Asteroid explorer, Hayabusa2, reporter briefing

May 9, 2019

JAXA Hayabusa2 Project

Topics

Regarding Hayabusa2,

- Results from the Crater Search Operation (Post-SCI)
- Science from the SCI collision experiment
- Future operations

Contents

0. Hayabusa2 and mission flow outline
1. Current status and overall schedule of the project
2. Crater Search Operation (Post-SCI) results
3. SCI collision experiment science
4. Future operation plans
5. Science related topics
6. Other topics
7. Future plans
・Reference material

Overview of Hayabusa2

Objective

We will explore and sample the C-type asteroid Ryugu, which is a more primitive type than the S-type asteroid Itokawa that Hayabusa explored, and elucidate interactions between minerals, water, and organic matter in the primitive solar system. By doing so, we will learn about the origin and evolution of Earth, the oceans, and life, and maintain and develop the technologies for deep-space return exploration (as demonstrated with Hayabusa), a field in which Japan leads the world.

Expected results and effects

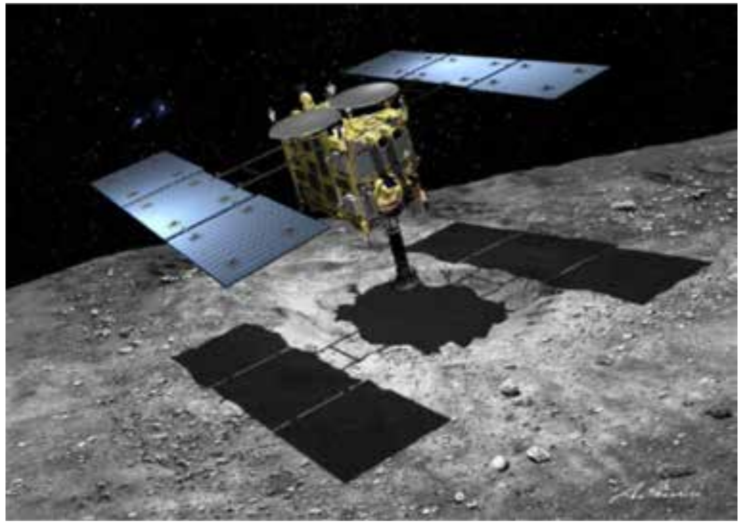
- By exploring a C-type asteroid, which is rich in water and organic materials, we will clarify interactions between the building blocks of Earth and the evolution of its oceans and life, thereby developing solar system science.
- Japan will further its worldwide lead in this field by taking on the new challenge of obtaining samples from a crater produced by an impacting device.
- We will establish stable technologies for return exploration of solar-system bodies.

Features:

- World's first sample return mission to a C-type asteroid.
- World's first attempt at a rendezvous with an asteroid and performance of observation before and after projectile impact from an impactor.
- Comparison with results from Hayabusa will allow deeper understanding of the distribution, origins, and evolution of materials in the solar system.

International positioning:

- Japan is a leader in the field of primitive body exploration, and visiting a type-C asteroid marks a new accomplishment.
- This mission builds on the originality and successes of the Hayabusa mission. In addition to developing planetary science and solar system exploration technologies in Japan, this mission develops new frontiers in exploration of primitive heavenly bodies.
- NASA too is conducting an asteroid sample return mission, OSIRIS-REx (launch: 2016; asteroid arrival: 2018; Earth return: 2023). We will exchange samples and otherwise promote scientific exchange, and expect further scientific findings through comparison and investigation of the results from both missions.



(Illustration: Akihiro Ikeshita)

Hayabusa 2 primary specifications

Mass	Approx. 609 kg
Launch	3 Dec 2014
Mission	Asteroid return
Arrival	27 June 2018
Earth return	2020
Stay at asteroid	Approx. 18 months
Target body	Near-Earth asteroid Ryugu

Primary instruments

Sampling mechanism, re-entry capsule, optical cameras, laser range-finder, scientific observation equipment (near-infrared, thermal infrared), impactor, miniature rovers.

Mission Flow

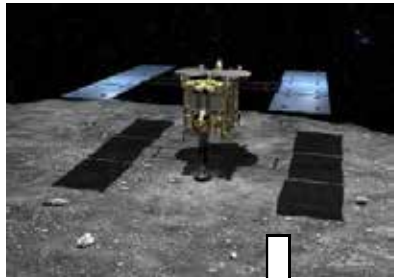
Launch → Arrival at asteroid

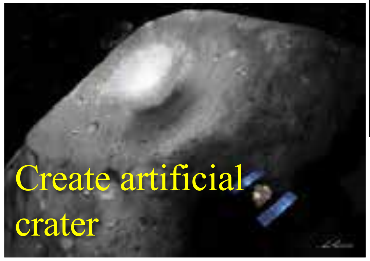
3 Dec 2014

Earth swing-by
3 Dec 2015

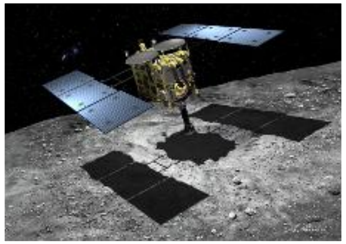
June 27, 2018

Examine the asteroid by remote sensing observations. Next, release a small lander and rover and also obtain samples from the surface.





Use an impactor to create an artificial crater on the asteroid's surface



After confirming safety, touchdown within the crater and obtain subsurface samples

Earth return ← Depart asteroid

late 2020

Nov–Dec 2019

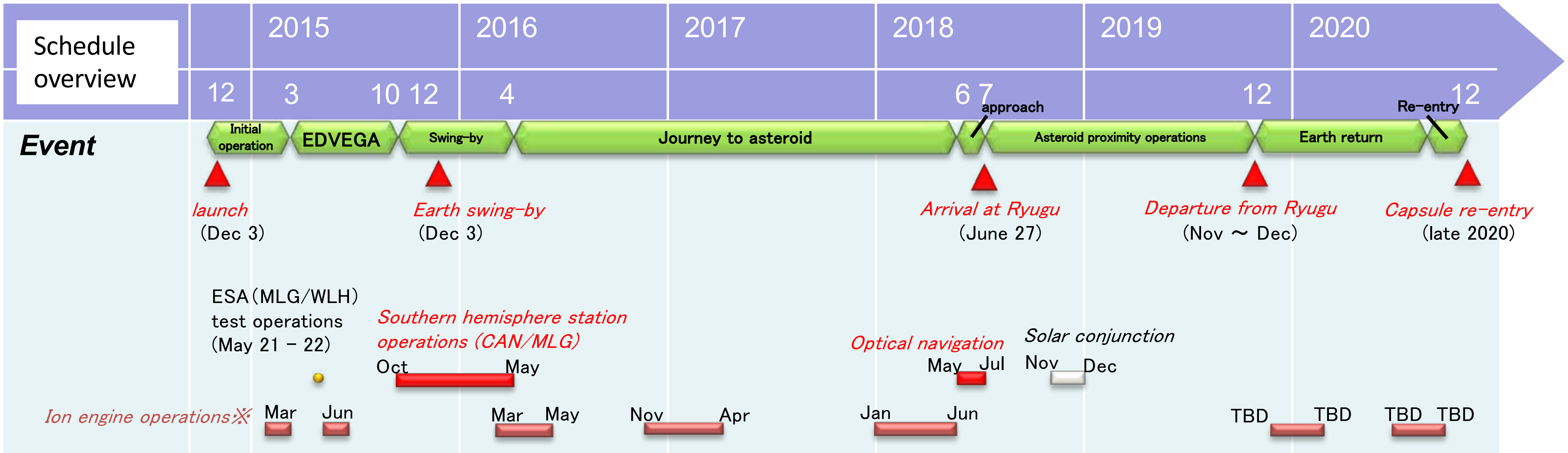
Sample analysis

(Illustrations: Akihiro Ikeshita)

1. Current project status & schedule overview

Current status：

- From April 23 ~ 25, the Crater Search Operation (Post-SCI) (CRA2) was performed to investigate the crater generated during the collision experiment.
- Future operation plans based on the results of the SCI operation.
- From May 14 ~ 16 a descent operation will be conducted to deploy a target marker.



2. Crater Search Operation (Post-SCI) results

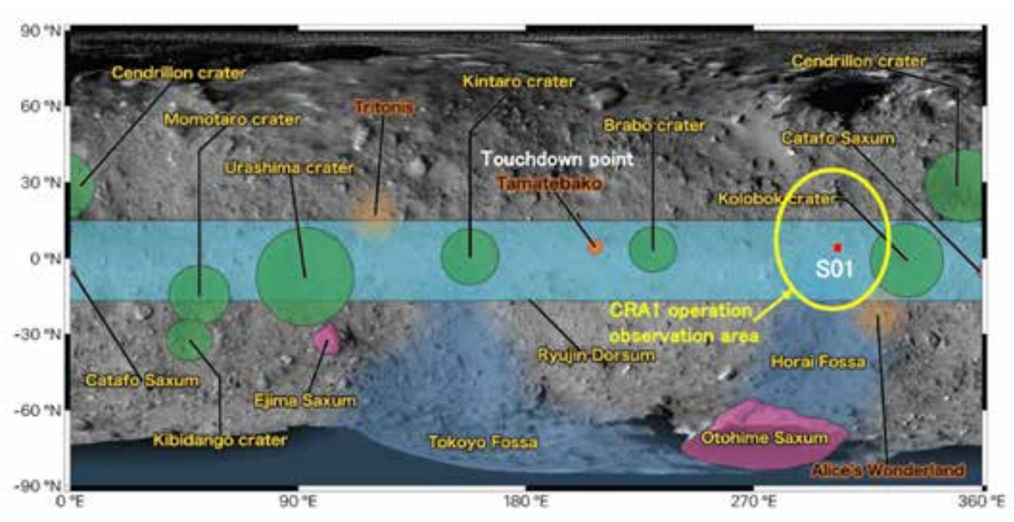
■Crater Search Operation (Post-SCI) (CRA2)

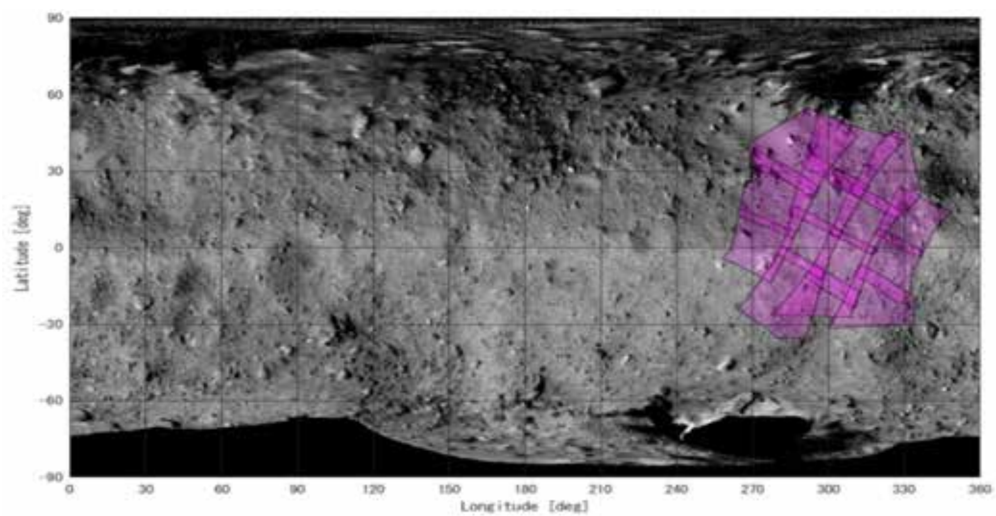
- Detailed data was acquired about the area where the Small Carry-on Impactor (SCI) appears to have collided.
- Operation：4/23～25
- Descent began 4/24 at 16:42 JST（onboard time）
- Reached a minimum altitude of approximately 1.7km on 4/25 at 11:16am JST（onboard time).

- Succeeded in imaging the crater → details in Chap.3
- The SCI generated the crater almost exactly on target.

2. Crater Search Operation (Post-SCI) results

CRA2 location



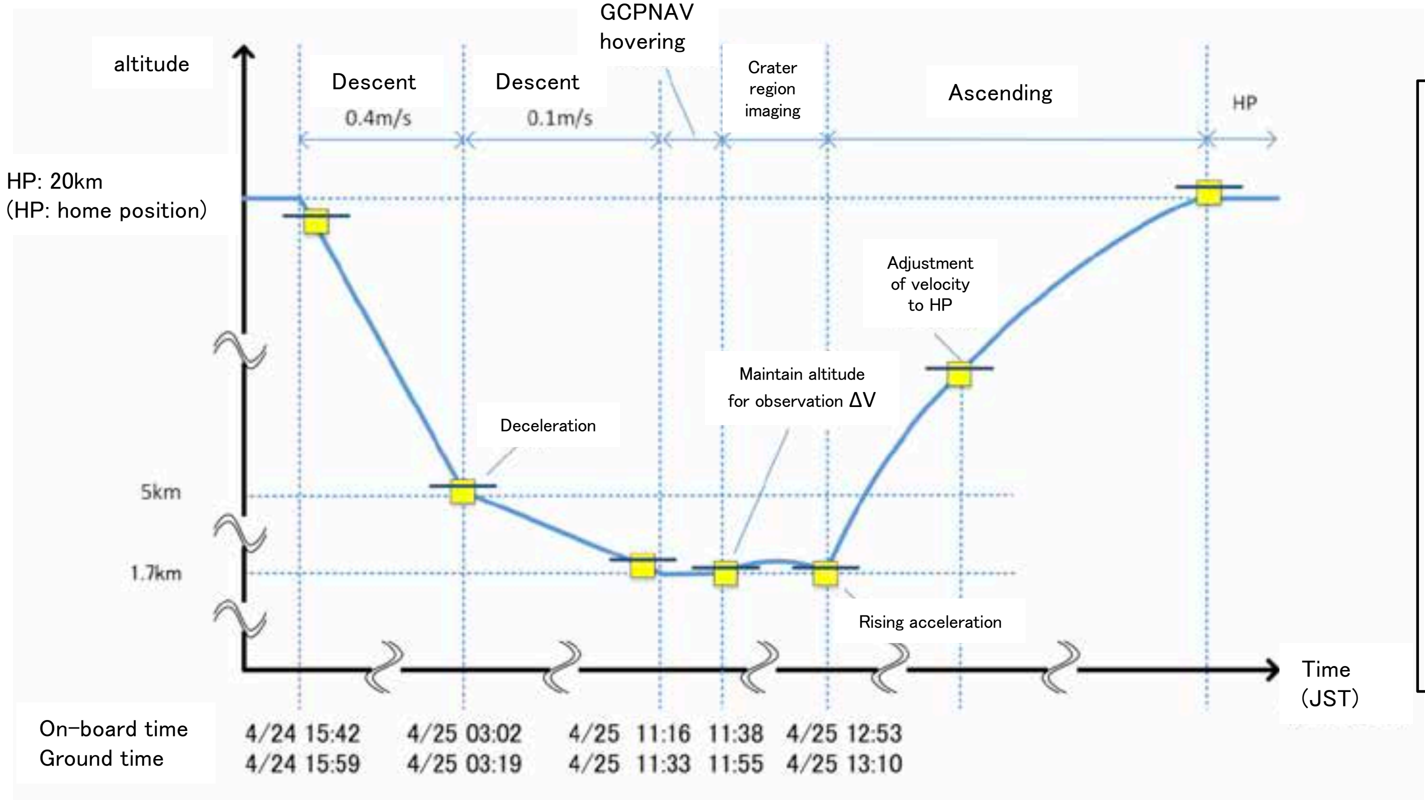


Note）The observation area for CRA2 is the same as the area observed in advance of the SCI operation by CRA1.

（Image credit：JAXA, University of Tokyo, Kochi University, Rikkyo University, Nagoya University, Chiba Institute of Technology, Meiji University, University of Aizu, AIST.)

2. Crater Search Operation (Post-SCI) results

Crater Search Operation (Post-SCI) (CRA2) results



- The observation were conducted while maintaining an altitude of about 1.7km.
- Detailed data was acquired on the area thought to be where the crater was generated by the SCI

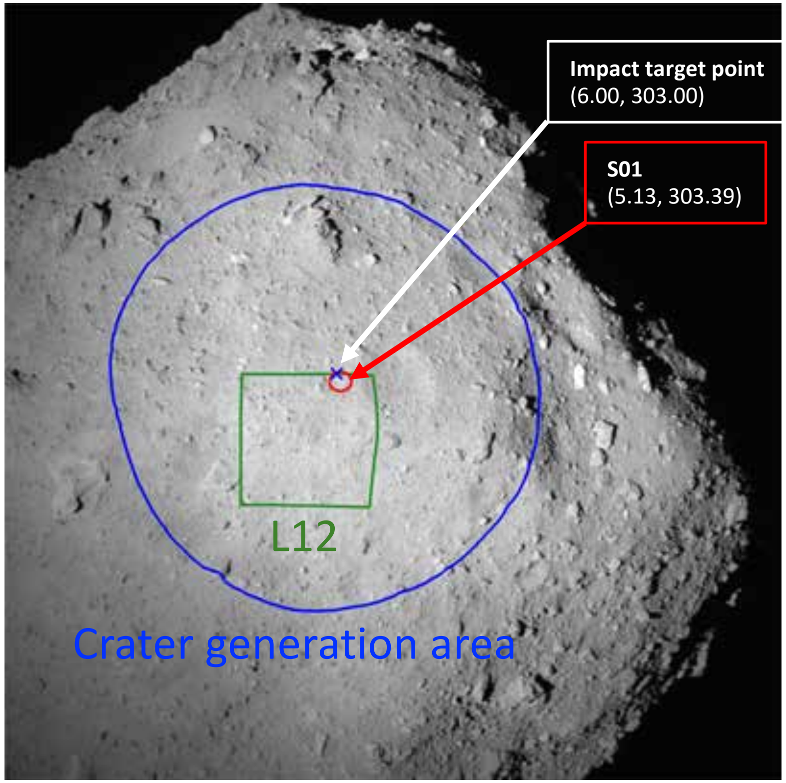
↓

Observations were made as planned.

※Actual operation time is the same as planned.

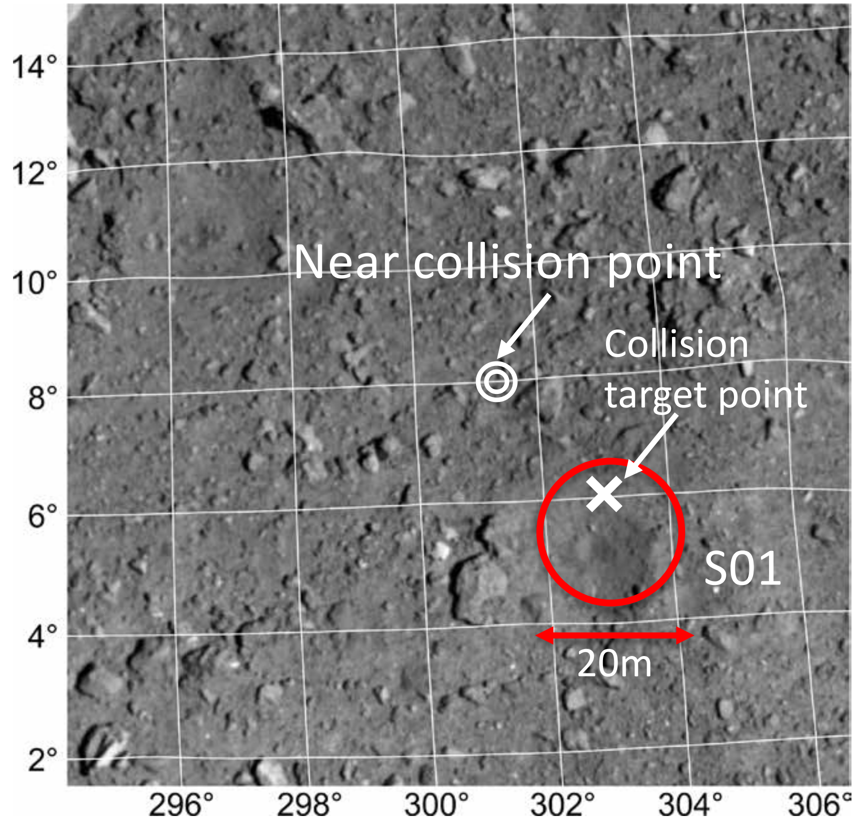
(Image credit：JAXA)

2. Crater Search Operation (Post-SCI) results



Note：Positions shown are approximate. The exact location of the SCI impact is being analysed.

Collision location（image taken prior to collision）

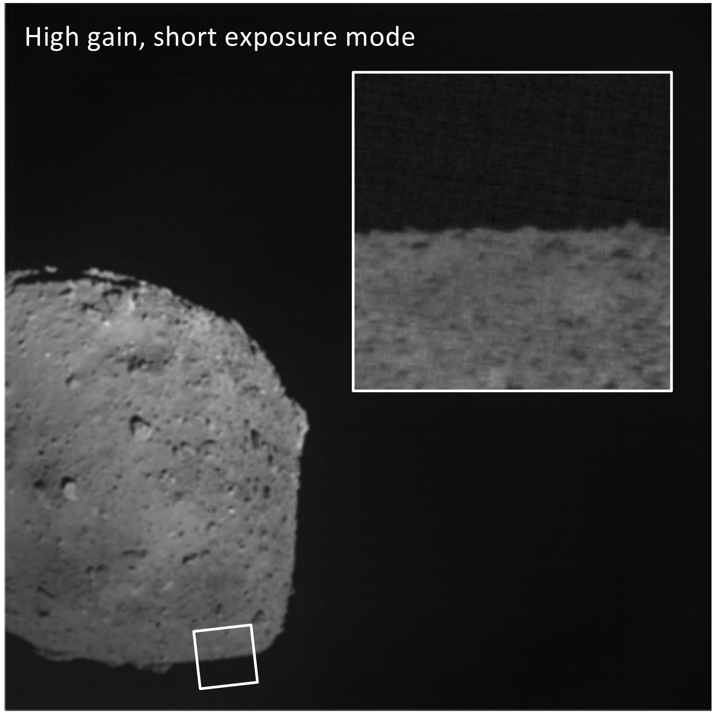


(Image credit: JAXA, University of Tokyo, Kochi University, Rikkyo University, Nagoya University, Chiba Institute of Technology, Meiji University, University of Aizu, AIST)

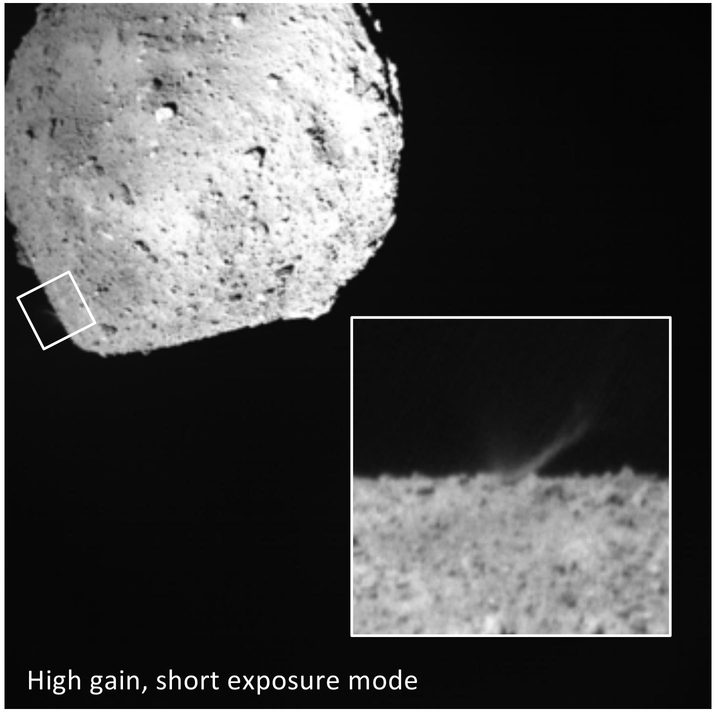
3. SCI collision experiment science: ejecta

- Image of collision ejecta with the DCAM3（digital camera）

About 14 seconds before the SCI operation



About 3 seconds after the SCI operation

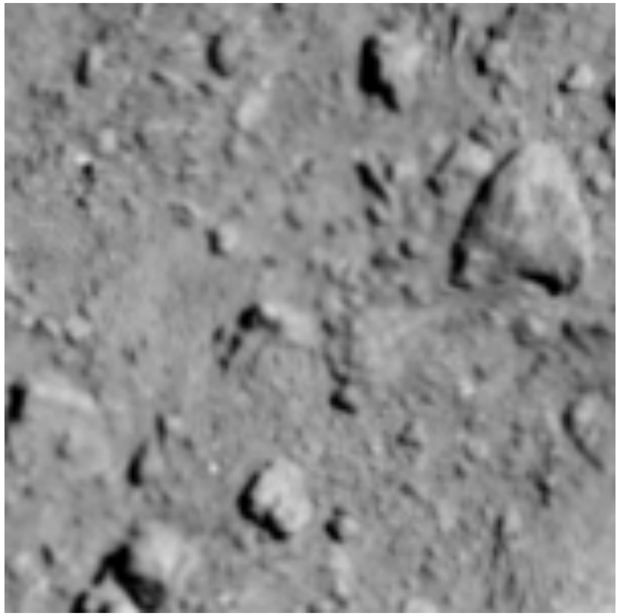


(Image credit: JAXA, Kobe University, Chiba Institute of Technology, Kochi University, University of Occupational and Environmental Health)

3. SCI collision experiment science: crater

- Terrain change before and after the SCI collision

Before the SCI collision 2019/03/22



After the SCI 2019/04/25

(Image credit: JAXA, University of Tokyo, Kochi University, Rikkyo University, Nagoya University, Chiba Institute of Technology, Meiji University, University of Aizu, AIST)

3. SCI collision experiment science: crater

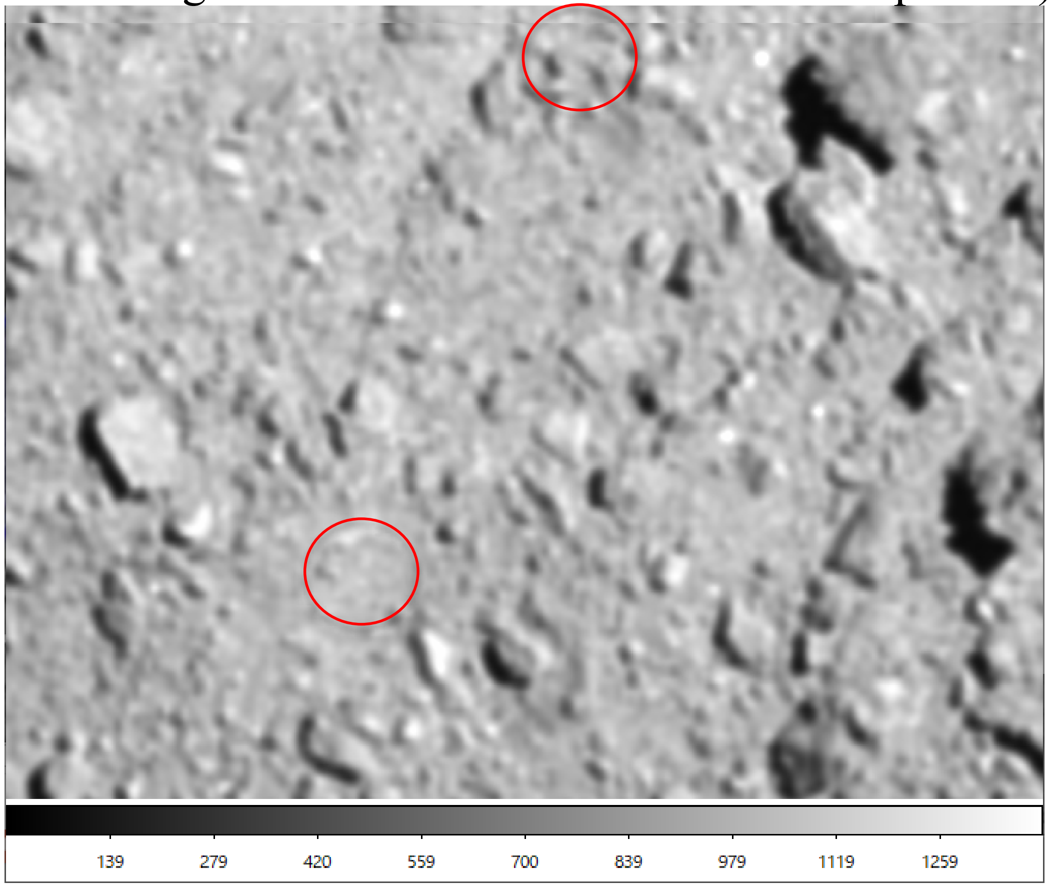
- Terrain change before and after the SCI collision.
  (Blink image before and after collision for comparison)
  – Crater formation
  – Boulder evacuated and moved
  – Boulders dispersed around the region

(Image credit: JAXA, University of Tokyo, Kochi University, Rikkyo University, Nagoya University, Chiba Institute of Technology, Meiji University, University of Aizu, AIST)

3. SCI collision experiment science: sub-craters

- Changes can be seen before and after the collision in regions other than the SCI crater.
  - Formation of cratered terrain (upper circle on right-hand figure)
  - Movement of boulders（lower circle）
- These changes are distributed along an arc on the surface of the asteroid.

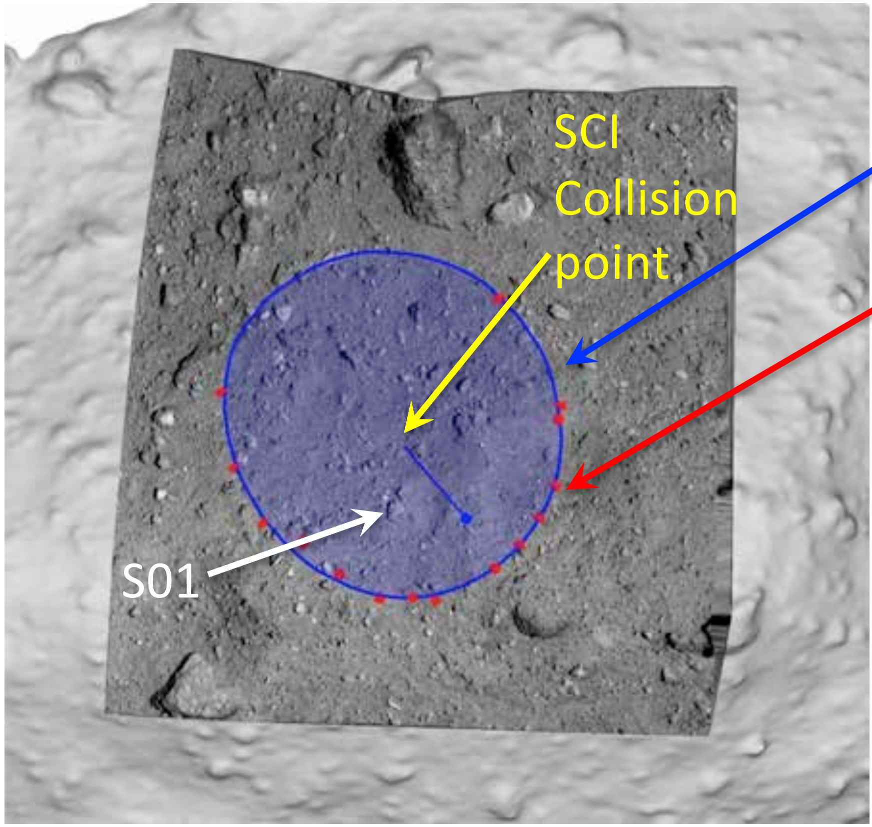
(Blink image before and after collision for comparison)

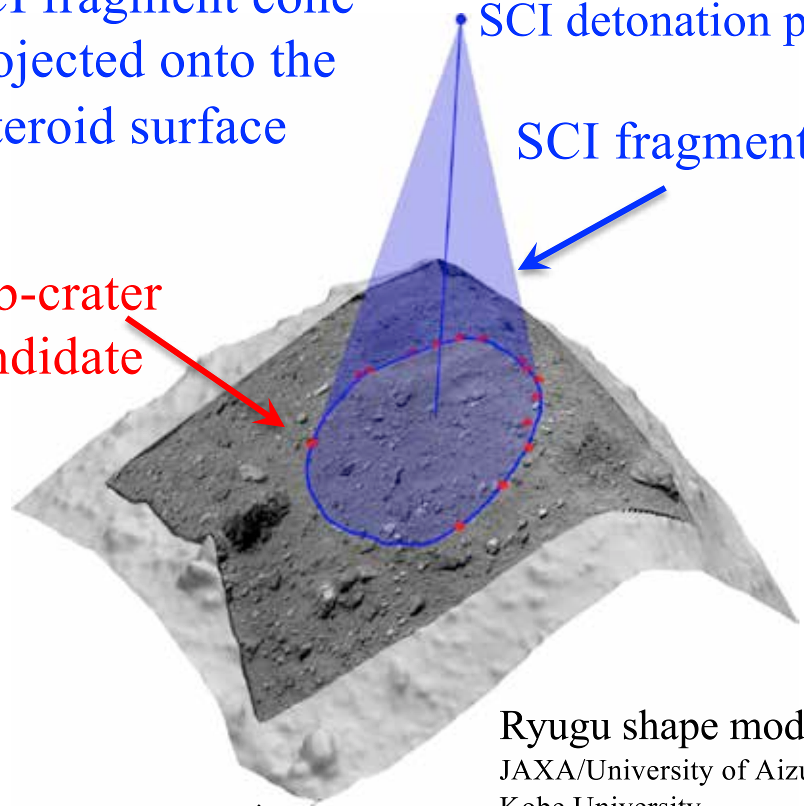


(Image credit: JAXA, University of Tokyo, Kochi University, Rikkyo University, Nagoya University, Chiba Institute of Technology, Meiji University, University of Aizu, AIST)

3. SCI collision experiment science: sub-craters

These craters were probably generated by SCI fragments.





(Image credit: JAXA)

Ryugu shape model
JAXA/University of Aizu/
Kobe University

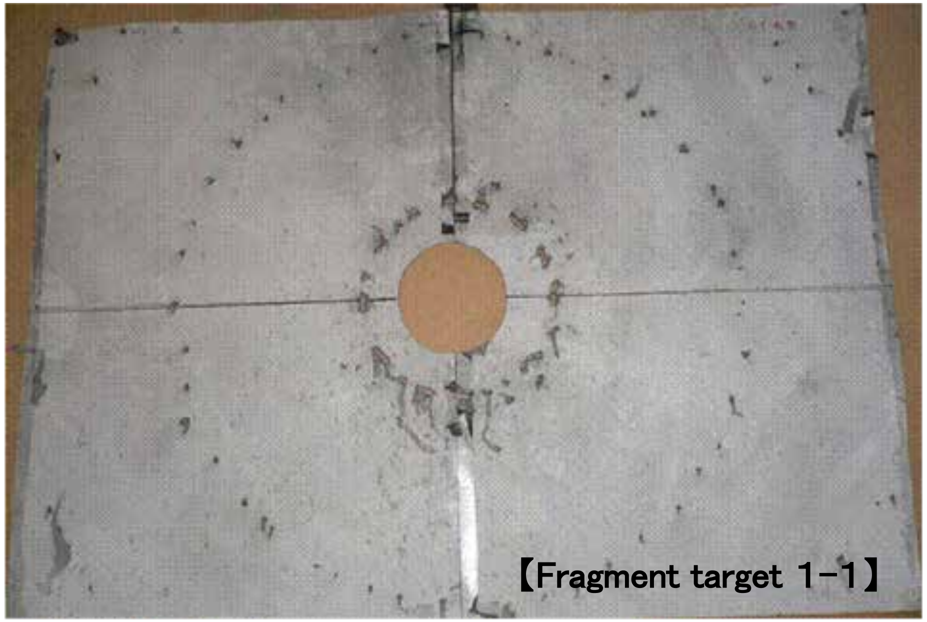
3. SCI collision experiment science: sub-craters

Reference

■ Test with SCI small model (diameter 5cm)
- Implemented in 2009
- Collision speed 2.1km/s

(animation)

■ Test with SCI ½ scale model (diameter 15cm)
- Implemented in 2011
- Collision with a paper and veneer target. Distribution of debris examined.



(Image credit: JAXA)

3. SCI collision experiment science: summary

- The SCI impact in the vicinity of the S01 area (distance about 25m) succeeded.
- Impact ejecta were seen for several hundred seconds (via DCAM3 images).
  - Low gravity increases the duration (by about 300 times longer than that on the ground).
  - Strong suggestion of ejecta deposited in the S01 area.
- A nearly circular change in topology over 10m in diameter was identified (via ONC-T images).
  - Evacuated crater shape: 2 – 3m depth. Side wall surface looks smooth.
  - Boulder movement (evacuation) can be seen as well as associated terrain change.
  - Changes to surface reflectivity (darkening) can also be observed (verification required).
  - An estimate of the surface strength and surface age of Ryugu can be estimated from the crater diameter (next page).
- Along an oval circumference*, the formation of secondary craters and boulder movement can be seen.
  - Presumed due to the collision of debris scattered forward from the SCI.

*More precisely: with the SCI detonation point as a vertex, this is the line of intersection between the debris cone and Ryugu's surface.

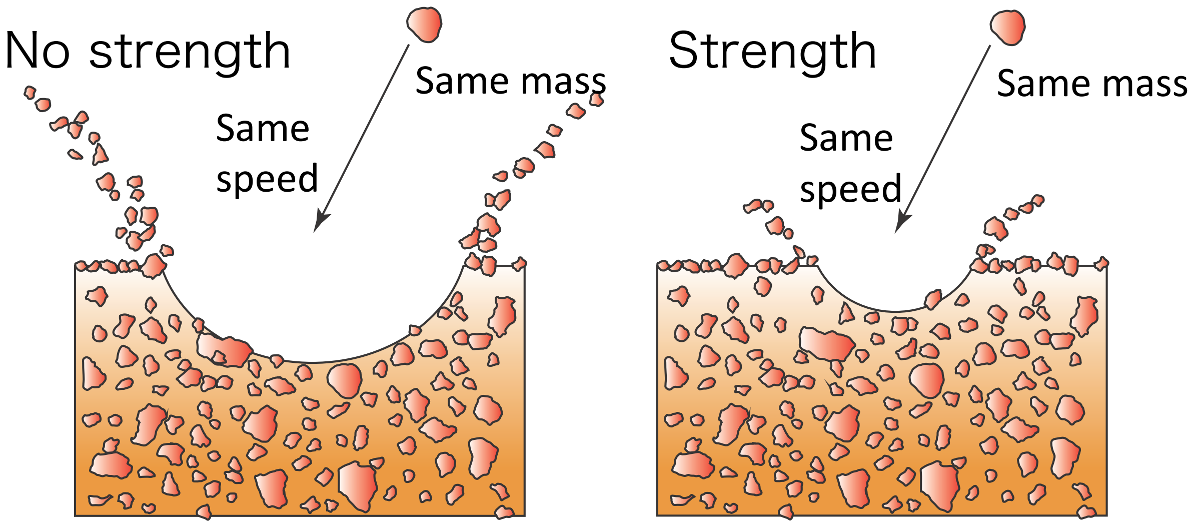
3. SCI collision experiment science: surface strength

The surface age of Ryugu that is estimated from the density of craters (number per unit area) strongly depends on surface strength.

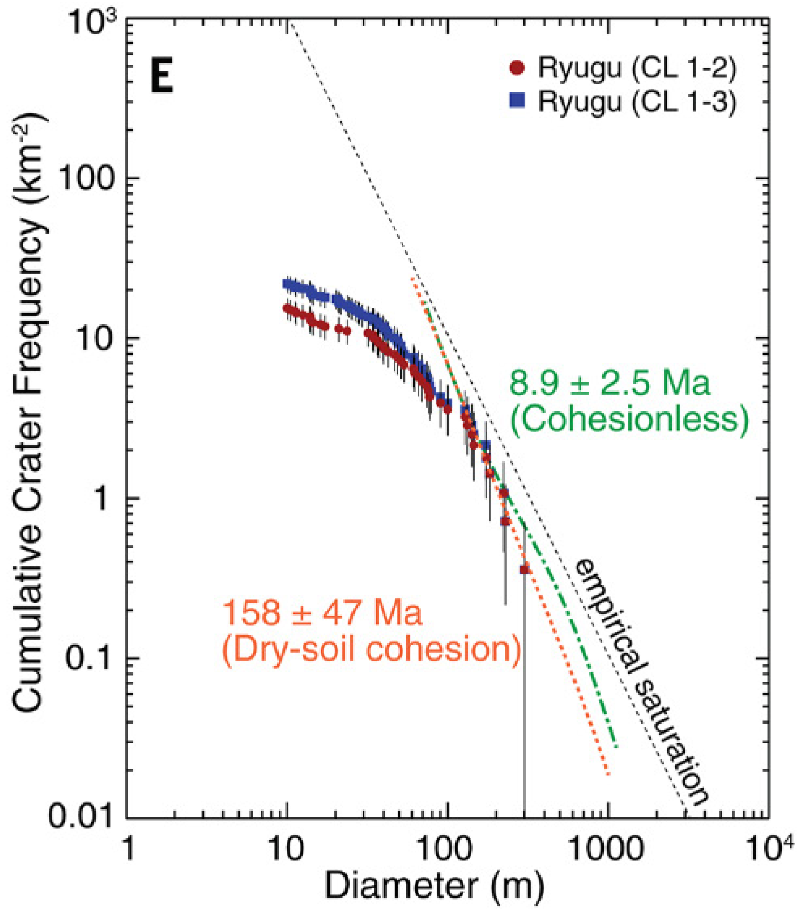
No strength → about 9 million years old (9 Ma)

With strength (2 atm) → about 1.6 million years old (160 Ma)

⇒ Strength can be estimated from the SCI collision test results

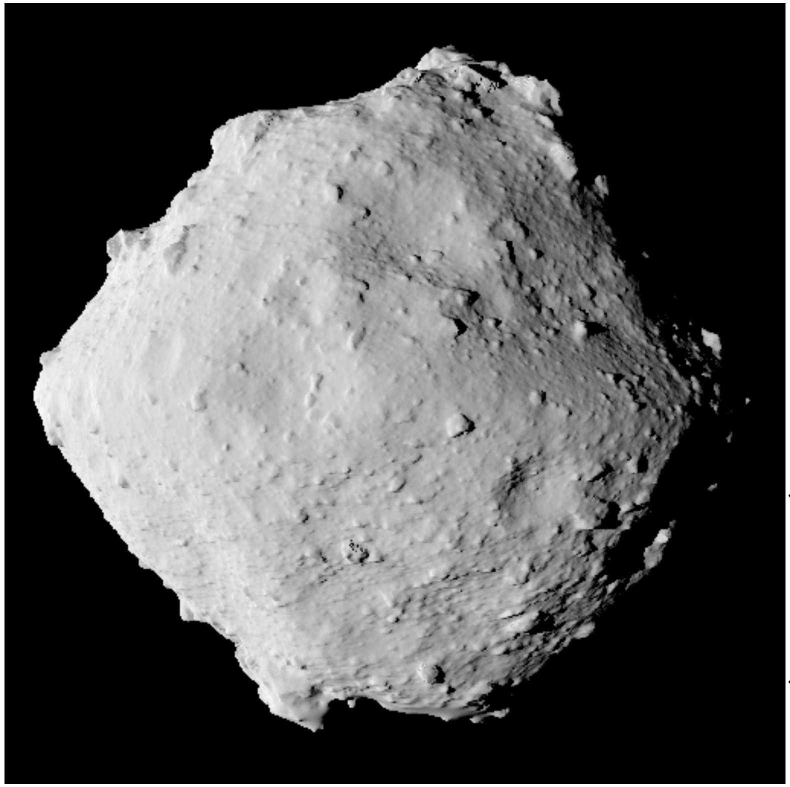


Sugita et al. 2019, Science



3. SCI collision experiment science: perspective

- If you know the strength of the surface…
  - Constrain the shape formation process and origin of Ryugu.
  - Transport of material from the asteroid belt → Earth
    - Meteorites / interplanetary dust formation processes
    - Meteorite disintegration process in the atmosphere
- Crater science
  - Empirical analysis of microgravity collisions
  - Establish scaling laws to connect ground experimental results with astronomical collision processes.
- Expectations for sub-surface sample acquisition
  - Asteroid surface mixing processes
  - Space weathering processes on C-type asteroid



(animation)

SfM shape model from Watanabe et al. 2019, Science
Image credit：JAXA/ University of Aizu / Kobe University.

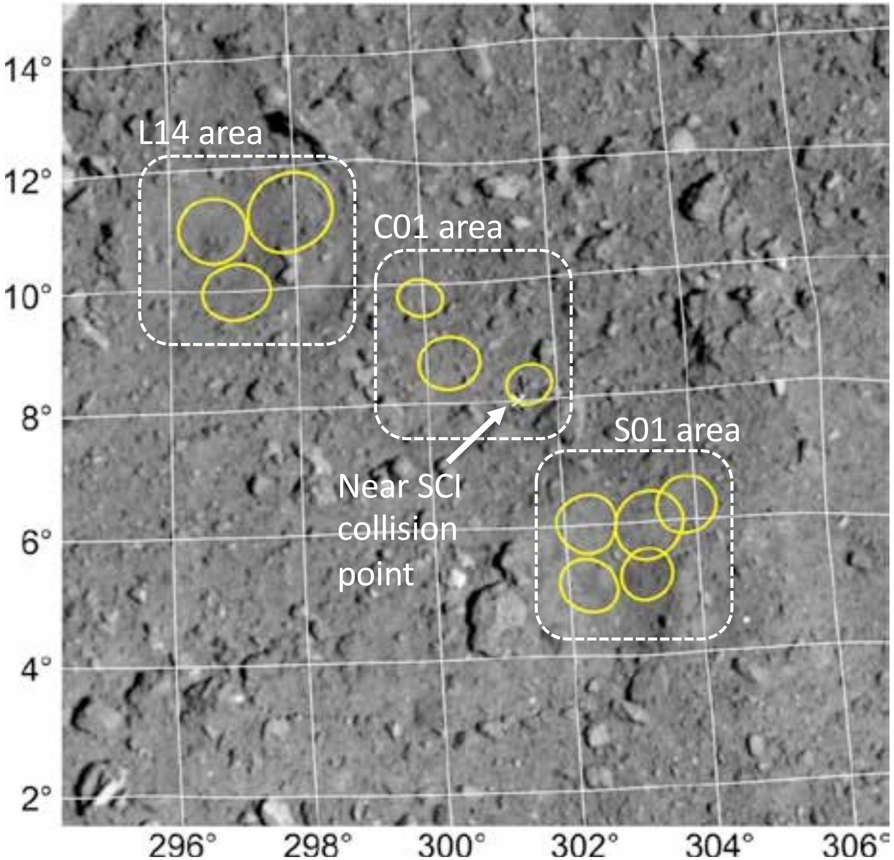
4. Future operation plans

■ Operation plan concept from May ~ July

- Currently, Ryugu is approaching the Sun (perihelion in September). It will only be possible to land on Ryugu until the start of July, after which the asteroid temperature will rise.
- By the beginning of June, the crater and state of the spacecraft will have been examined and it will then be decided if a second touchdown operation will be performed between the end of June and start of July.
  - If touchdown is performed, the target point will be selected from the area where there is ejected material from the artificial crater.
  - The name of this operation will be "pinpoint touchdown" (PPTD).
- 2 or 3 low altitude descent observations will be performed in May and June before the PPTD operation. While performing detailed topographical observations of the landing point candidates, a target marker will be dropped as a guide for landing in this region.
  - 1st: 5/14～5/16 Operation name：PPTD-TM1（described later）
  - 2nd: End of May Operation name：Decided later
  - 3rd: First half of June Operation name: Decided later

4. Future operation plans

■Currently identified touchdown candidate points



- CO1 is the area where the artificial crater was generated.
- S01 is that area that was observed in March this year as a backup candidate site for TD2.
- L14 is a TD2 candidate area in a newly evacuated area near the SCI collision point.
- The yellow circles denote all the currently identified touchdown candidate points (all are 6 ~ 12 m in diameter)

During the PPTD-TM1 operation, low-altitude observations will be made of the S01 area and a target marker will be dropped.

(image credit: JAXA, University of Tokyo, Kochi University, Rikkyo University, Nagoya University, Chiba Institute of Technology, Meiji University, University of Aizu, AIST)

4. Future operation plans

■Outlook for future touchdown operations

The decision to perform a touchdown operation will be based on consideration of the following points:

（1）Scientific & engineering value of the 2nd touchdown

- Is the risk during the touchdown operation small enough and the expected value of the second touchdown high enough?
- Is It highly likely that artificial crater ejecta can be collected?

（2）Feasibility of the touchdown operation

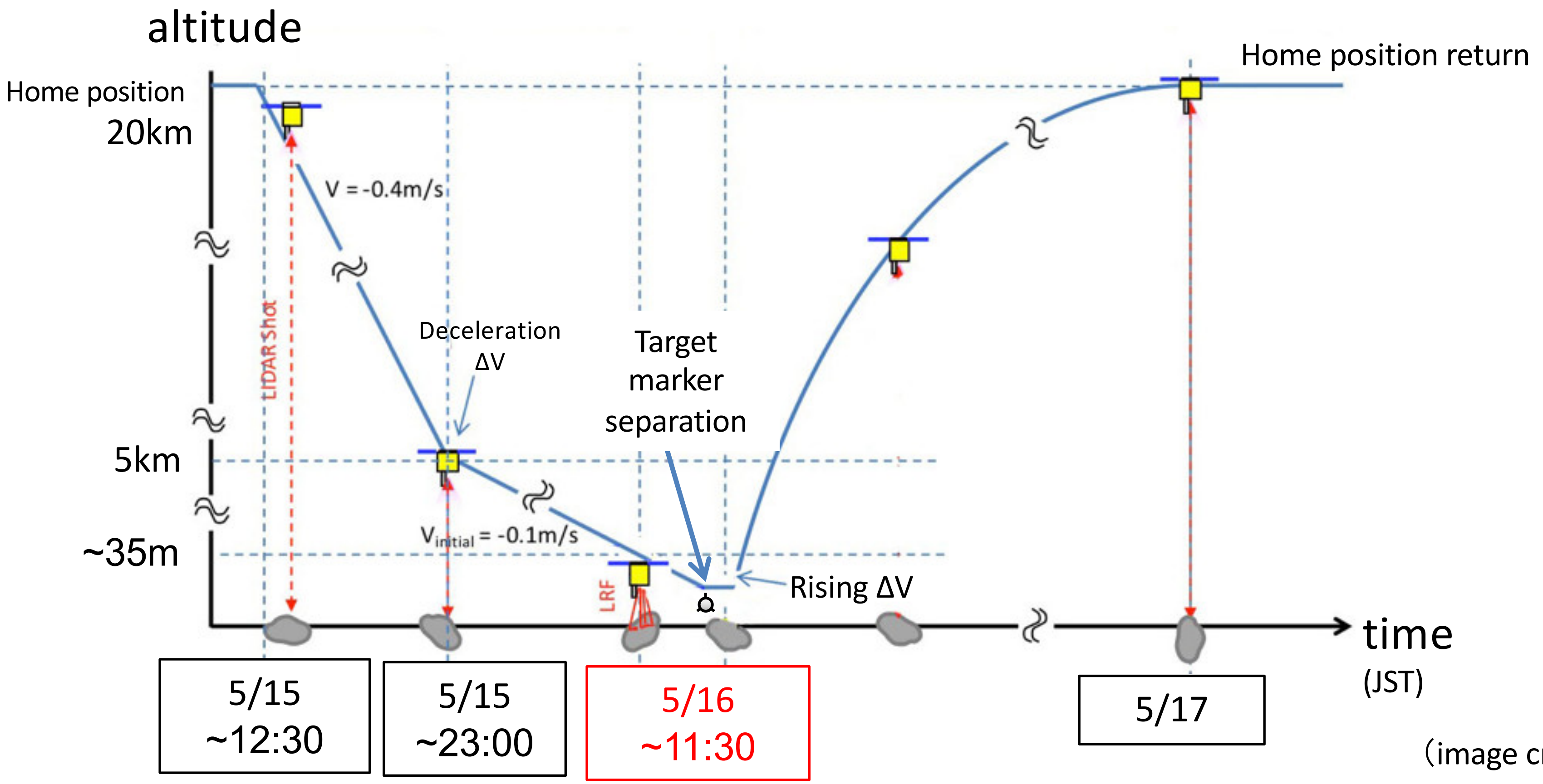
- Can the terrain information necessary for touchdown be obtained and a sufficiently safe touchdown sequence be designed?
- Can the target marker be dropped close to the touchdown target point?

（3）Spacecraft condition

- During the 1st touchdown, the optical system became cloudy due to dust. Can we confirm that a second touchdown can be performed without any problems given this situation?

4. Future operation plans

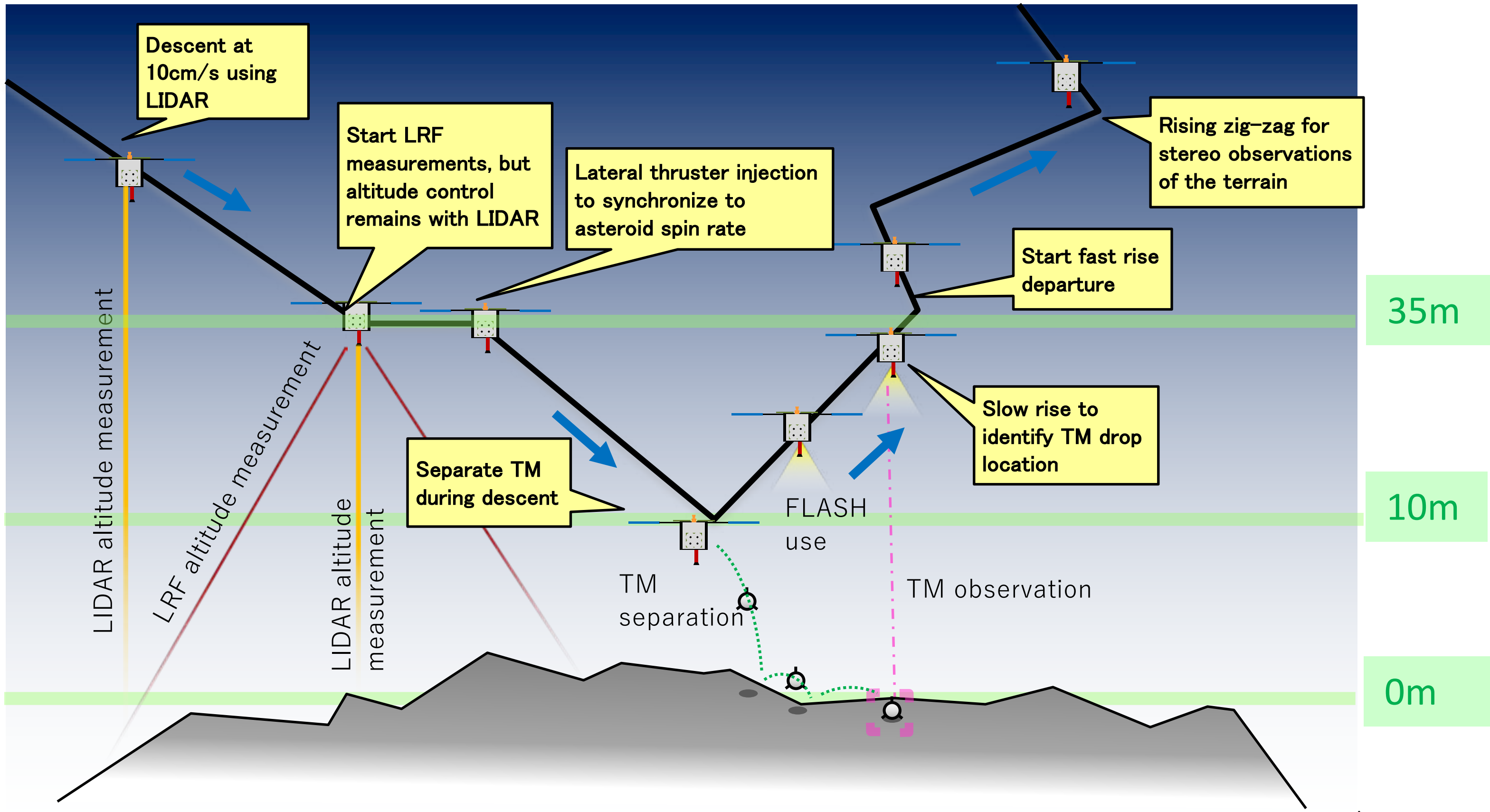
PPTD-TM1 operation



(image credit: JAXA)

4. Future operation plans

Low altitude sequence during PPTD-TM1 operation



(image credit: JAXA)

5. Science related topics

(1) The image of Ryugu was used for the cover of the April 19, 2019 issue of Science Magazine, which included research papers on results from the Hayabusa2 mission.（Right figure）

(2) A paper on Ryugu was also published in the Astrophysical Journal Letters（see next page）

・First author: Masatoshi Hirabayashi（Auburn University）

Science Magazine April 19, 2019 issue

5. Science related topics

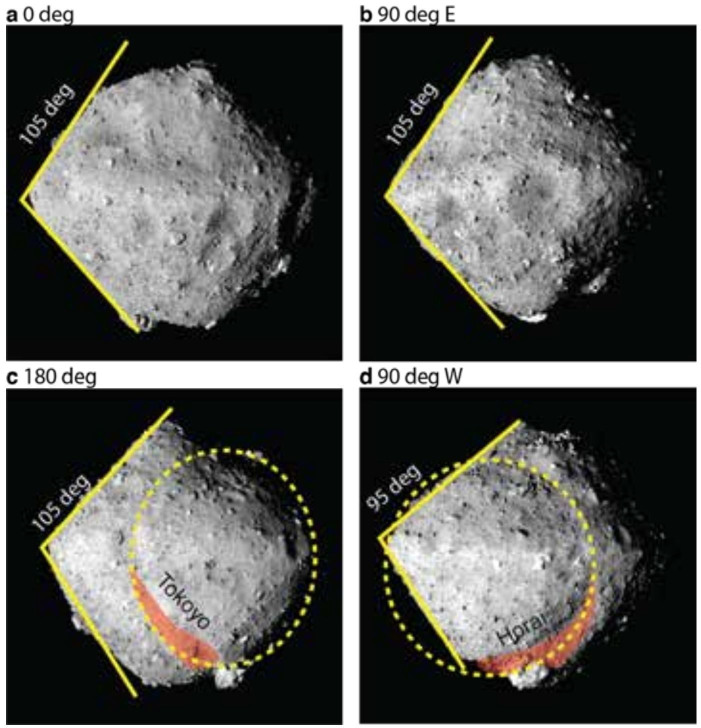
Article published in the Astrophysical Journal Letters

- Hirabayashi, M., and 28 colleagues, “The western bulge of 162173 Ryugu formed as a result of a rotationally driven deformation process,” The Astrophysical Journal Letters, 2019, 874, 1, doi:10.3847/2041-8213/ab0e8b

  https://iopscience.iop.org/article/10.3847/2041-8213/ab0e8b

  Date published：2019/3/26

- The shape of Ryugu differs from east to west, with the shape of the western bulge (near 90 degrees W in longitude) being potentially due to structural changes (such as a landslide or internal structural alterations) in the past when Ryugu was rotating at a higher speed.

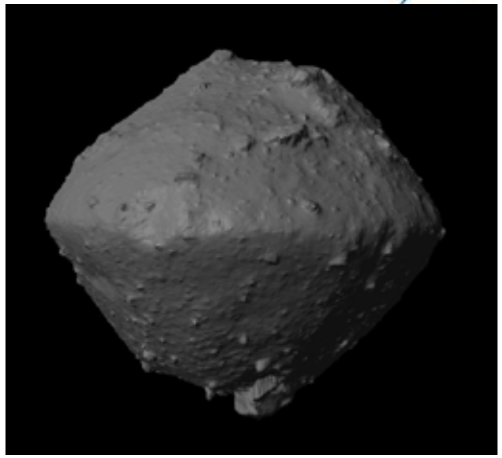


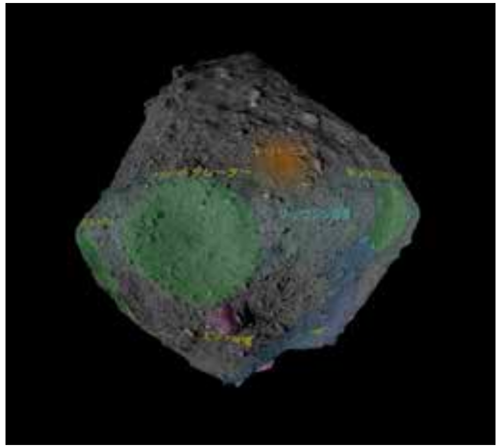
Hirabayashi et al, 2019 より

6. Other topics

Ryugu shape model release

- Presenting Ryugu's precise 3D model
- This will be released in a range of formats, in cooperation of the Japan Planetarium Association (JPA).
- While originally designed for JPA members, the files are accessible to anyone. Please do take a look.
- Access here: https://planetarium.jp/ryugu/





CG created from published Ryugu 3D data（from JPA Web）

7. Future plans

■ Operation plans

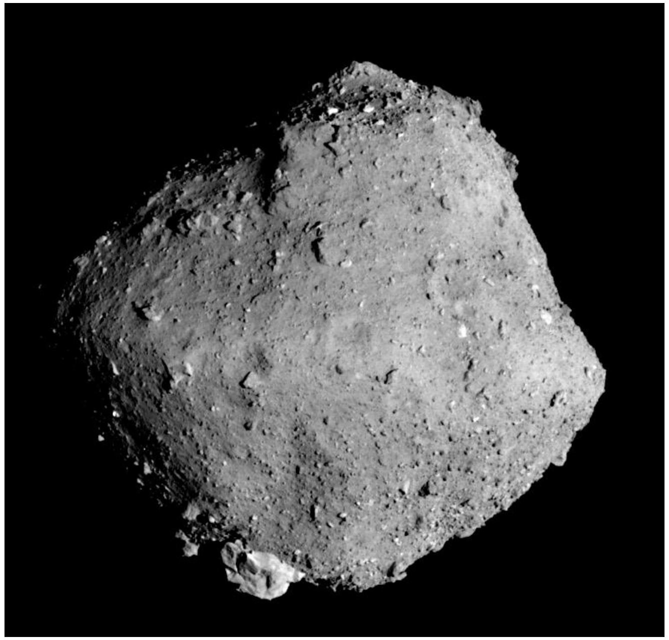
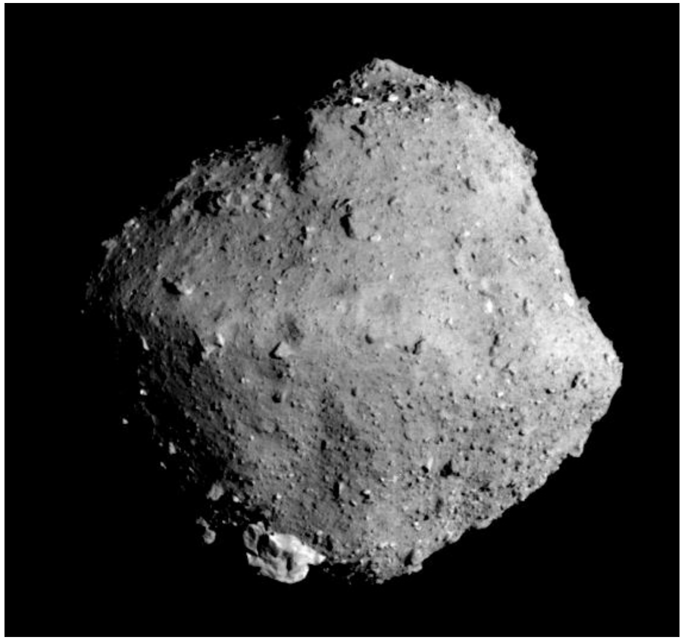
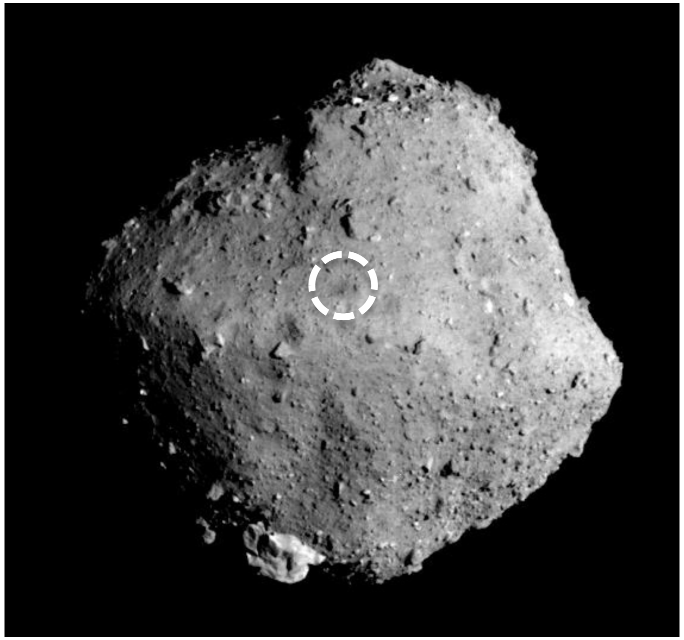
- May 14～16：Descent and target marker separation operation （PPTD-TM1）

■ Press and media briefings

- May 22　15:00　～：Press briefing session @ Tokyo office

Reference

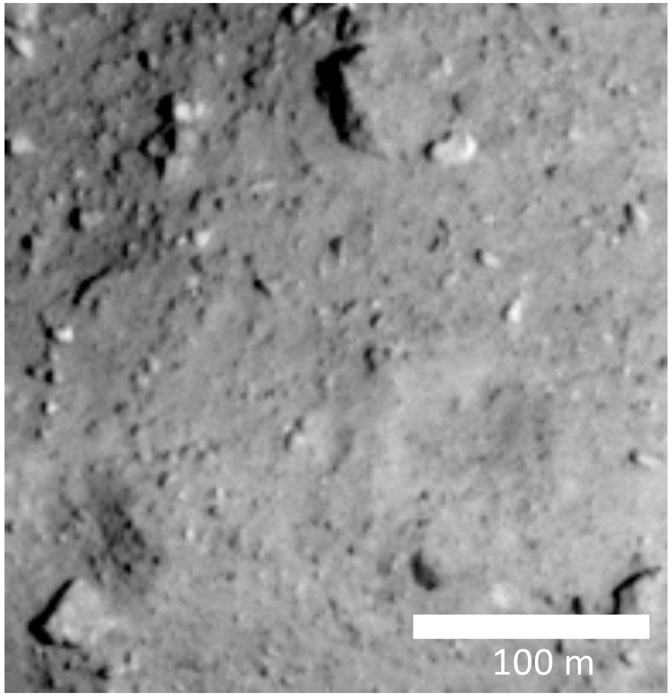
SCI collision area captured from the home position with the ONC-T

Before SCI collision	After SCI collision	After SCI collision（labelled）
		
2019-03-21 13:03（JST） altitude 14 km	2019-04-17 21:04（JST）, altitude 19 km	

(image credit: JAXA, University of Tokyo, Kochi University, Rikkyo University, Nagoya University, Chiba Institute of Technology, Meiji University, University of Aizu, AIST)

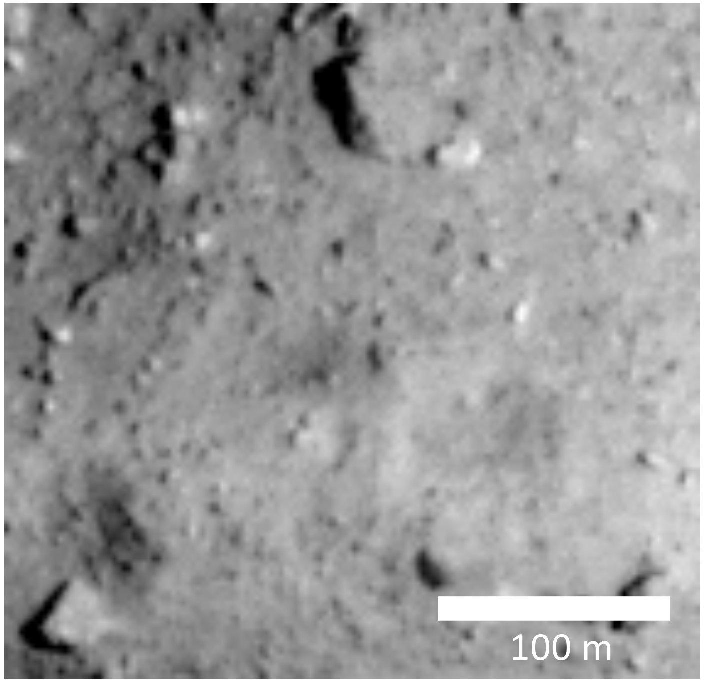
SCI collision area captured from the home position with the ONC-T

Before SCI collision



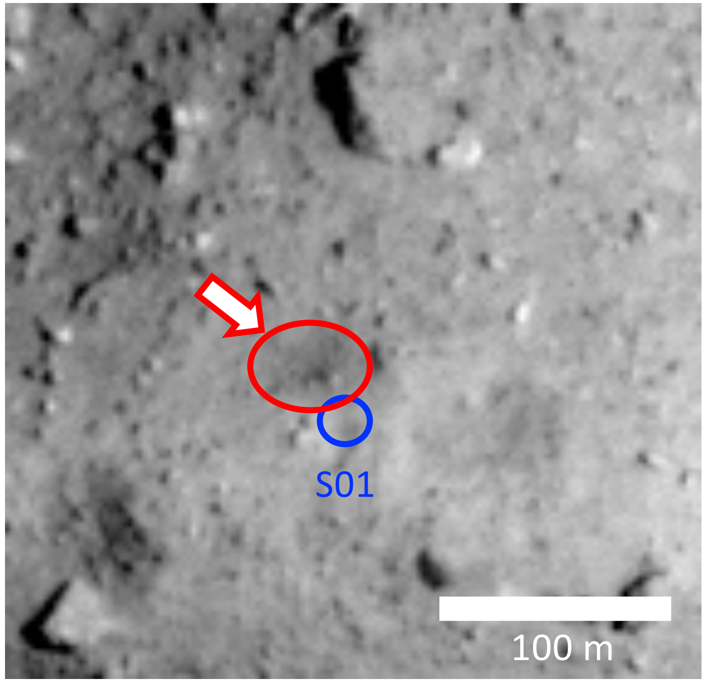
2019-03-21 13:03（JST） altitude 14 km

After SCI collision



2019-04-17 21:04（JST）, altitude 19 km

After SCI collision（labelled）



(image credit: JAXA, University of Tokyo, Kochi University, Rikkyo University, Nagoya University, Chiba Institute of Technology, Meiji University, University of Aizu, AIST)