

Seimei Telescope Users Meeting, Sep 3, 2025 @ Institute of Science Tokyo

Introduction to NAOJ/Subaru, Collaboration with Indonesia

Yusei Koyama

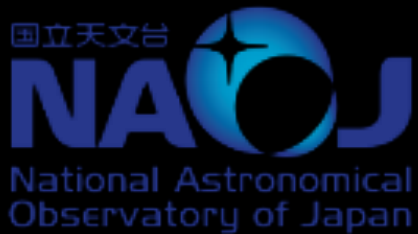
Head of Subaru Mitaka Office, Subaru Telescope,
National Astronomical Observatory of Japan (NAOJ)

Big Questions tackled by NAOJ

- 1.Does a rocky planet like Earth exist?
- 2.Does extraterrestrial life exist?
- 3.What is the true nature of dark matter and dark energy?
- 4.How did the universe begin?

The background of the slide is a deep space image featuring a variety of celestial objects. In the upper left, there are two overlapping ellipses containing clusters of blue and red dots, possibly representing distant galaxies or star fields. The rest of the background is filled with numerous galaxies of different shapes and colors (blue, red, yellow, orange) scattered across the dark void. In the bottom left corner, a large, detailed image of Earth is visible, showing continents and clouds. To the right of Earth, parts of Jupiter and Saturn are visible, showing their characteristic bands and rings. The overall theme is astronomy and space exploration.

Mission of NAOJ



To solve the mysteries of the Universe:

- We develop and construct large-scale cutting-edge astronomical research facilities and promote their open-use access,
- We contribute to the development of astronomy as a world-leading research institute, by utilizing a wide variety of large-scale facilities, and
- We bring benefits to society through public outreach of astronomy.

NAOJ's Organization

Founded in 1988

← Tokyo Astronomical Observatory, U.Tokyo(1888)
Mizusawa Latitude Observatory (1899)

...



→Institute of Astronomy, School of Sci., U.Tokyo(1988-)

~500 employee (Mitaka HQ ~300)

permanent positions: researchers ~80 engineers ~40

Annual budget ~13b JPY

Ministry of Education, Culture, Sports, Science and Technology (MEXT)

NINS(Natural Institutes of Natural Sciences) 2004-

NAOJ
National Astronomical
Observatory of Japan

NIFS
National Institute for
Fusion Science

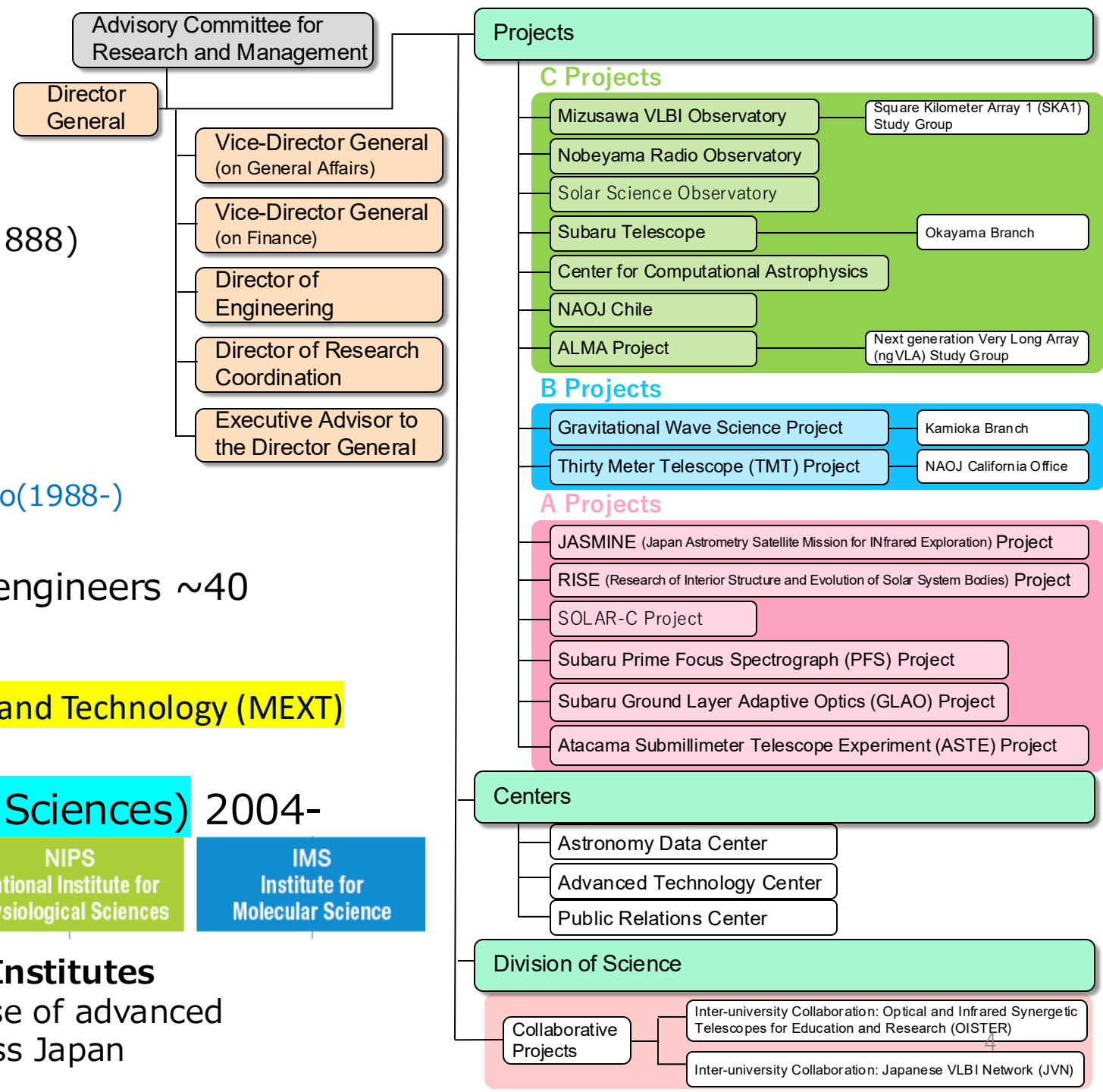
NIBB
National Institute for
Basic Biology

NIPS
National Institute for
Physiological Sciences

IMS
Institute for
Molecular Science

One of Inter-University Research Institutes

for joint research and extramural use of advanced
infrastructures for researchers across Japan



NAOJ domestic facilities



Ground-based telescopes all over Japan, in Chile and in Hawaii

A supercomputer for Astronomy **ATERUI III** by Center for Computational Astrophysics (CfCA)

Satellite telescopes **Hinode Solar telescope** with ISAS/JAXA(2006-) → **Solar-C** with ISAS/JAXA

Gravitational Telescope **KAGRA** with ICRR/UTokyo&KEK,

Seimei 3.8-m telescope with Kyoto Univ.

Large Facilities of NAOJ

Subaru Telescope

- Optical and Infrared Astronomy -

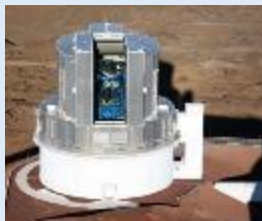
(Subaru upgraded to Subaru 2)

[Features]

- **8.2 meters** in diameter, one of the largest monolithic mirrors.
- Wide field optical imaging and spectroscopy: **HSC, PFS**
- Developing new science instruments using cutting-edge technologies; **ULTIMATE**

[Site]

- A site at an altitude of 4,200 m on Maunakea (Hawai'i, US).



Hawaii, USA

ALMA

mm & sub-mm Radio Astronomy
with NSF/NRAO and ESO

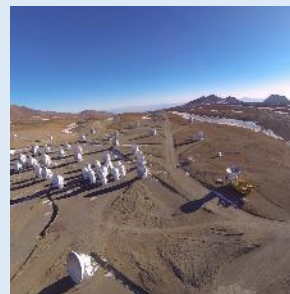
(ALMA upgraded to ALMA2)

[Features]

- Radio interferometer by combining fifty 12 m and twelve 7 m antennas, complemented with four 12 m antennas operated as single-dish (66 antennas in total) across 16 km wide area.
- Frequency coverage: 35-950 GHz

[Site]

- A site at an altitude of 5,000 m at Atacama Desert (Chile).



Chile

TMT

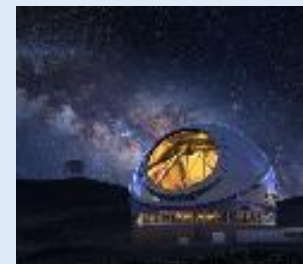
- Under construction with the US, Canada & India -

[Features]

- Aperture of 30 m enabling ~3x spatial resolution, ~10x light-collecting power, and ~100x sensitivity than 8-10m class telescopes. (~5x spatial resolution and ~20x sensitivity than *James Webb Space Telescope* for Near Infrared spectroscopy)
- Japan produces a telescope structure, primary mirror segments, and science instruments.
- Japan offers a unique scientific strategy, using TMT with the wide-field Subaru Telescope.

[Site]

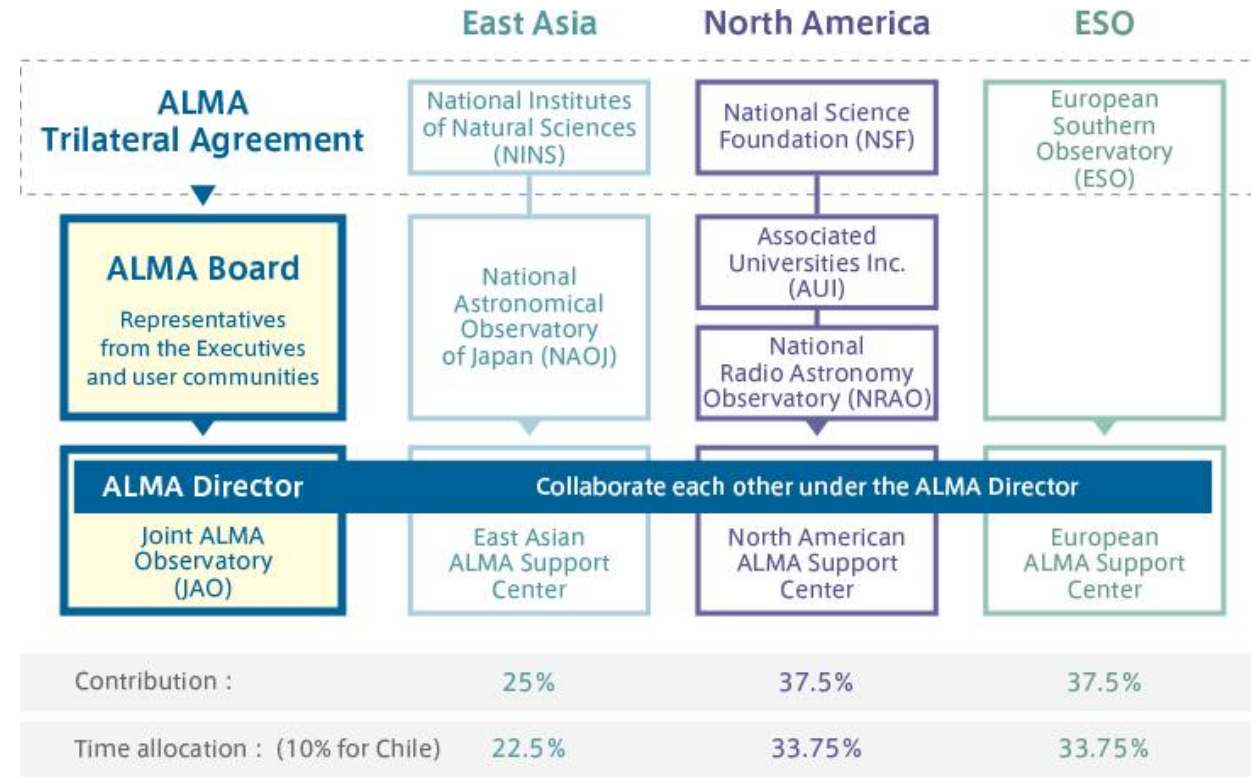
- A site at an altitude of 4,012 m on Maunakea (Hawai'i, US).



(Hawaii)

ALMA Organization

22 countries and regions collaborate



2011
Initial scientific observations begin with 16 antennas from Japan, the U.S., and Europe.

2012
Scientific results in early operations are presented.

2013
Inauguration ceremony was held at the Chilean site to begin full operations.

2015
Japan, US, and Europe signed the trilateral agreement on the operations of ALMA. This established a framework for continued international cooperative operations of ALMA by the three parties for the next 30 years and more.

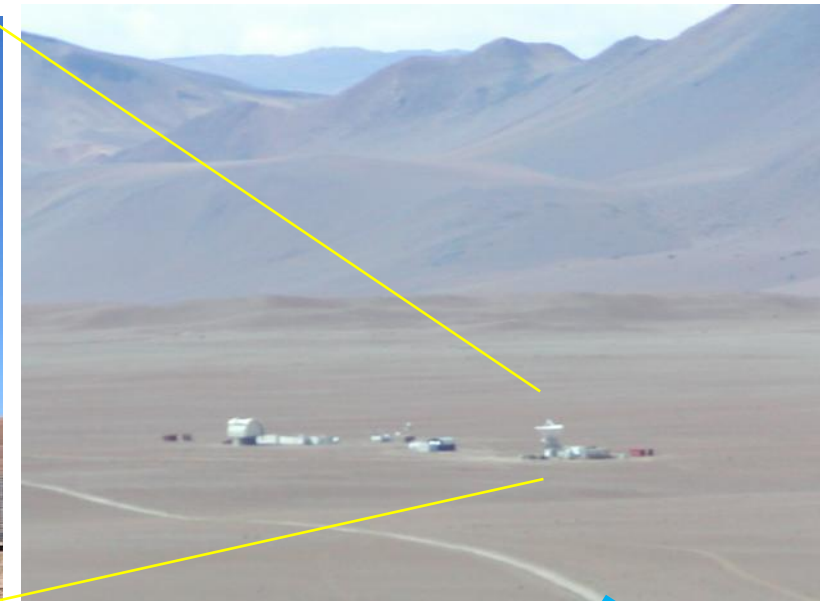


Signing ceremony for the trilateral agreement held in Tokyo in 2015

Total number of published papers until Mar.2024: 3716 (Japanese PI 545)

Atacama Submillimeter Telescope Experiment

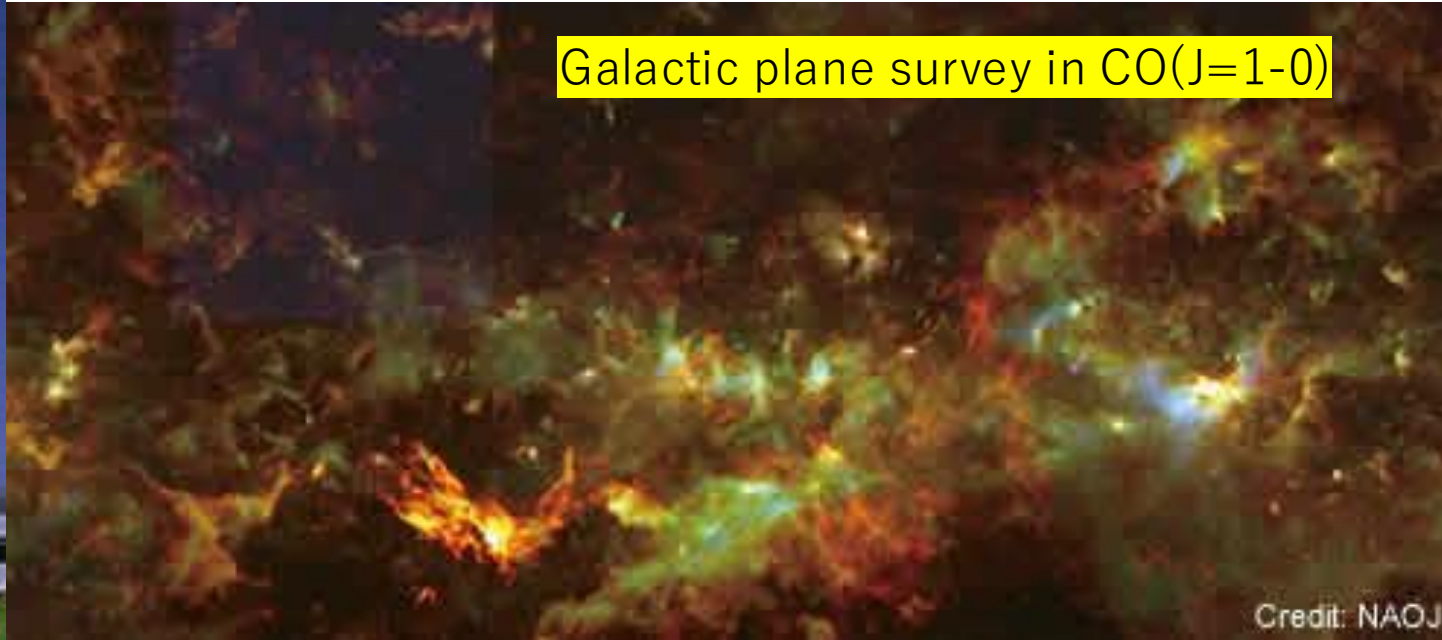
- 10-m submillimeter telescope
- Located in Atacama Northern Chile at 4800m
(1999-2001 in Japan, 2002- in Chile)
- Antenna System
 - Surface accuracy: $19\mu\text{m}$ ($\rightarrow \sim 40\mu\text{m}$?)
 - Pointing accuracy: $\sim 2''$ (rms)
- Heterodyne Receiver System
 - Frontends:
 - DASH345 (321-376GHz)
 - CAT8W (387-498GHz)
 - CAT10 (790-940GHz)
 - Backend: XFFTS
- Remote Operation



- https://aste.nao.ac.jp/index_e.html
- https://www2.nao.ac.jp/~aste-www/aste_wiki/pukiwiki/index.php?ASTE%20Wiki

ALMA

Nobeyama 45m Telescope



Inauguration in 1982
12 staffs as of July 2023

Notable Outcome:

- High velocity H₂O emission toward NGC4258
- Discovery of new molecules
- CO(J=1-0) Galactic Plane Survey (Data public)

11 receiver ports are available

Frontend: FOREST (82-116 GHz, 4 beam)

eQ* (30-50 GHz, 1 beam)

7BEE* (72-116 GHz, 7 beam)

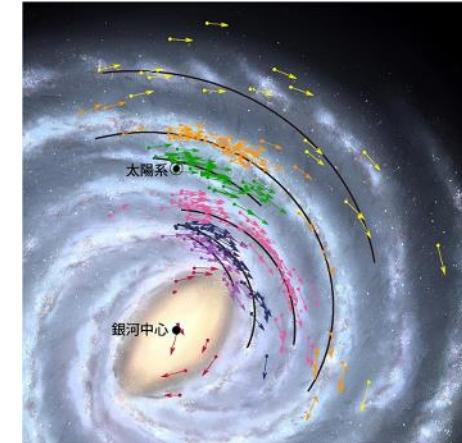
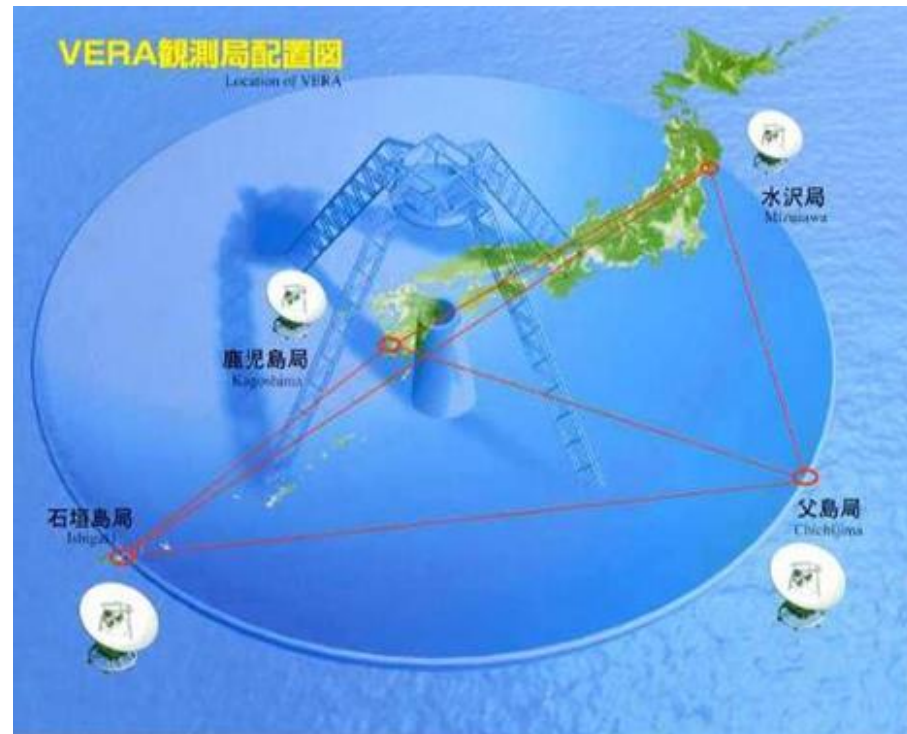
* under commissioning

Backend: SAM45 (2 GHz x 16 arrays)

RFSoc spectrometer (under development)

VERA & East Asian VLBI Network

VERA: VLBI array in Japan with four 20m dishes, 2-43 GHz



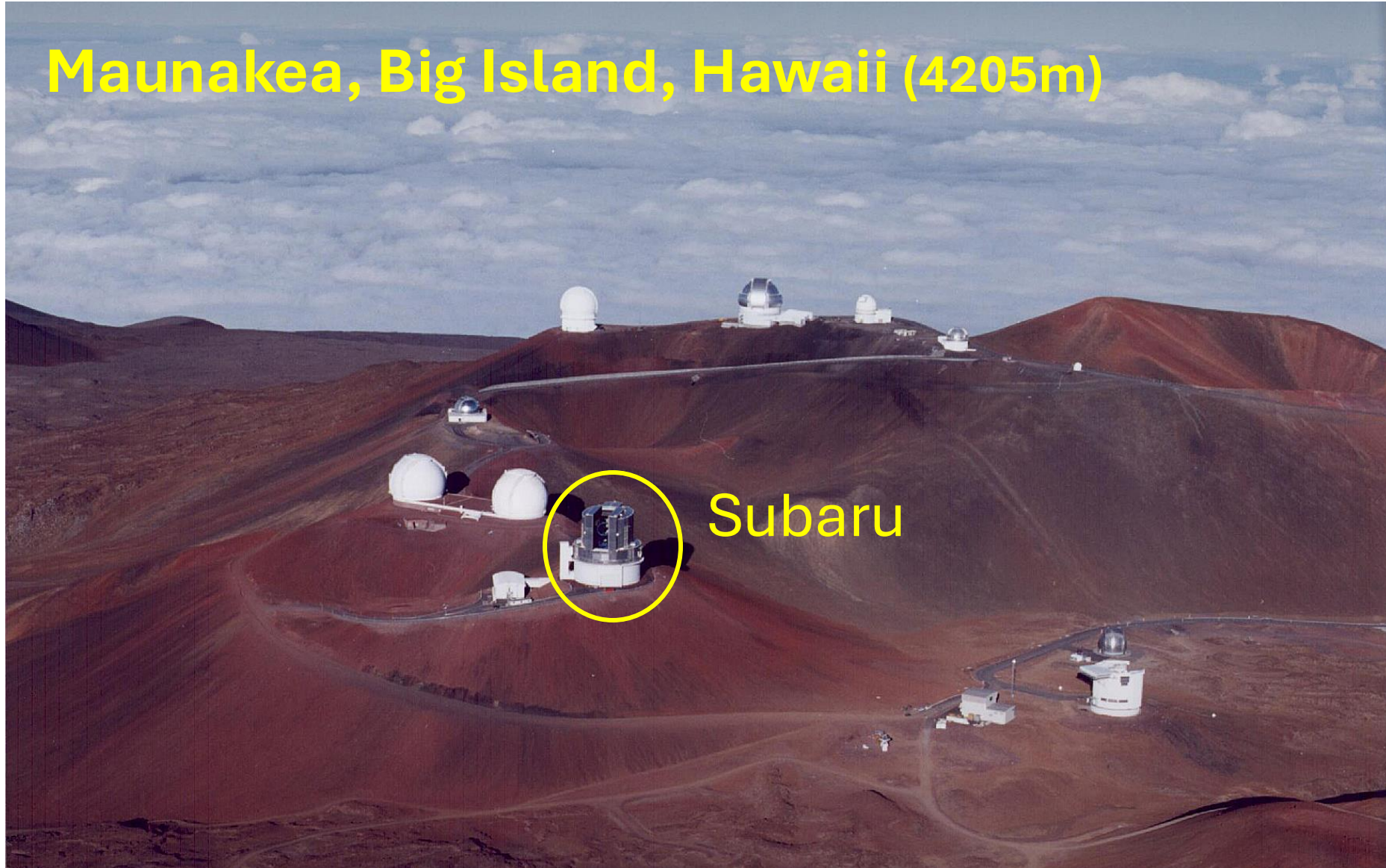
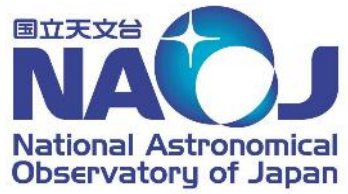
Galaxy's structure revealed by
VLBI astrometry (VERA, VLBA etc.)

**EAVN: combined VLBI array by
China, Korea, Thailand and Japan**





Subaru Telescope



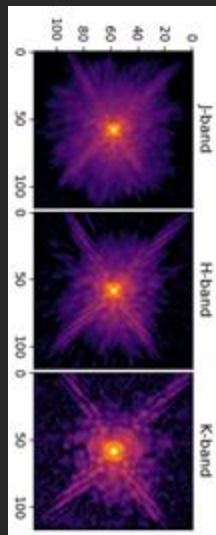


Subaru Telescope

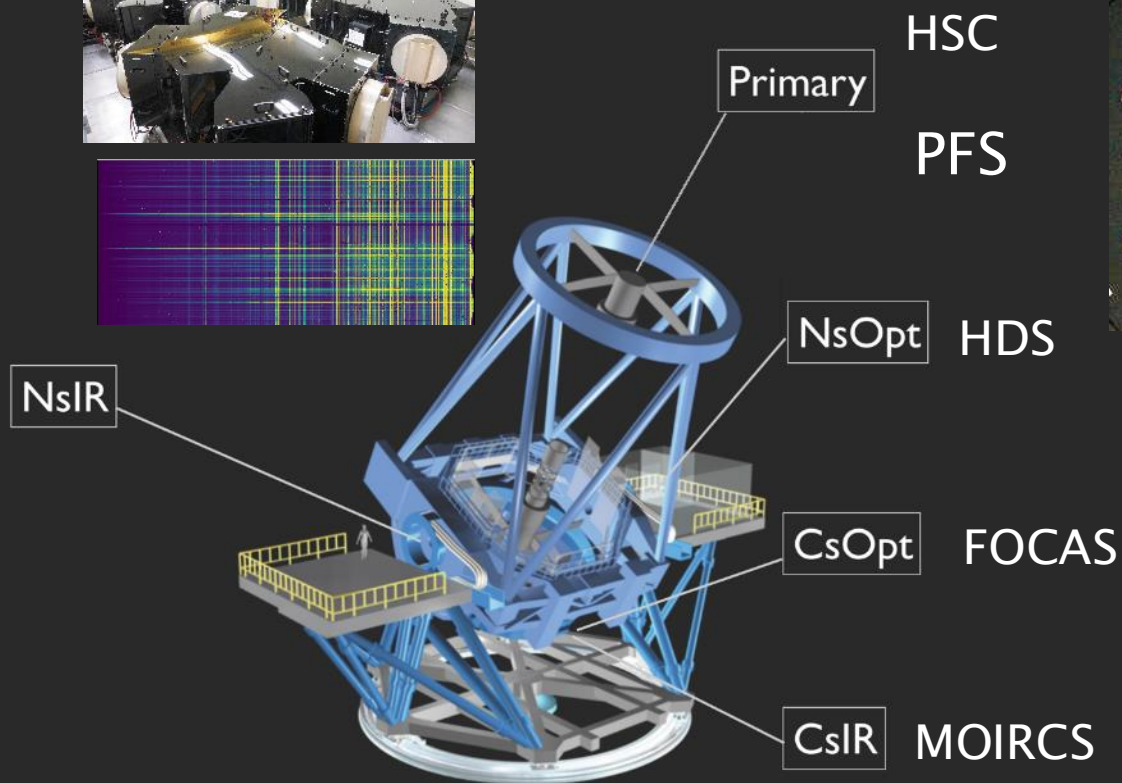
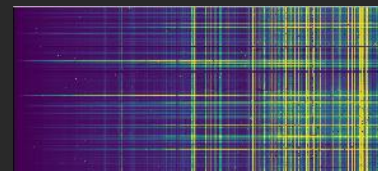
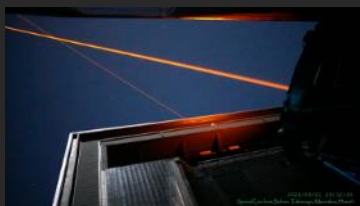


Facility instruments PI-type instruments

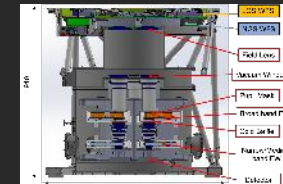
AO upgrade is ongoing:
188 $\rightarrow$ ~3000
in the number of elements



AO188	IRCS
	IRD
AO188 + SCExAO	CHARIS
	FastPDI
	MEC
	REACH (IRD)
	VAMPIRES



“ULTIMATE-Subaru” (GLAO + NIR wide-field instrument) is coming next !



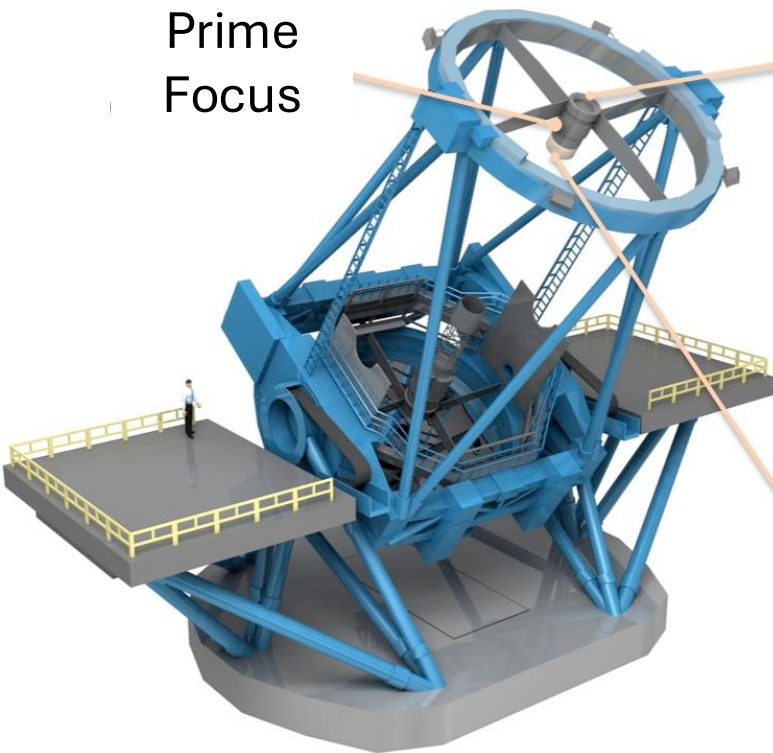


HSC (Hyper Suprime-Cam)

Science operation since 2014.

Legacy survey (with 330 nights) completed.

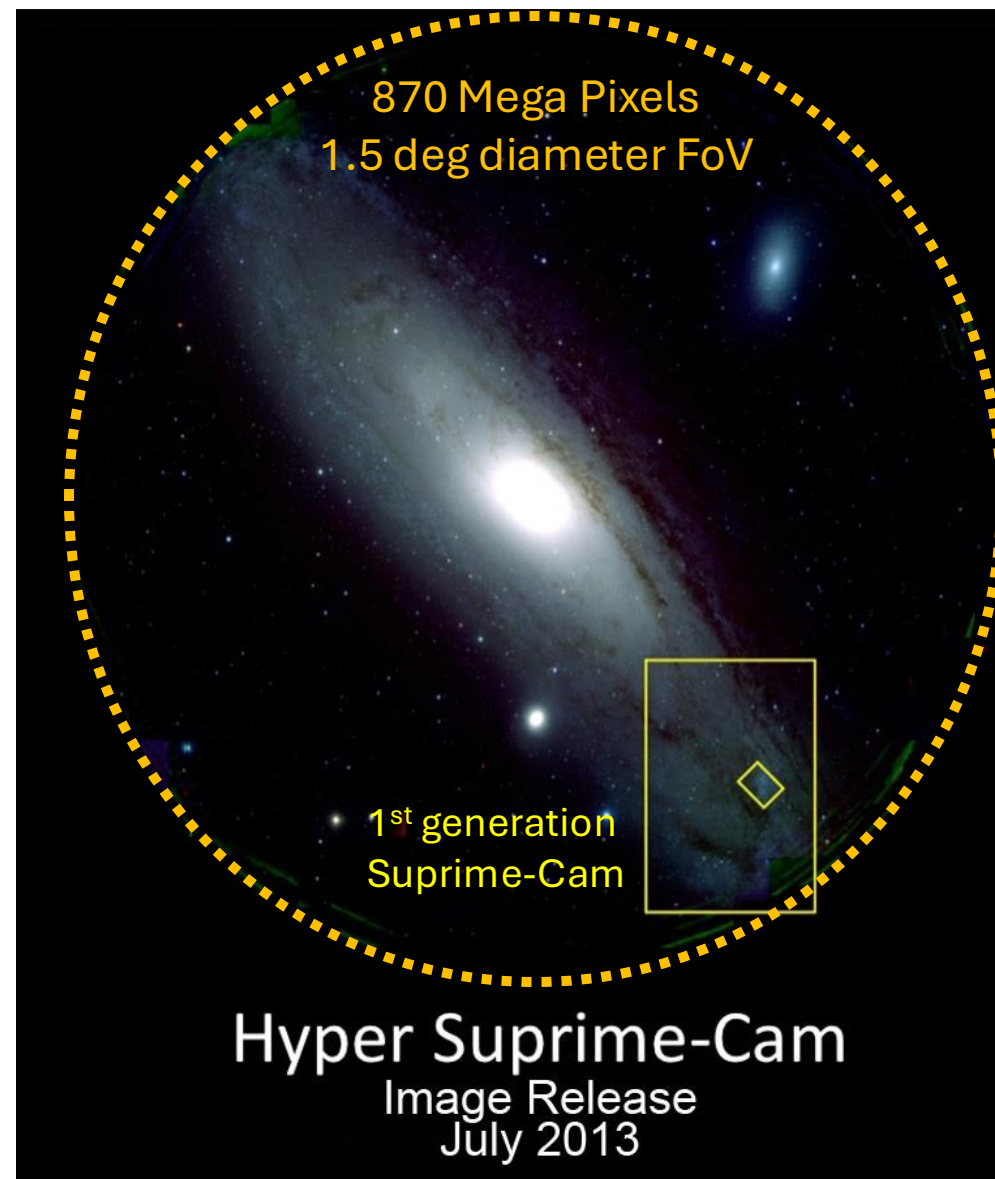
Prime
Focus



Subaru Telescope



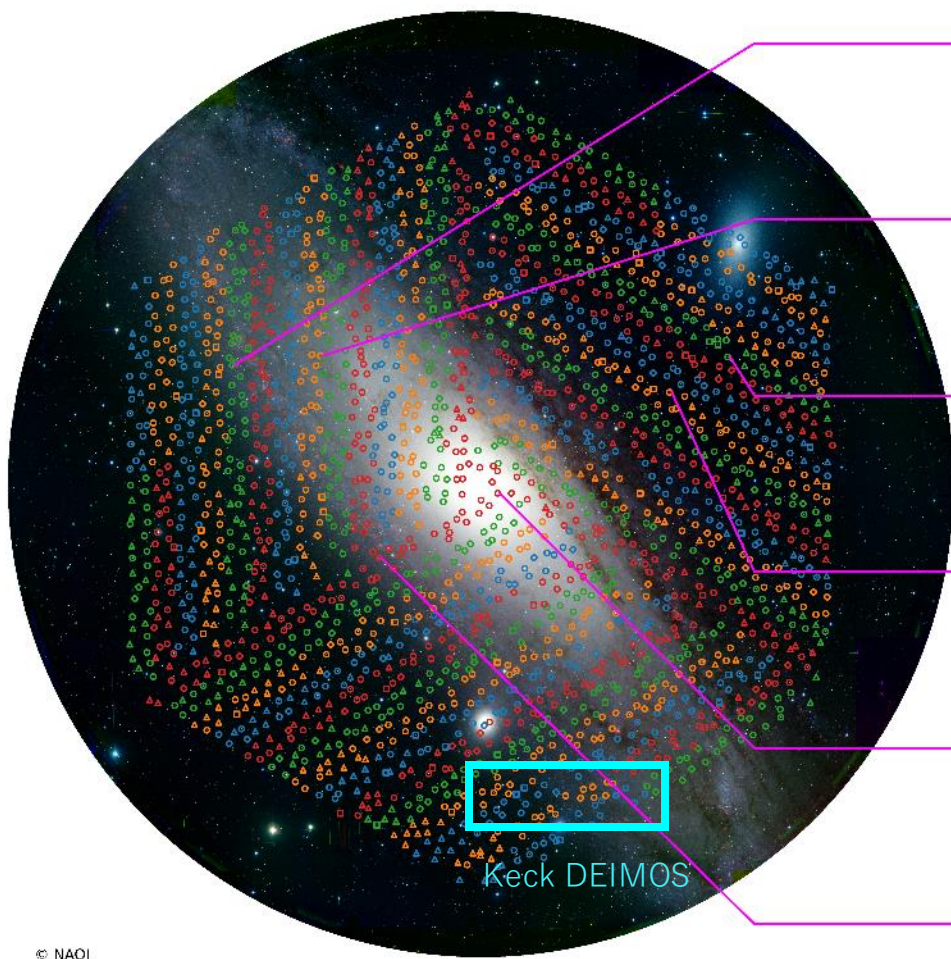
Hyper Suprime-Cam
(~3m height, ~3t)



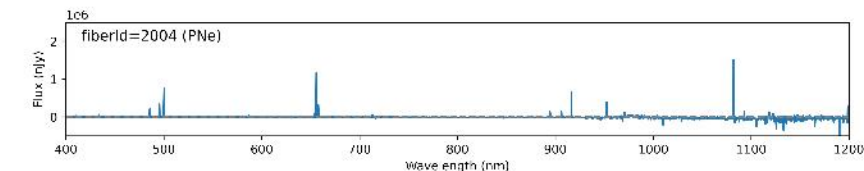
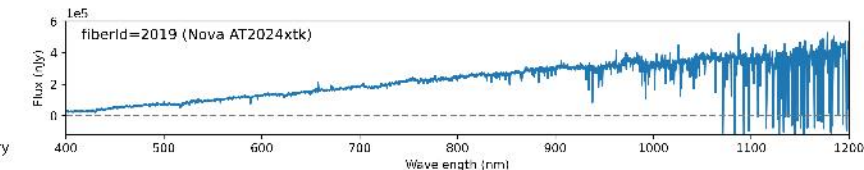
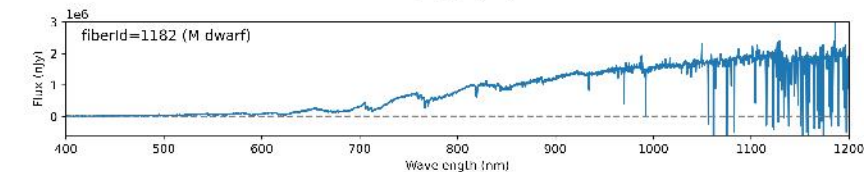
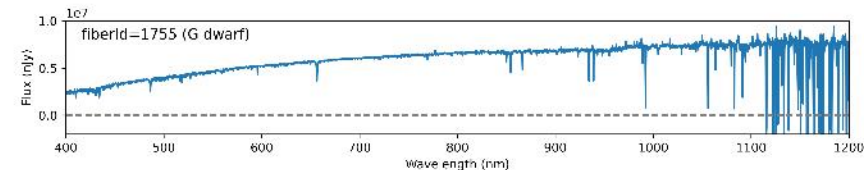
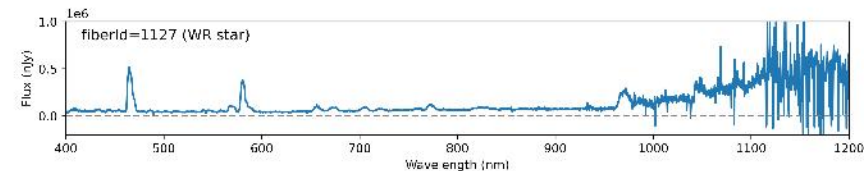
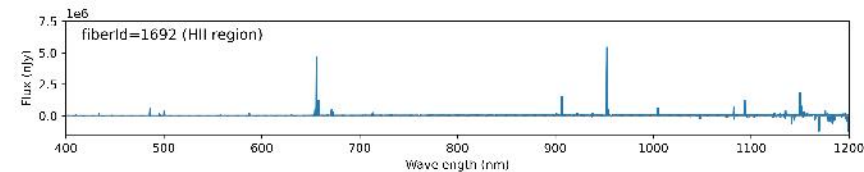


PFS (Prime Focus Spectrograph)

Science operation started in 2025! A large spectroscopic survey is now ongoing.



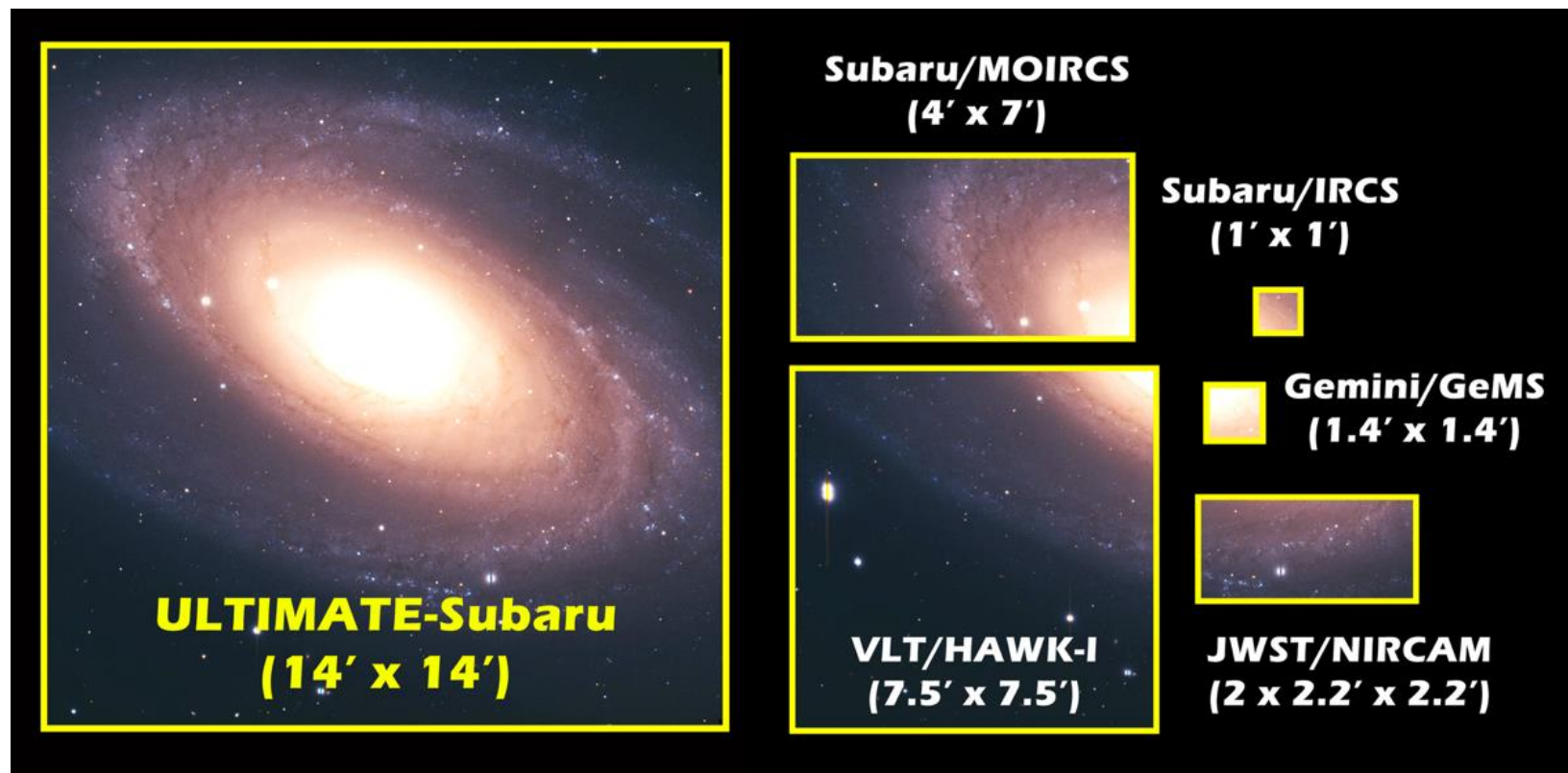
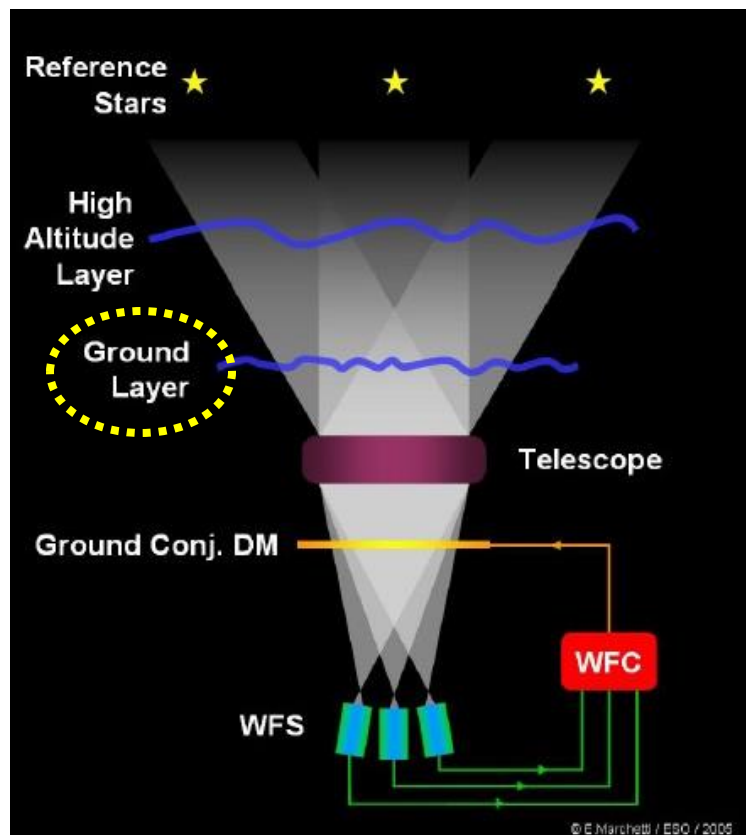
© NAOJ



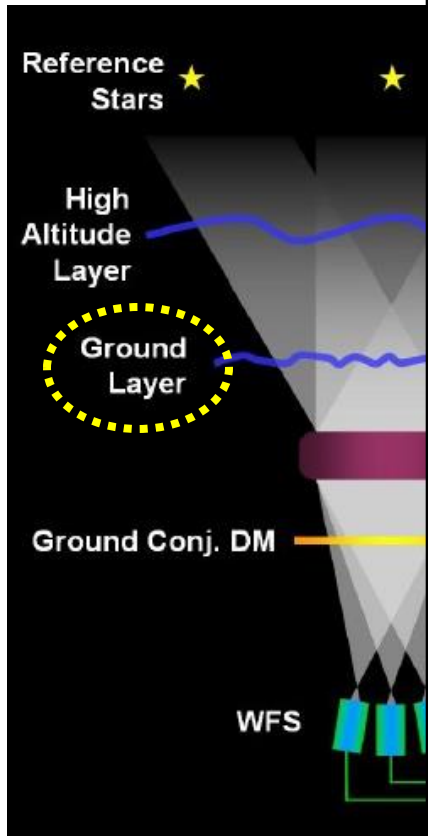
Very wide field of view (~ 1.3 deg ϕ), large multiplicity (~ 2400 fibers), broad wavelength coverage 380-1260nm

ULTIMATE-Subaru: wide-field + IR

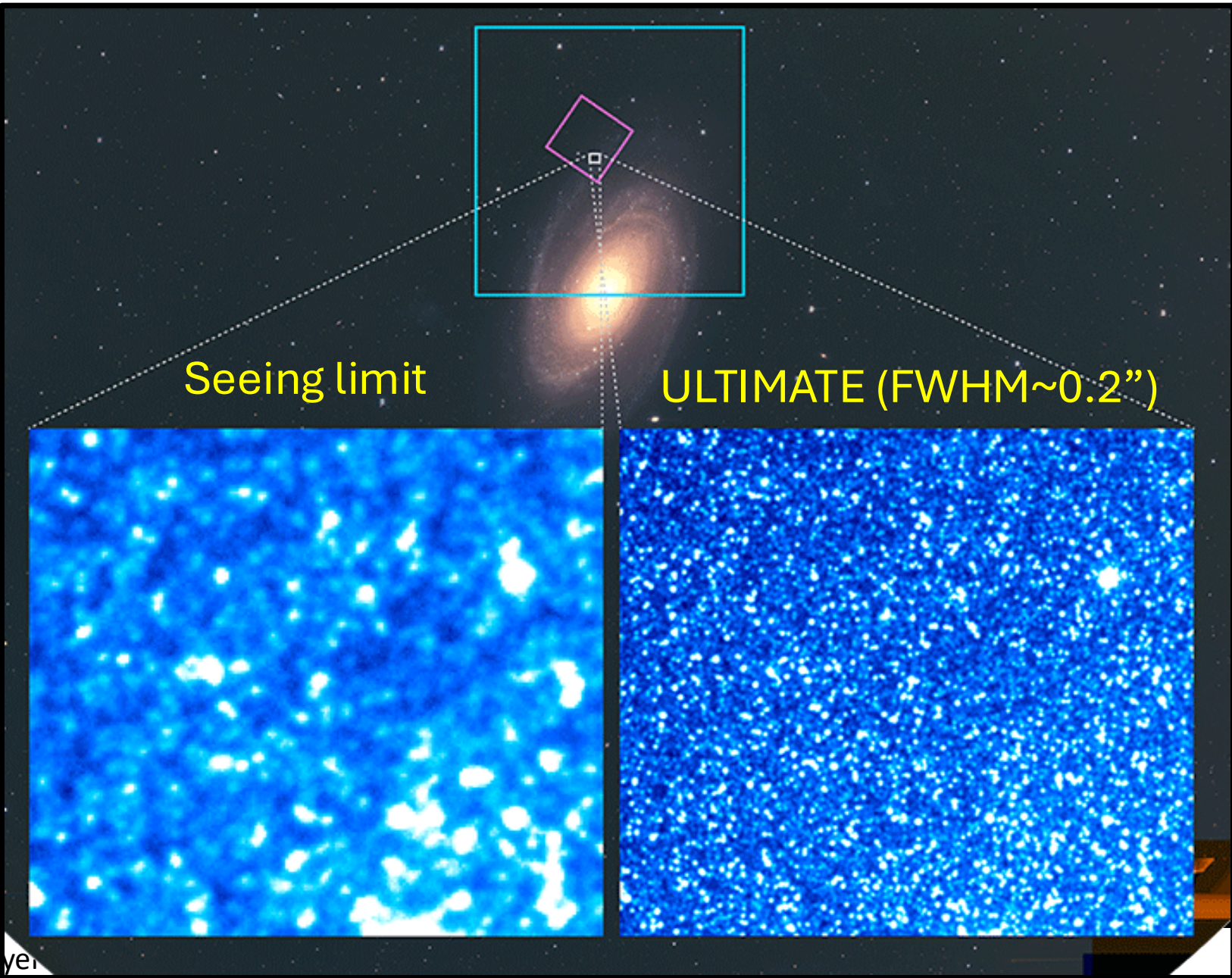
- Wide-field adaptive optics (**GLAO**) and wide-field IR imager (**WFI**).
- Improved image quality (**FWHM~0.2" in K-band**) over ~20-arcmin FoV.



- Wide-field a
- Improved im



Concept of Ground-Layer



d + IR

Subaru/IRCS
(1' x 1')



Gemini/GeMS
(1.4' x 1.4')



WST/NIRCAM
(2' x 2.2' x 2.2')



ULTIMATE
Subaru

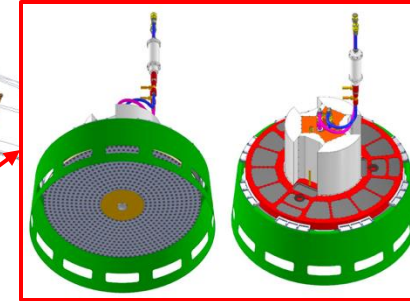
ULTIMATE-Subaru GLAO + Wide-field IR camera

Final Design phase



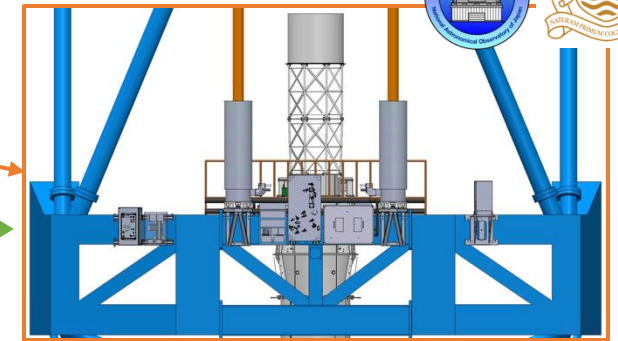
Adaptive Secondary Mirror

- 924 actuators over 1.2 m optical surface
- Control up to 1 kHz (~2 kHz goal)
- Replace the existing IR secondary mirror

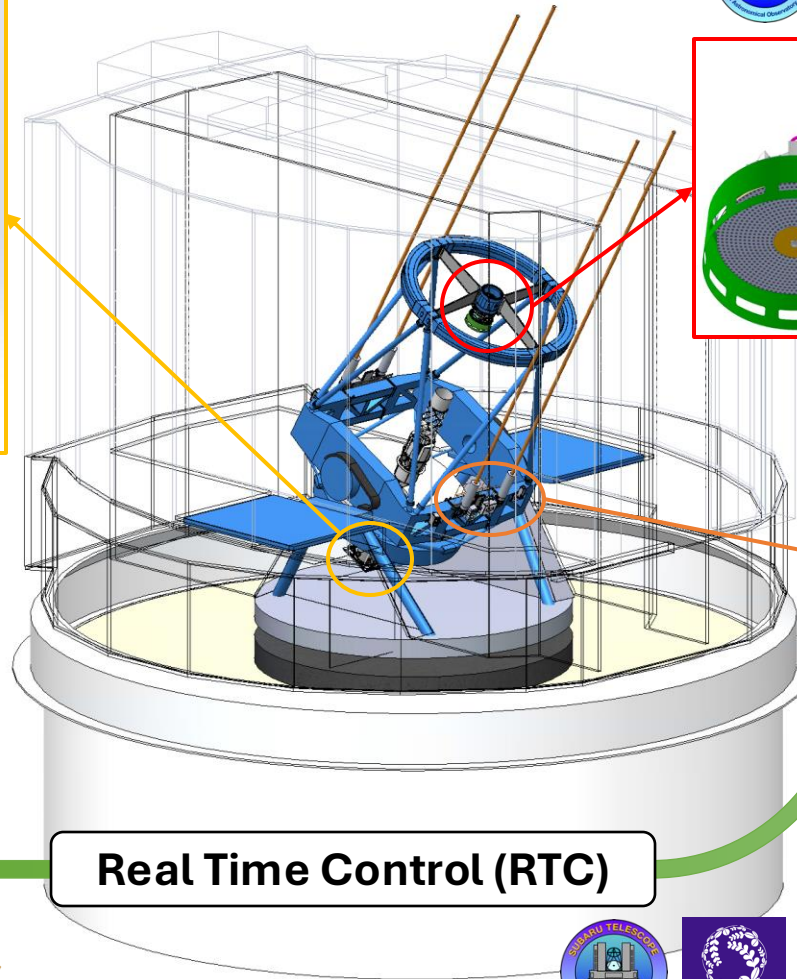


Laser Guide Star Facility

- Launch four laser beams from the side of the telescope.
- Generate 4 LGS constellation within < 20' diameter

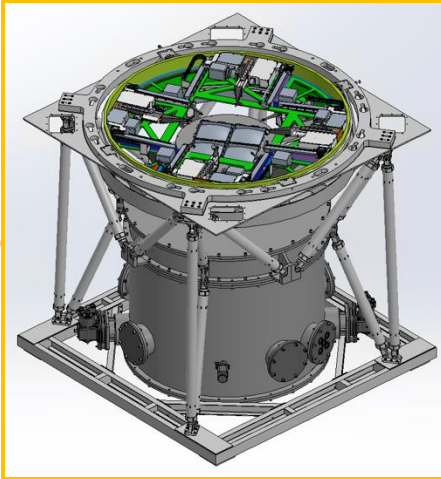


Real Time Control (RTC)

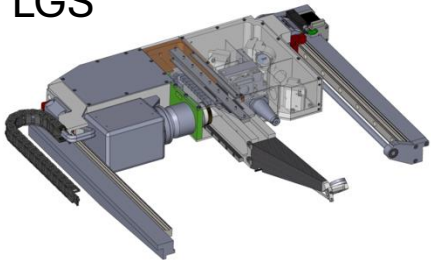


Wide-Field Imager (WFI)

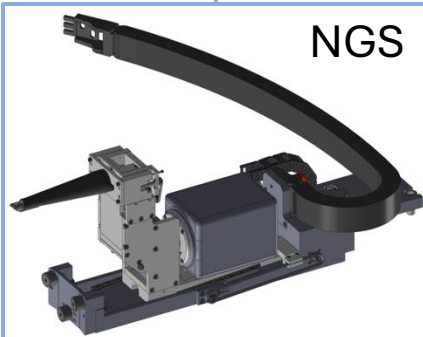
- Cassegrain instrument
- FoV ~ 14' x 14'
- λ : 0.9 – 2.5 μm



LGS



NGS



Wavefront Sensor (WFS)

- 4 Laser Guide Star (LGS) WFS
- 4 Natural Guide Star (NGS) WFS

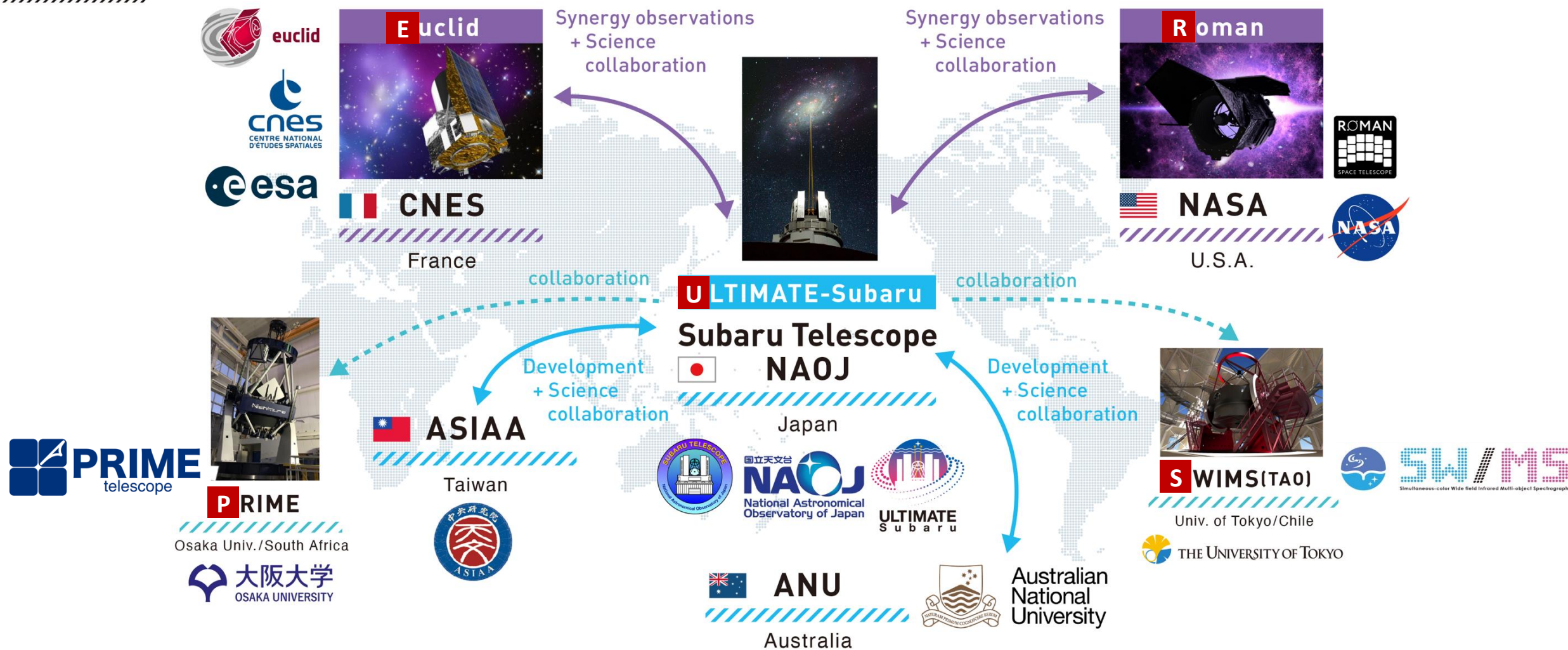




SUPER-IRNET: JSPS Core-to-Core Program

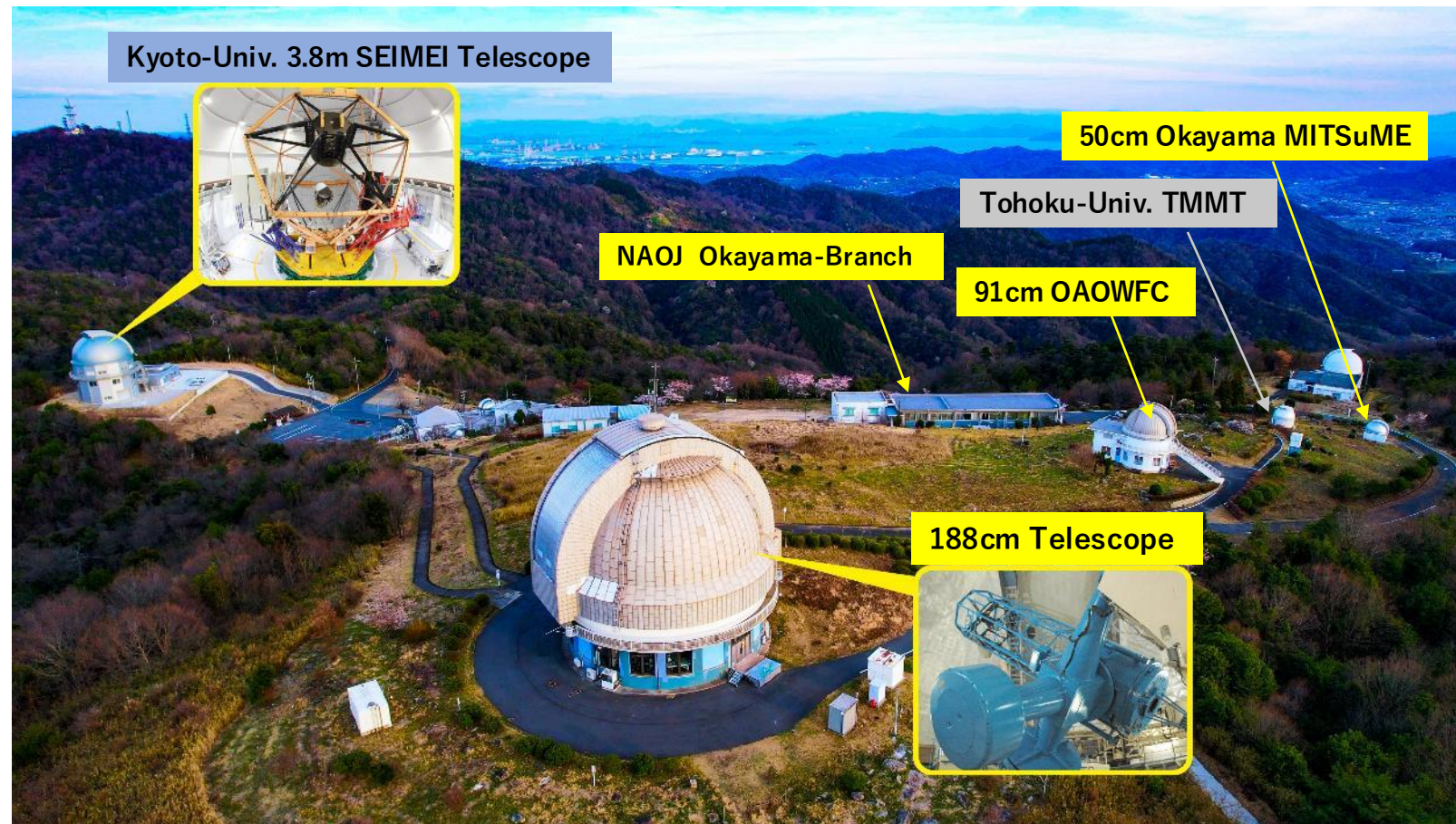
NAOJ is leading a program to promote wide-field + IR astronomy by connecting the community of **SWIMS/ULTIMATE/PRIME/Euclid/Roman** (FY2021-2025).

**SUPER
IRNET**



Okayama Branch (NAOJ) and Okayama Observatory (Kyoto Univ.)

Okayama Branch hosts the largest collection of optical/IR telescopes in Japan, including 3.8-m Seimei Telescope (Kyoto Univ.), 188-cm telescope, and 50-cm simultaneous 3-band imager MITSuME, etc. It is also a valuable observation site in East Asian region.



Advantage

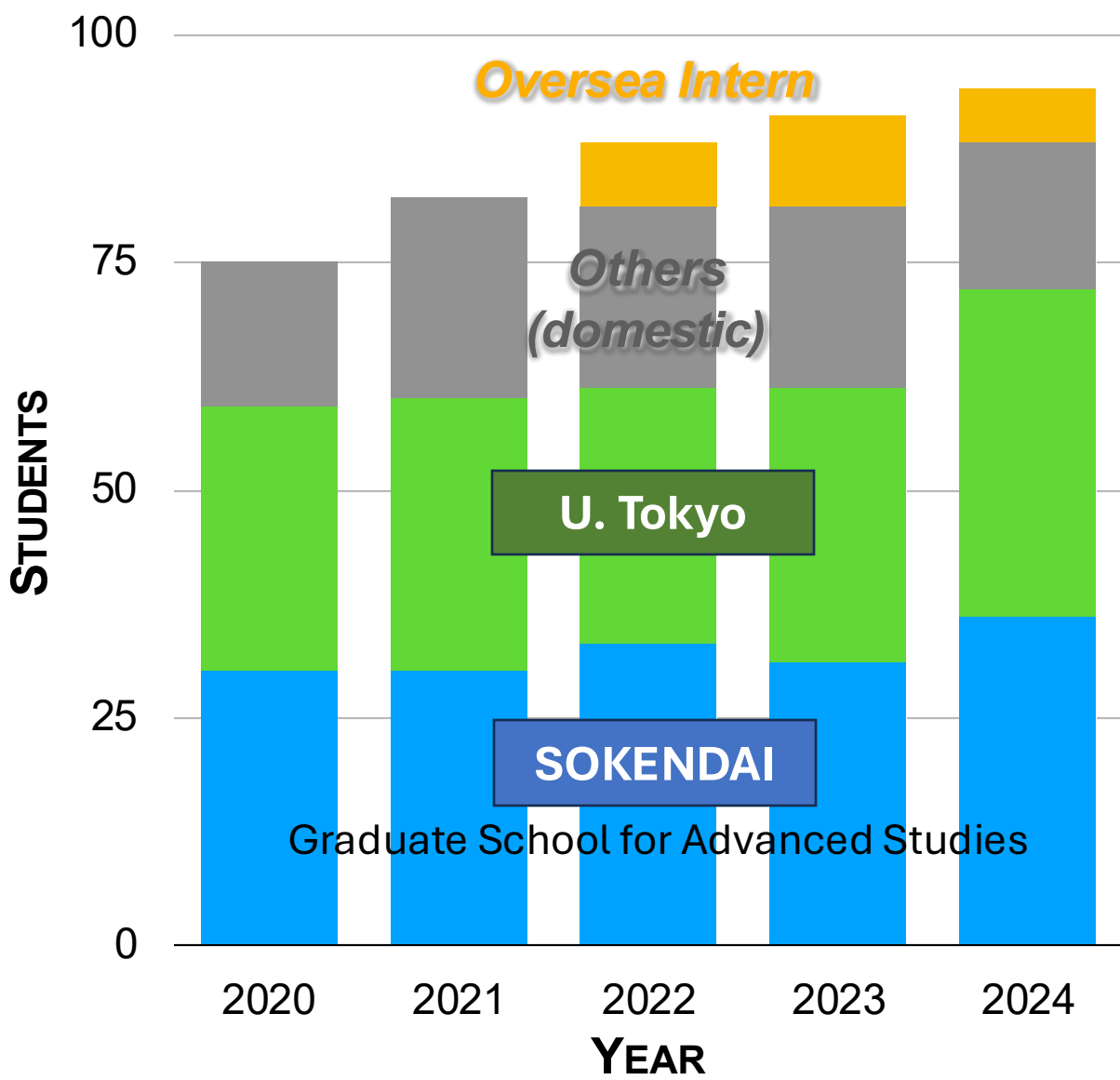
- Abundant observation time
○188cm, △Seimei
- Location
Domestic access, Longitude on earth
- Optimization for ToO (○Seimei)
Fast telescope, Quick instrument change

Main science

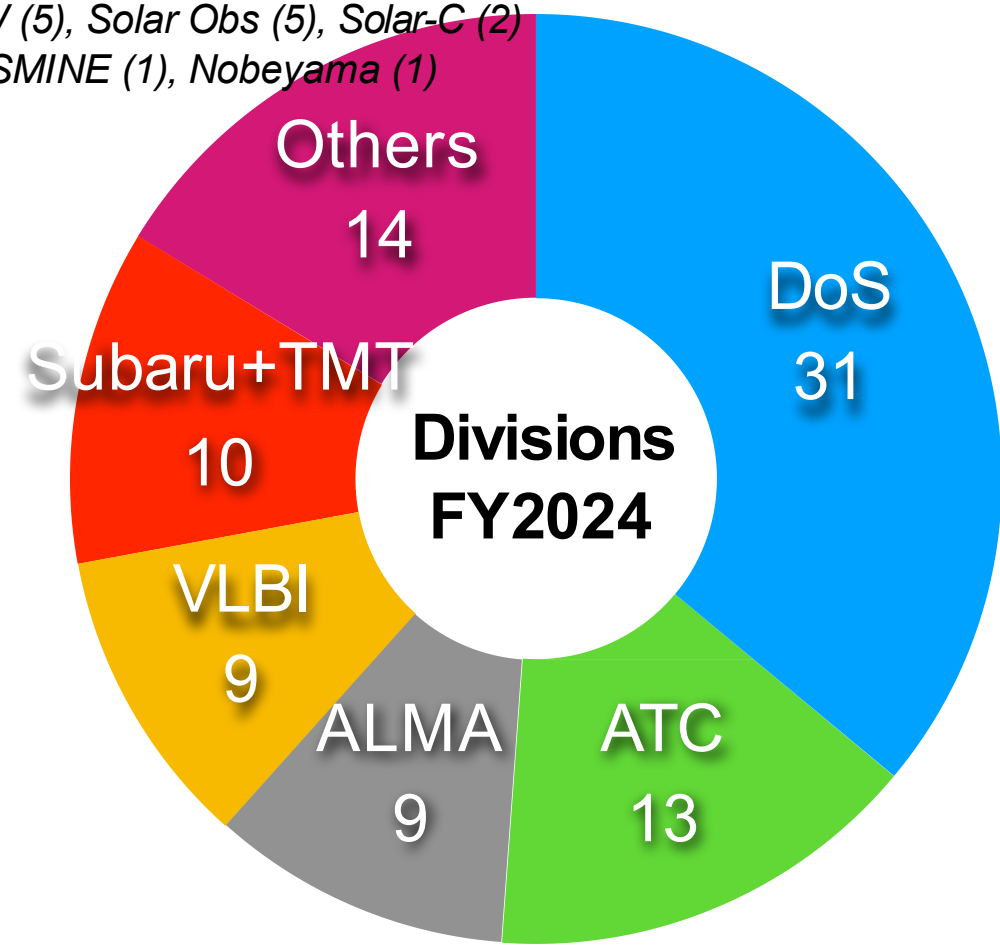
Time-domain astronomy

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

Student Statistics at NAOJ



GW (5), Solar Obs (5), Solar-C (2)
 JASMINE (1), Nobeyama (1)



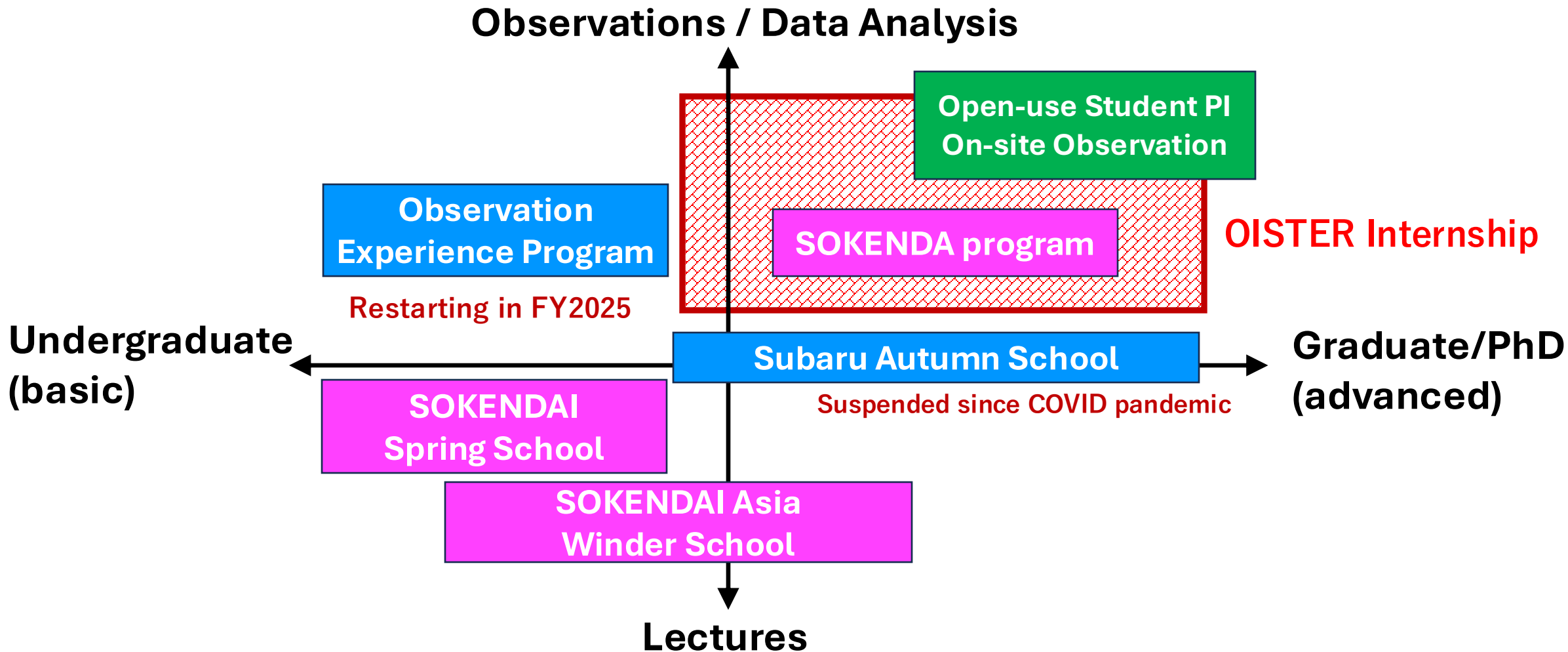
Education Programs at Subaru

- Subaru Observing Experience Program (for undergraduate students)
- Subaru Data Analyses School (for all young carrier scientists + students)
- On-site Observation for student PI openuse programs
- OISTER internship program
- SOKENDAI Summer Student
- ...



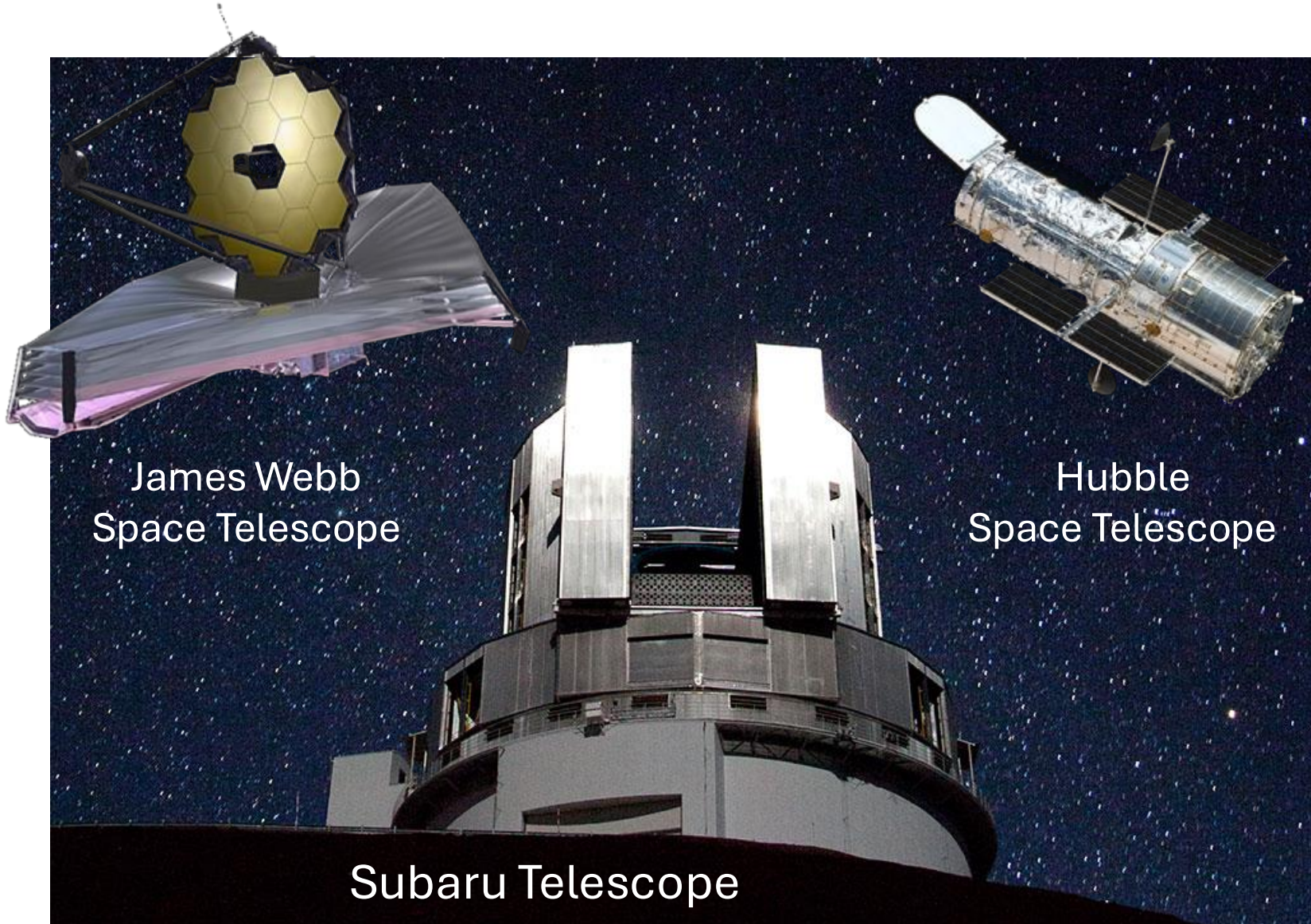
“Observing Experience Program” for undergraduate students @ Maunakea

Education Programs at Subaru



My experience with students from Indonesia

Abdurrahman Naufal
from Indonesia
(SOKENDAI, PhD 2025)



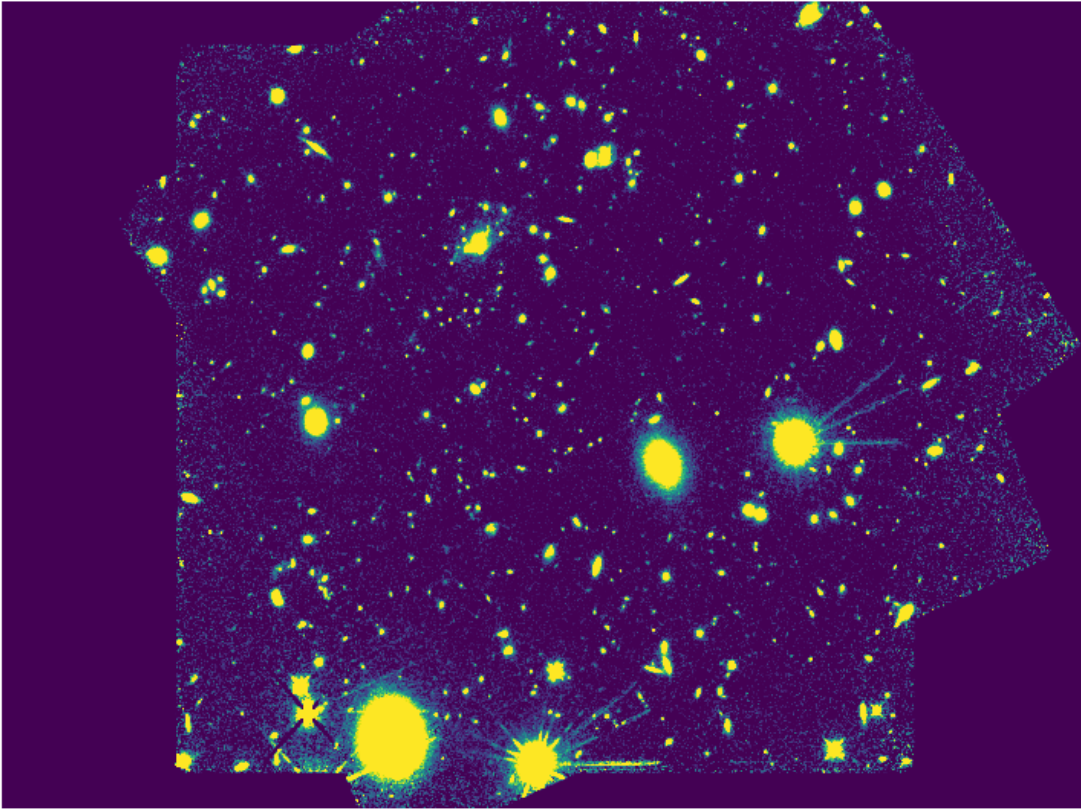
James Webb
Space Telescope

Hubble
Space Telescope

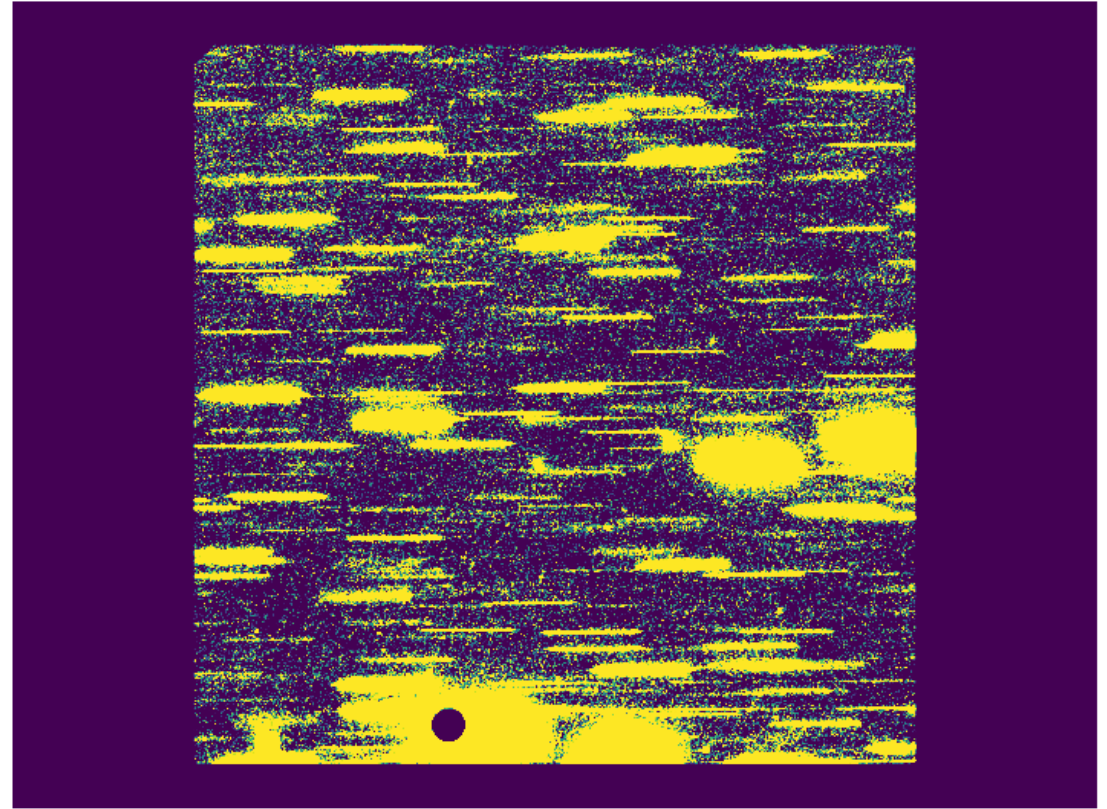
Subaru Telescope

My experience with students from Indonesia

F160W mosaic

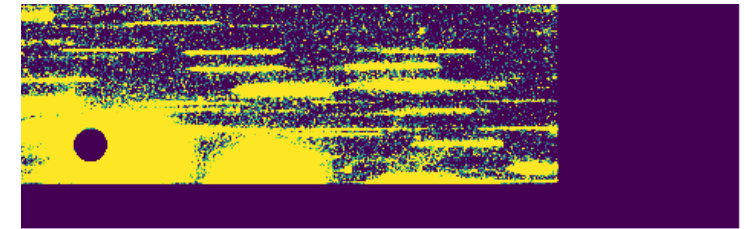
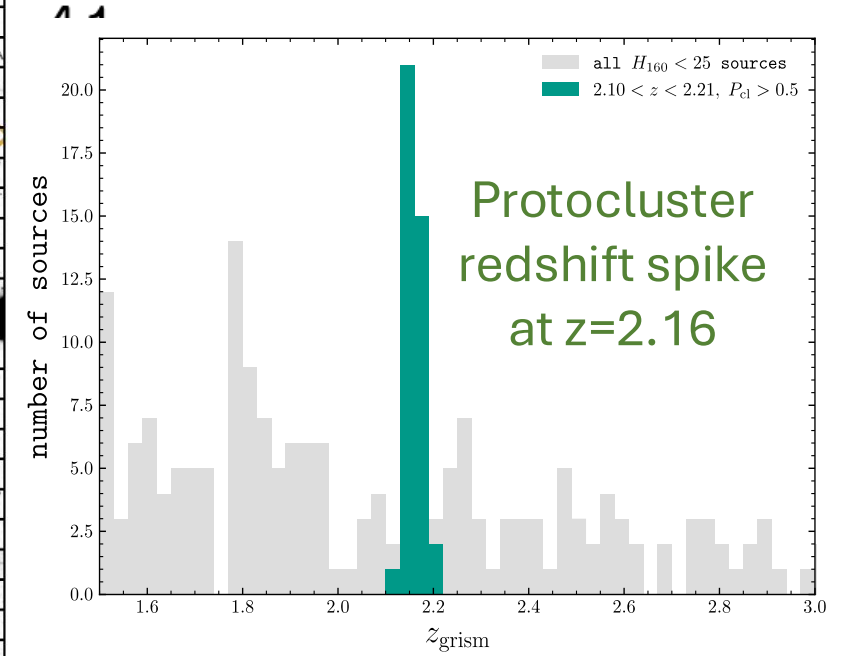
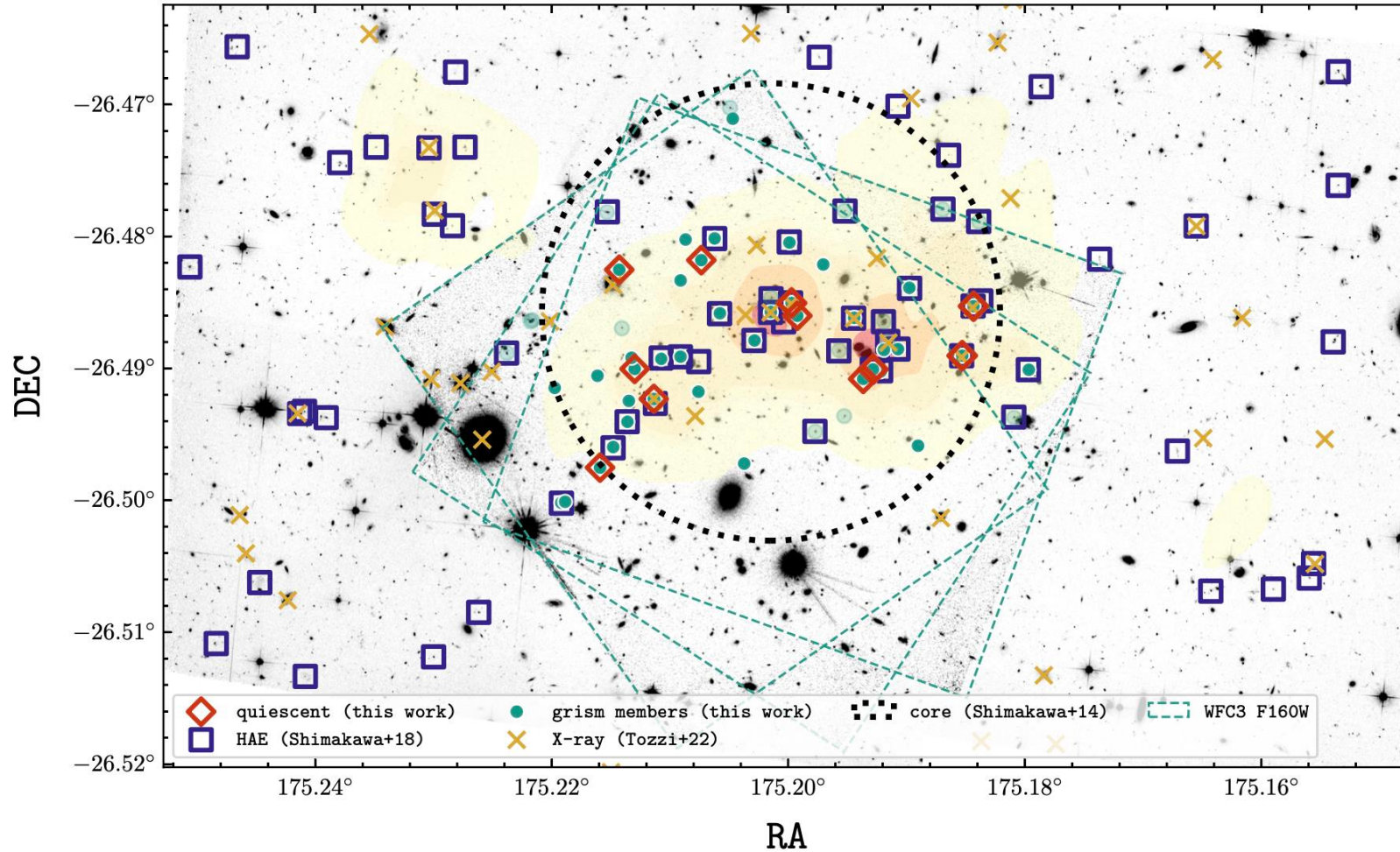


G141 exposure



Slitless spectroscopy of high-redshift galaxy clusters with HST
(Naufal, Koyama, et al. 2024)

My experience with students from Indonesia



Slitless spectroscopy of high-redshift galaxy clusters with HST
(Naufal, Koyama, et al. 2024)

Summary

- NAOJ is the Japanese national observatory, to support our astronomical community, and play leading roles in operation and construction of large astronomical facilities including Subaru, ALMA, TMT.
- Subaru Telescope is now 25 years old, but it is still producing cutting-edge science outputs with a suite of strong wide-field instruments (HSC, PFS, ULTIMATE) as well as unique instruments for exoplanets.
- Fostering young scientists/students in Japan (and in Asia) is always an important task for NAOJ/Subaru. Joining any of the ongoing Subaru education programs from Indonesia would be a good starting point to expand the scientists network.