TMT-AGE: Wide field of regard multi-object adaptive optics for TMT

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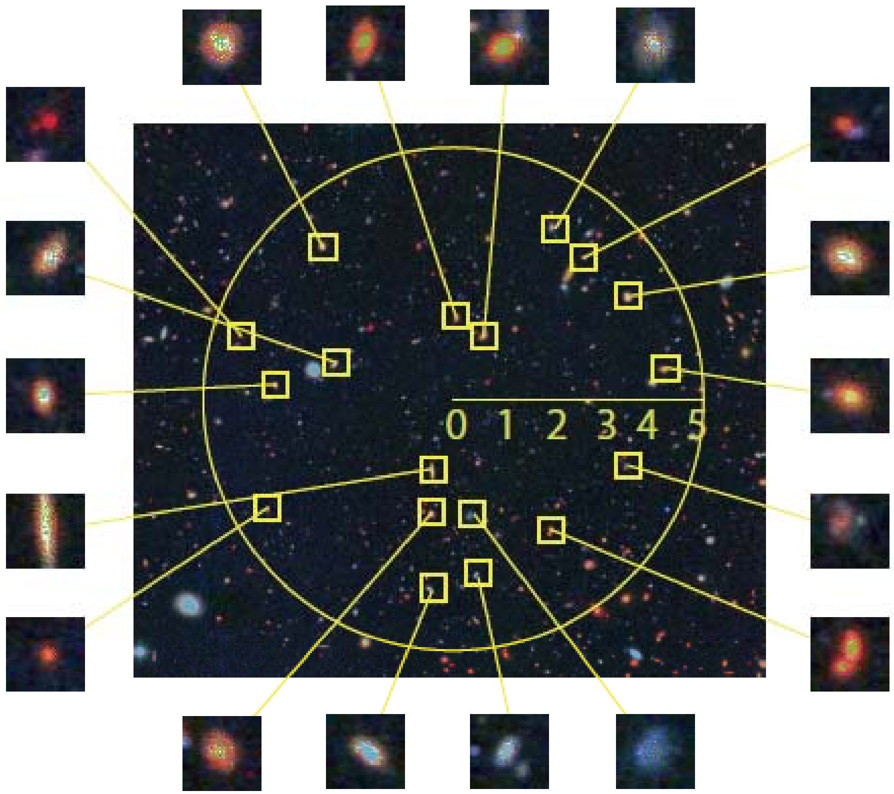
TMT-AGE:
TMT Analyzer for Galaxies in the Early universe

- Multi-IFU NIR spectroscopy of ~20 objects scattered in wide (d=10′) Field of Regard (FoR) assisted by MOAO correction
- Multi-Object Adaptive Optics apply optimal correction separately for each object with a DM in each science path.



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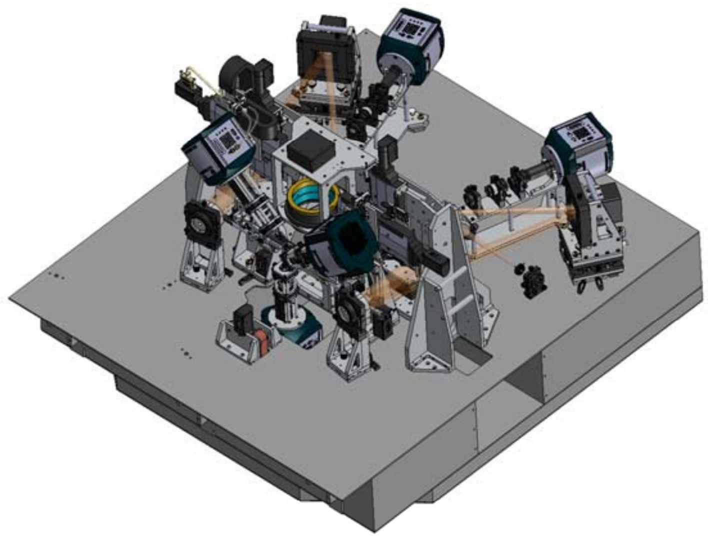
RAVEN : MOAO demonstration

- RAVEN is an MOAO engineering demonstration system on Subaru telescope. RAVEN project is led by U.Victoria and collaboration with Subaru and Tohoku Univ.



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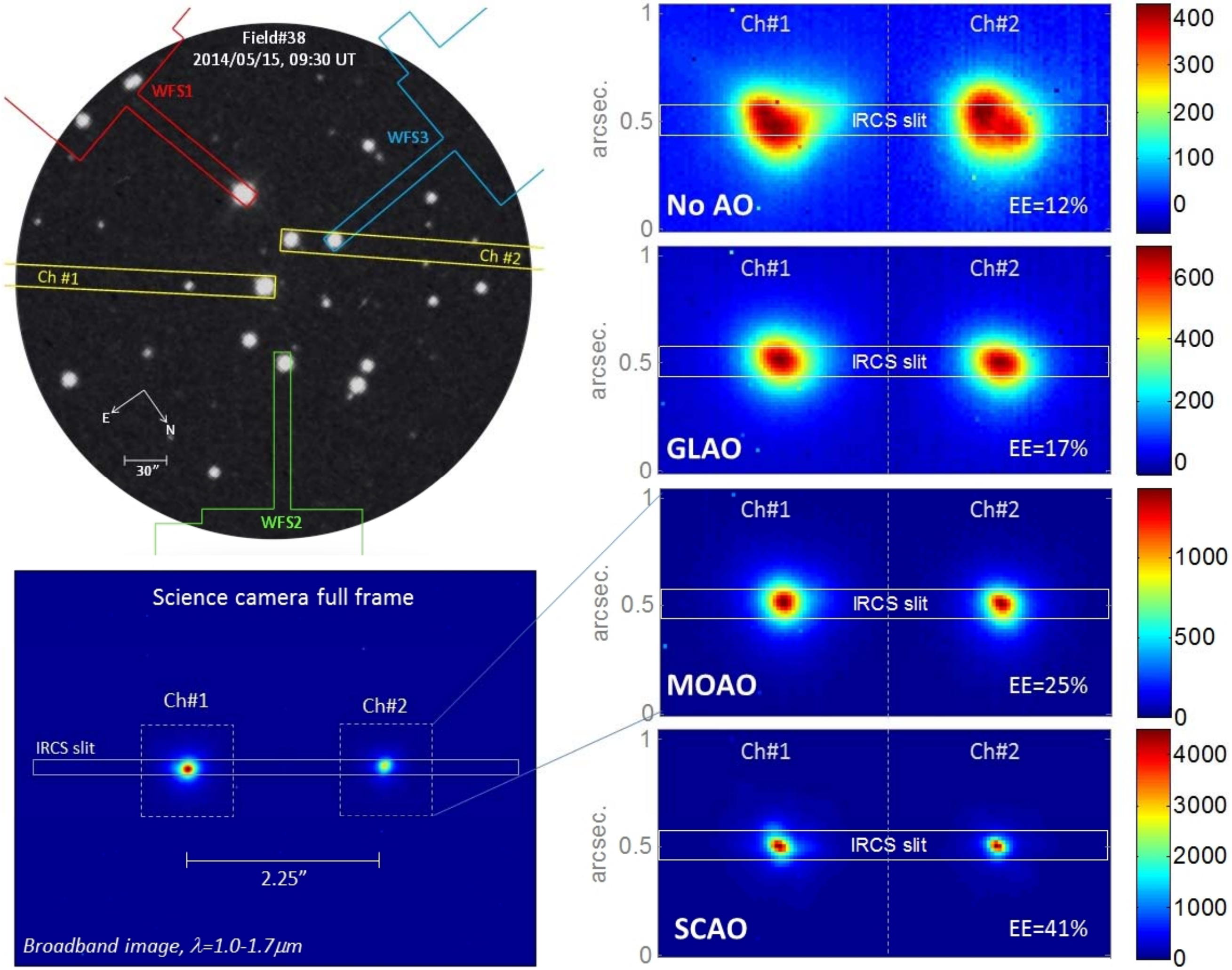
RAVEN : MOAO demonstration

- Simultaneous AO correction for two objects with three NGSs within d=3’ FoR.



SCIENCE DRIVERS

TMT-AGE

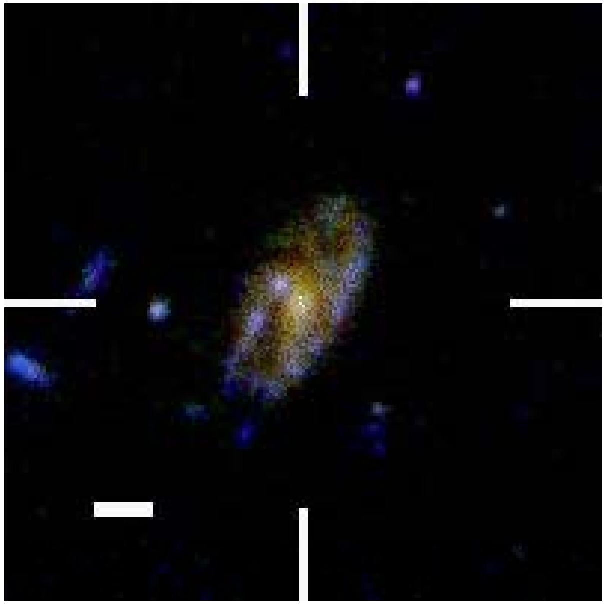
Three Science Drivers

1. Revealing the history of establishment of the internal structure of galaxies
   - Stellar / gas dynamics with spatially-resolved spectroscopy of z=1-5 galaxies.

2. Revealing the violent star-formation process during the formation phase of galaxies
   - Rest-frame UV emission / absorption line with integrated spectroscopy of z>5 galaxies.

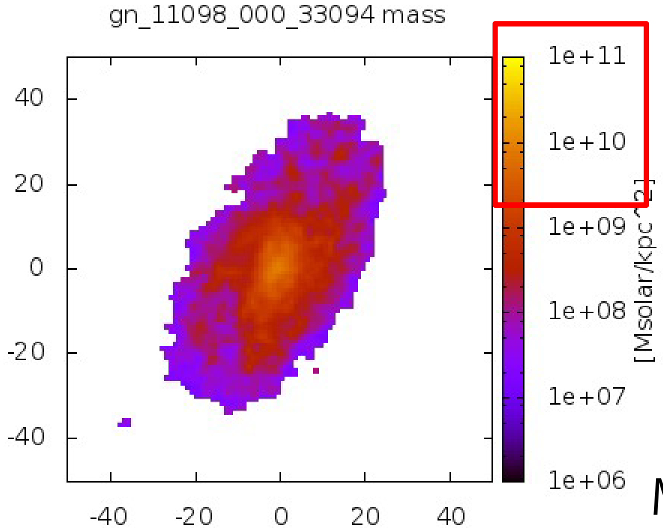
3. Identifying galaxies in the early universe (z>8)
   - By follow-up spectroscopy of candidates picked up by future wide-field IR surveys (Euclid, WFIRST, WISH,,,) from space.

1. Galaxy “establishment” history



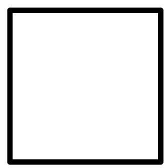
Example: a massive galaxy at z=1.3
0.06″ pixel map with FWHM=0.18″ (HST H-band FWHM) (FWHM=0.067″ with JWST)
10h, SN=10, R=3,000 detection limit:
H-band continuum detection limit corresponds to 6×10^{9} Ms/kpc^{2}
H-band unresolved line limit corresponds to 0.06 Ms/yr/kpc^{2}

<u>Stellar mass distribution</u>



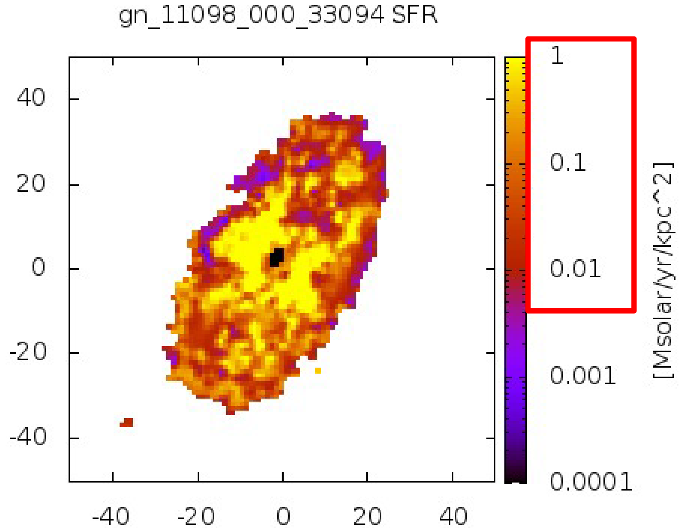
100x100 = 6″x6″

2″ FoV



Masuda 2014 Master Thesis

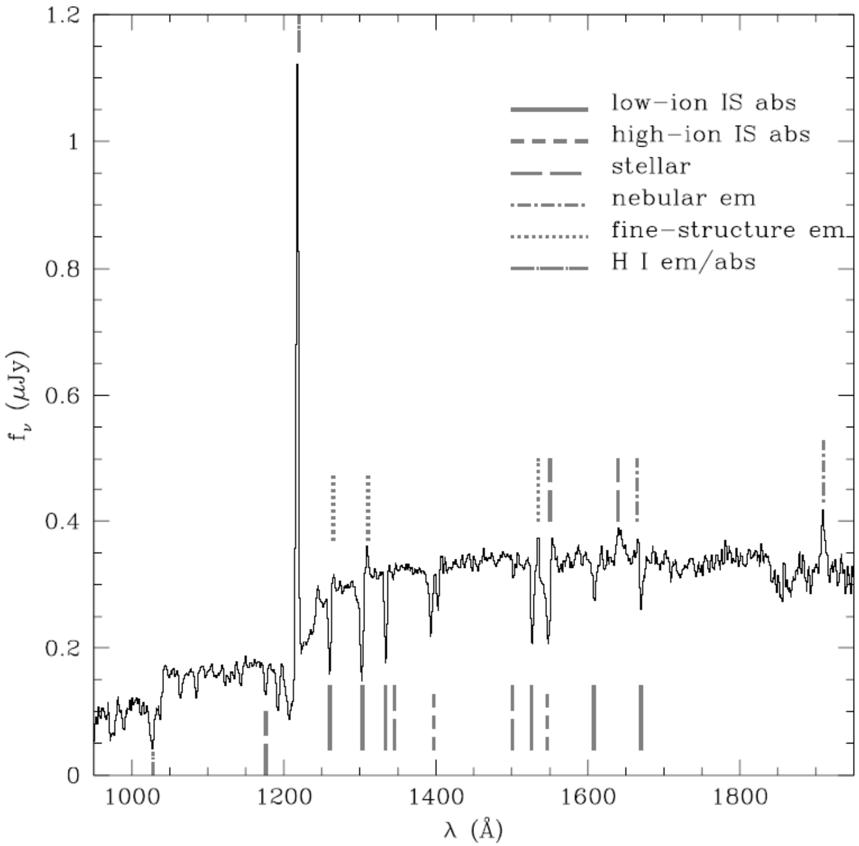
<u>Star-formation rate distribution</u>



100x100 = 6″x6″

2. Understanding star-formation in young galaxies

Average of rest-UV spectra of Z~3 star-forming galaxies

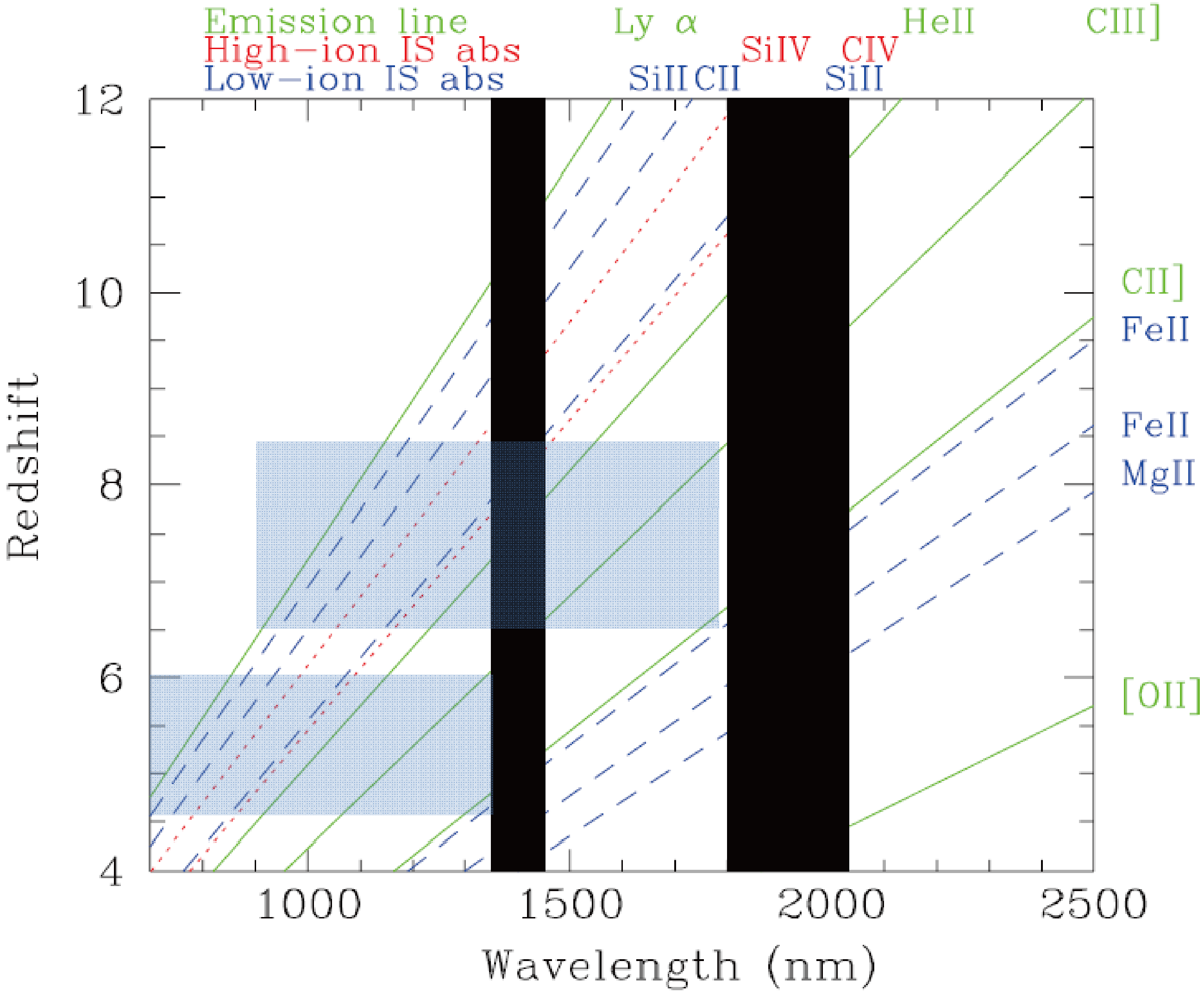


Shapley et al. 2003

- Rest-frame UV features of star-forming galaxies
  - Low-ion IS abs line:
    - ➢ Distribution and dynamics of neutral gas
  - High-ion IS abs line:
    - ➢ Distribution and dynamics of ionized gas
  - Stellar emission:
    - ➢ High-mass star contents
  - Nebular emission:
    - ➢ Galaxy rest-frame

Diagnostic lines for high-z galaxies

- Most of the redshifted diagnostic lines can be covered within 7000-18000A.



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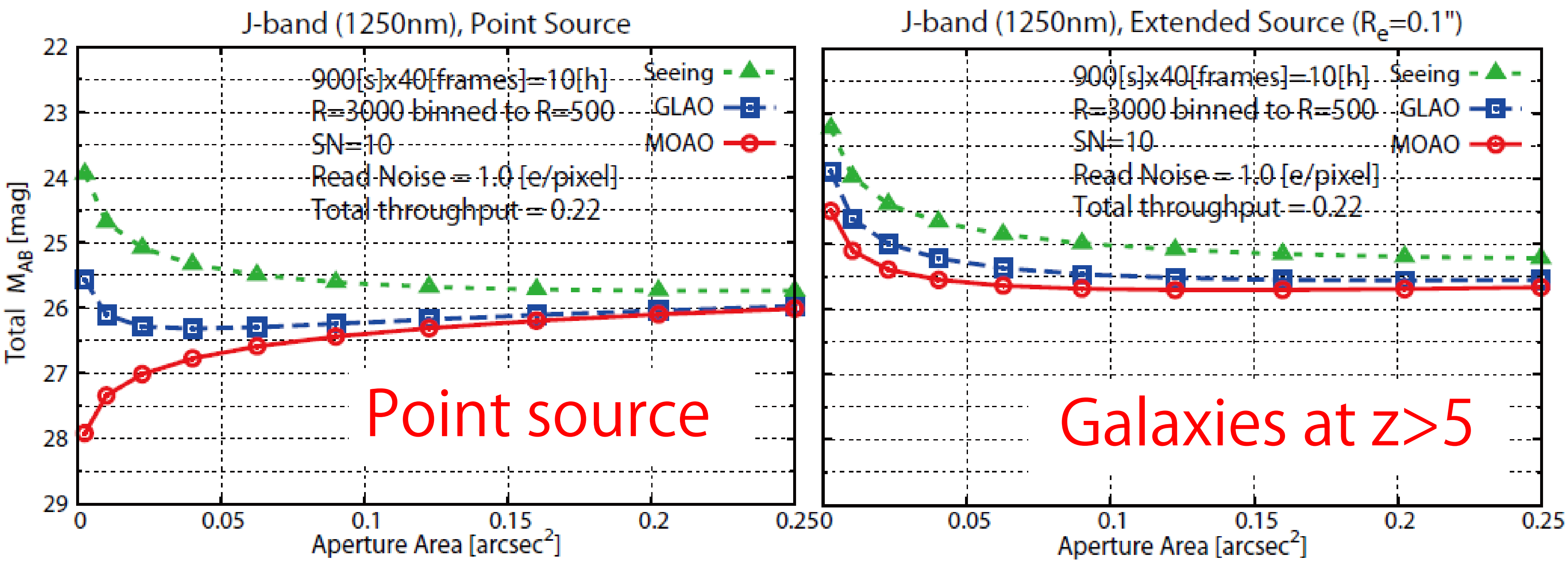
Baseline Detection limits – integrated J-band



- 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”

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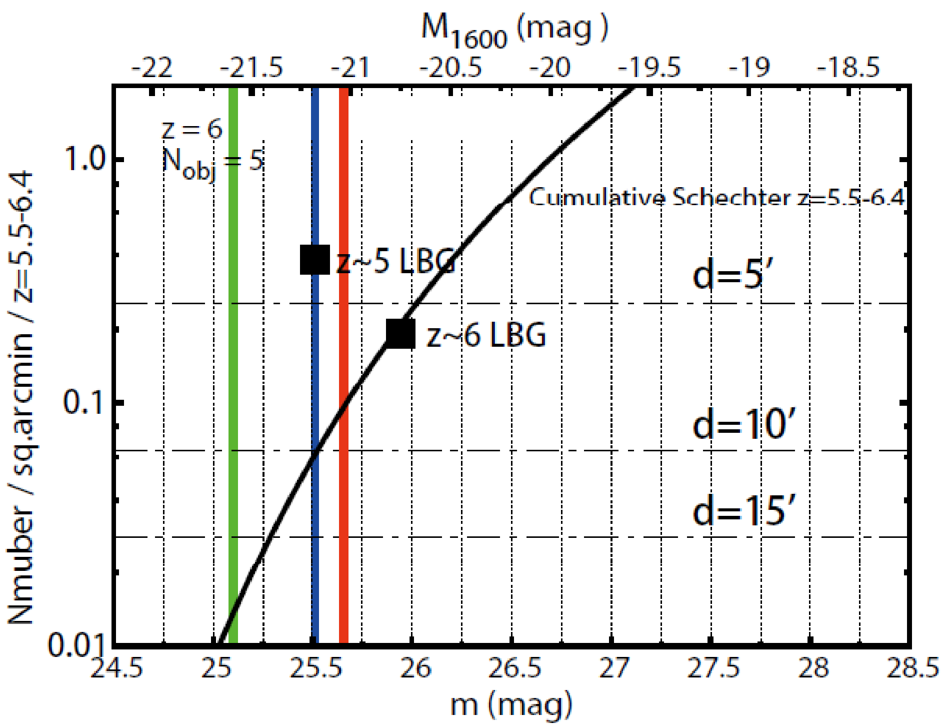
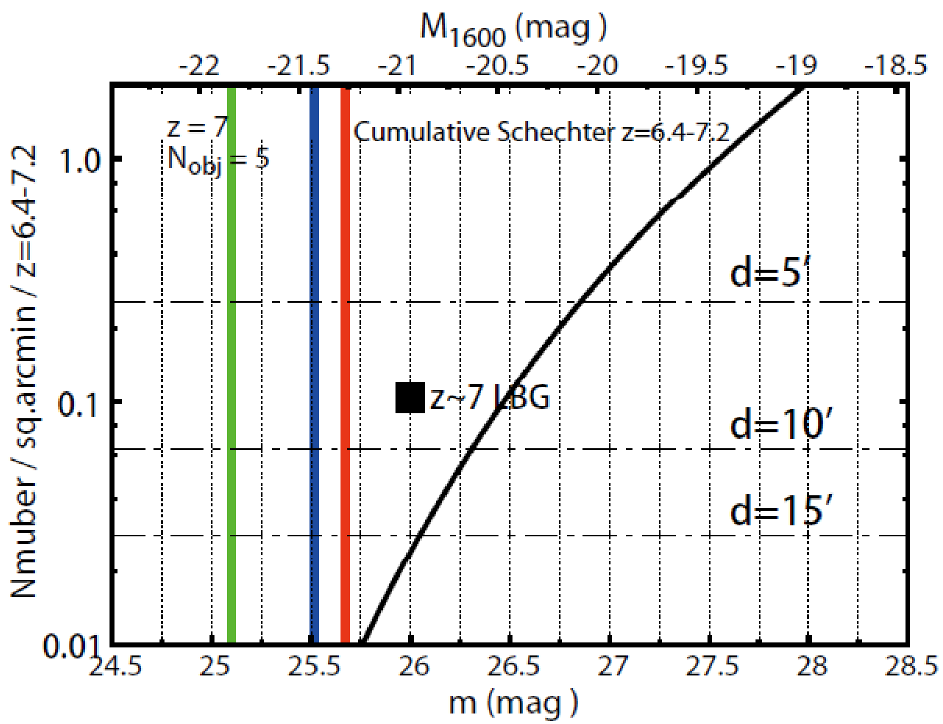
Number density

- 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

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Requirements

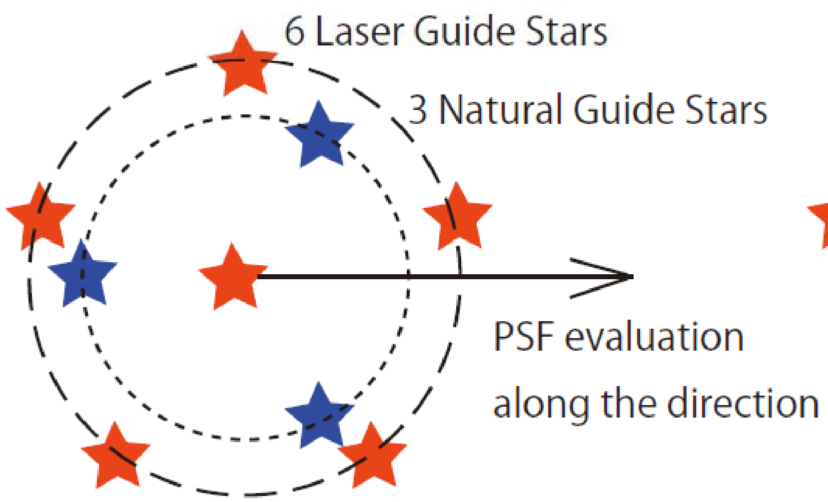
1. Spatially-resolved spectroscopy of z=1-5 galaxies.
   - High spatial and spectral resolution multi-IFU spectrograph within d=5′ FoR (IRMOS-like)
   - 0.05x0.05″ sampling IFUs with 2″ FoV
   - R=10,000 spectroscopy for v~30km/s

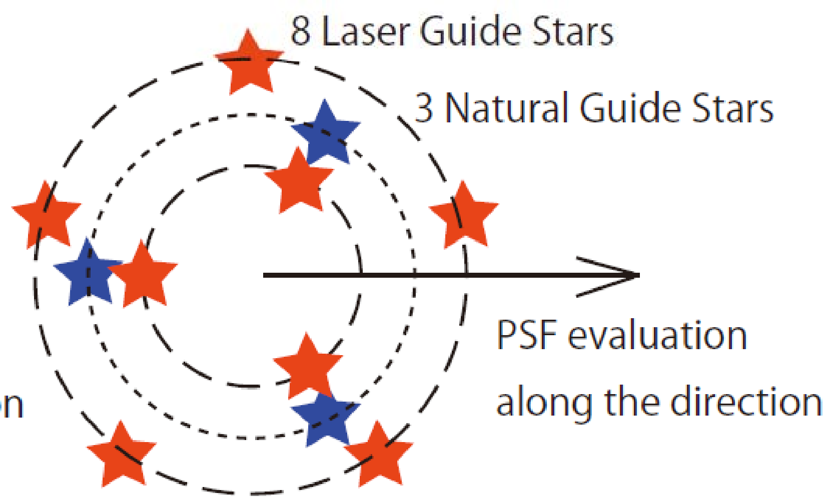
2. Integrated spectroscopy of z>5 galaxies.
3. Follow-up spectroscopy of candidates of z>8 galaxies
   - High-sensitivity with moderate AO correction in short NIR wavelength range within d=10′ FoR
   - 0.3x0.3″ – 0.5″x0.5″ aperture integrated spectroscopy
   - R=3,000 (5A resolution, 2A/pix) for absorption/emission lines with rest-frame EW of 1A.

MOAO PERFORMANCE FEASIBILITY WITHIN A WIDE FOR

AO performance simulation

- We check AO performance feasibility within d=10′ FoR with end-to-end AO simulator MAOS (Wang & Ellerbroek 2012) .
- We consider 6 LGS case and 8 LGS case with changing the radius of the asterism (those are within the scope of the TMT-LGSF specification [Subsystem Requirements Document]).





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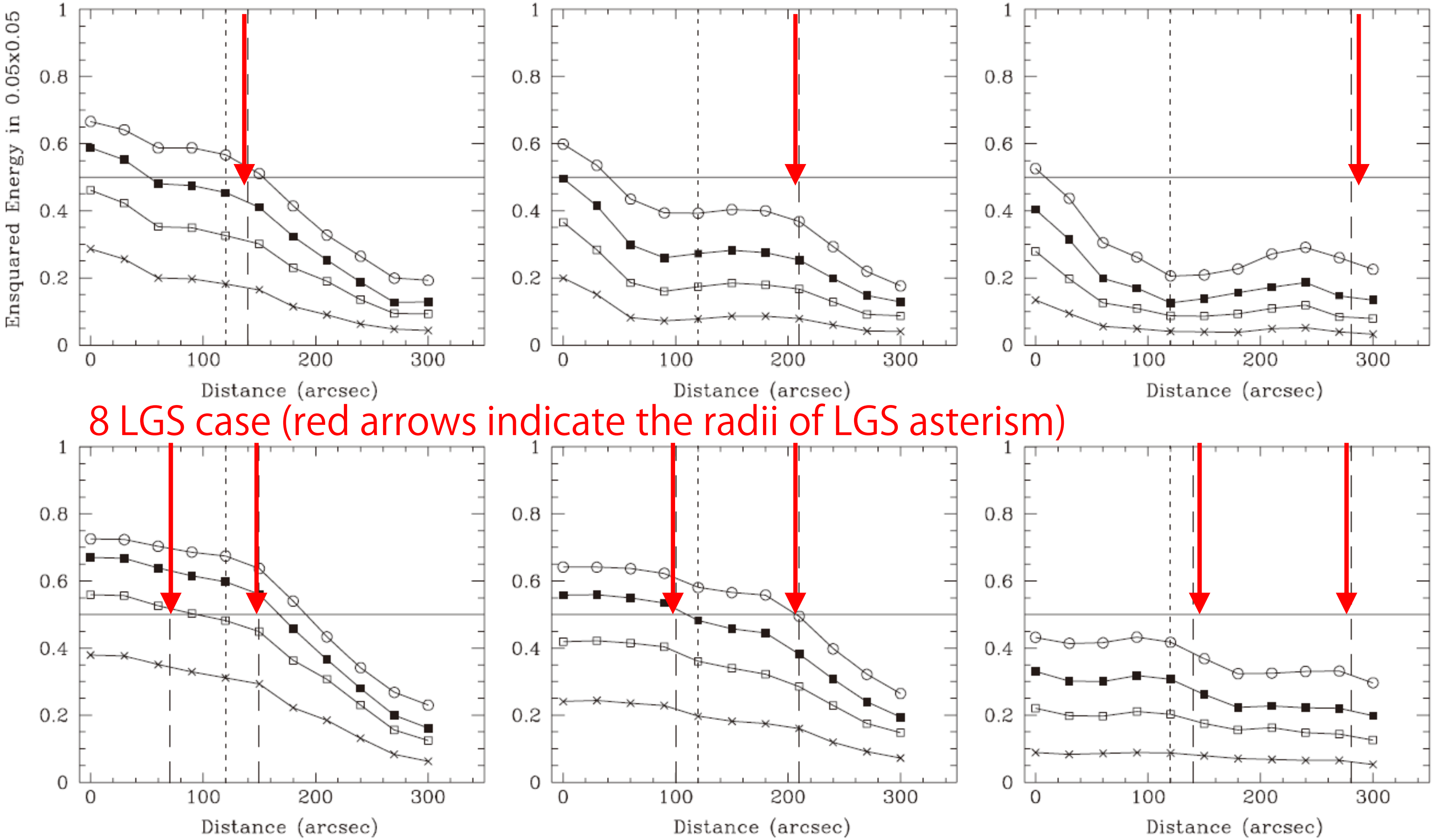
Ensquared E. Within 0.05x0.05"

6 LGS case (red arrows indicate the radius of LGS asterism)

8 LGS case (red arrows indicate the radii of LGS asterism)



LGS asterism in IRMOS

From top to bottom, K, H, J, 0.9um

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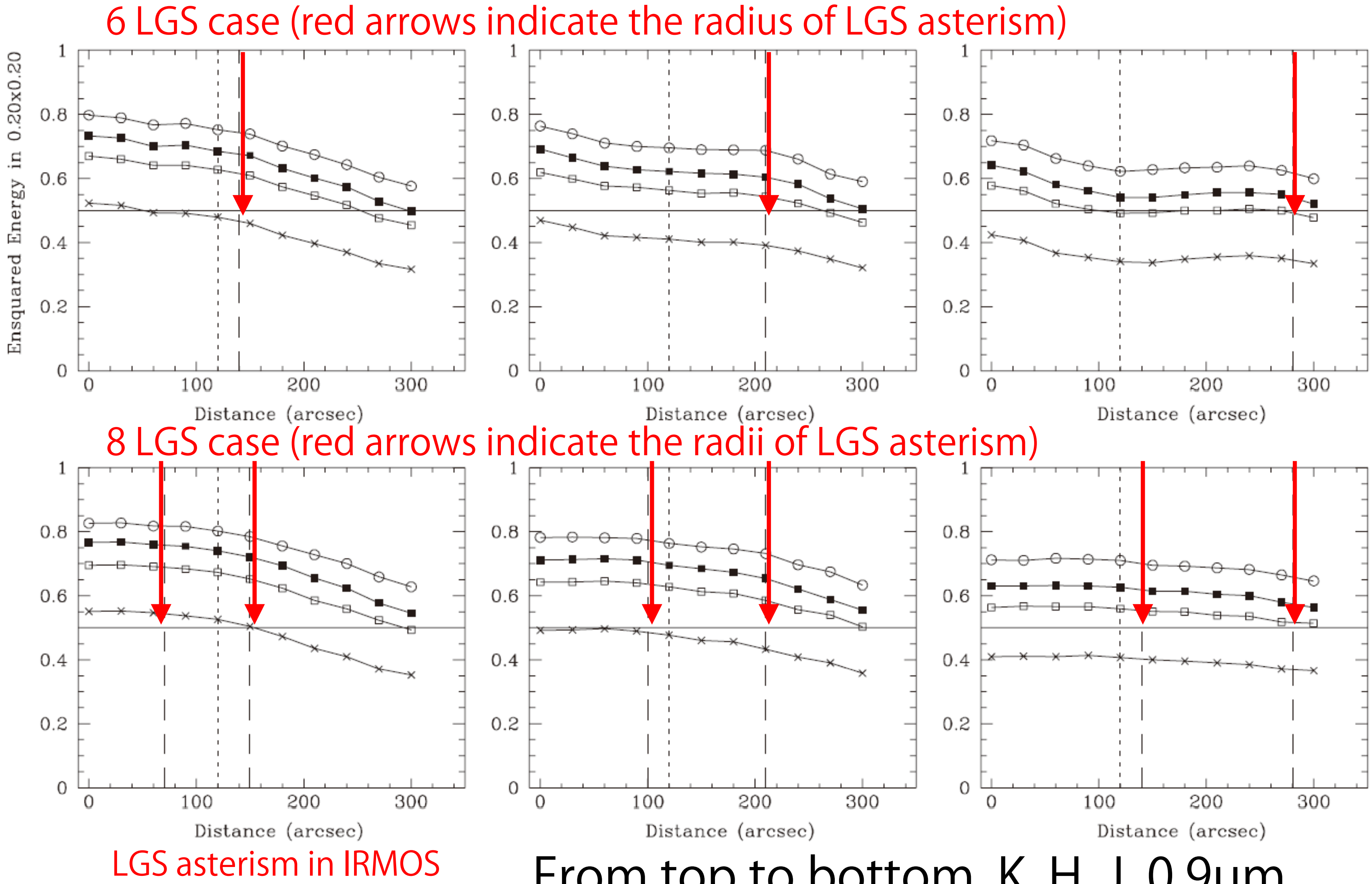
Ensquared E. within 0.2”x0.2”



From top to bottom, K, H, J, 0.9um

SYSTEM CONSIDERATION

MOAO SYSTEM DESIGN AND REQUIREMENTS FOR DMS

OPTICAL DESIGN FOR A COMMON DM SYSTEM

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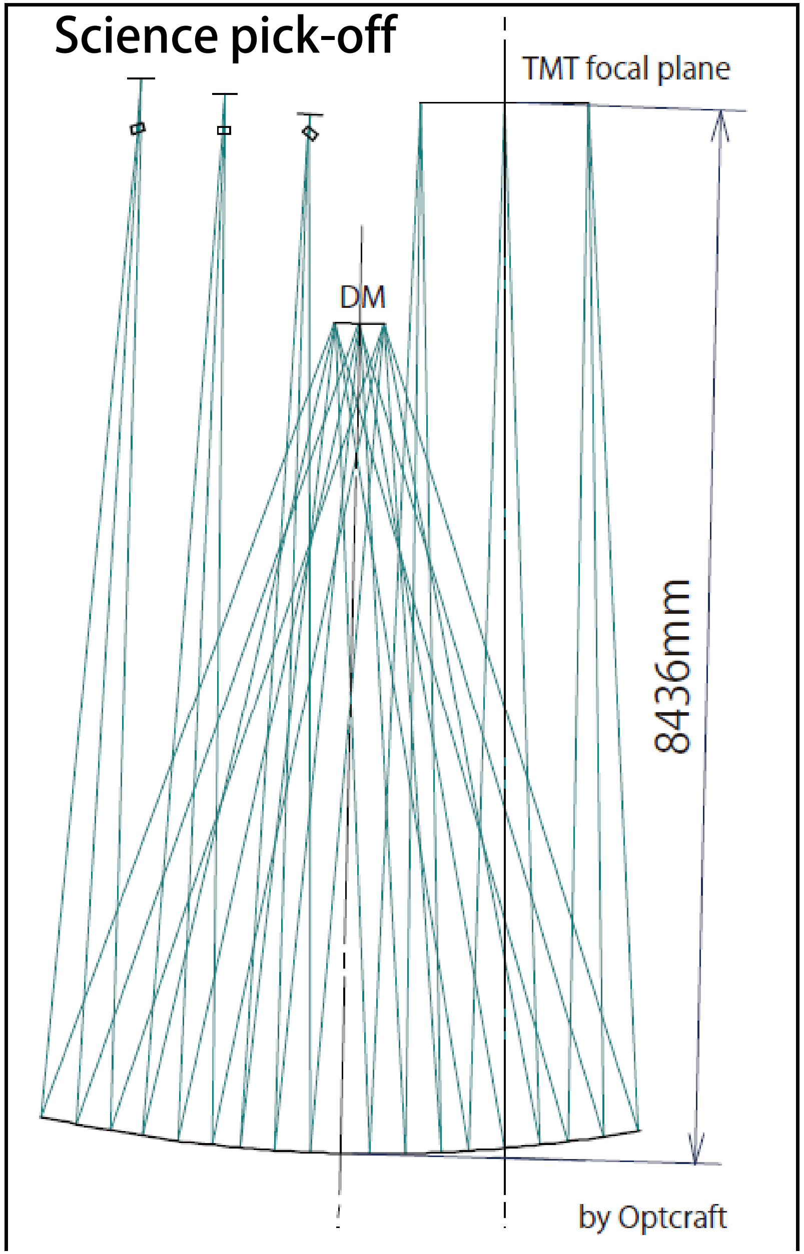
Optical designs for the common DM system

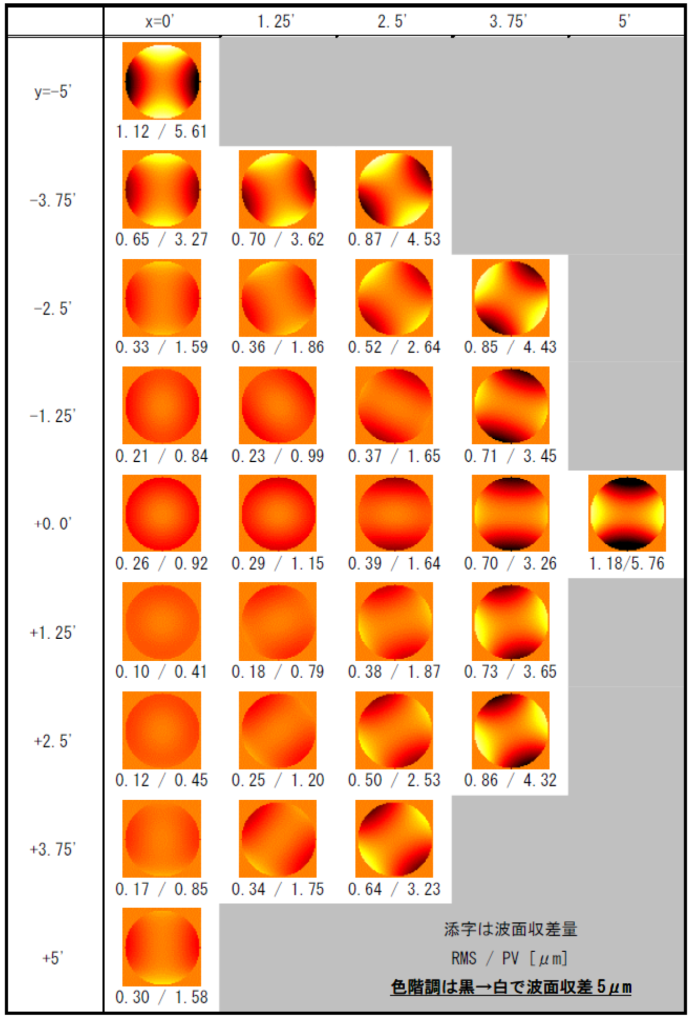


- At first, we consider modified Offner system, following IRMOS-Tipi design.
- Extendig FoR to d=10′.

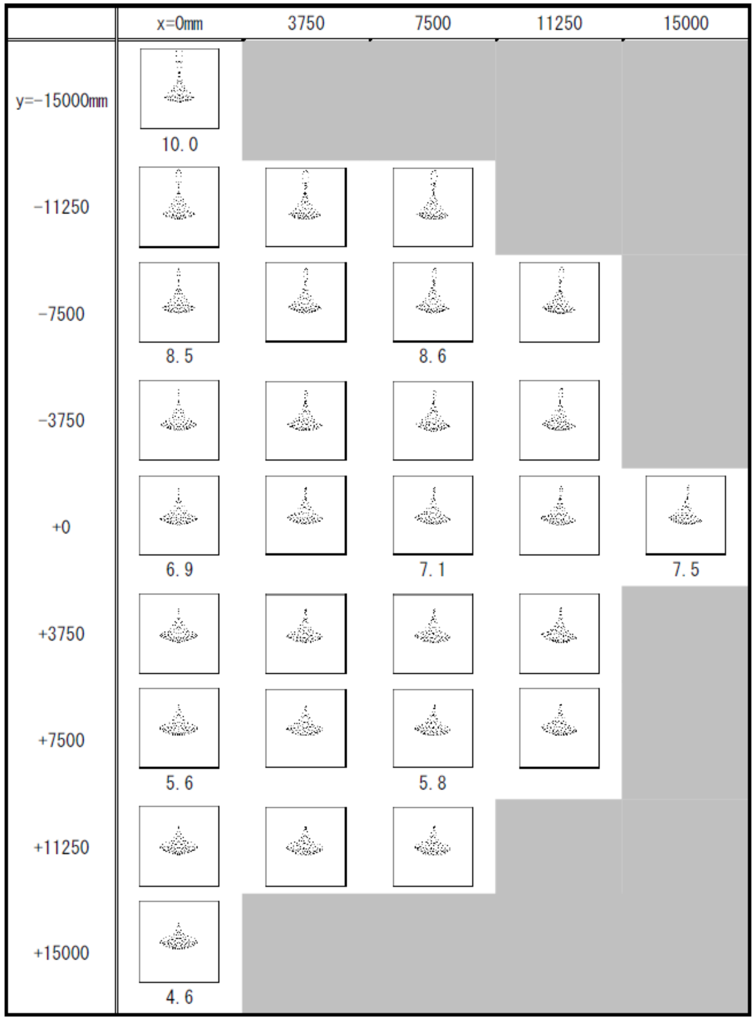
- Modified Offner system by Optcraft (T.Y.)

Performance

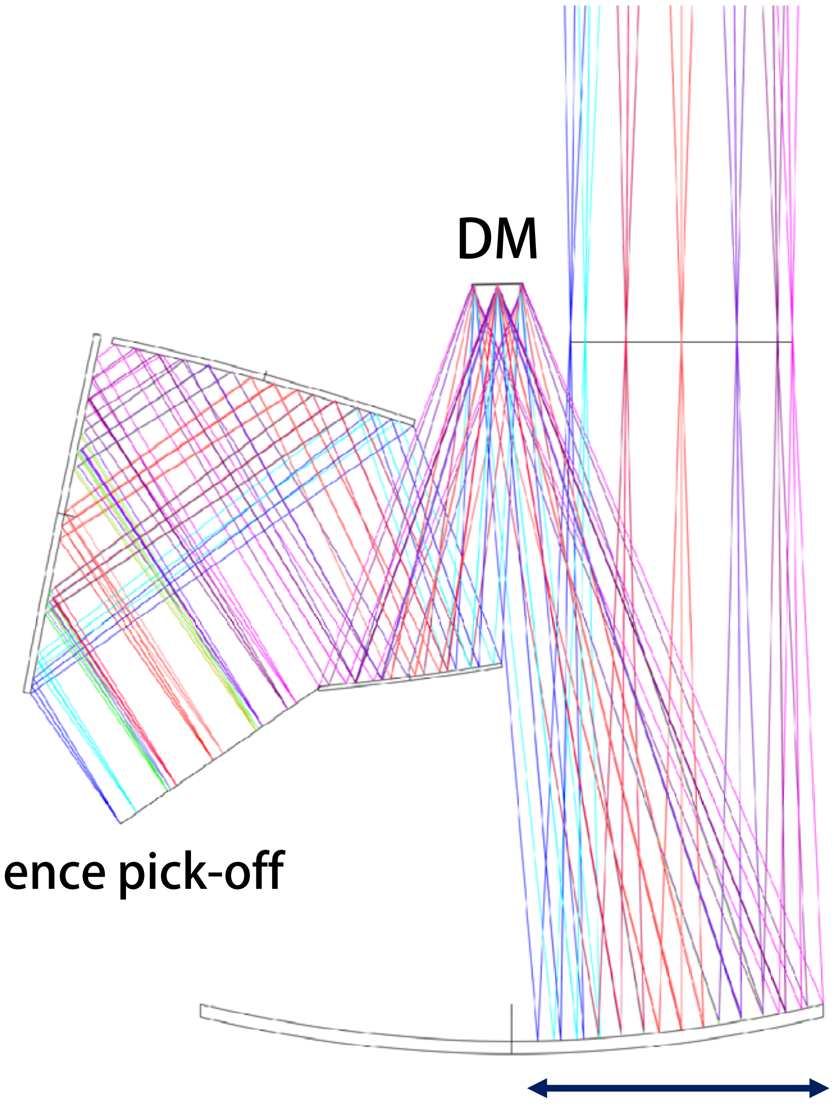
- Wavefront at pickoff focal plane
- For each FoR position



- Pupil image distortion at DM plane
- For each pupil position



Optical designs for the common DM system



- Three Mirror Array design with free form curve mirrors by Photocoding (Y.I.)
- Overall system size is about half of the size of the modified Offner design.

THANK YOU FOR YOUR ATTENTION

YOUR COMMENTS ARE WELCOME !