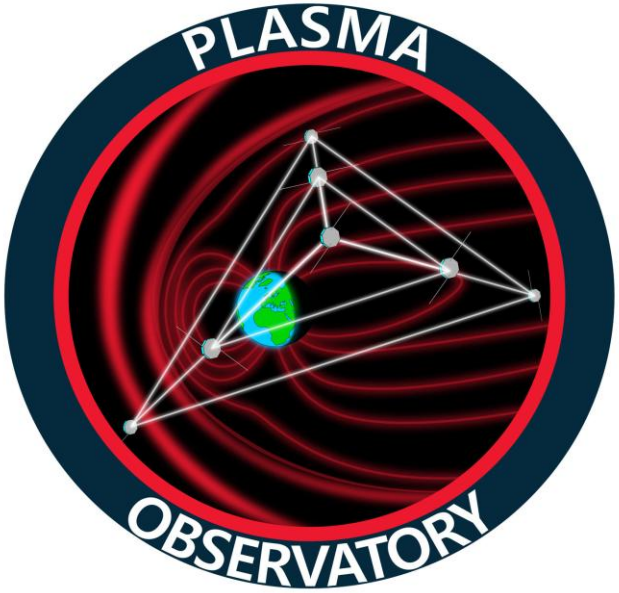

PLASMA
OBSERVATORY


HENON

Plasma Observatory

Science Theme

Unveiling plasma energization and energy transport in the near-Earth plasma environment through multiscale observations

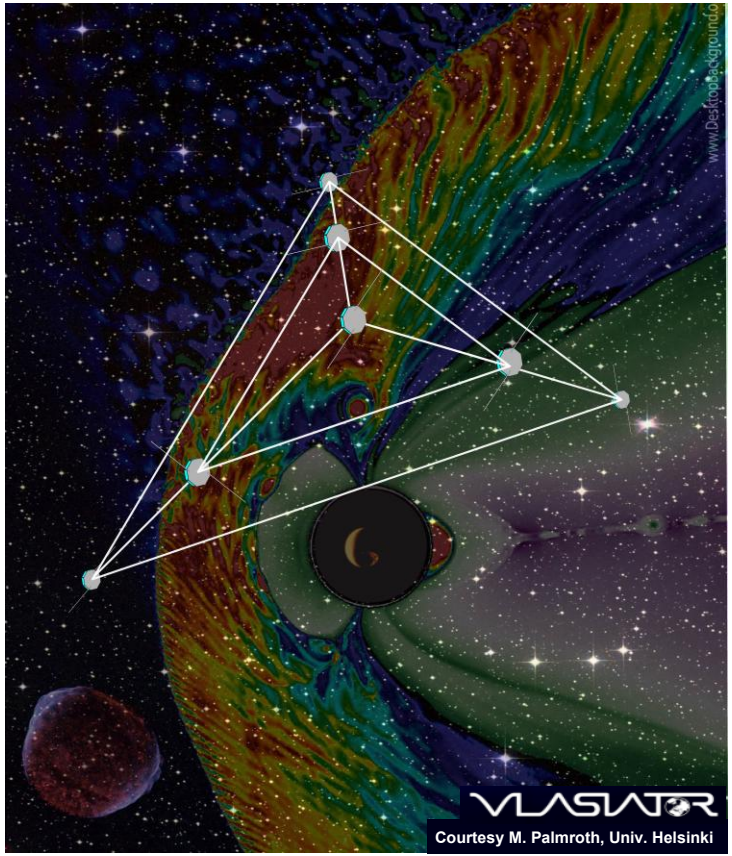
Scientific Question SQ1 - How are particles energized in space plasmas?

Scientific Question SQ2 - Which processes dominate energy transport and drive coupling between the different regions of the Earth's Magnetospheric System?

ESA M7 candidate in competitive Phase A.
Final M7 selection in June 2026. Launch 2037.

Large scientific community: 400+ researchers from 25 countries (17 in Europe) including US, Japan and China

Payload team including 10+ ESA countries with US and Japanese contributions



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WHY

Plasma is the main state of visible cosmic matter.

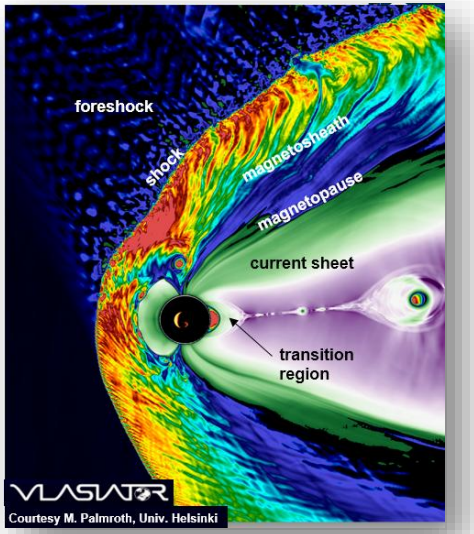
However, **we still miss the final comprehension of the plasma energization and energy transport mechanisms**.

These mechanisms are inherently driven by **coupling of plasma scales.**

WHERE

In the Earth' Magnetospheric System:

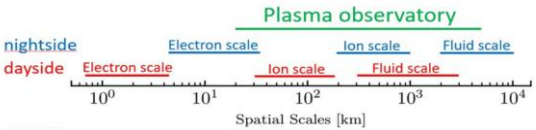
- Complex and highly dynamic with **massive energy transport** and **particle energization**
- Energy transport and plasma energization largest when **fluid scales** couple with smaller **ion scales**.
- Through **multi-scale processes** within **non-planar/non-stationary 3D structures** governed by **wave-particle interaction**

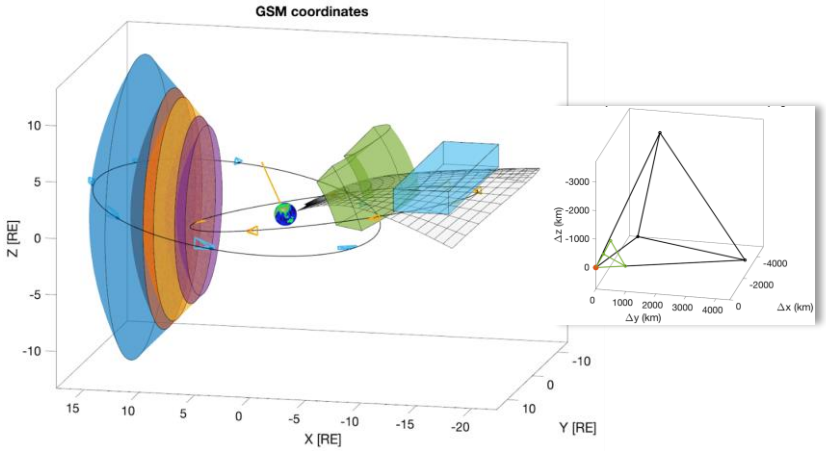


HOW

- **New multi-scale fields and particles measurements at both ion and fluid scales** required to ultimately understand **how our planet works**.
- **Constellation.** 7 SC in two tetrahedra sharing one corner.
- **Orbit (baseline).** Equatorial HEO 7 x 17 RE with 15° inclination

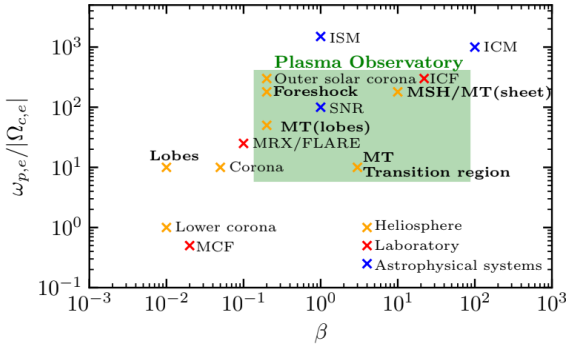
NSP	Inner (km)	Outer (km)
1	30	150
2	150	750
3	1000	5000

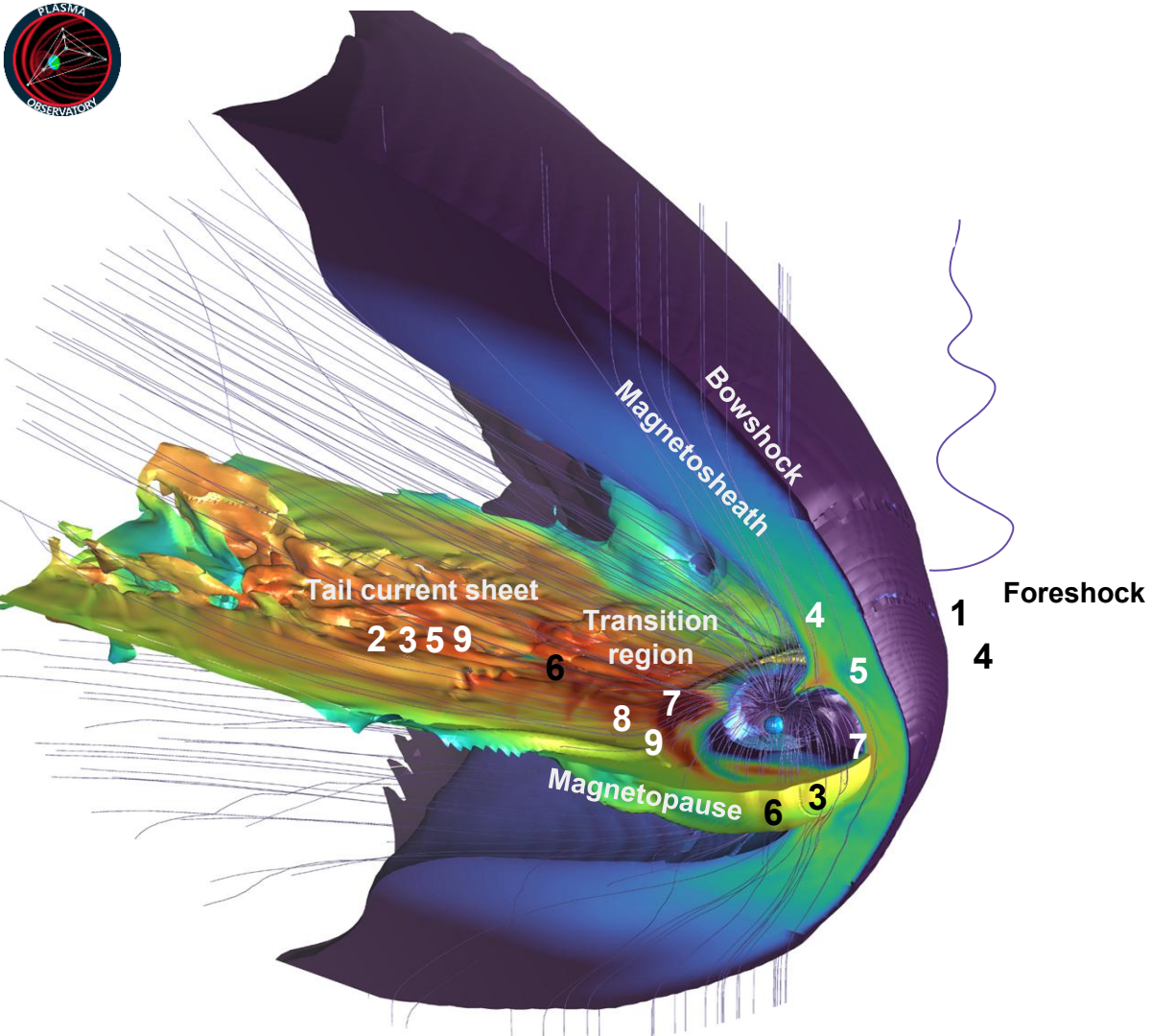




IMPACT

- Can help understanding of **distant plasma environments (solar, astro)** and **laboratory plasma.** Important for **Space Weather** comprehension.





Plasma Observatory Scientific Objectives

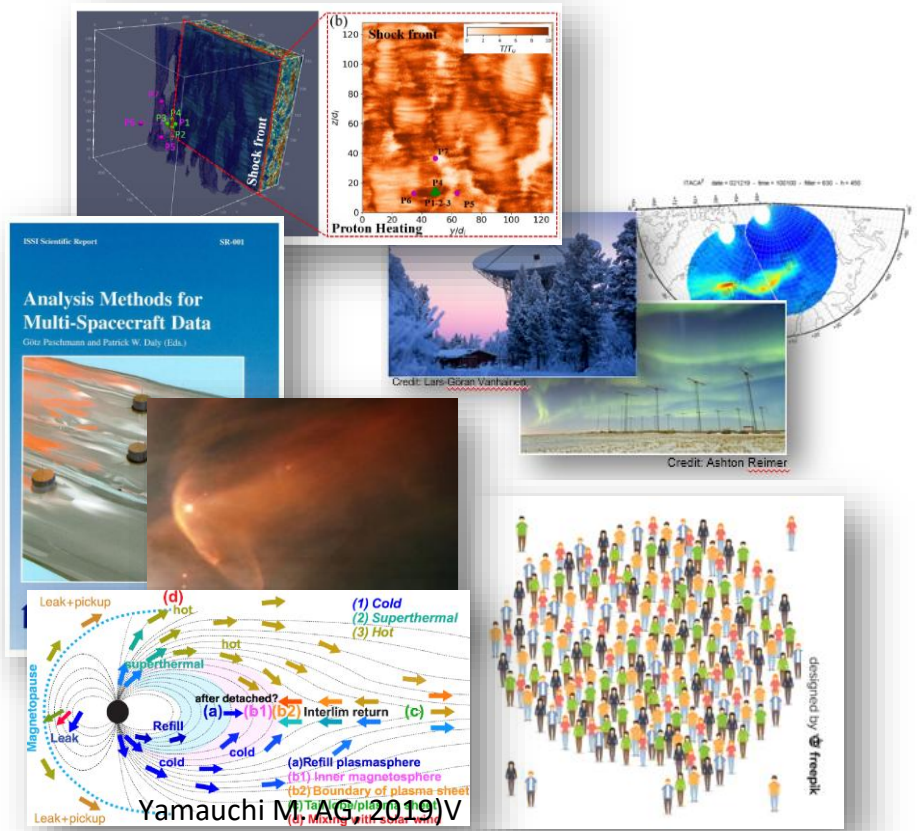
1. How are particles energized at shocks?
2. How are particles energized in plasma jets?
3. How are particles energized during magnetic reconnection?
4. How are particles energized by waves and turbulent fluctuations?
5. How do different processes combine to energize particles?
6. How is energy partitioned in different energy transport processes?
7. How do field-aligned currents connect different regions of the Magnetospheric system?
8. How do plasma jets interact with the Earth's dipole field in the transition region?
9. Which are the key plasma instabilities involved in energy transport?

PO Working Groups

See WG splinters on Wed

PO thematic Working Groups (with Lead and Co-Lead) to expand PO specific and crucial themes:

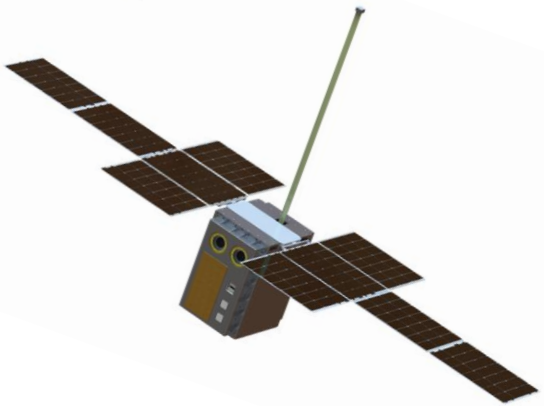
- *Numerical Simulations* (M. Alho, D. Trotta)
- *Multi-Point Data Analysis Methods* (G. Cozzani, A. Chasapis)
- *Plasma Astrophysics* (O. Pezzi, L. Comisso)
- *Scientific synergies/Additional science* (S. Benella, J.-L. Ripoll)
- *Ground-based observations* (SST Contact: J. Rae)
- *Public Outreach* (C. Forsyth)
- *Early Career Scientists* (M. Taylor)

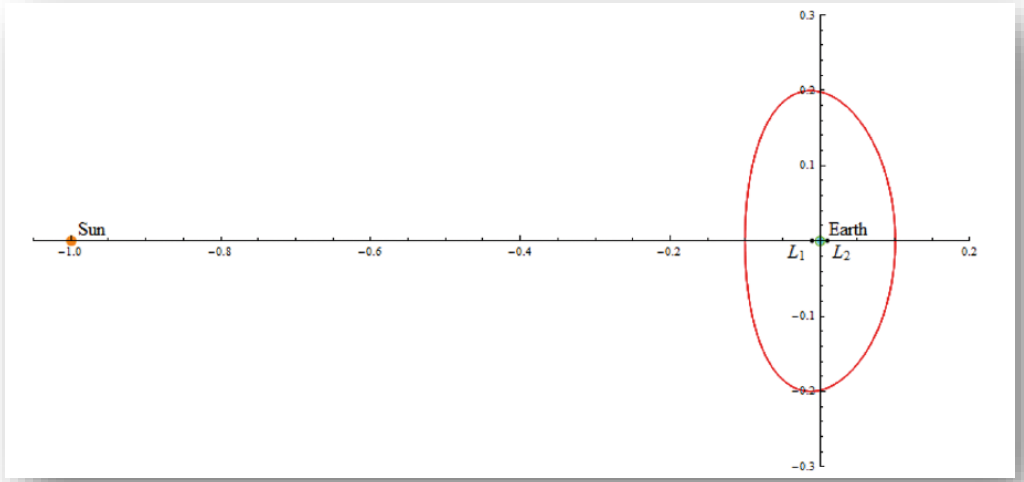



HENON

HENON concept

HENON is a **pathfinder** mission that **will explore for the first time ever the Distant Retrograde Orbit (DRO)** bringing a payload tailored **for Space Weather operations and science.**





Part of the ASI program ALCOR
Phase D study under the ESA GSTP program
Launch in January 2027

Platform: cubesat based on the HAWK-12 platform by Argotec

Payload: the Relativistic Electron and Proton Experiment (REPE), the Faraday Cup (FC) and the The MAGnetometer from Imperial College (MAGIC)

HENON goals

- Provide **a near real time monitoring** of the deep space environment well beyond L1
- Give an **exceptional outcome in terms of operational Space Weather: real time alerts** of solar energetic particles (SEPs) and interplanetary perturbations, offering a **10 times improvement in the lead time of geoeffective events** prediction

- Give **useful scientific data** to enhance our knowledge of Heliophysics

- **Fly for the first time ever the unexplored distant retrograde orbits (DROs),** which have a critical importance also in other space contexts
- **Demonstrate reliability, availability and maintainability of the CubeSat technologies in deep space mission**

RESERVE

Summary of SSCs measurement capabilities

Instrument	Measurement performance requirements
Ion and Electron Plasma Camera (iEPC)	**3D ion and electron distribution functions** Energy range: 10 eV-25 keV Time resolution: 250 ms Angular resolution: 22.5° Energy resolution ΔE/E = 20%
Ion Mass Composition Analyser (IMCA)	**3D mass-resolved ion distribution function (H+, He+, He++, O+)** Energy range: 10 eV-30 keV Time resolution: 2s Angular resolution: 22.5° Energy resolution ΔE/E = 20% Mass resolution m/Δm: H^+ >8, He^{++} >8, O^+ ≥3
Energetic Particle Experiment (EPE)	**Ion and electron distribution functions** Energy range: 30-60 keV Time resolution: 4s Angular resolution: ≥ 22.5° Energy resolution ΔE/E 20 %
BOX-Particles	Unique interface to SSC for MAG, EPE, iEPC and IMCA
Magnetometer (MAG)	**3D magnetic field** Frequency range: DC to 128 Hz Dynamic range: up to1000 nT Accuracy: 0.5 nT. Sensitivity: < 10^2 pT^2/Hz.
Search Coil Magnetometer (SCM)	**3D magnetic field fluctuations** Frequency range: 1 Hz - 8 kHz Sensitivity: [10^-3, 3.6 *10^-6, 10^-8, 2*10^-9, 2*10^-9] nT^2/Hz @ [1,10, 10^2, 10^3, 8*10^3]
Electric Field Instrument (EFI)	**3D electric field (via E·B=0)** Frequency range: DC to 0.25 Hz (4s spin period) Dynamic range: up to 1 V/m Accuracy: 1.5 mV/m for |E|<5 mV/m and 30% for |E|>5 mV/m
	2D/3D electric field fluctuations Frequency range: 1 Hz to 100 kHz Dynamic range: up to 0.5 V/m Sensitivity: [2*10^-11,3*10^-12,3*10^-12,3*10^-13,3*10^-14] (V/m)^2/Hz @ [10,10^2,10^3,10^4,10^5] Hz (higher in spin plane)
	Spacecraft potential @ 128 Hz
BOX-Waves	Unique interface to SSC for EFI and SCM

See talks by PIs

PO Scientific Organization

See talk by M. Taylor

Science Study Team (SST)

represents the community scientific interests during Phase A Study and produces the Assessment Study Report (“Yellow Book”)

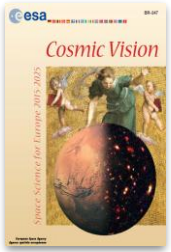
Takanobu Amano	University of Tokyo
Yuri Khotyaintsev	IRF, Sweden
Maria Federica Marcucci	IAPS-INAF, Italy
Cecilia Norgren	Uni Bergen, Norway
Alessandro Retinò	LPP, France
Aurora Simionescu	SRON, The Netherlands
Jan Soucek	IAP, Czech Republic
Julia Stawarz	Northumbria Univ., United Kingdom
Francesco Valentini	University of Calabria, Italy

Cross-Discipline Working Group (CDWG)

gives fundamental support to SST

Matthieu Berthomier	LPP, France
Malcolm Dunlop	RAL, United Kingdom
Markus Fraenz	MPS, Germany
Heli Hietala	Queen Mary, United Kingdom
Matthieu Kretzschmar	LPC2E, France
Rumi Nakamura	IWF, Austria
Jonathan Rae	Northumbria Univ, United Kingdom
Hanna Rothkaehl	CBK, Poland
Minna Palmroth	Univ. Helsinki, Finland
Andris Vaivads	Univ. Ventspils, Latvia

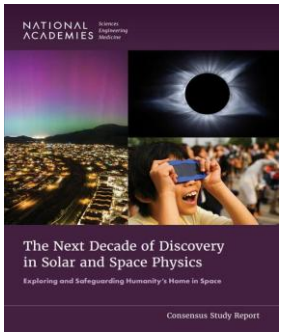
Multi-scale constellations: strong programmatic international framework towards a new era of magnetospheric physics in mid/late 2030s



...it is now vital to move on from Cluster, which has four satellites operating in company at relatively large distances, to simultaneous observations at a much larger number of points…

From ESA Voyage 2050 report: *The importance of understanding the multi-scale processes of plasma is expected to become a coherent theme of the plasma Universe in the Voyage 2050 era.*
Plasma Observatory targets the two Voyage M-class themes :"*Magnetospheric Systems*" and "*Plasma Cross-scale Coupling*".

See also:
A. Retinò et al., Particle energization in space plasmas: towards a multi-point, multi-scale plasma observatory, Exp. Astr., 2021 (ESA Voyage 2050 White Paper)
D. Verscharen, …, A. Retinò, et al., The Plasma Universe:ACoherent Science Theme for Voyage 2050, Front. Astron. Space Sci., 2021



Plasma Observatory explicitly mentioned in Helio Decadal Survey

Possible synergy with Links magnetospheric constellation (24x spacecraft focused on mesoscales -> PMO scales)

NASA budget cuts ???

Cross-scale coupling in key regions of the Earth's magnetosphere focusing on kinetic scales

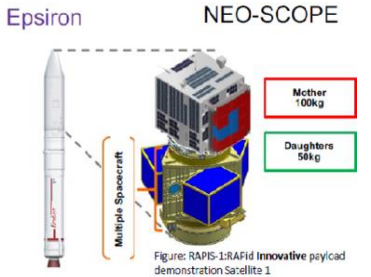


Image credits: Y. Saito (ISAS-JAXA)

+ coordination with current & future ground observatories such as SuperDARN, ALIS4D, EISCAT3D, INTERMAGNET etc. to provide for the first time a multi-scale coverage of the Magnetospheric System from kinetic to global scales !