ULTIMATE Subaru

# ULTIMATE-Subaru: Project Overview and Current Status

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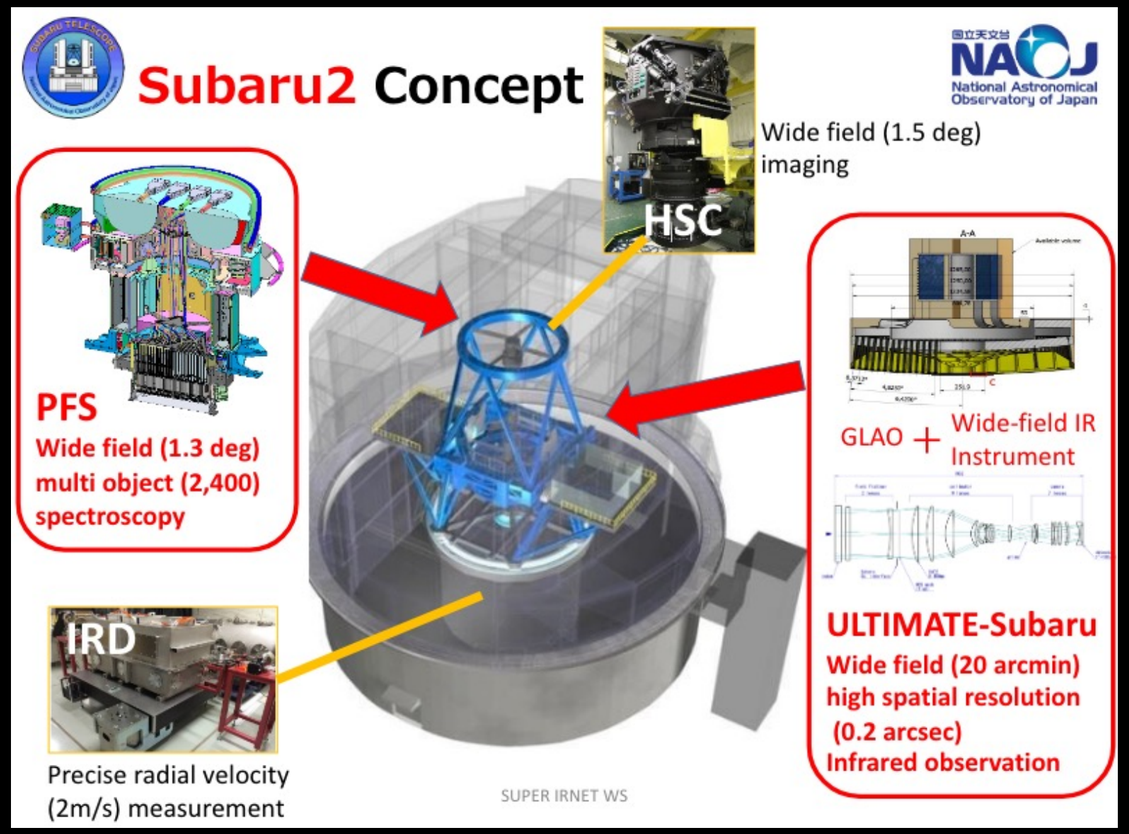
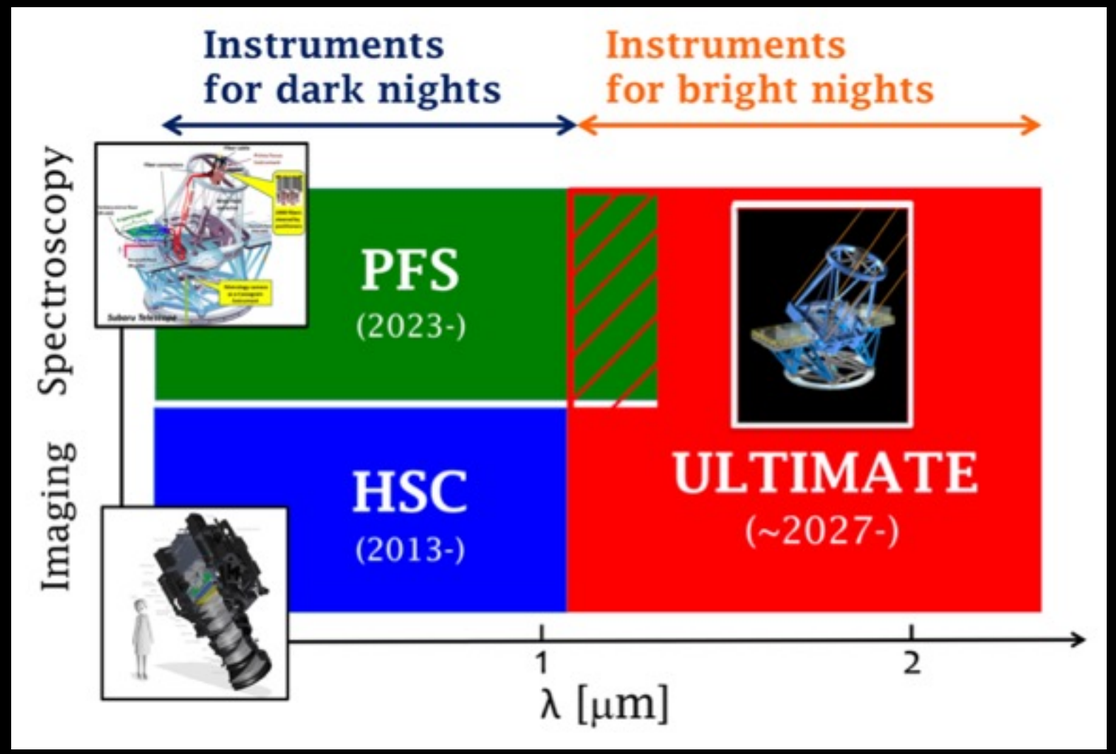
Subaru UM FY2021 (Jan 10, 2022)

# SUBARU 2: SUBARU'S WIDE-FIELD STRATEGY IN 2020S

Subaru will provide "Legacy Survey data" using HSC, PFS and ULTIMATE




Slide courtesy of M. Yoshida presented in the SUPER-IR net seminar #1

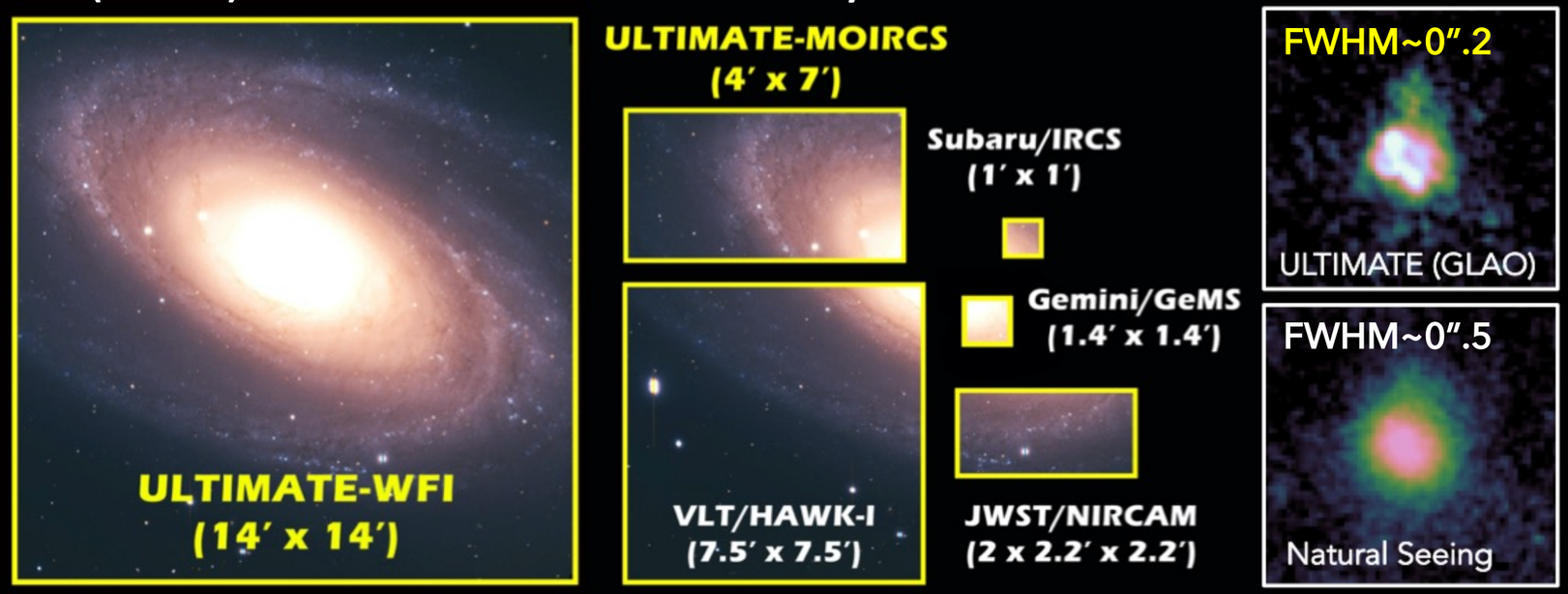



ULTIMATE is an essential step to expand Subaru's wide-field survey capability toward Near-Infrared

Subaru Telescope will start the "Subaru 2" concept from FY2022.

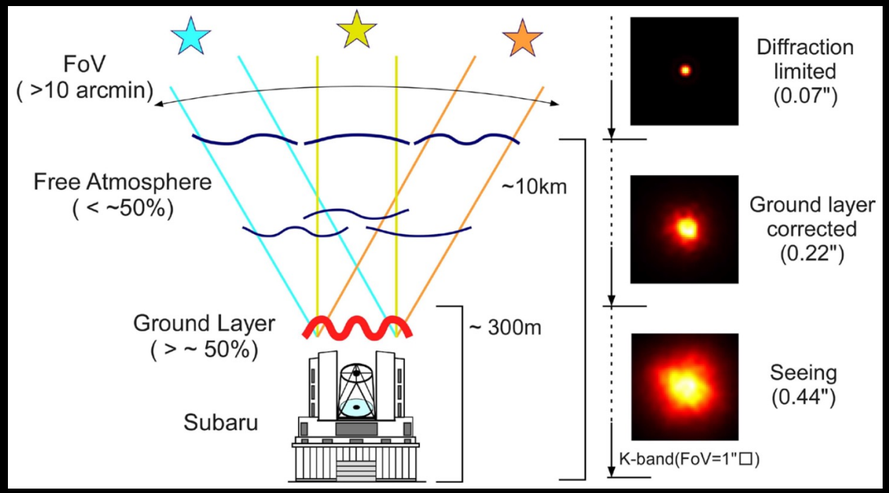
# WIDE-FIELD + HIGH-RESOLUTION NIR SURVEYOR WITH GLAO

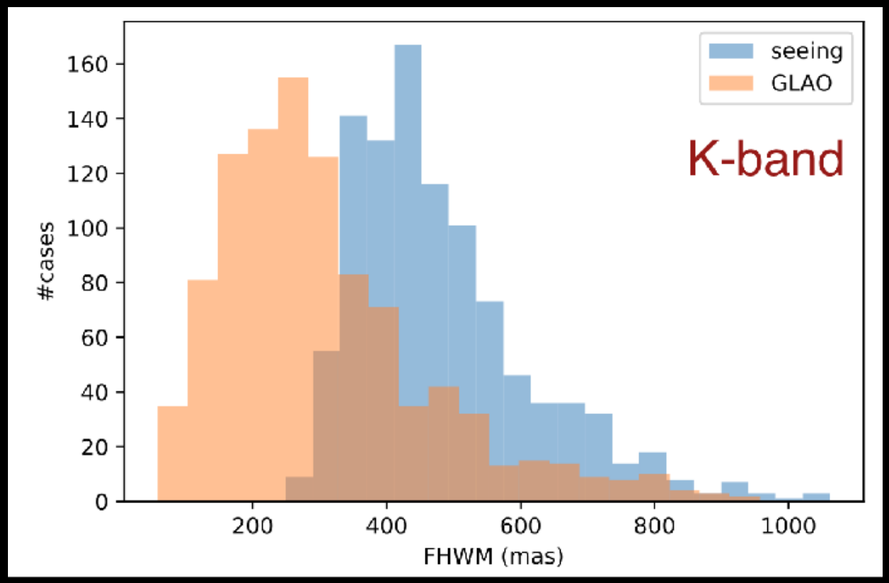
**NIR (K-band) facilities available in 2020s and beyond**









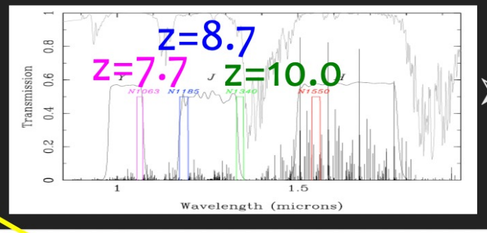

## Key parameters :

- Median FWHM ~ 0″.2 @K-band uniformly over $\phi$ ~20′ FoV
- Factor of ~ 2 seeing improvement in any seeing condition
- Sky coverage ~ 100%

# KEY SCIENCE: "BIRTH", "GROWTH", "DEATH" OF GALAXIES IN THE CRADLE OF COMIC STRUCTURE

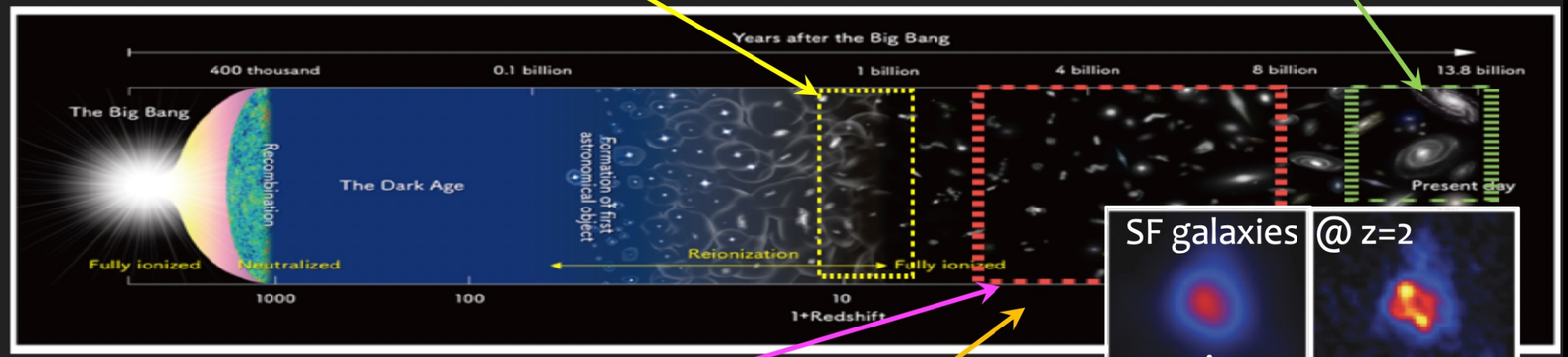
## 1. First galaxies (birth)

- Detect LAEs (+LBGs) in the epoch of reionization (z>>7) with ultra-deep NB(+BB) NIR imaging




## 4. End products

- Dissecting nearby galaxies @ D<100Mpc with BB+NB to GMC scale.





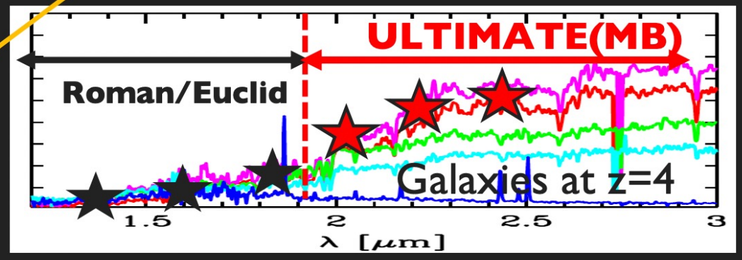


## 2. Stellar build-up (growth)

- Deep & sharp & panoramic NB Hα/[OIII] imaging galaxies at "cosmic noon"(z=0.5-3.5)

## 3. Quenching (death)

- Tracking down the rest-optical SEDs of galaxies @ z~5 with BB/MB imaging (in K-band).




Planning a Large Survey program using the SSP

## ULTIMATE SCIENCE TEAM

Project Scientist (Y. Koyama)

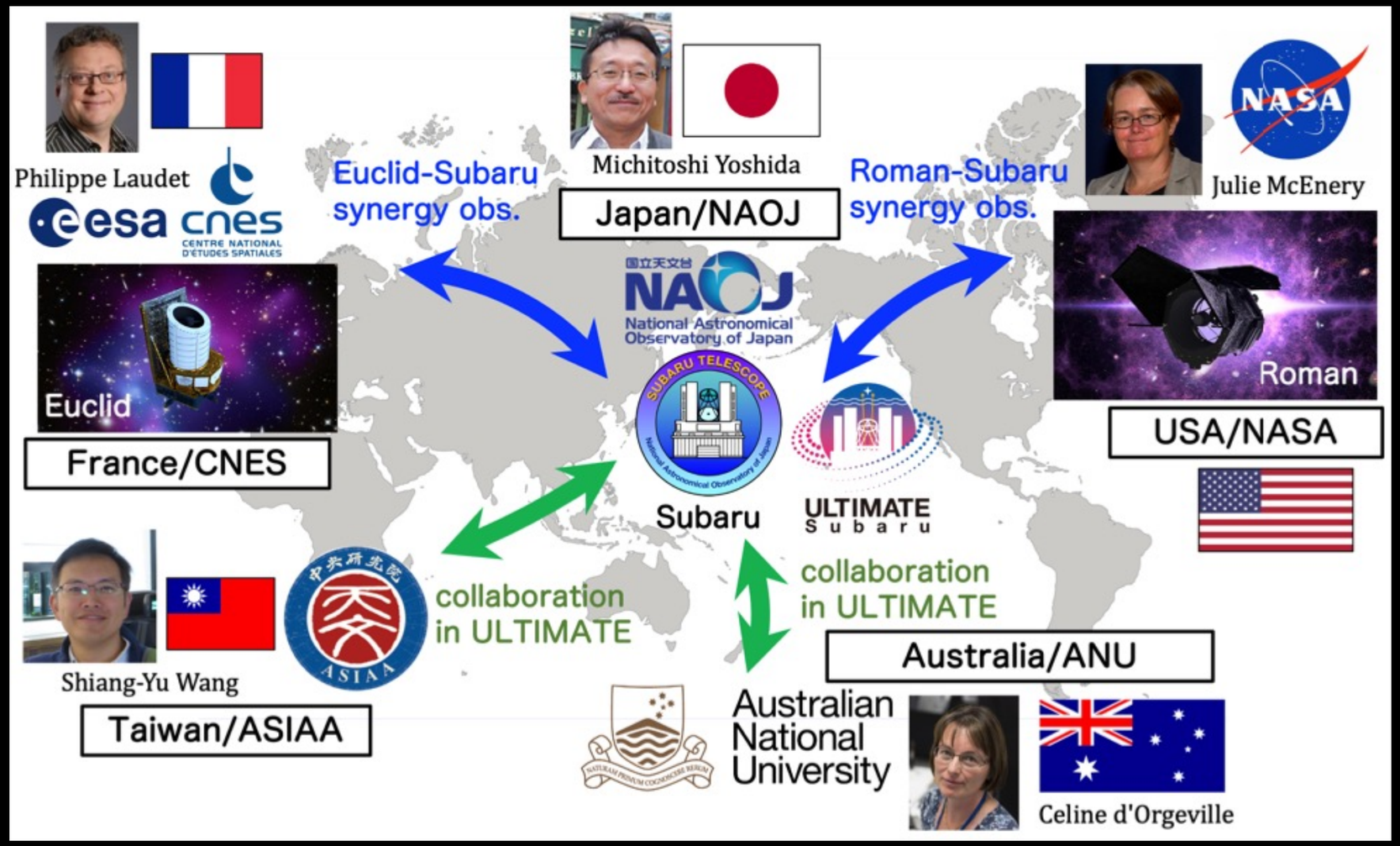
- A. High-redshift
- B. Local Universe/Our Galaxy/Solar System (including synergy with JASMINE)
- C. Time Domain Science

More than 100 domestic/international scientists are participated

Summarized ~200 pages documents entitled "ULTIMATE Science Whiter Paper" presented in Sci. Inst. CoDR.

# JSPS CORE-TO-CORE PROGRAM

"International research network toward the era of deep and wide NIR survey of the universe with space and ground-based telescopes"

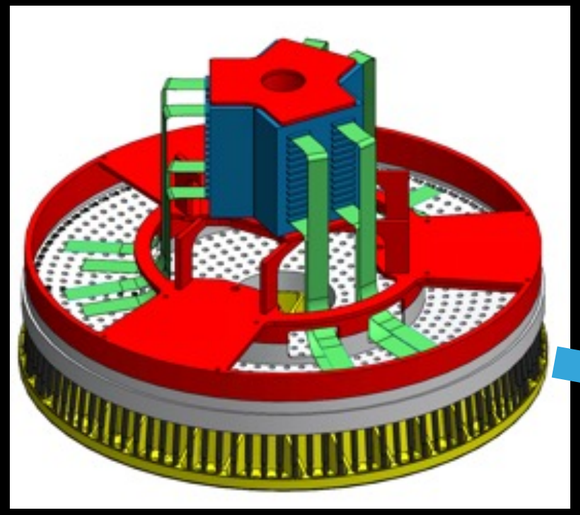


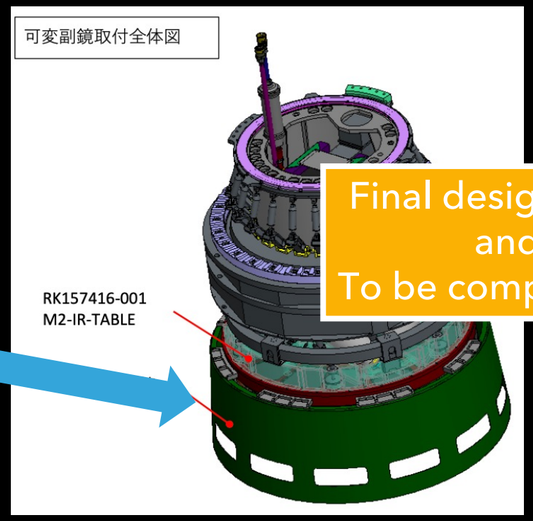

- Program approved in FY2021 for 5 years until FY2025.
- ULTIMATE science team plays leading roles in this program.
- Discussing
  - Scientific synergy among the future NIR survey programs including ULTIMATE.
  - Technical collaboration in the ULTIMATE instrumentation.

# GLAO SUB-SYSTEMS AND THEIR STATUS

## (1) Adaptive Secondary Mirror

$\phi$=1260mm deformable mirror with 924 actuators

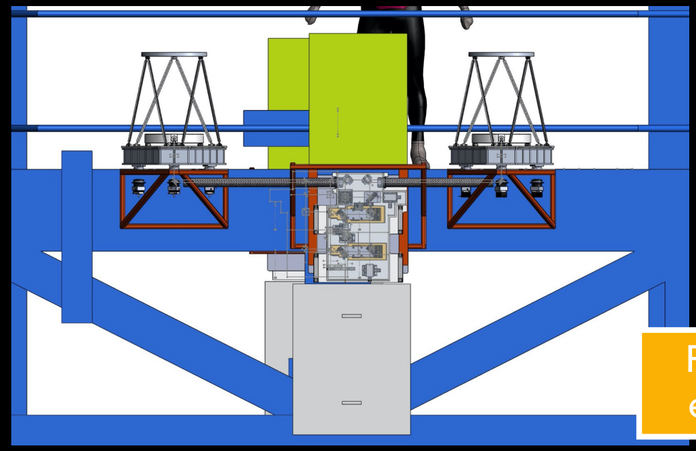





Final design with AdOptica and MELCO.
To be completed in FY2021.

## (2) Laser Guide Star Facility

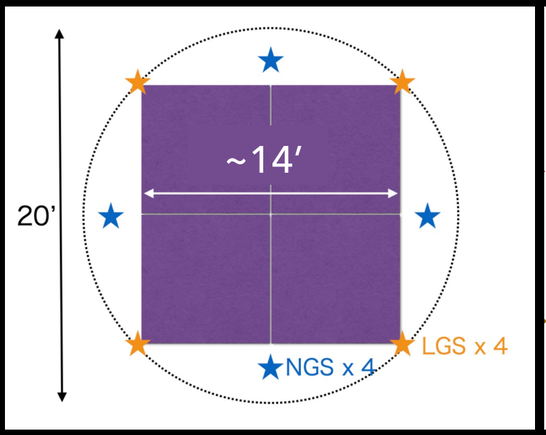
TOPICA fiber laser(589nm) x 2, generate 4 LGSs

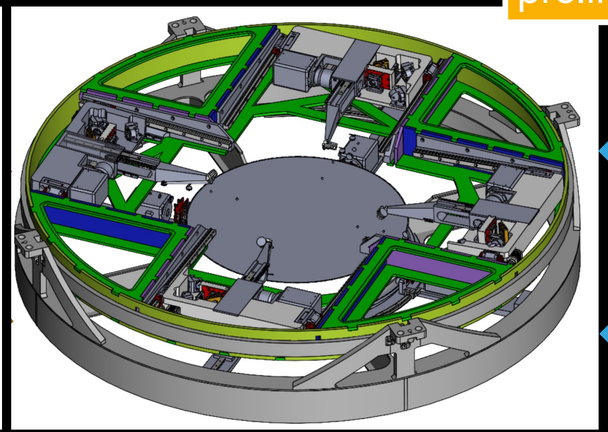


Preliminary design in early 2022 with ANU

## (3) Wavefront Sensors (LGS, NGS)

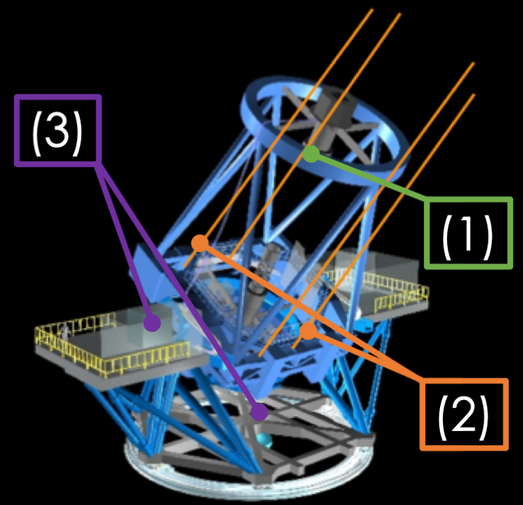
Finalizing Cs WFS preliminary design with ANU



4 LGS Wavefront Sensors

4 NGS Wavefront Sensors




GLAO PDR in mid-2022

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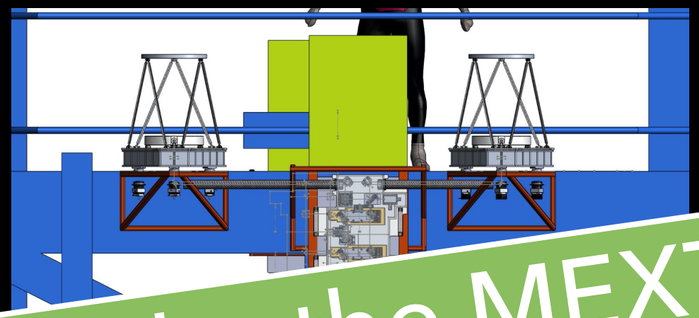
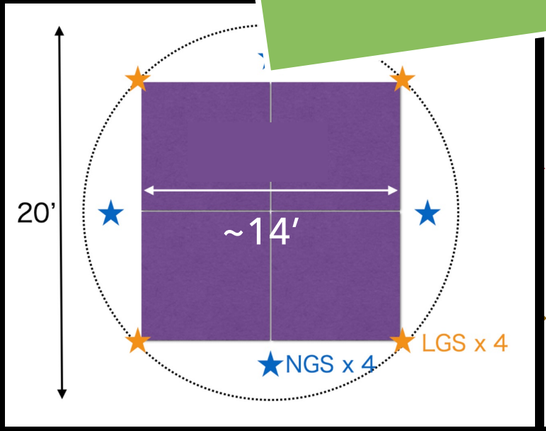
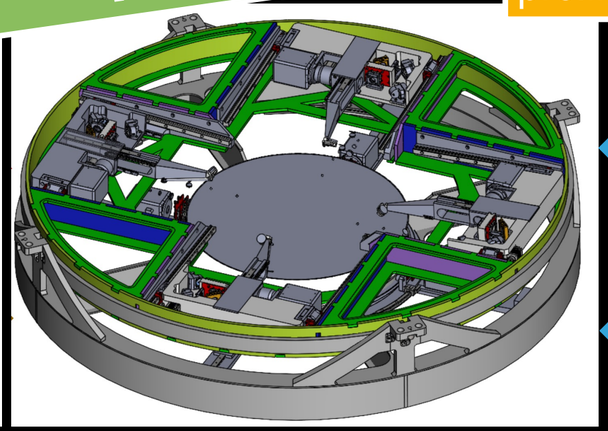


esign in
h ANU

GLAO project got funded by the MEXT supplementary budget in FY2021.

## (3) Wave



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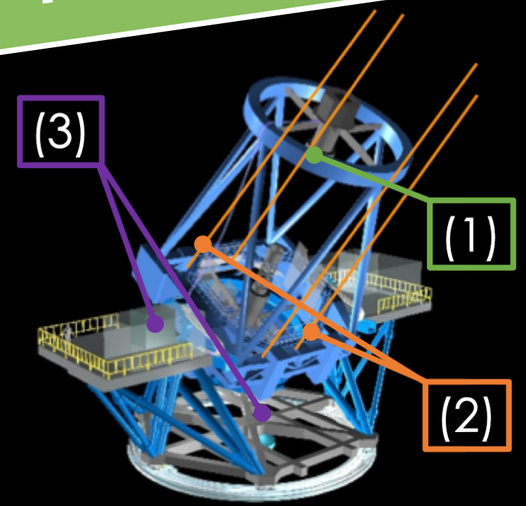
preliminary design with ANU

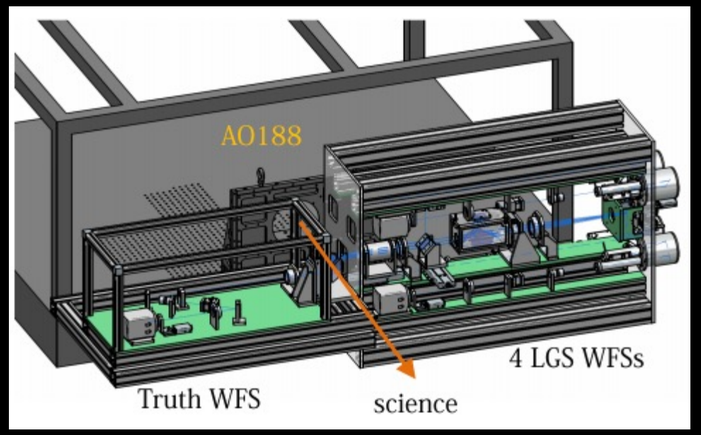


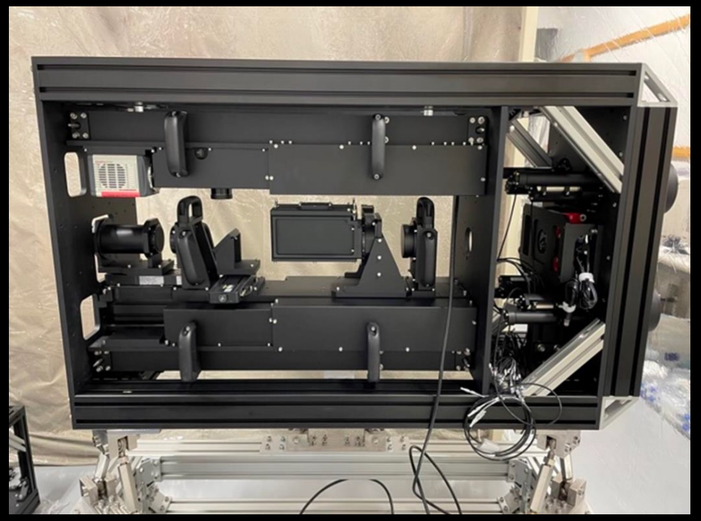

GLAO PDR in mid-2022

# KEY TECHNOLOGY PROTOTYPING

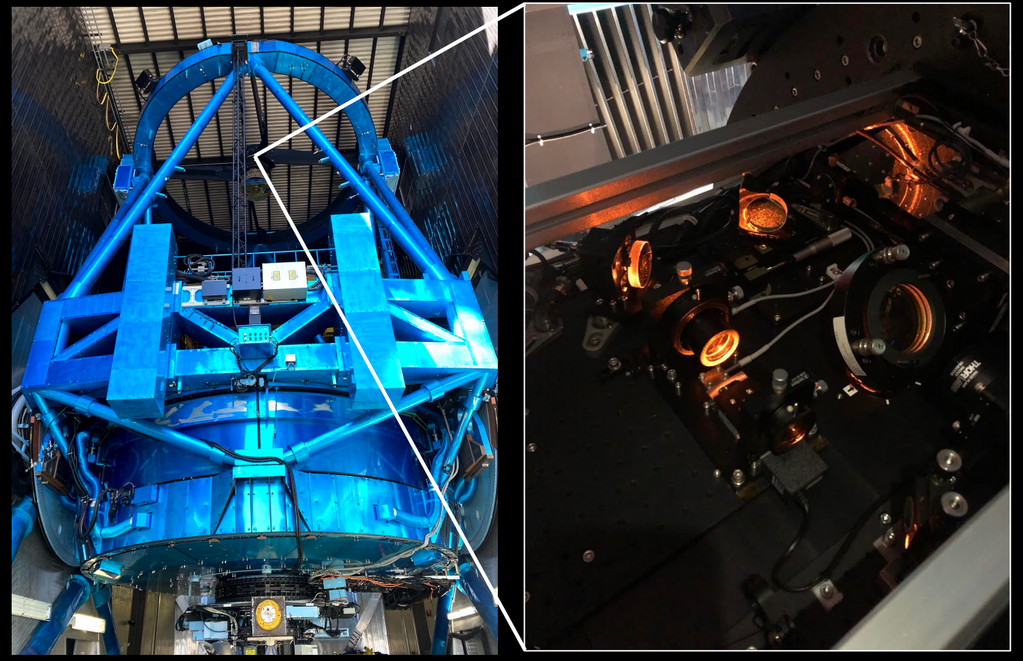
ULTIMATE-START project : Laser Tomography AO system with 4 laser beams
(PI: M. Akiyama at Tohoku Univ.)

- Laser Tomography Wavefront Sensor (4 x SH-WFS) has been developed and being tested at Tohoku Univ.
- TOPTICA laser guide star has been integrated at Subaru to provide 4 laser beams.
- LTAO will be initially commissioned with AO188 in FY2022, and later be used with the ASM, providing a narrow-field (<10”) LTAO mode in ULTIMATE.



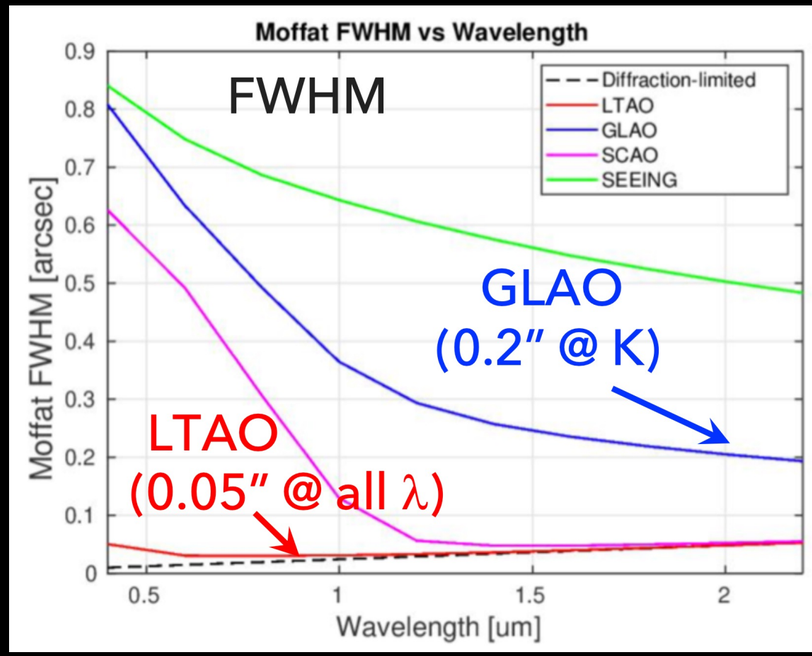



4 SH-WFS being tested at Tohoku Univ.



New Laser Guide Star system integrated at the Subaru

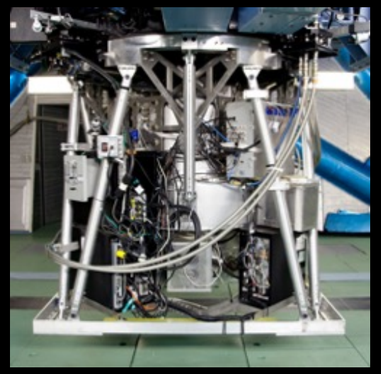
Diffraction-Limited Spatial Resolution from Visible to NIR



# NEW WIDE-FIELD NIR INSTRUMENTS WITH GLAO

## FIRST LIGHT INSTRUMENT

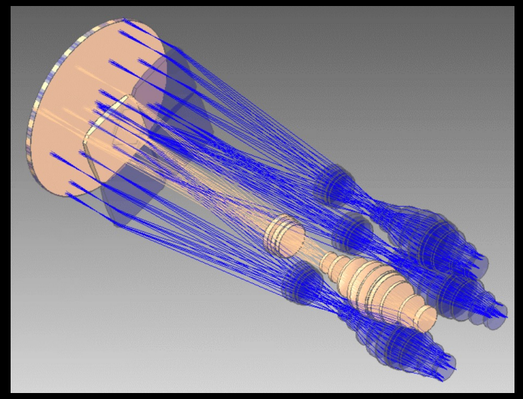
- Reuse MOIRCS at Ns. IR



- FoV ~ 4' x 7'  (0".12/pix)
- Wavelength: 0.9 - 2.5 um
- Imager/MOS spec (R500-3000)

## FACILITY INSTRUMENT FOR LARGE IMAGING SURVEY

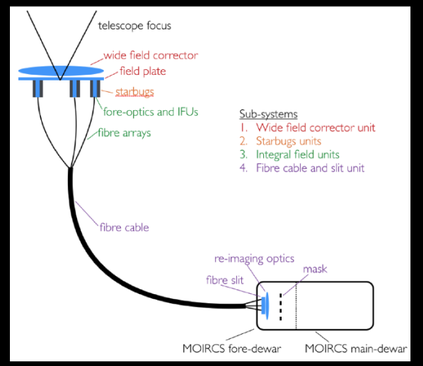
- Wide-field imager (WFI) at Cs.



- FoV ~ 14' x 14' (~0".1/pix)
- Wavelength: 0.9-2.5 um
- Wide-variety of narrow/medium band filters

## MULTI-IFU CONCEPT

- Fiber-bundle multi-IFU at Cs



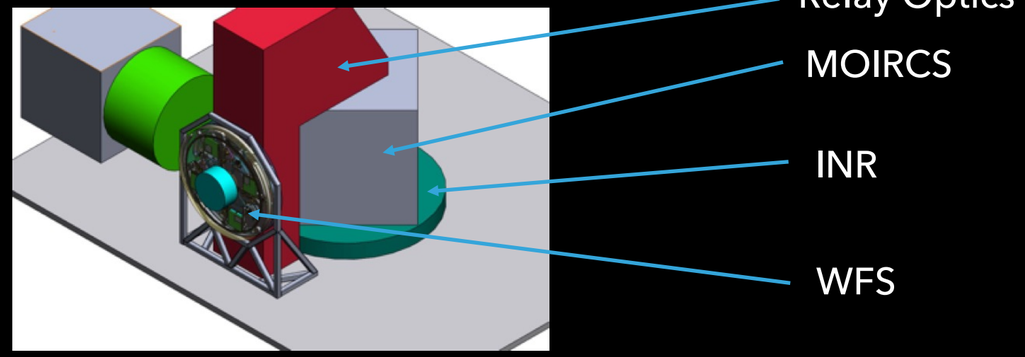

Multi-IFU concept by AAO (Ellis et al. 2016)

- Feed to the existing spectrograph MOIRCS=R500-3000 or PFS (R=2000-5000)
- Patrol field: ~ 14' x 14'
- IFU FoV: 1".2 x 1".2
- Number of IFUs: 8-13
- Wavelength: 0.9 - 1.8 um

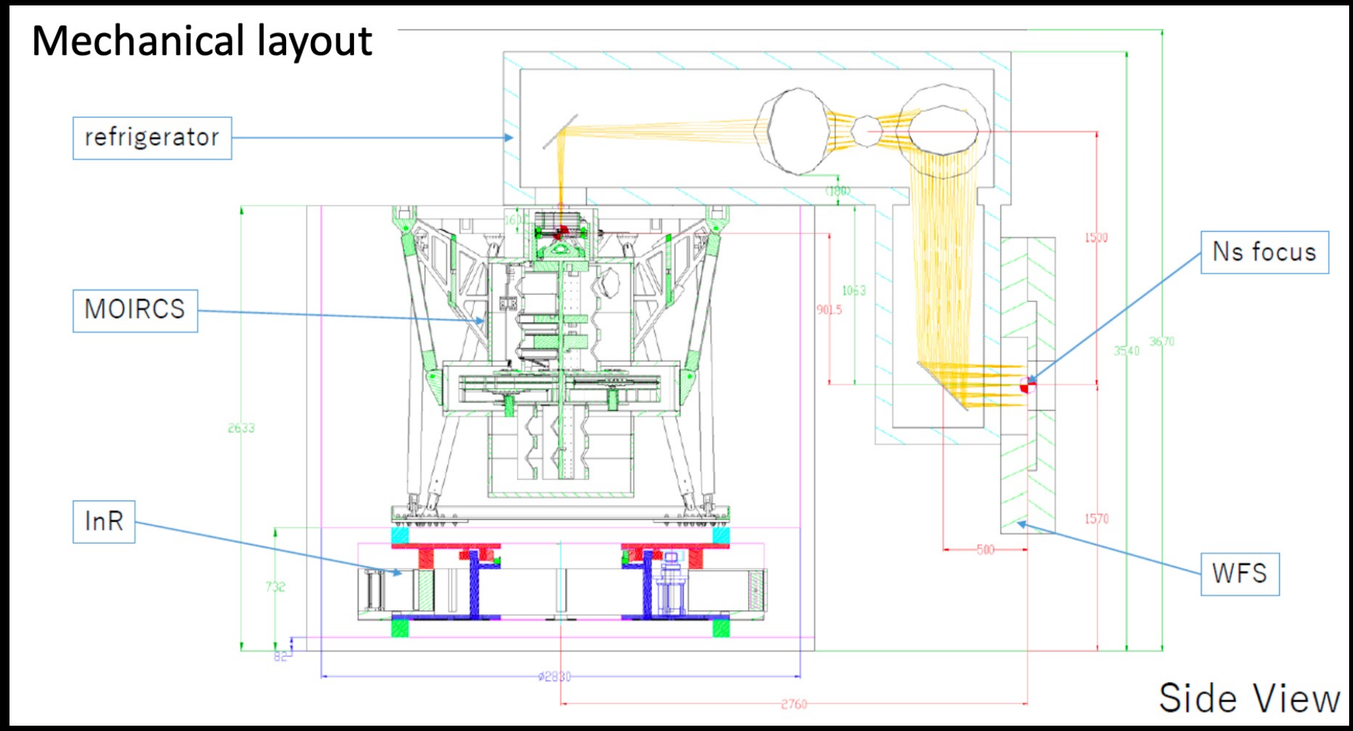
**Successfully passed a conceptual design review on June 2021**

# MOIRCS UPGRADE FOR ULTIMATE

- MOIRCS relocation to the NsIR to feed the GLAO corrected light and to have more stable (gravity-invariant) platform for the MOS observation.
- MOIRCS at NsIR conceptual design conducted by ASIAA
- Relay optics should be cooled down to -30degC to keep the sensitivity gain by GLAO at K-band.

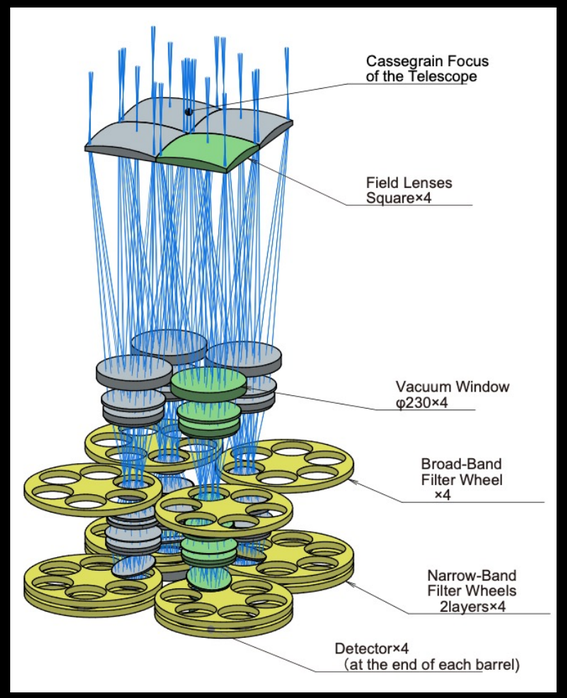


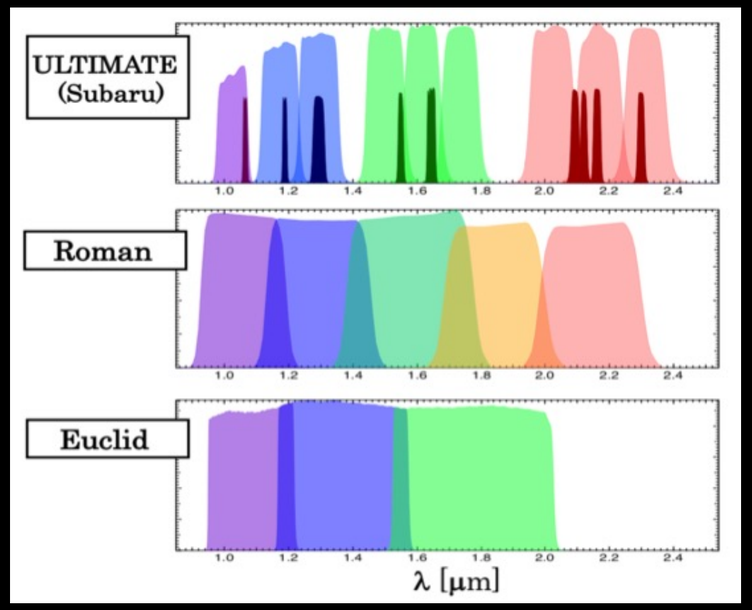

| Band | Wavelength [$\mu$m] | Width [$\mu$m] | Cs BG | NsIR BG w/o Relay | NsIR BG with Relay | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 278 K | 273 K | 263 K | 253 K | 243 K | 233 K |
| Ks | 2.14 | 0.32 | 15.92 | 15.87 | 15.49 | 15.61 | 15.76 | 15.83 | 15.85 | 15.86 |
| K1 | 2.02 | 0.14 | 15.59 | 15.58 | 15.49 | 15.52 | 15.56 | 15.57 | 15.58 | 15.58 |
| K2 | 2.17 | 0.14 | 15.96 | 15.92 | 15.53 | 15.65 | 15.80 | 15.87 | 15.90 | 15.91 |
| K3 | 2.32 | 0.13 | 15.67 | 15.53 | 14.68 | 14.90 | 15.22 | 15.39 | 15.48 | 15.51 |
| H | 1.64 | 0.30 | 15.20 | 15.20 | 15.20 | 15.20 | 15.20 | 15.20 | 15.20 | 15.20 |
| H1 | 1.50 | 0.12 | 15.27 | 15.27 | 15.27 | 15.27 | 15.27 | 15.27 | 15.27 | 15.27 |
| H2 | 1.61 | 0.11 | 15.21 | 15.21 | 15.21 | 15.21 | 15.21 | 15.21 | 15.21 | 15.21 |
| H3 | 1.73 | 0.12 | 15.32 | 15.32 | 15.32 | 15.32 | 15.32 | 15.32 | 15.32 | 15.32 |
| J | 1.25 | 0.16 | 16.48 | 16.48 | 16.48 | 16.48 | 16.48 | 16.48 | 16.48 | 16.48 |
| J1 | 1.17 | 0.13 | 16.75 | 16.75 | 16.75 | 16.75 | 16.75 | 16.75 | 16.75 | 16.75 |
| J2 | 1.29 | 0.12 | 16.51 | 16.51 | 16.51 | 16.51 | 16.51 | 16.51 | 16.51 | 16.51 |



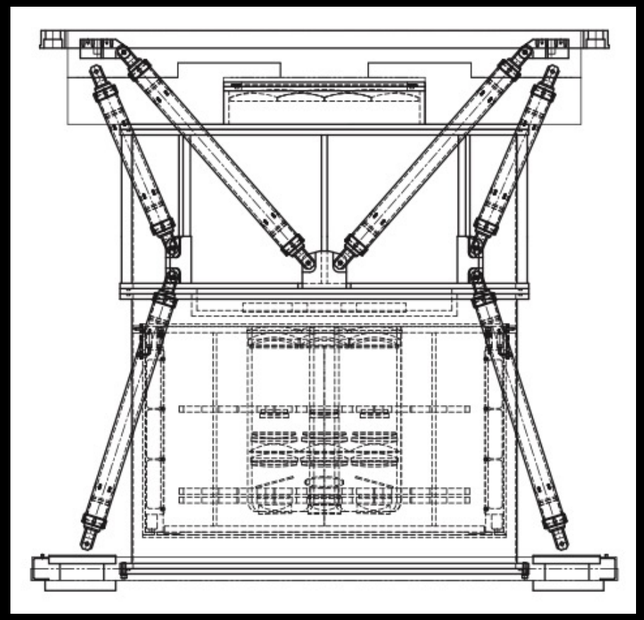
# WIDE-FIELD IMAGER (WFI) CONCEPTUAL DESIGN

- Feasible optical design that realizes 14'x14' FoV (Φ~20') with < 0".1 image quality at 0.9~2.5 micron.

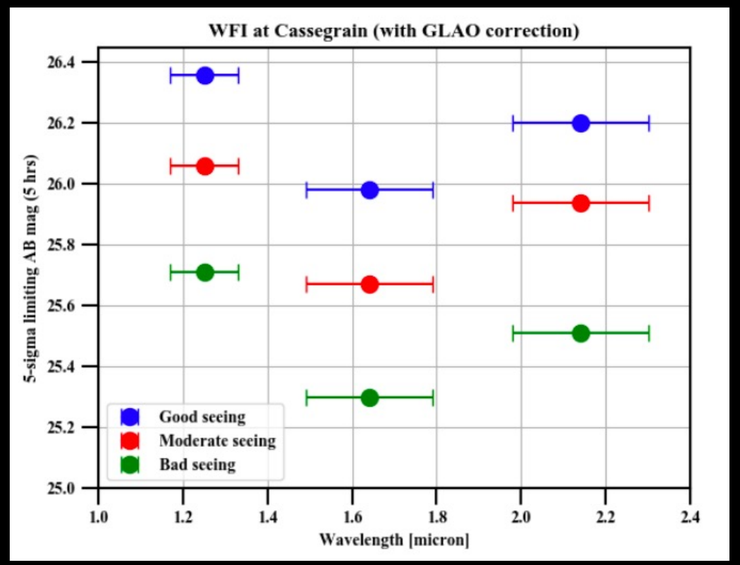



- Designed to equip with a wide-variety of BB, MB, and NB filters (max 15 filters at a time).



- Cryostat supported by truss structure to mount the instrument on the Subaru Cassegrain interface

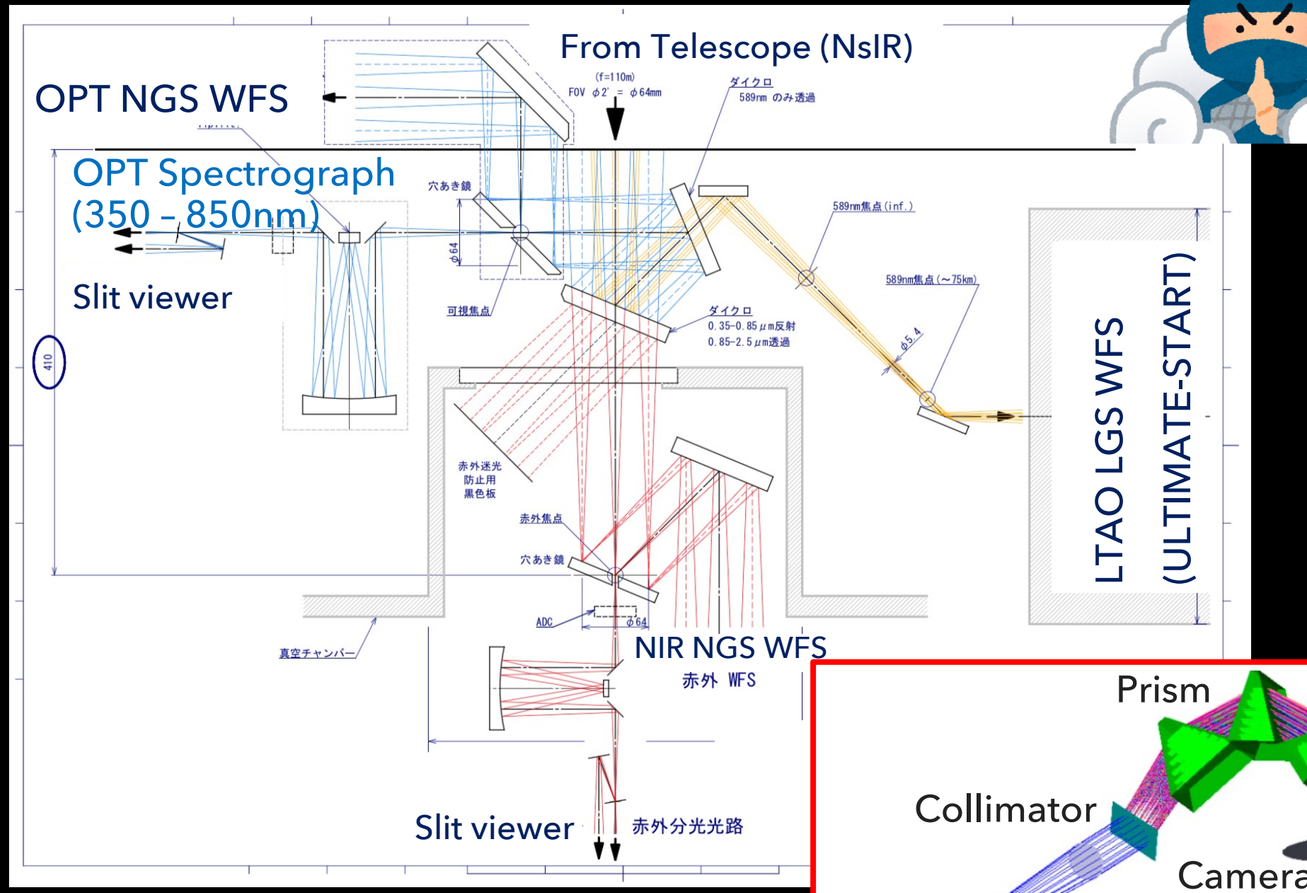


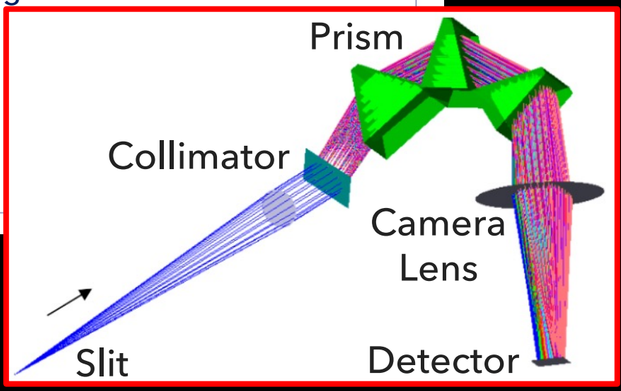

- Reach K~26 mag with 5 hrs integration under normal seeing condition

# NARROW-FIELD MODE OF ULTIMATE: LTAO + NINJA

NINJA : Single-object, High-throughput spectrograph covering VIS-NIR simultaneously

- Funded by a JSPS Kiban-S program (PI: M. Yoshida)
- Simultaneous wavelength (350nm – 2500nm) with R~4000 (TBD) spectral resolution.
  - OPT ch: 350-850nm
  - NIR ch: 850-2500nm
- Pursuing “ULTIMATE” sensitivity with a diffraction-limited spatial resolution using the LTAO + ASM developed for ULTIMATE.
- To be installed at the NsIR platform.
  - Sharing the platform with MOIRCS and SCExAO (feasibility study ongoing)



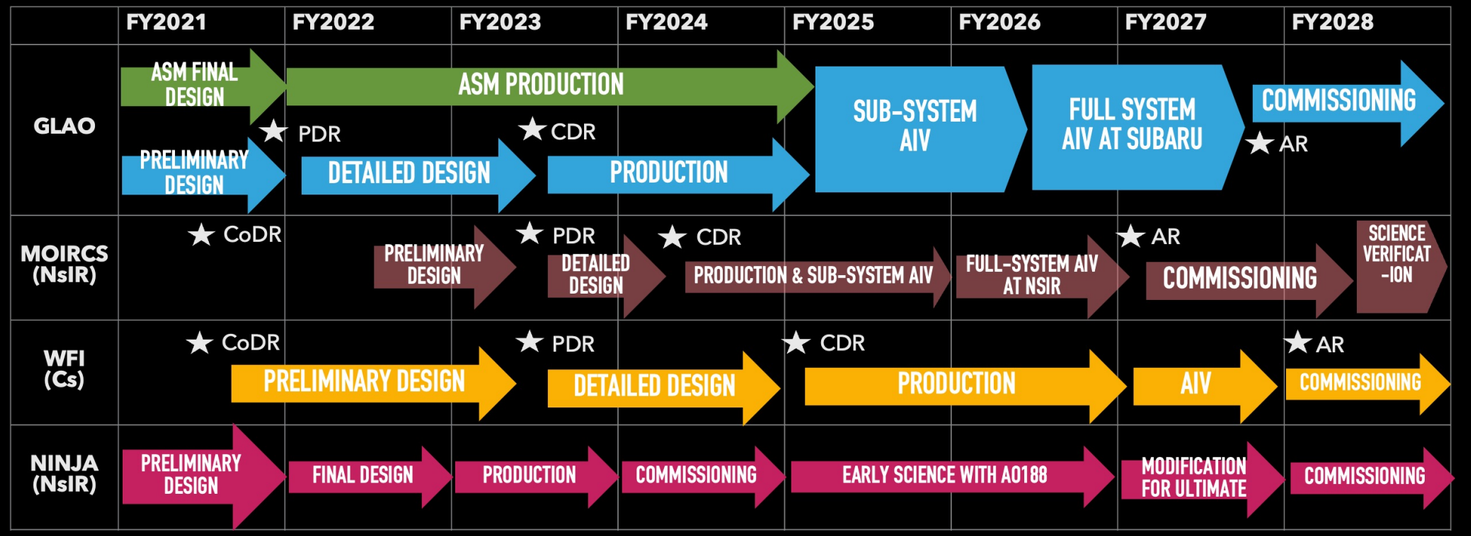
# SUMMARY

- ULTIMATE-Subaru: next-generation wide-field NIR survey instruments with GLAO

- GLAO project
  - Got funded by FY2021 MEXT supplemental budget.
    - Start production of the Adaptive Secondary Mirror from early FY2022.
  - GLAO full-system PDR in mid-2022

- Science Instruments
  - Wide-field Mode (GLAO)
    - FWHM~0”.2 @K-band, 20’ FoV
    - MOIRCS, WFI conceptual designs
  - Narrow-Field Mode (LTAO)
    - FWHM~0”.05 @ Vis-NIR <10” FoV
    - NINJA got funded by JSPS Kiban-S

*Expected First Light in FY2027*




Critical decision must be made in mid-FY2022 whether to go or not to go with MOIRCS at the NsIR together with NINJA.

➡ Need Community’s Input!
We will organize “Workshop on the future NIR spectroscopic capability at the Subaru Telescope (TBD)”.