TMT-AGE:

TMT Analyzer for Galaxies in the Early universe

広視野多天体近赤外線面分光装置
TMT 第２期装置の提案

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Three Science Drivers for TMT-AGE

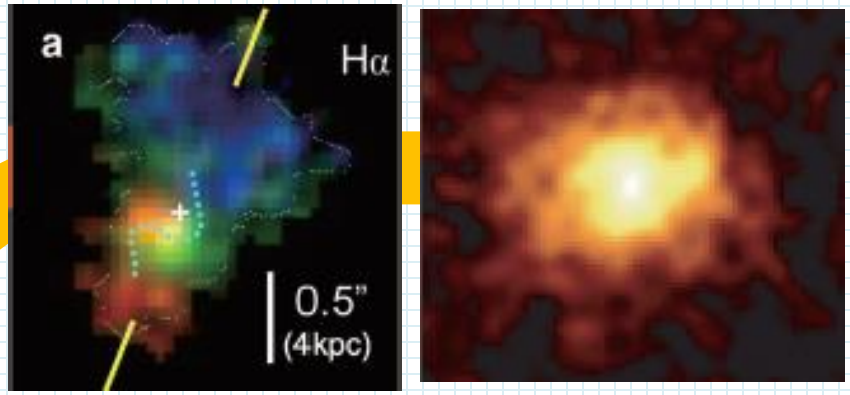
1. How is the internal structure of local galaxies established ?
   現在の銀河の内部構造はどのように確立したか？

2. What is going on in galaxies in the early universe ?
   宇宙初期の銀河内部でどのような現象が起こっているか？

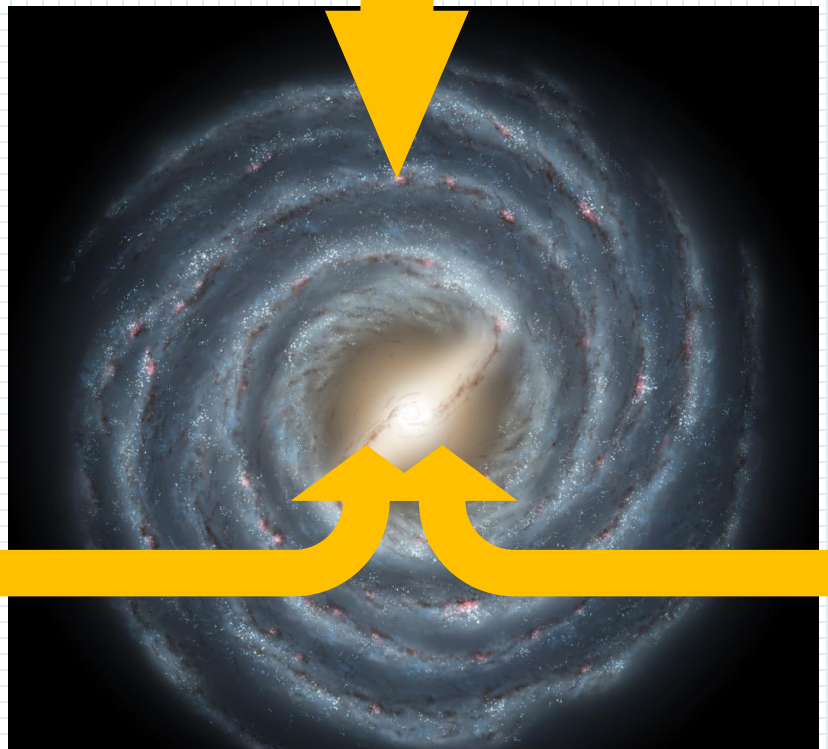
3. Hunting for galaxies/AGNs at z>6
   宇宙初期の銀河とAGNの探査を行う。

1. How is the internal structure of local galaxies established ?

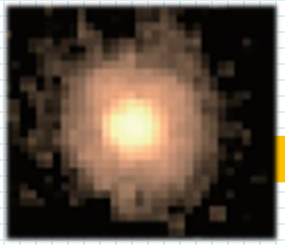
Turbulent / high surface-density disks at high-z



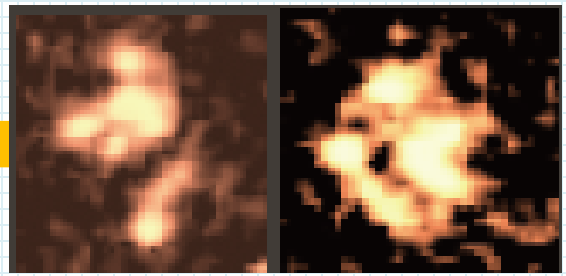
Typical galaxy seen in the local universe



Very compact galaxies at high-z



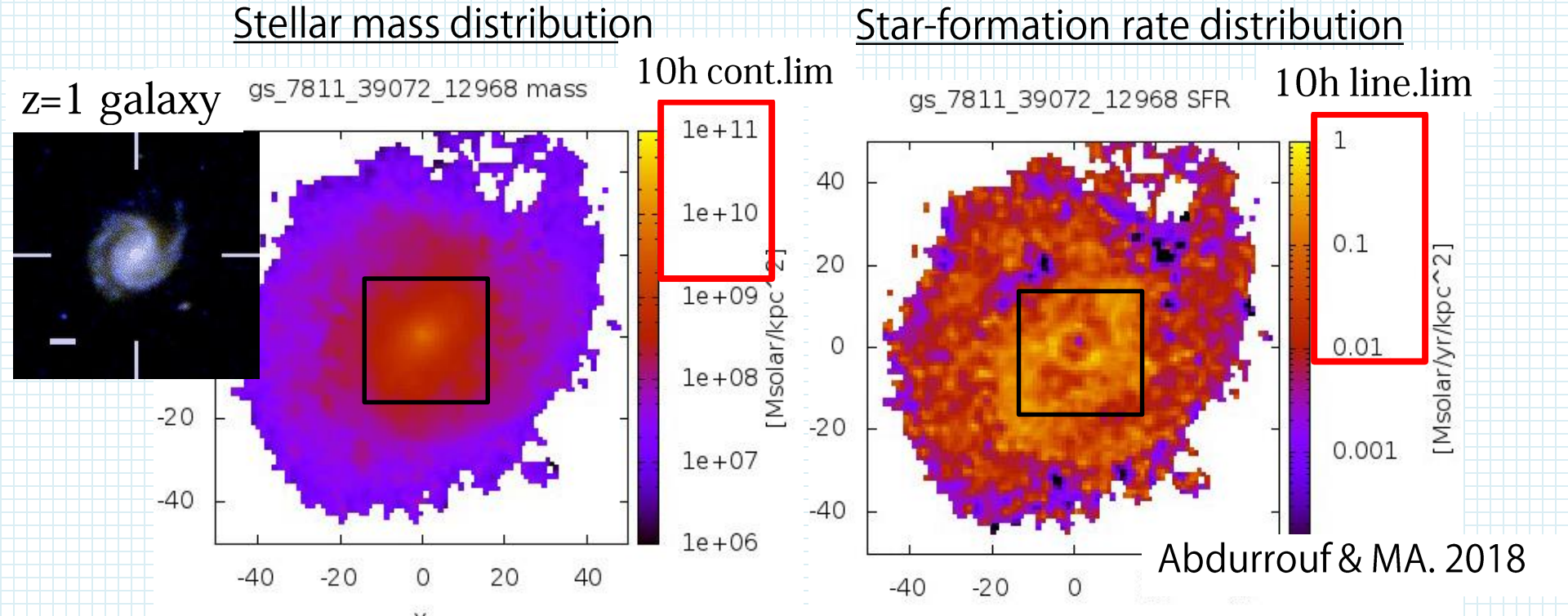
Clumpy galaxies at high-z



1. How is the internal structure of local galaxies established ?

Missing information :
"stellar dynamics" and its cosmological evolution.

TMT can measure the local stellar dynamics of galaxies at z>1.



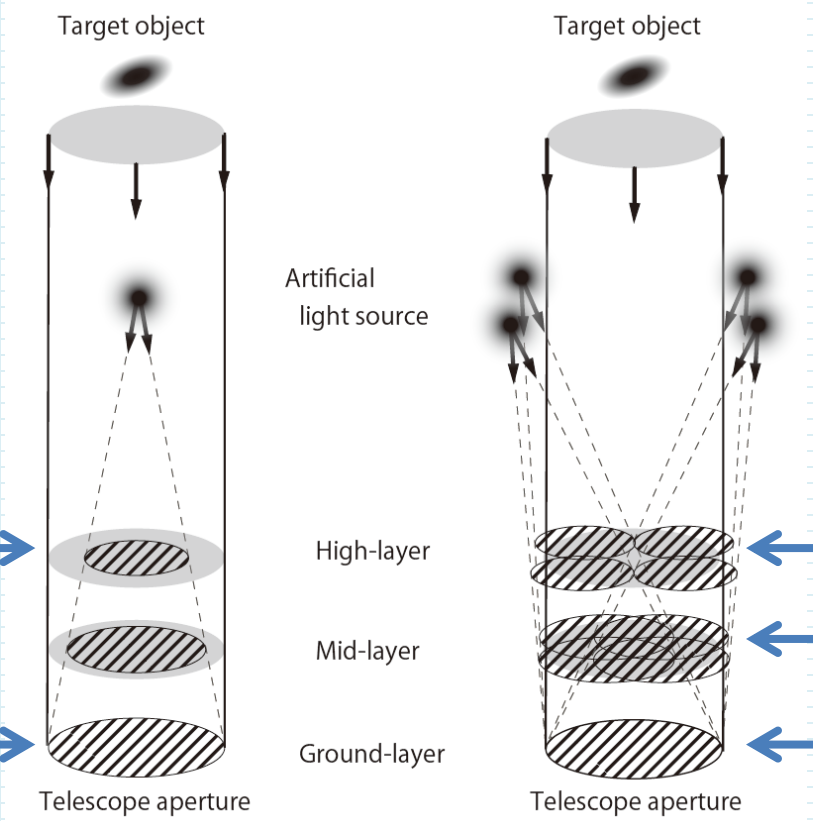
Requirements (High-Res and High-Sen modes)

1. Spatially-resolved spectroscopy of z=1-5 galaxies.
   - High spatial and spectral resolution deployable multi-IFU spectrograph covering wide target field.
   - 0.05x0.05″ sampling IFUs with 2″ FoV
   - R=10,000 spectroscopy for v~30km/s

2. Integrated spectroscopy of z>5 galaxies.
3. Follow-up spectroscopy of candidates of z>8 galaxies
   - Wide-field high-sensitivity (moderate AO correction) multi-object spectrograph in short NIR wavelength range
   - 0.3x0.3″ – 0.5″x0.5″ aperture integrated spectroscopy
   - R=3,000 (5A resolution, 2A/pix) for absorption/emission lines with rest-frame EW of 1A.

Tomographic AO system

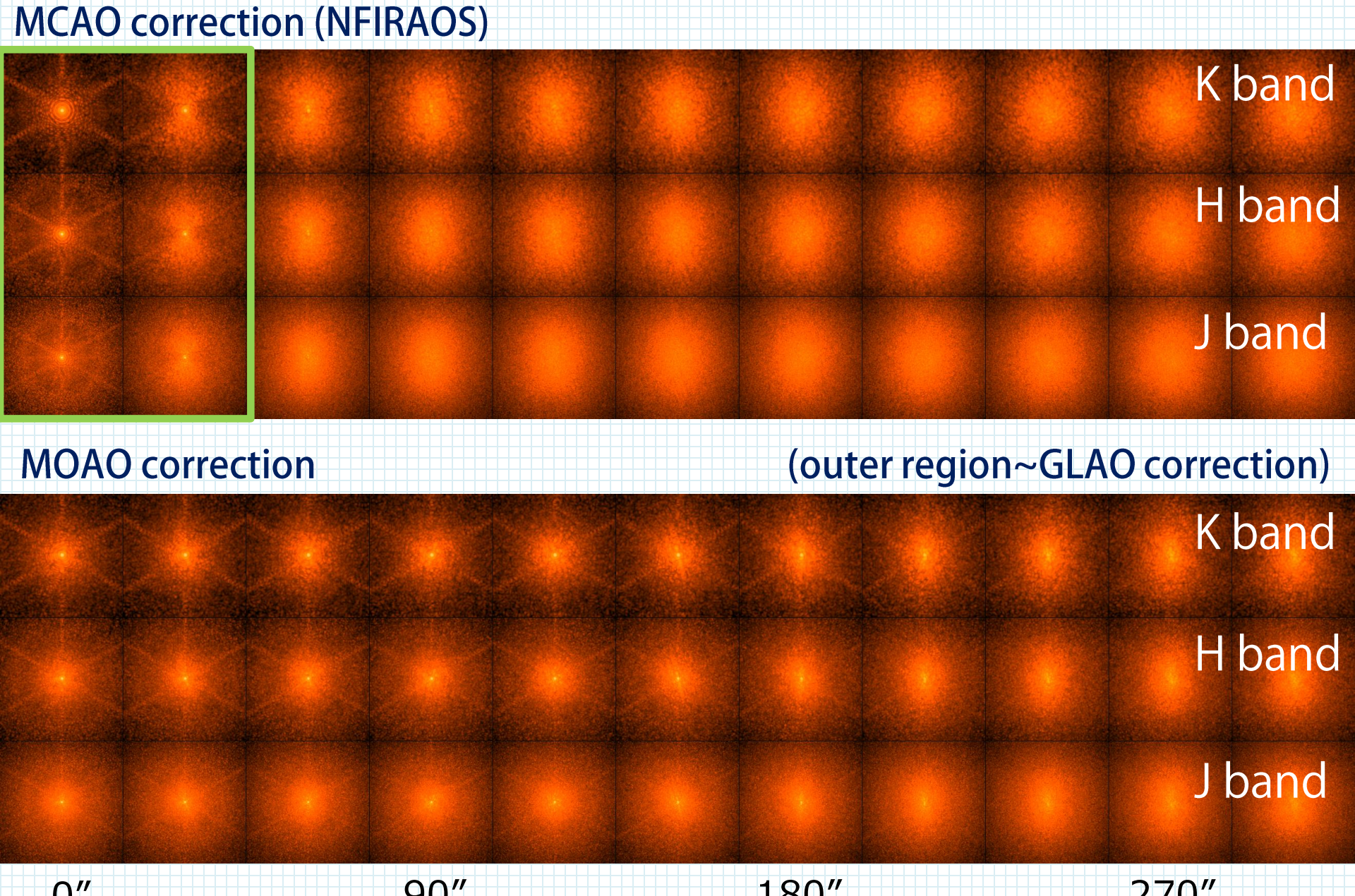
- In the classical AO system, integrated wavefront distortion is measured with one light source, i.e. turbulence layers are degenerated.
- In the tomographic AO system, multiple light sources are used to estimate the turbulence layer at each altitude separately.



Integrated/
Degenerated

Separated
"3D" estimates

Comparison between PSFs with different AO systems



AO performance prediction

- Green : TMT-IRMOS (r=2.5′ FoV with MOAO correction)
- Red circle : TMT-wide field AO ~ GLAO-like correction
- (Red square : TMT-wide field AO with a new algorithm under an ideal condition)

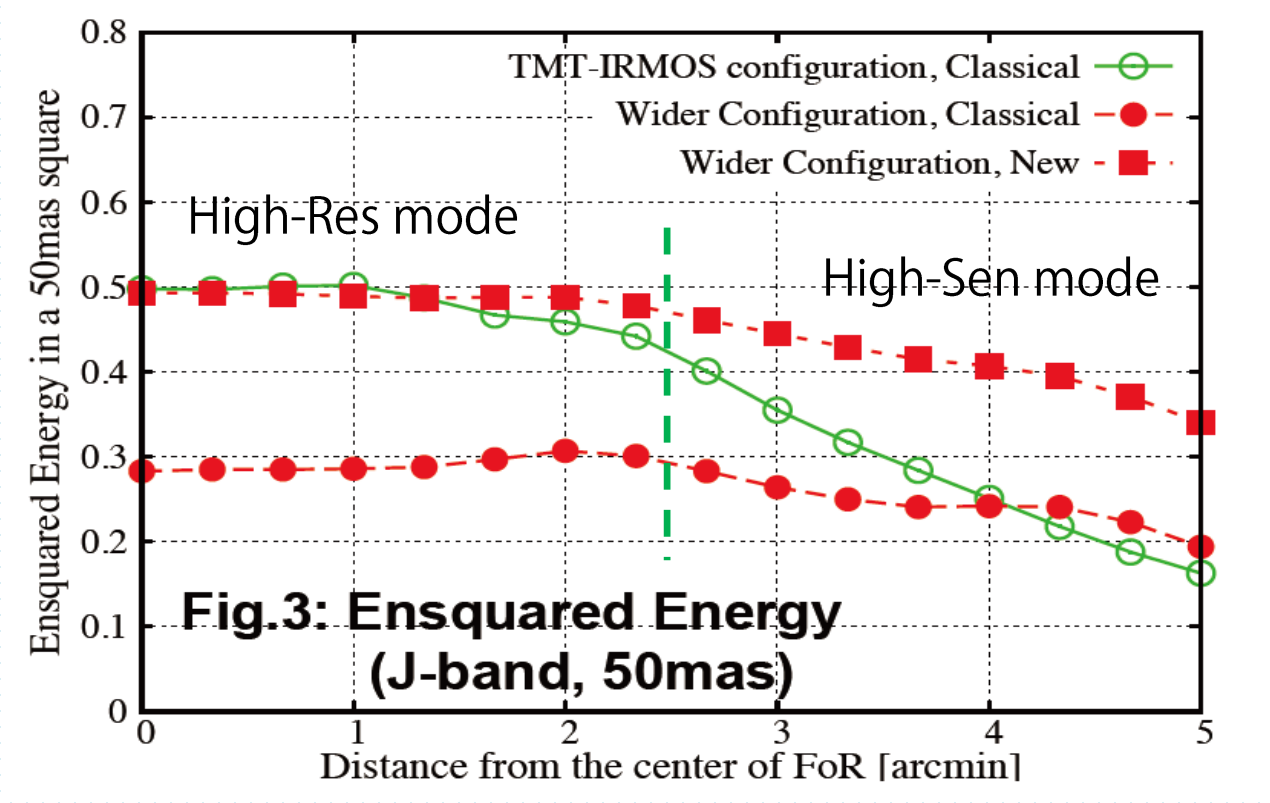


Fig.3: Ensquared Energy (J-band, 50mas)

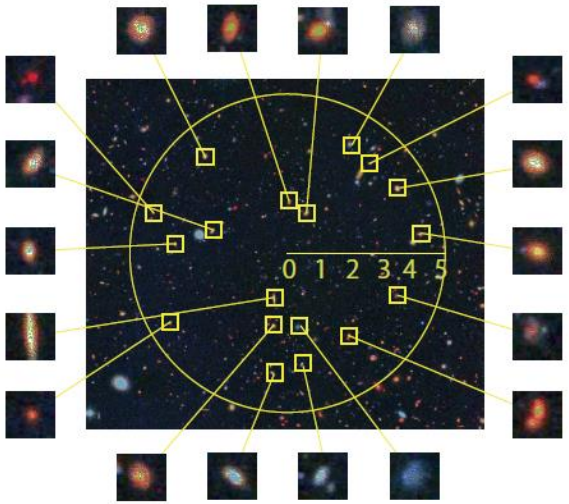
Y.Ono et al. 2014 SPIE, Y.Ono et al. 2016

AO-correction in wide field = GLAO+MOAO

TMT focal plane

Ground-Layer Adaptive Optics
Correcting for common turbulence within d=10′ FoV

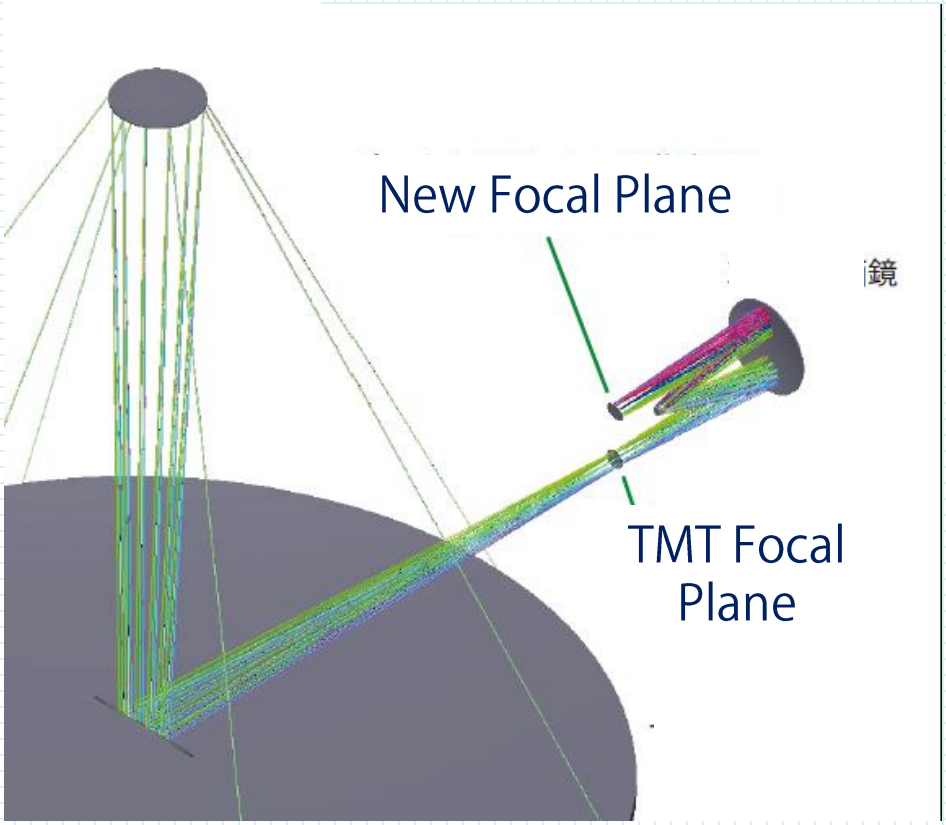
R-theta pick-off opt-mechanics
for 20 objects in the corrected FoV

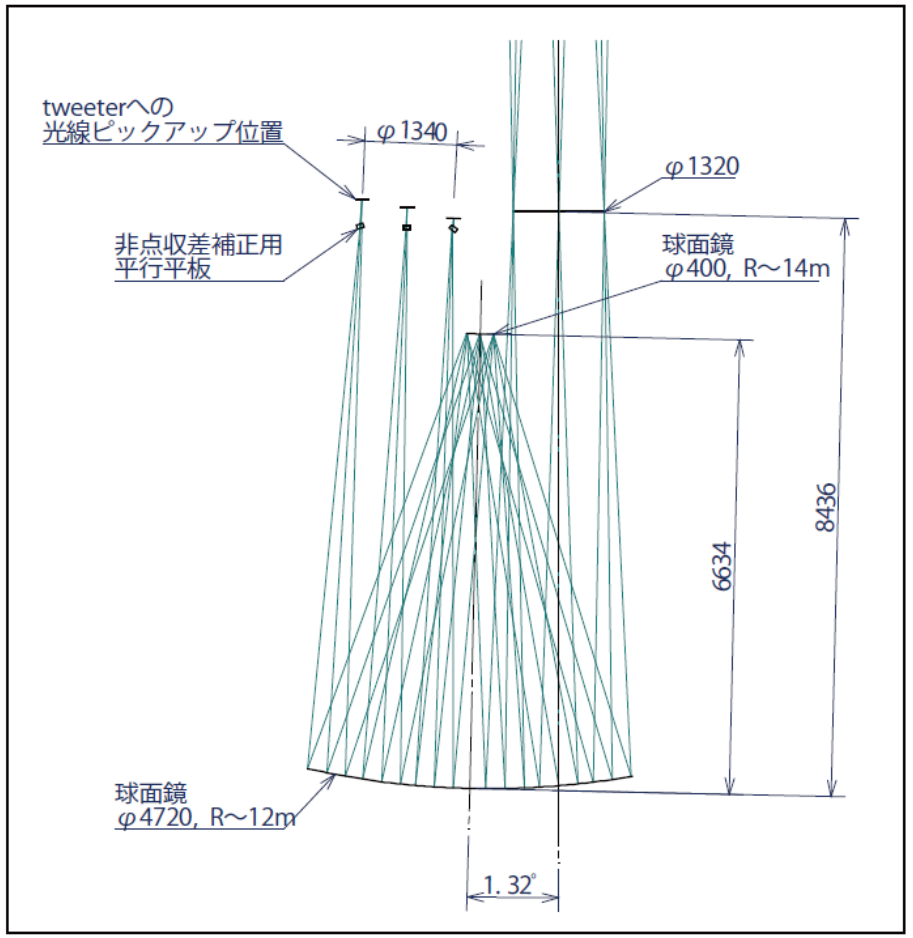


Multi-Object AO correction
for each science path independently

Ground-layer AO optical design

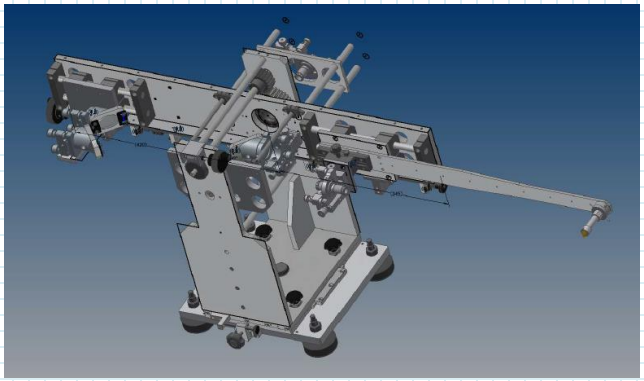
- d=10’ FoV AO optical design.

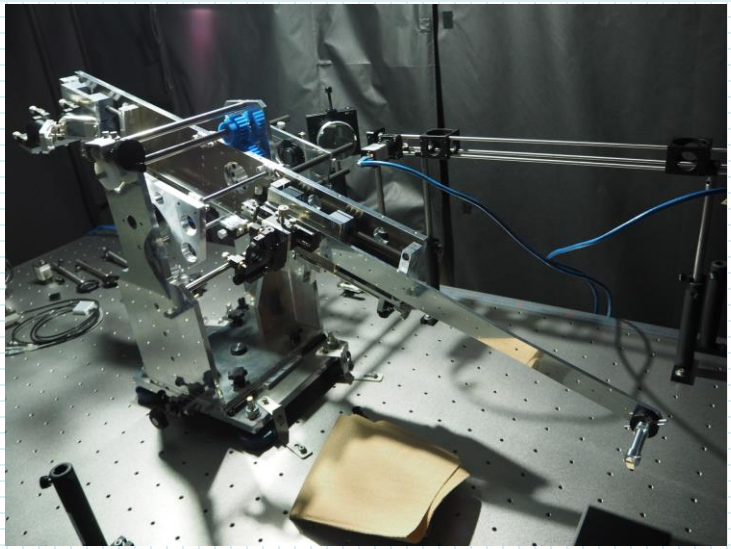




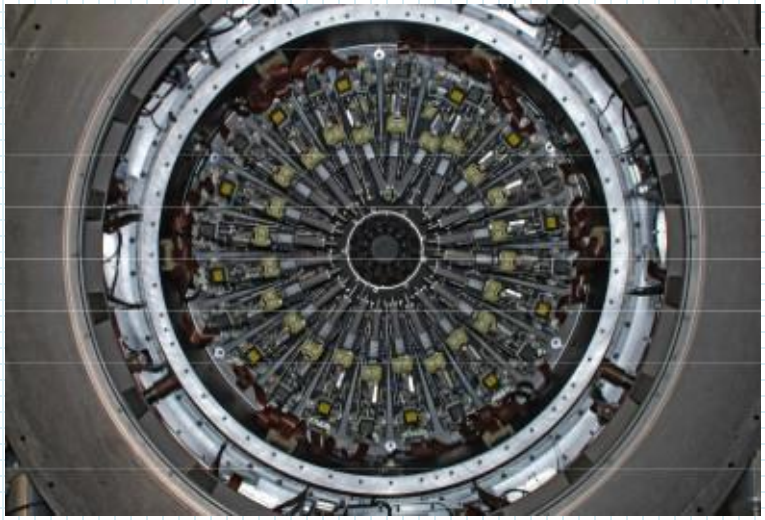
Pick-off Opt-mechanics Mock-up

- Classical r-theta pick-off arm system.
- 20 pick-off arms will be put around the corrected focal plane.

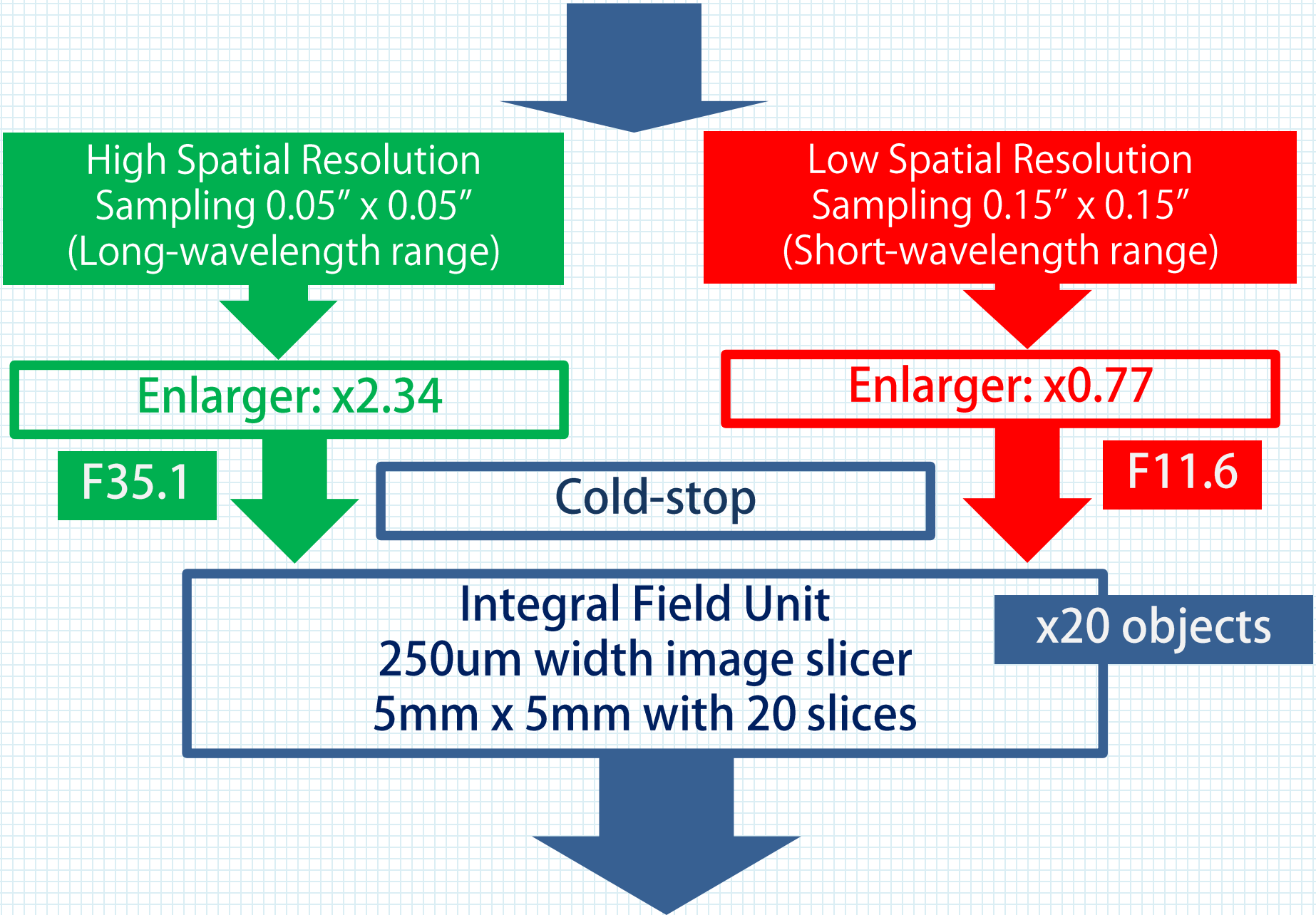




VLT KMOS (w/o AO)



Overview of the optical path



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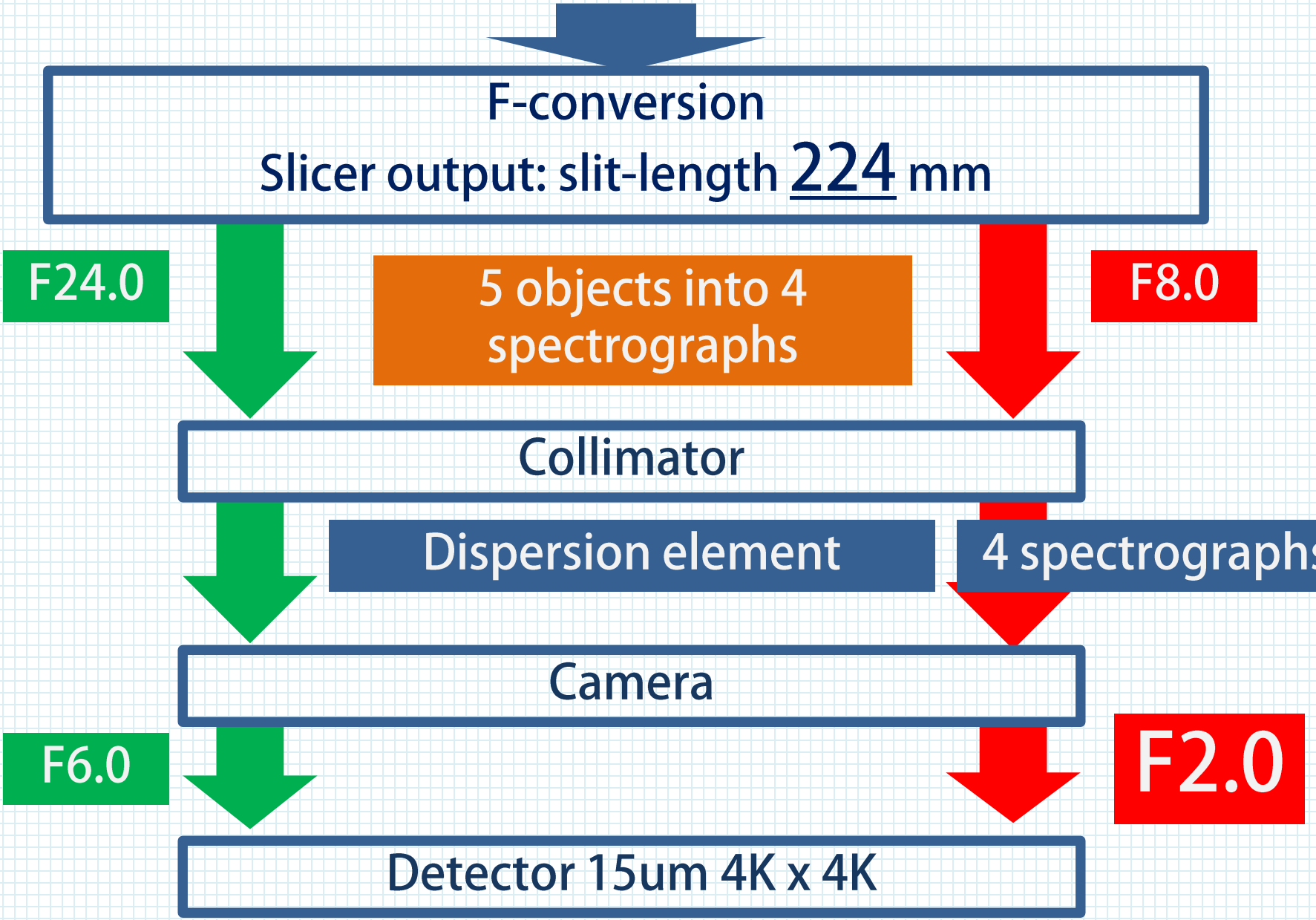
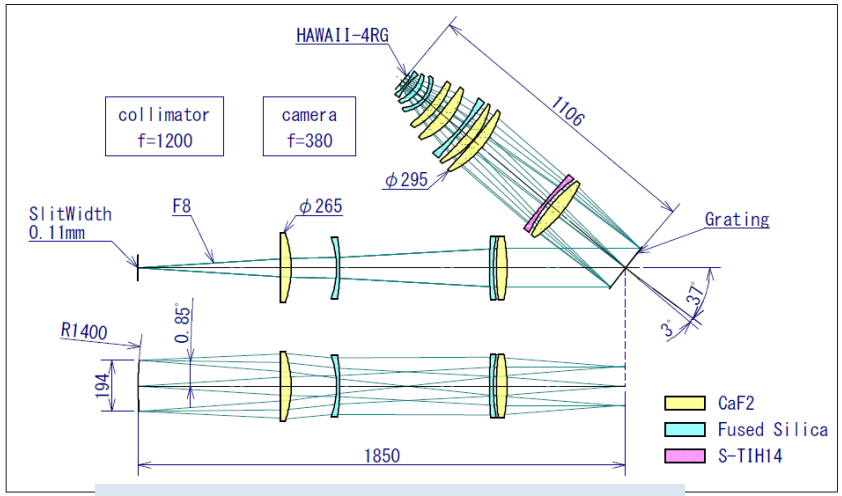
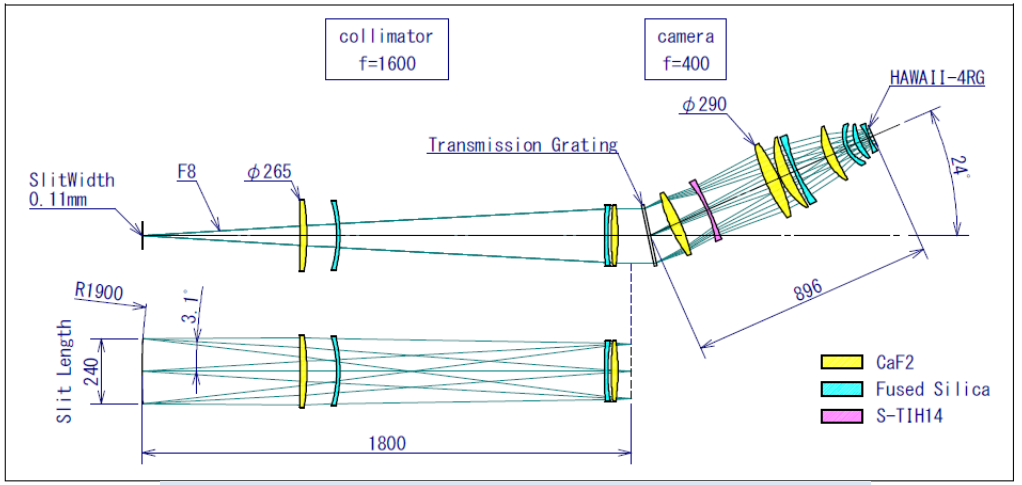


Spectrograph trade study (F2.5 / F8)

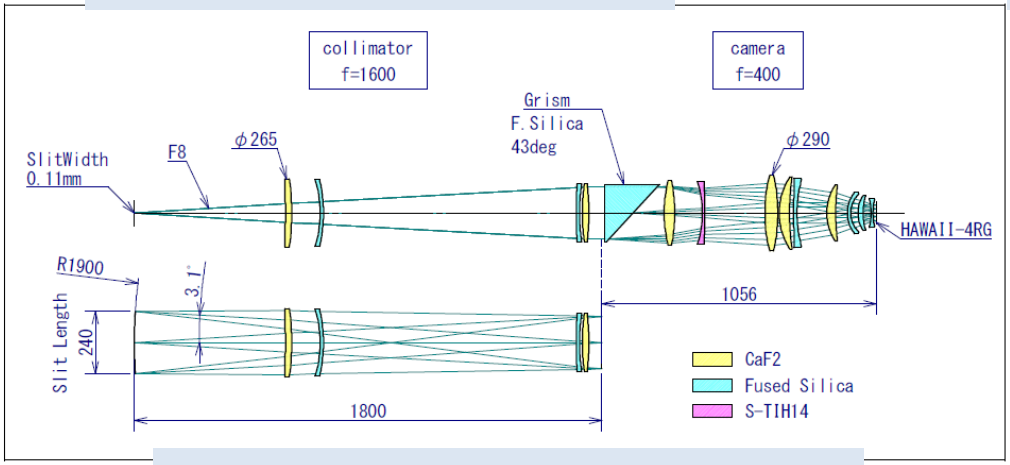
- Optical design studies for F2.5 spectrograph with slit length of 240mm by Optcraft.



reflective grating design



transmission grating design



grism design

These camera system require 9-10 lenses including CaF2 lens with 290-295mm diameter.

Wide-field AO development path

- We kicked-off laser tomography AO experiments with a JSPS funding as the first step of the wide-field AO systems.

✓ 1. Tomography AO correction with 3 NGSs : RAVEN

● 2. Laser Tomography AO experiment with 4 LGSs :
  - ➢ Install 4 LGSs + WFSunit

ULTIMATE-START

3. Laser Tomography AO correction
  - ➢ Installing high-order DM

4. Ground-layer AO system : ULTIMATE-Subaru
  - ➢ Installing adaptive 2ndry

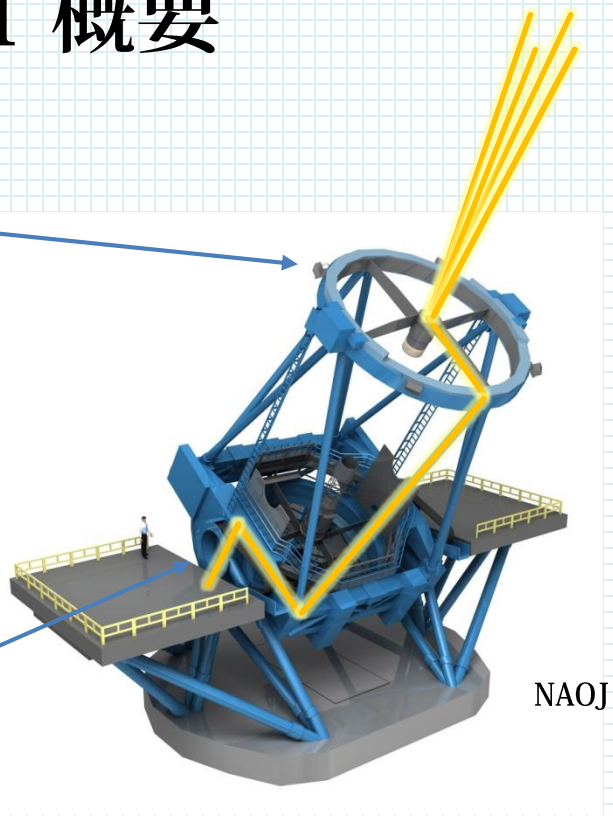
5. Wide-field multi-AO system : TMT-AGE

ULTIMATE-START 概要

① レーザーガイド星×4

- 20Wの高輝度レーザー
  (589nm,TOPTICA社)
- 副鏡の上にある1つのレーザー送信
  望遠鏡から4本のビームを打上。

赤外ナスミス台



NAOJ

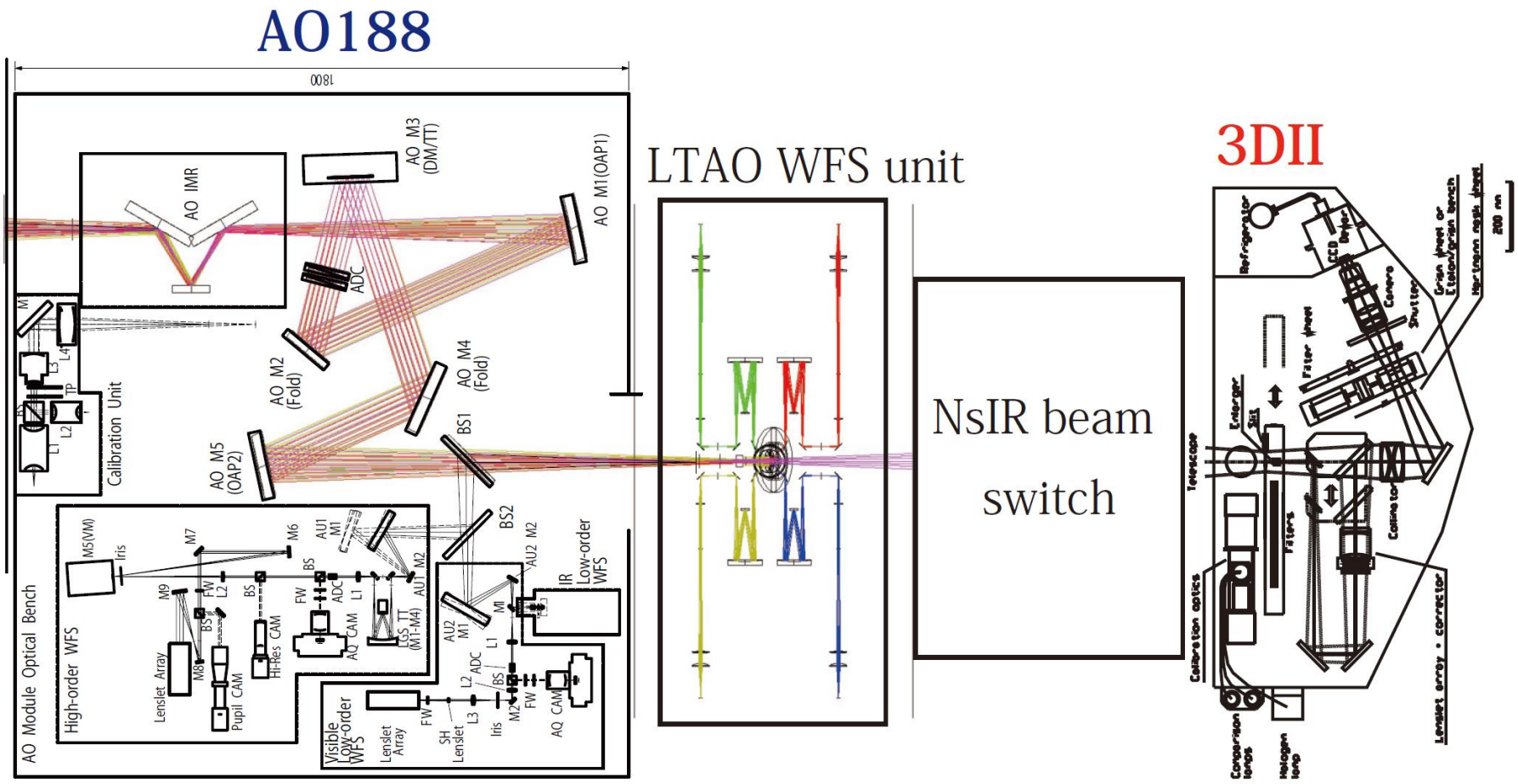
② 波面センサー×4

- 4つのレーザーガイド星の波面測定
- 波面センサーの設置場所

AO188の前のAG/SH→AO188の後ろ

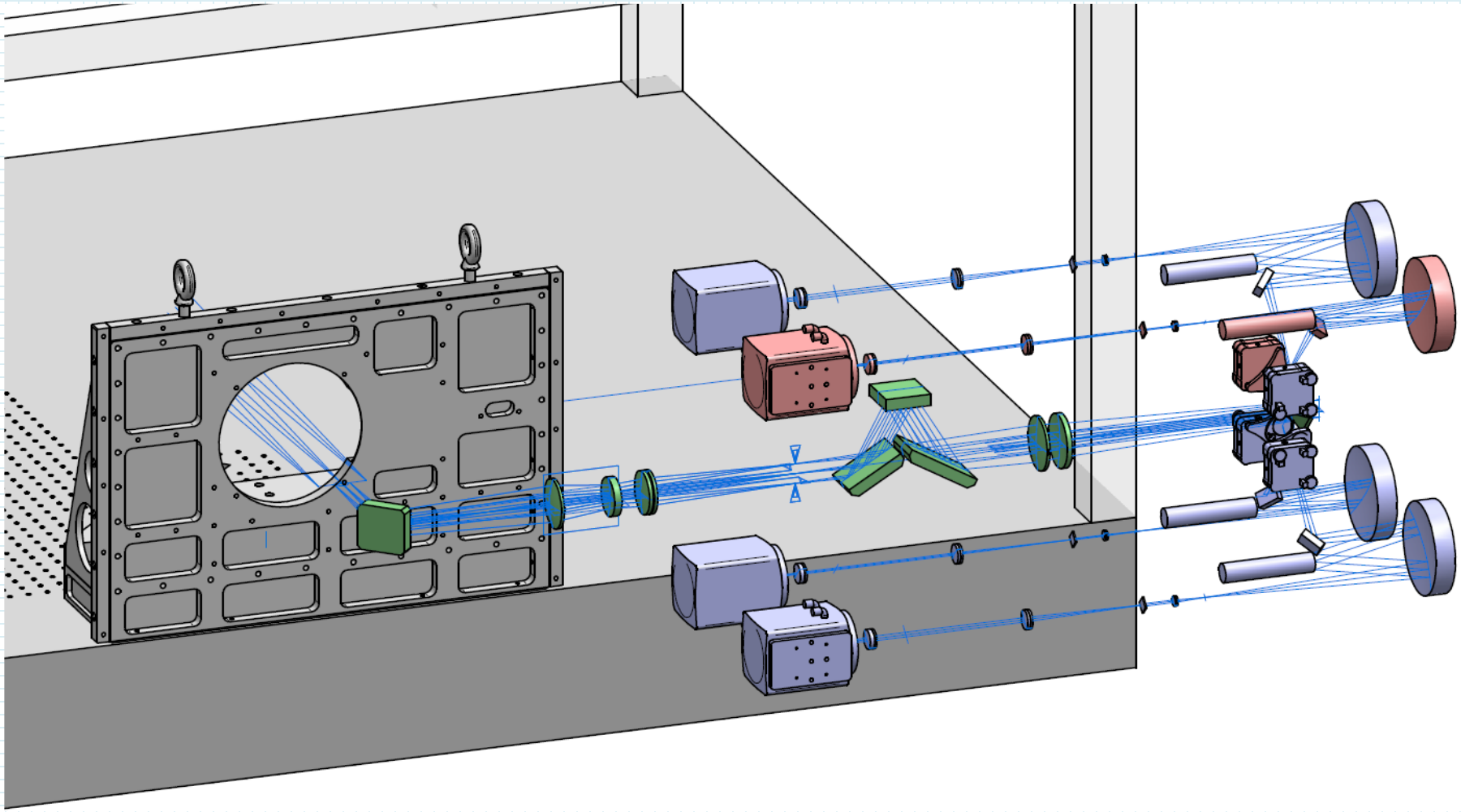
波面測定と面分光観測

- 4台のシャックハルトマン型波面センサーをAO188の後ろに配置しトモグラフィー波面推定を行う。

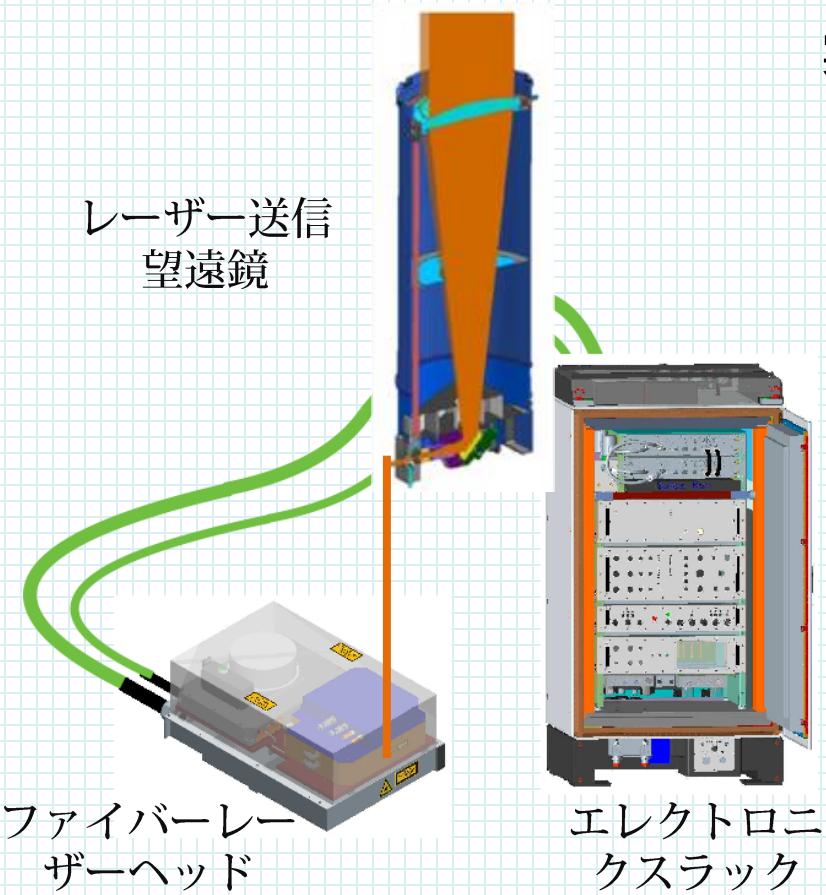


トモグラフィー波面センサー：オプトクラフト

- ビームスプリッターでピックオフの後は水平方向に展開する予定



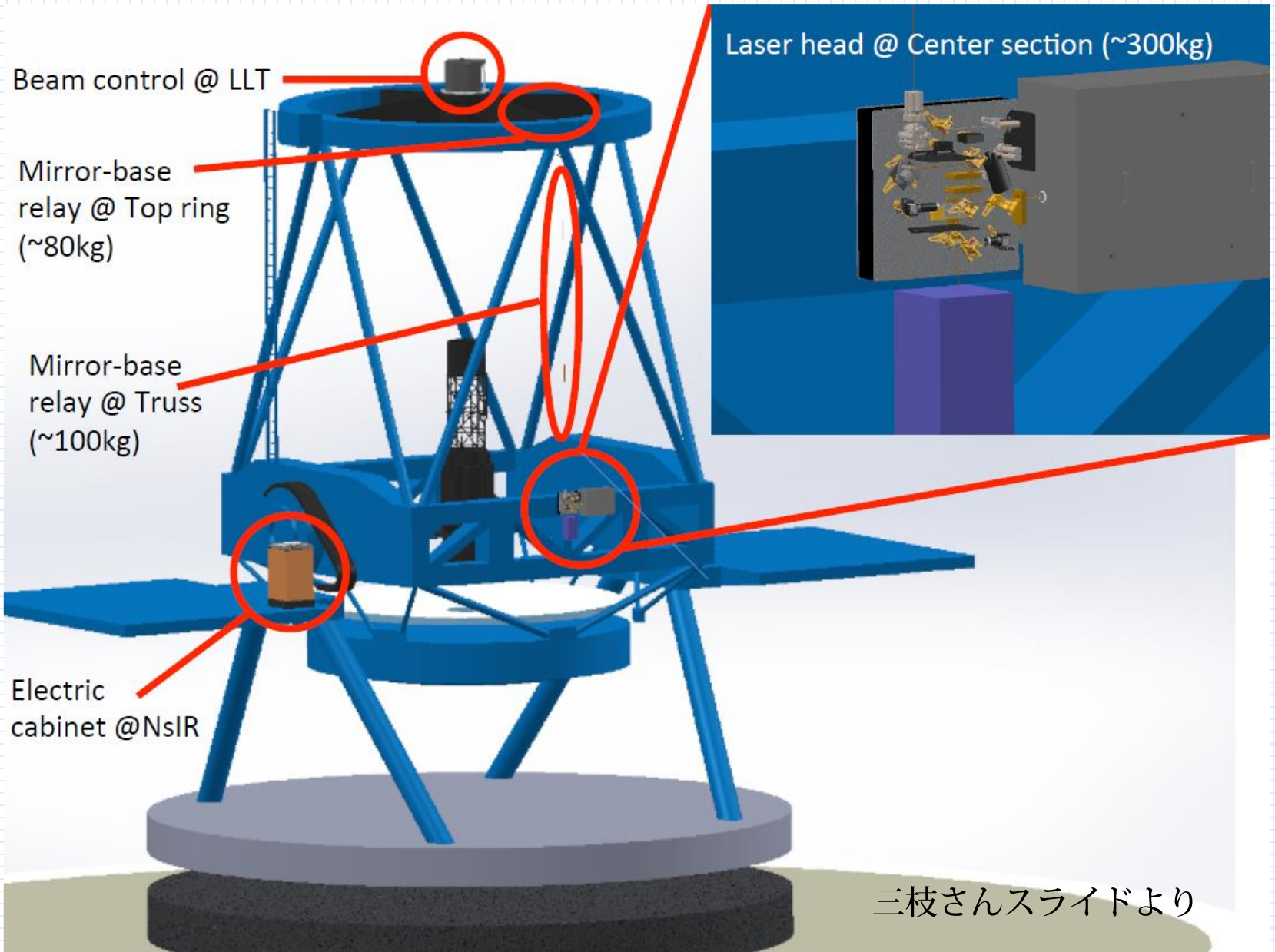
高輝度レーザーの実装 (美濃和・三枝)



実験室では既に高輝度が得られることを確認されており、S19B 期には実装・試験予定。

- TOPTICAのファイバーレーザーをすばる望遠鏡に実装し、現在用いているレーザーガイド星に対して 10 倍以上の明るさを達成する。

レーザー送信系の全体像



三枝さんスライドより

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ULTIMATE-START

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詳しくは大金ポスター参照

4. Ground-layer AO system : ULTIMATE-Subaru
  - ➢ Installing adaptive 2ndry

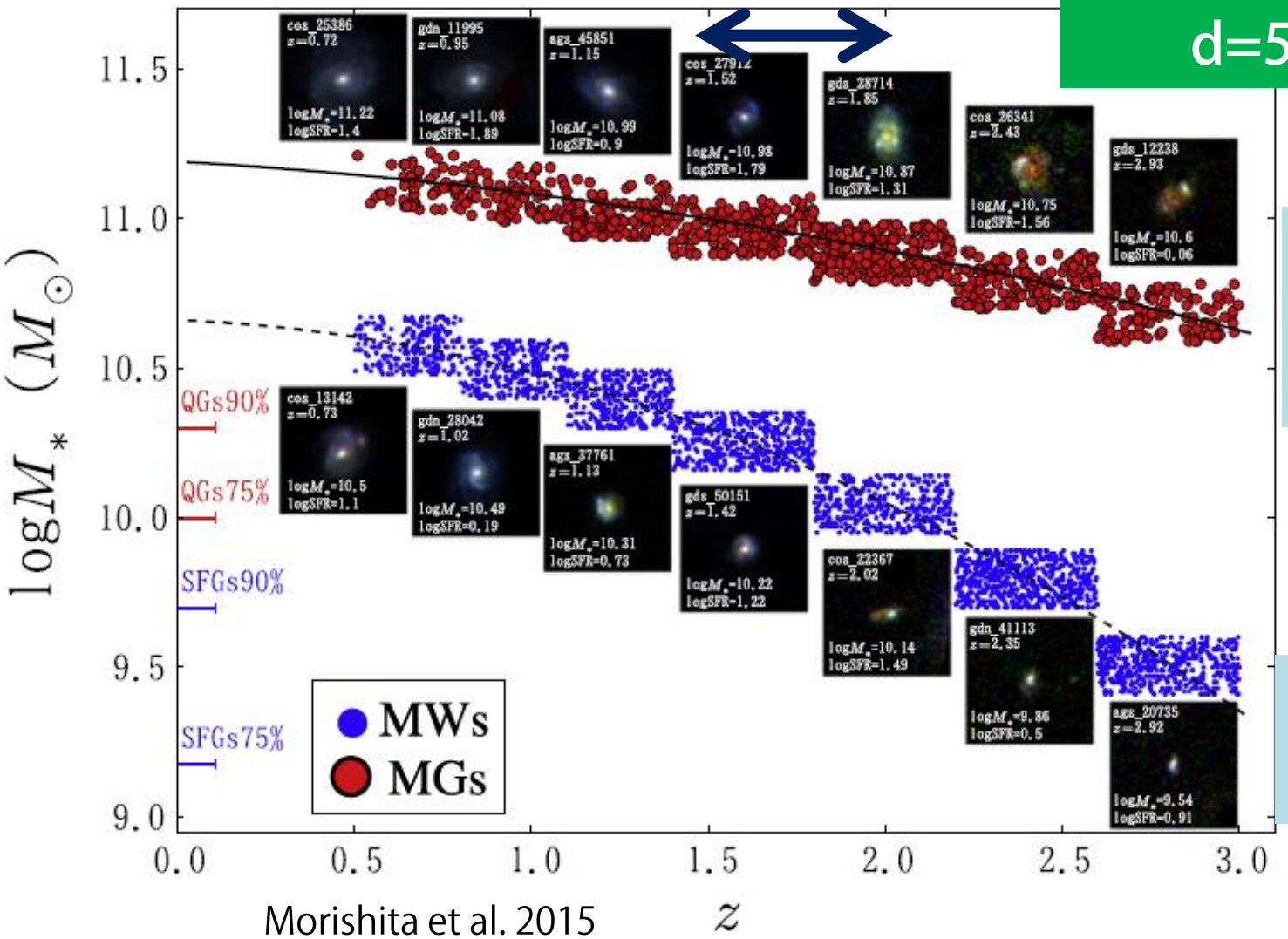
5. Wide-field multi-AO system : TMT-AGE

ADDITIONAL SLIDES

Targets of Multi-IFU Observations

4000A in J-band

>10 objects in d=5' FoV



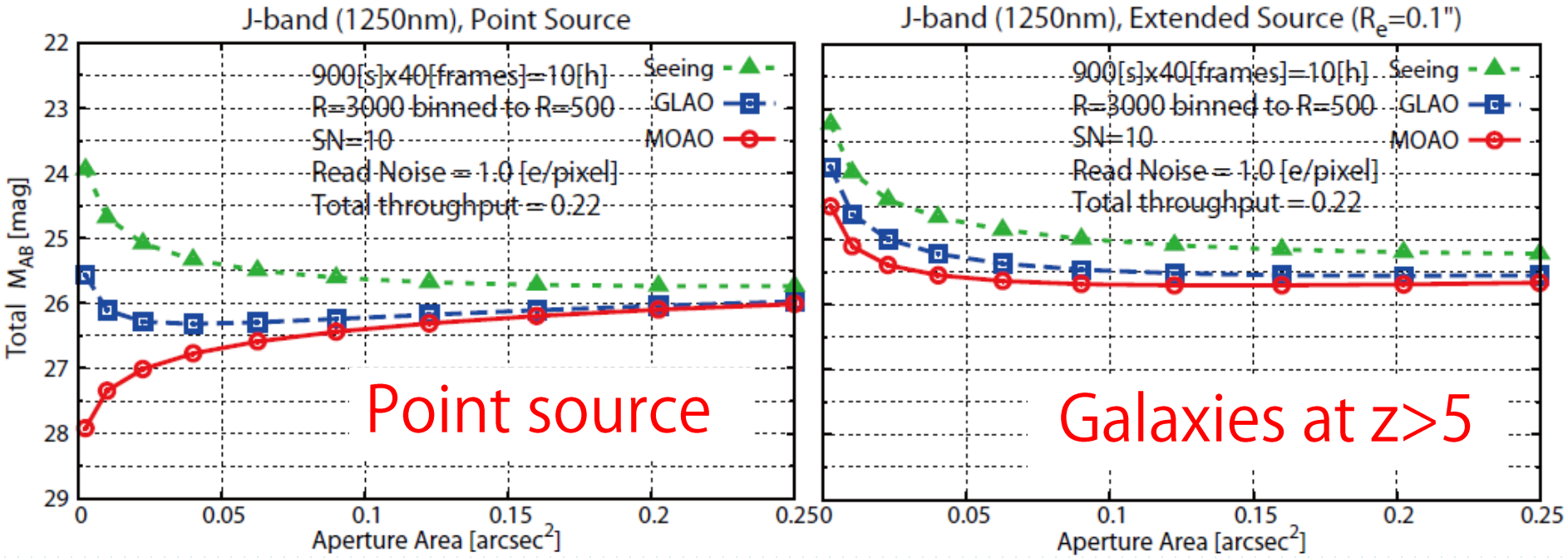
Stellar mass evolution of massive ellipticals

Stellar mass evolution of MW analogs

Morishita et al. 2015

Number density from MOIRCS Deep Survey results

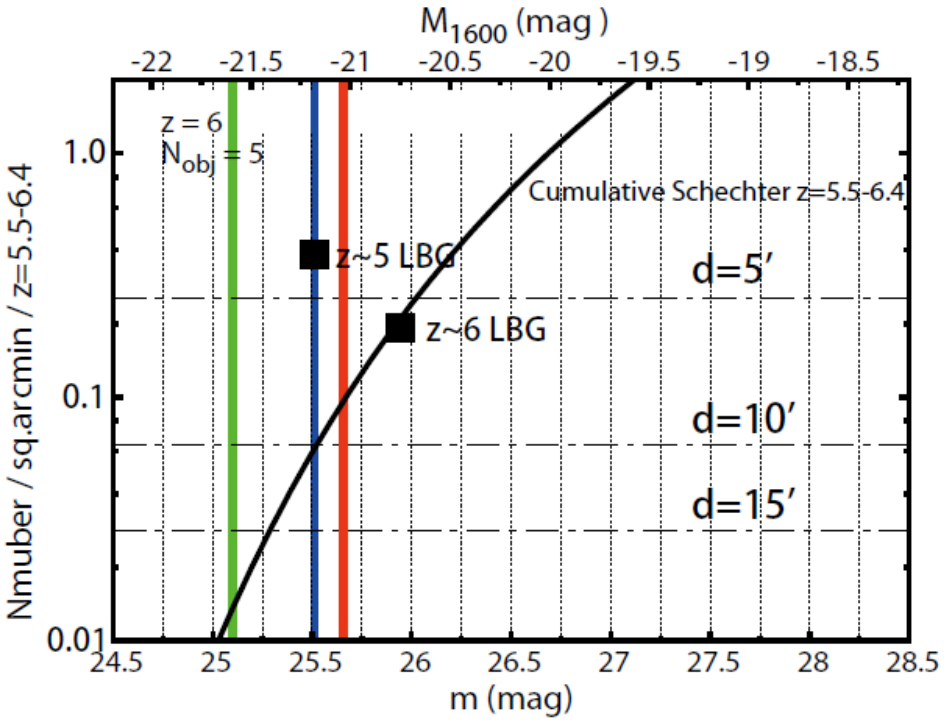
Baseline Detection limits – integrated J-band

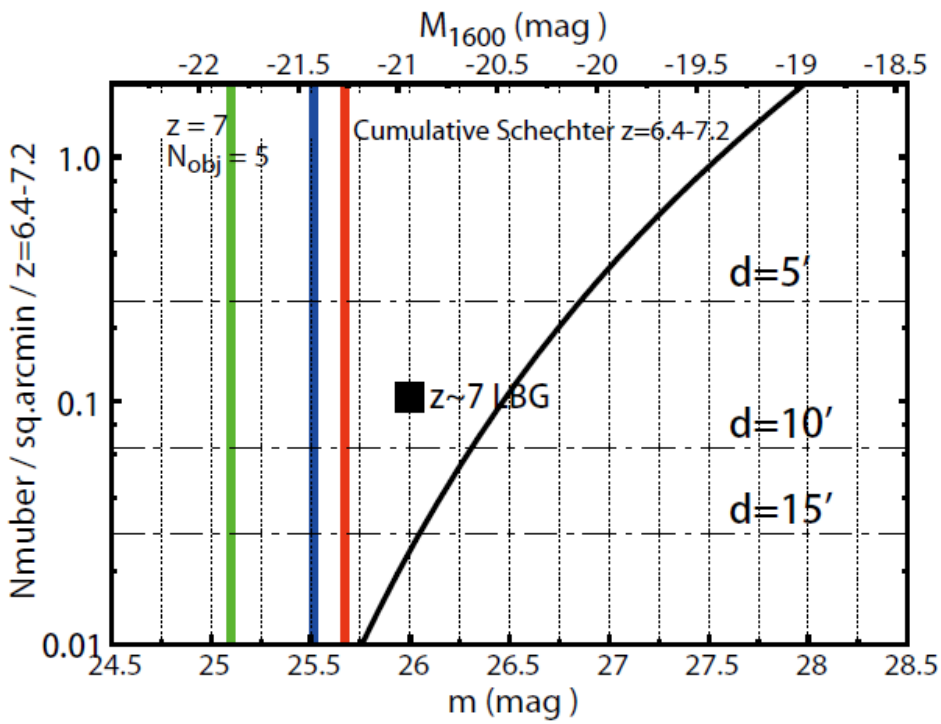


- Red (MOAO), blue (GLAO), green (seeing-limit) lines show the detection limits for each system with different aperture size.
- SN=10 for continuum with 10h integration
- R=3,000 spectroscopy binned to R=500
- Typical size of z>5 galaxies: effective radius of 0.1”

Number density

- Red (MOAO), blue (GLAO), green (seeing-limit) lines show the detection limits for each system.
- Number density of luminous z~6-7 LBGs is not so high.





Filled squares from Bouwens et al. 2014,
V-dropout for z~5, i-dropout for z~6, and Y-dropout for z~7