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

AO-assisted wide-field multi-object NIR spectrograph concept

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Three Science Drivers for TMT-AGE

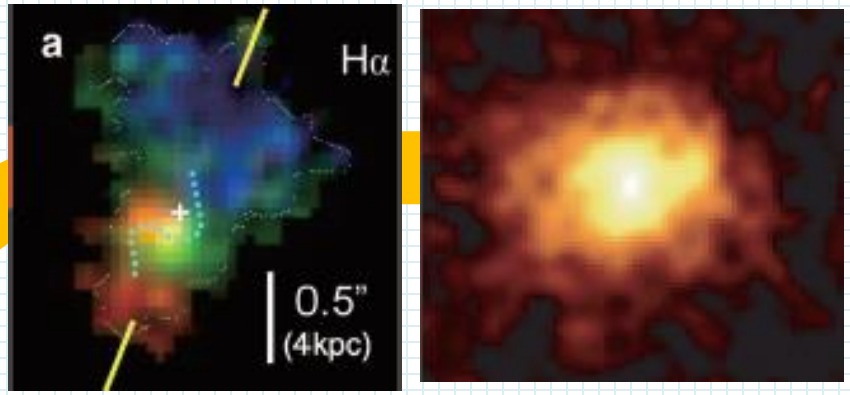
1. How is the internal structure of local galaxies established ?
   現在の銀河の内部構造はどのように確立したか？

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？

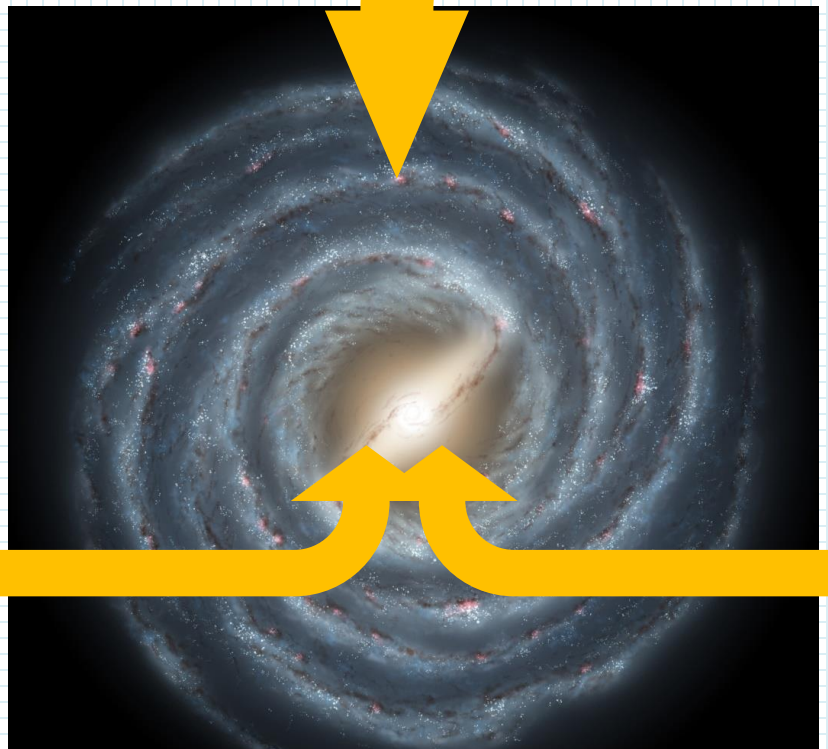
3. Hunting for galaxies/AGNs at z>6
   宇宙初期の銀河とAGNの探査を行う。

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

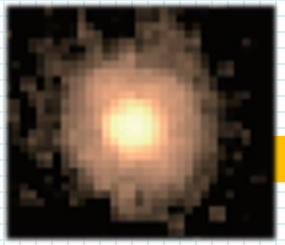
Turbulent / high surface-density disks at high-z



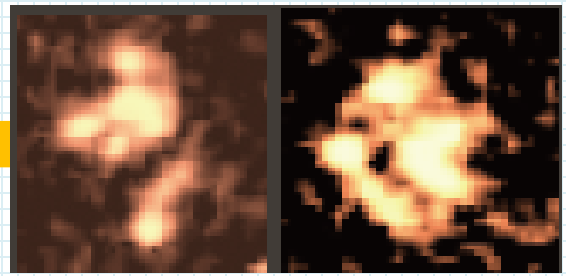
Typical galaxy seen in the local universe



Very compact galaxies at high-z



Clumpy galaxies at high-z



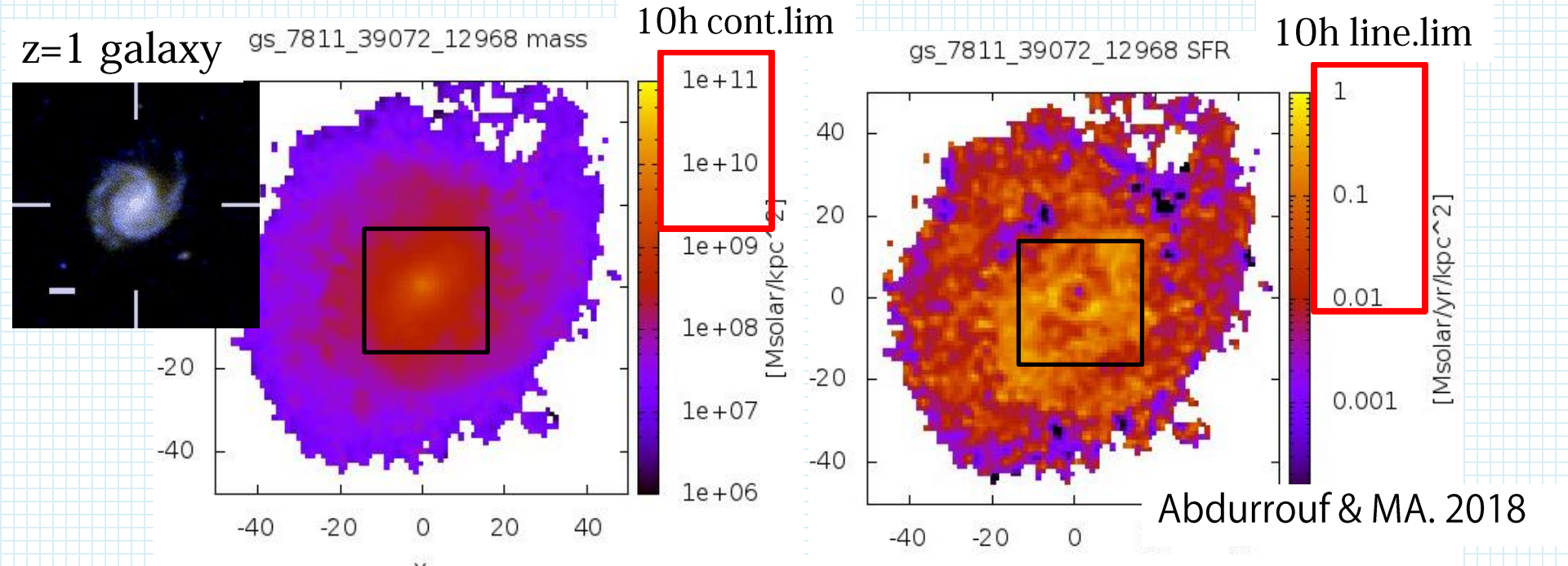
1. How is the internal structure of local galaxies established ?

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

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

Stellar mass distribution

Star-formation rate distribution

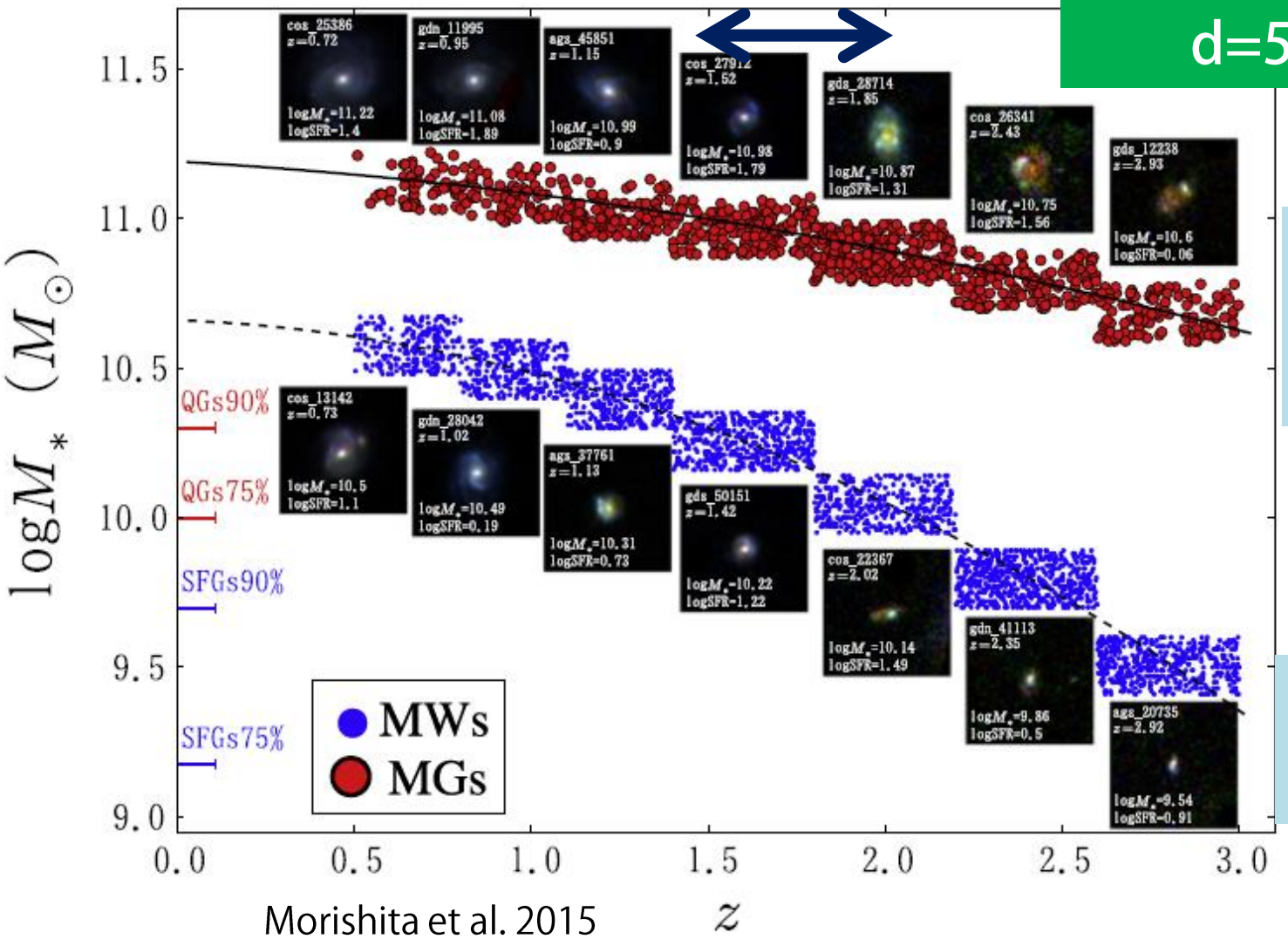


Abdurrouf & MA. 2018

Targets of Multi-IFU Observations

4000A in J-band

>10 objects in d=5' FoV



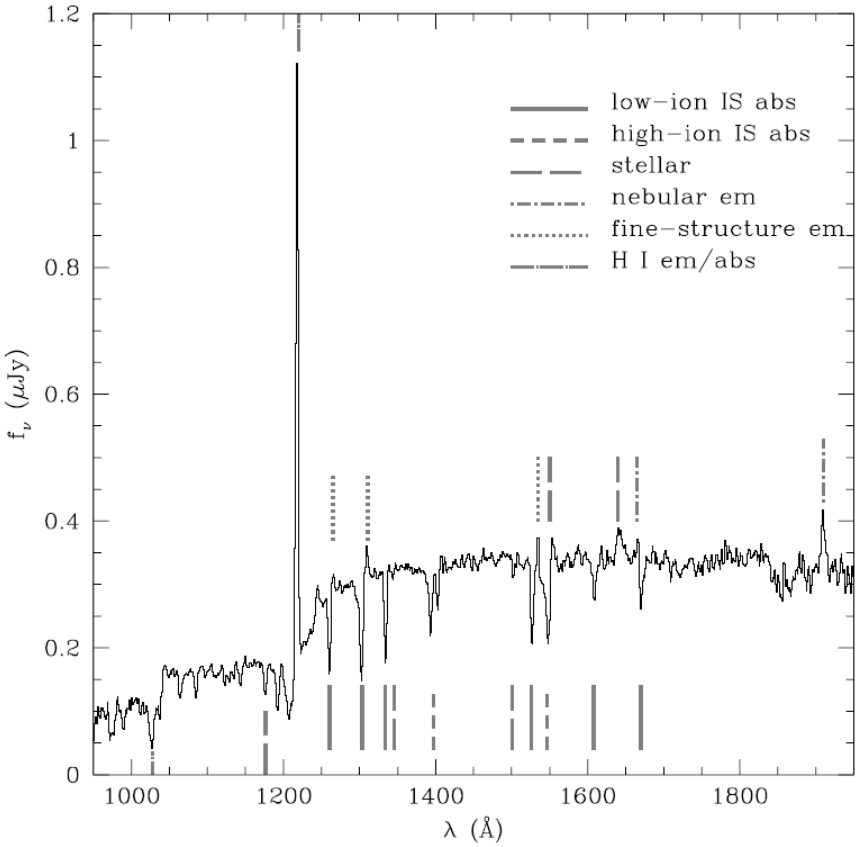
Stellar mass evolution of massive ellipticals

Stellar mass evolution of MW analogs

Morishita et al. 2015

Number density from MOIRCS Deep Survey results

2. What is going on in galaxies in the early universe ?



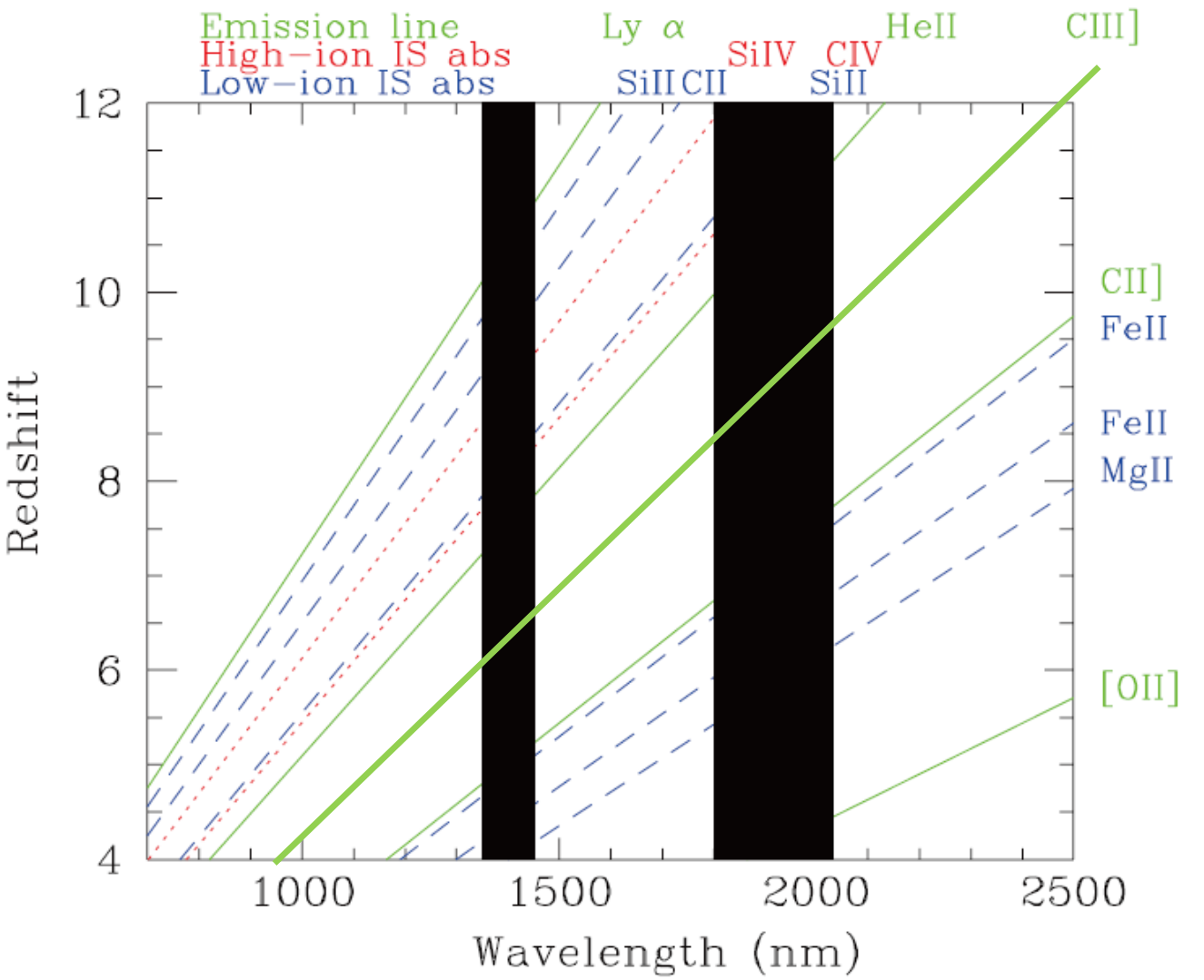
Average of rest-UV spectra of z~3 star-forming galaxies

Shapley et al. 2003

- TMT observations of rest-frame UV features of star-forming galaxies can reveal :
  - 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

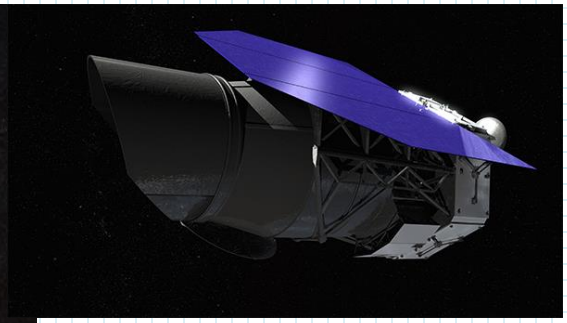
Diagnostic lines for high-z galaxies

- Most of the redshifted UV diagnostic lines fall within 700-1800A for galaxies at z>5-9.



3. Hunting for galaxies/AGNs in the early universe

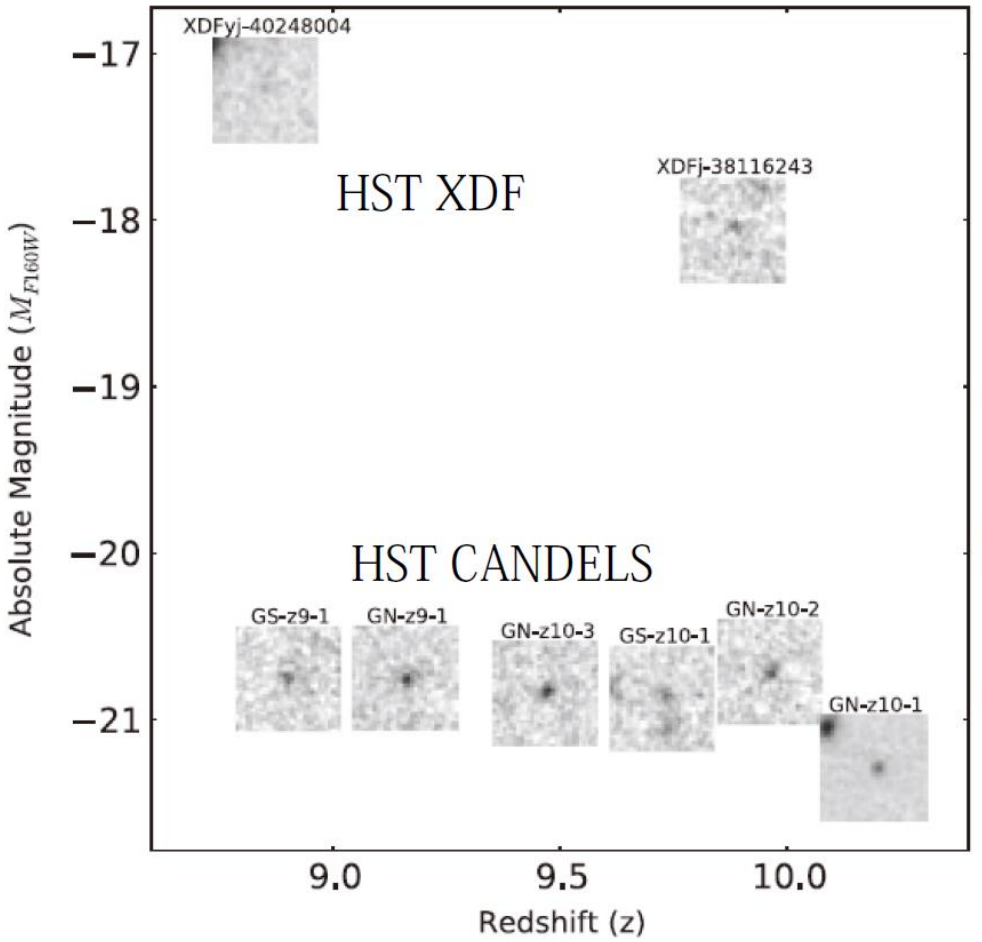
- Follow-up spectroscopy of candidates of high-z galaxies / AGNs picked up by wide-field IR surveys (Euclid, WFIRST, SPICA,,,), and wide-field X-ray surveys (Athena, LYNX,,,) from space.



d~10′

High-z galaxy survey parameter space

- FoV, apparent magnitudes, and continuum spectroscopy limits.



HAB=30 WFIRST deep (~10 sq.deg)

HAB=29

TMT Med-res point-source 10h

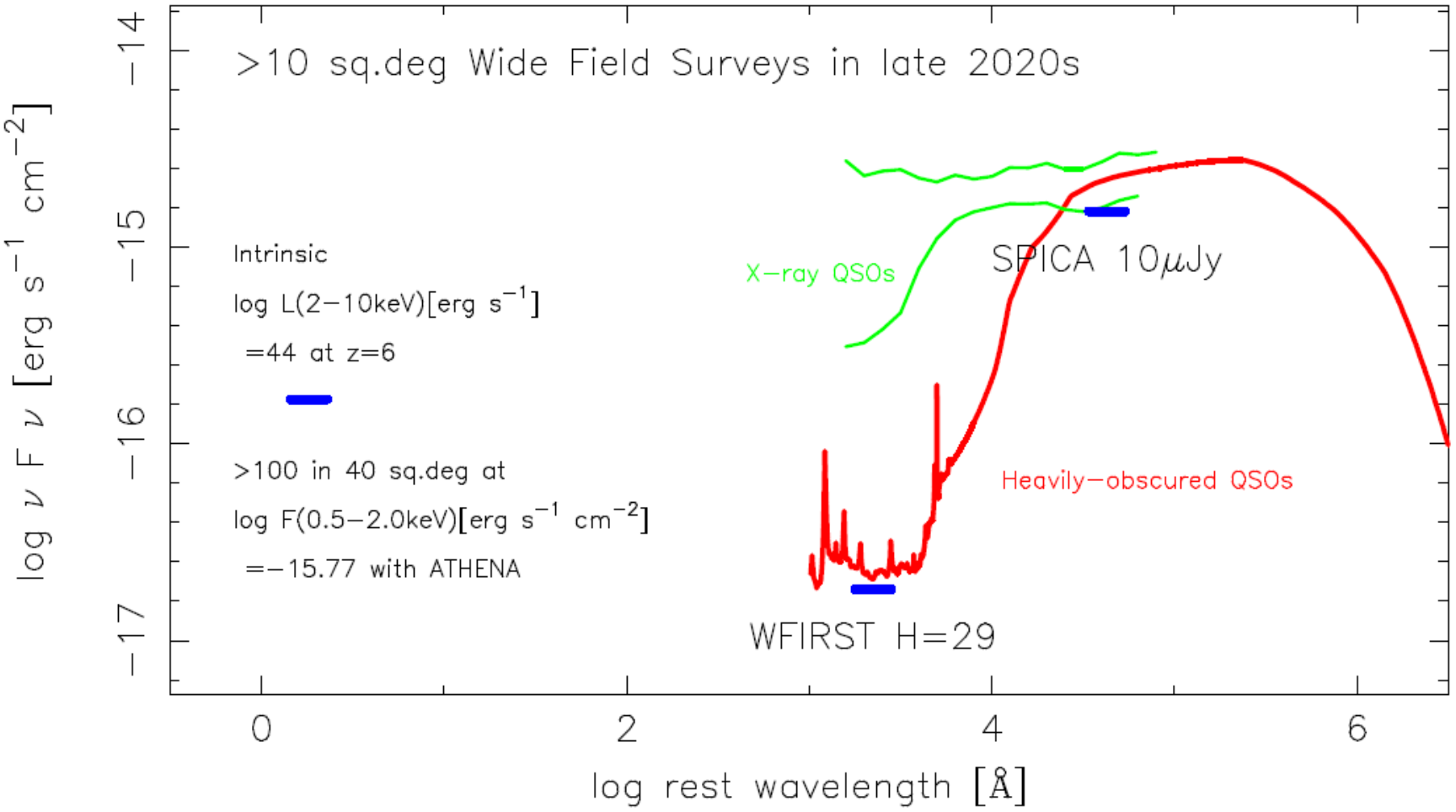
TMT Med-res galaxies 10h

WFIRST wide (~1000 sq.deg)

HAB=26

Highly accreting SMBHs
Obscured AGNs at z>6

- Depth of >10 sq.deg wide-field surveys in late 2020s X-ray / NIR / FIR compared to the obscured QSO SED.



System Requirements

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

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.
   - >10 objects in 10 arcmin diameter FoV

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

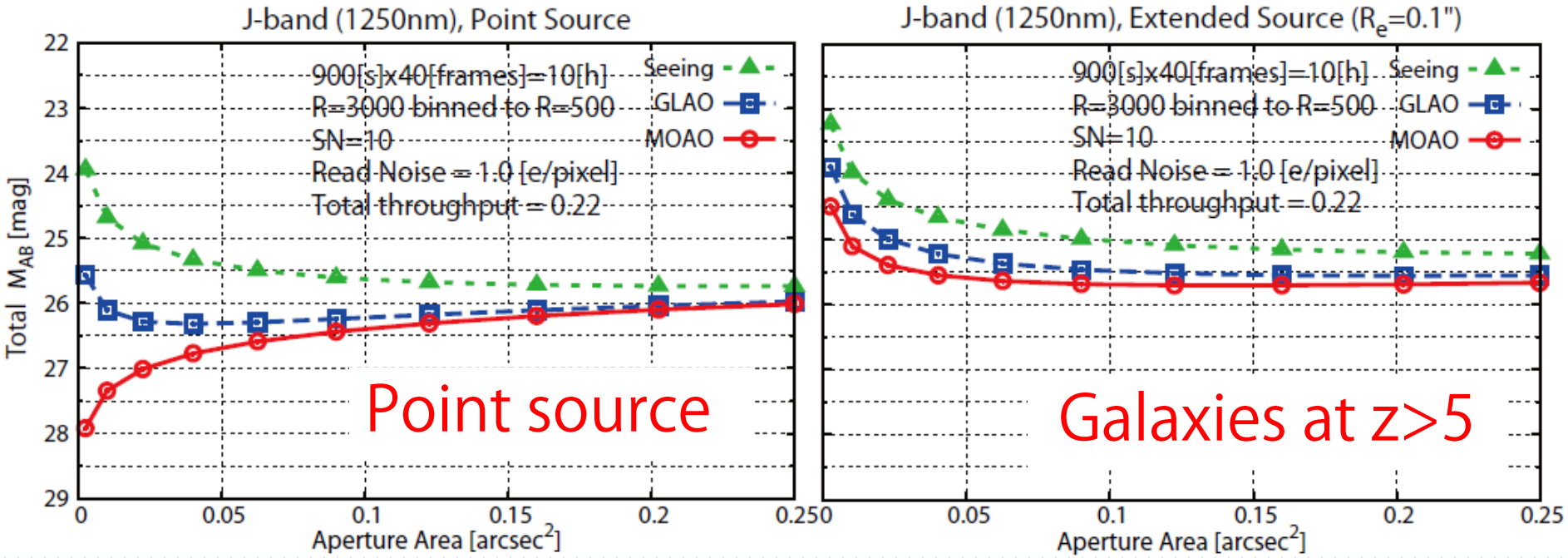
3. Laser Tomography AO correction
  - ➢ Installing high-order DM

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

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

ADDITIONAL SLIDES

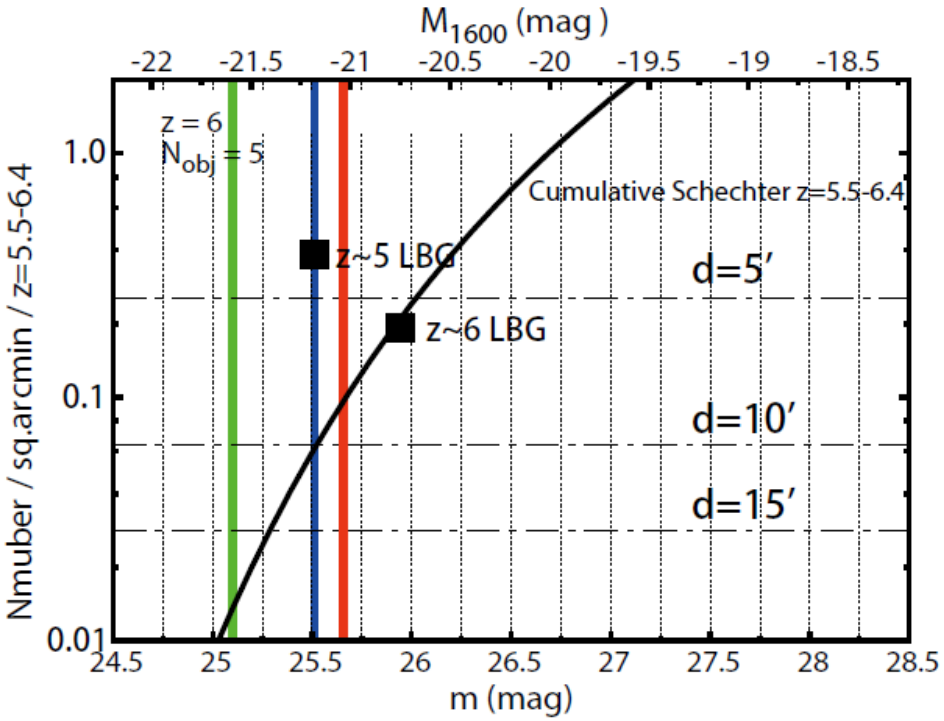
Baseline Detection limits – integrated J-band

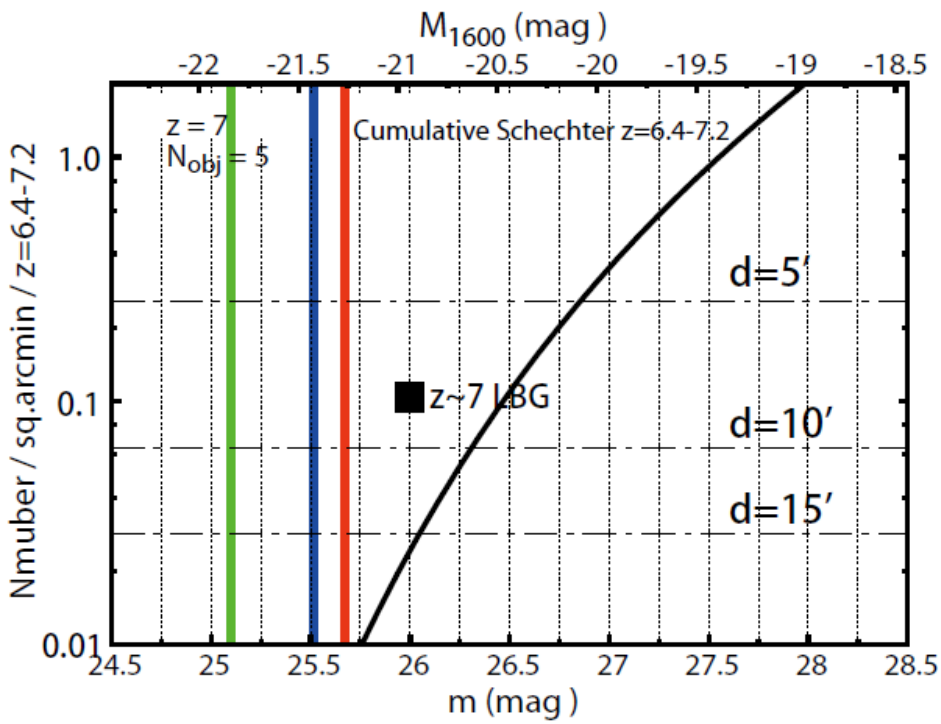


- Red (MOAO), blue (GLAO), green (seeing-limit) lines show the detection limits for each system with different aperture size.
- SN=10 for continuum with 10h integration
- R=3,000 spectroscopy binned to R=500
- Typical size of z>5 galaxies: effective radius of 0.1”

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