SWIMS-IFU
Development and engineering observation at Subaru telescope

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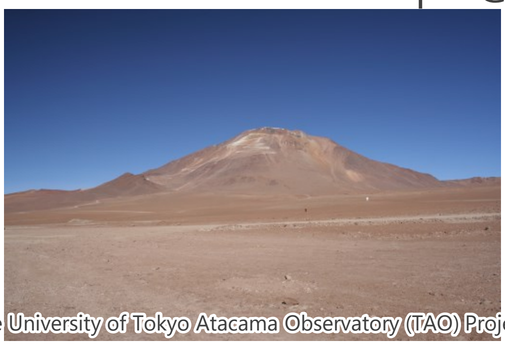
SWIMS

(Simultaneous-color Wide-field Infrared Multi-object Spectrograph)

Near-infrared Imager and spectrograph

For TAO 6.5 m telescope @ Chajnantor (5640 m), Atacama, Chile



The University of Tokyo Atacama Observatory (TAO) Project

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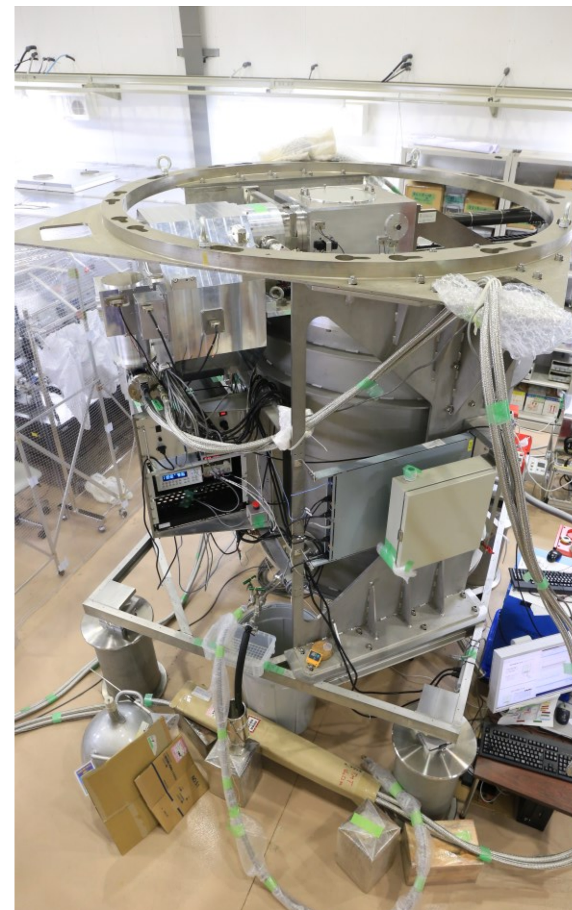
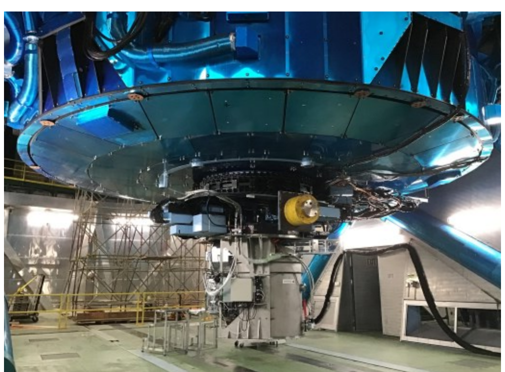


Also operated at Subaru telescope

- Engineering observations in 2018-2020
- Open-Use as a PI-type instrument in 2021-2022



SWIMS at Cassegrain focus
of the Subaru telescope

SWIMS

(Simultaneous-color Wide-field Infrared Multi-object Spectrograph)

Two-color simultaneous observation

0.9 – 1.4 (Blue arm) / 1.4 – 2.5 μm (Red arm)

4 HAWAII-2RG detectors on each arm
(Currently 2 detectors on each arm)

Wide field imaging

Φ9′.6 at TAO

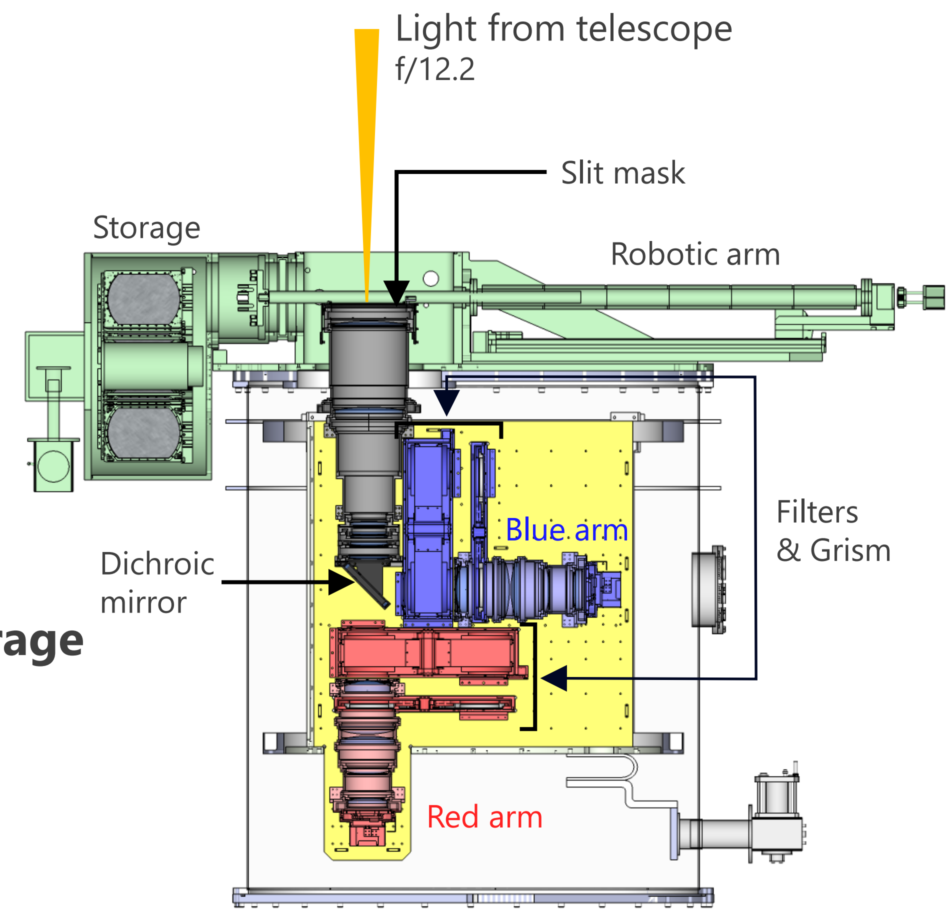
6′.7 × 3′.3 at Subaru
due to the number of detectors

Wide simultaneous wavelength coverage

0.9 – 2.5 μm simultaneous spectroscopy

$\lambda/\Delta\lambda$ ~ 1000

Multi-objects ~ 30 objects



Add integral field spectroscopy mode by developing image-slicer IFU

Basic Concept of SWIMS-IFU

Handle in the same way as slit masks

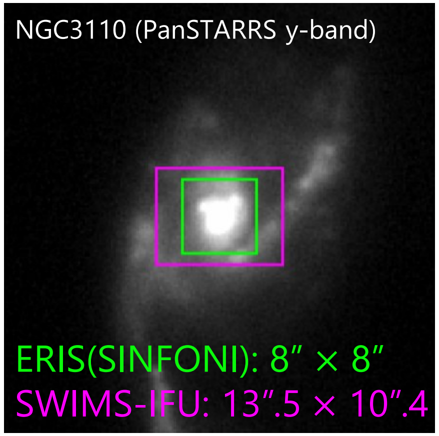
→ Compact (< 235 × 170 × 55 mm^3) and light in weight (< 1kg)

Specification

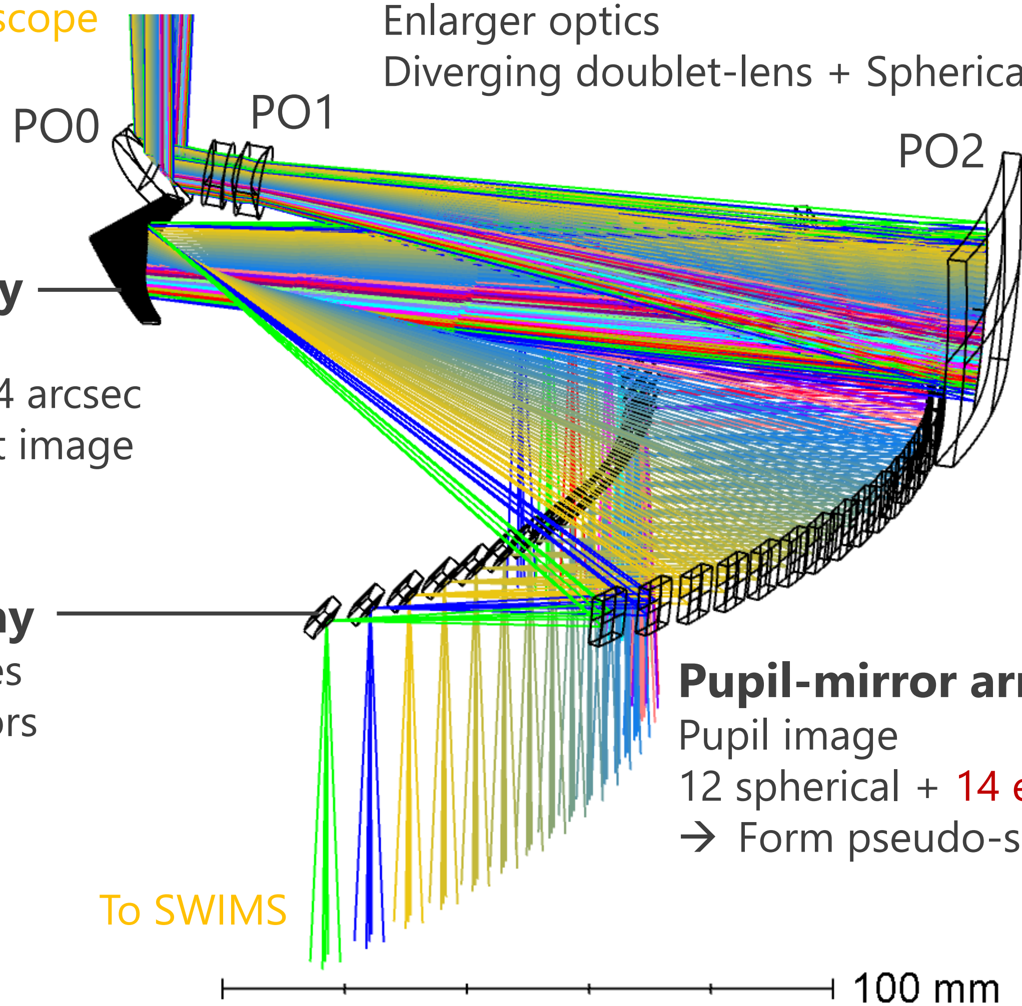
Larger FoV than existing NIR IFS instruments by optimizing for seeing limited observation
→ More than twice the area of the FoV of VLT/ERIS(SINFONI) of 8″ × 8″

Efficient observation of spatially extended object/area over the entire NIR wavelength

Field of View	**13″.5 × 10″.4** (13″.5 × 4″.8)
Slice Width x Number	0″.4 × 26 (12)
Wavelength Coverage	0.9 – 2.5 µm
$\lambda/\Delta\lambda$	Blue arm: 875 – 1500 Red arm: 750 – 1250



Optics of SWIMS-IFU



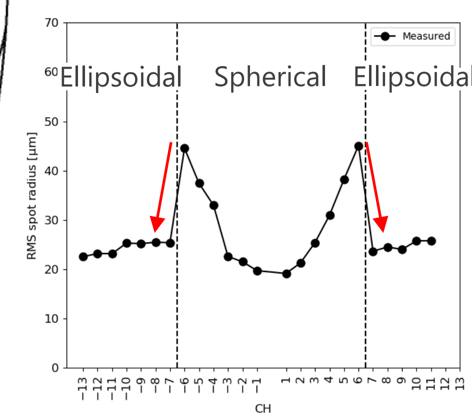
Enlarger optics
Diverging doublet-lens + Spherical mirror

Slice-mirror array
26 flat mirrors
0.52 mm width = 0.4 arcsec
→ Divide the object image into 26 regions

Slit-mirror array
Pseudo-slit images
26 spherical mirrors

Pupil-mirror array
Pupil image
12 spherical + 14 ellipsoidal mirrors
→ Form pseudo-slit images on slit mirrors

Image quality measured at Lab

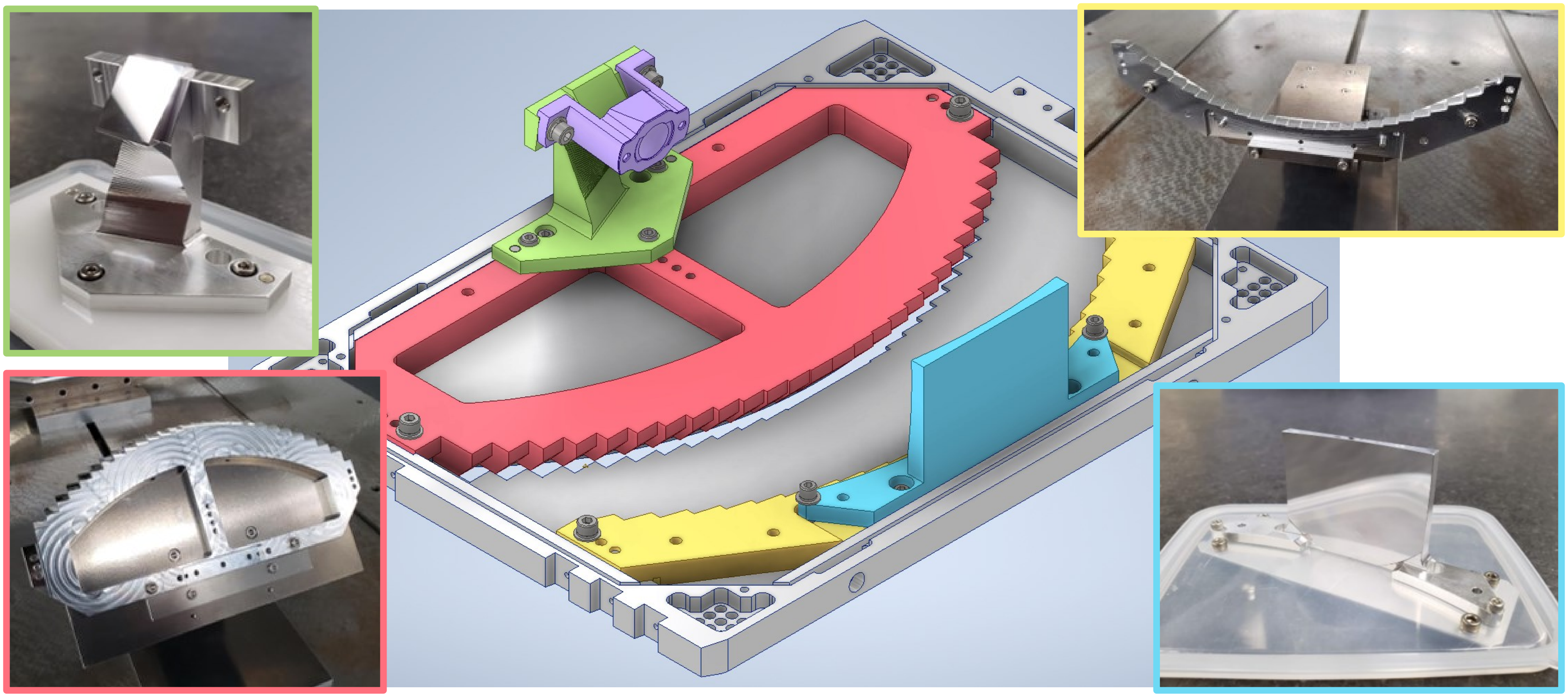


Development using ultra-precision cutting

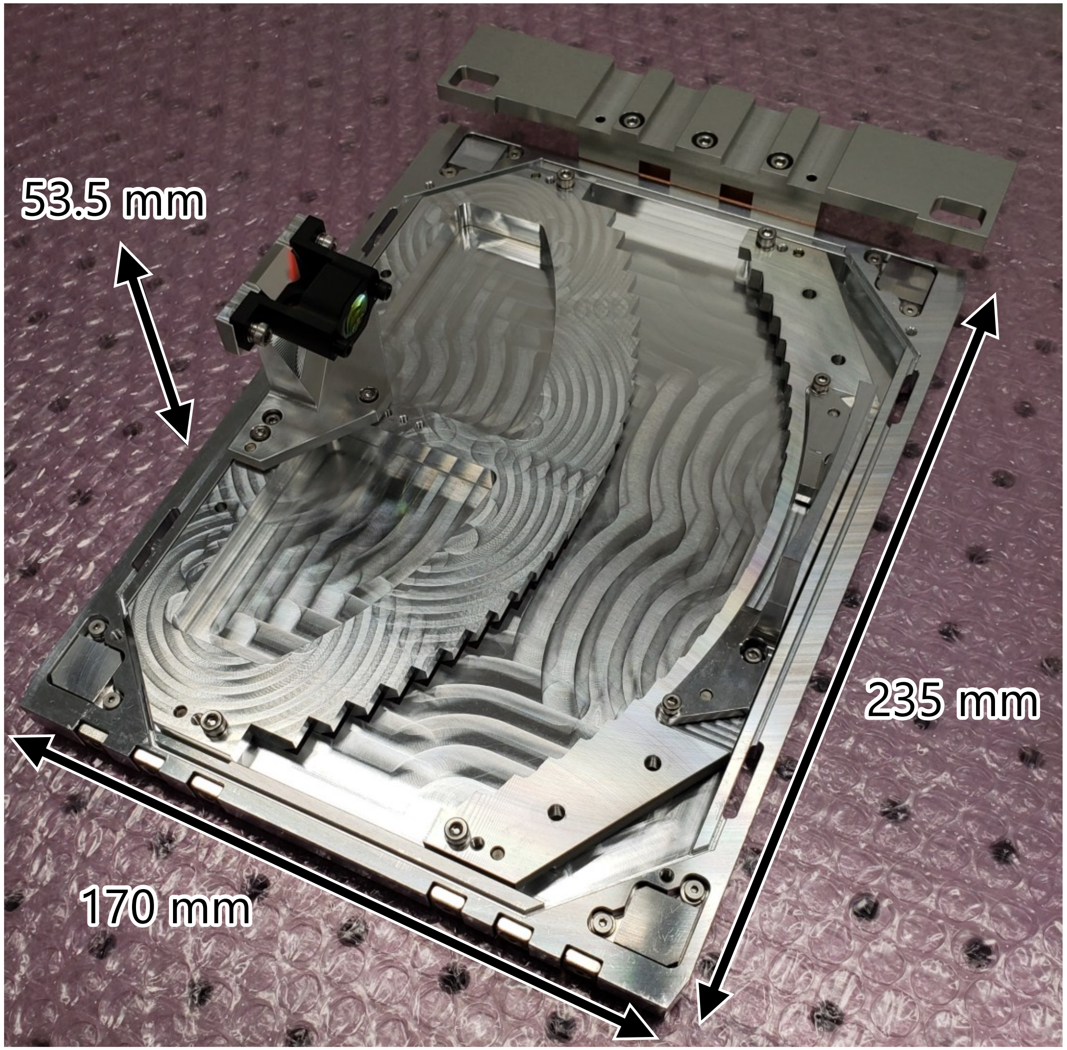
Ultra-precision cutting = Ultra-precision machine + Precise diamond tools

Simple assembly by monolithic fabrication & ultra-precision machined flat surfaces

High-quality mirror surfaces: Roughness RMS < 10 nm, Shape error P-V < 300 nm



Completed SWIMS-IFU



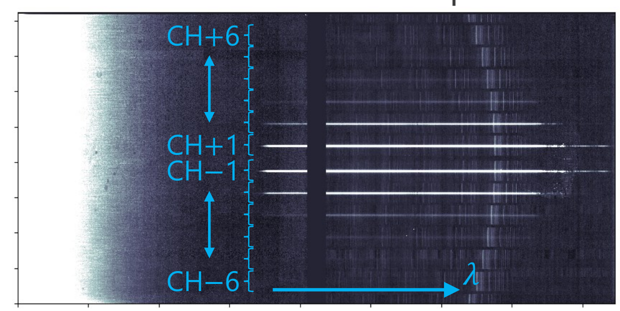
Observations at Subaru telescope

First engineering observation (S22A)	
Date	First-half night on Mar. 27, 2022
Weather	Clear
Engineering items	● Object acquisition ● Standard star (IFU imaging & spec.) ● Globular cluster (IFU imaging)

Second engineering observation & Open-Use observation (S22B)	
Date	Dec. 2nd and 3rd, 2022
Weather	Mauna Loa eruption

Standard star at the center of FoV

Blue arm: 0.9 – 1.45μm



Red arm: 1.45 – 2.5μm

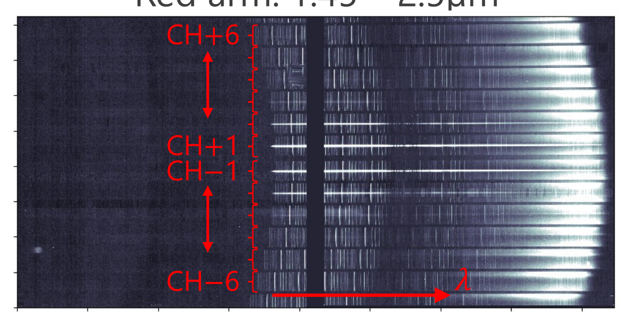
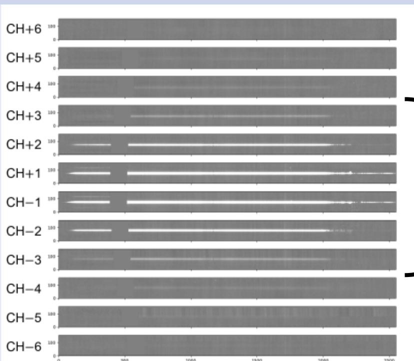


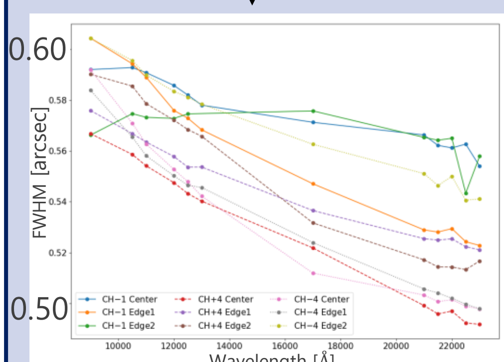
Image quality

~ 0.5-0.6 arcsec including seeing (seeing=0.45-0.49 arcsec): As designed.

Image quality at the slice mirror



Standard star spread across ~ 6 slices



→ **FWHM = 0.49 – 0.60 arcsec (Expected 0.50 – 0.53 arcsec)**

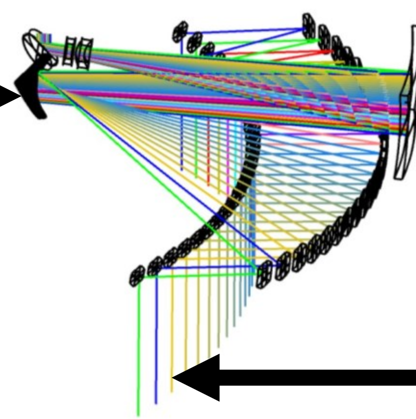
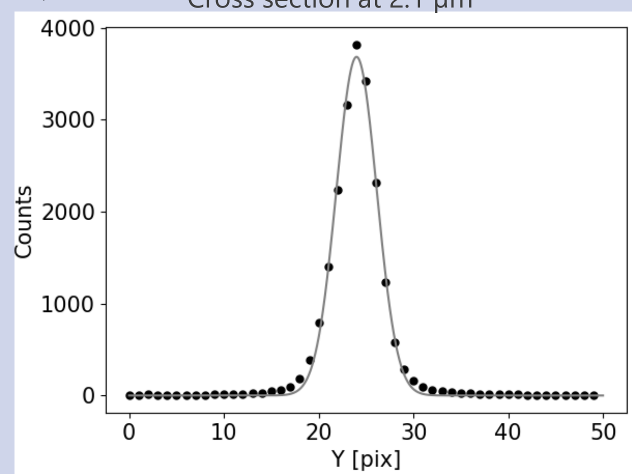


Image quality at the detector

Spatial extent of observed spectrum
= Final size of stellar image

Cross section at 2.1 μm



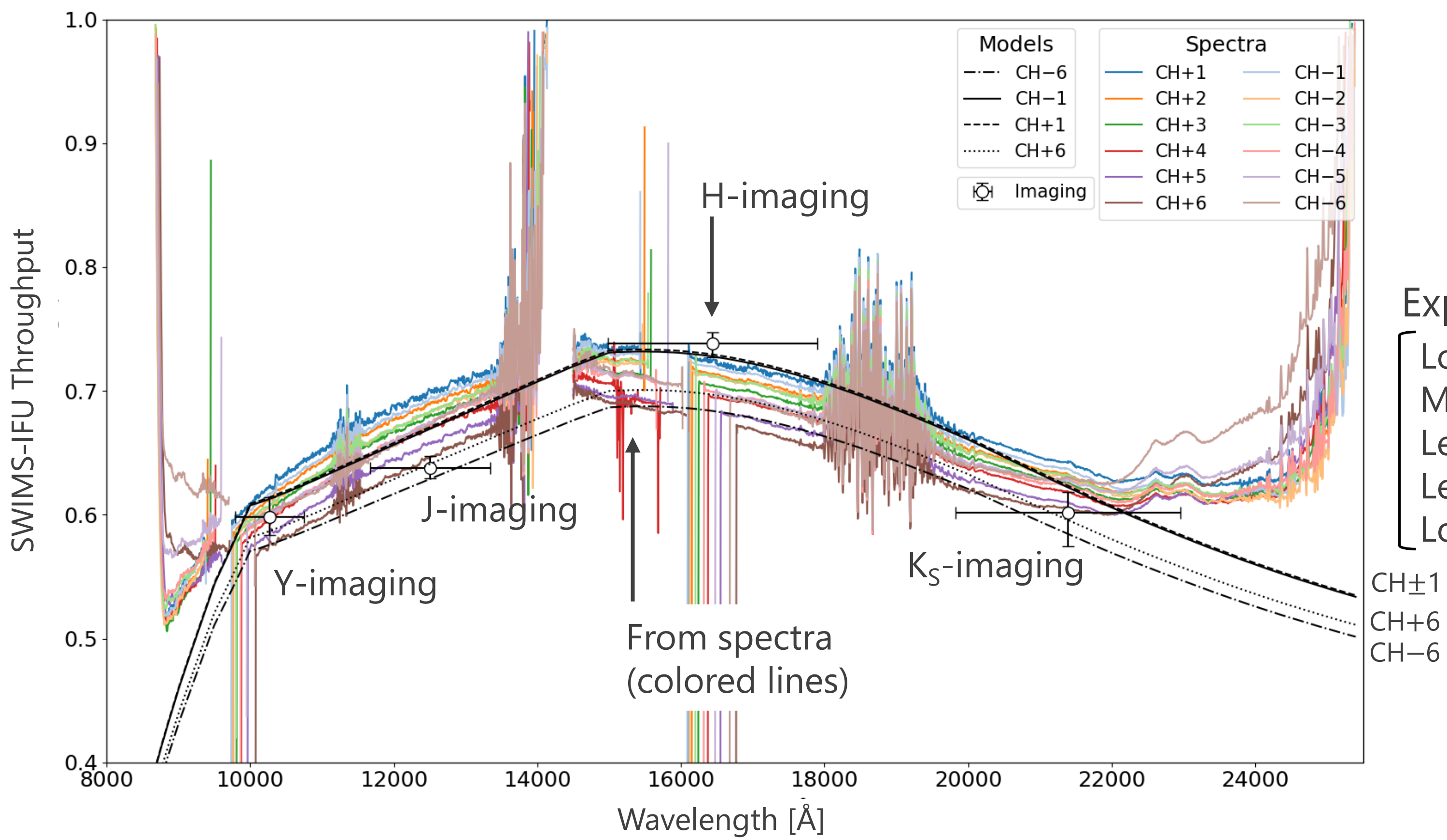
Measured at 1.0, 1.2, 1.6, 2.1 μm

→ **FWHM = 0.46 – 0.65 arcsec (Expected 0.53 – 0.56 arcsec)**

Throughput

Measured from dome flat data with and without SWIMS-IFU

→ Consistent with the expected value: 55 – 70 %



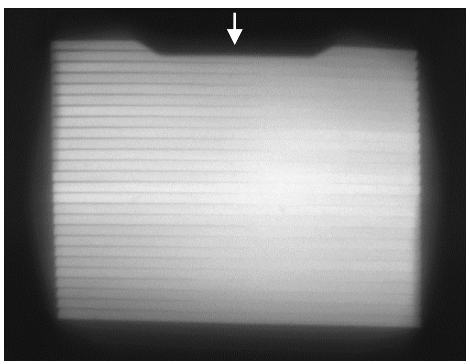
Expected values
- Loss by scatter
- Mirror reflectivity
- Lens AR coating
- Lens transmittance
- Loss by vignetting

Toward TAO 6.5 m telescope

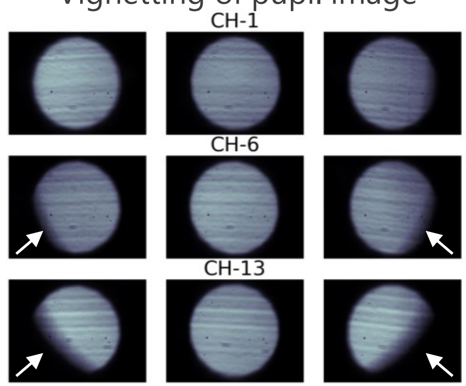
Fix some problems

1. Vignetting by PO1 lens → Redesign enlarger optics
2. Thermal stray light → Minimize entrance aperture + modify pupil position

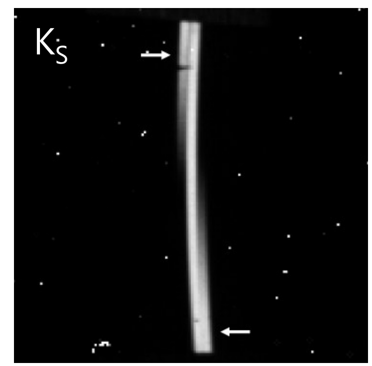
Vignetting of FoV



Vignetting of pupil image



Thermal stray light



Additional improvement to achieve better performance

1. Better image quality → Use aspherical surfaces
2. Better throughput → Change the mirror material and/or coating

Summary

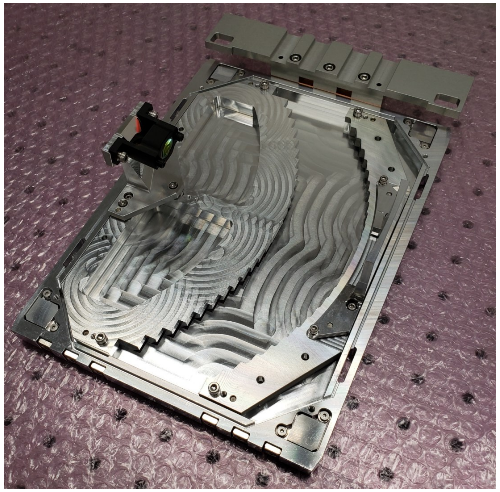
SWIMS-IFU is an image-slicer type IFU
with a larger FoV than existing NIR IFS instruments.

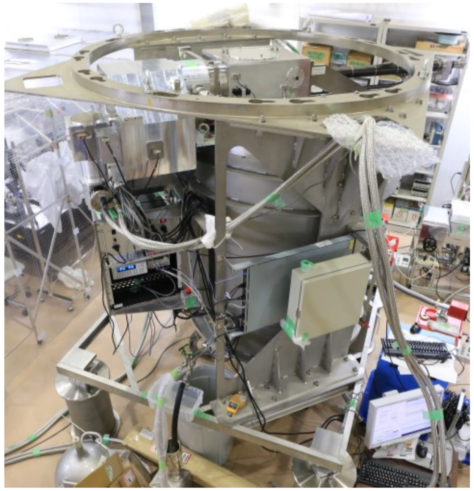
The optical design is compact and easy to assemble,
which is realized using the ultra-precision cutting technique.

The SWIMS-IFU at the Subaru telescope has been completed and
its performance was confirmed through engineering observations.

Development of a new SWIMS-IFU for the TAO 6.5 m telescope.

We would like to appreciate the support by Subaru telescope!!





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