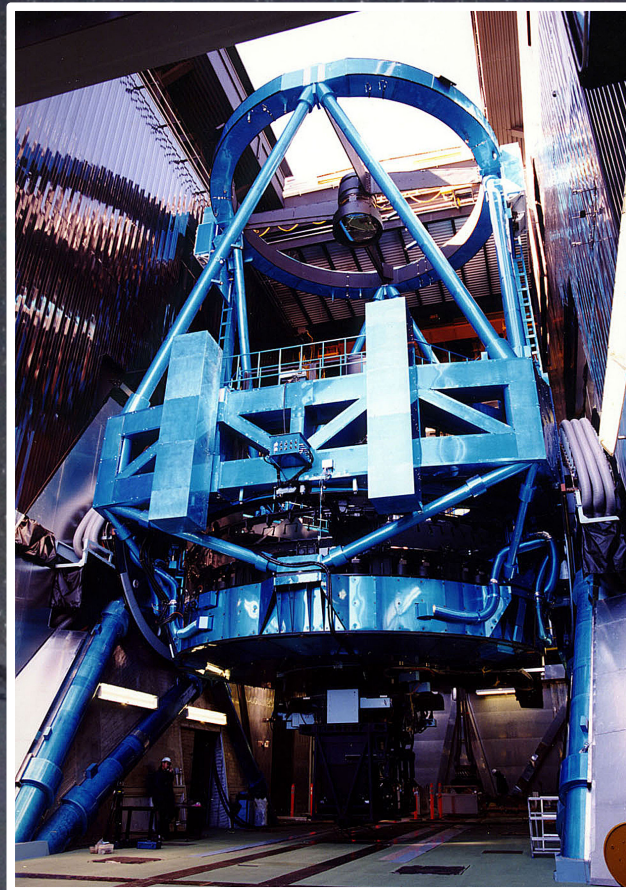


Introduction of Subaru Telescope Instruments

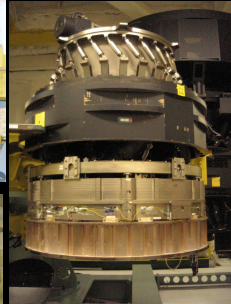
Tomo Usuda (SUBARU)



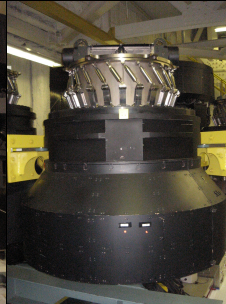
Four foci on Subaru

POpt

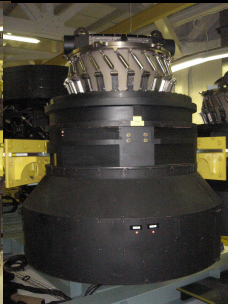
CsOpt-M2



IR-M2



NsOpt-M2



PIR

Nasmyth-IR (6t)

F/13.6

FOV~3' ϕ

ImR

LGS/AO188

Prime: Opt & IR

F/2.0

FOV~30' ϕ

Nasmyth-Opt (6t)

F/12.6

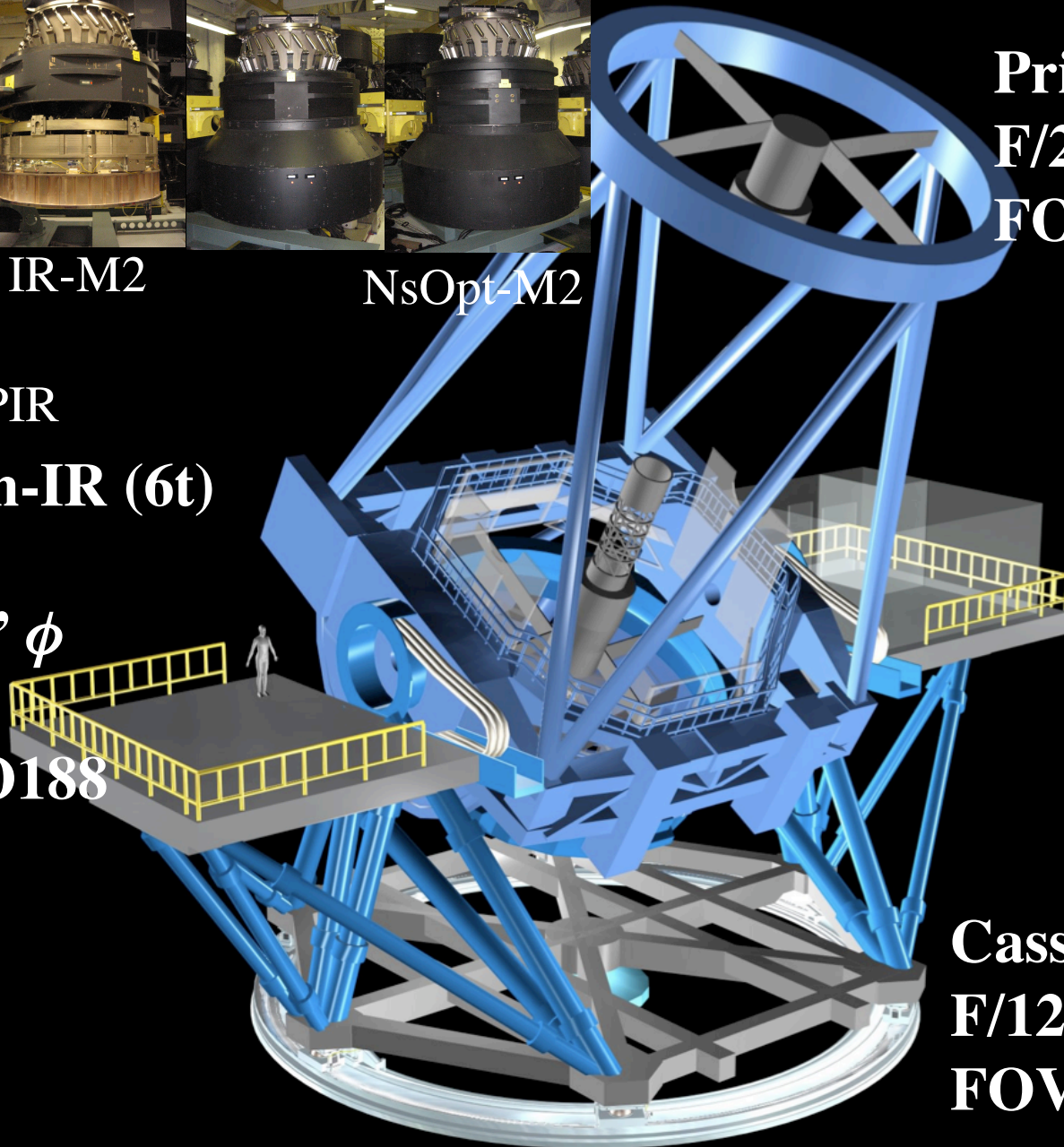
FOV=3~4' ϕ

ADC / ImR (b & r)

Cassegrain: Opt & IR

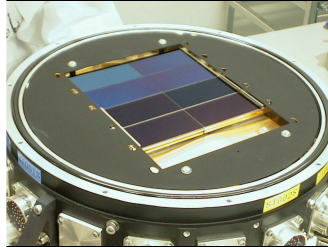
F/12.2 / ADC

FOV~6' ϕ / AO36



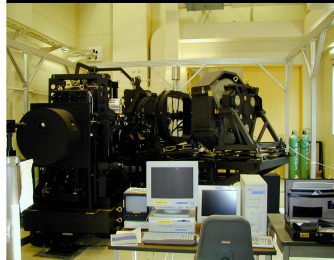
1st Gen Instruments (1999~2005)

- *PF*



Suprime-Cam
(34'x27')

- *Nas*



HDS



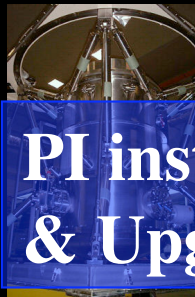
OHS/CISCO

Decommissioned

- *Cass*



FOCAS



CIAO



AO36



IRCS



COMICS

PI inst. & Decommissioned
& Upgrade @ Ns focus

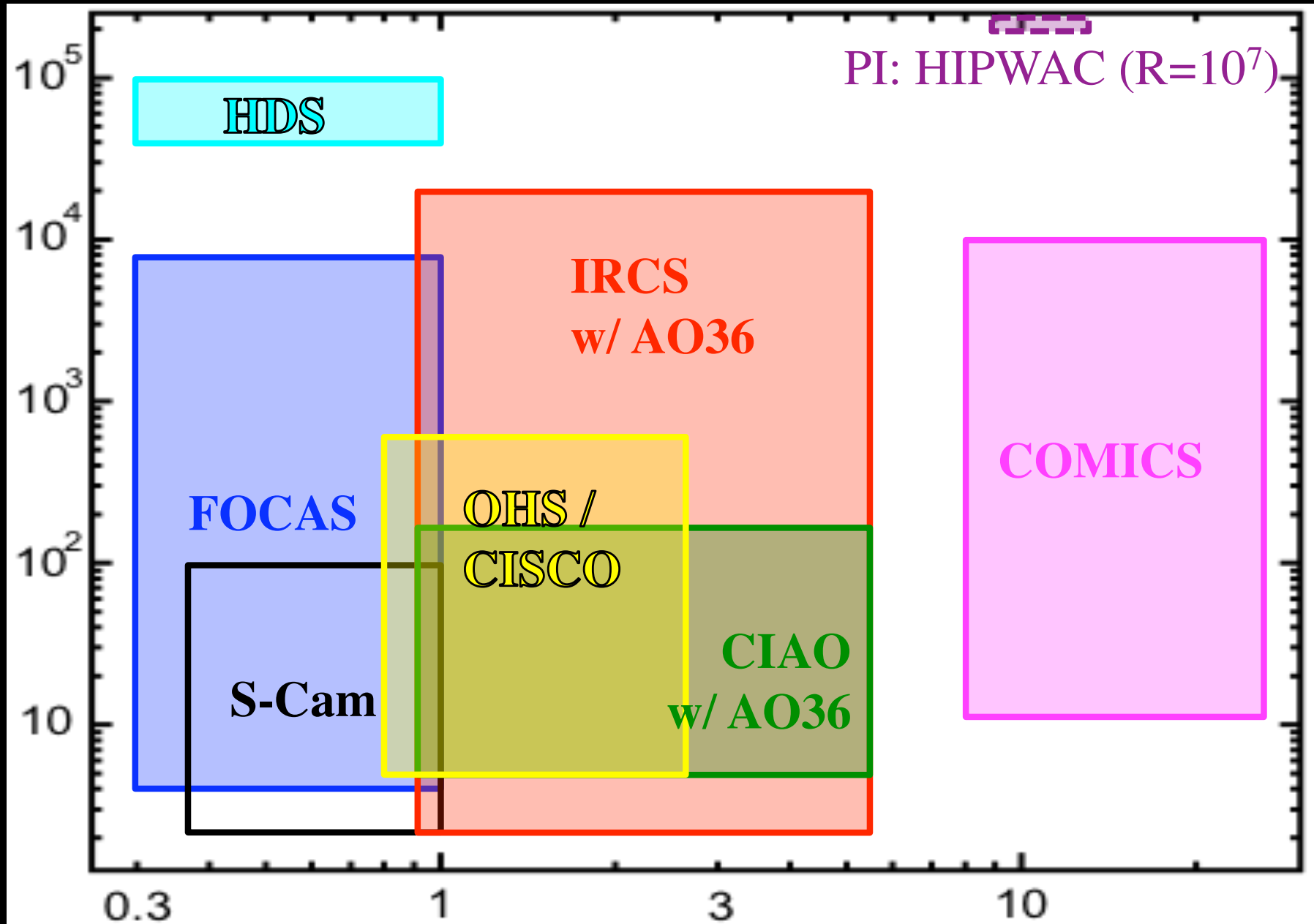
Optical

NIR (1~5 μ m)

MIR (10~20 μ m)

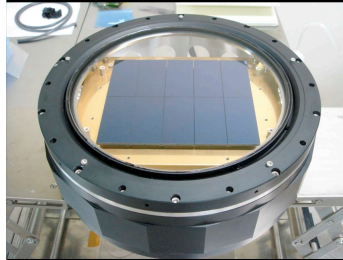
1st Gen Instruments (1999~2005)

Spectral Resolution [$\lambda/\Delta\lambda$]



2nd Gen Instruments (2005~2009)

- *PF*



Suprime-Cam

(34'x27') CCD upgraded (2008)

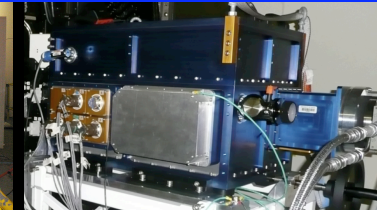
- *Nas*



HDS



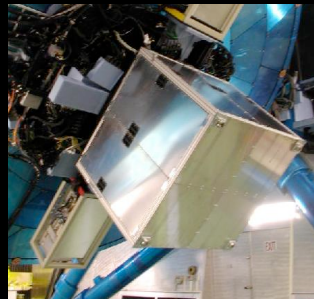
**LGS/AO188: IRCS (2008)
& (HiCIAO in 2009)**



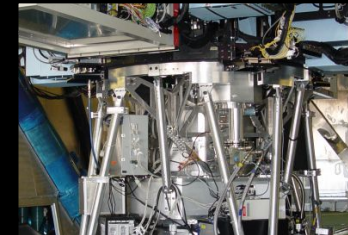
- *Cass*



FOCAS (Kyoto 3DII)



(CIAO)



**(4'x7' / 2005)
MOIRCS**



COMICS

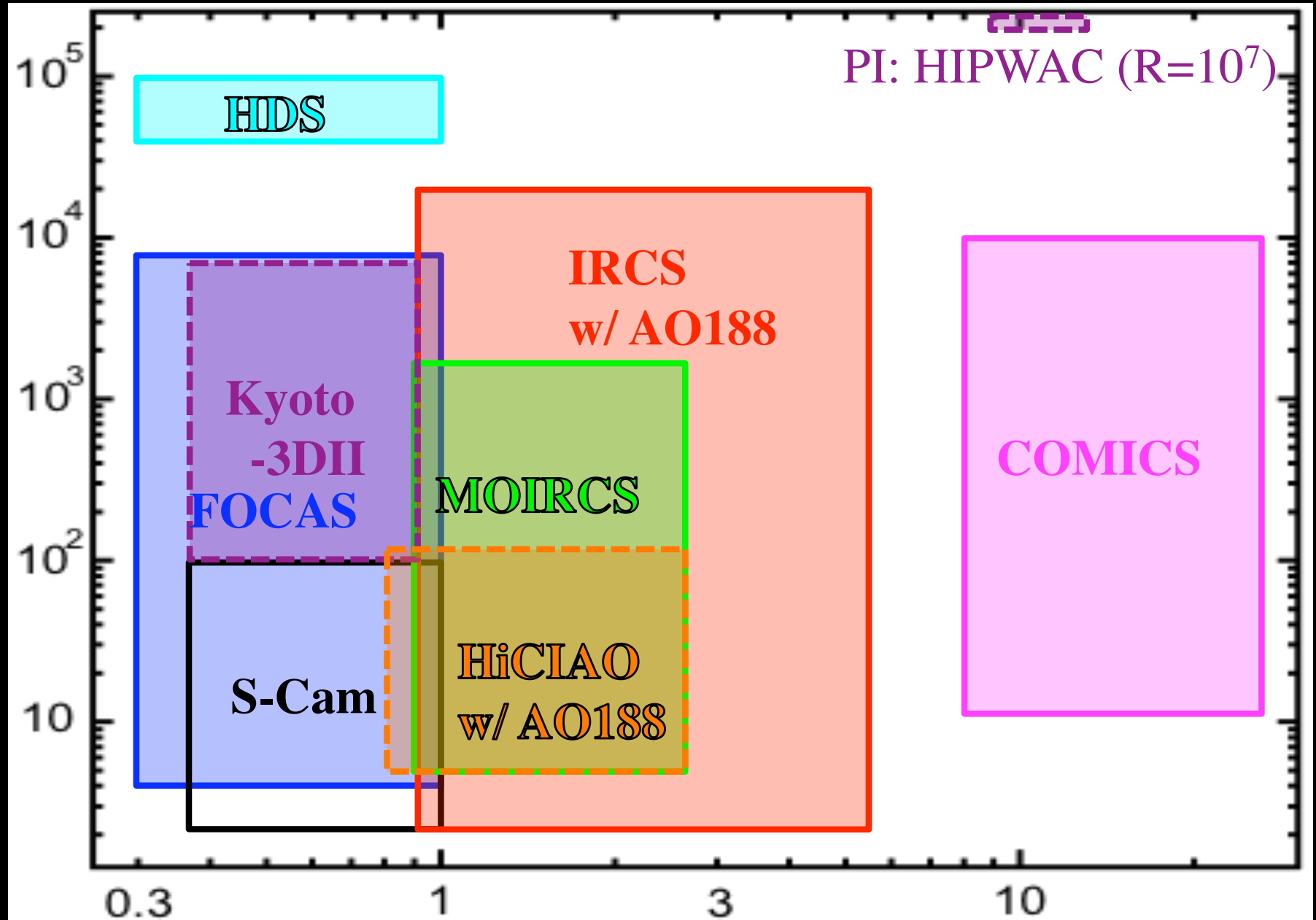
Optical

NIR (1~5 μ m)

MIR (10~20 μ m)

2nd Gen Instruments (2005~2008)

Spectral Resolution [$\lambda/\Delta\lambda$]



Wavelength [μm]

Optical Instruments

Suprime-Cam : FOV=34'x27', Ten 2k x 4k CCDs w/ 0.2''/pixel

- 10 Filters: $B, V, R_c, I_c, g', r', i', z', NB711, NB816, NB921$, etc.
- Since 2008, **Hamamatsu Fully-Depleted CCDs (>40% @1 μ m)**

HDS : Two 2k x 4k CCDs w/ 0.14''/pixel, Slit length=2~60''

- Slit width=0.2~4'', **R=36,000 arcsec (cf. 100,000 w/ 0.38'')**
- Two Image Rotator: Blue & Red optimized, **I₂ cell** since 2006

FOCAS : FOV=6' ϕ , Two 2k x 4k CCDs w/ 0.1''/pixel

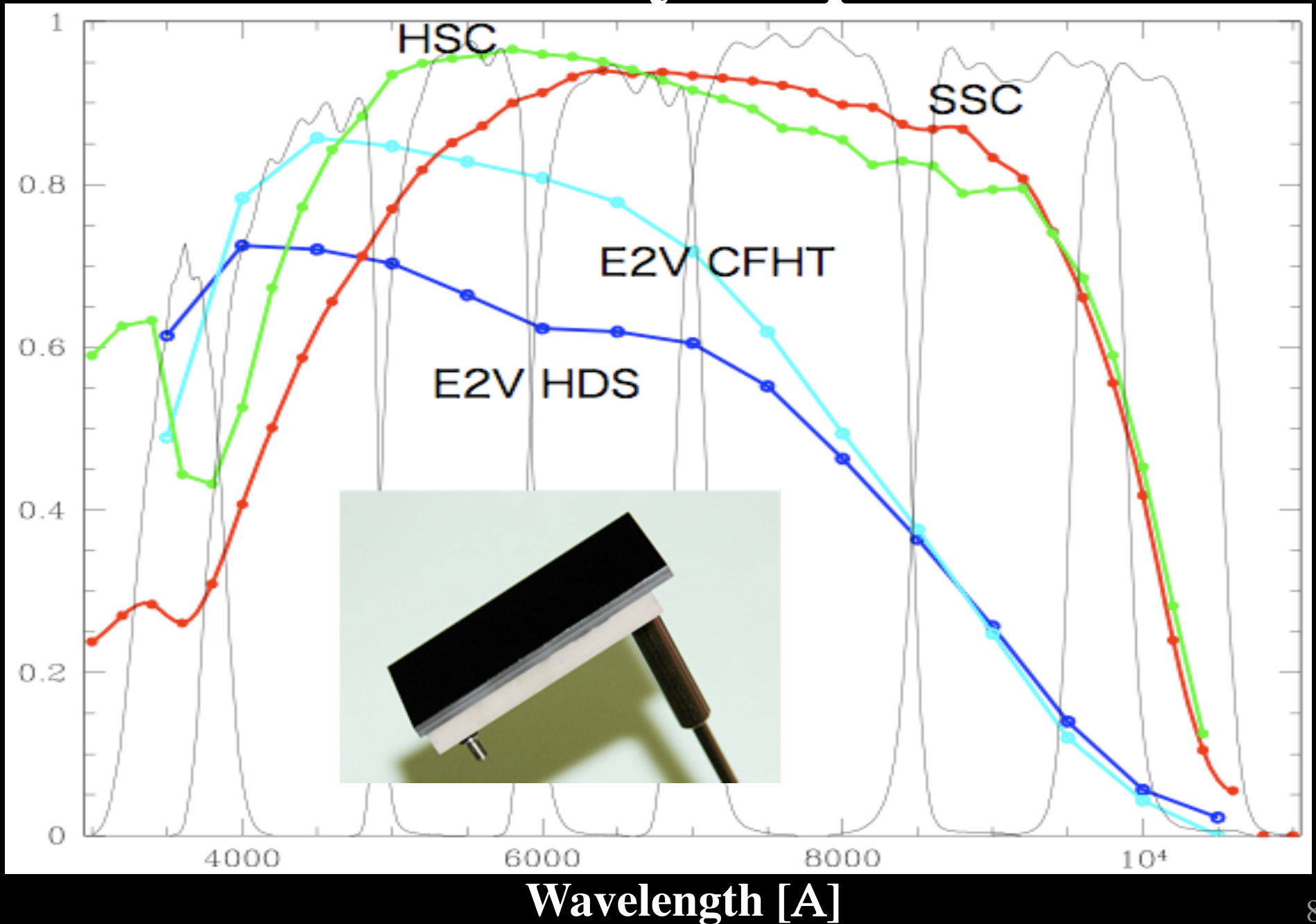
- 8 grisms, Slit width=0.2~2'', **R=250~7,500 w/ 0.4''**
- 10 MOS mask w/ **~50 slits** (max 100)
- Linear & Circular Polarimetry for long slit spg & imaging

PI: Kyoto 3DII

- **Fabry-Perot** : FOV=1.9'x1.9' w/ 0.056''/pixel, R=400 & 7,000
- **IFS w/ MLA** : FOV=3.4''x3.4'' w/ 0.094''/pixel, R~1,200

Hamamatsu Fully-Depleted CCD

Quantum Efficiency



Infrared Instruments

MOIRCS : $\lambda=0.9\sim2.5\mu\text{m}$, Two HAWAII-2 (0.12''/pix, **FOV=4'x7'**)

- 3 grisms (R=600~1,600 w/ 0.5'' slit) & 2 VPH (R=3,000 for J,H)
- **18 MOS mask w/ ~50 slits**

IRCS : $\lambda=0.9\sim5.5\mu\text{m}$, 1k x 1k ALADDIN III (12, 20, 52 mas/pix)

- 18 Filters: *z,J,H,H+K',K',K,L',M',CH₄, [FeII], H₂, Br γ , PAH* etc.
- R=100~2,000 w/ grisms, R~20,000 w/ Echelle (wide λ coverage)

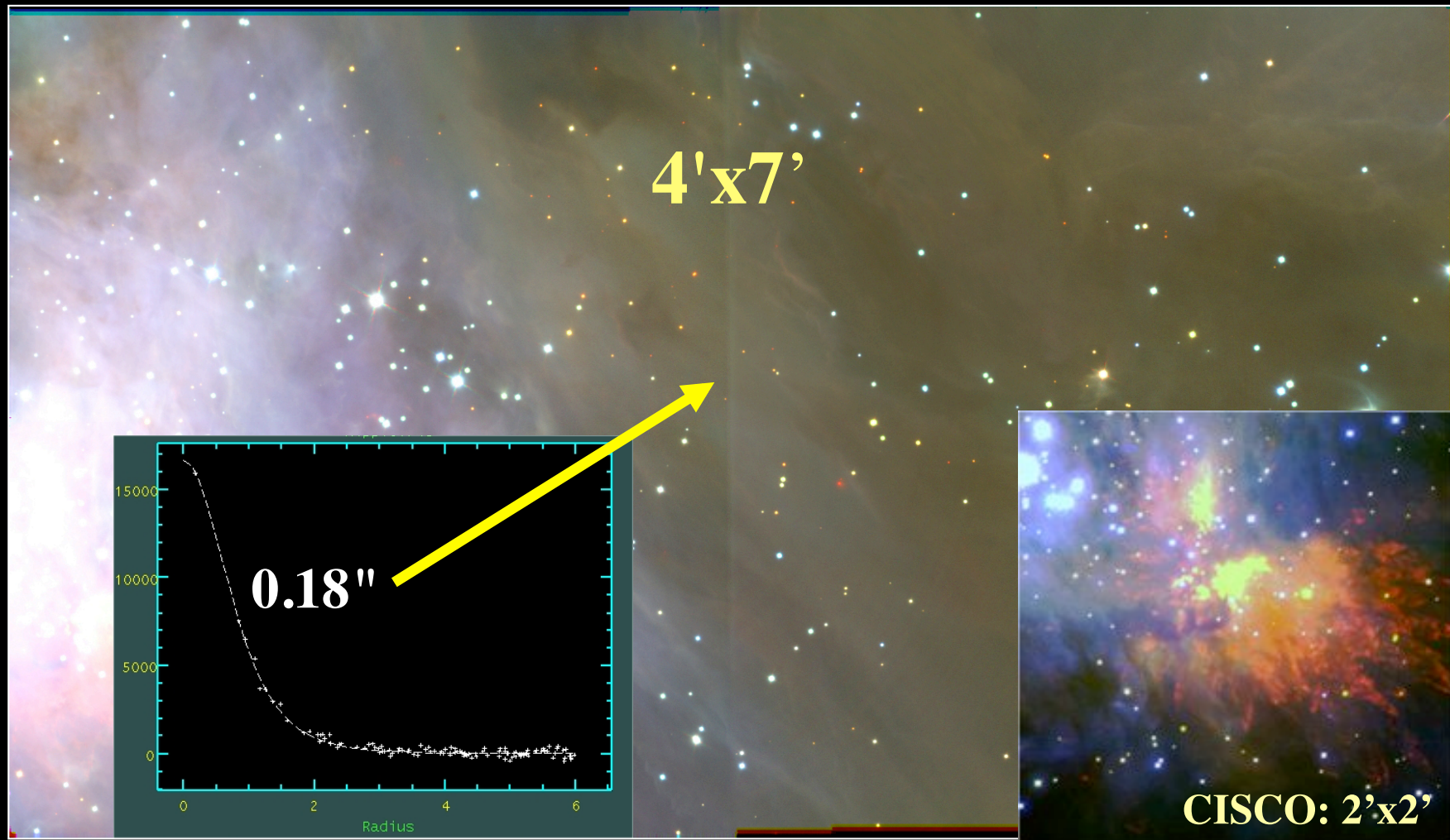
COMICS : $\lambda=8\sim25\mu\text{m}$, Six 320x240 Si:As (cf. 5 for spg)

- 0.13''/pix, FOV=42''x32'', max 60'' chopping
- 15 Filters: 6 N-band cont, 5 N-band NB, 4 Q-band cont
- R=250~11000 w/ 0.33'' slit with 5 gratings

PI: HiCIAO : $\lambda=0.85\sim2.5\mu\text{m}$, HAWAII-2RG (0.01''/pixel)

- FOV=20''x10'' (PDI), 5''x5'' (SDI), ADI
- 4 occulting masks: 0.2'', 0.3'', 0.4'', 0.6'' $\rightarrow$ **~10E-5.5**

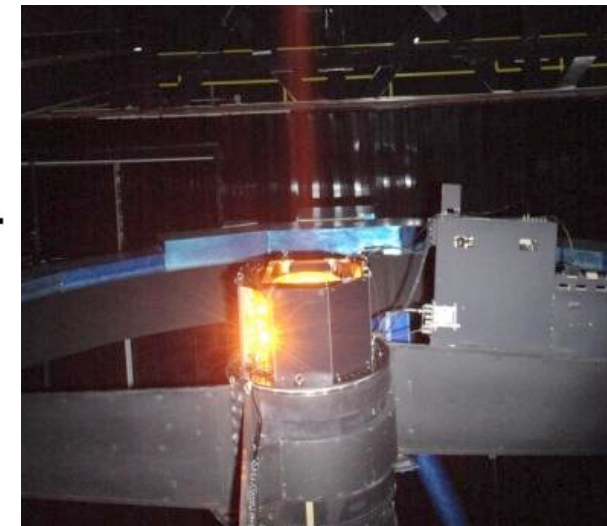
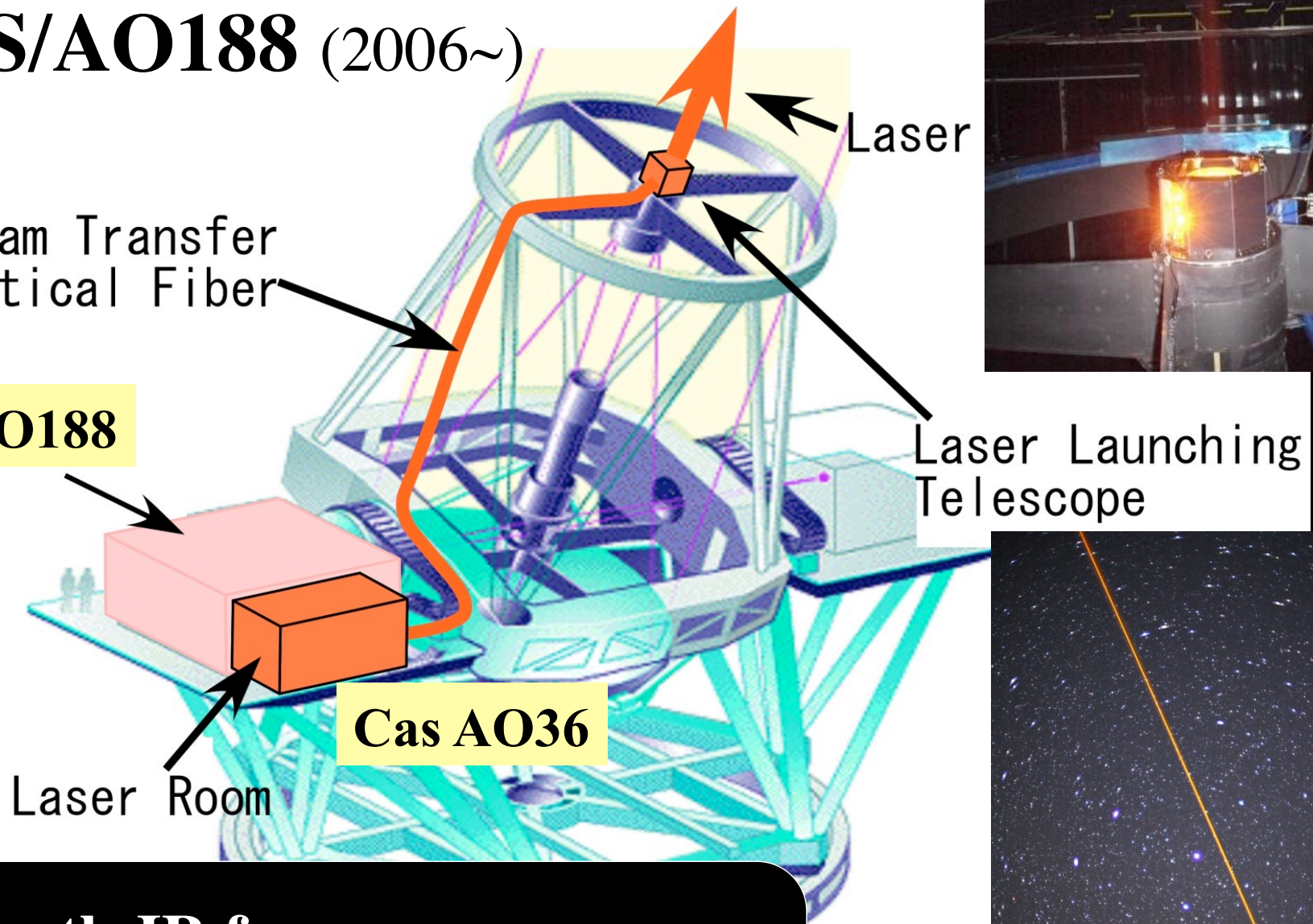
MOIRCS: Wide field & Superb image quality



Best image size : $0.18''$ (without adaptive optics)

Good image quality ($0.2'' \sim 0.3''$) is always available over the field under good seeing

LGS/AO188 (2006~)



Laser Launching Telescope

Nasmyth-IR focus
Curvature sensors w/ 188 act.
LGS output~6.5W, R~10.7 mag



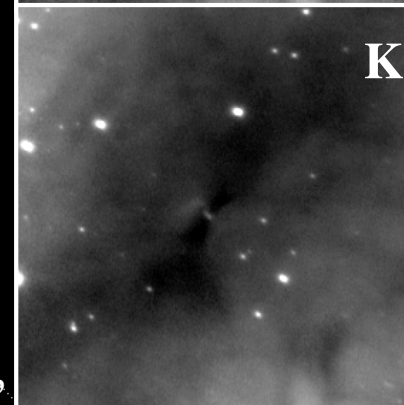
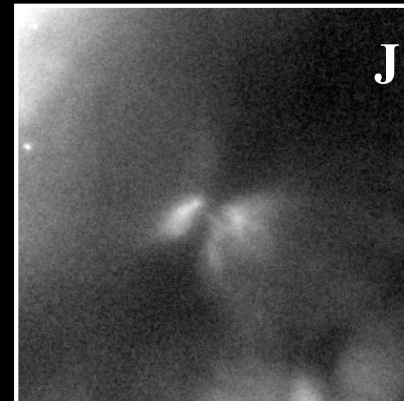
AO188 NGS: Performance



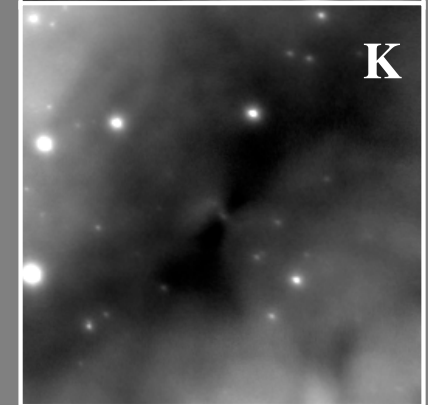
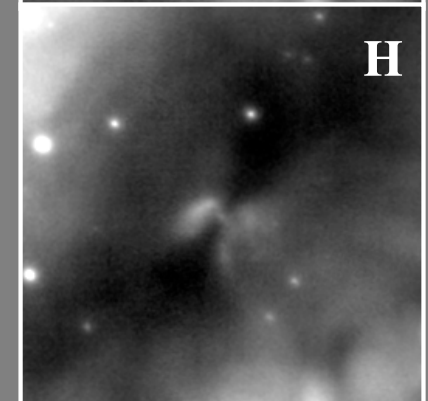
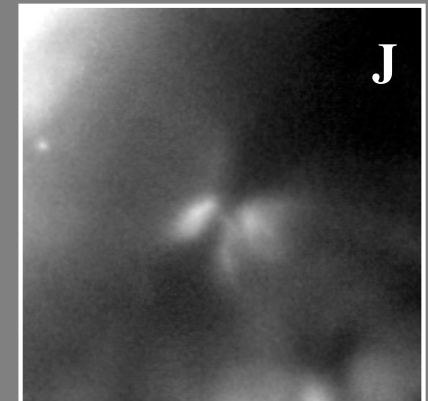
**IQ @ shorter wavelength
much improved**

IRCS 52mas Camera

55"x 55"

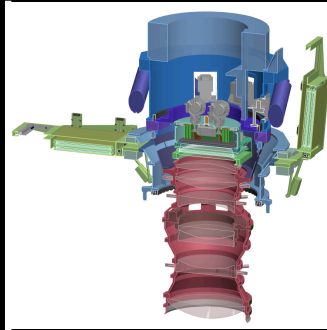


AO36+IRCS

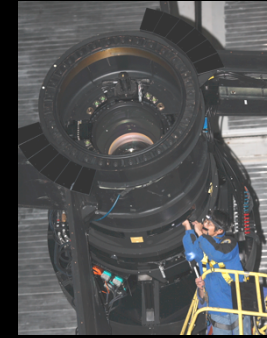
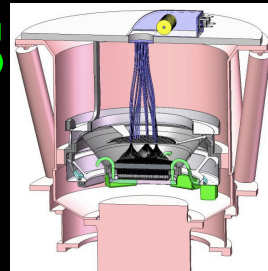


3rd Gen Instruments (2010~)

- *PF*

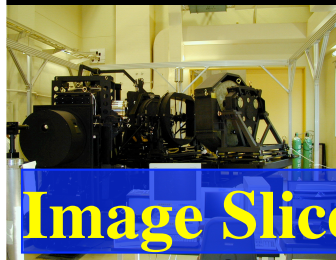


Hyper S-Cam
WF MOS
(1.5 deg ϕ
/ 2011~)



FMOS (2010)
(30' ϕ / JH)

- *Nas*



HDS

Image Slicer mode



LGS/AO188: with
IRCS, (HiCIAO), (K-3DII), ExAO

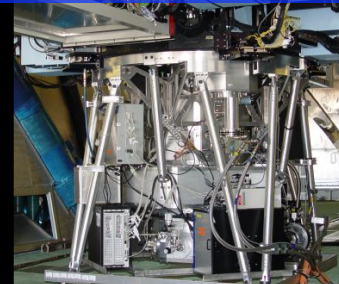
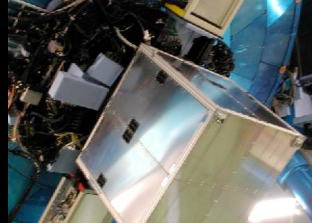


- *Cass*



CCD upgraded (2010)

FOCAS (Kyoto 3DII)



MOIRCS



COMICS

Optical

NIR (1~5 μ m)

MIR (10~20 μ m)

Near Future Instruments

FMOS (from 2010): FOV=30' ϕ , $\lambda=0.9\sim1.8\mu\text{m}$, **400 x 1.2'' ϕ fiber**

- Cooled ($T=-55\text{C}$) two spectrographs w/ OH suppression
- $R=500$ (1 time exp) & 2,200 (4 times exp)

IRCS-HRU (from 2010): Additional High Spect. Resolution Unit

- $\lambda=1.4\sim5.5\mu\text{m}$, ORION 2k x 2k InSb, w/ IR gas cell (NH_3)
- **$R=70,000$ w/ Si Immersion Grating ($n\sim3.4$)**

Subaru Coronagraphic ExAO (from 2010)

- PIAA Coronagraph, Coronagraphic WFS, MEMS(1024) $\rightarrow$ **$<10\text{E-7}$**

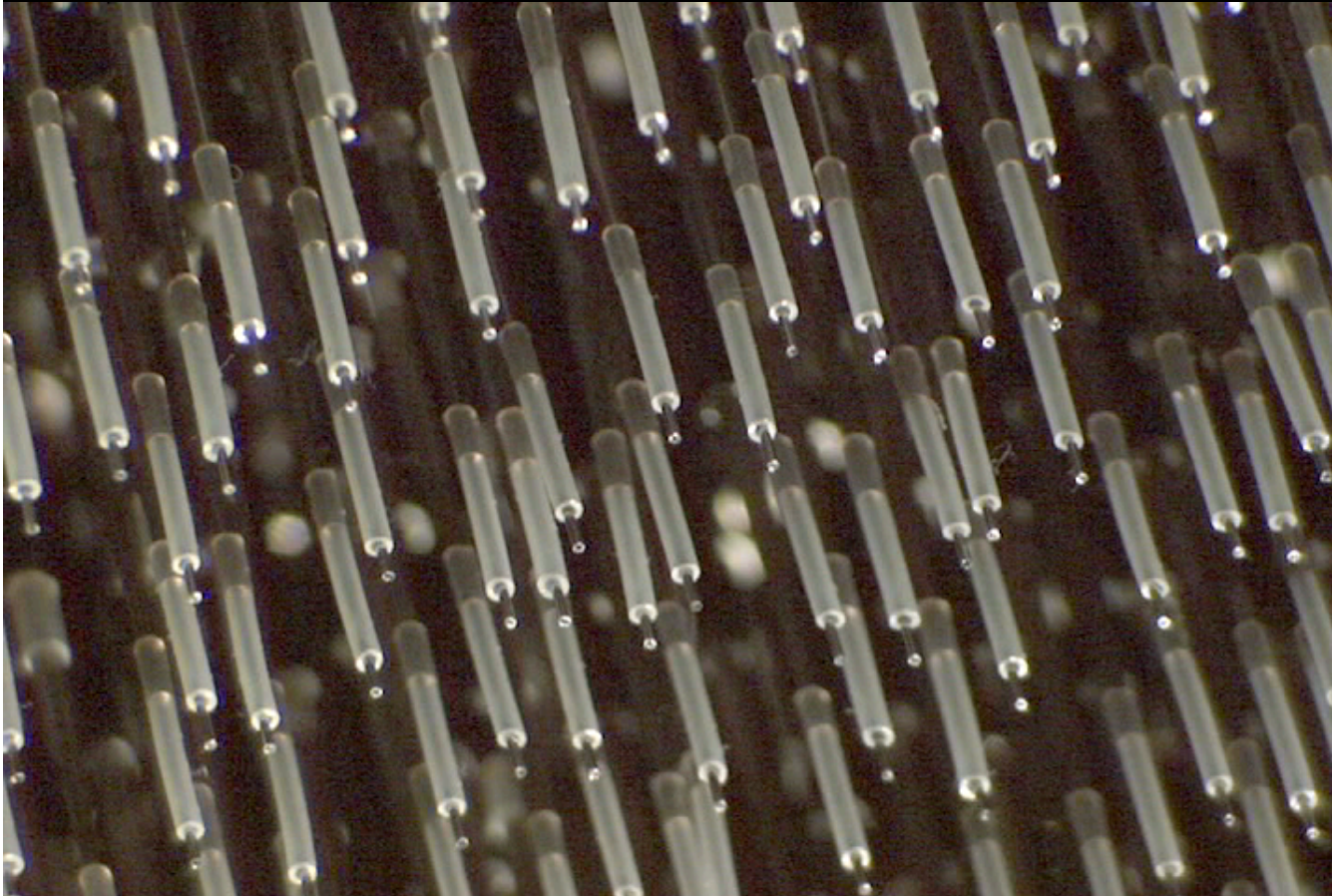
Hyper Suprime Cam (from 2011)

- FOV=**1.5 deg ϕ** , 116 2k x 4k FDCCD, $\lambda=0.4\sim1.1\mu\text{m}$
- **6 Filters (60cm ϕ)**: *Broad* ($g', r', i', \text{etc.}$), *Narrow* (goal: $\delta\lambda < 1 \text{ nm}$)

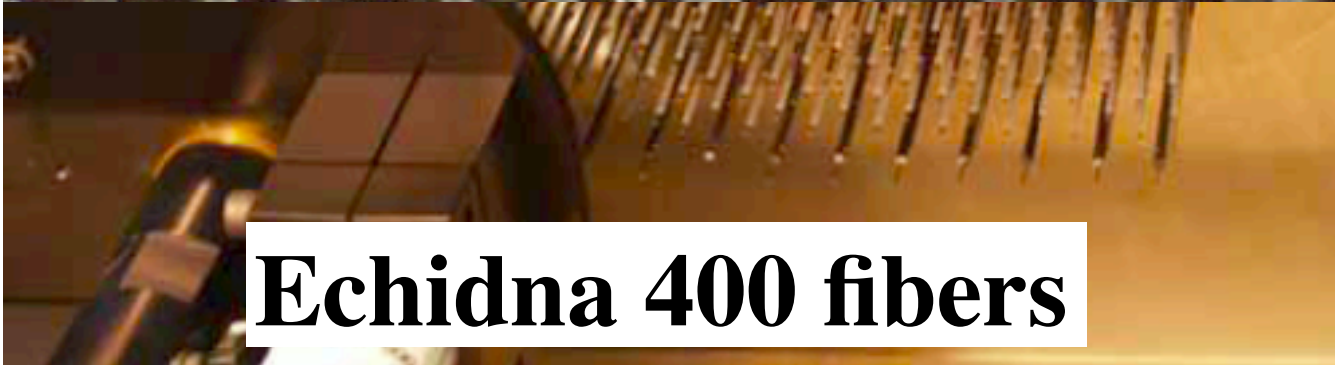
WF MOS (from 201x): **Collaboration with Gemini**

- FOV=1.3 deg ϕ (share HSC's WFC & PFU), **2400 x 1.2'' ϕ fiber**
- 3 Spectrograph w/ $R=1,500\sim5,000$ (2400 fibers) / $R=20,000$ (600)

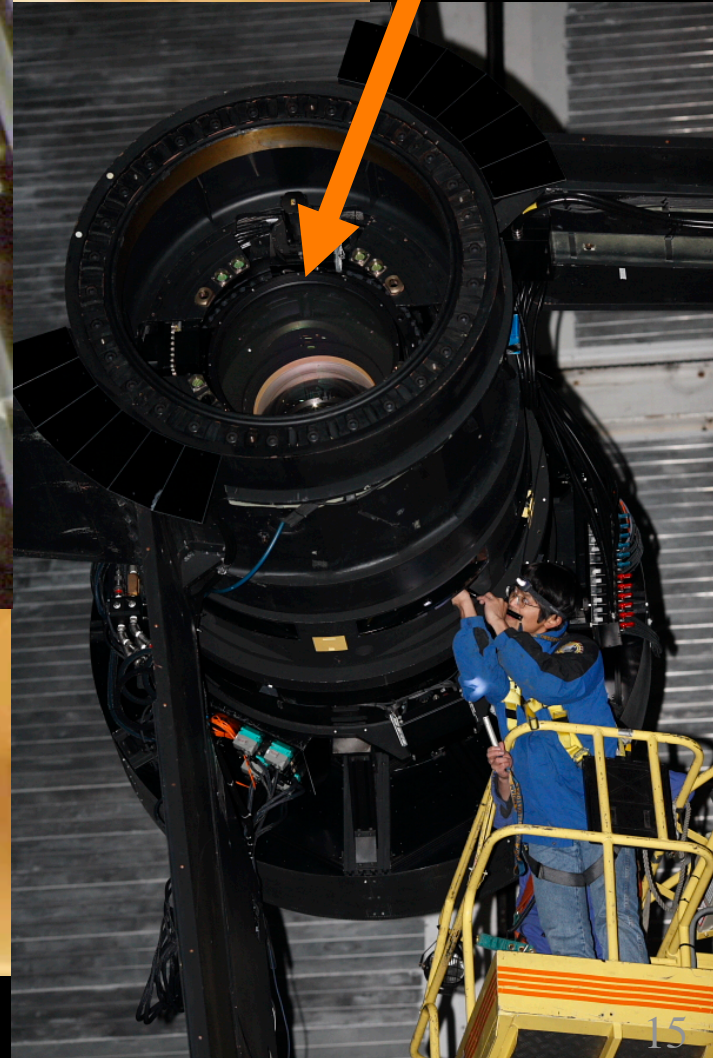
FMOS



Echidna 400 fibers

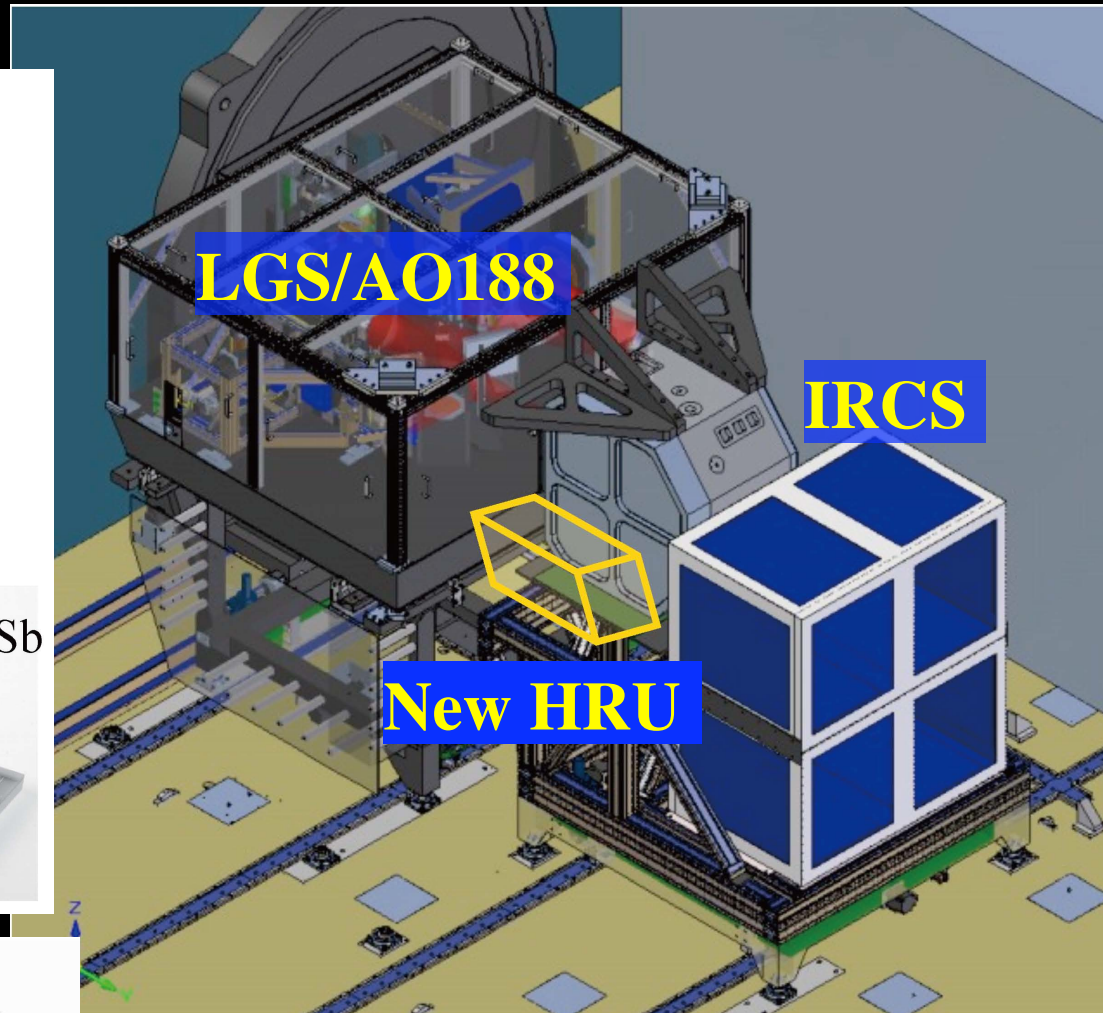
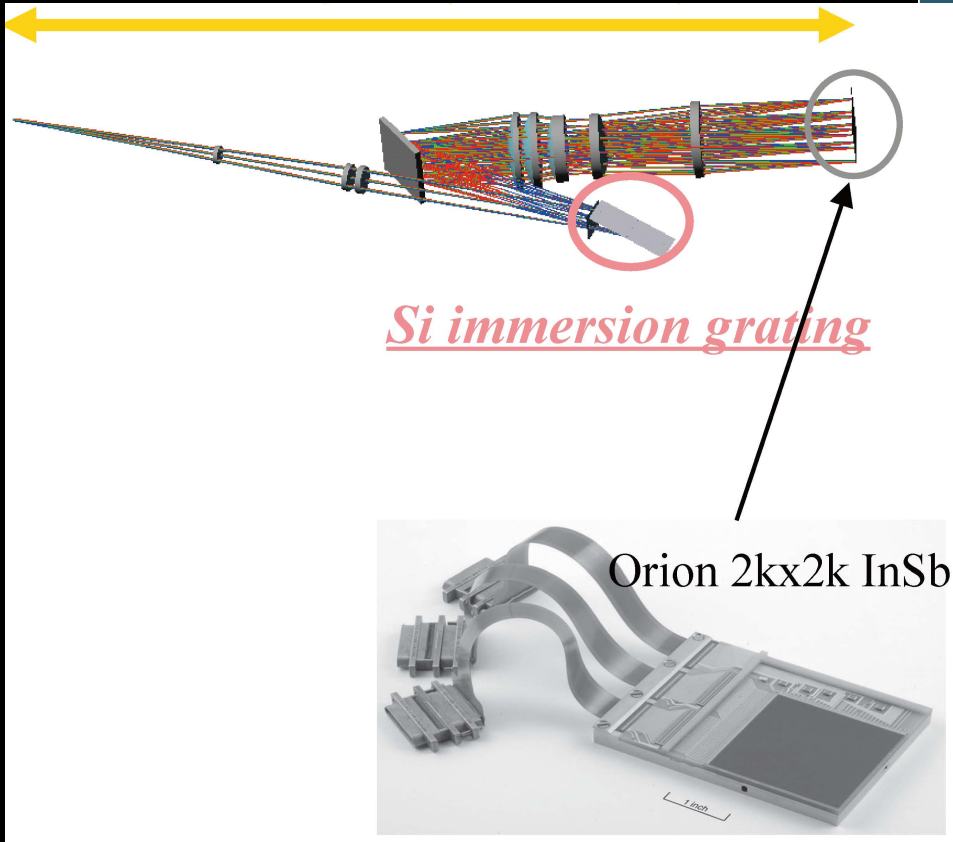


**Prime Focus
Corrector**

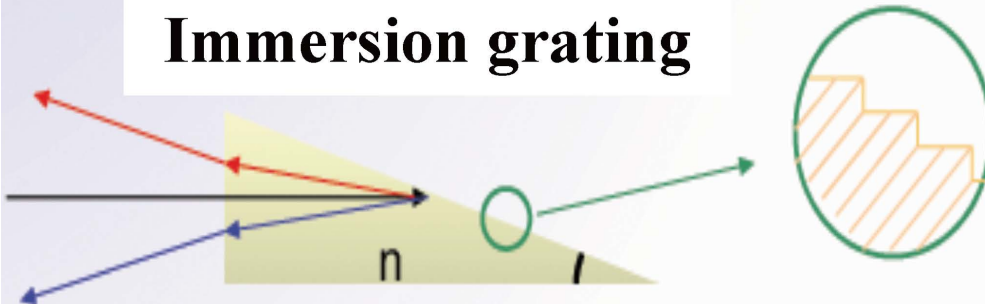


IRCS upgrade: High Spectral Resolution

500mm

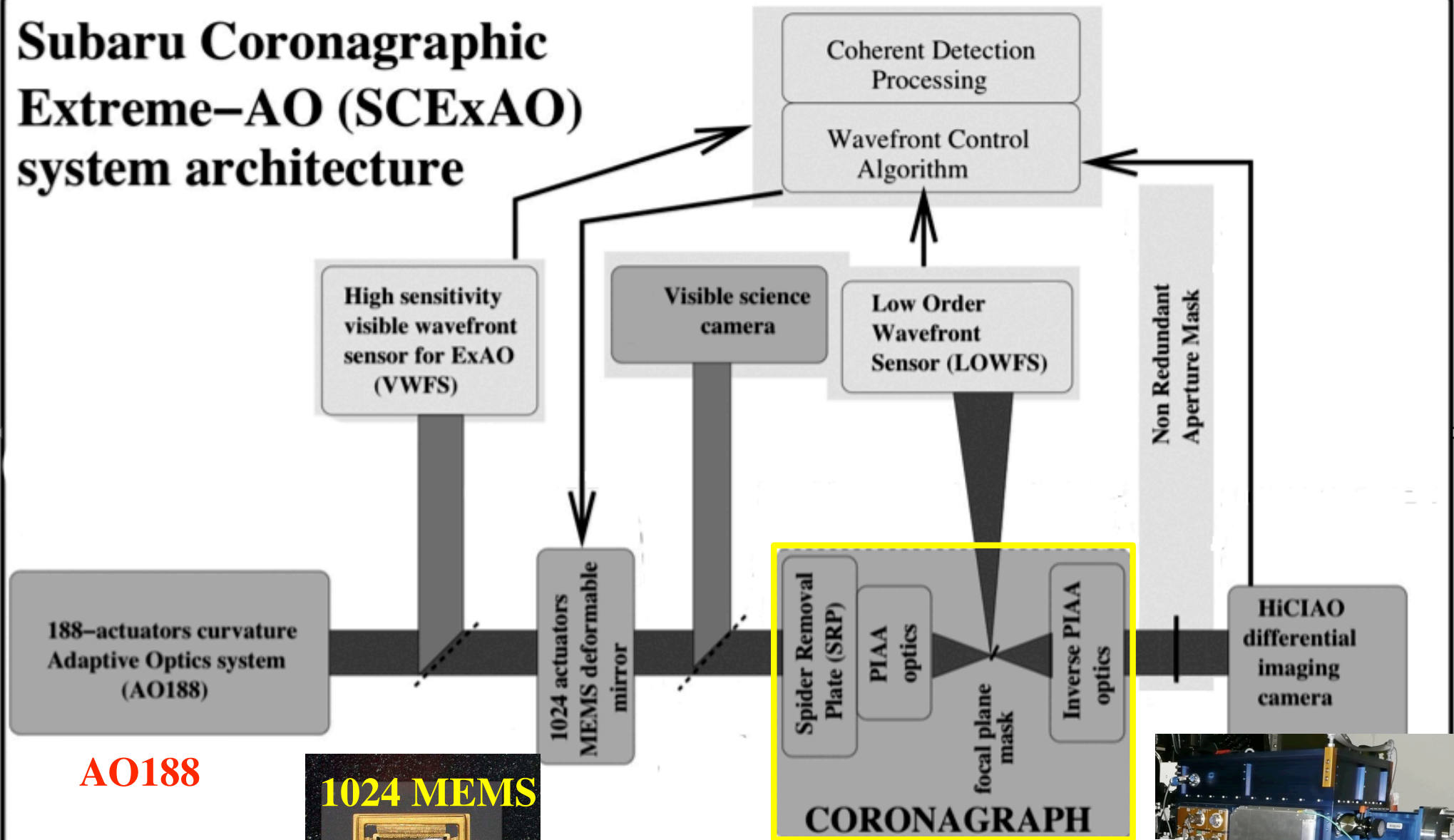


Immersion grating

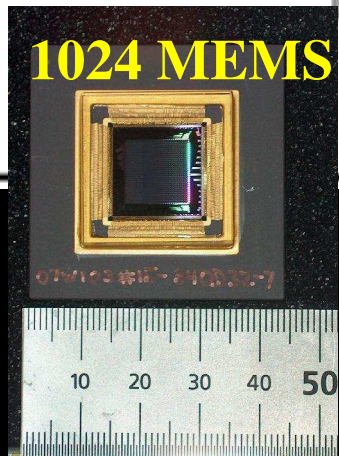


Compact & Add-on Unit

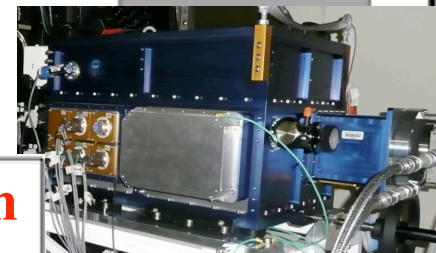
Subaru Coronagraphic Extreme-AO (SCExAO) system architecture



AO188

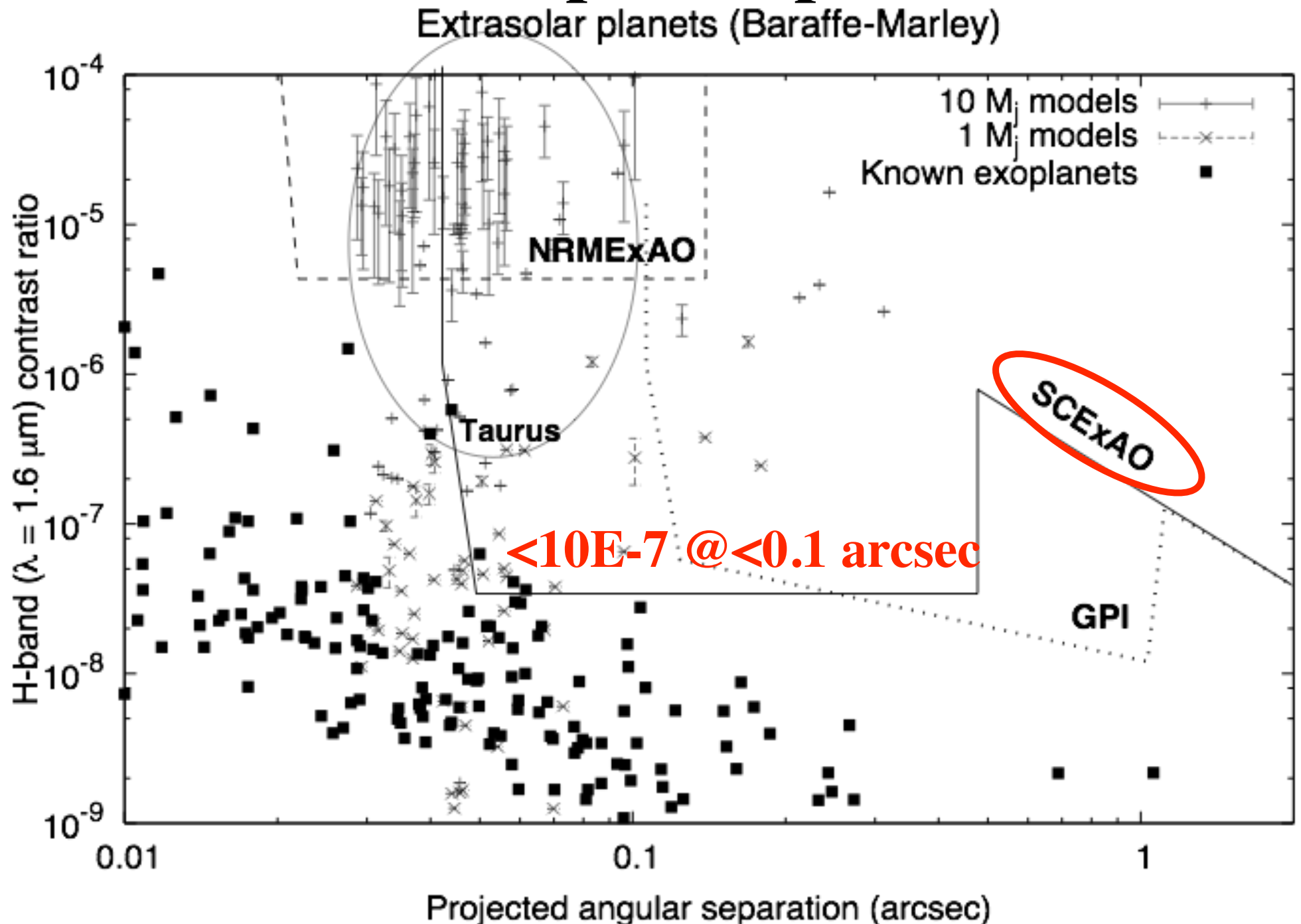


Silk hat $\Rightarrow$ Gaussian beam



HiCIAO

SCExAO: Expected performance



Hyper Suprime Cam (HSC)

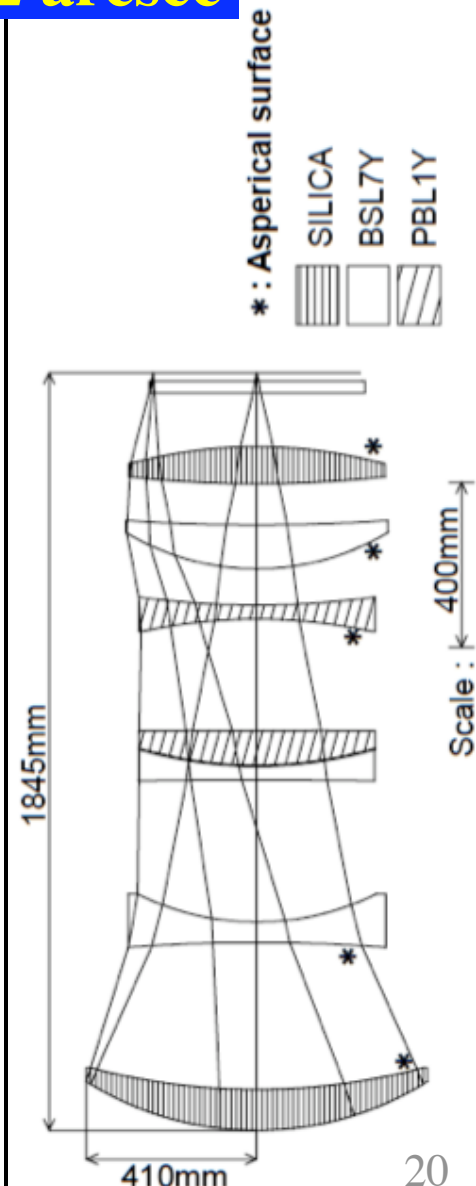
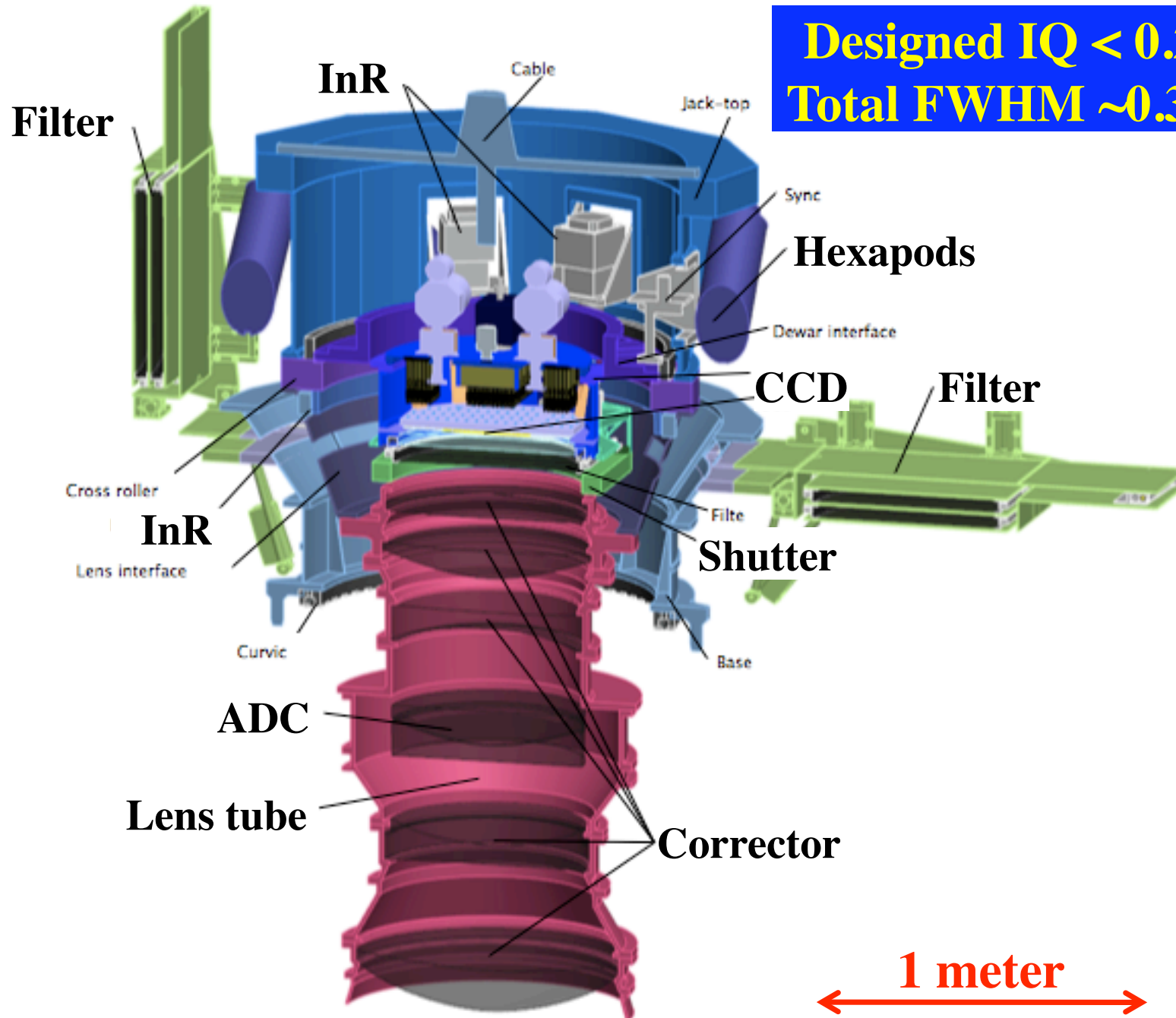


**Current PFU &
Suprime Cam**



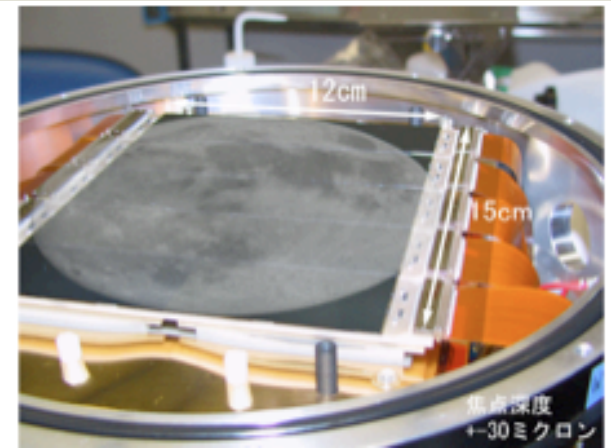
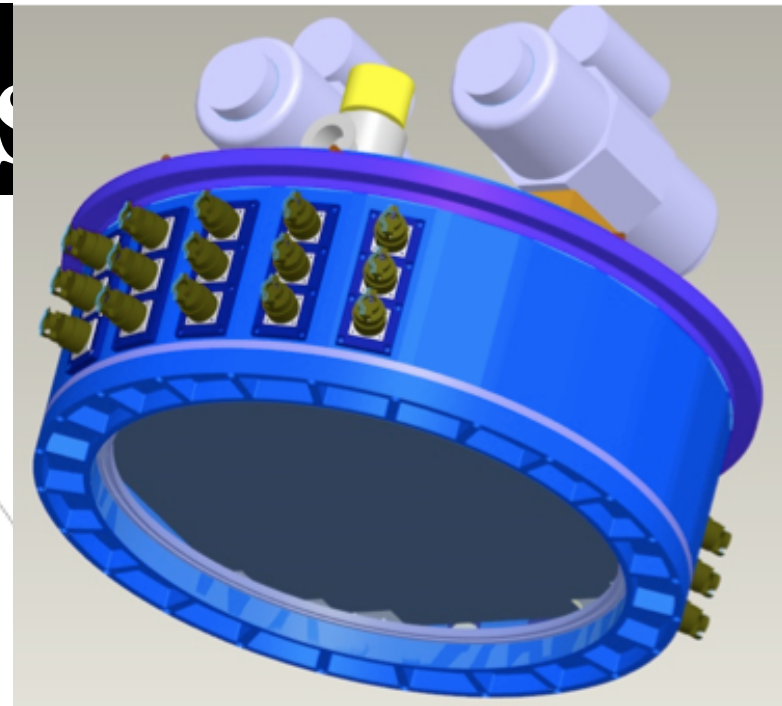
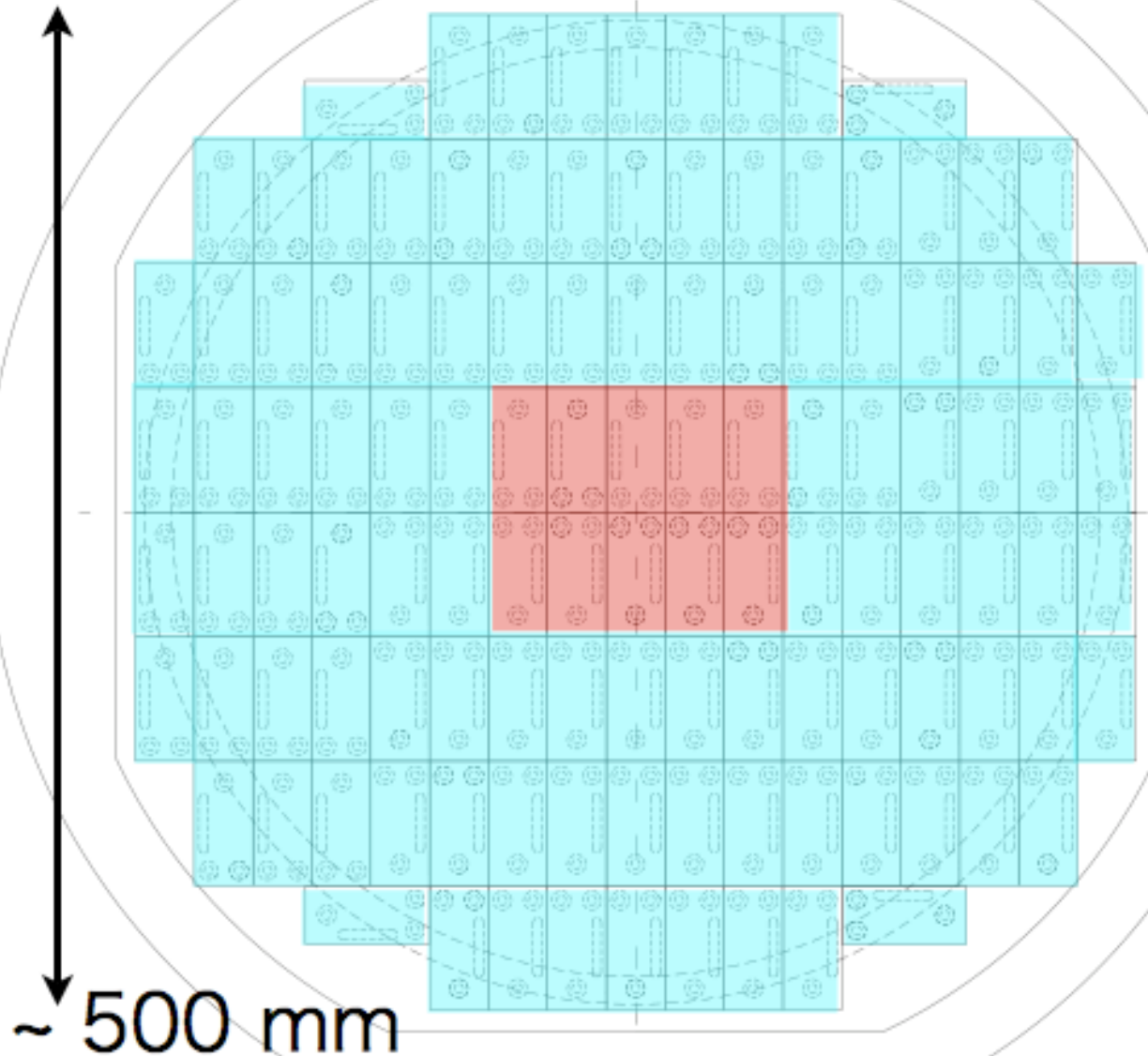
Hyper Suprime Cam (HSC)

Designed IQ < 0.2 arcsec
Total FWHM ~0.32 arcsec



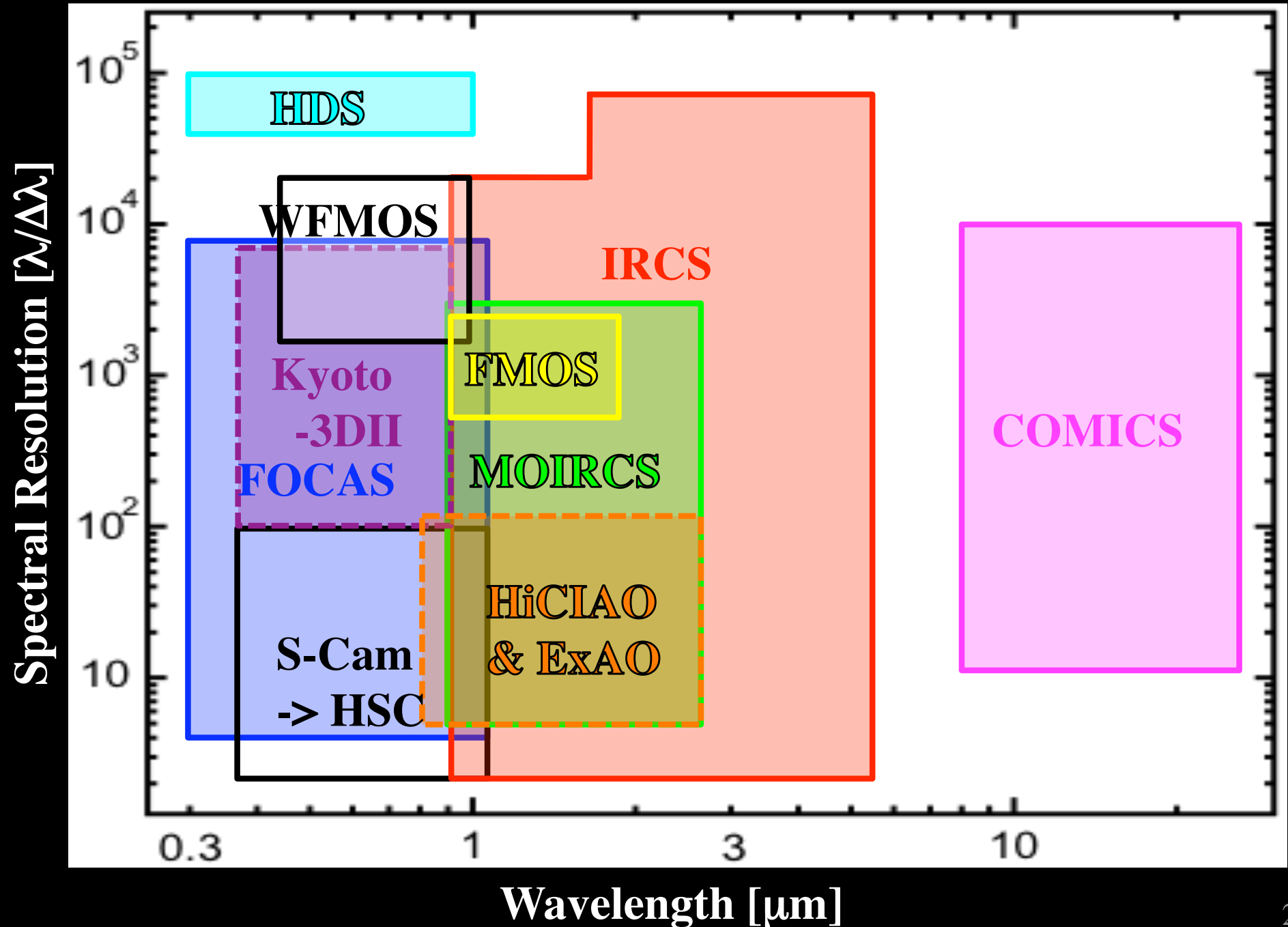
Hyper Suprime Cam (HSC)

116 CCDs (HSC) vs. 10 (S-Cam)



SiC monolithic
cold plate

3rd Gen Instruments (2005~2008)



Summary

- Subaru Telescope has started with 1st gen. **7 instruments + 1 AO36** from 1999 with very smooth the instrument exchange, provide great success!
- 2nd gen: MOIRCS (7' x 4' JHK MOS), LGS/AO188 & IRCS/HiCIAO ($\sim 10^{-5.5}$ contrast)/Kyoto-3DII, S-Cam CCD upgrade
- 3rd gen: **FMOS** (0.5 deg ϕ , 400 fibres MOS at JH), **IRCS-HRU** ($R=70,000$), **SCE_xAO** ($< 10^{-7}$ contrast), **Hyper S-Cam** (1.5 deg ϕ), **WFMOS** (Optical 2400 fibers w/ Gemini collaborations)
- **No other plans** now due to lack of budget. However, the current lineups will be still extremely powerful in next decade. Of course continue try to get more budget!