EPSC Abstracts
Vol. 18, EPSC-DPS2025-1753, 2025, updated on 06 Jun 2026
https://doi.org/10.5194/epsc-dps2025-1753
EPSC-DPS Joint Meeting 2025

Pallas Interstellar: A Dual-Purpose Mission to a Primordial Asteroid and the Local Interstellar Medium

Audrey Vorburger[1], Stas Barabash[2], Yoshifumi Futaana[2], Martin Jutzi[1], Antoine Pommerol[1], Martin Rubin[1], André Galli[1], Joseph O'Rourke[3], Julie Castillo-Rogez[4], Jonas Hener[5], Onur Çelik[5], Ralf Srama[6], Paolo Tortora[7], Sonia Fornasier[8], and Daniel Schmid[9]
[1]Physics Institute, University of Bern, Bern, Switzerland (audrey.vorburger@.unibe.ch)
[2]Swedish Institute of Space Physics, Kiruna, Sweden
[3]School of Earth and Space Exploration, Arizona State University, Tempe, CA, USA
[4]Jet Propulsion Laboratory, Pasadena, CA, USA
[5]Delft University of Technology, Delft, The Netherlands
[6]Institute of Space Systems, University of Stuttgart, Stuttgart, Germany
[7]Department of Industrial Engineering, University of Bologna, Bologna, Italy
[8]Observatoire de Paris-Paris Cité University, LESIA, Meudon, France
[9]Space Research Institute, Austrian Academy of Sciences, Graz, Austria

We present “Pallas Interstellar”, an ESA M8-class mission concept with a dual scientific focus: the detailed exploration of asteroid (2) Pallas and the in-situ investigation of the local interstellar medium beyond 2 AU. By integrating a high-speed flyby of Pallas with a cruise phase optimized for pristine interstellar sampling, remote sensing of the interstellar interface, and using dual-purpose, complementing instrumentation, this mission offers a unique opportunity to address foundational questions in both planetary science and astrophysics within a single mission.

Pallas is a uniquely compelling target as a likely intact protoplanet and the probable parent of an impact family that includes several near-Earth asteroids. It is the third most massive body in the main asteroid belt, containing ~7% of the main belt’s total mass. Pallas is further distinguished by its high orbital inclination (34.8°), primitive B-type spectral classification, and a bulk composition that is likely intermediate in volatile content between that of Ceres and Vesta—the two protoplanets previously explored by the Dawn mission. Spectroscopic data from ground- and space-based observatories indicate the presence of hydrated minerals and carbonates on Pallas, suggesting early aqueous alteration processes. Yet its relatively high albedo and lack of key absorption features hint at substantial surface processing, possibly due to high-energy impacts. These conflicting signals raise fundamental questions about its internal structure, volatile inventory, and thermal evolution—questions that cannot be answered without direct spacecraft observations.

Our proposed flyby, timed near Pallas’ ecliptic crossing, exploits optimal illumination conditions and minimal spacecraft trajectory inclination change. It delivers high-resolution imaging, infrared spectroscopy, neutron spectroscopy, gas and dust mass spectrometry, and radio science to determine the surface composition, map hydrated minerals, detect (potential) outgassing, and constrain Pallas’ bulk structure, porosity, and mass. Crater distribution and basin morphology are analyzed to reconstruct Pallas’ violent collisional history, shaped by its dynamically excited orbit and high-speed impact environment. Together, these data help determine the extent to which Pallas underwent internal differentiation and preserved a primitive volatile inventory—key constraints on models of early planetary accretion. Furthermore, in situ magnetic field and plasma measurements help us to understand how Pallas interacts with the solar wind plasma, constrain the internal conductivity structure and determine whether it retains strong remanent magnetization from a formation among nebular fields in the protoplanetary disk. These observations also constrain the properties of any potential neutral gas envelope and enable the detection of possible outgassing activity.

Beyond the asteroid encounter, the spacecraft traverses a region of the Solar System (>2–3 AU) where heliospheric interference with the interstellar medium is substantially reduced. This cruise phase enables transformative interstellar science. A neutral mass spectrometer is targeted at detecting and characterizing inflowing interstellar neutrals, including species like H, D, O, and others, which are difficult to observe at 1 AU due to solar ionization losses and radiation pressure. A dust analyzer samples interstellar grains with statistically significant numbers, constraining their size distribution, composition, and dynamical filtering processes. An energetic neutral atom (ENA) imager remotely senses the global structure of the heliospheric boundary, benefiting from reduced background levels and improved parallax geometry. A plasma and magnetic field suite provides essential context for solar wind and pickup ion conditions at heliocentric distances rarely visited by dedicated heliophysics missions.

We will further evaluate options for enhancing the mission's scientific return. Specifically, we will analyze the trade-offs of (i) adding a second Pallas flyby for temporal evolution studies, (ii) targeting a second, potentially active, asteroid in the main belt, and (iii) extending the heliocentric distance to prioritize interstellar measurements. We will also investigate the addition of a kinetic impactor—either passive or active—to excavate and analyze subsurface material during the Pallas flyby, balancing its added complexity against potential breakthroughs in understanding volatile retention and regolith stratigraphy as well as surface material mineral and isotope composition.

By linking the preserved record of planetary accretion on Pallas with direct sampling of our galactic surroundings, this mission illuminates how early Solar System evolution was shaped by both internal processes and external astrophysical environments. It also establishes a pathfinder model for dual-purpose planetary and heliophysics missions operating beyond Earth orbit—critical for advancing ESA's scientific vision into the 2030s and beyond.