すばる次世代補償光学系に期待すること
What we demand for the next generation Subaru AO
- Kick off -

1. Current+
2. Next-generation

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What do we demand for "current+" system

1. Sky coverage, larger is better

   For example, good correction with R=18mag TT-guide star with 60" distance, see later.

   NIR TT-guide star (TT-correction with AO-corrected stars) ?

2. Information on PSF at target position. Possible ? How reliable ?

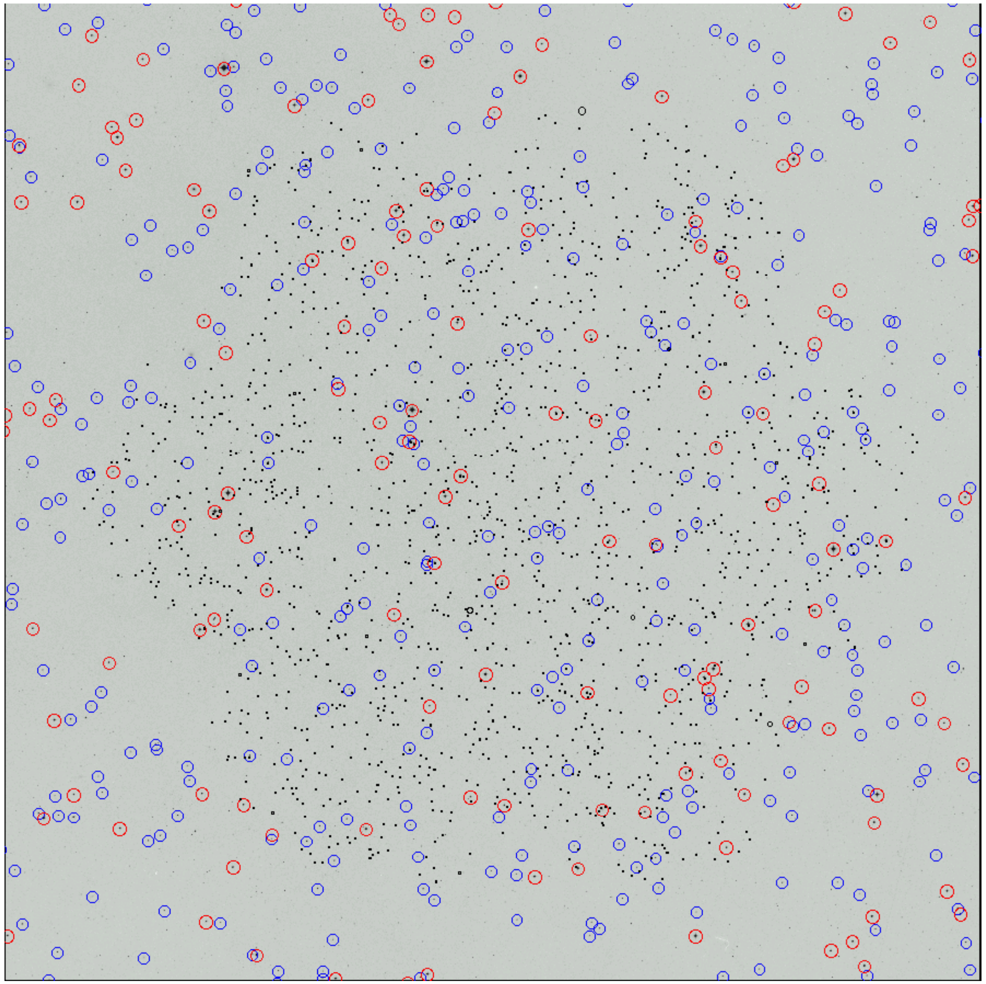
   Especially for narrow fov observations. Accuracy with FWHM=0.10"+-0.02", see later.

Sky coverage limitation

Yes of course with NGS AO

K-band SR~0.2 with R=13mag @ 30" (blue) ~6%@SXDS

K-band SR~0.1 with R=15mag @ 30" (red) ~3%@SXDS



SXDS fov

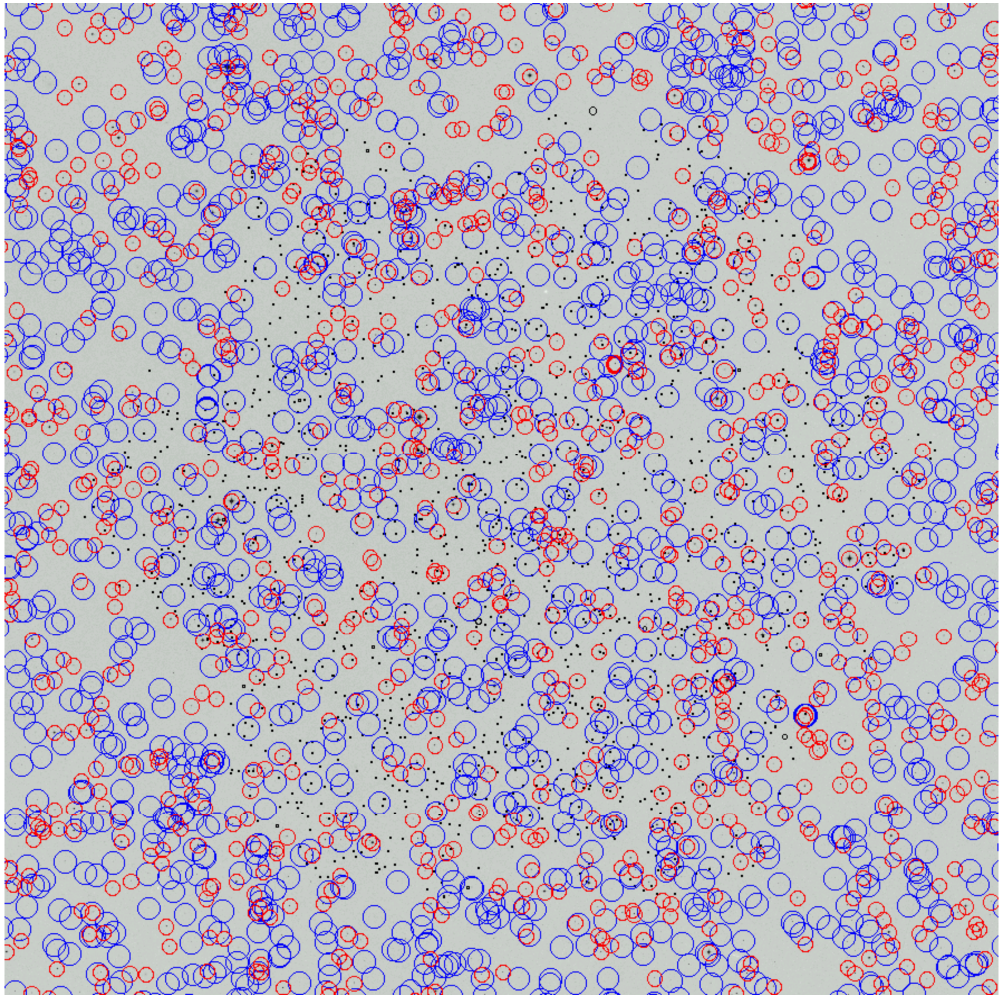
~1000 X-ray sources are plotted with small dots

Sky coverage limitation

Even with LGS AO (Keck LGS)

K-band SR~0.2 with R=16mag @ 40” (blue) ~16%@SXDS

K-band SR~0.1 with R=18mag @ 60” (red)   ~58%@SXDS



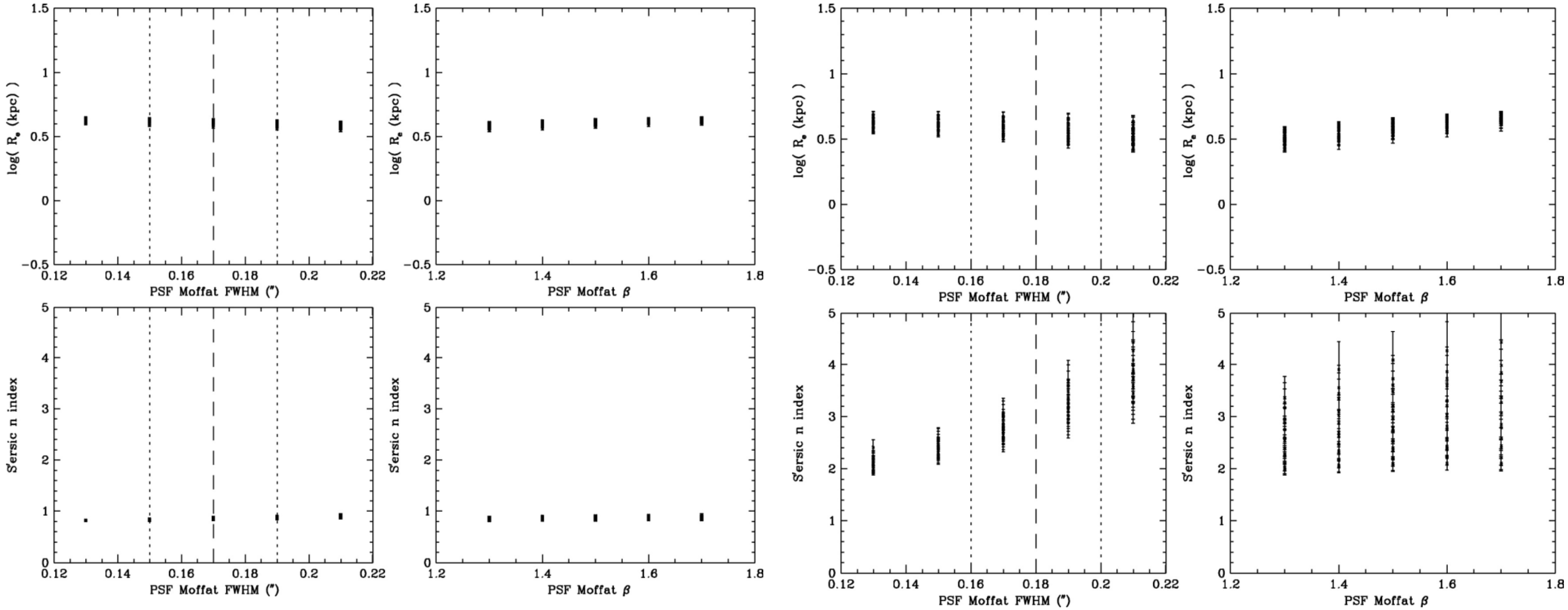
SXDS fov

~1000 X-ray sources are plotted with small dots

PSF estimation

Feasible ? With what accuracy ?

- No estimation necessary for point source spectroscopy.
- Required accuracy is not so high for morphological studies of distant galaxies. Best fit morphological parameters do not severely depend on model PSF used.



MA+2008

Very high accuracy required for QSO host galaxy studies.

Next-generation general-purpose AO and Subaru's originality

Targeting "cutting-edge + big size + general-purpose" = "costly and time-consuming" instrument ? Or chose either of one ?

Next-generation general-purpose AO and Subaru's originality

Unique AO instrument of ground-based 8-10m class telescope in the era of JWST(2014 launch) ?

Competitive instrument even in the TMT(2018?) era ?

Wide field ? At least 5-10' scale FoV. High-resolution version of NIR (prime-focus) wide-FoV camera.

2.2' x 2.2' x 2 0.03" sampling with JWST NIRcam

High-spectral resolution ? R=3000 or higher with wide spectral coverage, at leaset one octove.

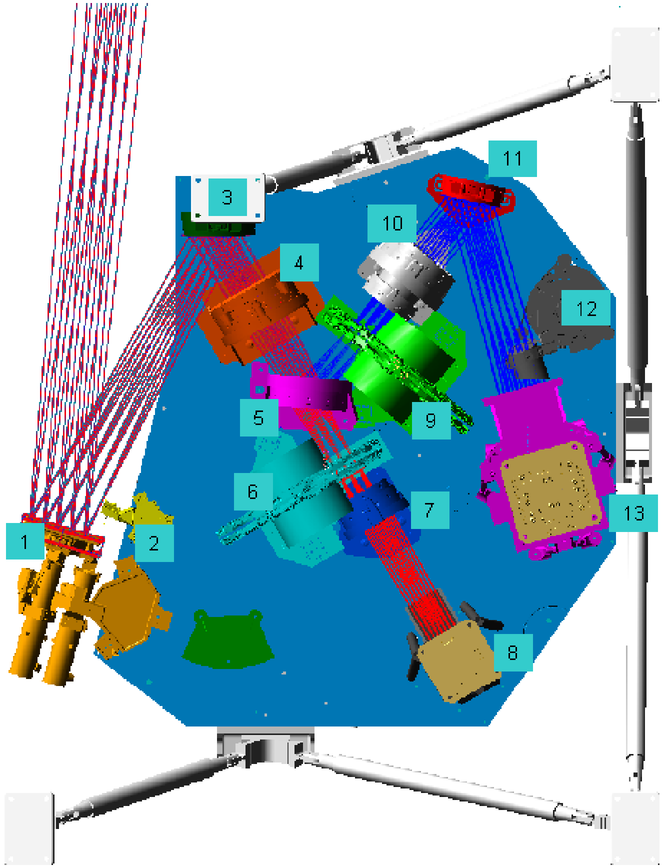
R<1000-3000 0.1-0.2" sampling with JWST NIRspec

Shorter wavelength range ? High-spatial resolution observation in wavelength range 1um or shorter.

NIRCam Design Features

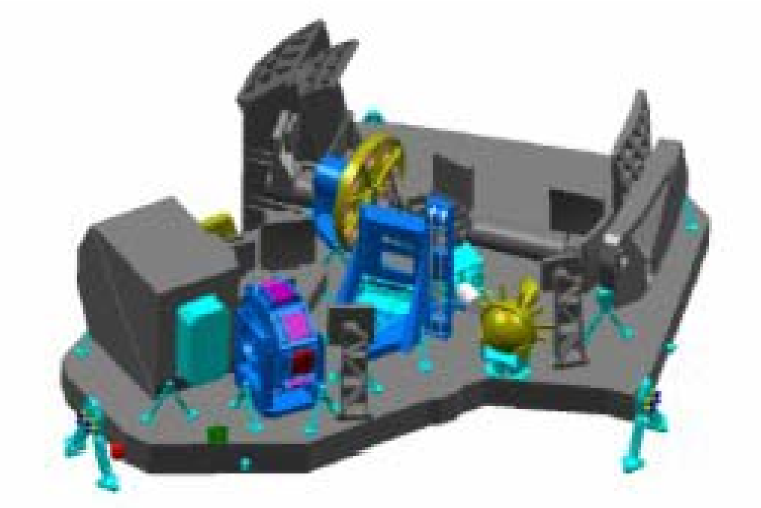
U of Arizona (M. Rieke) plus Lockheed ATC

- NIRCam images the 0.6 to 5μm (1.7 - 5μm prime) range
  - Dichroic used to split range into short (0.6-2.3μm) and long (2.4-5μm) sections
  - Nyquist sampling at 2 and 4μm
  - 2.2 arc min x 4.4 arc min total field of view seen in two colors (40 MPixels)
  - Coronagraphic capability for both short and long wavelengths
- NIRCam is the wavefront sensor
  - Must be fully redundant
  - Dual filter/pupil wheels to accommodate WFS hardware
  - Pupil imaging lens to check optical alignment

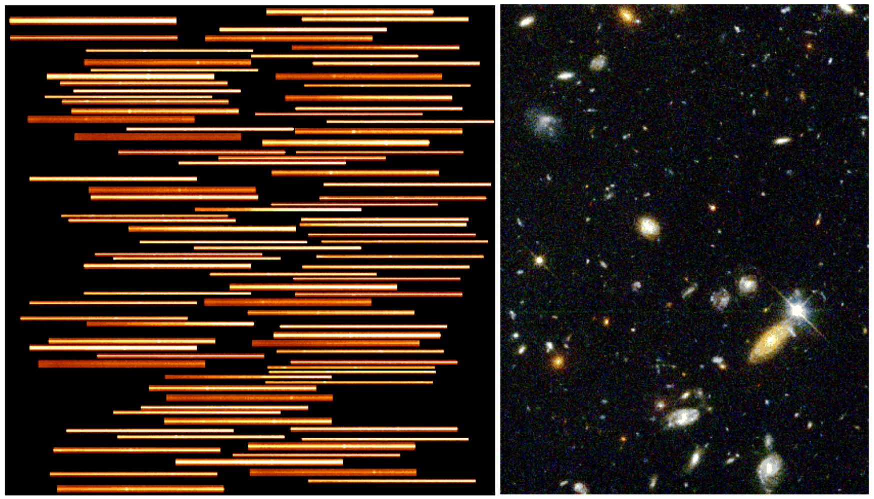


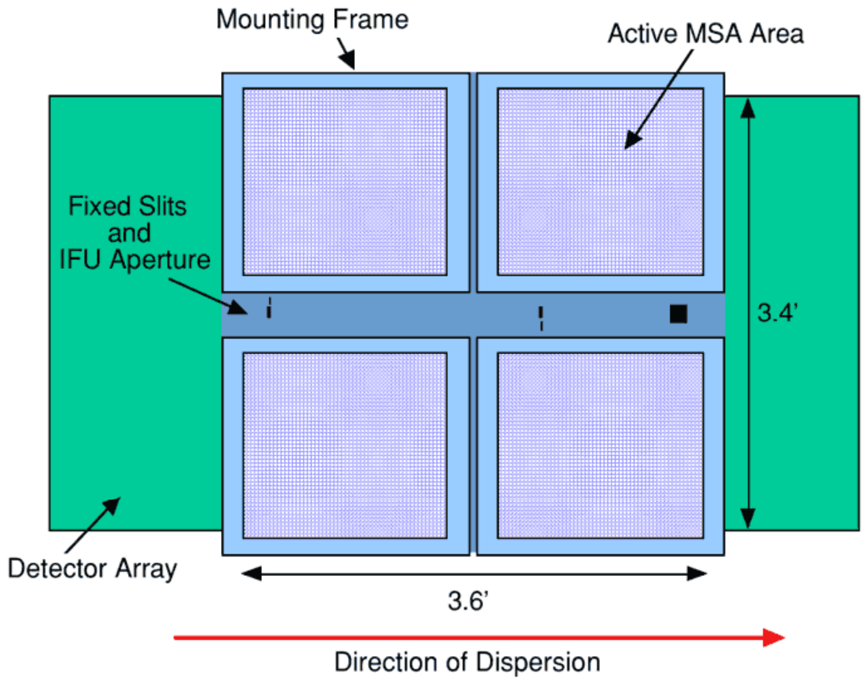
1	Pick-Off Mirror Assembly
2	Coronagraph
3	First Fold Mirror
4	Collimator Lens Triplet
5	Dichroic Beamsplitter
6	Long Wave Filter Wheel Assembly
7	Long Wave Camera Triplet
8	Long Wave Focal Plane Housing
9	Short Wave Filter Wheel Assembly
10	Short Wave Camera Triplet
11	Short Wave Fold Mirror
12	Pupil Imaging Lens
13	Short Wave Focal Plane Housing

NIRSpec



- Multi-object dispersive spectrograph (MOS) for 1-5 µm
- R~1000 or R~100 for MOS
- MOS pixels ~0.2", and cover a ~ ~3'x3' field
- Capable of observing > 100 objects simultaneously.
- Several fixed slits and an IFU (3"x3") are also available with R as high as 3000.
- Being built by the European Space Agency





Directions, which do you want ?

Ultra-deep observation of individual target / 個別天体の深観測：

Spectroscopy of very high-redshift galaxies: Lya emitter @ z=7

High-SN, R~10,000 spectroscopy of QSOs : GP trough of z=6-7 QSOs

Require higher SR
= Extending shorter wavelength range
With high sky coverage (targets are very rare)

Direction 1
~ Keck-NGAO
~ Gemini-GEMS

Deep observation of multiple targets / 多天体の深観測：

NIR spec. of red gals at intermediate z: Galaxies, AGNs @ z=1-3

Moderate SR
Wide FoV multi-object

Direction 2
~~Gemini-GEMS~~

Very-high spatial resolution of individual / 個別天体高空間分解能観測：

High resolution observation of nearby galaxies: AGNs, stellar pops galaxies

OPTICAL w.length range JWST will not reach,
Higher spatial resolution than HST in optical

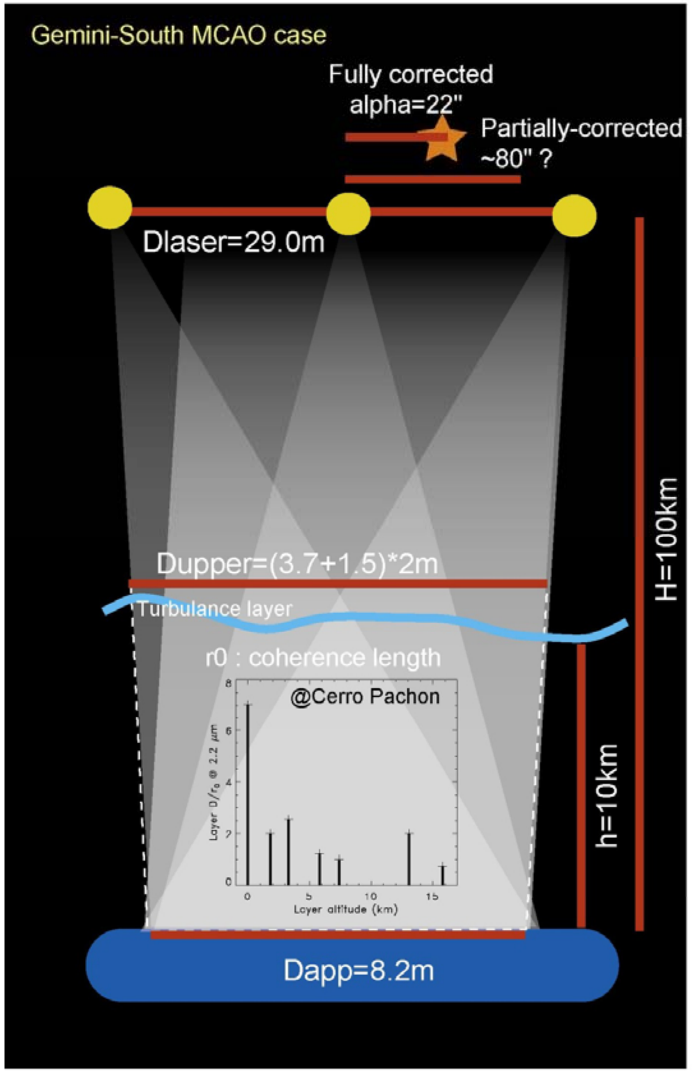
Direction 3
Subaru-SCExAO ?
Gemini-GPI ?

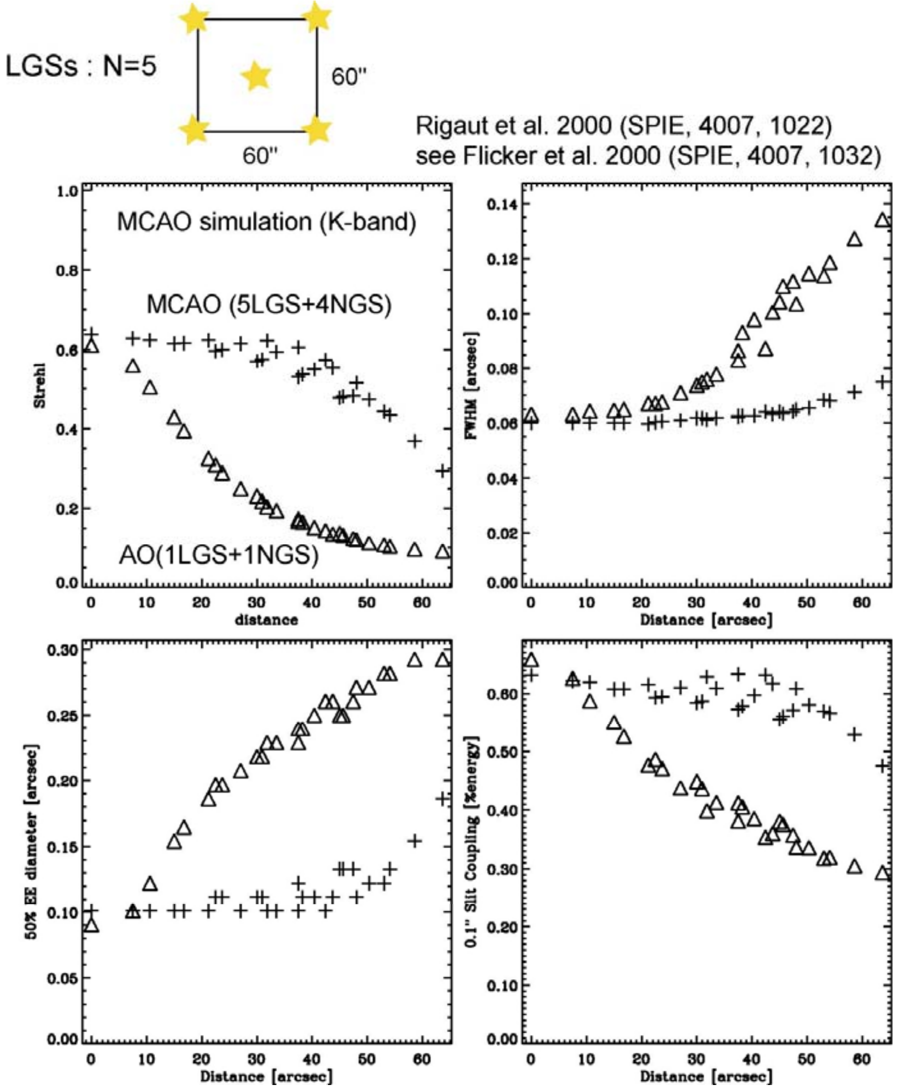
Sky coverage limitation with next-gen.

With MCAO(Gemini GEMS)

- 2’ fov covered with 3 TT guide stars brighter than R=18.5
- 10% sky coverage at galactic pole with SR 0.6 in K-band
- 3 R<18.5 stars within 60” = 15% @SXDS
- Degraded operation mode with 1 or 2 TTgs

Direction 1, not 2 : Gemini GEMS





GEMS is wide-field MCAO, but the expected performance is more closer to Keck NGAO (Direction 1), i.e. small FoV.

Sky coverage limitation with next-gen.

With tomographic-AO (Keck NGAO)

Requirements similar to Gemini GEMS?

the various sensors for both narrow and wide field science is shown in Figure 3. A variable LGS asterism with one LGS on-axis and five LGS in a pentagon is shown. This asterism can be expanded or contracted for the particular science case and atmospheric conditions. Three additional LGS are used to point near the tip-tilt (TT) NGS to maximize their image sharpening.

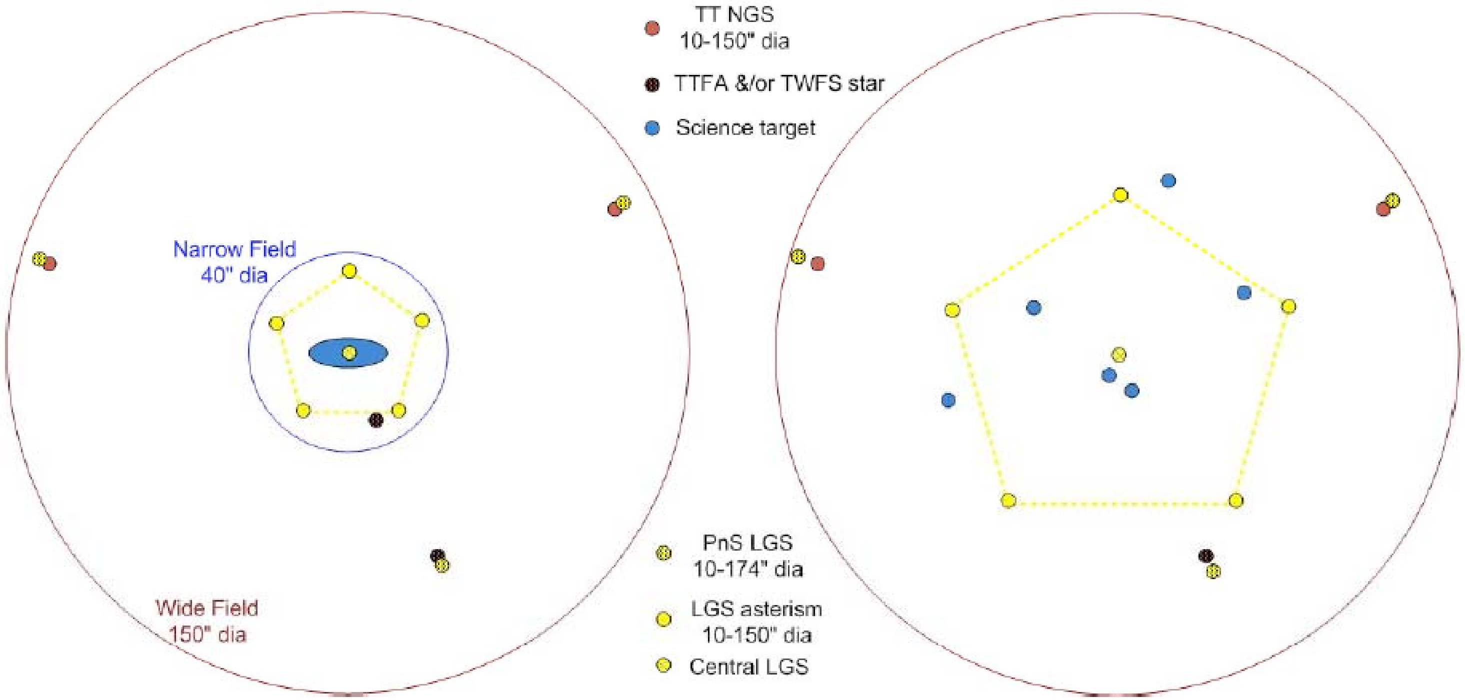
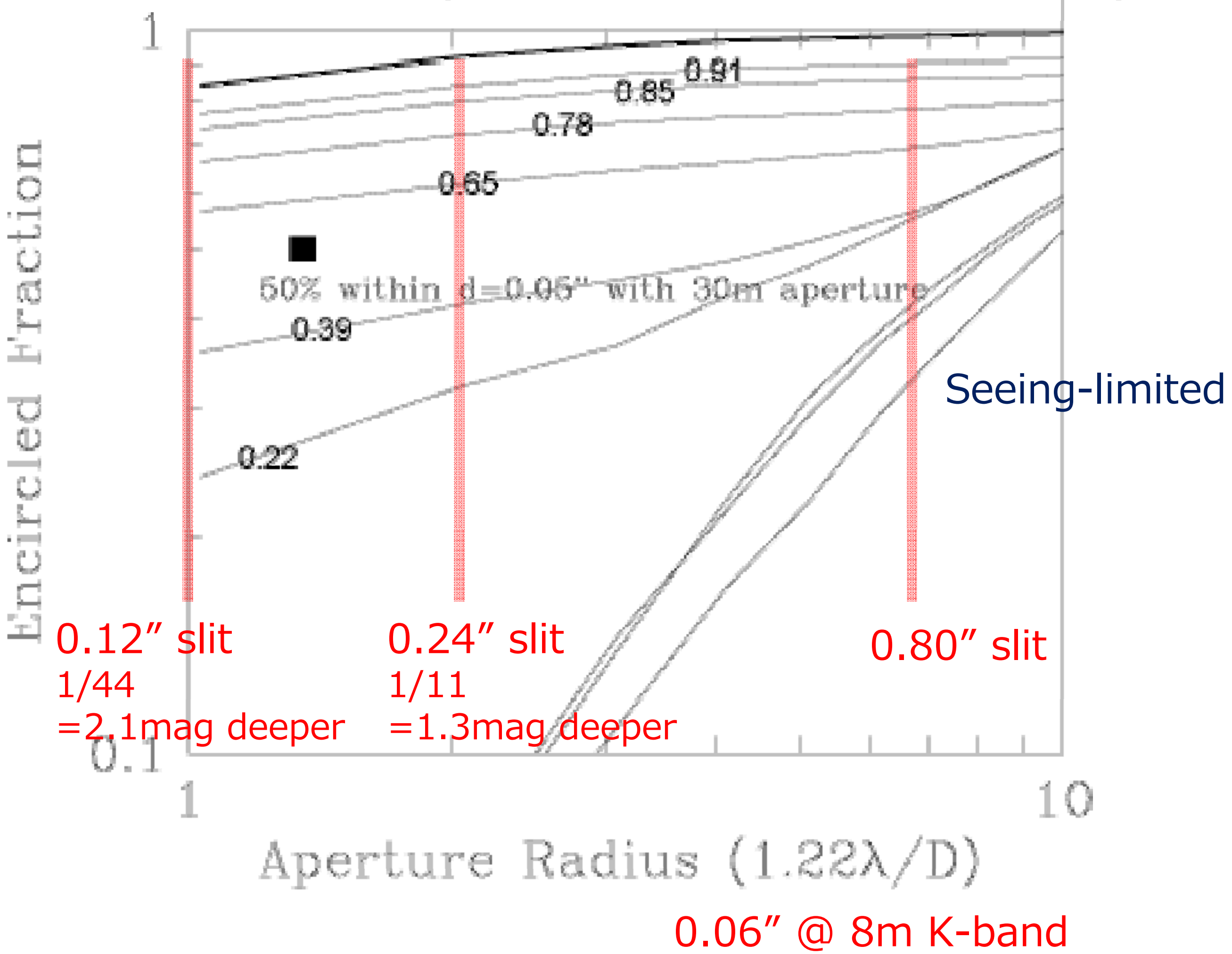


Figure 3: Narrow-field (left) and wide-field (right) LGS asterisms.

3.2 Opto-mechanics

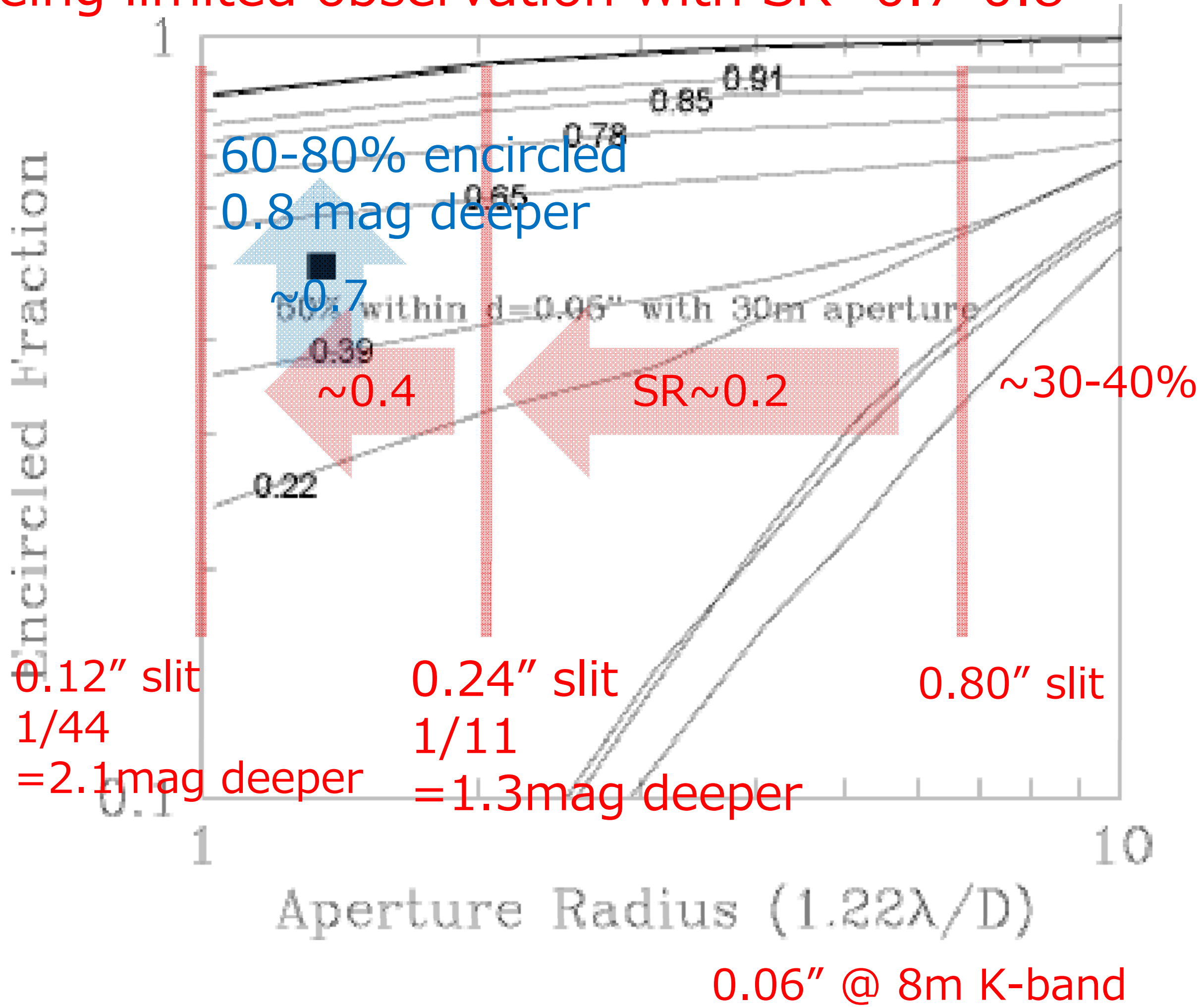
What SR do we want ?

Fraction of light within a slit varies with slit width. Different lines represent different SR ratio (shown with small numbers)

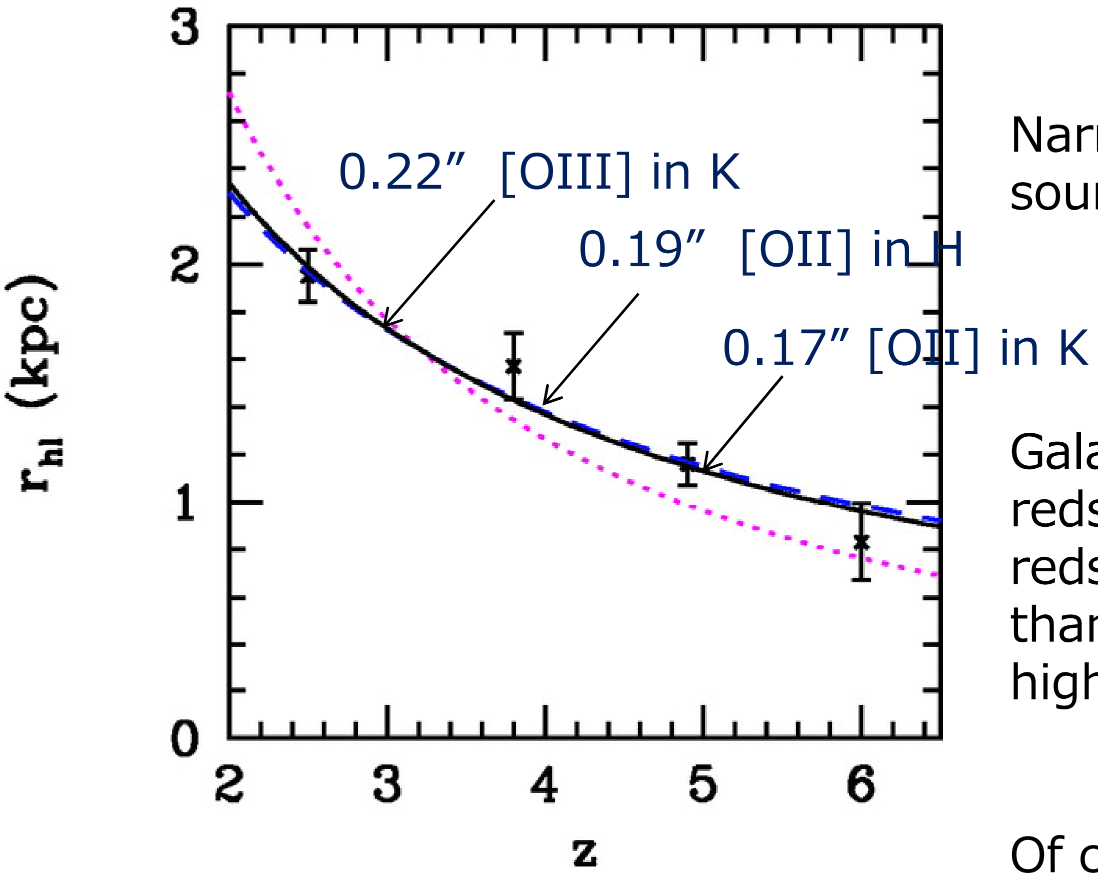


What SR do we want ?

If background limited and point source, then, 3 mag deeper than current seeing limited observation with SR=0.7-0.8



BUT, the gain with higher SR is small for spec. of entire gals (extended obj.)



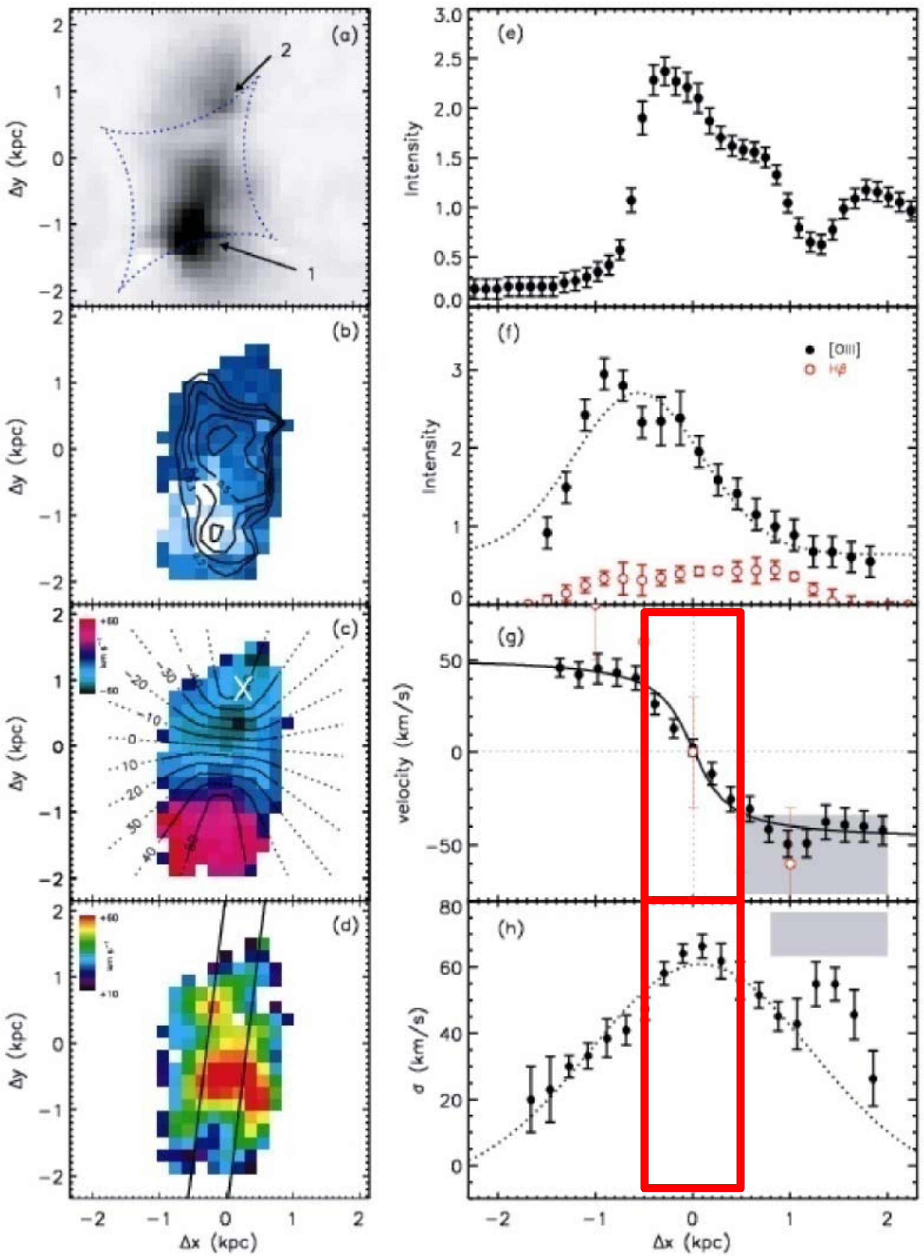
Bouwens et al. 2004, ApJ, 611, L1

Narrower slits can be used for point sources with higher SR, BUT,,,

Galaxies at the intermediate redshifts (or at even higher redshifts) are significantly extended than diffraction limit, the gain with high SR will be smaller.

Of course, you can do spatially-resolved studies with high SR…

Spatially-resolved obs. of distant gals



Z=3 galaxy is observed with effectively 100pc (20-40mas) resolution thanks to gravitational lensing effect (Stark et al. 2008 Nature, 455, 755)。

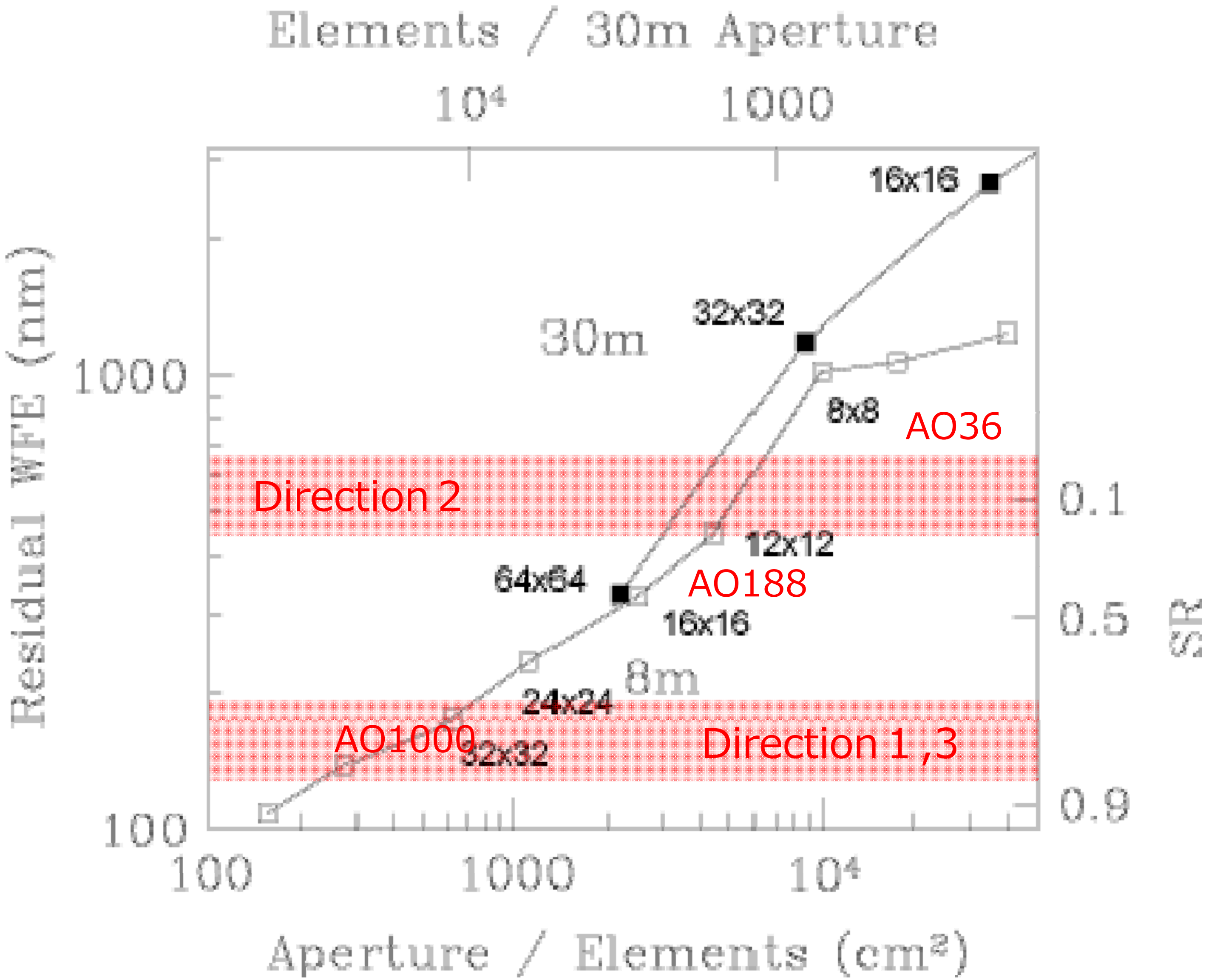
Clear rotation is detected for the first time with this very high spatial resolution.

Need to resolve 10km/s scale velocity structure, R~10,000 is necessary.

Major velocity structure within 1kpc (~0.1”)

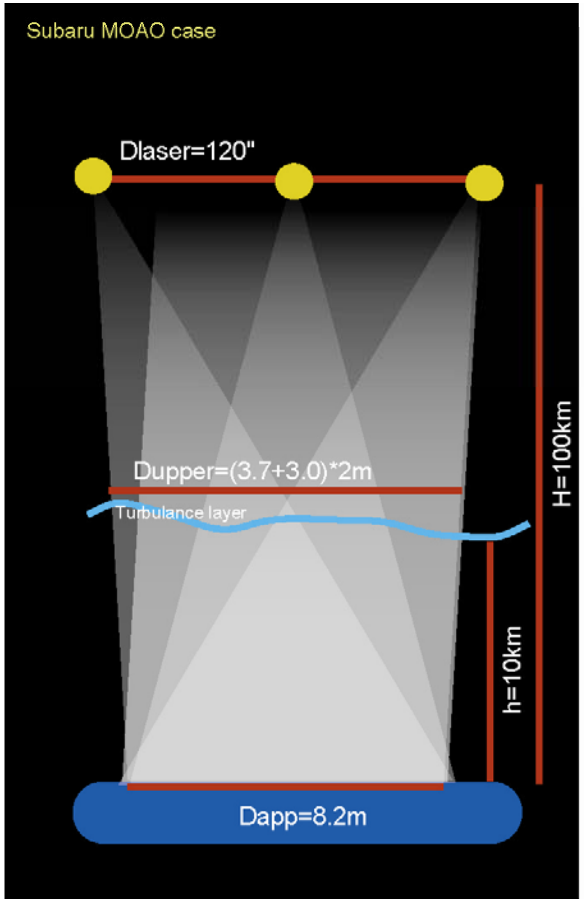
Considering required amount of light to achieve high-spatial and high-spectral resolution, this science case is for TMT ???

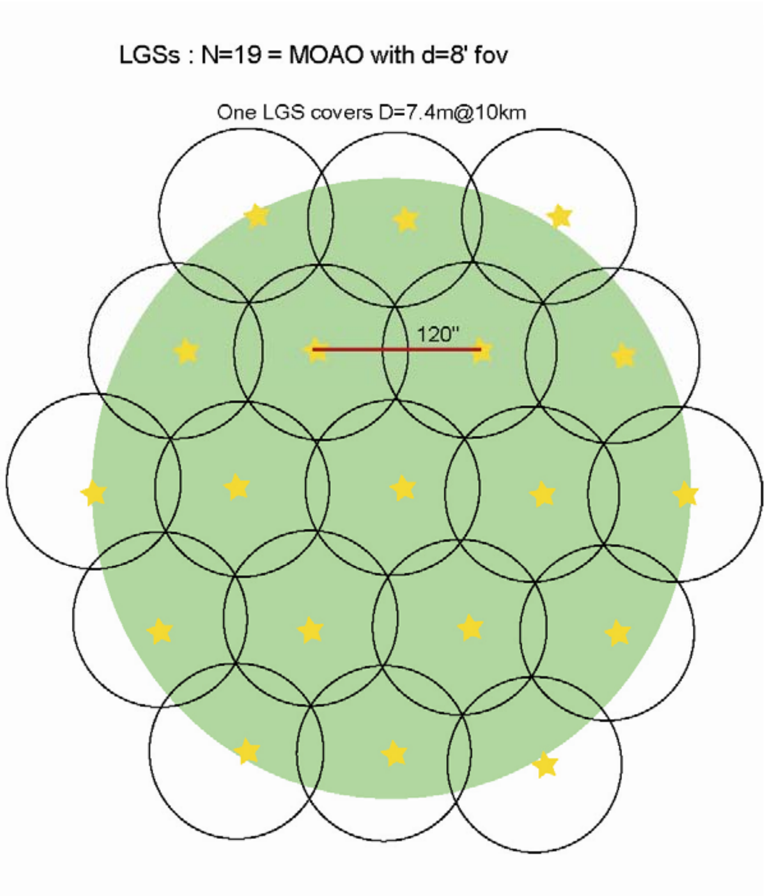
Target SR and required elements

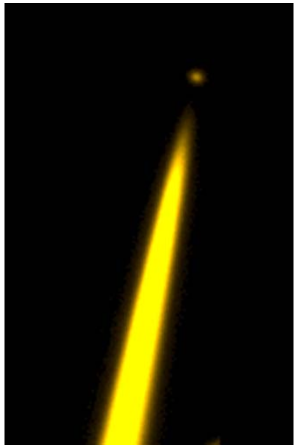


What kind of inst do we need if dir 2 ?

Wide FoV (d=8') MOAO multi-object spec (only with long slits=no IFUs), R=3,000 double-beam spectrograph with zJHK coverage ?







Difficult to realize due to Rayleigh-scattering ?

Summary (in J)

個別天体の深観測： HSCデータベースとの親和性は高い

高赤方偏移の銀河の分光: Lya emitter @ z=7

QSOの中分散(R~10,000)高SN分光：Gun-Peterson trough of z=6-7 QSOs

より高いSR (0.6-0.7 @ K-band = 1,000 elements) で、	Direction 1
=より短い波長 (~9000Aなど) で、	~ Keck-NGAO
高い sky coverage (>50%：GS:R=18mag,60",1GS) で。	~ Gemini-GEMS

多天体の深観測： MOIRCSなどの蓄積

中赤方偏移の赤い銀河の分光観測: Galaxies, AGNs @ z=1-3

そこそこのSR (0.1-0.3 @ K-band ~ 100 elements) で、	Direction 2
広い視野(5-10' scale)で多天体同時に。	

個別天体の高空間分解能観測： わが道を行く？

銀河中心の高空間分解能観測: AGN, stellar pops in local galaxies

JWST の届かないより短い波長(<9000A)で。	Direction 3
HSTで分解できなかったものを分解(SR=0.1@1um)。	Subaru-SCExAO ?

Future works: until the next WS

Directions 1,3

Simulate Keck NGSAO-like, Gemini GEMS-like instruments

1. The expected performance can be confirmed ?
2. How shorter wavelength range can we reach ?

Direction 2

Simulate trade-off between SR and size of FoV.

Next round, which direction is the most attractive scientifically ? Which one do you want ?

Do we need next generation general-purpose AO ? Small-scale grade up (SCeXAO, IRWFS etc) or engineering (RAVEN) are not sufficient ?