Simulating Observations of z~2 galaxies with GLAO

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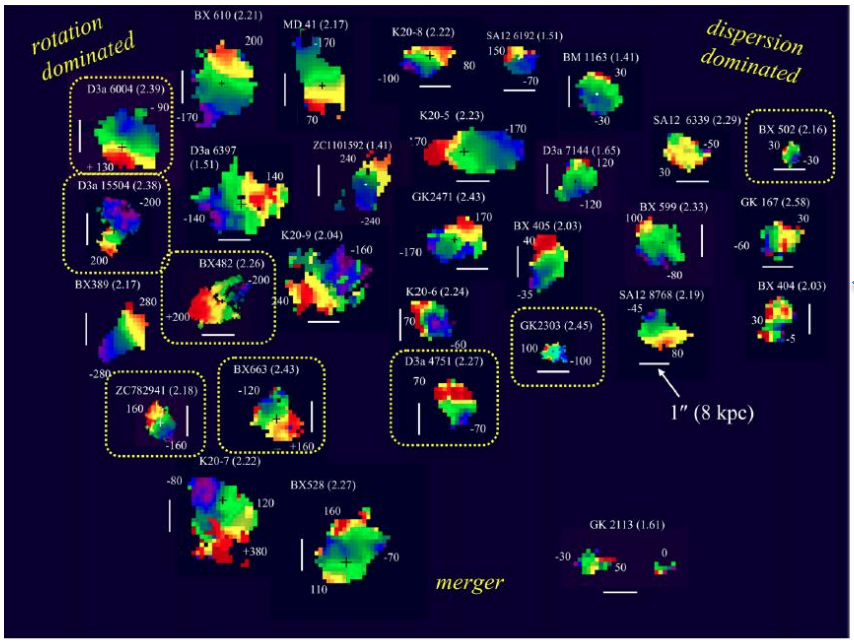
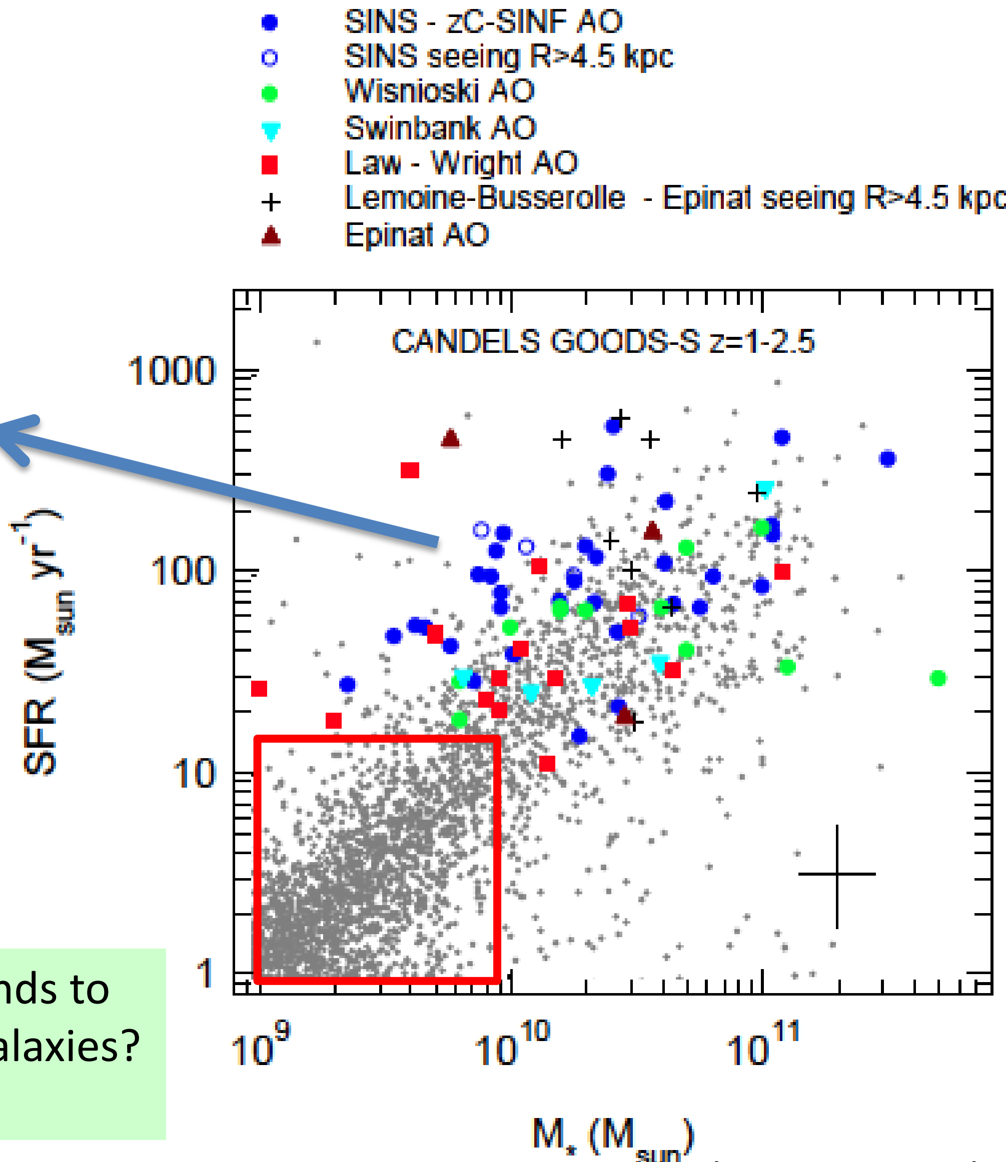
Motivation

- What is the most unique capability of the GLAO instrument?
- GLAO will start observation from somewhere around 2020
  → It is important to think about the uniqueness of the Subaru GLAO comparing to TMT and any other space based telescope.
- Evaluate the competitiveness of GLAO imager, MOS spec., and IFU spec.
- Case study for z~2 galaxies by simulating the actual observations.

Science requirement: Sensitivity

SINFONI spectroscopic survey of z~2 star forming galaxies (Forster Schreiber+09)

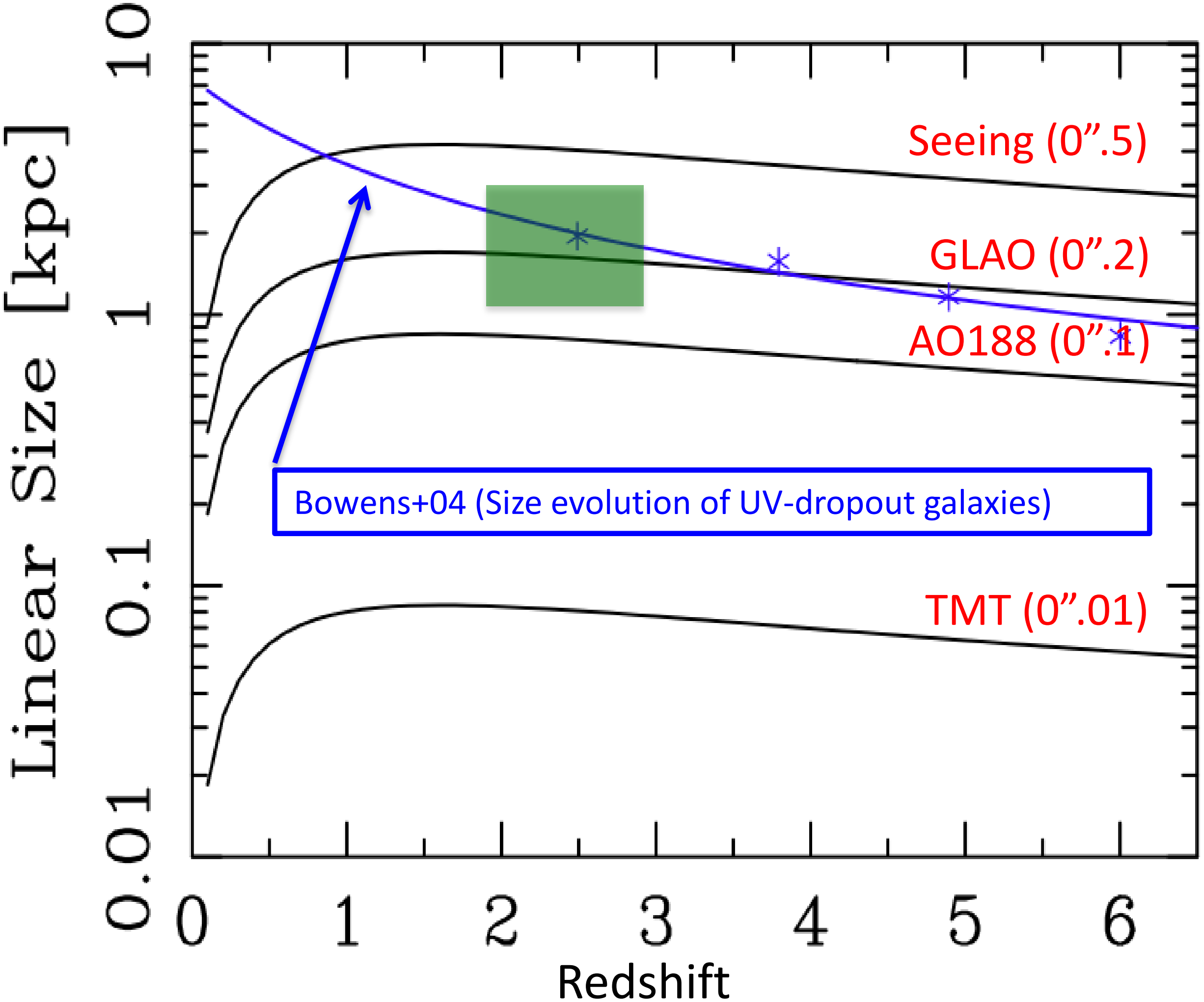




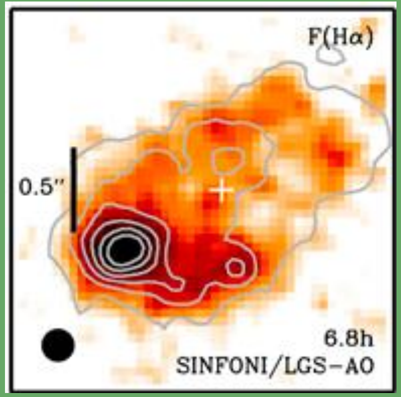
(Newman+13)

- Can we detect Hα emission line corresponds to SFR ~ 1-10 M_{sun}/yr to study < 10 $^{10}M_{sun}$ galaxies?

Science requirement: Spatial Resolution



Star-forming galaxies
(Forster-Schreiber+11)



- Can we spatially resolve ~1kpc scale star-forming clumps at z~2?
- Can we reconstruct morphological parameters of z~2 galaxies?

Simulating GLAO observation of z~2 galaxies

- z~2 galaxy sample selection
  - HST/WFC3 H-band (F160W) image of z~2 galaxies
    - Highest resolution image currently available
  - Data from CANDELS (Koekemoer et al. 2011) GOODS-S survey whose survey area (~120arcmin^2) is comparable to the GLAO instrument
  - Selected K_{AB}<23.9 BzK galaxies from MUSYC（Cardamone et al. 2010) catalog
    - z=2.1-2.6 star-forming BzK with spec-z: 40

      --- K-band imaging/spectroscopy
    - z=1.3-1.7 passive-BzK with phot-z: 6

      --- H,K-band imaging/spectroscopy

GLAO galaxy simulation recipe

1. Extracted galaxy morphological parameters

   --- Sersic profile fit: Effective radius Re, Sersic index N, Axis ratio, and Position angle

   ※ Simple convolution of the WFC3 image may not reproduce well the GLAO image since WFC3 spatial resolution (FWHM~0".18) is worse than the best GLAO resolution (FWHM~0".15).

2. Construct the model galaxy image from the morphological parameters without any PSF convolution.

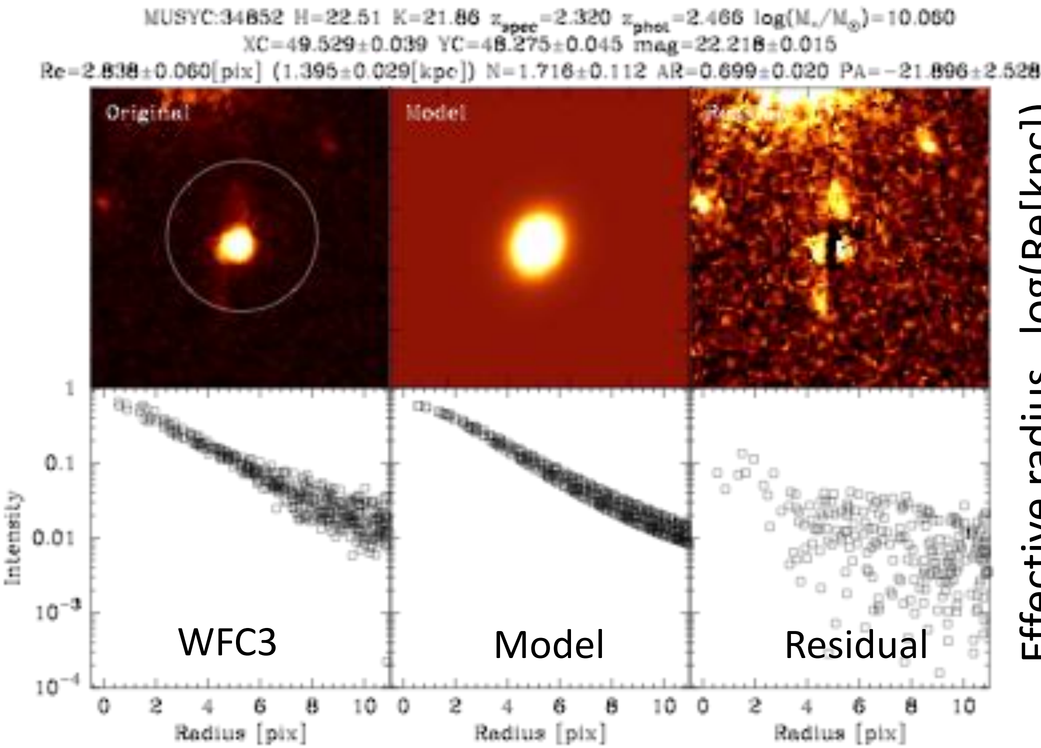
3. Convolve the model galaxy image with the GLAO PSF

4. Add noise corresponds to 5 hrs integration

   We used 5hrs integration time and 5sigma S/N for all simulation, so as to evaluate the limitation in just 1 night observation.

Star-forming BzK at z=2.1-2.6 (Model)

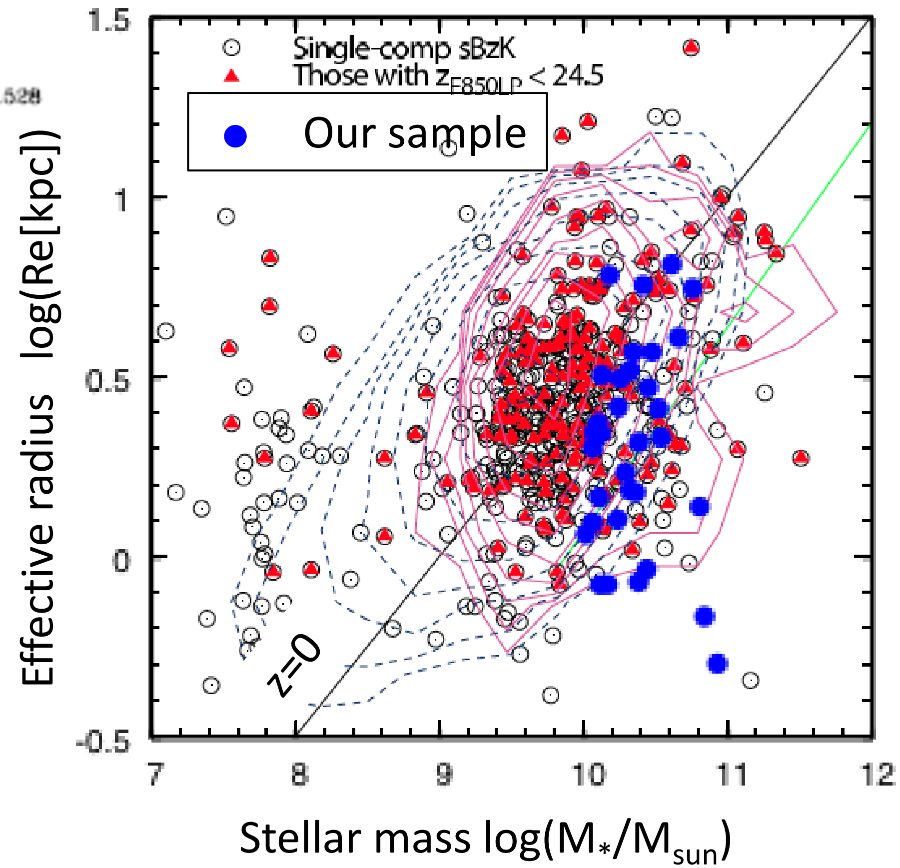
Modeling sBzK galaxies based on GOODS-S WFC3 image (CANDELS)



Sersic profile

$$\Sigma(r) = \Sigma_0 \exp\left\{-b_n\left[(r/r_e)^{1/n}\right]\right\}$$

Comparison with z~2 sBzK sample at GOODS-N (Yuma et al. 2011)

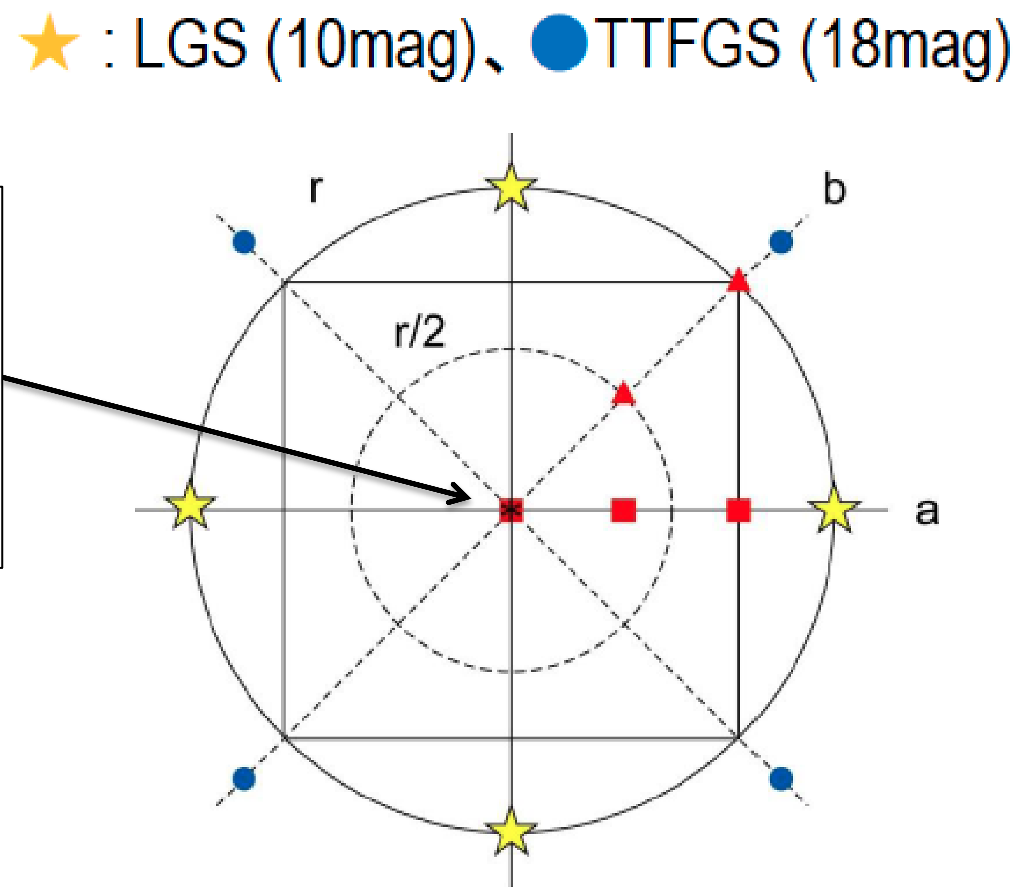


GLAO PSF

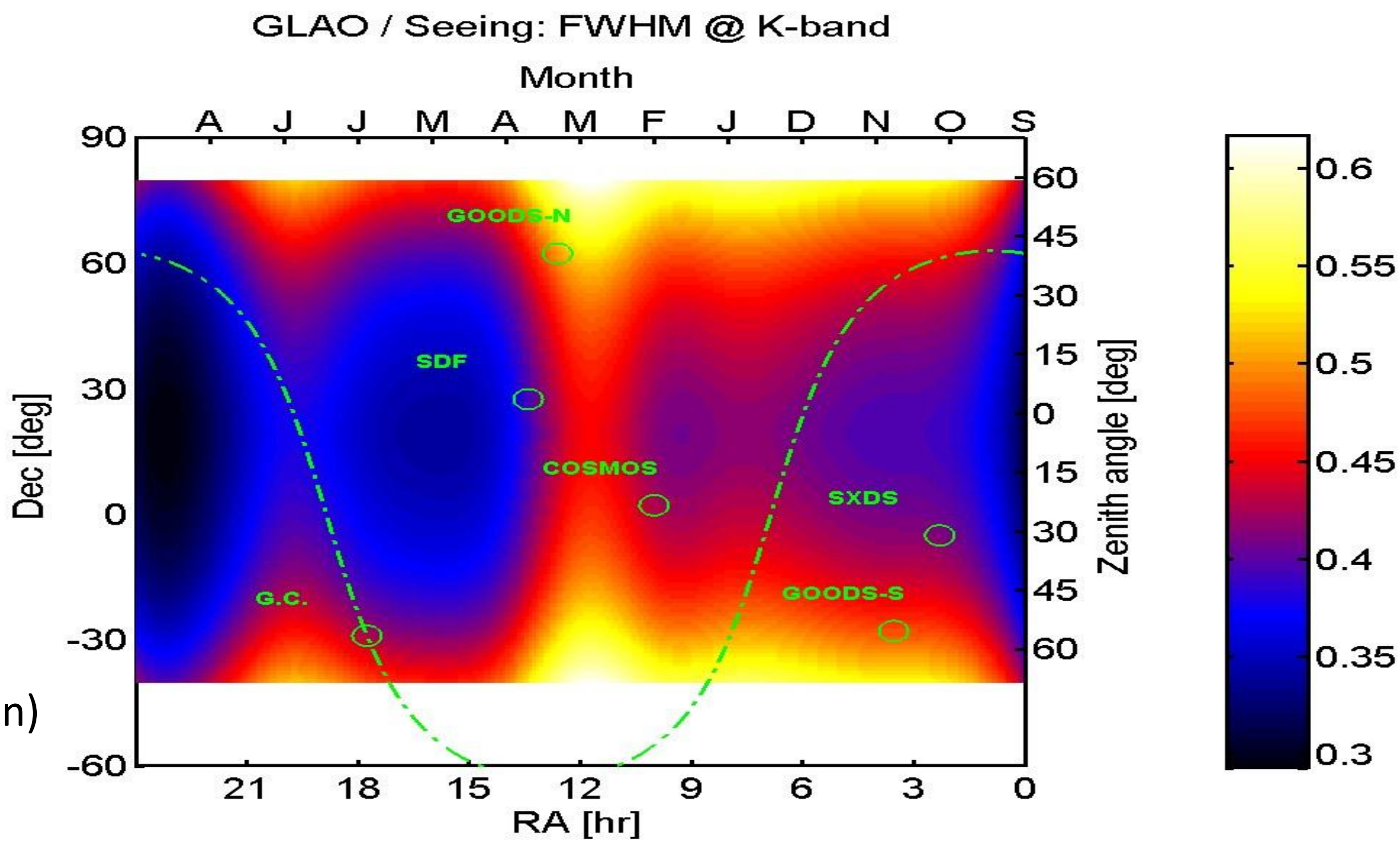
(from Oya-san's talk)

We used the center PSF at the moderate seeing condition to simulate the observation of z~2 galaxies.

Seeing condition :
- Bad (75%) : 0".56@K
- Moderate (50%): 0.44@K
- Good (25%): 0".35@K



PSF for each target field



(from Oya-san)

- Subaru Deep Field (Dec =+27.5deg) → Apr, z=15deg
- COSMOS (Dec=+2.2deg) → Feb, z=15deg
- SXDF/UDS (Dec=-5.2deg) → Oct, z=30deg

Summary of the PSF used in this simulation

	COSMOS	SDF	SXDF
Zenith angle	15	15	30
Month	Feb.	Apr	Oct
FWHM(Seeing)@K	0”.48	0”.46	0”.48
FWHM(GLAO)@K	0”.23	0”.18	0”.22

Simulated Observations

- Wide Field NIR imaging
  - Broad-band (BB) imaging
  - Narrow-band (NB) imaging

- Multi-Object Slit (MOS) spectroscopy
  - Emission line
  - Continuum

- Multi-IFU spectroscopy
  - Emission line

Imager

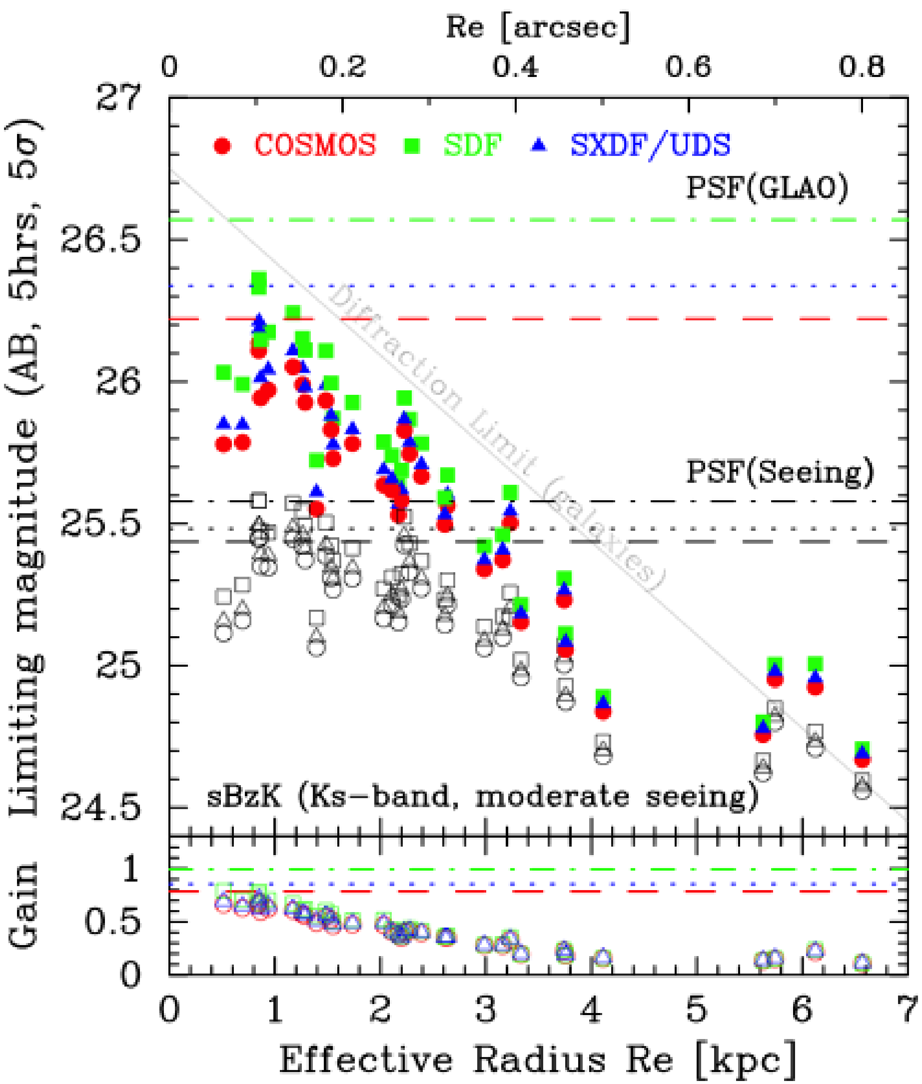
Baseline Specification

Wavelength	0.8μm – 2.5μm
Plate Scale	0.10"
FoV	13.6' x 13.6'
Detectors	4 Teledyne H4RGs (4 x 4096 x 4096 pixels)
Filters	Broad-band and Narrow-band filters

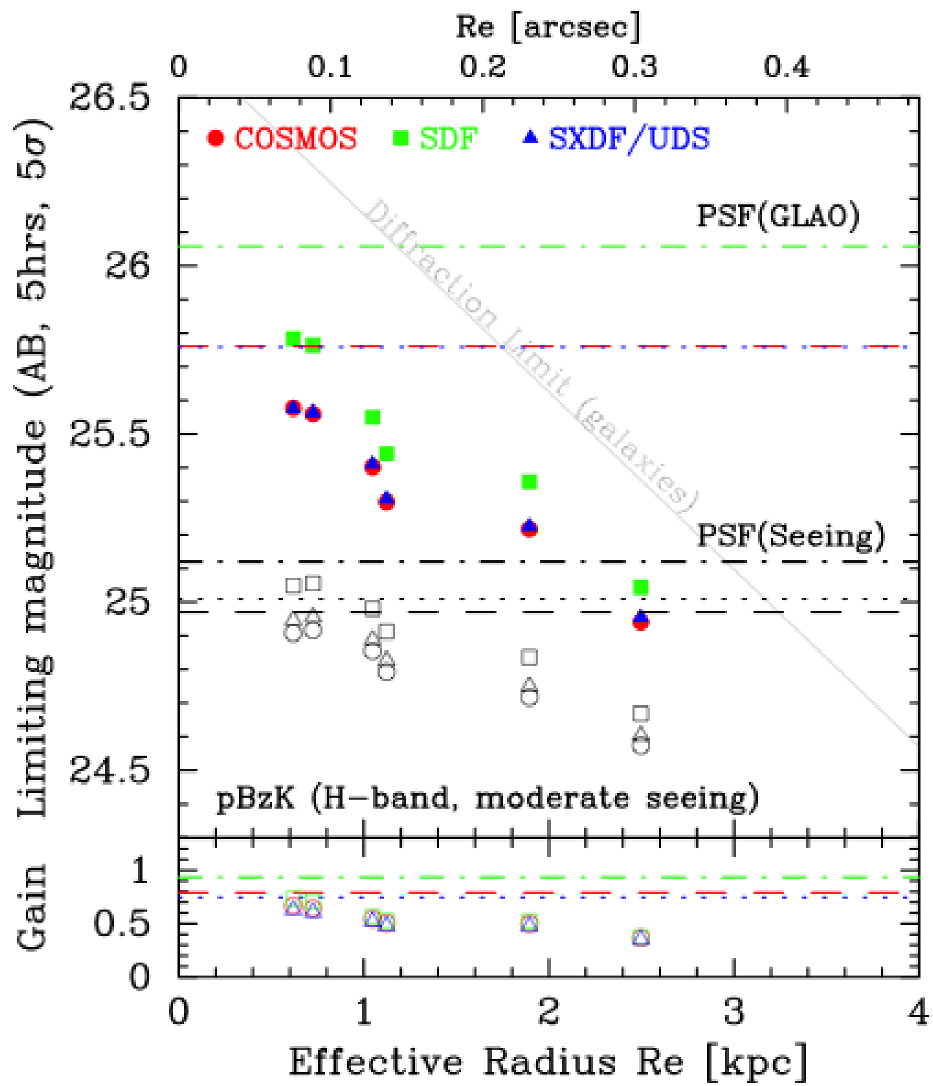
- Wider than any NIR imager on 8m class telescopes
- The instrument throughput is assumed to be same as VLT/HAWK-I (~60%@JH, ~50%@K)
- Seeing performance is just same as VLT/HAWK-I

Broad-band imaging: Sensitivity

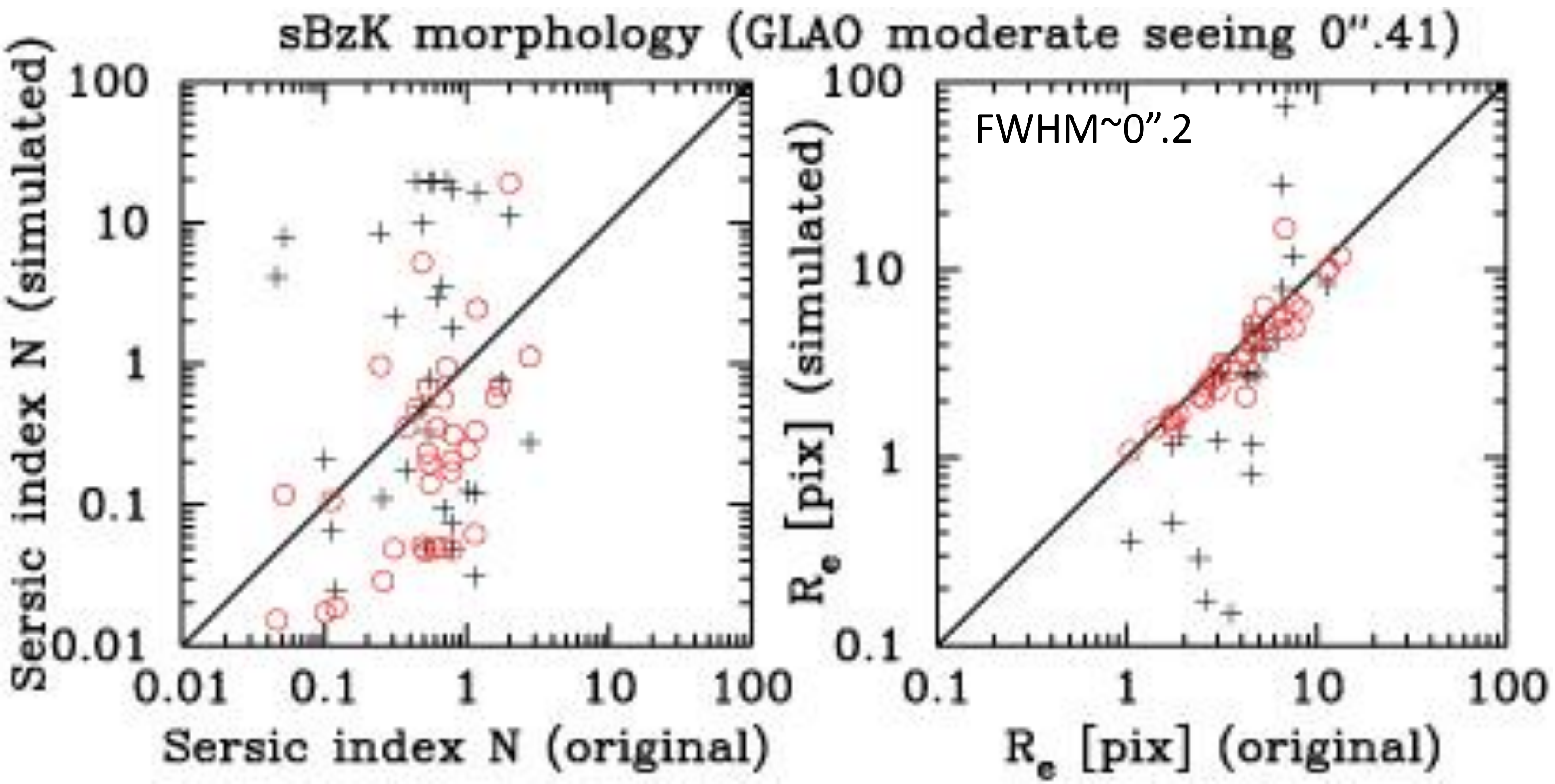
Star-forming galaxies at z~2
(Ks-band)



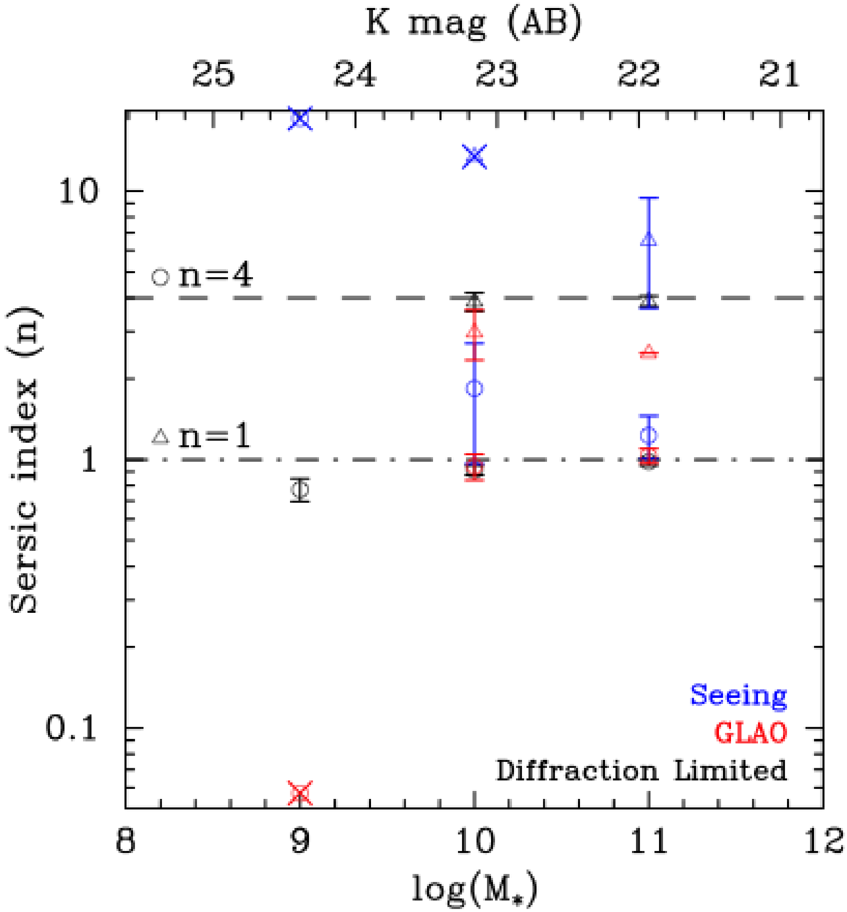
Passively evolving galaxies at z~1.5
(H-band)

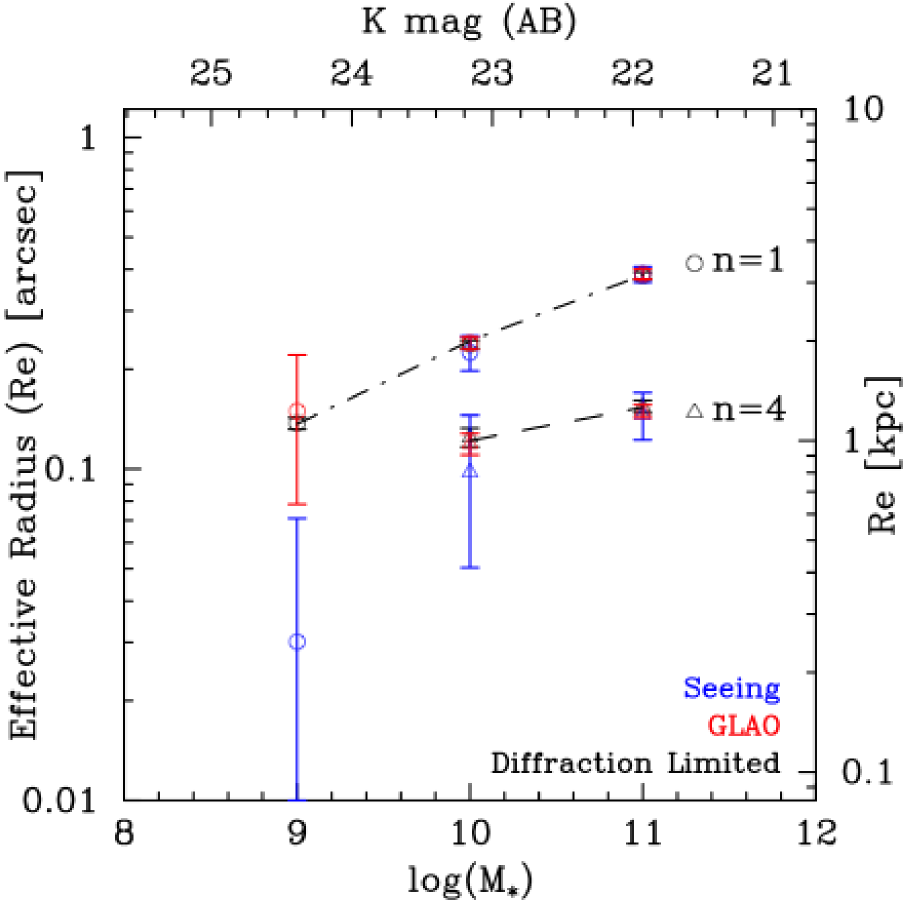


Morphological study with GLAO as of 2011, 2012



BB imaging: Possibility for reconstructing the morphological parameters with GLAO imager



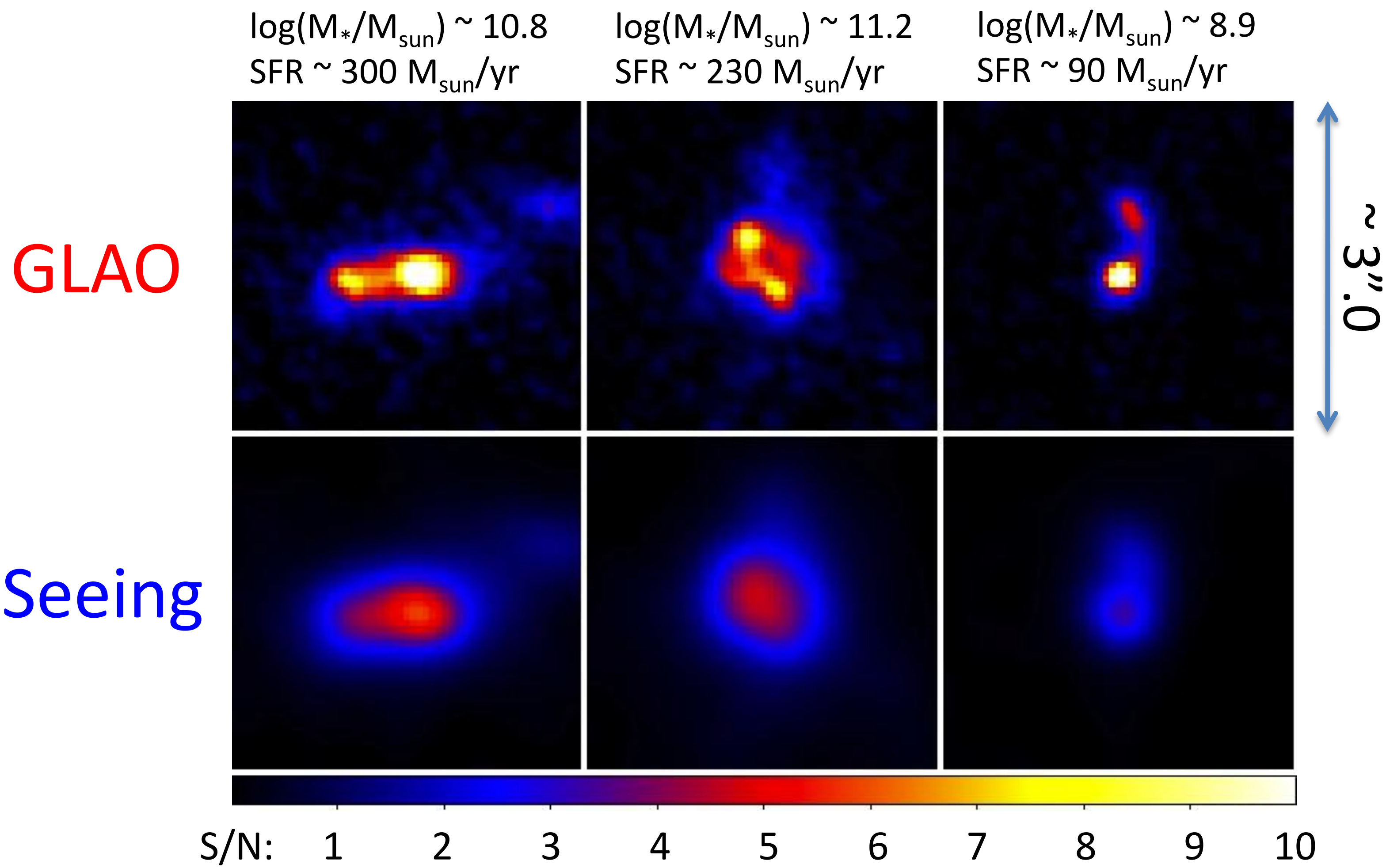


BB imaging: summary

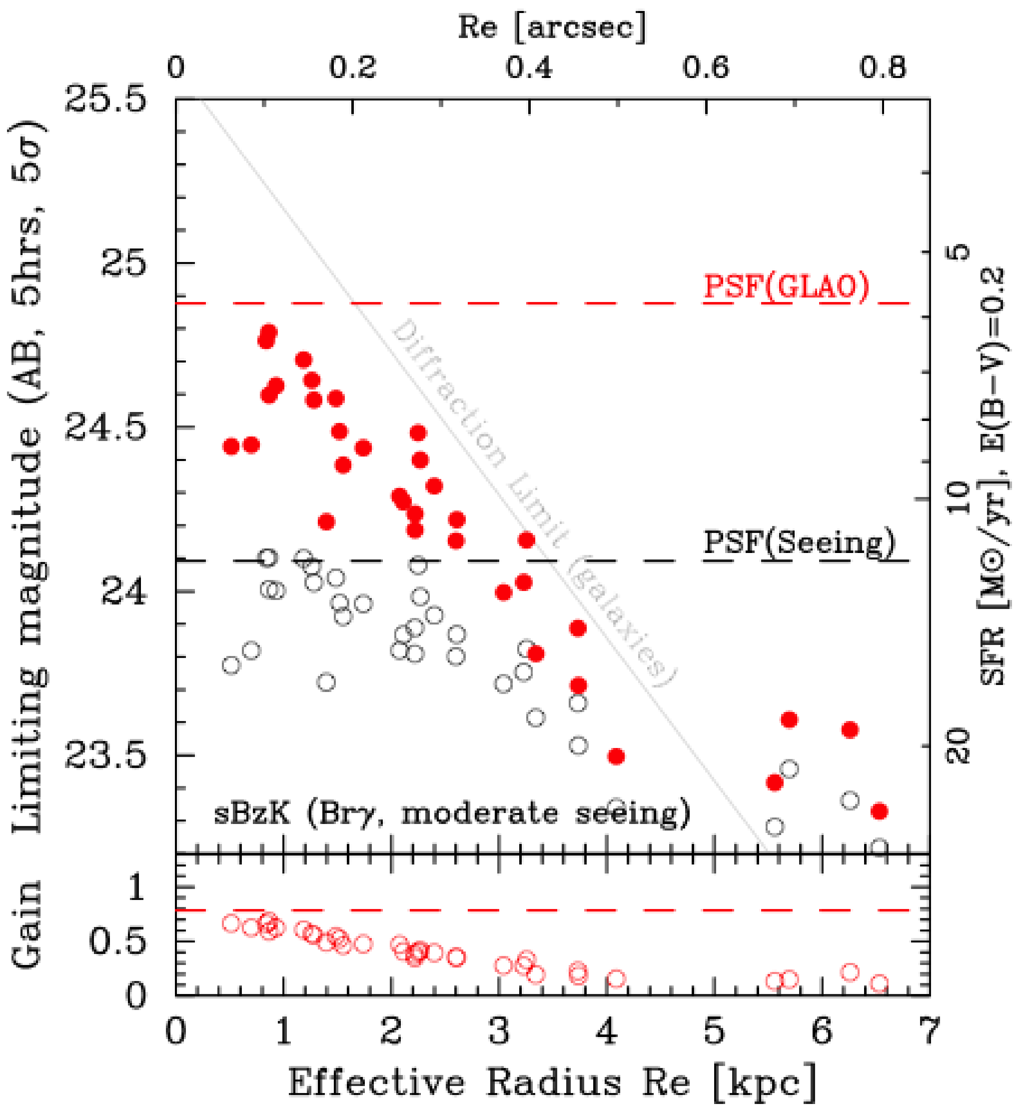
- Simulated z~2 galaxy imaging in H, K-band with new GLAO PSF which takes into account the PSF difference according to the zenith angle and seasonal seeing change.
- The point source sensitivity gain against the normal seeing instruments (such as VLT/Hawk-I) is different for each field. (1.0 mag for SDF, 0.7 mag for COSMOS)
- The sensitivity gain for galaxies are almost same for all fields.
  - 0.3-0.6 mag for compact galaxies (<3kpc).
  - Hereafter, we used COSMOS PSF to simulate the observations of z~2 galaxies.
- The limiting mag. is more than 3 magnitude brighter than TMT or JWST (~30mag in K, Wright et al. 2010).
  - Broad band imaging cannot be competitive
  - Wide-field capability might be useful for finding rare objects like passively evolving galaxies.
- Morphological parameters (Re, N) can be reconstructed from the GLAO image for galaxies whose mass is larger than 10^{10} M_{sun}
- For lower mass galaxies 10^9 $M_{sun,}$ we can reconstruct size (Re), but cannot reconstruct Sersic index.

Narrow-band imaging: Hα map

- Simulated Brγ-image of Hα emitters at z=2.3 with 5hrs integration
  - made from HST/WFC3 images of star-forming galaxies in SXDF (Tadaki+13)



NB imaging: Sensitivity for detecting Hα from z~2 galaxies



NB imaging: Summary

- Star-forming clumps in galaxies can be clearly resolved with GLAO NB imaging.
- GLAO can reach about 0.3-0.6 mag deeper than VLT/HAWK-I for compact galaxies (<3kpc)
- Brγ-imaging can reach Hα emitters with SFR < 10Msun/yr for compact galaxies with re < 3kpc.
  - Wide field NB-imaging can be a good sample provider for the IFU study with TMT
- JWST/NIRCAM (F212N) can reach about 1.8 mag deeper than GLAO NB image for galaxies with re~2kpc and more for point sources (from Iwata-san's calculation).
  - More than 100hrs integration required to achieve similar depth as JWST/NIRCAM.
  - Legacy type survey could achieve this integration.

Multi-Object Slit Spectrograph

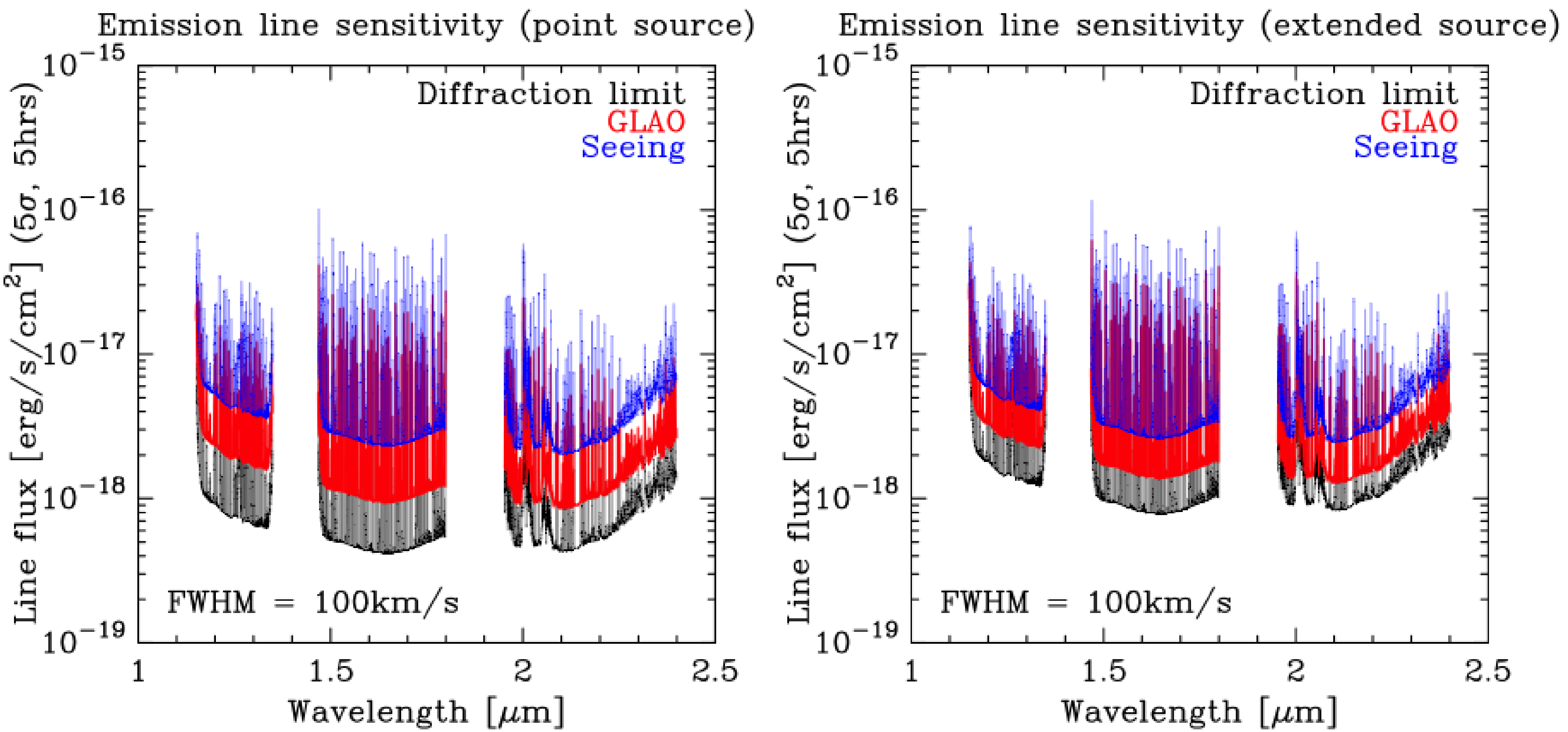
Baseline Specification

Wavelength	0.8μm – 2.5μm
Plate Scale	0.10"
FoV	13.6' x 13.6'
Detectors	4 Teledyne H4RGs (4 x 4096 x 4096 pixels)
Filters	Broad-band and Narrow-band filters
MOS	Multi Slit Mask
λ Dispersion	~3000

- Keck/MOSFIRE type instrument with 13'x13' FOV
  - Wider FOV than any existing MOS spectrograph on 8m class telescopes
- Assume similar throughput as Keck/MOSFIRE
  - the highest throughput ever achieved (30-40%@JHK)
  - Seeing performance is just same as Keck/MOSFIRE
- Slit width is assumed to be 0".4 which is 2 times wider than GLAO PSF.

MOS Spec.: emission line sensitivity

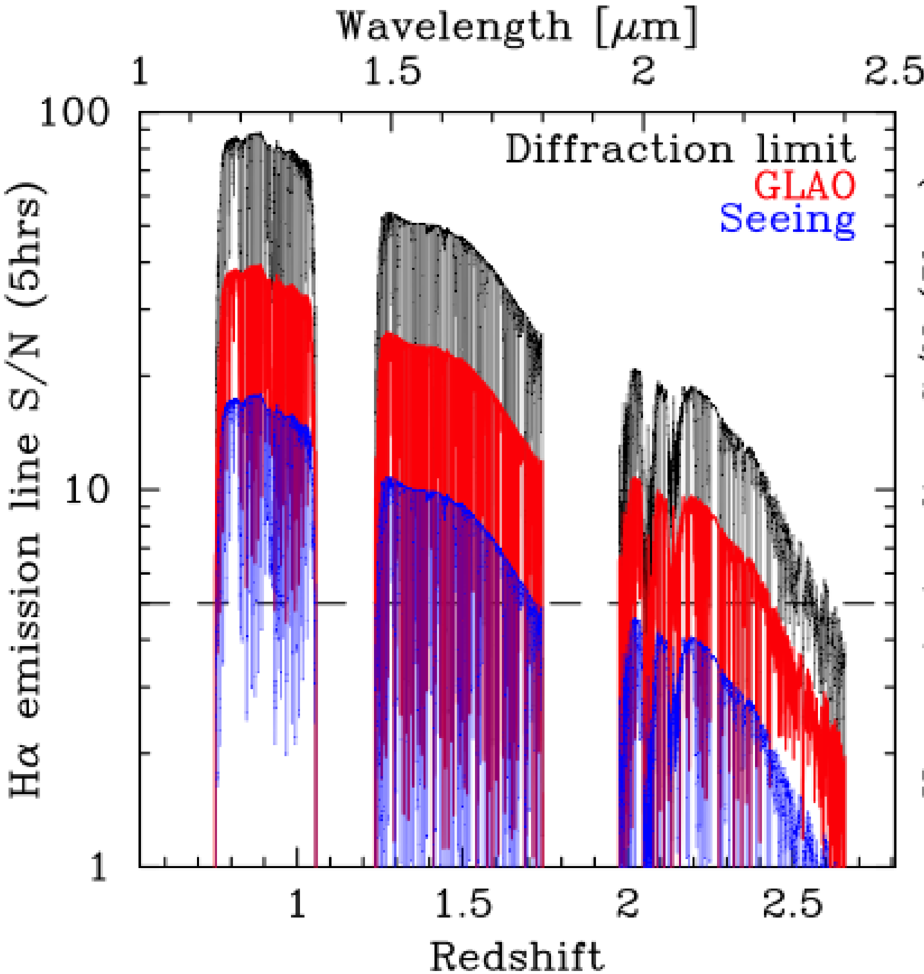
- Emission line 5σ sensitivity for point source and extended source (Re~1kpc or ~ 0".12 and N=1) with 5hrs integration.



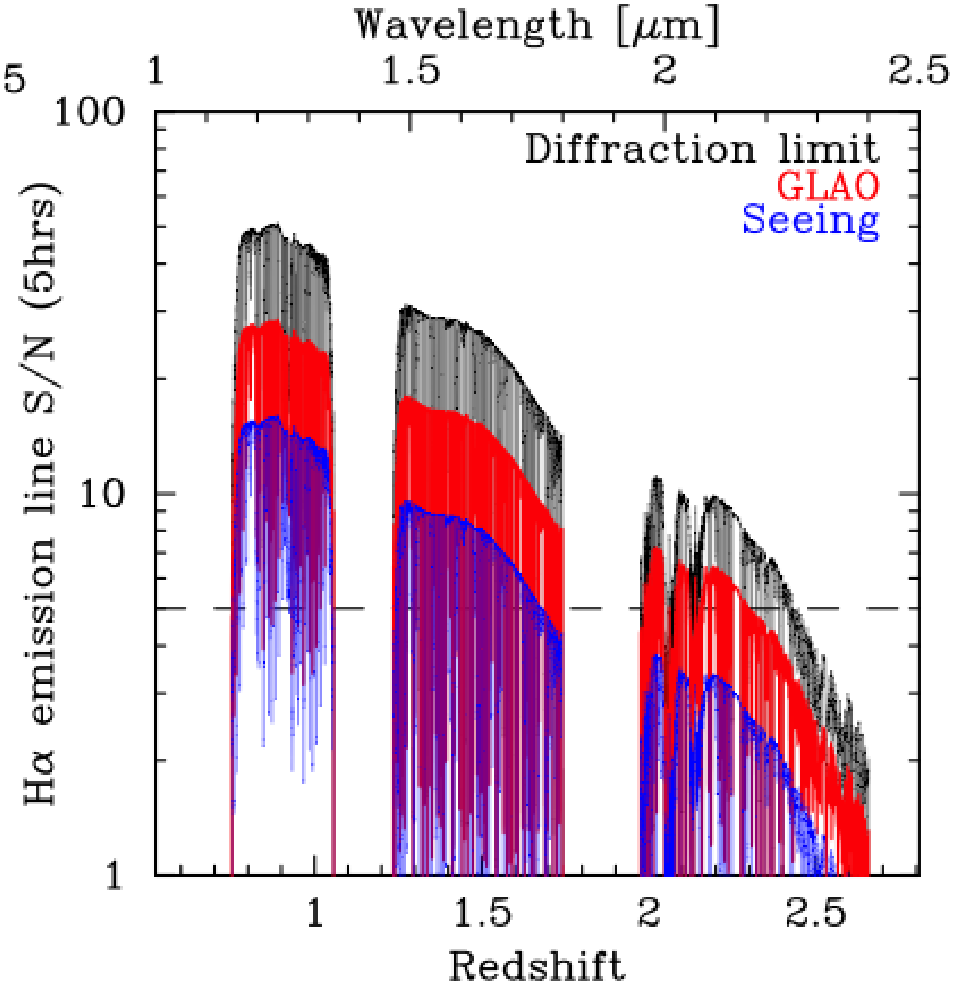
MOS Spec.: Emission line sensitivity

- S/N of Hα emission line flux which corresponds to SFR~ 1 M_{sun}/yr (assume E(B-V)=0.2) with 5hrs integration

(Point Source)

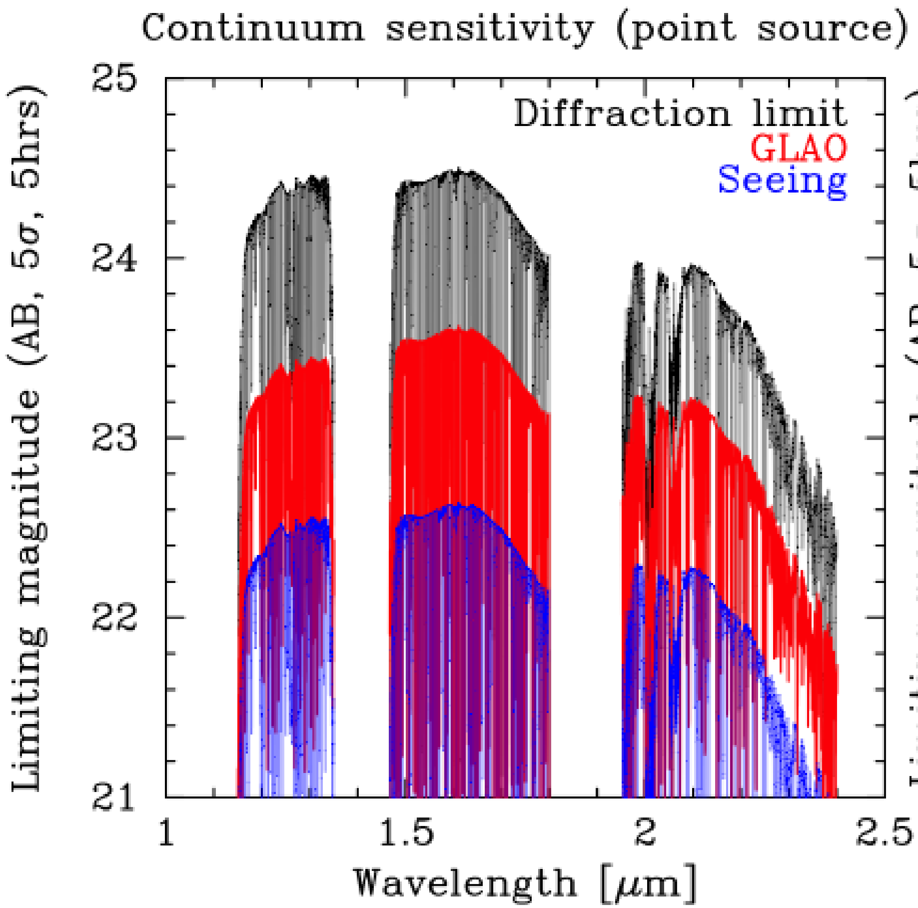


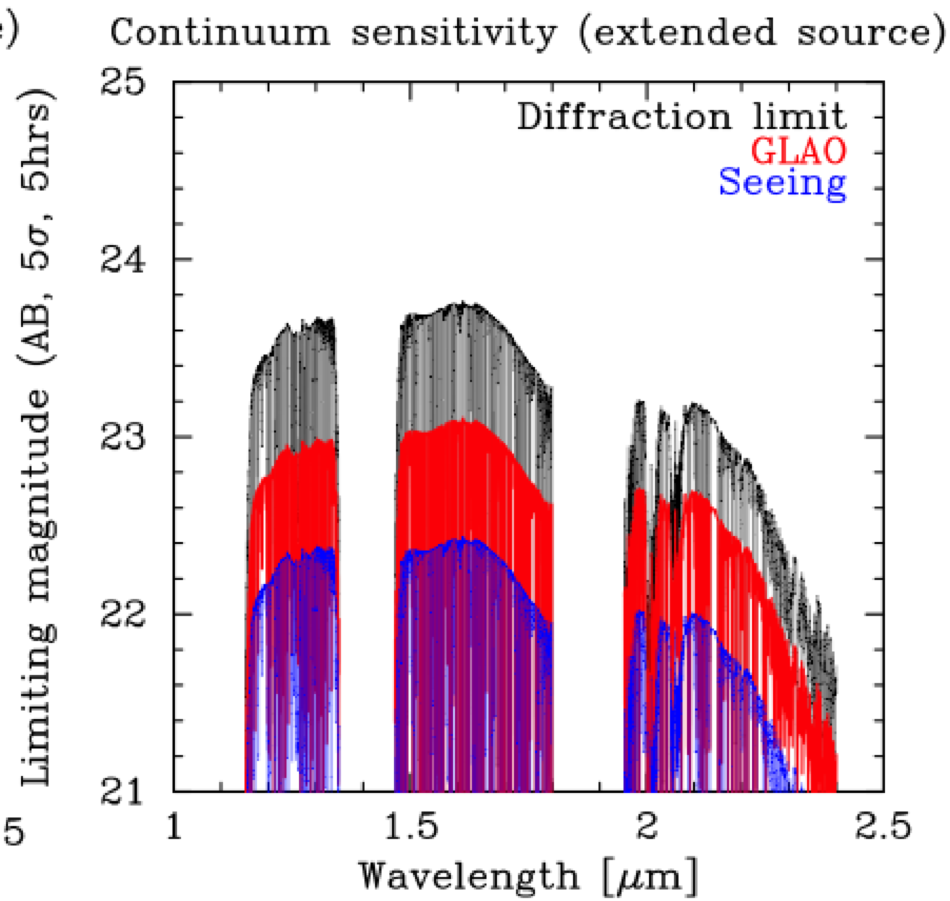
(Extended Source)



MOS spec.: Continuum Sensitivity

- Continuum 5 σ sensitivity for point and extended source with 5hrs integration





MOS. Spec: Summary

- Emission line: GLAO can increase the S/N of emission lines by 2 times higher than MOSFIRE.
- SFR~1M_{sun}/yr can be detected with Ha emission line located between sky emission line.
- Provides better sensitivity than NB-imaging, which enables redshift confirmation of the Ha-emitter discovered by NB imaging.
- Although TMT can achieve 3 times better S/N than GLAO (based on Law et al. 2006), the MOS capability is still required to enable rapid follow-up of the target discovered by GLAO NB imaging.
- Continuum sensitivity is worse than K~23mag. Follow-up spectroscopy of z~2 passive galaxies discovered by BB imaging should be done by TMT.

Multi Object IFU

Baseline Specification

Wavelength	0.8μm – 2.5μm
Spatial Sampling	0.125"
FoV per IFU	1.75" x 1.75"
Number of IFUs	24 (TBD)
Detectors	3-4 H2RGs? (TBD)
Patrol Area	~ 13'
λ Dispersion	~3000
Imaging Capability	*No*

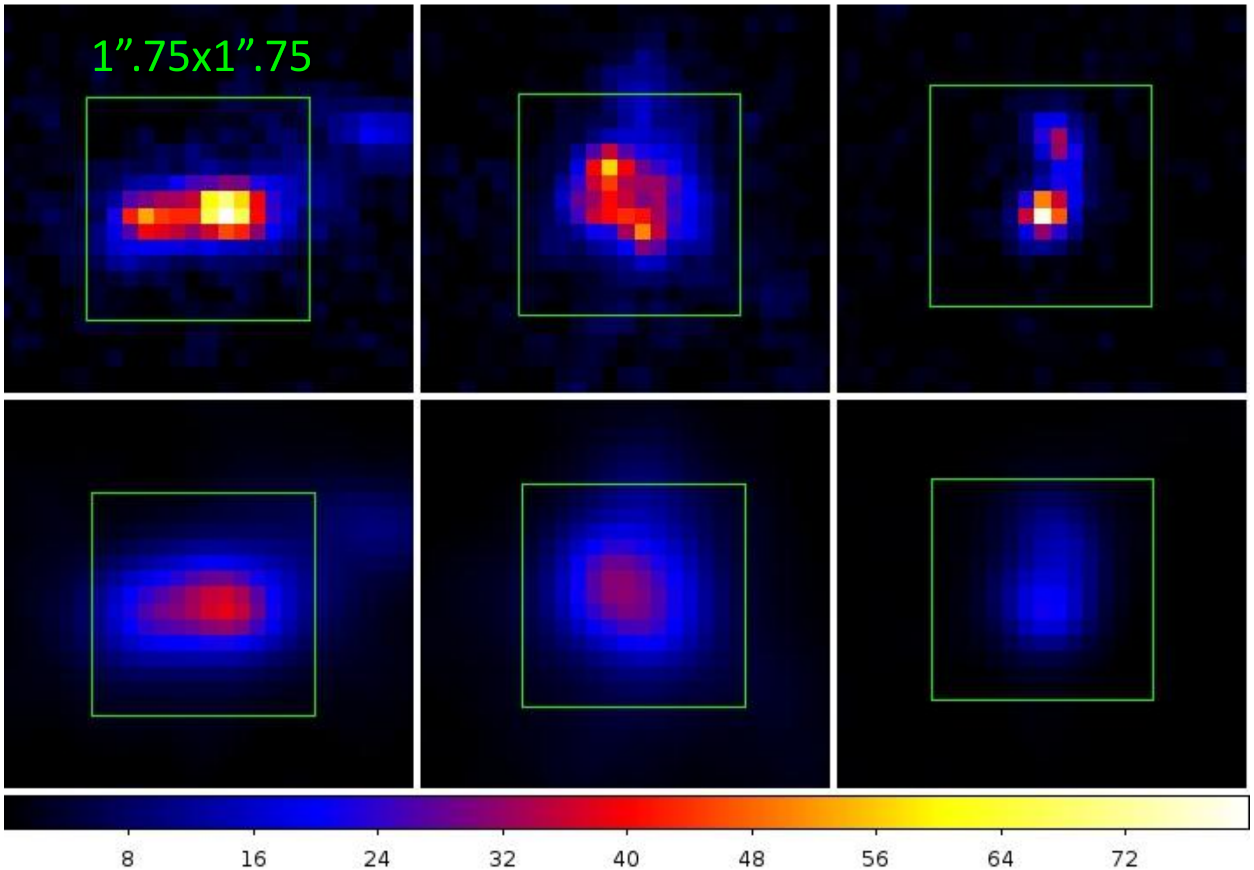
- VLT/KMOS type multi-IFU
- Throughput is assumed to be 80% of MOSFIRE due to the optical components for IFUs.

Multi-IFU: mock image

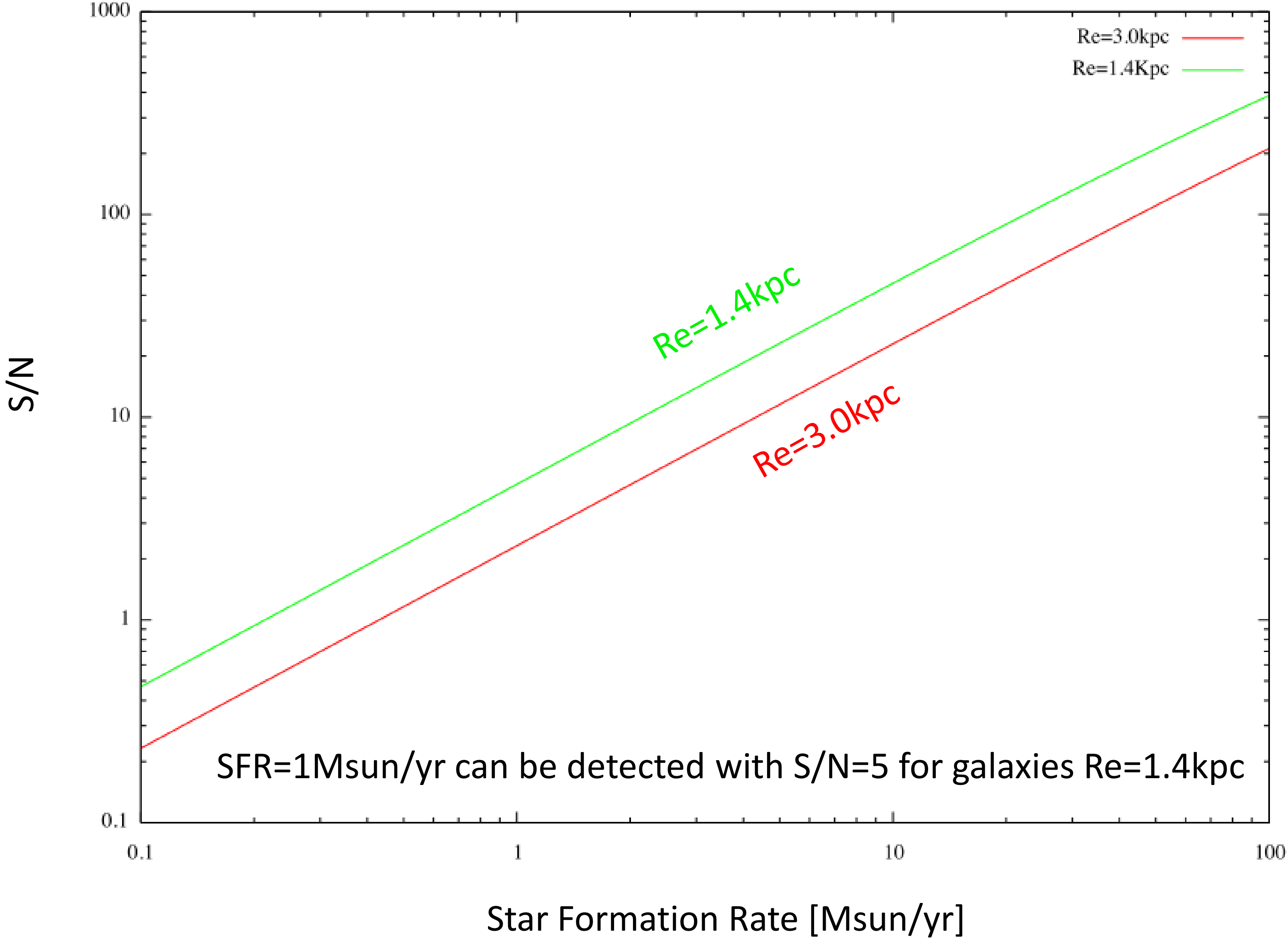
- Simulated IFU S/N map of Hα emitters at z~2.3
  - same objects as we used for NB imaging

GLAO

Seeing



Multi-IFU: Sensitivity



Multi-IFU: Summary

- Star-forming cramps can be resolve with IFU.
- GLAO IFU spectrograph can be detected Hα emission line from z~2 galaxies corresponds to SFR~ 1Msun/yr, if size of galaxies is less than 2 kpc.
- TMT/IRIS can detect SFR~1Msun/yr from similar size galaxies with S/N>40 (Wright et al. 2010)
- To be competitive with TMT/IRIS, GLAO IFU should have multiplicity of targets with more than 64 pick-off arm.
  - Need to investigate if this number is technically possible.

Conclusion

Competitive less competitive Competitive??? (in Japanese 微妙）

- Broad band imaging is not very competitive against the TMT/JWST, although >0.5mag gain can be obtained from the normal seeing instrument.
- NB imaging can reach the galaxies with SFR <10 Msun/yr, which can be good targets to follow-up with TMT IFU.
- Emission line sensitivity is only 3 times worse than TMT/IRIS, which could be competitive by combining with the GLAO NB imaging survey.
- Continuum sensitivity is less competitive as we can detect galaxies brighter than 23 mag in K-band.
- Multiple-IFU could be competitive against TMT/IRIS if we can have more than 60 pick-off arms , but it is better to invest TMT/IRMOS.

Any comment or request for the simulations of GLAO observations are welcome.

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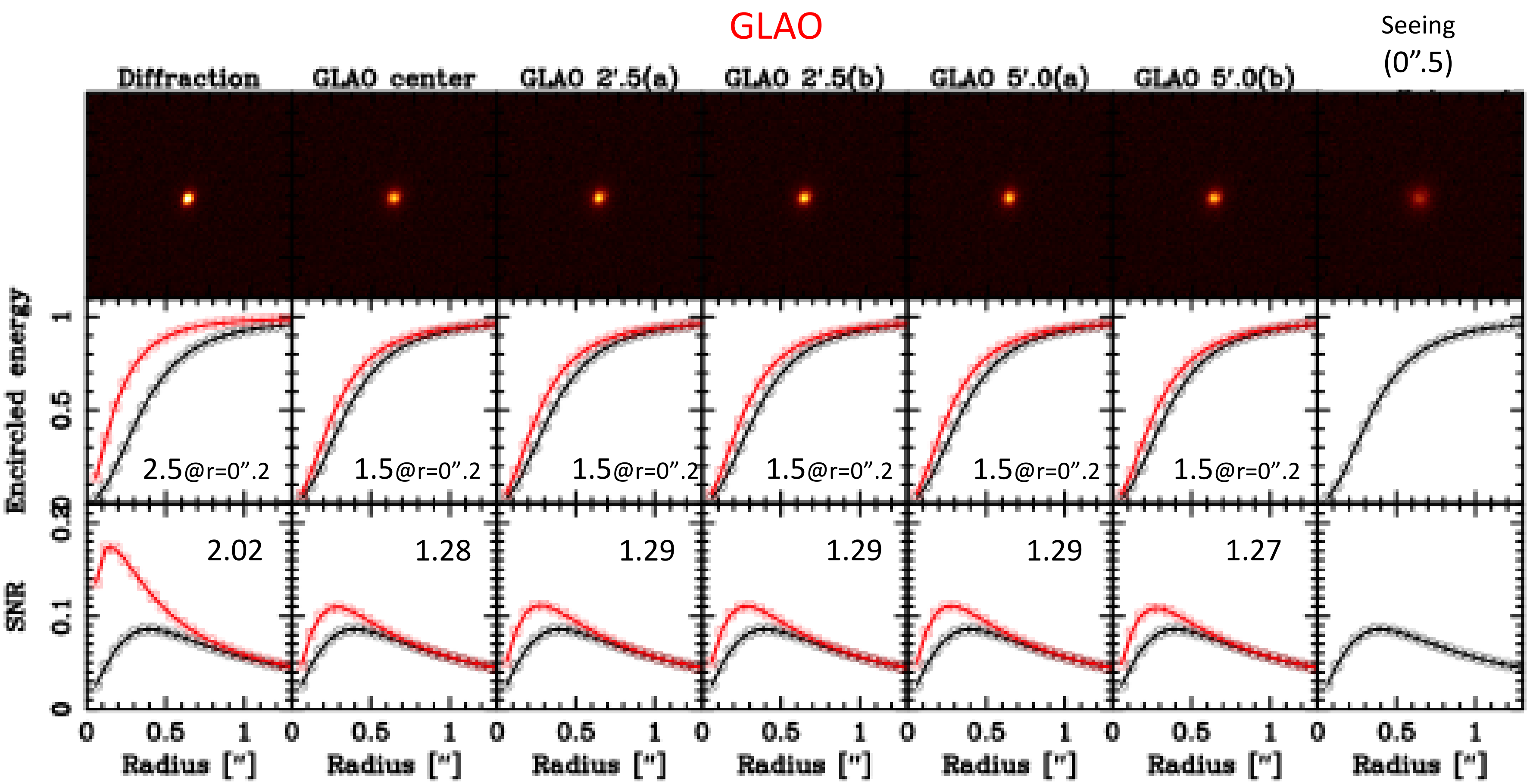
Star-forming BzKs at z=2.1-2.6 (GLAO image)

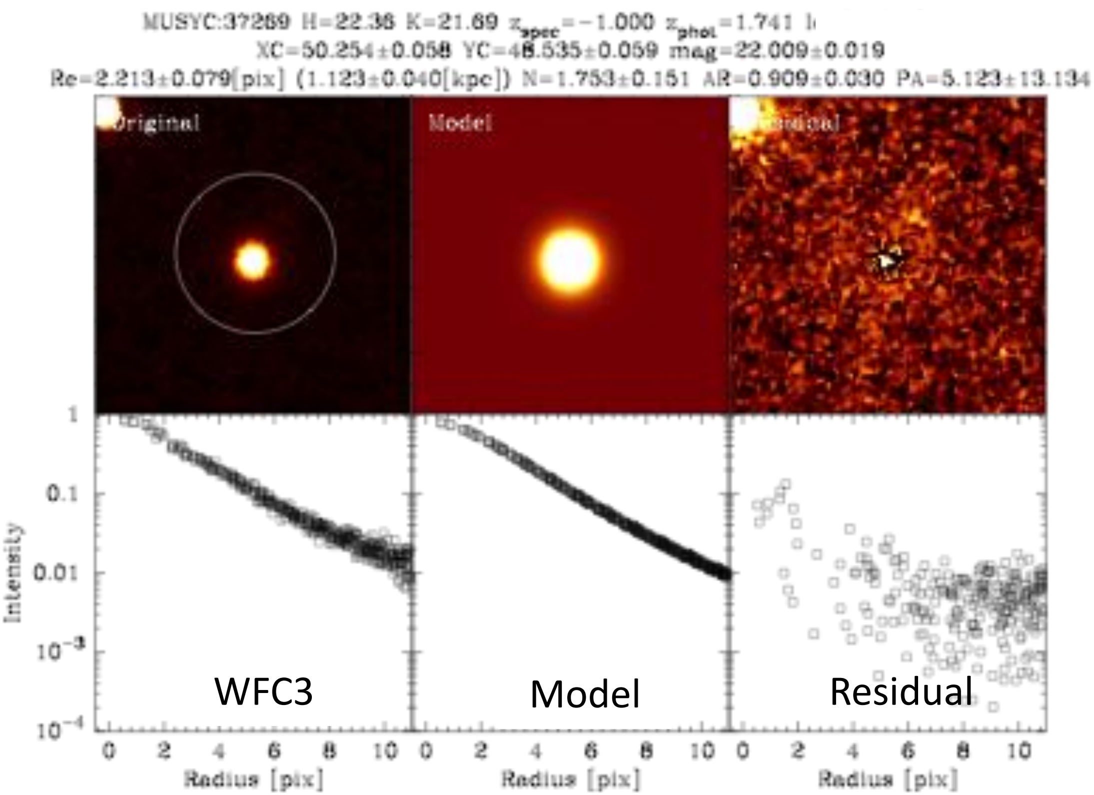
- Assuming 5 hours integration in K-band under moderate seeing condition (0”.5)



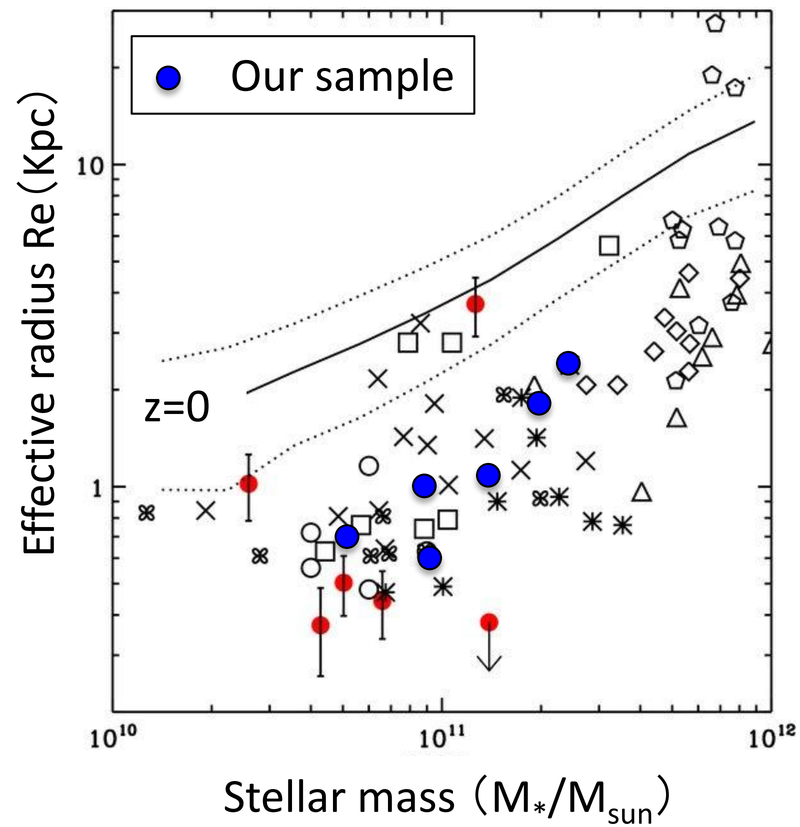
MUSYC 34852: z_{spec}=2.32, H=22.5, K=21.9, log (M_*/M_{sun})=11.1, R_e=1.4[kpc], N=1.7

Passive BzKs at z=1.3-1.7 (Model)

Modeling pBzK galaxies from GOODS-S WFC3 image (CANDELS)

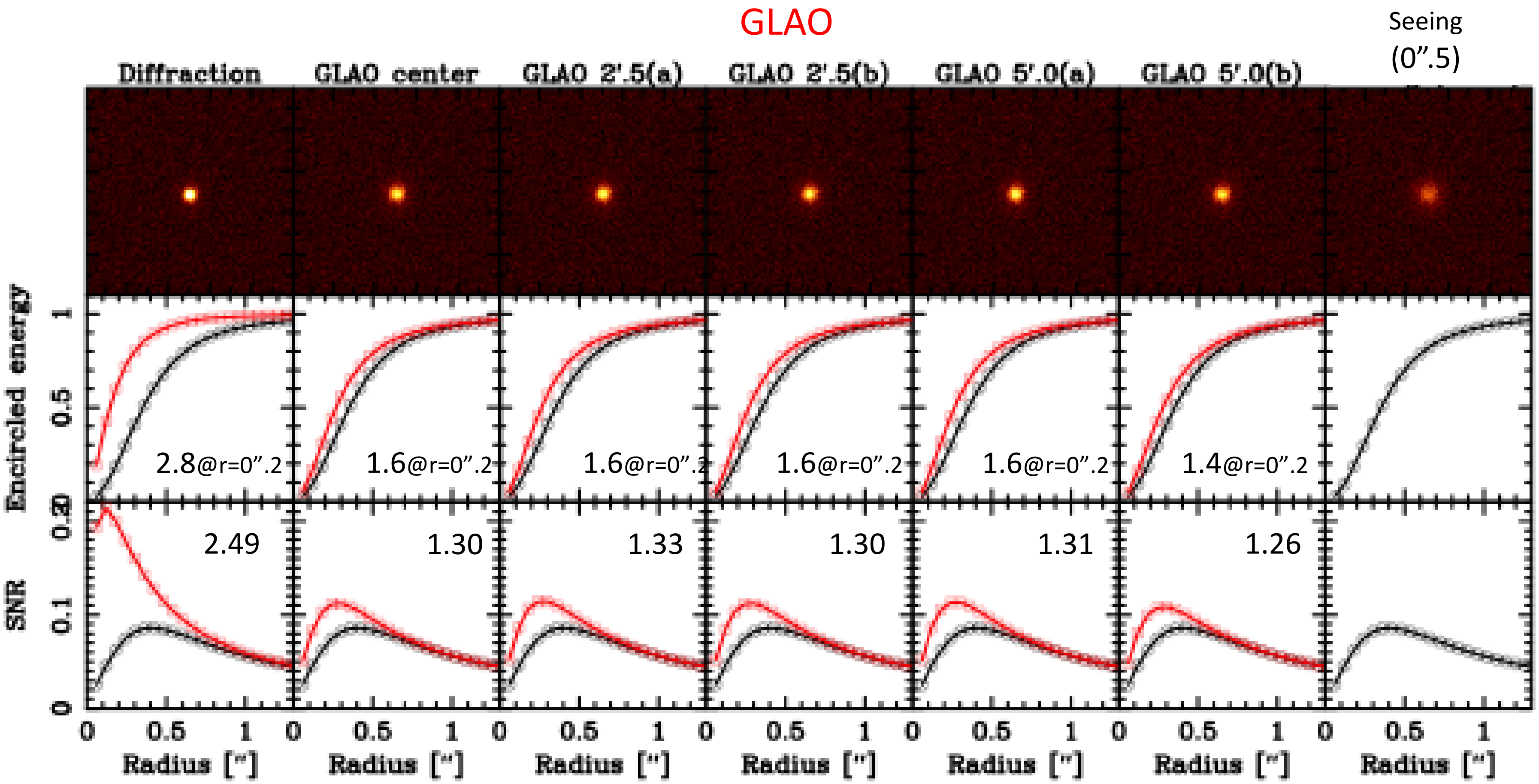


Comparison with the other z~2 passive galaxies at HUDF (Cassata et al. 2010)



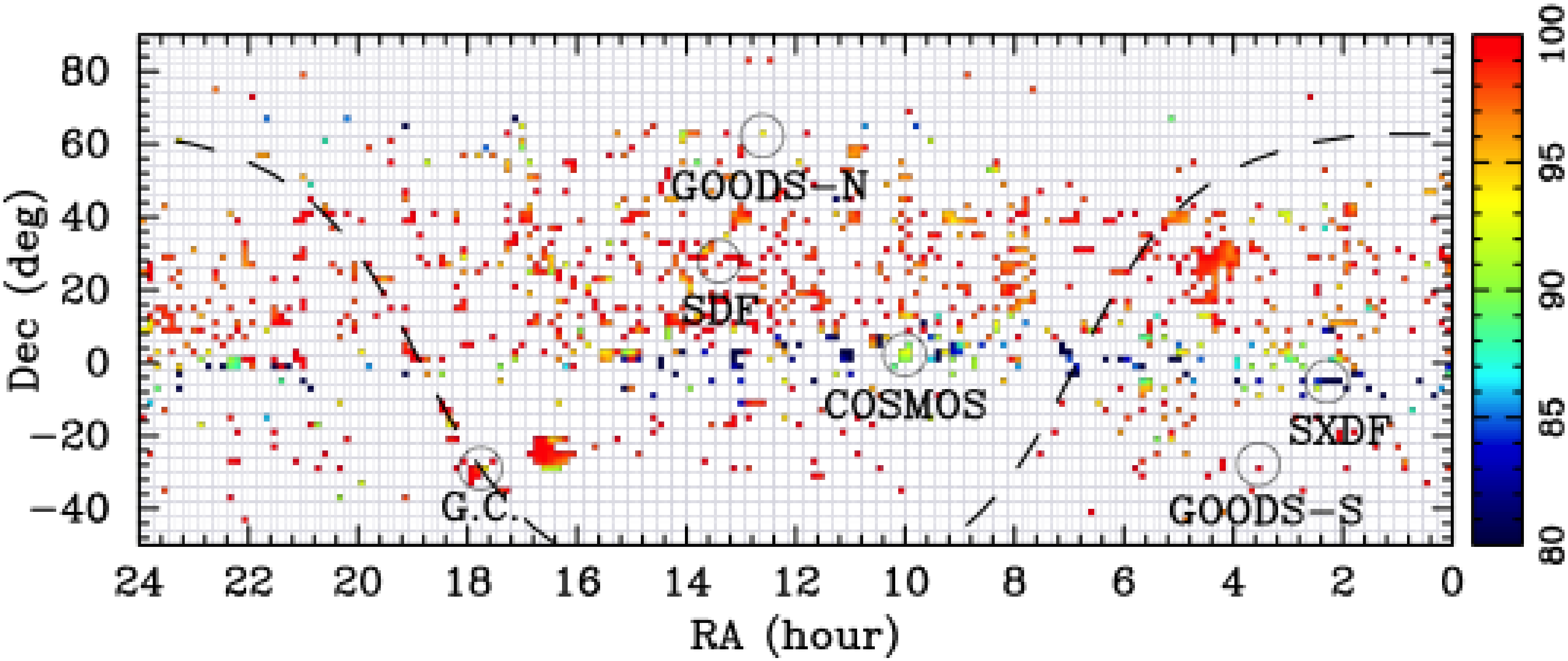
Passive BzKs at z=1.3-1.7 (GLAO image)

- Assuming 5 hours integration in H band under moderate seeing condition (0”.5)

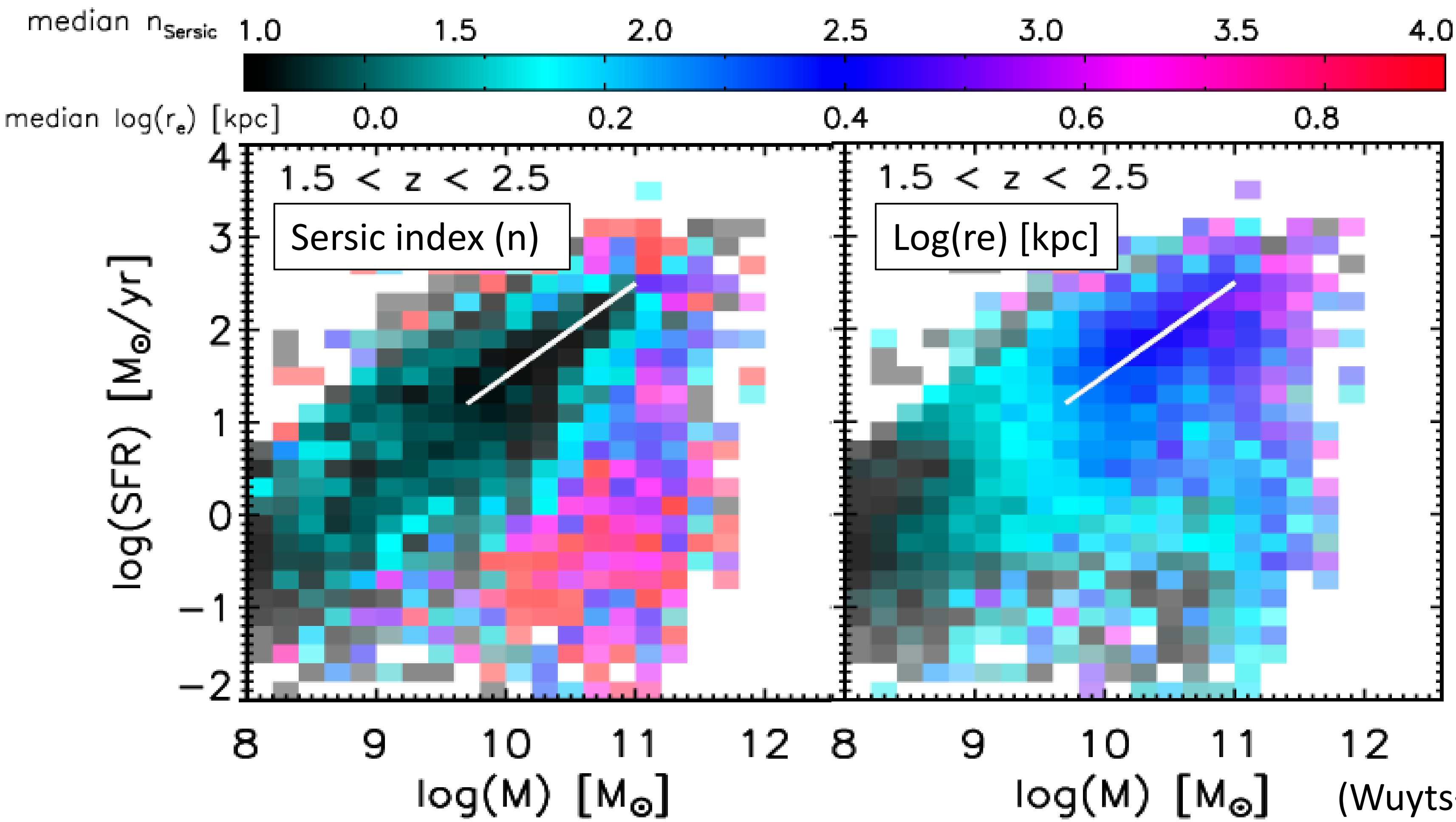


MUSYC 37269: z_{phot}=1.74, H=22.4, K=21.7, log (M_*/M_{sun})=11.1, R_e=1.1[kpc], N=1.7

Impact of the LGS satellite closure



BB imaging: Morphological study



(Wuyts+2011)