すばる望遠鏡レーザートモグラフィ補償光学 + Kyoto3DII で探る星形成銀河の内部構造進化

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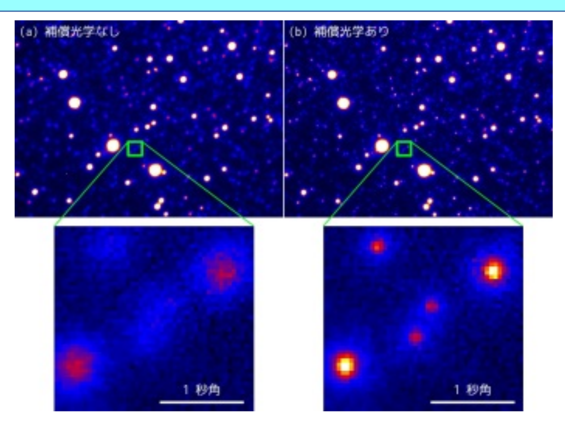
ABSTRACT

Now the telescope which achieves the highest spatial resolution in the visible wavelength is the Hubble Space Telescope (0.05"). In order to resolve internal structure of disks and bulges of the galaxies at high redshifts, we need higher spatial resolution in the wavelength range. For resolving this problem, we use a technology of Adaptive optics. Adaptive optics (AO) is a technique for allowing observation at high spatial resolution on the ground by correcting wave distortion by turbulence in real time. In our laboratory, we are developing laser tomography adaptive optics (LTAO) for the Subaru telescope to accomplish near diffraction limit with the 8.2-m Subaru telescope in the visible wavelength (0.02") which is higher spatial resolution than Hubble Space Telescope and JWST. It is expected that we can spatially resolve properties of high-redshift galaxies such as stellar kinematics and morphology. We report the predicted performance with the LTAO on Subaru, and discuss current status of the development and future prospects of the project as well as science cases.

1. What is Adaptive Optics?

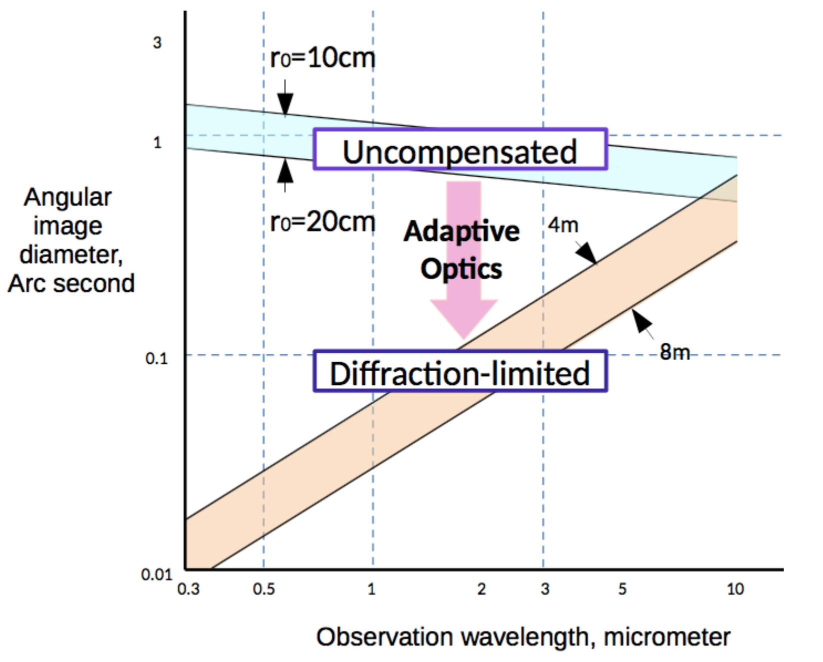
The effect of atmospheric turbulence is severe in ground-based observations. This turbulence makes the wavefront from the stars distorted into bumpy surface and prevent us from carrying out observations at high spatial resolution. AO is a technology that measure the turbulence of wavefront of reference stars and then recover the undistorted wavefront by using that information. Using AO, we can improve the spatial resolution of images

Images of the globular cluster M3



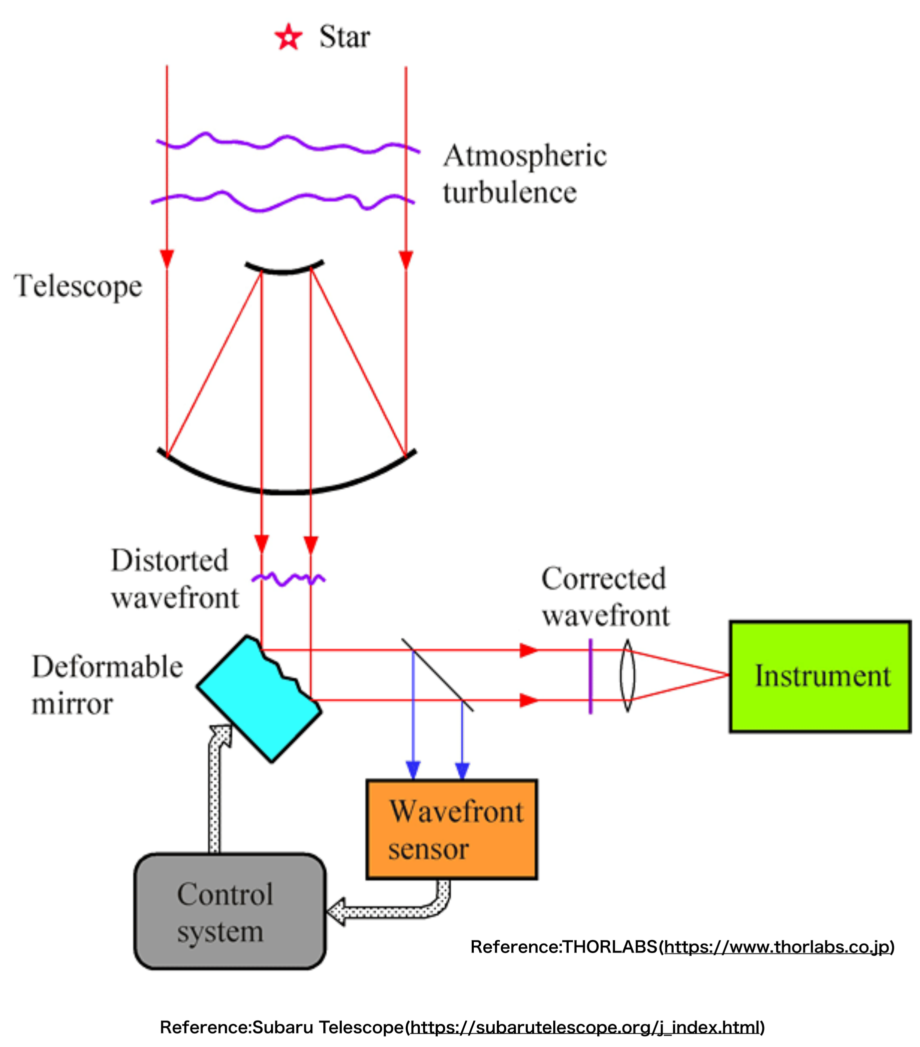
without adaptive optics | with adaptive optics

Reference:Subaru Telescope(https://subarutelescope.org/j_index.html)



Without seeing, a resolution is determined by the size of the diameter of a telescope. With seeing, resolution is determined by r_0. r_0 is a scale within which the distorted wavefront can be regarded as flat, and called the Fried parameter(10〜20cm@500nm). When wavelength is a smaller than 10um, resolution is determined by r_0.

Schematic diagram of Adaptive Optics



Reference:Subaru Telescope(https://subarutelescope.org/j_index.html)

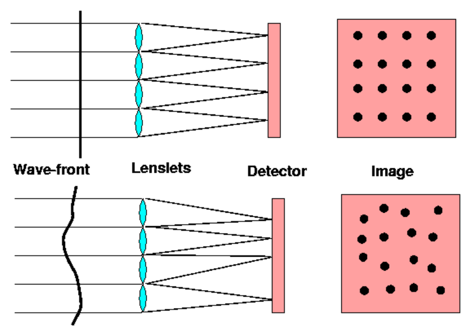
-Laser
589.2nm laser excites Na atoms at 90km height. The Na atoms re-emit the visible light, producing an artificial star.

-Deformable Mirror
The shape of mirror is controlled by actuators.

←Deformable mirror used in Subaru currently

Reference:Subaru Telescope(https://subarutelescope.org/j_index.html)

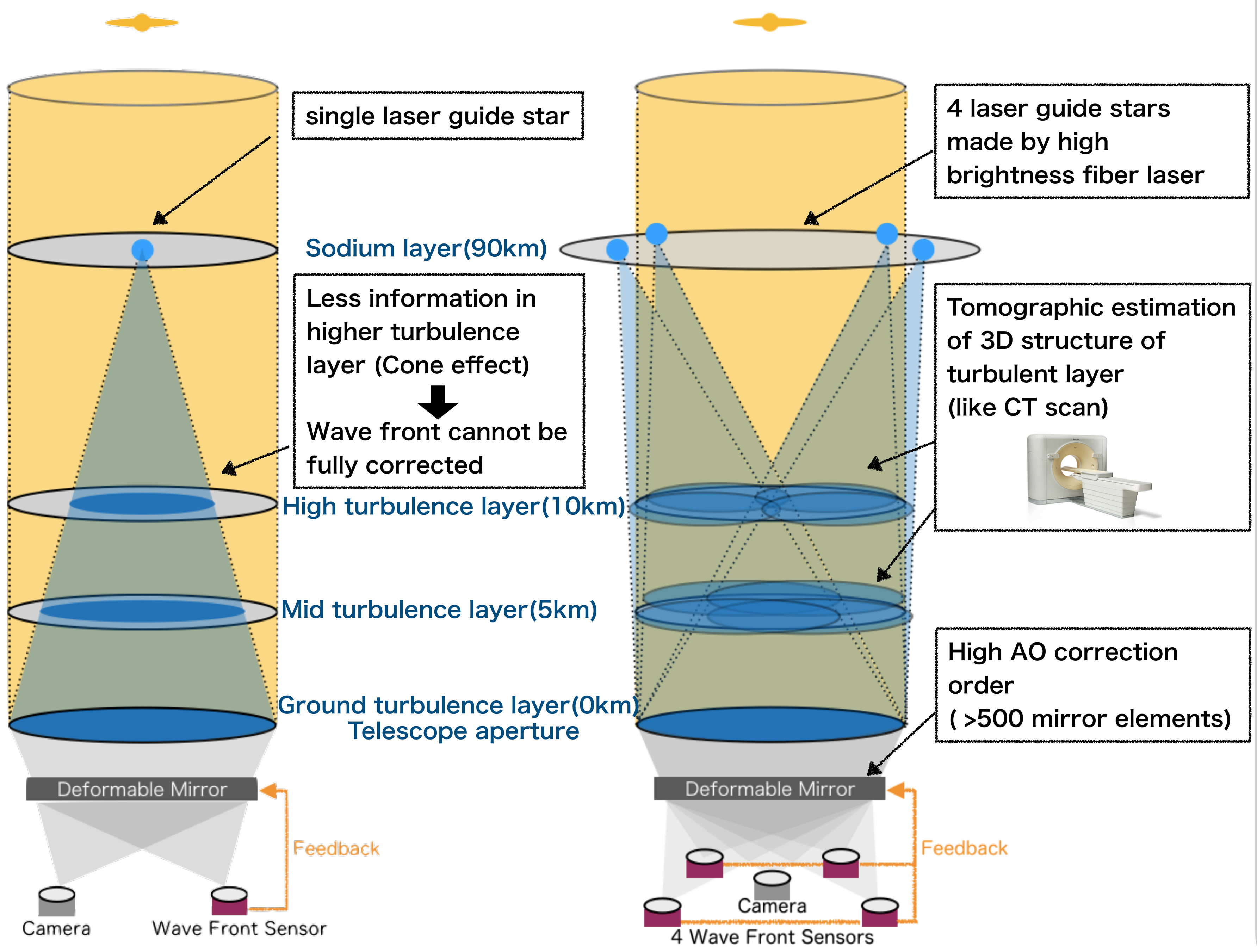
-Wave Front Sensor
Shack-Hartman wave fronts sensor
(Wave front shape is measured with a micro lens array.)



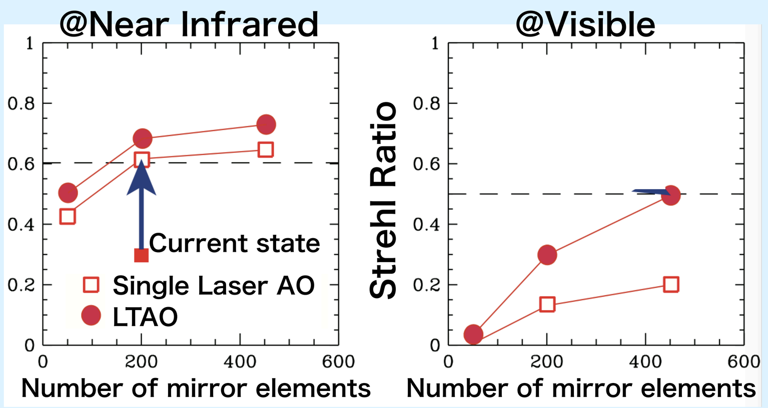
Reference: http://www.ctio.noao.edu/~atokovin/tutorial/intro.html

2. Current AO system VS New LTAO system

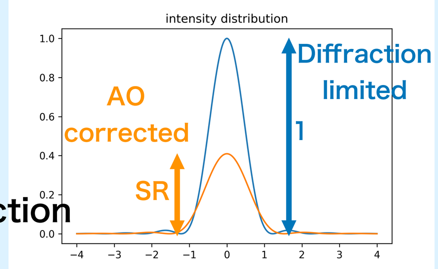
Current AO system (Subaru AO188)	New LTAO system (Laser Tomography AO)

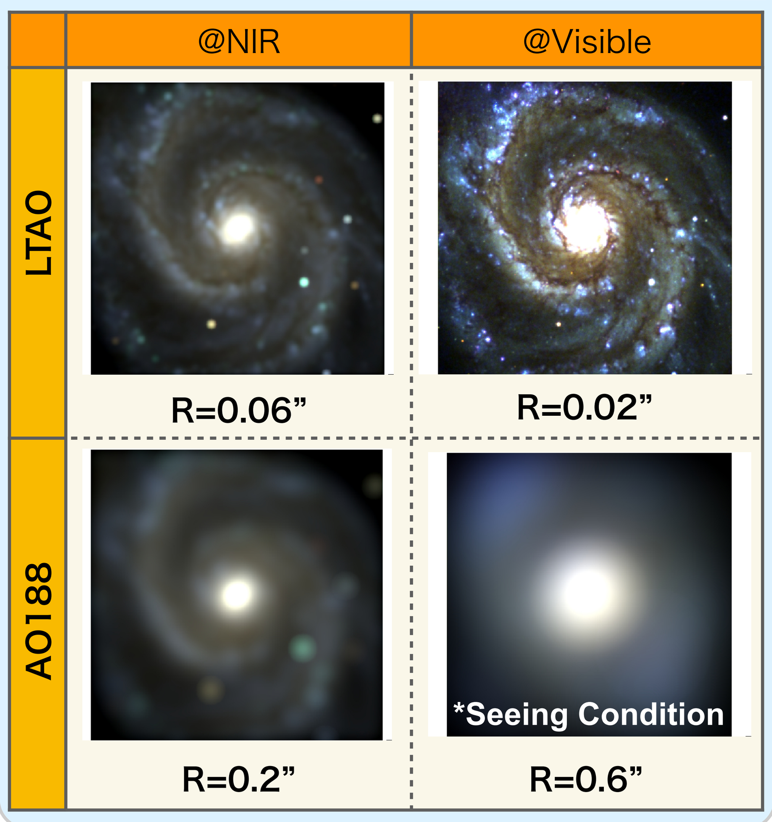


Simulation of Performance



Strehl Ratio(SR) represents AO correction level. SR>0.5 can be regarded as diffraction limit



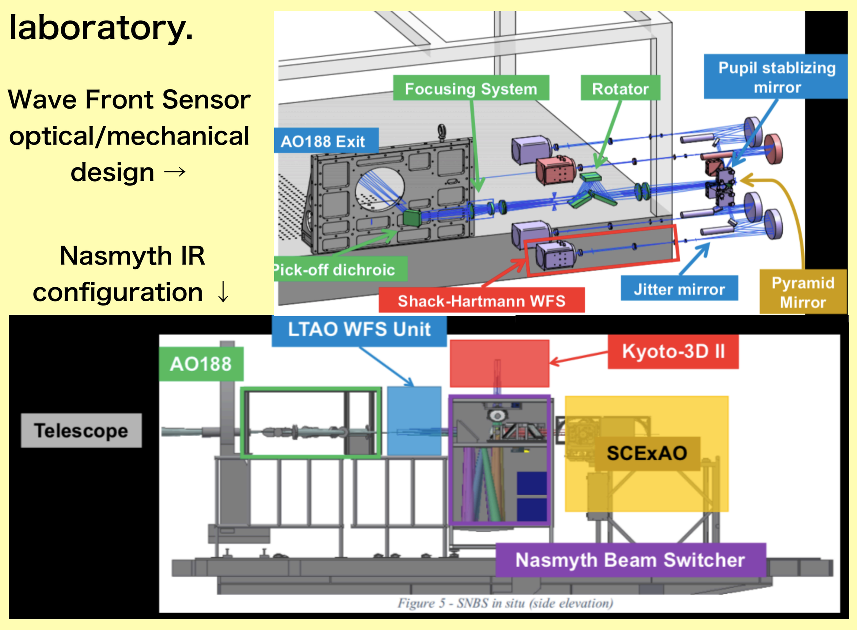


3. Status Report

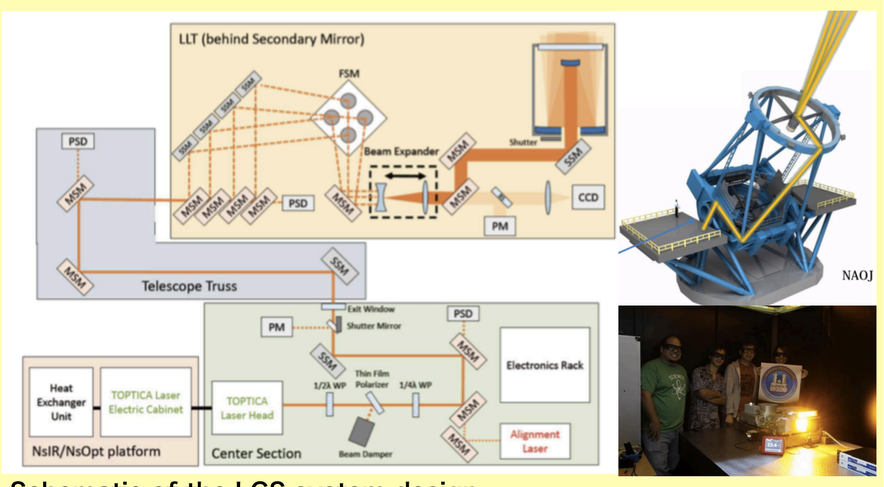
Wave Front Sensor Unit
Optical design has already been fixed and now we are arranging a prototype instruments in our laboratory.

Wave Front Sensor optical/mechanical design →

Nasmyth IR configuration ↓



Laser Guide Star System
The four artificial stars will be crated by a 20W TOPTICA fiber laser. The asterism radius of LGSs is adjustable from R=5" to 20" on sky. The fiber laser is under testing in laboratory in Hilo.



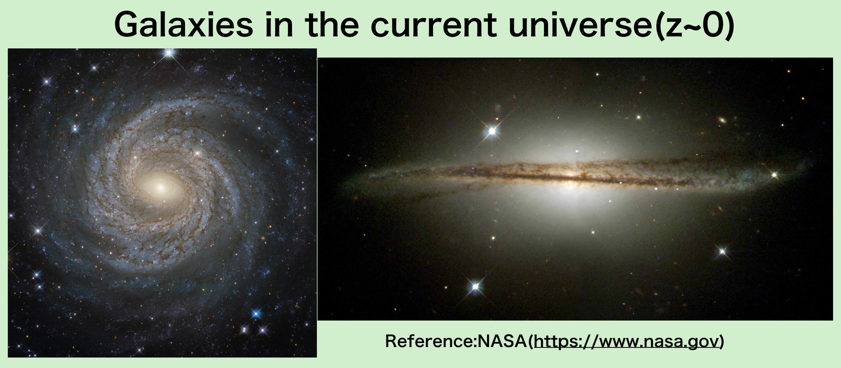
Schematic of the LGS system design

4. What will be revealed by the new LTAO system?

→ The process of establishing galaxy's morphology

Galaxies dominating in the early universe were different from that in thecurrent universe

Galaxies in the current universe(z~0)

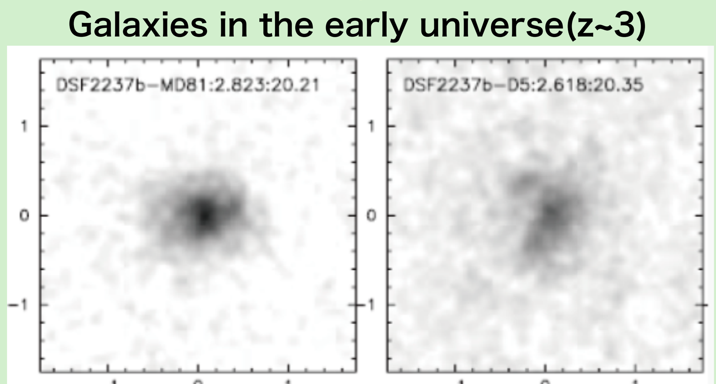


Reference:NASA(https://www.nasa.gov)

- Bulge has low surface-density
- Disc is thin

Large morphological differences!

Galaxies in the early universe(z~3)

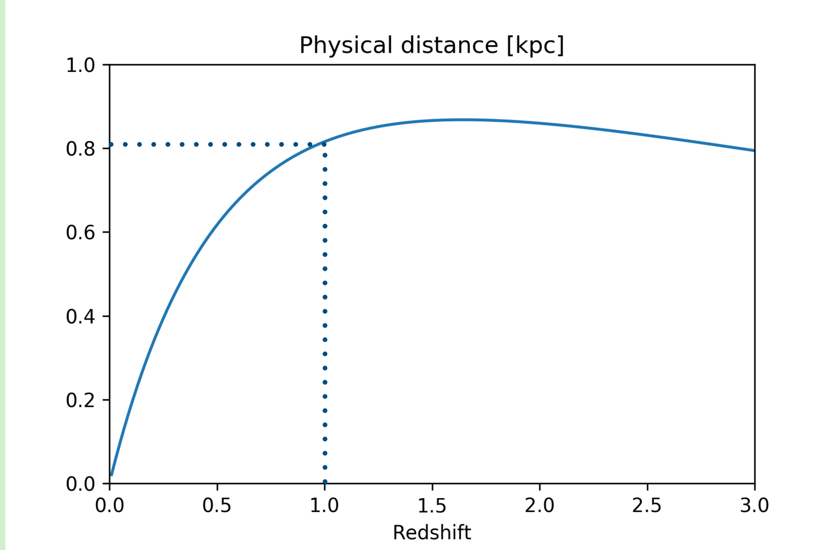


Reference:ApJ Supplements 175.ppl

- Some galaxies have high surface-density
- Some galaxies have very thick disc

We can reveal morphological and dynamical structure of galaxies at z~1 by high resolution observation

@z~1 with resolution 0.1", We can resolve <1kpc!



Science Cases
- Disc structures of star-forming galaxies @z~1
- Bulge formation in galaxies @z~2
- Star formation clumps of clumpy galaxies @z>1
- Kinematics of compact quiescent galaxies @z~1
- Estimation of BH mass of dwarf galaxies @z<1
- Gas outflow from AGN galaxies @z<1 etc. . .

What is your science case with the high spacial visible IFU observations?
Let's discuss about more science cases !

The performance of the instruments

@Visible wavelength range, we can do Integral Field Spectroscopy using Kyoto3D II to reveal the stellar dynamics evolution.

Main Parameter of Kyoto3D II

Field of View	3.1"x2.5"
Spacial scale	0.084"/lens
Spacial Resolution	0.2" FWHM(with AO)
Wavelength Resolution	R~1200
Wavelength Range	640-740 nm (Grism No.4) 720-920 nm (Grism No.5)

@Near Infrared wavelength range, we can do Photometry using IRCS to reveal the stellar distribution evolution.

Main Parameter of IRCS

Field of View (High Resolution mode)	21.06"(with AO)
Pixel scale (High Resolution mode)	20.57(+/-)0.04" (with AO)
Field of View (Low Resolution mode)	54.04"(with AO)
Pixel scale (Low Resolution mode)	52.77(+/-)0.04" (with AO)

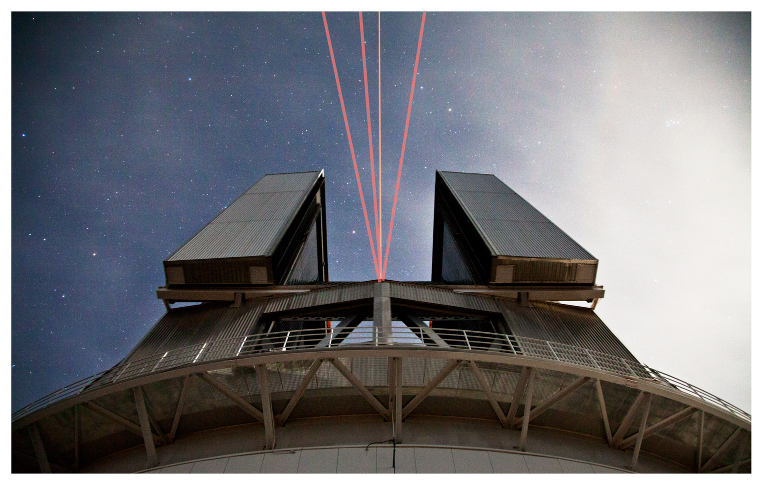
5. Summary

① AO is a necessary technique in ground-based observation using large aperture telescope.

② In our group, we are developing new Laser Tomography Adaptive Optics system.

③ The new system will make it possible to do high resolution observation in both of Visible and NIR wavelength range.

④ In science, the new system will be useful to reveal the evolution of galaxies' morphological structures such as stellar distribution or dynamics.



Reference:Subaru Telescope(https://subarutelescope.org/j_index.html)