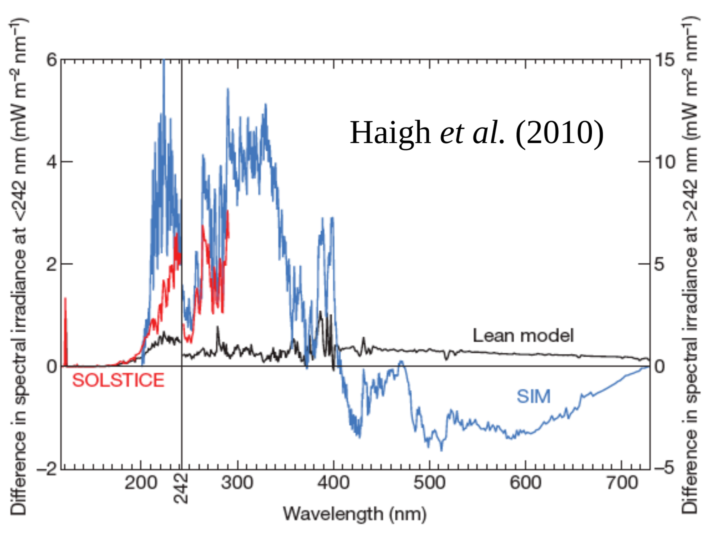
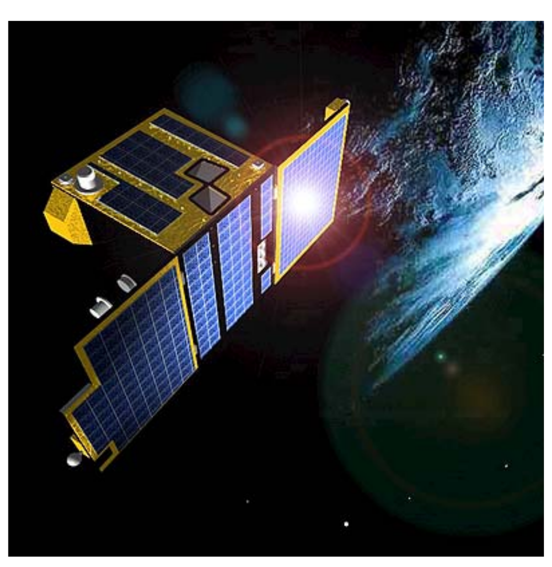


Figure 1 | Difference in solar spectrum between April 2004 and November 2007. The difference (2004–2007) in solar spectral irradiance (W m^{-2} nm^{-1}) derived from SIM data[4] (in blue), SOLSTICE data[8] (in red) and from the Lean model[5] (in black). Different scales are used for values at wavelengths less and more than 242 nm (see left and right axes respectively).

New Microsatellite for UV & FUV Variability and Space Weather *building on PICARD and PROBA-2*

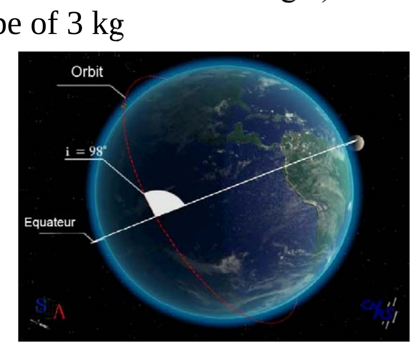


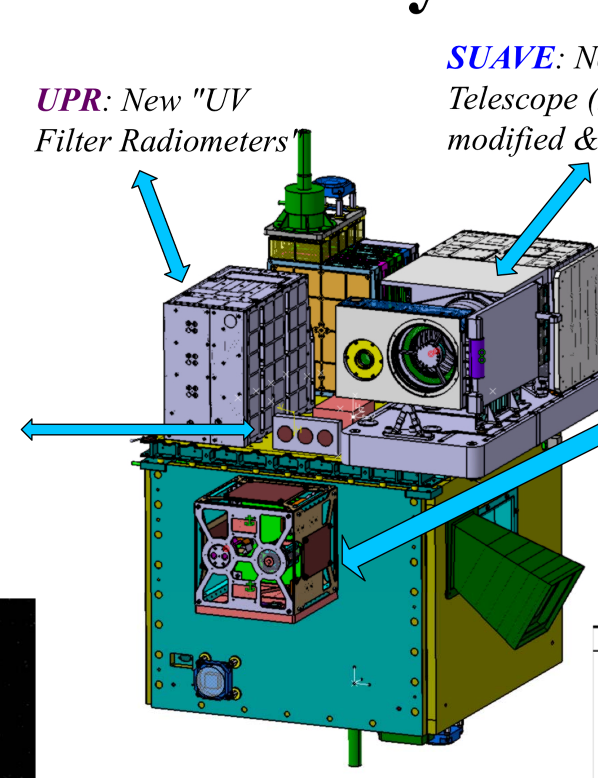
ESA/PROBA-2: LYRA, SWAP, Magnetometer and Ionosphere

CNES/PICARD: SODISM, PREMOS and SOVAP

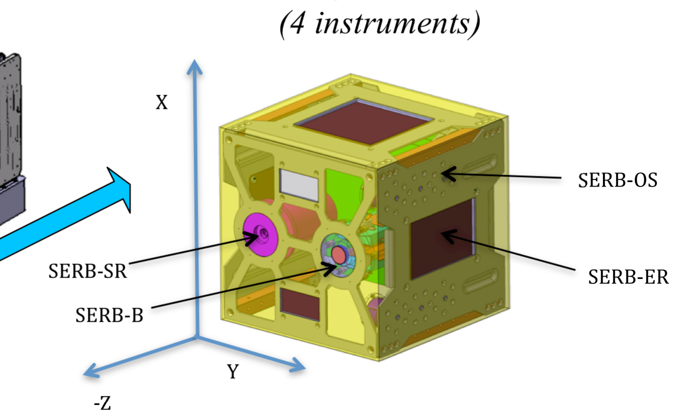
SWUSV: Space Weather & Ultraviolet Solar Variability Microsatellite

- **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 64 UV filter radiometers (48 redundant) for Lyman-Alpha, CN bandhead (385-390 nm) and UV from 180 to 400 nm by 20 nm
- Scientific Vector Magnetometer & Thermal Plasma Measurements Unit and Langmuir Probes (SGVM & TPMU+DSLP from ESA/PROBA-2)
- **SERB** (Solar irradiance & Earth Radiative Budget): 4 instruments in a 20 cm cube of 3 kg
- Orbit with "almost" permanent Sun viewing (alike PICARD):
  - Sun synchronous orbit
  - Ascending node: 06h00
  - Altitude: > **725 km**
  - inclination: 98.29°
  - Eccentricity: 1.04×10^{-3}
  - Argument of periapsis: 90°





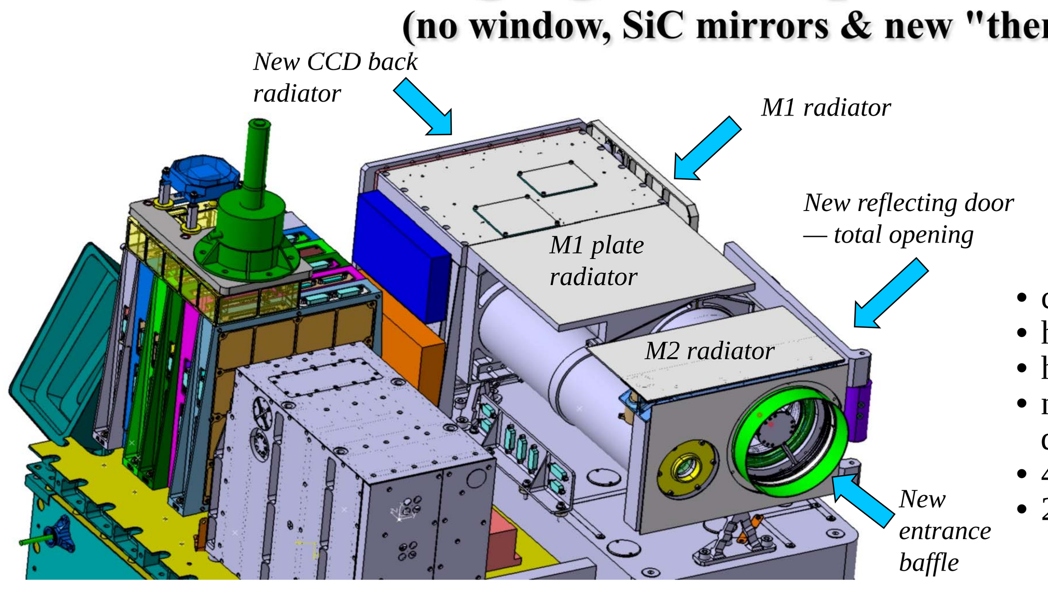
SWUSV is based on the same CNES/Myriade platform than PICARD



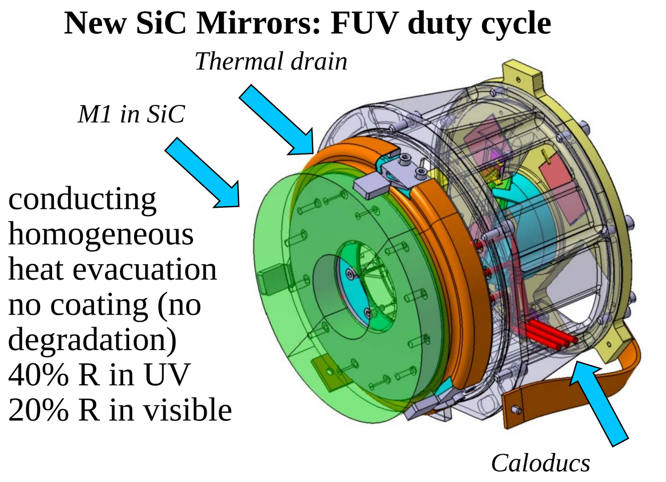
Instrument	*Instrument Type*	*Channel*
SERB-OS	*Optical sensor*	*310 nm, Δ20 nm (measuring O3)* *350 - 450 nm (polar albedo, particle size)* *535 nm, Δ20 nm (ref. for differential measures)* *760 nm, Δ20 nm (measuring altitude of cloud top)* *880 nm, Δ50 nm (particle size)* *940 nm, Δ20 nm (water vapor 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)*

FUV Imaging Telescope (evolution & optimization of SODISM)

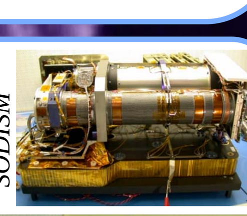
(no window, SiC mirrors & new "thermal" door and radiators)



New SiC Mirrors: FUV duty cycle



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



SODISM

Filters wheel (x2)

M1 integrated

Space Weather Instrumentation

- Science Grade Vector Magnetometer (SGVM ESA/PROBA-2)
- Dual Spherical Langmuir Probes (plasma density and temperature)
- Thermal Plasma Unit (ionosphere characterization: electron temperature, floating potential, ion temperature, concentration and composition)

Filter Radiometers FUV, MUV & UV: "extending PREMOS & LYRA"

Absolute variability is mainly at Lyman-Alpha and between 180–400 nm; then we implement 64 channels (48 redundant):
- Lyman Alpha 121.6 nm (4 at different rates)
- CN bandhead at 385–390 nm
- 11 radiometers of Δ20 nm from 180 to 400 nm

The 121.6 and 200–220 channels support the imaging mode of SUAVE

Note that the TSI (Total Solar Irradiance) is now measured by SERB-SR

Conclusion

The microsatellite program proposed, SWUSV, is unique, answering the needs for early detection of Flares and CMEs, and to understand the stratospheric dynamics influence on climate by providing the necessary tools to measure and quantify the FUV, MUV, UV variability influence and origin. The program benefit of the very recent technology developments carried for the CNES/PICARD and ESA/PROBA-2 microsatellite programmes, building on them and 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 2017–2018, and able to rapidly provide the lacking inputs 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 may start a definition phase in 2014.

Background illustration: Lyman Alpha filtregram 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.