Asteroid explorer, Hayabusa2, reporter briefing

April 27, 2021

JAXA Hayabusa2 Project

Topics

Introduction to spectral profile results from the Ryugu samples in curation and scientific achievements, and status report of the spacecraft.

Contents

1. Overview of the current project status

■ Spacecraft operation

- Spacecraft operation is normal and travel continues smoothly towards the destination of the Extended Mission. The plan for future ion engine operations was reviewed, and the start of the next operation was changed to the end of May.

■ Curation work

- High definition optical microscope images continue to be acquired of the particle/bulk aggregate samples returned from Ryugu.
- The results of observations of the returned sample show characteristics of the hydrous and carbonate minerals that indicate the presence of water in the Ryugu parent body (details on following pages)

2. Spectral Profiles of Ryugu Return Sample

- Spectroscopy of bulk return sample has started as part of the initial description under non-destructive and non-contaminated conditions since January 2021
- Performed with FTIR (NIR continuous spectroscopy) and MicrOmega (NIR hyperspectral microscopy).
- The same features are found in both spectral profiles
  - 2.7μm absorption, related to water (-OH), the similar feature observed in NIRS3 spectrum
  - 3.4 μm absorption, related to organics (-CH) and/or carbonate (-CO_3)
- These features are the evidence that the returned sample did originate from Ryugu.
- Indicative of a primitive sample of the Solar System, containing water or carbon related materials (waiting for in-depth analyses with higher accuracy and resolution)

2. Spectral Profiles of Ryugu Return Sample

- Examples of spectra (FTIR & MicrOmega)
  - Absorption features seen at 2.7 and 3.4 μm

Chamber A

5 mm

© MicrOmega/IAS/CNES

Wavelength-selected image enhance (few) grains with specific composition, within bulk material.
[Red] : OH-enriched grain

2. Spectral Profiles of Ryugu Return Sample

- 3D movie using MicrOmega
  - Observation down to sub-mm scale structures
  - Identification of different compositional materials

3D image emphasizing the presence of few grains with specific composition: [Red] A largely OH-enriched grain

3. Scientific results: Distribution of hydrous material on Ryugu

Overview

The distribution of absorption from hydrous minerals (0.7μm band) was obtained with the Optical Navigation Camera, ONC-T. Accuracy was improved by combining test data obtained before launch with the data obtained after arrival at Ryugu. It was confirmed that the 0.7μm absorption is strong in the low latitude area where the sample was collected.

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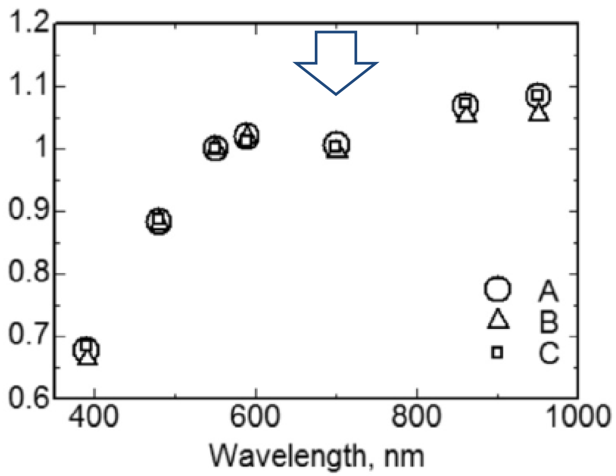
https://doi.org/10.1016/j.icarus.2021.114348

3. Scientific results：Distribution of hydrous material on Ryugu

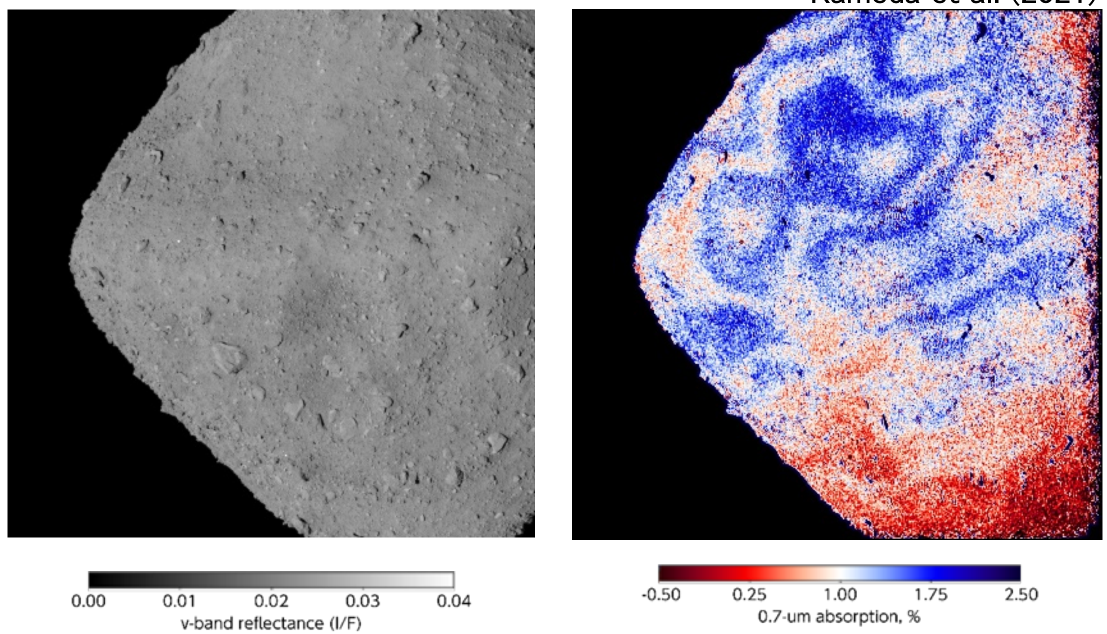
0.7μm absorption (approx. 3-4%)
Indicates the presence of hydrous minerals. Disappears at high temperatures.



Hydrous minerals (0.7μm) absorption measured by the ONC-T before launch (Murchison meteorite). Modified from Kameda et al (2015)

Using the 0.55μm, 0.7μm and 0.86μm out of the 7 filters available on the ONC-T, the absorption was measured from the reflectance of 0.7μm wavelengths with respect to 0.55μm and 0.86μm.

Kameda et al. (2021)

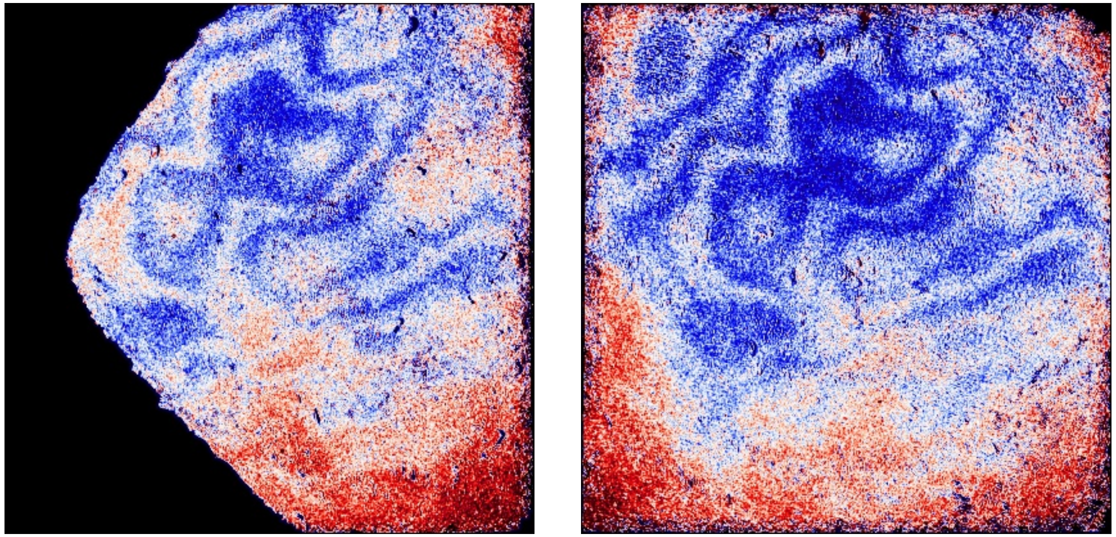


Blue in the figure on the right shows regions with strong absorption. Average absorption seemed to be detected at about 1%, with regional differences with absorption as much as about 0.5% …???

3. Scientific results: Distribution of hydrous material on Ryugu

But a similar distribution was obtained in an entirely different location! This suggested that the pattern was actually a characteristic of the instrument…

In order to detect 3 – 4% absorption, the required accuracy is about 1%. The cause of this pattern was that the detector had an uneven sensitivity of about 0.5%.



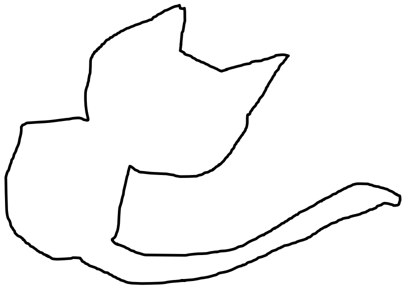
Kameda et al. (2021)

The sensitivity distribution (data needed to correct unevenness in the sensitivity) was acquired before launch at room temperature, but the detector temperature when Ryugu was observed was lower.

Although the test had revealed that the value of the average sensitivity of the entire image differed depending on changes in temperature, the data was limited in range due the test equipment and time restrictions.

It was found that the sensitivity distribution at room temperature and that at low temperature on the detector surface are slightly different.

This phenomenon was confirmed using a detector with the same sensor as the ONC that had been prepared before launch.

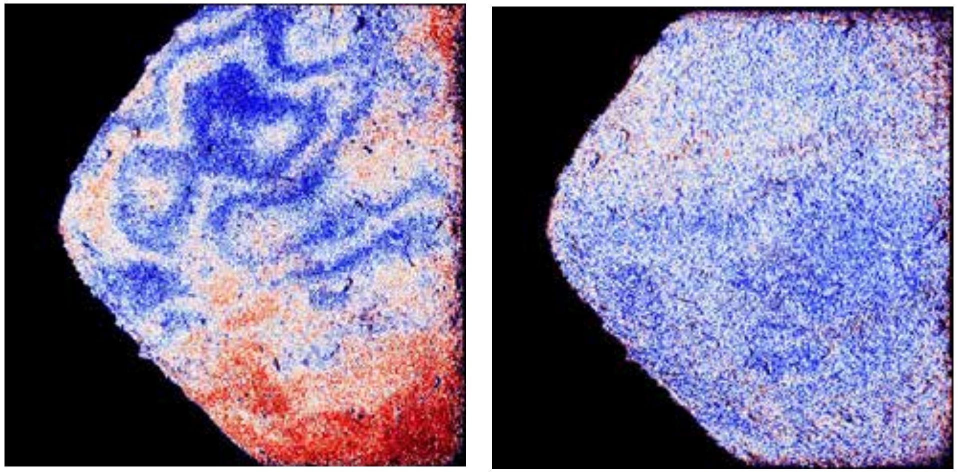


The research team referred to this as the "cat pattern"

3. Scientific results：
Distribution of hydrous material on Ryugu

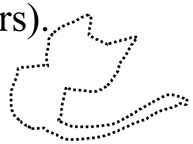
Generate new sensitivity distribution data for low temperatures using a large number of 288 images acquired of Ryugu → re-correction

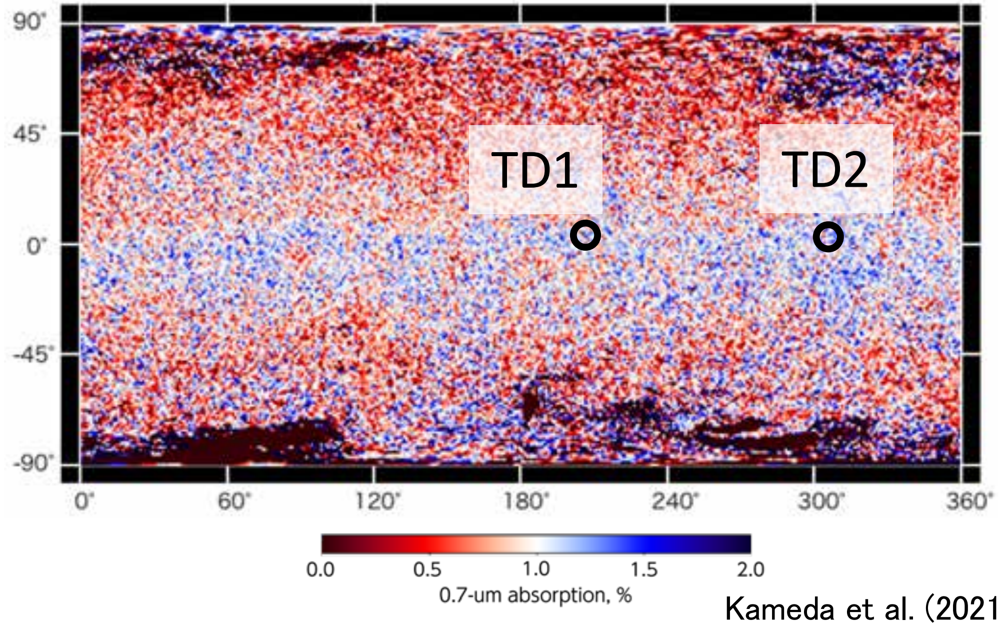
Correction accuracy for sensitivity unevenness was <u>improved by around 2-3 times</u>. The results confirmed a regional different of 0.1 – 0.2% for 0.7μm absorption.



Kameda et al. (2021)

Successful correction! (The cat pattern disappears).
0.7 μm absorption distribution is now visible.

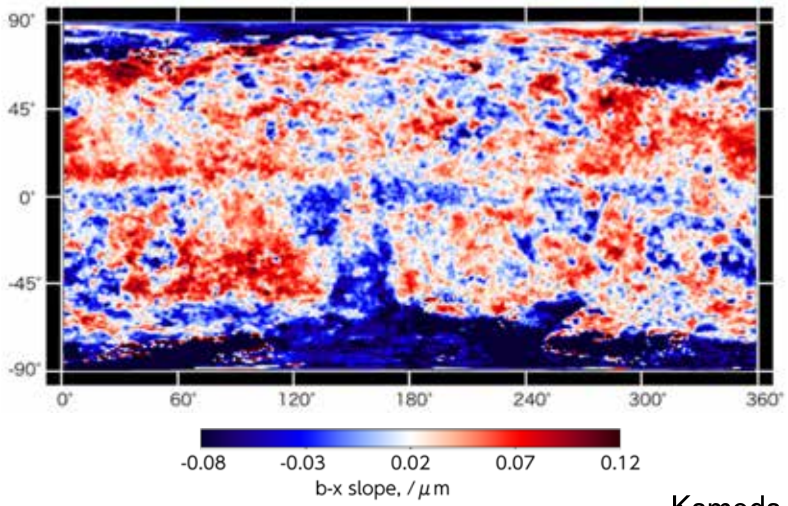


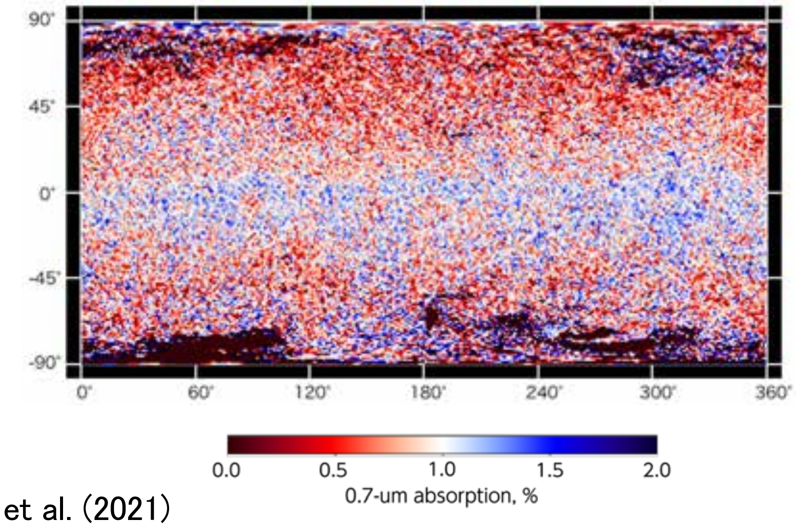


Kameda et al. (2021) (modified)

Low latitudes show slightly strong 0. 7μm absorption than the overall average. As the samples were obtained in this low latitude region (black circles), it is possible that the sample could be collected at a location on Ryugu that contains a large amount of hydrous minerals.

3. Scientific results: Distribution of hydrous material on Ryugu





Kameda et al. (2021)

The results of this research will be used when considering the development and observation plan for the Martian Moons eXploration Mission (MMX) cameras.

Although Ryugu is a black body that looks almost monochromatic, there are regions that are slightly bluer and those that are more red. The 0.7 μm absorption tends to be stronger in the blue region.

(Upper left figure highlights blue and region regions.)

→ Blue regions are freshly exposed surface material and show absorption of hydrous minerals that have not been exposed to high temperatures.

→Consistent with previous results (Morota et al., 2020, etc)

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4. Scientific results： Polarization observation with ground-based telescopes

Overview:

In September – December 2020, polarization observations of asteroid Ryugu were conducted at four facilities in Japan and overseas (Fig 4-1) and the degree of polarization of Ryugu was discovered to be the highest recorded in history for an observation of a small Solar System body (Fig. 4-2). The degree of polarization is thought to indicate the characteristic surface conditions such as mineral composition and grain size of the pebbles and sand on the asteroid surface.

While Ryugu was comprehensibly observed from ground and space telescopes before the mission, and by the Hayabusa2 spacecraft, the degree of polarization had not been measured and there was no substitutable observation. The results from the observation was scientifically important as they can be compared with the polarization of the sample returned by Hayabusa2. This is only the second case after the Moon to obtain the maximum value of polarization and a comparative sample from a celestial body. This result was published in The Astrophysical Journal Letters, April 20, 2021(DOI: 10.3847/2041-8213/abee25)

Fig 4-1: telescopes and instruments used in this observation (image credit for each in parentheses). From left: Kanata Telescope + Hiroshima Optical and Near- InfraRed Camera HONIR (Hiroshima University), Nayuta Telescope + Wide Field Grism Spectrograph WFGS2 (Hyodo Prefectural University), Pirka Telescope + Visible Multispectral Imager MSI (Hokkaido University), Bohyunsan Astronomical Observatory 1.8m telescope + Triple Range Imager and Polarimeter TRIPOL#3 (Seoul University)

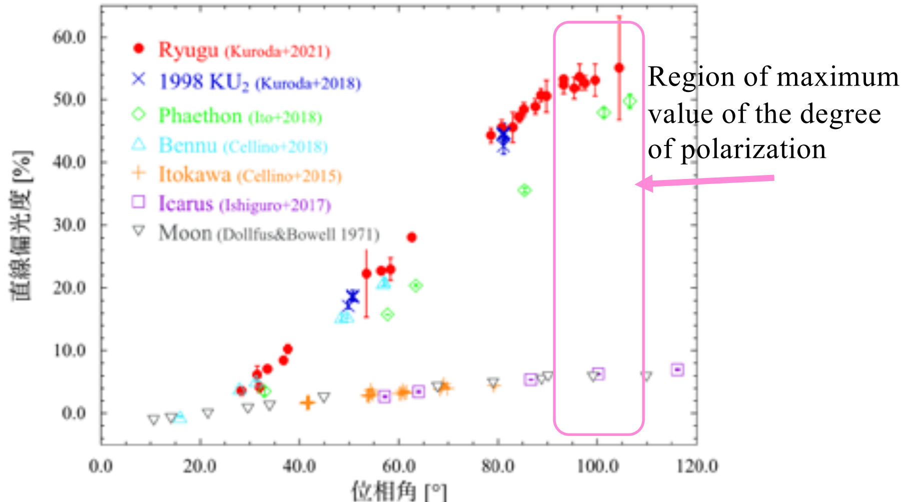


Fig 4-2: Asteroid phrase angle – polarization plot. Red circles indicate the degree of polarization of Ryugu (credit: Kyoto University)

4. Scientific results：
Polarization observation with ground-based telescopes

Background

○ What is the degree of polarization？

The light source is sunlight (wave vibrates in different directions = unpolarized)

→ When this hits an object it is reflected or scattered and a strength bias is created in one direction of vibration. The degree of this strength is the degree of polarization, which depends on type, shape and size of the substance.

Polarized sunglasses utilize the fact that scattered light is polarized in one direction.
Image diagnostics put the degree of polarization to practical use in surveys such as ground disaster monitoring and land use (JAXA, NICT).

○ Purpose of measuring the degree of polarization for small Solar System bodies.

When the phase angle (Fig 4-3) changes, the degree of polarization also increases or decreases.
The aim is to identify the physical state of the surface layer from the characteristics (maximum value and trend) of the change in the degree of polarization

- Objects with low degrees of polarization
  Moon (observed in the latter half of the 20th century, measured in samples)
  Asteroid Itokawa (destination of Hayabusa) etc.

- Objects with high degree of polarization (>40%)
  Asteroid 1998 KU_2 & Phaethon (planned destination of DESTINY$^+$) etc
  Due to lack of information about the surface layer, the cause of high degrees of polarization cannot be identified.

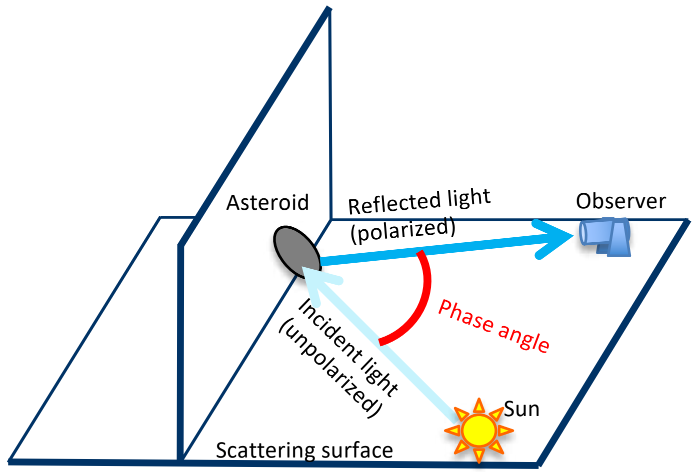


Fig 4-3
Diagram of the phase angle (credit: Kyoto University)
The phase angle is the angle between the Sun, asteroid and an observer and changes daily. Only some small bodies (near-Earth asteroids and comets) can be observed with large phase angles from the ground.

Ryugu, whose surface conditions have been well investigated, was the optimal target for identifying what kind of physical quantities the degree of polarization depends on.

4. Scientific results：
Polarization observation with ground-based telescopes

Results of this research:

・Asteroid Ryugu shows a high degree of polarization, with values up to 53% → highest value measured in the history of small Solar System bodies.

As this is the polarization of the entire body, it is thought that a special surface layer exists over a wide area.

・Characteristics of the surface layer suggested by the degree of polarization

The contribution from submillimeter-sized particles was estimated through comparison with the degree of polarization in meteorites.

(1) Possibility that submillimeter-sized grains are present over most of the surface layer.

(2) Possible that submillimeter-sized grains are gathered to form larger rocks. The surface image captured by MASCOT (Fig 4–4) shows many rocks with a dark cauliflower-like structure, supporting this idea.

Fig 4-4
The image of the surface of Ryugu observed by MASCOT
(credit：MASCOT/DLR/JAXA)

Future outlook:

By measuring the degree of polarization in the returned sample, the effects from the surface layer on the degree of polarization such as particle size and roughness can be clarified. In addition, the surface structure of Ryugu—lost during the sample collection–will be reproduced.

If the link between the surface state and degree of polarization can be demonstrated so that the surface state of a celestial body can be estimated without relying on exploration, it will be possible to trace the history of many celestial body evolutions, and this will greatly contribute to the elucidation of the origin and evolution of the Solar System.

Collaborators: Daisuke Kuroda (Kyodo University), Jooyeon Geem, Sunho Jin, Yoonsoo P. Bach, Jinguk Seo, Masateru Ishiguro (Seoul National University), Hiroshi Akitaya (Chiba Institute of Technology / Hiroshima University), Jun Takahashi, Aoi Kawakami, Miyako Tozukka (University of Hyogo), Koki Takahashi, Tomohiko Sekguchi (Hokkaido Kyoiku University), Hiroyuki Naito (Nayoto City Astronomical Observatory), Kana Makino (Nayoro City University), Shuji Sato (Nagoya University), Hioroshi Sasago (Sasago Co., Ltd.), Koji Kawabata (Hiroshima University), Makoto Wataanbe (Okayama University of Science), Seiko Takagi, Kiyoshi Kuramoto (Hokkaido University), Makoto Yoshikawa, Sunao Hasegawa (JAXA)

5. Spacecraft status

- After the Earth return, the deployable camera control unit（CAM-C）failed.
  - This is likely to have occurred from the deterioration due to radiation. CAM-C no longer starts normally and image capture is no longer possible.
  - The cause and possible recovery were investigated, but the project judged this to be a failure.
  - This means it is no longer possible to shoot with CAM-H. CAM-H played the full rile of capturing the images at the moment of touchdown.
- Deterioration of spacecraft parts
  - Failures have occurred to the heater that maintains the temperature of the chemical propulsion system thruster injection, but this has been recovered via a backup and labor-saving operations will continue towards the destination celestial body.
  - The spacecraft has exceeded its design lifespan and one of the goals of the Extended Mission is the accumulate and experience the deterioration conditions. We will continue to make effective use of the valuable deep space navigation opportunities.

5. Spacecraft status

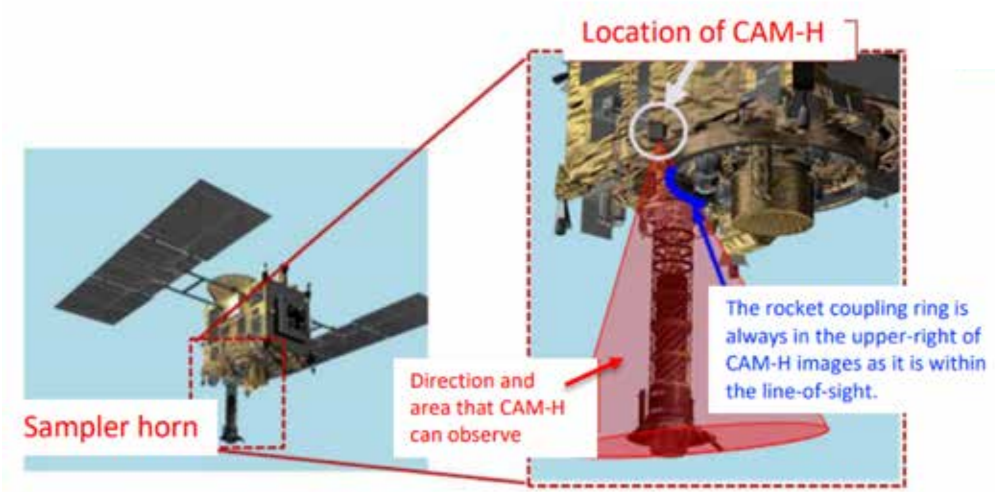
（credit：JAXA）

【CAM-H image captured on 2019.10.16】
This was the last image captured by CAM-H

The results from CAM-H became one of the major achievements that represented Hayabusa2. The camera was installed using donations from the public. We would like to express our sincere gratitude to everyone who supported us and share this wonderful sense of accomplishment with you all.

(Reference) Deployable camera control unit (CAM-C) and related equipment

The deployable camera control unit (CAM-C) is the device that controls the Deployable Camera (DCAM3) and the sampler horn monitor camera (CAM-H). It is installed inside the spacecraft. DCAM3 was separated at Ryugu on April 5, 2019.



Sampler horn monitor camera (small monitor camera head CAM-H) mounting location and field of view direction

Sampler horn monitor camera (small monitor camera head CAM-H)

(image : JAXA)

(Reference) Typical images captured by CAM-H

2014/12/5
Image when the sampler horn extended

2018/10/25
Touchdown 1 Rehearsal 3 (TD1-R3)

2019/2/22
Image at the time of touchdown 1

2019/7/11
Image at the time of touchdown 2

(credit: JAXA)

6. Future plans

■ Operation schedule

2021/4～ Continued regular operation

Ion engine operation schedule to start from the end of May (change from previously reported schedule)

■ Open call for capsule exhibition tour

We are accepting applications from venues in different locations within Japan for the traveling exhibition of the sample return capsule, scheduled to open after August.

- ➢Applications open：4/27（Tuesday）
- ➢Application deadline：5/21（Friday）
- ➢Notification of results：6/18 (Friday)

For details, please see application guidelines.

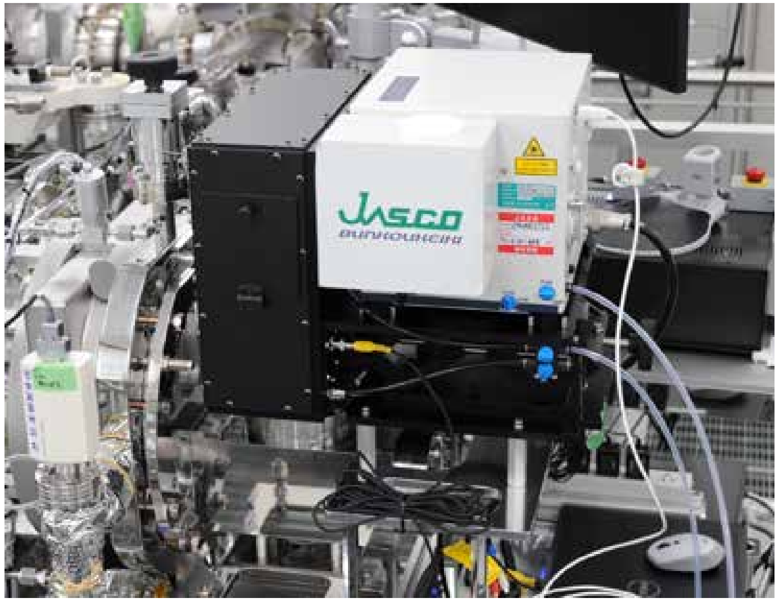
■ Press and media briefings

2021/5 TBD Press briefing

Reference

FTIR（Fourier Transform Infrared Spectroscopy）

- wavelength : 1 ~ 4μm continuous spectroscopy
- Spot diameter : 1 ~ 6mm



（credit : JAXA）

MicrOmega (Near-Infrared Hyperspectral Microscope)

NIR spectroscopy for non-contaminated/non-destructive description of return sample

- wavelength range: 0.99-3.65 μm
- spatial resolution: 22μm/pixel
- observation area: 5x5mm
- mounted on a small lander MASCOT
- AXA-CNES intl. collaboration
- developed by IAS

（image：JAXA）