# On-sky performances of SWIMS on the Subaru Telescope

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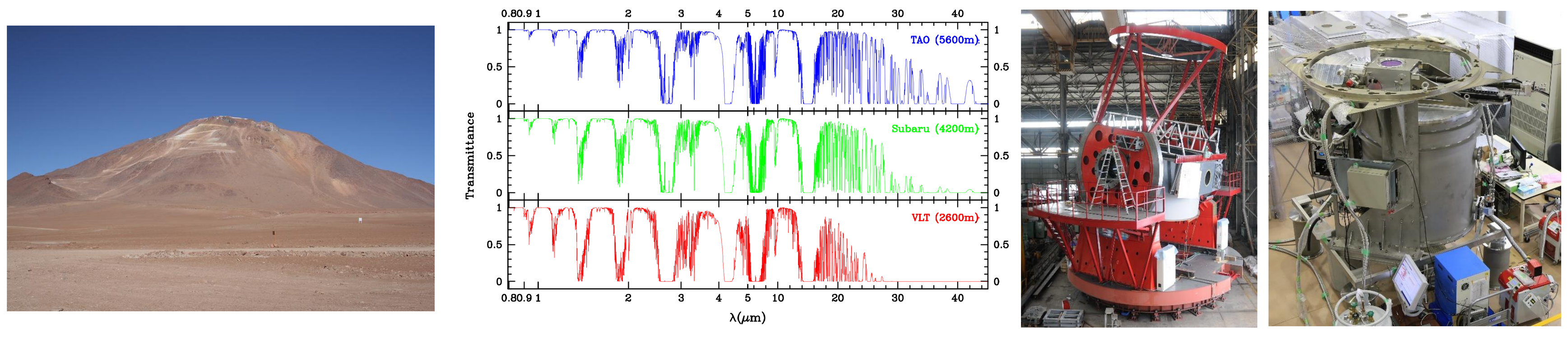
## 1. The University of Tokyo Atacama Observatory (TAO) Project and NIR instrument SWIMS:

The University of Tokyo Atacama Observatory (TAO) project (PI: Yuzuru Yoshii), promoted by Institute of Astronomy, the University of Tokyo, is now constructing a **6.5m telescope** at the highest site on Cerro Chajnantor (**5640m altitude**) in northern Chile.




a. Cerro Chajnantor, an altitude of 5640m, is located at Atacama plateau in northern Chile.
b. Simulated atmospheric transmittance by ATRAN, with PWV (Precipitable Water Vapor)=0.5mm (Cerro Chajnantor), 1.0mm (Mauna Kea), and 2.6mm (at 2600m altitude), from top to bottom.
c. The 6.5m telescope, preassembled in Japan.
d. The near-infrared instrument, SWIMS, for the 6.5m telescope.

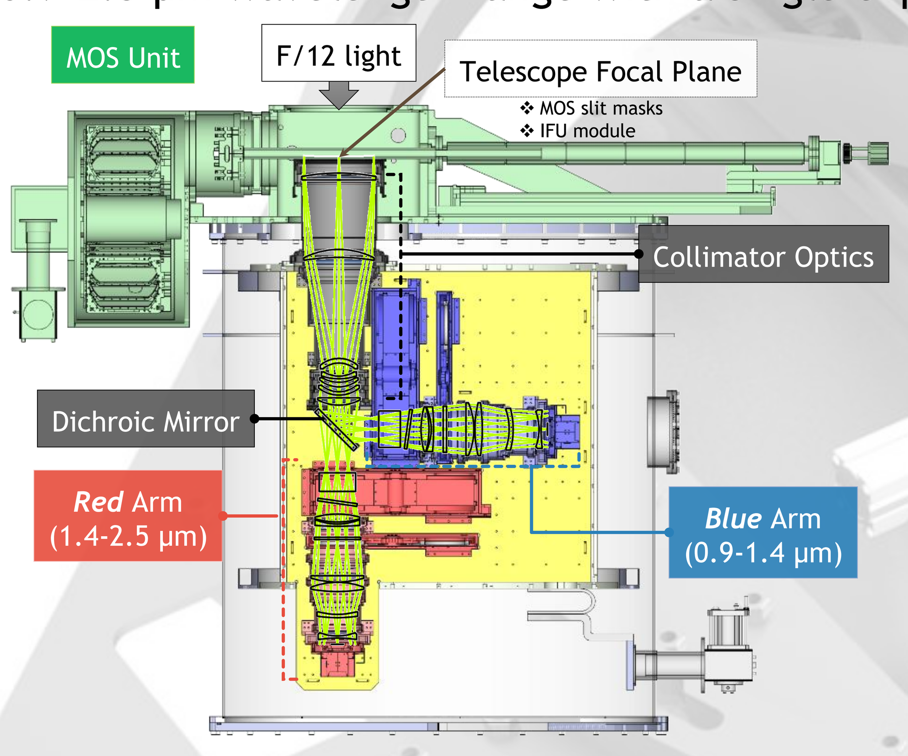
SWIMS (PI: Kentaro Motohara) is one of the 1st generation instruments for the 6.5m telescope, covering an almost continuous atmospheric window which appears in the NIR wavelength of 0.9 to 2.5 μm. To evaluate and optimize its on-sky performance, we have carried it into Subaru Telescope in 2017, and has conducted engineering observations.

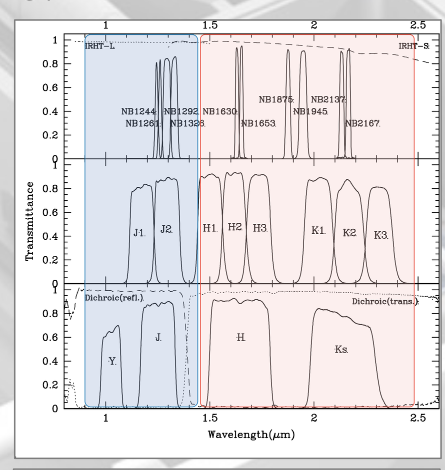
- ✓ Imaging first light in May 2018 and MOS first light in Jan 2019.
- ✓ Accepted to be used for open-use programs on shared-risk basis on the Subaru Telescope as a PI instrument from S21A until S22B.

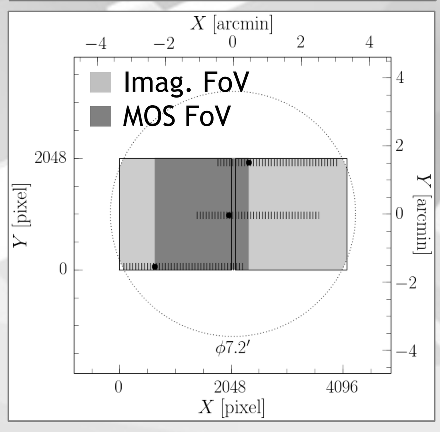
## 2. SWIMS Overview

See also http://www.ioa.s.u-tokyo.ac.jp/TAO/swims/?Summary_for_Subaru_S21B_CfP.

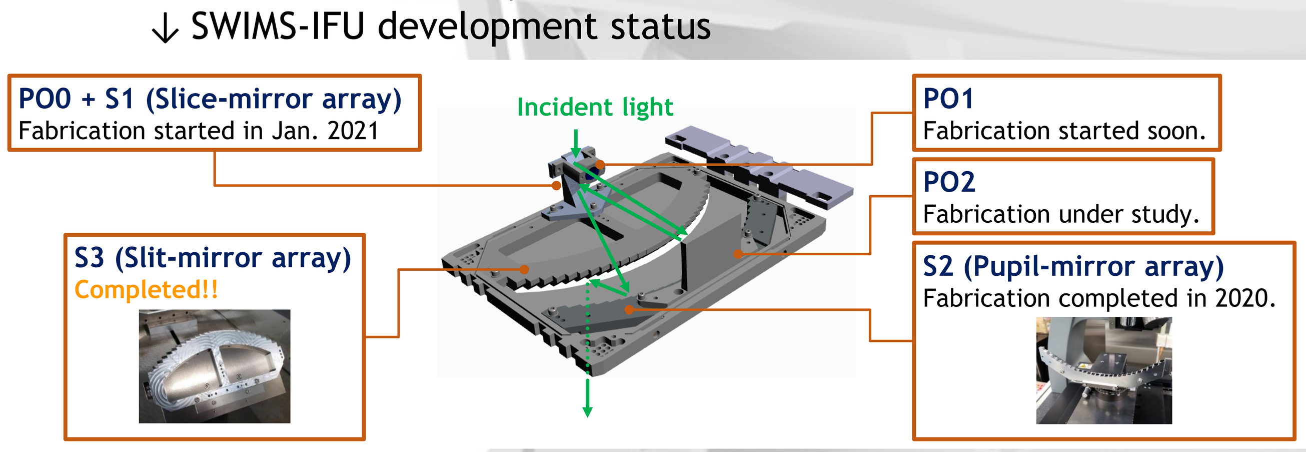
SWIMS covers the whole NIR wavelength of 0.9--2.5 μm with two optical arms (*blue* arm: 0.9--1.4 μm and *red*: 1.4--2.5 μm) and is capable of two-color simultaneous imaging or λ/Δλ ~ 1000 multi-object spectroscopy (MOS) at 0.9-2.5 μm wavelength range with a single exposure.



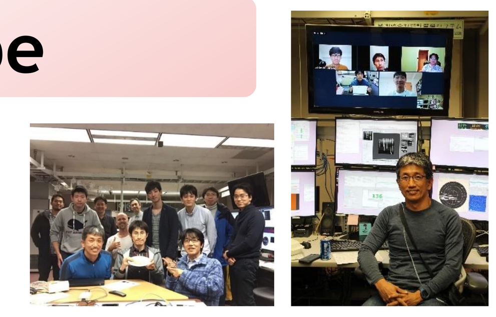

↑ Schematic layout of SWIMS
Transmittance curve of filters ↗
Layout of field-of-views→
↓ SWIMS-IFU development status




**Instrument Parameters**

| | |
|---|---|
| Observation Mode | Imaging<br>Multi-object spectroscopy(MOS)<br>Integral field spectroscopy (IFS) (lab test in FY2021) |
| Field of View | 6.7' × 3.3' (Imag.), 2.8' × 3.3' (MOS), 13.5" × 4.8" (IFS) |
| Spatial Resolution | 0.095"/pixel |
| Wavelength Range | 0.9-1.45 / 1.45-2.5 μm (*blue* / *red* arm) |
| Detector | HAWAII-2RG (two arrays/arm) |
| Filters<br>Broad-band (BB)<br>Medium-band (MB)<br>Narrow-band (NB) | <br>*Y, J, H, $K_s$*<br>*J1, J2, H1, H2, H3, K1, K2, K3*<br>*N1244, N1261, N1292 (Paβ), N1326, N1630, N1653, N1875 (Paα), N1945, N2137, N2167* |
| Grism | *YJ* (2.40 Å/pix, R ~ 700 - 1100 w/ 0.5" slit)<br>*HK* (4.57 Å/pix, R ~ 600 - 1000 w/ 0.5" slit) |
| MOS multiplicity | ~20 objects/mask (w/ 12" length per slit) |
| IFS parameters | 0.4" sampling/slice, 13 slicers |
| System Throughput | Imaging ~ 40%, Spectroscopy ~ 20% |
| Sensitivity (1hr, 5σ)<br>Imag. (φ1.0"aperture, 0.5" seeing)<br>Spec. (cont., R=1000, 0.5" slit, 0.6" seeing)<br>Spec. (line, R=1000, 0.4" slit, 0.5" seeing) | <br>*Y*=25.2, *J*=24.9, *H*=24.2, $K_s$=24.4 (AB mag)<br>*Y*=20.1, *J*=20.5, *H*=20.5, $K_s$=20.4 (AB mag)<br>*Y*=1e-16, *J*=5e-17, *H*=6e-17, $K_s$=6e-17 (erg/s/cm²) |

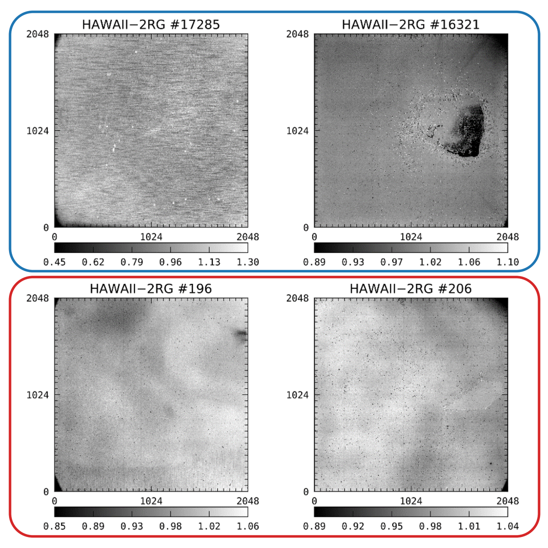
## 3. Performances on the Subaru Telescope

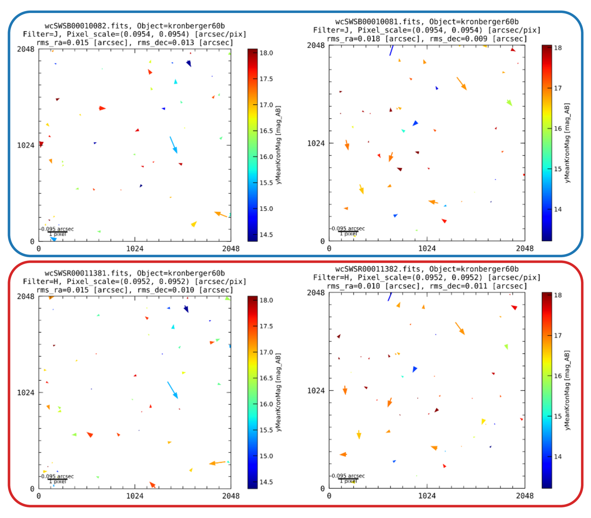


A total of 7.5-night engineering observations have been allocated in May-June 2018, Jan 2019, and Oct 2020.

### [Imaging performance]

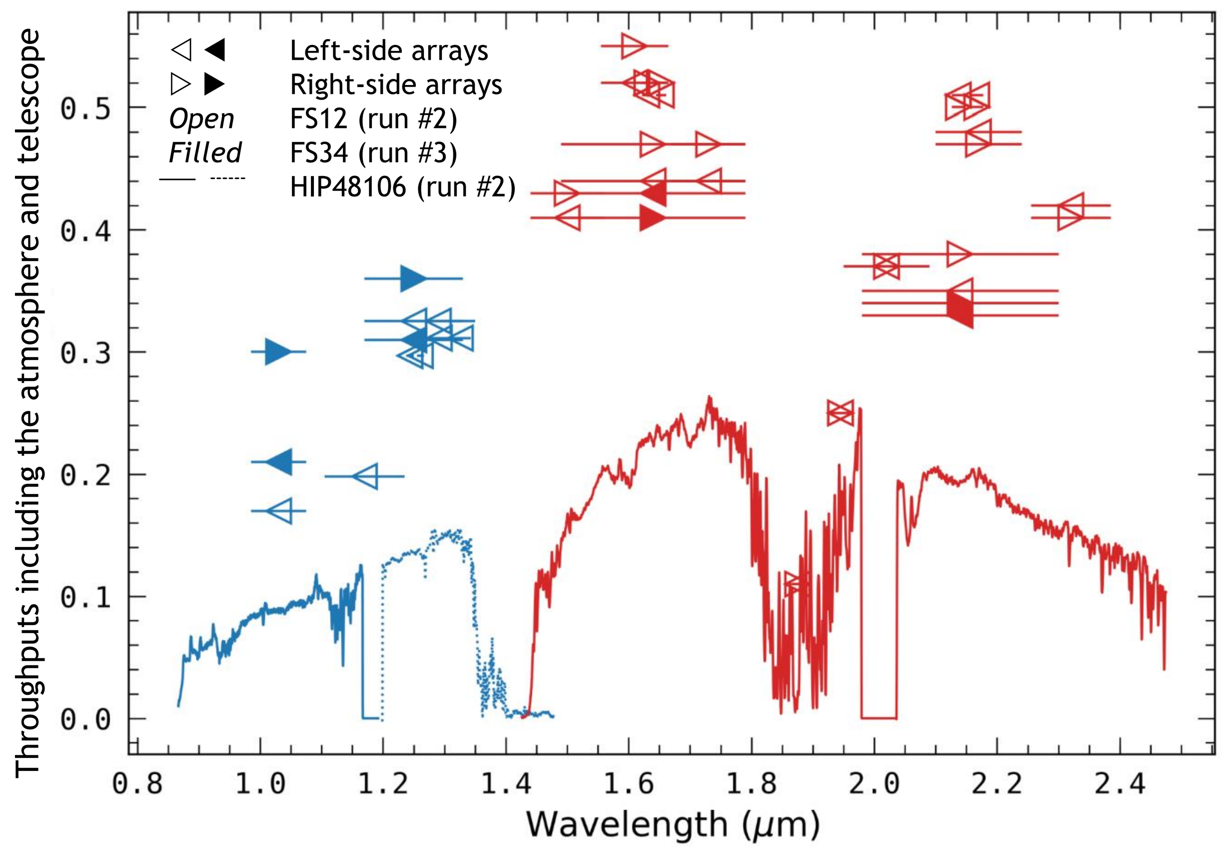
Dome-flat images (*J*, *H*) as rough array cosmetics →
Left (right) corners of the left (right) arrays are vignetted, as designed, by the collimator optics. The array #16321 has a large defect on the right half. Observers may avoid the defect by dithering in the imaging mode and slit-mask design in the MOS mode.



← Image distortion (*J*, *H*)
The residuals after "linear" astrometry (x/yshift, x/yscale, and rotation), show no (<< 1pixel) distortion patterns over FoV, as designed. Also, the astrometry gives a pixel scale of 0.095 "/pixel and FoV of 6.7' x 3.3'.

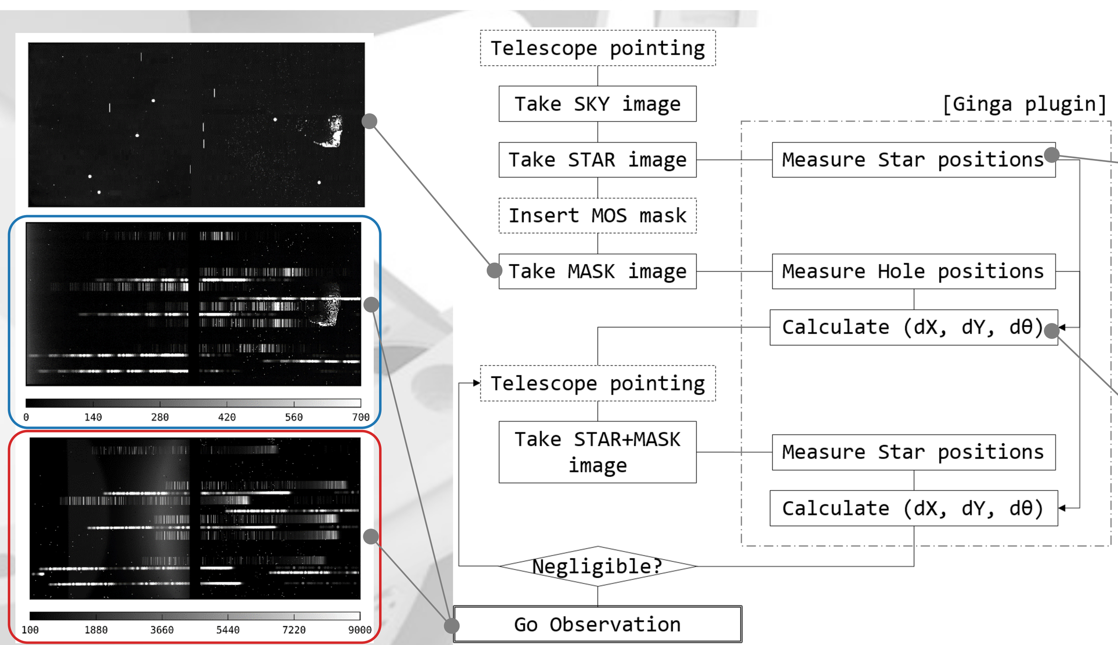
↓ Total throughputs (symbols)
The left array (#17285) on the *blue* arm (◁) has lower throughputs at shorter wavelengths, probably due to lower QE in addition to the lower telescope reflectivity.

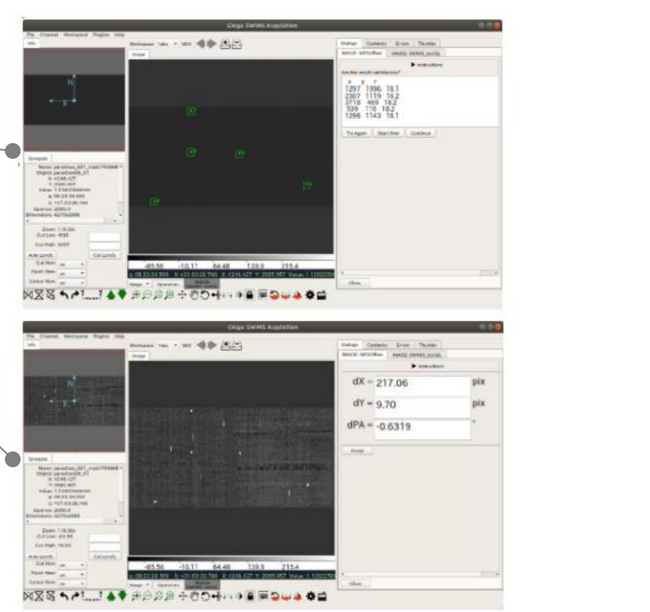



It has been confirmed that those have been improved by recoating the M2 of the telescope by a factor of ~1.2, as shown with ◀ .

### [Spectroscopic performance]

← Total throughputs (lines)
The similar trend (lower in bluer) as in the imaging mode is seen.
Note that the *blue* spectrum longer than 1.2 μm (dotted line) is obtained with an older array which has been replaced before the run #3, and some improvement on QE is expected.



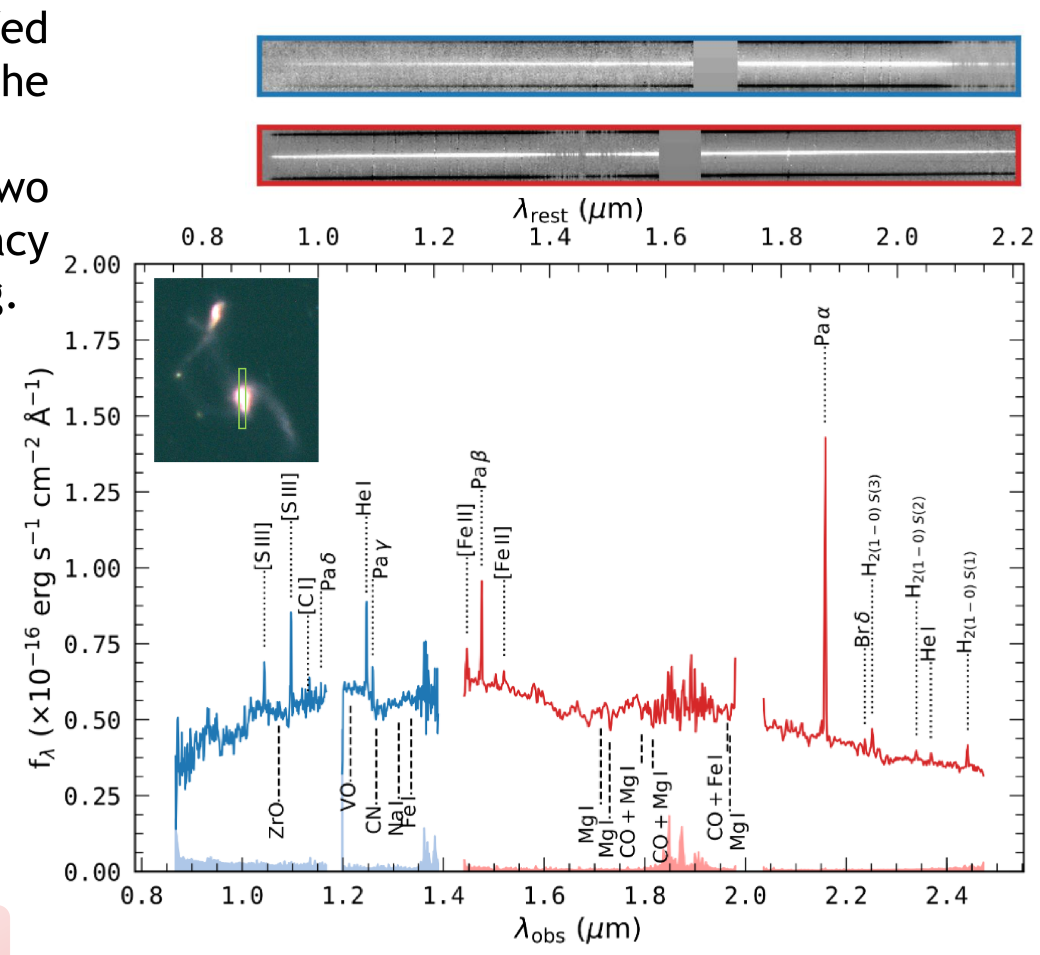



↑ MOS target acquisition sequence
(Similar to the sequence of MOIRCS)
1. Measure and compare positions of stars and alignment holes.
2. The resulting transformation matrix is fed back to the telescope pointing and the instrument rotation angle.

The process is usually converged with two iterations (~15min) down to pointing accuracy of ~1 pixel (~0.1") and rotation of ~0.05 deg.

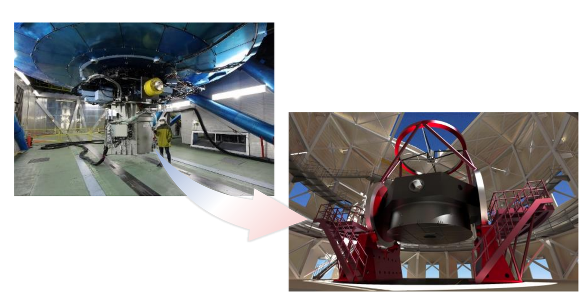
↑ MOS acquisition software
It runs on Ginga as a plugin, and the measurement of positions is interactively carried out.

Fully-extracted 1D spectrum →
of a star-forming galaxy ($K_s$ ~ 14 $mag_{AB}$) at redshift ~ 0.15 with on-source integration time of 2400s.
→Spectral sampling per resolution element: 2.40 Å/pixel, 4.57 Å/pixel
→Resolving power (Δλ/λ) with 0.5" slit: 810 (*Y*), 990 (*J*), 680 (*H*), and 890 ($K_s$)




## 4. Future Schedule

| | |
|---|---|
| 04/2021- | Open-use operation on the Subaru Telescope (S21A-S22B) |
| (Q2/2022 | Engineering first light of TAO 6.5m telescope) |
| Q4/2022 | Transportation to Chile |
| Q1/2023- | Full science operation on TAO 6.5m telescope |



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TAO PROJECT The University of Tokyo Atacama Observatory