EPSC Abstracts
Vol. 13, EPSC-DPS2019-915-3, 2019
EPSC-DPS Joint Meeting 2019


EPSC
EPSC-DPS Joint Meeting 2019
15–20 September 2019 | Geneva, Switzerland

# First result of Hayabusa2 impact experiment on Ryugu

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## Abstract

The impact experiment on asteroid Ryugu by Small Carry-on Impactor (SCI) onboard Hayabusa2 was successfully accomplished on April 5$^{th}$, 2019. The growth of an ejecta curtain at the impact point was clearly imaged by Deployable Camera 3 (DCAM3). The 10-m class artificial crater formed by the impact was observed by Optical Navigation Camera (ONC) during a subsequent low-altitude operation of the spacecraft. These results are going to be applied for verifications of the planetary impact theories, as well as for investigations of the material and physical condition of the subsurface.

## 1. Introduction

The Japanese asteroid explorer Hayabusa2 arrived at C-type asteroid Ryugu in June, 2018. The initial observations have revealed the unexpected nature of the top-shape and boulder-rich surface of this asteroid. Ryugu, and also Bennu explored by NASA OSIRIS-REx, have many craters with morphologies consistent with impact origin, and their low number densities for smaller craters suggest that their surface is relatively young [1,2]. However, their specific age estimates depend strongly on the crater scaling law on asteroids. In the first year of the asteroid rendezvous phase, Hayabusa2 succeeded several special operations including a first touch-down, and the impact experiment by Small Carry-on Impactor (SCI) and Deployable Camera 3 (DCAM3) as one of the most complicated events.

## 2. Scientific objectives

The mission objective of SCI is to expose a subsurface material as ejecta deposits around the crater, as well as on the crater floor by excavating the asteroid surface. It enables us to provide a good opportunity for the sampler to collect subsurface materials which are expected to be fresher than the surface materials. The remote-sensing instruments also have a chance to observe the exposed subsurface materials. Concurrently, the impact experiment gives us a rare opportunity to verify the conventional crater scaling laws at microgravity and on the real asteroid materials, especially for the crater size and the ejecta velocity distribution [3].

The scientific objective of DCAM3 focuses on the crater formation process: observations of size, shape, and amount of ejecta, and their growth with time. These results are used to verify the ejecta scaling law, and they could reflect physical properties of the subsurface layer, such as strength, particle size, and porosity. Thus, DCAM3 might provide information of the subsurface condition masked by a plenty of boulders.

## 3. Instrument and operation

SCI is a separable unit of a 30-cm cylinder shape containing explosive of 4.7 kg for acceleration of the projectile [4]. DCAM3 is also a separable unit of a 10-cm circular cylinder containing two independent systems: a real-time low-resolution camera system (DCAM3-A) and a high-resolution scientific camera system (DCAM3-D) [5]. In the impact experiment, SCI was separated from the spacecraft and launched a copper projectile of 2 kg onto Ryugu at 2 km/s to make an artificial crater. Before the SCI impact, DCAM3 was also separated at a position of about 1-km distance from the collisional location and took side-view images of the impact, while the spacecraft hid behind Ryugu to avoid the debris.

Low-altitude remote-sensing observation tours by the spacecraft were also conducted before and after the impact experiment. Surface maps of images were made by Optical Navigation Camera - Telescope (ONC-T), Thermal Infrared Imager (TIR), and Near Infrared Spectrometer (NIRS3) at 1.7 km altitude, and the images of both tours were compared to identify the newly excavated crater.

# 4. Ejecta and crater

Figure 1 shows the first DCAM3-D image that was taken at approximately three seconds after the projectile collision. The impact ejecta of an inverted truncated cone shape, so-called "ejecta curtain," generated from the surface was clearly found. It indicated that the impact occurred on rather "non-cohesive" surface, not a hard rock. The ejecta curtain at three seconds had an asymmetric shape, and this feature is hardly explained by an oblique impact because the impact angle was estimated to be > 45º with respect to the local horizontal plane.

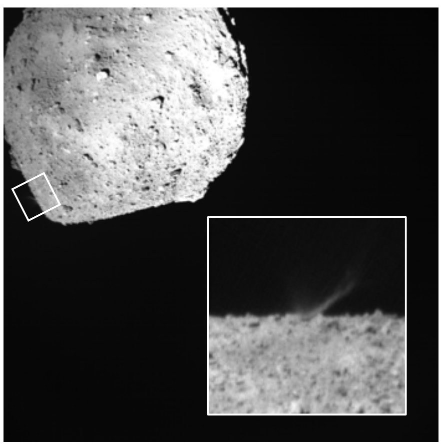

Figure 1: The first image of the impact ejecta taken by DCAM3-D, at about three seconds after the impact.

An image of the new crater is shown in Figure 2. This image was taken by ONC-T in the low-altitude operation at 1.7 km altitude. By comparing with images in the pre-impact observation, the excavated topography and surrounding dark splashes were newly found in the post-impact images. A crater rim also appeared as a part of a semicircle in the image. The estimated location of the crater rim is shown as a dashed curve. The crater size was ~15 m in diameter from a point on the rim to an opposite.

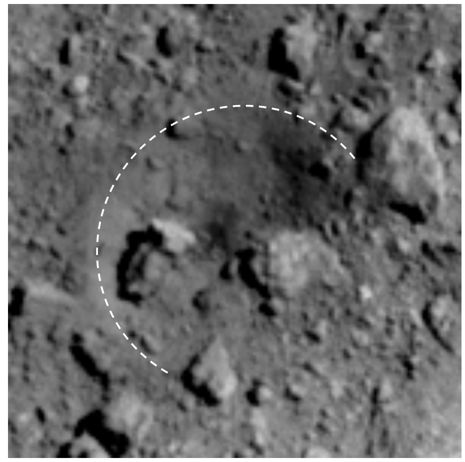

Figure 2: The image of the SCI artificial crater taken by ONC during the low-altitude operation after the impact experiment.

The impact point (i.e., the center of the semicircle) is estimated to be on the rough surface covered with pebbles, or on the edge of the large boulder. It is considered that the large boulder closely located at the impact point interfered the cratering process, and stopped excavation on the right bottom side. This is consistent with the asymmetric shape of the ejecta curtain seen in Figure 1. Since the estimated crater size is almost the same as that predicted on the ideal sand field [3], the formation of such a large crater is surprising on the pebble or boulder-rich field on Ryugu, and it has an impact on studies of the cratering physics and Ryugu's surface evolution.

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