A mission concept for in-orbit particle collection around asteroids

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Abstract. This work presents a new mission concept for sample collection missions around asteroids. Starting from the heritage of mission Hayabusa2, a kinetic impactor is used to generate fragments, which are then collected in orbit. The work discusses the feasibility of the mission, possible collection strategies, and the preliminary concepts of operations.

Keywords: Asteroid, Ejecta, Sample Collection.

1 Introduction

Space exploration missions to asteroids have always drawn the attention of the scientific and engineering community given the challenges they pose and the possibility they present to further our knowledge of the Solar System. Asteroids carry fundamental information on the evolution of our Solar System. They are rich in valuable resources such as metals, silicates, and water, which could be exploited through future asteroid mining missions, and enable long-duration mission self-sustaining. The physical composition of asteroids remains, in most cases, poorly understood with the means available from ground. Space missions can be exploited to improve the knowledge by collecting and studying samples of asteroids. Several missions have visited asteroids and other small bodies; however, only few have orbited, landed, or impacted on them. Examples are JAXA missions Hayabusa and Hayabusa2, ESA Rosetta, and NASA OSIRIS-REx and DART. One of the most challenging aspects of such missions is to collect and sample asteroids material by means of an on-ground collection, involving landing (or touchdown) and mining. Starting from the heritage of Hayabusa2, which successfully reentered a capsule with asteroid sample in Australia, we envision the possibility to explore new approaches for asteroid particle collection.

In this context, starting from the heritage of the Hayabusa2 mission [1], we propose a novel mission concept (Fig. 1) in which the spacecraft hits the asteroid using a small kinetic impactor. Such an impact will generate a plume of ejecta, similar to the one produced by the impact of the Small Carry-on Impactor (SCI) of Hayabusa2 on asteroid Ryugu. However, differently from Hayabusa2, we envision the possibility of collecting the fragments of the plume directly in orbit; therefore, without landing or touch down. This mission concept is part of the Horizon-2020 Marie Skłodowska-Curie Action CRADLE (Collecting Asteroid-Orbiting Samples) [2].

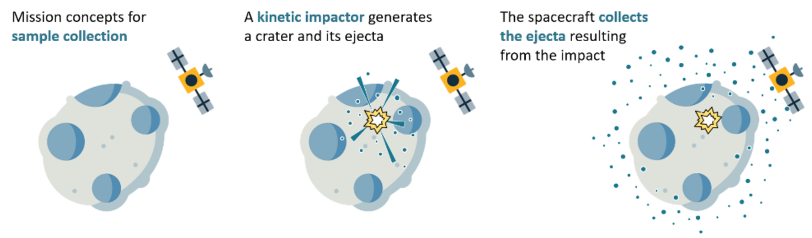

Fig. 1. Schematics of the mission phases.

2 Methodology

To assess the possibility of collecting the particles generated by the impact, it is necessary to study their motion and understand how they distribute in time around the asteroid under the effect of the perturbations. Specifically, we estimate the flux of particles around the asteroid in time (Fig. 2) so that, knowing the position and surface of the spacecraft, we can estimate the number of particles the spacecraft can collect. This is achieved, first, by modelling the impact phenomenon via a distribution function [3]. The distribution is used to draw weighted samples for the fragment cloud that are then propagated, and their trajectories stored at snapshots in time. These weighted samples are then used to estimate the particle density and speed of particles around the asteroid, which are needed to obtain the fluxes.

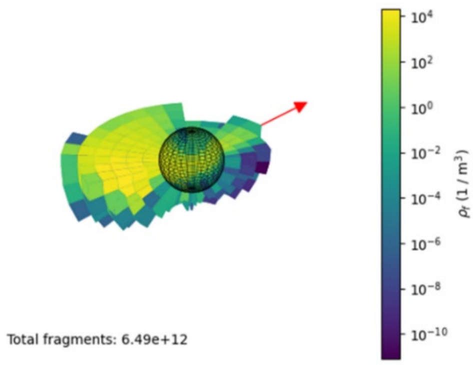

Fig. 2. Density of fragments around Ryugu 1 hour after the impact.

This methodology is used to identify what the regions with the highest concentration of fragments as function of time are, so to select the best location for collection for the spacecraft. Alongside the collection regions, in this presentation we discuss different collection scenarios, their characteristics, and the corresponding operational constraints with the aim of deriving the requirements for the spacecraft design.

Acknowledgments

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References

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