Laser Tomography Adaptive Optics bring-in instrument status overview

check Terao+2022, SPIE, 12185, 6
Akiyama+2020, SPIE, 11448, 1

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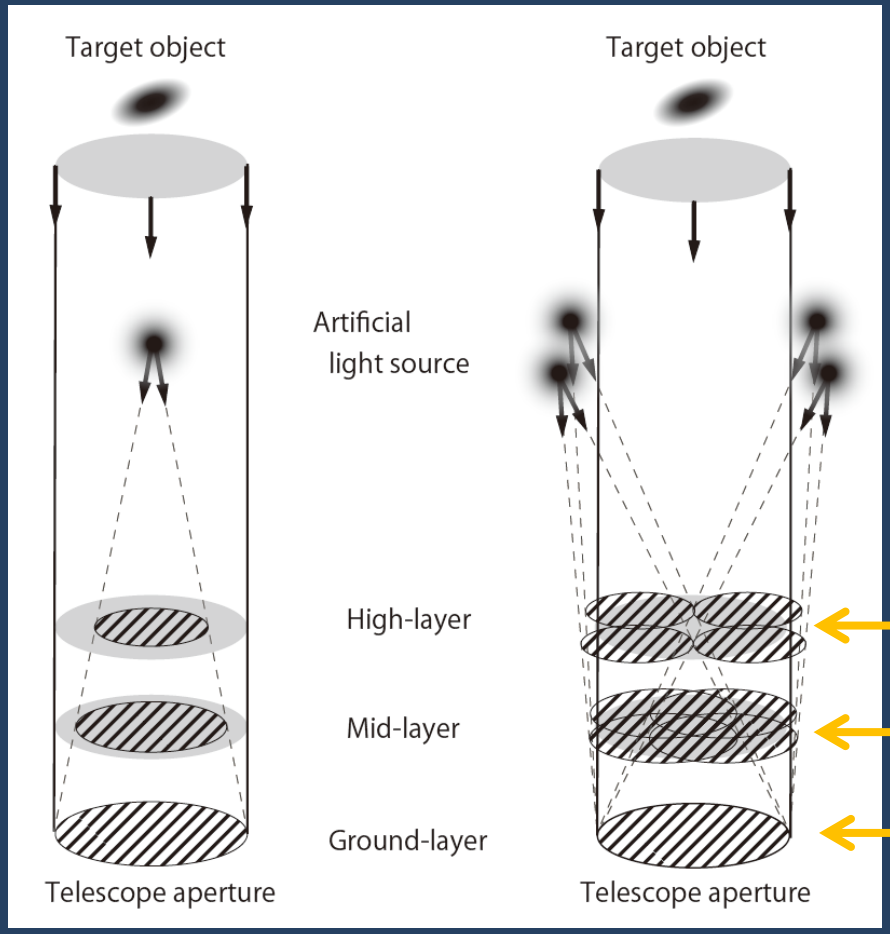
What is the Laser Tomography Adaptive Optics ?

Single LGS AO

Laser Tomography AO with Multi LGSs

Volume outside the cone will not be covered "cone-effect"

Integrated and degenerated turbulence

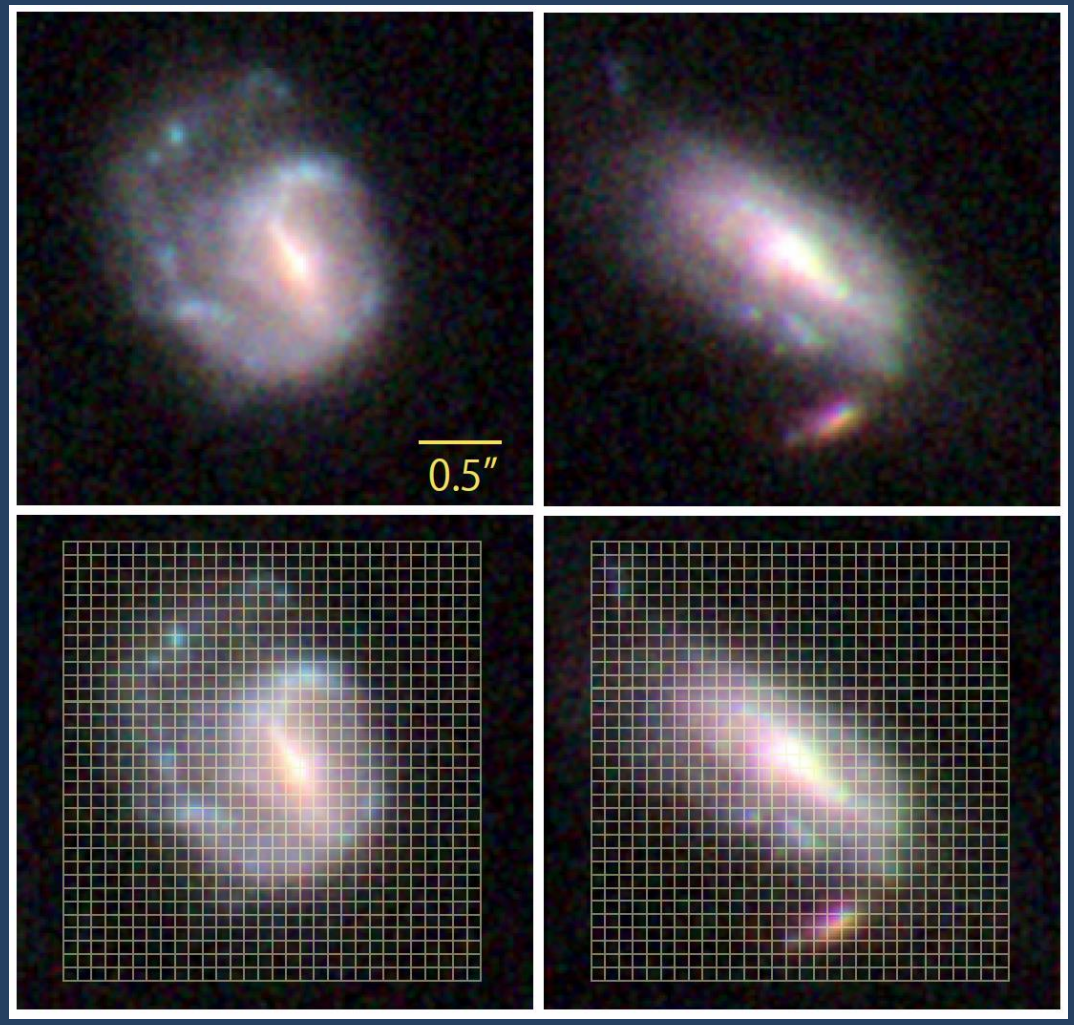


Entire light path will be covered

"Tomography" = Altitude separated 3D estimates of turbulence structure

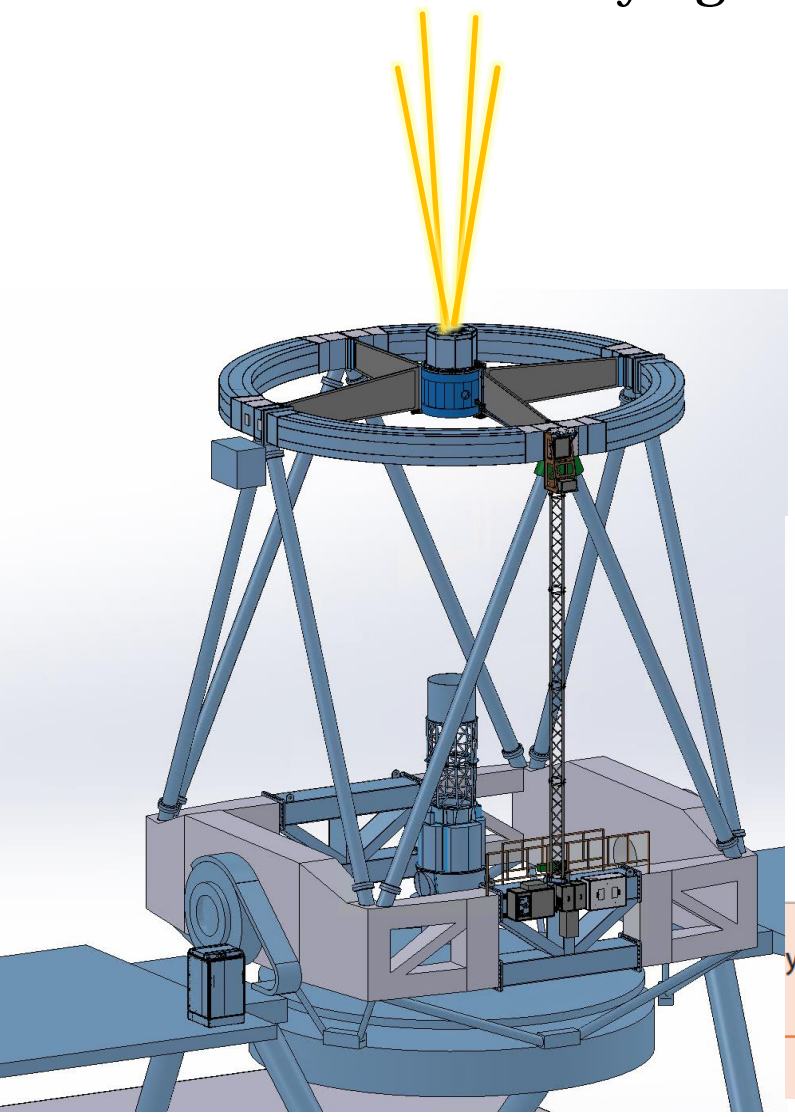
ULTIMATE-START × JWST

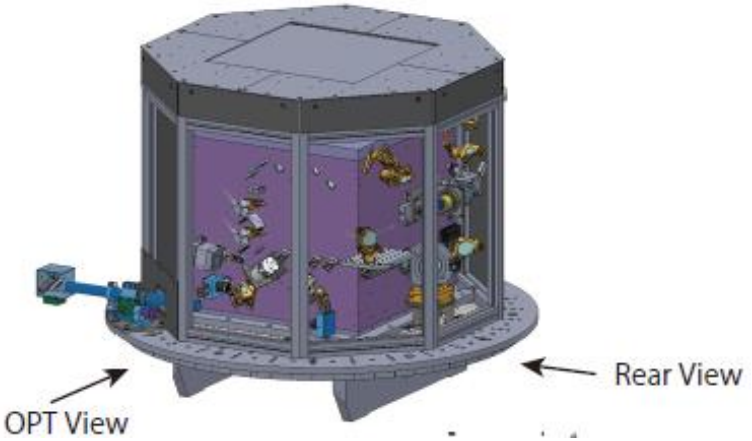
- JWST images of galaxies at z~1.
- High-spatial & high-spectral IFU spectroscopy with ULTIMATE-START + 3DII with 0.1” resolution.

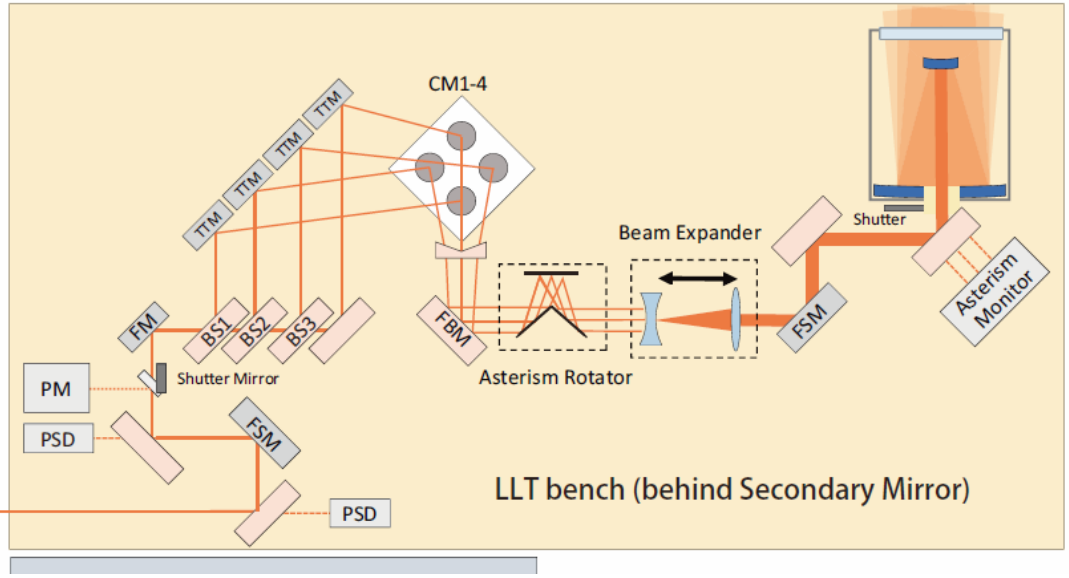


ULTIMATE-START overview

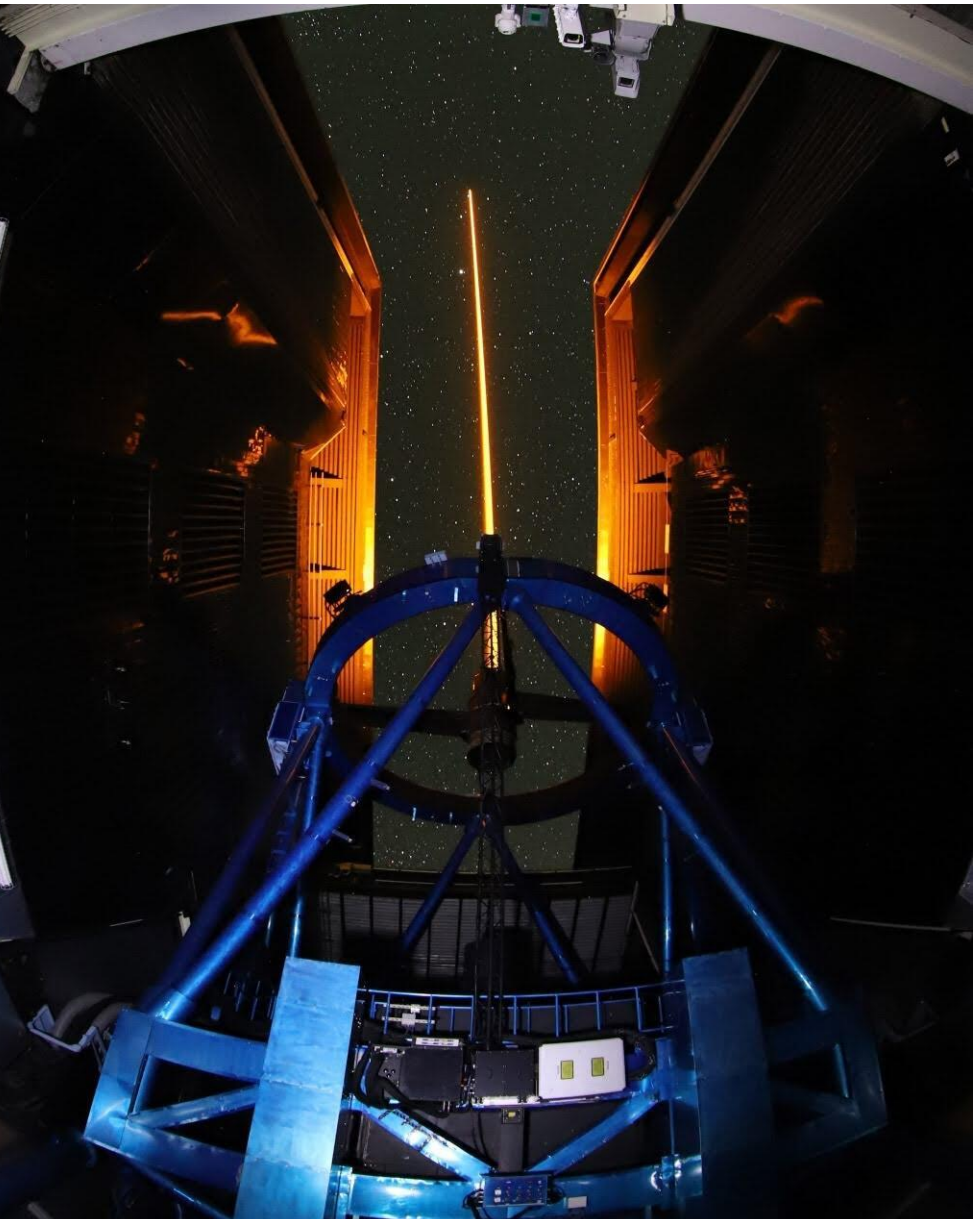
- Launch 4 LGSs modifying the existing Laser Launching Telescope.

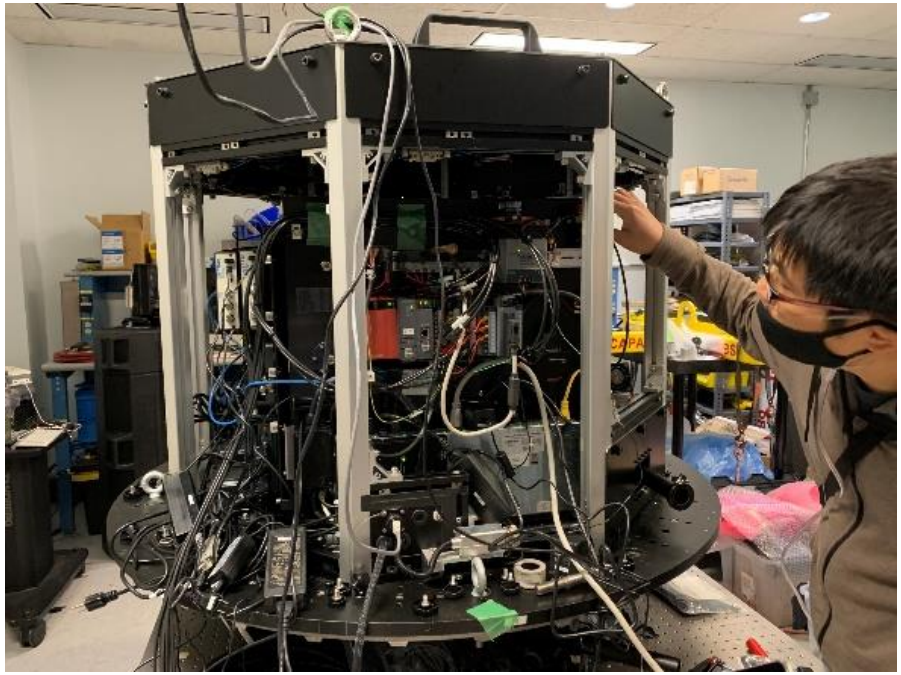






ULTIMATE-START overview

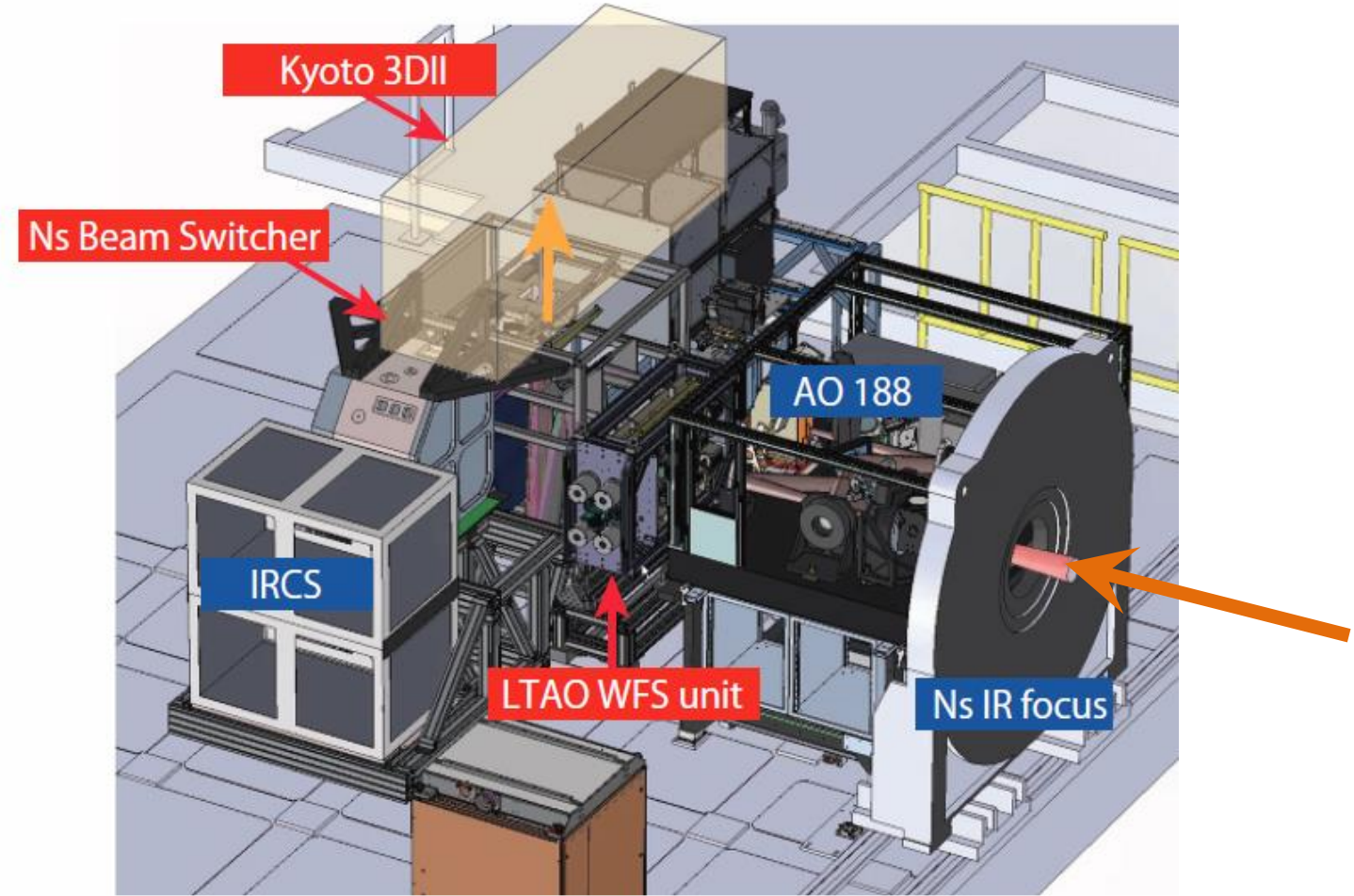




- Launching a single LGS is successfully completed.
- Modification to 4 LGSs launching will be done in 2023.

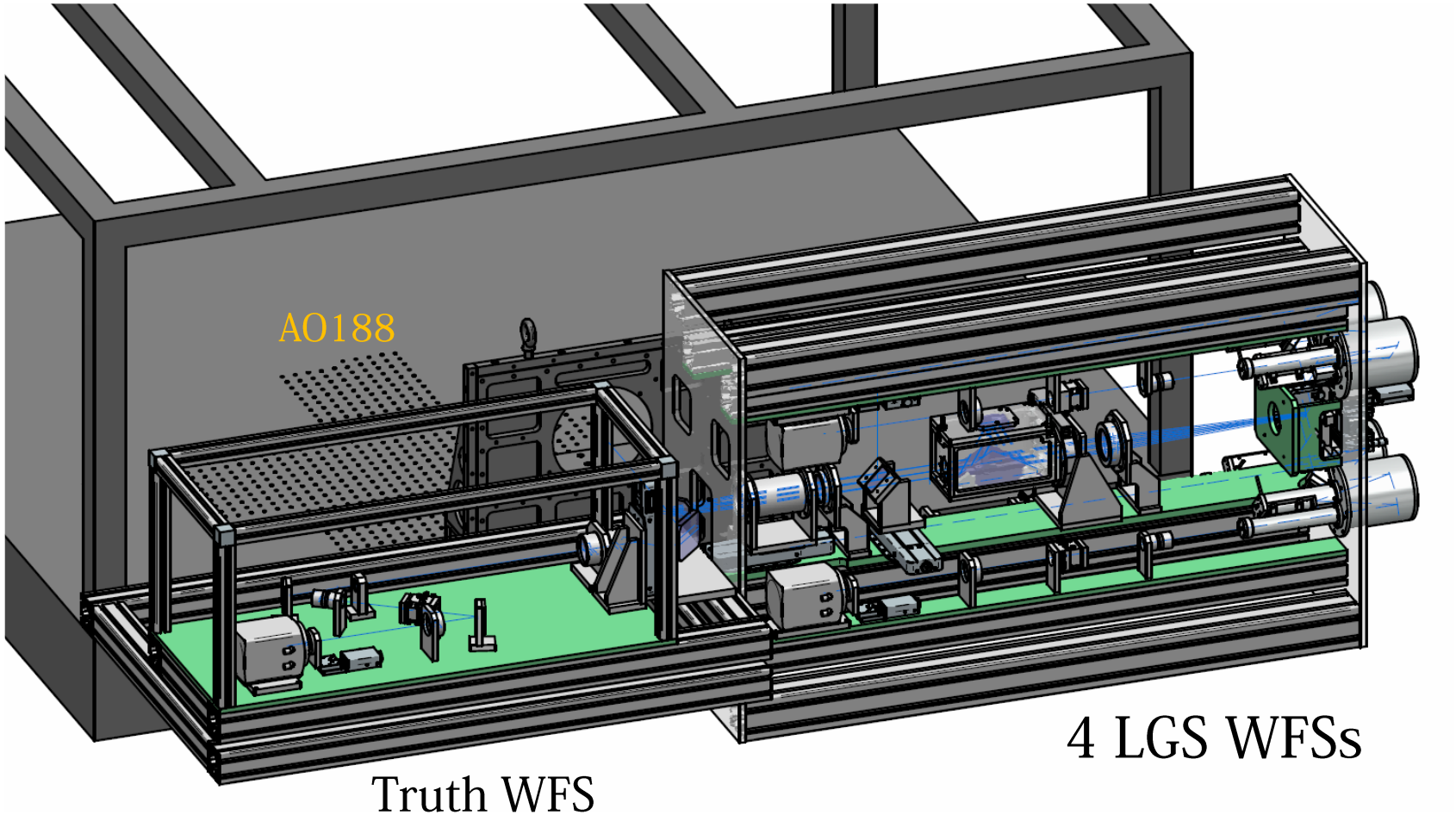
ULTIMATE-START overview

- Tomography wavefront sensing unit will be located after the AO188.
- Corrected light will be delivered to multiple instruments (IRCS, SCExAO, Kyoto-3DII, NINJA) through the Ns Beam Switcher system.



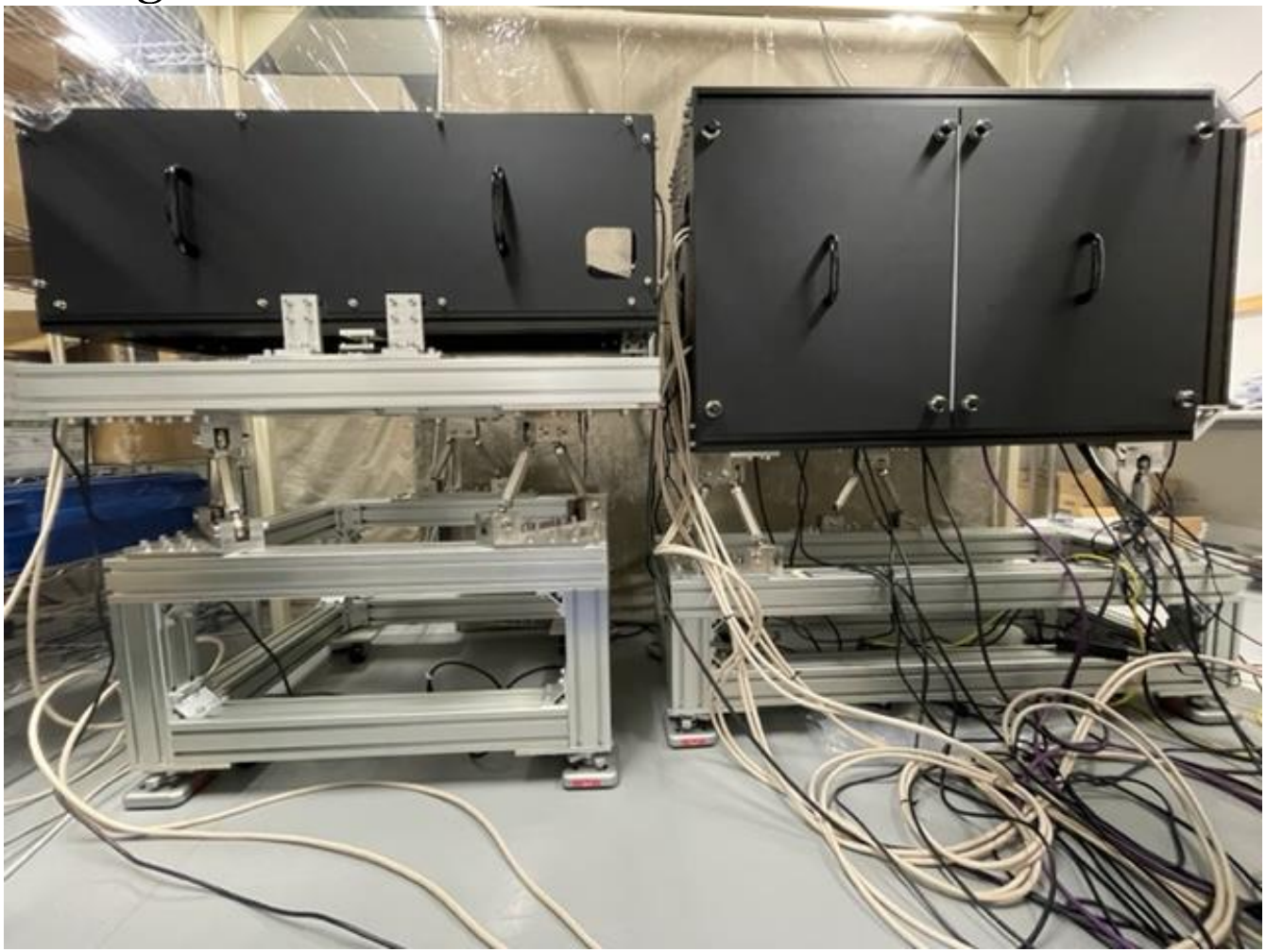
ULTIMATE-START overview

- WFS unit consists of 4 LGS SH-WFSs and 1 NGS SH-WFS to check the AO correction with the same pupil sampling.



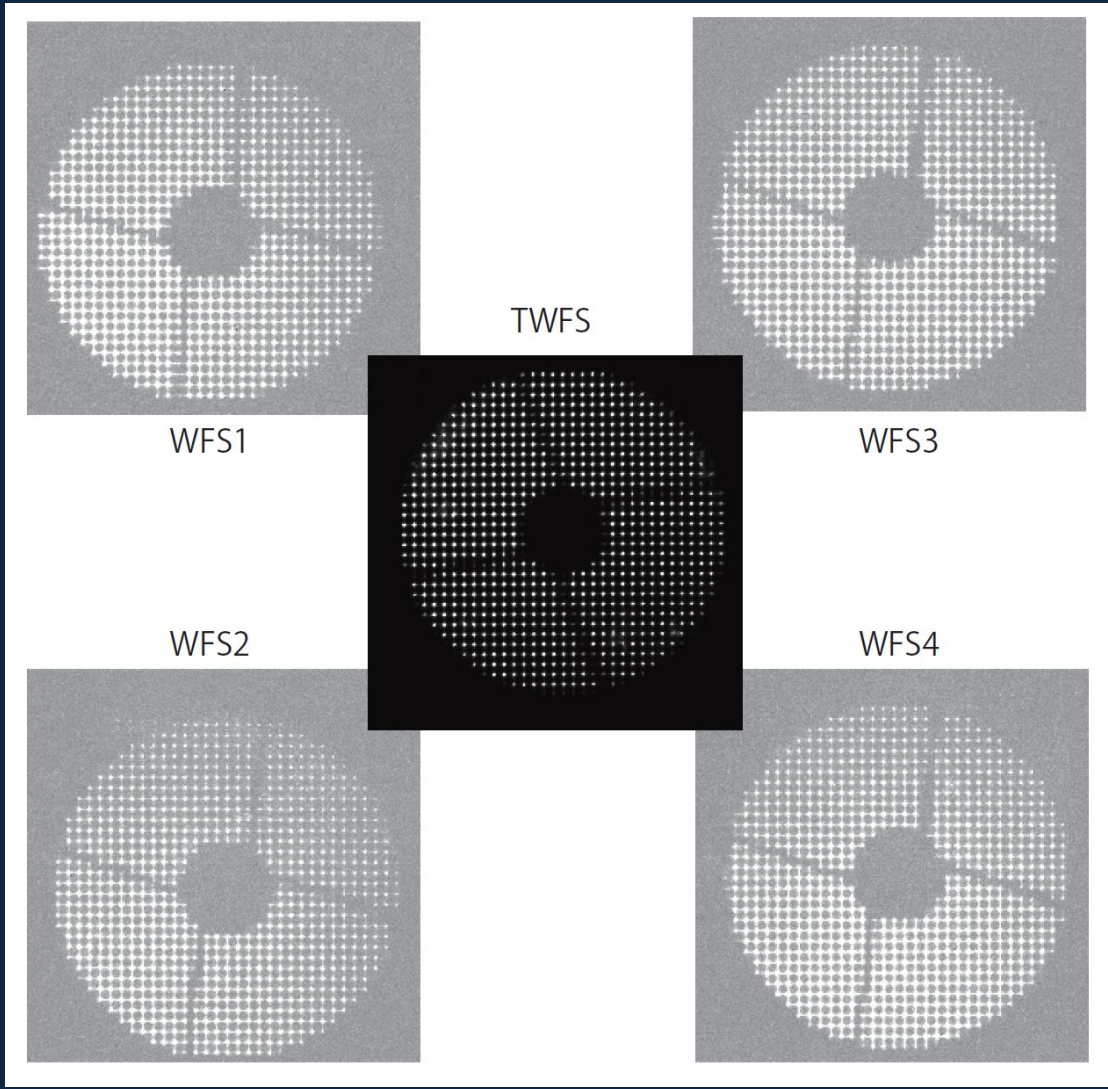
ULTIMATE-START overview

- The WFS unit is under optical testing in Tohoku univ. with a calibration light source.



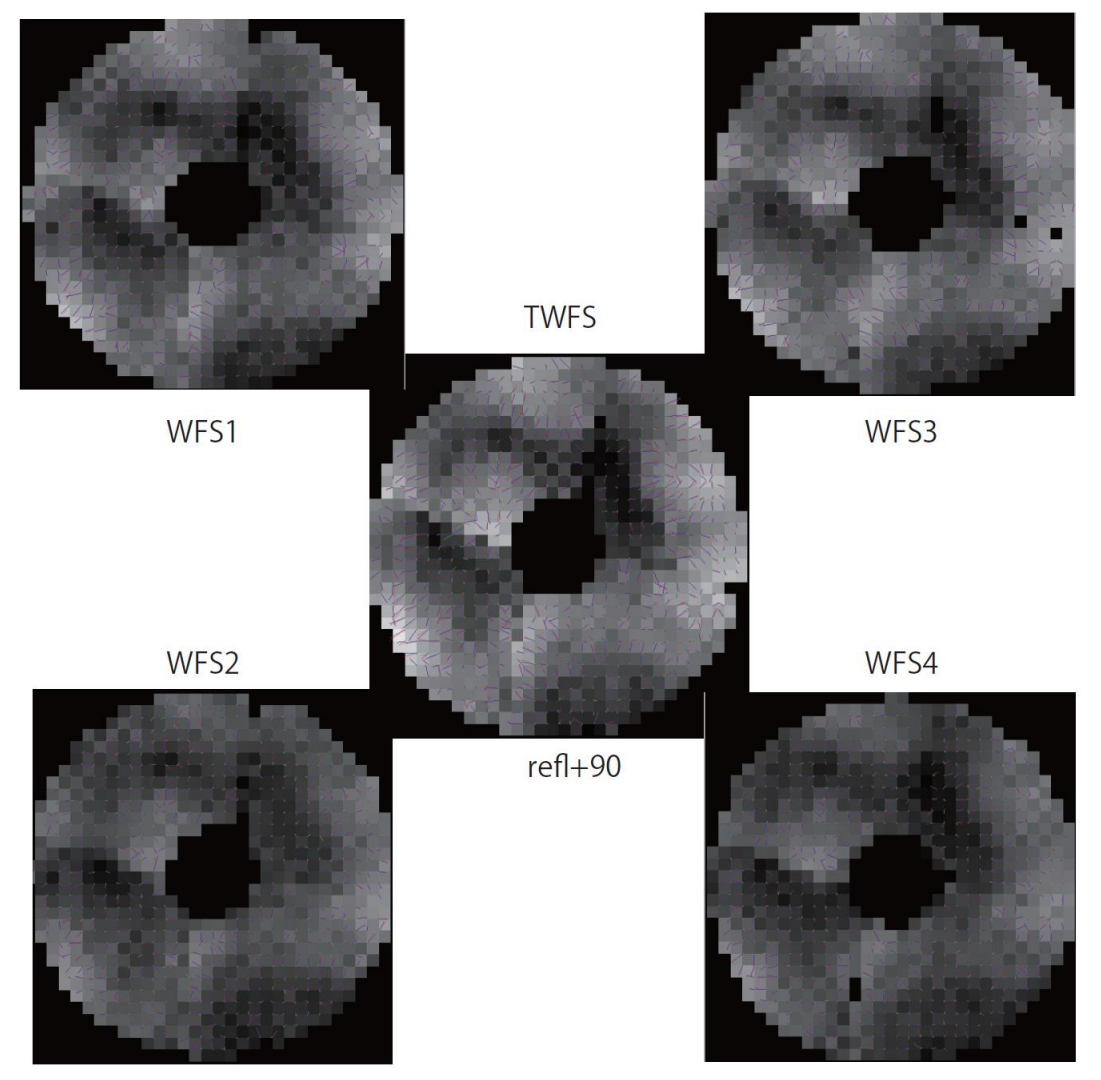
ULTIMATE-START overview

Images of 4 LGS SH-WFS + 1 NGS SH-WFS with the calibration light source.



ULTIMATE-START overview

Reconstructed wavefront map from each SH-WFS.

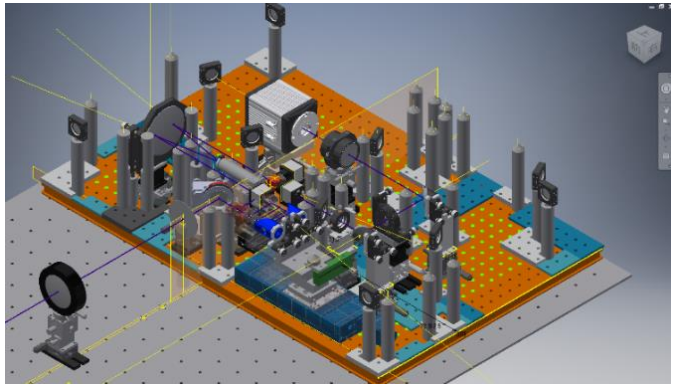


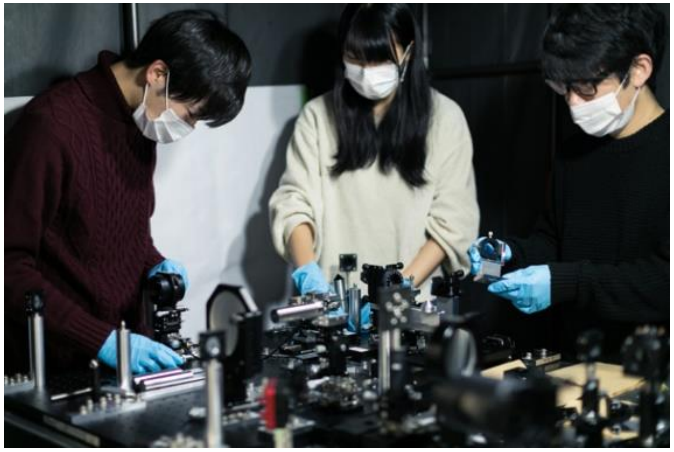
ULTIMATE-START overview

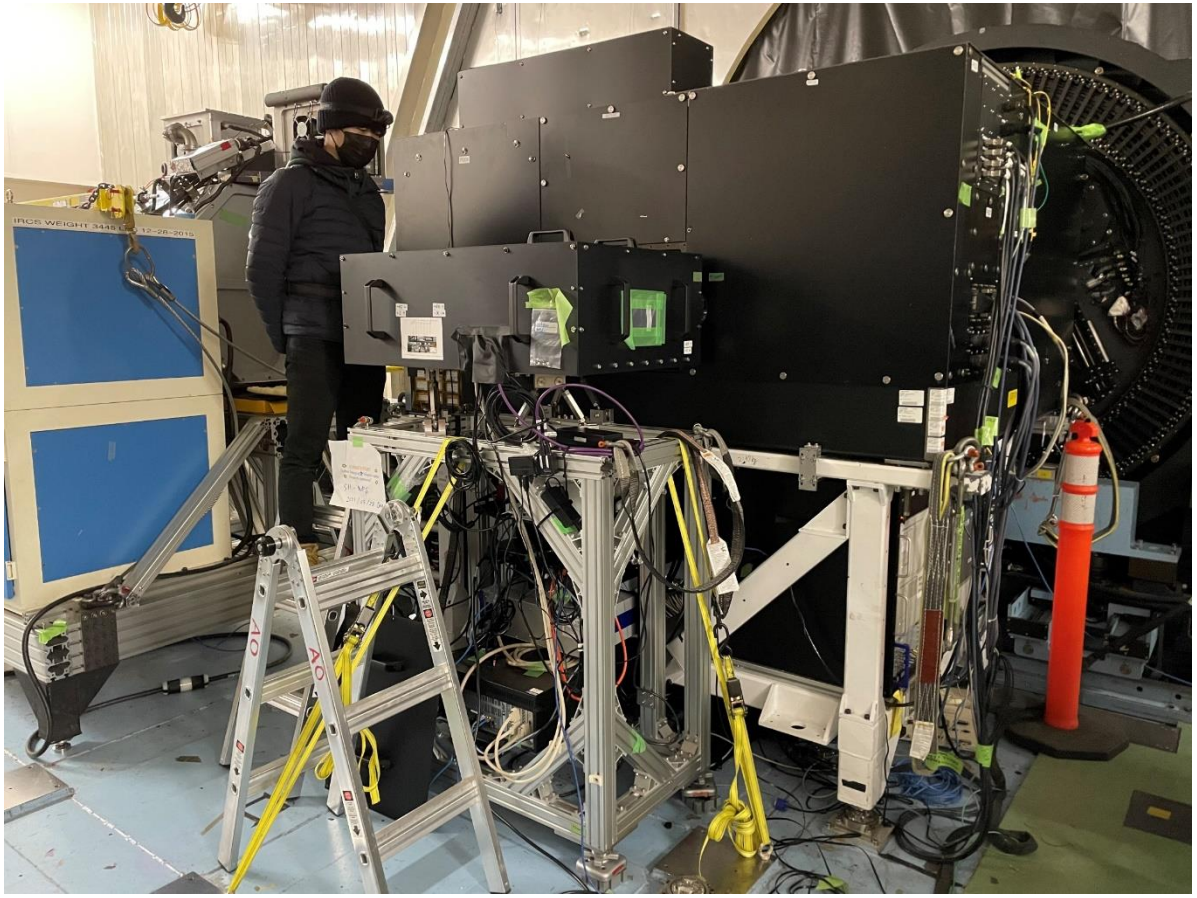
64x64 elements DM is under development in collaboration with the SCExAO team

Prototype 32x32 SH-WFS

We conducted a demonstration of wavefront measurements by attaching a prototype 32x32 SH-WFS unit after AO188.





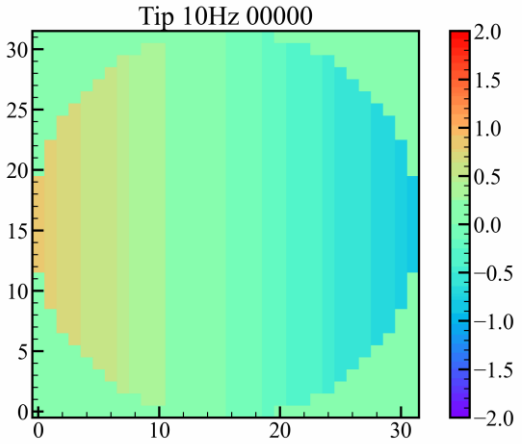


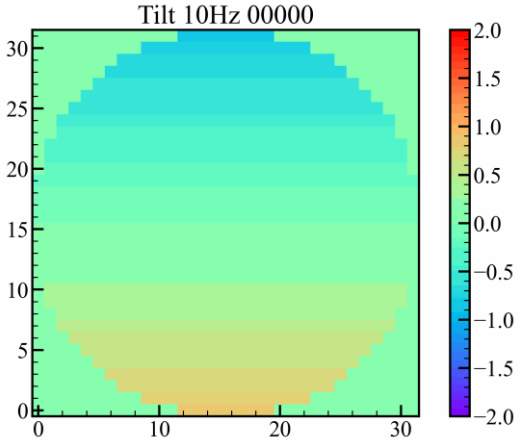
Prototype 32x32 SH-WFS

Testing effects of the “rolling-shutter” readout mode of the sCMOS camera (with high-QE and low-RON).

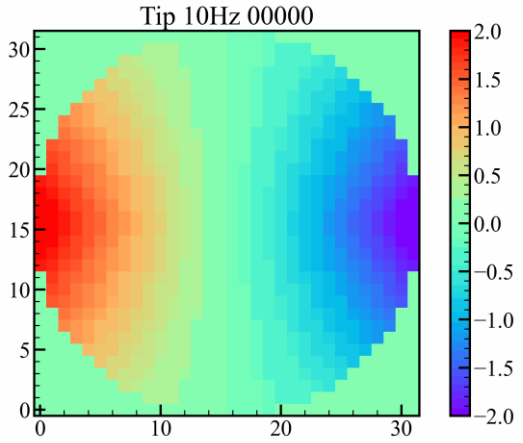
see Ogane+2022, SPIE, 12185, 21

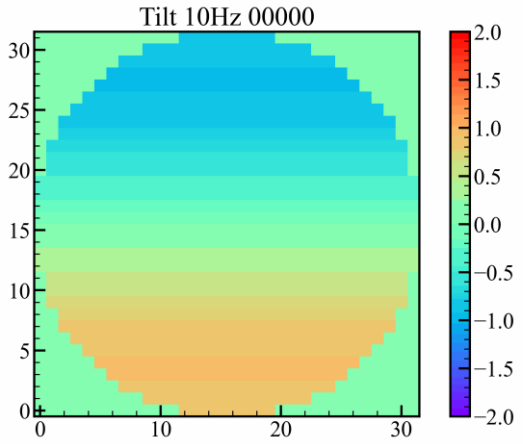
Global shutter





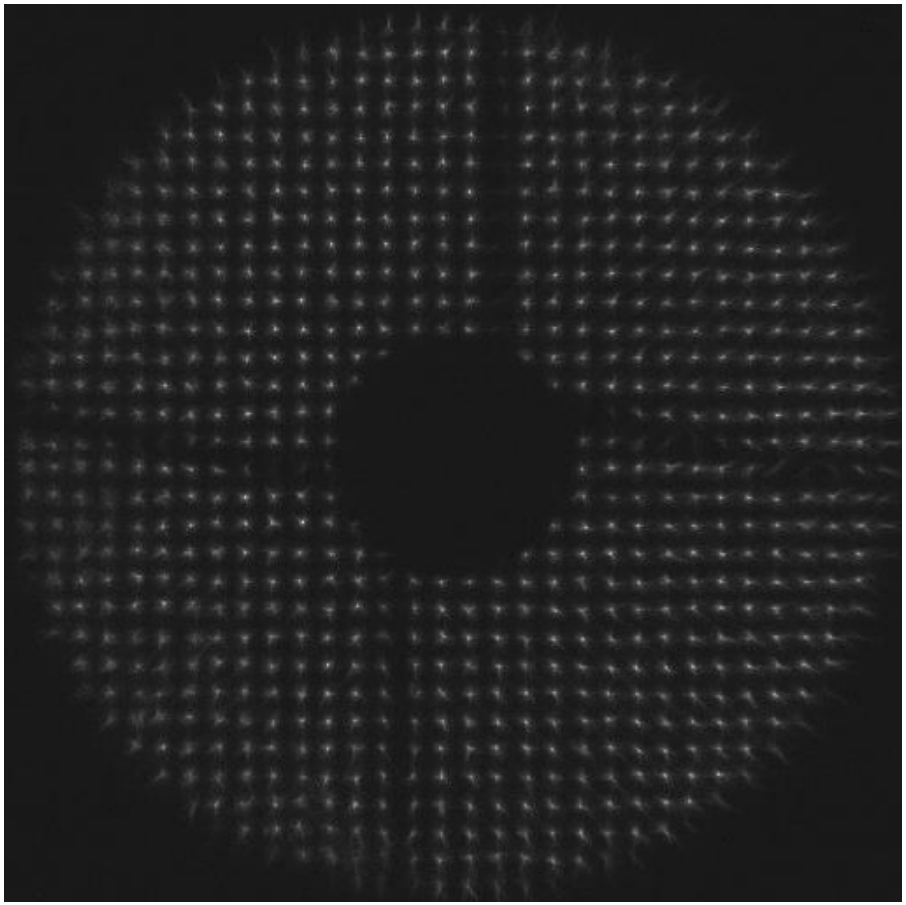
Rolling shutter





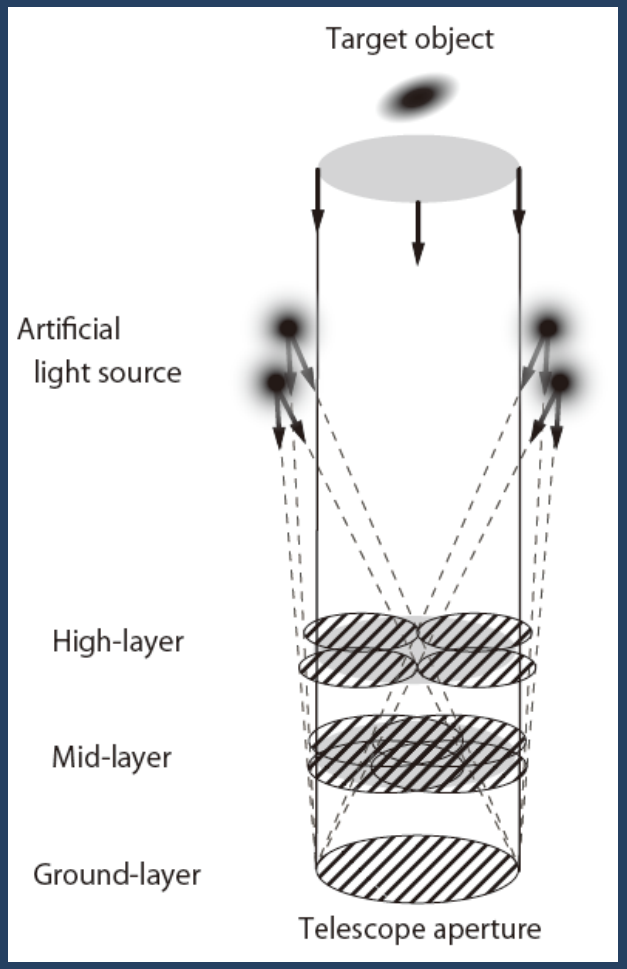
Prototype 32x32 SH-WFS

SH-WFS image of a bright star
Every 100 frames with 400 FPS



Reconstructed wavefront
Every 10 frames with 400 FPS

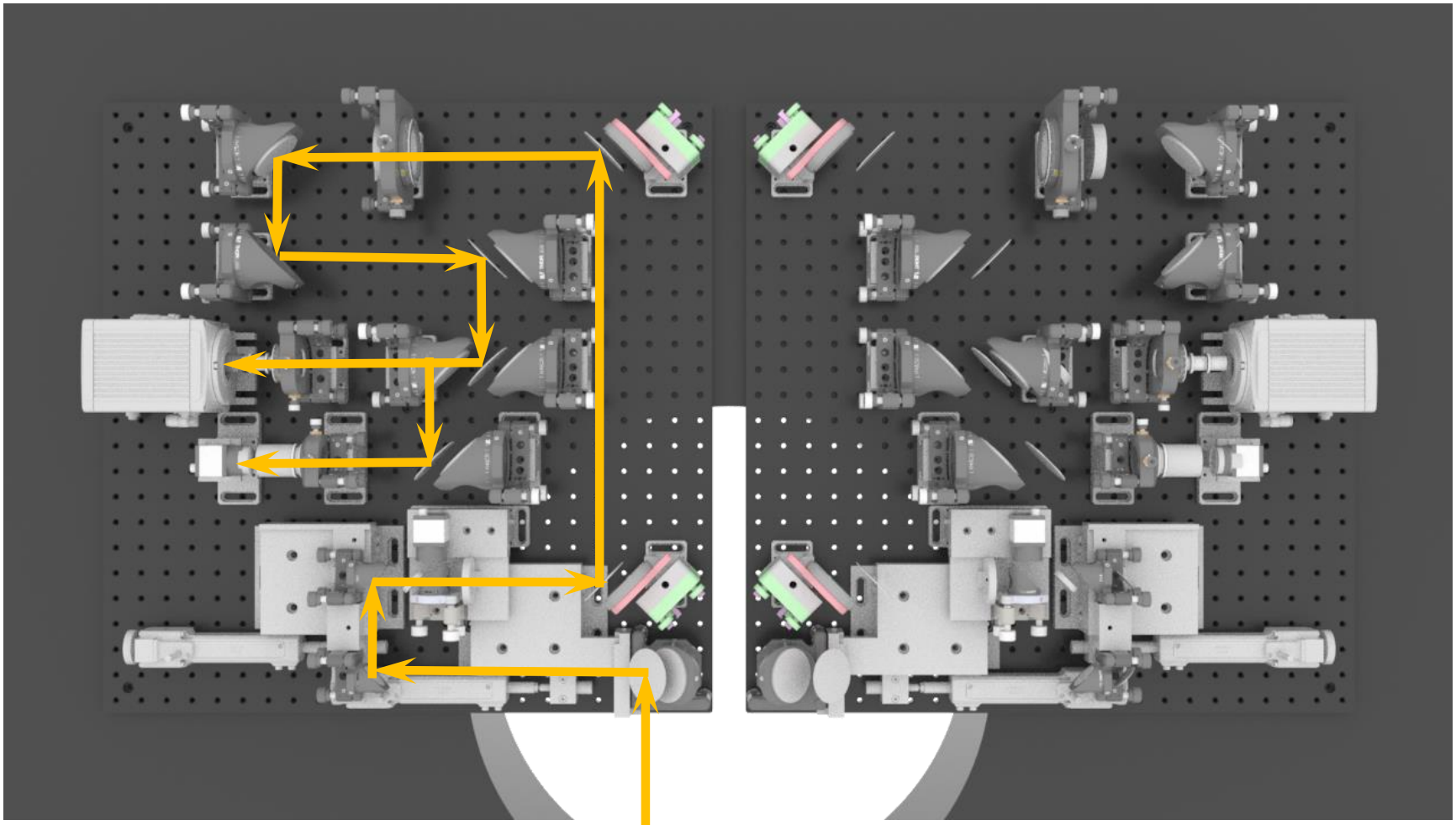
Understanding turbulence behavior is a key in LTAO



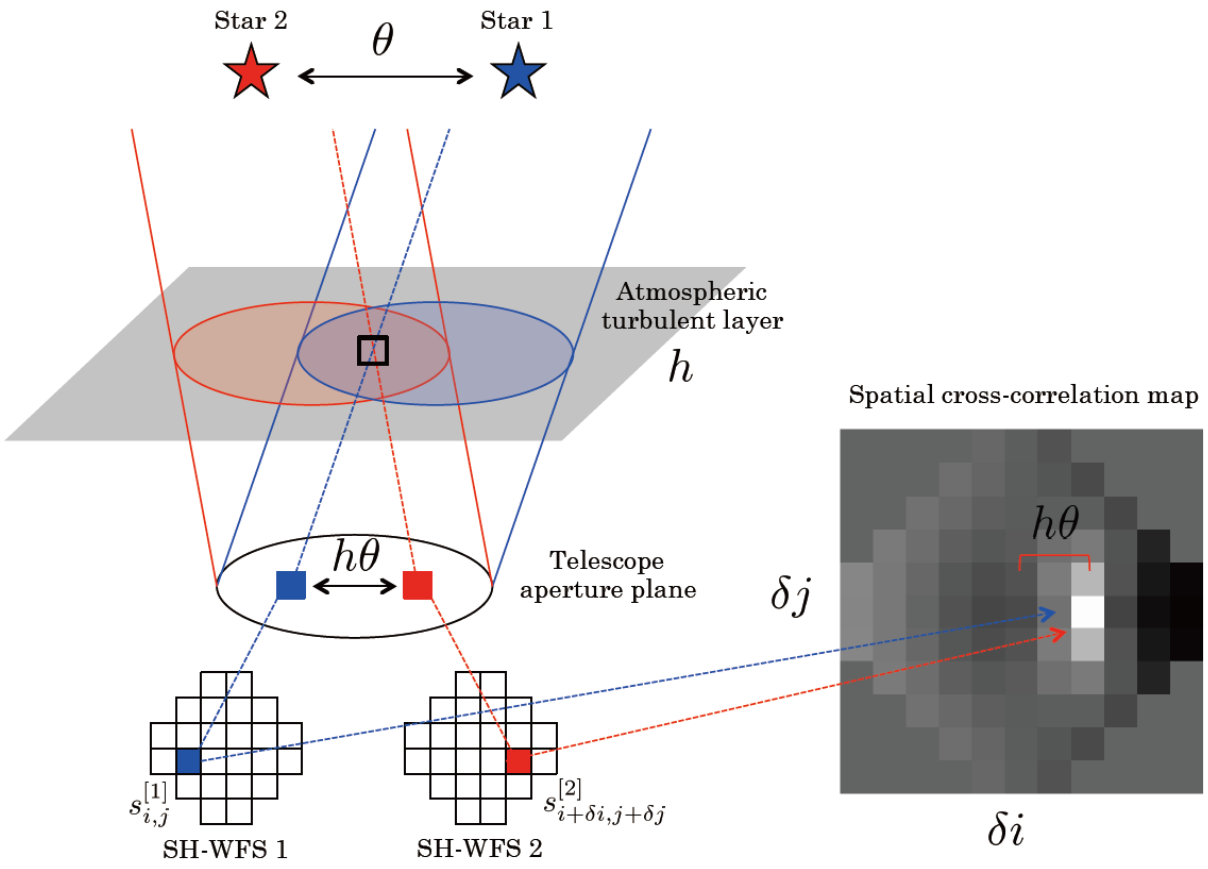
TURBULENCE PROFILING ON SUBARU

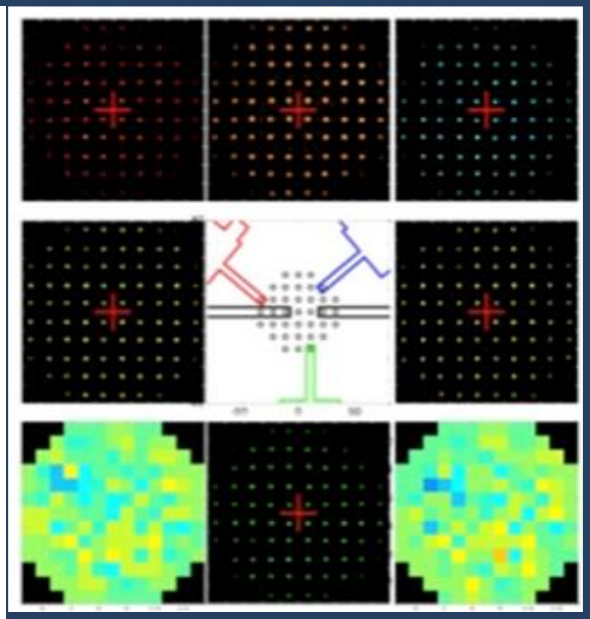
Subaru on-telescope measurements with

- 2 SH-WFSs with 2cm sampling of a part of the 8m primary.



Atmospheric Turbulence Profile with correlation measurements : SLODAR





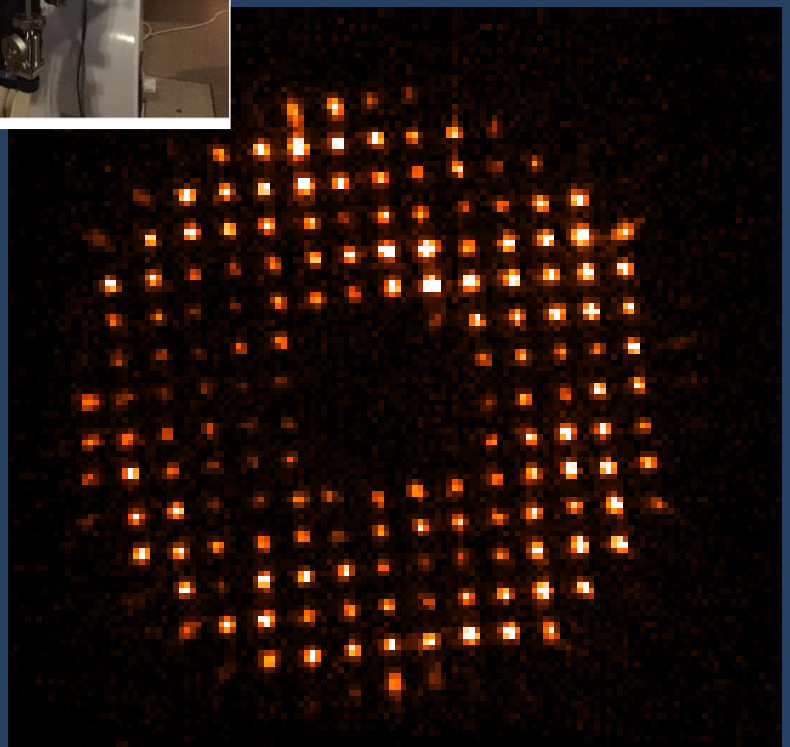
Subaru/RAVEN multi-WFS images

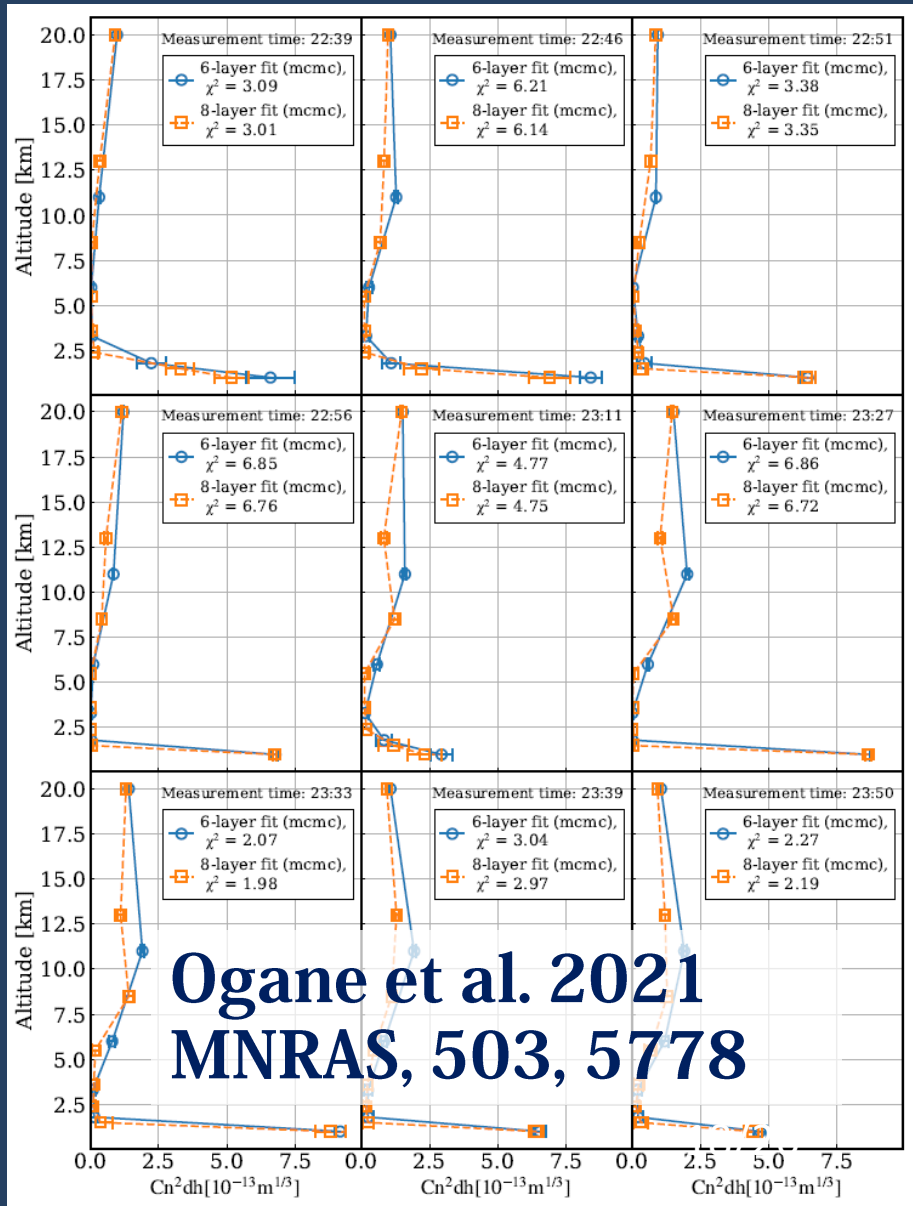
Ono et al. 2017 MNRAS, 465, 4931

- Turbulence height profile can be estimated with taking cross-correlation between two WFSs monitoring two different reference stars.

Atmospheric Turbulence Profile with scintillation measurements : SH-MASS

2.5cm sampling of 50cm primary of the Tohoku Univ. telescope.



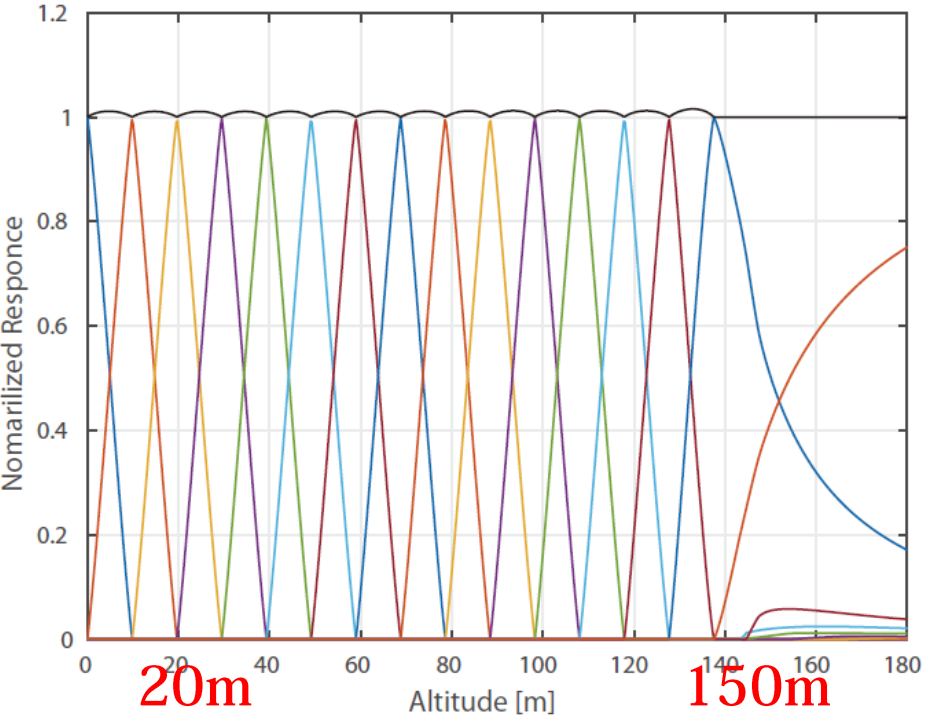


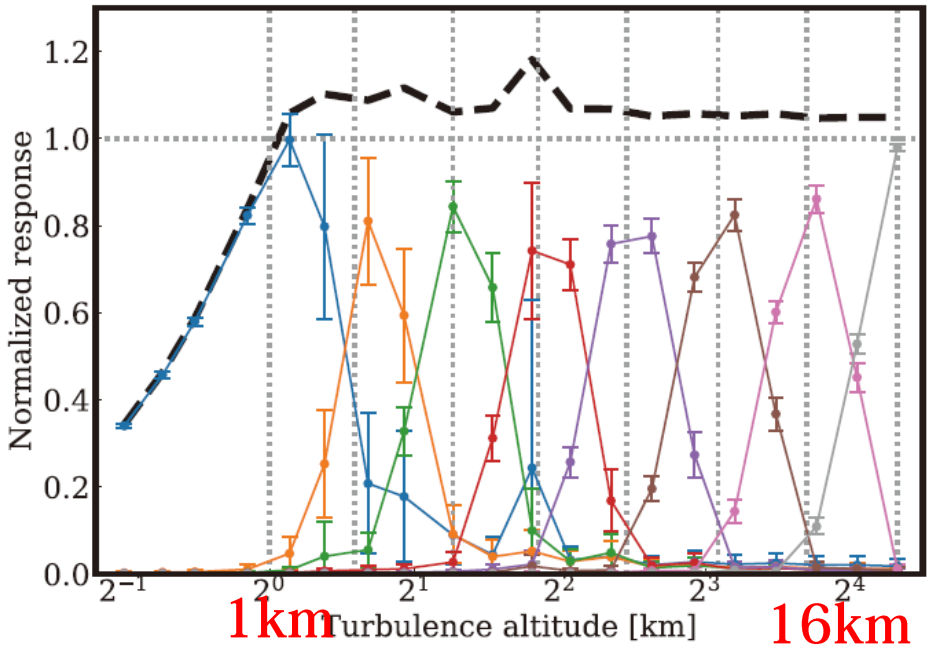
Ogane et al. 2021 MNRAS, 503, 5778

Subaru on-telescope measurements with

SLODAR × SH-MASS

Sensitivity to atmospheric turbulence at each altitude

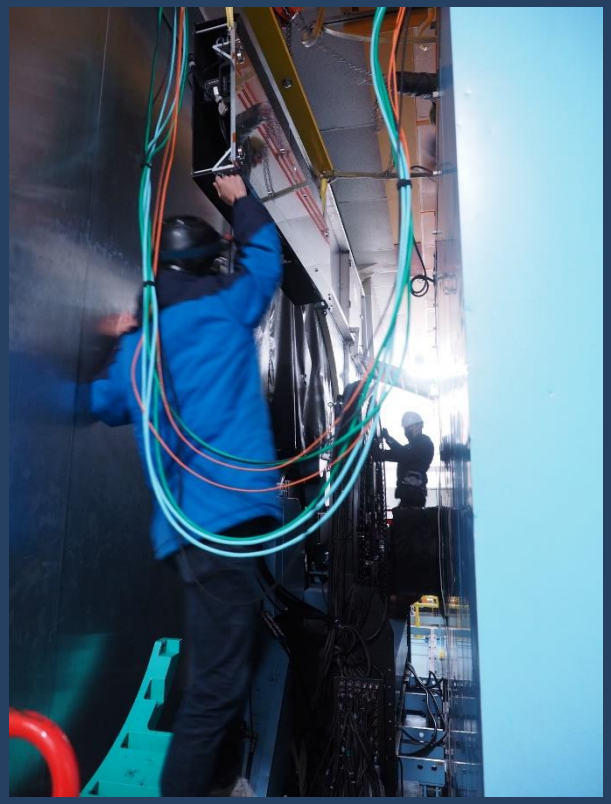


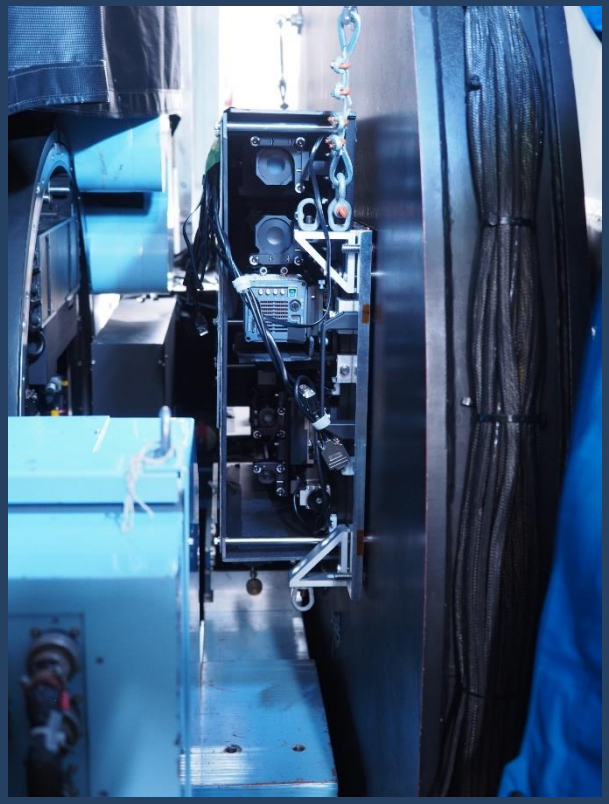


High altitude resolution of ~10m

High altitude measurement up to 16km

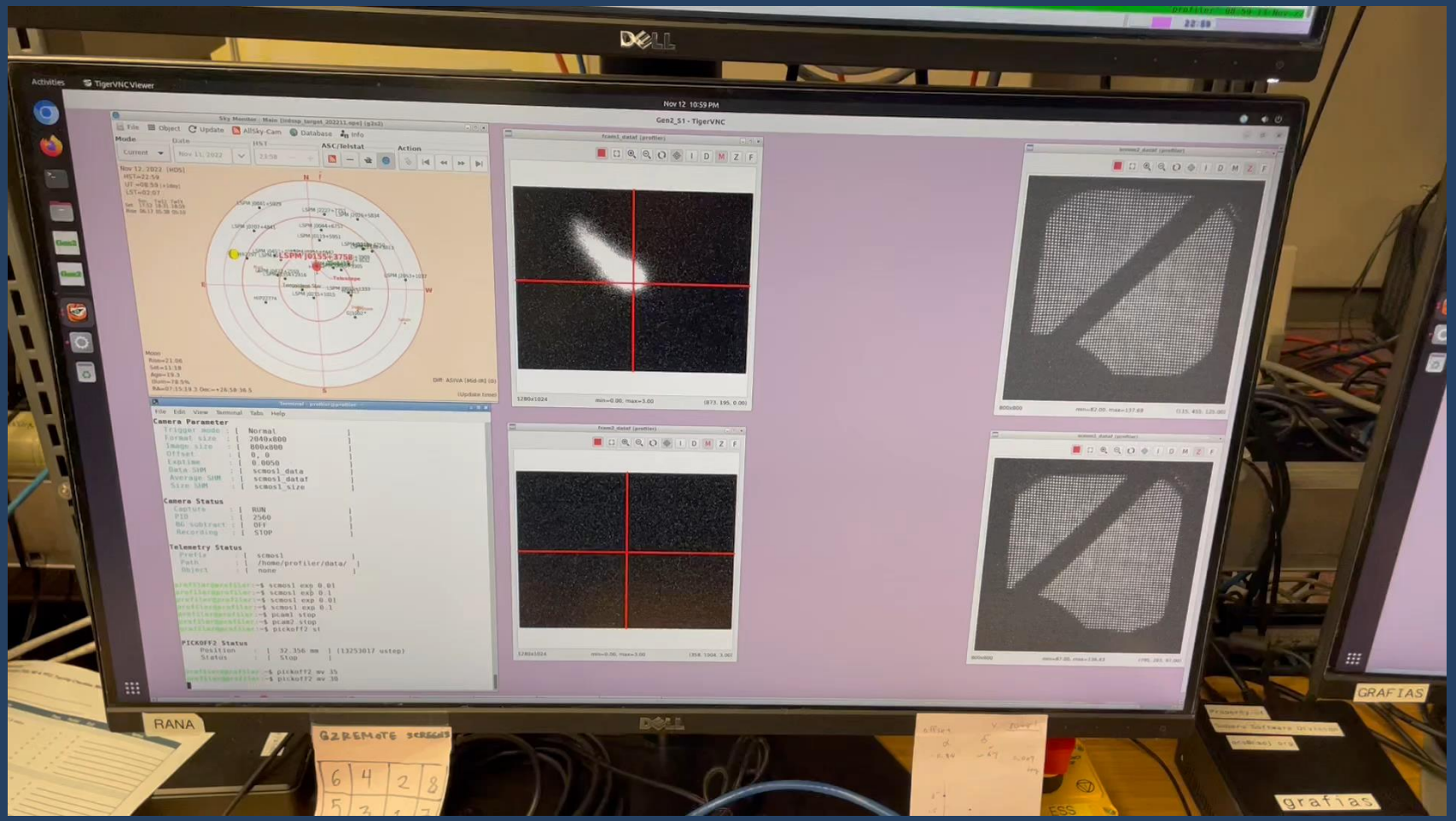
Subaru on-telescope measurements





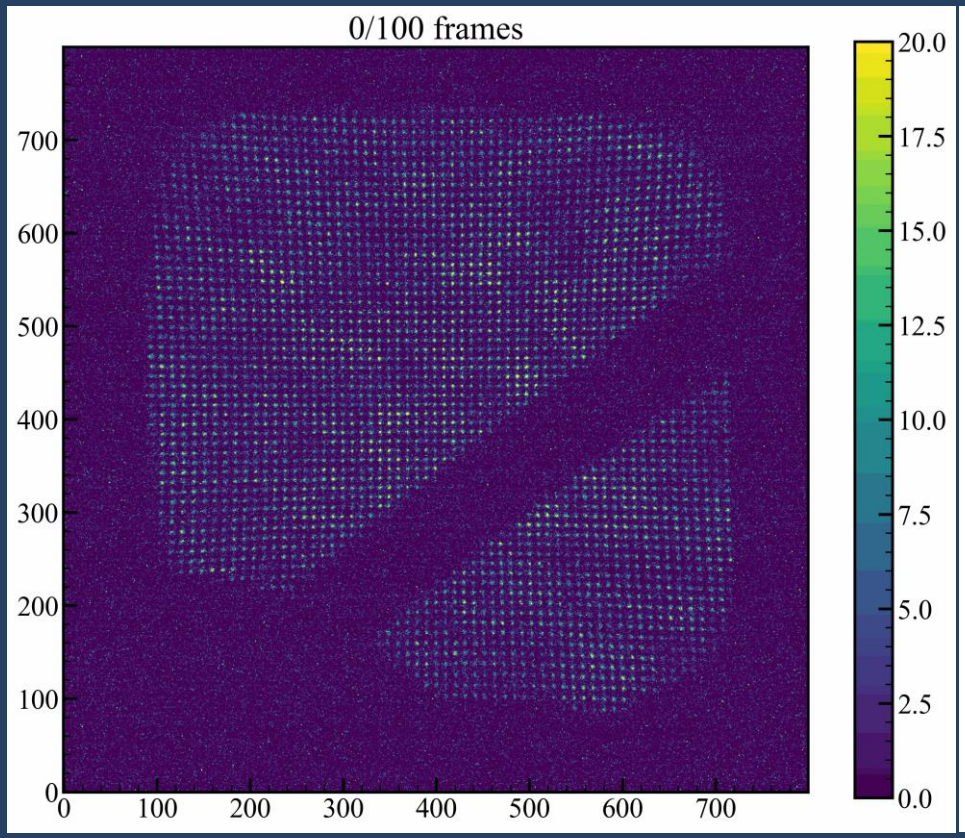
Subaru on-telescope measurements

Successful acquisition onto 2 SH-WFSs.

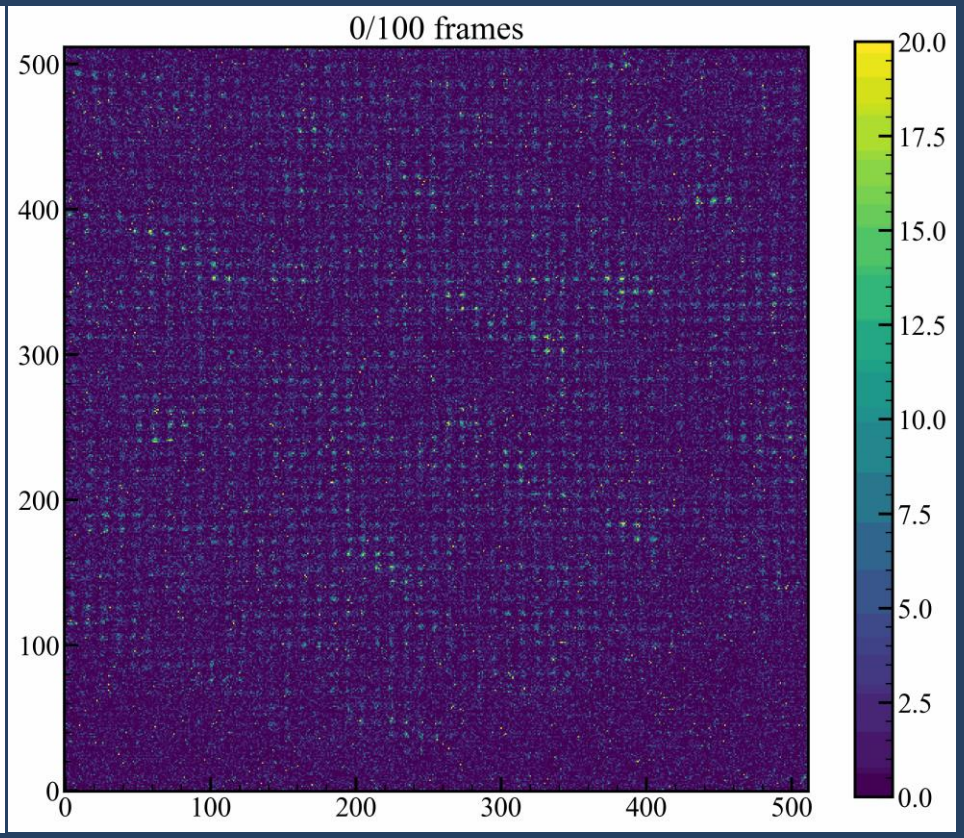


Subaru on-telescope measurements

800x800 : < 80x80 spots



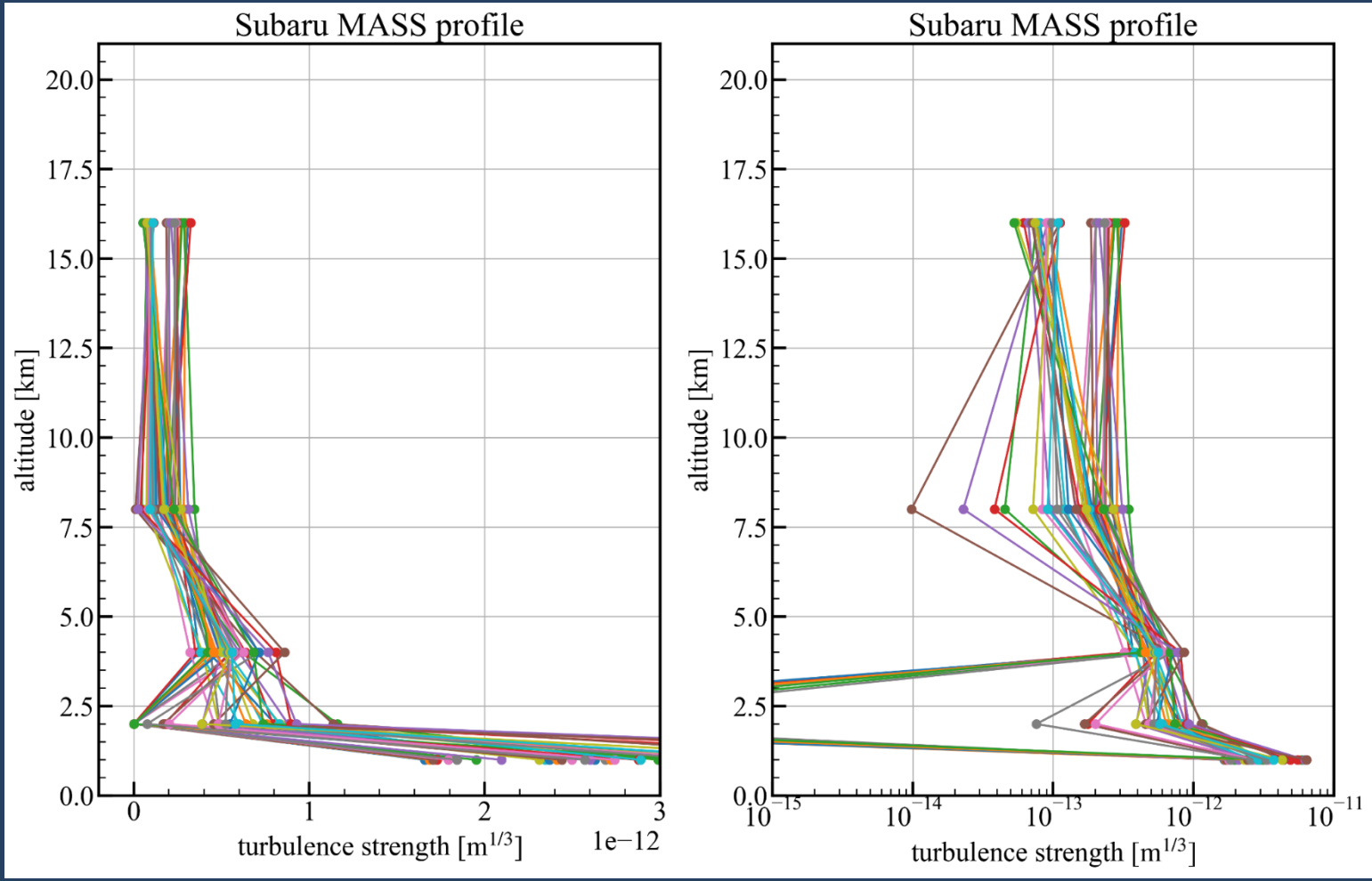
512x512 : 175fps, 50x50 spots



Ogane in prep.

Subaru on-telescope measurements

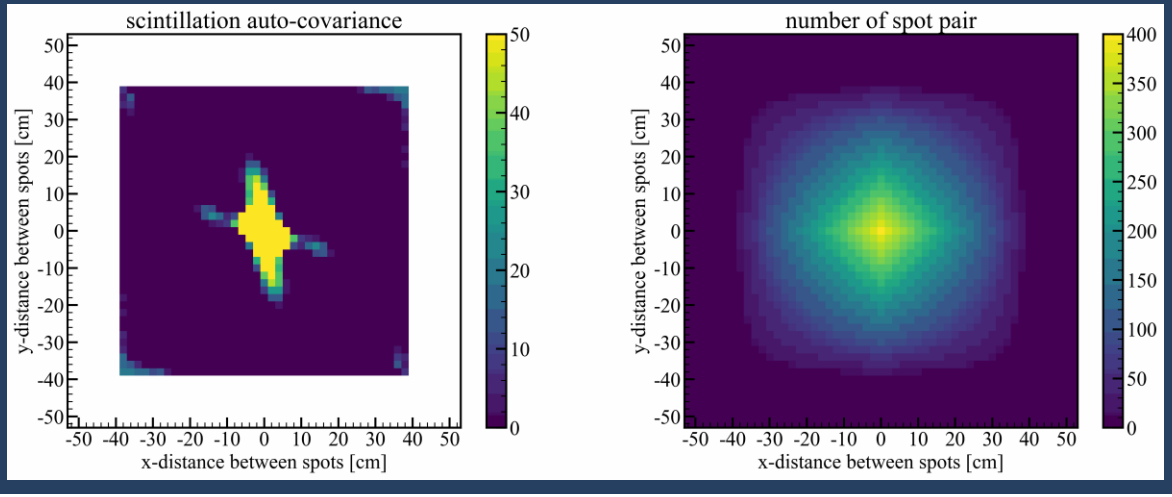
Preliminary profile from the SH-MASS measurements.



Ogane in prep.

Subaru on-telescope measurements

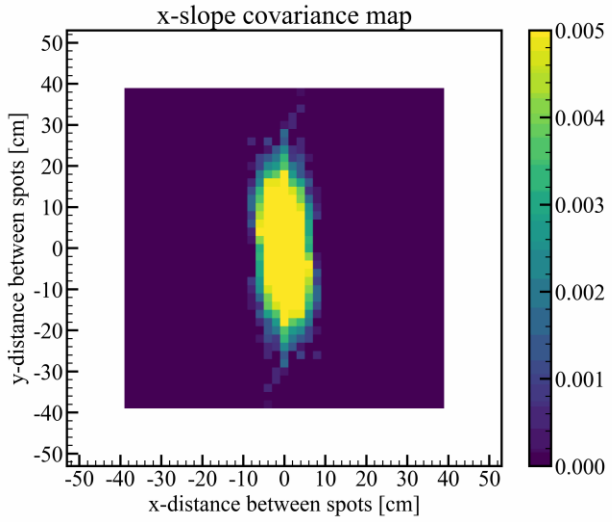
Correlation analysis detects multiple turbulence layers moving in different directions.

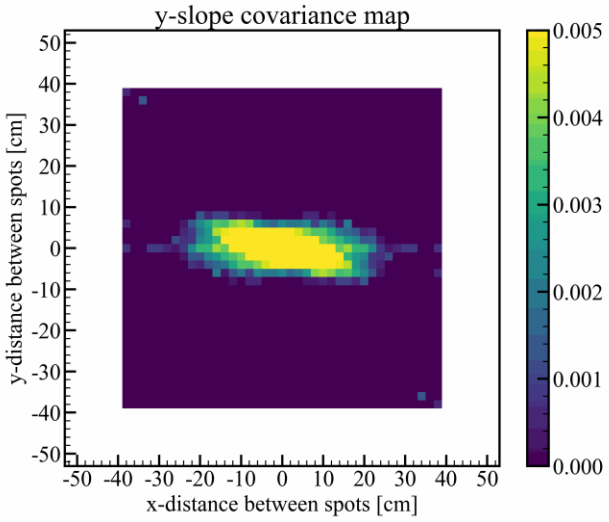


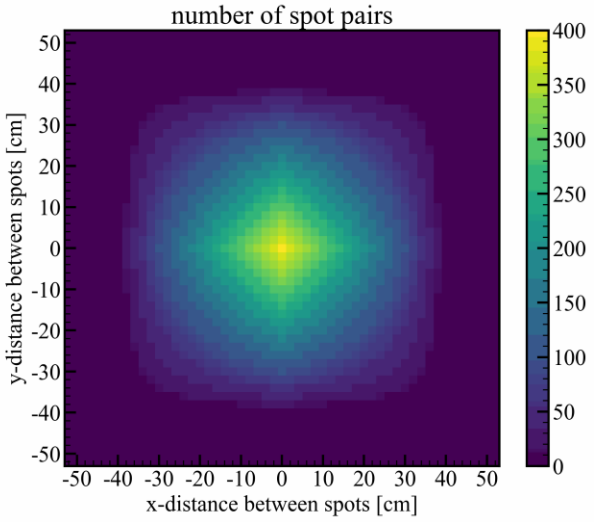
Correlation in scintillation

Ogane in prep.

Correlation in x-y slopes

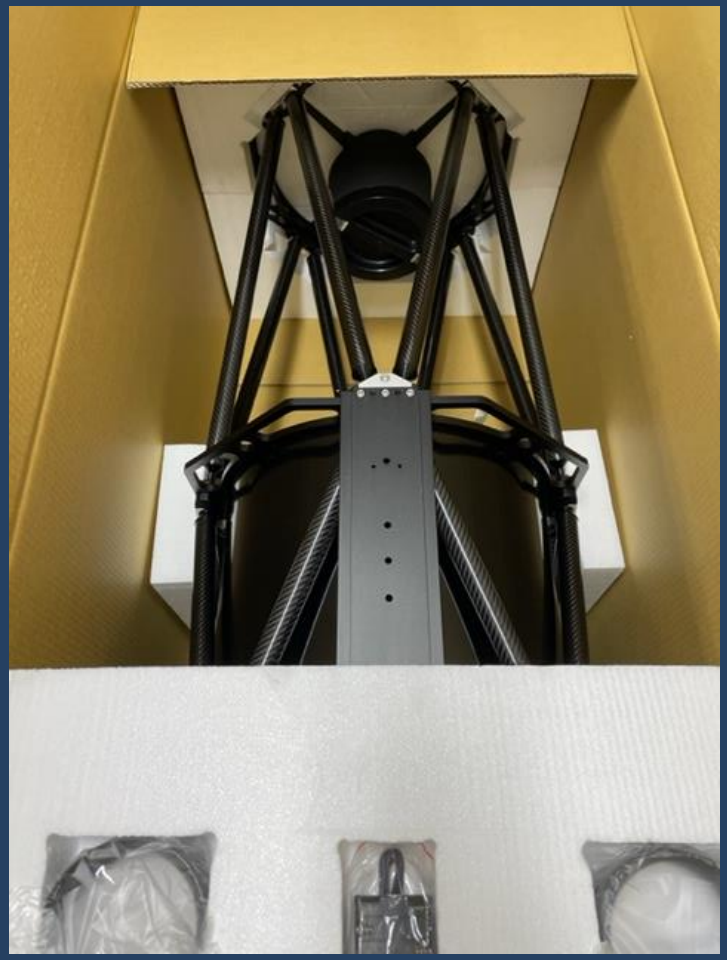






Toward real-time measurements

Small telescope for the simultaneous measurements.



Schedule

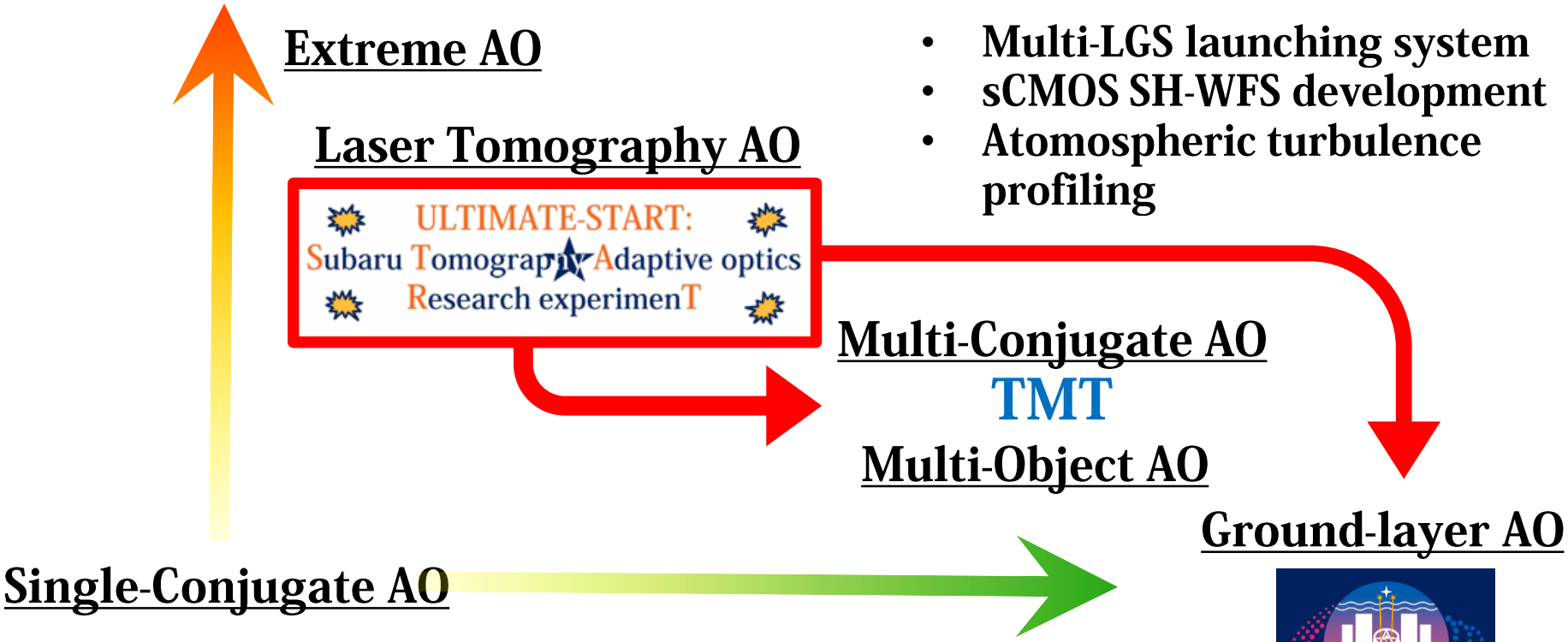
Transfer LTAO WFS unit to Hilo : early 2023
LTAO on-sky testing : 2024
3DII upgrade : 2023 – 2026
Science verification : 2027

	FY 2023 (R5)	FY 2024 (R6)	FY 2025 (R7)	FY 2026 (R8)	FY 2027 (R9)
NsIR beam switching optics installation	← →				
Tomography AO engineering observation and performance evaluation	←	→			
Kyoto 3DII update optical design	←	→			
Kyoto 3DII optics fabrication	←	→			
Kyoto 3DII optimized grism fabrication		← →			
Kyoto 3DII optics replacement and engineering observations		←	→		
Kyoto 3DII data analysis development	←	→			
Science observation as a bring-in instrument (Kyoto 3DII + ULTIMATE-START)				←	→

Future Directions beyond Subaru-LTAO

Precise correction

High-order correction

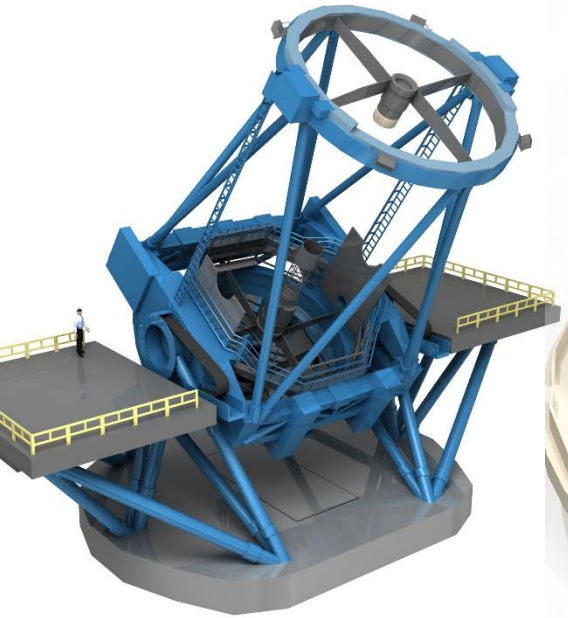


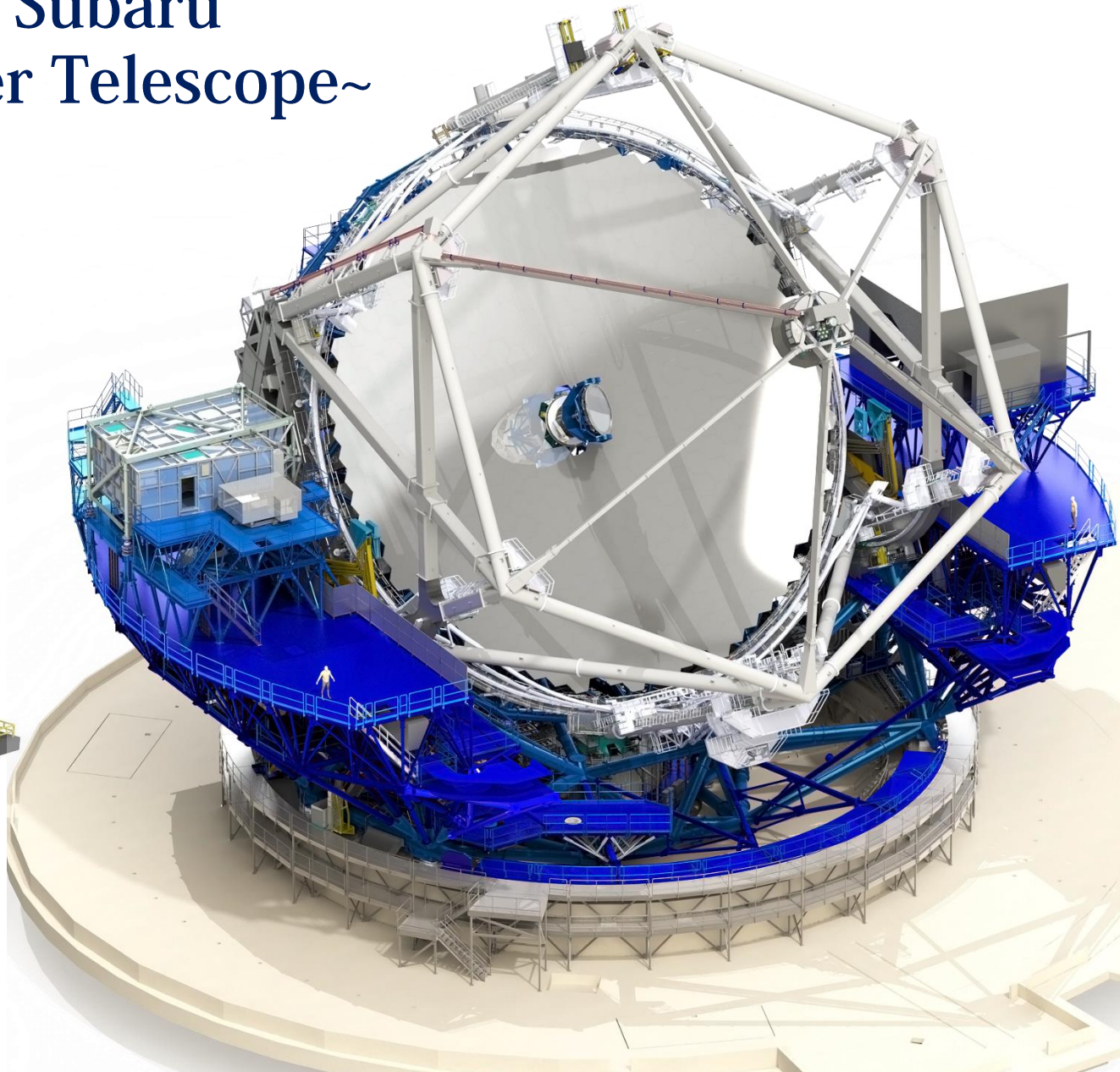
- Multi-LGS launching system
- sCMOS SH-WFS development
- Atomospheric turbulence profiling

Wide-field statistics

Wide spread multiple laser guide stars

Beyond Subaru
~Thirty Meter Telescope~





Acknowledgement

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