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# きぼう搭載微小粒子捕獲実験装置（MPAC）の観測結果について

## KIBO/MPAC EXPERIMENT SUMMARY

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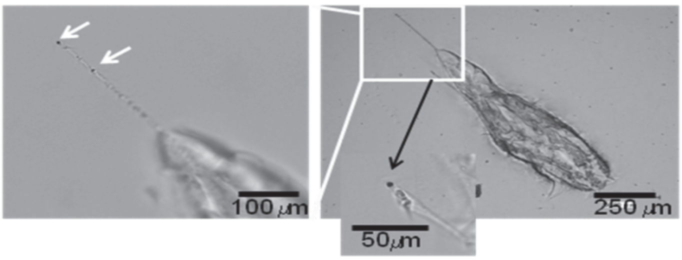
きぼう搭載微小粒子捕獲実験および材料曝露実験（JEM/MPAC&SEED 実験）装置は宇宙環境計測ミッション装置（SEDA-AP）の搭載装置の一部として、2009 年 7 月に STS-127（2J/A）に打ち上げられ、ISS に取り付けられた。JEM/MPAC&SEED 実験装置は宇宙空間に約 8.5 ヶ月曝露され、2010 年 4 月に地上へ回収された。この内 MPAC 実験はスペースデブリ、マイクロメテオロイド等の宇宙空間に存在する微小粒子を捕獲し、その起源や分布量を把握する実験である。捕獲実験サンプルにはシリカエアロジェルと金プレートが用いられた。本発表において、衝突孔の速度分布、方向分布及び入射フラックス等の得られた観測結果について報告する。

JEM/MPAC&SEED experiments are composed of a Micro-Particles Capturer (MPAC) and Space Environment Exposure Device (SEED), which are installed in the outboard platform of “KIBO” in the ISS. KIBO/MPAC is an experiment to capture space debris or micro-meteoroids, and clarify the origin and amount of distribution. Silica-aerogels and Au-plates of MPAC samples were exposed to space for about 8.5 months. We presents the distribution of impact velocity, kinetic energy, and flux in impact holes confirmed with these samples.




An example of a Impact hole and capture particles on aerogel

# KIBO/MPAC EXPERIMENT SUMMARY

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## Over View

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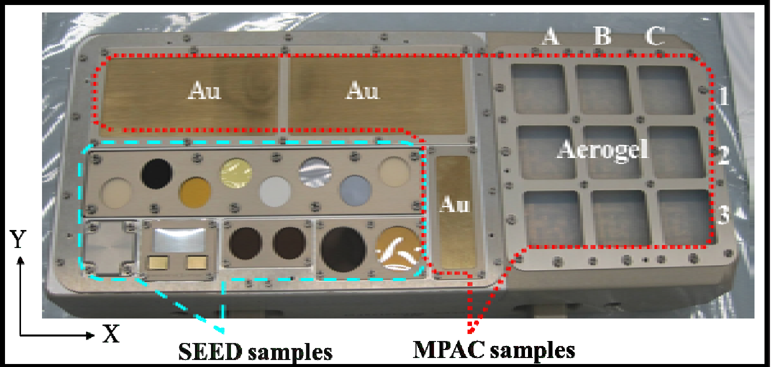
# 1. Introduction

JEM/ MPAC&SEED (Japanese Experiment Module/Micro-Particles Capturer and Space Environment Exposure Device)




MPAC is an experiment to capture space debris or micro-meteoroids, and clarify the origin and amount of distribution.

MPAC&SEED structure was installed in the outboard platform of "KIBO" in the ISS.

Exposure period : 8.5months (259days)

Aerogels : capture particles and estimate the impact parameters

Au-Plates : measure the number of impact holes and observe the shape.

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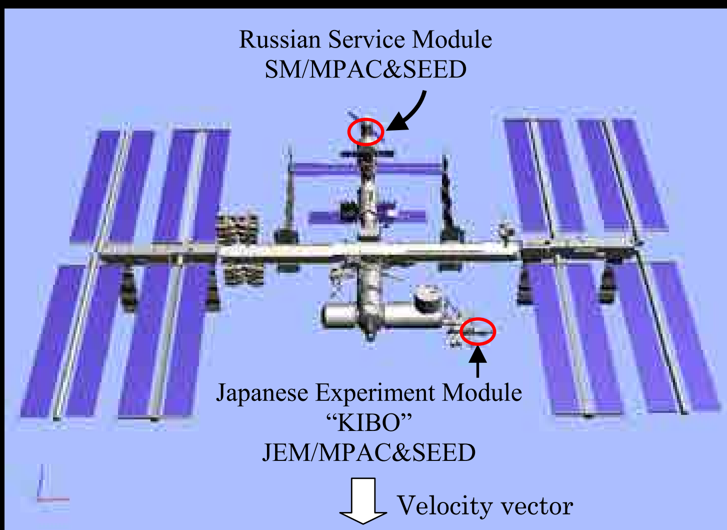
Comparison the result of JEM/MPAC and SM/MPAC

SM/MPAC was the first debris capture experiment installed in the Service Module (SM) of Russia.




JEM/MPAC was installed at the front of the ISS, and the exposure side was only RAM (front face) .

SM/MPAC was installed behind the ISS, and the exposure side was RAM and WAKE (rear face)

We compare the collisional behavior of the micro-particles by the difference in the install position to ISS.

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## 2. Observation Method

All the samples were observed by the CCD scope while searching for impact features with an overlapped view.

<1> The feature had a crater-like rim and/or central peak.

<2> The feature had radial cracks and/or ejecta.

<3> The feature had a shape similar to those induced by hypervelocity impact experiments.

- Class I atisfied all <1> ~ <3> criteria.
- Class II satisfied one or two criteria.

→ Impact (It is possible that space debris and micrometeoroids are the origins.)

- Class III doesn't fulfill criteria

→ Track (signs of some impact are visible, possibiliy of secondary debris.)

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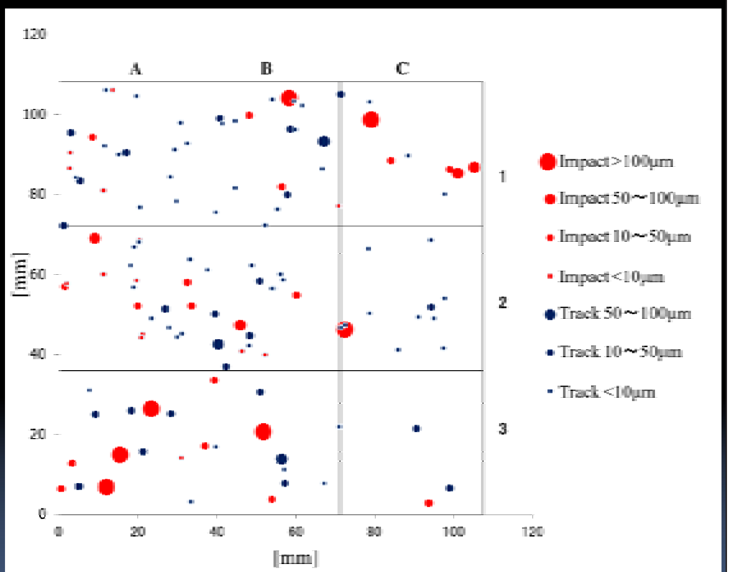
## 3. Observation by CCD Scope

- Hardly any degradation and discoloration was observed on the surface of aerogels.
- 41 impact holes were found on the aerogels, and 83 tracks.
- In Au-plates, 15 impact holes were found.
- The density of the impact hole was about 3500/m². This means particles of about 5000/m²/year collided with the ISS in one year.




Distribution of impact holes and tracks on aerogels

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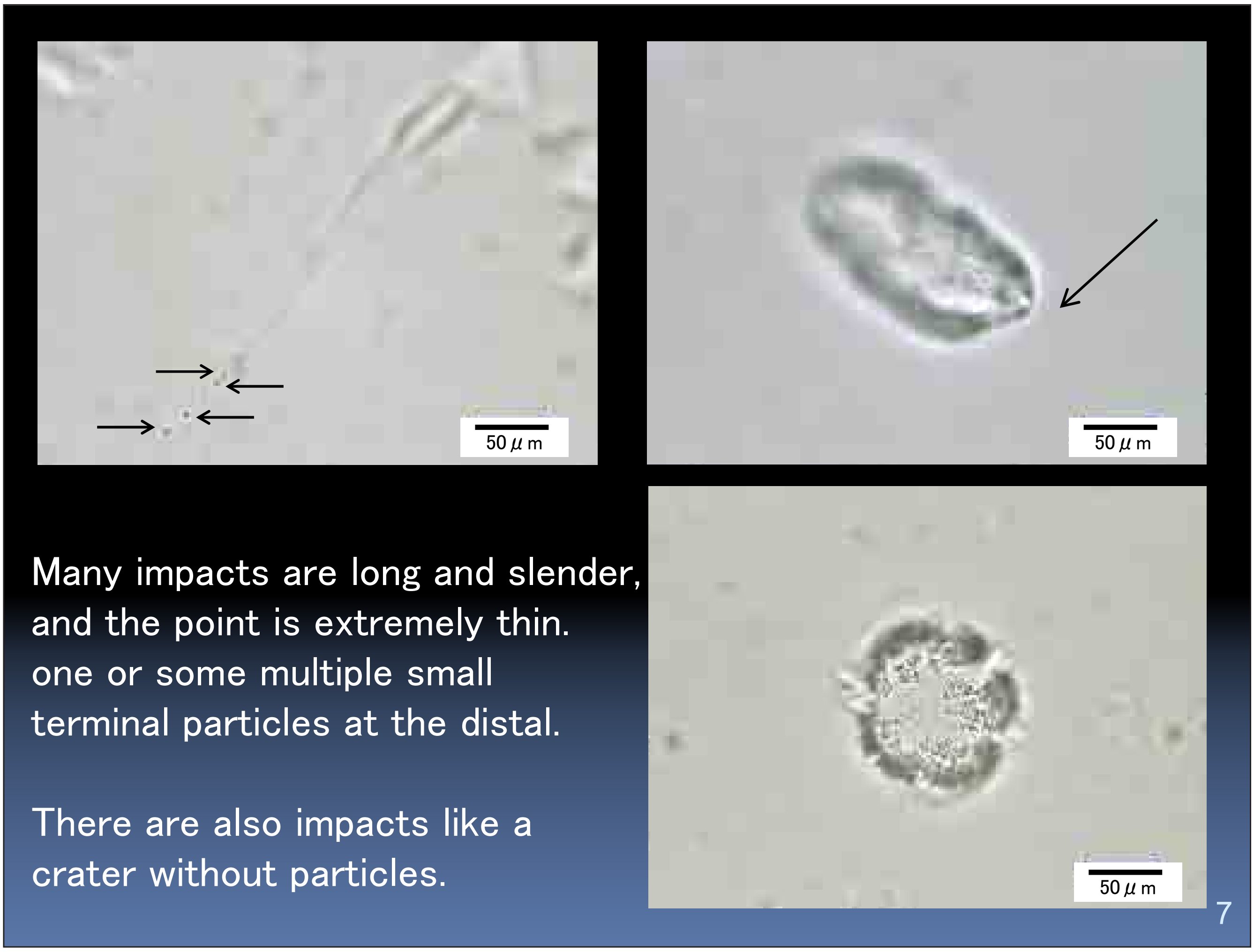
50 μ m
50 μ m
Many impacts are long and slender,
and the point is extremely thin.
one or some multiple small
terminal particles at the distal.
There are also impacts like a
crater without particles.
50 μ m
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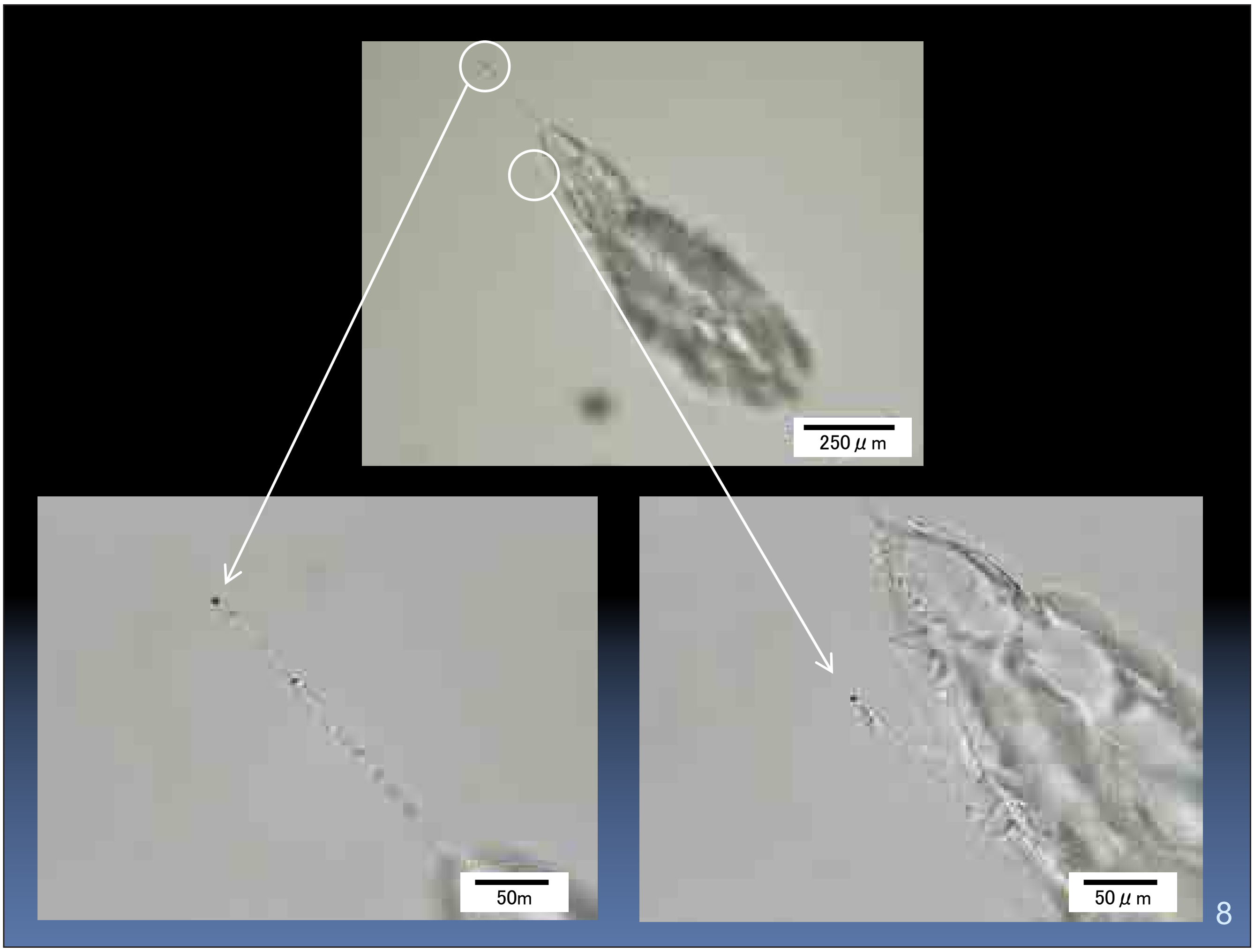
250 μ m
50m
50 μ m
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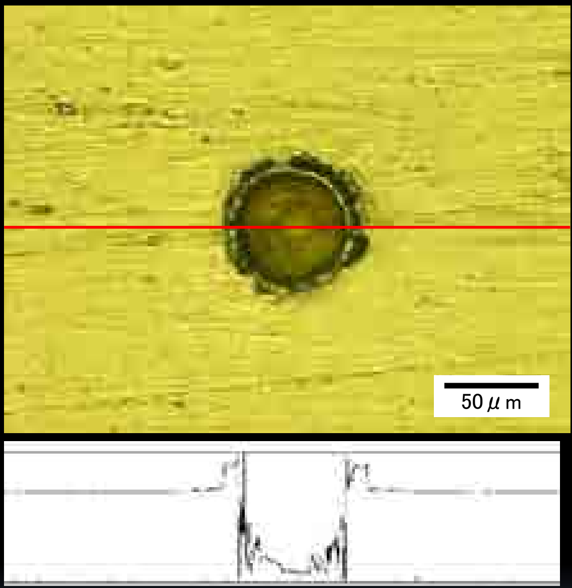
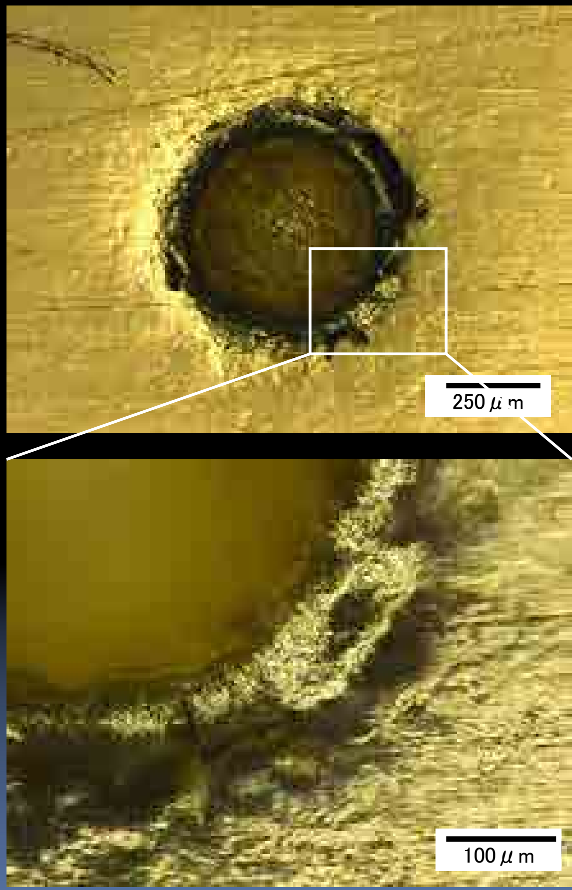



Super-depth synthesis chart

Impacts on Au-plates were of the crater type. The rims were turned over and swelled out.

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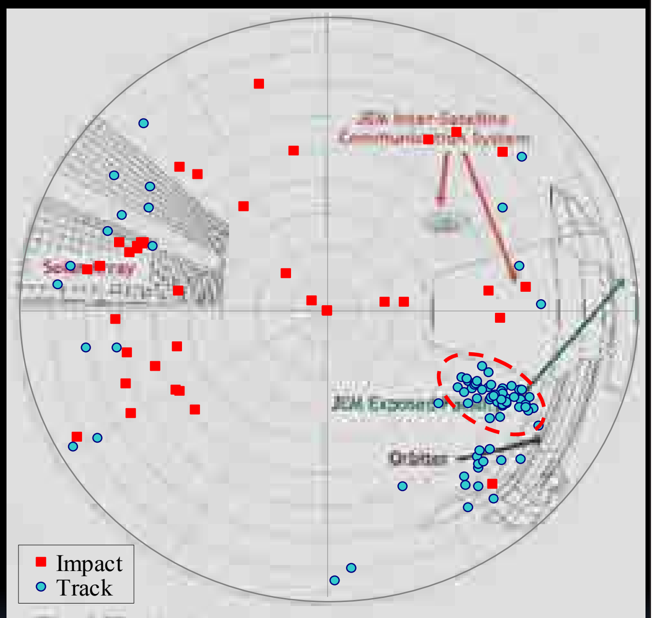
## 4. Distribution of Azimuth & Elevation

Many tracks were concentrated ($\alpha$: 20～60, $\varepsilon$: 20～40)

➡ These were similar shapes, and may have been formed at the same time.

Their origins are JEM Inter-Satellite Communication System or the Orbiter ?




Hemispherical view from JEM/MPAC&SEED

- Orbiter thrusters may fire during docking/undocking operations

➡ Secondary debris occurred at this time.

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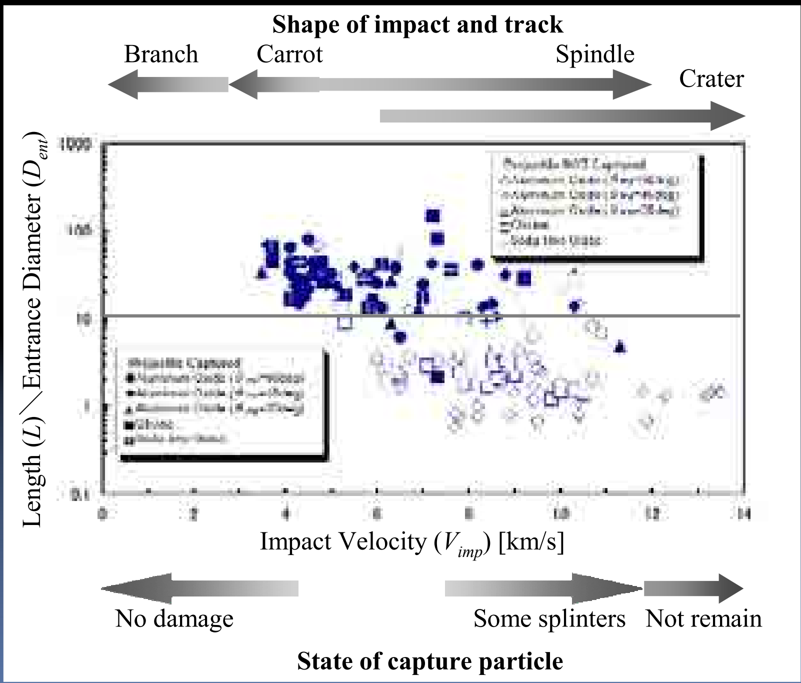
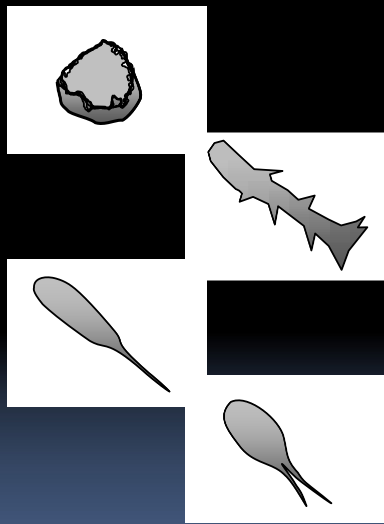
# 5. Presumption of Impact velocity

**The Ground Hypervelocity Impact Experiment** (Prof. of International Symposium on SM/MPAC&SEED Experiment, Kitazawa.et.al) : The experiment which made various size and material micro-particles collide aerogels.



Relation of the aspect ratio of the impact hole ($L/D_{ent}$) with impact velocity ($V_{imp}$)

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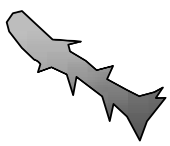
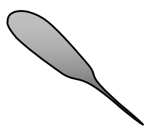
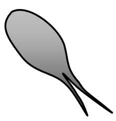
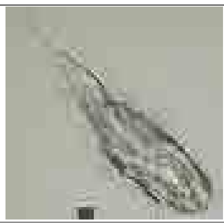
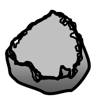
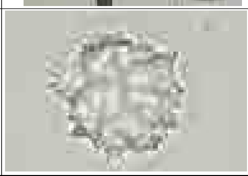
Comparison of the result of the ground experiment and JEM/MPAC experiment.

| | Shape | $V_{imp}$ | JEM Observation Example |
|---|---|---|---|
| Branch |  | ＜3km/s |  |
| Carrot |  | 3～5km/s |  |
| Spindle |  | 5～12km/s |  |
| Crater |  | 6km/s＜ |  |

Many of impacts on JEM/MPAC aerogels are Crater type.

Impact velocity ($V_{imp}$) is more 6km/s. At impact without particles, more than 12km/s.

Many of tracks are $L/D_{ent}$ =10～30, and Carrot or Branch type.

Impact velocity ($V_{imp}$) is 3～5km/s.

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# 6. Flux

## 6.1. ClassI

- The exposure period of JEM/MPAC experiment is shorter, and its area is also smaller than SM/MPAC experiment.
- Although, flux (ClassI) of JEM/MPAC is larger than SM/MPAC.

Comparison of JEM/MPAC with SM/MPAC

| | JEM | SM |
|---|---|---|
| Exposure Period [day] | 259 | 315 |
| Area (RAM) [$m^2$] | $1.12\times10^{-2}$ | $3.35\times10^{-2}$ |
| Count [number] | 13 | 2 |
| Flux [number/$m^2$/year] | 1500 | 350 |

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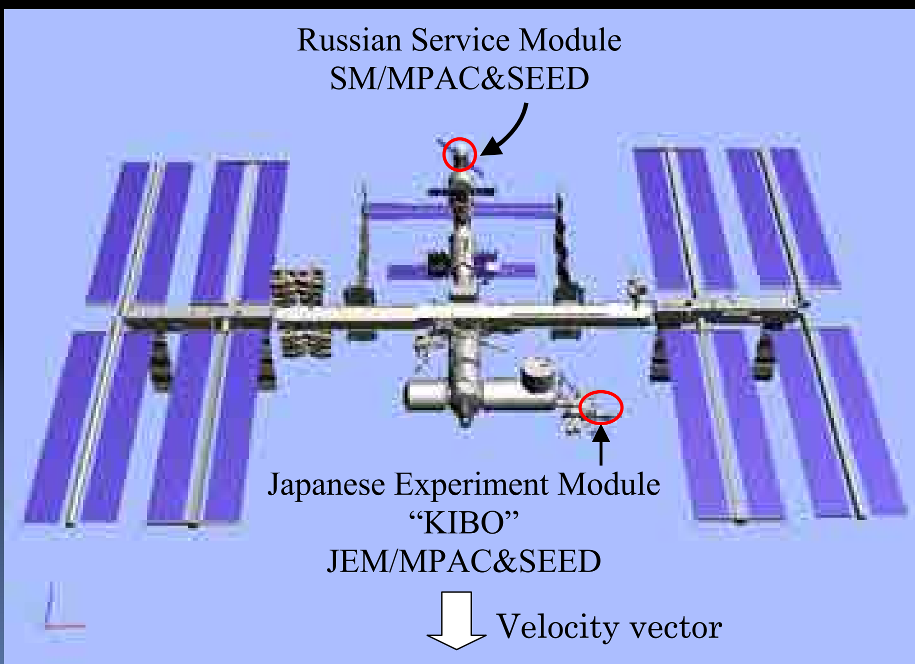
- This is a caused by the install position. With JEM/MPAC samples, since there is nothing that is interrupted at the front, it is thought that more particles collided for a short period of time compared with SM/MPAC samples.

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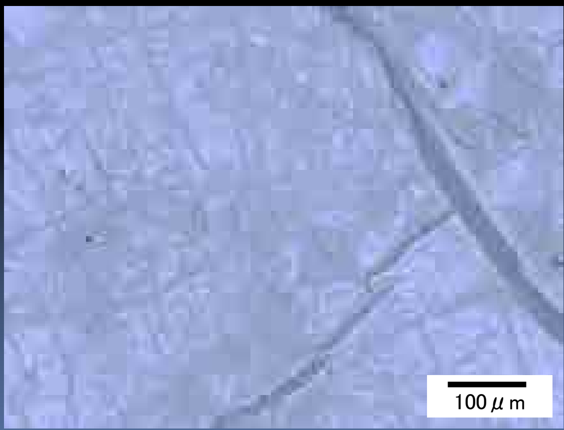
- As for SM/MPAC aerogels, surface discoloration and crack were seen as the exposure period became long.
  → Discernment of class I impacts became difficult.
- As for JEM/MPAC aerogels, discoloration and crack are not almost.
  → Class I impacts remained without being erased.




SM/MPAC Aerogel


JEM/MPAC Aerogel

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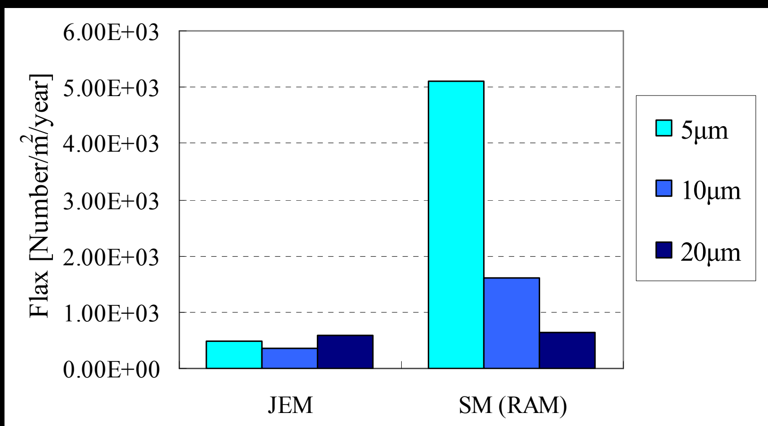
# 6. Flux

## 6.2. ClassI～III




Flux (classI～classIII)

- Contrary to the case of only the class I, all the flux containing class I ～ III of JEM/MPAC is less than SM/MPAC。

JEM/MPAC：Many of collision things are substance of space origin

SM/MPAC： substance of space origin＋secondary debris of ISS

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# 7. Summary

- Micro-particles that existed in space were captured, and their signs observed.
- There is a concentration region in angle distribution of tracks.

➡ Influence by docking of an orbiter

- Impact Velocity（$V_{imp}$） Impacts : 6～12km/s　Tracks : 3～5km/s
- Flux （class I）　　JEM＞SM
- Flux （class I～III）　SM＞JEM

➡ The difference in a install position is the cause

JEM/MPAC samples : substance of space origin

SM/MPAC samples : secondary debris of ISS

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# 8. Future Prospects

- We are conducting Raman spectroscopy analysis of captured particles in JEM/MPAC aerigels.


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- A future subject is establishing the method of analysis of buried particles (several microns in size) in aerogels.
- Micro particles forming micro-meteoroids were found in the SM aerogel . (pyroxene)
- There is also the potential for micro-meteoroids to be captured in the JEM aerogel. The result of future analysis is expected.