



ULTIMATE-Subaru Project Status

Yosuke Minowa
(Subaru Telescope)
on behalf of

ULTIMATE-Subaru working group

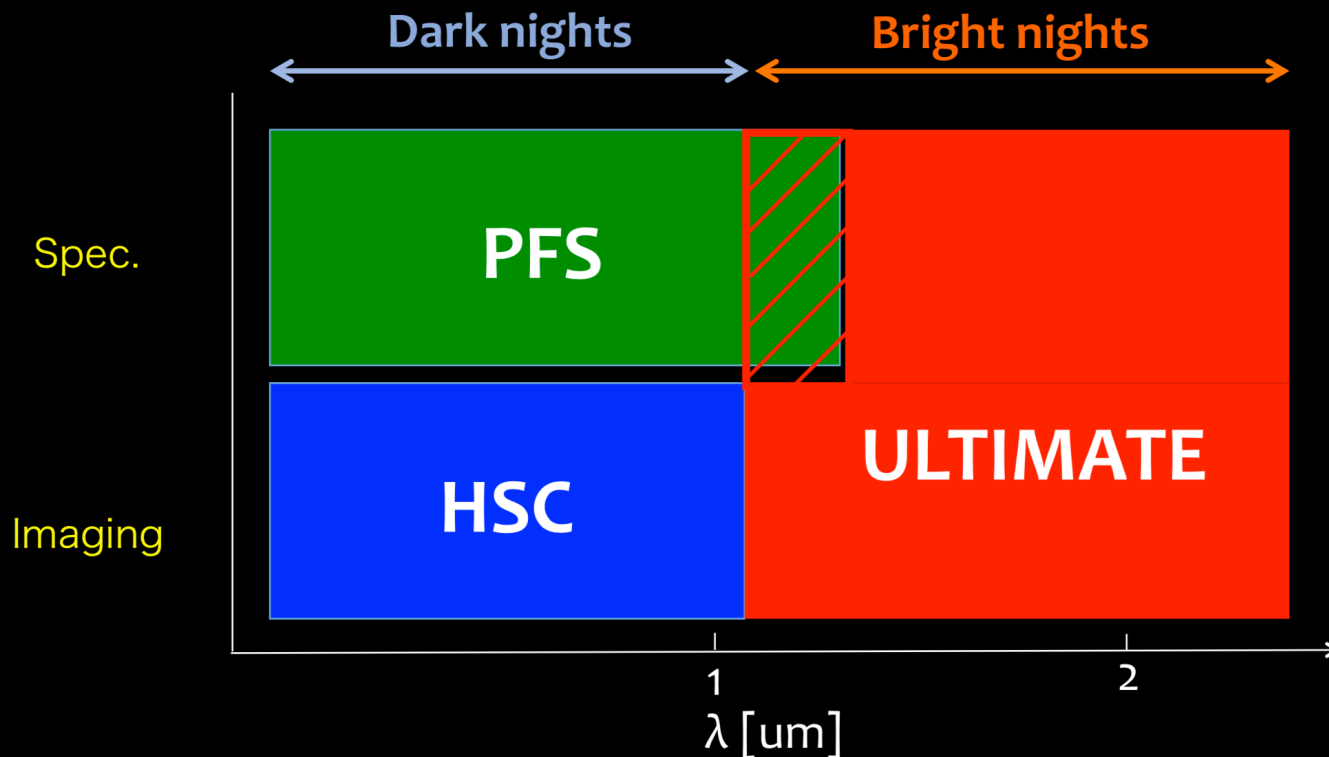
PI: Michitoshi Yoshida (Director, Subaru)
Yusei Koyama, Ikuru Iwata, Yoshito Ono,
Takashi Hattori, Christophe Clergeon,
Ichi Tanaka, Naruhisa Takato (Subaru),
Yutaka Hayano, Shin Oya, Hideki Takami (NAOJ),
Masayuki Akiyama, Tadayuki Kodama,
Tatsuhiro Watanabe (Tohoku)
Kentaro Motohara (Univ. of Tokyo)
Francois Rigaut, Celine D'orgeville, Gaston
Gausachs, Nick Herrald, Visa Korkiakoski (ANU)
Nobuo Arimoto (Seoul National Univ.)

<http://www.naoj.org/Projects/newdev/ngao/index.html>

Subaru's Wide-Field Strategy in 2020s

Recommendation from Subaru Science Advisory Committee
(representative of the Subaru's community)

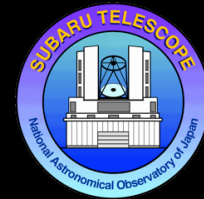
1. Very wide-field optical imager HSC (2013)
2. Wide-field multi-object spectrograph PFS (2019)
3. Wide-field near-infrared imager and MOS spectrograph including AO assisted IFU ULTIMATE-Subaru (2025)



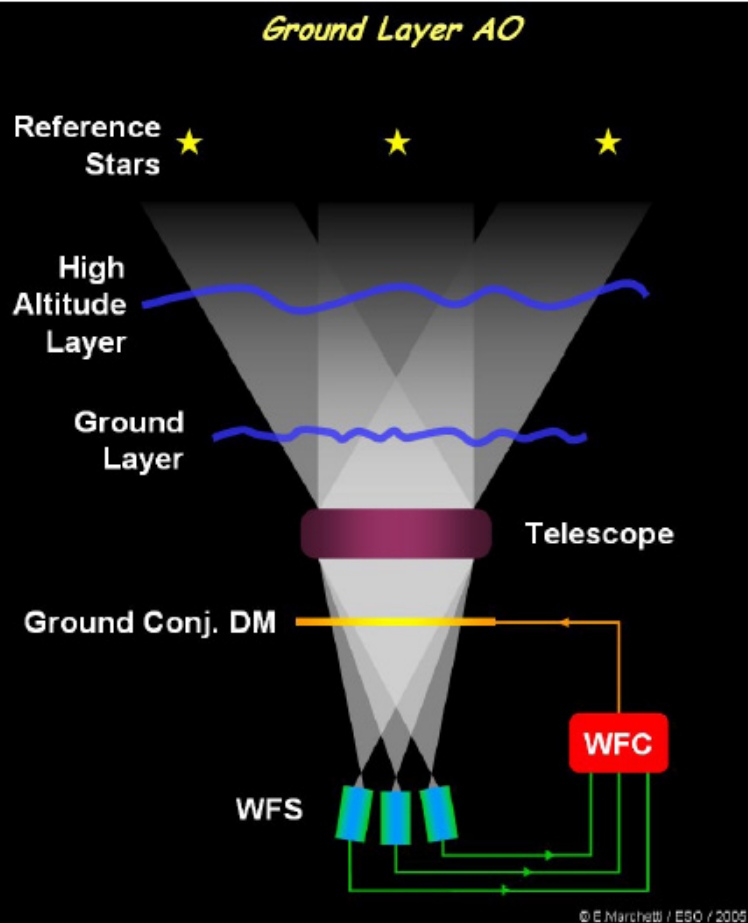
Extend Subaru's survey capability to near infrared

Subaru's Next Facility Instrument Plan

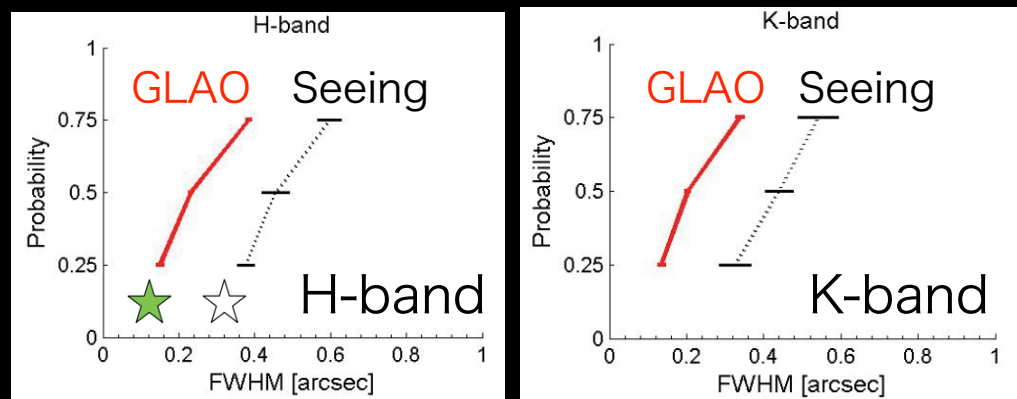
ULTIMATE-Subaru



Ground-Layer Adaptive Optics X Wide-Field near-infrared instrument



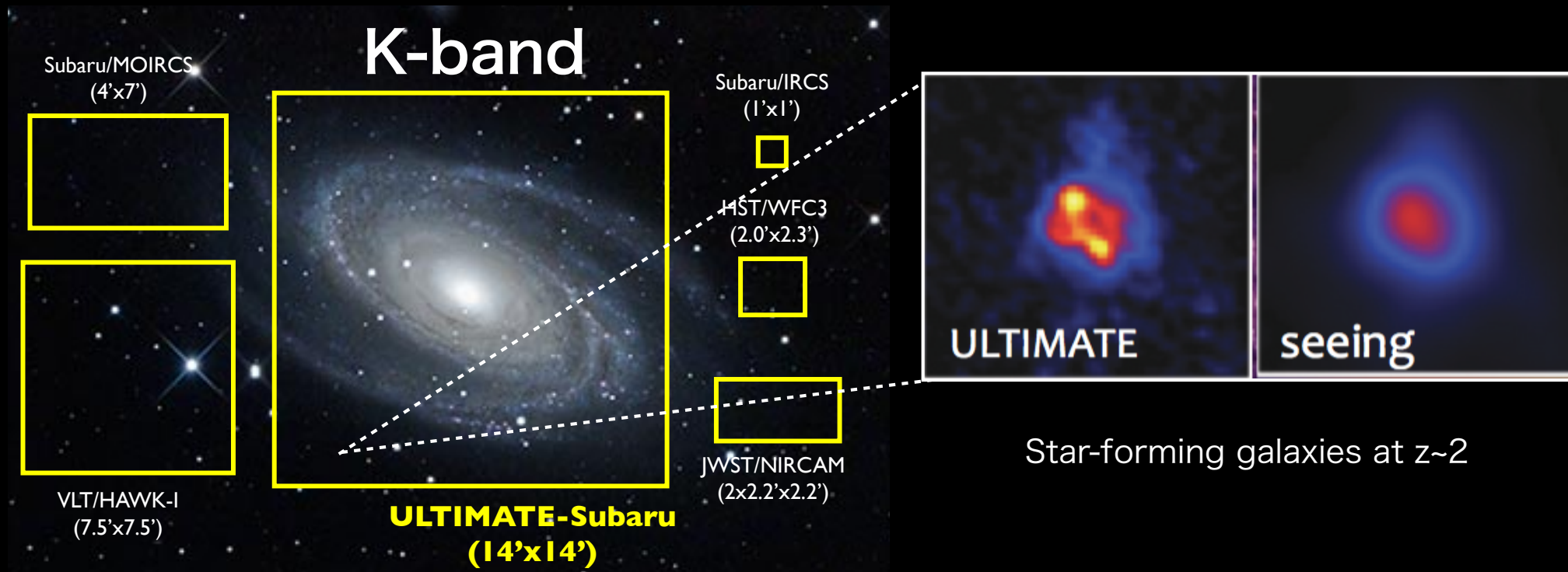
GLAO performance simulation at Subaru
(Oya et al. 2014)



☆ On-sky performance verification with RAVEN

- Uniform seeing improvement over ~ 20 arcmin FoV
- FWHM $\sim 0''.2$ at K-band, which is equivalent to HST and WFIRST

High-resolution wide-field NIR survey capabilities to explore the high-redshift universe



ULTIMATE-Subaru will deliver

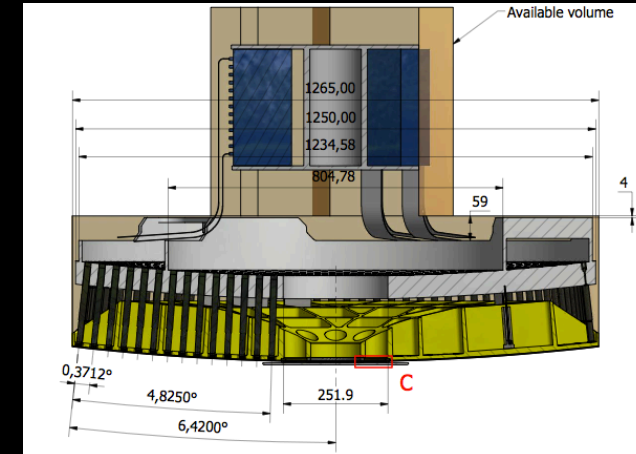
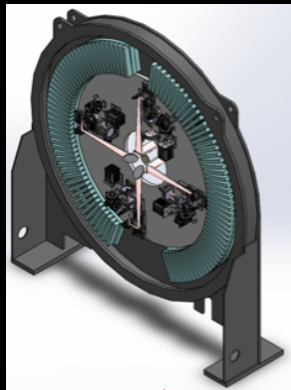
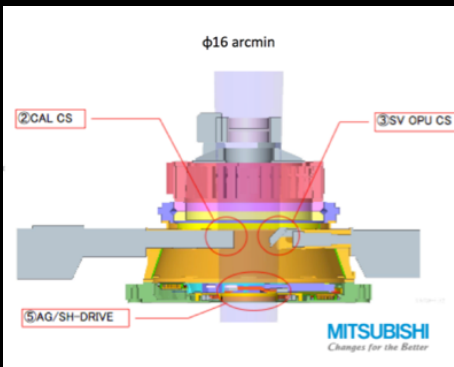
- Subaru's original High-redshift targets to follow-up with TMT
- Spatially-resolved studies of the objects found by HSC/PFS
- SDSS like comprehensive imaging/spec. survey for high-redshift universe ($z > 2$).
- Synergy with the future surveys by wide-field satellites (good synergy with WFIRST)

ULTIMATE telescope upgrade

(1) Adaptive Secondary Mirror

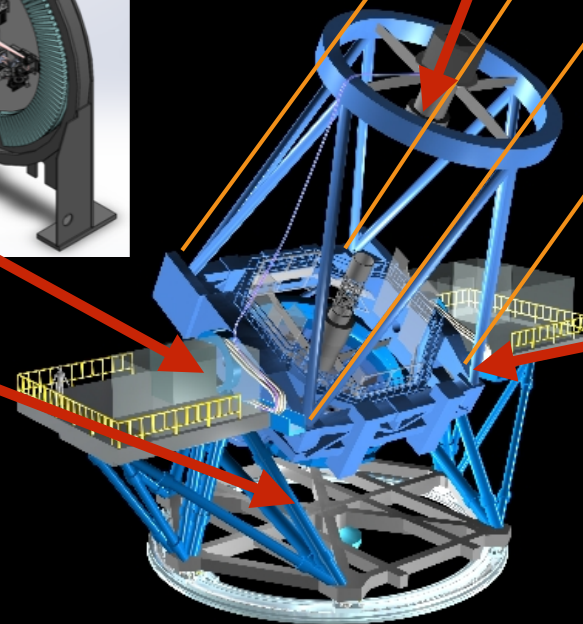
(3) Wavefront Sensors

Cs. Focus (FoV~20 arcmin) Ns.IR Focus (FoV~10 arcmin)



Preliminary Subaru ASM design by Microgate ADS

(2) Laser Guide Star system



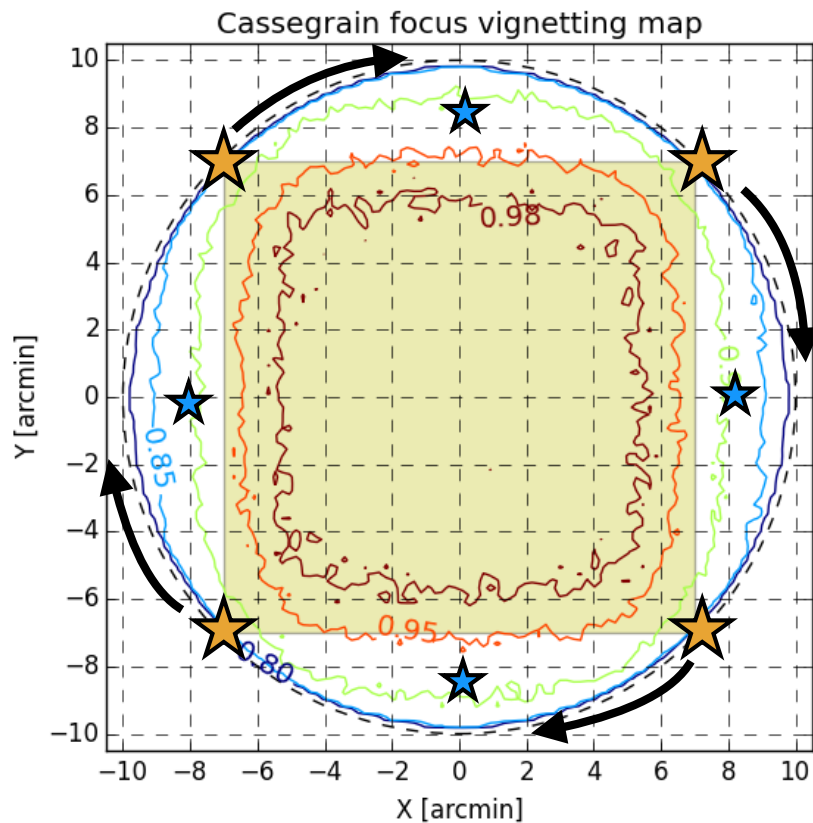
TOPTICA fiber laser(589nm) x 2
Generate 4 laser guide stars



Field coverage

Maximize the field of view to enhance the uniqueness of the ULTIMATE-Subaru

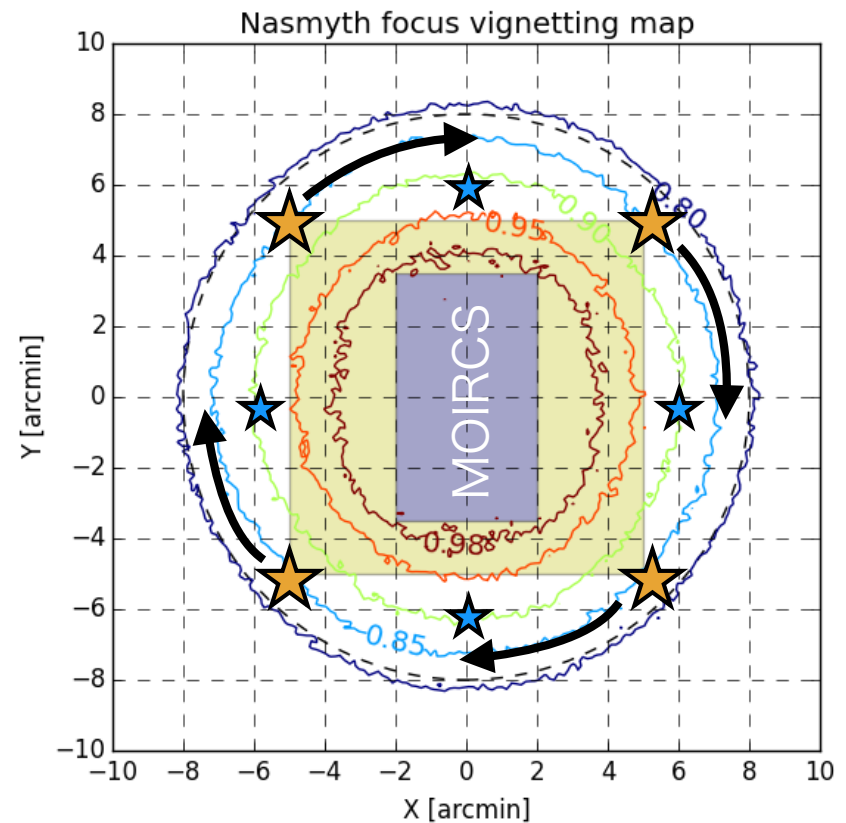
Cassegrain Focus



$\phi \sim 20$ arcmin

Science FoV: 14' x 14'

Nasmyth Focus



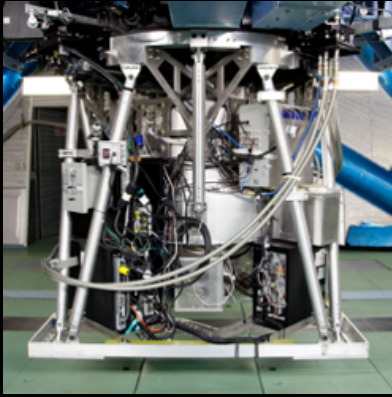
$\phi \sim 14$ arcmin

Science FoV: 10' x 10'

New Wide-field Instrument for ULTIMATE

Phase 1

- Reuse MOIRCS at Ns. IR

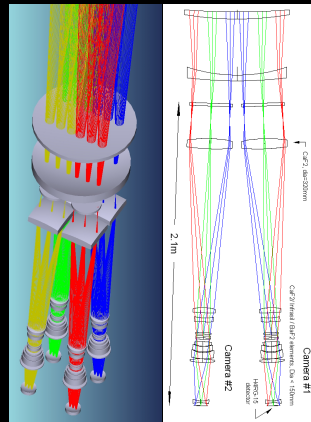


MOIRCS

GLAO first light instrument

Phase 2

- Wide-field imager (WFI) at Cs.



Imager concept by HIA (J. Pazder)

- Workhorse instrument for large SSP imaging survey
- Wide-variety of narrow/medium band filters

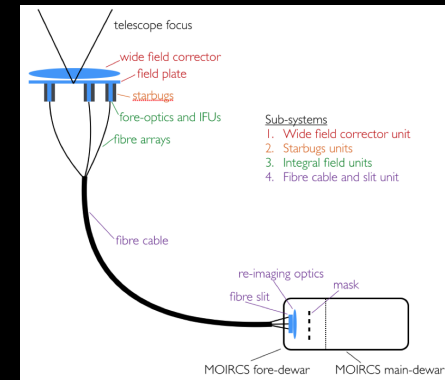
K-band Sensitivity improvement

- 0.8-1.0 mag (PSF)
- 0.5 mag (galaxies with $R \sim 2$ kpc)

Survey power is 20 times higher than MOIRCS at Cs

Phase 3

- Fiber-bundle multi-IFU at Cs



Multi-IFU concept by AAO (S. Ellis)

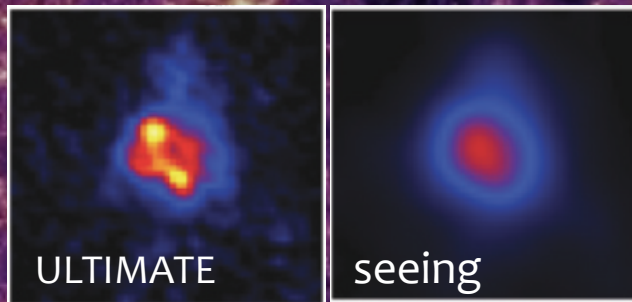
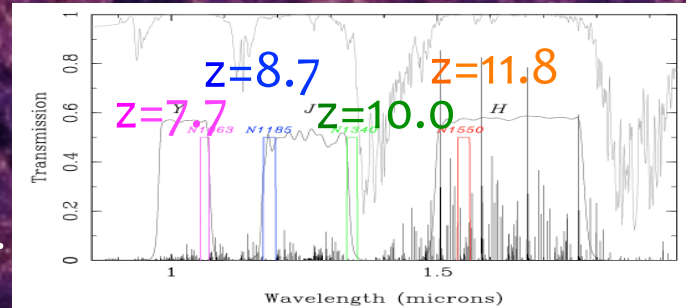
- Unique instrument for large kinematic survey like MANGA/SAMI.
- Feed to the existing spectrograph (MOIRCS/PFS)

Key science : Evolution of the Universe

“Birth, Life, Death” of galaxies in the cradle of large-scale structure

I. First galaxies (birth)

- Unprecedentedly deep NB imaging to detect galaxies a “cosmic dawn” ($z \gg 7$).
- Go beyond the depths of JWST.
- Extension of HSC optica NB survey

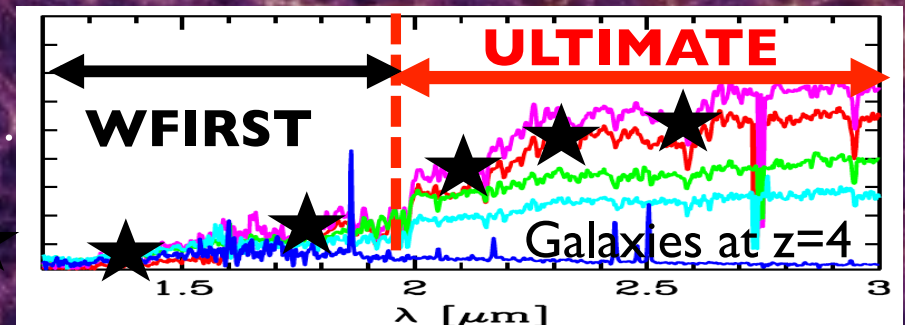


2. Stellar build-up (life)

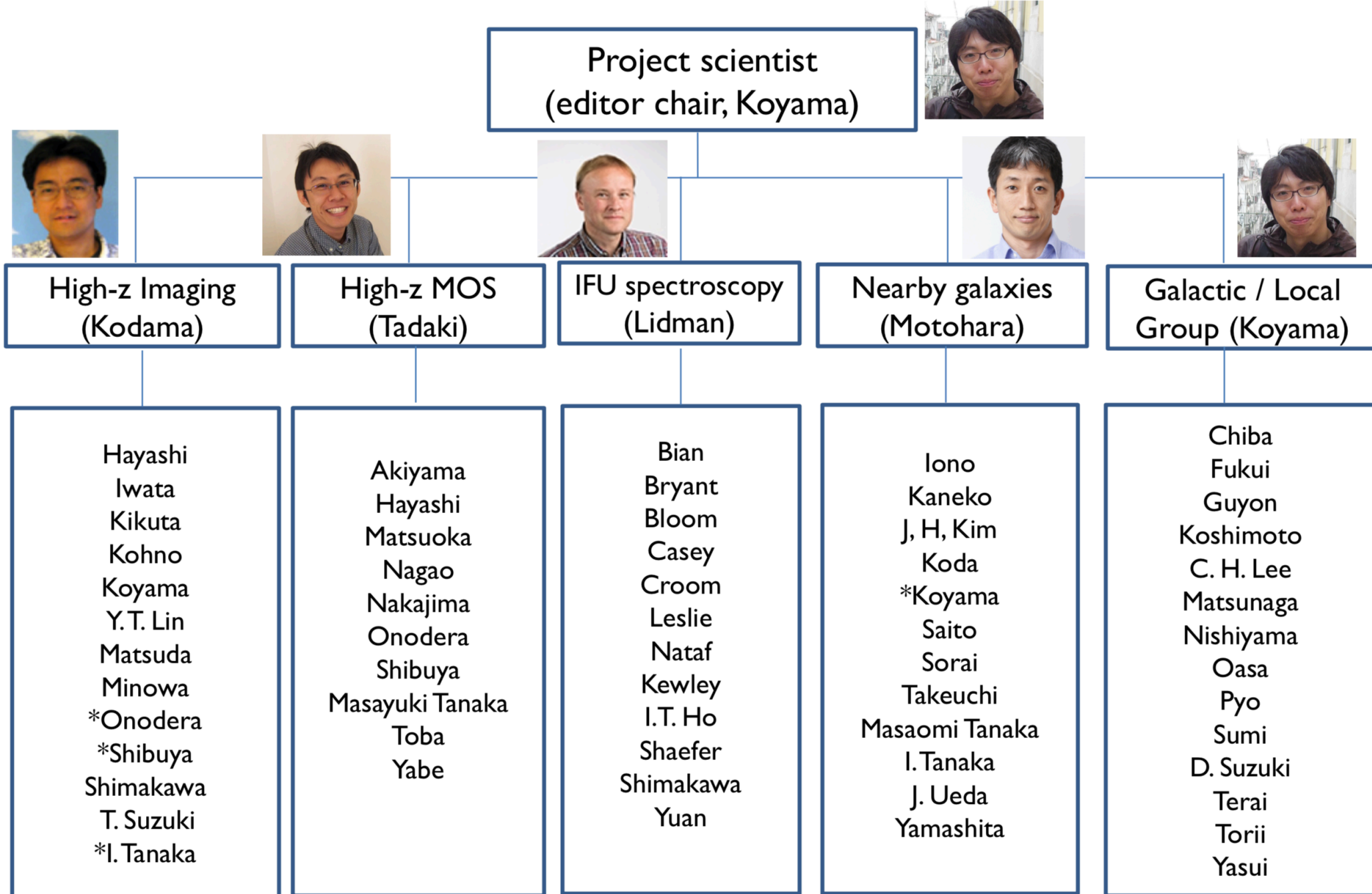
- Origin of Hubble sequence: bulge, disk, and black hole growth
- Deep & sharp & panoramic NB imaging and 3-D spectroscopy of galaxies at “cosmic noon” ($z=0.5-3.5$)

3. Quenching (death)

- Tracking down the “passive” galaxies to $z \sim 5$ with deep BB/MB imaging (in K-band).
- Environment of dead galaxies: do first galaxies die in isolation or in clusters? ★
- Great synergy with WFIRST.



Science team organization toward CoDR2018



Dawn of the ULTIMATE-Subaru

ULTIMATE-Subaru has been kicked off in 2017

- JSPS grant (Kiban-S: ~1.6M USD for 5 years) has been allocated for ULTIMATE-START (Akiyama-san's talk)
- Upgrade the existing instruments
 - * GPU-based real-time system development for SCExAO, AO188, and ULTIMATE
 - * Develop high efficiency grism for MOIRCS

International collaboration

- Collaboration with ANU through the Subaru-Australia short-term agreement
- Looking into the possibility to extend the collaboration with ANU after the short-term agreement
- Looking for more collaborators for GLAO and wide-field instruments

ULTIMATE-Subaru: activities

Past, On-going and future

(1) Adaptive Secondary



- Subaru is going to develop ASM with Adoptica and Mitsubishi.
- Phase1 Feasibility study by Adoptica has been started

(2) Laser



- 1st TOPTICA laser system will be delivered to Subaru on Mar, 2018 for AO188
- LLT and diagnostic system design and development

(3) Tomography WFS



- System optimization based on GLAO simulation (ANU, Tohoku Univ., Subaru)
- Conceptual design of WFS unit at Nasmyth and Cassegrain (Subaru, ANU)
- RTS development for AO188 and ULTIMATE
- Prototyping of SH-WFS at Tohoku Univ.

(4) Wide-Field Instruments



- Multi-IFU conceptual design by AAO (S. Ellis)
- Wide-Field imager conceptual optical design by NRC-HIA (J. Pazder)
- Prototyping of the Starbug positioner
- Conceptual design of the wide-field imager

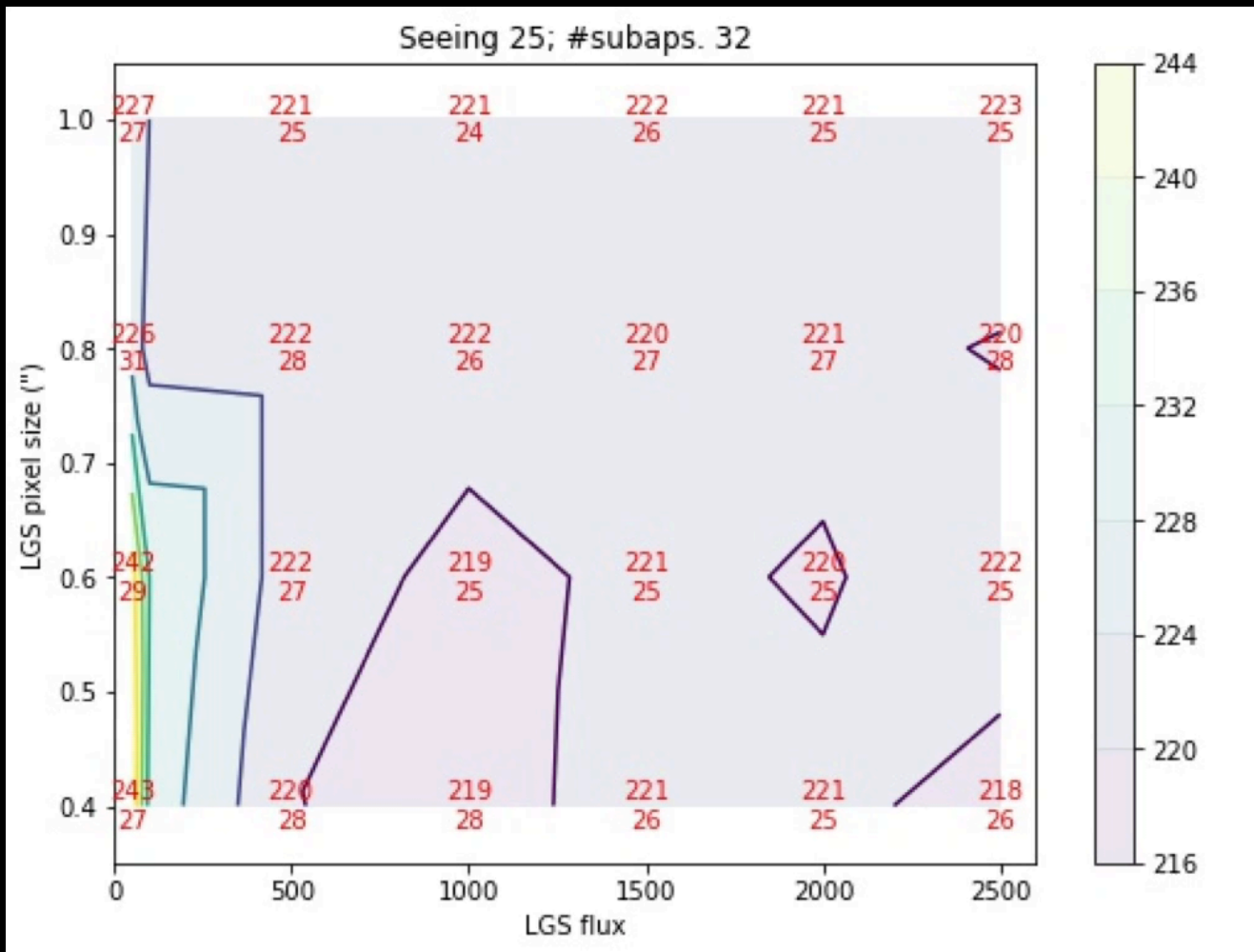
(5) Science

- Contributions from domestic/international collaborators



ULTIMATE-Subaru Science Workshop @ Mitaka (2016/6/16-17)

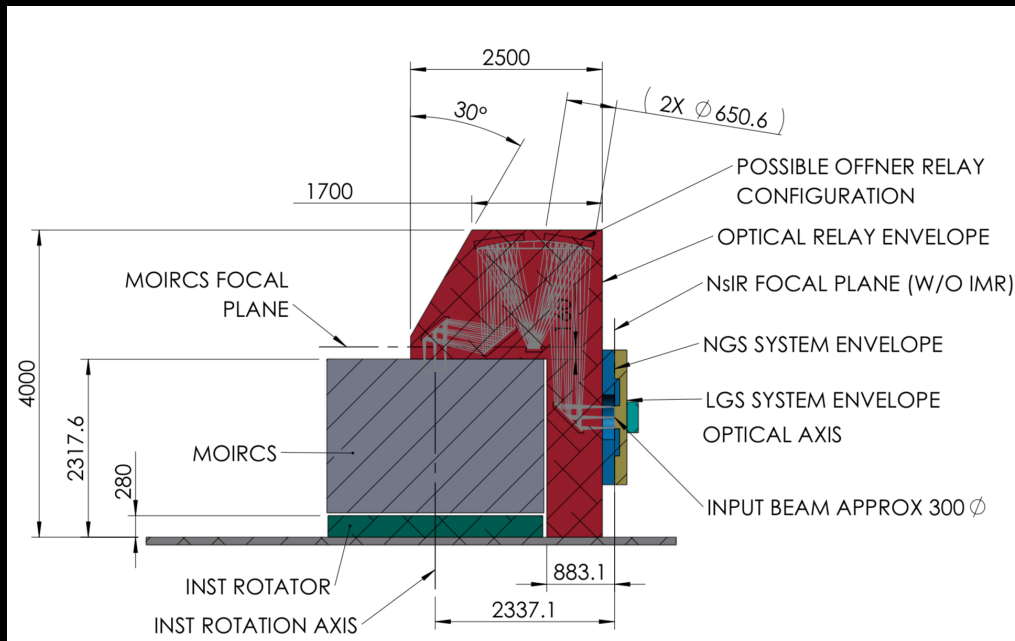
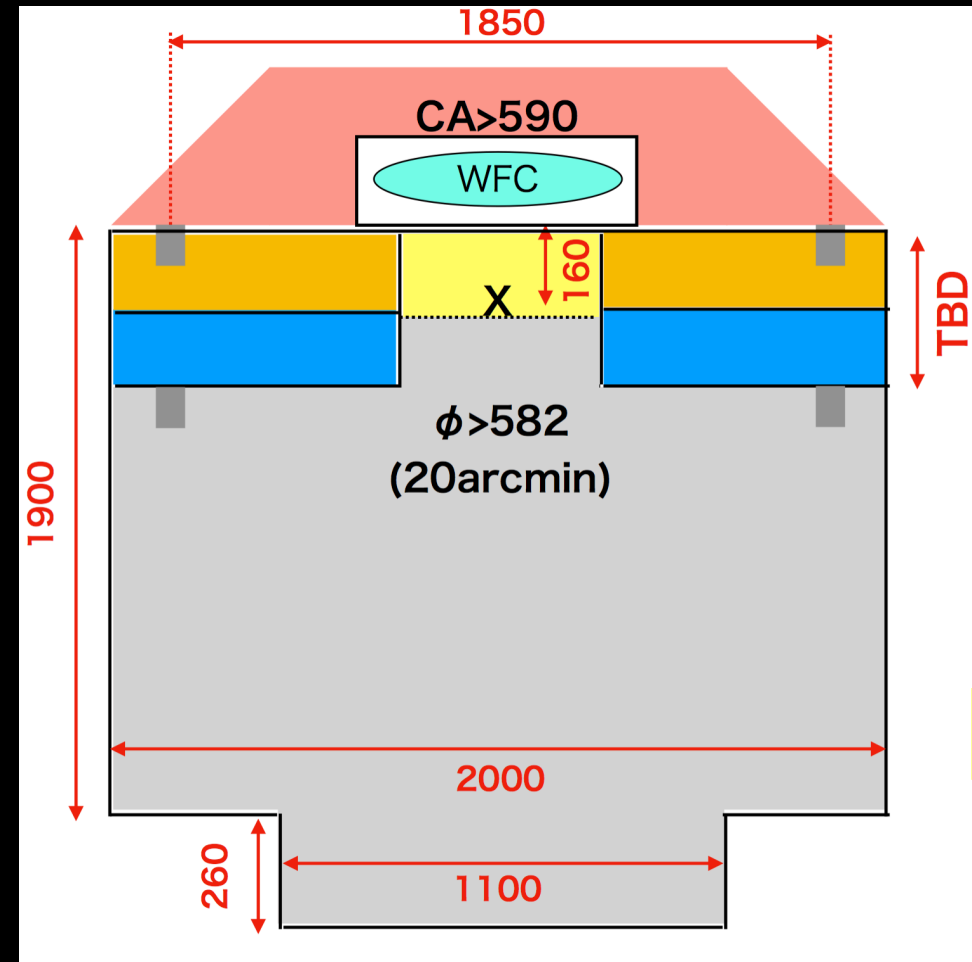
GLAO performance simulation



- Use conservative turbulence profile with more turbulent layers at $< 100\text{m}$.
- More statistics on the GLAO FWHM.
- **GLAO reduces the FWHM by 50% in any condition.**
- **Uniform PSF over the science FoV**

Preliminary simulation results by F. Rigaut and V. Korkiakoski at ANU

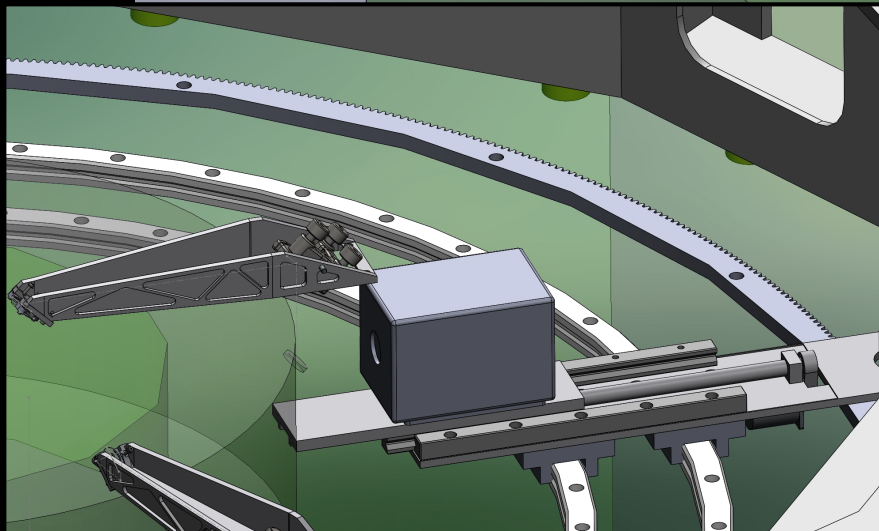
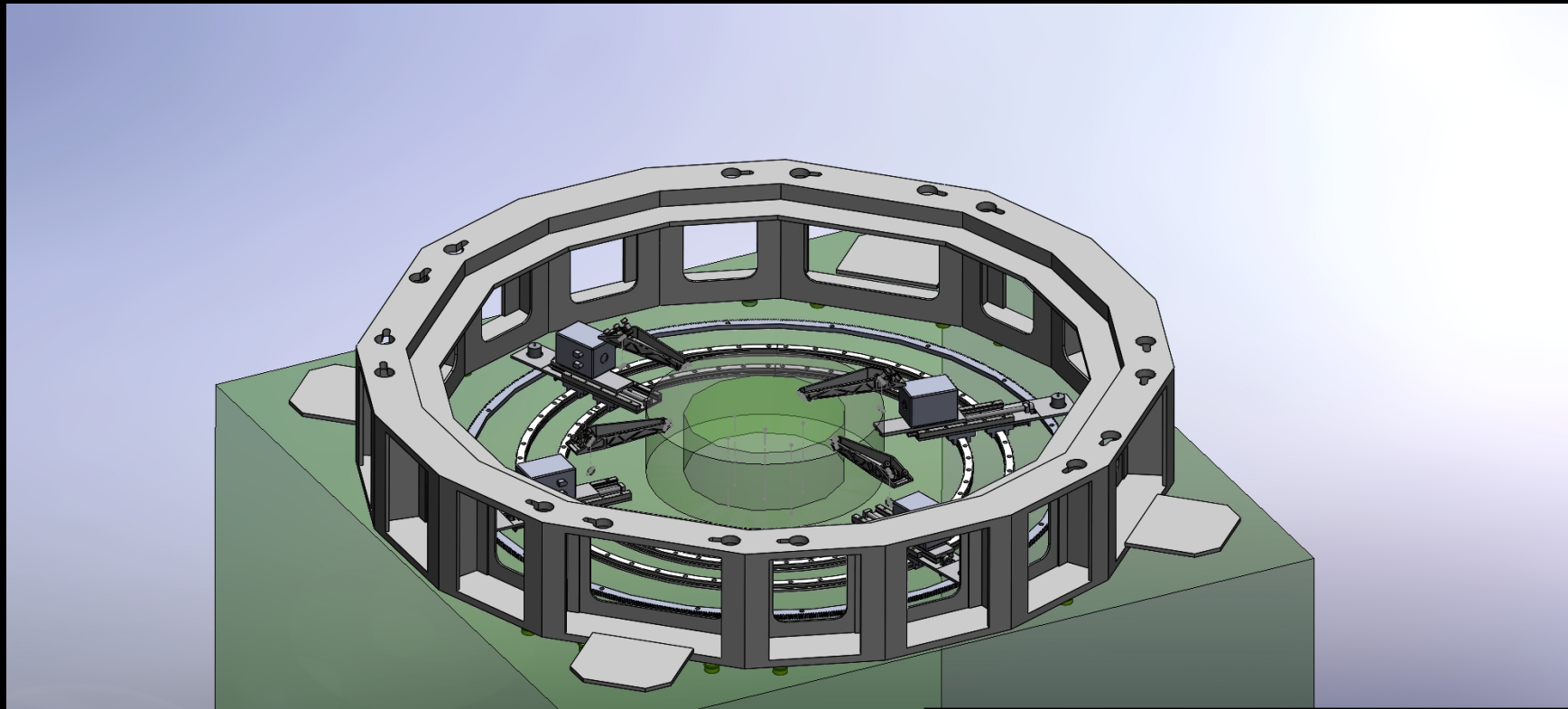
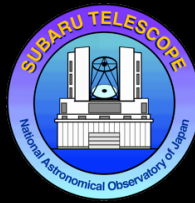
Cassegrain



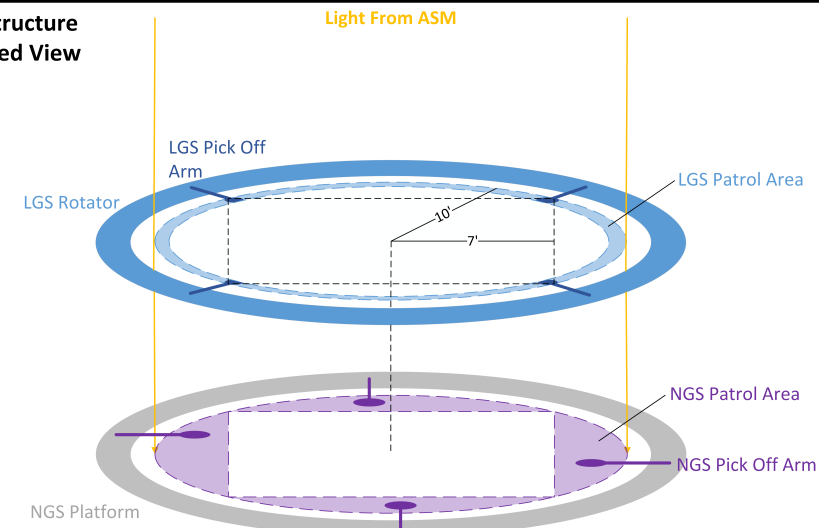
NGS WFS

Instrument
cryogenic

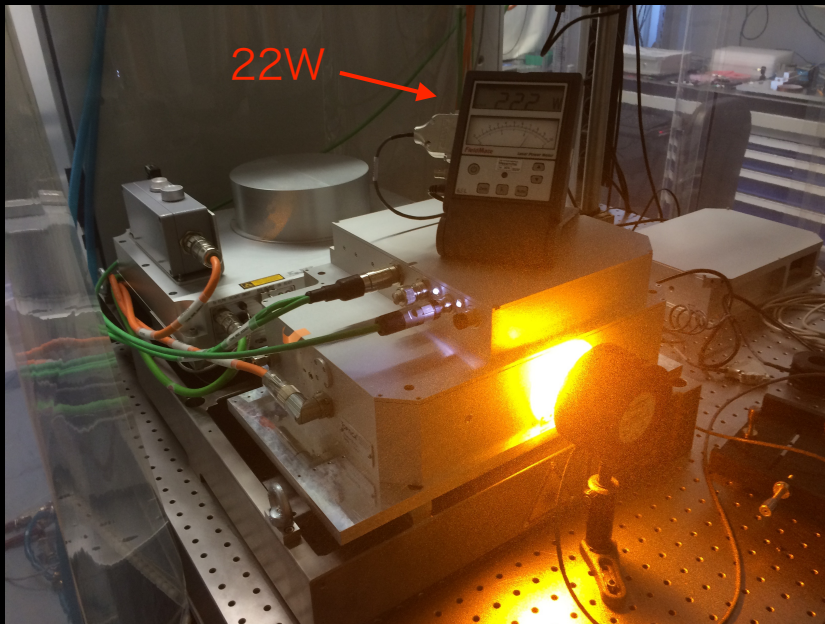
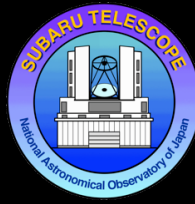
Wavefront sensor Adapter Flange (WAF) conceptual design by ANU



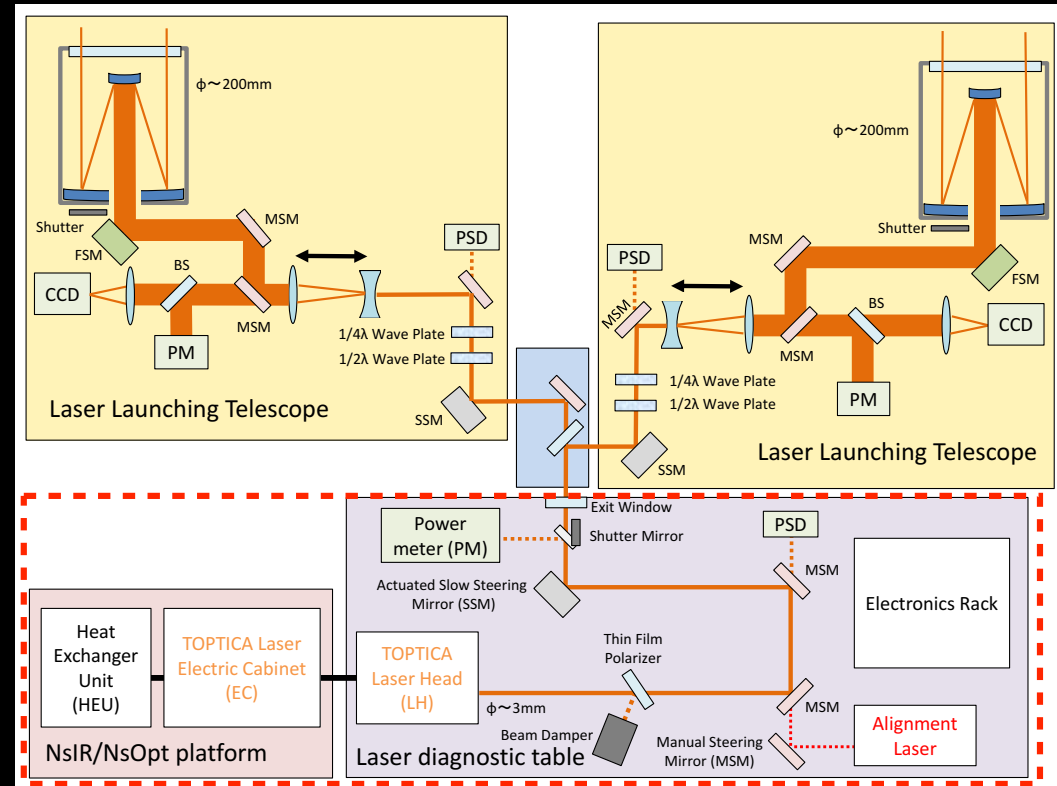
WAF Structure
Projected View



Laser Guide Star facility (LGSF)



TOPTICA laser for Subaru



Will be developed soon by ULTIMATE-START

- Use two TOPTICA fiber lasers to generate 4 LGS
- Assembly of the 1st laser has been completed at TOPTICA factory
- The 1st laser will be used for AO188 (ULTIMATE-START) from FY2019
- Same optical mount will be used for ULTIMATE-Subaru in future.

Team Organization

ULTIMATE-Subaru working group



PI: Subaru Director

M. Yoshida

Project Manager

Y. Minowa

Project Scientist

Y. Koyama

AO

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M. Akiyama (Tohoku), Y. Hayano (ATC)

Instrument

T. Hattori, I. Iwata, I. Tanaka,
K. Motohara (Tokyo)

Science

Y. Koyama, T. Kodama, K. Motohara

International collaboration

GLAO system design
WFS and LGS development

WFI system design and
development

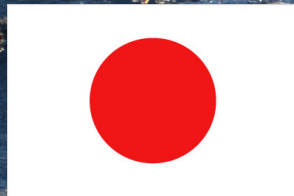
M-IFS system design and
development

Domestic and International scientists

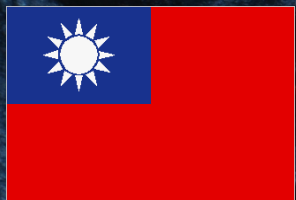
- Develop science case for ULTIMATE
- Summarize scientific requirement for determining the instrument and GLAO specifications.

ULTIMATE collaboration meeting

2018/1/15-16

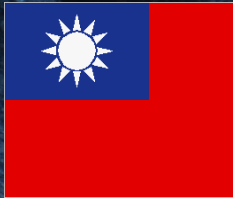
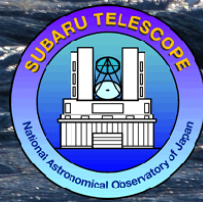


- Current status of the ULTIMATE-Subaru
- Schedule to implement the ULTIMATE subsystem
- Collaboration framework
- Science case developed by science working group
- International science working group



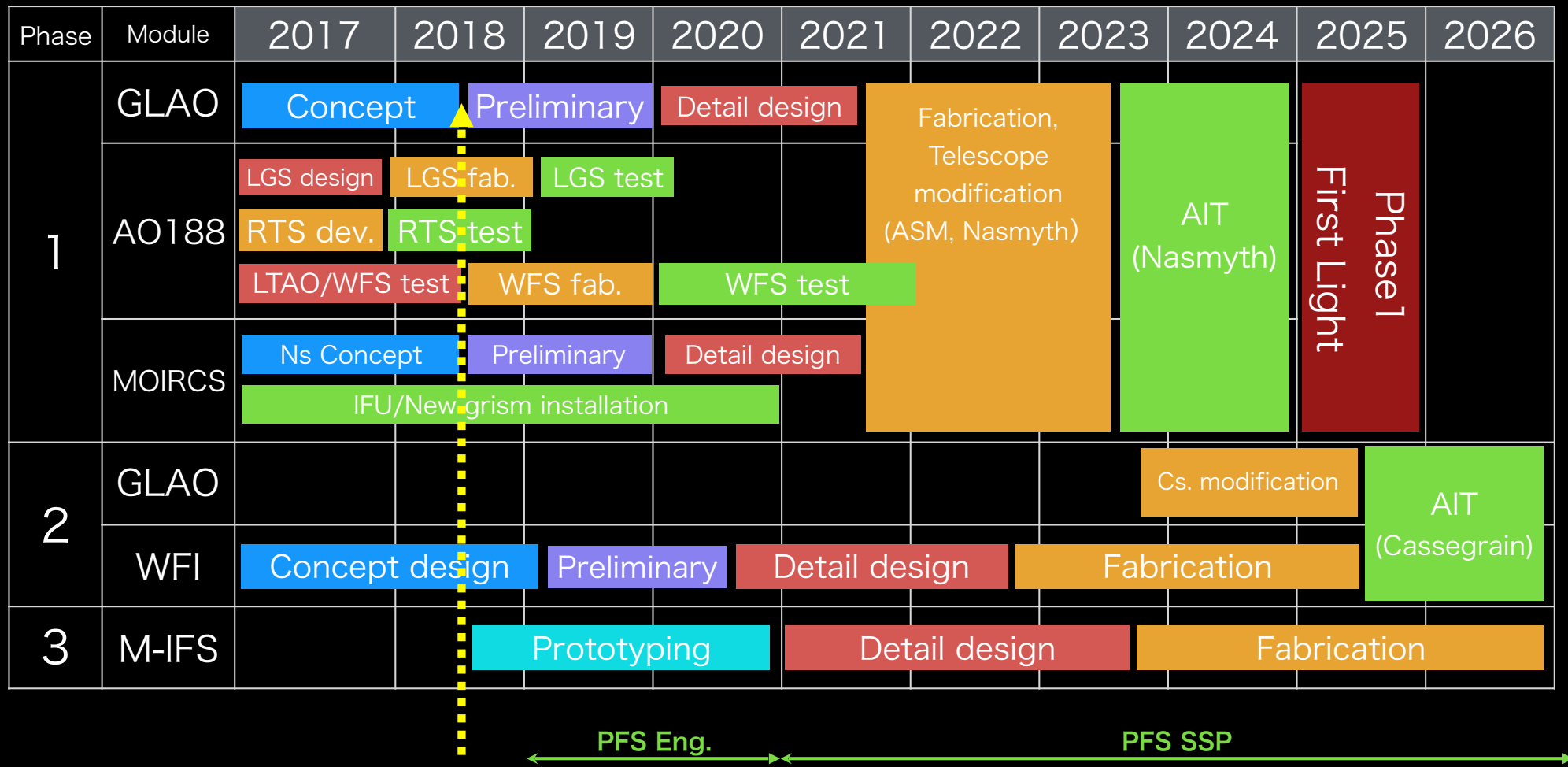
ULTIMATE collaboration meeting

2018/1/15-16





ULTIMATE-Subaru: Schedule



GLAO CoDR planned in early July, 2018

Summary

- ULTIMATE-Subaru is a Subaru's next generation facility instrument plan after PFS. Science and development team is led by the observatory.
- ULTIMATE-Subaru will develop a ground-layer AO system and wide-field near-infrared imager, which provide $\sim 14 \times 14$ arcmin² FoV with $\sim 0''.2$ spatial resolution in K-band.
- Instrument development will be done in phased approach starting from the upgrade of the existing AO system. Science output at each phase is expected.
- AO188 upgrade project to kick-off the ULTIMATE-Subaru (ULTIMATE-START) is funded. LGS and WFS design and fabrication are ongoing.
- Conceptual design of the GLAO is ongoing in collaboration with Australia. CoDR will be at mid-2018
- Expecting involvement from international collaborators for GLAO, wide-field imager (WFI), and multi-IFU spectrograph (M-IFS).
- We will first develop GLAO as an upgrade of telescope capabilities and develop dedicated science instruments (WFI and M-IFS) later, while continuing early science with the existing instrument (MOIRCS). Expected first light of GLAO+MOIRCS is around 2025.