

# Okayama Telescope Cluster

A Hub for Time-Domain Astronomy and Global Collaboration

Akito Tajitsu  
(Subaru Telescope Okayama Branch, NAOJ)

NAOJ Future Planning Symposium 2024  
Dec 5, 2024

**Okayama Branch** hosts the largest collection of optical/IR telescopes in Japan, including 3.8-m Seimei Telescope (Kyoto Univ.), and 188-cm telescope etc. It is also a valuable observation site in East Asian region.

## Advantage

- Abundant observation time  
○188cm, △Seimei
- Location  
Domestic access, Longitude on earth
- Optimization for ToO (○Seimei)  
Fast telescope, Quick instrument change

## Main science

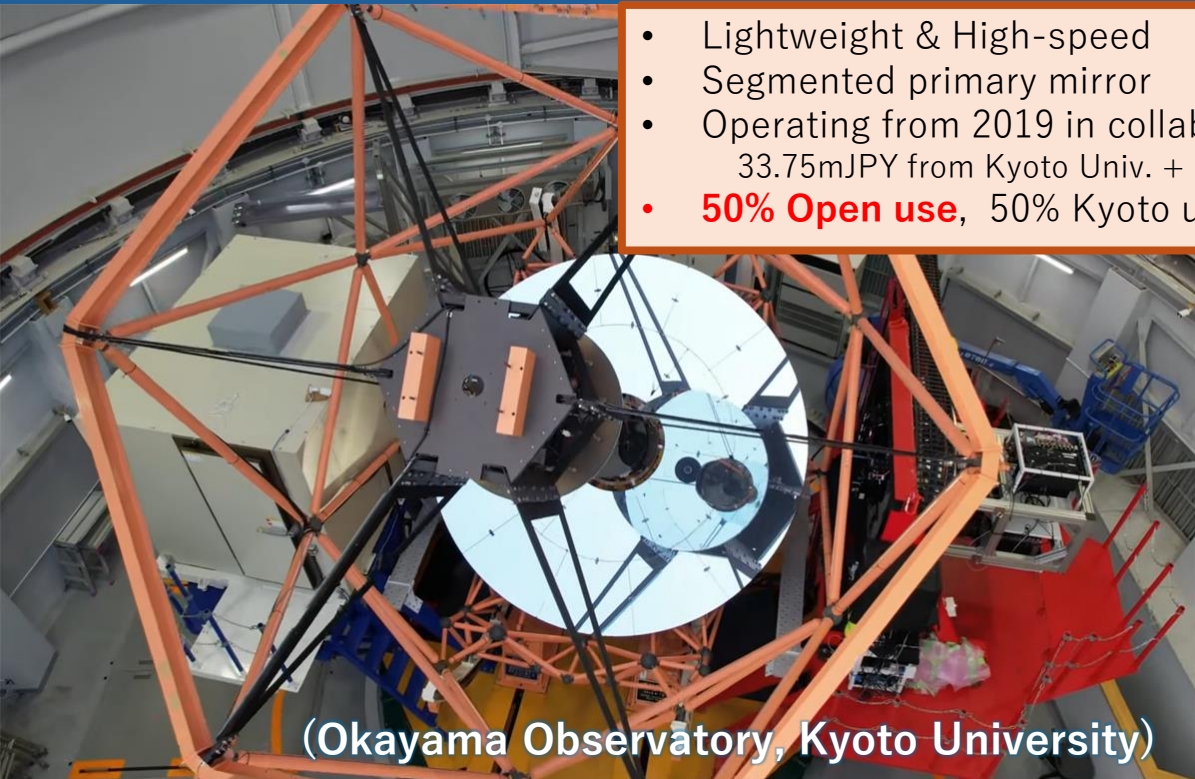
## Time-domain astronomy

- Rapid response obs. of transient events
- High-cadence and long-term monitoring  
exoplanets  
various explosive events...

Furthermore, the facility will aim to serve as a **center for research collaboration and personnel exchange across Asia**, including Indonesia, where *Seimei Telescope #2* is currently under construction.

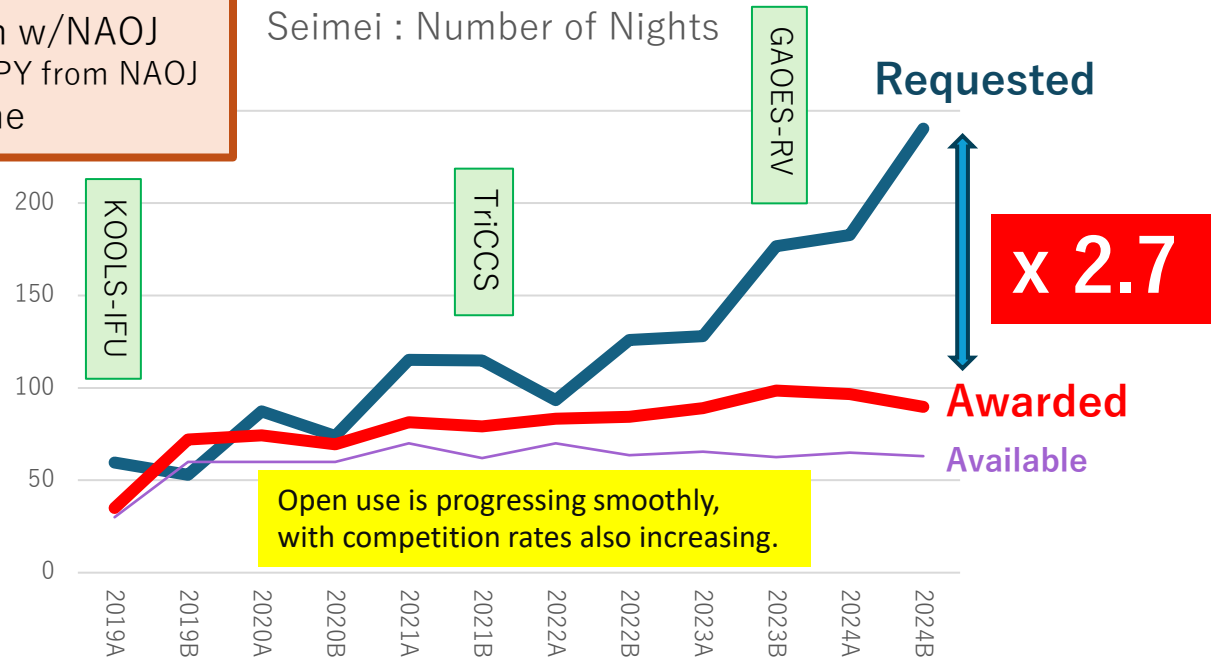


# 3.8-m SEIMEI Telescope



- Lightweight & High-speed
- Segmented primary mirror
- Operating from 2019 in collaboration w/NAOJ  
33.75mJPY from Kyoto Univ. + 33.75mJPY from NAOJ
- **50% Open use**, 50% Kyoto univ. time

Seimei : Number of Nights



(Okayama Observatory, Kyoto University)

- Full remote obs. (since Jan. 2024)
- Queue & Automatic triggered ToO are under testing.

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## KOOLS-IFU

Optical Low-dispersion Spectrograph with Integral Field Unit



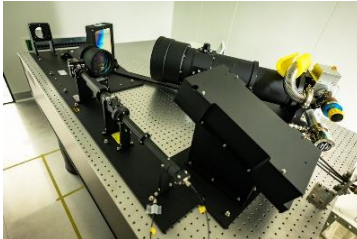
## TriCCS

High-speed Tricolor CMOS Camera and Spectrograph



## GAOES-RV

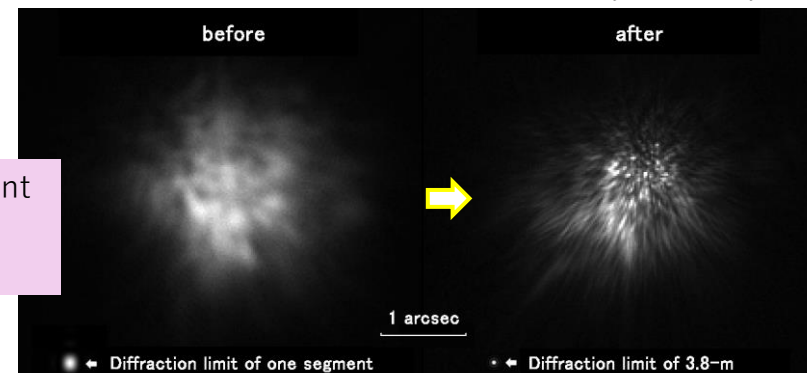
High-dispersion Echelle Spectrograph for RV measurement



©Okayama Observatory, Kyoto University

Changes to each instrument can be completed within a minute.

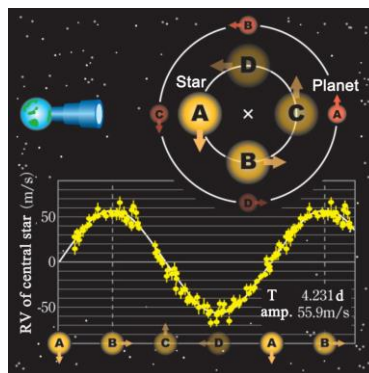
Succeeded for co-phase adjustment to get speckle image (2024.7)  
→ AO w/segmented mirror





Dec. 2, 2024

- Operating through an agreement between NAOJ / Tokyo Tech (Science Tokyo) / Asakuchi-city).
- Based on the fees paid by telescope users.  
**No operation fees from NAOJ budget**
- Operation has been suspended from Sep 2022 by dome trouble, but **it is expected to be resumed soon.**

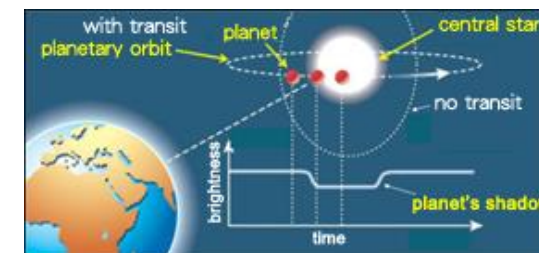


## Doppler search w/HIDES-F

- From early 2000s, **more than 50 planets** discovered using I2-cell on the high dispersion spectrograph (HIDES).
- The planets discovered account for 30% of the world's discoveries in giant stars.
- Extension planned to smaller and farther planets for searching solar-system analogues.

## Transit measurement with MuSCAT

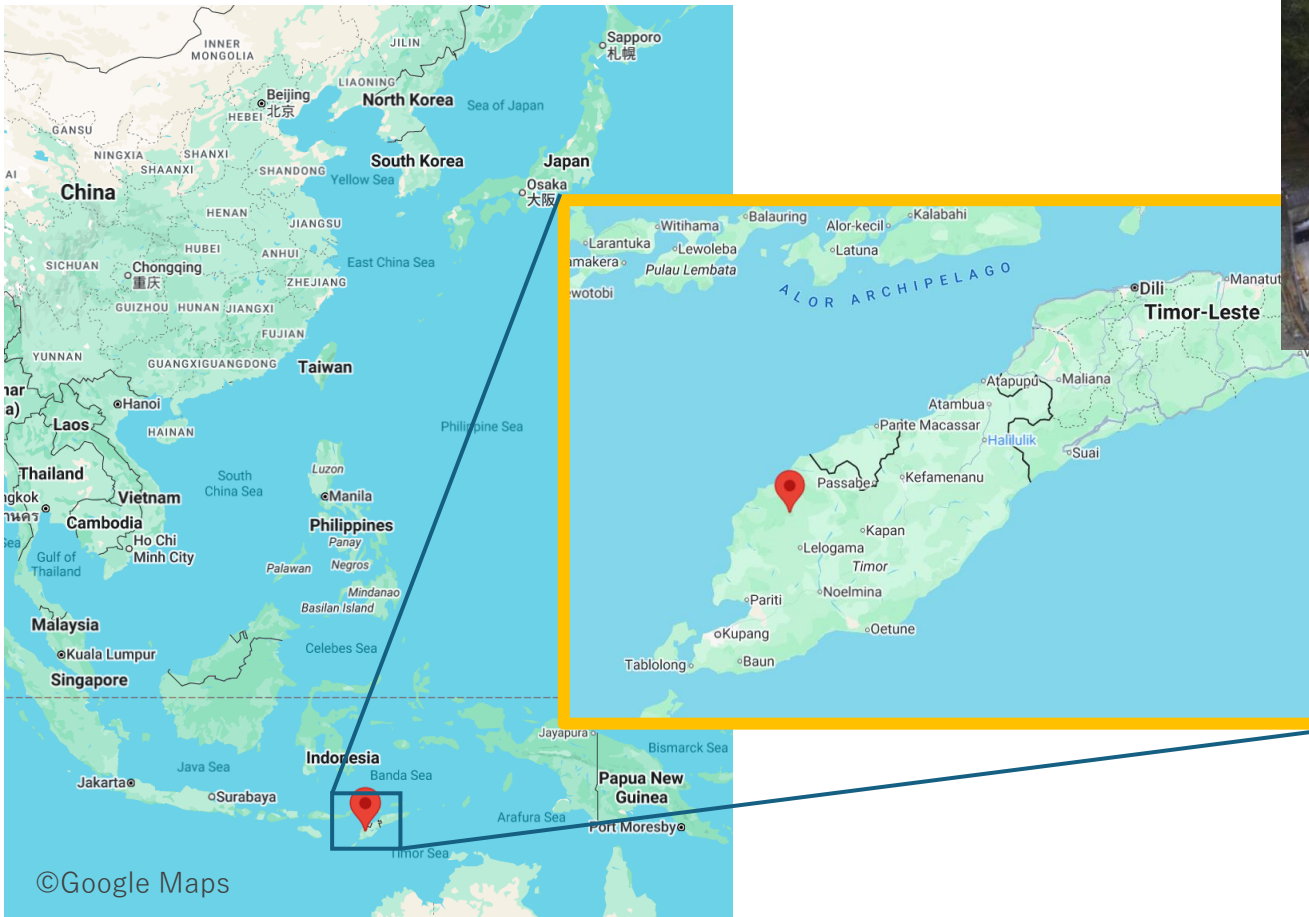
- **Photometry accuracy of ~0.2mmag**
- A worldwide network built with 3 identical instruments for **24-hr continuous observation.**
- Follow-up of PLATO be conducted.



## Development base for New technologies "Astro-comb"

- **Joint development with AIST** since 2014.
- RV measurement accuracy  
**Several tens of cm/s** (theoretical limit <10 cm/s)  
[Conversion of spectral image drift on the detector into RV]
- Improvement of the spectrograph for that high precision also on-going.
- The results be applied to **Subaru and TMT.**

# Indonesian New Telescope



©Observatorium Nasional Timau (BRIN)

Indonesia is currently constructing an identical model of SEIMEI telescope in Mt Timau of West Timor.

- $9^{\circ} 35' 50.2''$  S,  $123^{\circ} 56' 48.5''$  E
- Alt. 1300m
- Seeing  $\sim 0.6''$
- Seimei development team in Kyoto-univ. is collaborating w/Indonesia.
- User-level discussions have already begun at the 2024 Seimei UM.

There is a strong desire for Japan to provide telescope and observational instrument technology.

SEIMEI users in Japan have expressed a strong demand for time-sharing arrangements due to the advantages of observing the southern sky under favorable conditions.

An excellent opportunity to establish a start point for international collaboration targeting not just the EA region but the **entirety of Asia**.

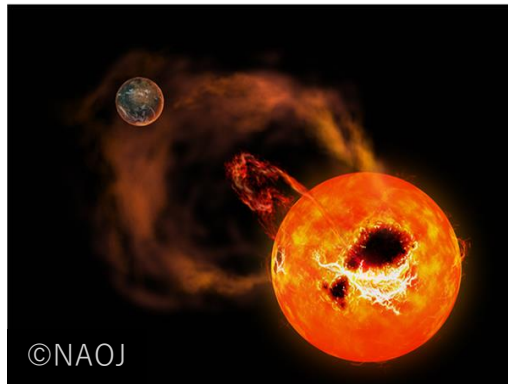
# Scientific goals①

As this involves future plans for **an open-use facility already in operation**, it is difficult to narrow down the "scientific goals" to a single focus.

However, if one were to identify a primary scientific theme, it would likely center around **time-domain astronomy**. Below are some key science topics expected to take the lead:

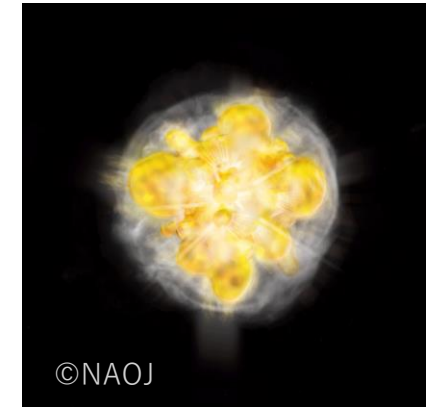
## [Transient Objects : Supernovae, Novae, GW-counterparts etc.]

Rapid (spectroscopic) observations as soon as possible after discovery will be a key focus. Regular observations of this kind aim to enhance our understanding of the circumstellar material (CSM) surrounding progenitor stars.



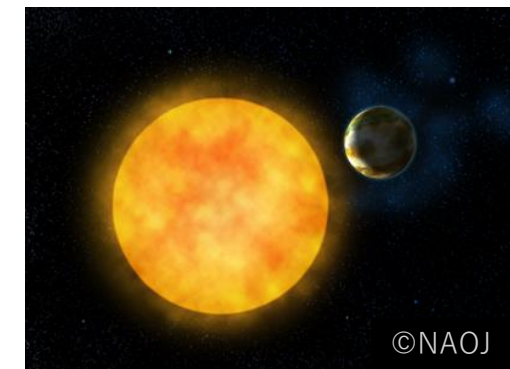
## [Stellar Superflares]

Recent studies have revealed that superflares can occur even on solar-type stars. Future observational research will aim to clarify both the conditions under which superflares arise (e.g., the role of dark spots and other stellar phenomena) and their consequences (e.g., the mass and energy of plasma ejections and their impact on the surrounding environment).



## [Exoplanets]

Using an innovative spectrograph that combines ultra-high spectral resolution of up to 300,000 with cm/s-level ultra-precise radial velocity measurements, the facility will take on the challenge of discovering Earth-like planets.



## ▼ Human resource development

As the largest group of optical telescopes in Japan, fostering talent through shared use is also a critical mission. To support this, it is essential to maintain and improve observational instruments with international competitiveness.

## ▼ Technology development and transfer

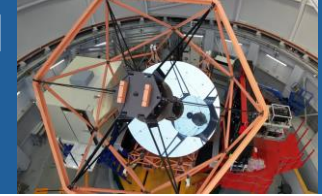
As Japan's largest and only segmented mirror telescope, SEIMEI is developing unique control technologies. Additionally, it is collaborating with other domestic institutions on “Astro-comb” technology development using the 188 cm telescope. These technologies and the skilled personnel involved will be transferred to contribute to large-scale telescopes such as Subaru and TMT.

## ▼ International collaboration

We have already initiated international personnel exchanges. The “SEIMEI-2” telescope in Indonesia is currently under construction and will soon enter its commissioning phase. Indonesian counterparts are seeking knowledge and technical expertise from Japan in all aspects, including telescope control and instrument development, leading to an increase in visits and collaborative efforts.

Furthermore, the Indonesian site is highly attractive to Japanese users.

This presents an opportunity to establish a hub for talent exchange in Asia, a region with relatively few large telescopes compared to global standards.



# MIDSSAR (Mid Dispersion Spectrograph for Stellar Activity Research)

Medium-resolution spectrograph dedicated to H  $\alpha$  and Ca II HK lines, capable of simultaneous observation with GAOES-RV (510-590nm).

*Ongoing w/JSPS fund (50mJPY)*

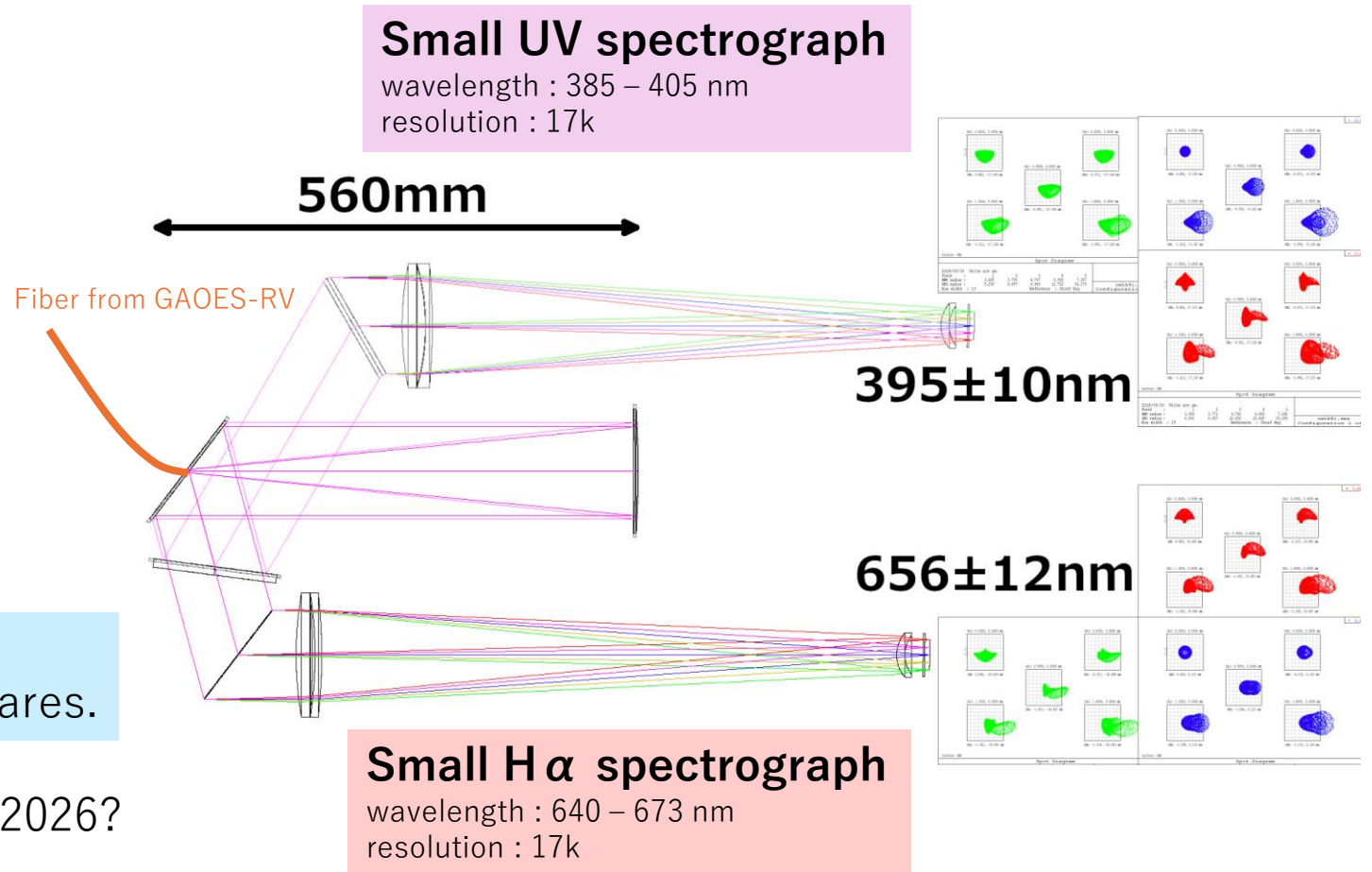
Main target : **Superflare stars**

- metal lines (Fe etc.)  $\rightarrow$  GAOES-RV  
from photosphere  
**dark spot**
- H  $\alpha$ , Ca II HK  $\rightarrow$  MIDSSAR  
from chromosphere  
**flare**

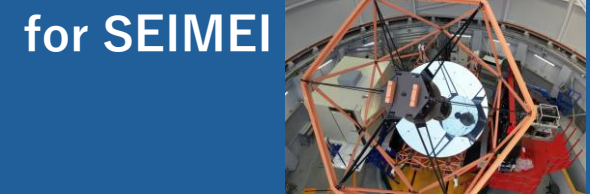
CMOS detectors for fast readout.

Conduct observational research that directly links dark spots on photosphere with superflares.

First light  $\sim$ 2026?







# SEICA (Second-generation Exoplanet Imager w/Coronagraphic AO)

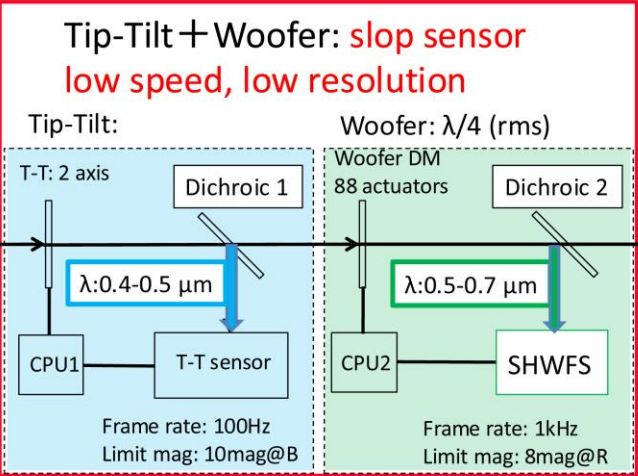
Objective: **Direct imaging of exoplanets + Instrument development**

*Ongoing w/JSPS funds (200mJPY)*

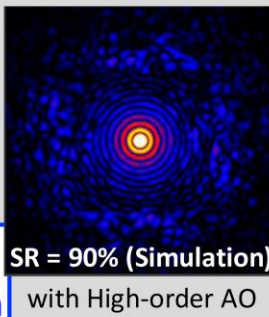
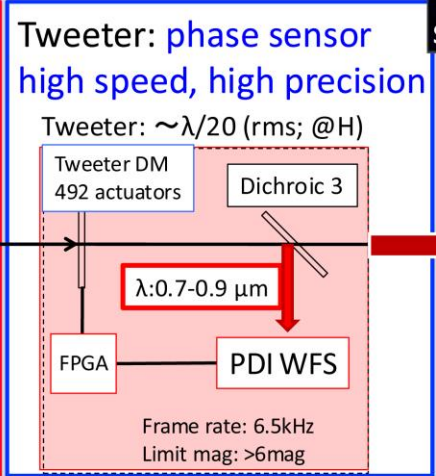
1. **Detection and characterization of Jupiter-mass planets** at angular separations greater than 0.2 arcseconds (2 AU at 10 pc).
2. **Development of advanced technologies** for the planet imaging instrument (for TMT).

High precision (SR 0.9 →  $\lambda/20$ ; rms @H band)  
 → High speed control (5-10 kHz)  
 High resolution (24x24 / aperture)

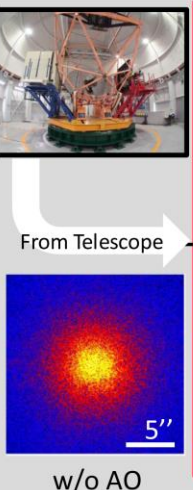
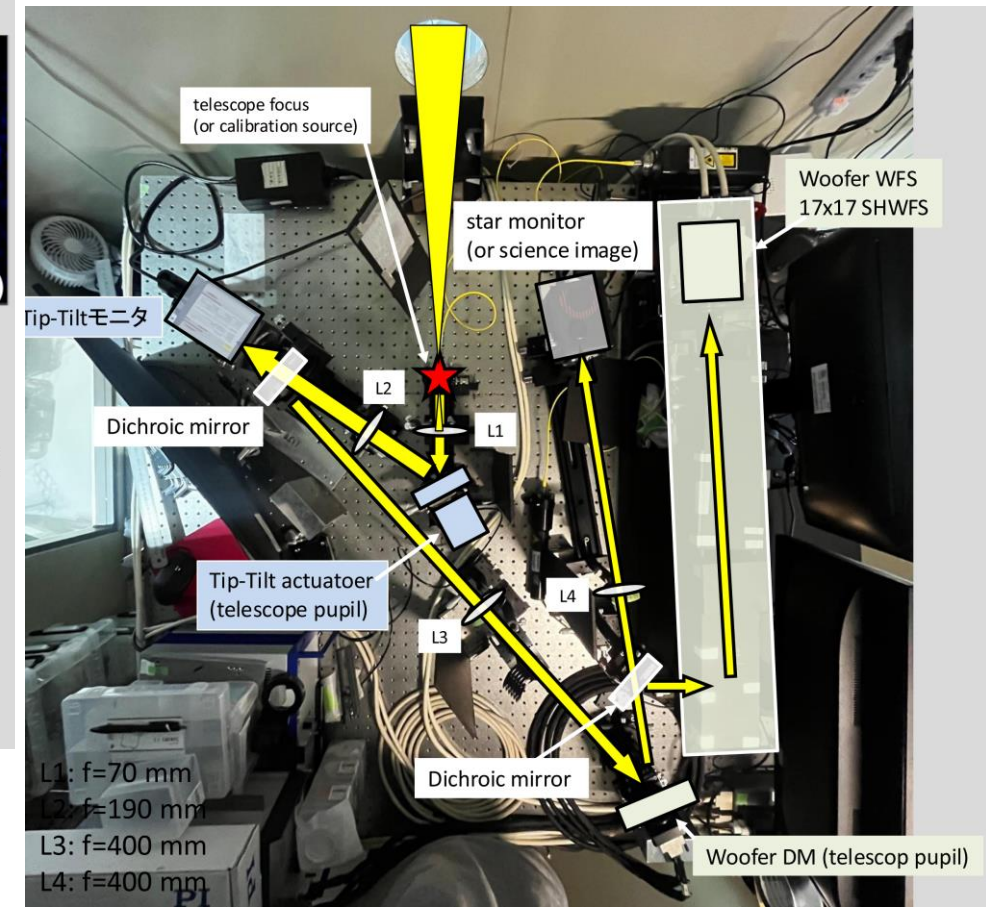
## 1. Low-order AO



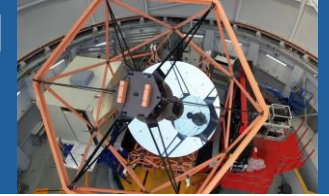
## 2. High-order AO



Coronagraph



- In July 2024, the successful phasing of the segmented mirror was achieved (p3), allowing for the start of actual AO testing.
- A combination test with the tweeter is planned to be conducted within FY2025.



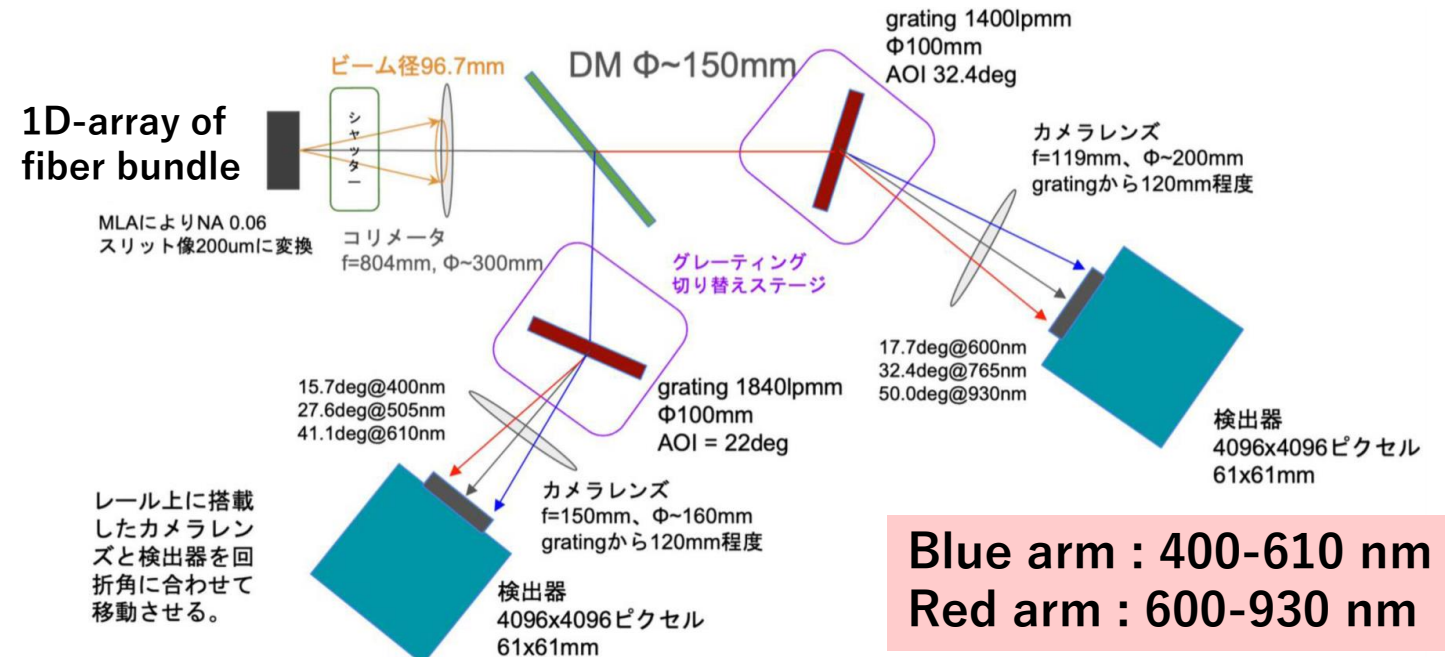
# Next-generation KOOLS-IFU

KOOLS-IFU : low-dispersion integral field spectrograph  
 opened for open use since the launch of the SEIMEI telescope in 2019.  
 based on Kyoto-3D spec. developed in 1990s.  
 Kyoto Univ. is now considering to develop a successor instrument.

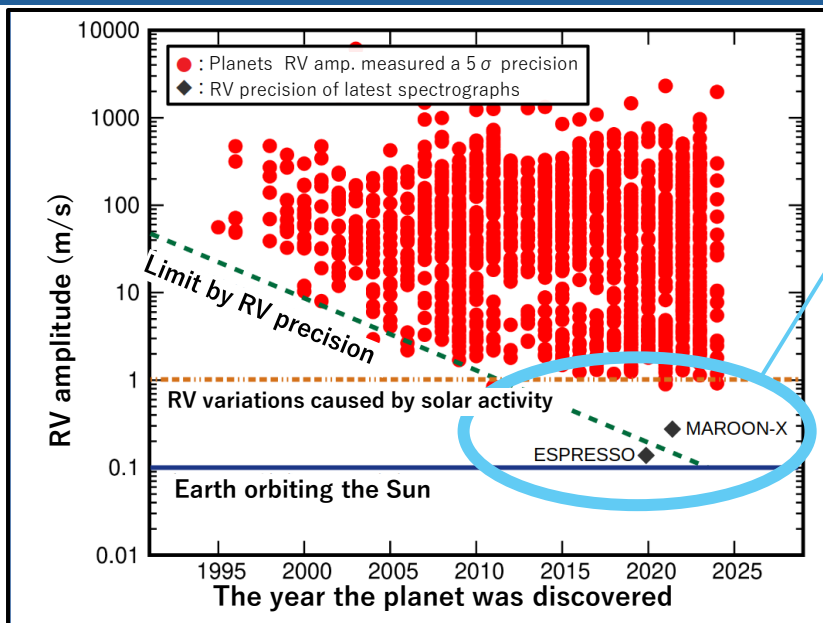
**Applying to competitive fund**

- Increase the FoV through the use of **Dual IFU**
- Wide wavelength range (400-930nm) even w/Mid-resolution (R~4,000).
- High efficiency
- Polarimetry unit

	new	old
IFU FoV	<b>(15"x15") x2</b> OBJ/OBJ OBJ/Sky etc.	8"x8"
wavelength	<b>400-930nm</b> Blue/Red arm	410-890nm 580-1020nm 430-590nm 580-800nm
resolution	500~ <b>4000</b>	500~2000
POL	○	×
limit	<b>~1 mag deeper</b>	



# Super-High-Resolution Spectrograph



✓ Since 2010, the RV amplitude of the host stars corresponding to the discovered planets has **bottomed out at ~ 1 m/s**.

✓ Since the latest spectrographs have achieved a precision of <30 cm/s, **the current detection limit is constrained not by instruments but by stars.**

**Applying to JSPS fund (500mJPY)**

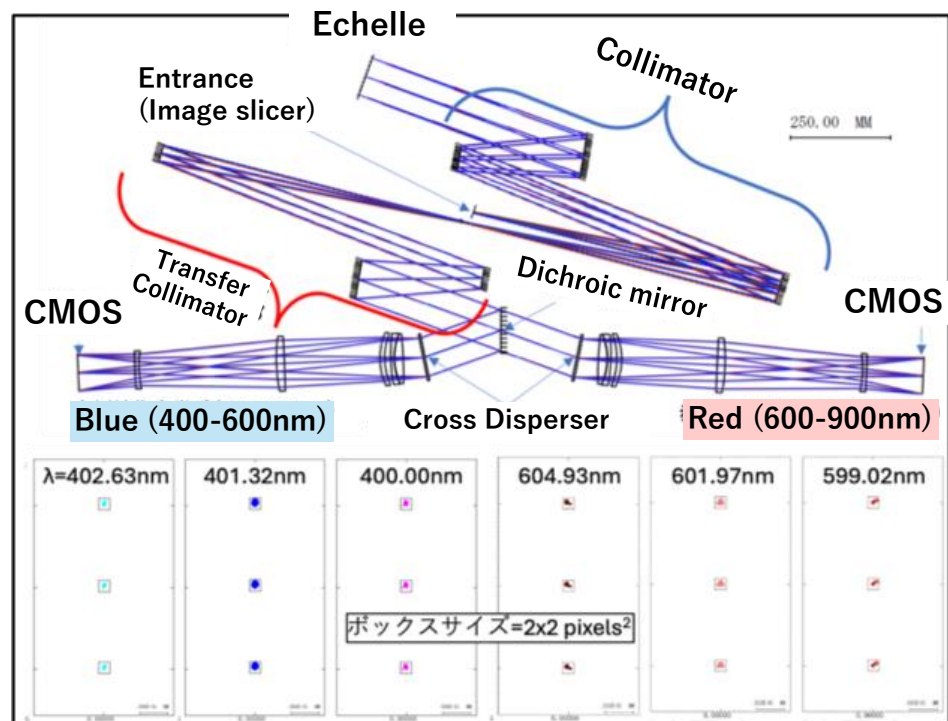
→ **Sato-san's talk**

©PhotoCross

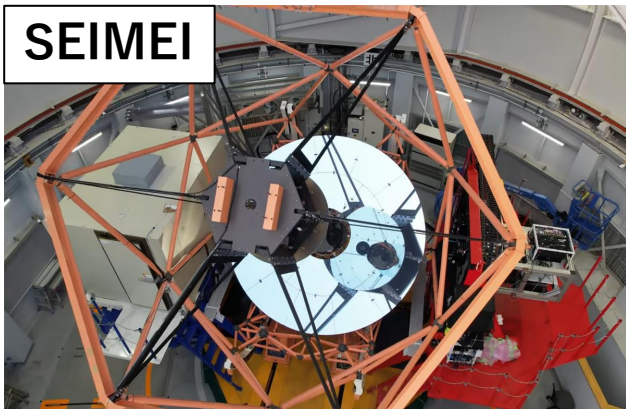
## HRS w/ 5 "Super"

- I. **Super** high wavelength resolution :  $R \sim 300,000$
- II. **Super** precise wavelength standard :  $< 10 \text{ cm/s}$  by Astro-comb
- III. **Super** high time resolution :  $\sim \text{sec}$  scale by large format CMOS
- IV. **Super** wide wavelength region : 400-900nm by large format CMOS
- V. **Super** long-term & high cadence observation :  $> \text{year}$  by 188cm

- ✓ **Understanding the variability phenomena of solar-type stars at the cm/s level**
- ✓ **Searching for Earth-like planets orbiting solar-type stars in the vicinity of the Sun**



**Preliminary design of Super-HRS optics & spot diagram**



As of 2024, there are 13 optical ground-based telescopes with apertures of  $> 8\text{-m}$  in operation worldwide, placing **SEIMEI's size (3.8-m) ~30th globally.**

However, within the Asia region, SEIMEI is still the largest among general-purpose telescopes. The upcoming large telescope plans toward ~2030 in Asia are

- EAST (up to 8-m) in Tibet by Peking Univ.
- MUST (6.5-m) in Qinghai by Tsinghua Univ.

Since the number of large telescope is still limited, SEIMEI will undoubtedly remain a valuable large optical telescope in the region over the next decade.

It is important to maintain and enhance the capabilities to promote rapid-response and long-term monitoring observational research, leveraging the advantageous.

## ▼ Optimization for ToO

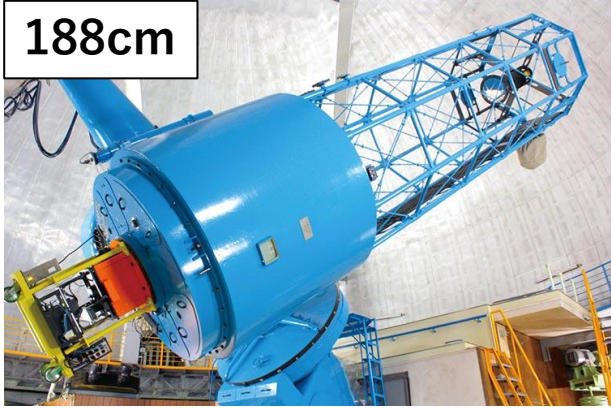
- ✓ High-speed telescope  $\sim 4\text{ deg/sec}$  (x8 faster than Subaru)
- ✓ Quick instrument change ( $< 1\text{ min}$  to change each instruments)
- ✓ Full-remote access
- Automation for triggering (on going)

## ▼ Instruments

Since all instrument development relies on competitive external funding, the plan involves uncertainties.

- ✓ TriCCS : Fast 3-colors CMOS camera. Up to 98fps.
- GAOES-RV + MIDSSAR : RV accuracy  $\sim 1\text{m/s}$ . (typical for similar inst.) Optimized also for superflare.
- *Next-generation KOOLS-IFU*: FoV  $\rightarrow$  x8. 1mag deeper.  
standard high-performance medium-to-low dispersion integral field spectrograph

188cm



With no other large telescope projects planned domestically, 188-cm telescope's value, including its advantageous longitude, is likely to persist. By allocating telescope fees, it is easy to dedicate the telescope as an exclusive resource for specific projects.

## ▼HIDES-F

The telescope and instrument (HIDES-F), which has been dedicated to exoplanet research for over 20 years, is nearly unique on a global scale and is particularly advantageous for long-period planet searches.

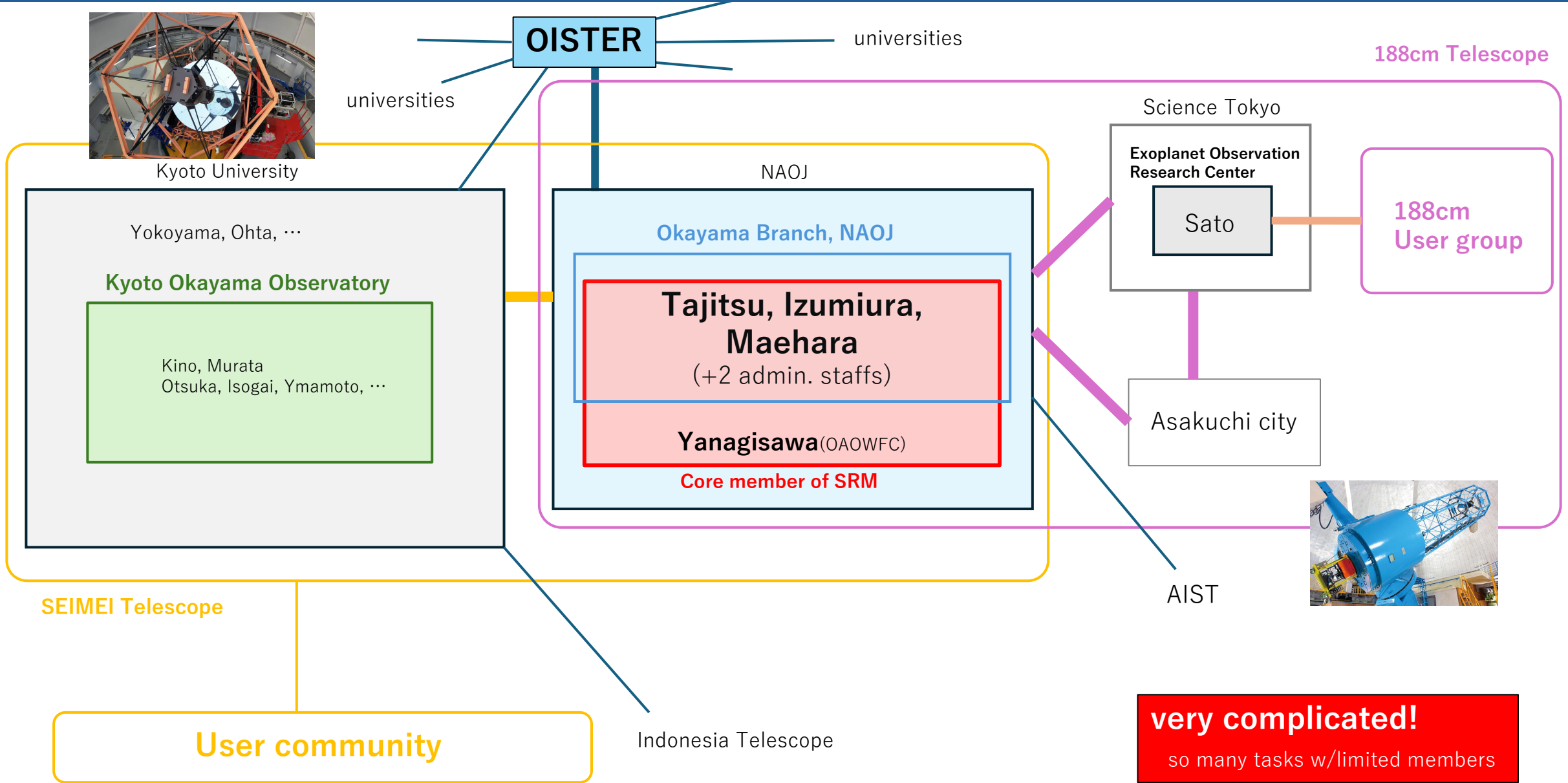
## ▼ MuSCAT

The operation of four identical instruments deployed globally, enabling continuous 24-hour observation, makes the 188 cm telescope essential for this project. An automatic exchange mechanism with HIDES-F and other instruments is currently under consideration.

## ▼ Super-HRS (next plan)

This is almost the first plan to continuously obtain stellar spectra using a spectrograph with a wavelength resolution of 300,000. The project is highly unique, drawing on the technologies we have developed, including the image slicer development accumulated over time, and Astro-comb technology developed in Okayama. Now that large-format CMOS cameras are generally available, this is an ideal time to lead and realize this plan.

# Project Organization



**very complicated!**  
so many tasks w/limited members

# Cost assessments, budget line and status

**Okayama Branch**  
**30mJPY/year** from NAOJ Management Expenses  
*(Current : 22mJPY . This may increase if additional researchers are hired.)*

**Total**  
**~60mJPY/ year**  
**from NAOJ**



**SEIMEI Telescope**  
**33.75mJPY/year** from NAOJ w/agreement

**MIDSSAR, SEICA** under construction based on external funds

**Next KOOLS-IFU** ~ 500mJPY applying to external fund

**188cm + other OAO telescopes**  
**0 JPY/year** from NAOJ budget  
operated by telescope fees paid by users

**Super-HRS** ~ 500mJPY applying to JSPS fund

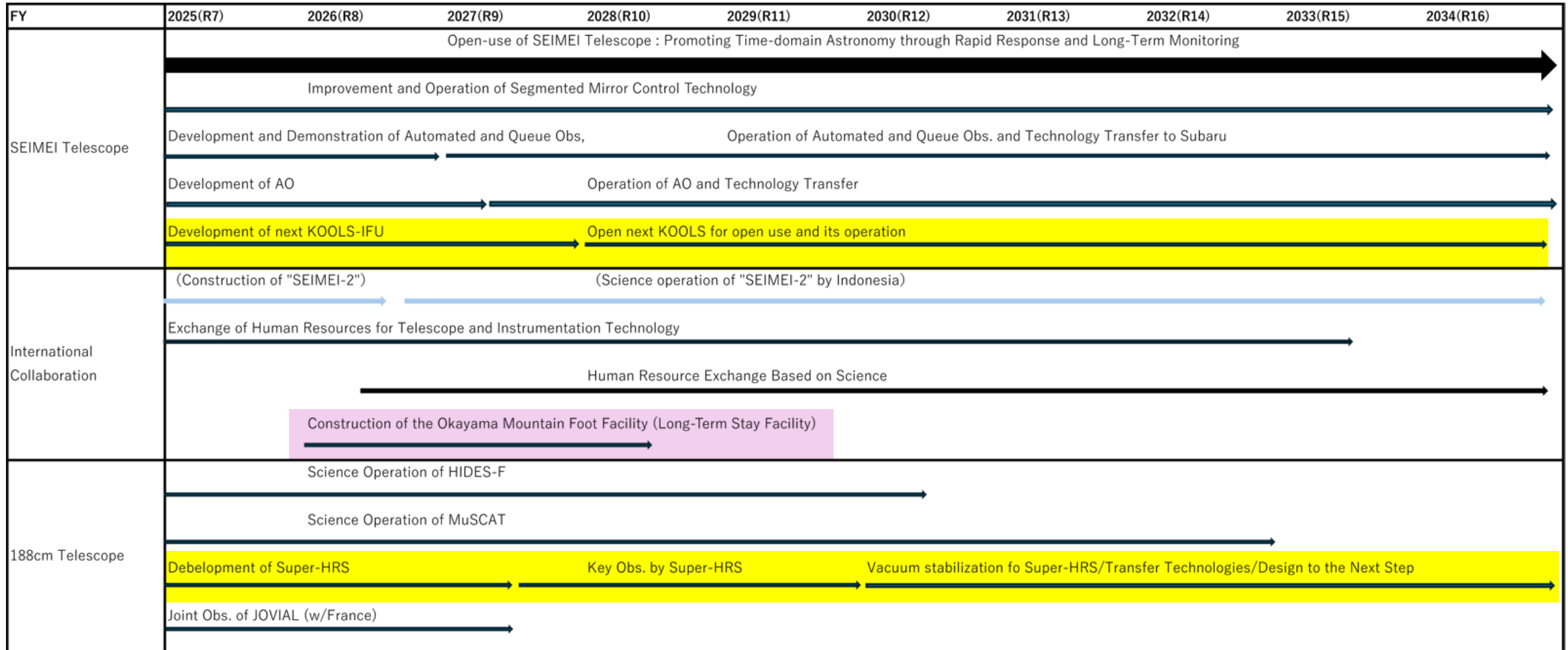
New instrument development is fundamentally carried out through competitive funding.

To function as an international collaboration hub, the current bedrooms in Branch HQ are inadequate for long-term stays.

Around 2026-28, there may be a need to expand accommodation facilities or develop stay facilities at the foothills to support long-term visitors.

We hope to secure overseas support for this purpose.

# Entire Schedule





## 【SEIMEI Telescope】

The central focus is **time-domain astronomy**.

- Leveraging its characteristics suited for ToO and its unique geographic advantages, the development and improvement of instruments to maintain international competitiveness will continue.
- Testbed for development (such as AO with segmented mirrors)
- Human resource development

## 【188cm Telescope】

The central focus is **exoplanet science**.

- We will develop a completely new Super-HRS (Super-High-Resolution Spectrograph) and accelerate the search for a second Earth with a fresh approach.

## 【International collaboration base in Asia】

- With the development of the Seimei II telescope in Indonesia as a catalyst, it will become a hub for international collaboration with Asian countries, focusing on human resource exchange.

## Cost estimation

~30 mJPY from NAOJ management expenses  
+  
33.75 mJPY for SEIMEI Telescope

- Instrument development will be based on competitive funding (which inherently introduces uncertainty into the plans).
- 188 cm telescope is operated entirely using user fees, with no funding from NAOJ.
- The current facilities are not suitable for long-term stays by overseas researchers, making it necessary to secure funding (including from partner countries) for renovations.