7th IAA Planetary Defense Conference

26-30 April 2021, Online Event

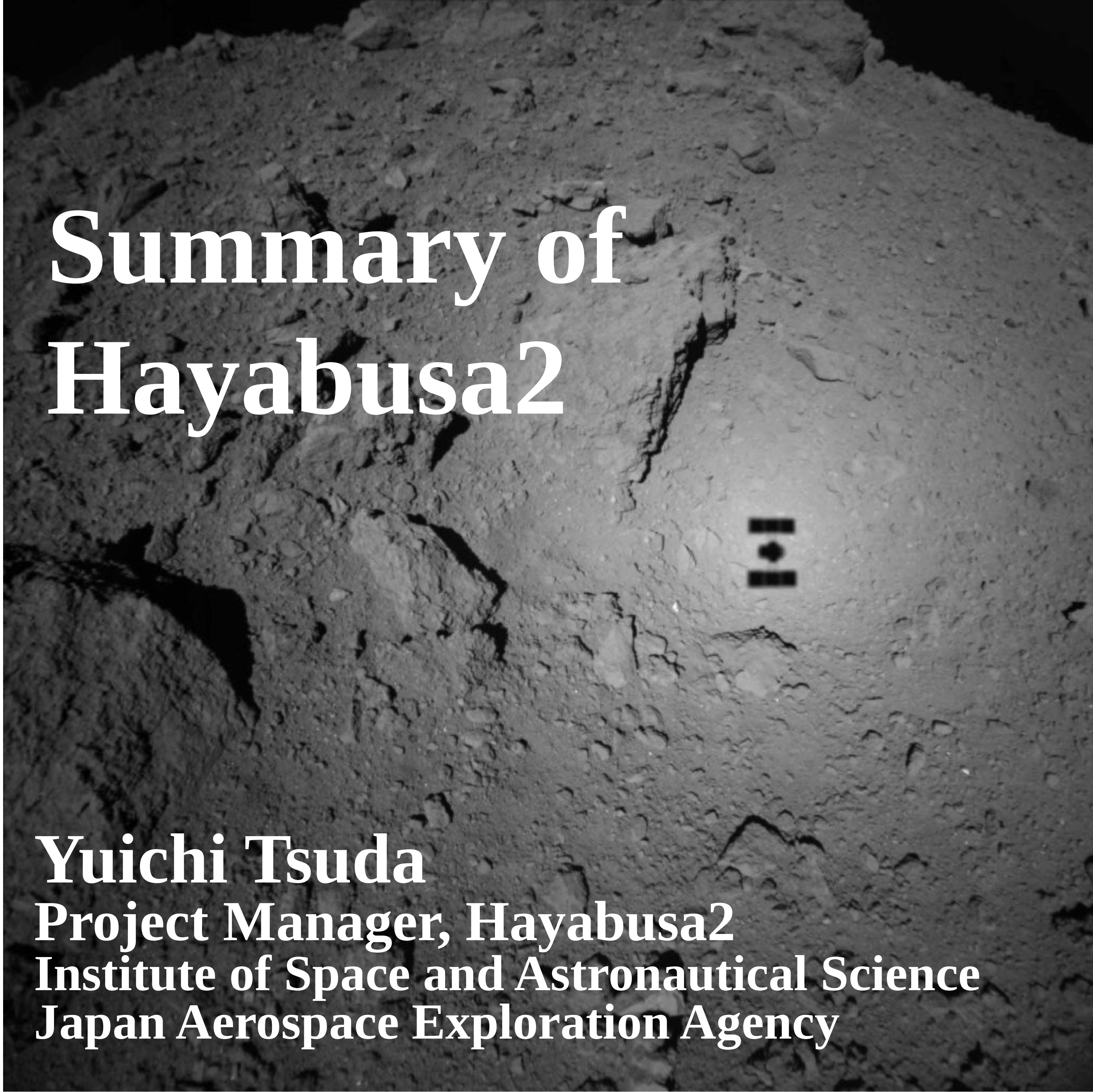
Hosted by UNOOSA in collaboration with ESA

Session 2: Hayabusa2

Chair: Makoto Yoshikawa

Presenters: Y. Tsuda, JAXA | T. Saiki, JAXA |
M. Arakawa, JAXA | S. Sugita, The University of Tokyo |
T. Okada, JAXA | M. Hirabayashi, Auburn University

Summary of Hayabusa2



Yuichi Tsuda
Project Manager, Hayabusa2
Institute of Space and Astronautical Science
Japan Aerospace Exploration Agency

Hayabusa2 Mission

- ✓ Sample return mission to a C-type asteroid “Ryugu”
- ✓ 52 billion km interplanetary journey.

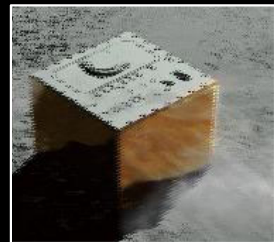
Launch
Dec.3, 2014

Earth Gravity Assist
Dec.3, 2015

Ryugu Arrival
Jun.27, 2018

MINERVA-II-1 Deployment
Sep.21, 2018

MASCOT Deployment
Oct.3, 2018



First Touchdown
Feb.22, 2019

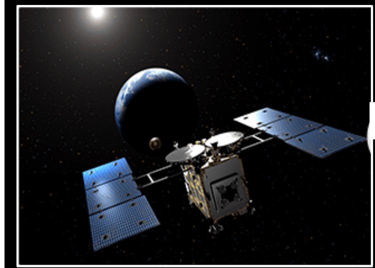
Kinetic Impact
Apr.5, 2019

Second Touchdown
Jul,11, 2019

Target Markers Orbiting
Sep.16, 2019

MINERVA-II-2 Orbiting
Oct.2, 2019

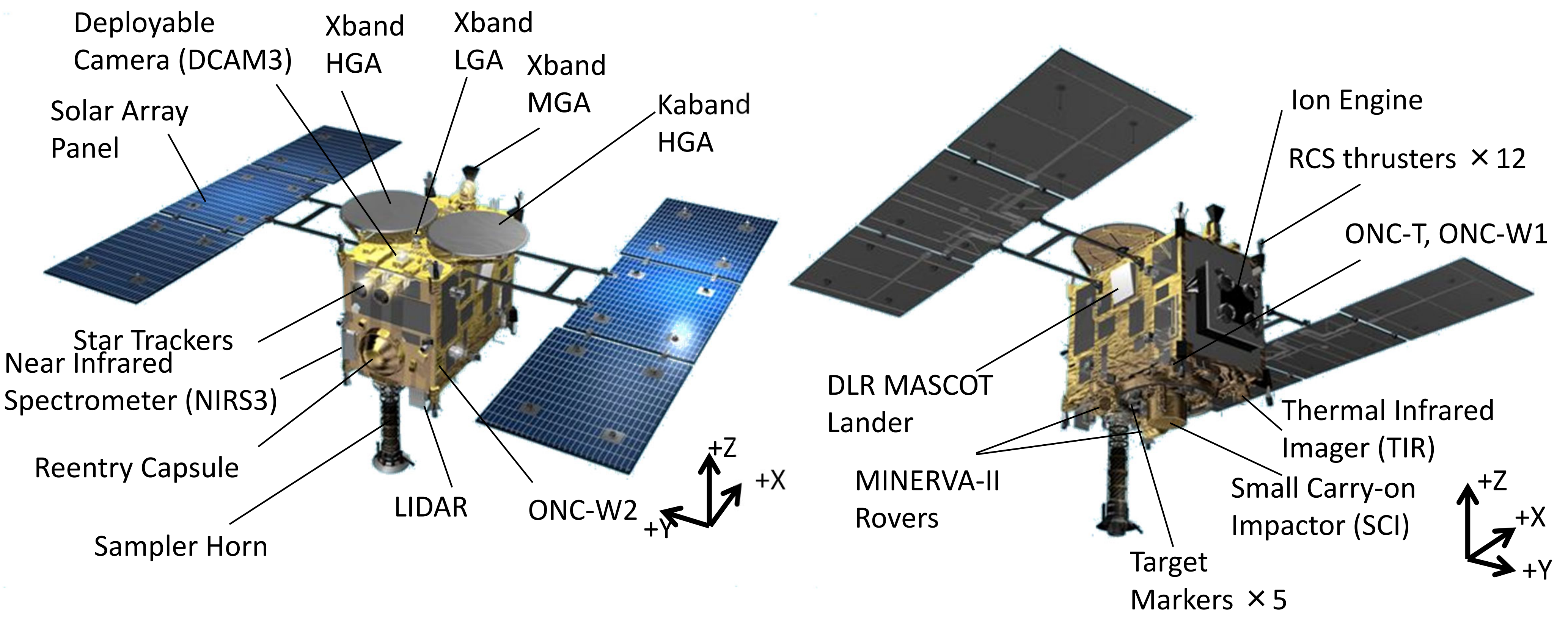
Ryugu Departure
Nov.13.2019



Earth Return
Dec.6, 2020

MD [D V|p srvlxp #534<#

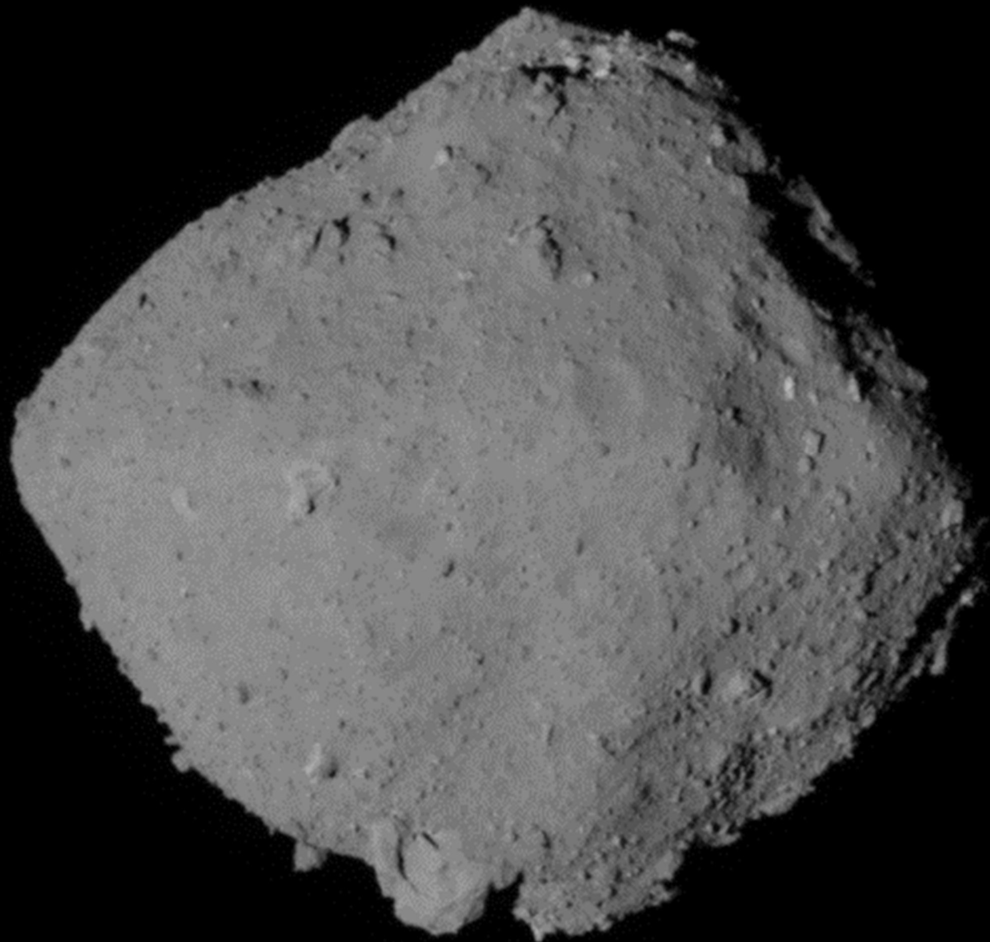
Hayabusa2 Spacecraft Overview



Launch Mass: 609kg
Ion Engine: Total ΔV=3.2km/s, Thrust=5-28mN (variable), Specific Impulse=2800-3000sec. (4 thrusters, mounted on two-axis gimbal)
Chemical RCS: Bi-prop. 20N thrusters ×12 (6 DOF maneuverability)
Solar Array Paddle: 2.6kW @ 1 a.u.
TT&C: X-band Uplink, X/Ka-band Downlink, 8-32Kbps, X/Ka RARR&DDOR capability

Arrival at Ryugu on June 27, 2018

- Top shape with a very circular equatorial bulge
- Spectrum type: Cb
- Diamter: ～900 m
- Mass: ～450 million ton
- Obliquity: ～8°
- Rotation period：P = 7.63 hours
- Reflectance factor（v-band）：0.02
- Terrain: Very bumpy

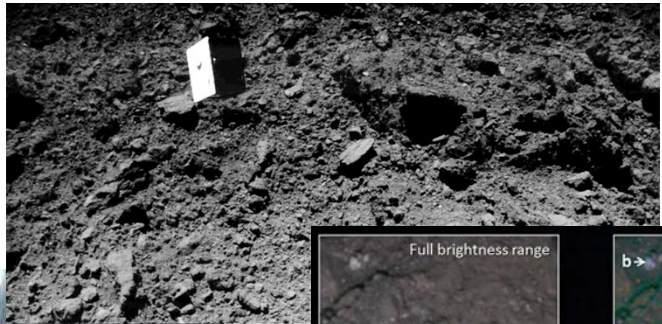


(C)JAXA, U of Tokyo, et.al.

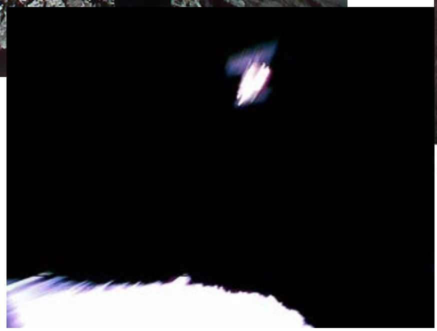
Accomplishments of Hayabusa2 (1/2)

1. Mobile activity of exploration robots on small body
2. Multiple robots deployment on small body

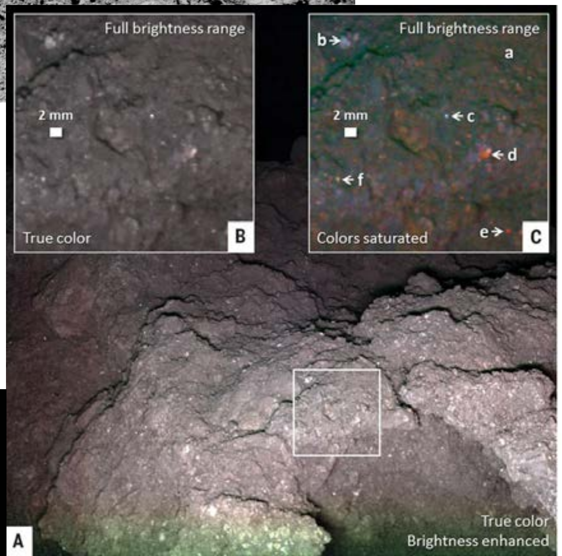
MASCOT taken by ONC-W2



MINERVA-II-1A image

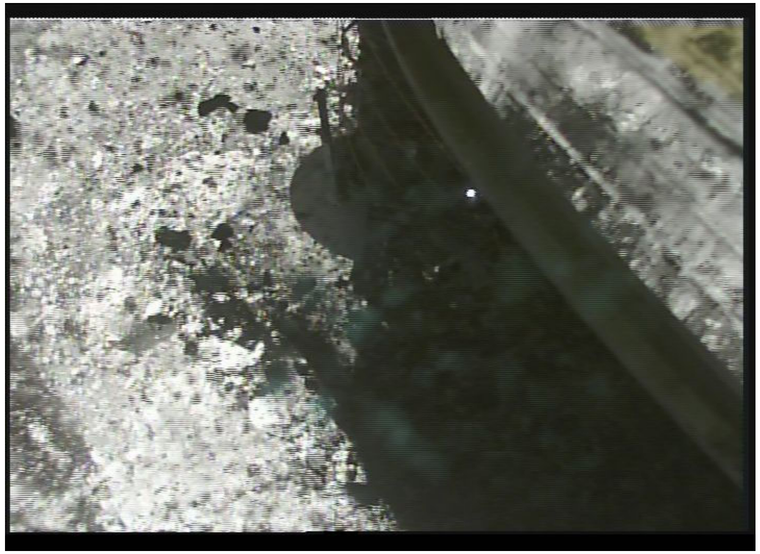


MINERVA-II-1A image

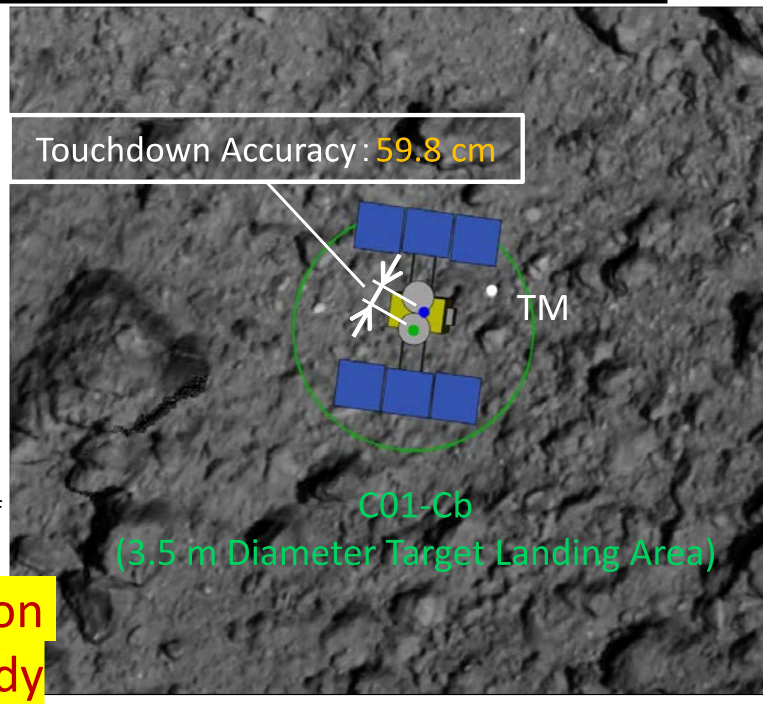


MASCOT images

CAM-H image at the 1st touchdown



Landing accuracy of the 2nd touchdown



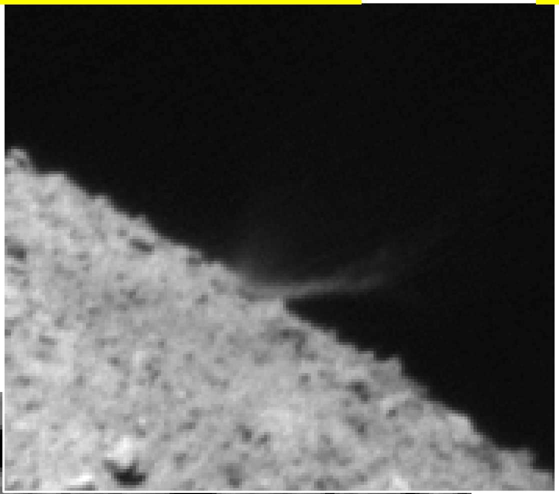
3. 60cm-accuracy landing and sampling on extra-terrestrial celestial body

image credit: JAXA

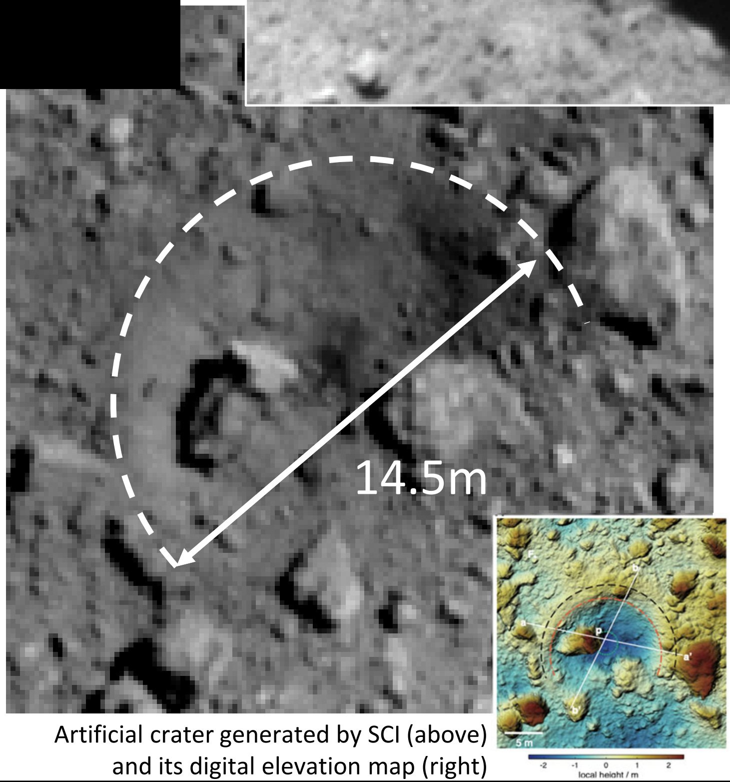
Accomplishments of Hayabusa2 (2/2)

4. Artificial crater forming and detailed observation of impact process

Impact ejecta observed by DCAM3



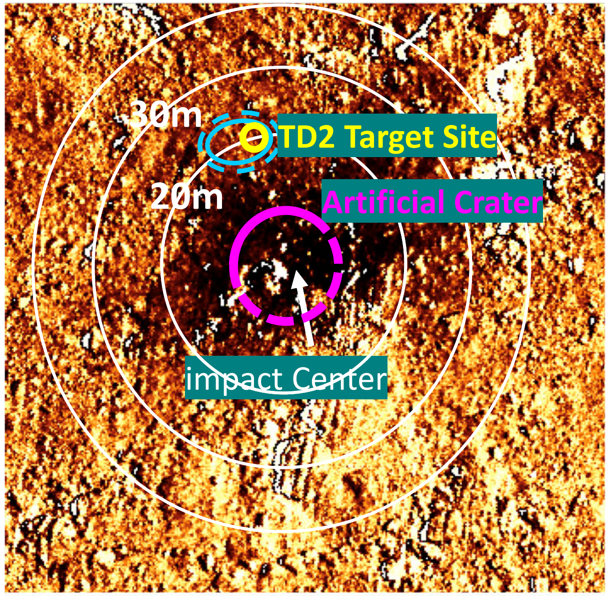
Deployed SCI taken by ONC-W1

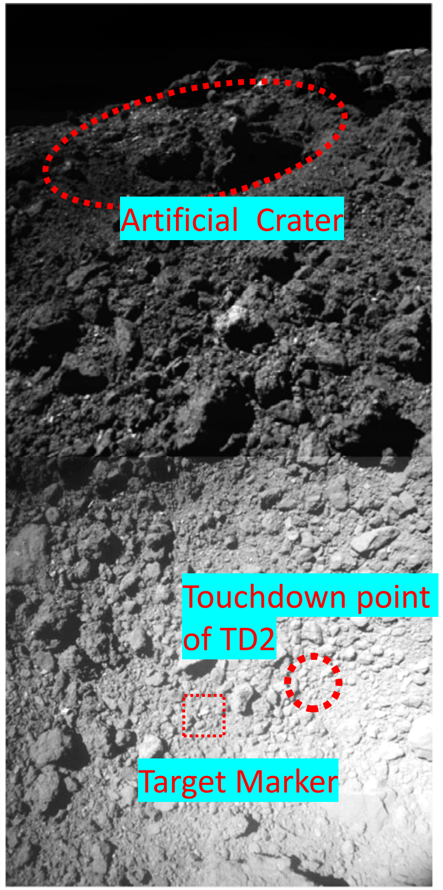


Artificial crater generated by SCI (above) and its digital elevation map (right)

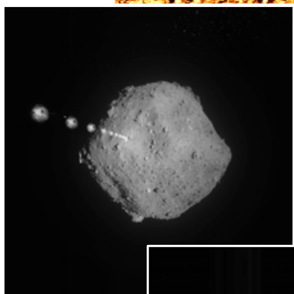
5. Multiple landing on extra-terrestrial celestial body
6. Access to subsurface material

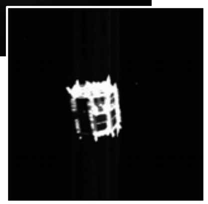
Accumulation of Impact ejecta around artificial crater

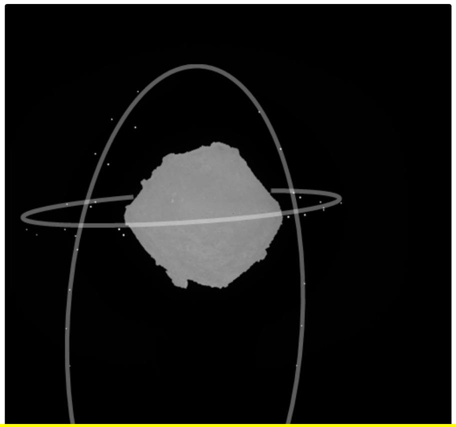




Artificial crater and TD2 point in one view





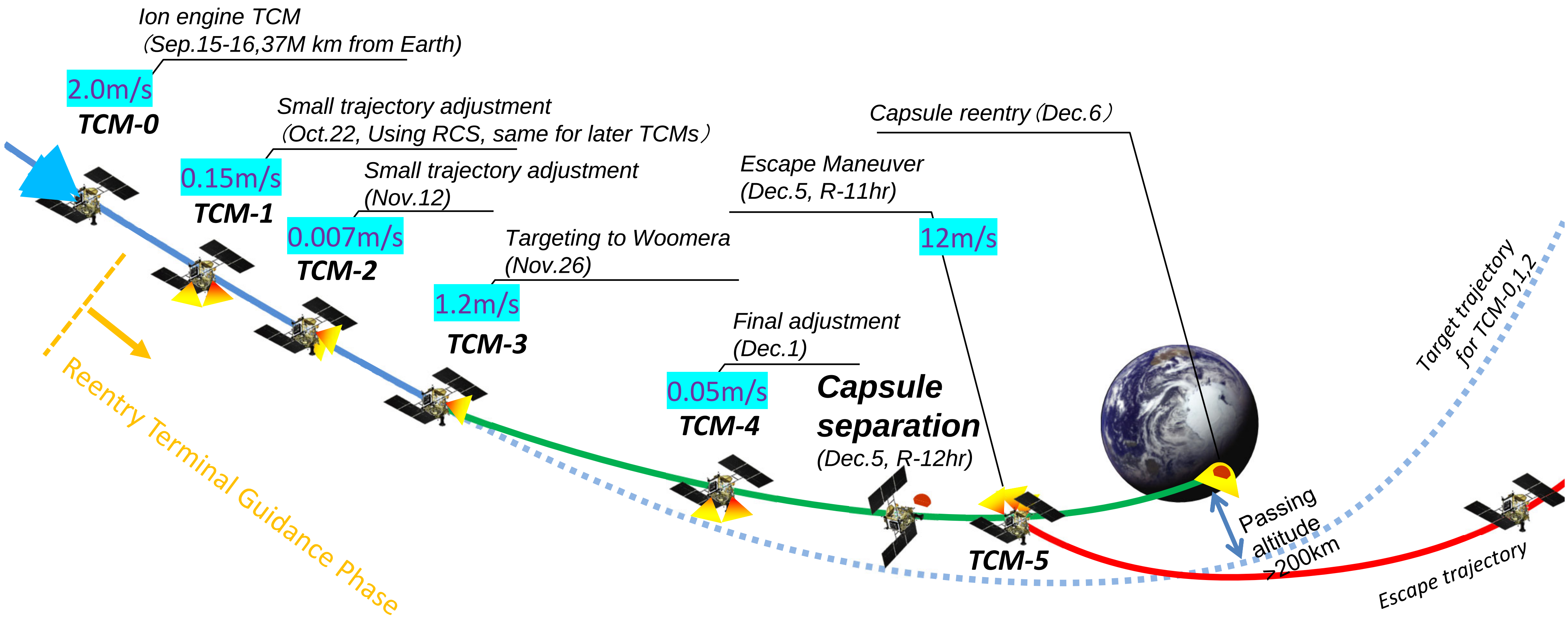


7. Smallest-object constellation around extra-terrestrial celestial body

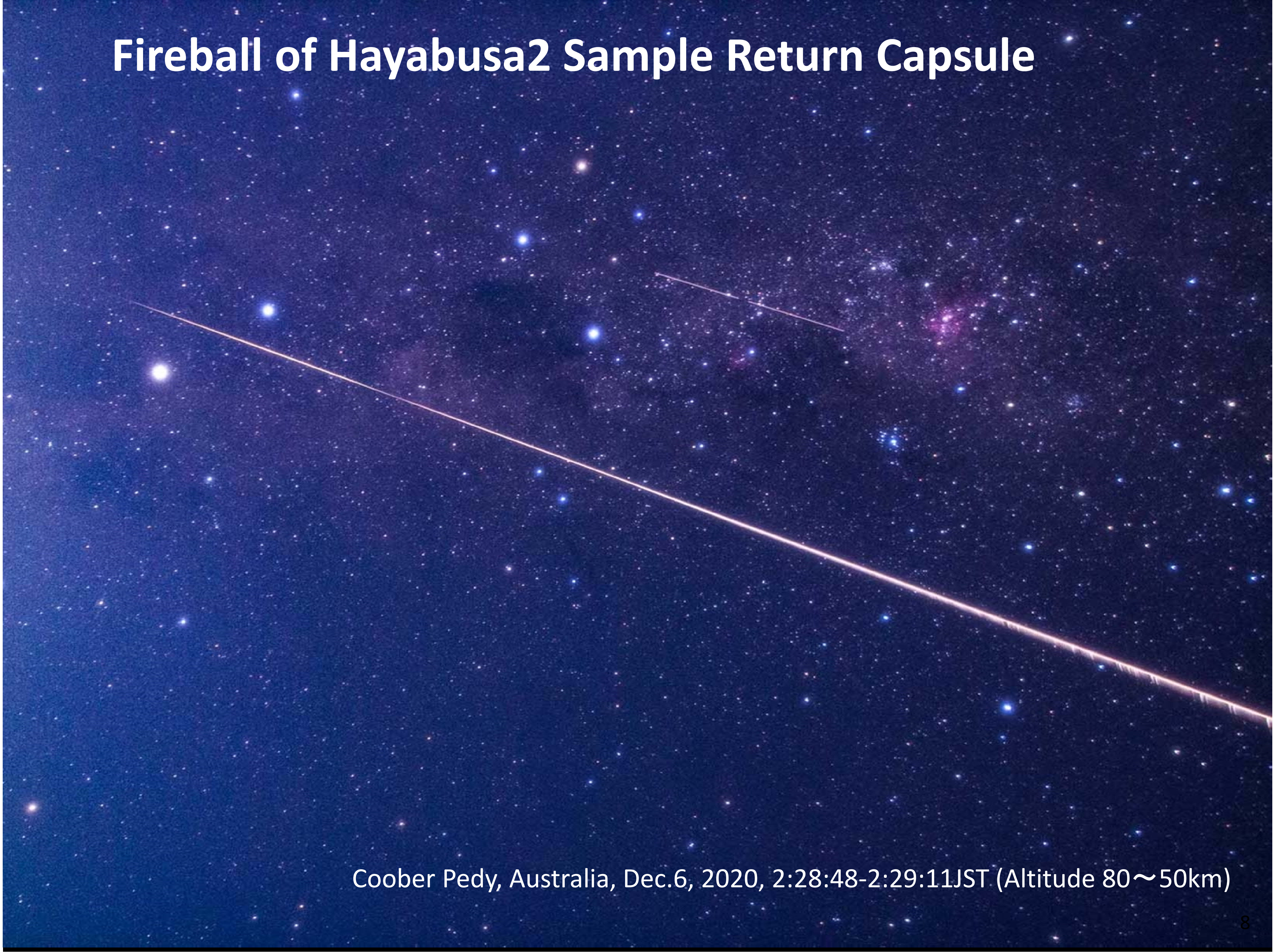
image credit: JAXA

Reentry Terminal Guidance Phase

- 5 TCMs in the last 2 months before Earth return.
- The SRC was separated 12 hrs before reentry.
- The spacecraft diverted from the reentry trajectory 11 hrs before reentry.



Fireball of Hayabusa2 Sample Return Capsule



Coober Pedy, Australia, Dec.6, 2020, 2:28:48-2:29:11JST (Altitude 80～50km)

Sample Return Capsule recovery

Dec.6 (JST)	
02:28	SRC reentry
02:32	SRC beacon signal detected
02:54	SRC landed (loss of beacon signal)
04:47	SRC found
08:03	SRC arrived at Quick Look Facility
11:13	Fore-heat shield found
12:31	Aft-heat shield found
Dec.7	
22:30	SRC shipped to Japan
Dec.8	
11:27	SRC carried into curation facility

57hr!
(requirement 100hr)


Ryugu samples found in the sample container!
Sample yield : 5.4g (requirement: 0.1g)

Significance of Hayabusa2

Science

Space Exploration Engineering

Planetary Defense

Planetary Resource

Hayabusa2 is pushing forward the boundaries of small body surface activity

ACCESS / ROVING / SAMPLING / IMPACTING

December 6 @Sagamihara Space Operation Center

Image by leaving Hayabusa2 after divert maneuver, Dec.6, 2020, 6:30JST, 88,000km)

Mission completed! ...and continuing to Extended Mission

December 14@Landing Point, Woomera

Session 2: Hayabusa2
Hayabusa2's kinetic impactor

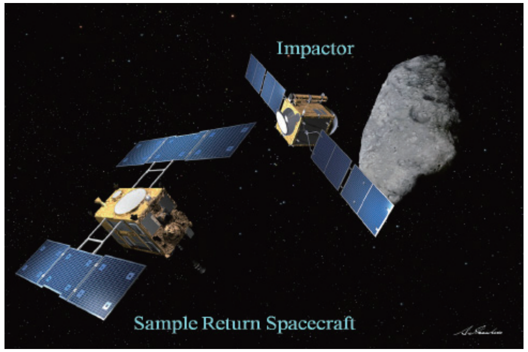
Takanao SAIKI (JAXA)
Hiroshi Imamura, Hirotaka Sawada, Kazunori Ogawa, Yuya Mimasu, Yuto Takei, Masahiko Arakawa, Toshirhiko Kadono, Koji Wada, Atsushi Fujii, Fuyuto Terui, Naoko Ogawa, Go Ono, Kent Yoshikawa, Makoto Yoshikawa, Satoru Nakazawa, Yuichi Tsuda

7th IAA Planetary Defense Conference
26-30 April 2021

Impact experiment of Hayabusa2

- Sub-surface exploration
  - A surface investigation alone is not sufficient.
    - Asteroid surface is altered by cosmic rays, solar wind particles, …
  - Investigating the internal structure and sampling “fresh” underground materials were required to learn about the evolution of asteroids and our solar system.
  - <u>Investigating asteroid’s structure is important for the planetary defense.</u>

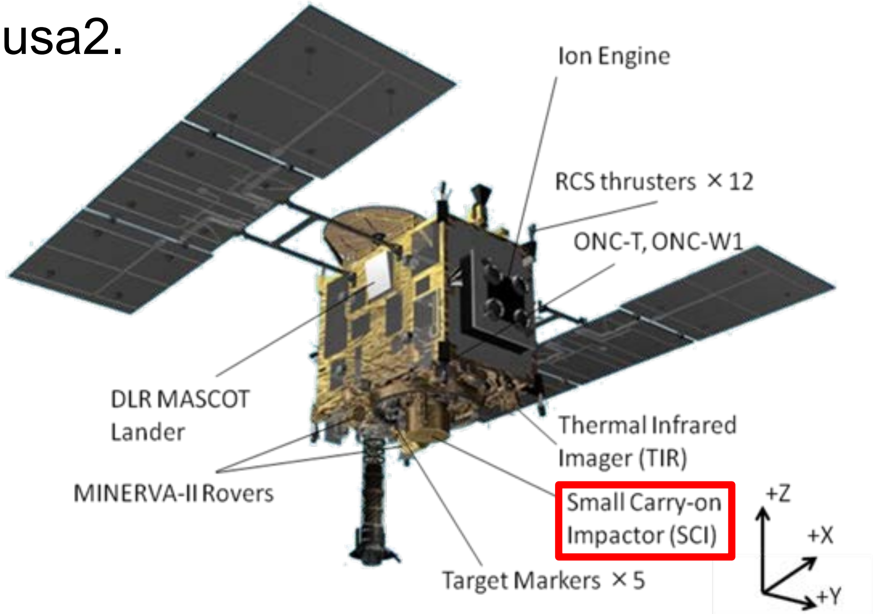
- Artificial crater generation via kinetic impact.
  - Small body impact missions: Deep Impact / DART
    - Large impactor spacecraft.
    - Huge impact energy.
    - A 300 kg-class impactor spacecraft was studied in the early concept study phase.
      -> not realized due to the financial circumstances.
  - JAXA developed a new low-cost small impact system.
    - Small Carry-on Impactor (SCI)

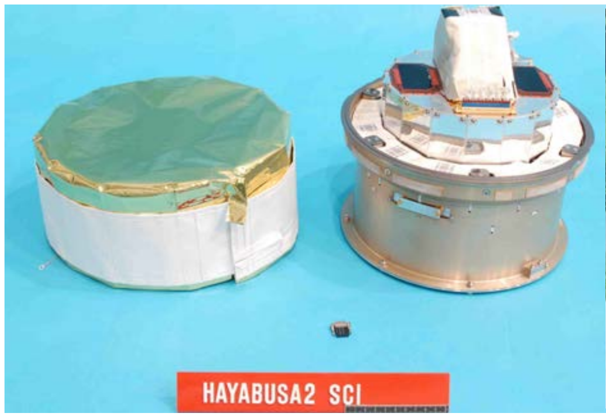


Small Carry-on Impactor

- SCI: Small Carry-on Impactor
  - Small kinetic impact device (Space cannon, bomb)
    - It was mounted on the bottom panel of Hayabusa2.
  - SCI was used after rendezvous with Ryugu.
    - It had to accelerate the impactor by itself.
  - Explosive propellant charge
    - 2 kg copper impactor.
    - Impact velocity: 2 km/s.
  - Very simple system
    - No GNC function.
    - Attitude: spin stabilization.

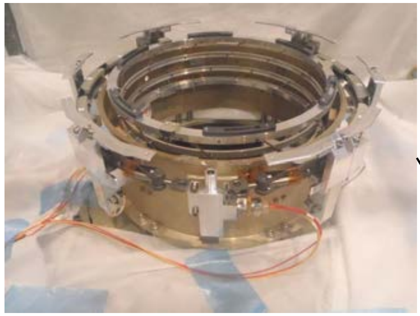
-> developed at low cost.





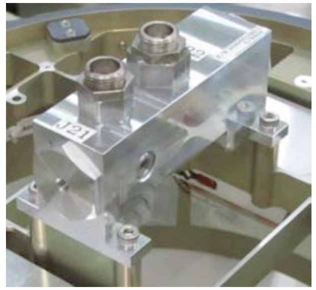
Configuration of SCI

Separation mechanism
(helical spring)

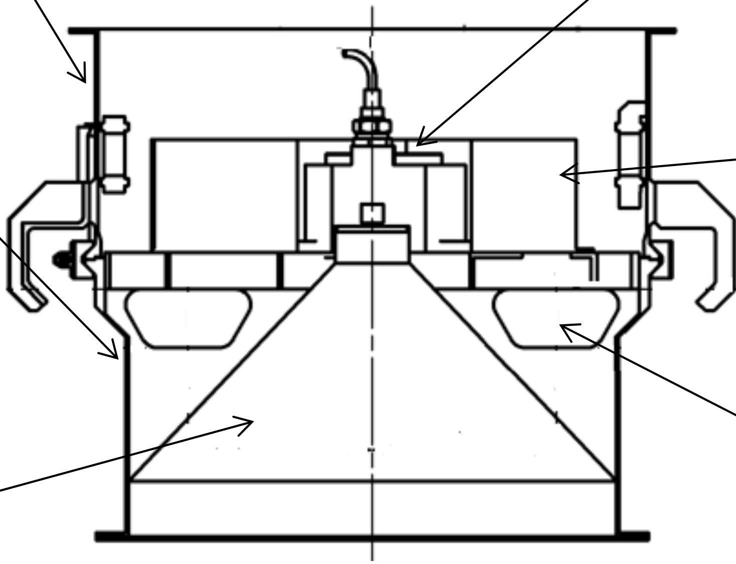


Total: 18kg
Separation mechanism: 4kg,
Main body: 14kg

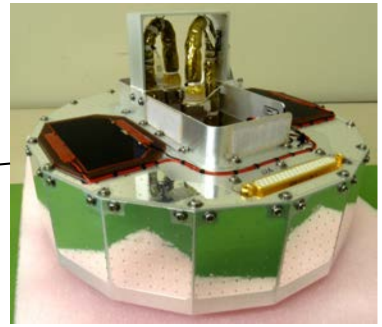
Safe & arm device
(Incl. detonator + booster)



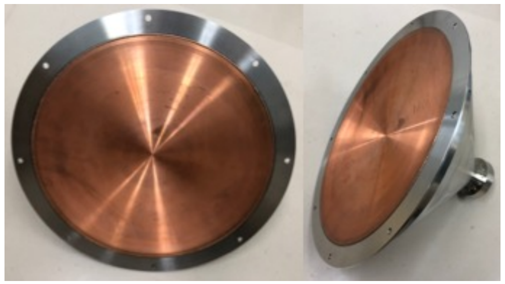
Main body



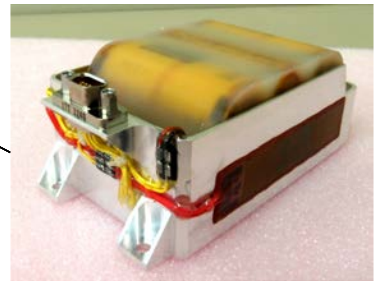
Electric device
(sequencer, ignition circuit)



Shaped charge



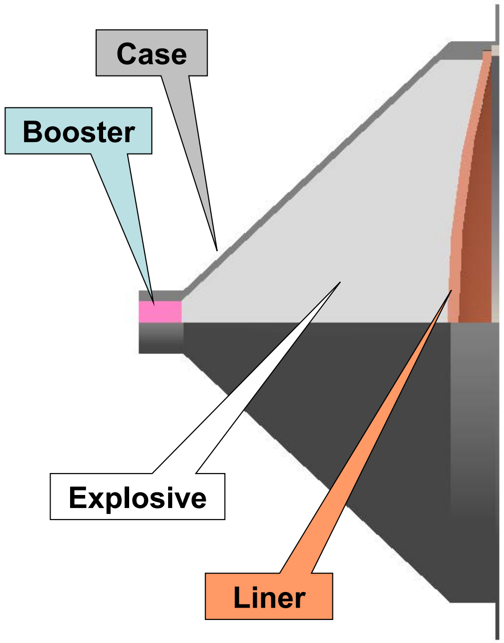
Primary battery

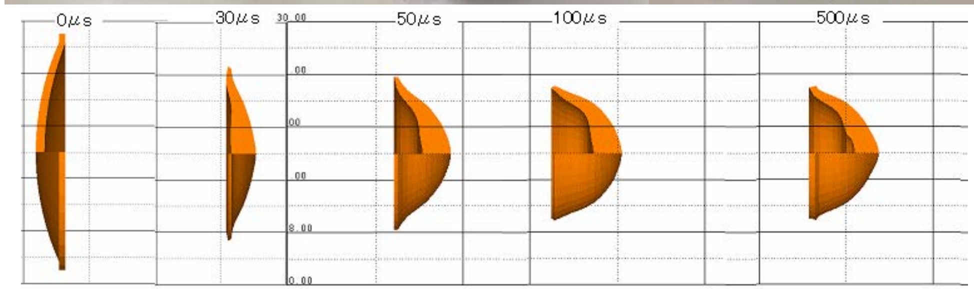


Shaped charge

- Weight: About 9.5 kg (Explosive: 4.7kg, Liner: 2.5kg)
- Explosive: HMX-based plastic bonded explosive (PBX)
- Acceleration time: Very short (less than 1 ms.)
- Problem: The powerful explosive destroys the SCI main body and scatters many high-speed fragments.

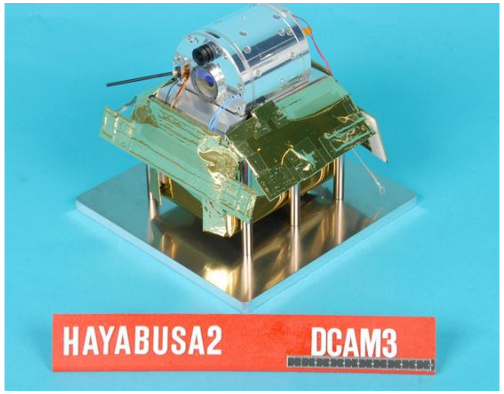
-> Complicated operation.

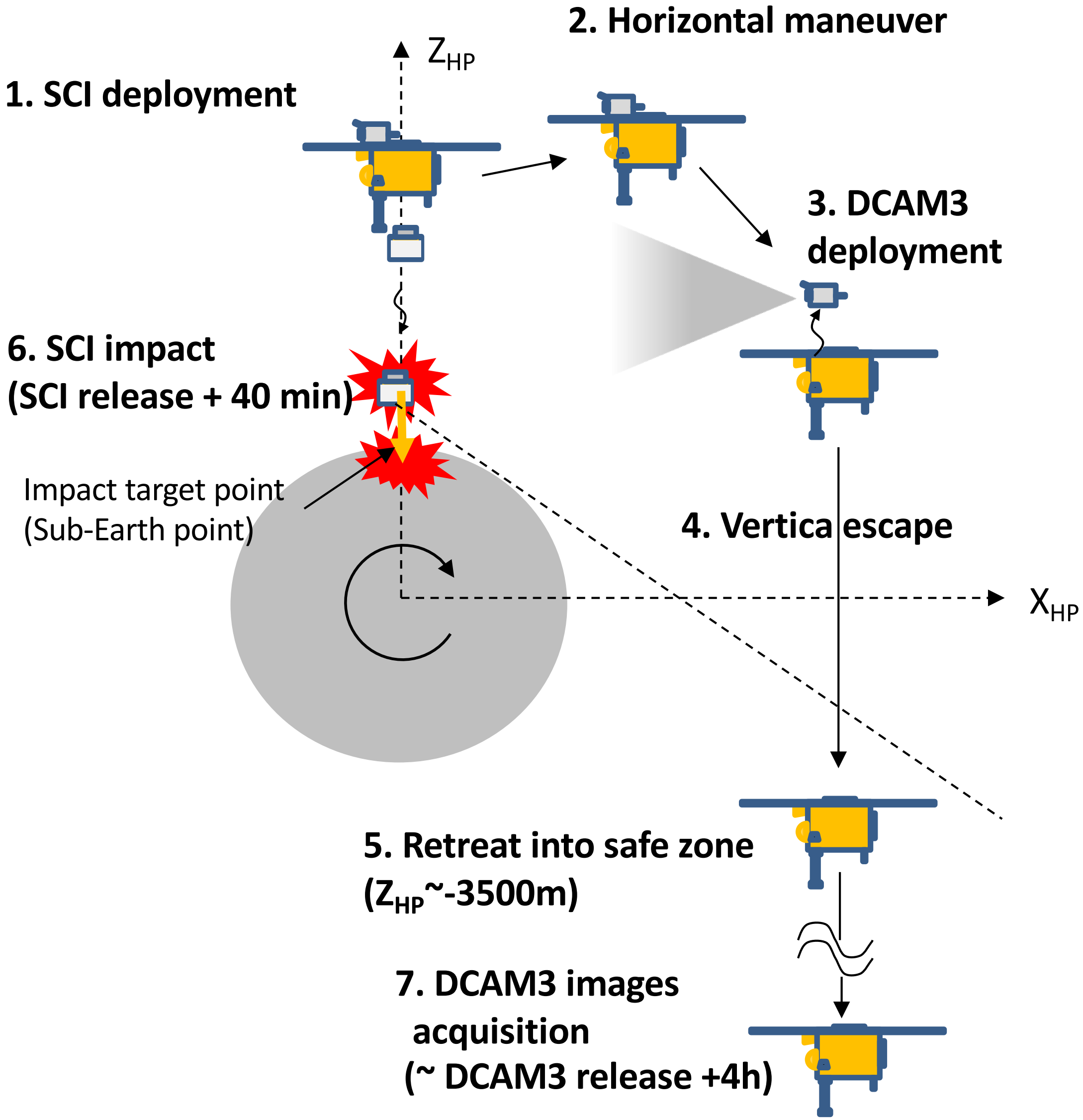




Impact operation sequence

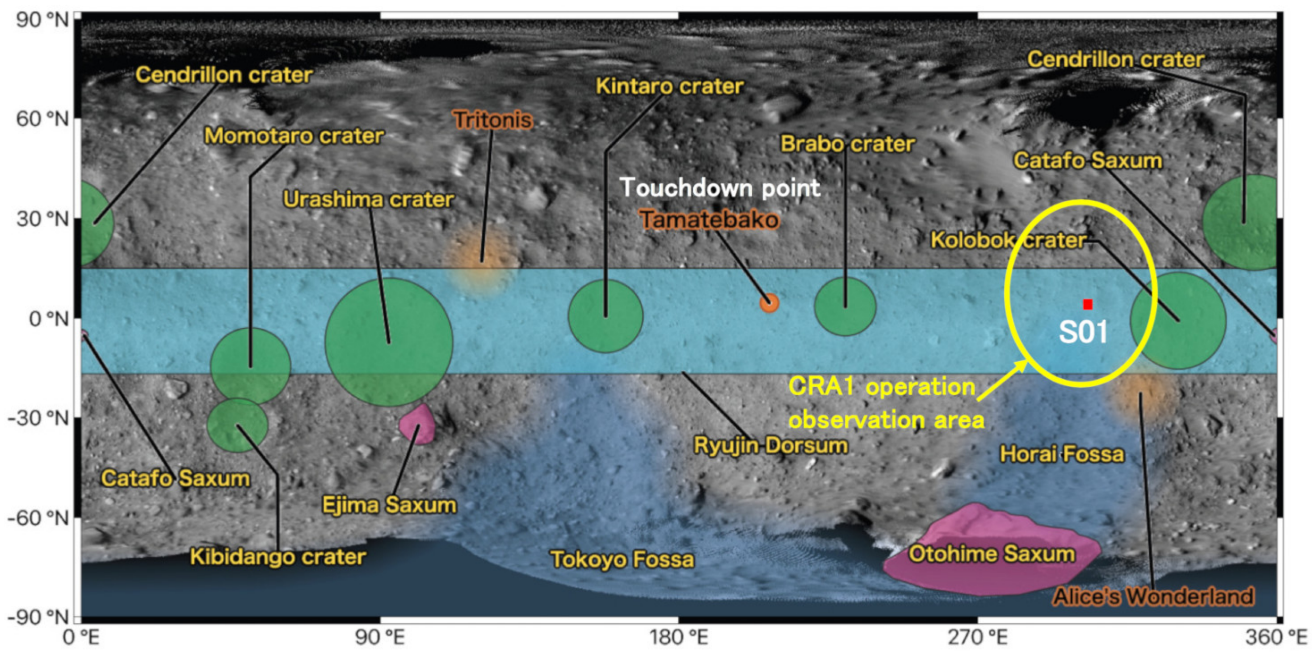
- Escape maneuver
  - Hayabusa2 must escape to the safe zone behind Ryugu's limb to avoid the debris and ejecta.
- Sequence of impact operation
  1. SCI Separation. Alt: about 500m
  2. Horizontal maneuver.
  3. DCAM3 deployment.
  4. Vertical maneuver.
  5. Retreat into safe zone.
  6. SCI impact. (40 min after the SCI release).
  7. DCAM3 images acquisition

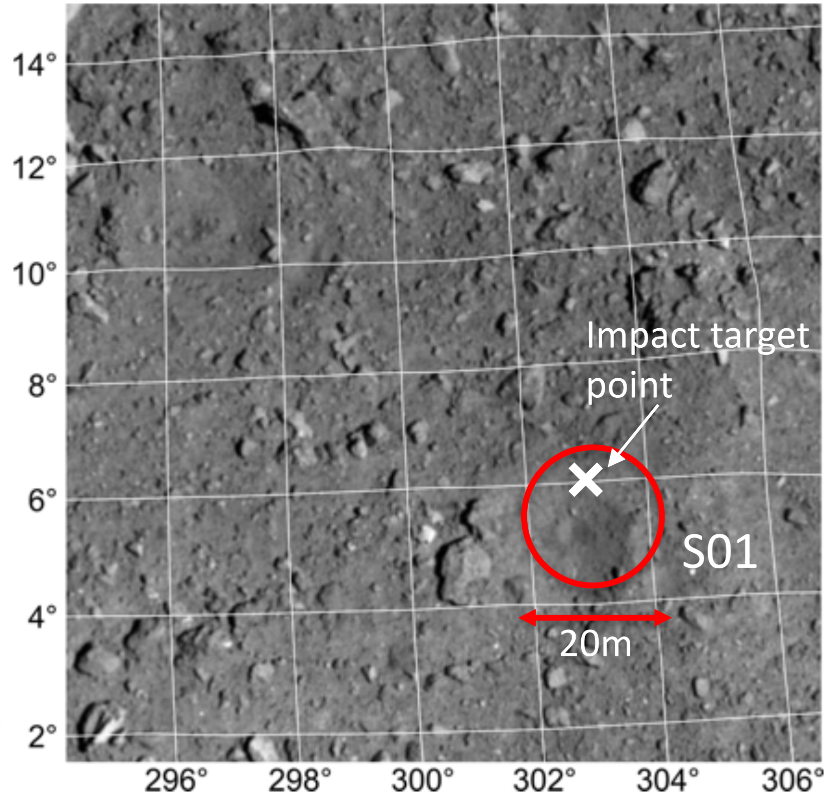




Impact Target

- Impact Target: Lat=6degN, Lon=303deg
  - On the equatorial ridge of Ryugu.
  - Near S01 area (Flat area found by the global survey)
- Impact epoch: 2:36:10 on April 5 2019.
  - SCI release: 40 min before the impact epoch.

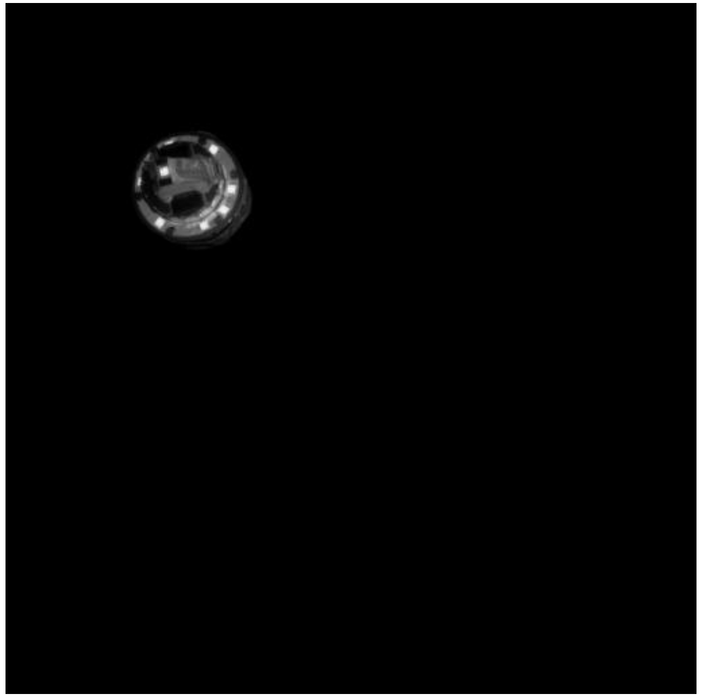




SCI impact experiment

- Impact experiment: April 4-5, 2019

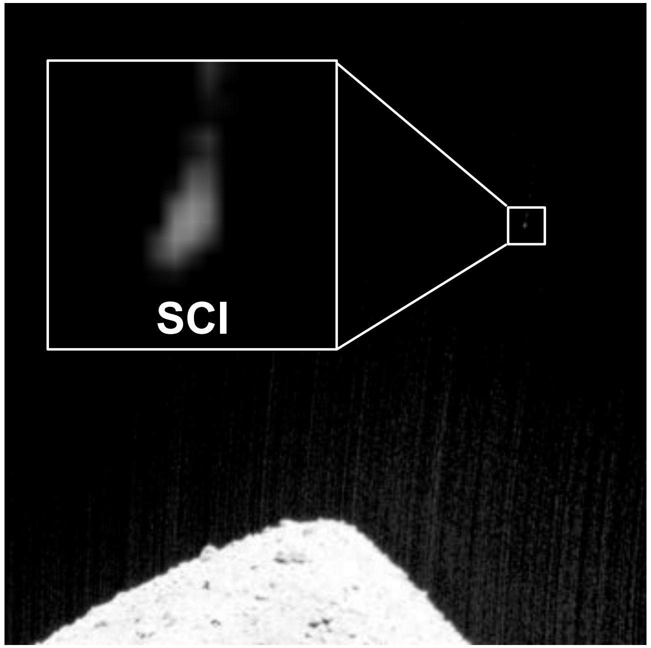
Time(UT)	Events
Apr. 4 04:00	Start descent (40cm/s, alt=20km)
Apr. 5 00:21	SCI ON
00:44	Begin GO/NOGO judgement
01:05	Send GO commands
01:44	Target altitude arrival & start hovering
01:52:20	+Z dV (final dV before SCI sep.)
01:56:11	**SCI separation, alt=500m**
01:57:37	+X dV (evacuation dV 1)
02:02:26	-Z dV (evacuation dV 2)
02:10:07	-X dV (evacuation dV 3)
02:14:25	**DCAM3 separation**
02:15:27	-Z dV (evacuation dV 4)
02:36:10	**SCI explosion & impact !**
07:22	Stop observation command to DCAM3



Released SCI (1:56:17)

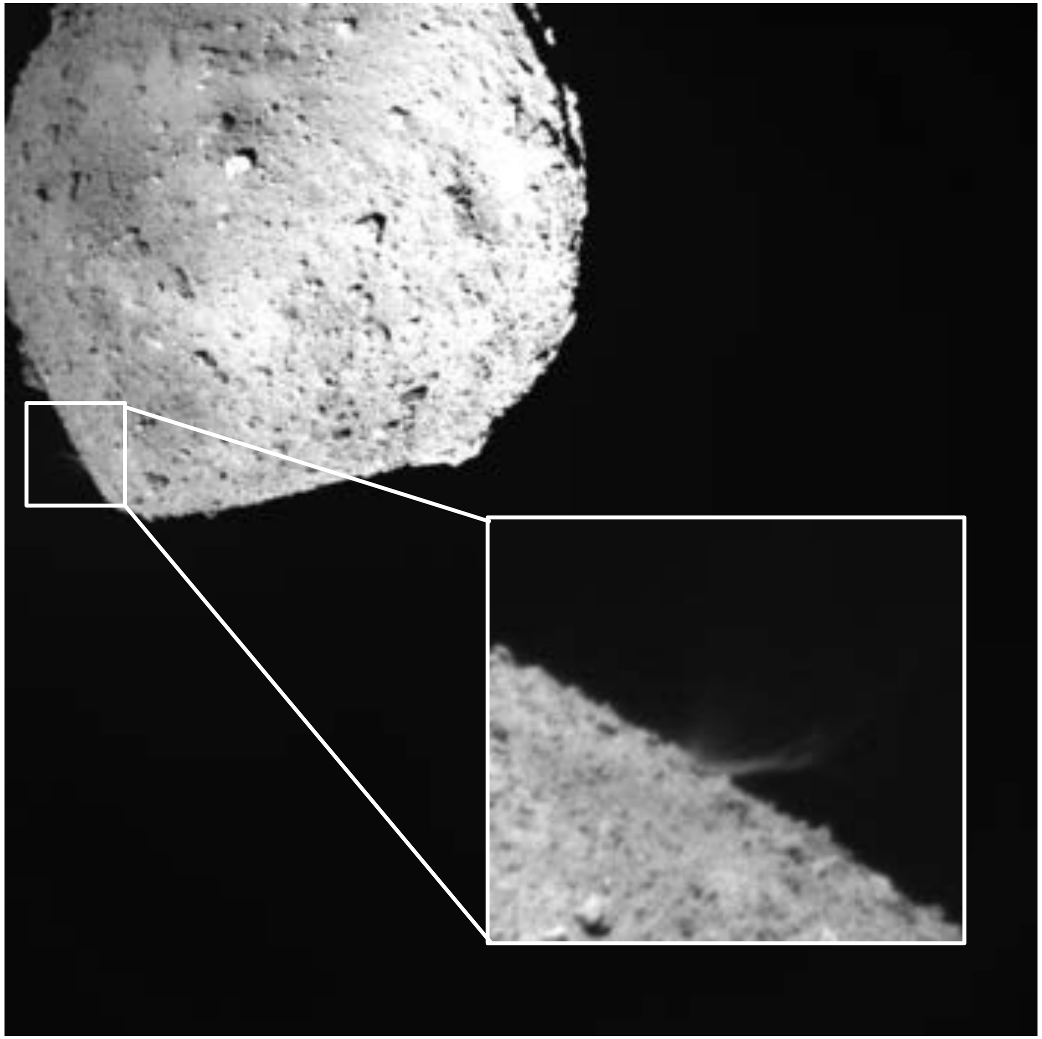
DCAM3 images

- Photos from DCAM3



185sec before SCI ignition

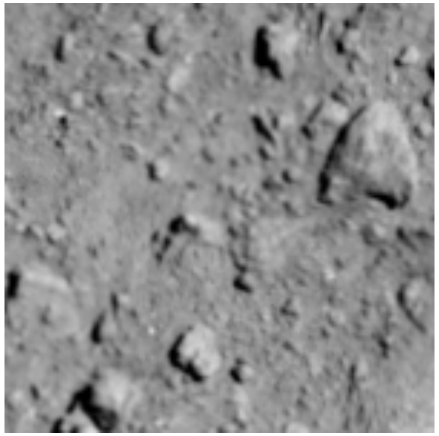
2sec after the impact (analog camera)

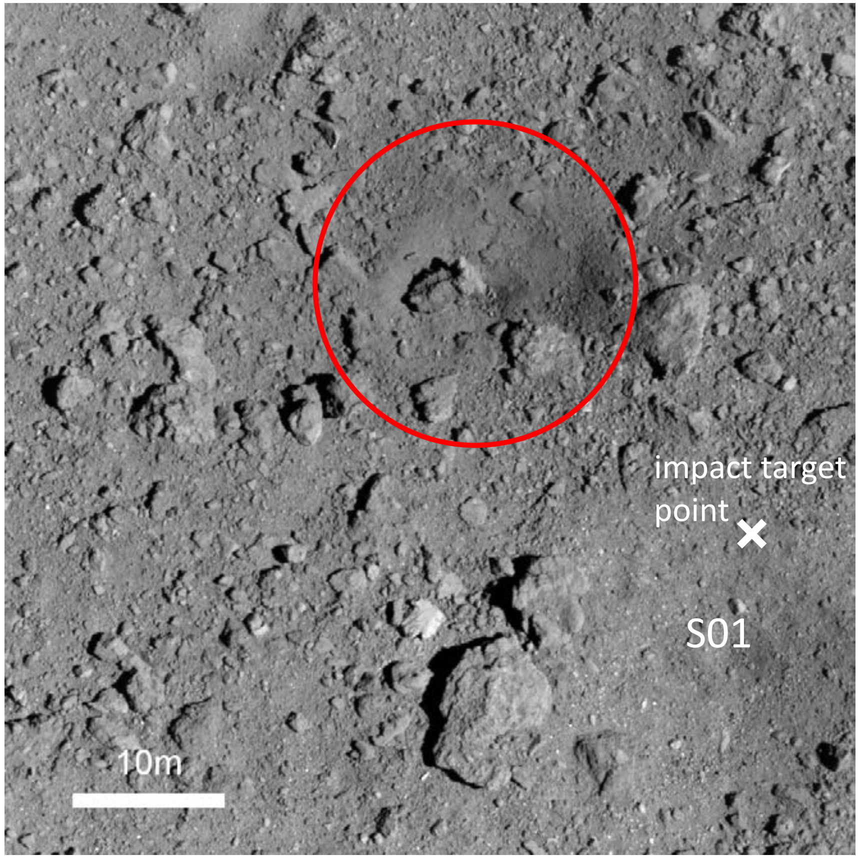


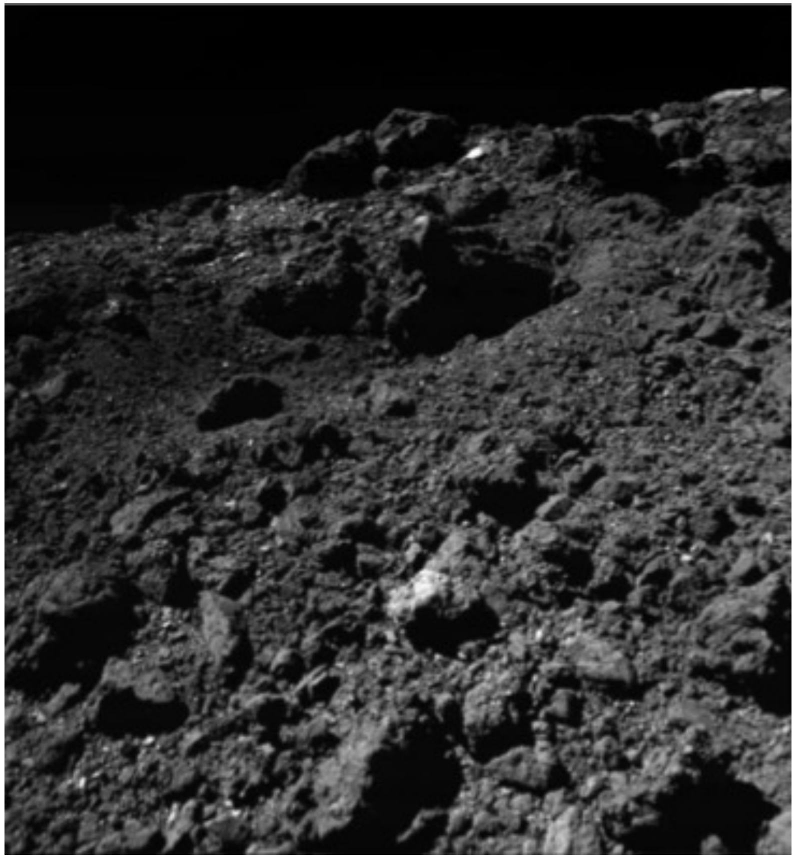
3sec after the impact (digital camera)

Artificial Crater

- 15m class crater
  - ◆ Impact position: only 20m off from the target !
  - -> The SCI was released with small velocity & pointing errors.
- July 11, 2019: 2nd sampling (North of crater).







Summary

- The investigation of the sub-surface structure and materials was the new objective of Hayabusa2 that was not seen with Hayabusa.

- Hayabusa2 was equipped with a compact kinetic impactor (SCI) and a small deployable camera (DCAM3).

- The spacecraft, SCI, and DCAM3 worked perfectly in the impact experiment on April 5, 2019.
- A15m-class artificial crater was created, and its formation process was observed by the DCAM3.

- Impact energy of the SCI is too small to deflect the asteroid.
- However, the SCI is an important tool for planetary defense because the artificial crater gives us valuable information about the structure of small bodies.

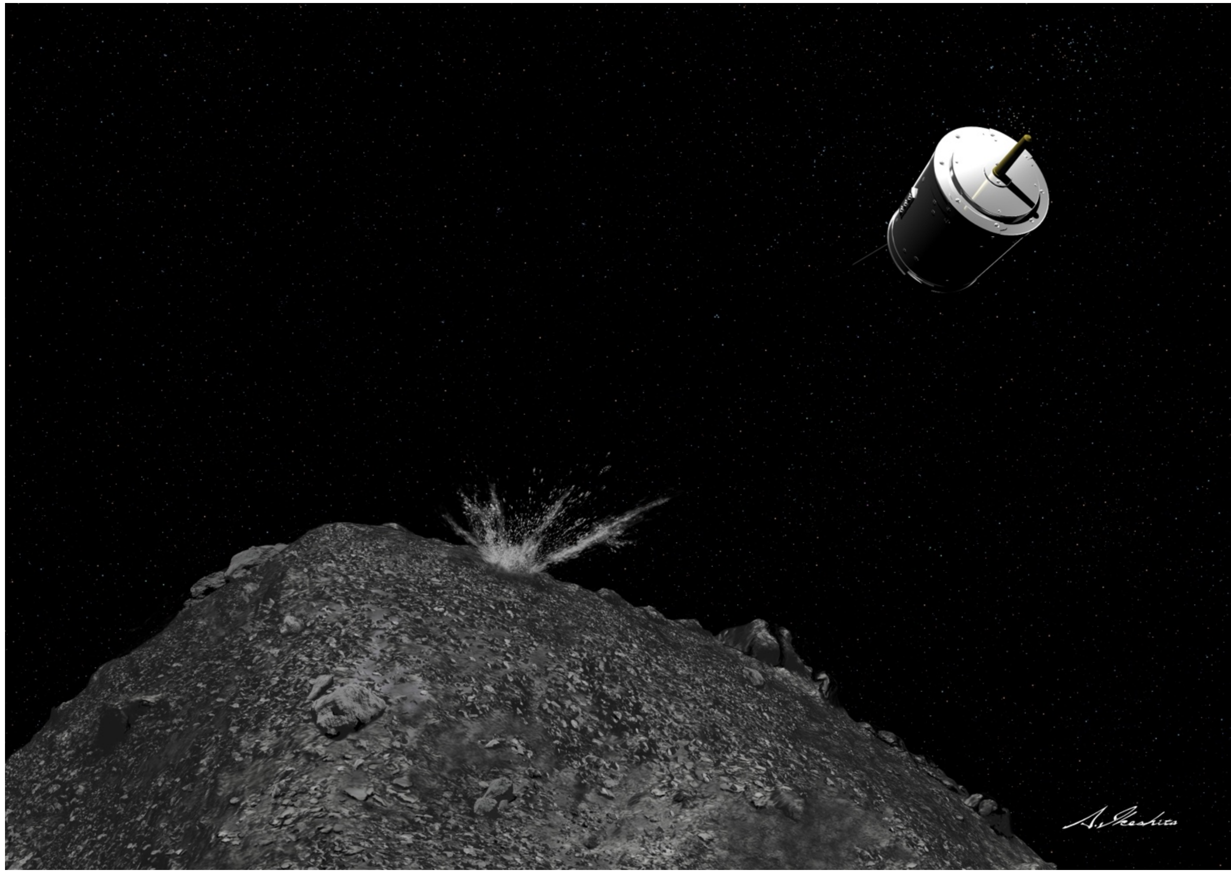
Artificial impact crater on Ryugu formed in the gravity dominated regime

M. Arakawa[1], K. Wada[2], K. Ogawa[3], T. Kadono[4], K. Shirai[1], K. Ishibashi[2], R. Honda[5], N. Sakatani[6], Y. Shimaki[3]

1. Kobe University, 2. Chiba Institute of Technology, 3. JAXA, 4. , University of Occupational and Environmental Health , 5. Kochi University, 6. Rikkyo University

SCI Impact experiment on Ryugu

- **Artificial impact crater**
  - To excavate the subsurface and observe the asteroid interior.
- **Ejecta curtain**
  - Observed by Deployable CAMera 3 to study the mechanical properties of the surface.
- **Scientific aspects**
  - Supported Hayabusa2 scientific observations by remote-sensing instruments and sampling at touchdown.
    1. Sample science
    2. Remote sensing science
    3. Science for Planetary impact process

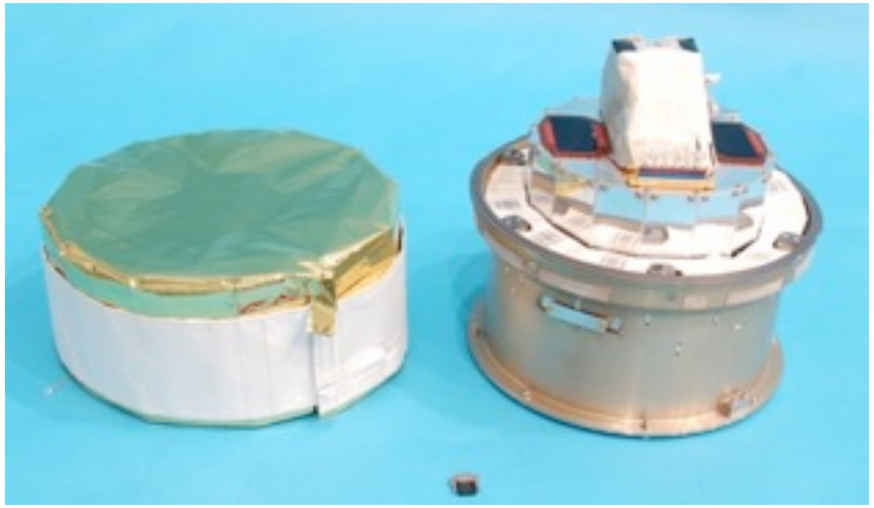


Instruments

SCI

Small Carry-on Impactor

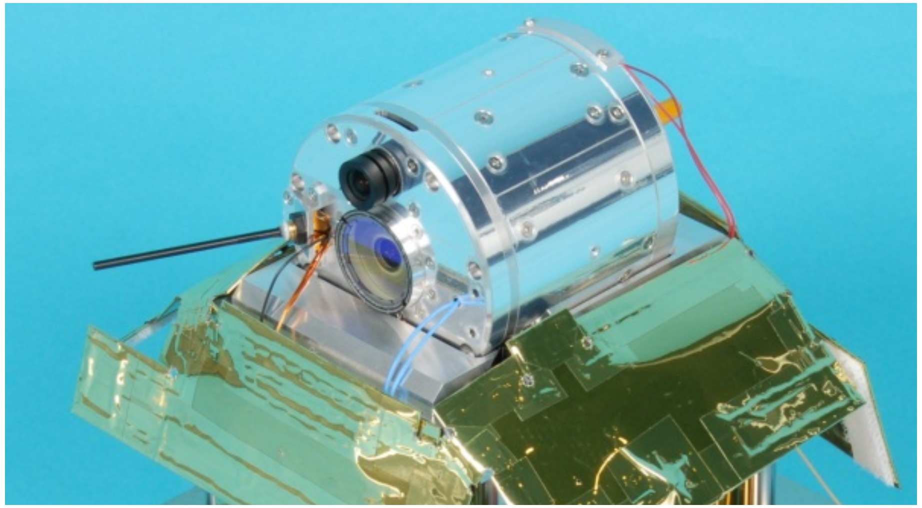
- Copper disk (30 cm) and explosive.
- Copper disk projectile (2 kg, ~ 2 km/s) deforms to a hollow spherical shell.
- First instrument to form artificial impact crater on asteroids.



DCAM3

Deployable CAMera in 3rd generation

- A tiny satellite composed of optics, sensor, transmitter, and battery.
- Specifications: < 1 m/pixel, 1 frame/sec, 74°x74° FOV.
- **In-situ observation of SCI impact on the surface of Ryugu**.



Overview of SCI, DCAM3 operation

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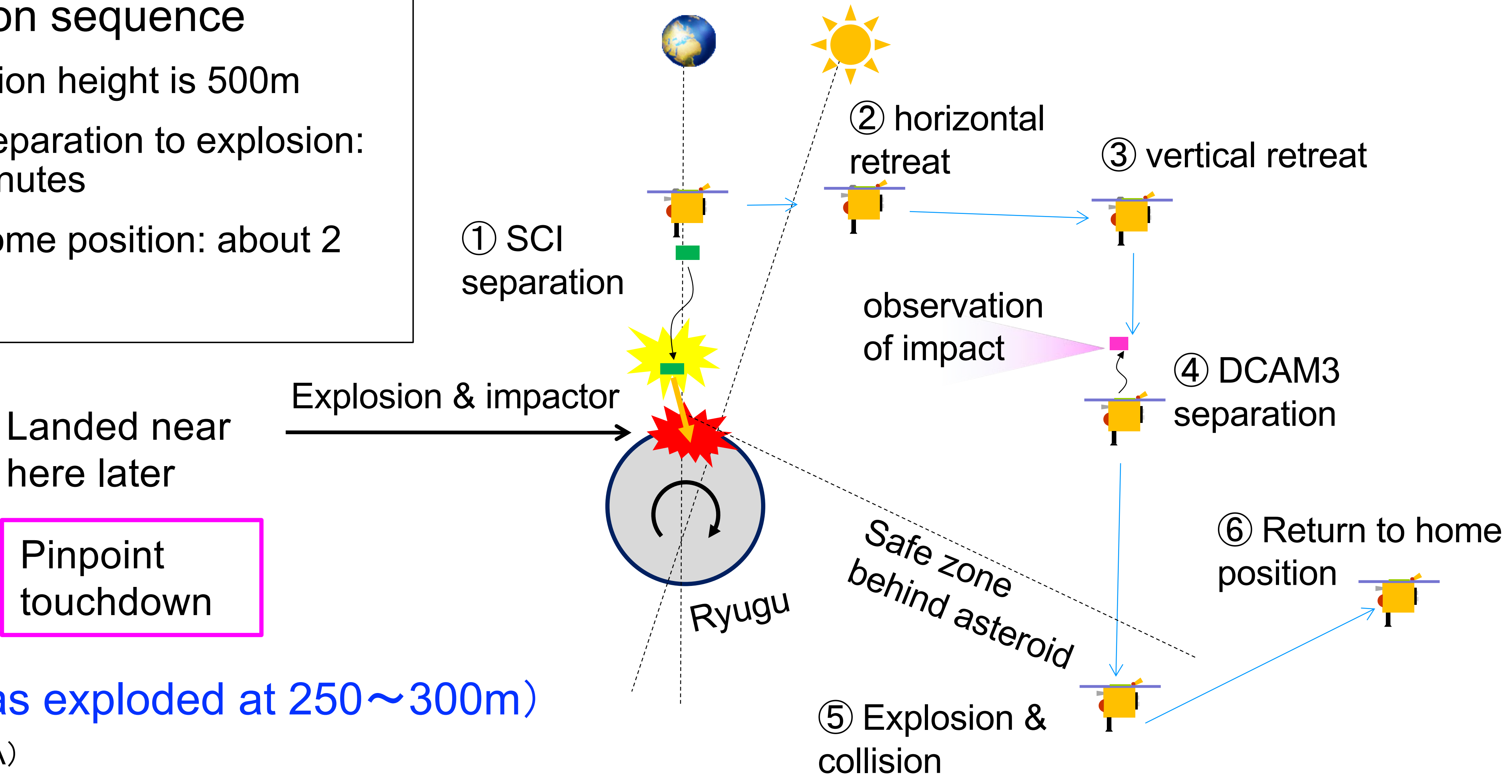
SCI operation sequence

- SCI separation height is 500m
- From SCI separation to explosion: about 40 minutes
- Return to home position: about 2 weeks



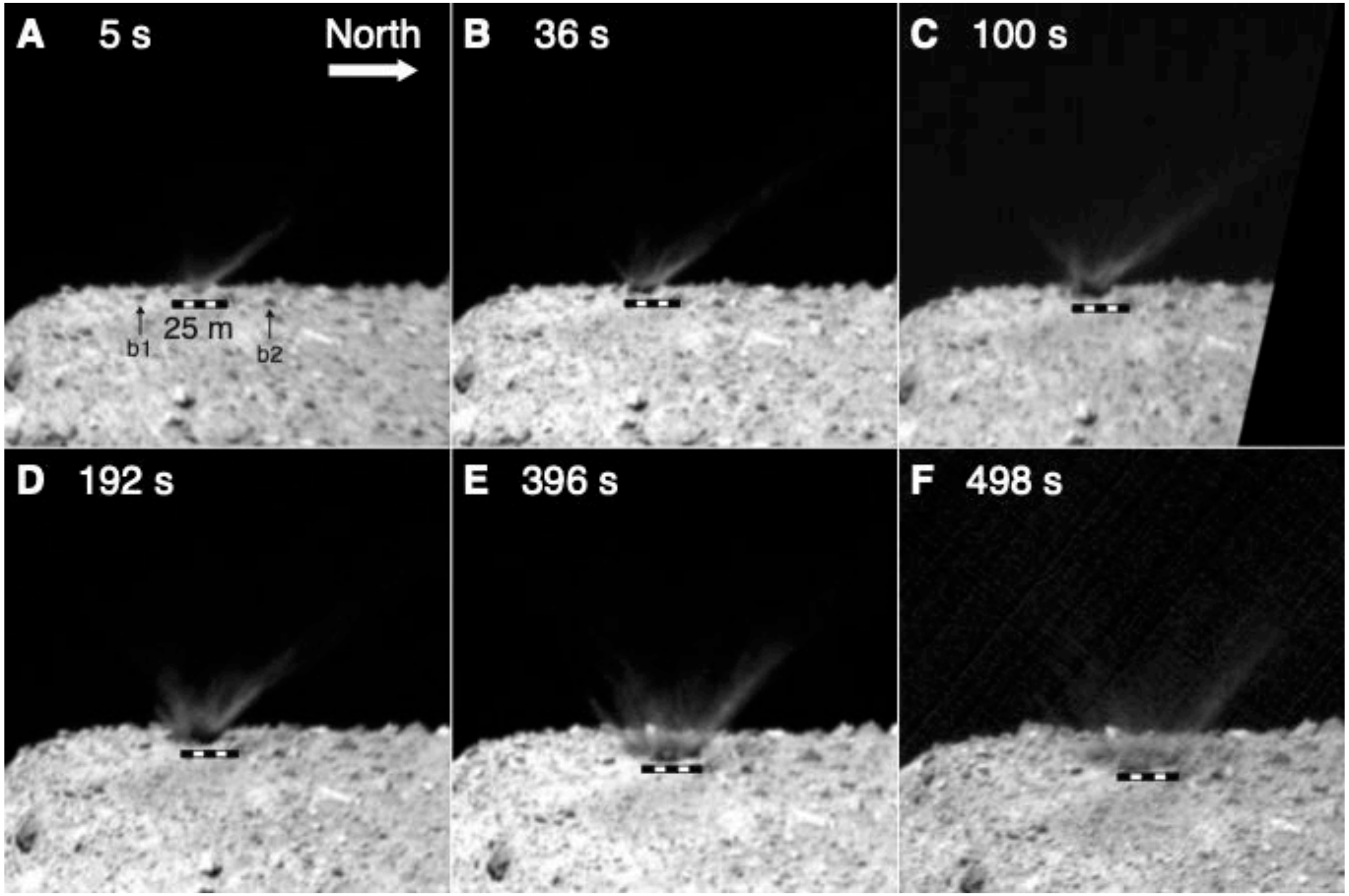
（SCI was exploded at 250～300m）

（image credit：JAXA）

Successive images of ejecta curtain growth observed by DCAM3

KOBE UNIVERSITY

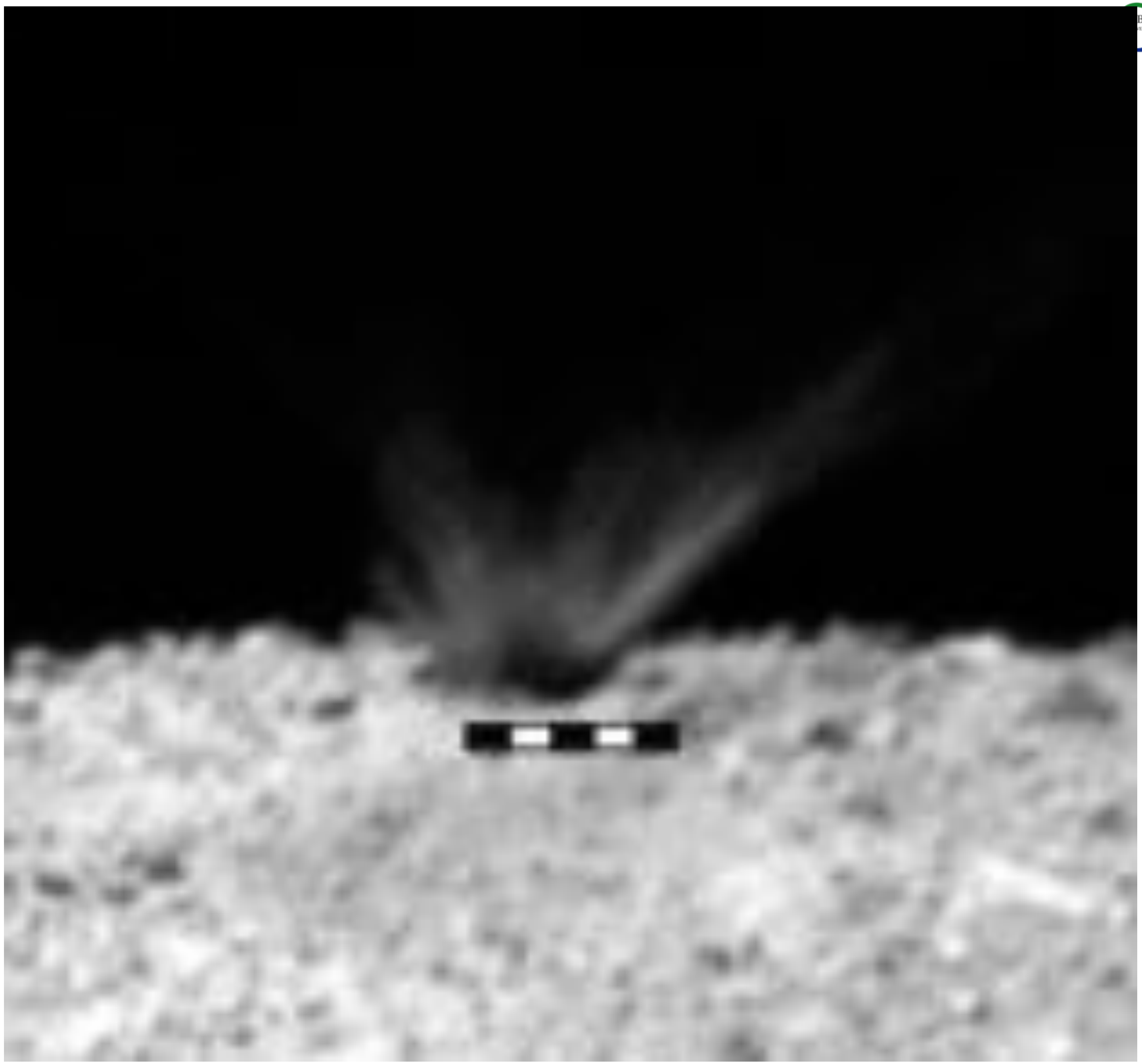
- Ejecta generated in the collision initially spray northward.
- Crater formation, excavation and deposition process, lasts for 500 seconds.
- No separation between the ejecta curtain and ground surface is observed.
- For the first 200 seconds, the crater appears to be growing. After this, the ejecta deposition is occurring.
- SCI carter could be formed in the gravity dominated regime



Arakawa et al., 2020

Ejecta curtain growth

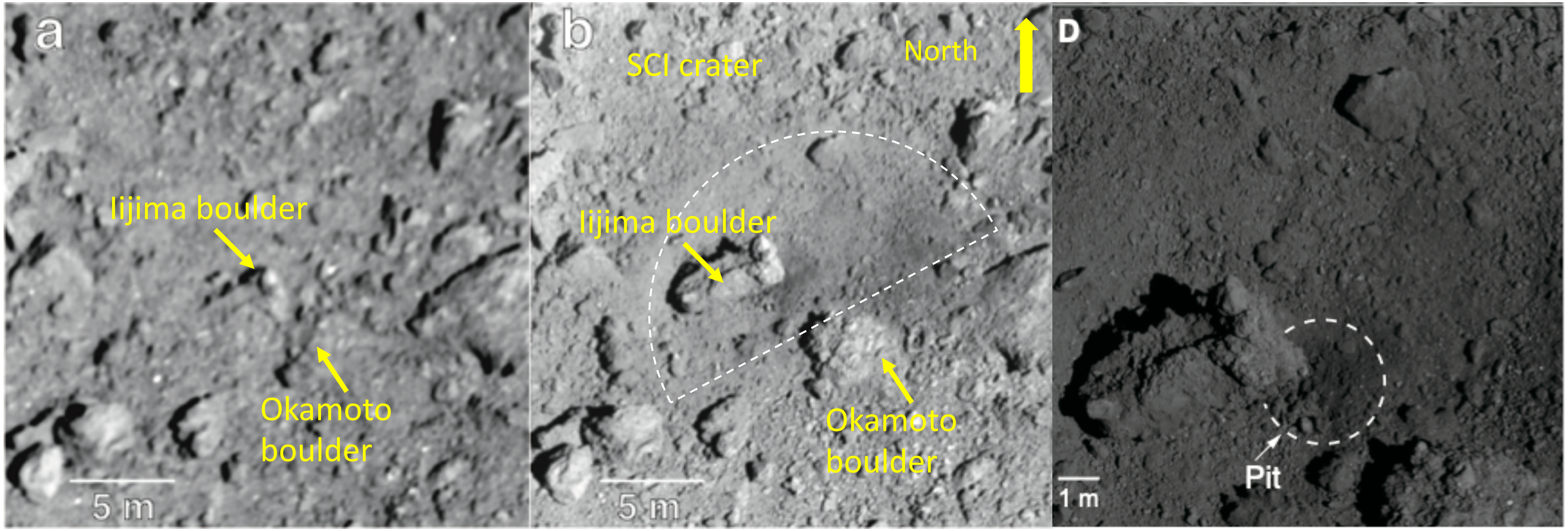
Close up images



North

SCI (Omusubi-Kororin) crater

- The crater is semi-circular. Southern growth was inhibited by the Okamoto boulder.
- Large boulder (Iijima boulder) moved 3m northwest.
- A pit about 3m in diameter was seen at the eastern end of the Iijima boulder.

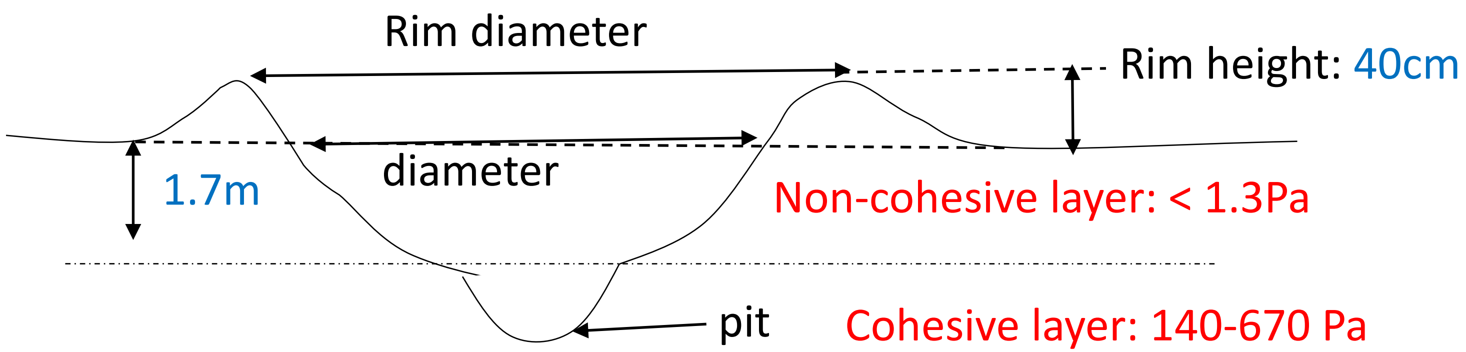


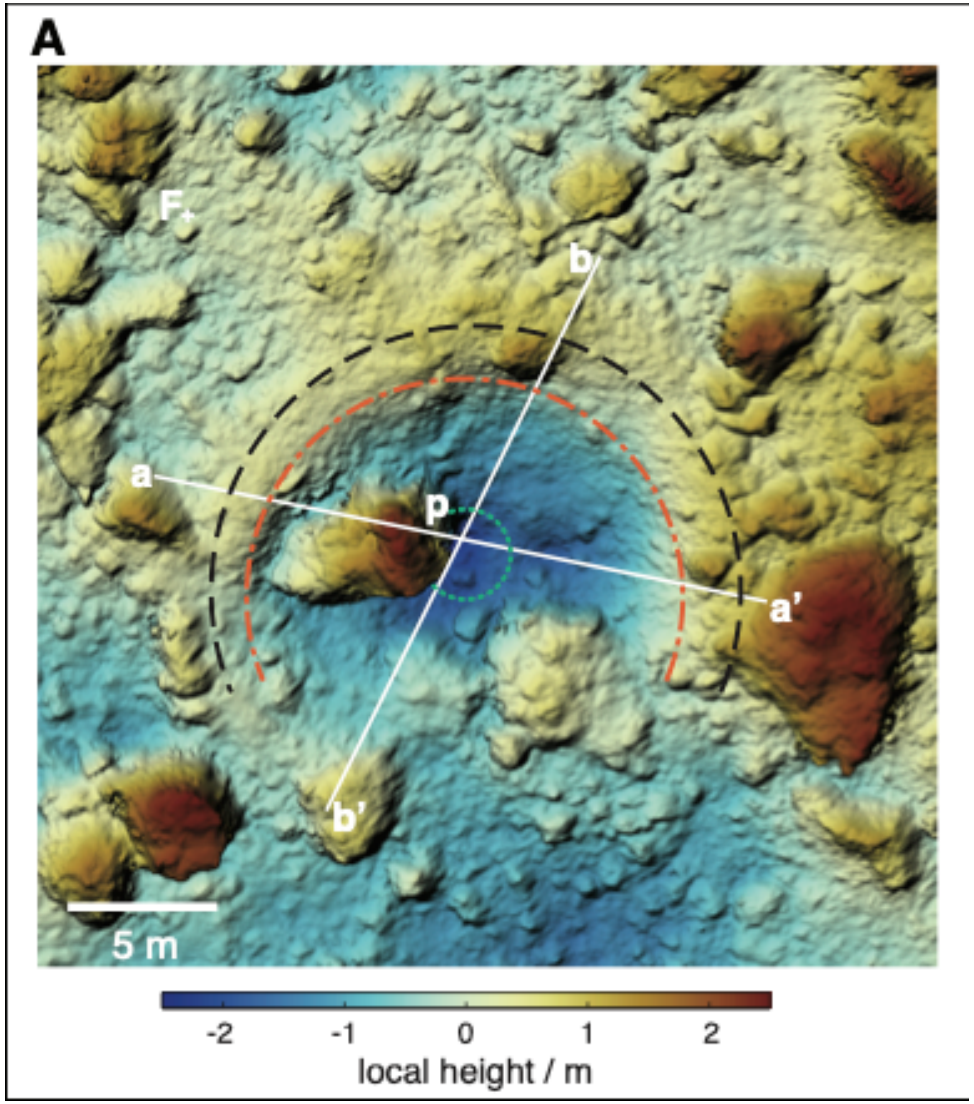
Before impact

After impact

SCI crater shape : Digital Elevation Map

- Diameter：14.5±0.8m
  - Crater diameter at 0m height.
- Rim diameter：17.6±0.7m
  - Distance between rim tops
- Pit diameter about 3m、depth 60cm
  - 140 – 670 Pa layer at bottom





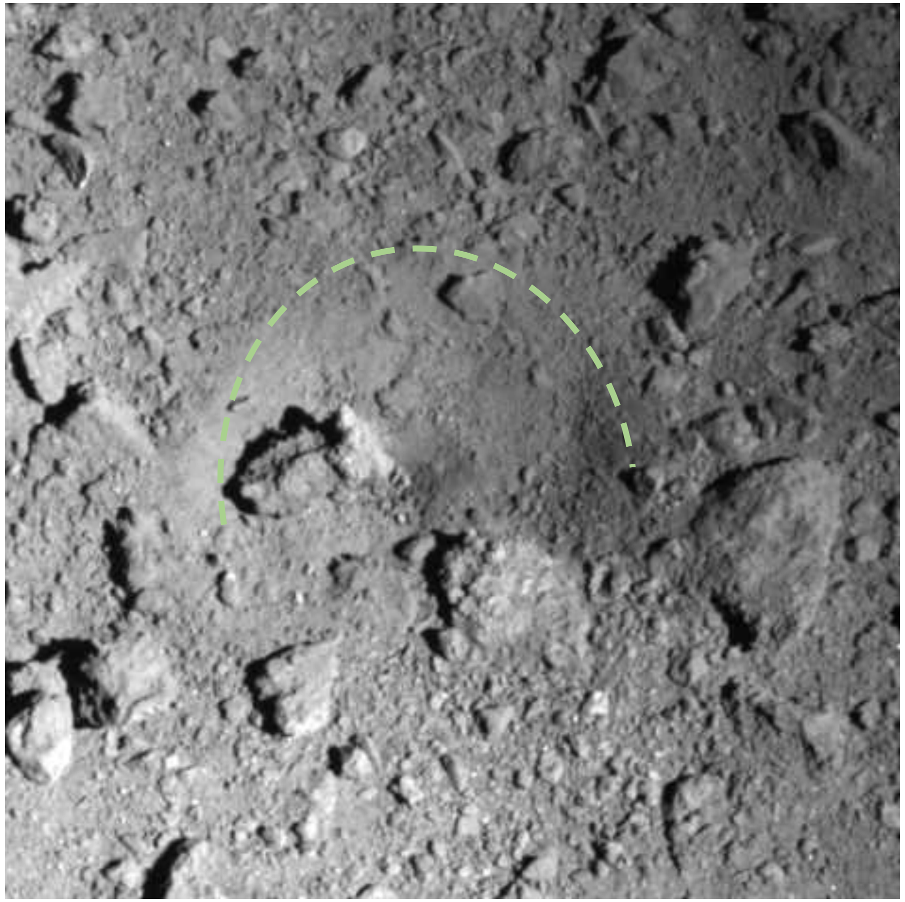
Arakawa et al., 2020

Comparison with ground experiments

- Artificial crater was formed by ground tests of the SCI. The size was about 2m.
- The SCI crater was about 7 times larger than that formed on Earth because of small gravity, 10^{-5} G.

- SCI crater diameter of 14.5 m is explained by the surface covered with sand-like regolith without cohesion.

（image credit：JAXA）



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

Summary

- Hayabusa2 Small Carry-on Impactor (SCI) formed an artificial impact crater (SCI crater) on the surface of asteroid Ryugu.
- The SCI crater is a semi-circle with the diameter of 14.5 m, and has a elevated rim. Ejecta curtain growth observed by Deployable CAMera 3 (DCAM3) showed the crater formation time longer than 200 s.
- These evidences show that the SCI crater was formed in the gravity-dominated regime, and the crater diameter was almost similar to that estimated from the scaling law for dry-sand.
- The surface boulder layer behaves like non-cohesive sand.
- The central pit was discovered and it may show the slightly cohesive subsurface layer with the strength of 140 – 670 Pa.

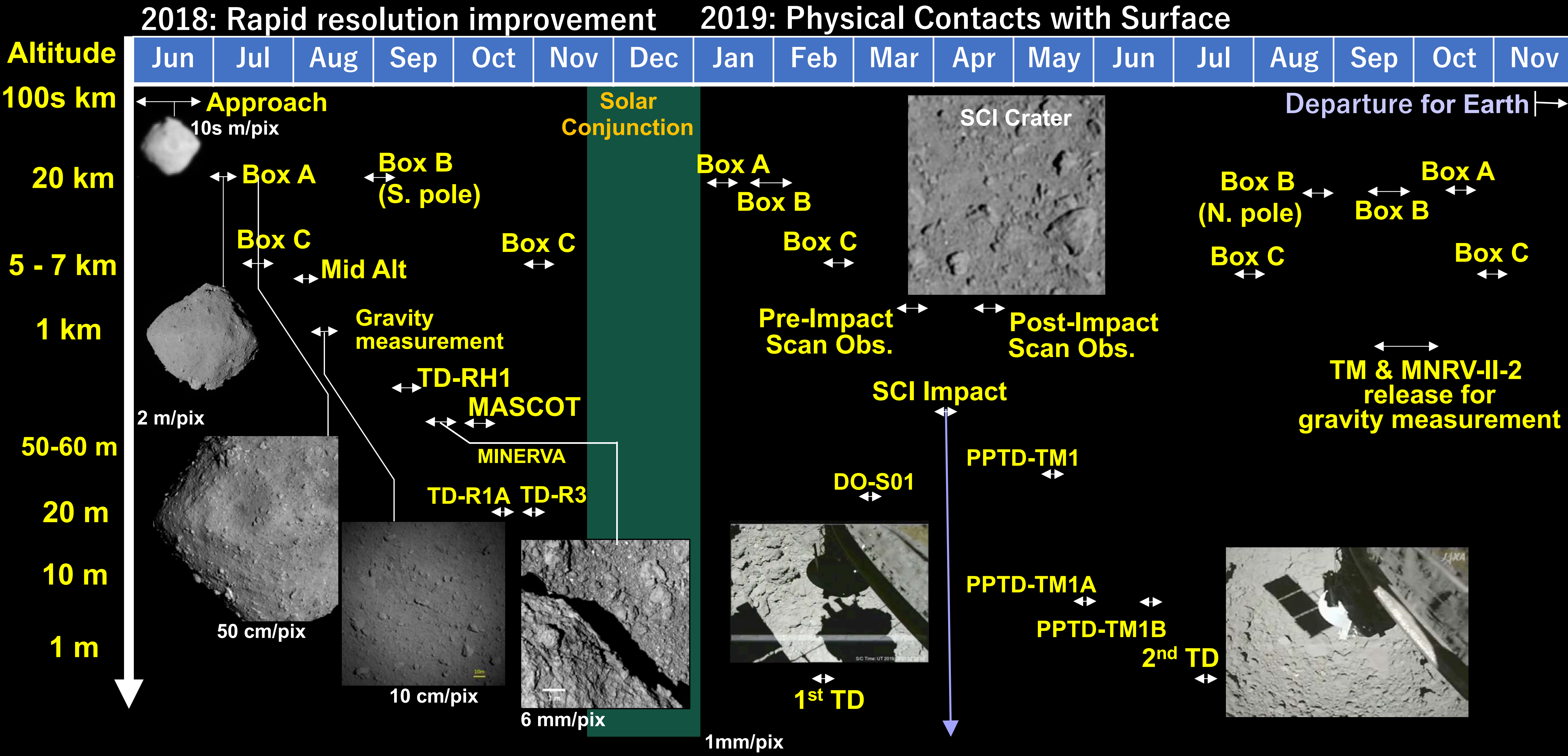
Physical properties of Ryugu revealed by proximity observations with Hayabusa2 science instruments

S. Sugita, T. Morota, R. Honda, S. Kameda E. Tatsumi, N. Sakatani, Y. Yokota, P. Michel, D. L. Domingue, S. E. Schröder, S. Watanabe, K. Kitazato, T. Okada, N. Namiki, N. Hirata, S. Tanaka, M. Yoshikawa, and Y. Tsuda

Planetary Defense Conference

April 26, 2021

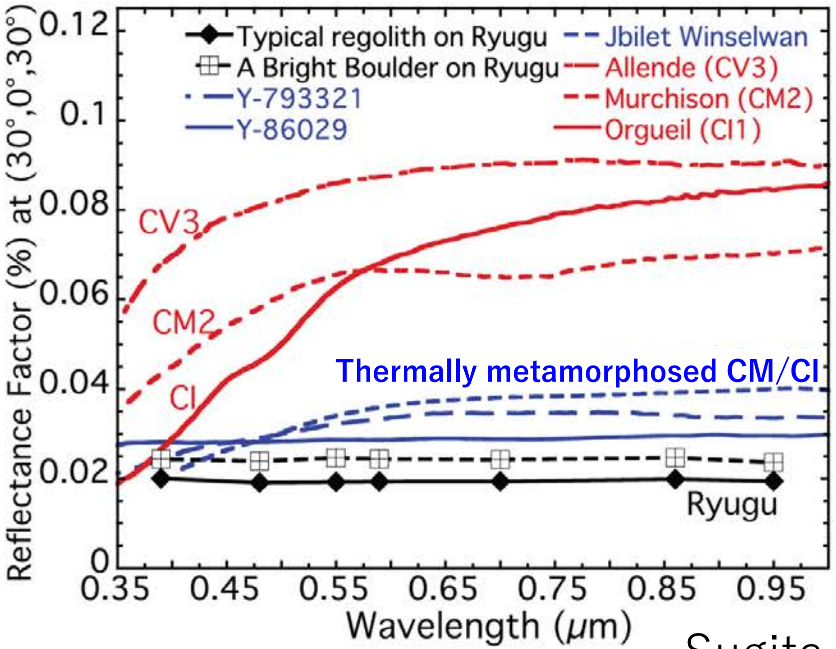
Hayabusa2 Actual Observation Timeline

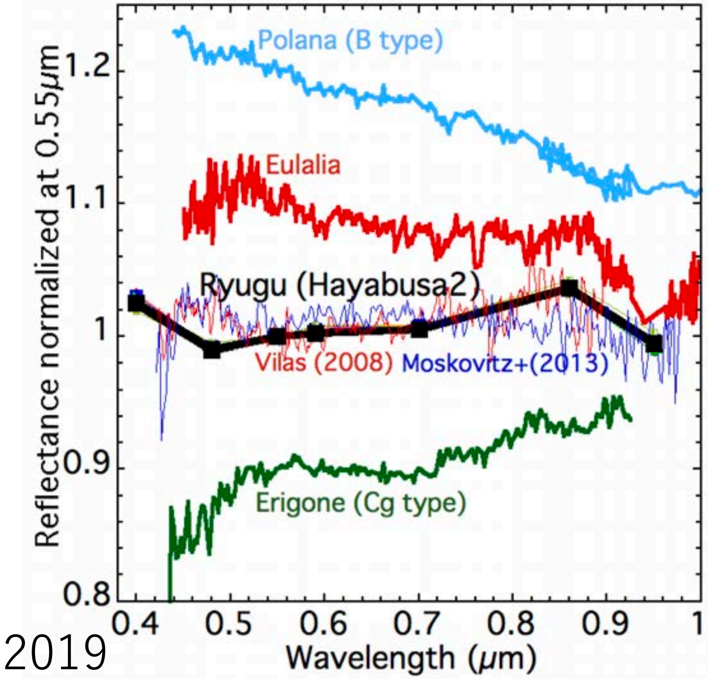


Sugita et al. (2019) Image credit : JAXA/UTokyo/Kochi U/Rikkyo U/Nagoya U/Chiba Inst Tech/Meiji U/U Aizu/AIST/IMU/

General Characteristics of Ryugu

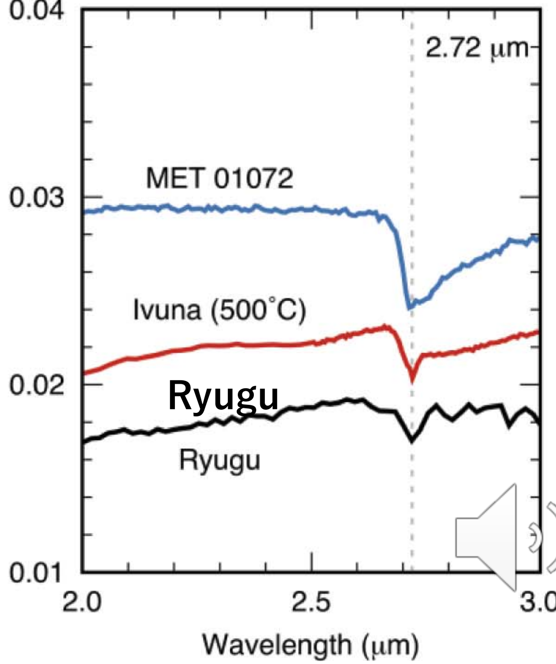
- **Top shape** (Watanabe+2019, Sugita+2019)
- **Rubble pile**
  - High abundance of large boulders (Sugita+2019)
  - Low ρ (1.19 g/cm^3) and high porosity (>50%) (Watanabe+2019)
- Consistent with **thermally metamorphosed CM/CI**.
  - Extremely low reflectance (1.9% in VIS-NIR) (Sugita+2019, Kitazato+ 2019)
  - Flat spectra w/o strong 0.7μm absorption band (Cb type) (Sugita+2019)
  - Weak but significant OH band (Kitazato+2019)





Sugita+2019

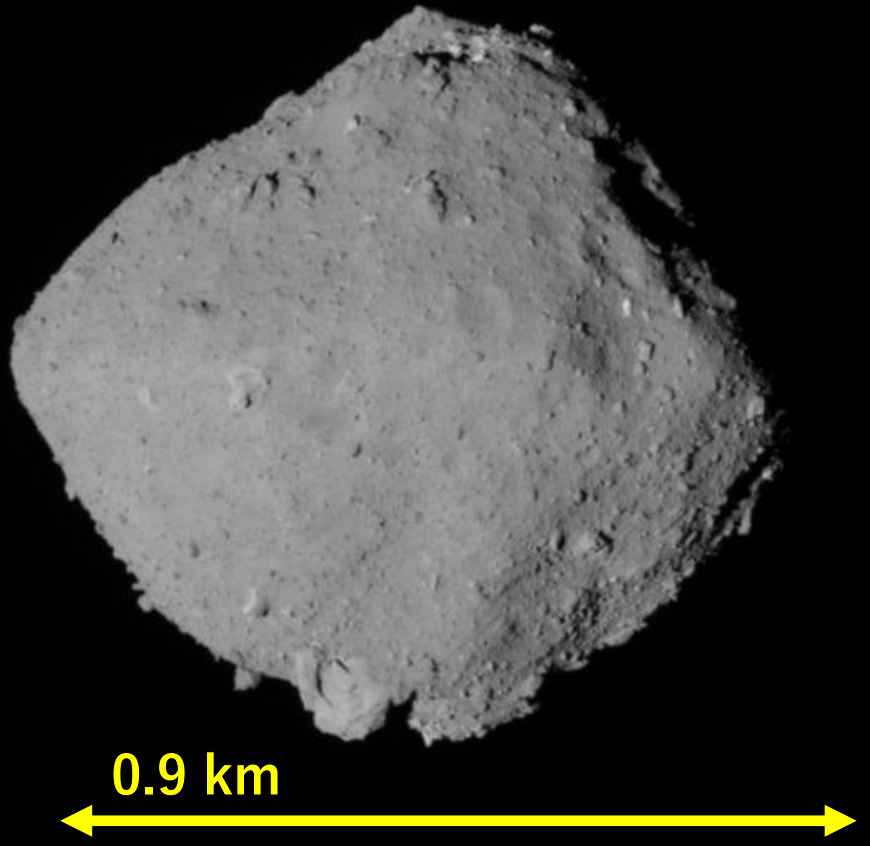
Kitazato+2019



The average boulder size on Ryugu is ~ **3m** (Sugita+2019 Sci)

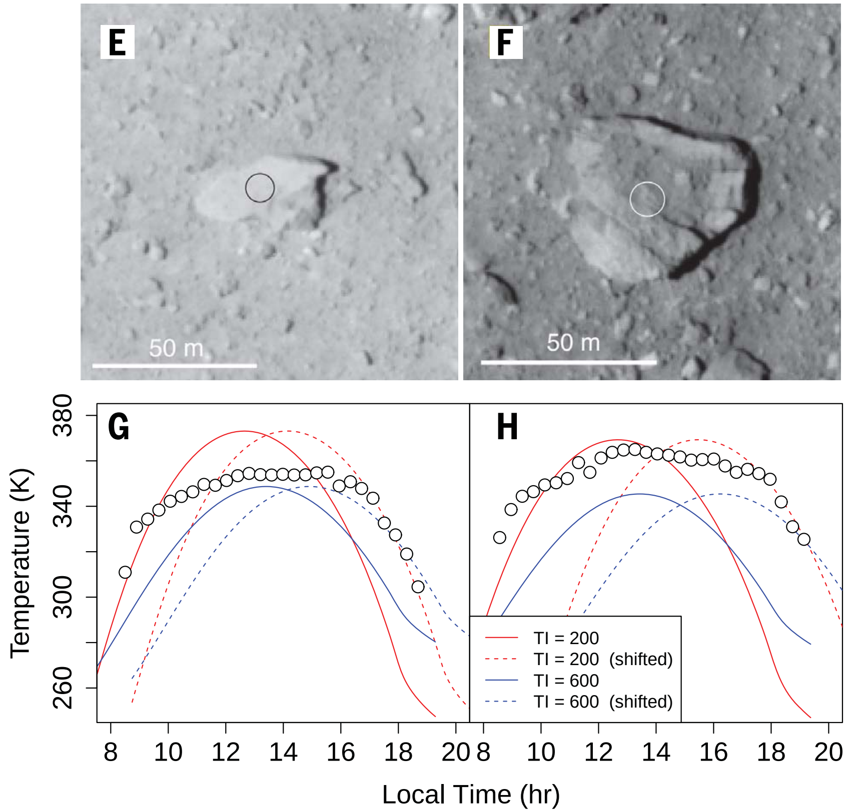
Much larger than ~**cm** expected from pre-arrival thermal inertia observation

150-300s $Jm^{-2}s^{-0.5}K^{-1}$ (Müller+2017A&A)



Thermal properties of Ryugu

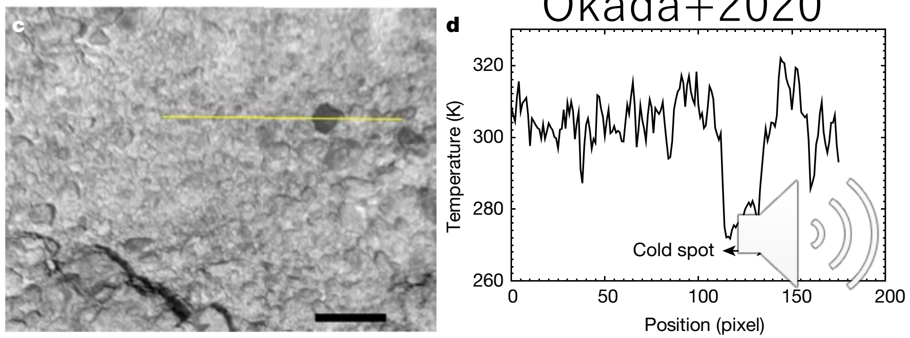
Sugita+2019



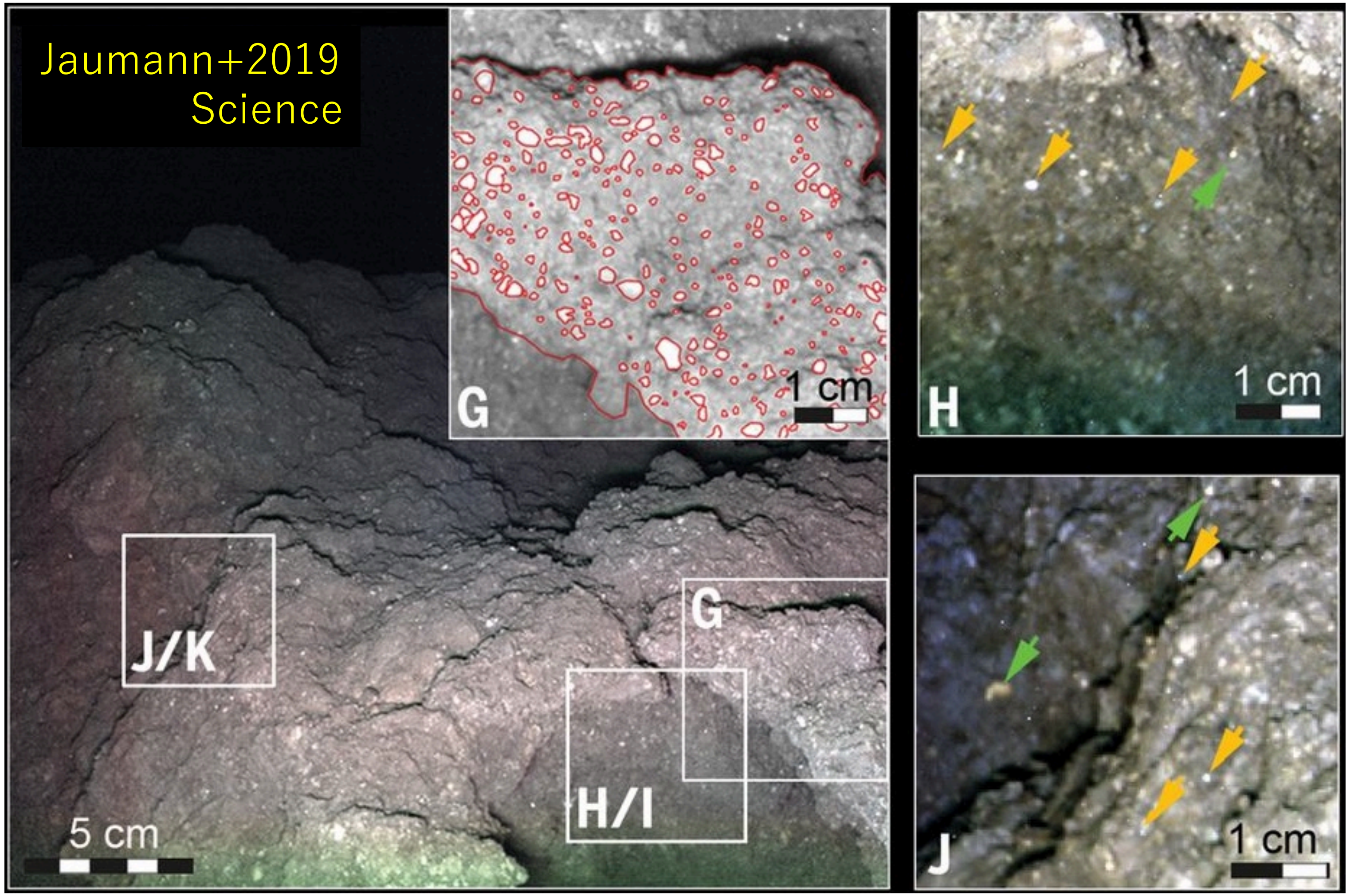
- Thermal inertia is ~300 $Jm^{-2}s^{-0.5}K^{-1}$ Consistent with **~cm size pebbles**.
  (Sugita+2019 *Science*, Okada+2020 *Nature*, Shimaki+2020 *Icarus*)
- No significant difference in thermal inertia between regolith and boulders.
- There are “cold boulders”(i.e., low porosity). But they are extremely rare (Okada+2020 *Nature*).
- ~300 $Jm^{-2}s^{-0.5}K^{-1}$ leads to 0.2-0.28 MPa of tensile strength (Grott+2019)

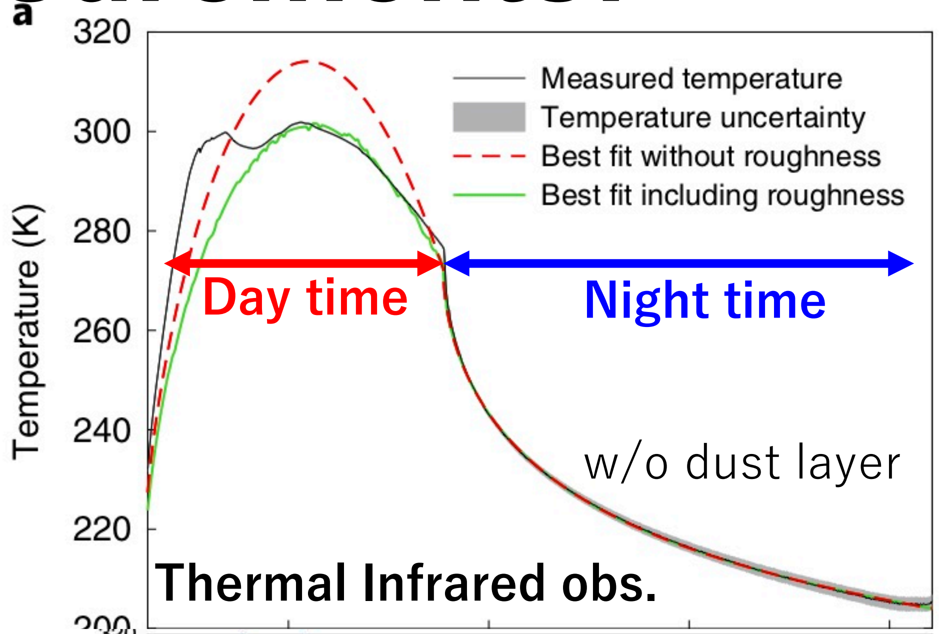
=> Ryugu is made of large high-porosity boulders.

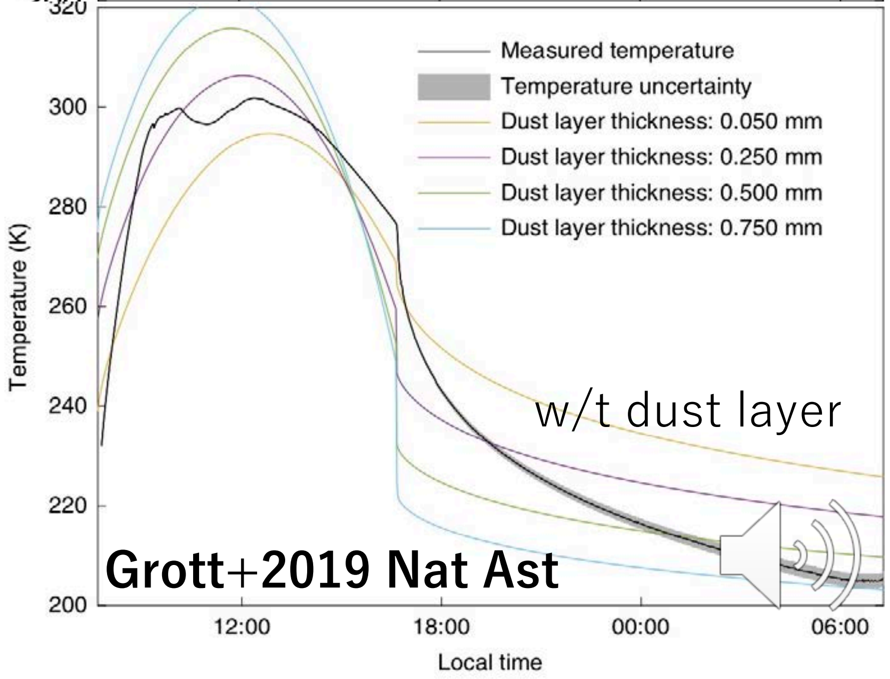
Okada+2020



MASCOT's *in situ* measurements!

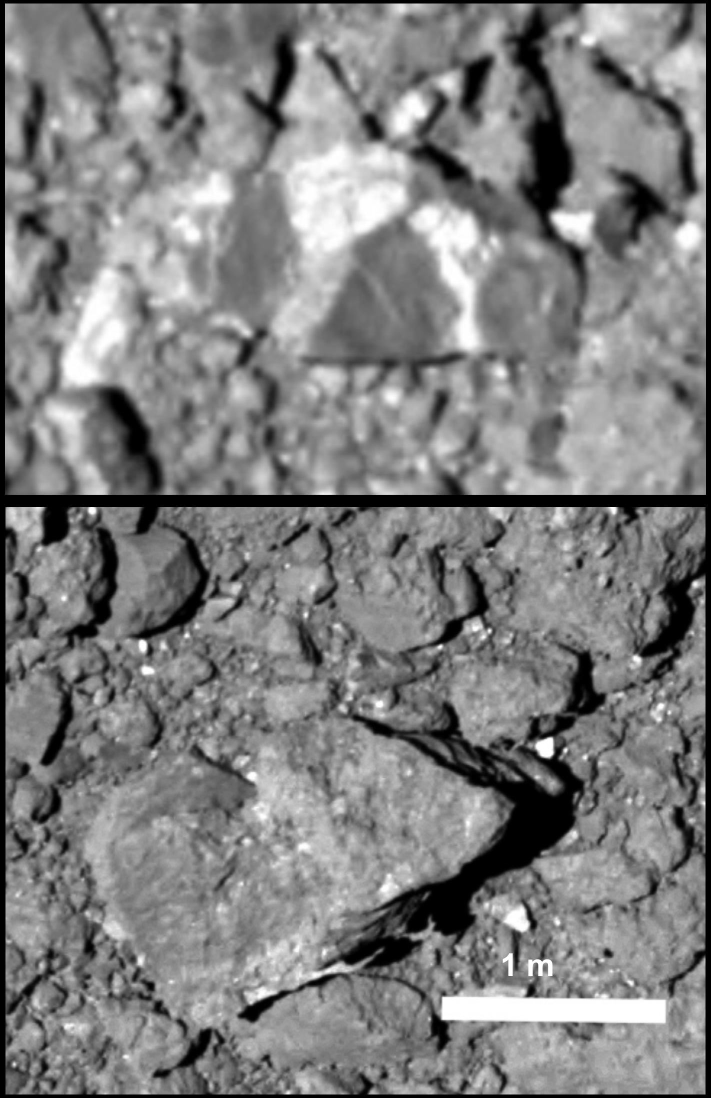




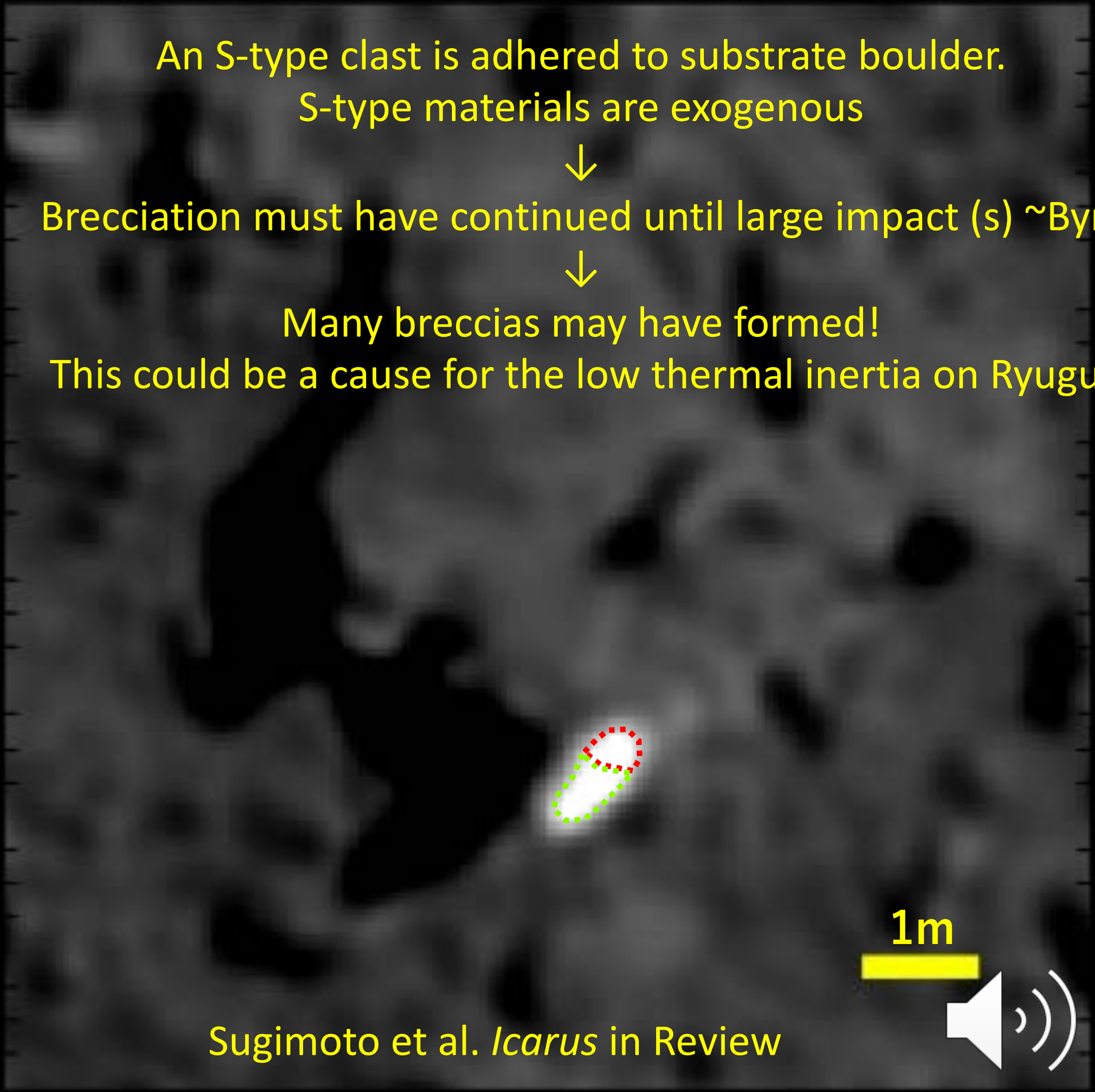


- Morphologies are similar between sub-mm-scale and m-scale images
- Lot of mm-scale inclusions in boulders => **No thick dust layer!**

Breccias on Ryugu



Sugita et al. (2019)



Sugimoto et al. *Icarus* in Review

Conclusions

- **Ryugu's spectral properties are consistent with thermally metamorphosed carbonaceous chondrites.**

- **Bulk density 1.19 g/cc is much lower than any carbonaceous chondrites.**
  ➡ High porosity >50%

- **A great gap between grain size (~cm) estimated from thermal inertia and actual average grain size (~3 m).**
  ➡ Ryugu is covered with large high-porosity boulders.

- **No thick dust layer on boulders.**
  ➡ Boulder bulk thermal inertia must be low.

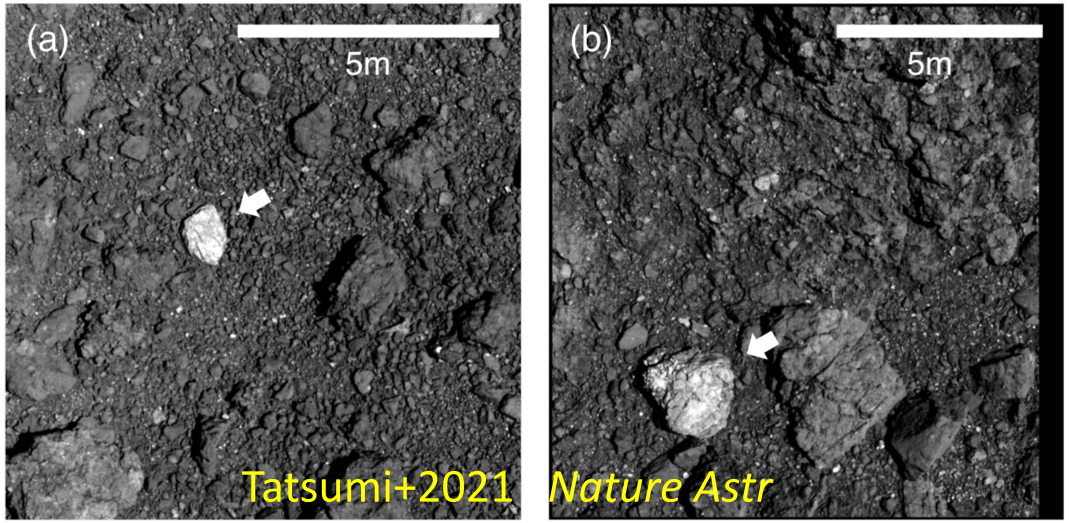
- **Many pieces of evidence for breccia on Ryugu.**

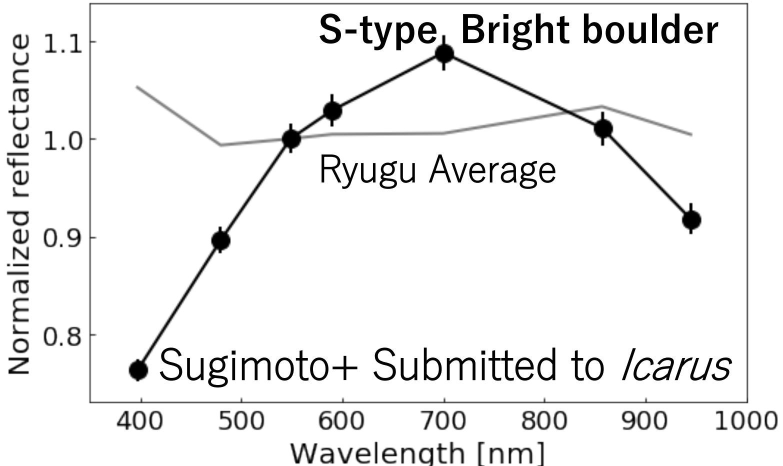
- **Breccia structure may be a significant cause for Ryugu's low thermal inertia.**

➡ Breccia structure may be an important factor to consider for planetary defense of low-albedo asteroids.

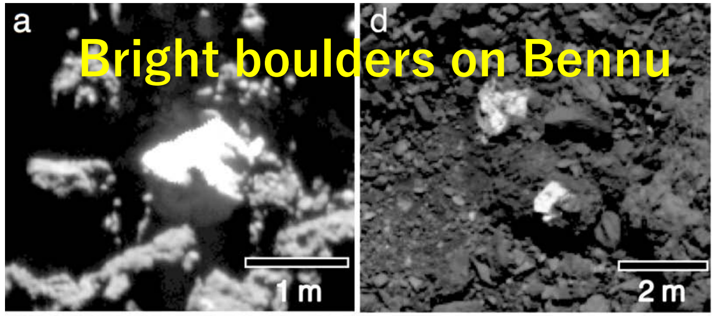
Bright boulders (BBs) on Ryugu and Bennu

- Ryugu is uniformly dark. (Sugita+2019 *Science*).
- Tatsumi+(2021 Nat. Geo) found 21 BBs. Most have **C-type** spectra; some have **S-type** spectra.
- **S-type BBs are likely exogenic** but too large to accrete on Ryugu after becoming current size.



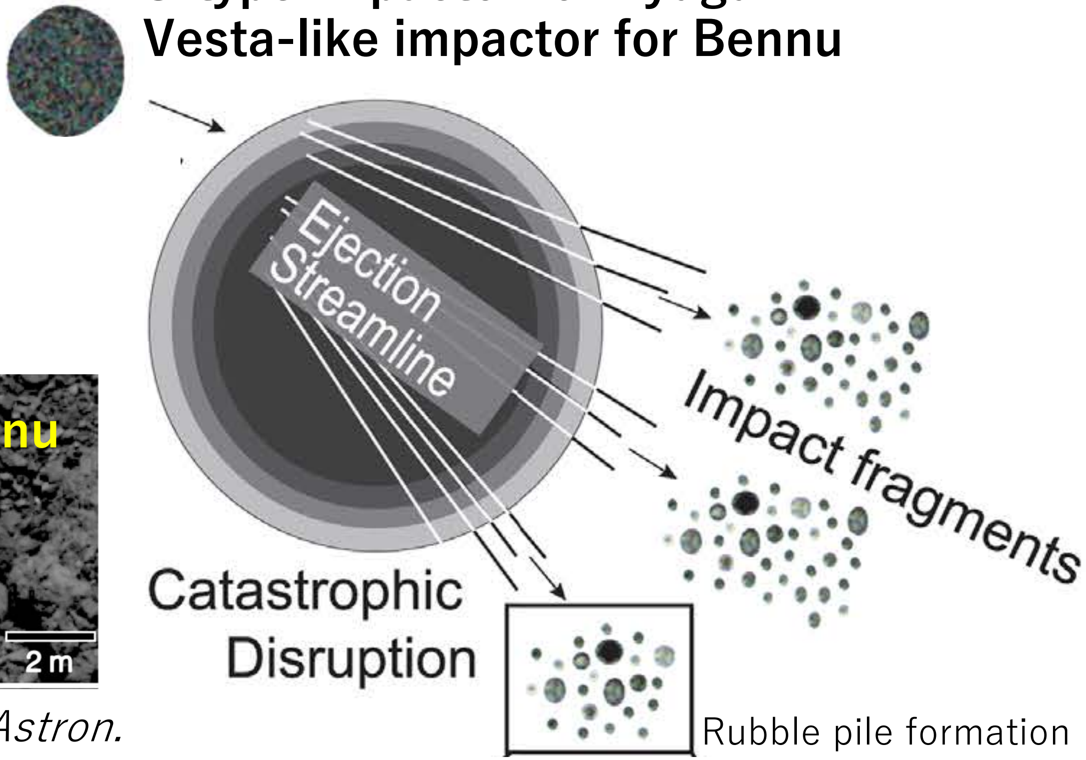


➔ S-type BBs are probably fragments from impactor(s) to Ryugu's parent body.

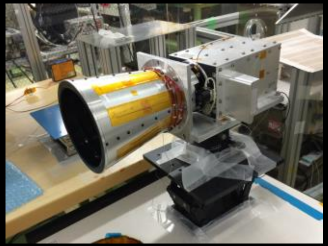


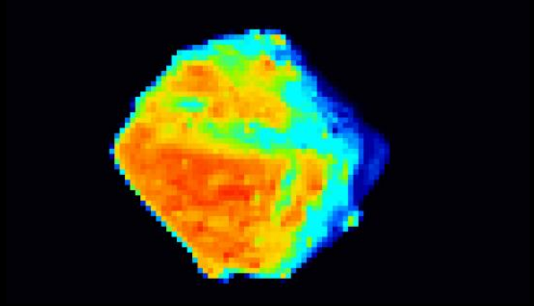
DellaGiustina+2021 *Nature Astron.*

S-type Impactor for Ryugu
Vesta-like impactor for Bennu



Thermal Imaging to Reveal Highly Porous Nature of C-type Asteroid Ryugu in Hayabusa2 Mission





7th IAA Planetary Defense Conference

2021/4/26-30 **Hayabusa2**

Tatsuaki Okada[1,2], Satoshi Tanaka[1], Naoya Sakatani[3], Yuri Shimaki[1], Takehiko Arai[4], Hiroki Senshu[5], Hirohide Demura[6], Tomohiko Sekiguchi[7], Toru Kouyama[8], Tetsuya Fukuhara[3], and HY2 TIR Team

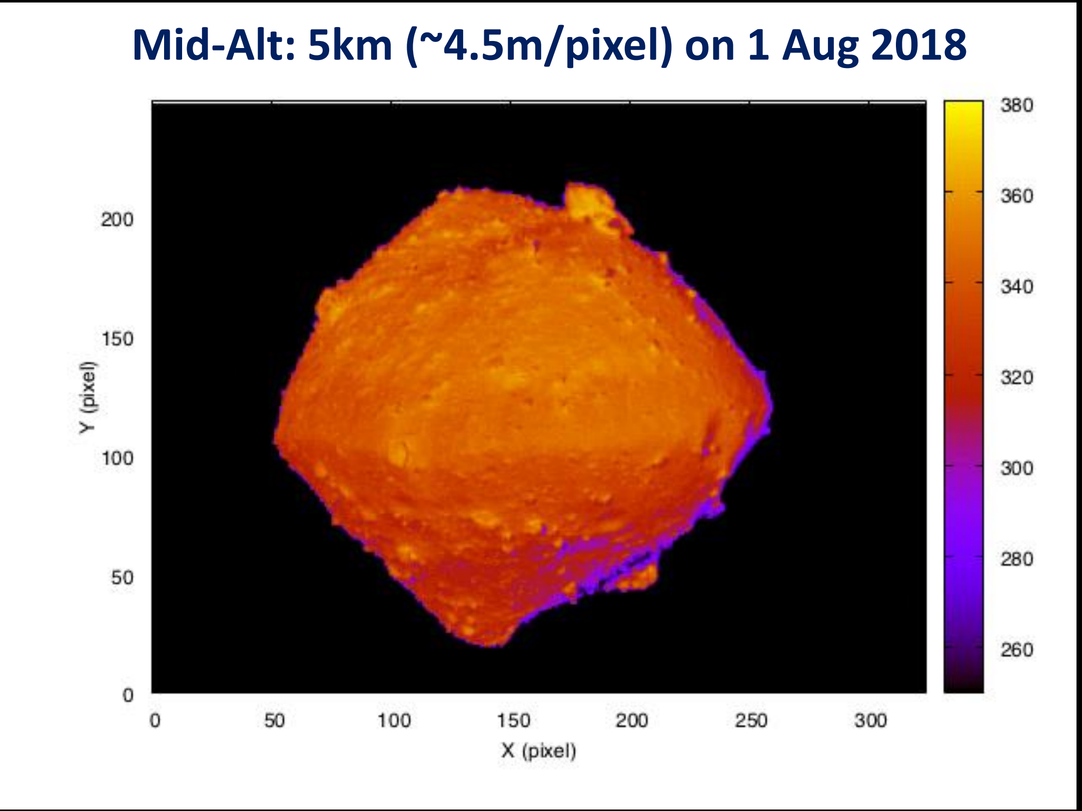
1: ISAS/JAXA, 2: Univ. Tokyo, 3: Rikkyo Univ., 4: Maebashi IT, 5: Chiba IT, 6: Univ. Aizu, 7: Hokkaido Univ. Edu., 8: AIST

One-rotation Global Thermal Images of Ryugu

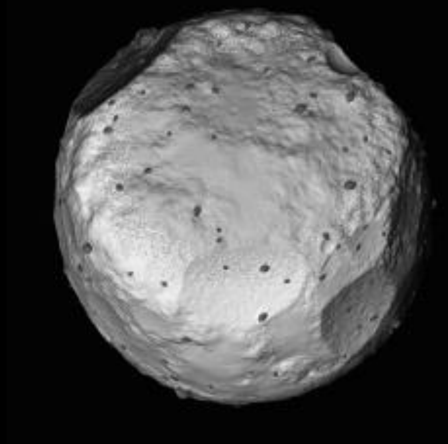
Something different from the predicted model

■ Mid-Alt Observations:

First global thermal images of an asteroid!



■ "Ryugoid" (Reference Asteroid Model)



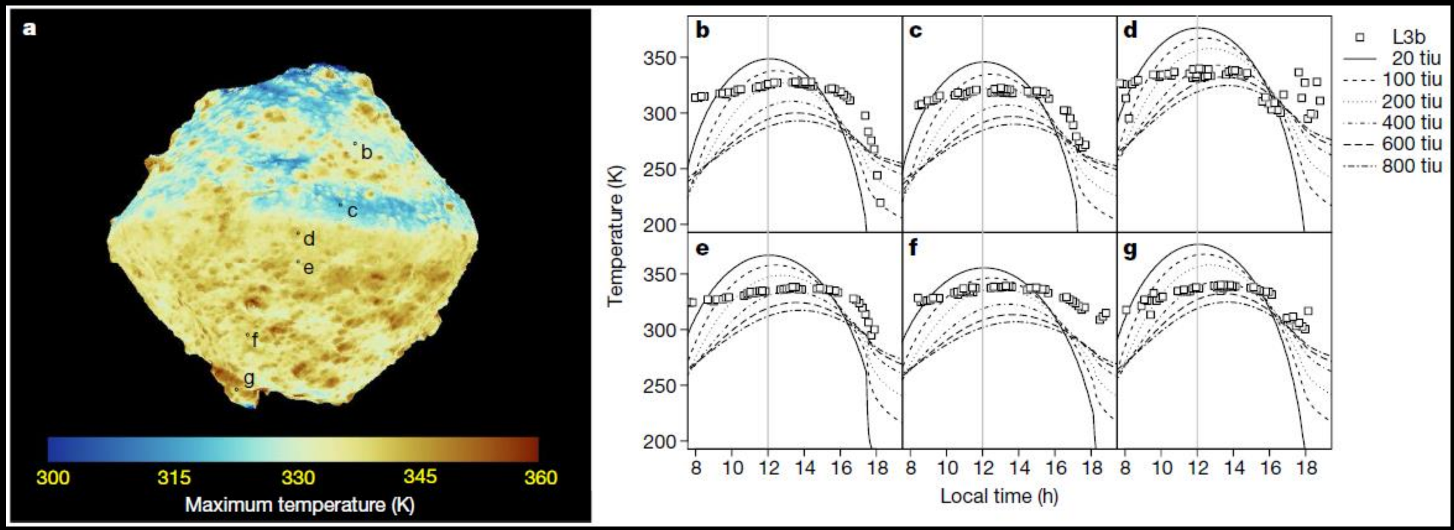
- Ryugoid has many cold boulders

↓

No cold boulders on Ryugu!

- No flat areas

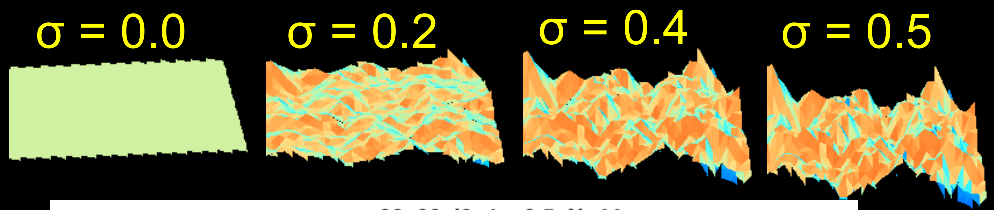
■ "Flat" Diurnal Temperature Profile

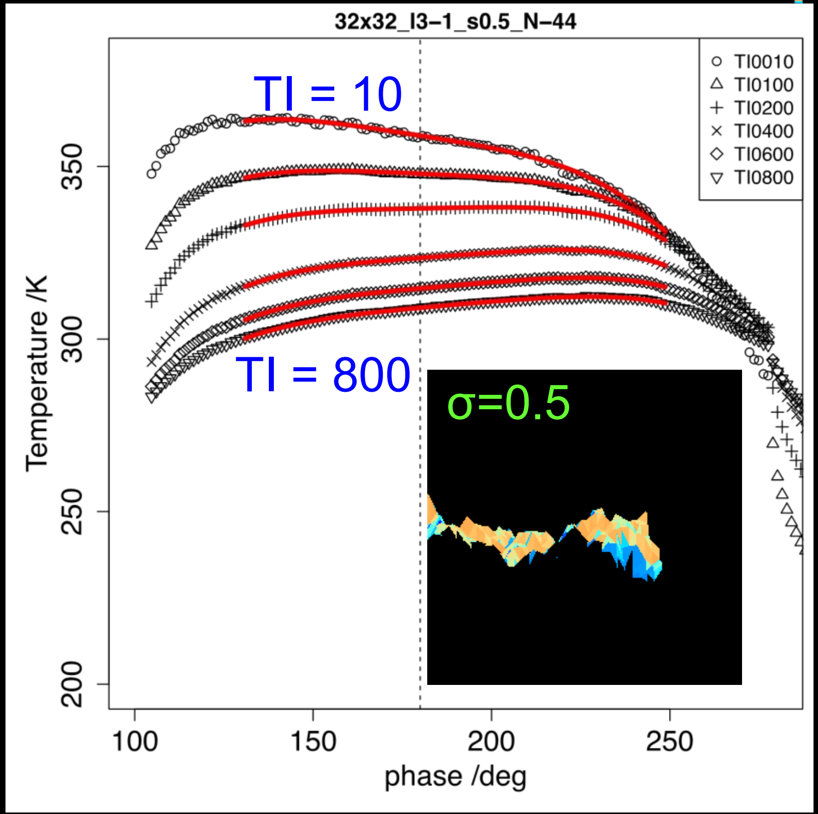


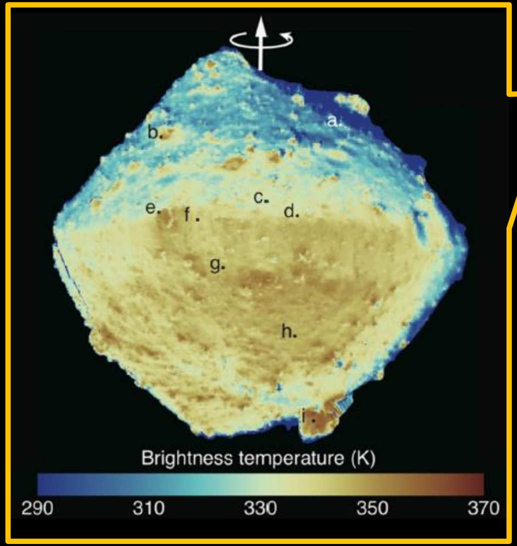
Highly Porous & Rough Surface on Ryugu!

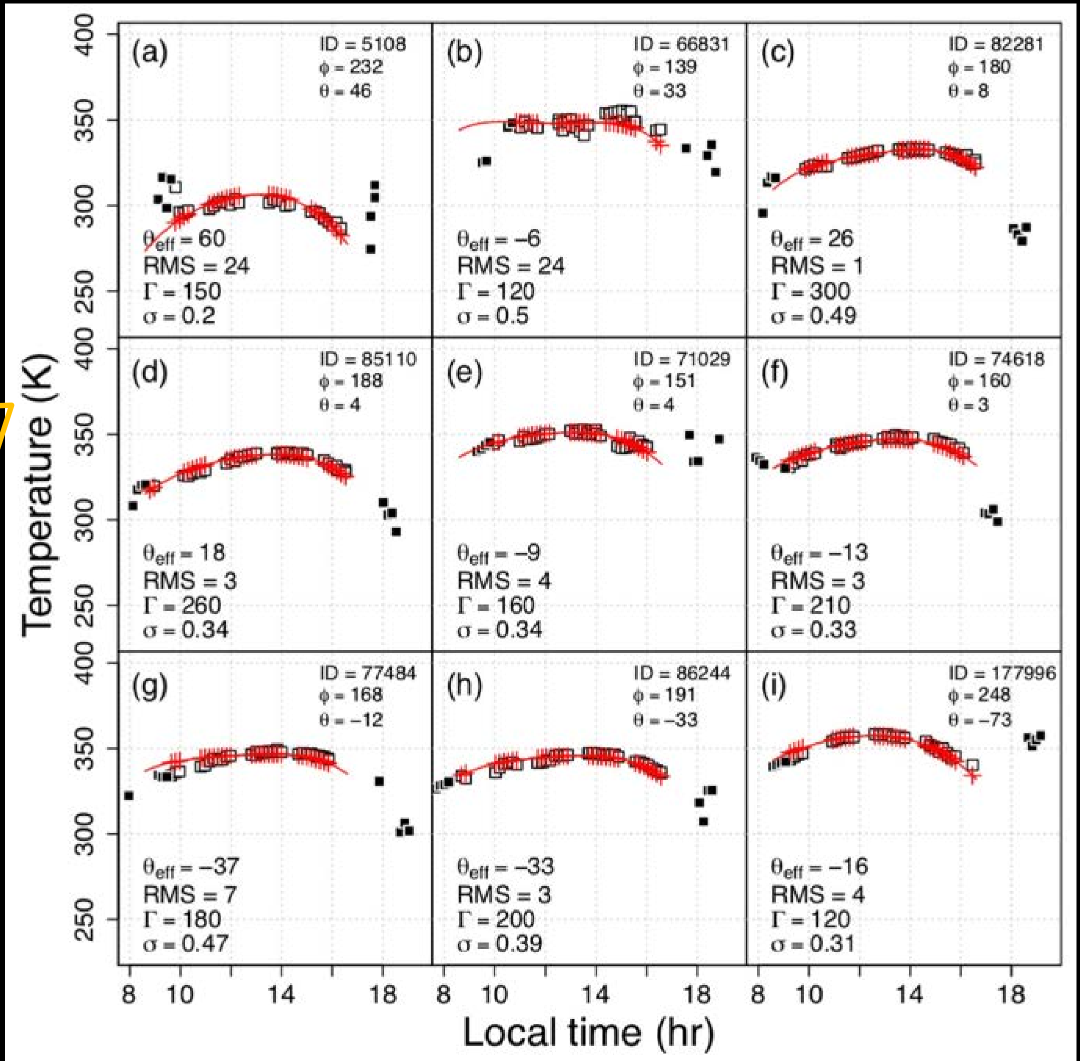
■ **Diurnal temperature profiles show that Ryugu surface is highly porous & rough!**

Shimaki+ Icarus (2020) / Senshu+ *in prep*
TI = 150~300tiu, Roughness = 0.3~0.5







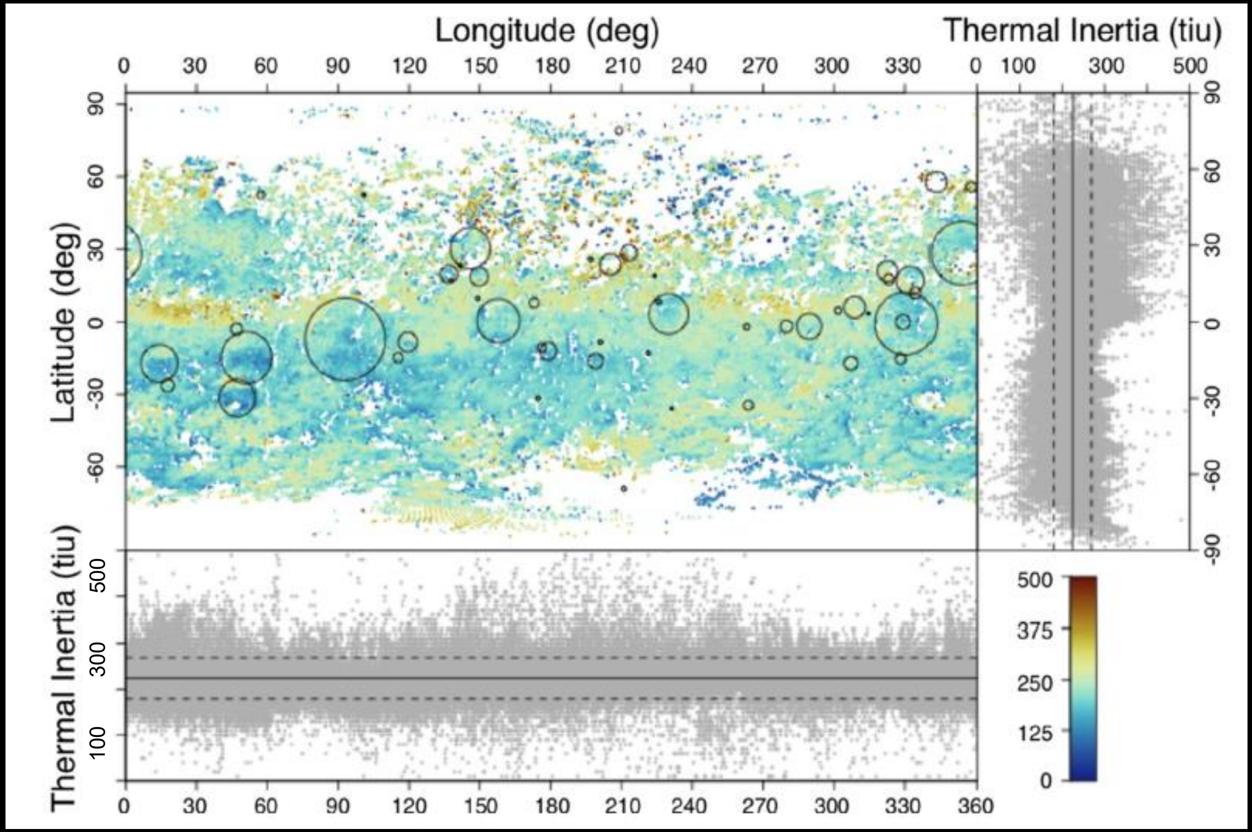


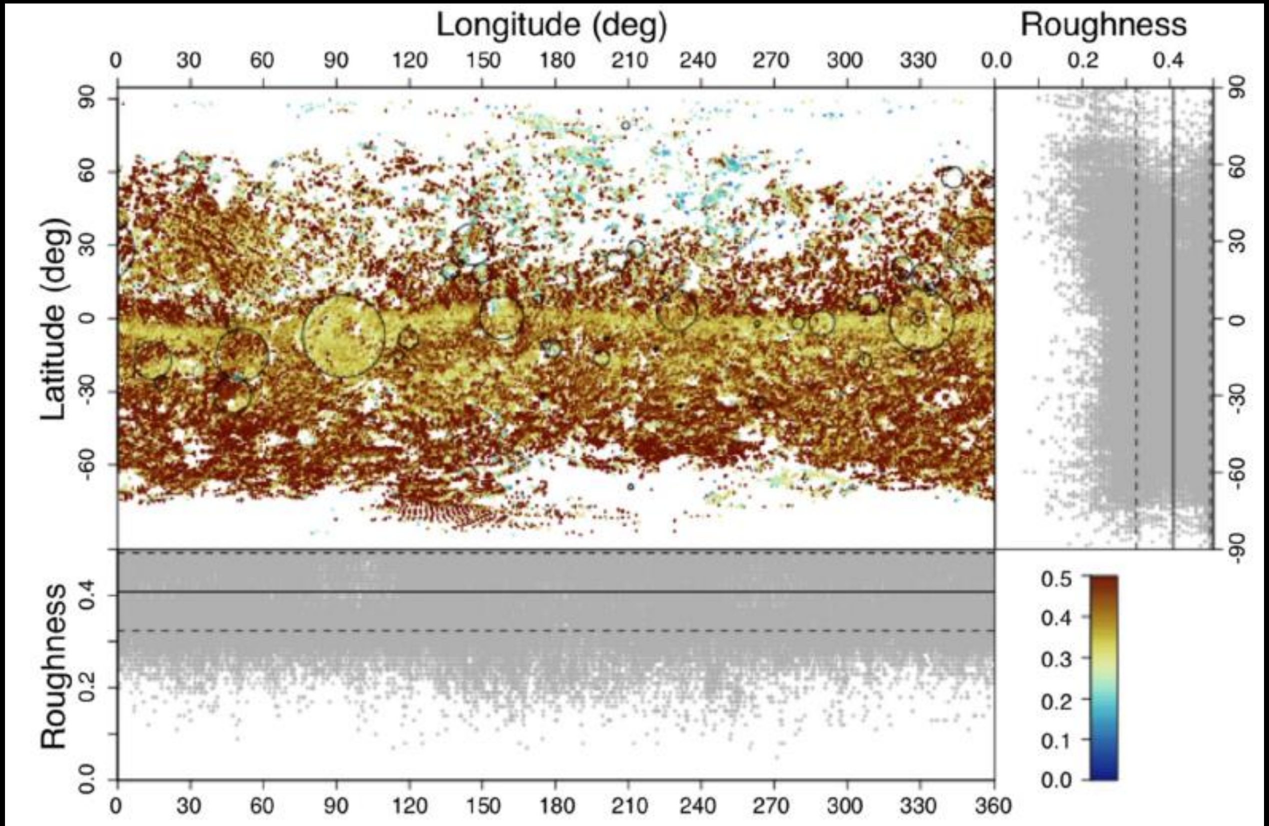
Highly Porous & Rough Surface on Ryugu!

■ Thermophysical model of Ryugu

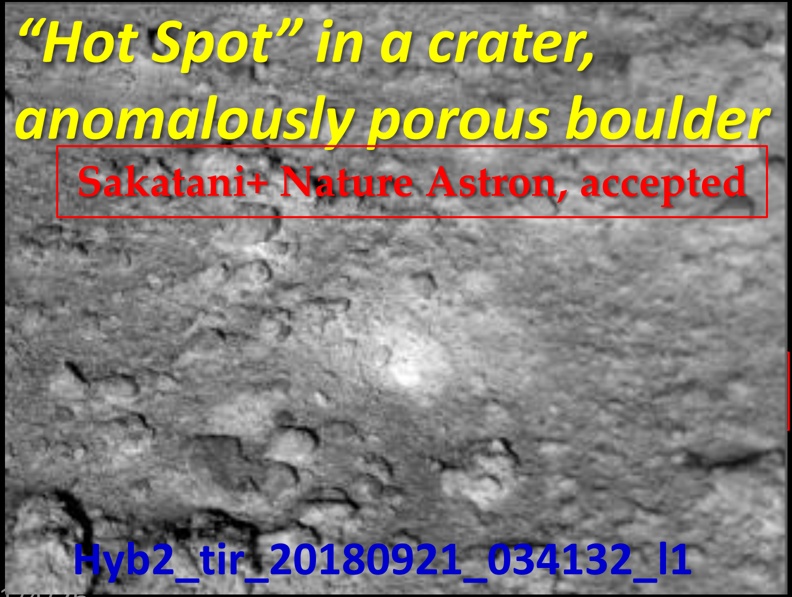
Shimaki+ Icarus (2020)

- Thermal Inerita = 225 ± 45 tiu
- Roughness parameter: σ = 0.41 ± 0.08

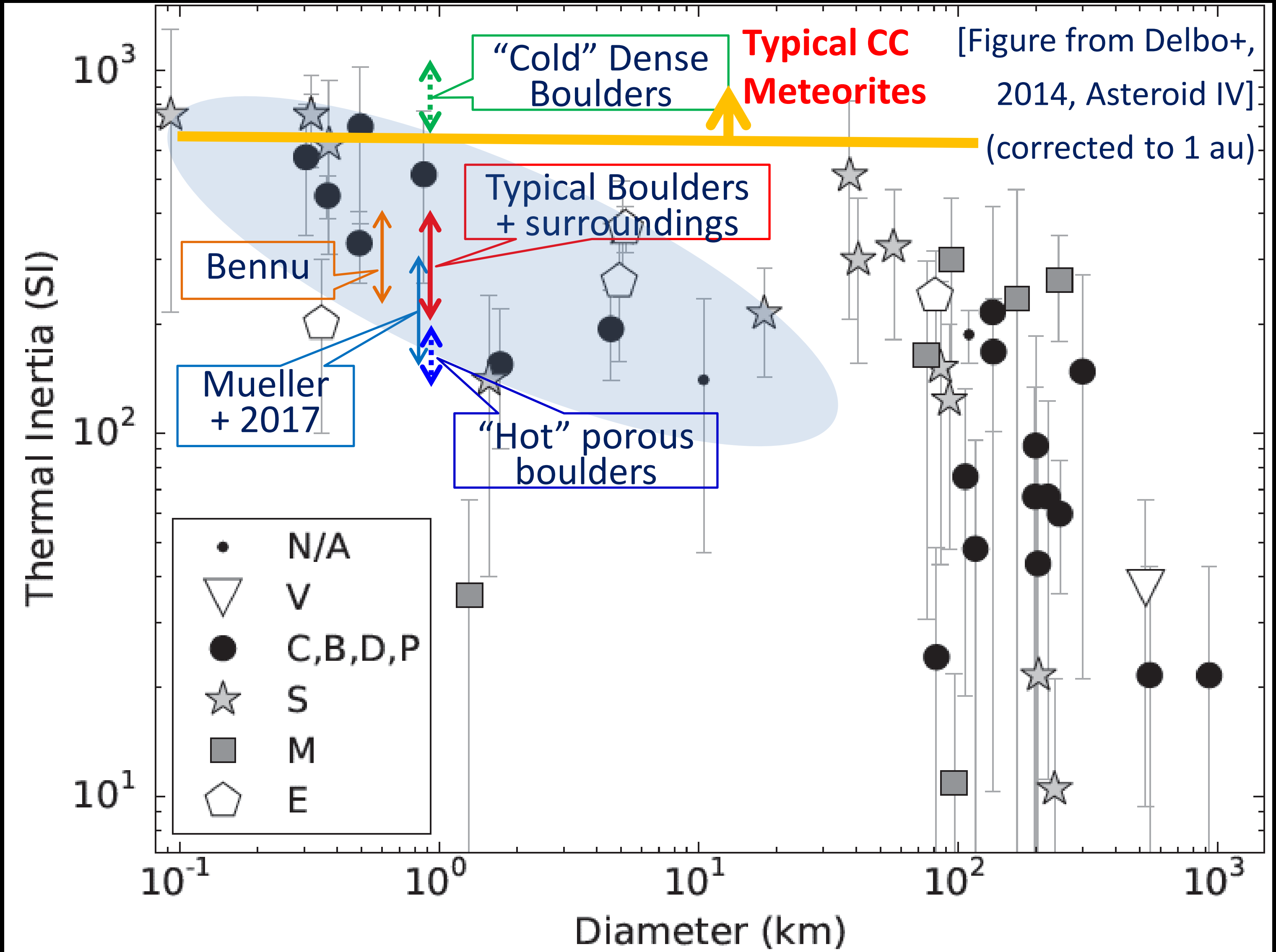




Cold Spot and Hot Spot – Porosity variations



■ Asteroid size vs Thermal inertia



Summary

The surface temperature and the derived thermal inertia of Ryugu was imaged by TIR, even in the night or shaded side.

The surface of Ryugu is covered with highly porous boulders and rocks (low strength).

The surface of Ryugu is very rough, to the scale of < 10cm (thermal skin depth).

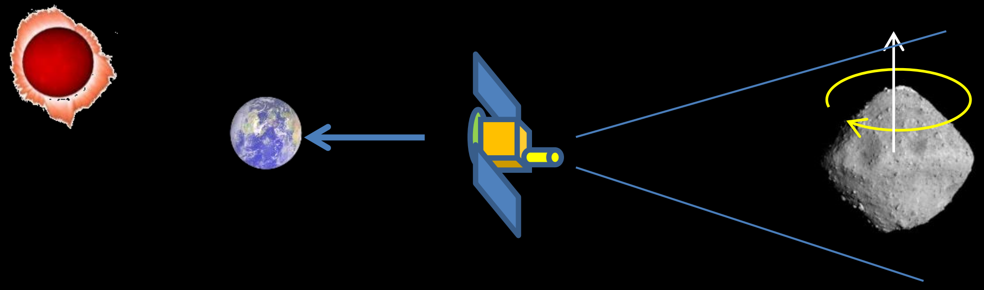
A variation of porosity is found on Ryugu, indicating the different degree of alteration in the parent bodies.

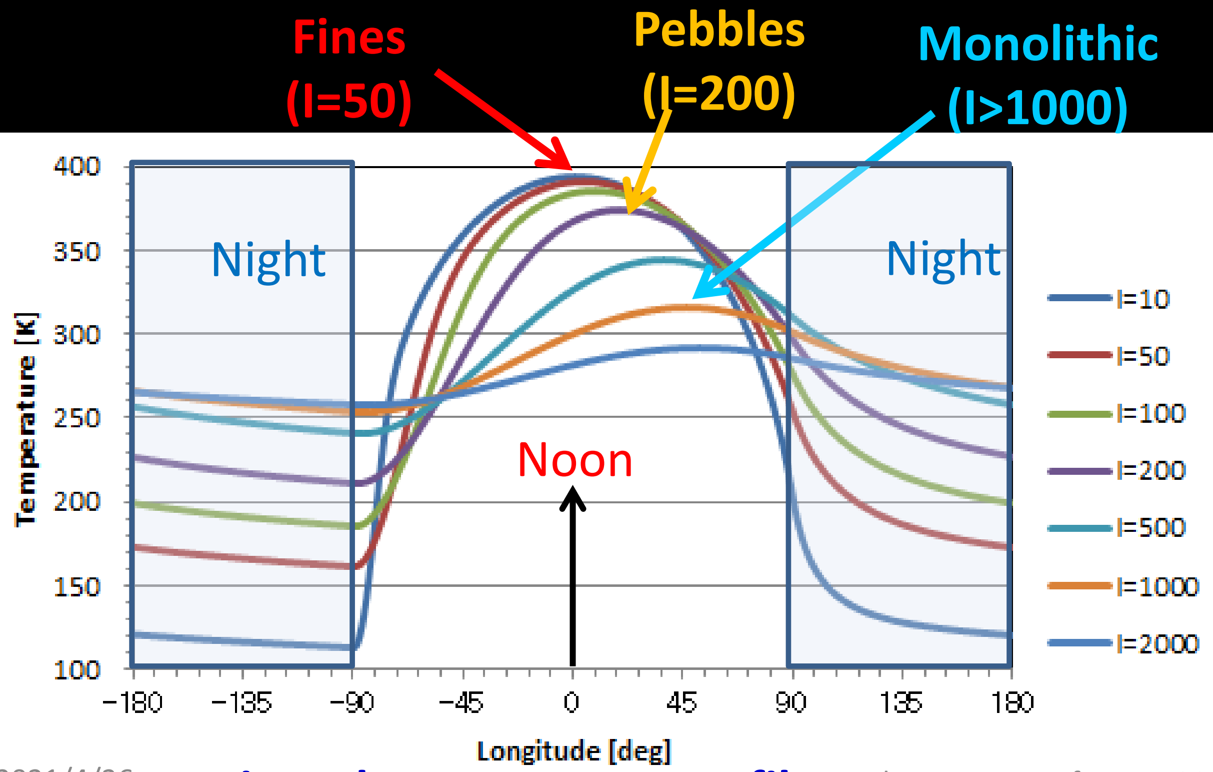
Thank you

Direct Thermal Observations in Hayabusa2

Temperature and its diurnal profile will reveal the properties

■Thermal Imaging from Home Position

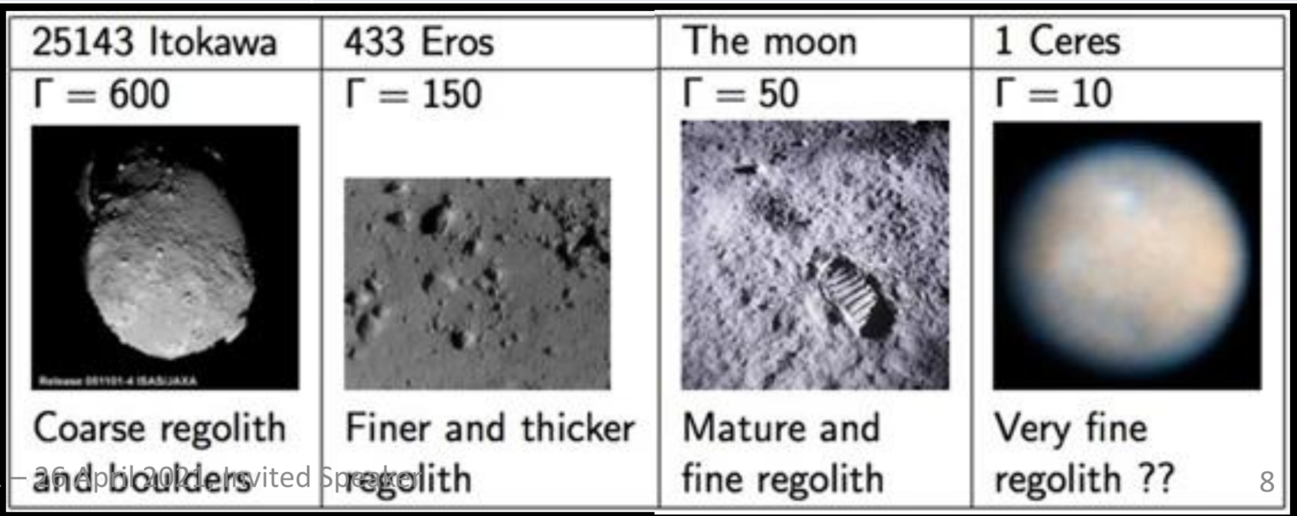




Diurnal temperature profile at 1au

■Thermal Inertia vs. Surface State

Thermal Inertia: I [J m^{-2} s$^{-0.5}$ K^{-1}]	$I = (k\rho C)^{0.5}$ Surface Physical State
~ 10	Very high porosity (~80%), Ceres, Martian soils
~ 50	Fine sand : Lunar regoilth (d ~ 100 μm or less)
100 ~ 200	Sandy regolith (d ~mm): Eros soil
200 ~ 400	Pebbles (d ~cm): Itokawa's Muses-Sea Regio
400 ~ 1000	Boulders, Rocks (d < m): Itokawa's rough terrain
1000 ~ 2000	Rocks with high porosity
2000 ~	Monolithic rocks



Hayabusa2 Extended Mission to rendezvous with Asteroid 1998 KY26: Investigations of an extremely small fast rotator for planetary defense

M. Hirabayashi, Y. Kim, Y. Mimasu, N. Sakatani, S. Watanabe, Y. Tsuda, T. Saiki, S. Kikuchi, T. Kouyama, M. Yoshikawa, S. Tanaka, S. Nakazawa, Y. Takei, F. Terui, H. Takeuchi, A. Fujii, T. Iwata, K. Tsumura, S. Matsuura, Y. Shimaki, S. Urakawa, Y. Ishibashi, S. Hasegawa, M. Ishiguro, D. Kuroda, S. Okumura, S. Sugita, T. Okada, S. Kameda, S. Kamata, A. Higuchi, H. Senshu, H. Noda, K. Matsumoto, R. Suetsugu, T. Hirai, K. Kitazato

Session 2: Hayabusa2, 13:15-14:15 Vienna, 6:15-7:15 CDT

IAA Planetary Defense Conference 2021

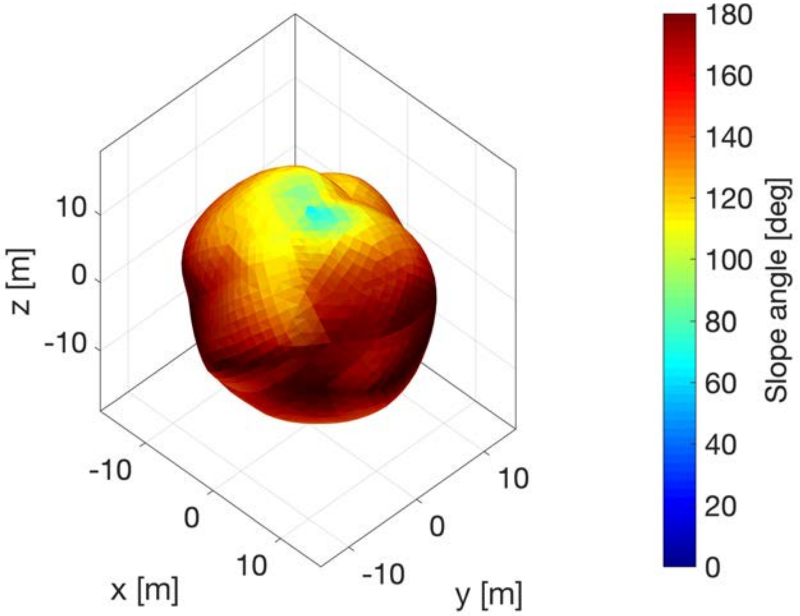
The Hayabusa2 extended mission is a small-body rendezvous mission that uses the already-flying Hayabusa2 spacecraft.

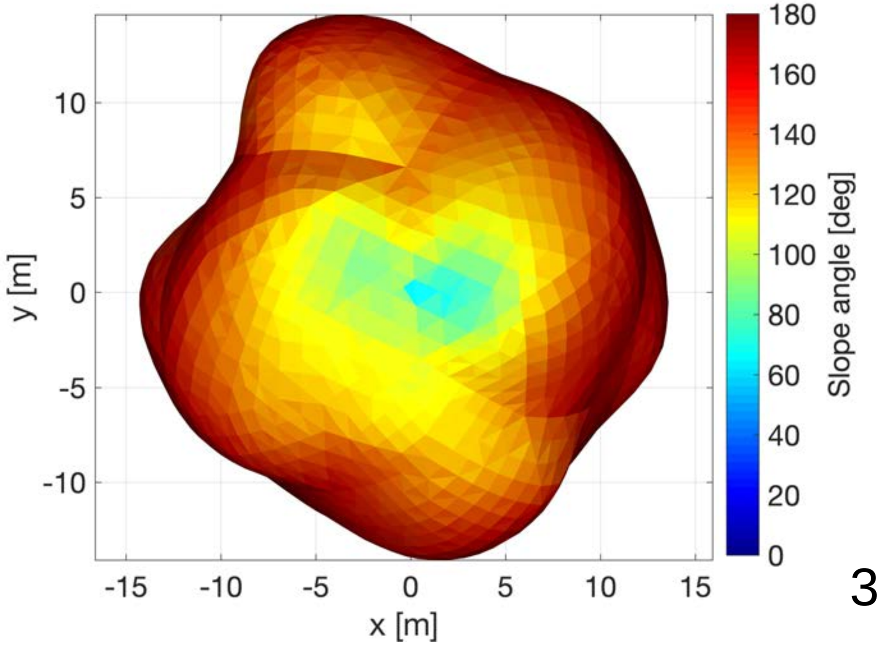
- The extended mission follows its nominal mission that returned samples from the C-type asteroid, Ryugu, in December 2020.
- The spacecraft is currently flying without no critical issues.
- The extended mission explores:
    - Scientific advances in the inner solar system evolution and planetary defense, and
    - Engineering technologies for extremely long-term explorations.
- The extended mission is planned to continue until 2031.
- We are about to start the extended mission.

The rendezvous target is asteroid 1998 KY26, a fast rotator with a size of ~30 m and a spin period of 10.7 min.

- Because of the fast spin, the surface slope exceeds 180 deg in major regions.
- Materials on the surface should be shed unless there is an attractive force.
- This asteroid is also considered to be a target of NASA's human spaceflight missions.

Properties	Values
Shape	Spheroidal
Equivalent diameter	~30 m
Spin period	10.7 min
Tumbling mode	Not observed
Taxonomy	B, C, F, G, D, and P

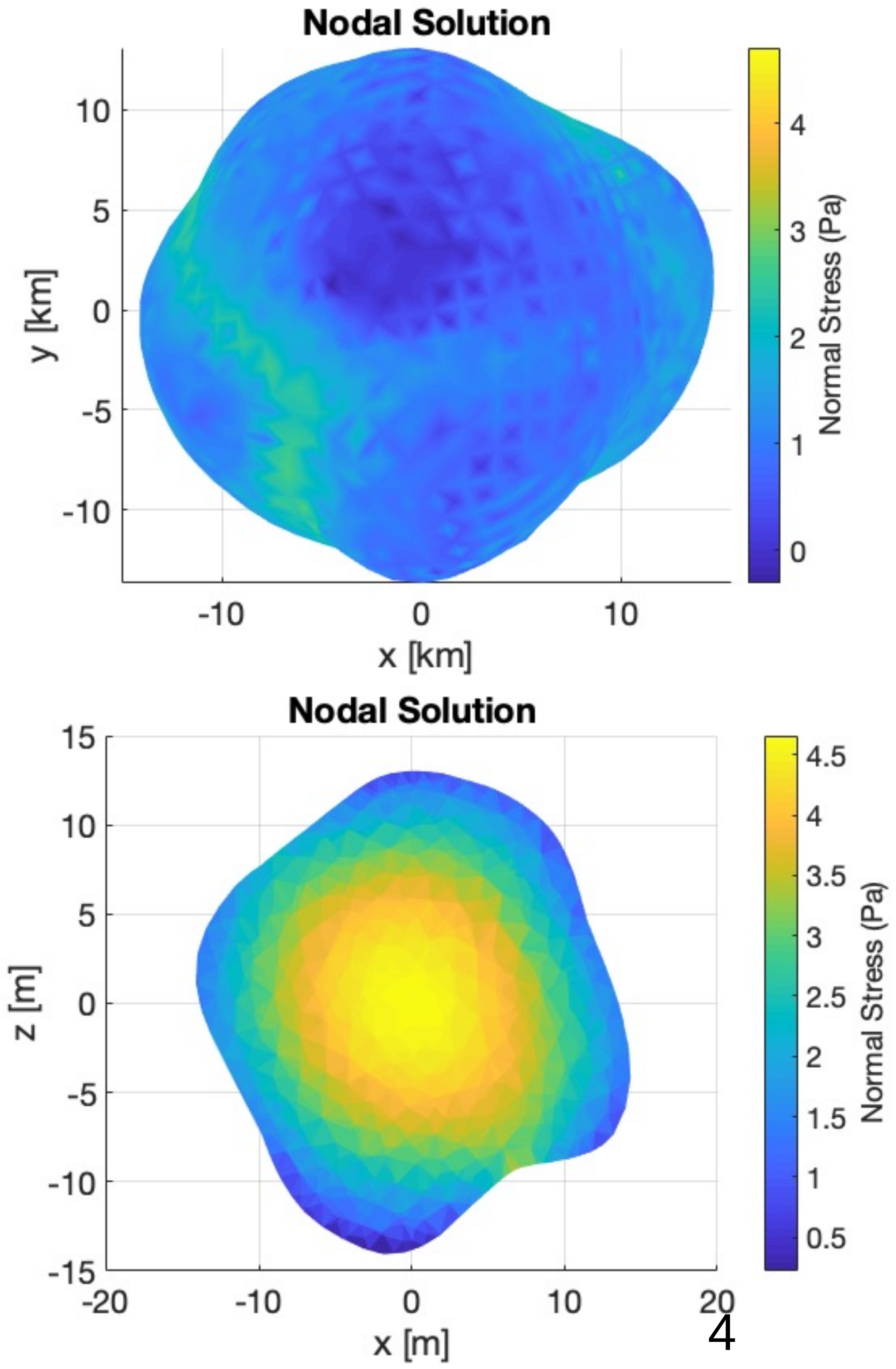




Using the shape model by Ostro et al., 1999

Because of the fast spin, 1998 KY26 is expected to have unique surface and internal conditions.

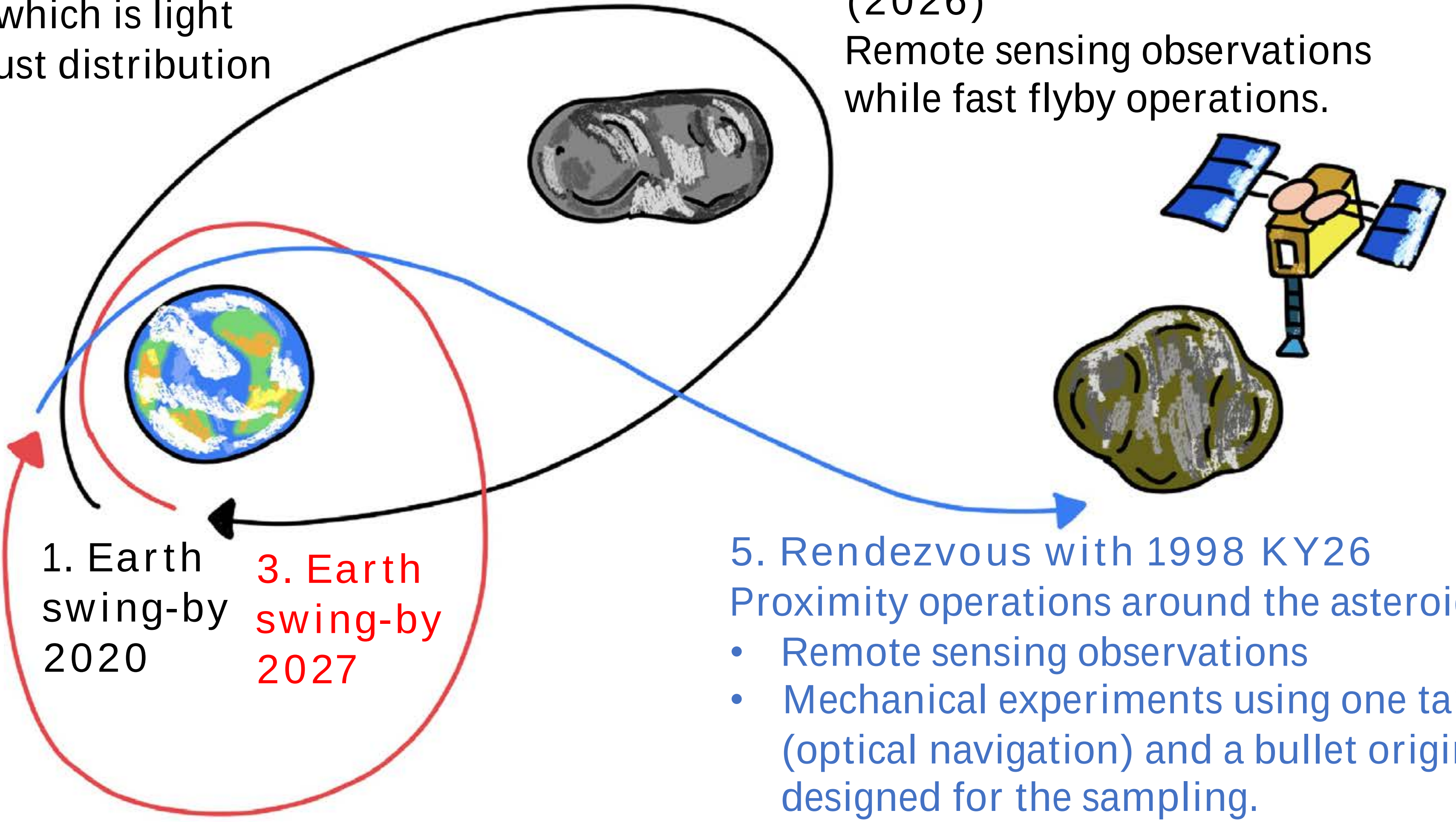
- The stress components reach positive, and thus the interior always experience tension. However, the magnitude is not significantly high.
  - This asteroid is likely a monolithic, given the formation process.
  - However, given the stress level, a rubble pile structure is also a possible option.
- Loose materials can not exist in surface regions unless there is cohesion. If there exist such materials, there are additional attractive forces.
- Fractures, craters, and other geomorphological features correlate with this asteroid’s evolution.
- Earlier radar observations imply that materials are dark, so it may be possible that this asteroid may be a carbonaceous asteroid.



The mission contains five phases: three swing-by operations, one flyby at an asteroid, and a rendezvous with 1998 KY26.

Long-term cruise to observe
- Zodiacal light, which is light scattering by dust distribution
- Exoplanets.

2. Flyby at 2001 CC21 (2026)
Remote sensing observations while fast flyby operations.



4. Earth swing-by 2027

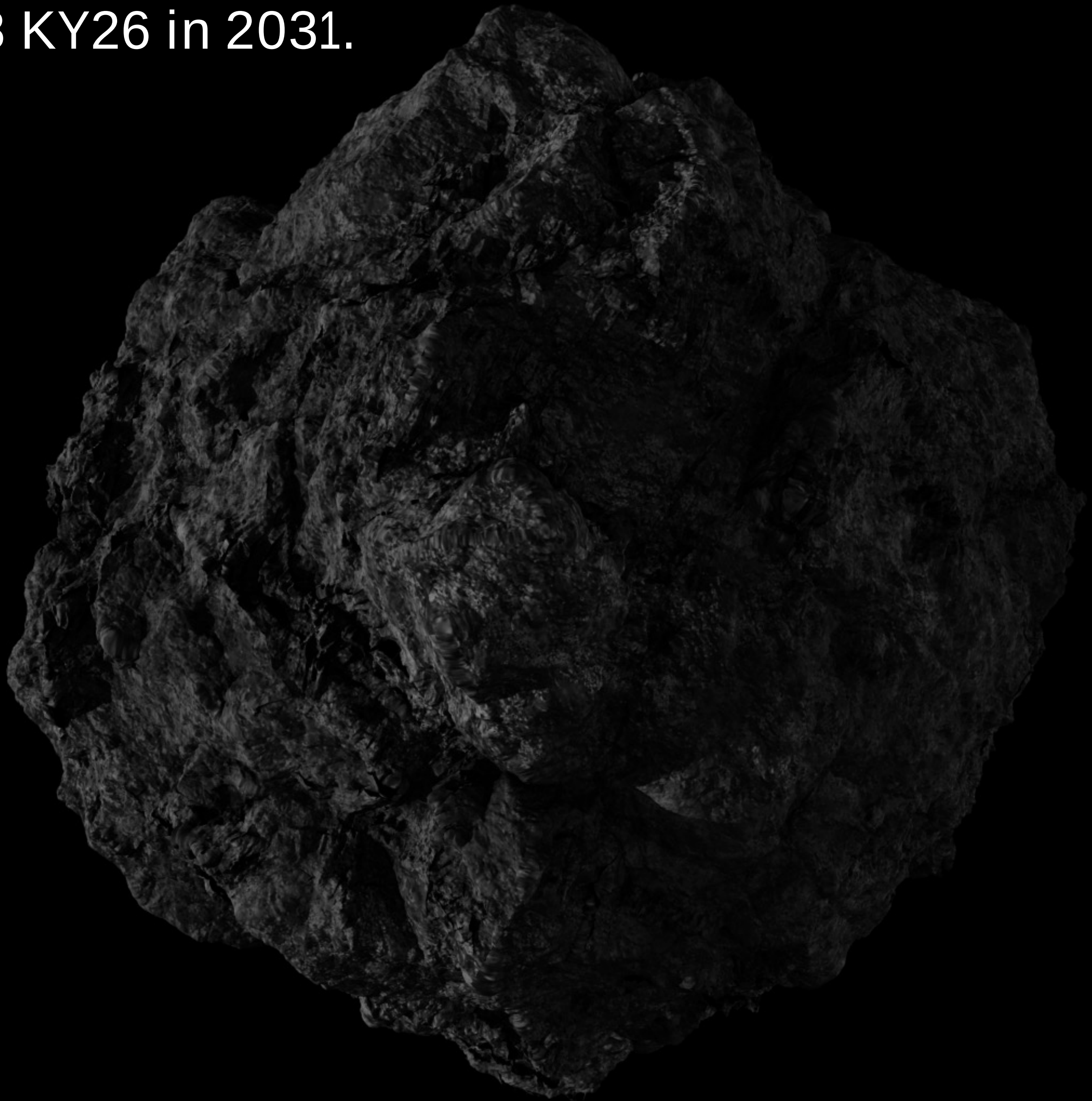
1. Earth swing-by 2020

3. Earth swing-by 2027

5. Rendezvous with 1998 KY26
Proximity operations around the asteroids
- Remote sensing observations
- Mechanical experiments using one target marker (optical navigation) and a bullet originally designed for the sampling.

Thrilled to see 1998 KY26 in 2031.

JAXA and LiVE



Thank you!
Questions?

7th IAA Planetary Defense Conference

26-30 April 2021, Online Event

Hosted by UNOOSA in collaboration with ESA

Q&A

Session 2: Hayabusa2

7th IAA Planetary Defense Conference

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Hosted by UNOOSA in collaboration with ESA

Break

Up next: Official Conference Opening