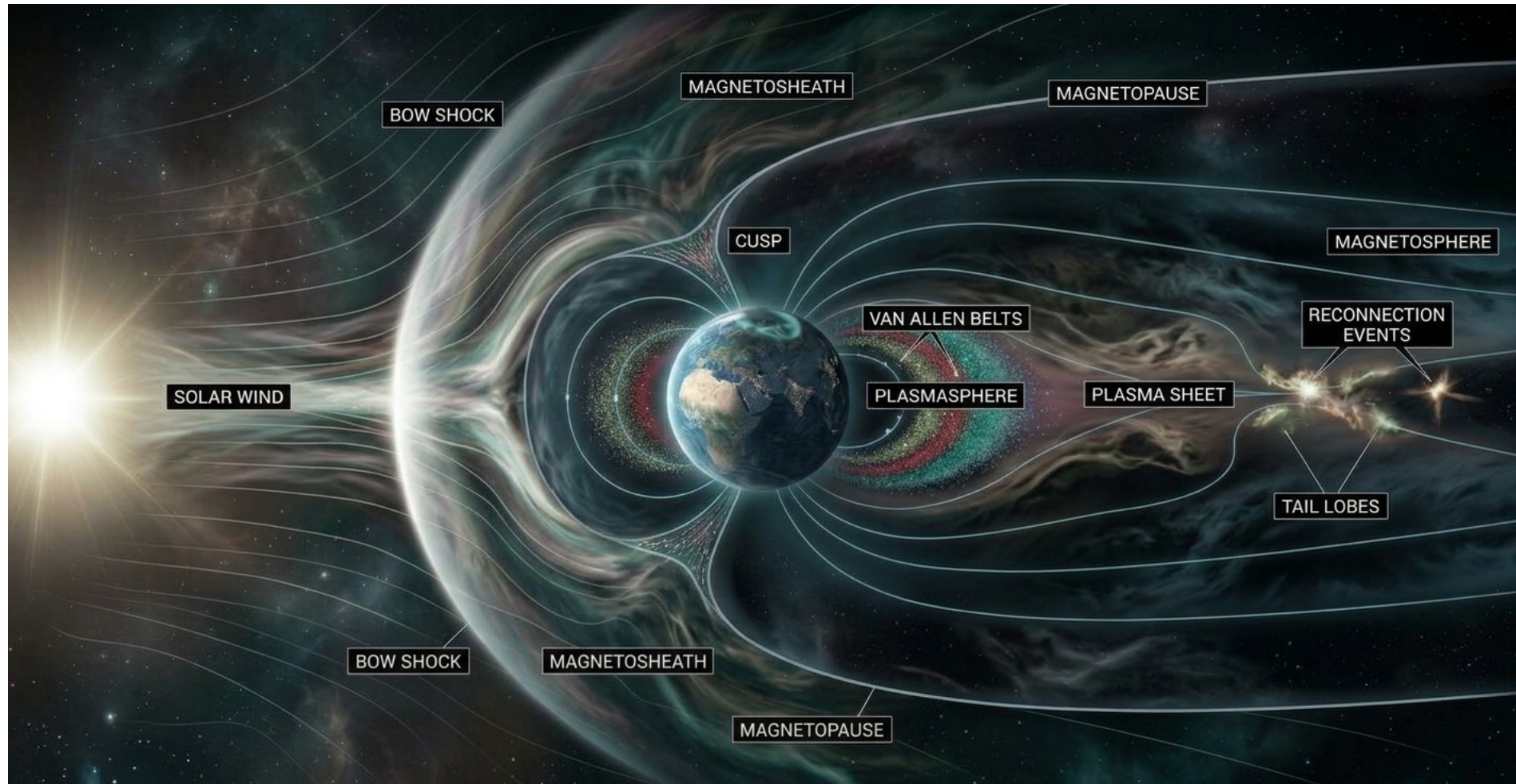


Towards an international lunar orbiter for UV imaging

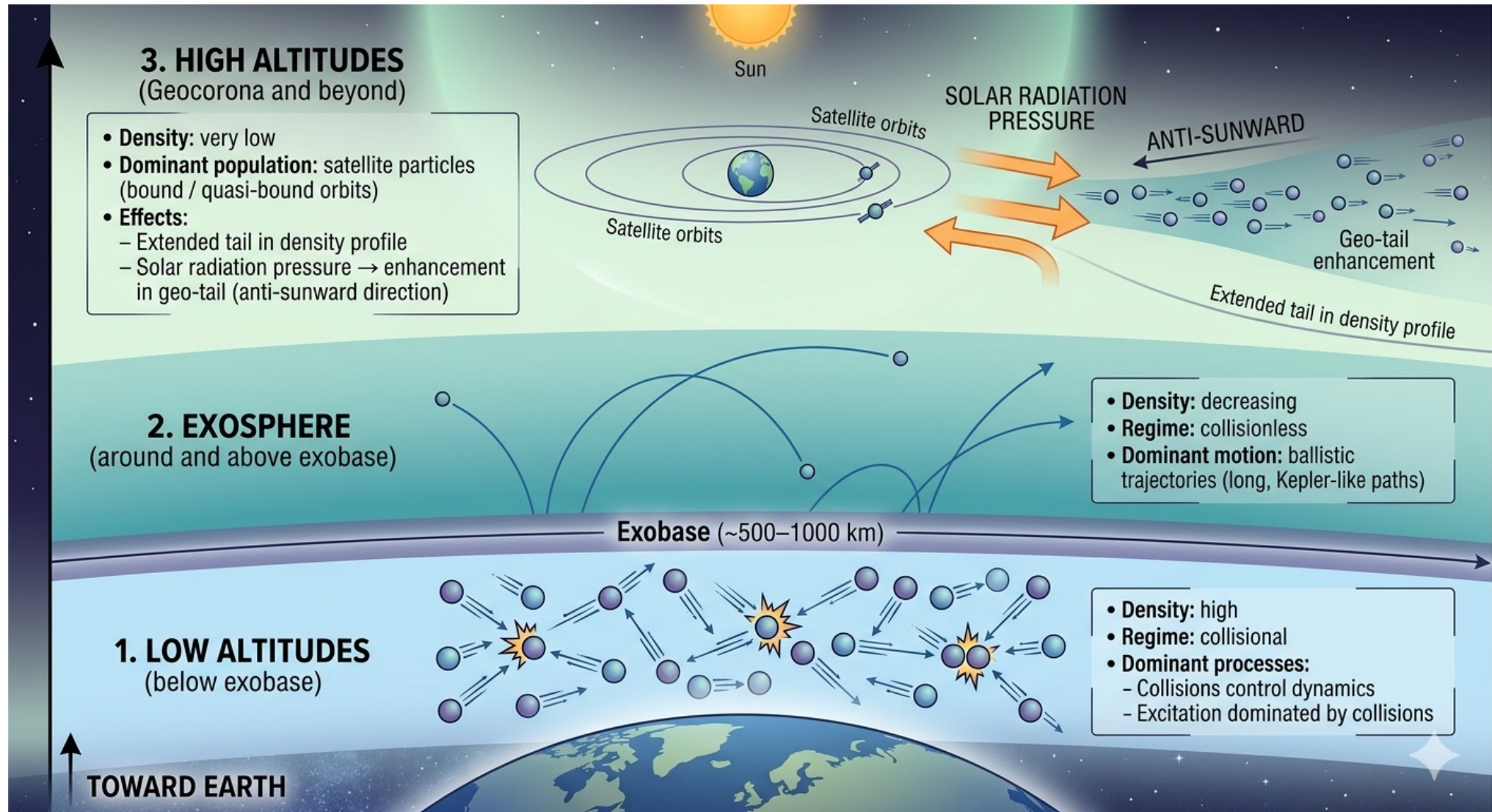
Ana Inés Gómez de Castro, Emanuele Bertone, Marina Izquierdo, Miguel
Chávez, León Restrepo, Shingo Kameda



Understand the interaction between the Earth and the Sun on global scales



From Earth to space -

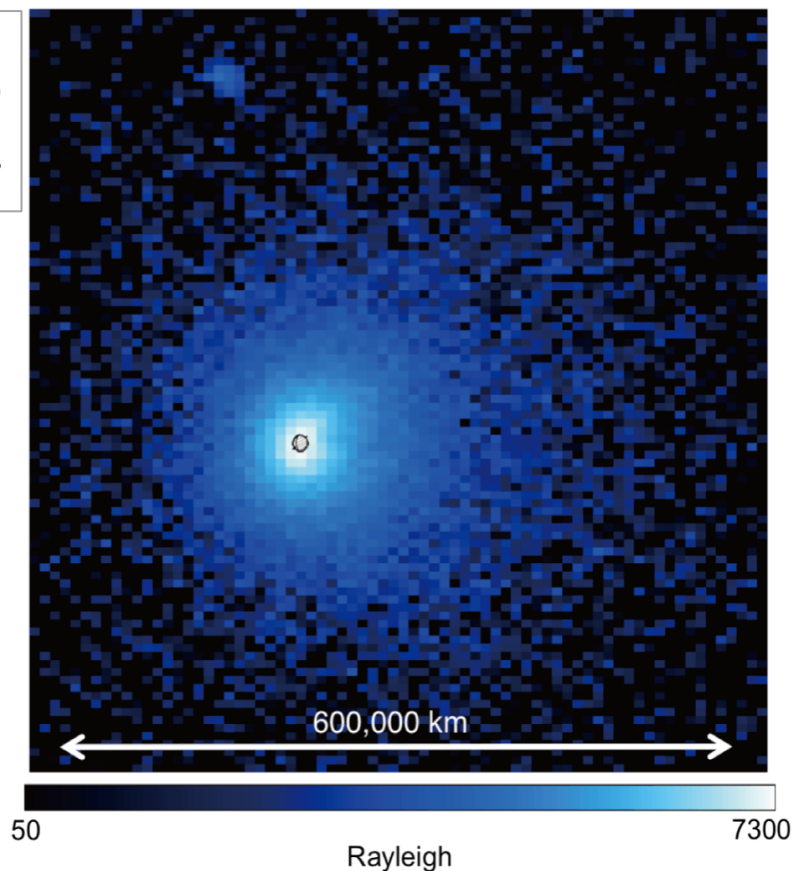


The Moon is an ideal location for observing the Earth

The Earth exosphere seen for 0.1 AU

HI 122 nm
PROCYON (JAXA)

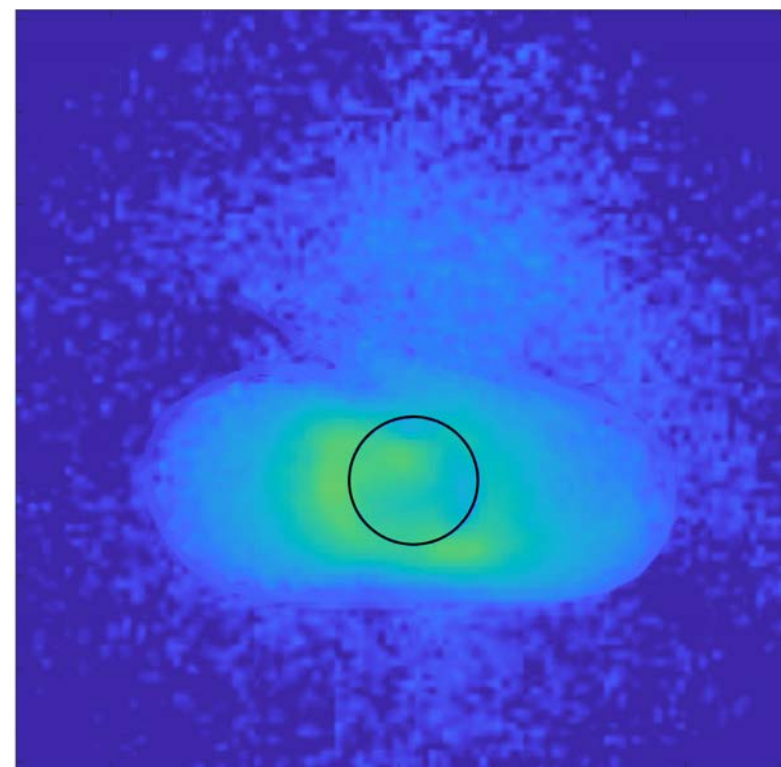
Kameda et al. 2017



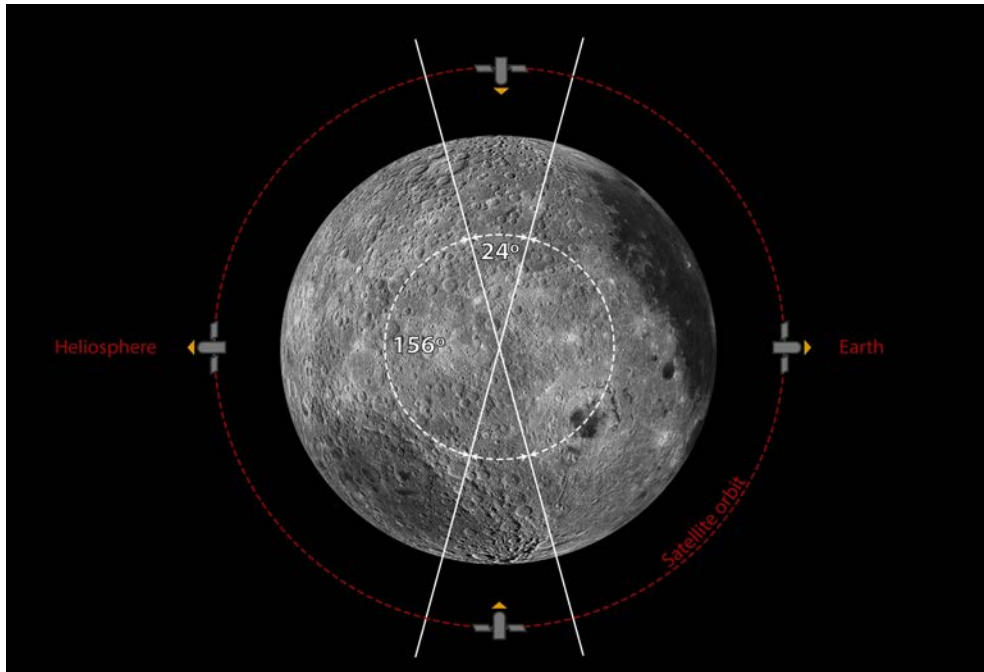
The Earth magnetosphere seen from the Moon

HeII 30.4 nm
Change'3 (CSA)

Xiao et al. 2023



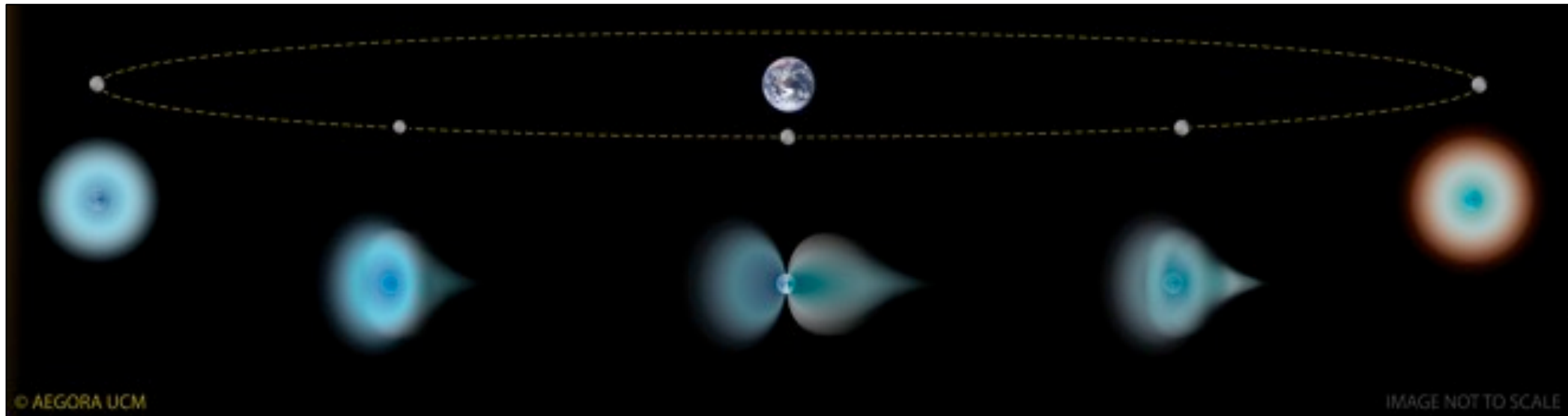
... as an exoplanet – on the path to HWO



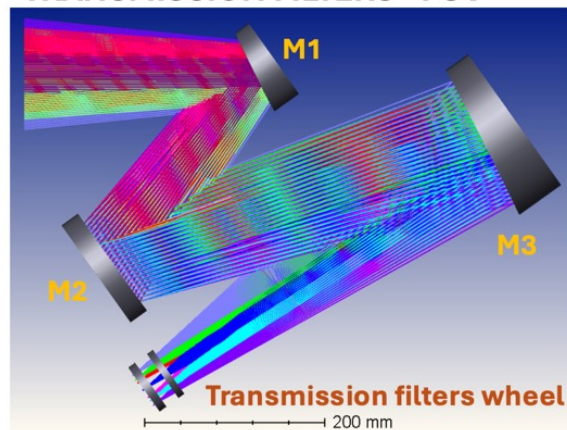
Orbital requirements:

- High inclination lunar orbit
- Height above the surface > 400 km

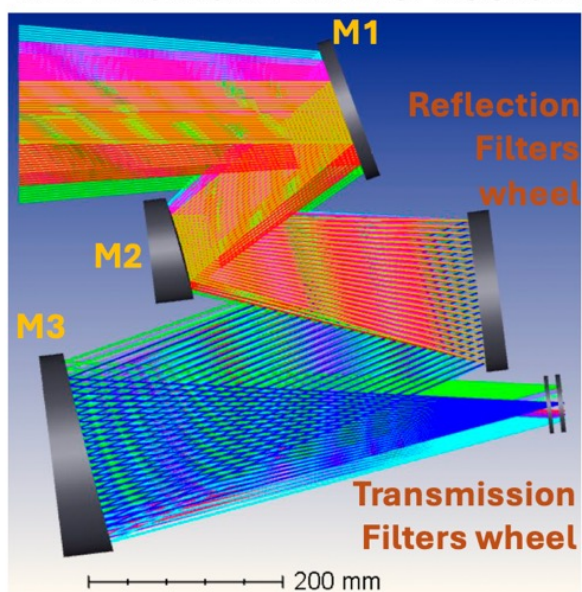
A high-inclination orbit expands scientific opportunities from Earth and Solar System science to time-domain astrophysics.



TRANSMISSION FILTERS - FUV



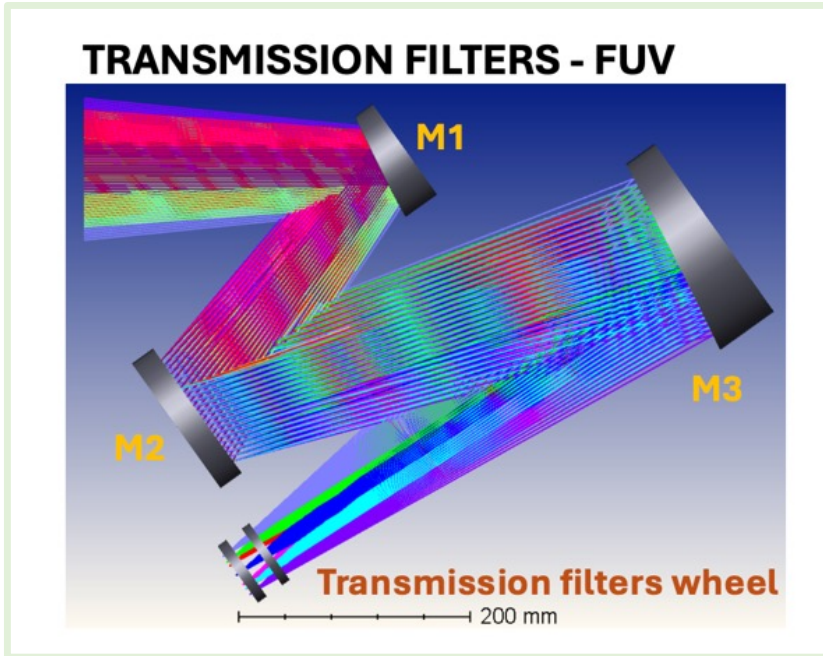
REFLECTION+TRANSMISSION



Filter Name	Target Wavelength h (nm)	Central Wavelength (nm)		Aeff ₀ (cm ²)	OoBRF
		Peak	Weighted Ave		
T122N	121.567	121	125.2162	0.38	11.7862 (1.5890)
T130N	130.217 130.486 130.603	133.8	136.4375	0.42	25.5569 (1.0549)
T164N	164.042	157.4	163.0880	0.28	81.1947 (0.3855)
FRT122N	121.567	121.2	121.7908	0.27	14.0266
FRT130N	130.217 130.486 130.603	130.0	130.1227	0.24	8.3886
FRT164N	164.042	163.2	163.9208	0.18	4.8921

More efficient transmission optics and a mechanically optimized optical design.

FINAL DESIGN



- Telecentric design, to homogenize the range of incidence angles on the filter.
- FoV: $9.8^\circ \times 11.5^\circ$. Different along each axis due to geometric distortion.
- **PSF: 1 arcmin**
- Mirror Geometry:
 - M1: Oblate ellipsoid, off-axis, $\varnothing 96$ mm
 - M2: Hyperboloid, on-axis, $\varnothing 132$ mm
 - **M3: Aspheric surface (r^4 , r^6 , r^8 coefficients), off-axis, $\varnothing 178$ mm**

FILTERS

Ly α , OI, He II – for the Earth
UV1, UV2 – mid passband – generic applications
UV0 – CsI photocathode band



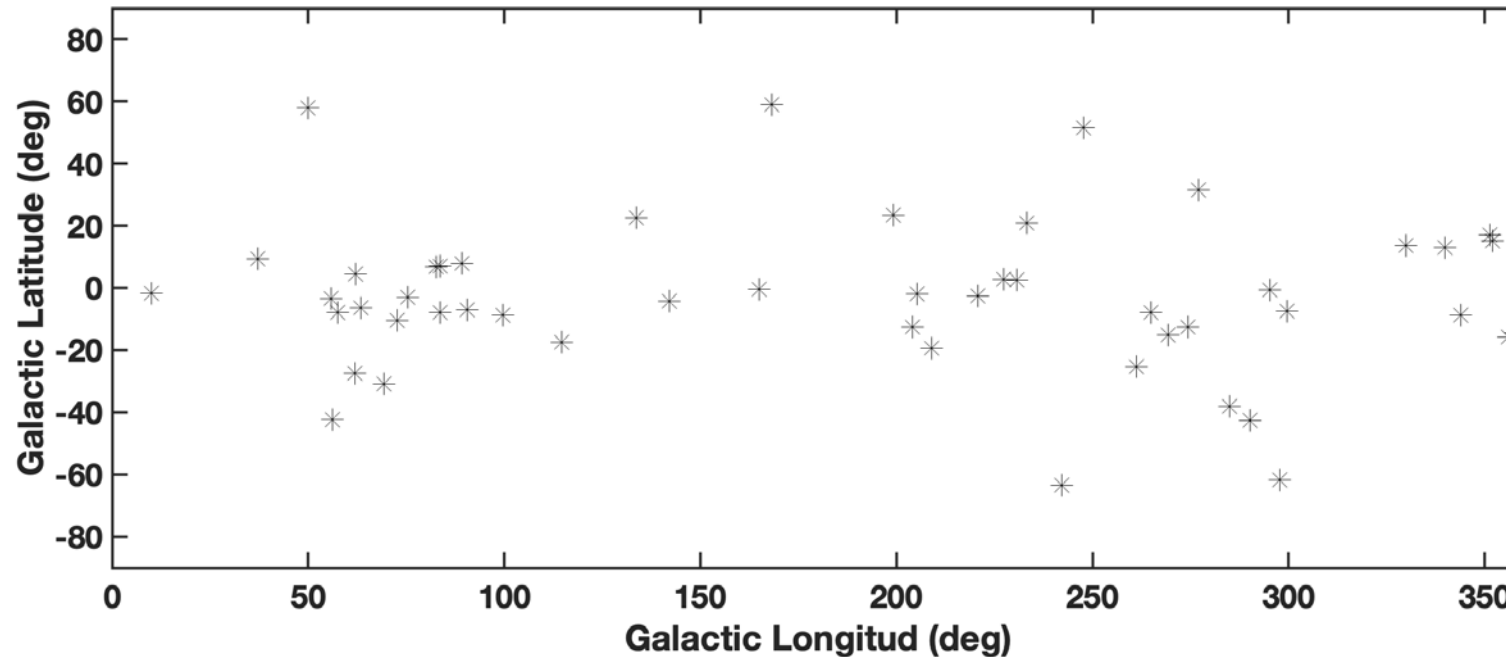
Gimbal developed by
SENER for EUCLID

Gimbal tracking system – exposure time > 2 s

(at the cost of 1 extra reflection)

Time domain astrophysics with OUL

Emission line stars: late-type stars, irregular variables, dwarf novae, classical novae, and symbiotic stars that will be reach $\text{SNR} > 10$ with OUL in < 2 s in $\text{Ly}\alpha$



Result of the blind search over the IUE Archive – emission line stars

KEY SCIENTIFIC OBJECTIVES

- **Characterization of temporal variability in massive stars.** Measure changes in ultraviolet emission associated with stellar winds, mass-loss episodes, rotational modulation, and circumstellar environments in O- and B-type stars.
- **Identification of the physical mechanisms driving stellar variability.** Investigate the roles of magnetic fields, pulsations, rotation, accretion, and wind instabilities in producing ultraviolet variability across different classes of stars.
- **Monitoring of accretion-powered systems.** Characterize ultraviolet variability in X-ray binaries and related systems to study accretion processes, mass transfer, and the interaction between compact objects and their stellar companions.
- **Detection and characterization of stellar flares and superflares.** Measure the frequency, duration, and energy distribution of ultraviolet flares from active stars, particularly M dwarfs, providing constraints on stellar magnetic activity and its impact on planetary environments.
- **Investigation of stellar pulsations in the ultraviolet.** Monitor Cepheids, RR Lyrae stars, Delta Scuti stars, and related variables to study pulsation mechanisms and evaluate the diagnostic potential of ultraviolet observations for asteroseismology and distance determination.
- **Assessment of the impact of variability on stellar evolution.** Quantify how mass loss, magnetic activity, and pulsations influence the evolutionary pathways of stars across different regions of the Hertzsprung–Russell diagram.

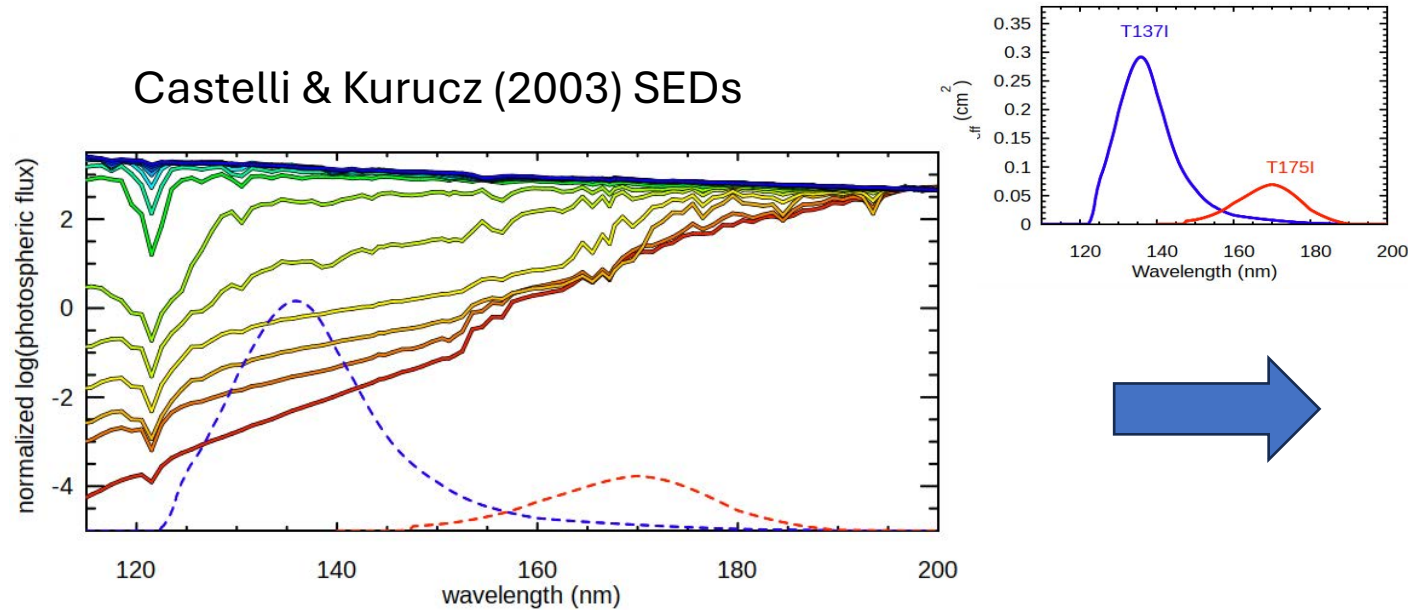
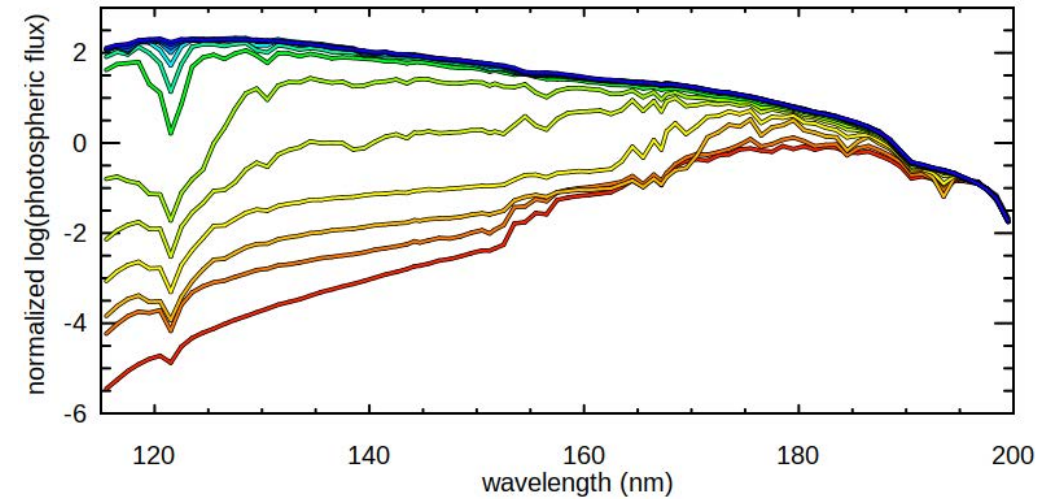
Magnetically active stars within 20 pc of the Sun - detectability with OUL



Target	Flux (erg cm ⁻² s ⁻¹)	UV tracers	Count Rate (ct/s)	Total time required for SNR ~ 10 (s)
AB Dor ¹	5×10^{-12}	CIV	0.2	500
AD Leo ²	7×10^{-12}	CIV	0.3	340
AU Mic ³	8×10^{-12}	CII, SiIII, NV	0.3	325

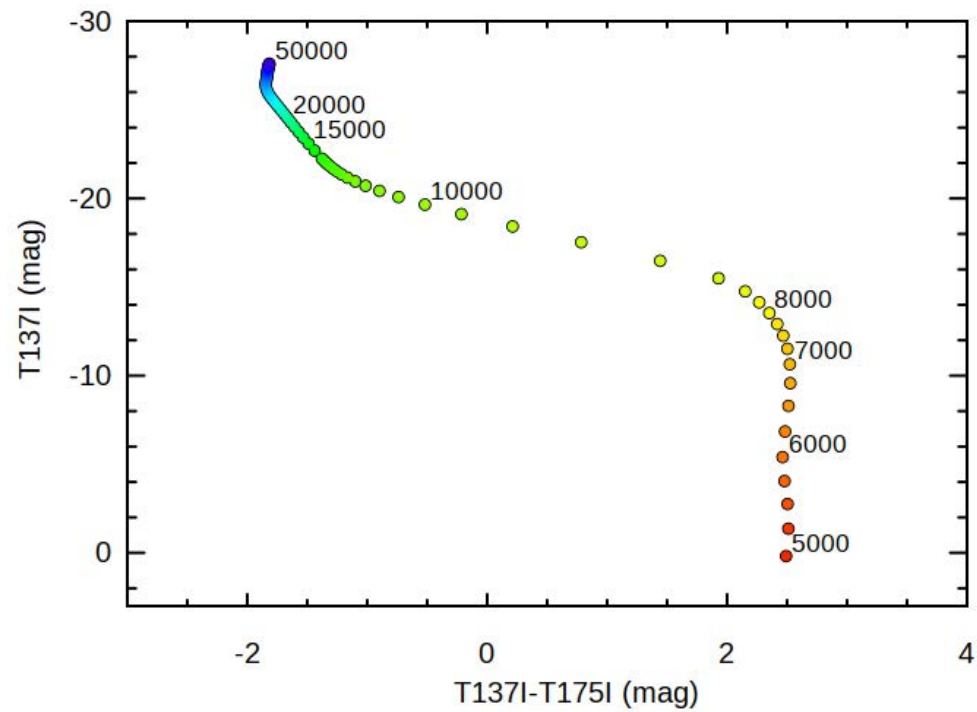
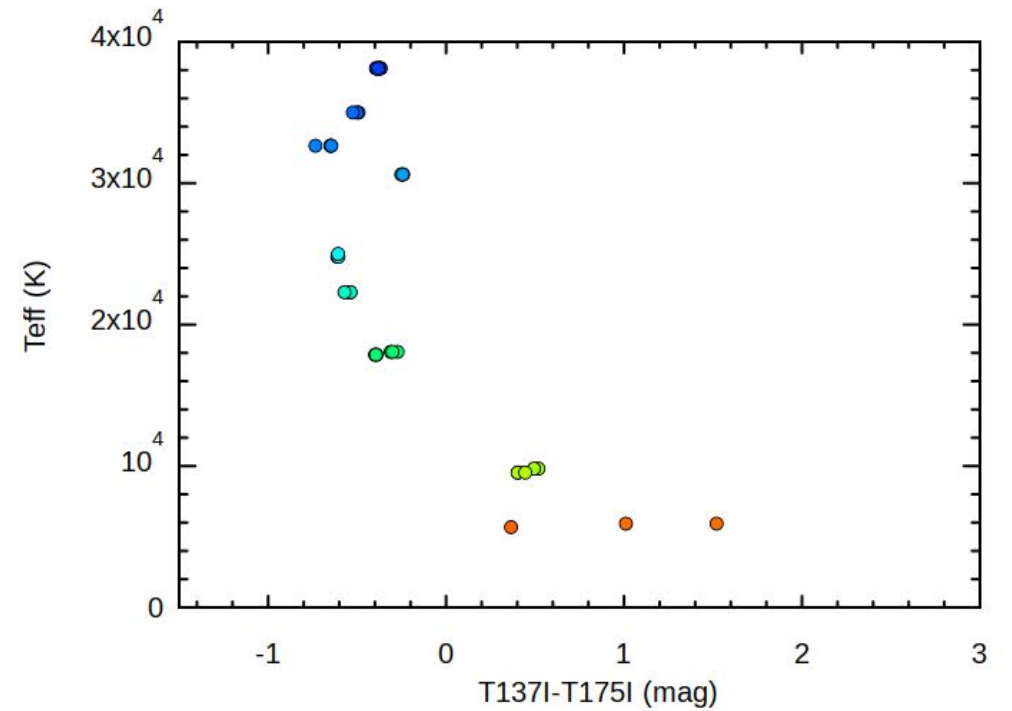
Massive stars and the HR diagram with OUL

Castelli & Kurucz (2003) SEDs



Teff=5000 K (red) to 10000 K, with a step of 1000 K,
Teff= 15000 K to 50000 K (blue), with a step of 5000 K

The (T137I-T175I) color is suitable to distinguish stars of spectral type B and A



**In Spain, OUL is being funded by the Spanish Space Agency
and managed through the ESA/PRODEX scheme
within the GSTP program**

TECHNOLOGY MATURATION & FLIGHT HERITAGE

General Support Technology Programme

Converting promising space concepts into fully tested, flight-ready hardware for future European missions.

Bridging the Gap to Flight Readiness

Successive Engineering Stages

Moves laboratory innovations through rigorous testing to complete qualification.

De-Risking Future Missions

Ensures mature technology availability for science and commercial launches.

Industrial Capability Building

Strengthens European competitiveness and supply chain autonomy.



KEY METRICS

GSTP Scale and Annual Impact

~€200M

Yearly Budget

Sustained investment across ESA member states

TRL 6–9

Target Maturity

Qualification and full in-orbit demonstration

150+

Annual Procurements

Active contracts issued to European industry

100%

Targeted Funding

Dedicated purely to space technology maturation

4 Strategic Pillars



Enabling Missions

Timely technology availability for ESA and national space programs.



Fostering Innovation

Creating new commercial products while de-risking engineering.



Competitiveness

Strengthening European industry positioning in global markets.



Non-Dependence

Securing European sovereign sources for critical technologies.

Element 1: DEVELOP

ESA DRIVEN

Building Blocks & Missions

Supports technology developments for future missions, terrestrial spin-ins, and transversal technology targets across ESA priorities.

- ✓ De-Risk Assessment Initiatives
- ✓ Advanced Manufacturing Techniques
- ✓ Standardized Satellite Sub-Systems

GSTP Compendia

Periodic competitive tenders targeting strategic tech themes like AI, Quantum, and Space Security.

Cross-Cutting Frameworks

Establishes standardized building blocks to accelerate system integration across European primes.

Element 2: MAKE

INDUSTRY INITIATED

Market-Driven Proposals

Allows companies to submit unsolicited proposals for commercial space hardware and software products.

 Permanent Open Call in esa-star (AO7935)

CO-FUNDING SCHEME

Shared Risk & Investment

Co-funded activities designed to strengthen industrial competitiveness, agility, and sustainability.

 Co-funding up to 75% for SMEs

Element 3: FLY

In-Orbit Demonstration (IOD / IOV)

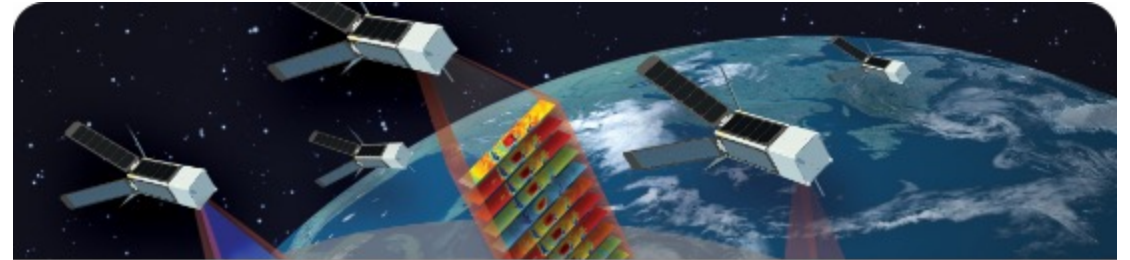
Validates new technologies, payloads, and platforms directly in the operational space environment.

Small Missions & CubeSats

Implements agile, low-cost flight opportunities on CubeSats, MicroSats, and rideshare missions.

Open Submission Channel

Permanently open call for proposals on OSIP (Open Space Innovation Platform).



Cross-Cutting Space Applications



Earth Observation & Climate

Advanced optical, radar, and lidar instruments for planetary monitoring.



Space Sciences & Exploration

Robotics, deep-space autonomy, and scientific instrumentation.



Space Safety & Clean Space

Active debris removal, zero-debris tech, and space weather monitoring.



Navigation & Transportation

Propulsion, re-entry systems, and precise satellite positioning.

TECHNOLOGY MATURATION & FLIGHT HERITAGE

General Support Technology Programme

Converting promising space concepts into fully tested, flight-ready hardware for future European missions.

Summary

- **OUL** is an instrument primarily designed to observe Earth's extended gaseous envelope as if Earth were an exoplanet.
- The trade-off studies conducted by the OUL consortium have resulted in an instrument that also offers valuable capabilities for time-domain astrophysics.
- The project will enter the optical testing phase in 2027.

The instrument's scientific potential extends beyond its original mission objectives



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