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European component of the AIDA mission: science investigation of a binary system

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Abstract

The European component of the Asteroid Impact & Deflection Assessment (AIDA) mission has been redesigned and is called Hera hereafter. Hera is a small mission of opportunity built on the previous AIM concept, whose objectives are to investigate a binary asteroid, the outcome of a kinetic impactor test, and thus to provide extremely valuable information for asteroid impact threat mitigation and science purposes [1]. The second component of AIDA is NASA's DART mission [2]. The target is the binary near-Earth asteroid (NEA) (65803) Didymos. In particular, its secondary is the target of the DART mission. With its 163 m-diameter, it allows for the first time to gather detailed science data not only from a binary asteroid but also from the smallest asteroid ever visited.

1. Introduction

The science return of Hera is similar to that of AIM [1] except for the direct measurement of the internal structure from a low-frequency radar instrument placed on the surface of the asteroid, which is not included in the current Hera baseline [3].

2. Science return

Although the requirements for Hera are focused on planetary defense, the bonus science return from this mission will be outstanding as it will include:

- First detailed images of a binary asteroid in orbit, offering informed constraints to models describing binary formation and dynamics, and verifying/constraining predictions from the radar shape model.
- First images and in-situ compositional analyses of the smallest asteroid ever visited, enabling the determination of the geophysical and compositional properties of such a small body compared to larger ones.
- Understanding of physical/compositional properties and geophysical processes in low gravity, with implications for our understanding of small-body surface properties and their evolution.
- First documentation of an asteroid-scale impact outcome (from DART), orders of magnitude beyond laboratory scales.

The last item will provide crucial data to validate numerical simulations of hyper-velocity impacts that are used in planetary science (planet and satellite formation, impact cratering and surface ages, asteroid belt evolution). It will offer new constraints for collisional evolution models of small-body populations and planetary formation.

About 15% of NEAs larger than 200 m in diameter are binaries, and many of these may be similar to Didymos. Therefore, some systematic process is expected to be at the origin of the creation of such systems. According to current knowledge, the YORP spin-up of a rubble pile is the most likely process. The characterization of Didymos by Hera will provide information not only about an individual asteroid but also about a sizable fraction of near-Earth and potentially hazardous asteroids.

Hera will perform the geophysical characterization of the target. A big step will be achieved in our knowledge in such a low-gravity environment, in terms of shape, mass (and density), surface features, presence and kind of surface regolith, crater abundance and size distribution, boulder size distribution down to the resolution limit of the camera, as well as local slopes.

In addition to surface properties, indirect information on the internal structure will be obtained. Surface images allow for the evaluation of surface structures, such as lineaments, crater shapes, crater ejecta, boulder existence/distribution, and mass wasting features. From these features, information on material strength, cohesion, porosity, etc., can be derived both for the asteroid regolith and interior. For instance, if the largest boulders found at the surface are comparable in size to the asteroid itself, this can indicate that they were produced during a catastrophic disruption or reaccumulation event (like in some binary formation scenarios), and the asteroid is more likely to have a rubble-pile structure. The Radio Science Experiment will also contribute to internal structure estimates.

3. Conclusion and main message

Hera provides a robust and cost-effective means to perform a planetary defense validation test with a solid balance between risk and innovation. In the frame of the AIDA collaboration, Hera contributes to a truly international planetary defense initiative. It will bring completely new knowledge and insights on asteroid science that will be of great benefit not only to the planetary defense community as a whole but also to those seeking a deeper understanding of the processes underlying solar system formation. Hera builds upon a unique knowledge base gained in Europe with the Rosetta mission on close-proximity operations and offers a great opportunity to develop them further by increasing on-board autonomy and testing new technologies developed for future in-orbit servicing missions.

We note that: (1) NASA's New Frontier OSIRIS-REx sample return mission is on its way to the asteroid Bennu. Two other asteroid missions, namely Psyche to the metallic asteroid of the same name and Lucy to Trojan asteroids, have been selected in its Discovery program. Finally the CAESAR sample return mission to the comet 67P/Churyumov-Gerasimenkos pre-selected in the New Frontier program for a one year study with final selection at the end of 2018, for a possible launch in the mid-2020s; (2) JAXA's Hayabusa-2 sample return mission is currently visiting the asteroid Ryugu, and two other Japanese small body missions are under study, namely the sample return mission MMX to the martian moon Phobos and OKEANOS to Trojan asteroids; (3) CNSA is planning several sample return missions, including to the Moon and to Near Earth Asteroids.

Given the demonstrated international interest in small body science and all the studies and efforts made in Europe since the early 2000s, starting with the Don Quijote study (asteroid deflection test), the MarcoPolo and MarcoPolo-R studies (asteroid sample return) and the AIM study, this is the right time for the next European small body mission. Hera is a great opportunity to demonstrate that Europe keeps being on the front of small body research and maintains the visibility and expertise gained with Rosetta. A mission like Hera will certainly fire the imagination of young people and adults, as the science is accessible and understandable and is associated with fascinating challenges and goals.

Acknowledgements

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