

The Sun cubE onE (SEE) CubeSat mission

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The golden age of solar monitoring

HELIOPHYSICS SYSTEM OBSERVATOR

- 20 Operating Missions with 27 Spacecraft
- 14 Missions in Formulation or Implementation
- 1 Under Study



■ FORMULATION
■ IMPLEMENTATION
■ PRIMARY OPS
■ EXTENDED OPS

CubeSats				Hosted Payloads			
In Development				On Orbit			
AEPEX	Dione	CubIXSS	SunCET	ELFIN	CODEX		
AERO / VISTA	GTOSat	petitSat	DYNAGLO	SORTIE	LARADO		
CIRBE	ICOVEX	REAL	WindCube	CuPID	MinXSS-3		
CURIE	LAICE	SPORT		DAILI	OWLS		
CuSP	LLITED	PADRE			STORIE		

OPERATING & FUTURE

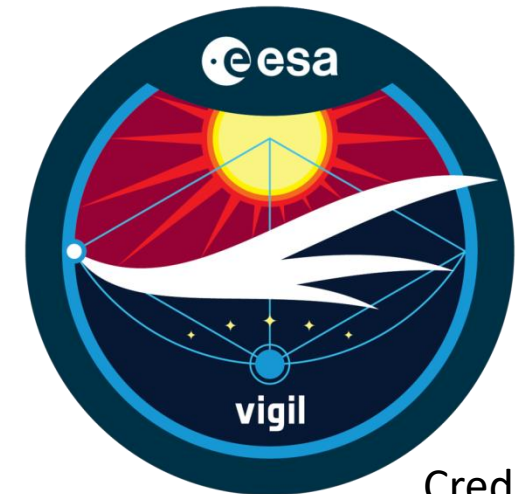


The golden age of solar monitoring

- Solar Hazards monitoring is a key asset is the **Space Safety & Security** paradigm.
- ESA, through the Space Weather Office, is building on this foundation to develop a **federated space-weather service-provision concept**.
- CAESAR is a project supported by ASI for the development of the ASPIS prototype of scientific data centre for Space Weather.



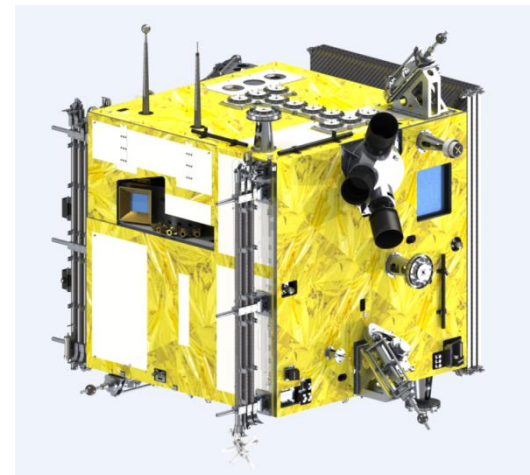
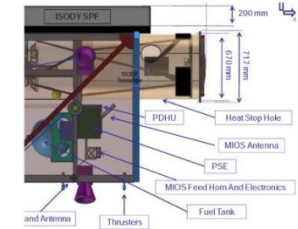
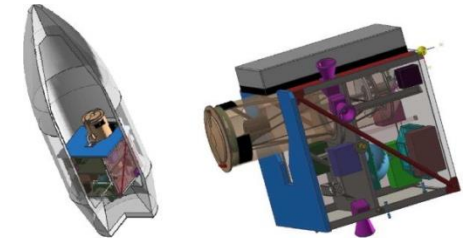
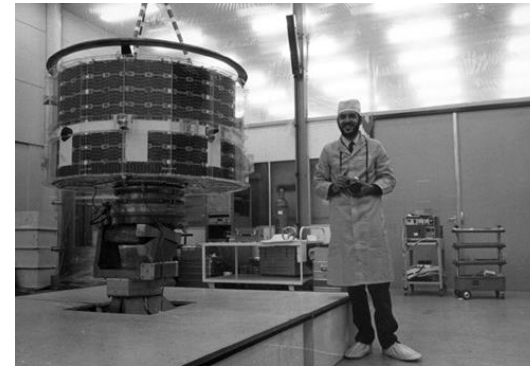
SEE could provide complementary information to current (Solar Orbiter, Parker Solar Probe, IRIS, MAXI, GOES, SDO, HINODE) and future (VIGIL, PROBA-3, SOLAR-C) missions.



Credits: ESA

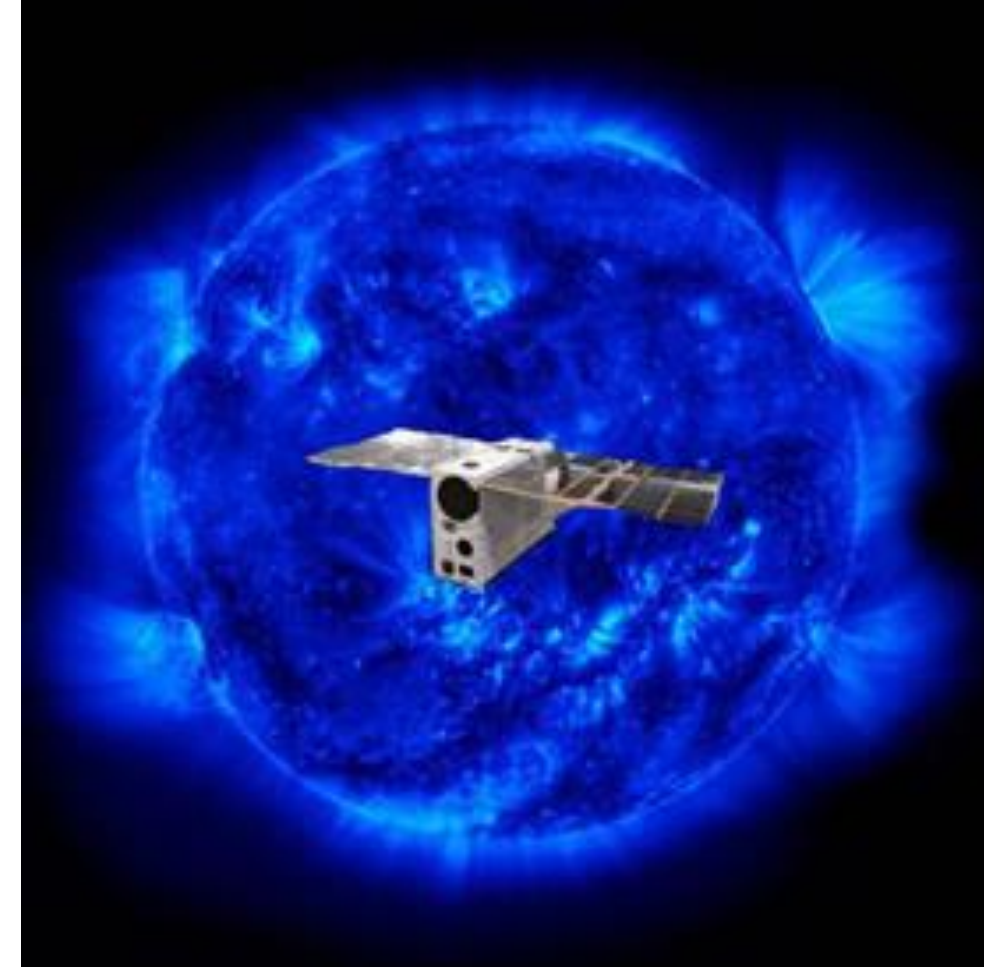
The SEE mission builds upon a wide SW community at national level: e.g. EU-SPARC: *Space Awareness for Critical Infrastructure & EU-IPS Ionospheric Prediction Service* (TPZ prime), SWERTO-LazioInnova, ASI ASPIS project and CAESAR project

1. The UNITOV Solar and Space Physics team has a very long practice in space missions (Pioneer probes 6, 7 & 8, Helios, HEOS-1 & 2, ISEE-2, ADAHELI, ADAHELI+), instruments (IPM, IBIS, TSST) and SW projects (SPARC, IPS, SWERTO, CAESAR).
2. INFN Roma2 has a three decades-old experience in the design, construction, integration and operations of space instrumentation on board satellites and manned space stations (e.g., Sileye; Altea; Lazio-Sirad; Altea-Lidal; PAMELA, CSES, Mini-EUSO)
3. Since 1962 Sapienza University of Rome has conducted research and experimental activities in the field of aerospace systems. The ARCA group conducts research and experimental activities in the areas of guidance, navigation and control of space vehicles and space robotics.



Sun CubE OnE (SEE) is a nano satellite (12U) for multispectral synoptic observation of the Sun.

- **SEE will image for the first time Full Disk Sun in the Mg II**
- **SEE will explore for the first time the solar SXR and HXR spectrum at fast cadence (nominal > 10 kHz)**
- SEE to provide a link between Astrophysics and Geophysics
- SEE as a sentinel to monitor Space Weather Events in a wide range of energies (UV-X-Gamma).
- SEE to address Space Weather Research & Services



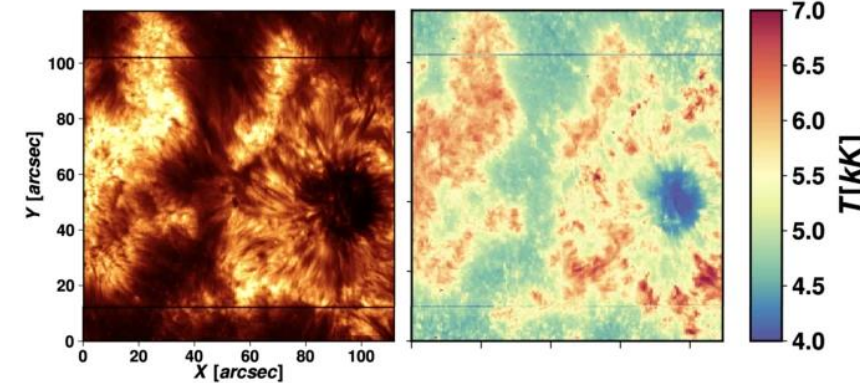
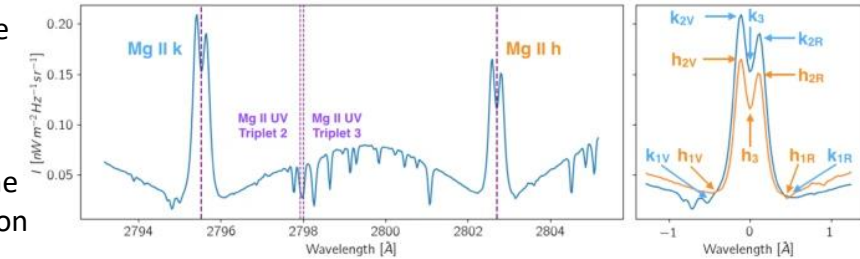
Sun-Earth connection

The **Mg II index** is commonly used as a proxy of the solar activity in the **Sun-as-a-star** paradigm.

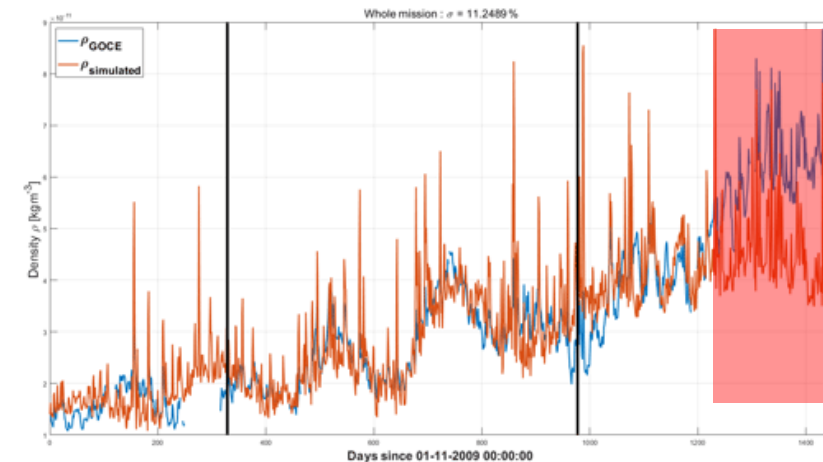
Solar UV irradiance variations correlates with:

1. the variations in **stratospheric ozone** concentrations (e.g., Berrilli et al., 2014). **Tropospheric** climate involves changes in **solar UV** flux at wavelengths that affect **ozone** production and radiative heating in the **stratosphere**.
2. the **density** of the **thermosphere**, crucial for **satellite drag** in LEO and VLEO (see [SpaceX Starlink satellites de-orbit](#))

The Mg II spectral range contains spectroscopic features that encode information about the physical conditions in the chromosphere, the region where these spectral lines originate.
Bottom panel adapted from Sainz Dalda et al., 2019



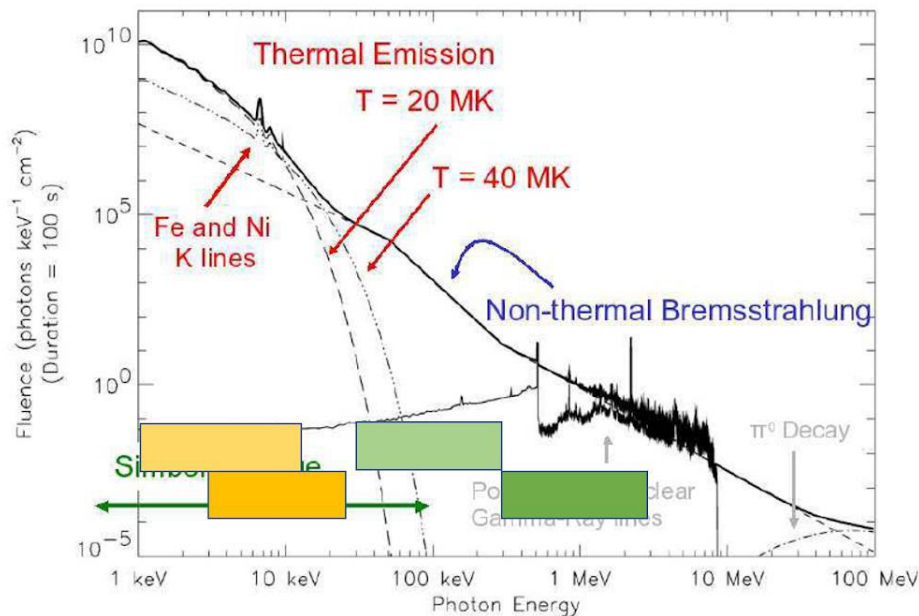
Thermospheric density synthesized (red line) from the optimal combination of A_p , Mg II and F10.7. Blue line shows GOCE thermospheric density data. From Bigazzi, Cauli & Berrilli, Ann. Geophys., 2020



- Monitor solar activity using **full disk** images in the **Mg II doublet** at 280 nm
- Monitor solar flare emission from **soft-X** to **Gamma ray** energy range

SEE X and Gamma Channels: energy bands

8: channels, 2 for each band
(redundancy and wider energy range)



3 KeV (GOES-B band:
1.5-12 keV)



6 KeV (GOES-A band:
3-25 keV)



30-300 keV (non-
thermal up to the
knee)



300-3000 keV
(emission lines)



SEE science will impact on:

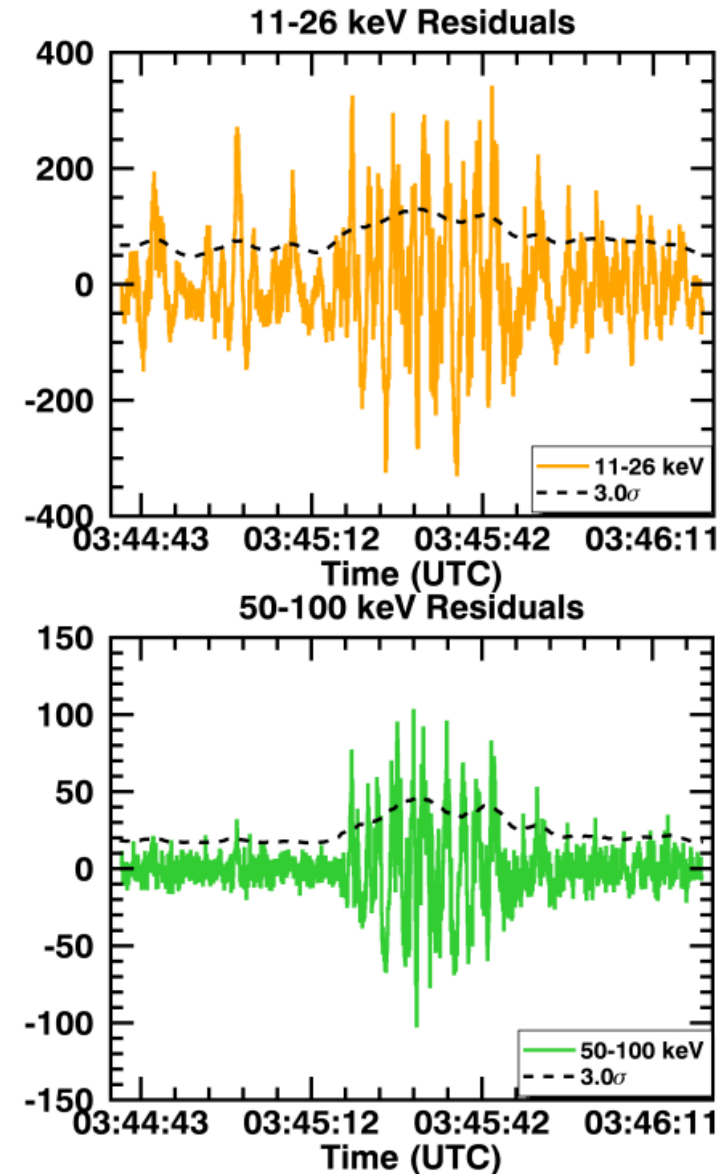
- Solar activity relation with the upper layers of the Earth's atmosphere (UV/ozone)
- multi-instrument/multi-wavelength/multi-messenger approach to space weather
- Space safety and human exploration

The high energy spectrum will be explored **from the KeV to the MeV** with unprecedented cadence (up to 10 kHz) to investigate the spectral variability connected to SW events (e.g. flares).

A new window on flare particle acceleration

- Solar flares are the **most powerful** non-stationary phenomena in the Solar System, releasing up to 10^{25} J within 10-100 s.
- Fast fluctuations in **Fermi Gamma-ray Burst Monitor** data from two M class solar flares occurred in 2011.
 - Subsecond resolution X-ray spikes and their quasiperiodic nature can reveal time of flight effects and indicate acceleration mechanisms.
- SEE will explore for the first time the solar **SXR** and **HXR** spectrum at **fast cadence** (> 10 kHz)
 - pre-flare and trigger signals, trying to distinguish the still not completely understood particle acceleration mechanism during flare events.

Subsecond fluctuations from Knuth & Glesener (2020)



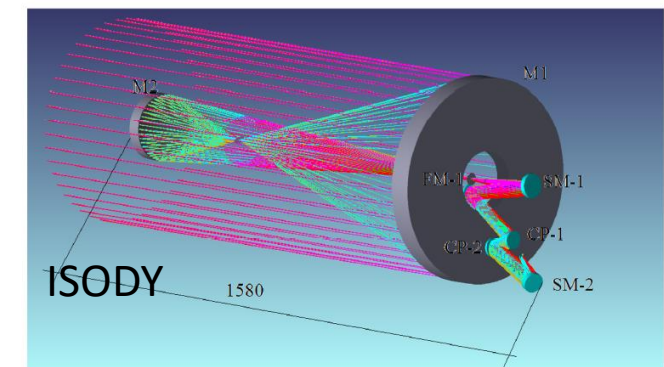
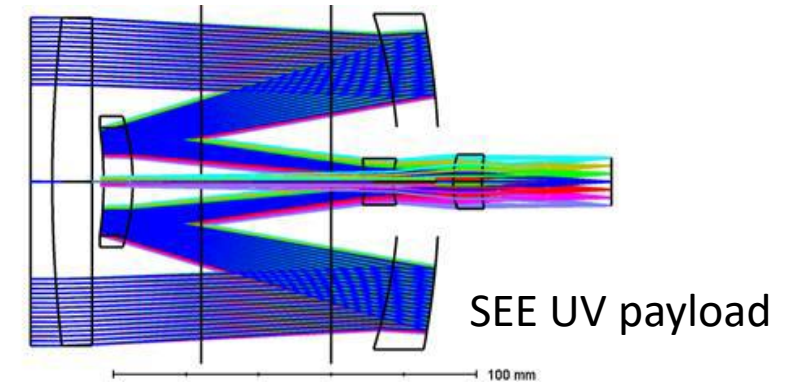
UV Mg II payload

The Mg II full disk imager proposed for this mission allows to map the radiative emission of the Sun at 280.0 nm, with a passband of 2 nm and a 9 cm aperture

The telescope is composed of 2 spherical mirrors and 3 spherical lenses. The compact design allows to fit the UV imager payload in less than 2U volume.

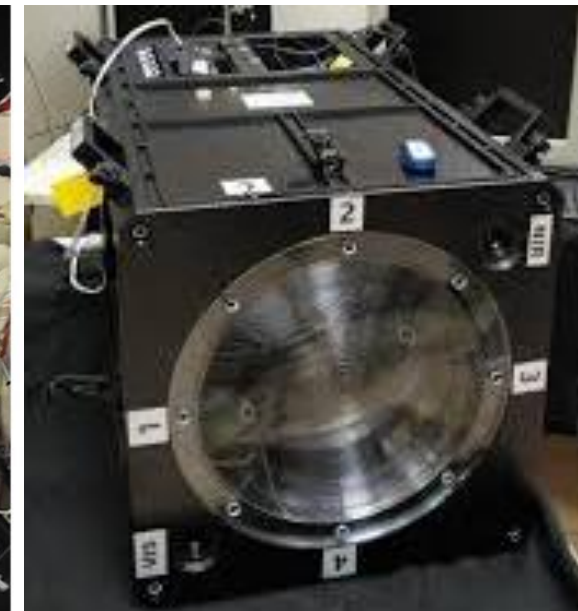
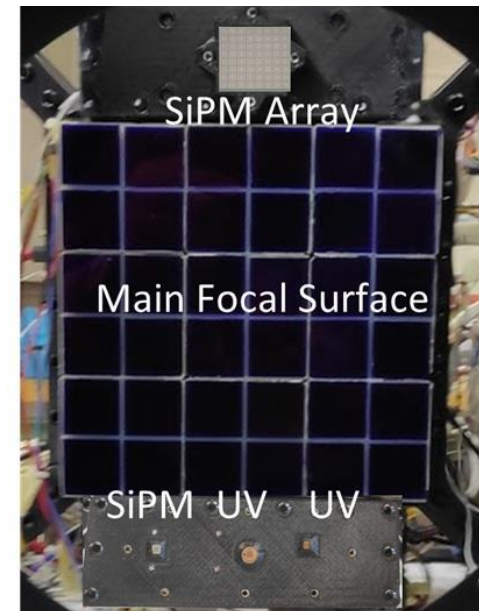
The distortion is less than 1% and the field curvature is less than the depth of focus of the instrument, causing negligible variation in terms of performances.

Heritage: *ArgoMoon camera and SCORE optical unit (Optec); the optical design of the ISODY payload on board of ADAHELI and ADAHELI+ and the design and realization of ground based optical instruments (UNITOV).*



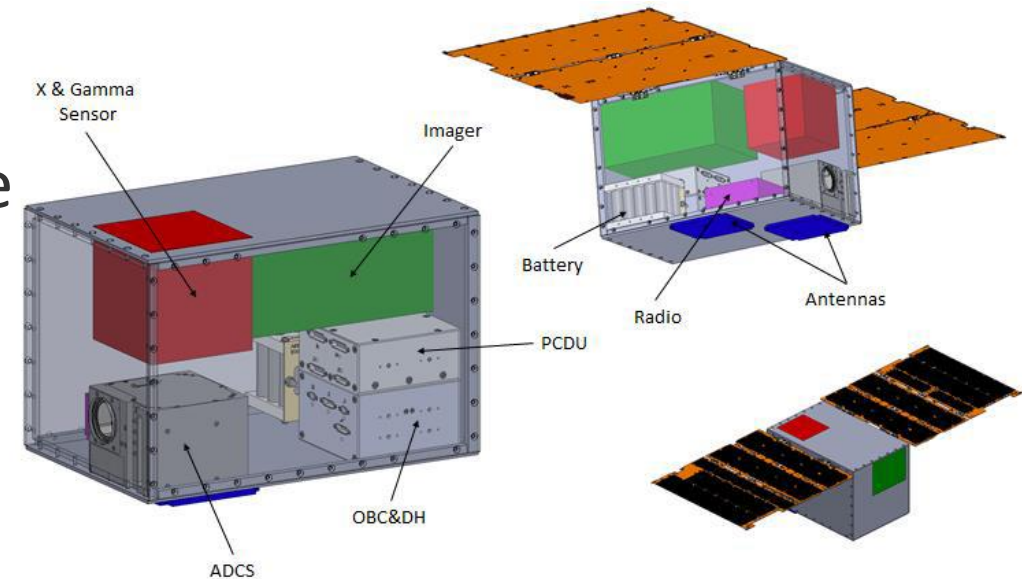
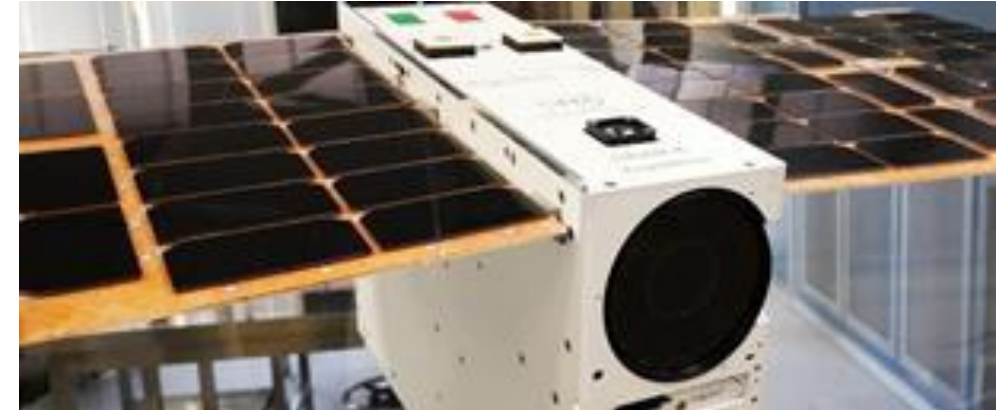
Gamma and X-ray payload

- The gamma and X-ray instrument is based on four (for redundancy and wider energy range) Silicon Photomultiplier (SiPM)-Scintillator detectors.
- The system is the evolution of similar ones already flown on previous/current missions on the International Space Station (ISS):
 - *In 2002 Lazio-Sirad, employing for the first time SiPMs in space*
 - *from 2019 Mini-EUSO, employing multi-pixel SiPM arrays).*
- Detectors: Hamamatsu MPPC (SiPM) and CsI(Tl) or Lyso(Ce) scintillator crystals (TBC).



Mini-EUSO experiment to study UV emission of terrestrial and astrophysical origin onboard of the International Space Station.

- SEE is a 12U CubeSat (up to 24 kg) based on the ARGOTEC HAWK platform, *currently used in LICIACube and ArgoMoon.*
- The HAWK platform provides: Attitude Determination and Control, Data Handling, Telemetry, Tracking & Command and Thermal Control.
- Most of the components already have TRL-9
 - Platform adapted from the HAWK deep space
 - Optical Unit from the OPTEC heritage, e.g. PRISMA and ArgoMoon
 - A possible sensor is the Teledyne e2v CIS115
 - SiPM already used in Mini-EUSO

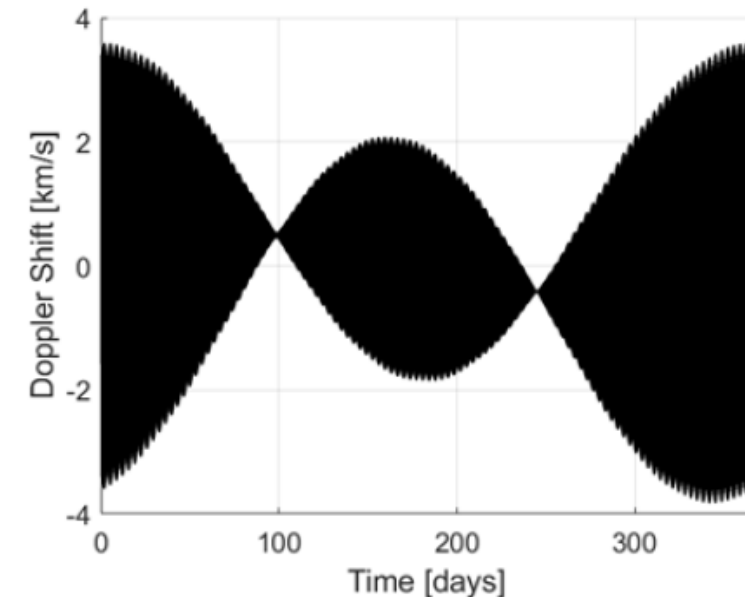
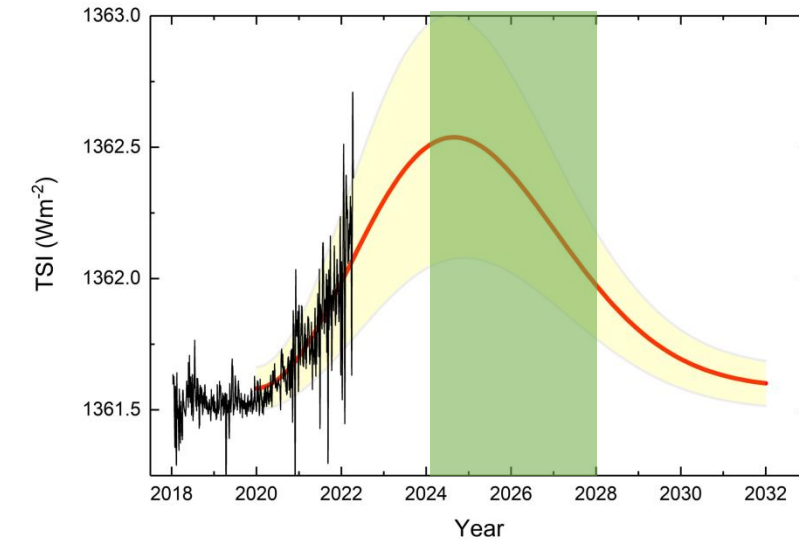


- The mission will last for 1 year + 1 year of possible extension.
- **Launches Opportunities: 2024-2026**
- The orbit chosen for the SEE is a circular Sun Synchronous Orbit (SSO) that allows low eclipse time.
- The maximum Doppler Shift due to the orbit has been preliminary evaluated to be 3.85 km/s .

Scientists Developed
New Model to Predict
Sunspot and Plage
Coverage for Solar
Cycle 25

NSO Blog

Prediction of Sunspot
and Plage Coverage for
Solar Cycle 25
Penza, Berrilli,
Bertello, Cantoresi,
Criscuoli, ApJL, 2021



- **Solar Physics**
 - **UV** solar magnetic structures
 - Particle acceleration in **solar flare** events
- **Space Weather impact: Solar Hazard** monitoring of **solar flares from UV to HXR**
 - Critical **infrastructures** and **Human exploration**
- **Sun-Earth** connection in the **UV**
 - **Ozone** modulation in the **stratosphere**
 - **Thermosphere density** (satellites drag)
- **Two major technological challenges for the SEE mission:**
 - The **miniaturization** of a **solar telescope** operating at 280 nm with a suitable heat rejector filter
 - The **miniaturization** of the X-ray and gamma-ray **detectors based on SiPM**

