The contribution of impact cratering in the production of regolith on asteroid surfaces: first application to the targets of AIDA and Hayabusa2 missions

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Space missions and thermal infrared observations show that asteroids are generally covered by a layer of centimeter-sized or smaller particles, which constitute the regolith. The formation of regolith generation has traditionally been attributed to the fall back of impact ejecta and by the break-up of boulders by micro-meteoroid impact. However, it has recently been found that thermal fatigue, induced by the diurnal temperature variations on asteroid surfaces, is an efficient mechanism of regolith production (Delbo et al. 2014). However, the relative contributions of impacts and thermal fatigue to regolith production is still not well established. Furthermore, the possible difference in regolith properties depending on the regolith formation mechanism is still not determined. Thus, more research is required to determine both the relative influence of the different mechanisms of regolith production, and the resulting regolith properties that may differ from one mechanism to the other.

We have developed a model to follow the fate of ejecta from a cratering event, accounting for solar tides, the asteroid’s gravity and the solar radiation pressure (Yu et al. 2017). The original objective was to determine the safest zones of observations for an observing spacecraft, in the framework of the AIDA mission study, or to protect a visiting spacecraft aimed at returning a sample, in the framework of the Hayabusa2 mission study.

The AIDA mission is a joint-collaboration between ESA and NASA, which aims at performing a test of deflection by a kinetic impactor of 600 kg at 6 km/s, using as a target the secondary (160 meters in diameter) of the binary asteroid Didymos, in 2022 (Cheng et al. 2016, Michel et al. 2016). The Hayabusa2 mission was launched on December 3, 2014, to the asteroid Ryugu (900 meters in diameter), and carries the Small Carry-on Impactor (SCI), which aims at performing an impact on the asteroid surface in 2019, using a 2-kg projectile launched at 2 km/s (Arakawa et al. 2017), and returning samples to Earth in 2020.

We applied our model to both scenarios. We defined various possible ejecta initial conditions (ejection velocities, size distribution) based on cratering scaling laws. We then followed the ejecta dynamics and fate as a function of the launching site on the asteroid. In both cases, we find that a small but non-negligible fraction of ejecta (up to 25% in the considered cases) contributes to the regolith by falling back on the asteroid’s surface. In the case of the binary Didymos, both the primary and the secondary experience re-accumulation of ejecta launched from the secondary.

Future work will be devoted to the investigation of a larger parameter space in terms of impact speeds, scaling law assumptions, asteroid’s size ... In parallel with studies of other regolith production mechanisms, this will allow us to better understand the relative contribution of all mechanisms as a function of asteroid’s size and history, and their implications on regolith properties. These studies will also allow us to be best prepared to interpret asteroid surface images sent by both NASA OSIRIS-REx and JAXA Hayabusa2 missions from 2018 to 2020, and possibly AIDA in 2022.

References: Arakawa et al. 2017, Space Science Review; Cheng et al. 2016, Plan. Space Sci. 121, 27-35; Delbo et al. 2014; Michel et al. 2016, Adv. Space Res. 57, 2529-2547 ; Yu et al. 2017, Icarus 282, 313-325.

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