The axial ratios of boulders on asteroid 25143 Itokawa: Comparison with fragments from impact experiments.

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Shape of Fragments

Laboratory Impact Experiment

Size \sim \text{less than } 0.1 \text{ m}

\frac{b}{a} \sim 0.7
\frac{c}{a} \sim 0.5

\text{Axial Ratio (mean)}
\frac{a}{b} : \frac{b}{c} = 2 : \sqrt{2} : 1

(Fujiwara et al. 1978, Capaccioni et al. 1984, Bianchi et al. 1984)
Shape of small asteroid

Light curve observation
(Catullo et al. 1984, Binzel et al. 1989, Harris and Pravec 2007)

The shape of small asteroid with size of $10^2 - 10^4$ m

The shape of fragments in laboratory impact experiments
Boulders on asteroids

The number of boulder (>15m) is 6760. (Thomas et al. 2001)
The number of boulder (>5m) is 373. (Michikami et al. 2007)

Numerous boulders were discovered.

We can estimate the shape distribution of fragments with size of 0.1-100 m.
Purpose

In order to investigate whether the shape distribution of boulders is similar to that of the fragments in laboratory impact experiments, we report the shape distribution of boulders with size of $10^{-1}$ to $10^2$ m on the surface of Itokawa.

<table>
<thead>
<tr>
<th></th>
<th>Size [m]</th>
</tr>
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<tbody>
<tr>
<td>Fragments in laboratory</td>
<td>$10^{-4}$-$10^{-1}$</td>
</tr>
<tr>
<td>Boulders on asteroids</td>
<td>$10^{-1}$-$10^2$</td>
</tr>
<tr>
<td>Small asteroids</td>
<td>$10^2$-$10^4$</td>
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</table>
Analysis

(I) Global mapping of boulders with size of 5-30m
Eight images acquired from AMICA data, 19-26th, October 2005 (1 pixel ~ 0.4 m)
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Eight images acquired from AMICA data, 19-26th, October 2005
(1pixel ~ 0.4 m) Distance from Itokawa 3.78-4.91km
◆ Analysis

(I) Global mapping of boulders with size of 5-30m
Eight images acquired from AMICA data, 19-26th, October 2005 (1pixel ~ 0.4 m)

(II) Small boulders with size of 0.1-5m
Six close-up images acquired from AMICA data, 9-12th, November 2005 (1pixel ~ 0.6–6 cm)
(II) Small boulders with size of 0.1-5m
Six close-up acquired from AMICA data, 9-12th, November 2005 (1pixel ~ 0.6–6 cm) Distance from Itokawa 60-600 m
Positive relief feature is defined as boulder.

Analysis

(I) Global mapping of boulders with size of 5-30m
Eight images acquired from AMICA data, 19-26th, October 2005 (1pixel ~ 0.4 m)

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• Positive relief feature is defined as boulder.
• We have measured the apparent axes $a$ and $b$, which represent the maximum dimensions of the boulder in two orthogonal planes ($a \geq b$).
The shape distribution of boulders

Fragment (<0.1m) in laboratory

- Number of boulders
- $b/a \sim 0.72 \pm 0.12$

Boulder (5-30m)

- Number of boulders
- $b/a \sim 0.61 \pm 0.19$

It looks like the typical boulders of Itokawa have more elongated shapes as compared with that of fragments in laboratory.
The shape distribution of small boulders

Fragment (<0.1m) in laboratory

Number of boulders

$\frac{b}{a} \sim 0.72 \pm 0.12$

Boulder (0.1-5 m)

Number of boulders

$\frac{b}{a} \sim 0.68 \pm 0.17$
(III) The boulder of Eros

**Boulder (60-220 m)**
[Image ID 015313598] Rim of Saddle region

**Boulder (4-17 m)**
[Image IDs 0156087736, 015588661]

**Boulder (0.1-4 m)**
[Image IDs 0157417133, 0157417198, 0157417593] Four close-up Images

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1.5km

230m

230m

54m

33m

12m

6m
The shape distribution of boulders (Eros)

The apparent mean axial ratios of Eros’s boulders are similar to that of fragments in laboratory.
## Summary

The apparent mean axial ratios ($b/a$) of boulders are

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<th>Size Range</th>
<th>Axial ratio</th>
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<tr>
<td>Itokawa</td>
<td>(373)</td>
<td>5-30m</td>
<td>0.61 ($\pm$0.19)</td>
</tr>
<tr>
<td>Itokawa</td>
<td>(2033)</td>
<td>0.1-5m</td>
<td>0.68 ($\pm$0.16)</td>
</tr>
<tr>
<td>Eros</td>
<td>(20)</td>
<td>60-220m</td>
<td>0.73 ($\pm$0.17)</td>
</tr>
<tr>
<td>Eros</td>
<td>(41)</td>
<td>4-17m</td>
<td>0.72 ($\pm$0.14)</td>
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<tr>
<td>Eros</td>
<td>(163)</td>
<td>0.1-4m</td>
<td>0.73 ($\pm$0.15)</td>
</tr>
<tr>
<td>(Laboratory)</td>
<td></td>
<td>&lt; 0.1m</td>
<td>0.72 ($\pm$0.12)</td>
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It looks like the typical boulders of Itokawa have more elongated shapes as compared with that of fragments in laboratory.

→ Why ???
**Discussion**

One possibility is that, the actual shape distribution of the boulders on Itokawa is similar to that of the fragments in laboratory.

**Eros**

- Seismic activity (Richardson et al. 2005)
- Gravity >> friction angle

**Itokawa**

- Gravity ~ friction angle
- Granular process (Miyamoto et al. 2007)

- >5m (boulder strands at the surface)
- <1m
End
Some boulders keep the original position and stranded at the surface.
This large boulder is even taller than they are wide, which is a rather unstable orientation.
The difference of the axial ratio between small boulder (< 5m) and large boulder (> 5m) on Itokawa
The apparent mean axial ratio decreases with increasing the size of boulders in the range from 0.1 to 5 m.

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<th>Axial ratio $(b/a)$</th>
<th>Size</th>
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<tr>
<td>0.68 $(\pm0.16)$</td>
<td>0.6-5.4 m</td>
<td>(495)</td>
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<td>0.66 $(\pm0.16)$</td>
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<tr>
<td>0.60 $(\pm0.16)$</td>
<td>2.0-5.4 m</td>
<td>(53)</td>
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Axial ratio: decrease  Size: increase
The apparent mean axial ratio decreases with increasing the size of boulders in the range from 0.1 to 5 m.

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Small boulder (>5m)

~70%?

Large boulder (>5m)

~50%?
The influence of the emission angle
We counted the boulders which were observed on the emission angle less than 20 degree. The axial mean ratio of these boulders (the counted number is 76) is $0.62 \pm 0.18$, and this value is similar to that of the total boulders over the entire surface.
Shape distribution of small and fast-rotation asteroids
According to Holsapple 2007, these asteroids are monolithic bodies generated by impact cratering or catastrophic disruption of the parent asteroids.
Small and fast-rotation asteroids (diameter < 200m and rotation period < 1hr)

The shape distribution of small and fast-rotation asteroids is similar to that of fragments in laboratory.
The mean axial ratio of fragments, boulders and asteroids
<table>
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<td>Asteroids</td>
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</tr>
<tr>
<td>Large Asteroids</td>
<td>0.80 (±0.17)</td>
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- Monolith
- Rubble Pile
- More spherical
Other possibility
Other possibility

1) The actual shape distribution of the boulders on Itokawa differs from that of the fragments in laboratory.

2) The influence of the phase angle on the axial ratio
Three axis ratio
Three axis ratio

Asteroids by light curve observation

\[ b/a \sim 0.76 \ (\pm 0.13) \]
\[ c/a \sim 0.64 \ (\pm 0.16) \]

Fragments in laboratory

\[ b/a \sim 0.72 \ (\pm 0.12) \]
\[ c/a \sim 0.49 \ (\pm 0.16) \]
Axial Ratio of Asteroid and Taxonomic classification
Axial Ratio of Asteroid ( < 10 km) and Taxonomic classification

Taxonomic classification according to the method of Tholen (1984, 1989).