Introduction to Ryugu Reference Project

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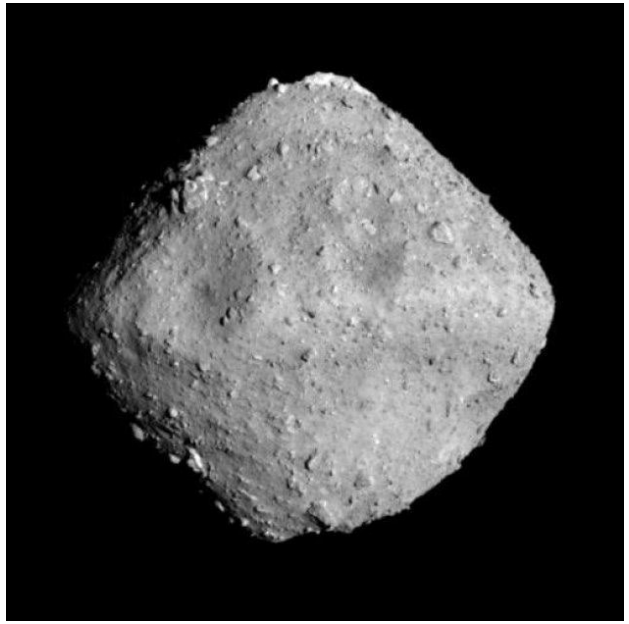
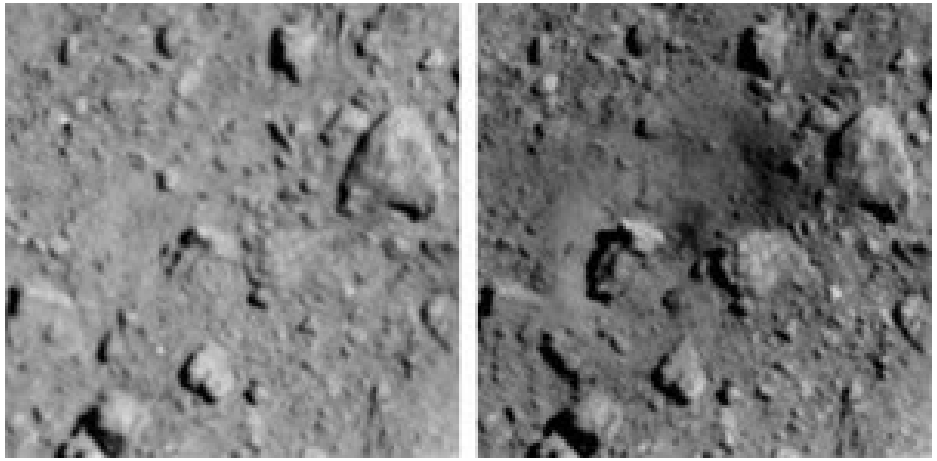
Hayabusa2 project

- Asteroid sample-return mission by JAXA
- Target: Ryugu (C-type asteroid rich in water and organic matter)
- Launched on Dec 3rd 2014, reached Ryugu on June 27th 2018
- **Sample collection #1: Surface materials** (**Chamber A: ~3 g**)
- **Sample collection #2: Sub-surface materials** (**Chamber C: ~2 g**)
- Left Ryugu in Nov 2019, returned to Earth on Dec 6th 2020



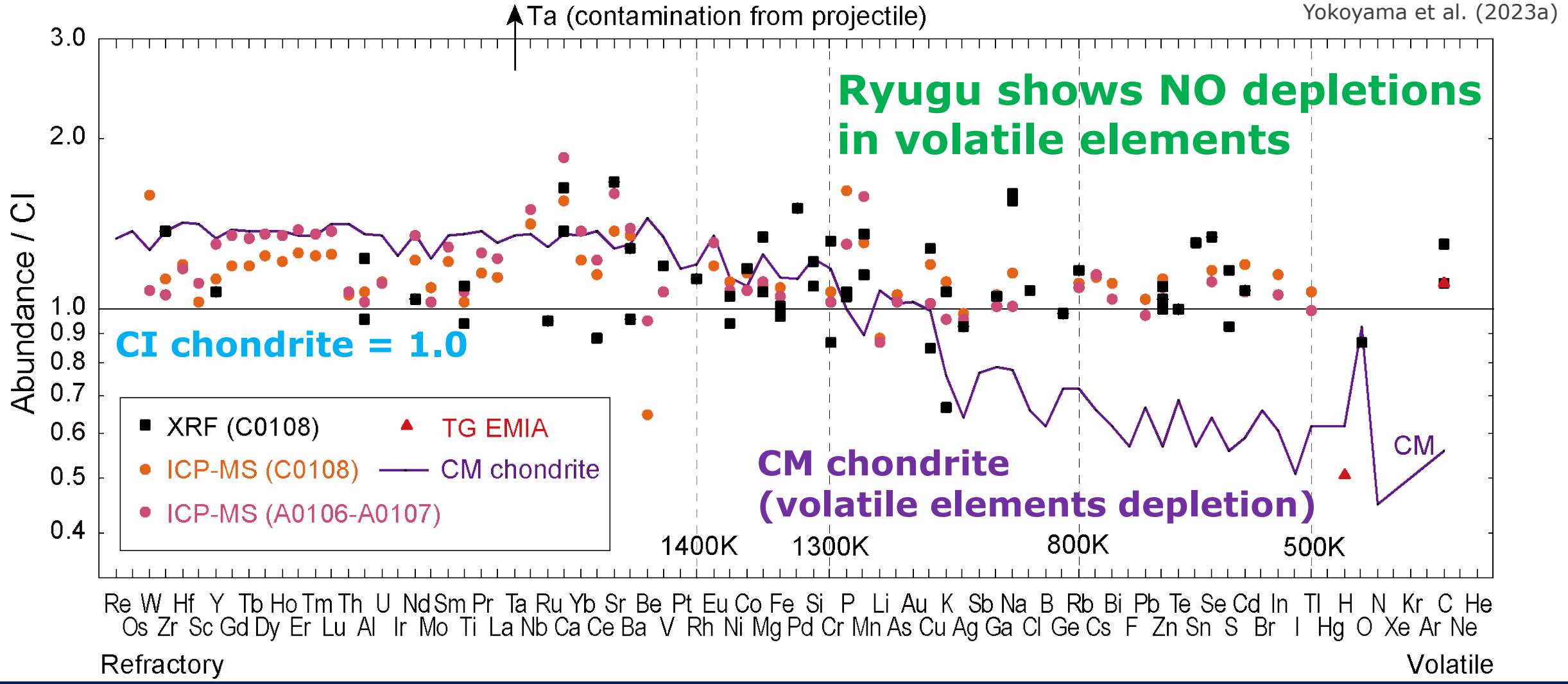
Ryugu



Hayabusa2 blasted craters on Ryugu

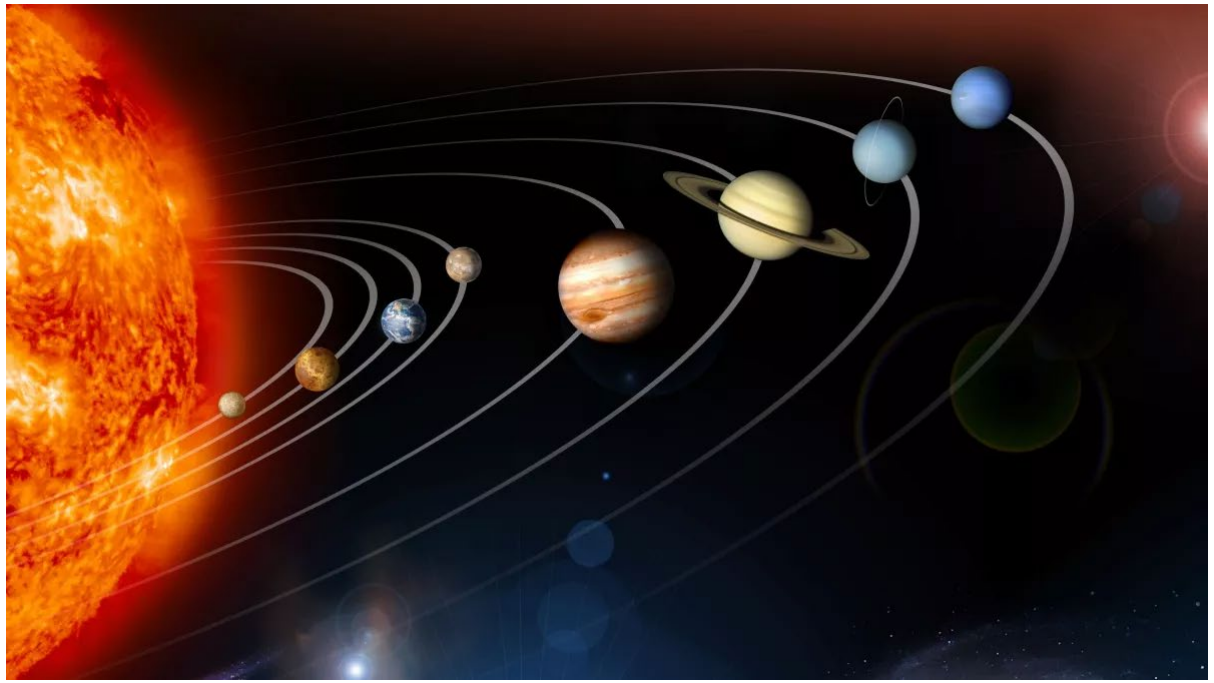
Hayabusa2 2nd touchdown on Ryugu

Elemental abundances of Ryugu



The pristine nature of Ryugu makes the returned samples ideal for constraining the composition of the Solar System.

Chemical composition of the solar system



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- Useful information about the initial conditions of the solar nebula and subsequent formation of Solar system objects.
- The elemental abundances of the Sun have been used to represent the chemical composition of the Solar System, since more than 99% of the mass of the Solar System is locked up in the Sun.

Solar System composition: Meteoritics

- **CI chondrite** (Ivuna-type chondrite) has elemental abundances that mostly match those of solar photosphere.
- Direct measurements in laboratories enable precise determination of chemical and isotopic compositions.
- There are ~70,000 meteorites on the Earth, but **ONLY 5** are recognized as witnessed-fall CI chondrites.

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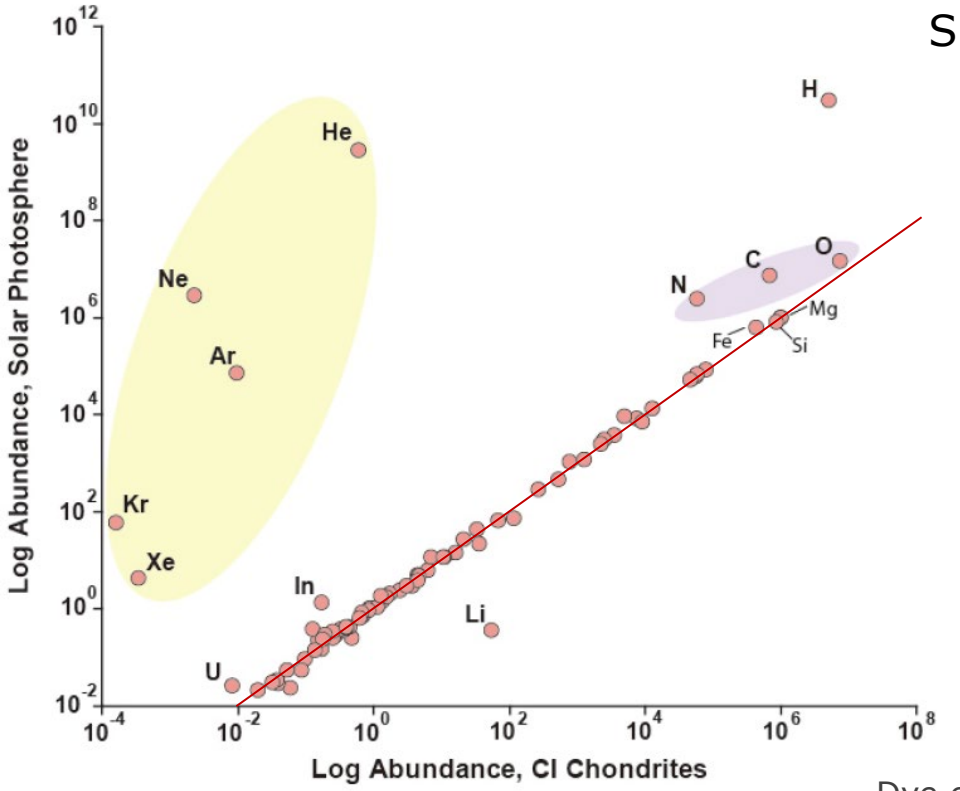
Wikipedia

Si = 10^6



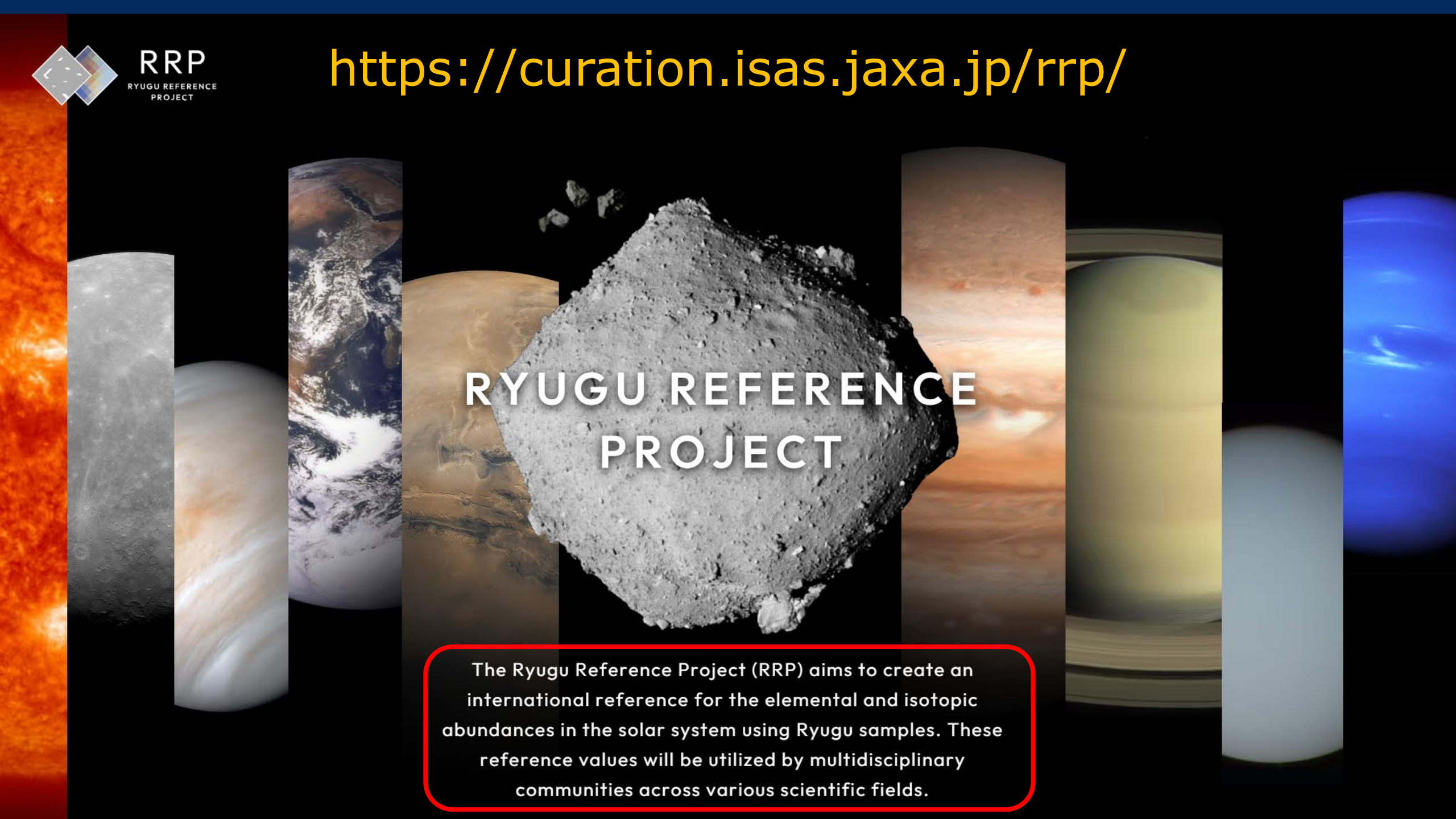
Dye et al (2014)

Problems

- Volatiles are depleted in CIs
- Li is enriched in CIs
- Terrestrial weathering

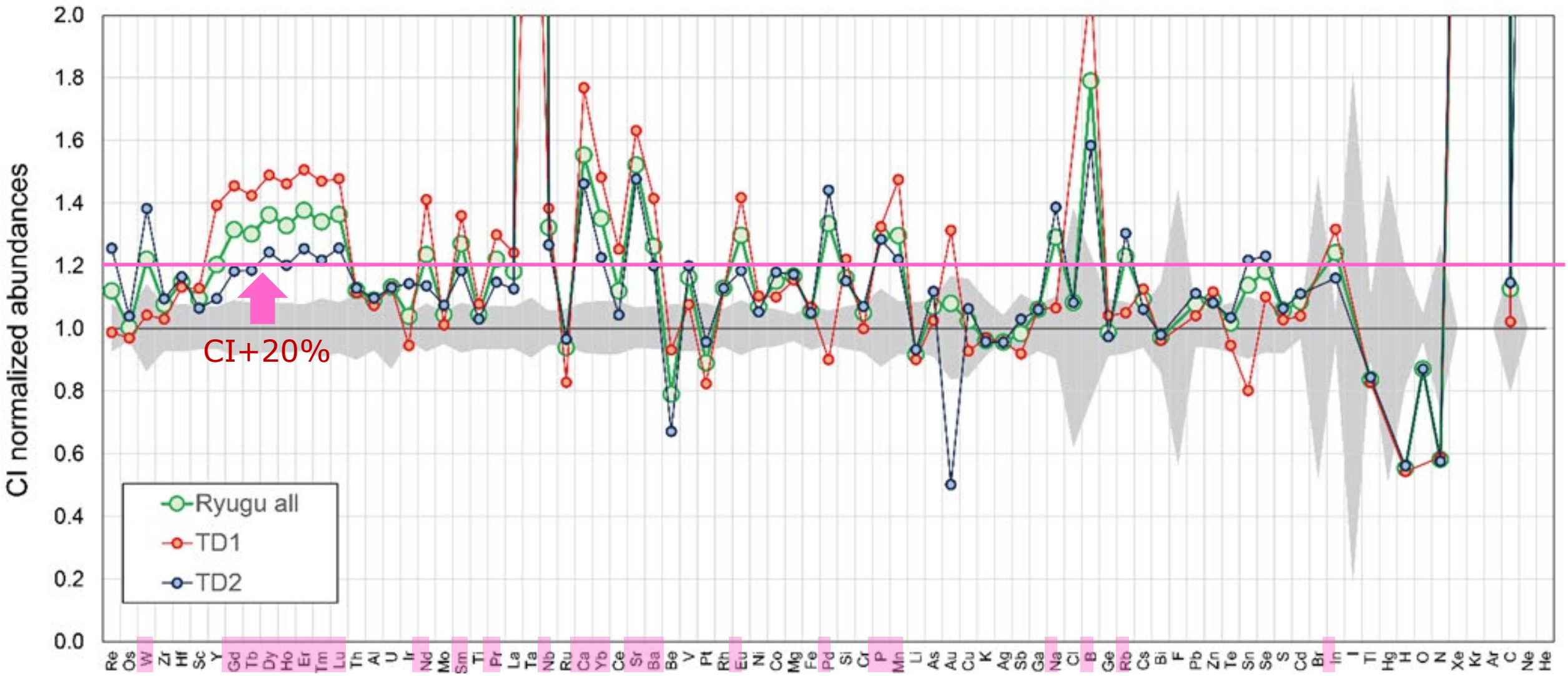
RRP
RYUGU REFERENCE PROJECT

https://curation.isas.jaxa.jp/rrp/



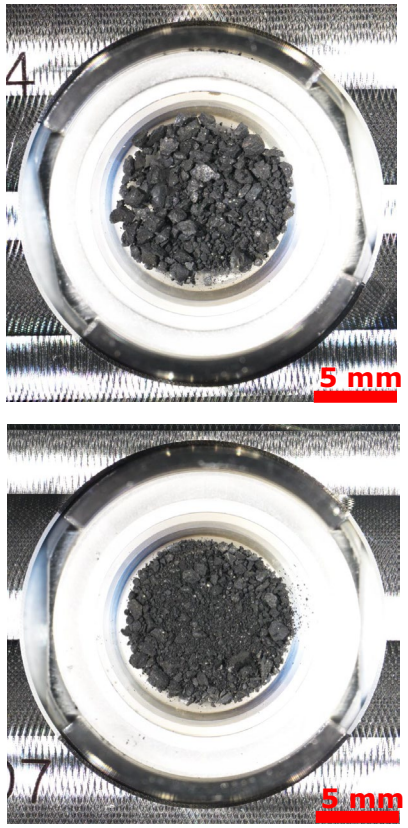
The Ryugu Reference Project (RRP) aims to create an international reference for the elemental and isotopic abundances in the solar system using Ryugu samples. These reference values will be utilized by multidisciplinary communities across various scientific fields.

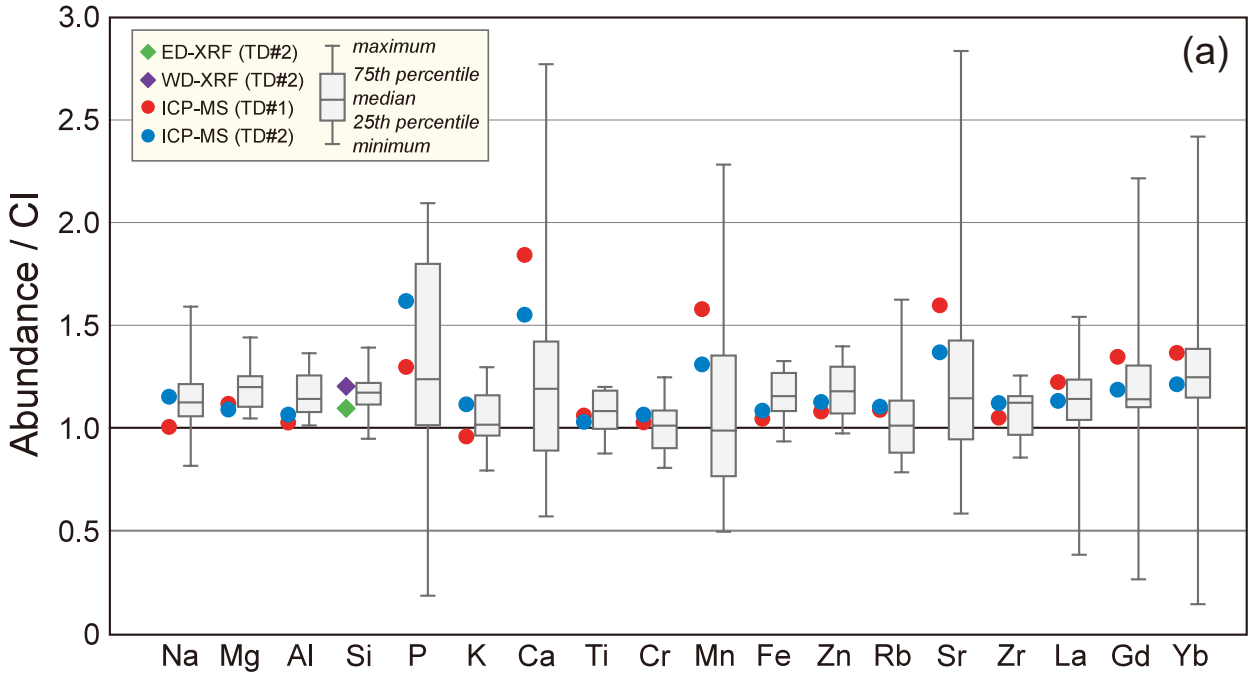
Inconsistency between Ryugu and CIs



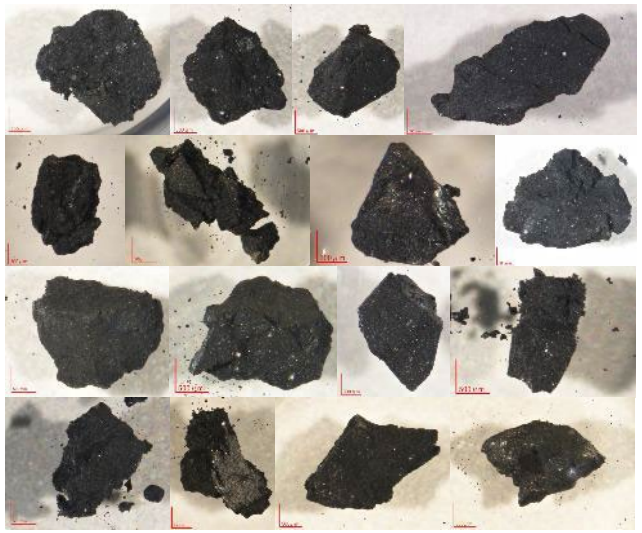
Chemical heterogeneity in Ryugu samples

Aggregate samples
(~25 mg)





Small particles
(0.2–3 mg)

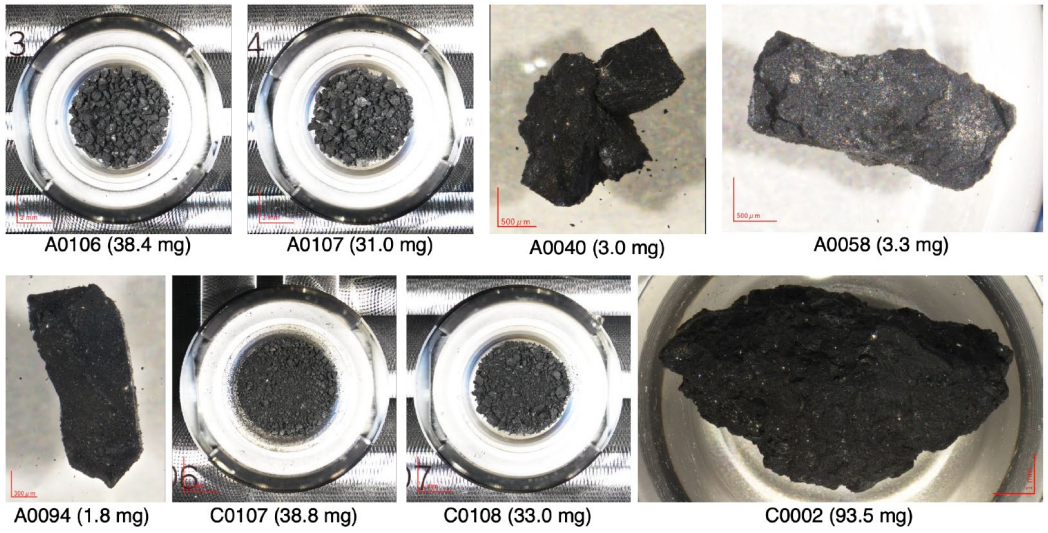


Data source:
Yokoyama et al. (2023)
Nakamura E. et al. (2022)
Ito et al. (2022)

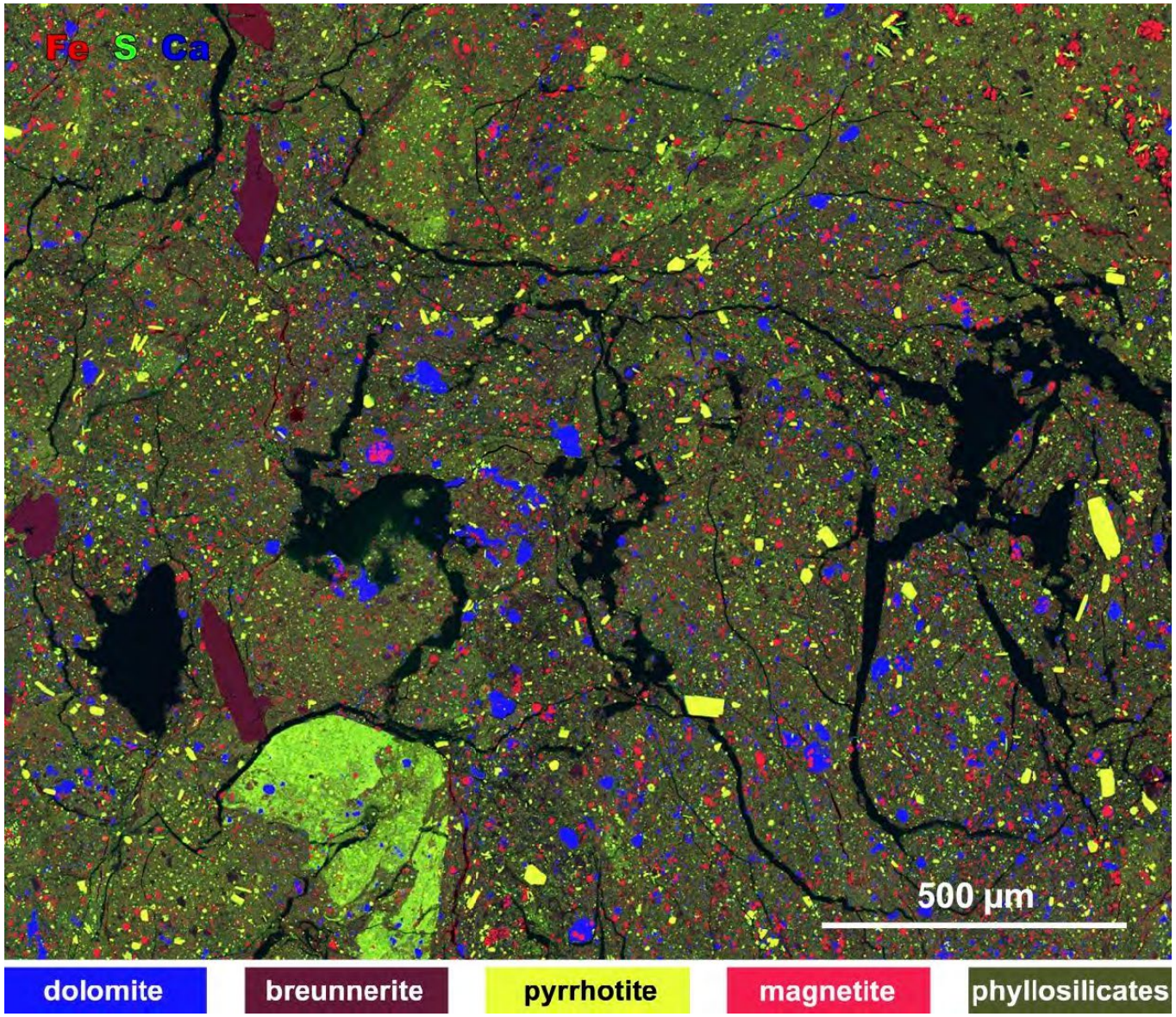
Small Ryugu particles are heterogeneous for some elements (nugget effect)

Ryugu mineralogy

- Ryugu samples consist of various minerals that formed during aqueous alteration in the parent body.



Yokoyama et al. (2023a)



$CaMg(CO_3)_2$ $(Mg,Fe)CO_3$ $Fe_{1-x}S$ $Fe^{3+}(Fe^{2+}Fe^{3+})_2O_4$ serpentine saponite

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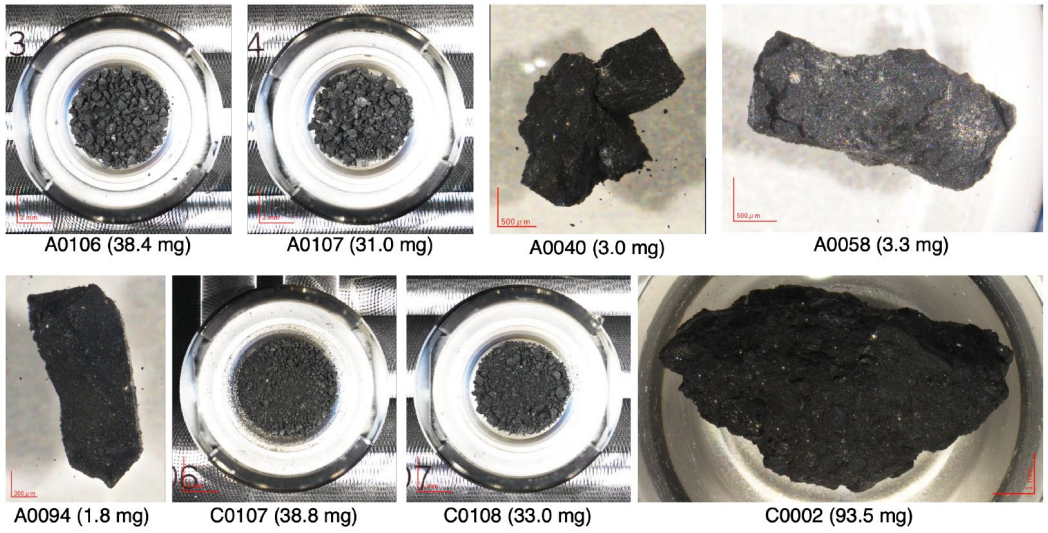

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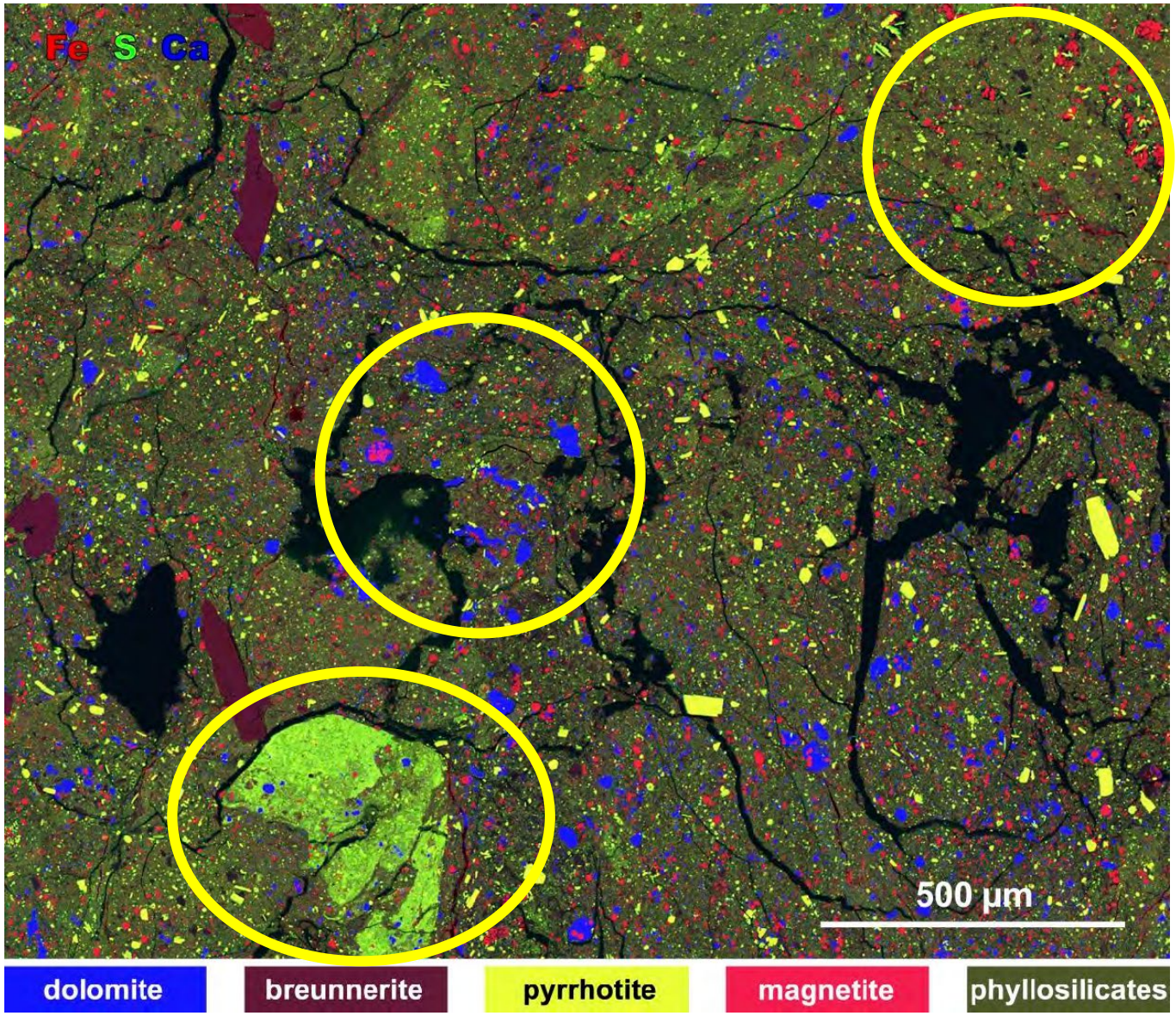


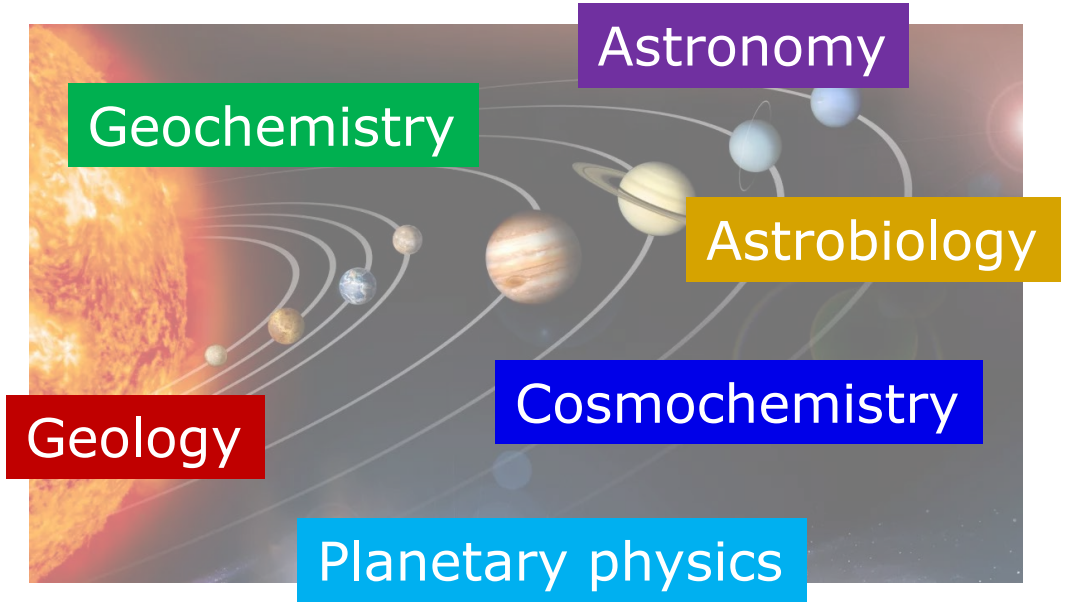
$CaMg(CO_3)_2$	$(Mg,Fe)CO_3$	$Fe_{1-x}S$	$Fe^{3+}(Fe^{2+}Fe^{3+})_2O_4$	serpentine saponite

Potential goals and expected activities of RRP

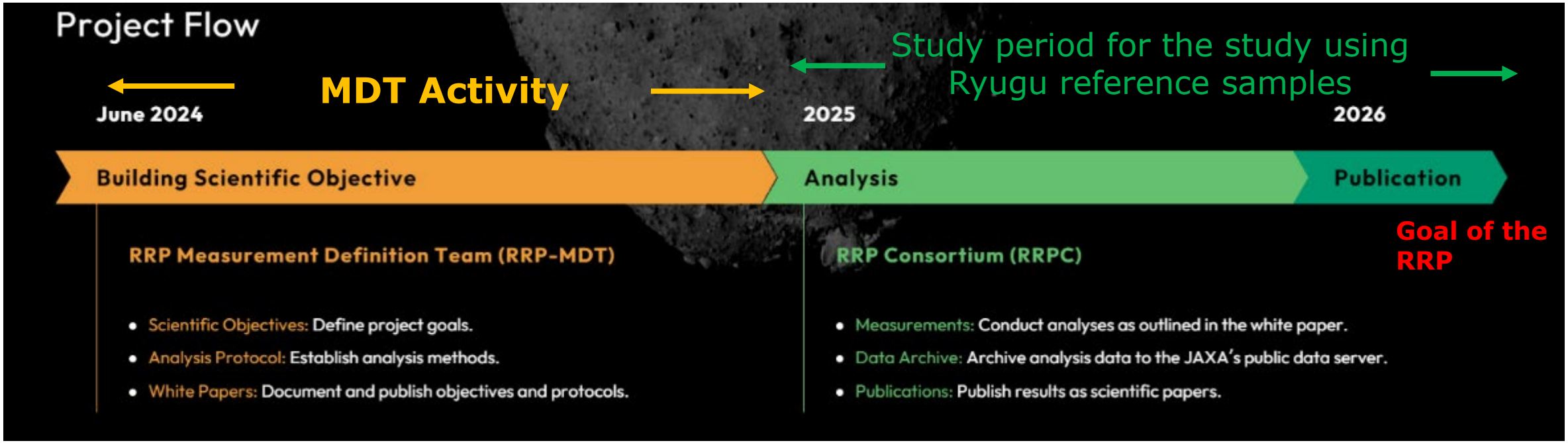
Provide new insights into the chemical composition of the Solar System via comprehensive analyses of relatively large amounts of Ryugu, CI chondrites, and possibly other primitive chondrites (e.g., Tagish Lake, Tarda).

The consistency must be evaluated between Ryugu, CIs, and Bennu, as well as the elemental abundances of the solar photosphere determined by improved spectroscopic measurements coupled with sophisticated atmospheric models.

The updated chemical composition of Solar System will be used by multidisciplinary communities in various scientific fields.



RRP activity flow



Ryugu **R**eference **P**roject **M**easurement **D**efinition **T**eam (**RRP-MDT**)

Ryugu **R**eference **P**roject **C**onsortium (**RRPC**)

RRP-MDT members

[Chemistry (bulk)]

- Tetsuya Yokoyama (Tokyo Institute of Technology)
- Nicolas Dauphas (The University of Chicago)
- Thorsten Kleine (Max Planck Institute for Solar System Research)
- Kun Wang (Washington University in St. Louis)
- Maria Schönbächler (ETH Zürich)
- Frederic Moynier (Université Paris Cité/IPGP)

[Mineralogy/Petrology]

- Ashley King (Natural History Museum, London)

[Program executives]

- Tomohiro Usui (ISAS/JAXA)
- Shogo Tachibana (U Tokyo, ISAS/JAXA)

[Organic chemistry]

- Daniel Glavin (NASA)
- Hikaru Yabuta (Hiroshima University)
- Yoshinori Takano (JAMSTEC)

[Gas/Volatiles]

- Guillaume Avice (Institut de Physique du globe de Paris (IPGP))
- Henner Busemann (ETH Zürich)

[Theory/Modeling]

- Katharia Lodders (Washington University in St. Louis)

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Chair

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Professor, Manager of Astromaterials Science Research Group

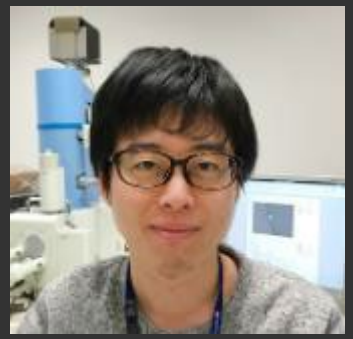
ISAS/JAXA

TACHIBANA Shogo

Specially Appointed Professor, ASRG / Professor, Utokyo

ISAS/JAXA

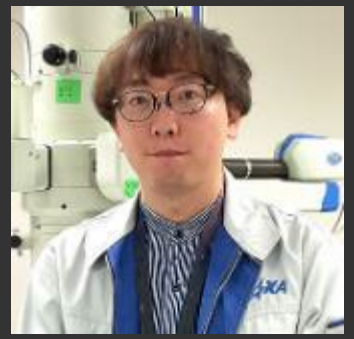
[Ex-officio members]



FUKAI Ryota

Specially-appointed Assistant Professor

ISAS/JAXA



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NAKANO Arisa
HATAKEDA Kentaro
TAHARA Rui

Summary

RRP-MDT's Roles and Responsibilities

1) Define the scientific goals and objectives of the Ryugu Reference Project (e.g., list of elements, isotopes, and chemical species in the Ryugu Reference; accuracy and precision required for the Ryugu Reference).
2) Recommend the analytical protocols that meet the project requirements (e.g., amount of Ryugu sample, uncontaminated powdering process, instrumentation, number of analysis runs).
3) File an MDT report with JAXA to publish as a community white paper.