HAYABUSA 2 IMPACT EXPERIMENT: FATE OF THE ASTEROID RYUGU EJECTA

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Abstract

After the success of Hayabusa mission, in December 2014, JAXA launched Hayabusa2 sample and return mission to Ryugu asteroid. Hayabusa2 spacecraft is currently in its interplanetary cruise phase, and it is scheduled to reach the asteroid Ryugu in 2018. The spacecraft is equipped with a small kinetic impactor aiming to investigate the properties of Ryugu internal materials. Hayabusa2 spacecraft will deploy scientific instruments to attempt the observation of the impact event, while the mother spacecraft will be placed in a safe location far from the impact point. Asteroid Ryugu is composed by highly porous material where cm size are likely to be ejected after the impact event. Natural impact phenomena on asteroid P/2010 observed from Rosetta spacecraft suggest that dust particles of 1 cm size in diameter can be captured for several months in orbit around the asteroid. This pose concern in the safety of Hayabusa2 spacecraft.

Introduction

During the asteroid proximity operations, Hayabusa2 spacecraft is set to a base position, Home Position (HP), at 20 km above the asteroid facing the sub-Earth direction (hoveing point). All operations such as trajectory conjunction manoeuvre, gravity measurement and fly-around observation, cratering and touch down start from HP and return to HP position after each mission operation. Hayabusa2 spacecraft is equipped with a Small Carry or Impactor (SCI), and it is expected to create a crater of 2-3 m size to allow the sampling of substrate asteroid materials. The SCI is a compact kinetic impactor released along the HP z-axis at 500 km from the asteroid surface to create an artificial crater on it with an impact velocity of 2 km/s. This work investigates the hazard posed by the asteroid ejecta dynamics to Hayabusa2 spacecraft. The fate of the asteroid ejecta is here investigated through numerical modeling for diameter-size dust particles of 0.01, 0.1, 1, and 1 cm. A high fidelity dynamical model is used to observe with numerical experiment if the ejecta can naturally follow long-term stable orbits that can preclude the spacecraft to touchdown the asteroid surface for collecting samples. Together with the numerical experiments, the dynamics close to the asteroid 1:1 resonance are here explored. Under the solar radiation pressure effect, numerical evidence of the presence of dynamical substitutes for Ryugu asteroid when the system is no longer autonomous are shown. The dust ejecta is also displayed in the Hill reference frame to verify if with our set of initial conditions dust particles can be trapped in terminator orbits.

High Fidelity Model

The equations of motion of the dust particles were studied mainly in the perturbed two-body problem both in the rotating (ACAF) and in a referential (ACF) reference frames centered at the asteroid. At a first approximation, the asteroid gravity was modeled using the triaxial ellipsoid harmonics (harmonics). As main perturbations, it was considered the effect of solar radiation pressure and the Sun gravity perturbation. The NASA Spire Toolkit was used to download the ephemerides of Ryugu, the Earth, and the Sun. At first, the dynamics of the four selected size of dust particles was studied in the ACF reference frame under the effect of solar radiation pressure perturbation near the stable 1:1 resonances (Figure 4) where the perturbation is shown in Figure 2. Figure 3 and 4 show the dynamics around the center for particles of 0.01 and 0.1 cm in diameter when the effect of SRP is taken into account. Diameters less than 0.01 cm break the stability showing an unstable impact trajectory. Figure 3. There is numerical evidence that particles with diameter major of 0.1 cm stay in a stable orbit close to the previous center equilibrium by suggesting the presence of a dynamical substitute.

Fate of Ejecta

The evolution of the ejecta after the SCI impact is investigated. The uncertainties in the impact point is identified through the initial Gaussian distribution in the mother spacecraft position (Figure 5.a) and velocity when the SCI is released. The SCI is released at a reference altitude of 510 m from the asteroid surface along the z-axis of the HP reference frame. The equations of motion are then integrated to identify the possible impact points of the SCI. For each impact point, the model of crater in Figure 5.b is used where the initial state of the ejecta is found through empirical laws. Once the initial state of the ejecta is determined, the equations of motion have been integrated for 30 days and the trajectory of the ejecta is shown in the ACF, Figure 5.c, ACF, Figure 5.d, and Hill, Figure 5.e, reference frames. This is done to check if with this set of initial conditions, dust particles can stay in orbit around the asteroid for long time. The same study is done for four different size of dust particles of 0.01, 0.1, 1 and 10 cm. A total of 51 impact are considered (the reference case) and for each impact 10,000 simulations have been run for each size particles with a total of 204,000 solutions investigated.

Discussion

Figure 7 shows the ToF as function of the x and angle coordinates. As one can see, there is an evolution of the picks. For very short ToF the longest dynamics are close to 0° and 360°. The more the ToF increases the more the picks tends to shift closer to 180°. Figure 8 shows the x coordinate evolution as function of the angle where a ToF of 22 chs is the longest for dust particles in 0.1 cm size. Although this study shows that for the cases analysed there is no risk for Hayabusa2 spacecraft after the SCI impact, further studies have to be carried out to finalise the stable regions around Ryugu and at which conditions on the asteroid surface particles can get there. A fully understanding of the dynamics around Ryugu using the asteroid shape model (polyhedron) is therefore necessary to have a high order precision of the dynamics close to the asteroid surface.

Conclusions

This research assesses the hazard posed by Ryugu ejecta dynamics on Hayabusa2 spacecraft. First, the dynamics close to the 1:1 resonances in the ACF reference frame are investigated under the effect of the solar radiation pressure perturbation. When solar radiation pressure is taken into account, the dynamics cease to be autonomous, therefore dynamical substitutes of the equilibrium points seem to appear in their replacement. A numerical analysis was performed in the ACF reference frame where the effect of SRP and the Sun gravity was taken into account. Uncertainties in the impact point of the SCI and a model for the impact dynamics was used to initiate the motion of the ejecta from the launching site. This study shows that particles of diameter size of 0.01, 0.1, 1 and 10 cm will leave the asteroid orbit in 40 hours.

References


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