

ESA D/SCI activities in area of Heliophysics

Matt Taylor, on behalf of D/SCI

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SOLAR SYSTEM EXPLORERS





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COSMIC OBSERVERS





COSMIC OBSERVERS







Heliophysics –

Synergetic Multi-instrument Interdisciplinary Multi-mission

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- S<u>w</u>arm constellation in polar orbit at 530 km

For the first time, the connection was made between these bursty bulk flows and geomagnetically induced currents.
These currents can cause large power outages, a major space weather impact on Earth.

 Cluster constellation in elliptical orbit between ~16,000 and ~116,000 km

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Comparative planetology –

Are atmospheric outflows stronger on planets with magnetic field than on planets without magnetic field?





Cluster + friends observed a 'highway' of Atmospheric ion escape during CME impact

Ion fluxes observed are stronger than on Mars or Venus.

[Zhang et al., ApJ, 2022]





Cruise phase



Cluster observes a Hot Flow Anomaly (HFA) caused by current sheet interaction with Bow Shock.

Rosetta magnetometer and ground based observe 10-45 s Pc3 waves

Connect HFA with Pc3 waves









Eastwood et al., JGR, 2011

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BepiColombo cruise science overview



- A journey of ~7 years : from October 2018 until December 2025, covering heliocentric distances of 0.3 1.2 AU
- Half solar cycle, including minimum and maximum of solar activity
- Several instruments are connected during the trip on special occasions, and some others are mostly continuously in operation, such as the magnetometer and the radiation monitor
- Good opportunities for collaborations with Solar Orbiter, Parker Solar Probe and other missions in the inner heliosphere, as well as for solar wind-planetary investigations during the flybys to Earth, Venus and Mercury





Coordinated observations with other missions



BepiColombo has contributed to several cruise studies, including coordination with multiple missions, such as:

- Wide spread Solar Energetic Particle (SEP) propagation in the inner solar system
- Coronal mass ejection (CME) propagations
- Effect of CMEs on SEP propagations
- Turbulence studies in the solar wind
- Planetary science during the flybys of Earth, Venus and Mercury
- Upstream solar wind monitor for other planets, such as Mars
 - \rightarrow Example of study (right figures)

Chi et al., 2023







Coordinated observations with other missions



Magnetosphere: April 10, 2020, 0:30 ~ 16:00





Coordinated observations with other missions









During cruise phase, BepiColombo is one more asset in the solar wind, and consequently, it can significantly contribute to heliophysics studies. For example, on 15 Feb 2022, a very large SEP followed by a CME impacted BepiColombo and was observed at mostly all solar longitudes







Swarm +THEMIS +MMS + Cluster + Geotail +Solar Orbiter+









Solar Orbiter: Tiny jets power the solar wind emerging from a coronal hole

2022-03-30 UT 04:30:30



Teamwork in the heliosphere: Parker Solar Probe + Solar Orbiter join forces to measure coronal heating rate

Telloni et al. (A&A 2023)

SMILE (Solar wind Magnetosphere Ionosphere Link Explorer)

SMILA

Cusp

Aurora

Investigate the dynamic response of the Earth's magnetosphere to the solar wind impact in a unique and global manner

Magnetosheath/ Magnetopause

Solar wind





ESAC Science Data Archive (ESDC) https://www.cosmos.esa.int/web/esdc/home



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X	ASPOC active spacecraft potential control		ASPOC active spacecraft potential	control	
ę	DWP wave-particle correlator		HEED high energy electron detect	or	
	EDI electron drift instrument EFW electric field double probe antenna		HIA ion spectrometer HID high energy heavy ion detect	or	
	FGM fluxgate magnetometer PEACE electron spectrometer		PEACE electron spectrometer STAFF/DWP search coil magnetor	neter / wave-particle experiment	
	RAPID energetic electron and ion spectrometer		Auxiliary, MAARBLE and ECLAT su	pport data	
	WBD radio receiver - electric field waveforms				
	Auxiliary, MAARBLE and ECLAT support data				

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ESAC Science Data Archive (ESDC) https://www.cosmos.esa.int/web/esdc/home

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	Solar Orbiter Archive			MATT TAYLOR (MTAYLOR)	
Mission Cluster DoubleStar Image: Cluster Data SEARCH Image: Cluster Time (begin/end) Image: Cluster Image: Cluster Image: Cluster <td< th=""><th>SOAR 1.6.1</th><th>WELCOME TO THE SO Solar Orbiter is a joint ES heliophysics: How does overarching scientific obj questions: • How and where do corona?. • How do solar trans • How do solar trans • How do solar trans • How do solar erupt heliosphere. • How does the solar and the heliosphere</th><th>LAR ORBITER ARCHIVE A-NASA collaboration that will address the central the Sun create and control the heliosphere? Th ective can be broken down into four interrelat the solar wind plasma and magnetic field originate i ents drive heliospheric variability. ions produce energetic particle radiation that fills the dynamo work and drive connections between the S e.</th><th>question of his primary, ed scientific n the e</th></td<>	SOAR 1.6.1	WELCOME TO THE SO Solar Orbiter is a joint ES heliophysics: How does overarching scientific obj questions: • How and where do corona?. • How do solar trans • How do solar trans • How do solar trans • How do solar erupt heliosphere. • How does the solar and the heliosphere	LAR ORBITER ARCHIVE A-NASA collaboration that will address the central the Sun create and control the heliosphere? Th ective can be broken down into four interrelat the solar wind plasma and magnetic field originate i ents drive heliospheric variability. ions produce energetic particle radiation that fills the dynamo work and drive connections between the S e.	question of his primary, ed scientific n the e	
PEACE electron spectrometer RAPID energetic electron and ion spectrometer STAFF search coil magnetometer and spectrum analyzer WBD radio receiver - electric field waveforms WHISPER relaxation sounder Auxiliary, MAARBLE and ECLAT support data	TOP FE	EATURES SEARCH Search through all SOAR data.	TIME SERIES Display data in time series.	PROGRAMMATIC ACCESS Access our content via HTTP requests. Normally used in scripts, application code or command line tools.	
		ADDITIONAL SCIENCE DATA INFORMATION Further information and documentation on the Science data production provided by the Instrument Teams. Use the links in these pages to better understand the Science data in the archive.	HELP Comprehensive guide to all aspects of using the Solar Orbiter Archive.	For questions, suggestions or problem reports, contact our Helpdesk.	

ESAC Science Data Archive (ESDC) https://www.cosmos.esa.int/web/esdc/home

Use of Twenty Years CLUSTER/FGM Data to Observe the Mean Behavior of the Magnetic Field and Current Density of Earth's Magnetosphere, Robert and Dunlop, JGR, 2022

Huge value when driving conditions (the Sun) have variability on decade time scales



D/SCI Future - Voyage 2050



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D/SCI recently solicited ideas from the broad scientific community of science themes to be covered in Voyage 2050 planning cycle (2035-2050).

https://www.cosmos.esa.int/web/voyage-2050

- Resulted in 3 Large-Class Mission Science Themes:
- "Moons of giant planets"; "from temperate exoplanets to the milky way"; "New Physical Probes of the early Universe"
- + continuation of Medium-Class missions selected through open calls.

These, in addition to the existing F class missions form the main mission components of the Science Directorate.



Most recently this involved a call for a Medium-size and a Fast mission opportunity. https://www.cosmos.esa.int/web/call-for-missions-2021

Has led to selection of F Class mission- ARRAKIHS will image faint galaxies in the nearby Universe and provide important measurement to test open questions in cosmology

And 5 M class Phase 0 studies





- CALICO proposes to perform in situ investigations of the organic and ammoniated materials and salt deposits on the dwarf planet Ceres, potentially offering insights into whether Ceres provides or provided the conditions to support life.
- HAYDN is an asteroseismological mission focused on homogenous, controlled large samples of stars in order to provide calibrators for several aspects of fundamental astrophysics, fostering the understanding of stellar physics and the internal structure of stars, inaccessible with other techniques.
- M-MATISSE aims to study Mars as a global dynamic system usinga 2 S/C configuration, targeting atmosphereionosphere-magnetosphere-solar wind interactions, and aiming to disentangle spatial and temporal effects on various processes driving the Martian system.
- Plasma Observatory is a multi-spacecraft mission to study the coupling of fluid and ion scales within astrophysical plasmas in near-Earth space, advancing the knowledge of particle energisation and energy transfer.
- THESEUS is a multi-instrument mission for transient astronomy, with focus on Gamma Ray Bursts, aiming at the exploration of the high-redshift Universe through studies of the explosions of the first massive stars and the identification of GW counterparts



Beyond M7 -

- The Long Term Implementation Plan will be discussed early next year following the planned adoption of the missions LISA and EnVision.
- From NASA Heliophysics perspective: Geospace Dynamics Constellation (6 spacecraft) and Dynamical Neutral Atmosphere-Ionosphere Coupling (2 Spacecraft) could have some European contribution, but the path forward is not yet clear (in particular given current NASA funding situation).
- D/SCI is in touch with NASA (& other agencies) to understand priorities and schedules in all areas of Science that the European community has expressed an interest in.



Long heritage of Heliophysics missions continues -

- Cluster is soon coming to the end of an illustrious career, as part of the international geospace and heliospheric fleet
- Solar orbiter is demonstrating the power of an interdisciplinary payload (and combined mission science)
- SMILE will soon provide the community with global scale observations of the Sun-Earth interaction.

M7 proposals showed a strong engagement and interest from the Heliophysics community The Heliophysics archives, provide a wealth of scientific data from our operational missions and hold the legacy of our mission and great potential for continued science.

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