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Heavy Metal – Exploring a magnetized metallic asteroid

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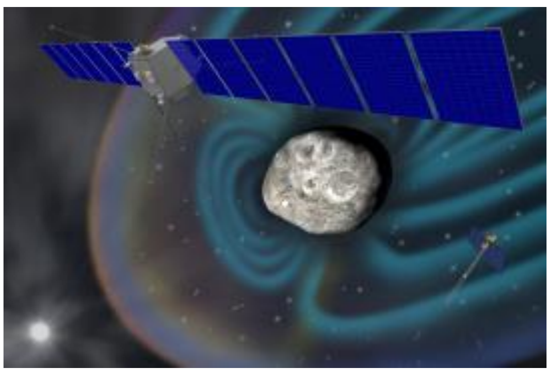
Abstract

This is an ESA/M5 proposal for a spacecraft mission to orbit and explore *(16) Psyche* – the largest M-class metallic asteroid in the main belt. Recent estimates of the shape, ~279×232×189 km and mass, ~2.7×10^{19} kg of *(16) Psyche* make it one of the largest and densest of asteroids, ~4.5 g cm^{-3}, and together with the high surface radar reflectivity and the spectral data measured from Earth it is consistent with a bulk composition rich in iron-nickel. *(16) Psyche* orbits the Sun with semi-major axis 2.9 AU, 3º inclination, and is as yet unexplored in-situ.



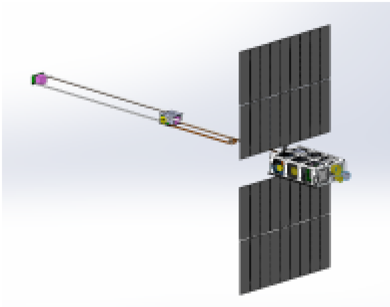
1. Science Objectives

The ESA/M5 mission *Heavy Metal* will investigate if *(16) Psyche* is the exposed metallic core of a planetesimal, formed early enough to melt and differentiate. High-resolution mapping of the surface in optical, IR, UV and radar wavebands, along with the determination of the shape and gravity field will be used to address *the formation and subsequent evolution of (16) Psyche, determining the origin of metallic asteroids*. It is conceivable that a cataclysmic collision with a second body led to the ejection of all or part of the differentiated core of the parent body. Measurements at *(16) Psyche* therefore provide a possibility *to directly examine an iron-rich planetary core, similar to that expected at the center of all the major planets including Earth*. Meanwhile, comparison with the terrestrial meteorite record will address *whether metallic asteroids are the parents of magnetized iron meteorites*. A short-lived dynamo producing a magnetic field early in the life of *(16) Psyche* could have led to a remnant field (of tens of micro Tesla) being preserved in the body today.

Like the large-scale magnetospheres of the Earth, Mercury, etc. and the induced magnetospheres of Venus and Mars, *(16) Psyche* is embedded in the variable flow of the solar wind. Whereas these planetary magnetospheres and induced magnetospheres are the result of intense dynamo fields and dense conductive ionospheres presenting obstacles to the solar wind, *(16) Psyche* may show an entirely new 'class' of interaction as a consequence of its lack of a significant atmosphere, the extremely high bulk electrical conductivity of the asteroid, and the possible presence of intense magnetic fields retained in iron-rich material. The small characteristic scale of *(16) Psyche* (~200 km) firmly places any solar wind interaction in the "sub-MHD" scale, in which kinetic plasma effects must be considered. *Heavy Metal* will *investigate if (16) Psyche has an extended magnetosphere* by mapping the local plasma density, composition, energy state and dynamics around the body, along with the magnetic field. By accurately mapping any internally retained magnetic field of *(16) Psyche*, we will address *the origin of any magnetization* (the possible remains of an early magnetic dynamo).

1.1 Need for a 6U CubeSat companion

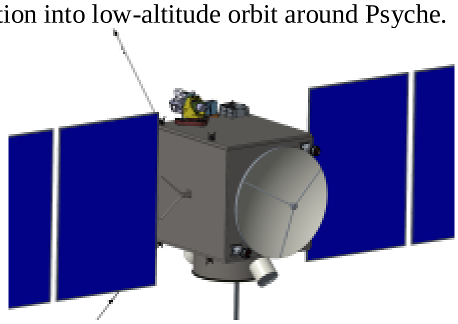
The possibility of remnant magnetization of the asteroid occurring only in localized regions, or otherwise being 'disordered' necessitates magnetic measurements close to the surface. A close approach (<100 km to the surface) with the main spacecraft is difficult due to the potentially complex gravity field and rapid rotation period of 4.2 hours of the irregular shaped asteroid. We propose instead to use a 6U CubeSat companion spacecraft to be inserted into a lower-altitude orbit for a short duration (1 month) before it makes a controlled crash toward the surface. This will facilitate near surface measurements of the magnetic field, the composition of any volatile products and produce truly high-resolution pictures of the surface, complementing the extensive measurements by the main spacecraft further away. Additionally, simultaneous measurement of the magnetic field at both the CubeSat and the main S/C will allow a detailed study of the induction of electrical currents in the asteroid surface by the solar wind.



2. The Spacecraft Mission

The *Heavy Metal* spacecraft will be launched from Earth with an Ariane 6.2 rocket in the time window 2029 – 2031, and by using electric propulsion, along with a possible gravity assist manoeuvre by Mars, arrive at *(16) Psyche* some 4 – 4.5 years later. The S/C is then planned to orbit the body for a period of 1 year, doing science operations, where after it may be sent to the surface for a controlled crash. During the nominal science operations, the main platform will orbit as close as 300-500 km from the centre of *(16) Psyche*.

Spacecraft: 3-axis stabilised, 45 m^2 solar array, launch mass 1430 kg. Carry a 6U CubeSat for insertion into low-altitude orbit around Psyche.



3. Science Instruments

Main S/C Instrument	PI / Institute
Optical Imager (NAC)	N. Thomas U. Bern, CH
Wide Angle Camera (WAC)	J. Trigo-Rodriguez CSIC-IEEC, Barcelona, ES
Infrared Imager / Spectrometer (IR)	M. C. De Sanctis INAF-IAPS, Roma, IT
UV Spectrograph (UVS)	K. Retherford SwRI, San Antonio, US
(Sub-)Surface radar	A. Herique IPAG, Genoble, FR
Magnetometer (MAG)	A. Masters Imperial College, London, UK
Plasma Spectrometer Package	Y. Futaana IRF, Kiruna, SE
Electric field & Cold Plasma	D. J. Andrews IRF, Uppsala, SE
Radio Science Experiment	P. Tortora U. Bologna, IT
CubeSat Instrument	**PI / Institute**
Narrow Angle Camera (NAC)	J. Trigo-Rodriguez CSIC-IEEC, Barcelona, ES
Volatile Composition Analyser (VCA)	Y. Futaana IRF, Kiruna, SE
Magnetometer (MAG)	N. Ivchenko KTH, Stockholm, SE

4. Summary and Conclusions

Heavy Metal is a mission of exploration to one of the major unexplored solar system bodies, and a potential window into conditions and processes in the early solar system, the formation of the terrestrial planets and their metal rich cores. Simultaneously, it will lead to new insights in space plasma physics and the interaction of magnetised bodies with the solar wind. The mission clearly falls within the scope of the ESA Cosmic Visions programme by addressing the major questions, *"What are the conditions for planet formation and the emergence of life?"* and *"How does the Solar System Work?"*.

Acknowledgements

The *Heavy Metal* team acknowledges the support from the Swedish National Space Board (SNSB) for financing the industrial study support from OHB-Sweden in preparation of this proposal. The contact persons of the *Heavy Metal* spacecraft and mission study at OHB-Sweden are Peter Rathsman and Stefan Lundin. Support has also been given from ÅAC Microtec in Uppsala regarding the CubeSat mission and design. The contact person there is Emil Vinterhav.

Website for the *Heavy Metal* project: http://www.irfu.se/Heavy_Metal