Results of Hayabusa Mission to NEA Itokawa

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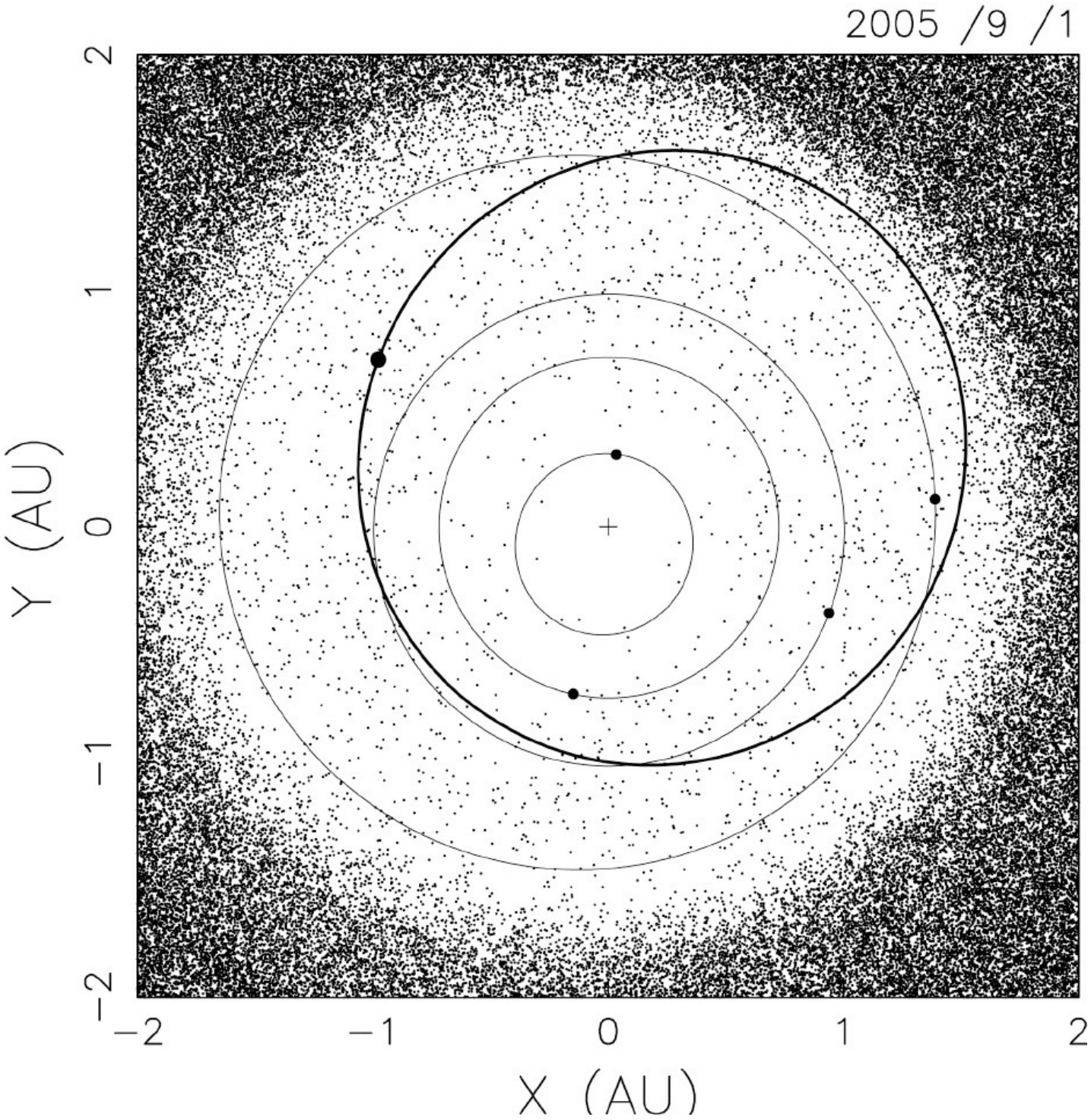
(ISAS/AXA)

Hayabusa Mission & Science Team

Asteroid Sample Return Mission "HAYABUSA"


Asteroid Sample Return Mission
"HAYABUSA"
after
/ MEF / JAXA · ISAS


2005 /9 /1
2
1
0
−1
−2
Y (AU)
−2
−1
0
1
2
X (AU)

Important feature of Hayabusa Mission from the point of Spaceguard

It revealed the nature of small asteroid, whose collision to the earth is more realistic.

Contents

1. Brief summary of Hayabusa mission
2. Images of Asteroid Itokawa
3. Structure of Itokawa

- Short comment for orbital evolution of Itokawa

Brief Summary
of
Hayabusa Mission

Hayabusa Mission

- **MUSES-C --------> Hayabusa** (= "falcon")

- **Technology demonstrator**

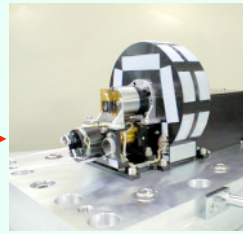
  Ion Engines, Autonomous Navigation and Guidance,
  Sample Collection under Micro Gravity, Reentry capsule,
  etc.

- **Science targets**

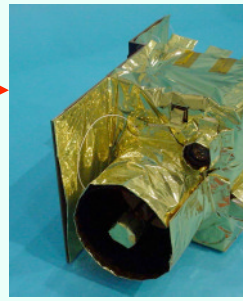
  To know the nature of sub-km sized S-type asteroid
  To investigate the relationship between asteroids and meteor
  To have key information for the origin and evolution of aster

Remote Sensing Instruments onboard

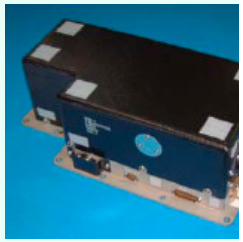
- **Multi-Spectral Telescopic Imager (AMICA)**
  - > CCD viewing angle 5.7°with 8 band-pass filters
  - > About 1500 still images obtained



- **Laser Altimeter (LIDAR)**
  - > Measurement accuracy of 1 m at 50m altitude
  - > 1,670,000 hits obtained



- **Near-Infrared Spectrometer (NIRS)**
  - > 64-channel InGaAs detector at wavelengths of 0.8~2.1 micron
  - > Viewing angle 0.1° (6-90 m per pixel spatial resolution)
  - > More than 80,000 spectra obtained

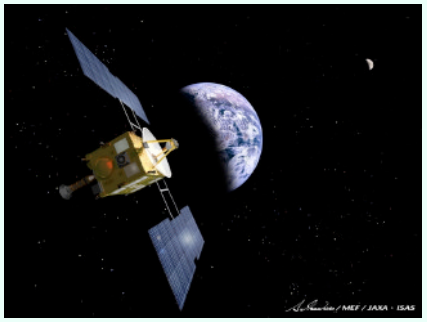


- **X-ray Fluorescence Spectrometer (XRS)**
  - > CCD viewing angle: 3.5°, 160 eV resolution at 5.9 keV
  - > 6,000 spectra from the asteroid surface obtained

Mission Scenario

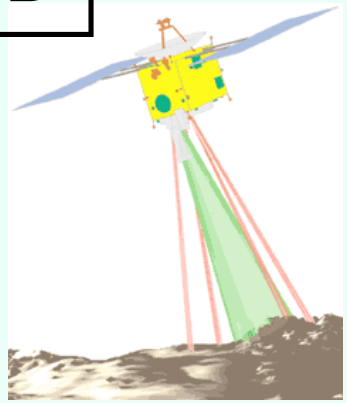
Launch
9 May 2003

A

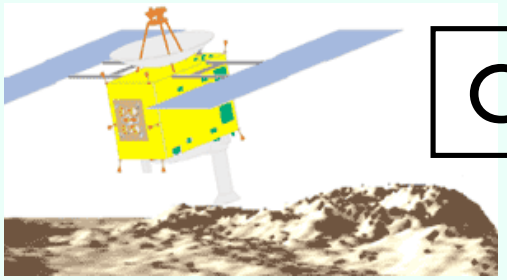


Earth Swingby
19 May 2004

B



Asteroid Arrival
12 Sept. 2005



C

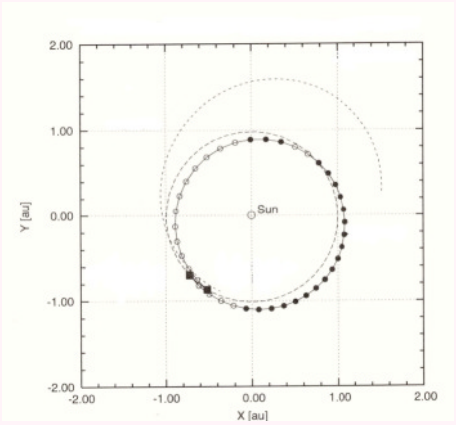
Observations, sampling

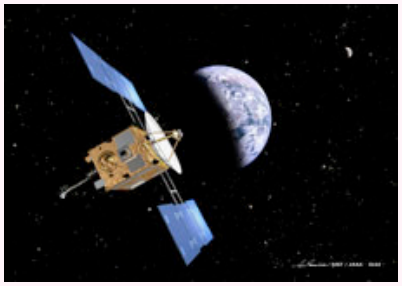
D

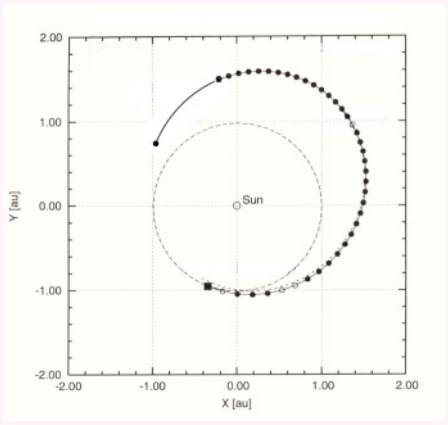
Earth Retur
~~June 2007~~
→ June 201

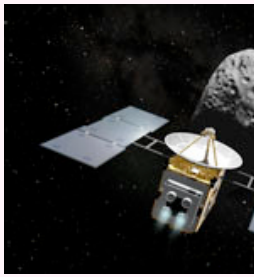
A

From Launch to Asteroid Arrival









9 May 2003 19 May 2004 12 Sept. 2

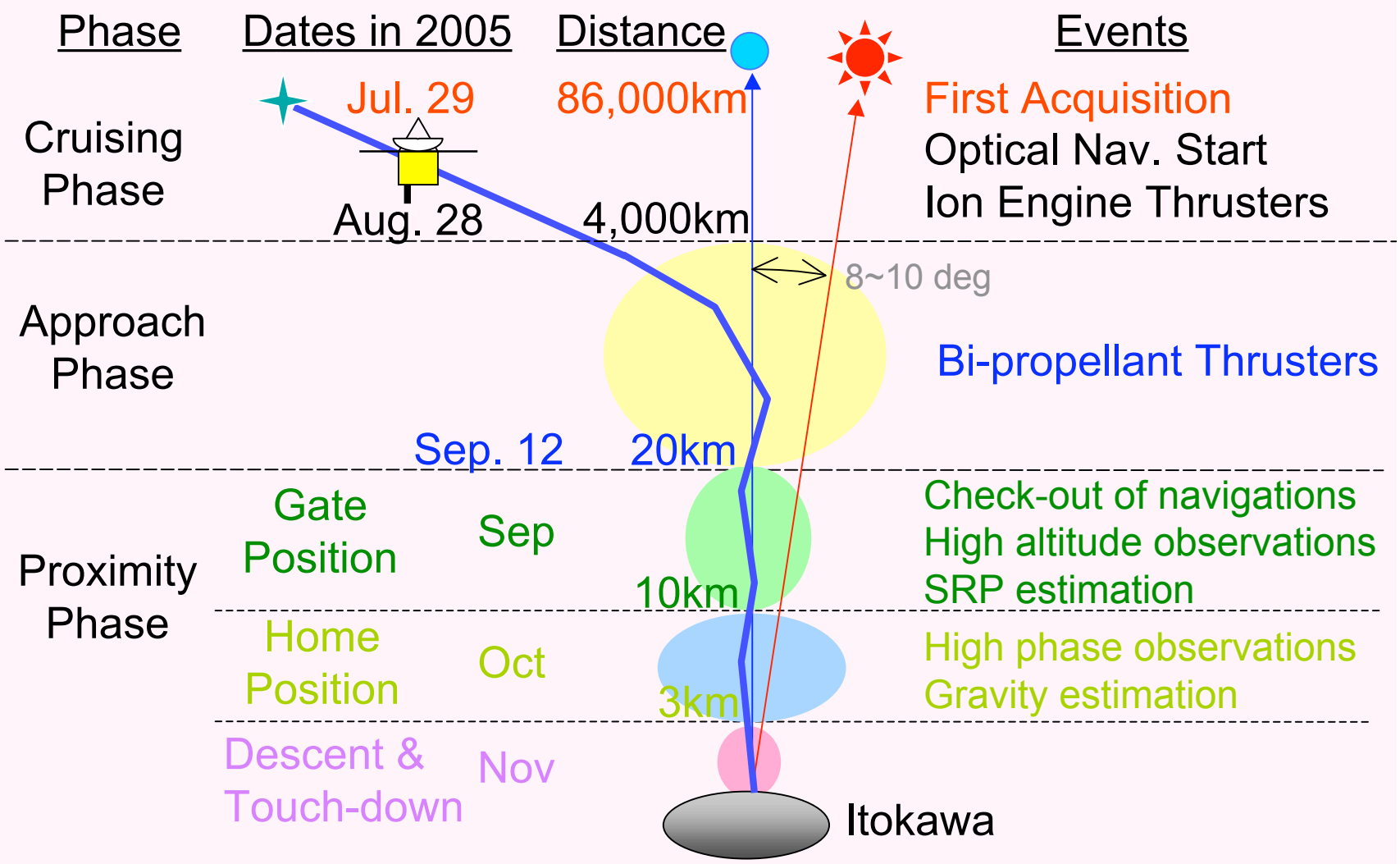
Launch Swingby Ar

IES IES

Conjunctio

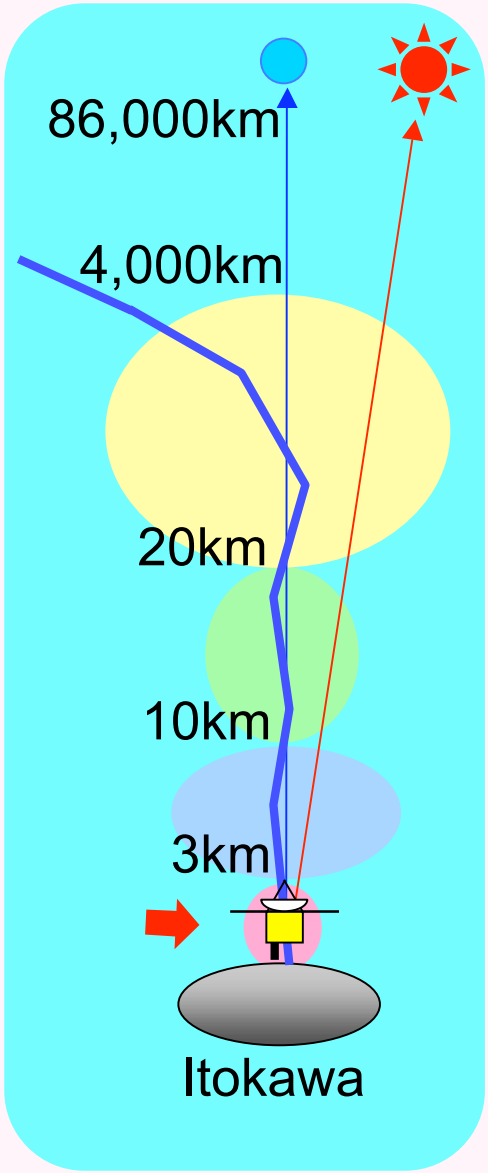
B

Approach and Observation Phase



C

Descent Rehearsal and Touch-down



2005

1.Rehearsal #1 ..... Nov. 4th

2. Nav & Guide Practice ..... Nov. 9th
(Target Marker Release#1)

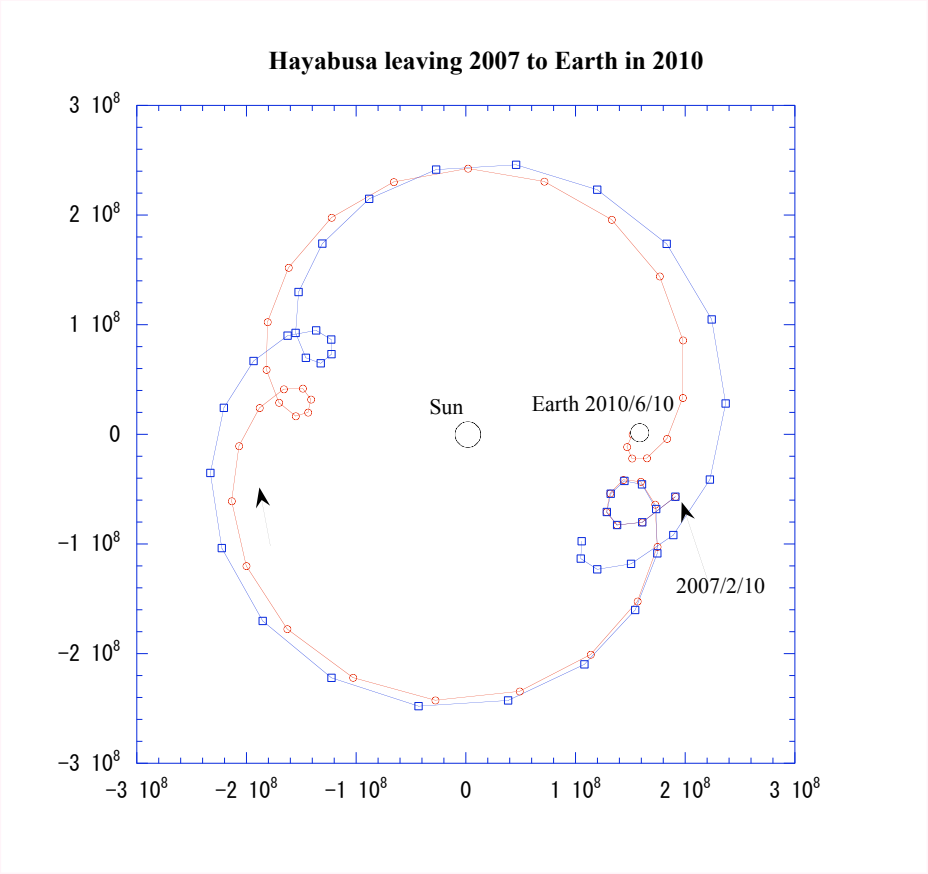
3. Rehearsal #2 ..... Nov. 12th
(MINERVA Lander Release)

4. Touch-down for Sampling#1 ..... Nov. 20th
(Target Marker Release#2)
(Two Touch-downs + One Landing)

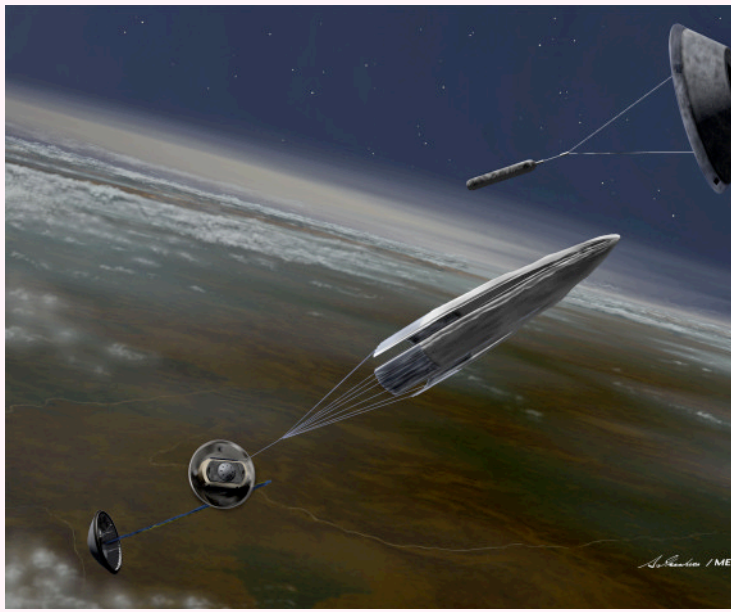
5. Touch-down for Sampling#2 ..... Nov. 26th
(One Touch-down + One Sampling CMD Issued)

D

Return to the Earth



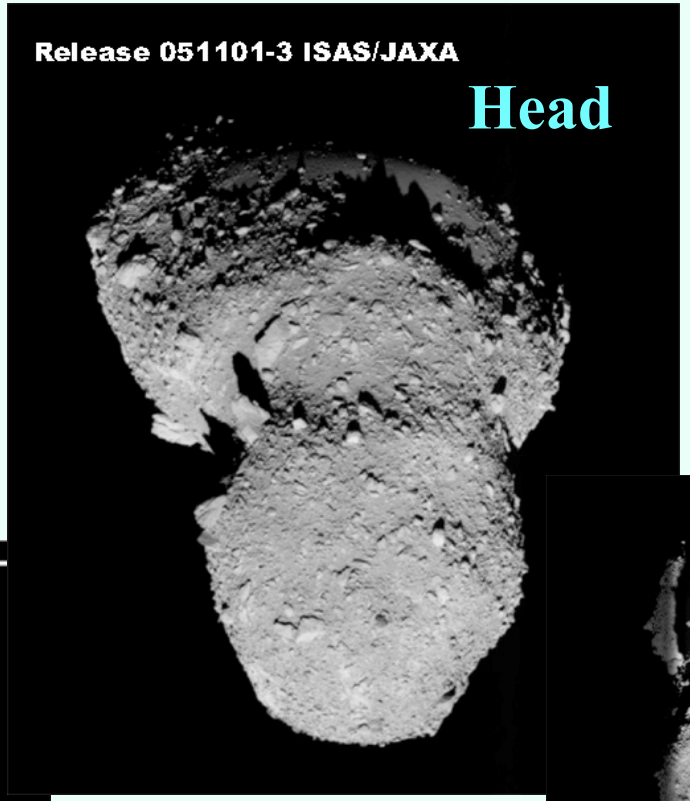
- Hayabusa will start its ion eng in March 2007, and it will com back to the earth in June 2010.
- There is enough Xenon gas fo return.

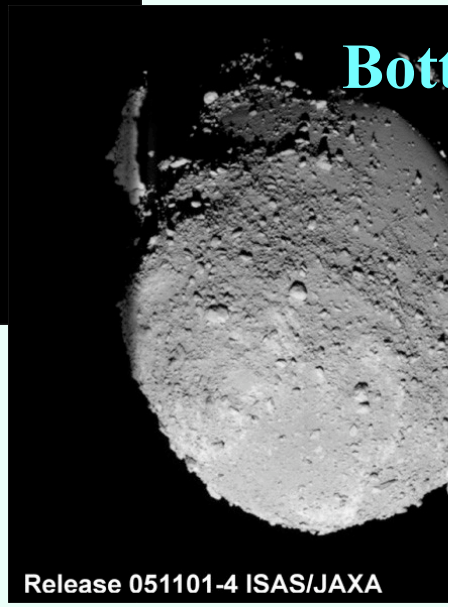


June 2010

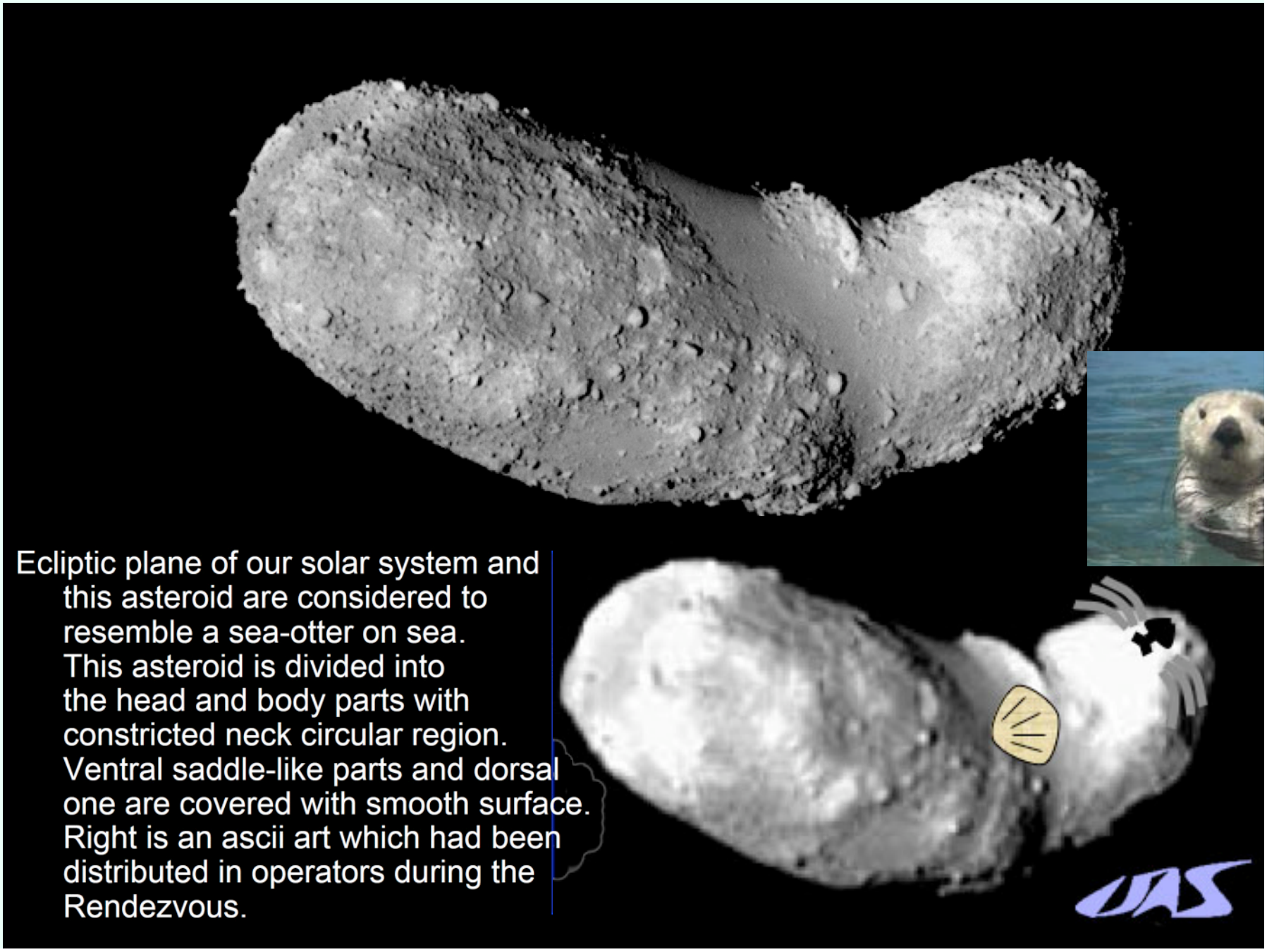
Images of Asteroid Itokawa

Images of Itokawa : whole



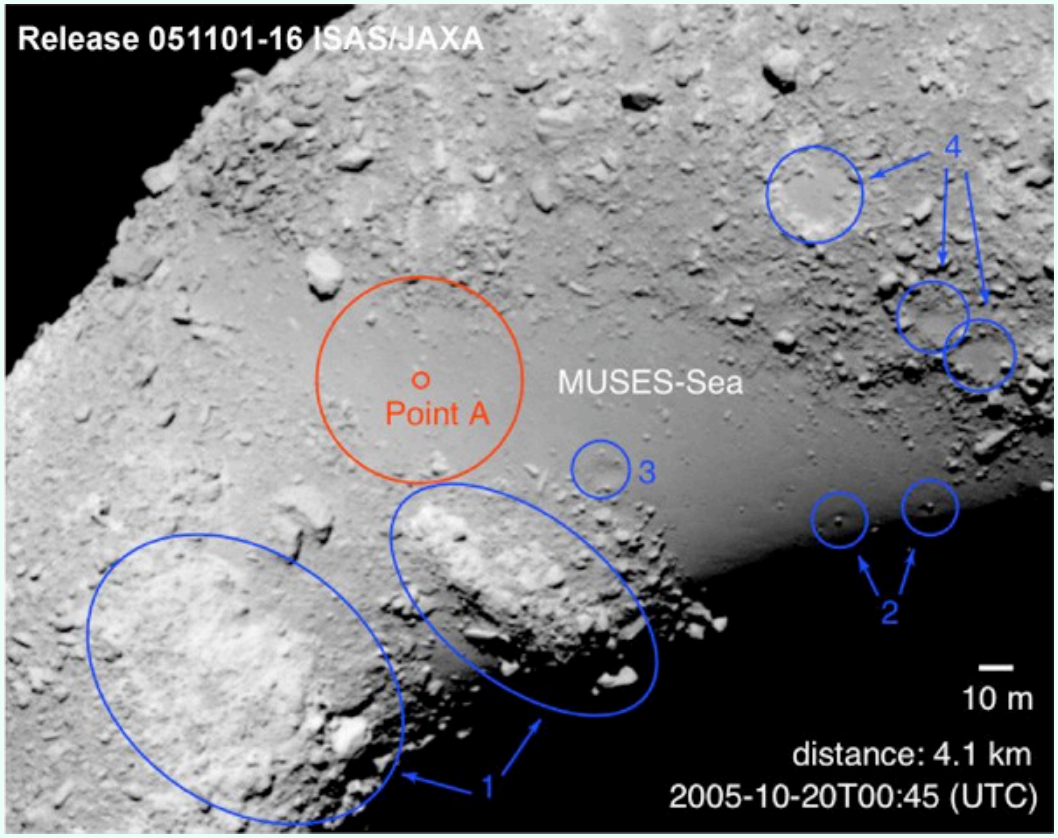


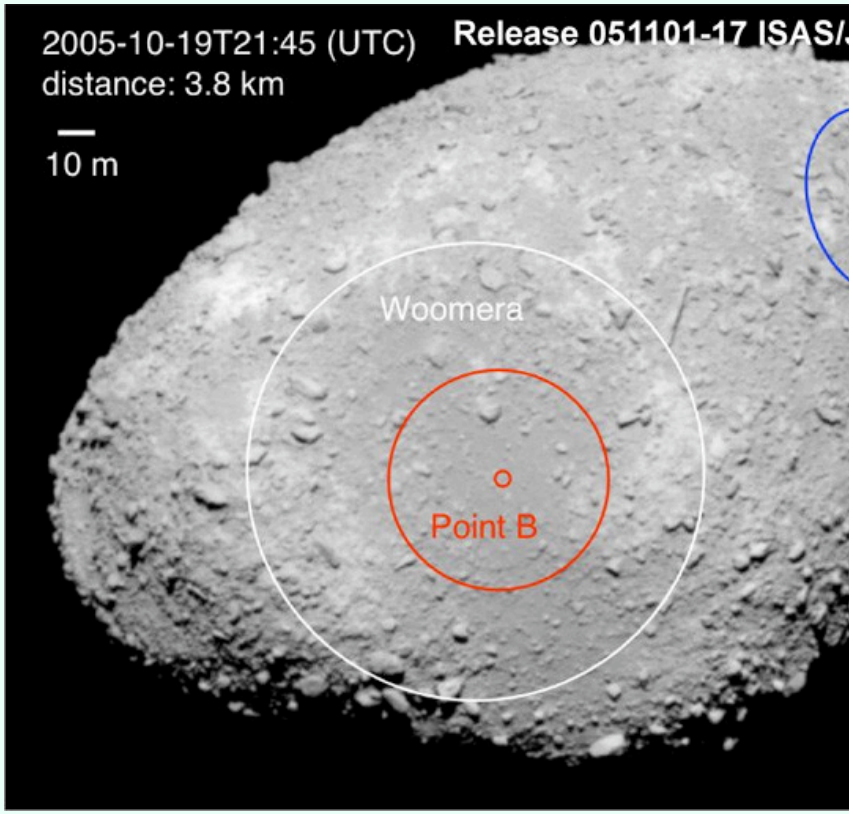
Global Shape of Itokawa: Sea Otter in Space?



Images of Itokawa

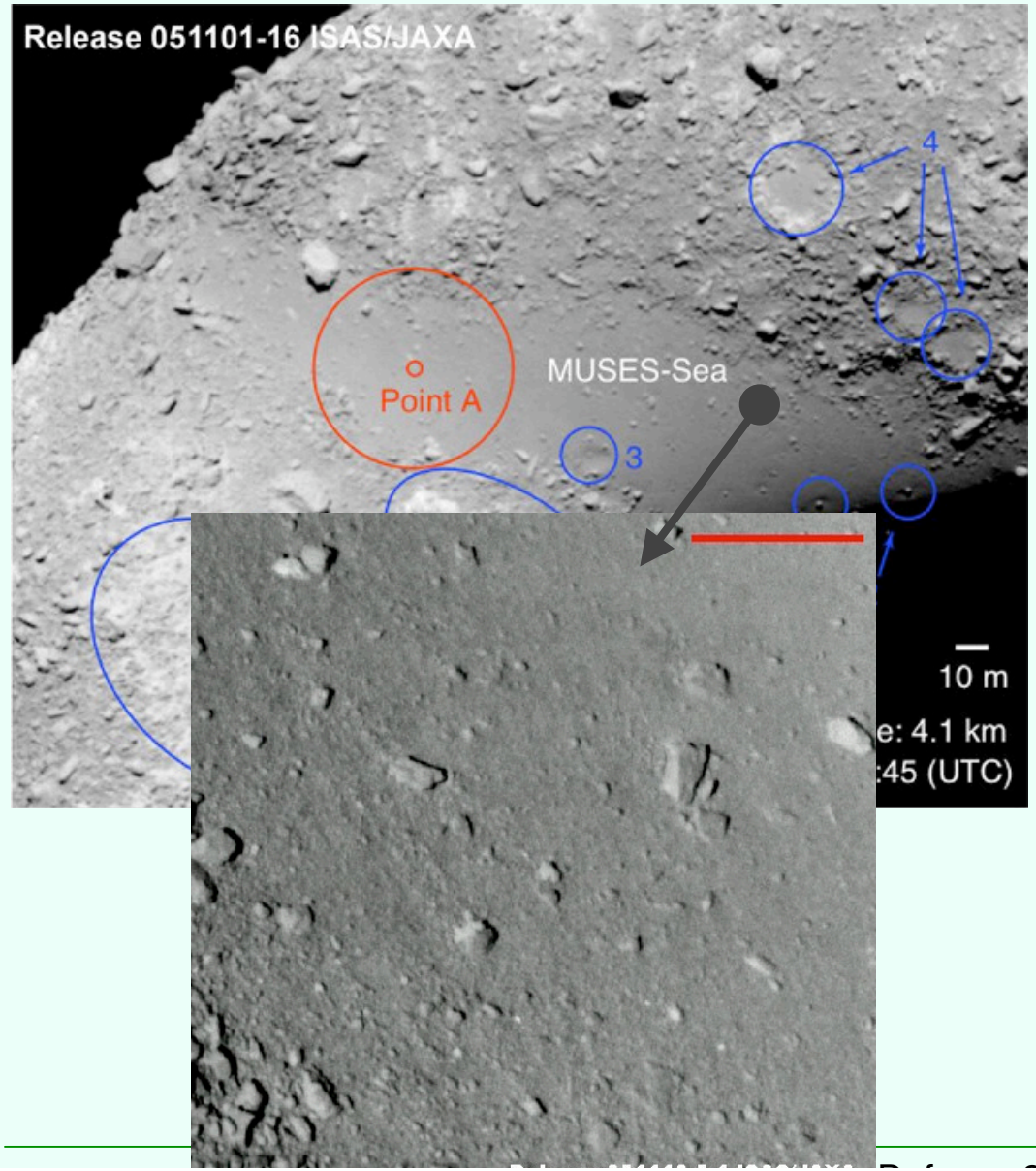
Smooth and Rough

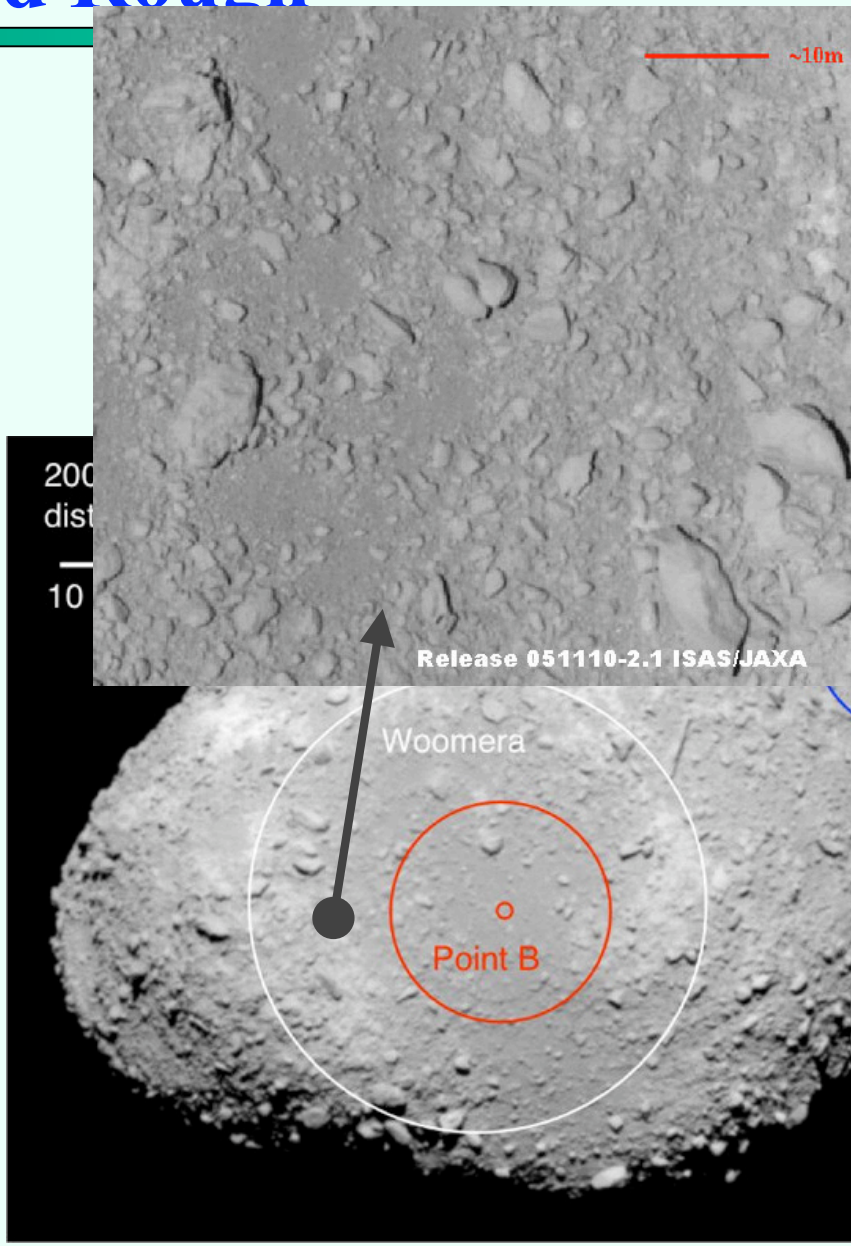




Images of Itokawa

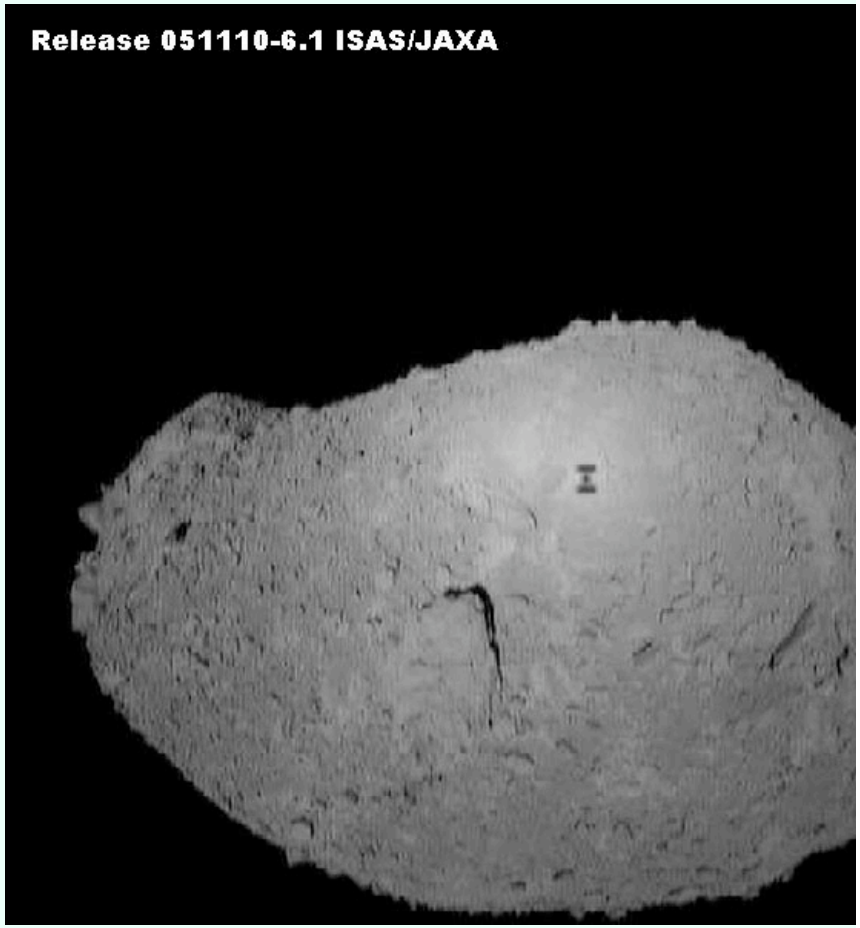
Smooth and Rough





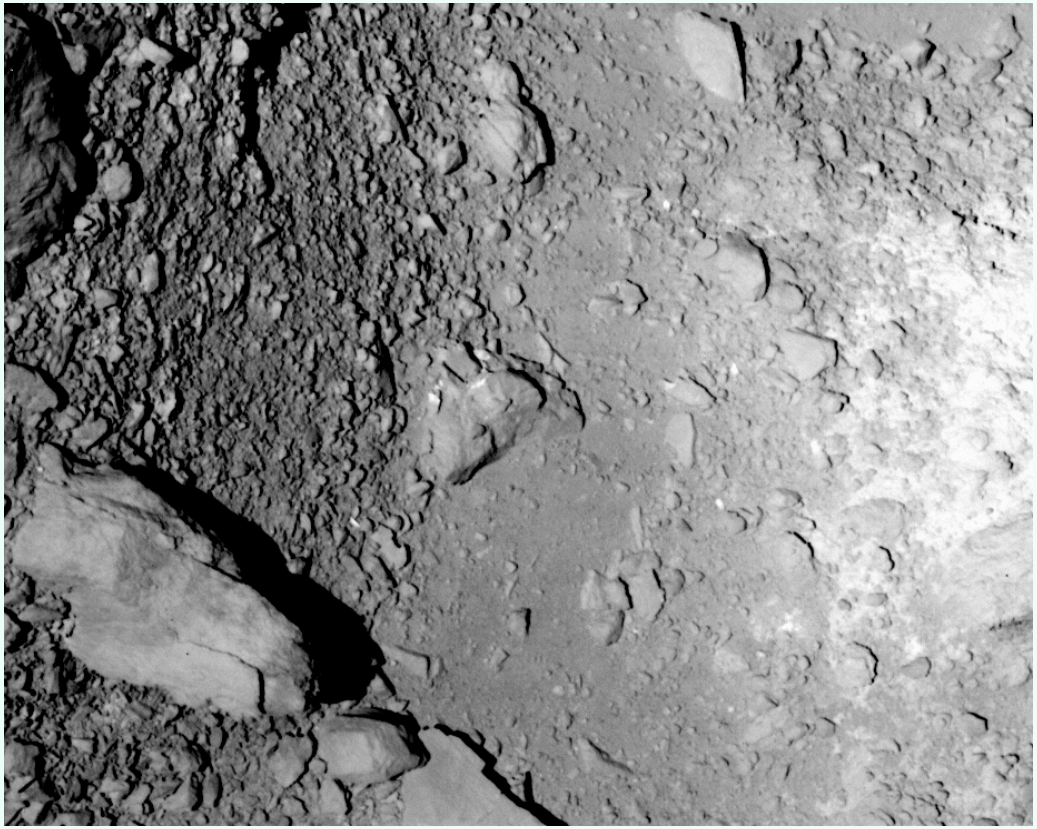
Images of Itokawa

Rough surface



Images of Itokawa

Large Boulders

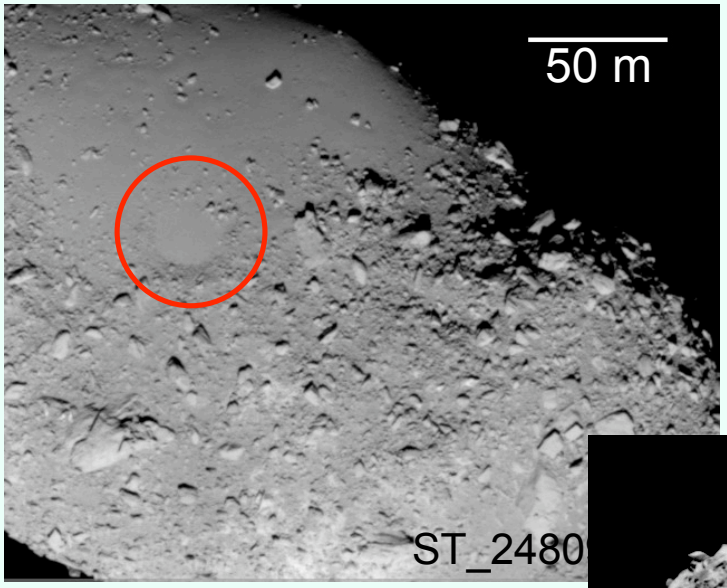


"Pencil"

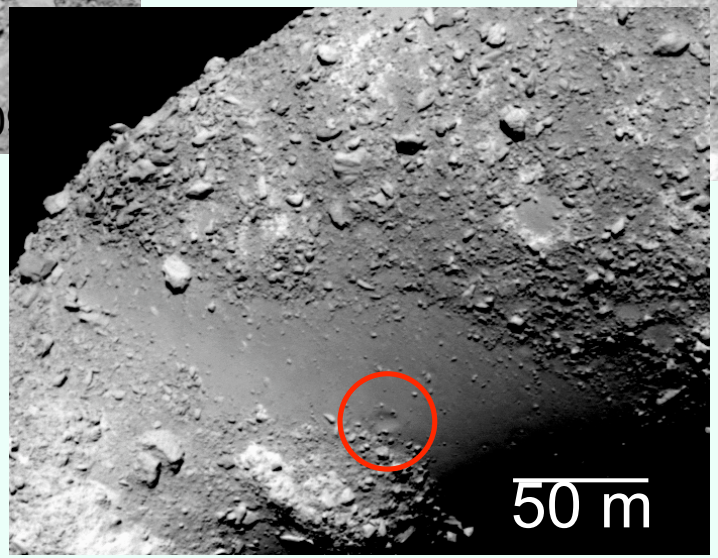
"Yoshinodai"

Images of Itokawa

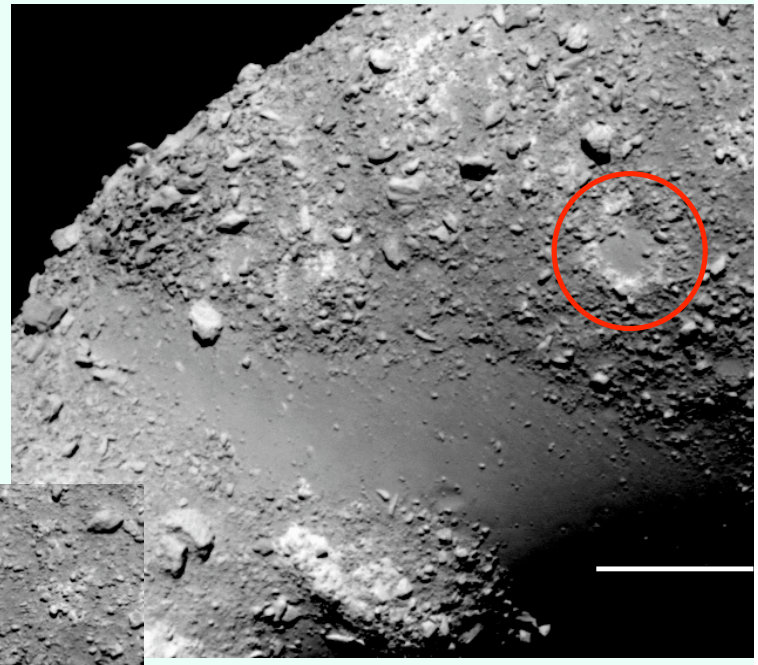
Craters



Fuchinobe (D=36m)



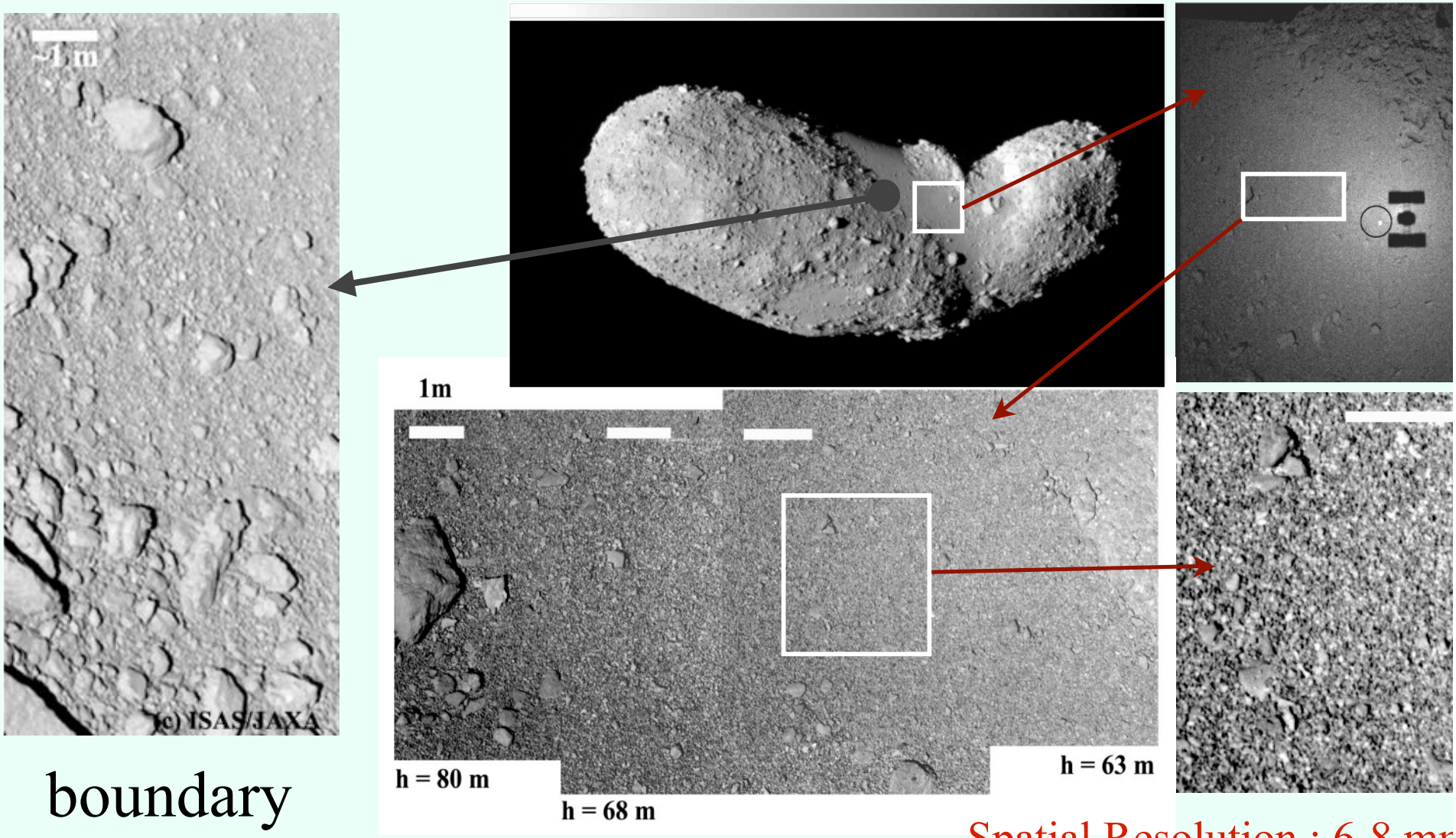
Kamisunagawa (D=10m)



Komaba (D=27m

Images of Itokawa

Close-up 1



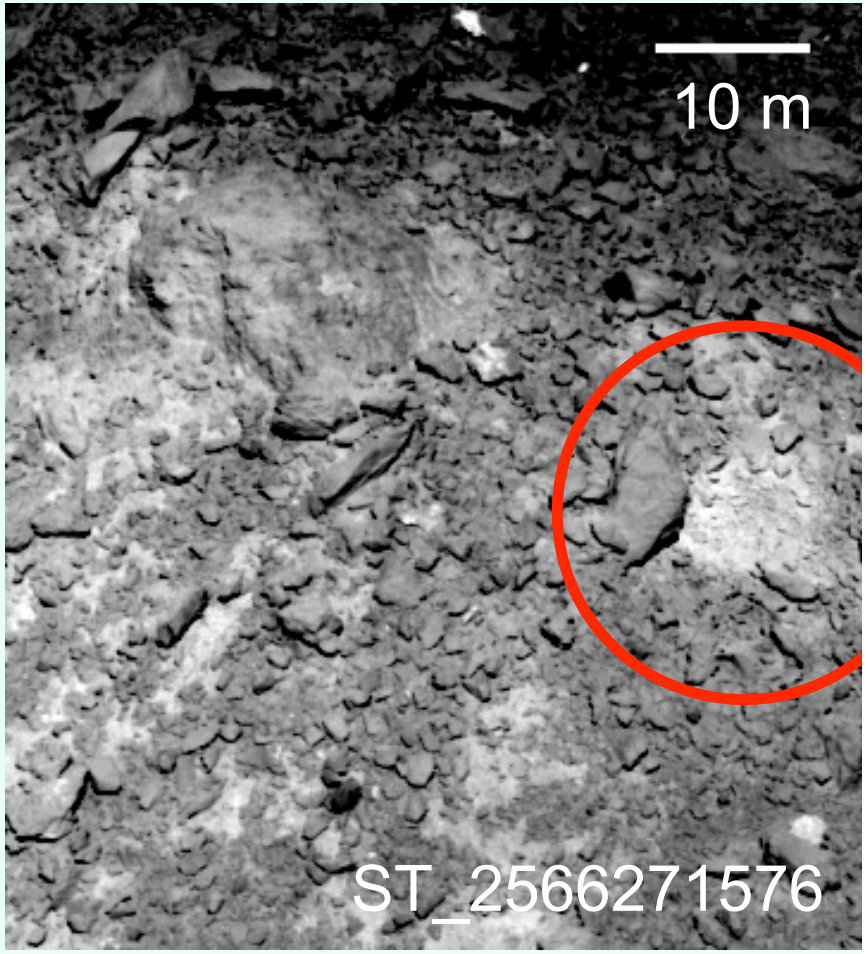
boundary

Spatial Resolution : 6-8 mr

Images of Itokawa

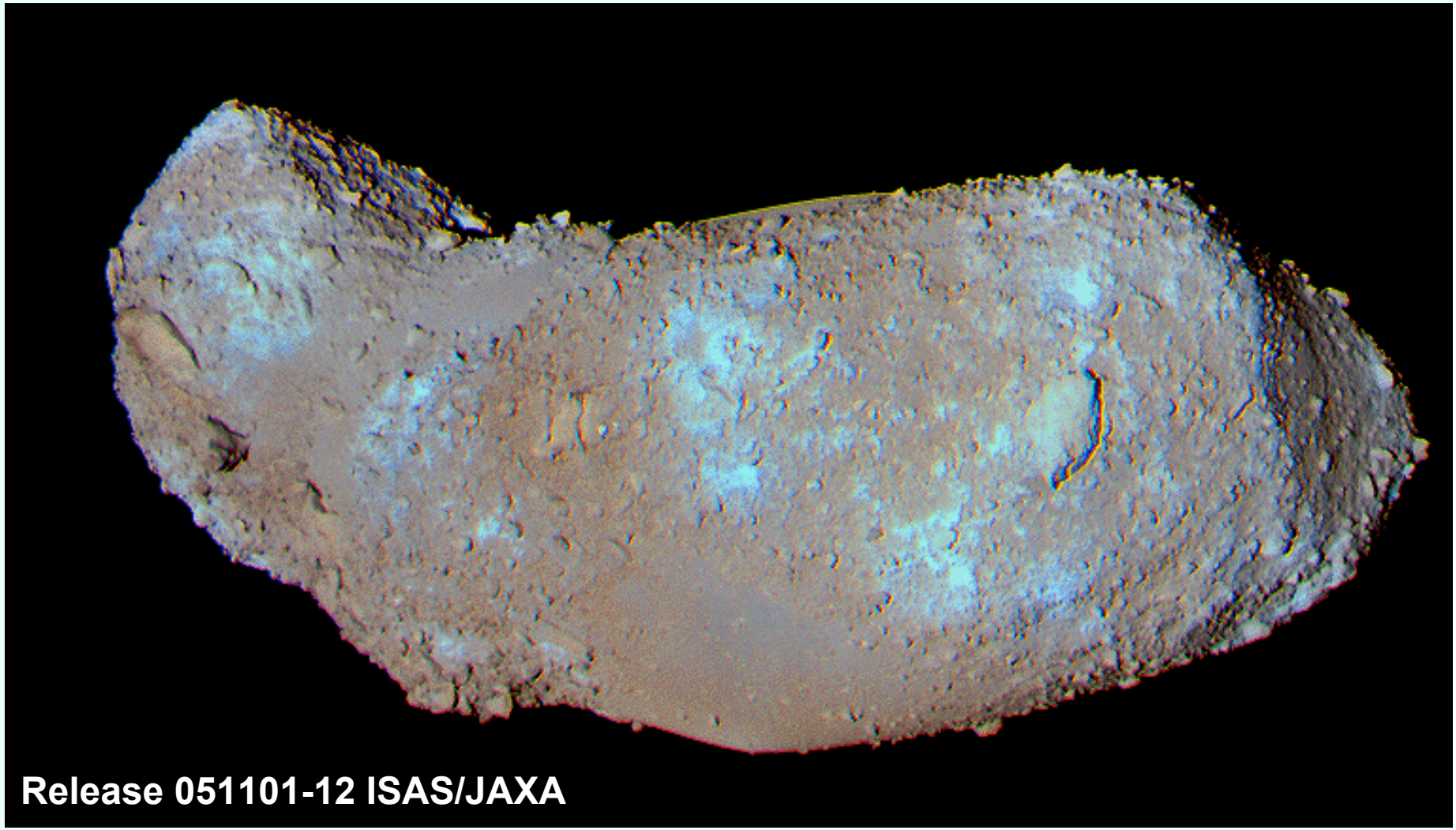
Close-up 2

At 59m
6mm/pixel



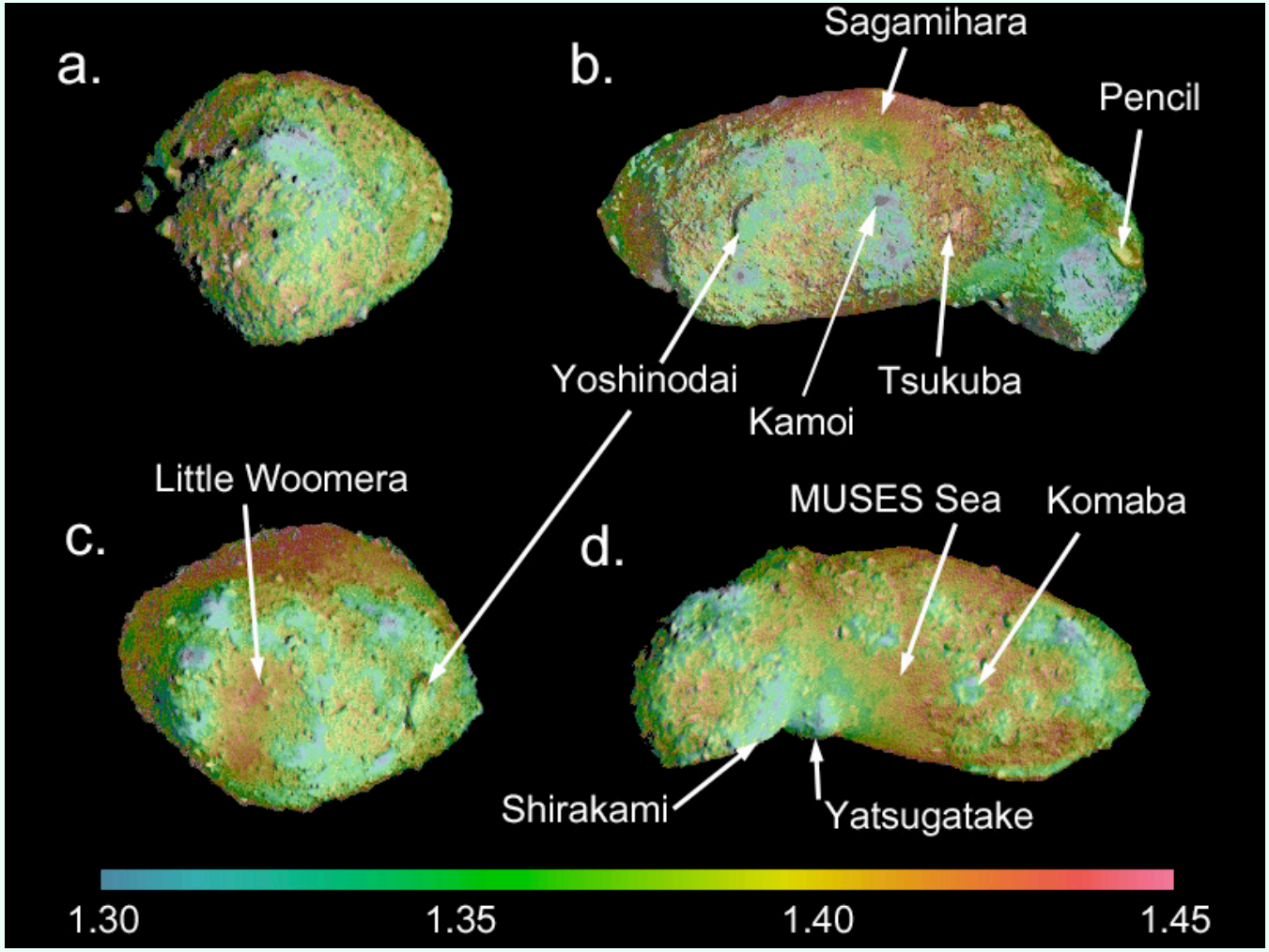
Images of Itokawa

color variation



Images of Itokawa

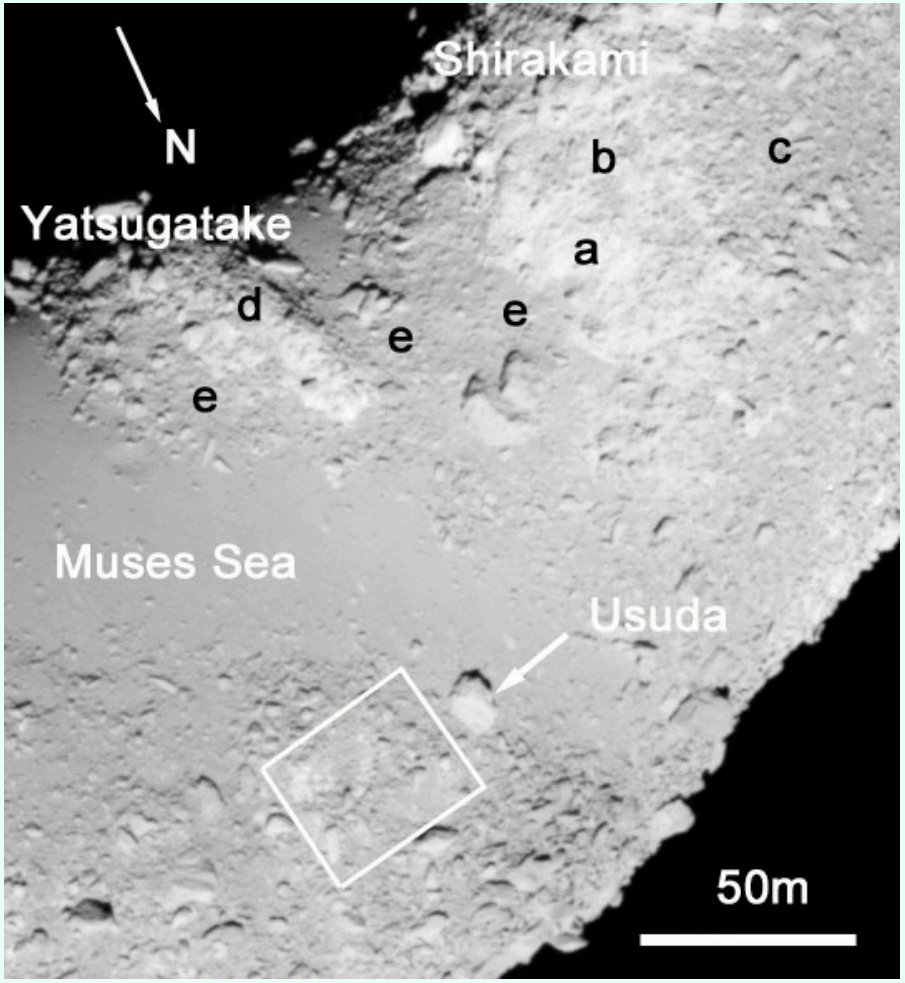
color variation

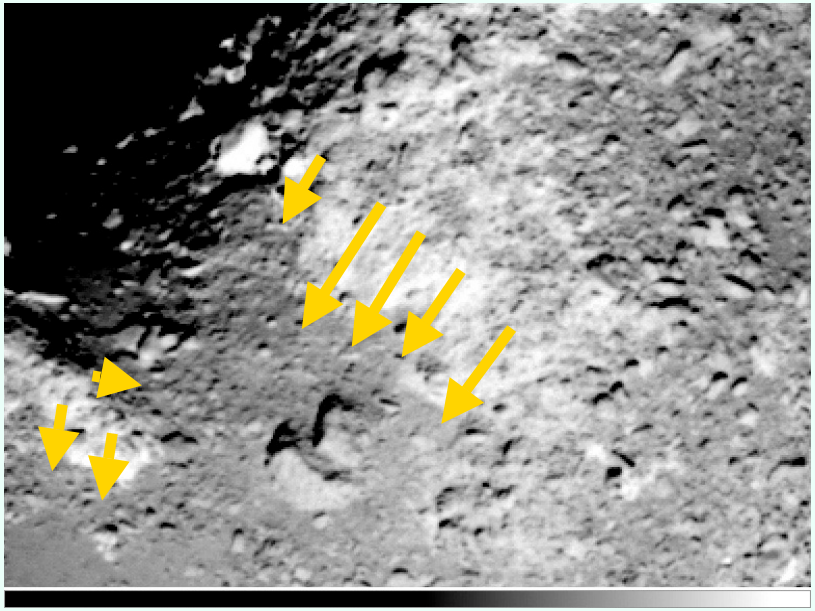


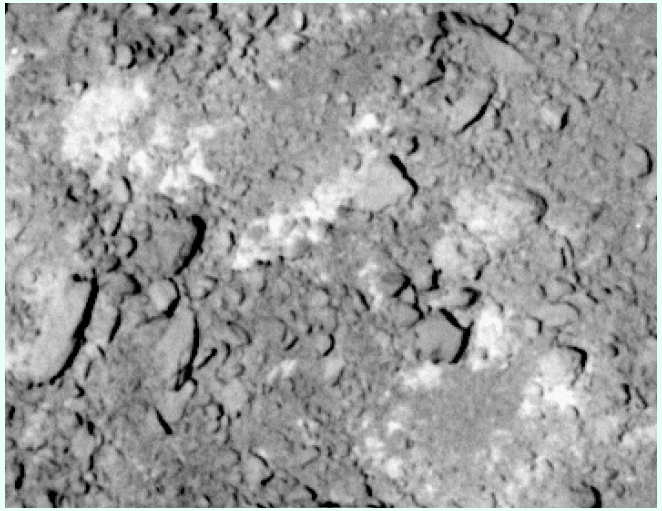
R(w-band) / R(b-band) Ishiguro et al. (2006)

Images of Itokawa

Bright Region

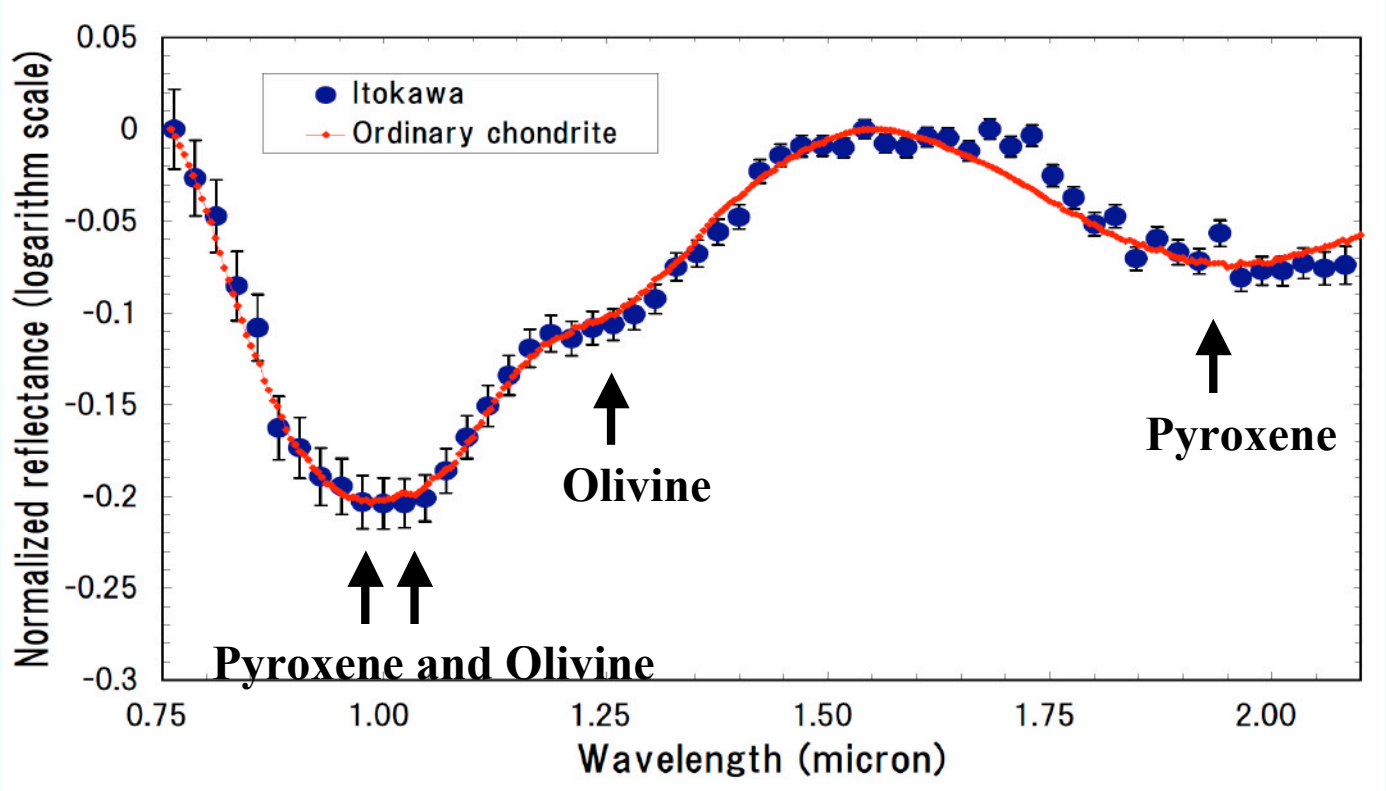




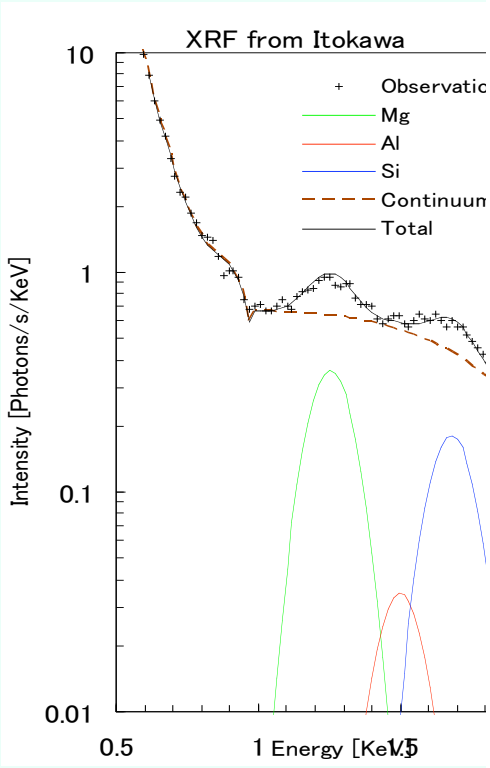


Near Infrared and X-ray Observatio

NIRS

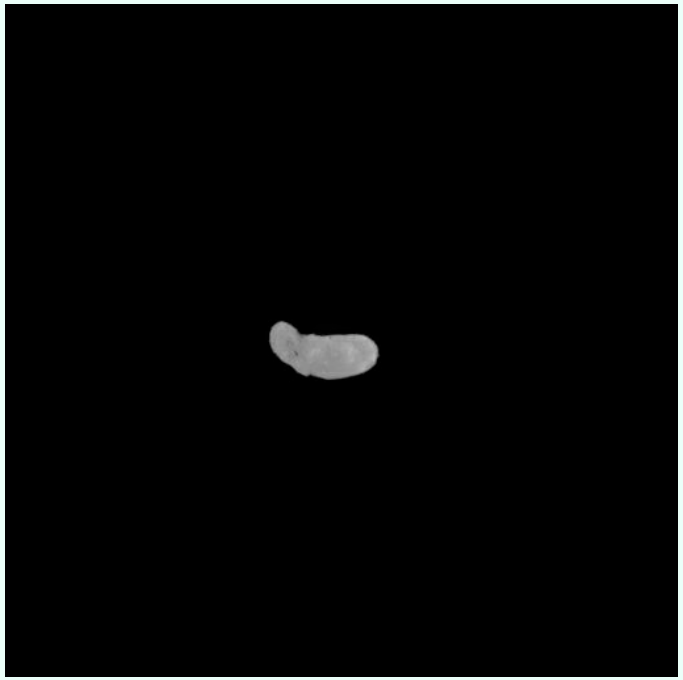


XRS

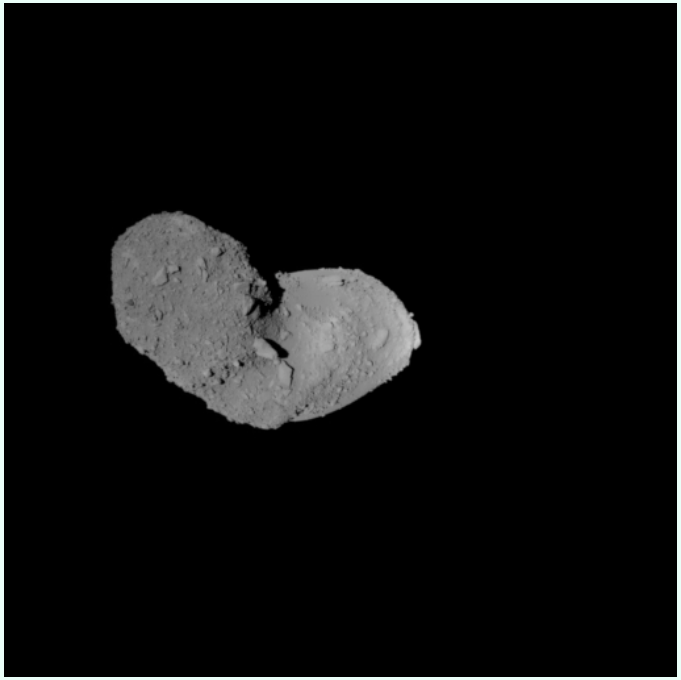


Surface of Itokawa ~ Ordinary chondrite (LL chondrit

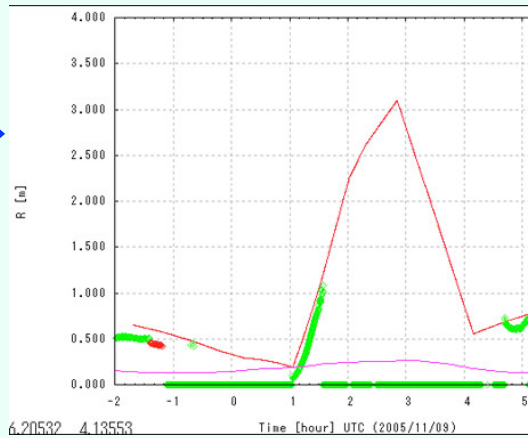
Rehearsal & Practice



Rehearsal #1

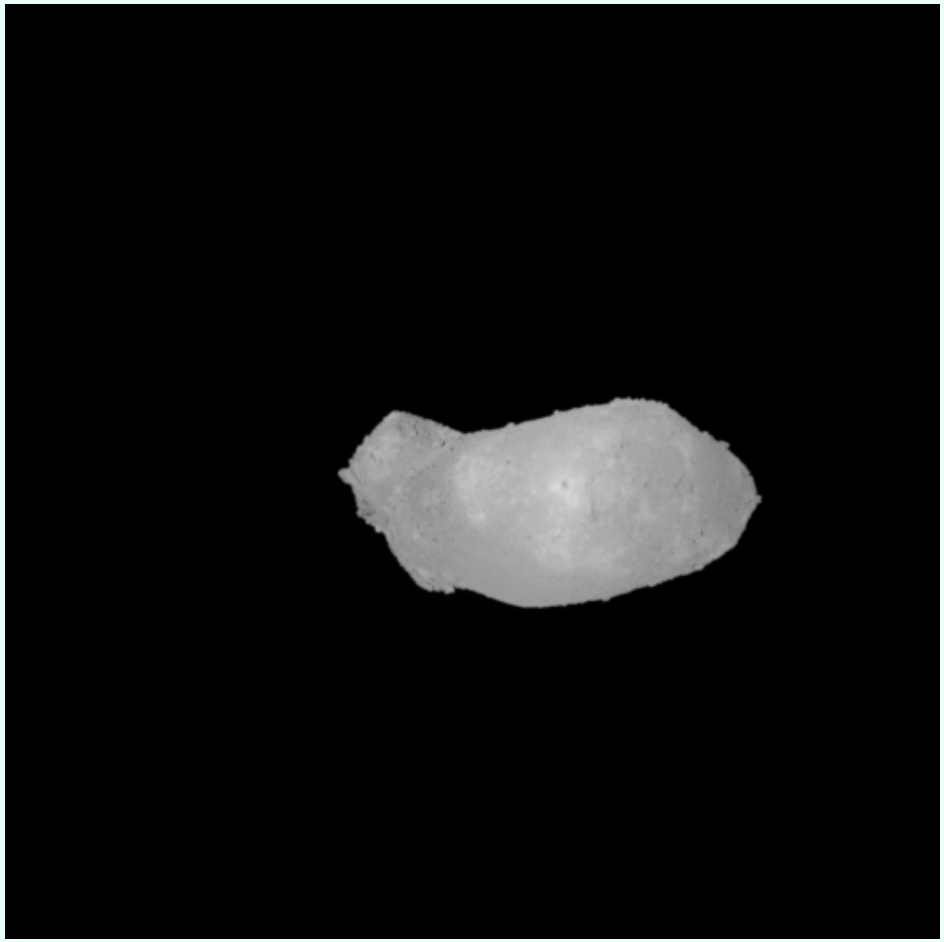


Nav & Guide Practice



Rehearsal #2

Touch-down for Sampling

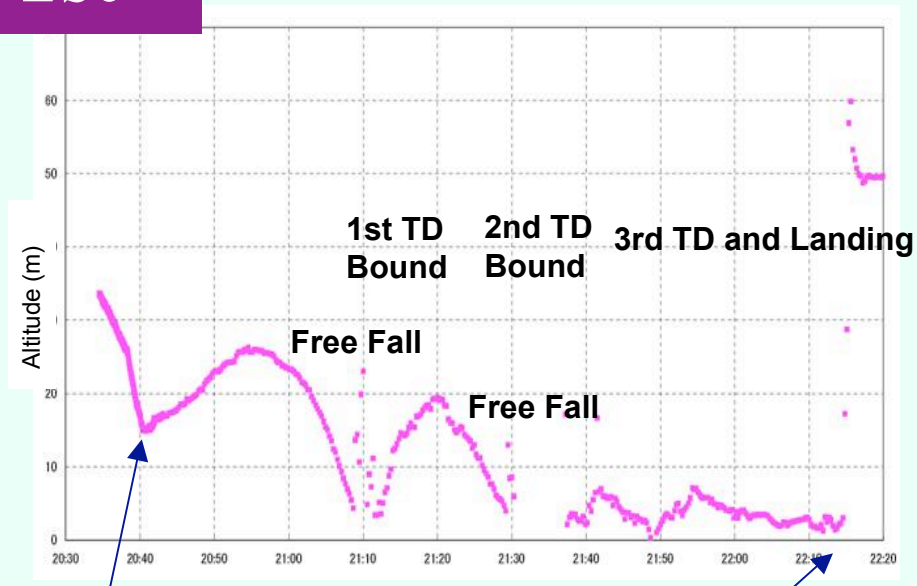


Touch-down for Sampling#1

Touch-down for Sampling#2

Touchdown

1st



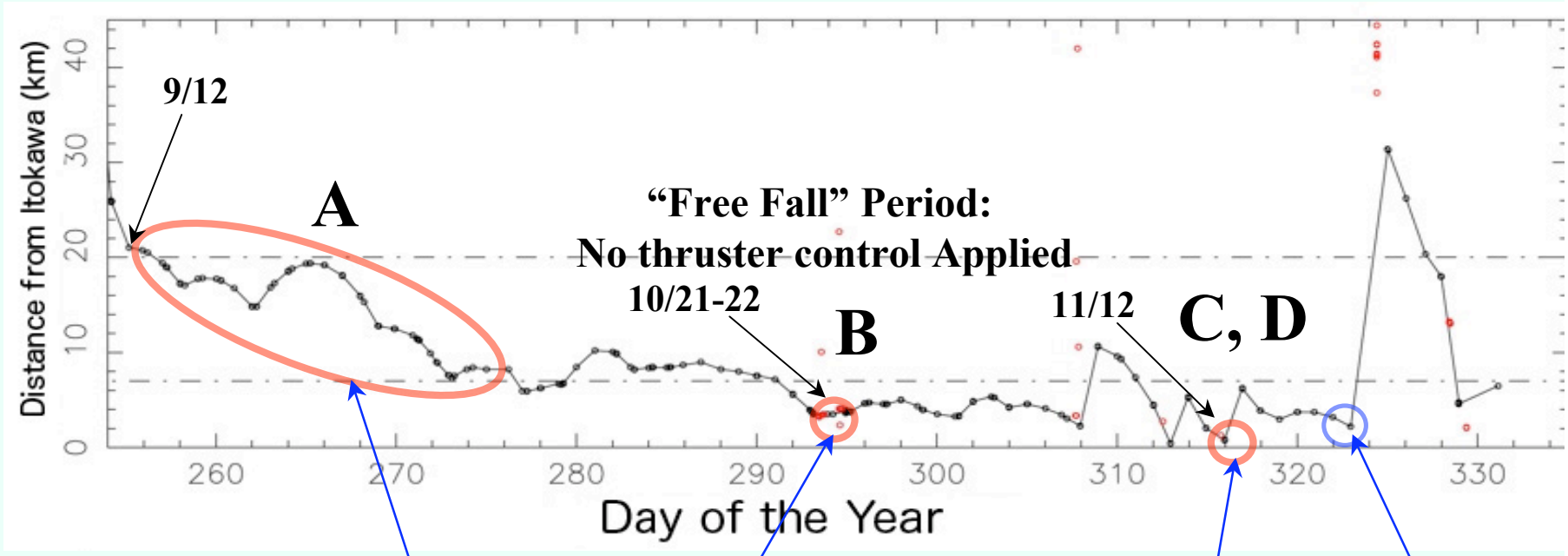
Obstacle was detected by FBS
TD sequence was terminated

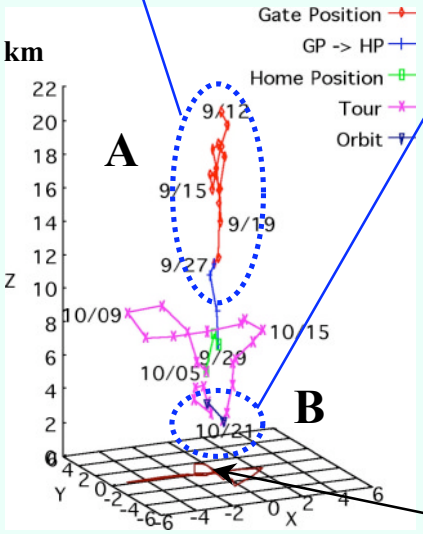
Escape dV
by ground command

2nd

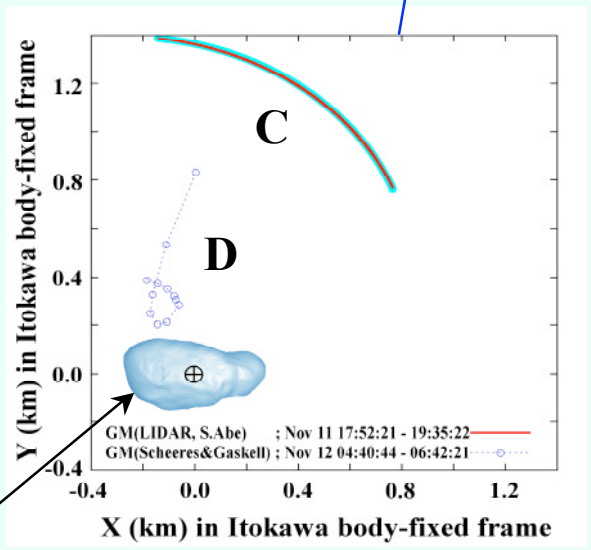
Structure of Itokawa

Mass Estimation





Itokawa



E

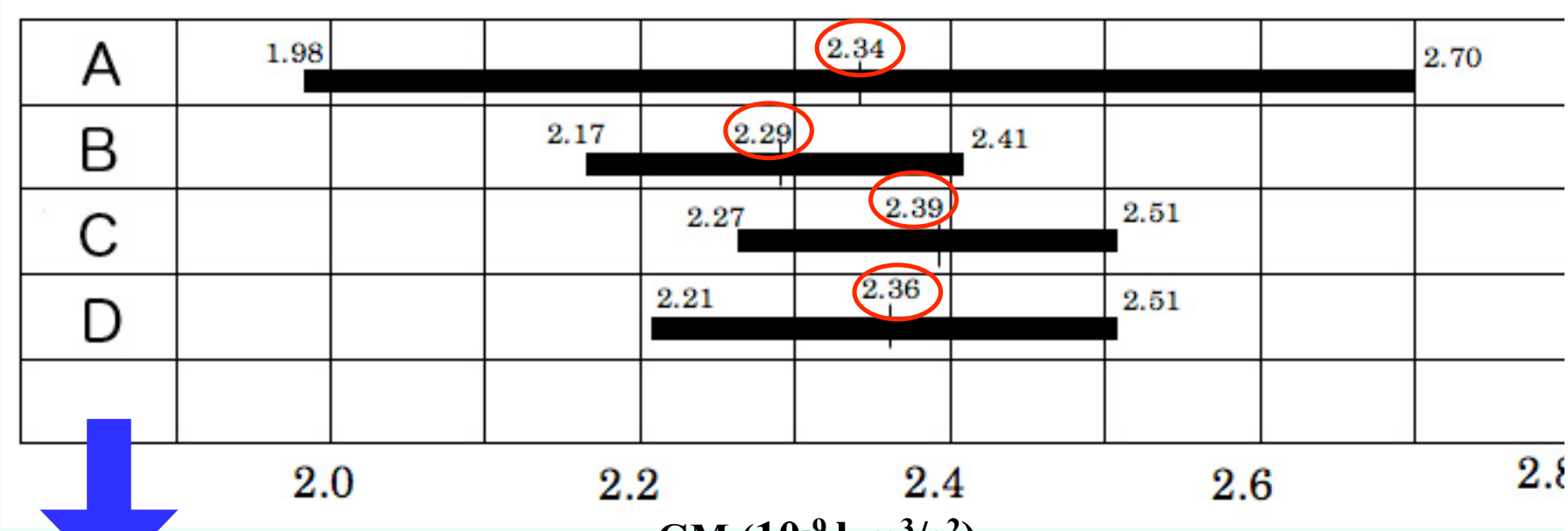
1st touch

Results of Mass Estimation

Groups	Period Data type	Distance from Itokawa	Model of Itokawa	**GM** **10^{-9} km^3/s^2**	Er
A	9/12～10/2 R&RR	20 - 7 km	point mass	**2.34**	15
B	10/21-22 R&RR, Opt., LIDAR	3 km	point mass	**2.29**	5
C	11/12 LIDAR, Opt.	1427 - 825 m	polyhedron	**2.39**	5
D	11/12 Opt., LIDAR	800 - 100 m	polyhedron	**2.36**	6
E	11/19 LRF	20 - 10 m	-	-	

Mass and Bulk Density of Itokawa

Estimated GM in each period (GM=Gravity Constant x Mass)



GM : (2.34± 0.07) x 10^{-9} km^3/s^2

Mass : (3.51 ± 0.105) x 10^{10} kg

Volume = (1.84 ± 0.092) x 10^7 m^3

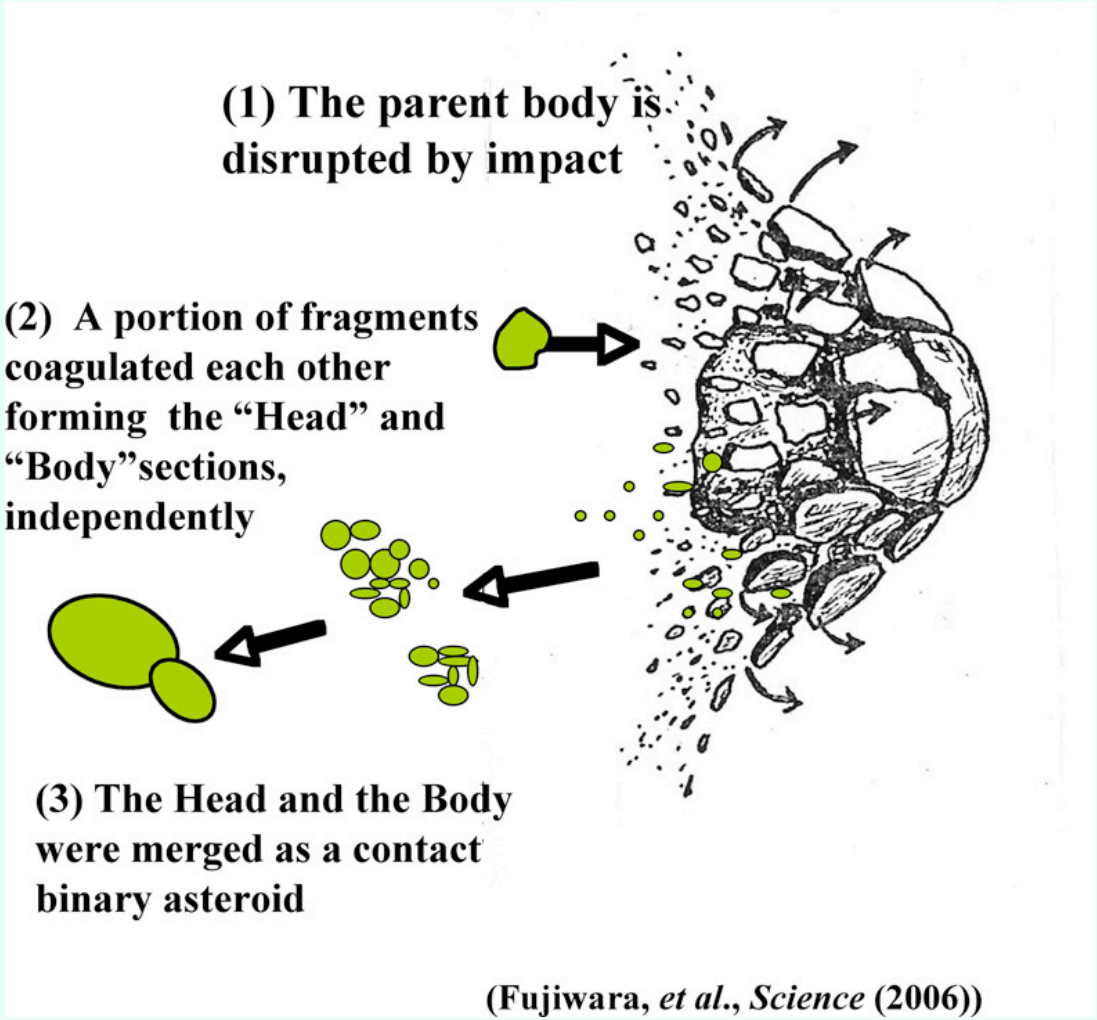
Bulk Density : 1.9 ± 0.13 g/cm^3

Ordinary chondrite

Density ~ 3.2 g/cm^3

Formation Scenario of Itokawa

"Rubble Pile" Hypoth



(Fujiwara, *et al.*, *Science* (2006))

- Extremely low bulk density fo S-type asteroid and high mac porosity of ~40 %
- Global shape is round rather blocky
- Surface is covered with many boulders
- No large structures extending the entire body (e.g., long line ridge found on Eros and Phob found
- Parts of some facets are expos on the surface (?)
- Slope is generally low (relaxed many areas)
- Large boulders cannot be forı during impacts to result the craters existing now on Itokav They must be associated with much larger impact events.

Short comment for orbital evolution of Itokawa

Orbital Evolution of Itokawa

Past

Inner edge of the asteroid belt

Secular resonance ν6, or Mars encounter

Present

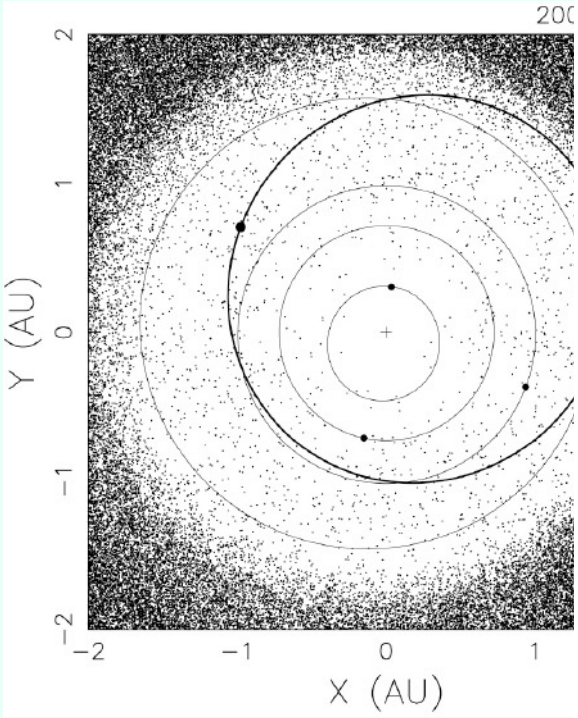
Apollo type orbit

Chaotic motion

Future

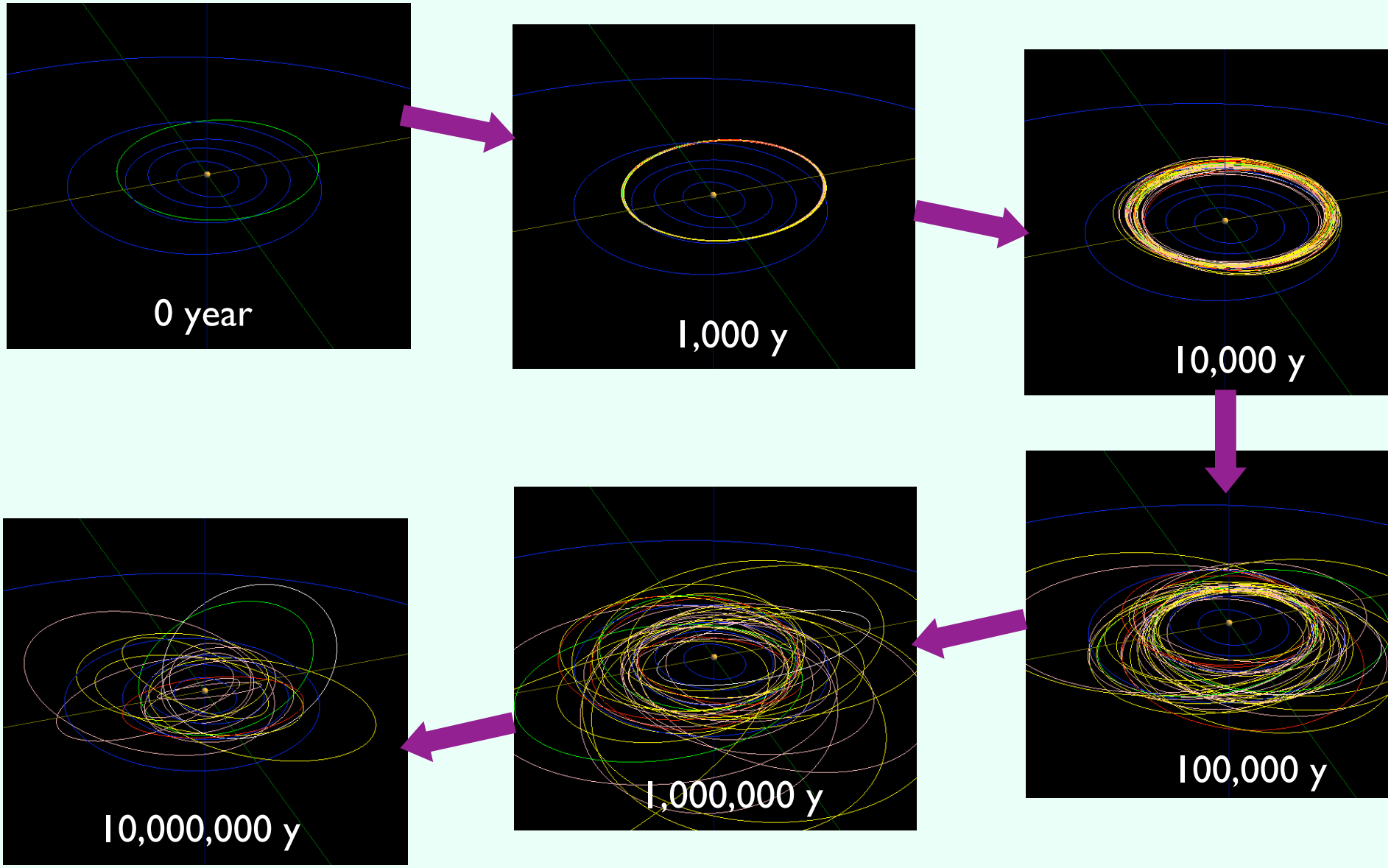
Collide with the sun or inner planets

Collision probability
the Earth is about on
one million years



by P. Michel and M. Yoshikawa

Chaotic Motion of Itokawa

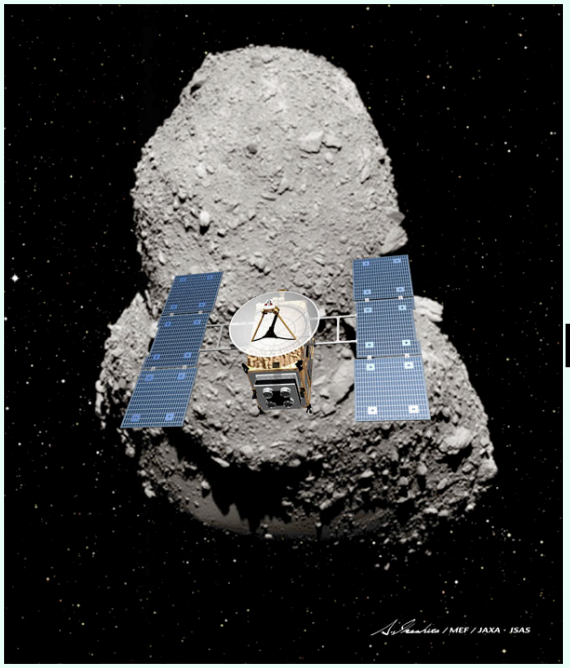


Summary

- Hayabusa revealed the nature of a small S-type NEO Itokawa.
- From the surface material and the bulk density, Itokawa is probably a rubble pile object.
- From the point of orbital evolution, Itokawa is considered to be typical NEO, and the estimated structure is important when we study about mitigation of such small objects.

Hayabusa-next

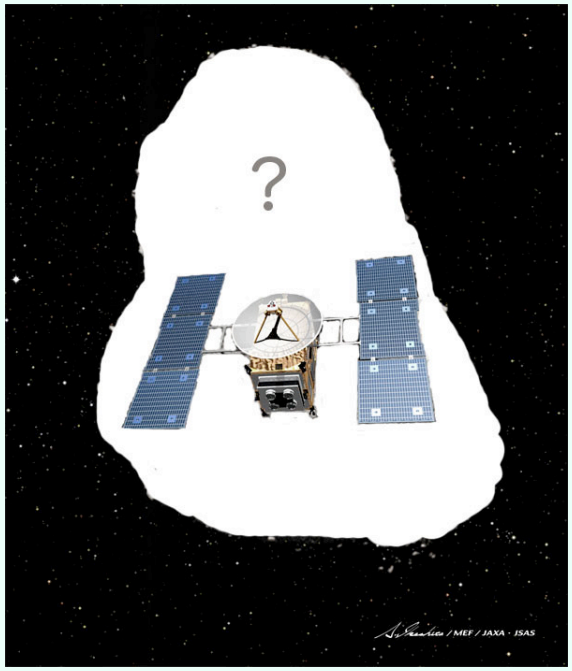
2003



Hayubusa

Itokawa = S-type

2010 ?

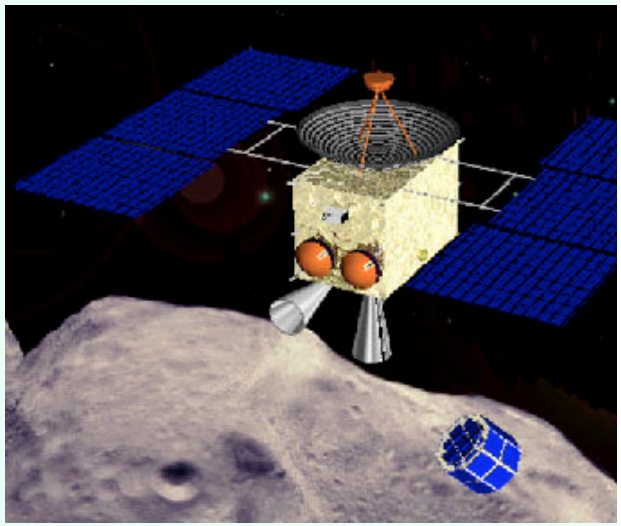


Hayubusa-2

C-type

(Copy of Hayabusa)

after 2015



Hayubusa-Mark2

(advanced mission)

Small World

Thank you