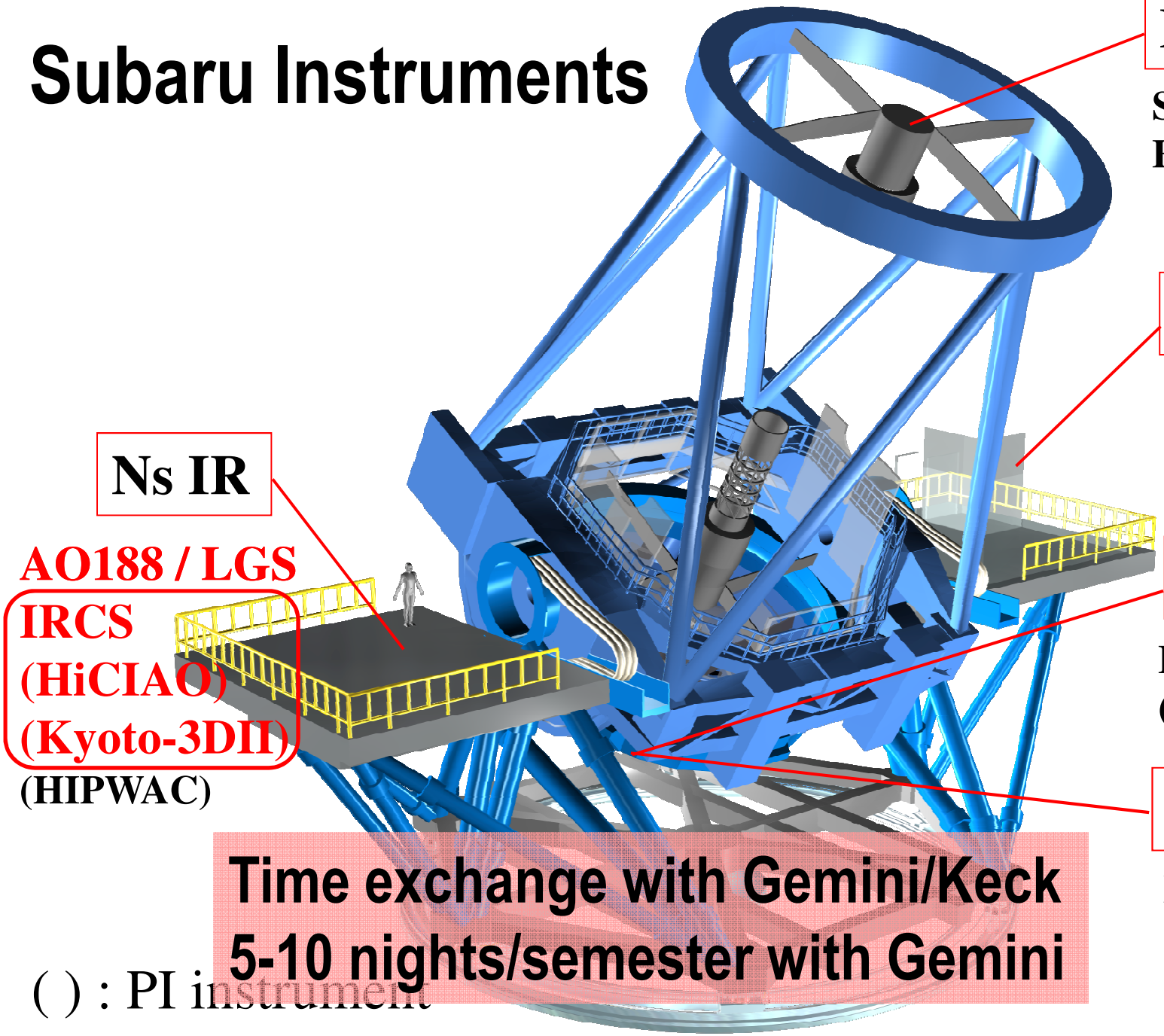
Future Instrument Plan of Subaru Telescope with Next Generation Adaptive Optics

Hideki Takami（Subaru Telescope, Mitaka）

2012/6/20 @ Victoria

Subaru Instruments



Primary

Suprime-Cam
FMOS

Ns Opt

HDS

Ns IR

AO188 / LGS
IRCS
(HiCIAO)
(Kyoto-3DII)
(HIPWAC)

Cs Opt

FOCAS
(Kyoto-3DII)

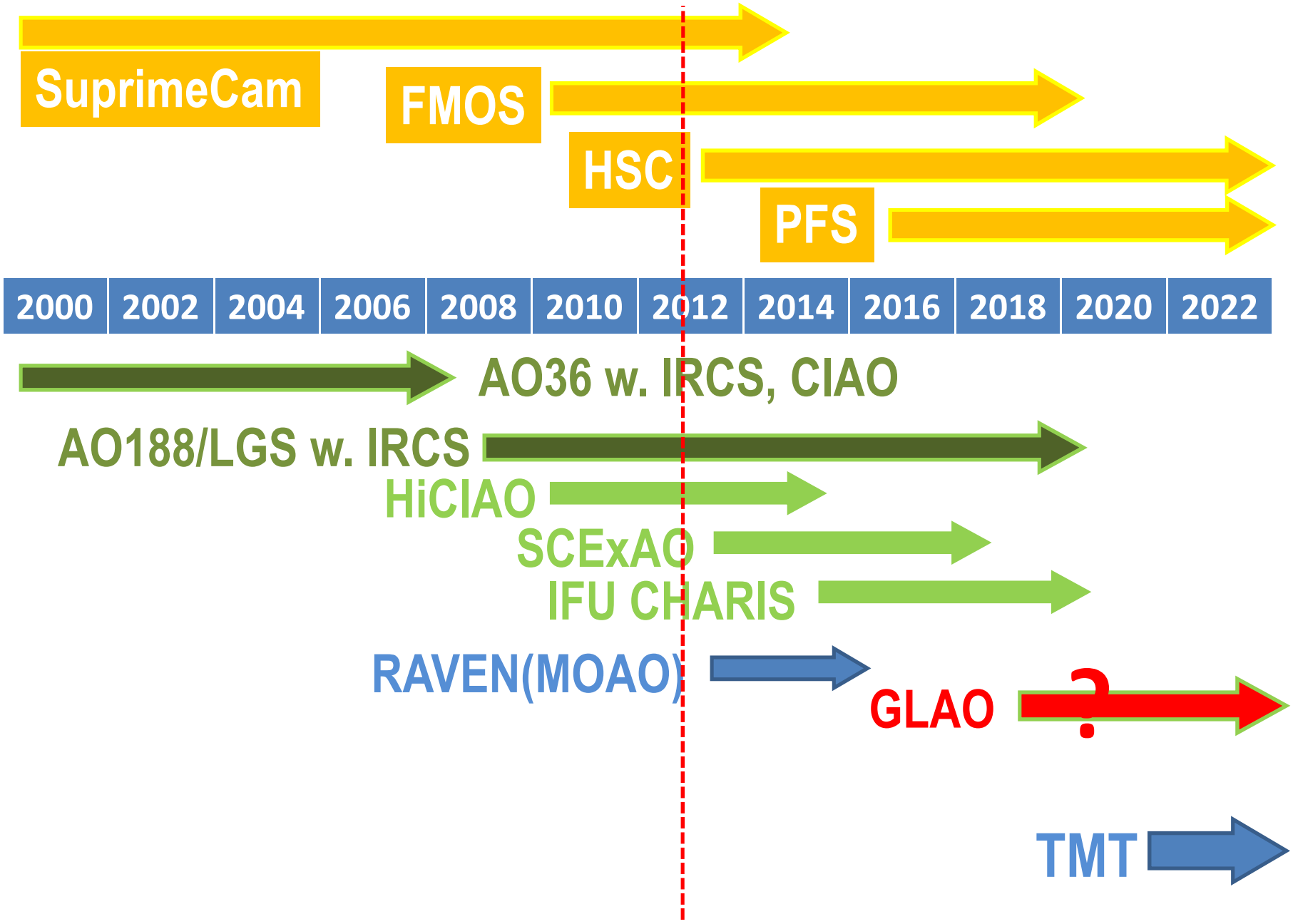
Cs IR

MOIRCS
COMICS

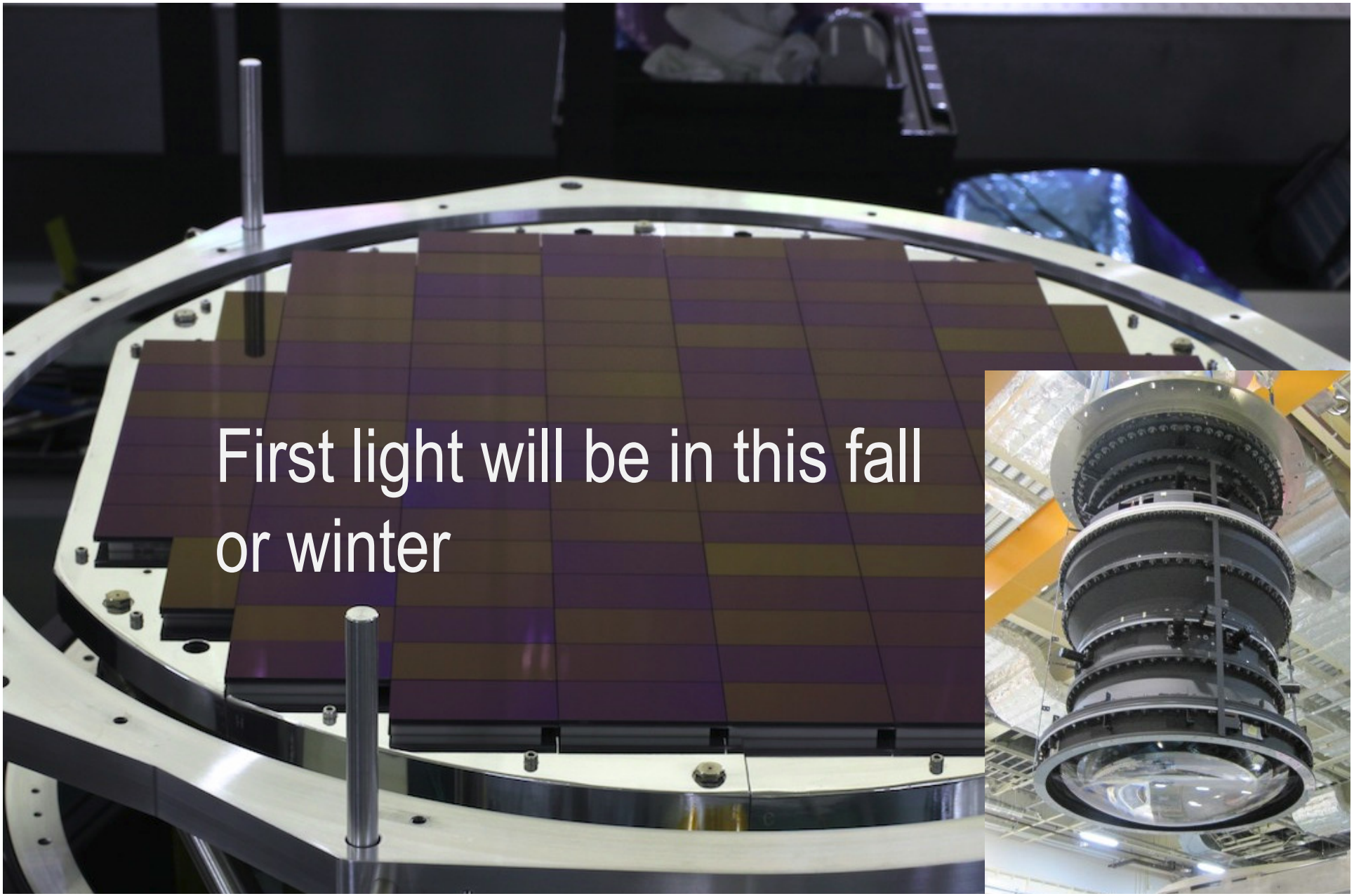
Time exchange with Gemini/Keck
5-10 nights/semester with Gemini

( ) : PI instrument

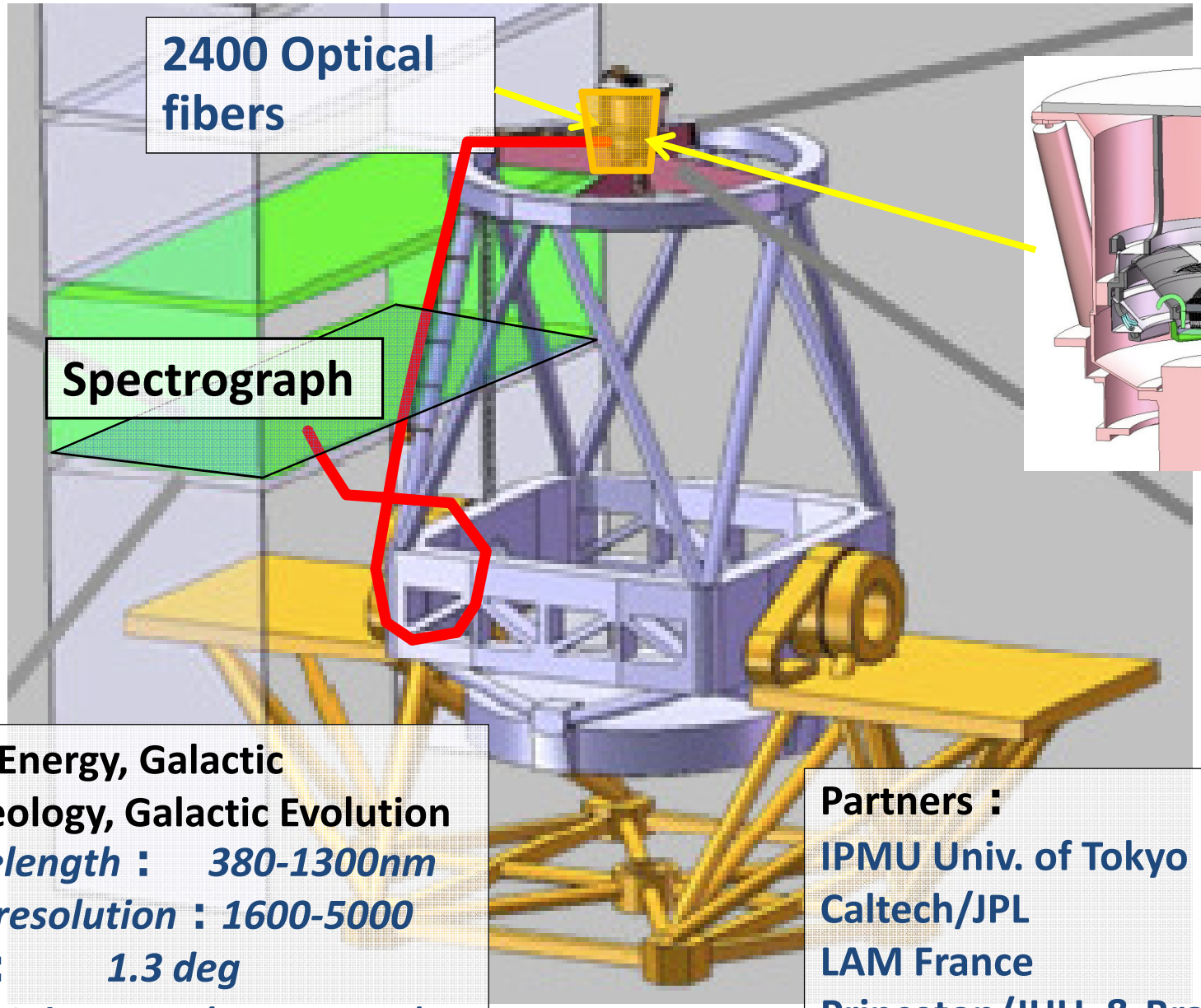
Subaru major instruments and AO programs

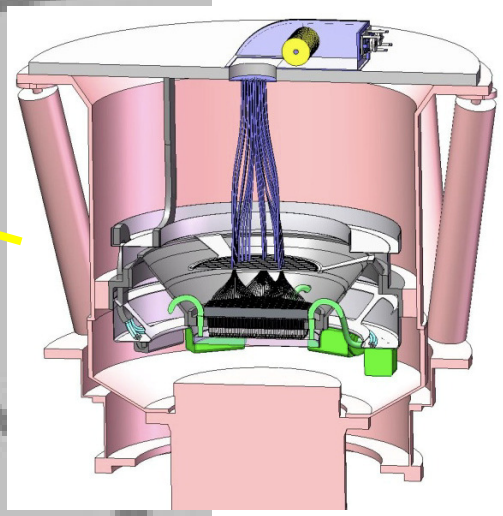


Hyper SuprimeCam ： 1.5 deg FOV 2012~



PFS project 2016~





Dark Energy, Galactic Archeology, Galactic Evolution

Wavelength **：** ***380-1300nm***

Spec resolution **：** ***1600-5000***

FOV **：** ***1.3 deg***

First Light: 2016 (CoDR 2012)

Partners：

IPMU Univ. of Tokyo

Caltech/JPL

LAM France

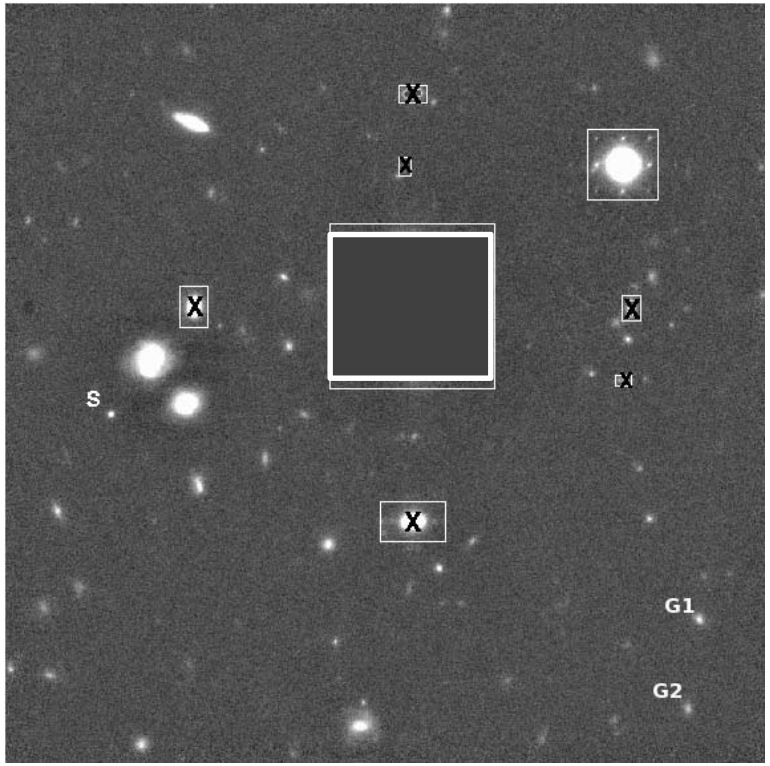
Princeton/JHU & Brazil

Subaru AO Overview

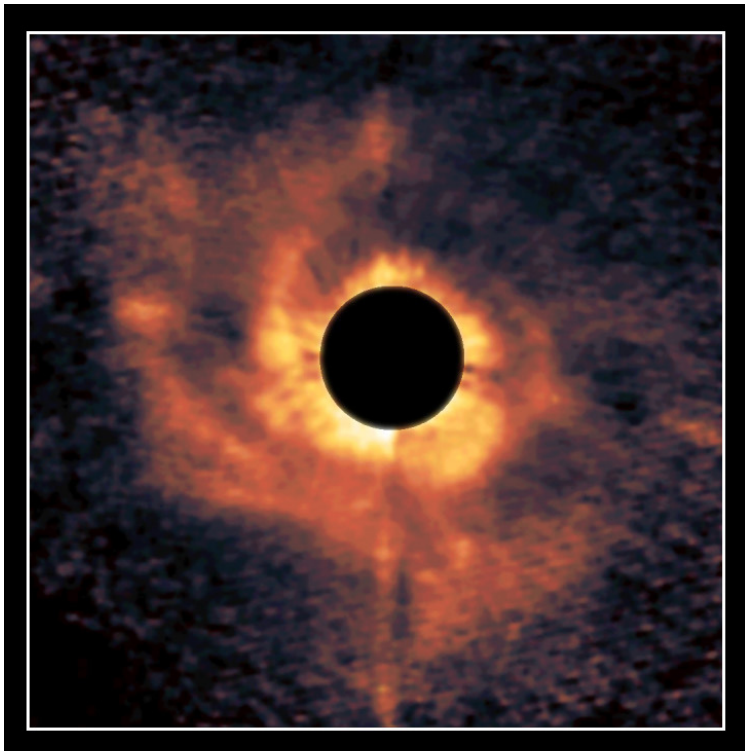
AO36 (2000-2008)

Subaru's first AO system with 36 element curvature sensor at Cassegrain focus.

Deep IR imaging
(Minowa et al. 2005)

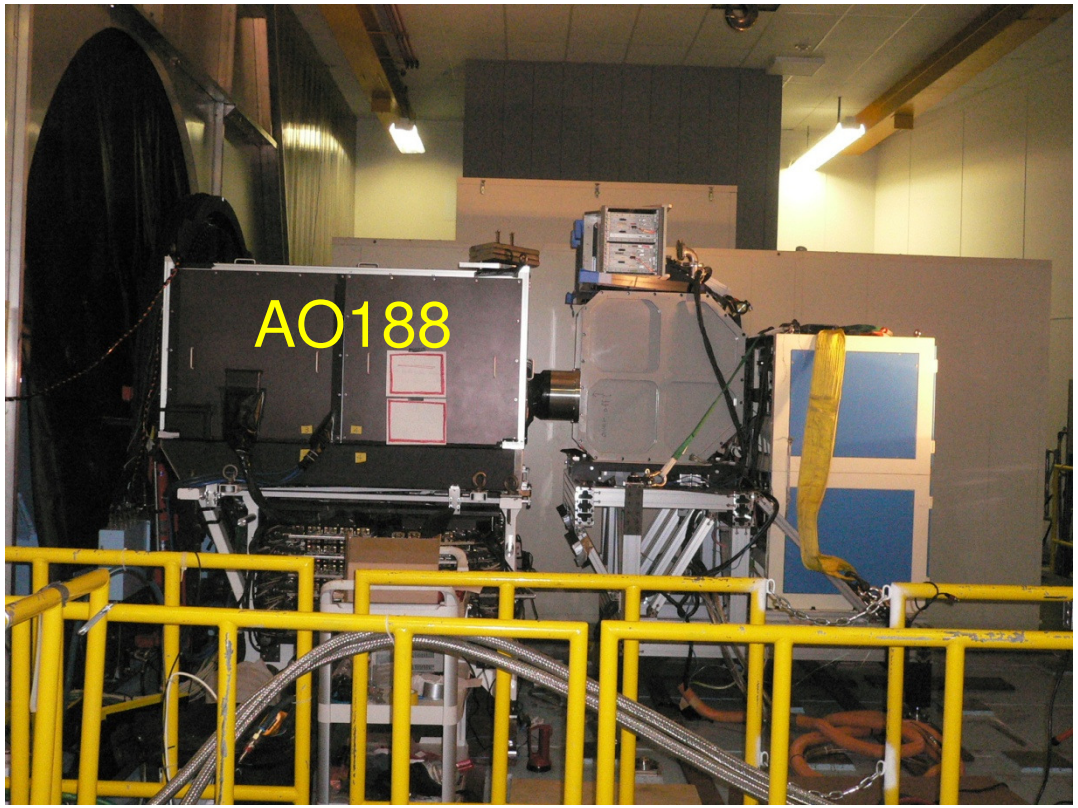


AB Aur: Protoplanetary Disk
(Fukagawa et al. 2004)

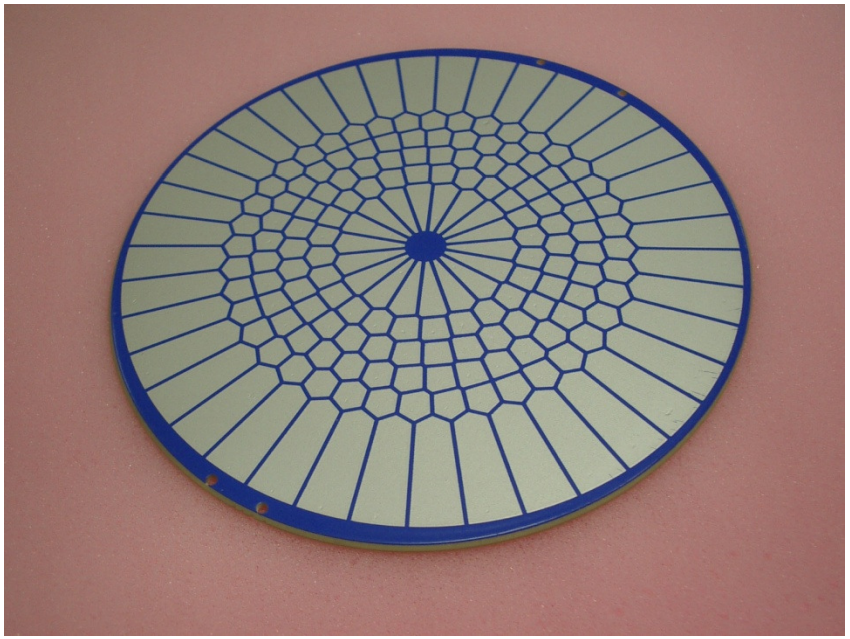


AO188 (2008-)

- Current AO system with 188 element curvature sensor, NGS/LGS mode at Nasmyth focus.

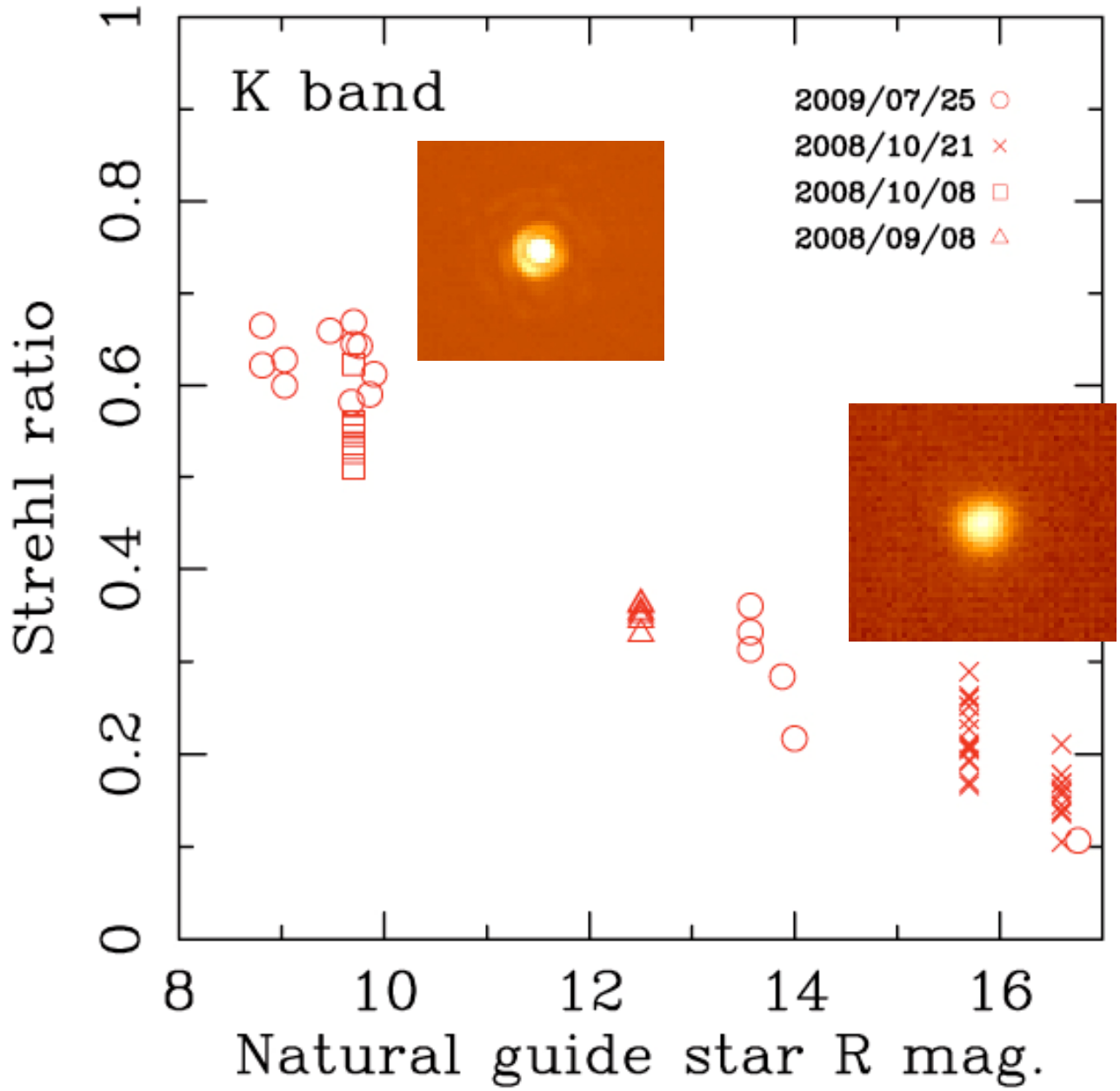


AO188 at Nasmyth focus



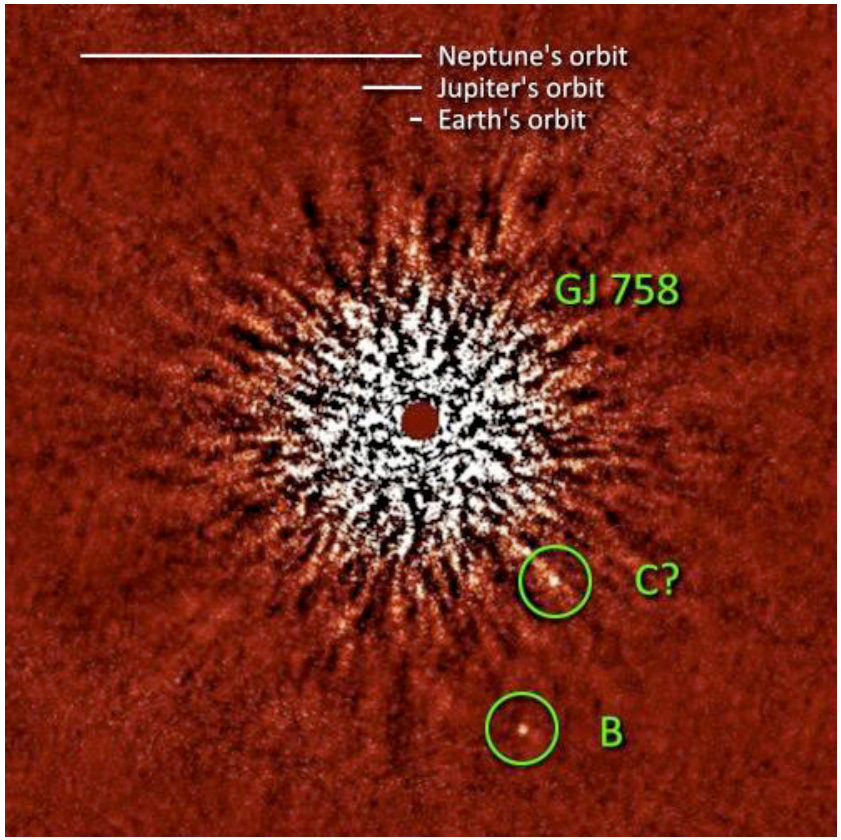
Bimorph deformable mirror with 188 elements (CILAS)

AO188(NGS) performance vs GS mag

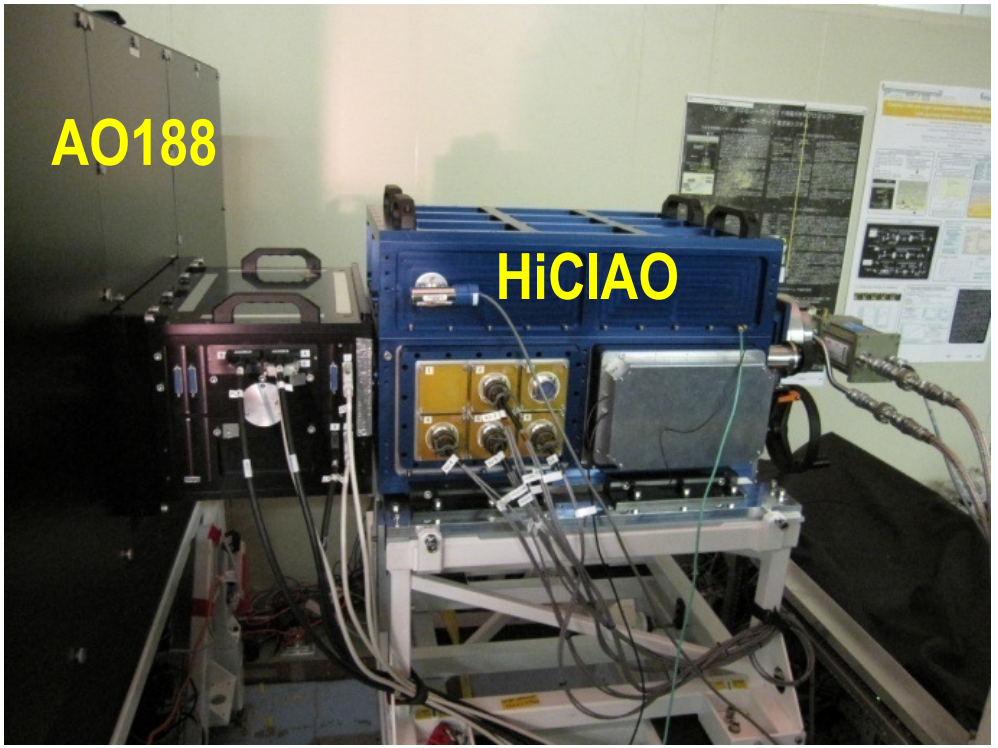


Science with AO188 (NGS)

Discovery of Exoplanet around Solar type star with AO188+HiCIAO (ADI mode）



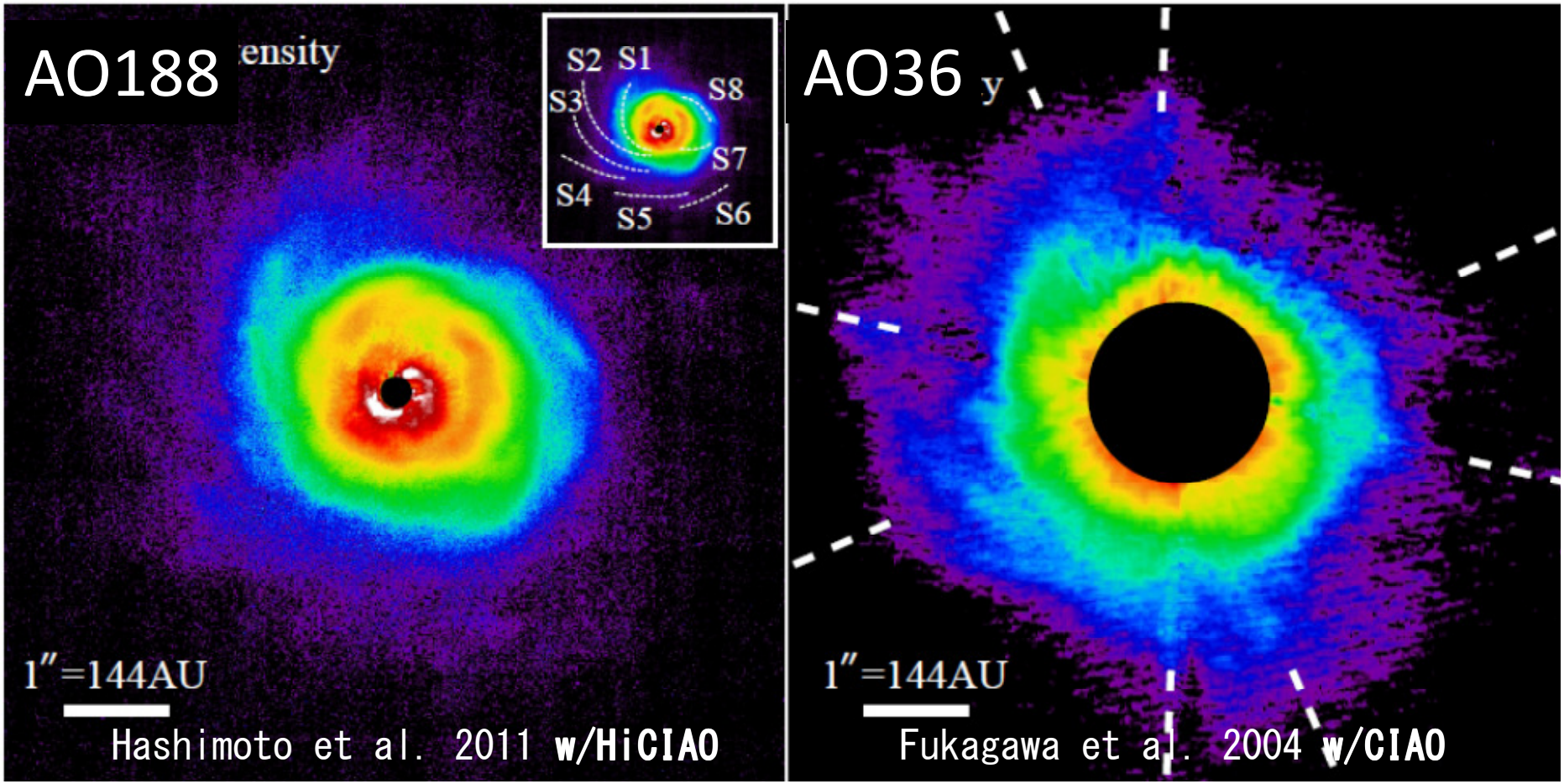
(Thalmann et al. 2009, 2011)



AO188+HiCIAO (Coronagraph with 2k x 2k detector

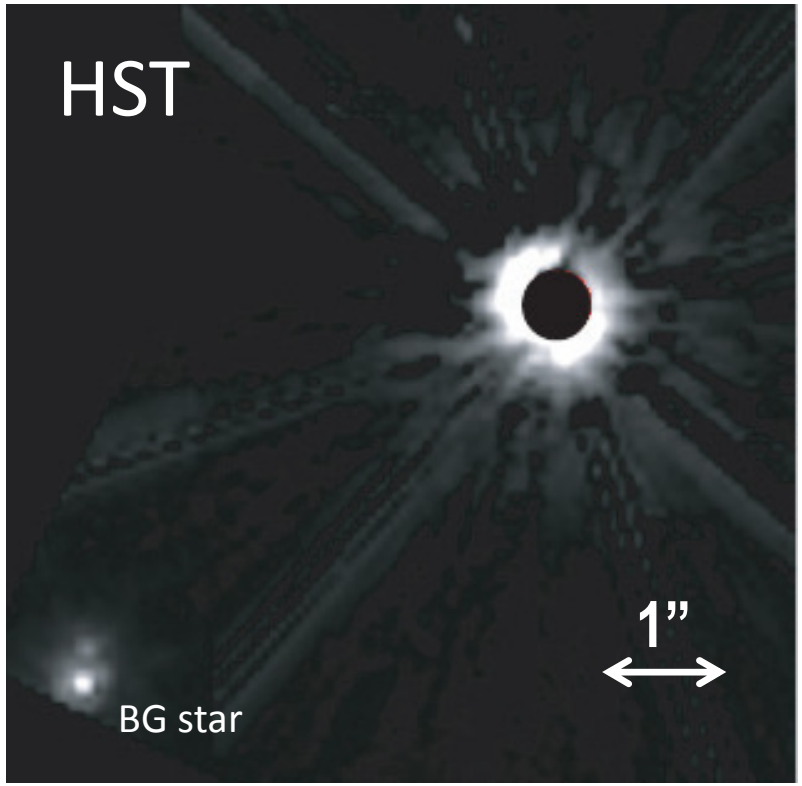
Sharpest and closest image of AB Aur Disk

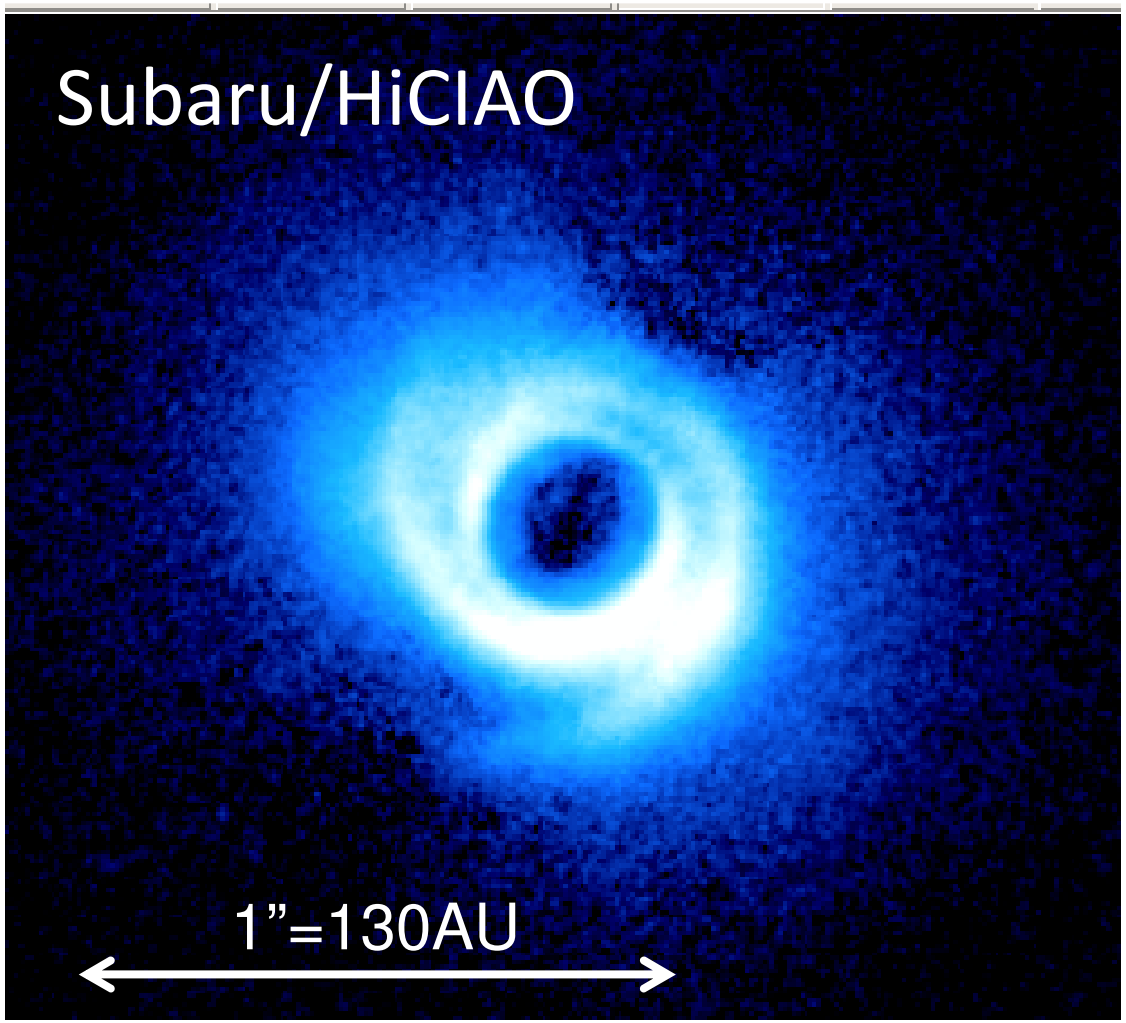
- **The first 'r<40 AU region' & '8 AU resolution' images (at λ=1.6μm)**
- PI image, but mostly INTENSITY pattern (not polarization pattern).
- Richest information near the central region (cf. HiCIAO vs. CIAO images)
- Hashimoto et al. 2011, ApJL



Mini-spirals within Neptune orbit around an F star SAO206462: perturbing planet?

(Muto et al. 2012) mass=1.7Mo, age=8Myr





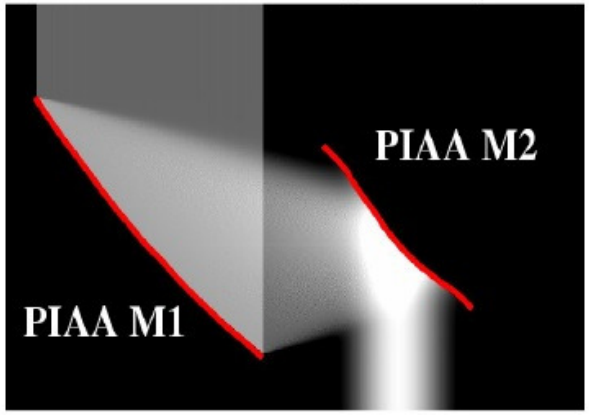
Subaru/HiCIAO - 0.3” mask

vs.

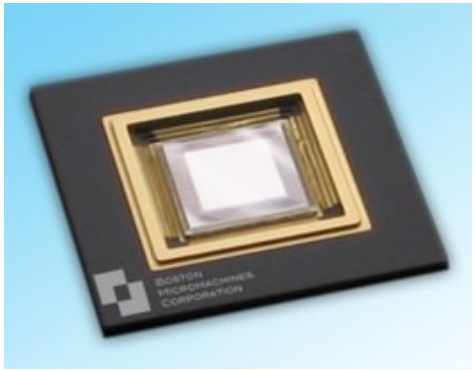
HST/NICMOS - 0.6”mask

(Grady+2009)

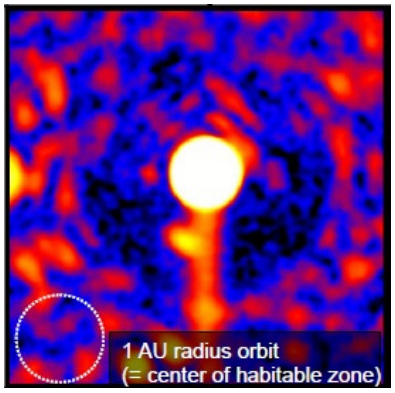
SCExAO (Extreme AO with coronagraph)



PIAA apodization coronagraph

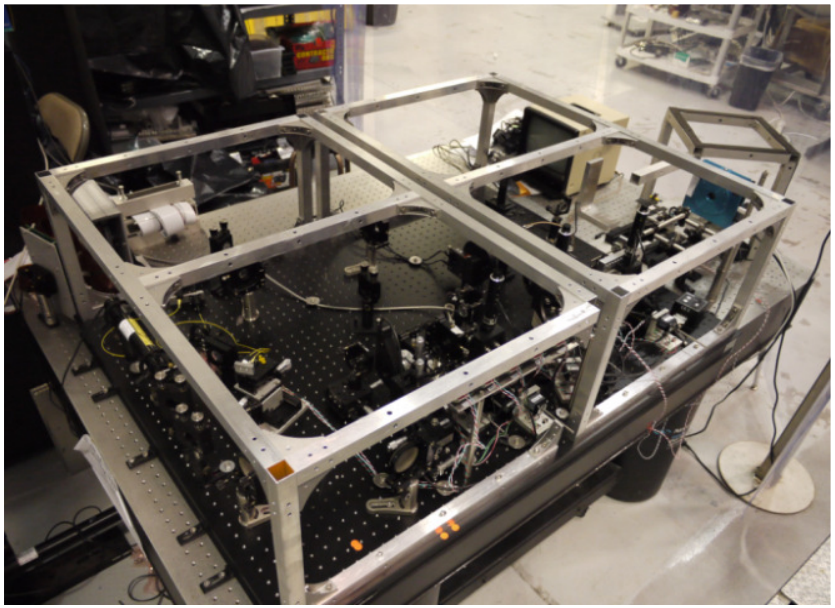


32x32 MEMS DM

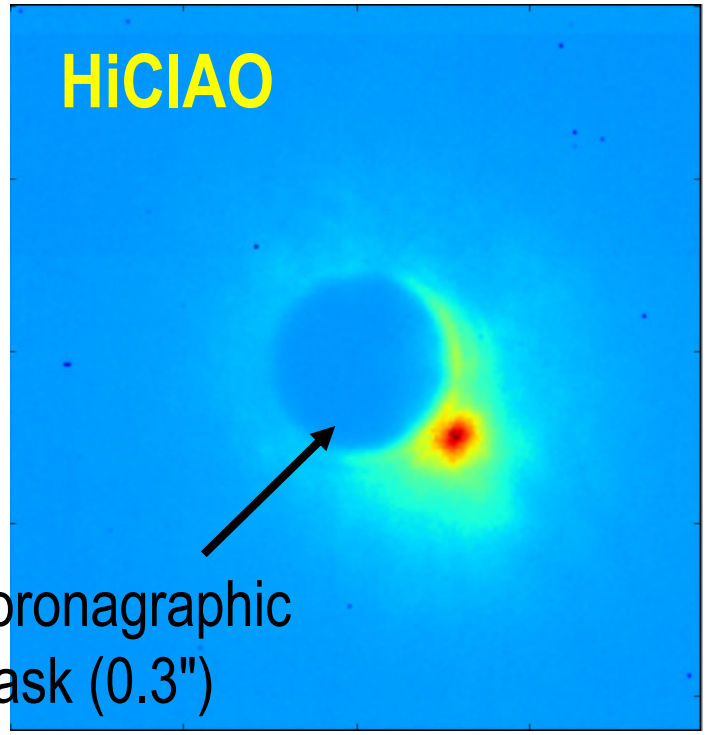


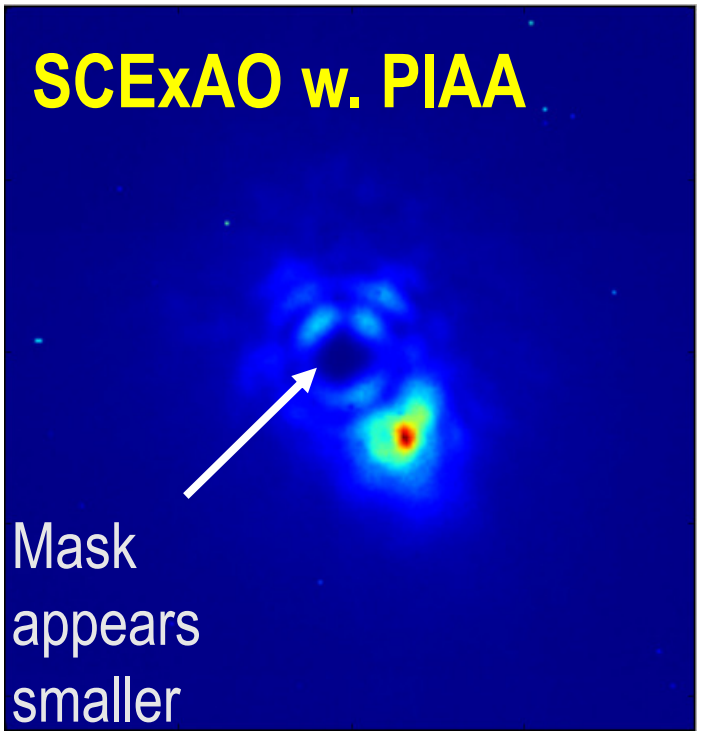
- reach 0.5～3λ/D
- 2e-7 (raw w/ PIAA)
- 3e-9 (speckle cntrl)

Onsky
Test 2011～



First light for SCExAO/HiCIAO (2012/2)



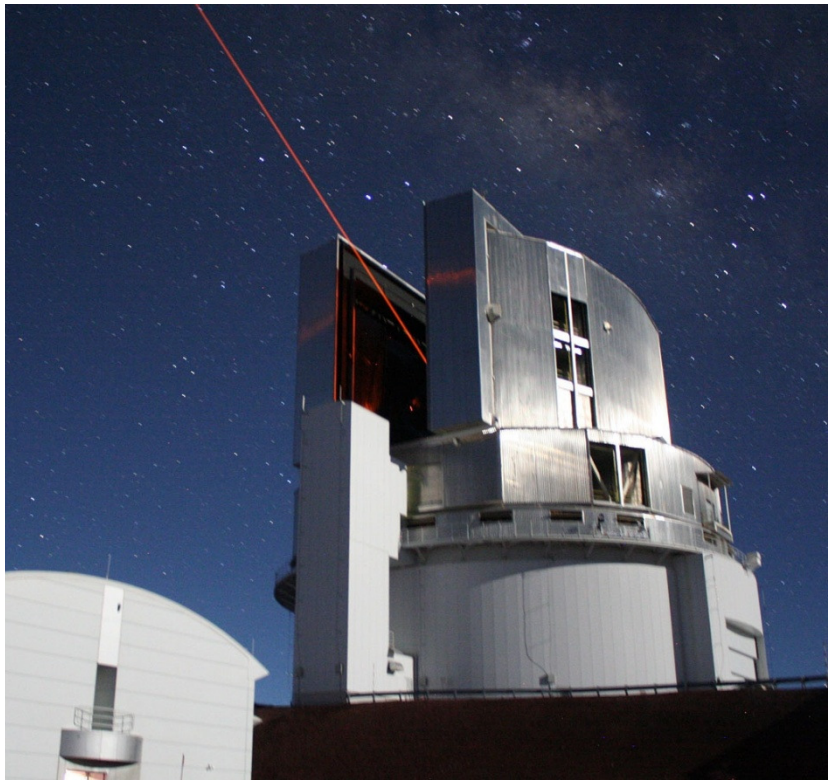


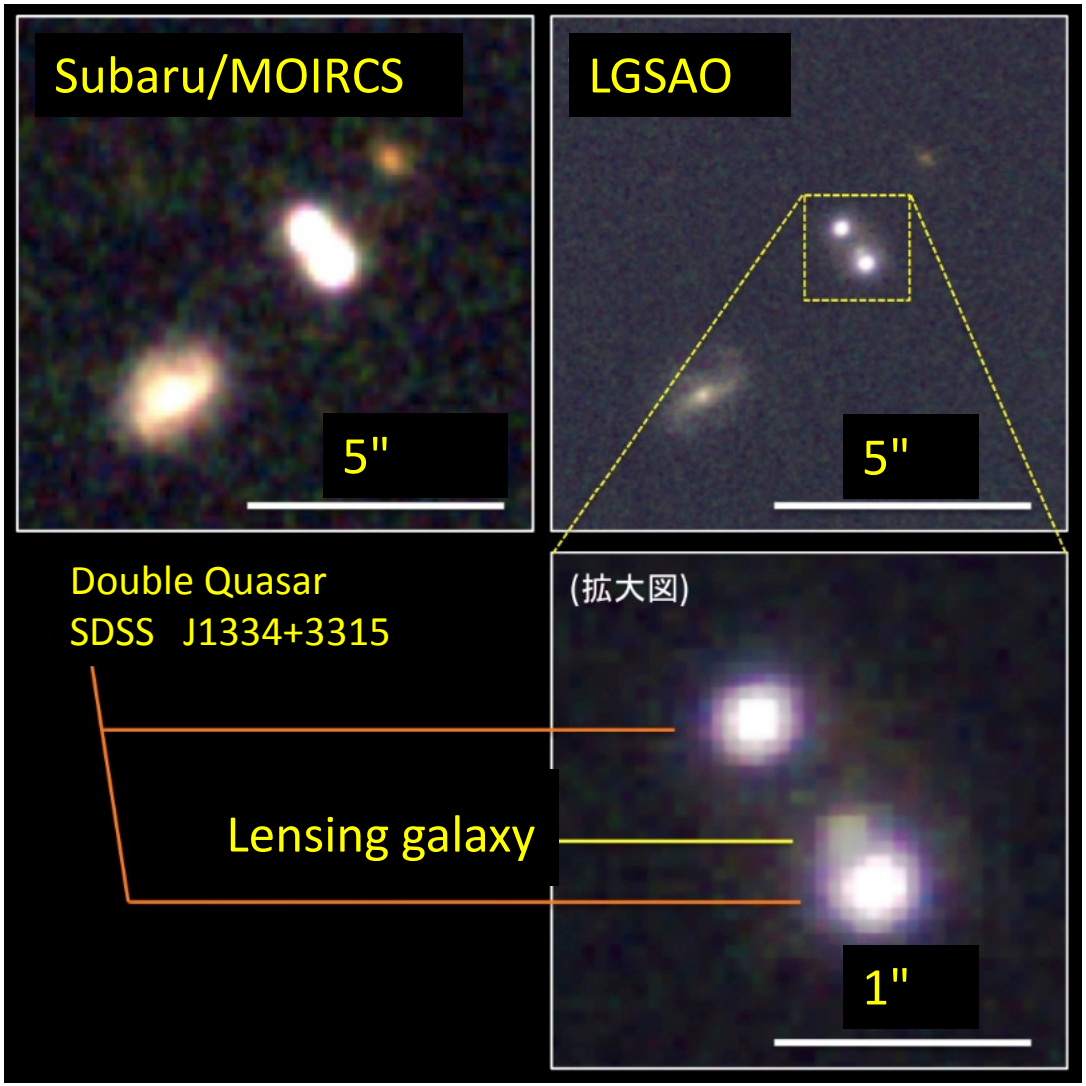
On-sky **inner working angle improved by a factor of three** with the PIAA coronagraph. Very fast seeing prevented any type of focal plane based wavefront control necessary for high contrast imaging.

AO188 LGS

AO188 LGS common use (2010~)

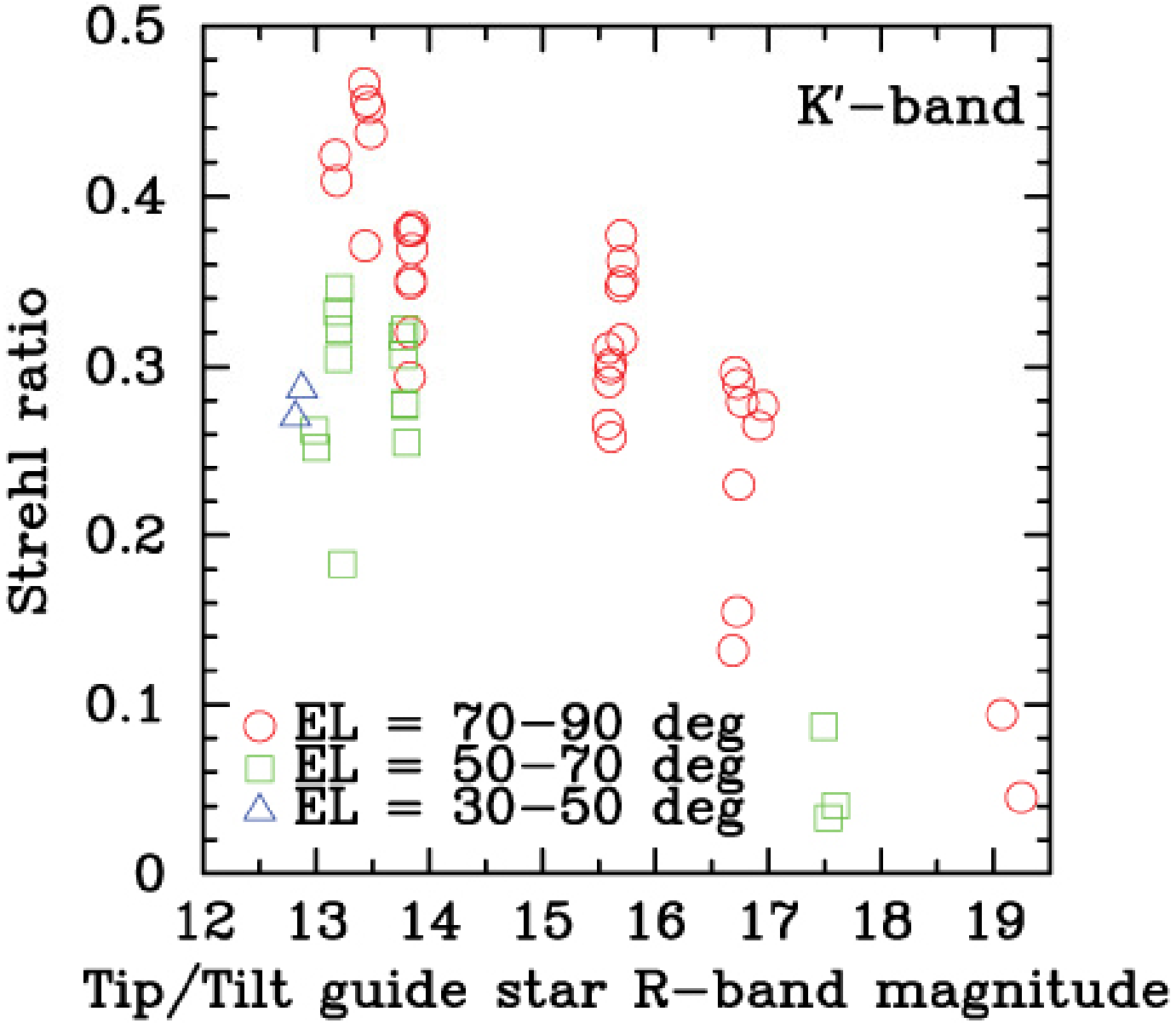
LGS: 5.4W sum frequency laser (2.4W on sky, now)
=> 11.8-13 mag





Discovery of lensing galaxy using Subaru LGS AO.
(Rusu et al. 2011)

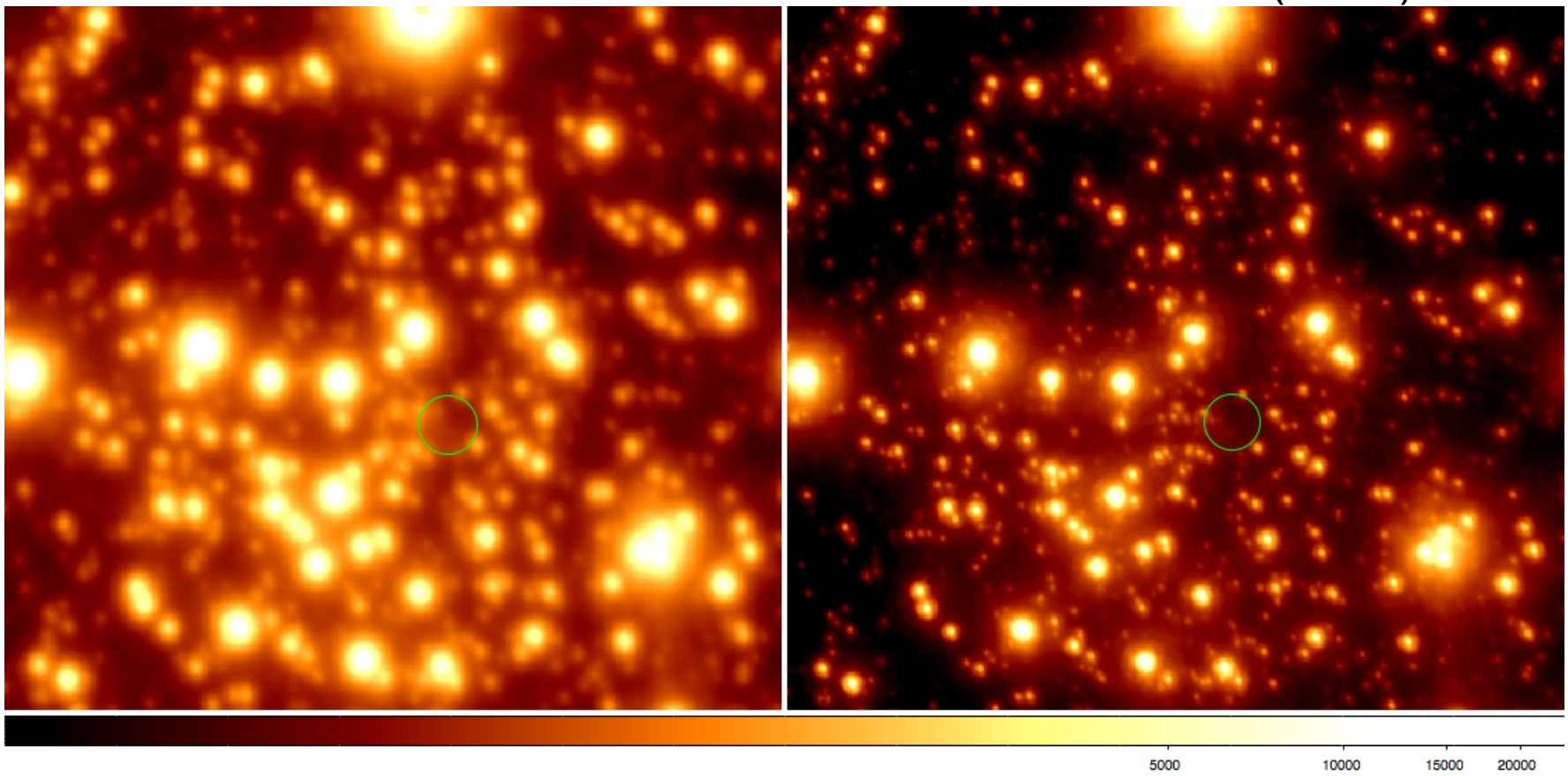
AO188(LGS) performance



Galactic Center observation with AO188LGS

AO36+CIAO (NGS)

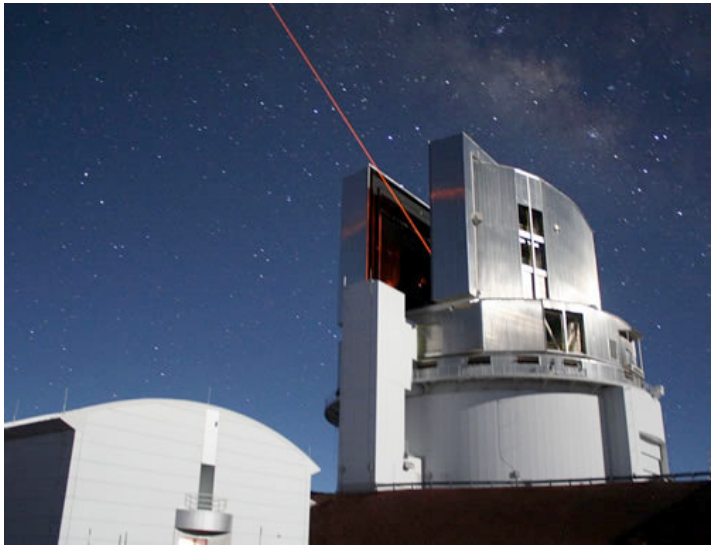
AO188+IRCS (LGS)



Nishiyama et al. 2009

Hayano et al. in prep.

Summary of Performance and Sky Coverage of AO188 NGS/LGS (under good seeing condition)



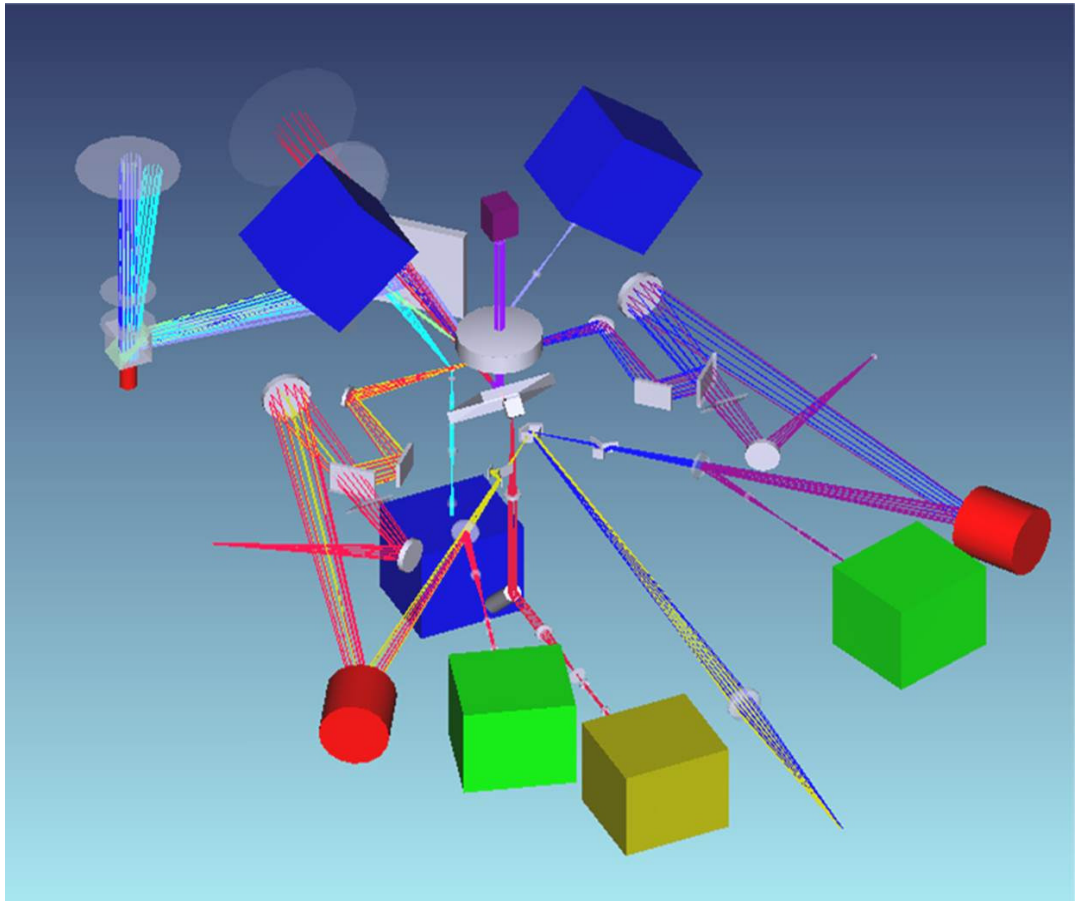
Conditions	Strehl ratio @K	Guide Star V_mag	Separation from GS	Sky Coverage
NGS (best)	~70%	8	<30”	<0.1%
NGS (moderate)	~40%	12	<30”	1 %
NGS (worst)	~10%	16	<30”	~ 30%
LGS (best)	~45%	14	<80”	~30%
LGS (moderate)	~30%	16	<80”	~50%
LGS (worst)	~10%	19	<80”	~100%

RAVEN (MOAO testbed)

MOAO Testbed at Subaru Telescope (collaboration with U.Vic and Subaru Telescope)

Technical demonstration for TMT30m telescope

- Open-loop test was successful.
- On-sky tomography is not yet
- 1st light at Subaru: ~2013



Subaru Next Generation Facility AO System

NAOJ needs to have an integrated plan of Subaru and TMT in 2020 era.

Subaru instruments should put priority on

- ***Wide field capability (HSC, PFS)***
- ***Complementary with TMT***

=> **GLAO** fits Subaru's unique strength

1) **GLAO** significantly improves wide field IR sensitivity (Wide field IR camera/spec is essential)
2) provide diffraction limited image for narrow FOV

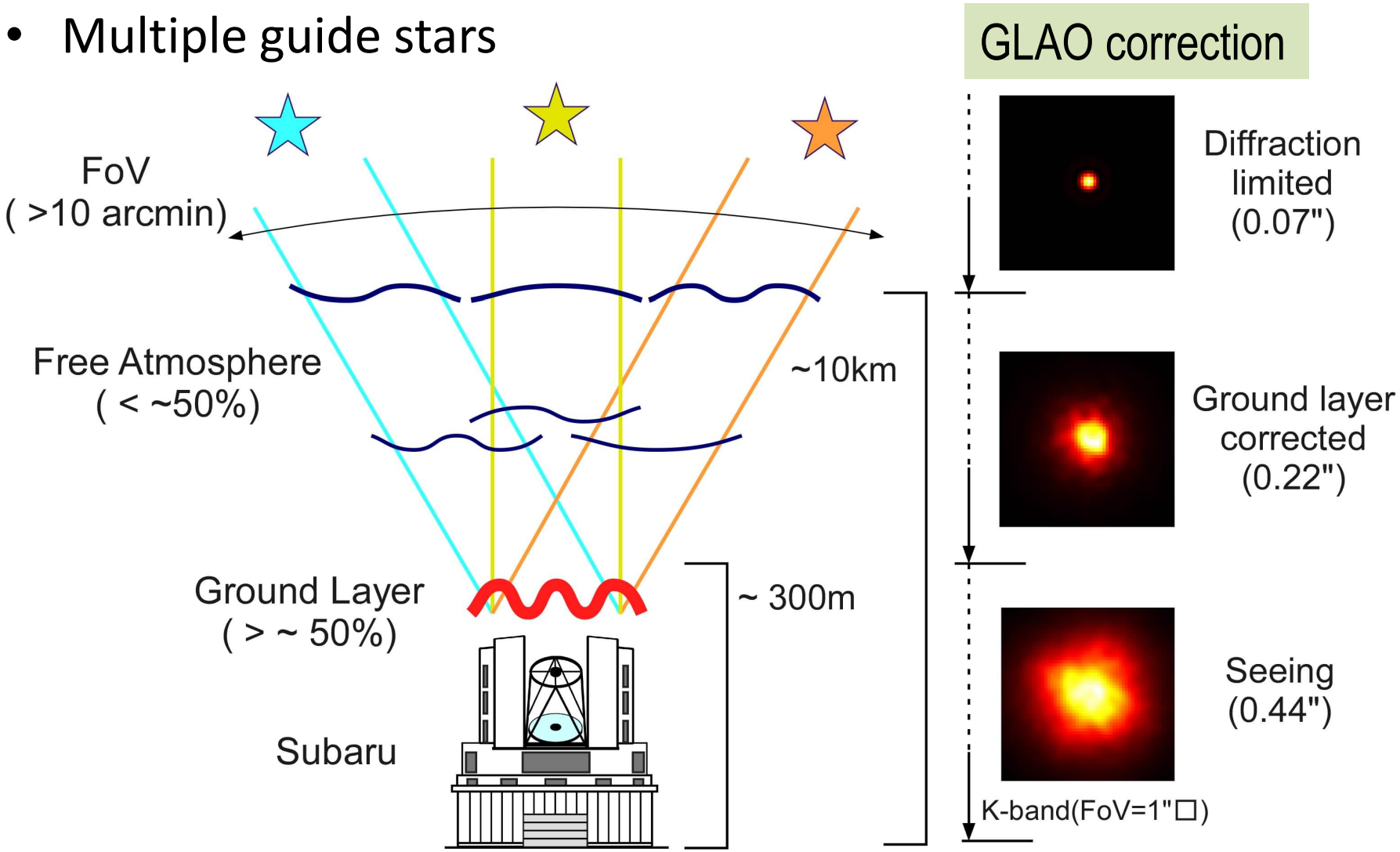
- spectroscopic survey of high-z galaxies, search for z>7 Lyα galaxies, Galactic archeology etc…

What is GLAO?

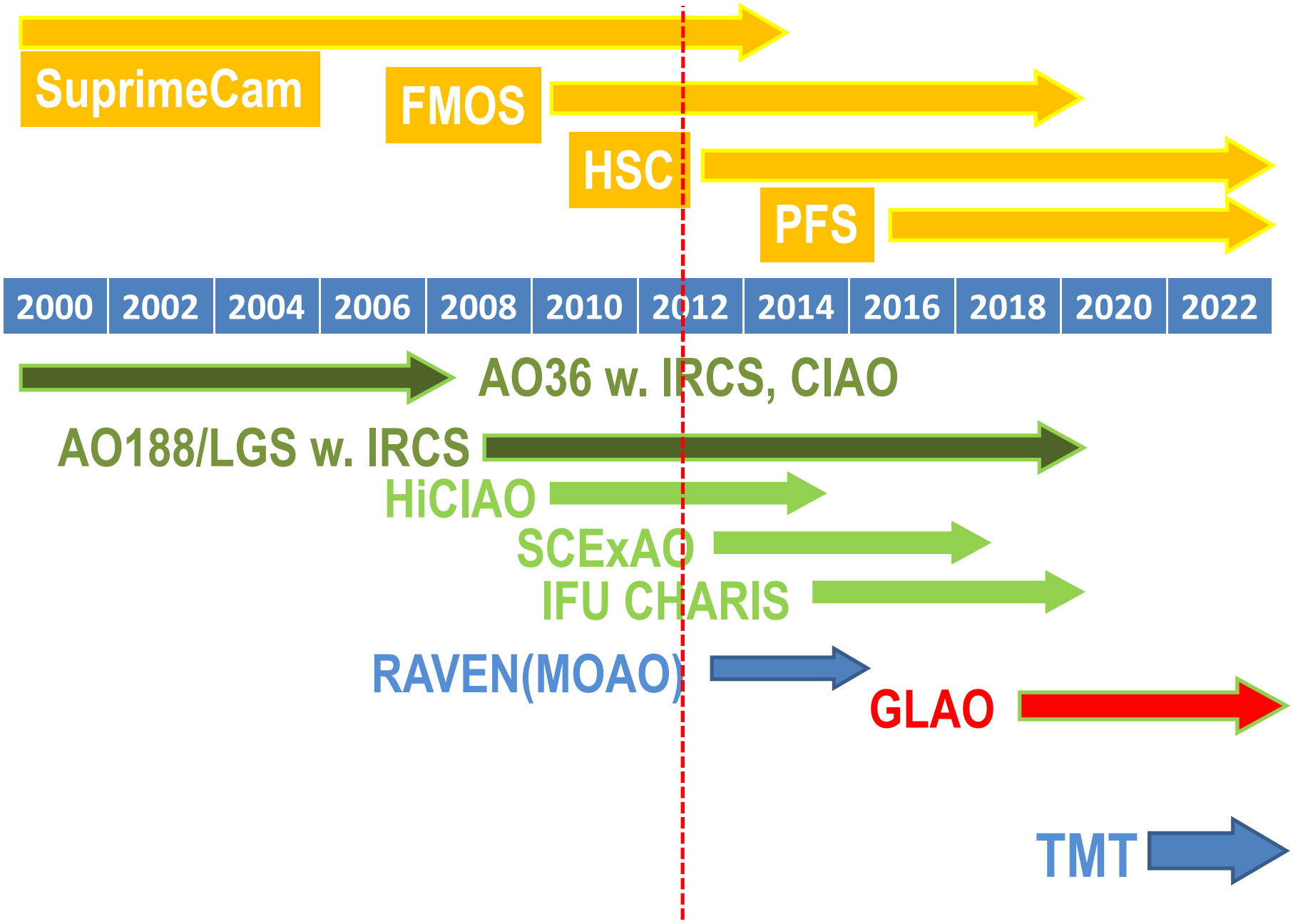
Wide-field AO (incl. GLAO) needs

Tomography

- Considering 3D structure of atmospheric turbulence
- Multiple guide stars

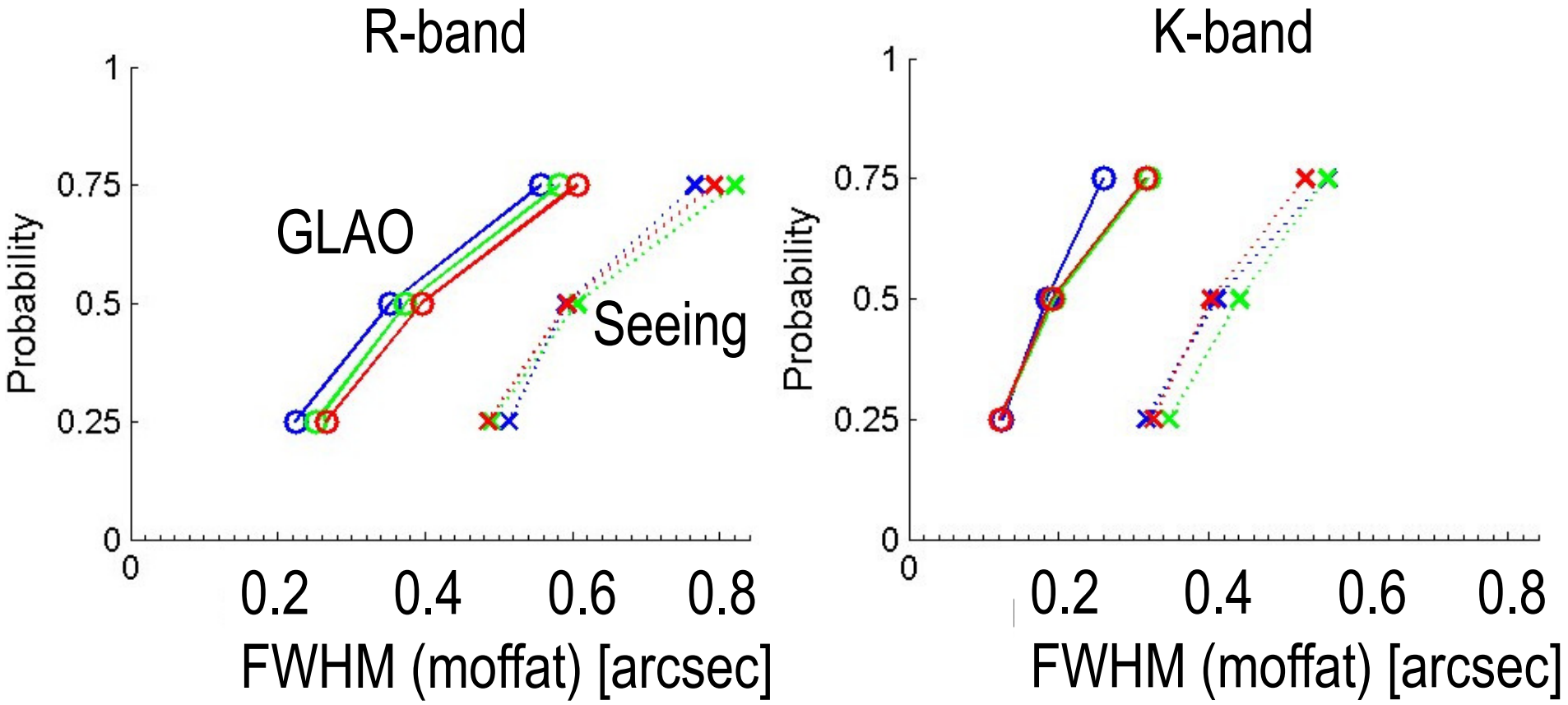


Subaru major instruments and AO programs



Performance of GLAO at Subaru Telescope

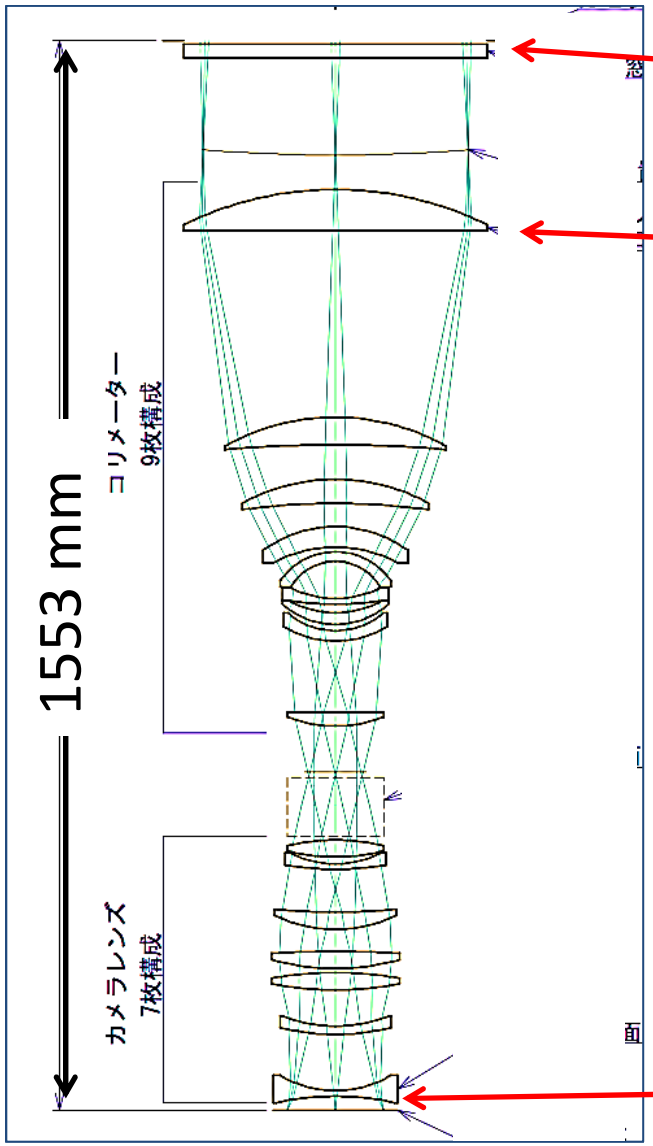
Seeing/FOV dependence of FWHM



FOV: blue: ϕ =10', green: ϕ =15', red: ϕ =20'

IR instrument for GLAO

Camera/spectrograph w. 13' FOV is possible.



Vacuum window

CaF2 lens 400mm dia.

Detector

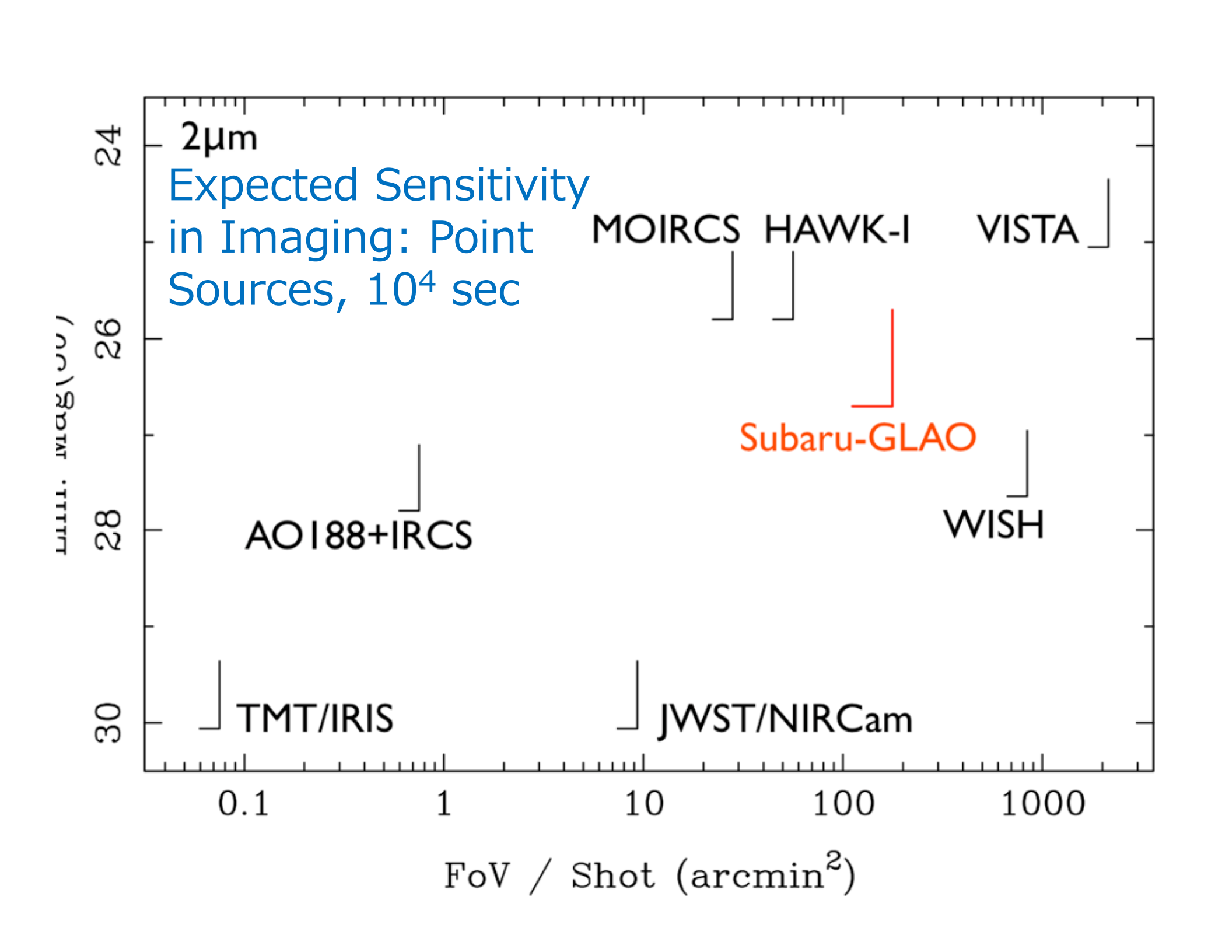
Preliminary Study of the Camera

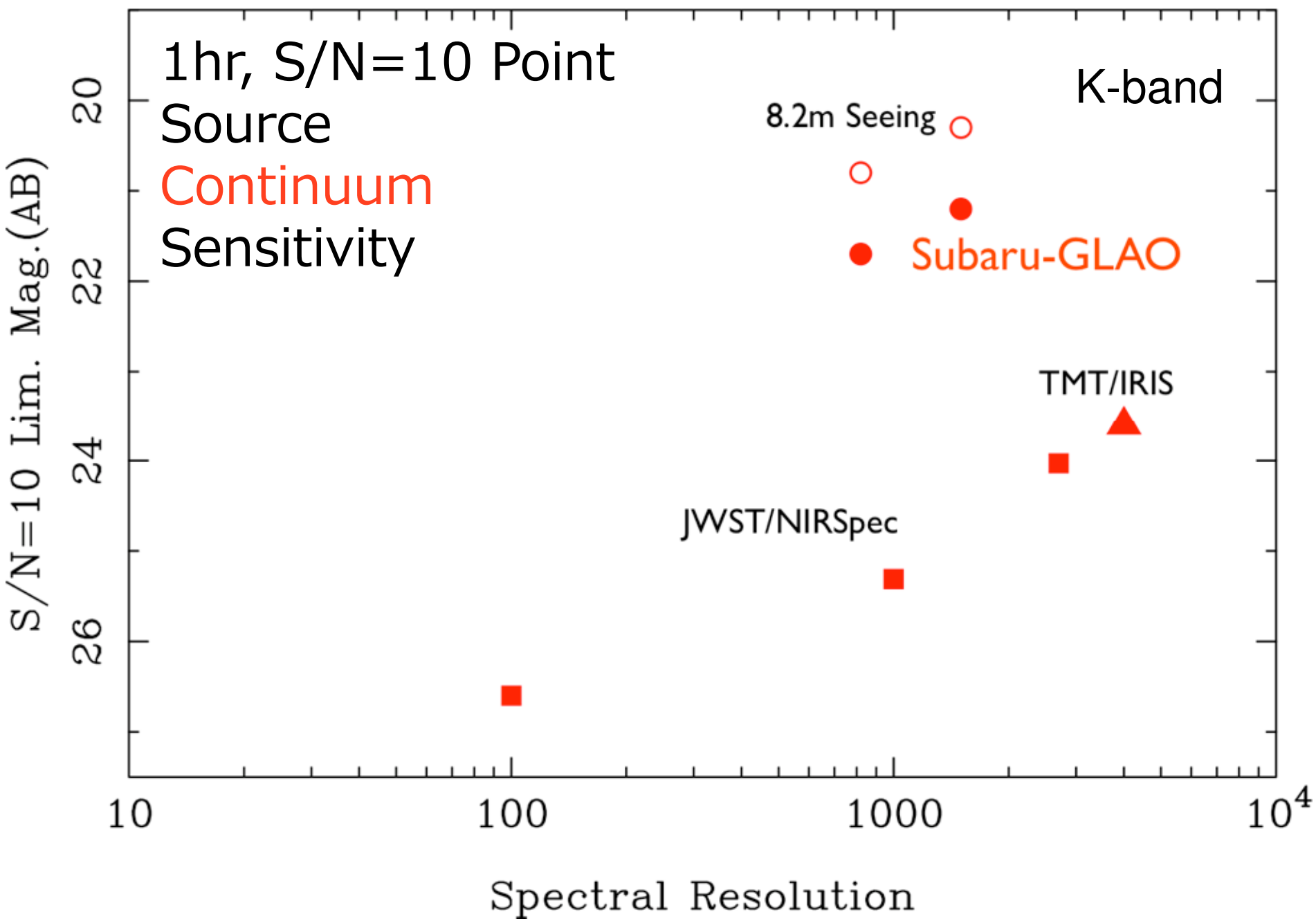
Field-of-View: Φ=13' at Subaru Cassegrain Focus.

Detector: H4RG x 4 → 150 arcmin^2

Modes: MOS and IFU

(Designed by Optcraft)


2μm
Expected Sensitivity in Imaging: Point Sources, 10^4 sec
MOIRCS
HAWK-I
VISTA
Subaru-GLAO
WISH
AO188+IRCS
TMT/IRIS
JWST/NIRCam
24
26
28
30
0.1
1
10
100
1000
FoV / Shot (arcmin^2)


1hr, S/N=10 Point
Source
Continuum
Sensitivity
K-band
8.2m Seeing
Subaru-GLAO
TMT/IRIS
JWST/NIRSpec
S/N=10 Lim. Mag.(AB)
20
22
24
26
10
100
1000
10^4
Spectral Resolution

Issues for GLAO

Activities

- Science cases
- Characterization of the local ground layer turbulence.
- Study of Adaptive secondary mirror , IR instrument.

Budget Issue

- Adaptive 2ry mirror + Laser system + Subaru modification + WFS + IR instrument > $30M, is beyond the level from available "grant" in Japan (maximum grant in Japan is ~$19M)

=> International collaboration is necessary.