Toward Multiview-Multispectral Sensing from the Martian Moons eXploration Spacecraft:

Imaging Ryugu with the Laboratory OROCHI Simulator

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and the TENGOO & OROCHI Camera Team

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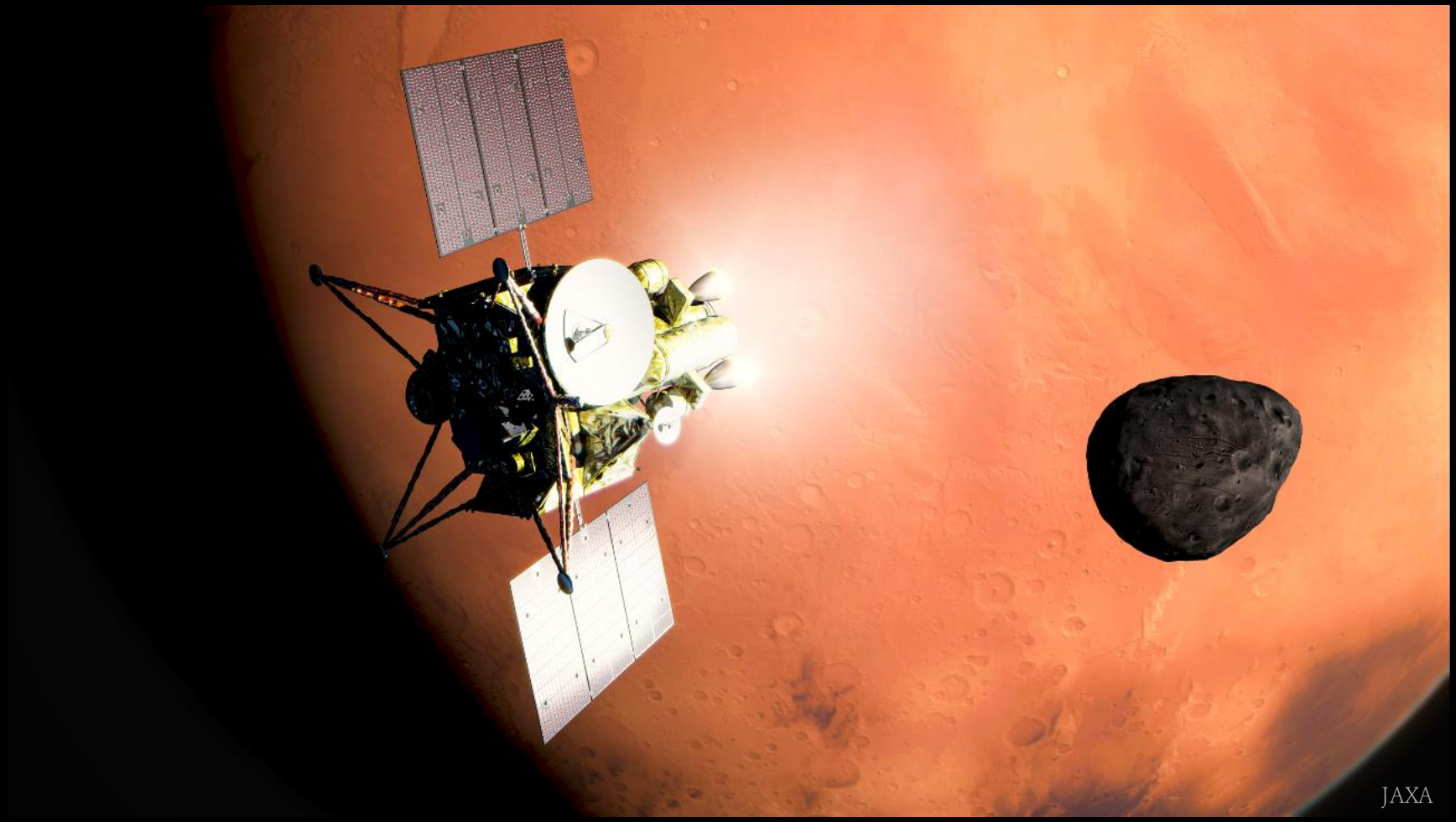
2. Institute of Space and Astronautical Science, JAXA, Japan

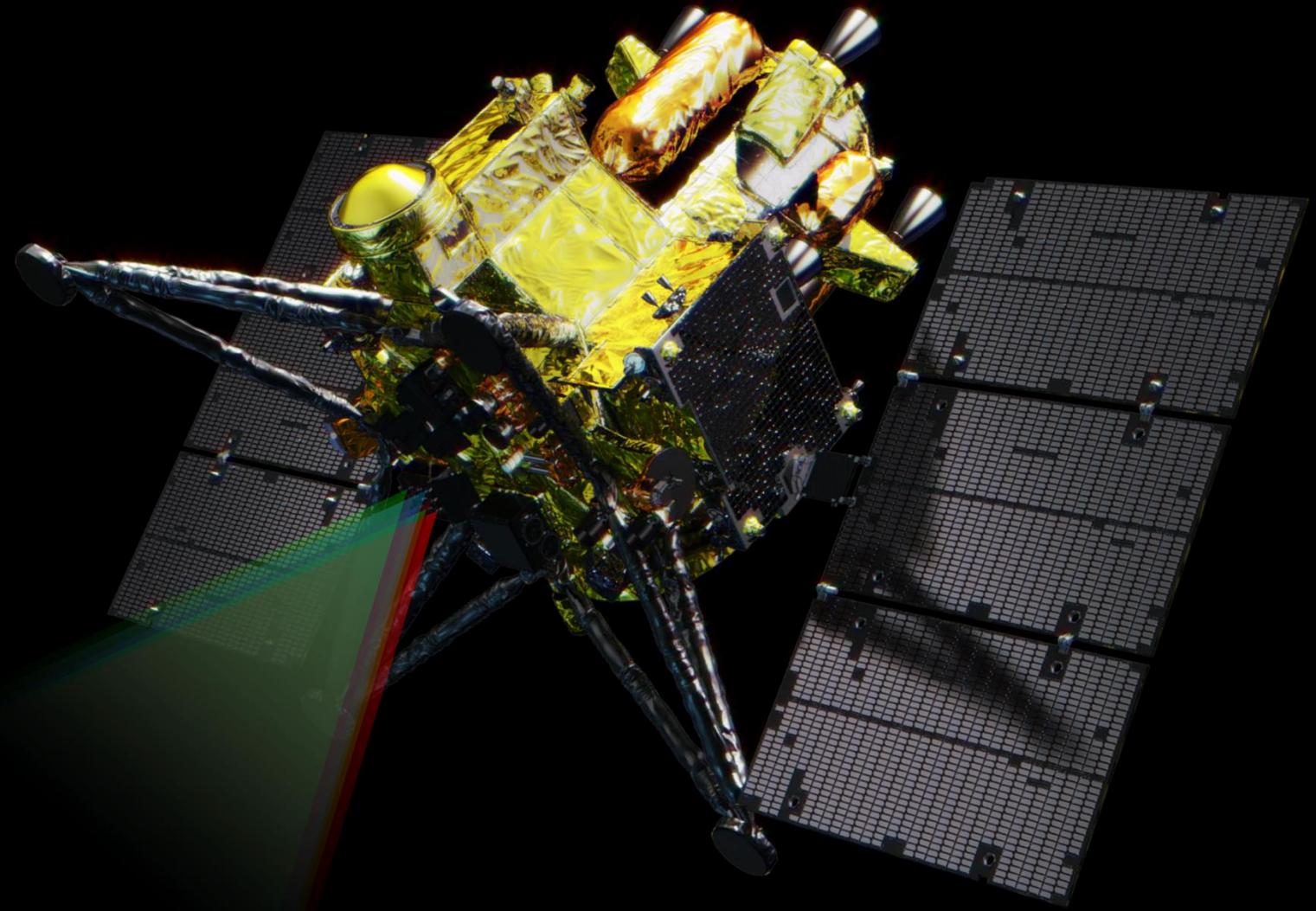
* Now at Natural History Museum, UK

MMX & OROCHI



JAXA

JAXA



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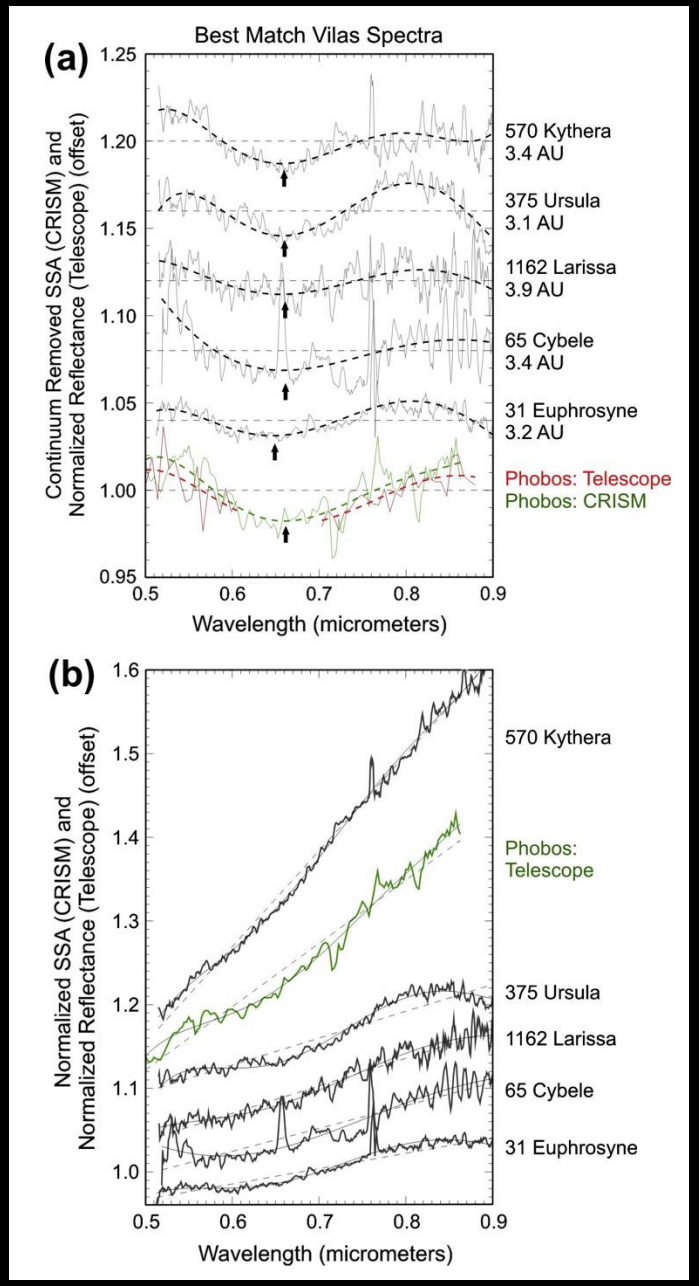
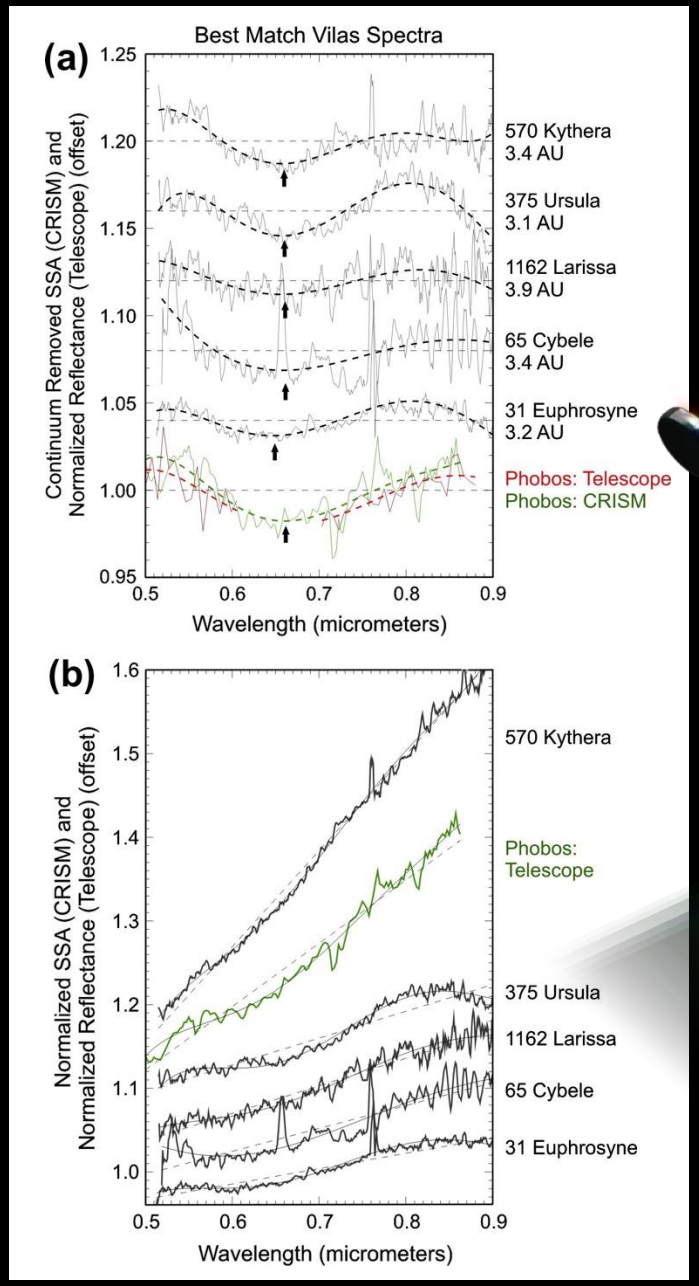
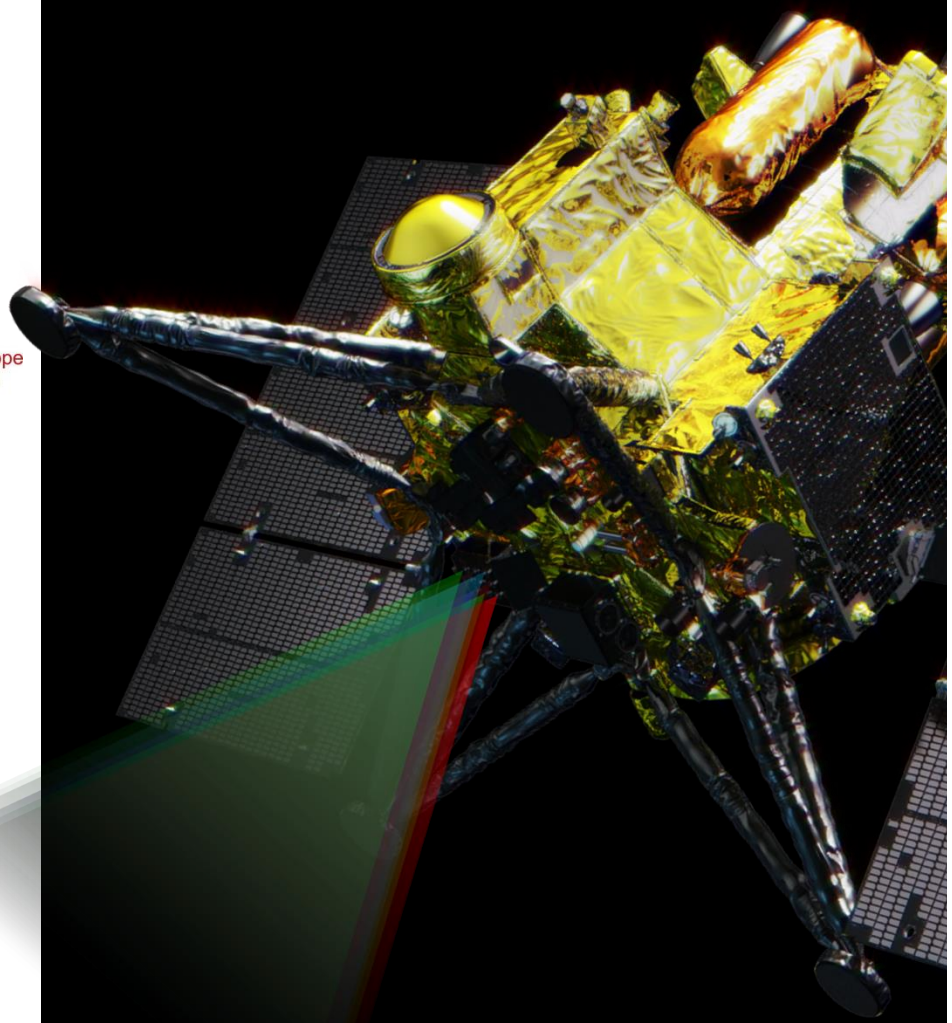


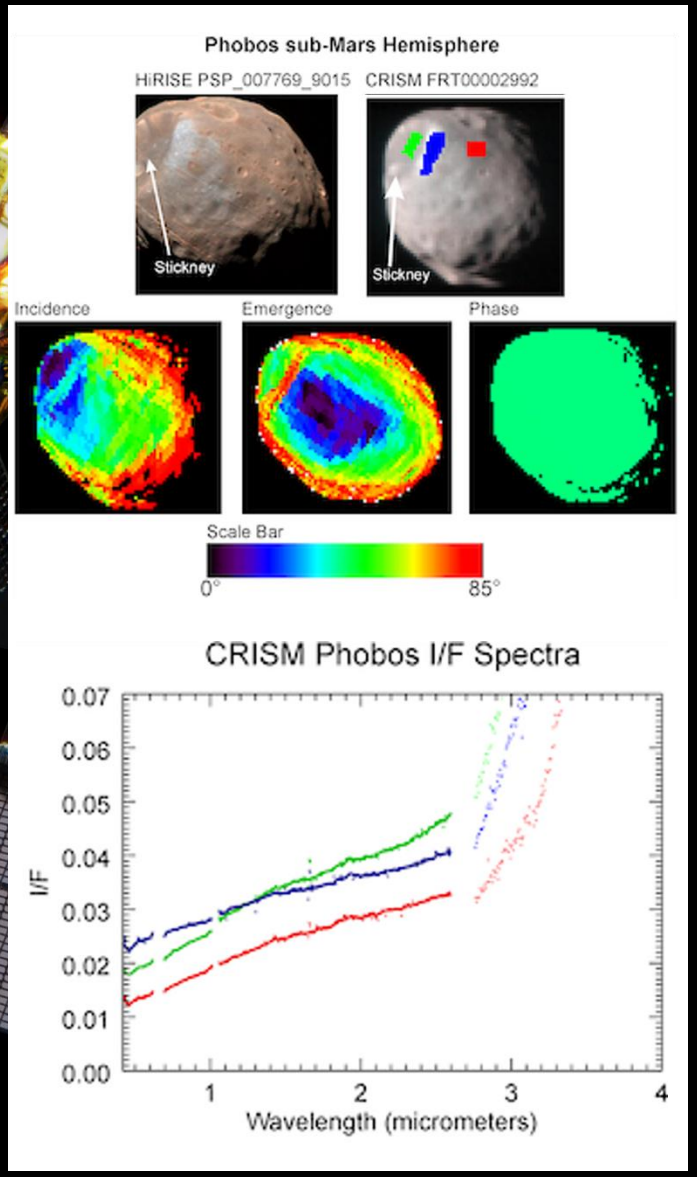
Fraeman et al 2014, *Icarus* (Fig. 6.)

JAXA



Fraeman et al 2014, *Icarus* (Fig. 6.)





Fraeman et al 2012, *JGR: Planets* (Fig. 2, 4)

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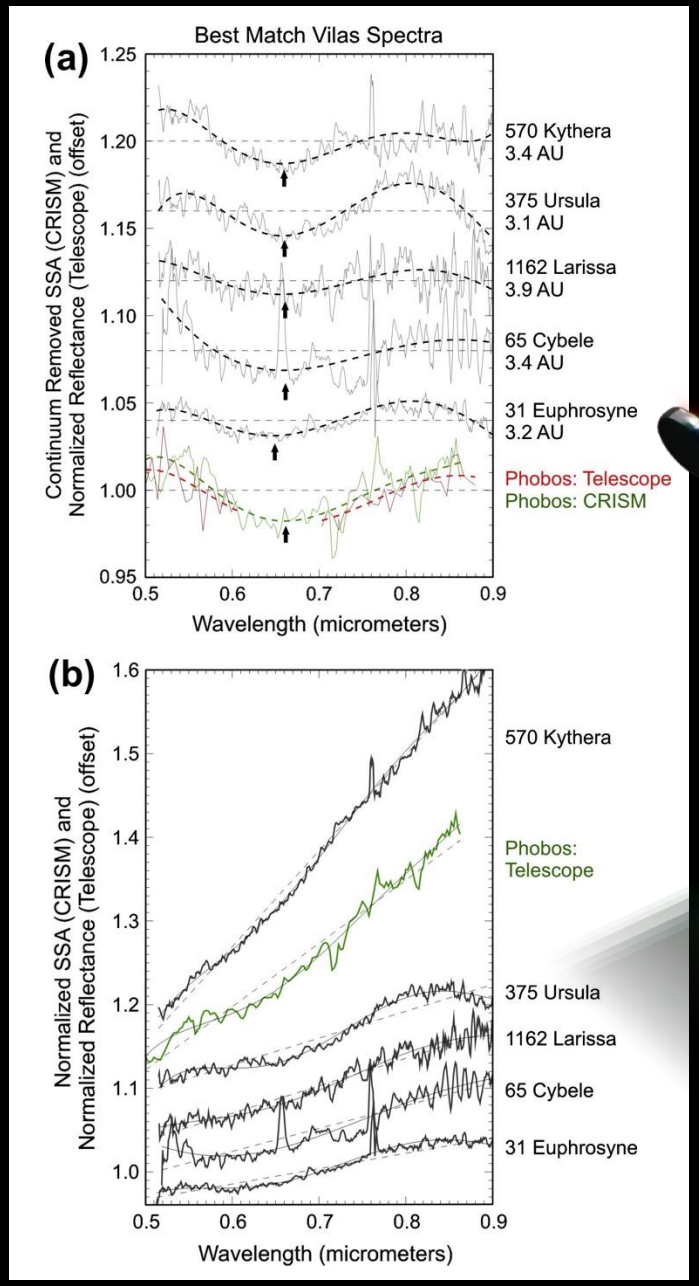
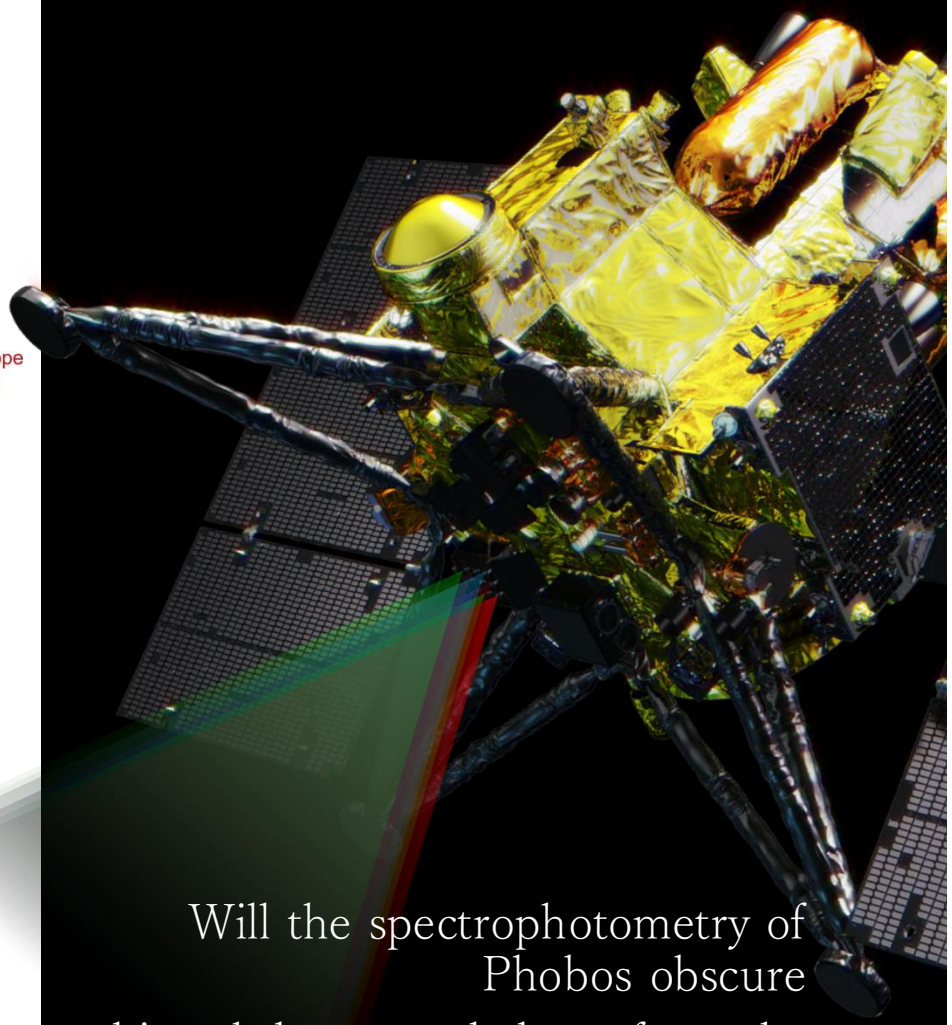
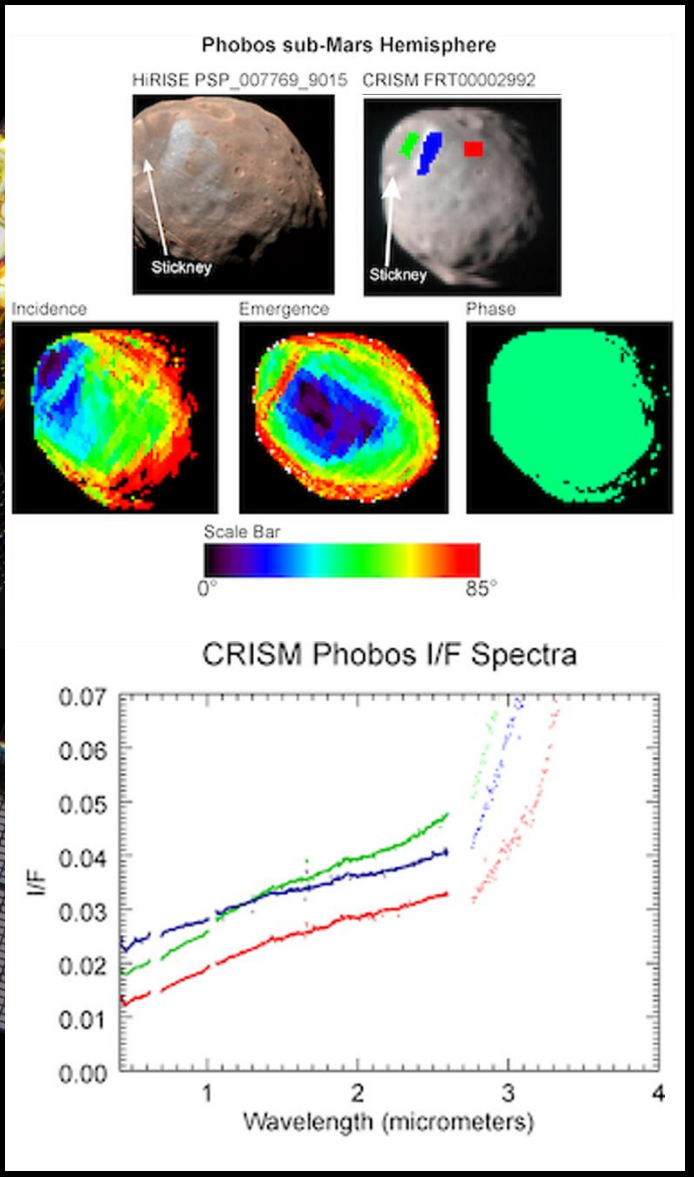


Fraeman et al 2014, *Icarus* (Fig. 6.)



Will the spectrophotometry of Phobos obscure this subtle spectral shape from the surface?



Fraeman et al 2012, *JGR: Planets* (Fig. 2, 4)

JAXA

OROCHI & LOROS

Optical

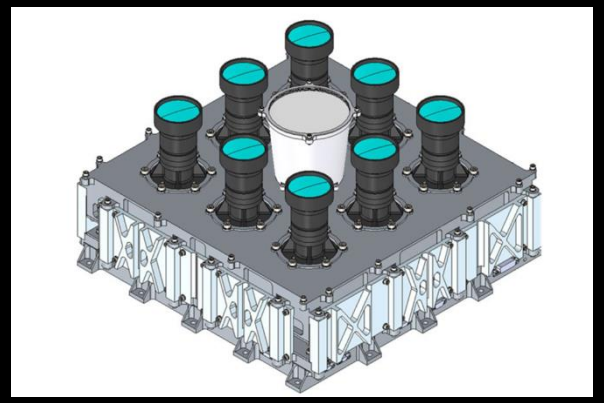
Radi-

Ometer composed of

C-

Hromatic

Imagers



Kameda et al 2021, *Earth, Planets & Space*

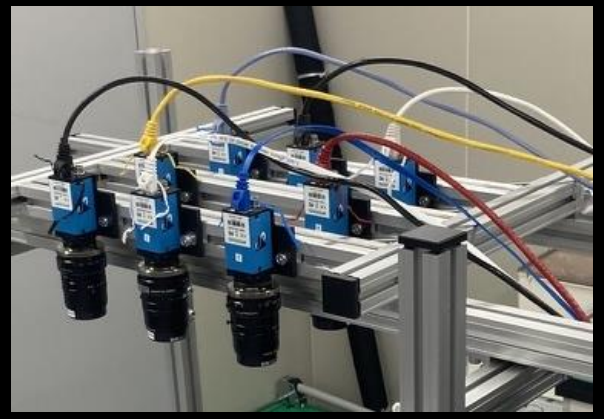
Laboratory

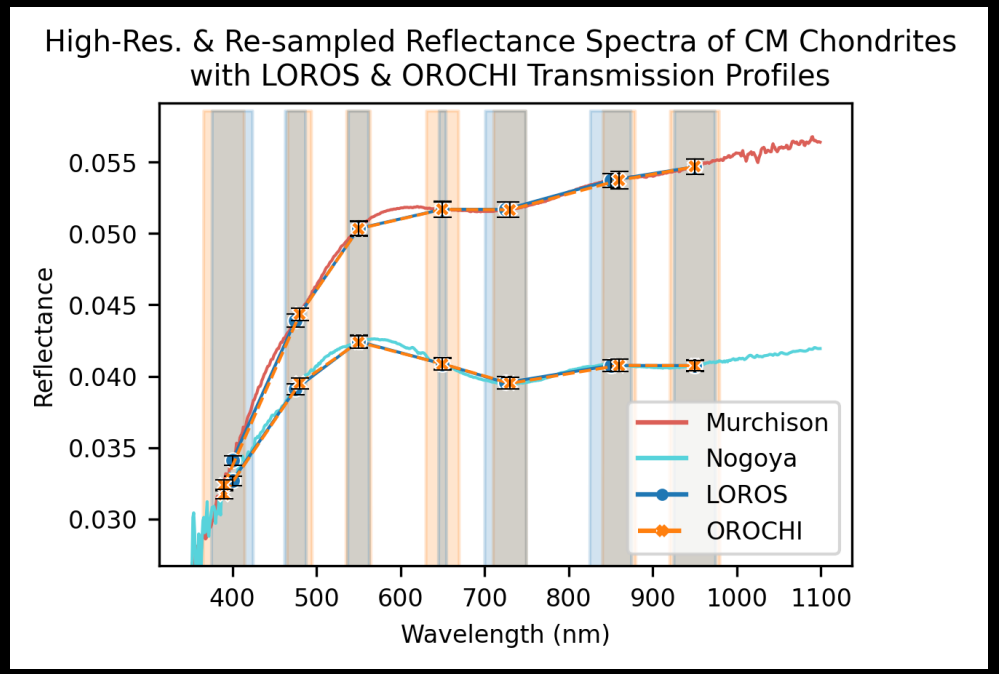
O

R

OCHI

Simulator





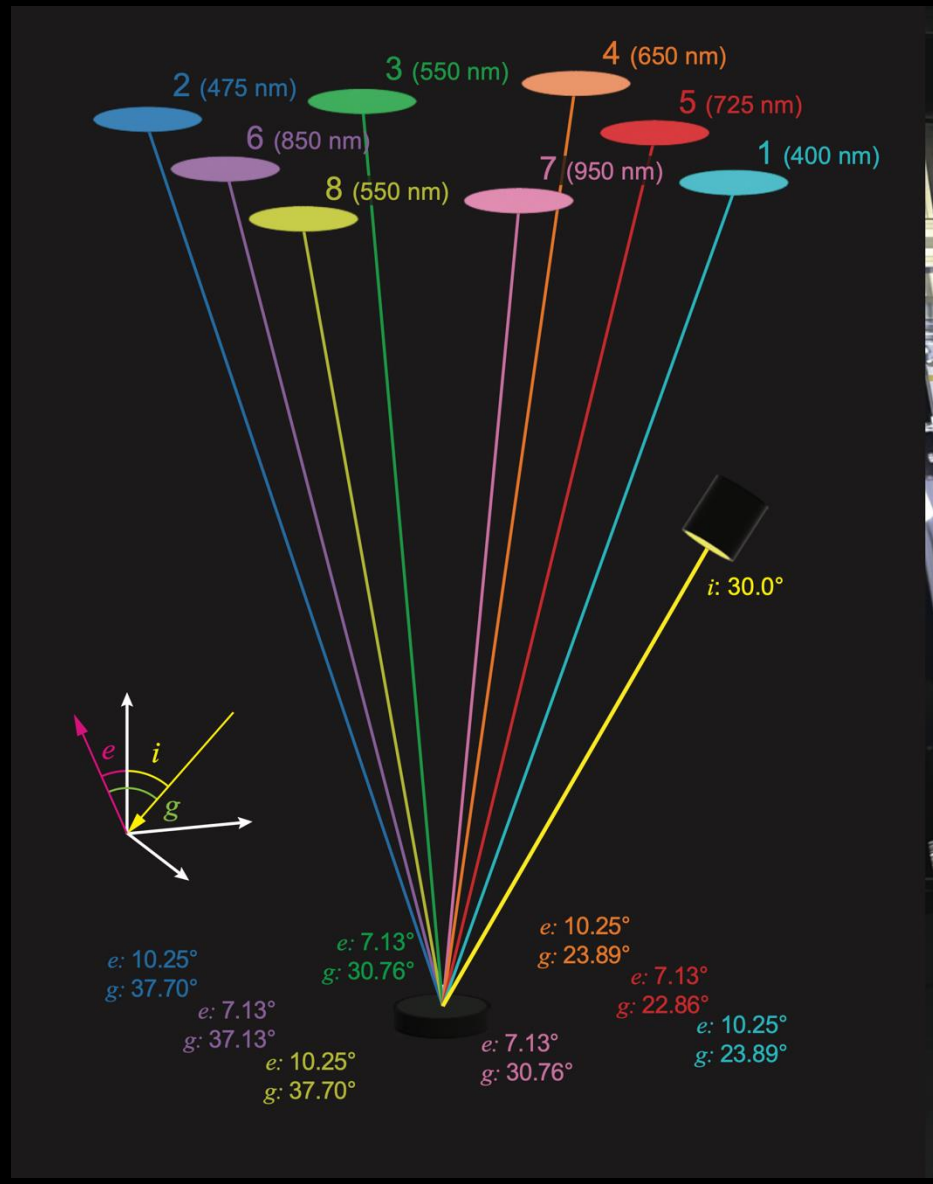
8 Camera system: 7 VNIR Spectral Channels

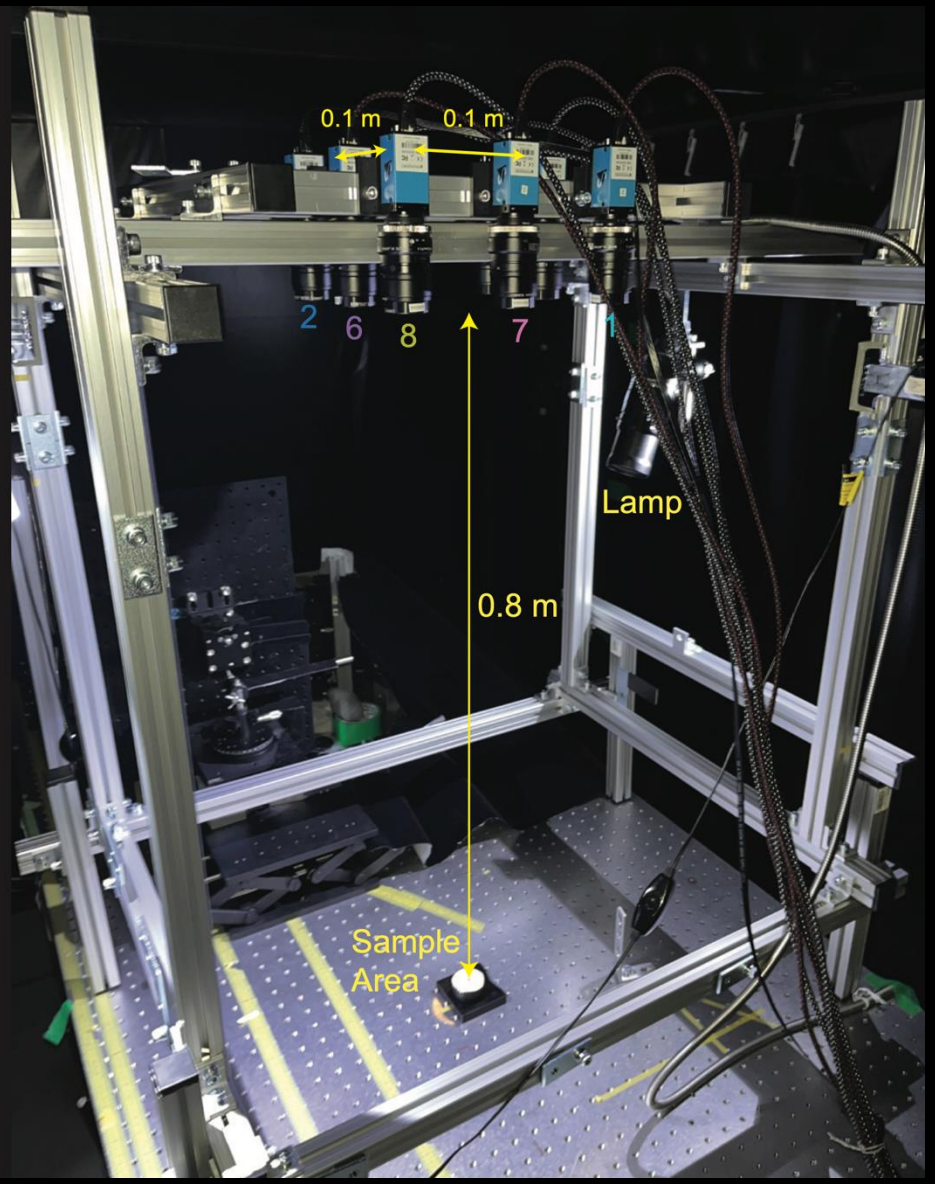
(Repeated 550 nm channel in 8th camera)

SNR-Max: 140

SNR 100 at 50% pixel exposure (shot-limited)

Ground Sample Distance @ 0.8 m: 360 μm / pix


2 (475 nm)
3 (550 nm)
4 (650 nm)
5 (725 nm)
6 (850 nm)
7 (950 nm)
8 (550 nm)
1 (400 nm)
i: 30.0°
e
i
g
e: 10.25°
g: 37.70°
e: 7.13°
g: 37.13°
e: 10.25°
g: 37.70°
e: 7.13°
g: 30.76°
e: 7.13°
g: 30.76°
e: 10.25°
g: 23.89°
e: 7.13°
g: 22.86°
e: 10.25°
g: 23.89°


0.1 m
0.1 m
2
6
8
7
1
Lamp
0.8 m
Sample
Area

LOROS Calibration

Spaceflight Instrument R&D Laboratory
Department of Physics, Rikkyo University

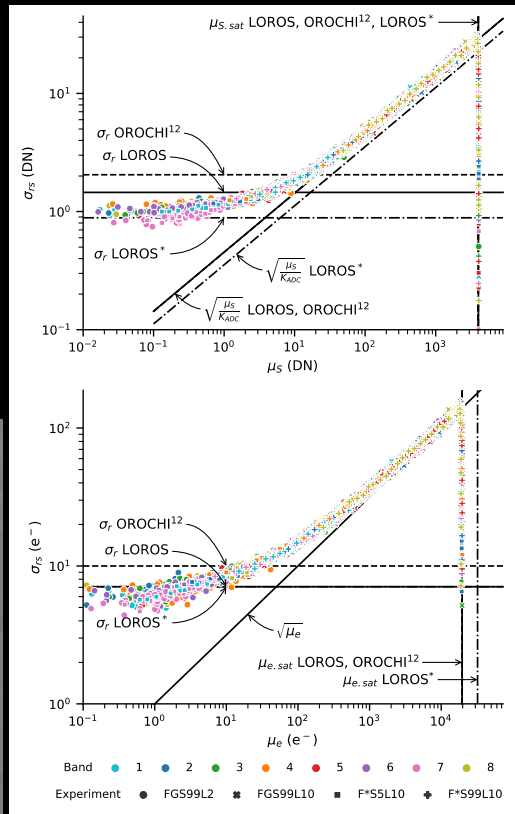
LOROS Radiometric Calibration

Validating equivalent performance of the Laboratory OROCHI Simulator (LOROS) with OROCHI

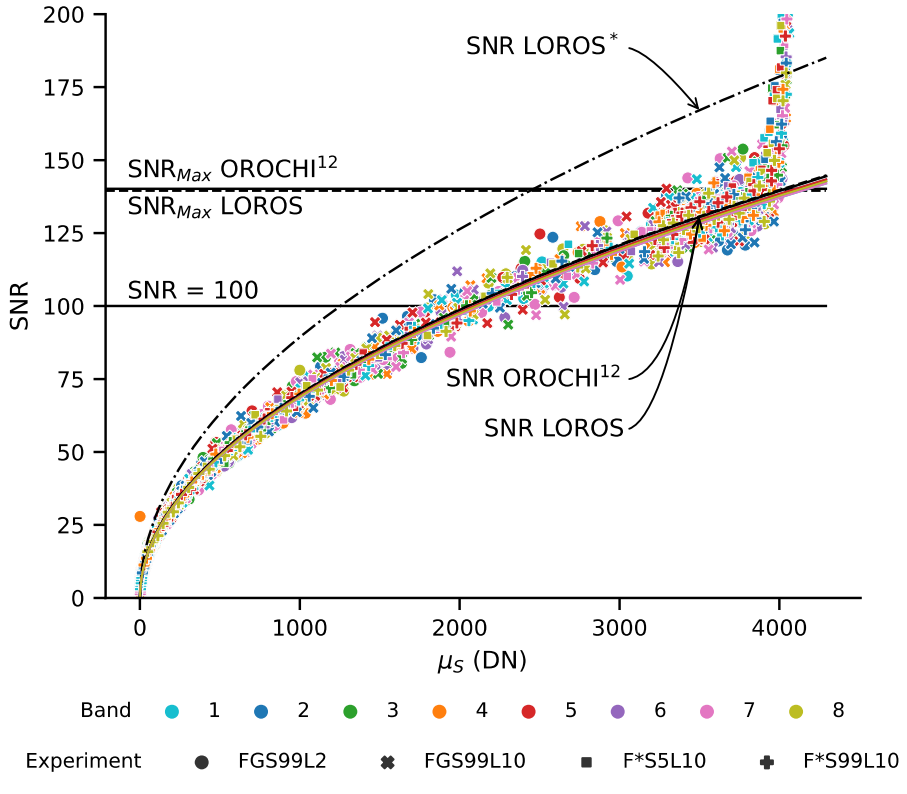
Raw Pixel Values

FPN Removed Noise

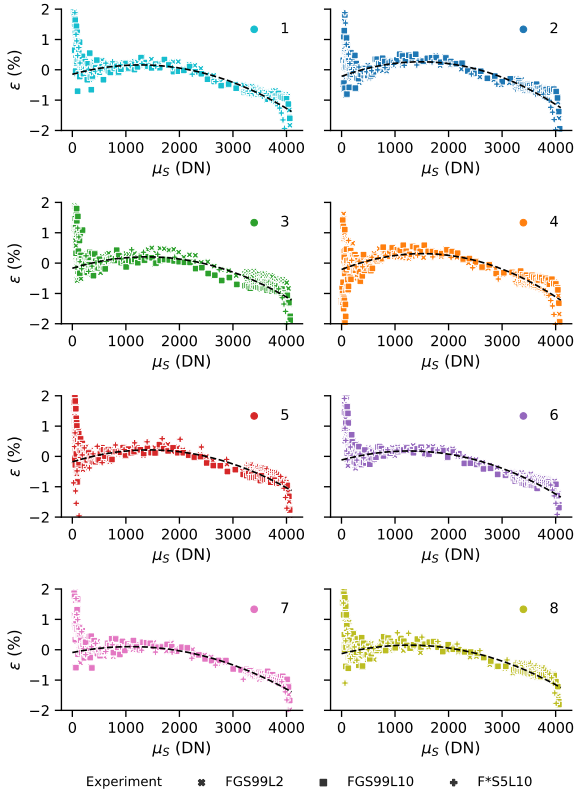
Photon Transfer Curve



Signal-to-Noise Ratio

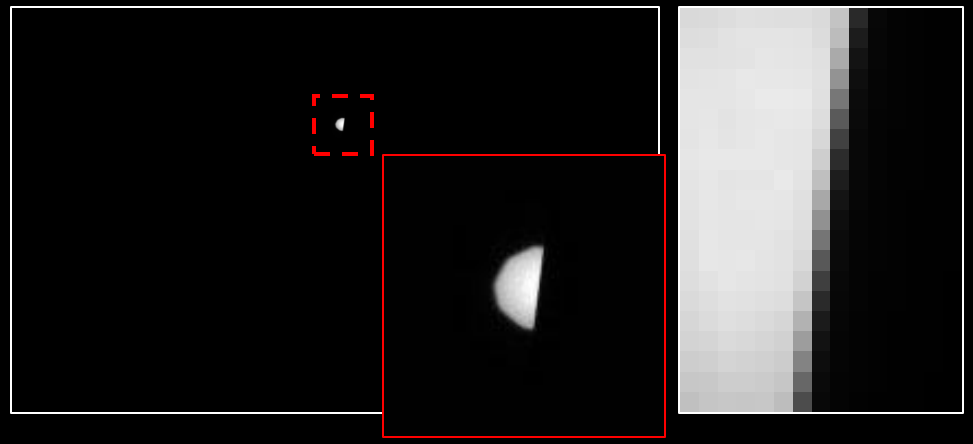


Linearity

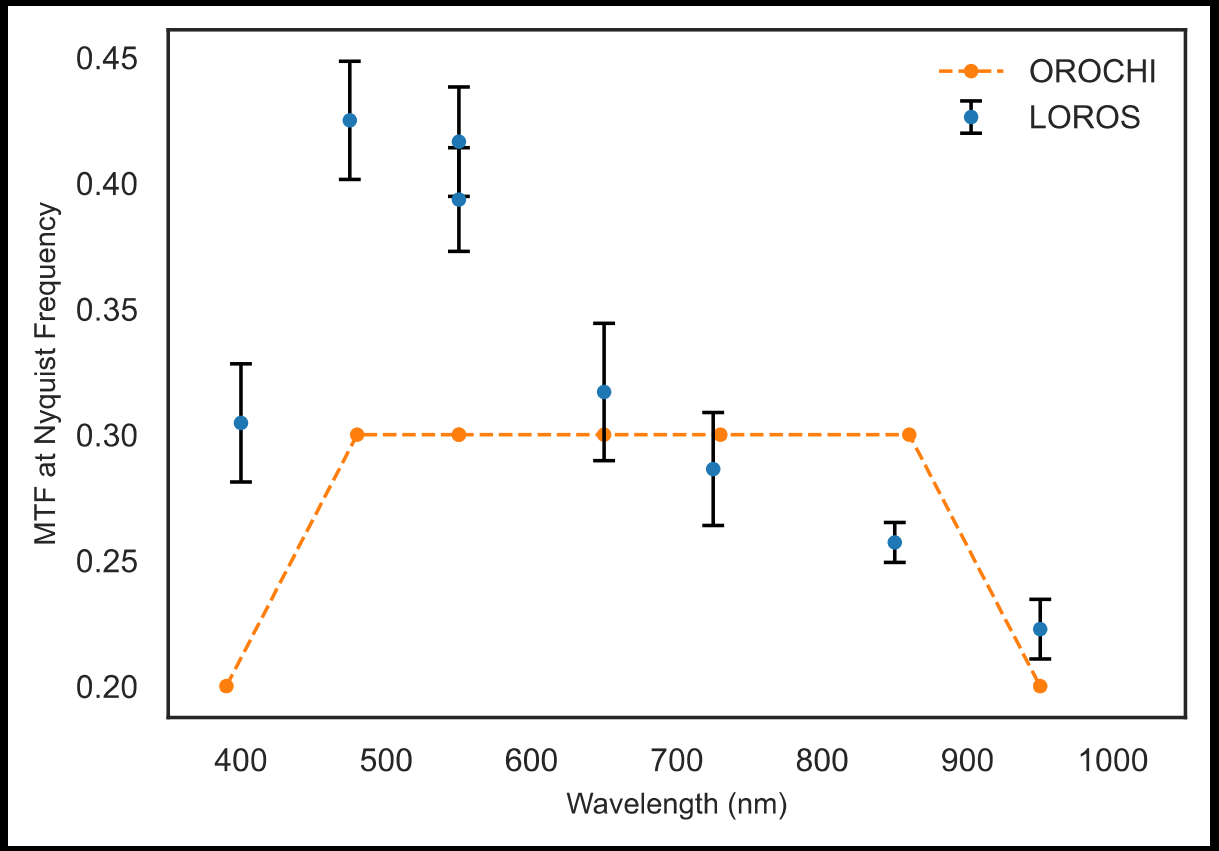


LOROS Optical Calibration

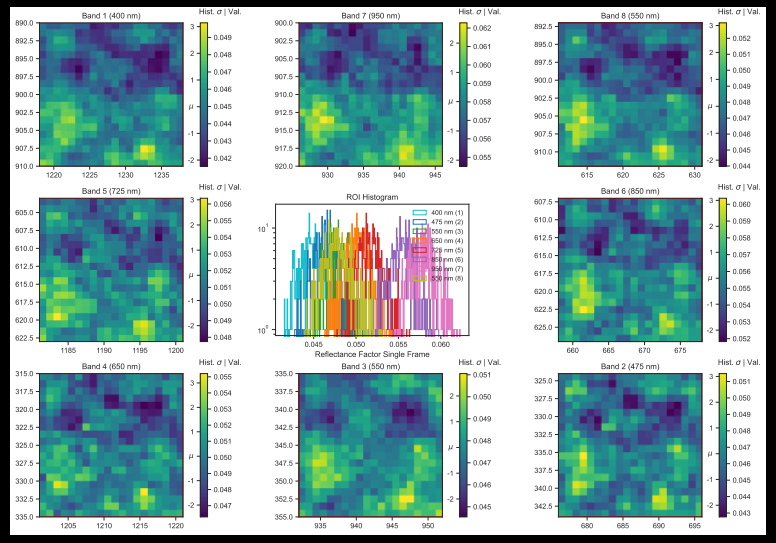
Validating equivalent performance of the Laboratory OROCHI Simulator (LOROS) with OROCHI

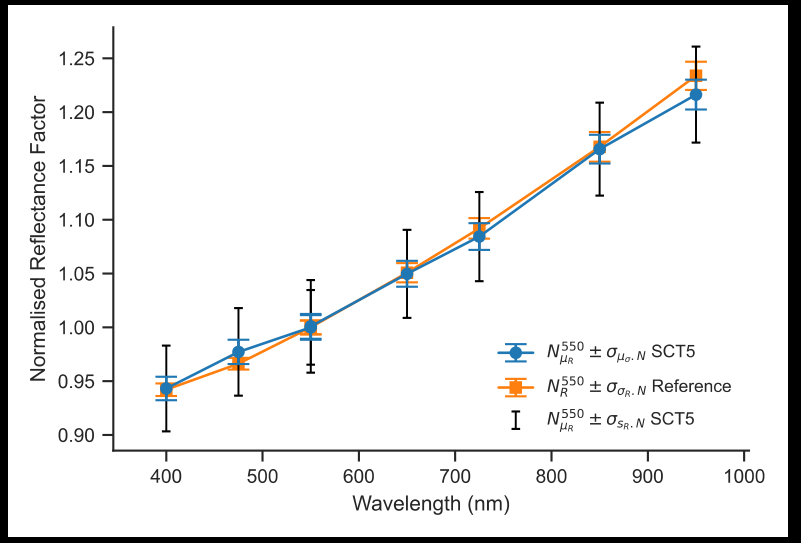


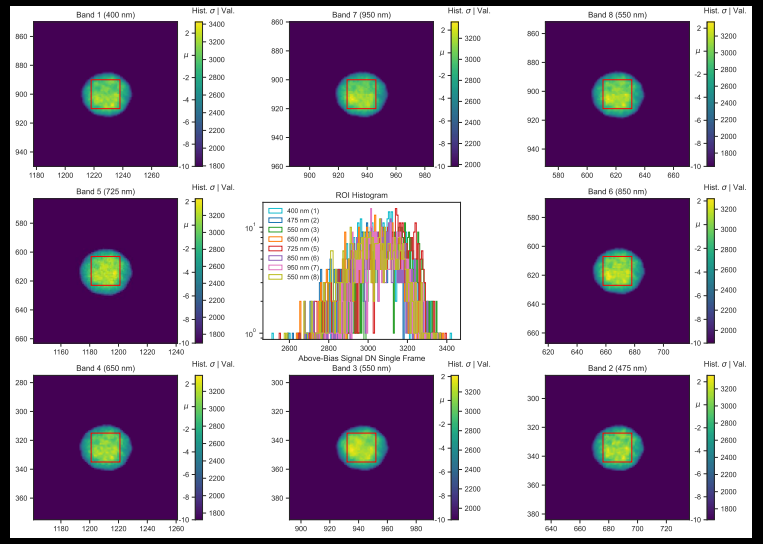
Modulation Transfer Function

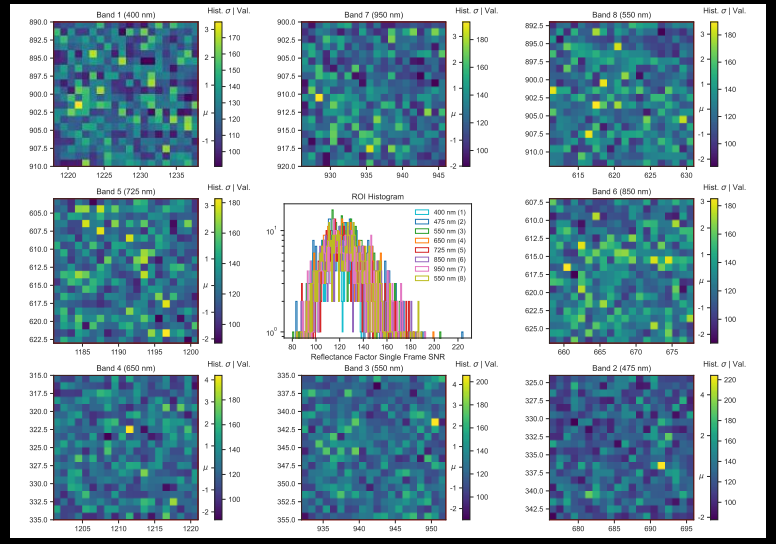


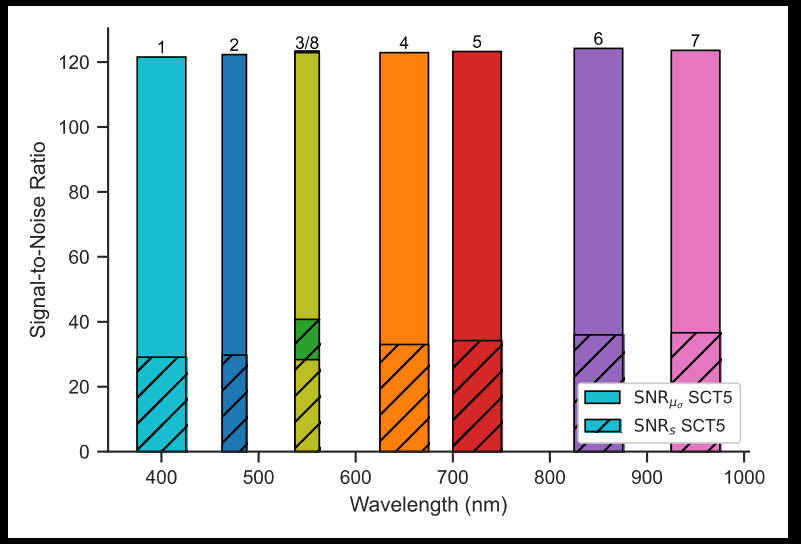
Reflectance Validation



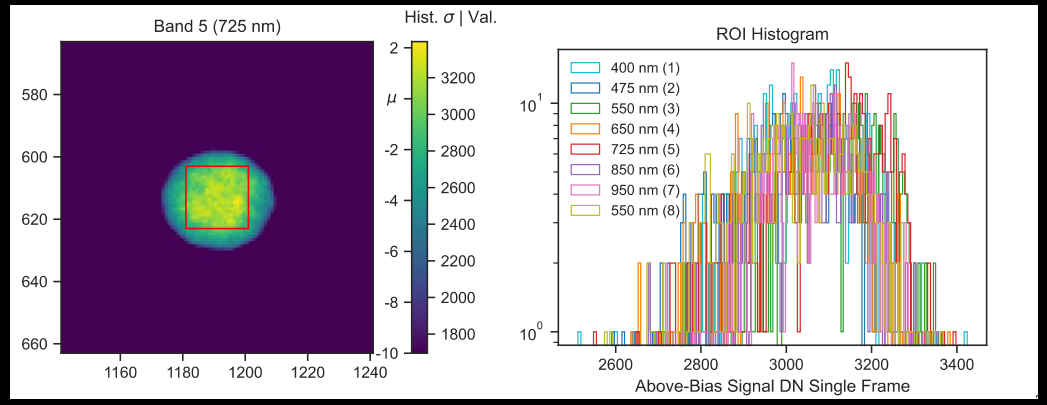


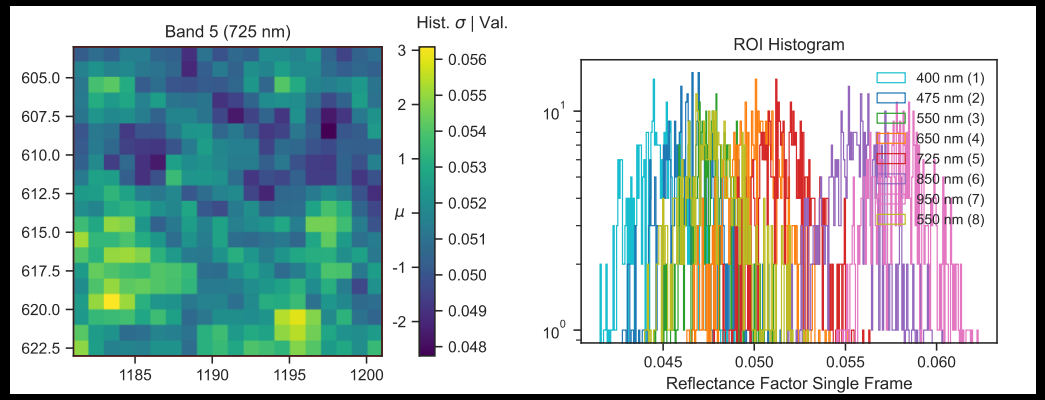


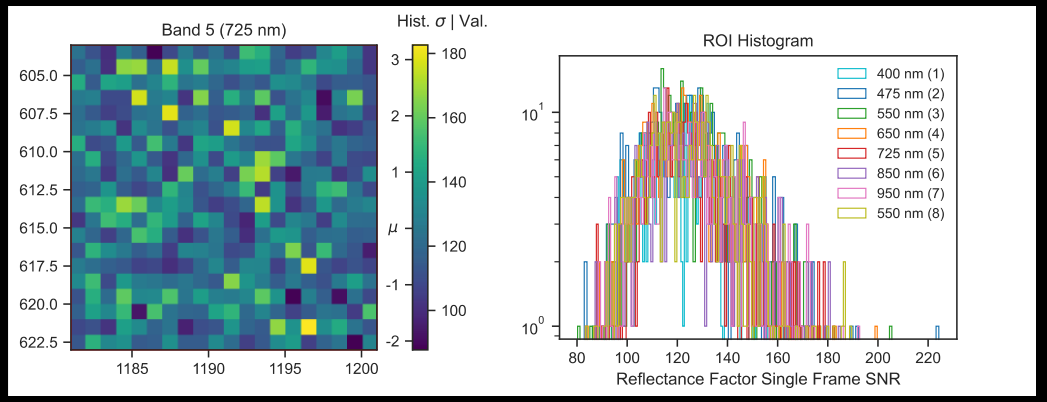


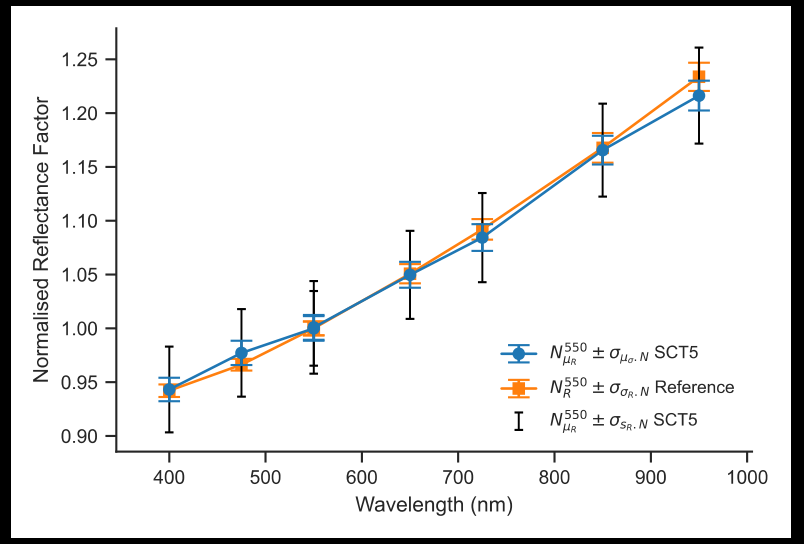


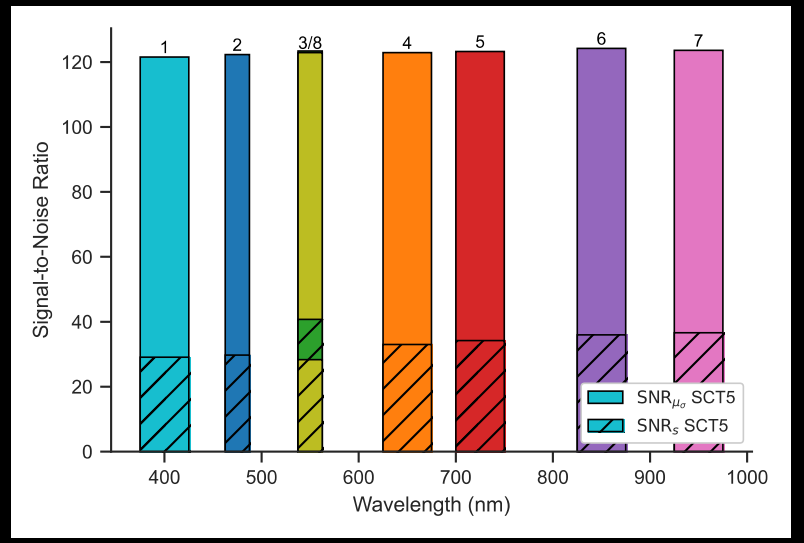
Reflectance Validation









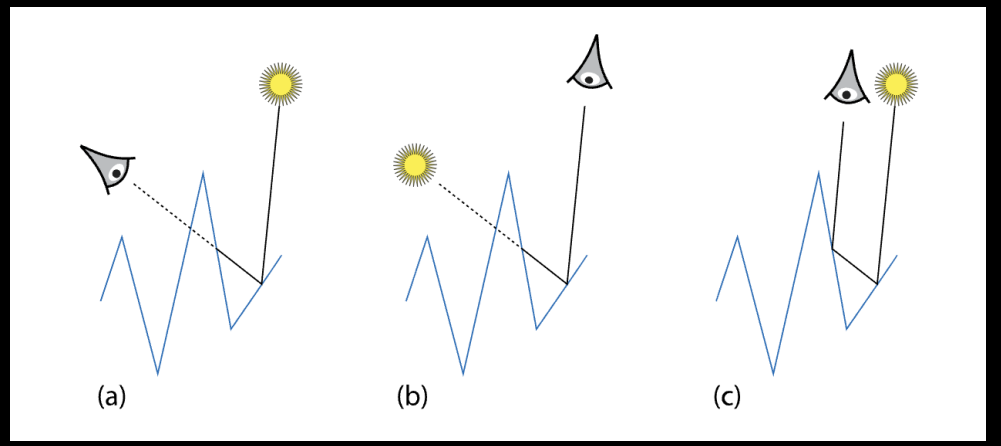


Imaging Ryugu

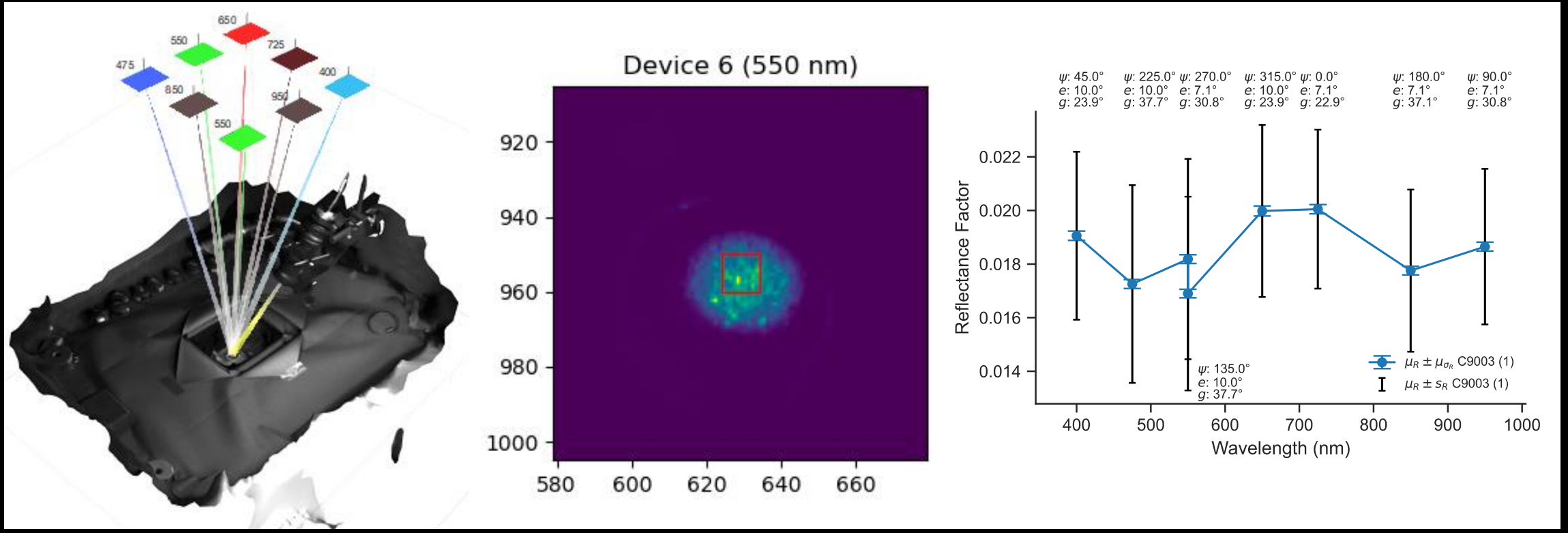
Extraterrestrial Sample Curation Centre
Institute of Space and Astronautical Science, JAXA, Japan

TOYAMA

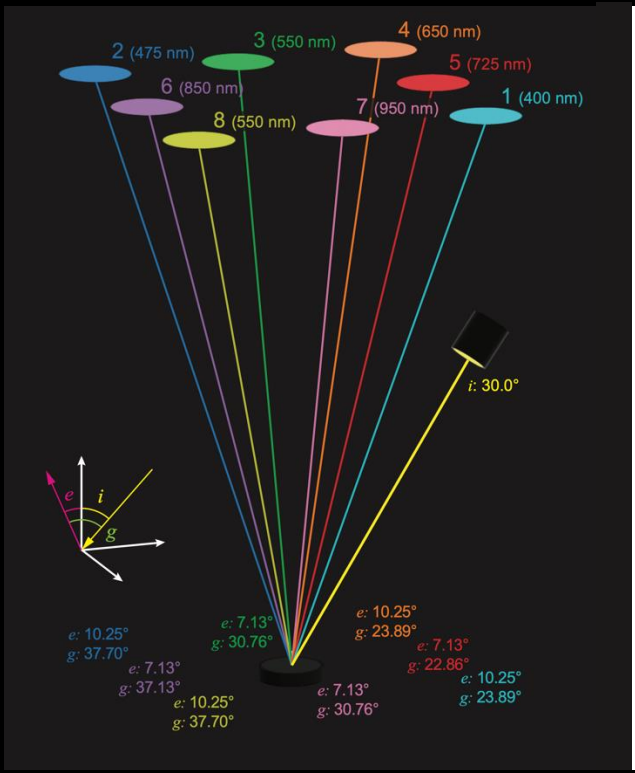
C9003 Aggregate
1 mm

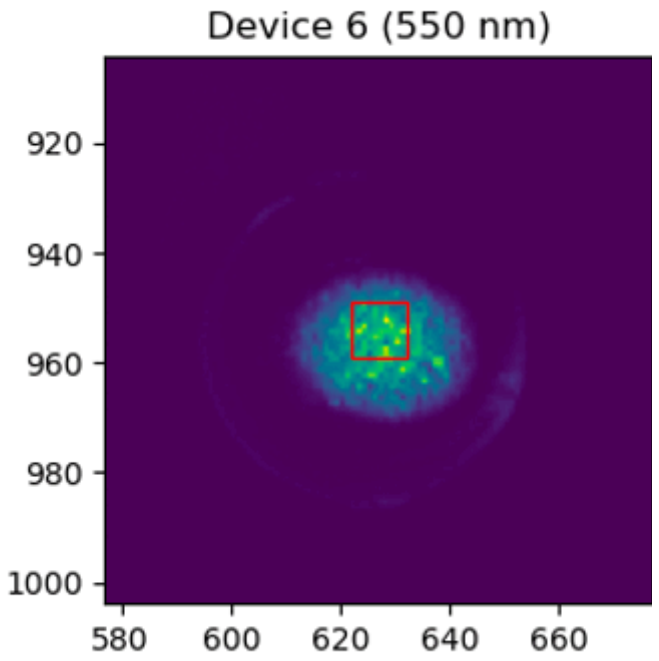

(a)
(b)
(c)

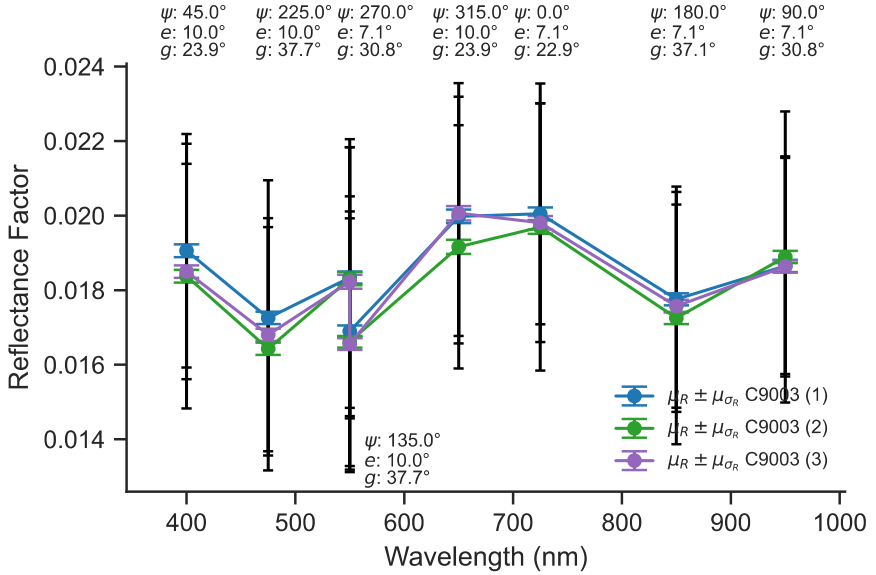
Fixed-Phase OROCHI Configuration



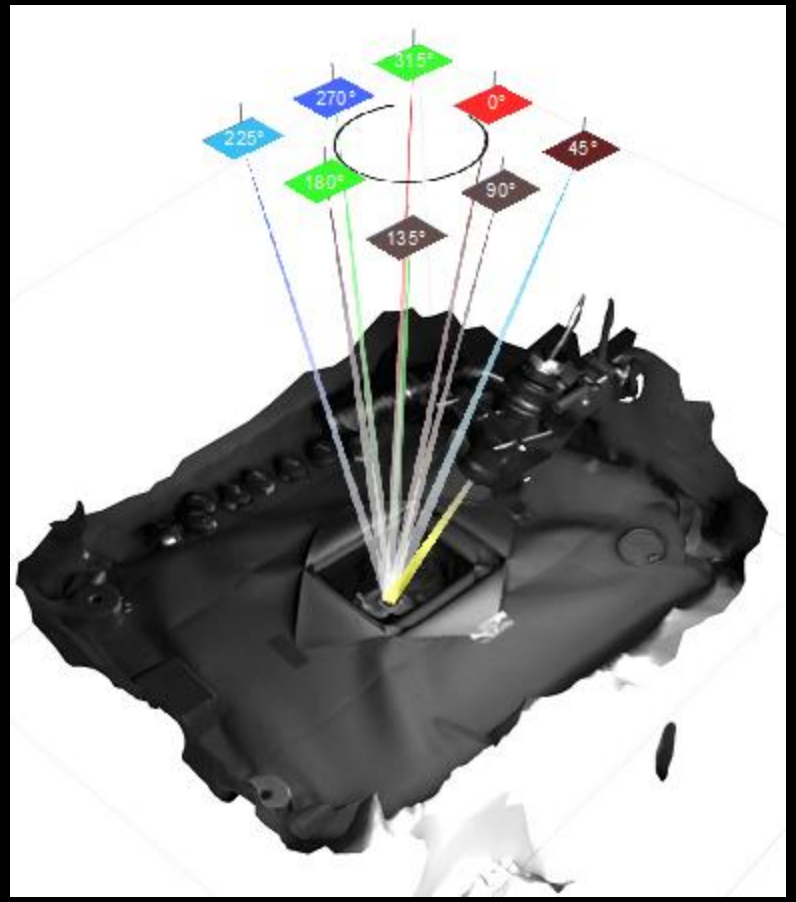
Fixed-Phase OROCHI Configuration

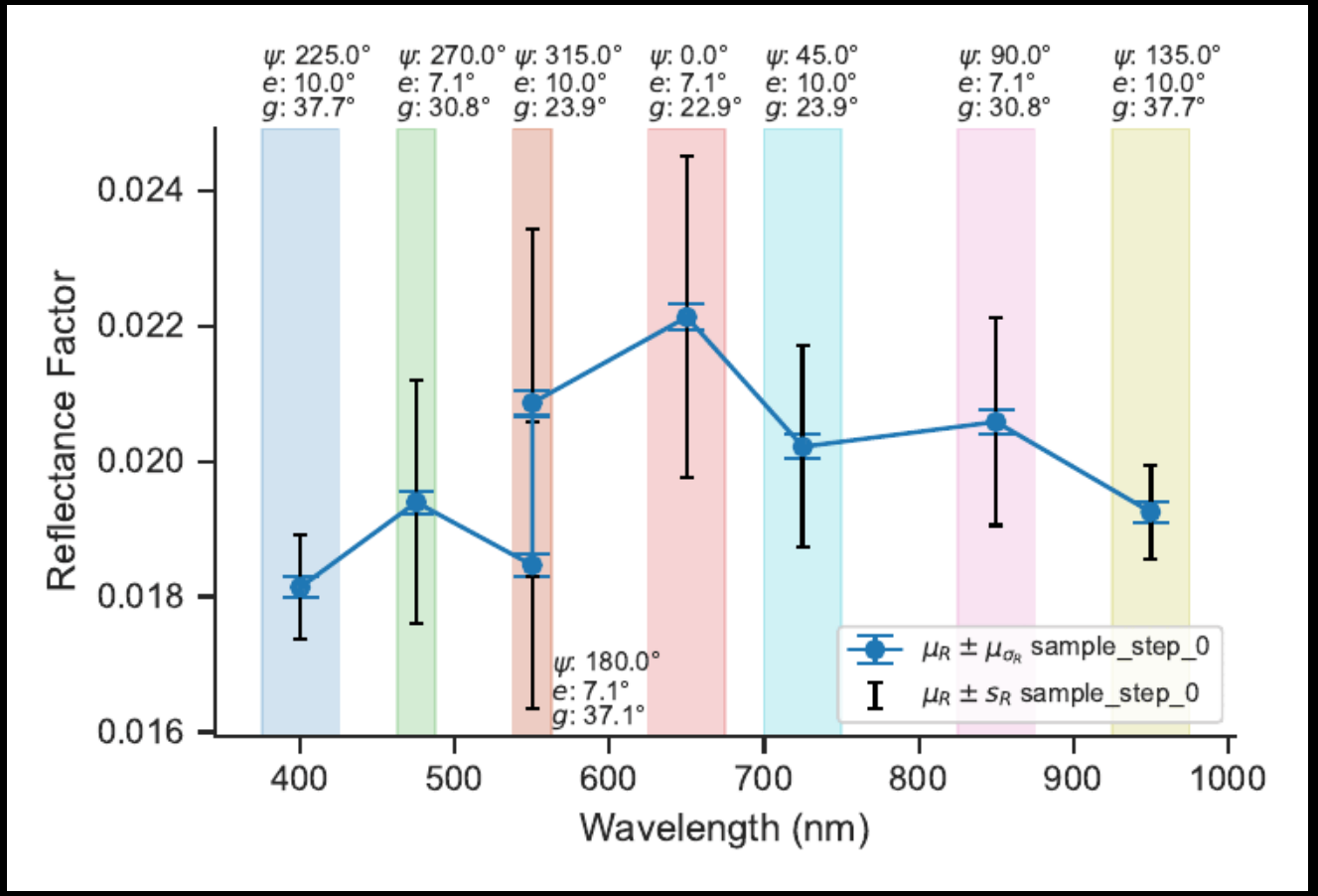




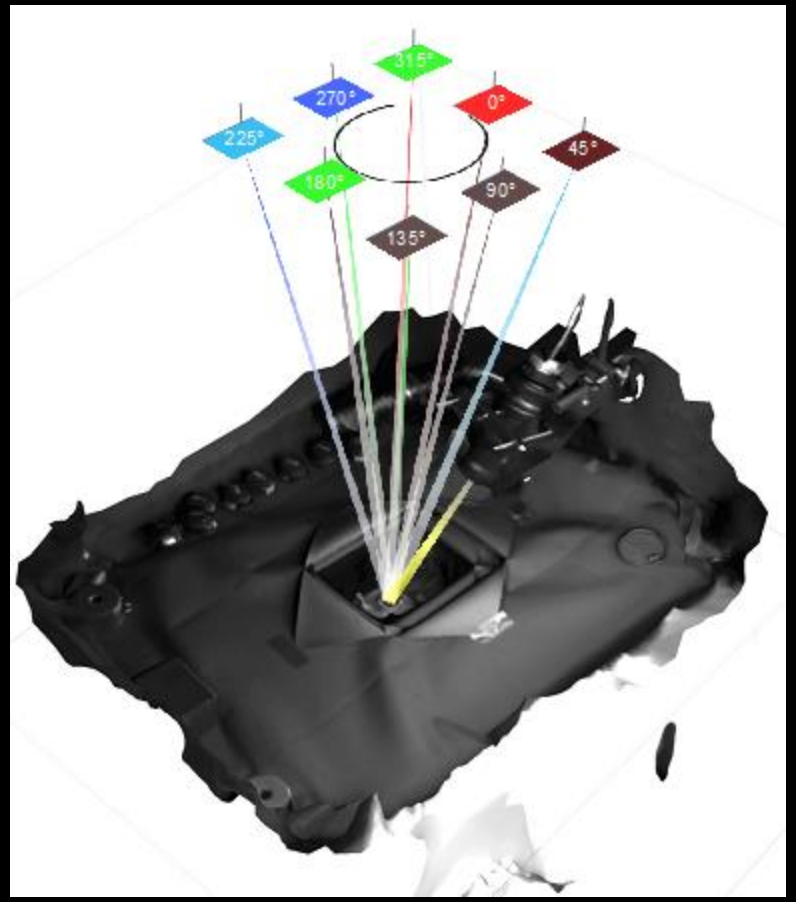


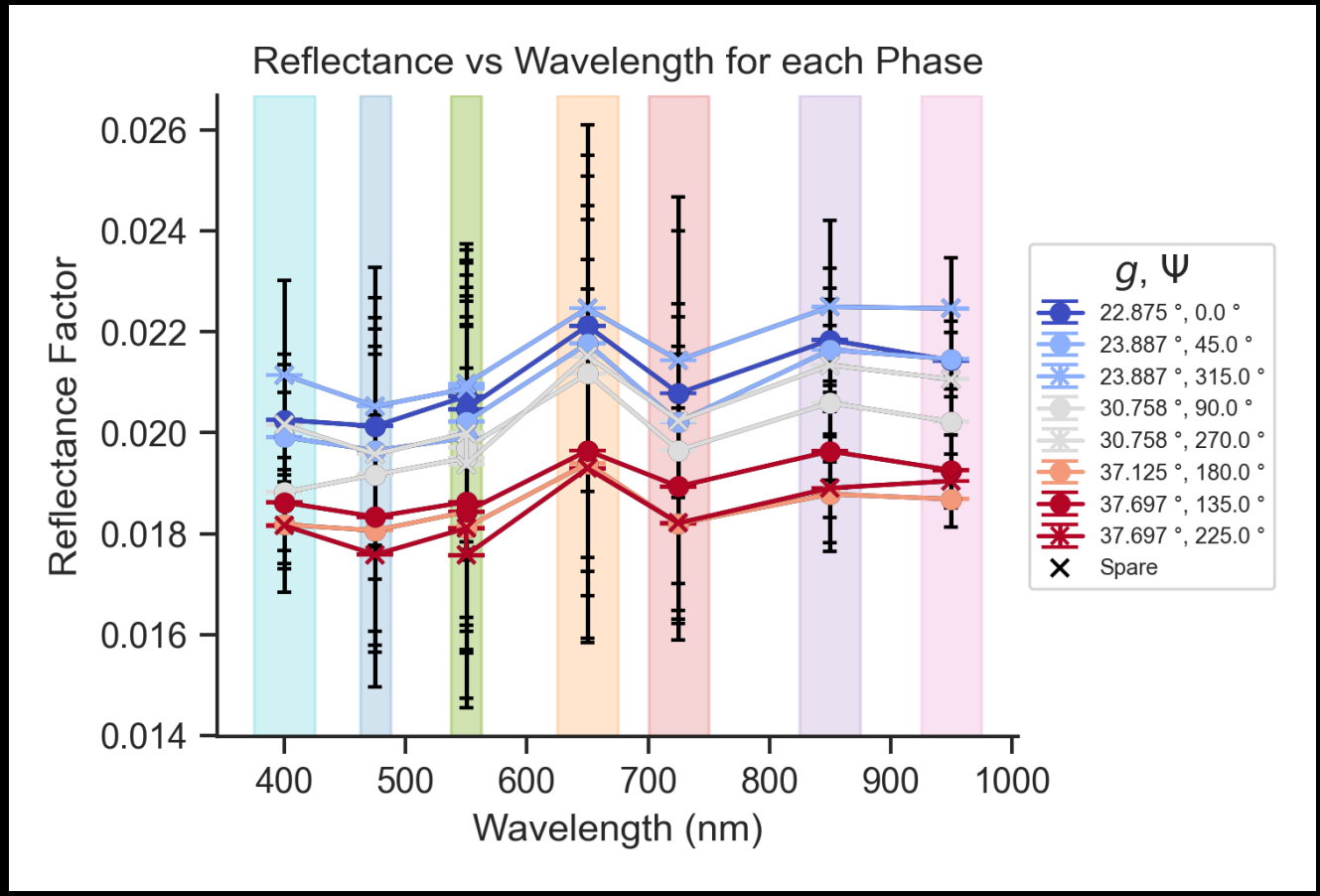
Multi-Phase Reflectance Spectra





Multi-Phase Reflectance Spectra





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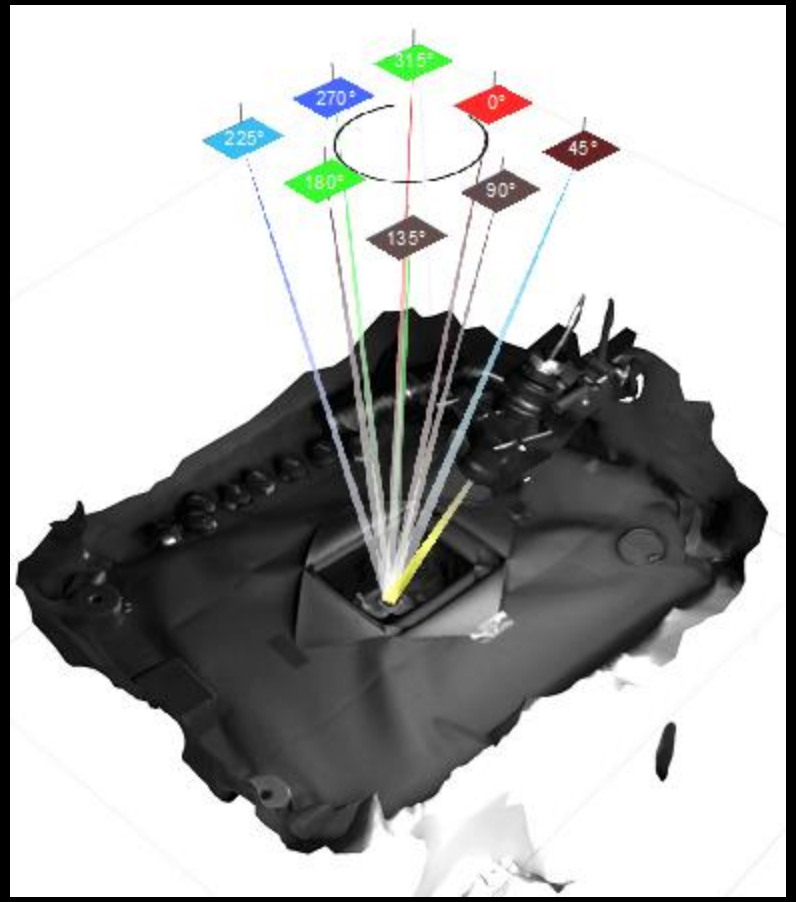
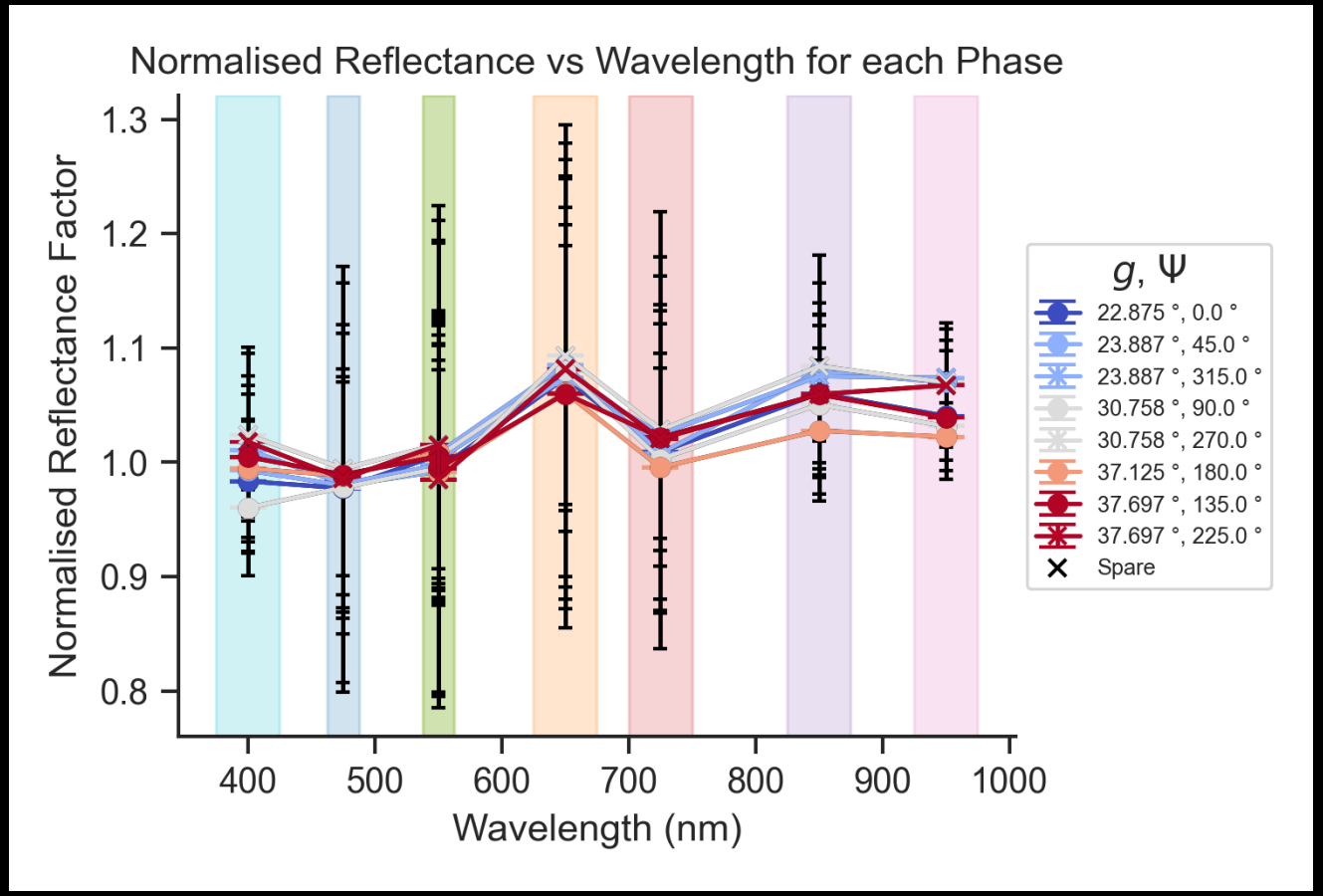
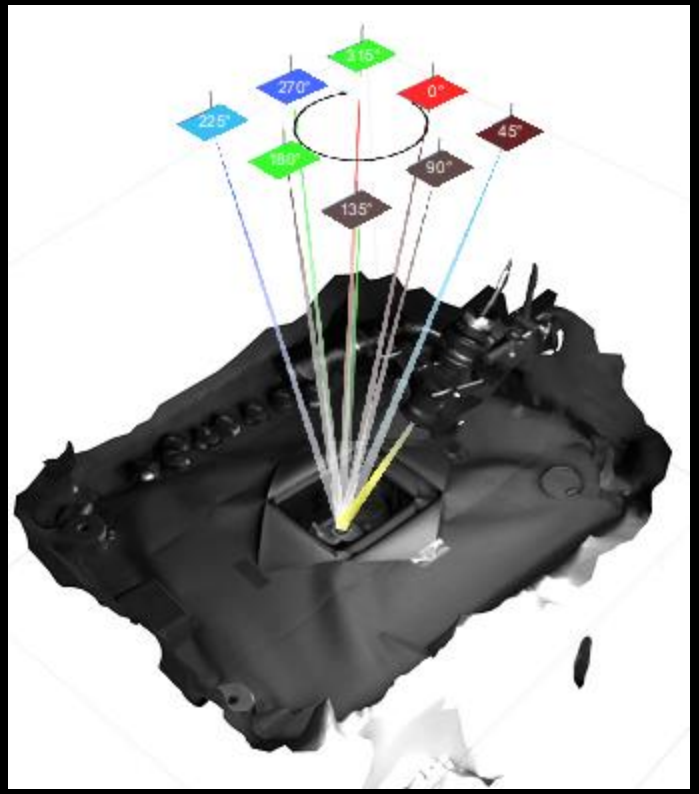
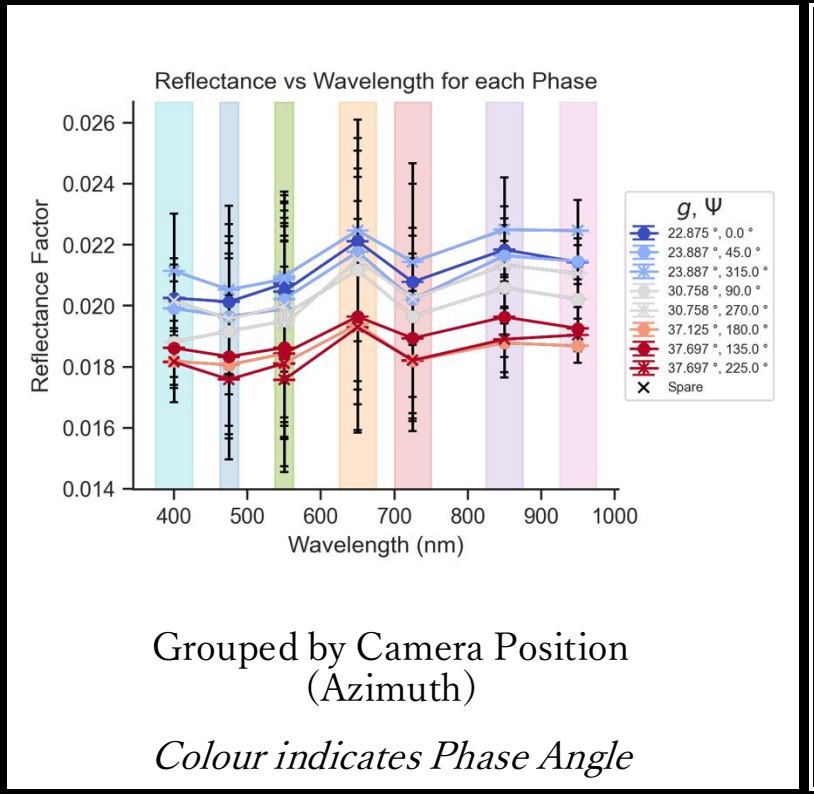




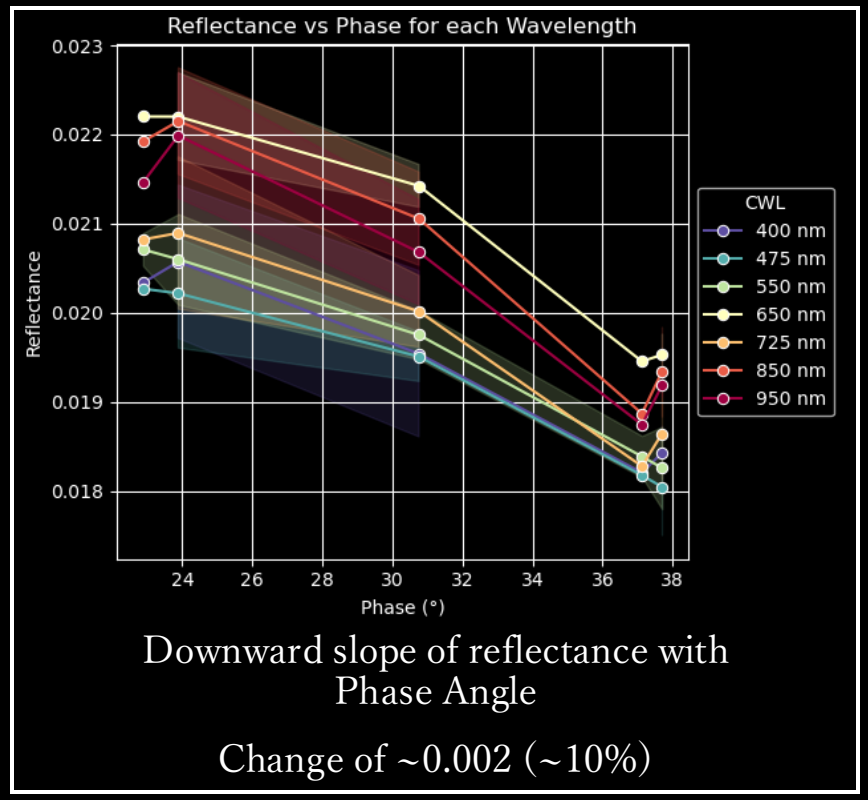
Multi-Phase Reflectance Spectra





Grouped by Camera Position (Azimuth)

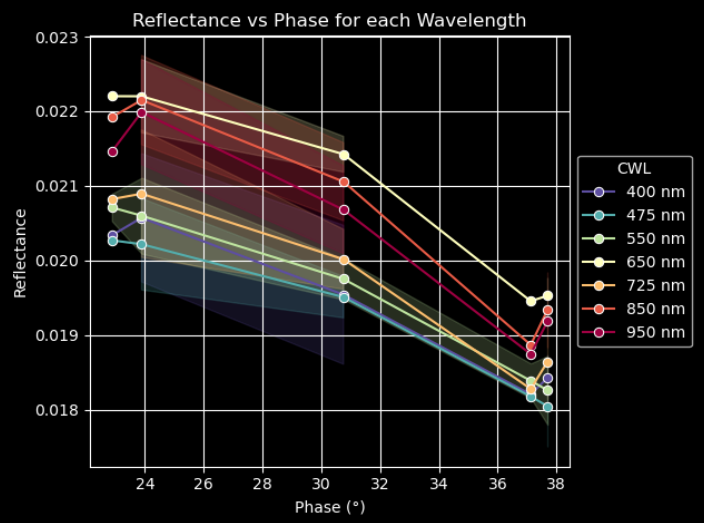
Colour indicates Phase Angle

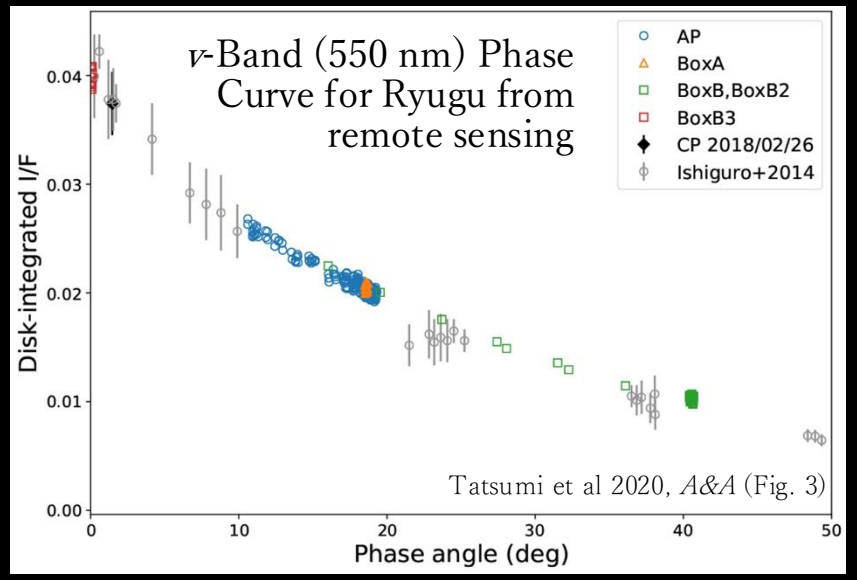


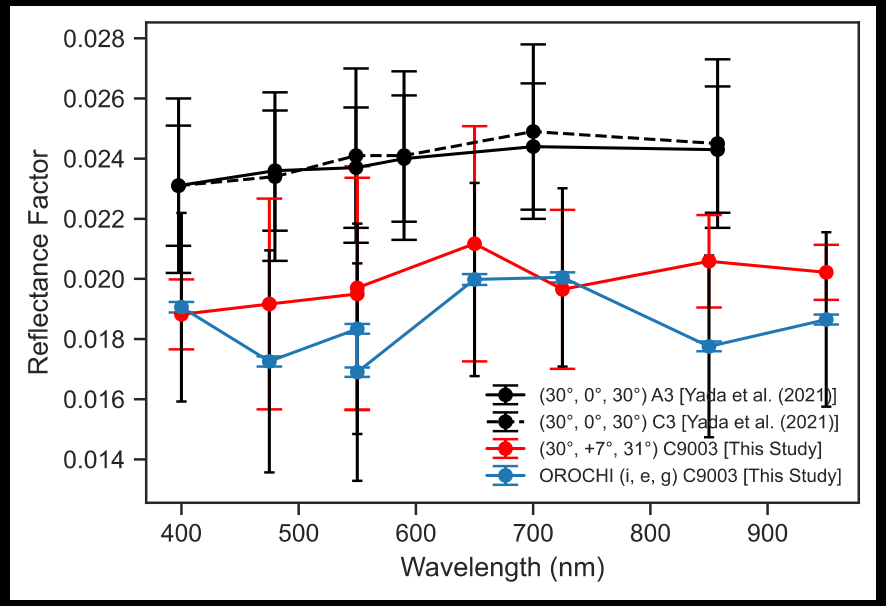
Downward slope of reflectance with Phase Angle

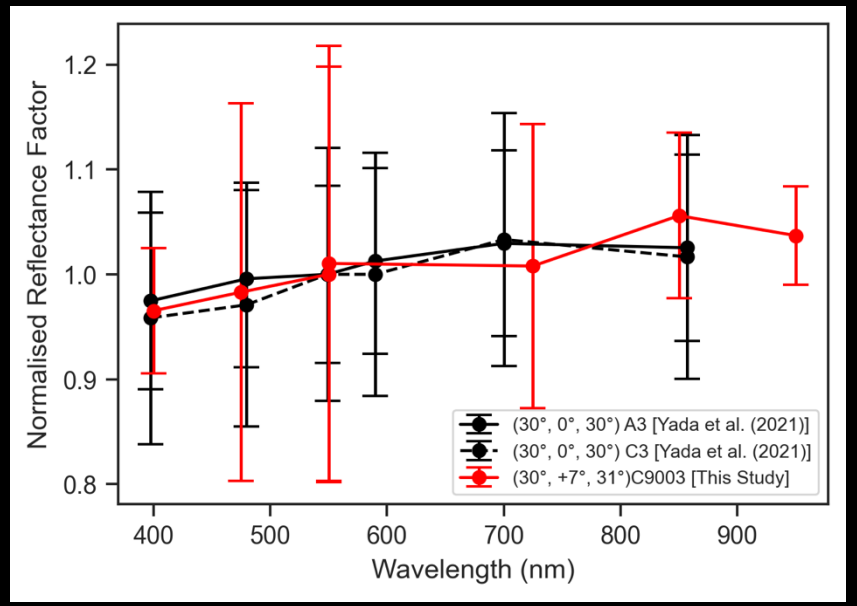
Change of ~0.002 (~10%)

Literature Comparisons



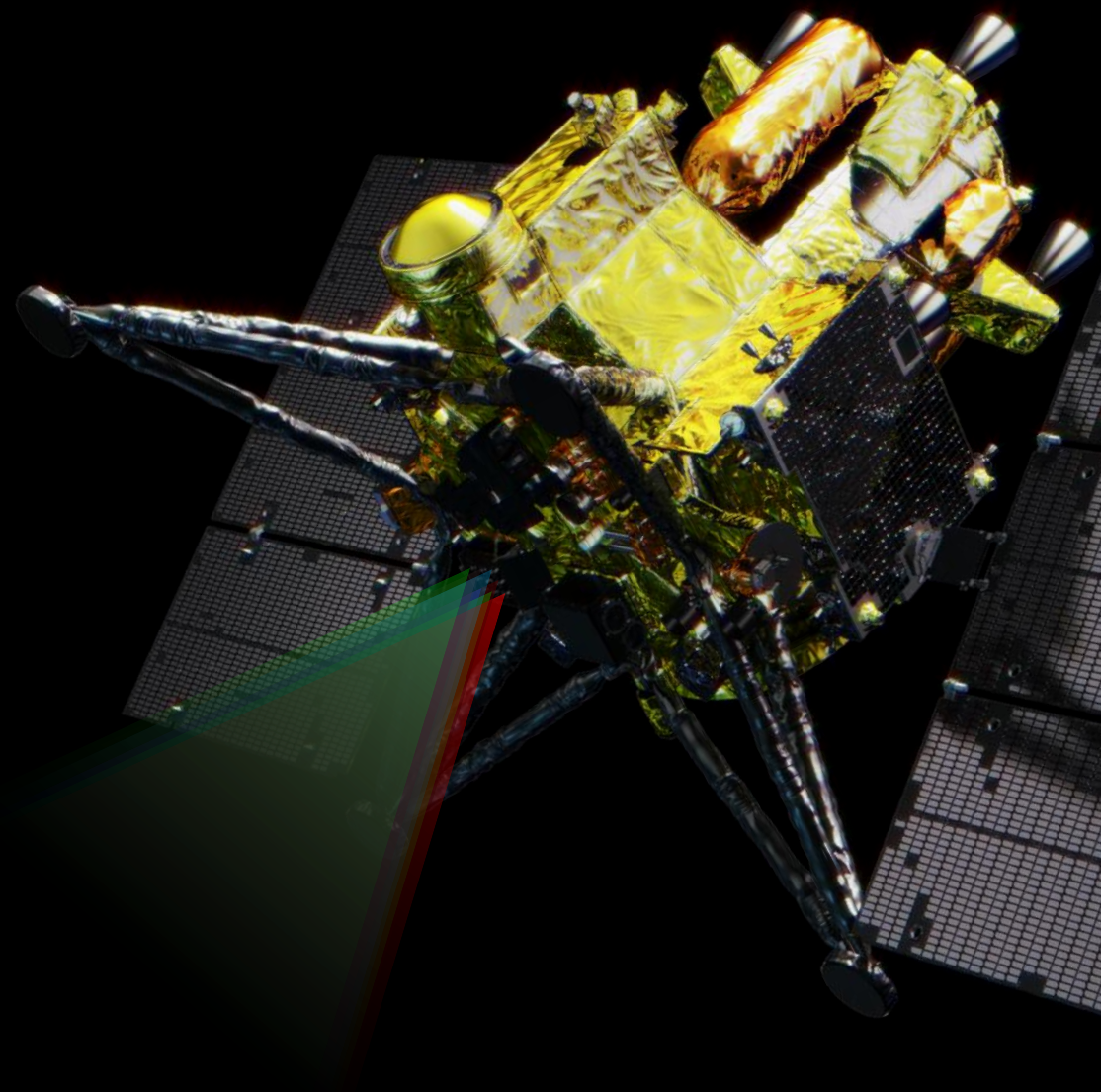






Conclusions & Summary

- Objectives:
  - Demonstrate:
    - MMX OROCHI Near-Field Surface Reflectance Imaging
      - SNR of 100 – 120 demonstrated for single-frame
    - OROCHI ESCuC Sample Imaging for Remote Sensing & Hayabusa2 ONC-T Comparison
      - Operation of LOROS at ESCuC
  - Investigate:
    - Phase-Angle Effects on OROCHI Near-Field Reflectance Imaging
      - Significant Phase Angle Effects
    - Phase-Angle Dependence of Ryugu Regolith VNIR Reflectance
      - Apparently significant, but possible systematic imaging issues require resolution



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ASJA · SOCIETY FOR THE PROMOTION OF SPACE SCIENCE · FOUNDED 1957

JAXA

MMX
Martian Moons eXploration

OROCHI Design

Optical

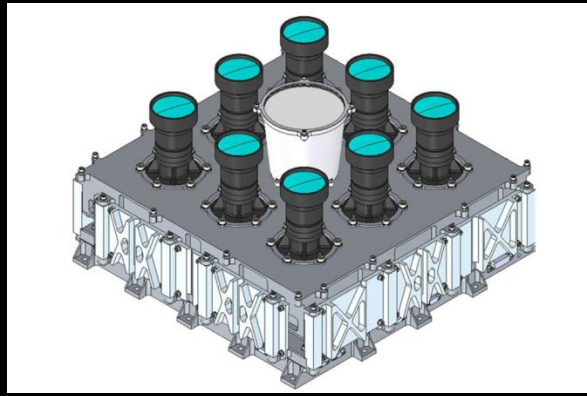
Radi-

Ometer composed of

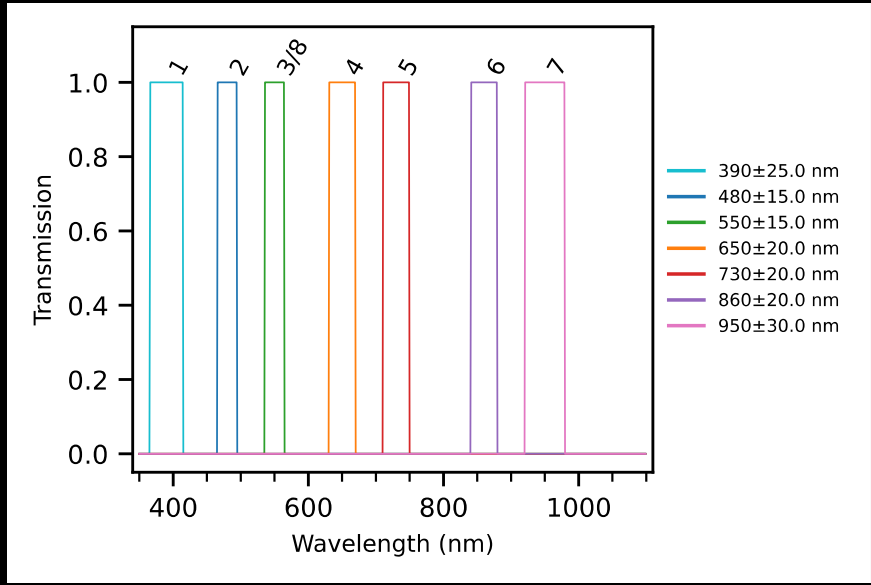
C-

Hromatic

Imagers



Kameda et al 2021, *Earth, Planets & Space*



8 Camera system: 7 Unique VNIR Spectral Channels

(Repeated 550 nm channel in 8th camera)

CCD:

- SNR-Max: 141
- SNR 100 at 50% pixel exposure (shot-limited)
- 8 MP, 20000 e- Full Well, 5.5 µm pitch

Lens:

- F/# 5.8 – 6.4, f-length 13.6 mm, iFoV 0.40 mrad,
- dFoV 83°
- Ground Sample Distance (GSD) @ 0.8 m: 320 µm

LOROS Design

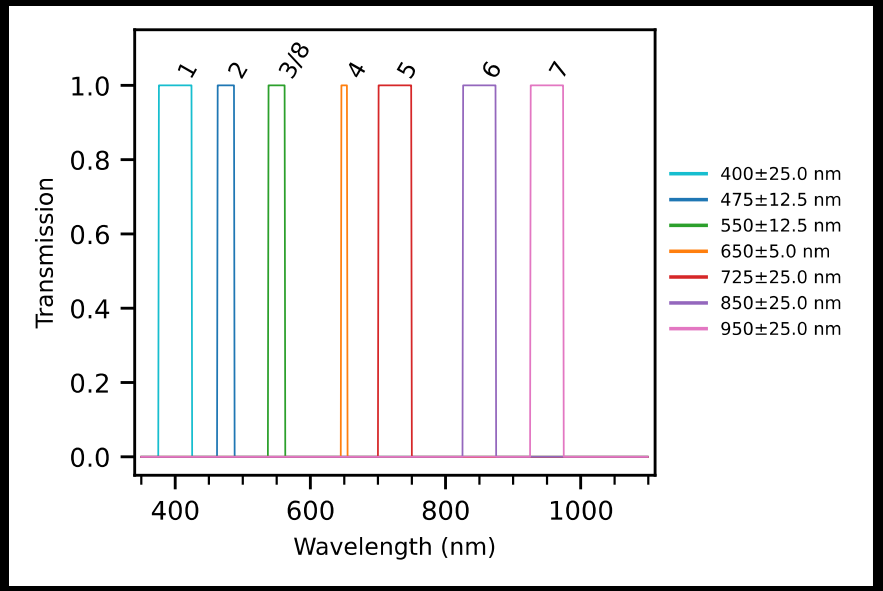
Laboratory

O

R

OCHI

Simulator



Rikkyo University Laboratory OROCHI Simulator

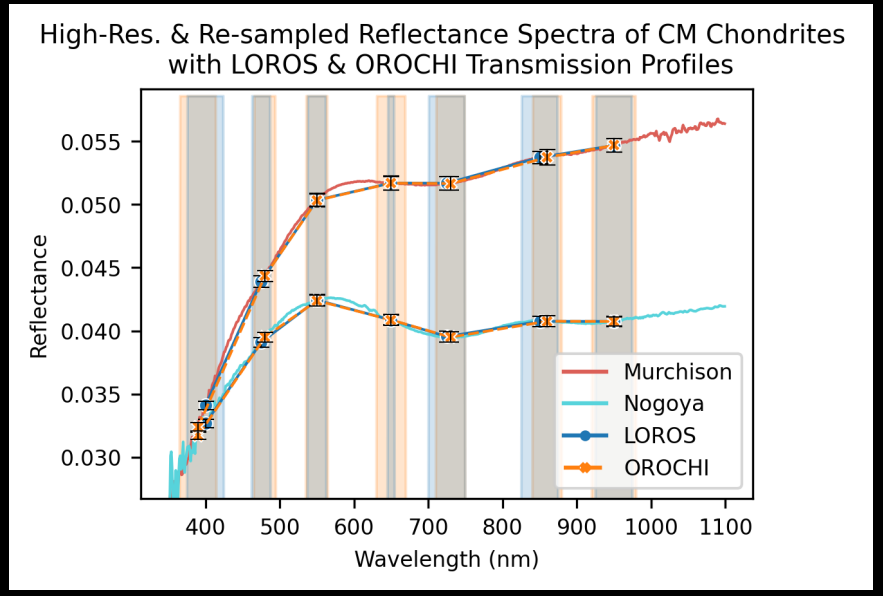
COTS Equivalent CMOS Sensor

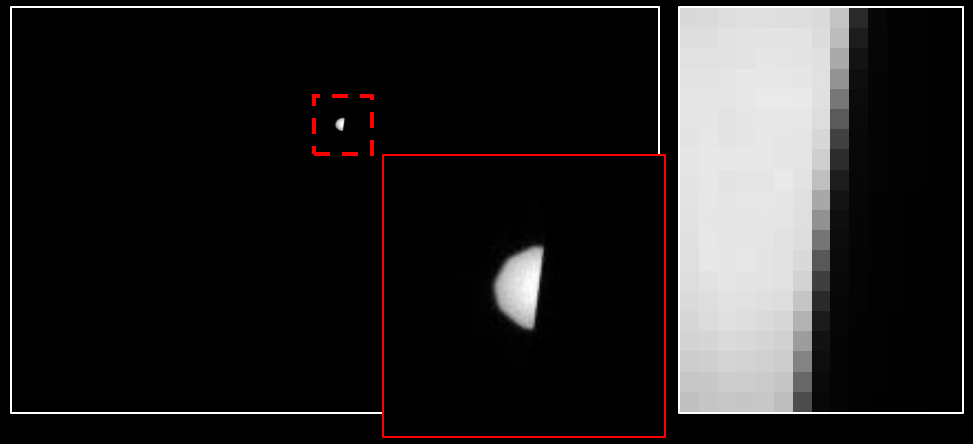
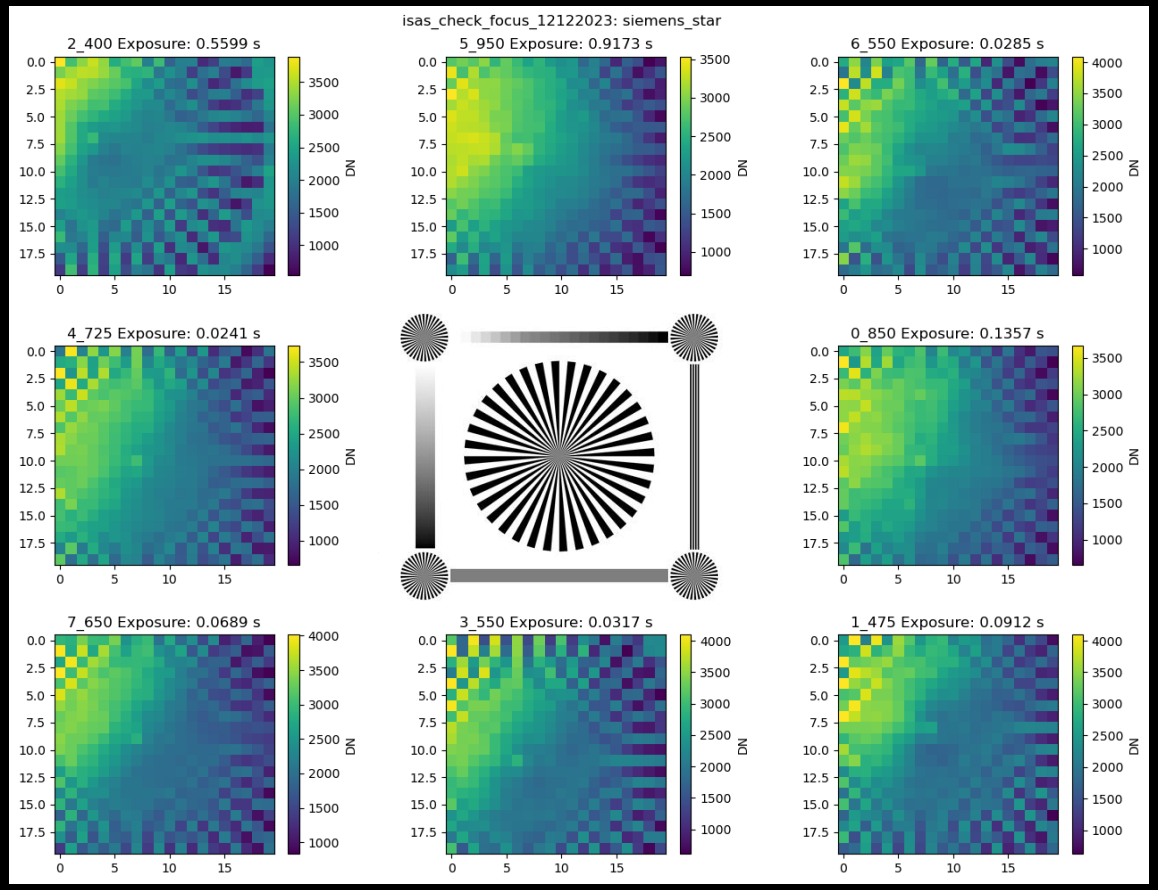
- SNR-Max*: 140
- SNR 100 expected at 51% pixel exposure (shot-noise)
- 2.3 MP, 19535 e- Saturation Capacity*, 5.86 µm pitch

COTS Equivalent Lens:

- F# 5.8 – 6.4, f-length 12.7 mm, iFoV 0.45 mrad,
- dFoV 55°
- Ground Sample Distance (GSD) @ 0.8 m: 360 µm

** gain tuned to 4.30 dB*



LOROS Optical Calibration

Validating equivalent performance of the Laboratory OROCHI Simulator (LOROS) with OROCHI