K-REACH:

Development of a K-band Fiber-fed Spectroscopic System with SCExAO & IRCS

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INTRODUCTION

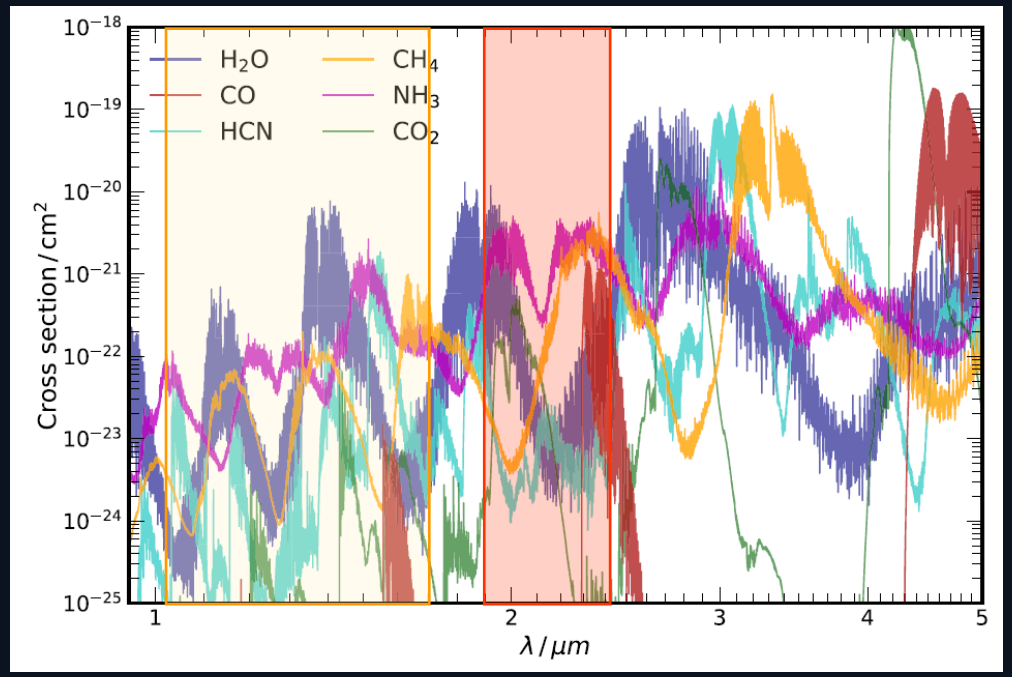
Scientific Motivation

- High-contrast + High-resolution spectroscopy is needed for atmospheric details of young gaseous exoplanets & brown dwarfs
- REACH enabled the spectroscopy in the YJH-band by the combination of SCExAO (ExAO) & IRD (Hi-res Spectrograph)
- K-REACH: expansion of High-contrast + High-resolution spectroscopy to K-band

Uniqueness

- Able to access strong molecular absorption in K-band, especially CO around 2.3 μm
- Simultaneous YJH-band spectroscopy with REACH (R=100000)
- Can be operated with/without coronagraph

REACH(YJH) K-REACH



Molecular cross-sections, T=1000 K, P=0.1 bar

Gandhi + 2020

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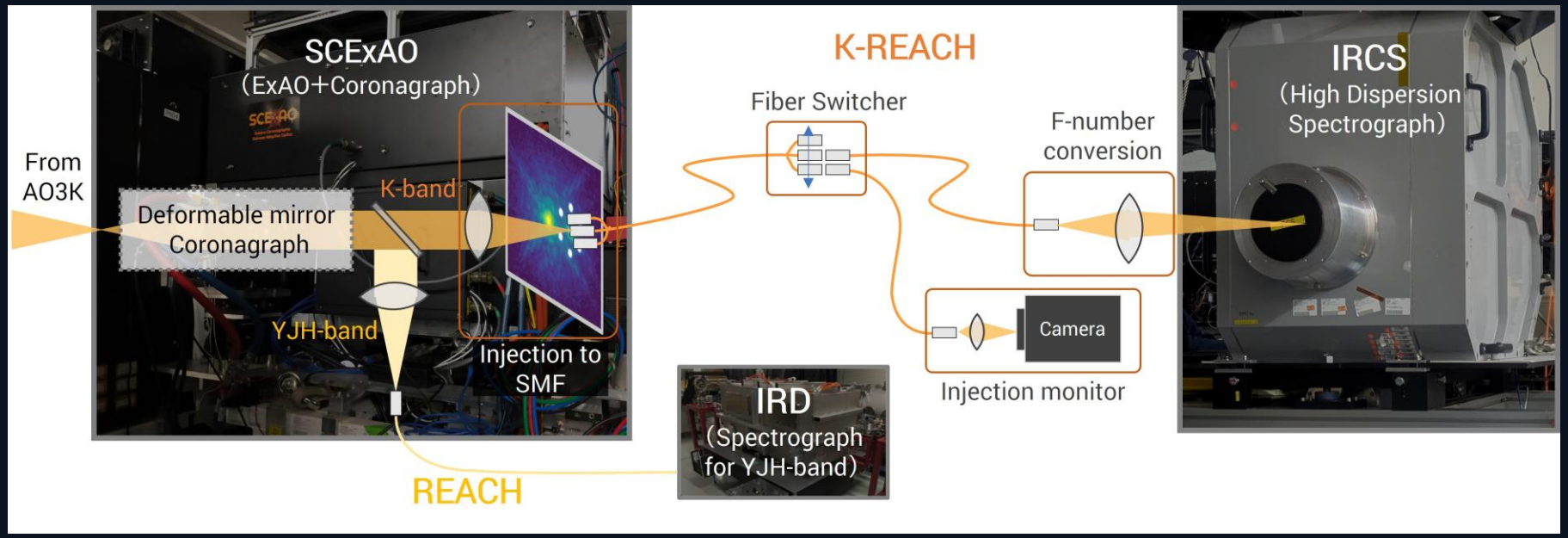
K-REACH Overview

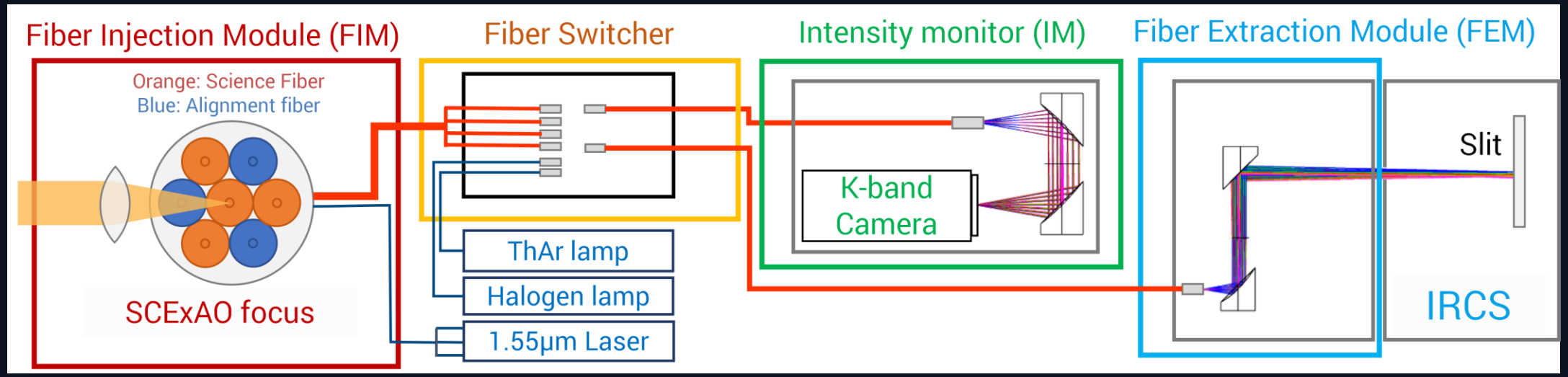


Key Specifications	
Spectral resolution	18,300 – 22,300
Spectral coverage	1.9-2.5 μm
Expected throughput	0.021 (0.1of IRCS+AO188)
Raw contrast	2e-3 @100 mas 1.5e-4 @500 mas 1.9e-5@1000 mas
Field of View	55 mas @2.2 um Can patrol 2x2 arcsec region

- SCExAO injects wavefront-corrected K-band light into an single-mode fiber(SMF) bundle at the focal plane
- The fiber delivers a diffraction-limited spatial mode to the IRCS spectrograph
- Monitoring module for optimized fiber injection throughput

OVERVIEW

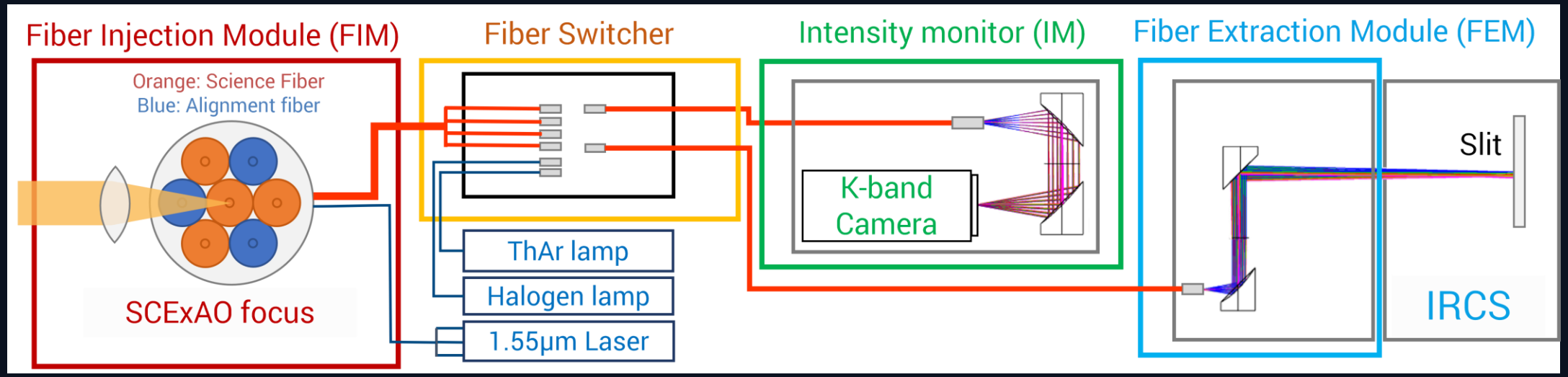
System architecture: Modules between SCExAO and IRCS

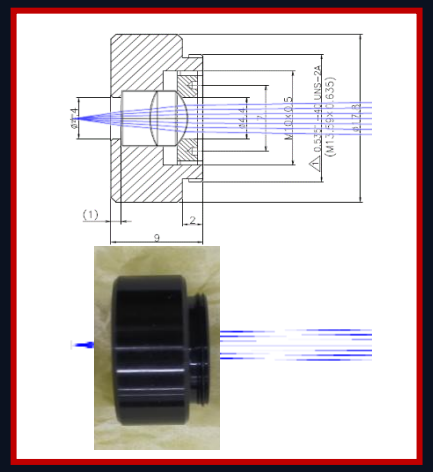


- Fiber bundle consisting of
  - Science fiber (central fiber)
  - speckle/background monitor fibers
  - Alignment fibers with 1.55 μm laser retro-injection
- Connect the science fiber in the bundle /calibration source fibers to the fiber going to IRCS/IM
- Measurement of intensity of light emerged from a fiber
- Feed it back to SCExAO to optimize fiber injection efficiency
- Optics converts the F number of light from the fiber and sends it to IRCS
- Fiber MFD (7.8um) with 2-pixel imaging at the echelle spectrometer focus

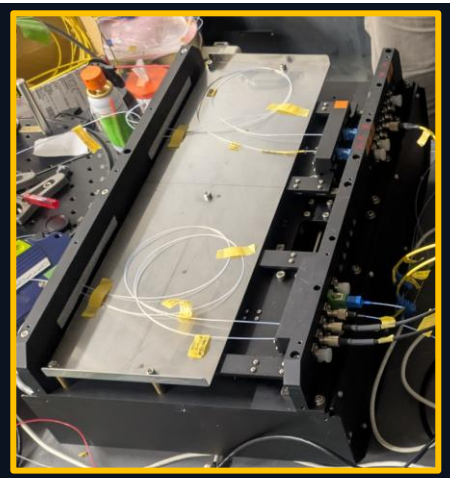
DEVELOPMENT

Development of each module

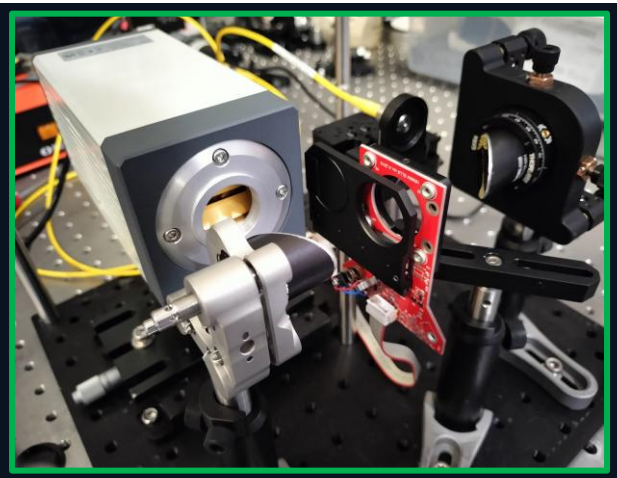




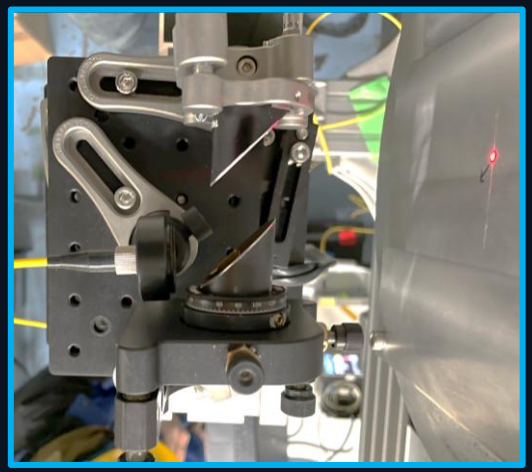
- Custom fiber injection lens
- Measured throughput of the fiber injection unit = 45% @2um



- Use the same model as the one whose performance has been demonstrated at REACH



- Re-image the SMF end using OAP mirror ×2
- Line camera allows monitoring of multiple fibers in the future



- Convert the F-number using OAP mirror ×2
- Output position & focus alignment by 5-axis motorized stage

DEVELOPMENT

Summit work & Eng. run timeline

2021 Apr Joined

Design& Assembly at Mitaka

2023 Jan

Fiber injection module
Intensity monitor module installation

2023 Jul

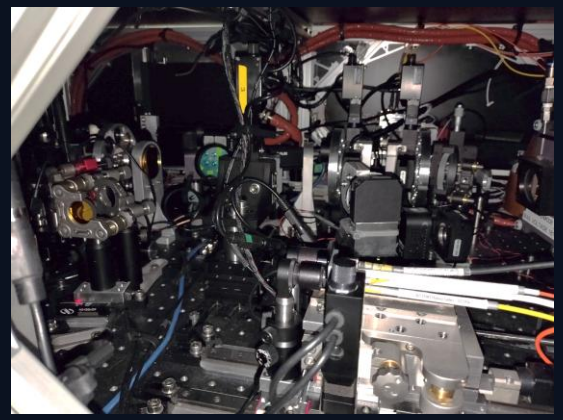
Upgraded monitor module installation

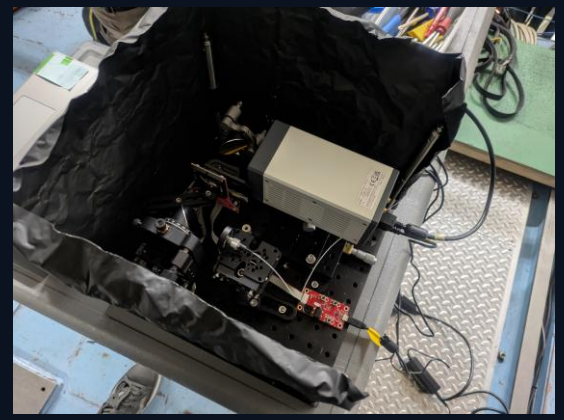
2025 Mar

FEM installation and output test

2025 Jul

Installation of all module/
On-sky test at Eng. run





- We developed the system module by module, started with the Fiber injection module
- Each module was tested at the summit before the on-sky demonstration of full system

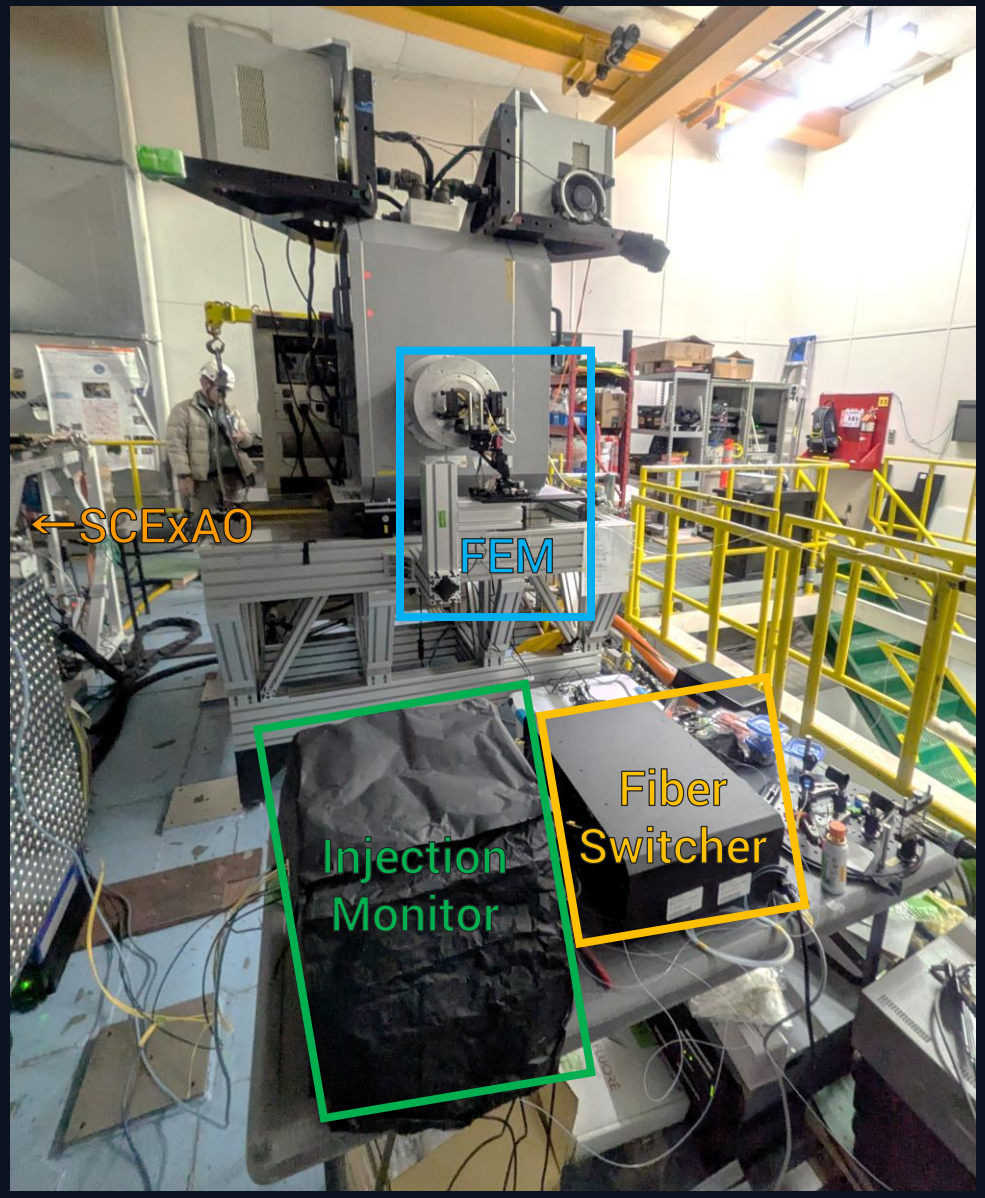
On-sky test at 2025/07 Eng. run

Date: 2025/July/08th 1st, 10th 2nd
Targets:

- Altair (K=0.24)
- HIP 84514A (K=2.0)
- Kappa And (K=4.6)

Mode: on-axis target fiber injection
Goal: verify K-band fiber injection and IRCS spectral acquisition

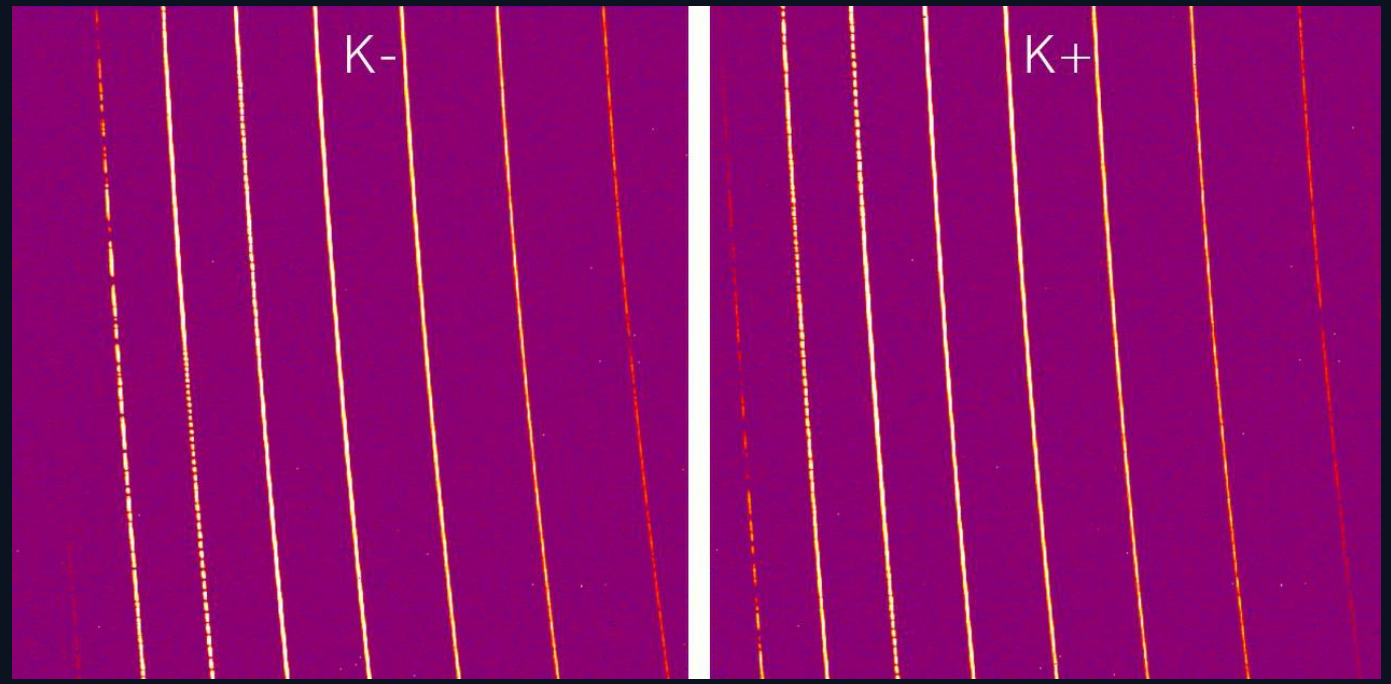
- All modules required for the science path were installed before the engineering run
- Once the Monitor module has measured the target flux and optimized the fiber injection, the science fiber was switched to FEM, and the spectrum was obtained with IRCS.



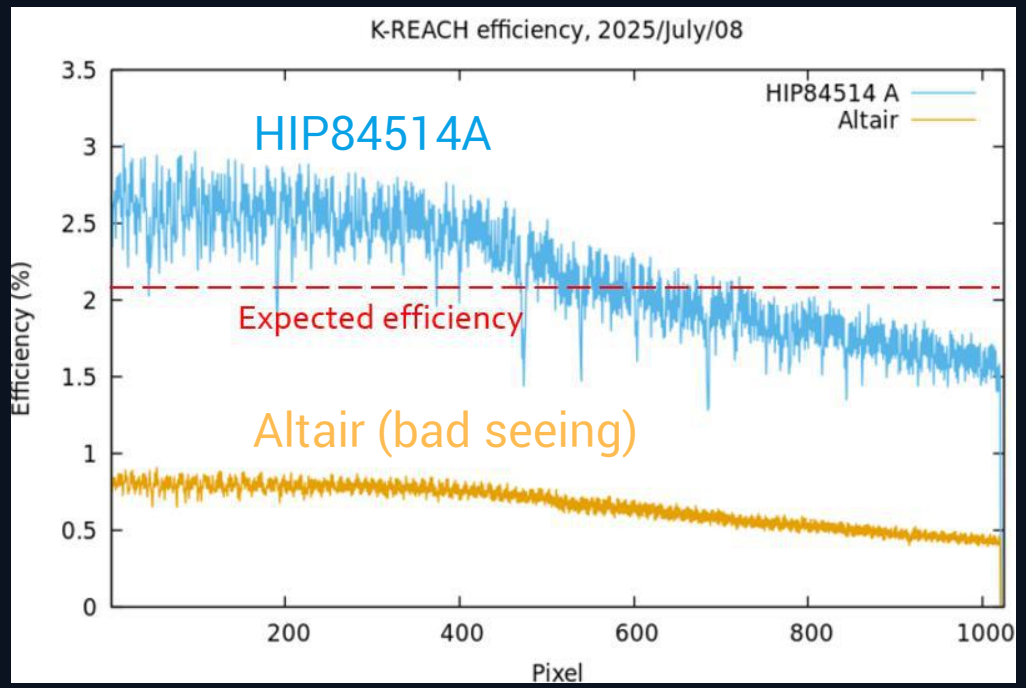
Result: On-sky K-band spectra and throughput

- We succeeded in observing the spectra of those targets
- Spectral resolution & wavelength coverage were comparable to standard IRCS observations
- The best throughput was 2.5%(HIP 84514A), consistent with the 2.1% expectation

→Future observation for fainter targets under a wider range of seeing conditions is necessary



K-band spectrum of Altair



Measured overall throughput

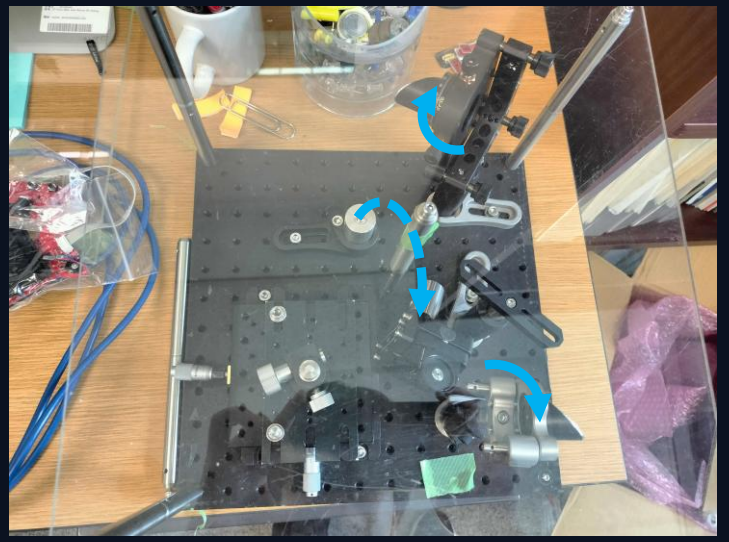
So, how was it working on the instrumentation at Subaru?

Rewarding things for me:

- Seeing our instrument operate on an 8-m telescope was a moving moment!
- Close collaboration with the SCExAO team, Subaru staff, and day crew was essential (I can't thank you enough)

Challenges I faced:

- (2021~2022) Remote communication due to the remaining impact of COVID-19
  →It took me a long time to understand the related instruments.
- The limited window of opportunity for the on-sky demonstration
  →Careful fallback planning is essential when a thesis project depends on limited telescope time
- Unexpected Damage to the optics during transport from Mitaka to Hilo
  → We can never pack too securely…



Summary and next step

Demonstrated

- The core K-REACH optical path was demonstrated on sky
- K-band spectra were acquired with IRCS through the SMF path.
- Best measured throughput was ~2.5%, consistent with the 2.1% expectation.

Future works

- Measure throughput for fainter targets and different seeing conditions.
- Precise injection for off-axis objects
- Simultaneous observations with REACH
- Install the FEM permanently in NBS without interfering with other observing modes.