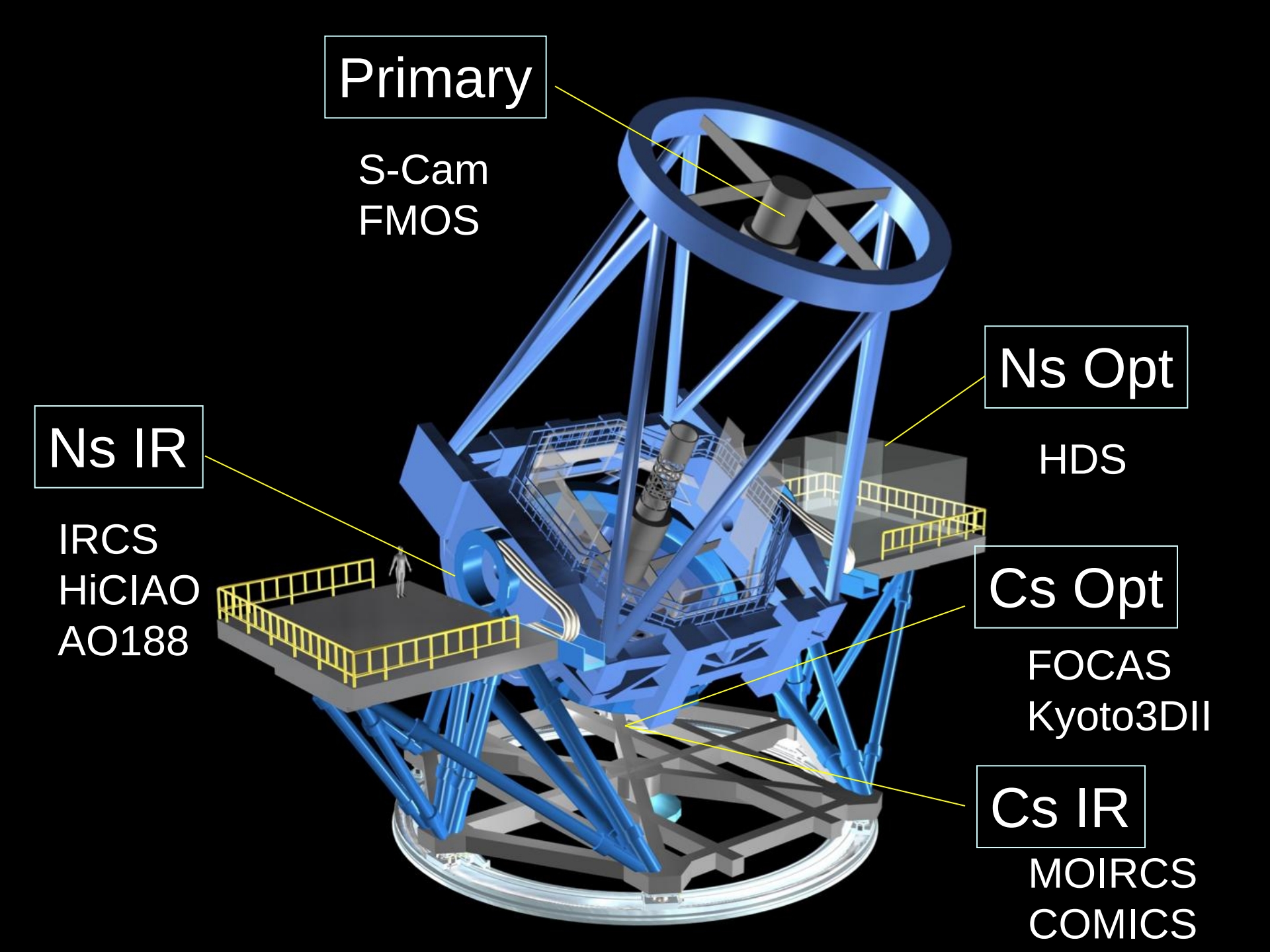
Instrumentation at the Subaru Telescope

- next 10 years -

Naruhisa Takato and Tomonori Usuda
(Subaru Telescope)


Primary
S-Cam
FMOS
Ns Opt
HDS
Ns IR
IRCS
HiCIAO
AO188
Cs Opt
FOCAS
Kyoto3DII
Cs IR
MOIRCS
COMICS

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-Depleterd CCDs (>40% @1↗m)**

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

- **Slit width=0.2~4", slit-width × R = 36,000 (e.g. R=100,000 @ 0.38")**
- **Two Image Rotator: Blue & Red optimized, I_2 cell since 2006**

FOCAS : FOV=φ6', 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), FDCCD in June 2010**
- **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~1,200l**

Infrared Instruments

MOIRCS : ↖=0.9~2.5↗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**

Infrared Instruments

MOIRCS : ↖=0.9~2.5↗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 : ↖=0.9~5.5↗m, 1k x 1k ALADDIN III (12, 20, 52 mas/pix)

- 18 Filters: *z,J,H,H+K’,K’,K,L’,M’, CH_4, [FeII], H_2, Br γ, PAH* etc.
- R=100~2,000 w/ grisms, R~20,000 w/ Echelle (wide ↖coverage)

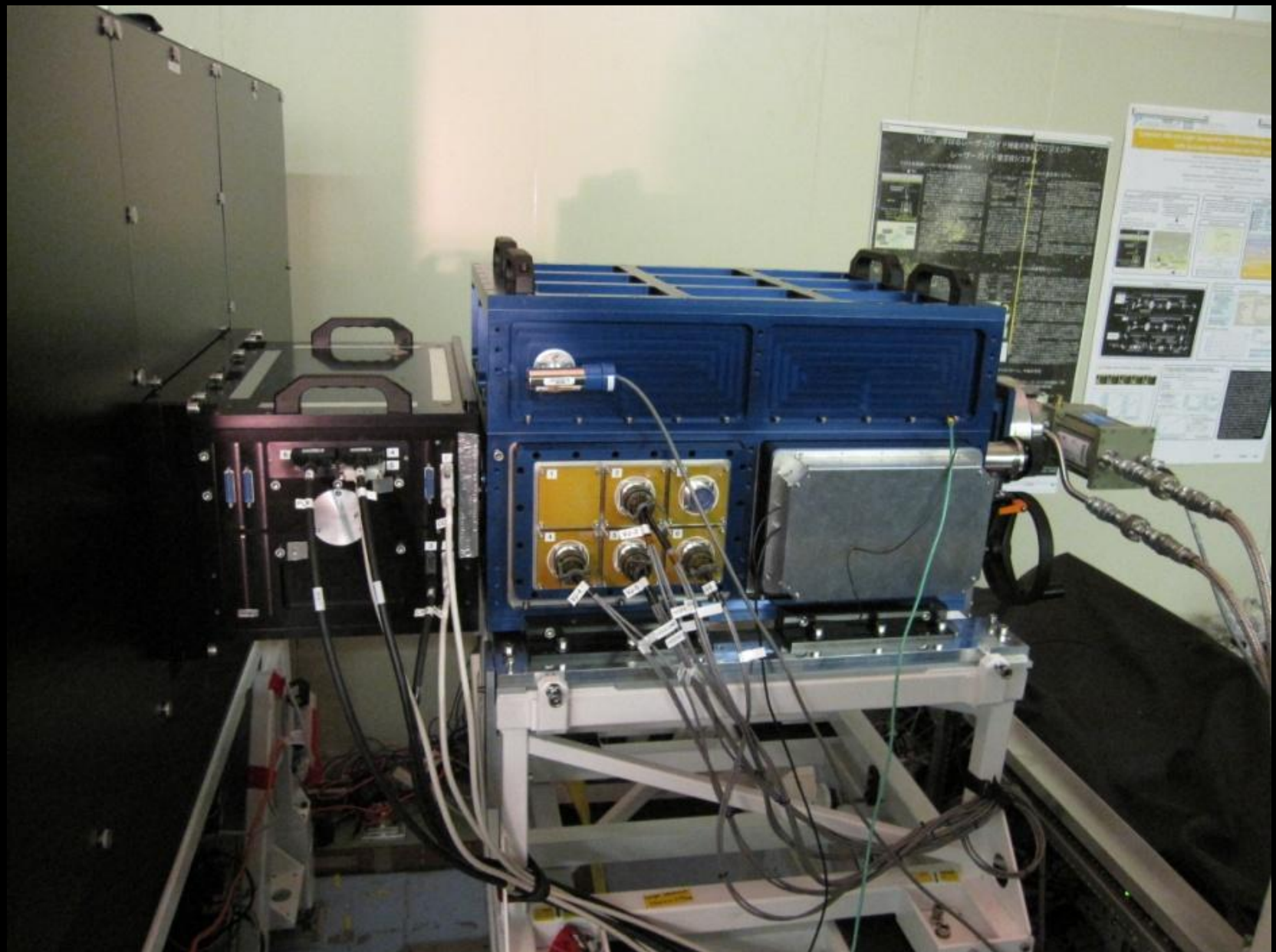
COMICS : ↖=8~25μm, Six 320x240 Si:As (cf. 5 for spg)

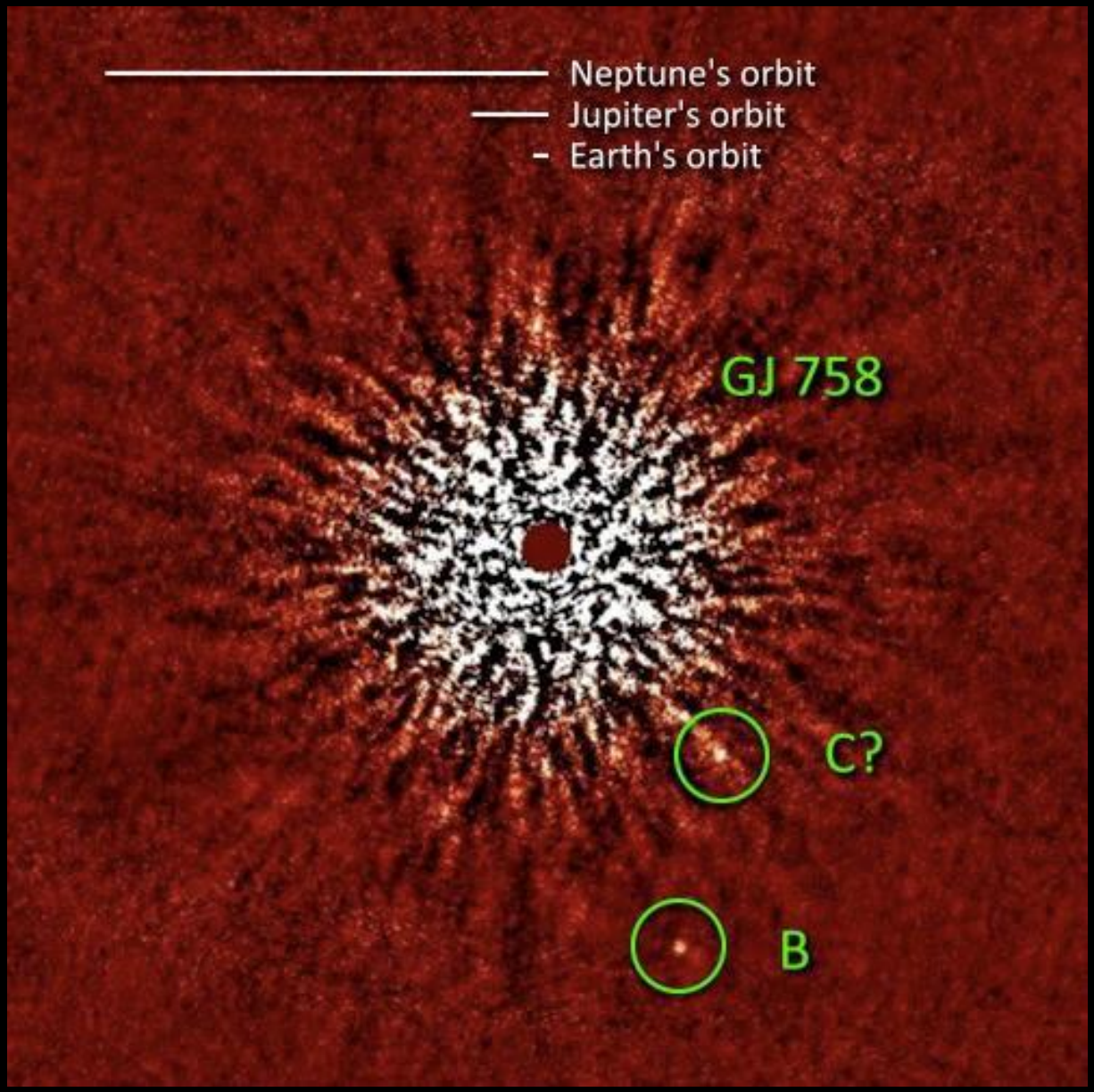
- 0.13”/pix, FOV=42”x32”, max 60” chopping
- 15 Filters: 6 N-band cont, 5 N-band NB, 4 Q-band cont
- R=250~11000 w/ 0.33” slit with 5 gratings

PI: HiCIAO : ↖=0.85~2.5↗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” → ~10E-5.5

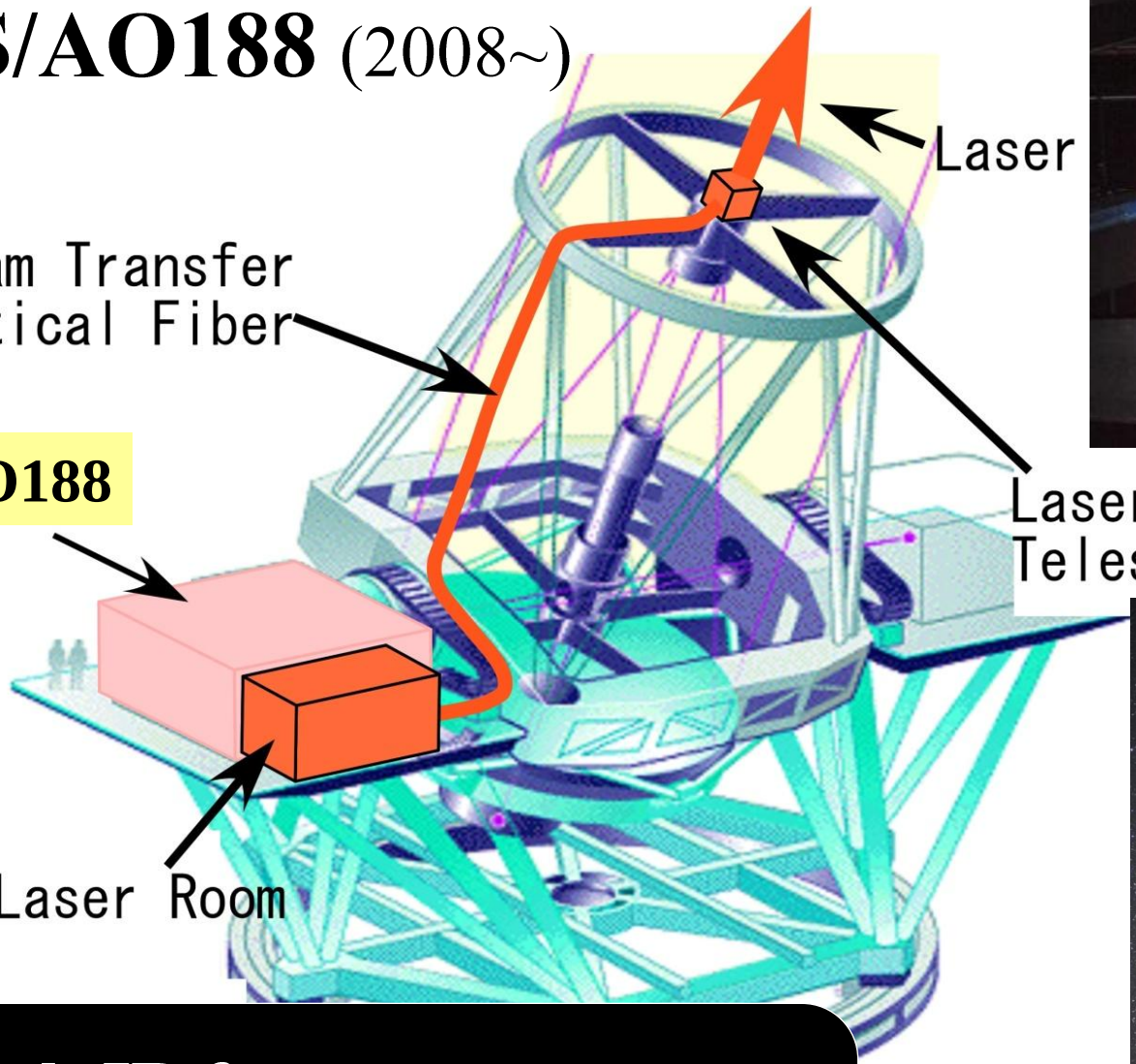
HiCIAO



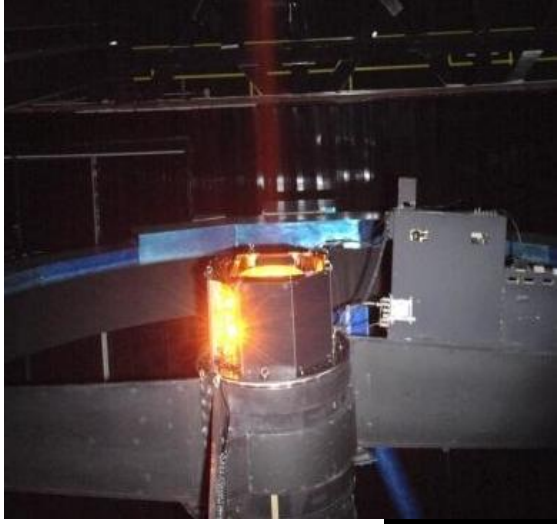


Thalmann+ 2009

LGS/AO188 (2008~)



LGS/AO188



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

3rd Generation Instruments

FMOS (2010~): FOV=φ30' , ↖=0.9~1.8↗m, 400 x φ1.2" fiber

- Cooled (T=-55C) two spectrographs w/ OH supplession
- R=500 (1 time exp) & 2,200 (4 times exp)

IRCS-HRU (from 2011): Additional High Spect. Resolution Unit

- ↖=1.4~5.5↗m, ORION 2k x 2k InSb, w/ IR gas cell (NH_3)
- R~70,000 w/ Si Immersion Grating (*n*~3.4)

Subaru Coronagraphic ExAO (from 2010)

- PIAA Coronagraph, Coronagraphic WFS, MEMS(1024)→ <10E-7

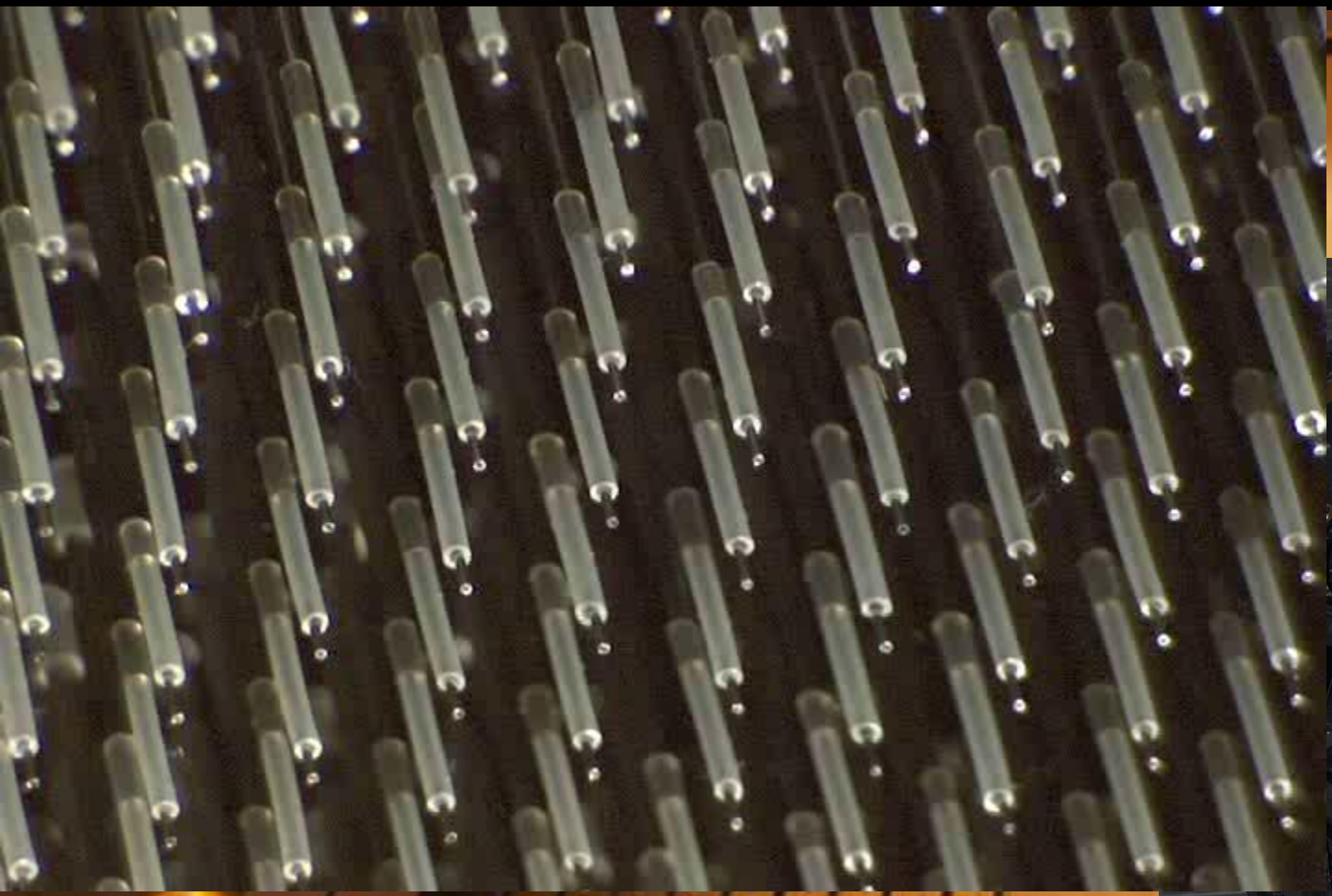
Hyper Suprime Cam (from 2011)

- FOV=φ1.5 deg , 116 2k x 4k FDCCD, ↖=0.4~1.1↗m
- 6 Filters (φ60cm): *Broad (g', r', i', etc.), Narrow*

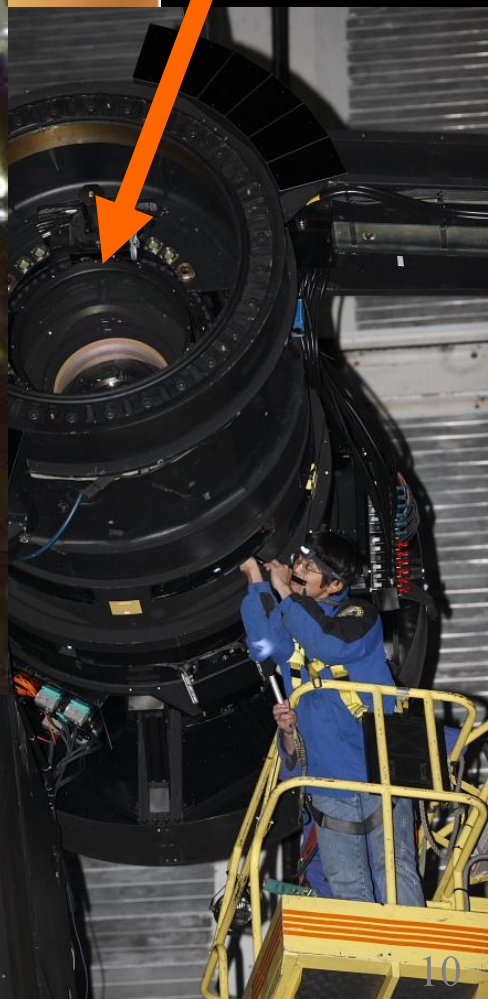
IRDI (IR Doppler Instrument) (from 2013): Funded in FY2010

- ↖=1.1~1.7↗m, 2 x H2RG, w/ Frequency Comb (~1m/s)
- R~70,000 w/ ZnSe Imm. Grating (*n*~2.4), Fiber fed

FMOS



Prime Focus Corrector



Echidna 400 fibers

3rd Generation Instruments

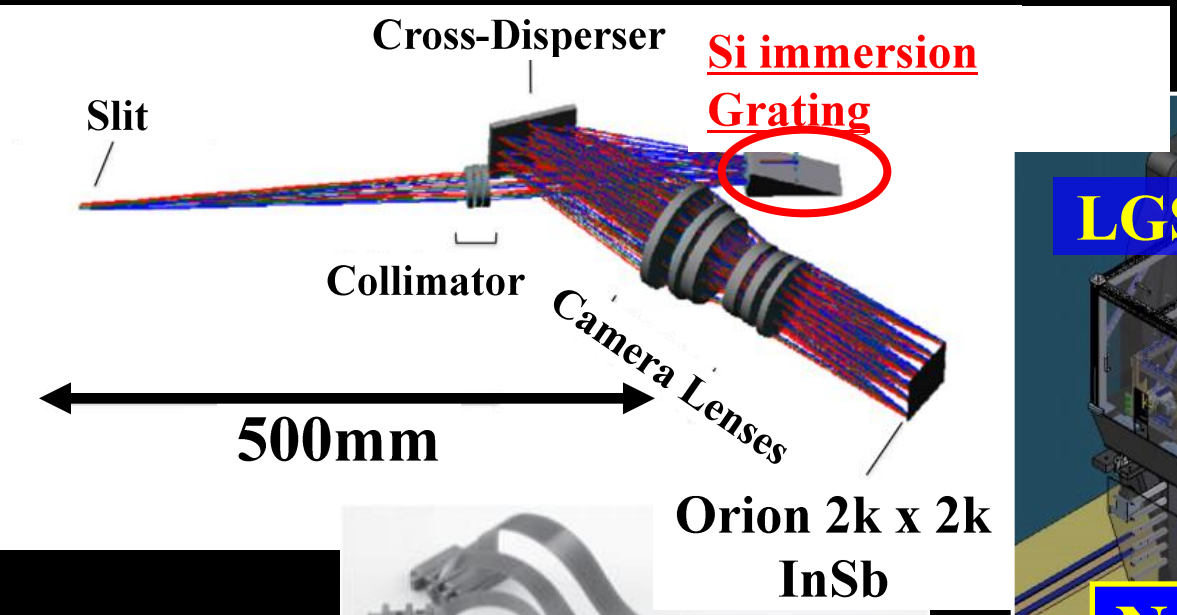
FMOS (2010~): FOV=φ30' , ↖=0.9~1.8↗m, 400 x φ1.2" fiber

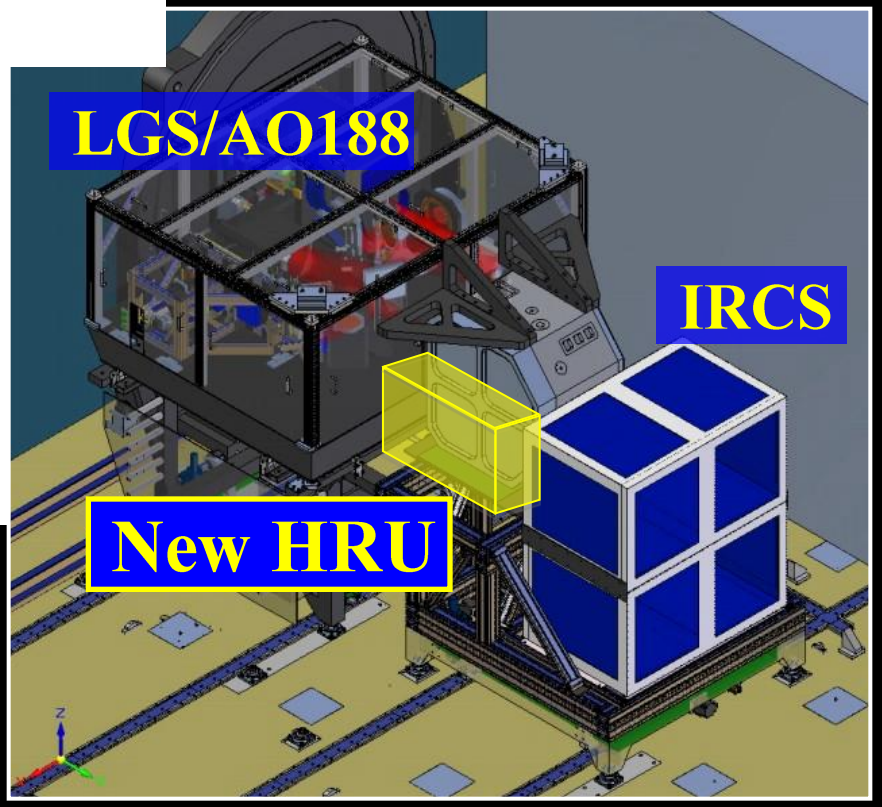
- Cooled (T=-55C) two spectrographs w/ OH supplession
- R=500 (1 time exp) & 2,200 (4 times exp)

IRCS-HRU (2012~): Additional High Spect. Resolution Unit

- ↖=1.4~5.5↗m, ORION 2k x 2k InSb, w/ IR gas cell (NH_3)
- R~70,000 w/ Si Immersion Grating (*n*~3.4)

IRCS HRU (High spectral Resolution Unit)





- Compact & Add-on Unit
- First @North Hemisphere
- Only 1 w/ LGS (& JR-WFS)

3rd Generation Instruments

FMOS (from 2010): FOV=30', ↖=0.9~1.8↗m, 400 x 1.2" fiber

- Cooled (T=-55C) two spectrographs w/ OH supplession
- R=500 (1 time exp) & 2,200 (4 times exp)

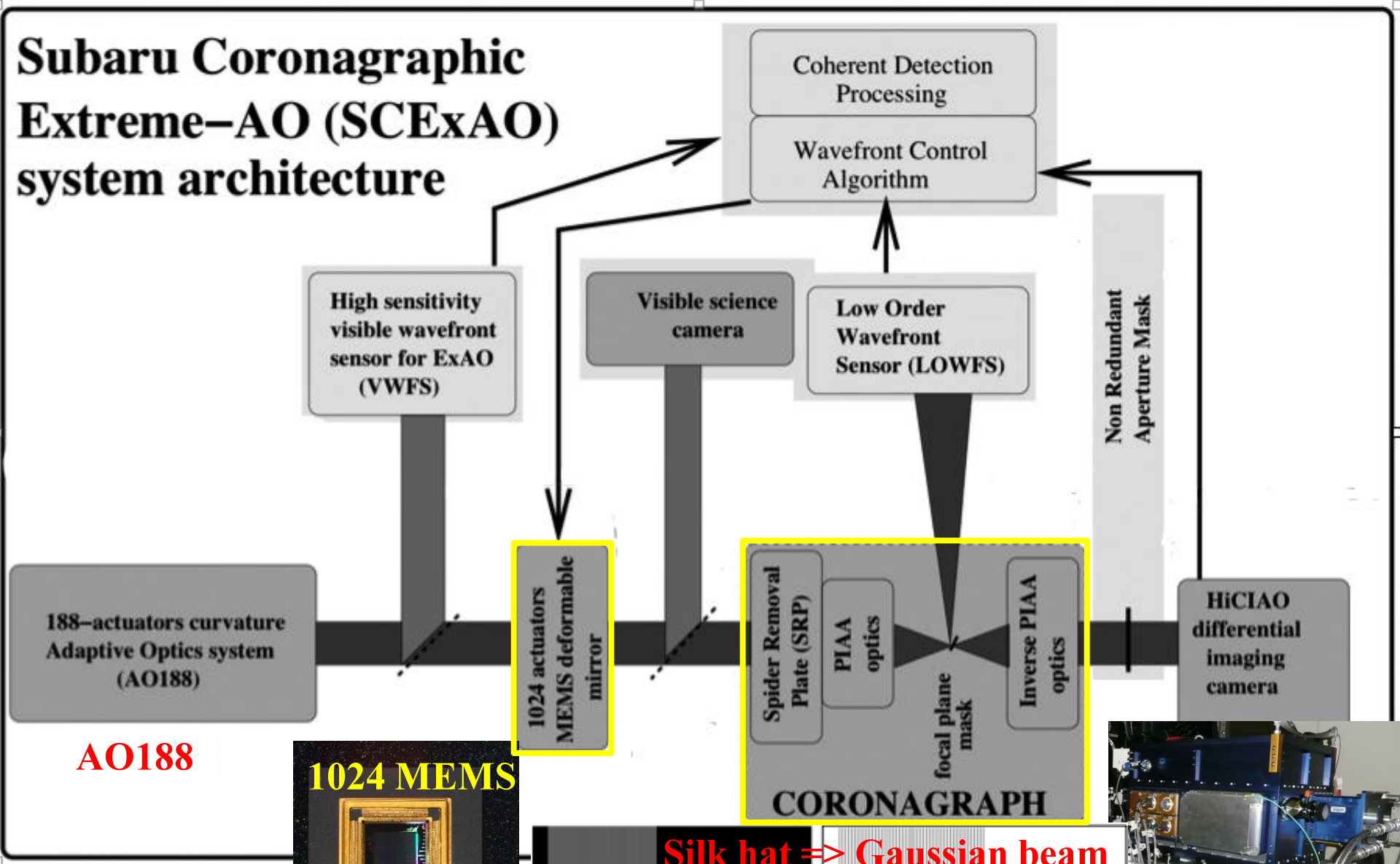
IRCS-HRU (from 2011): Additional High Spect. Resolution Unit

- ↖=1.4~5.5↗m, ORION 2k x 2k InSb, w/ IR gas cell (NH_3)
- R=73,000 w/ Si Immersion Grating (*n*~3.4)

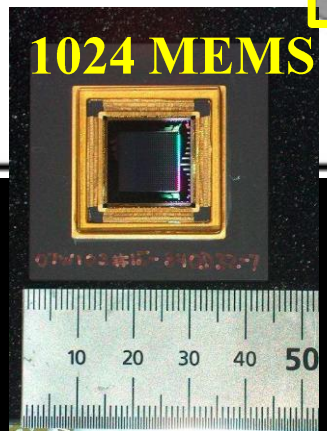
Subaru Coronagraphic ExAO (2010~)

- PIAA Coronagraph, Coronagraphic WFS, MEMS(1024)→ <10E-7

Subaru Coronagraphic Extreme–AO (SCExAO) system architecture



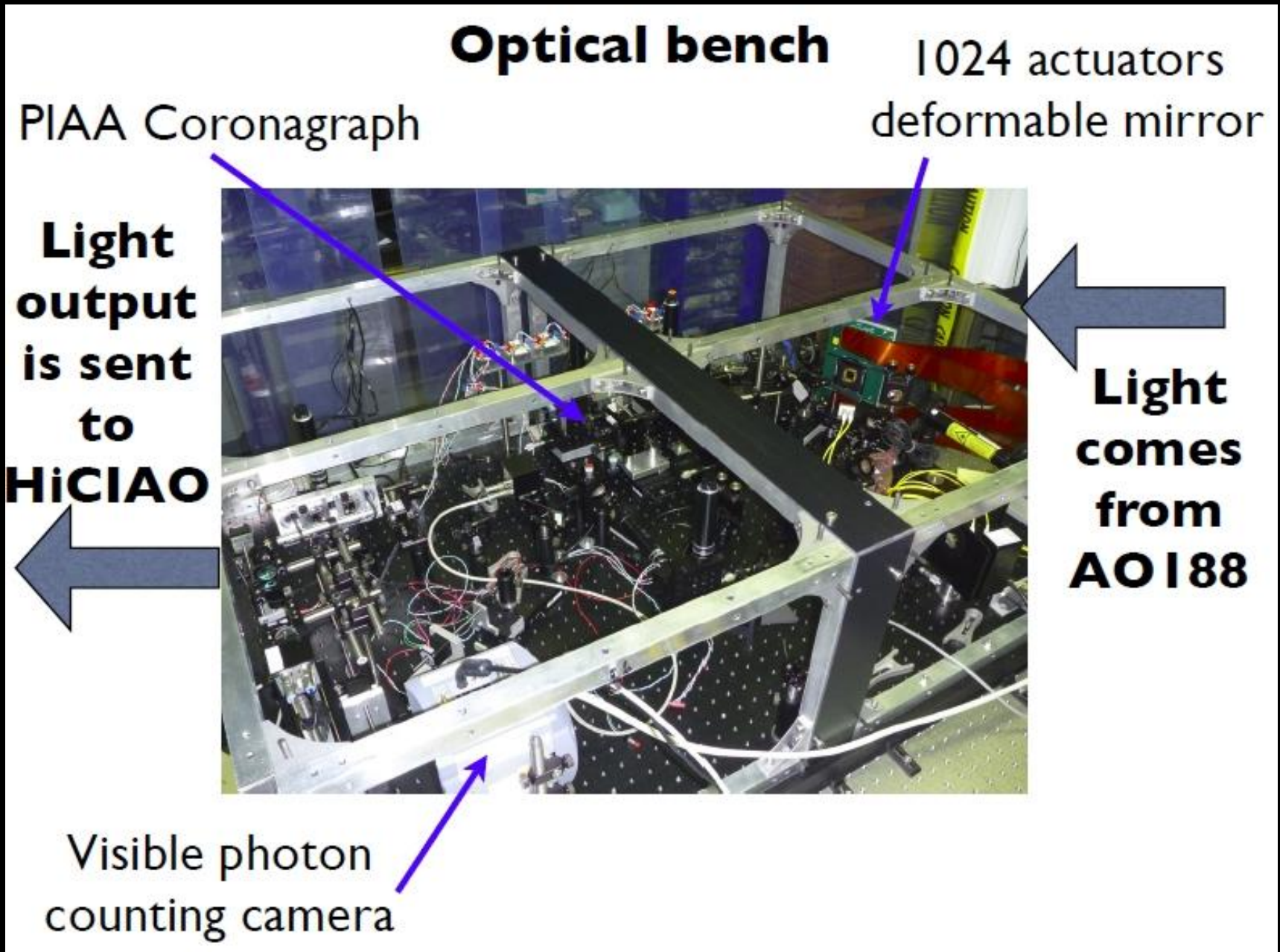
AO188



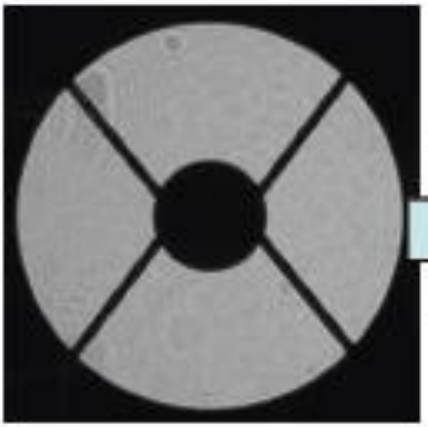
Silk hat => Gaussian beam

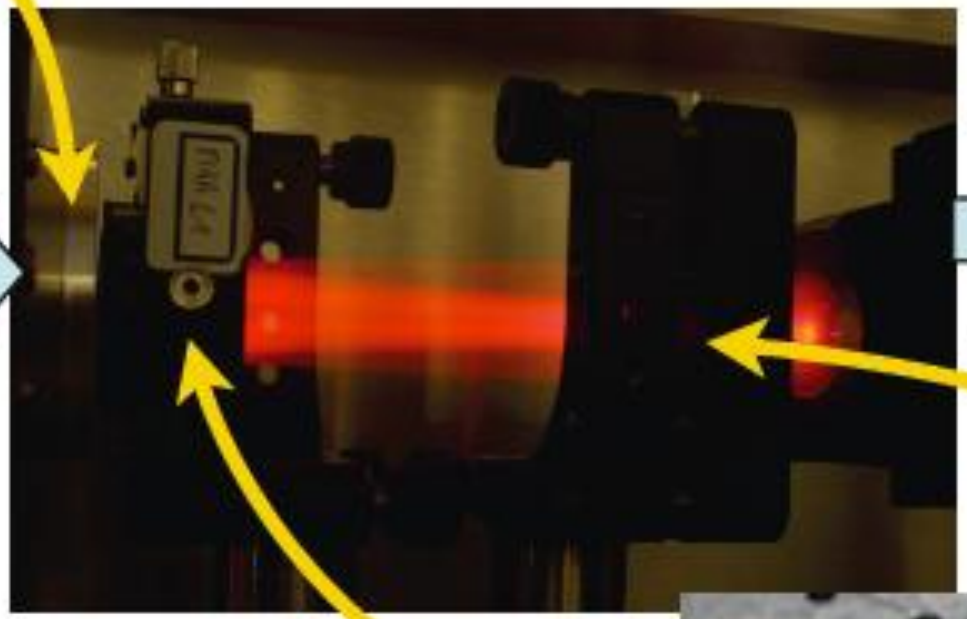
HiCIAO

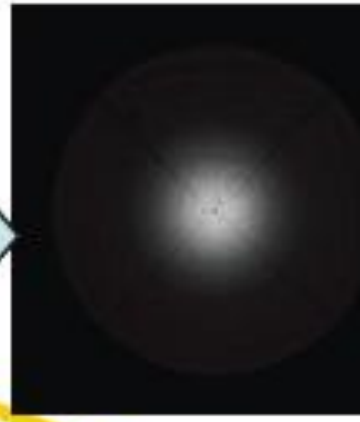
SCExAO

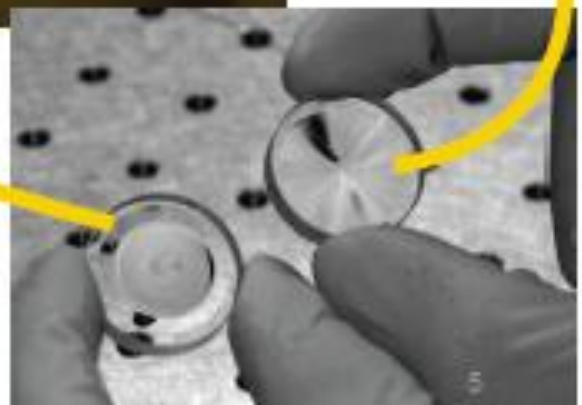

Optical bench
1024 actuators deformable mirror
PIAA Coronagraph
Light output is sent to HiCIAO
Light comes from AO188
Visible photon counting camera

PIAA lenses + spider removal plate apodize the Subaru pupil with no light loss









- On-axis lenses
- Lenses are 96 mm apart
- Apodize the beam
- Remove the central obscuration
- Spider removal plate to remove spiders

3rd Generation Instruments

FMOS (from 2010): FOV=30' ⤢, ●=0.9~1.8❍m, 400 x 1.2" fiber

- Cooled (T=-55C) two spectrographs w/ OH supplession
- R=500 (1 time exp) & 2,200 (4 times exp)

IRCS-HRU (from 2011): Additional High Spect. Resolution Unit

- ●=1.4~5.5❍m, ORION 2k x 2k InSb, w/ IR gas cell (NH_3)
- R=73,000 w/ Si Immersion Grating (*n*~3.4)

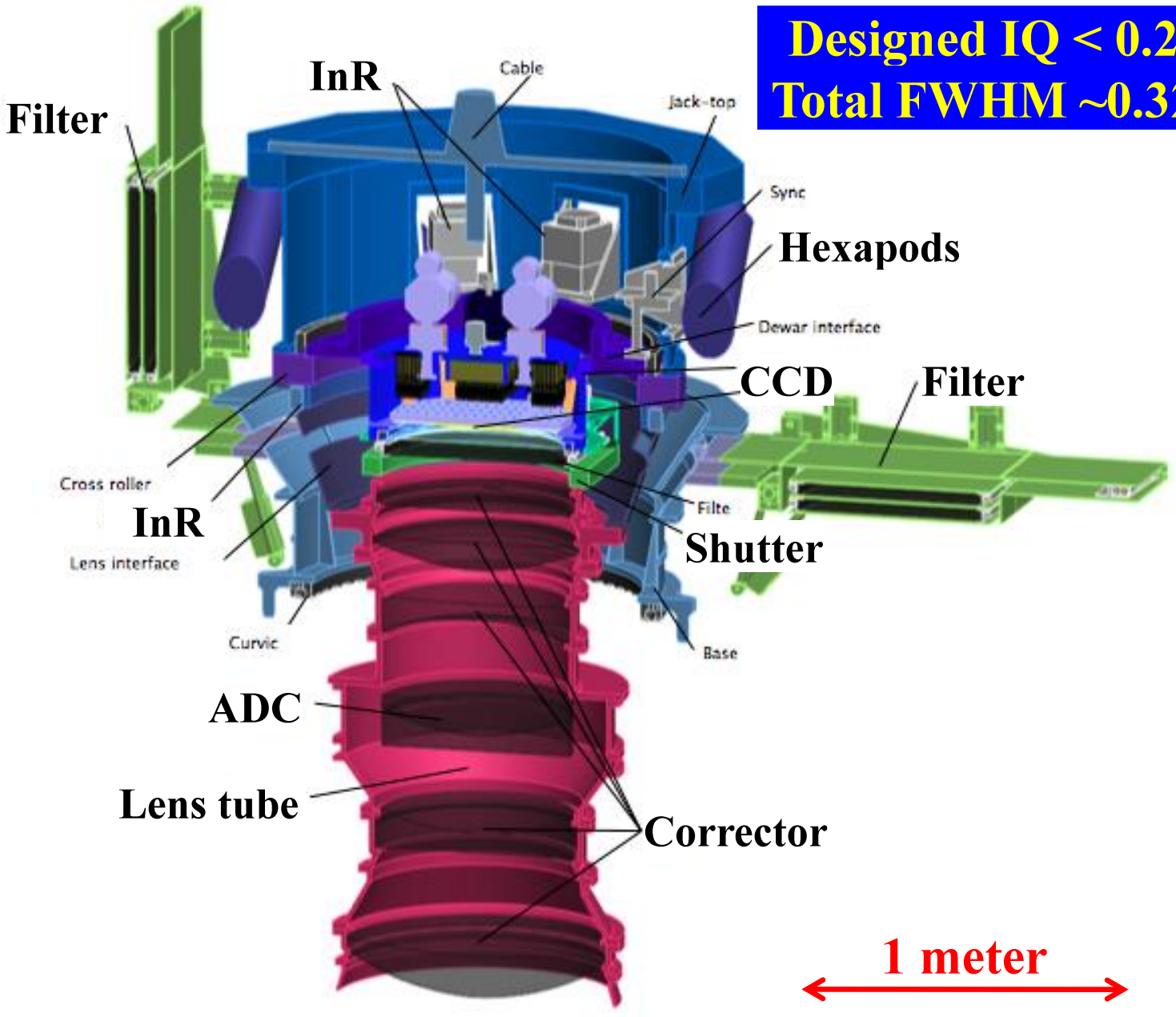
Subaru Coronagraphic ExAO (from 2010)

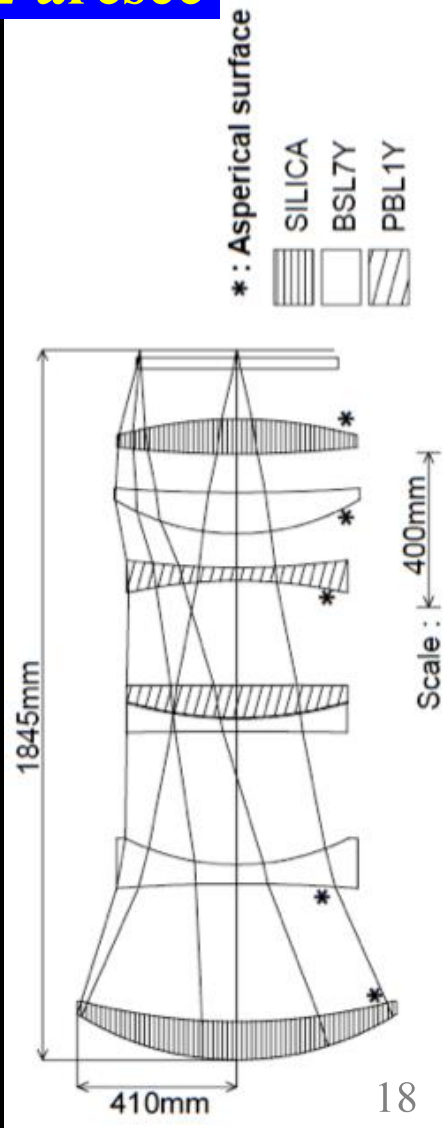
- PIAA Coronagraph, Coronagraphic WFS, MEMS(1024)→ <10E-7

Hyper Suprime Cam (from 2011) w/ ASIAA, Princeton, etc.

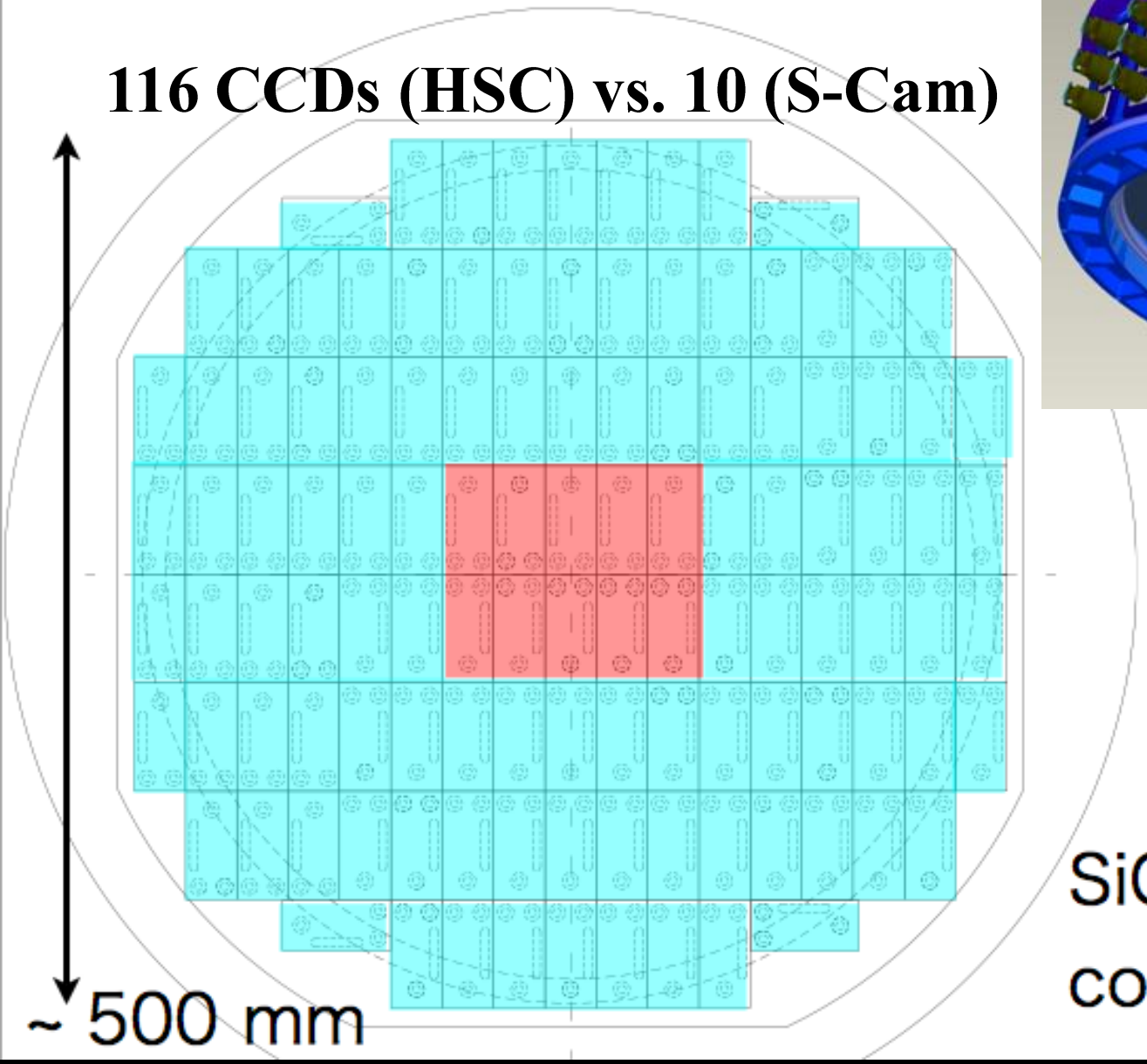
- FOV= φ 1.5 deg, 116 2k x 4k FDCCD, ⬉=0.4~1.1⬈m
- 6 Filters (φ 60cm): *Broad (g', r', i', etc.), Narrow*

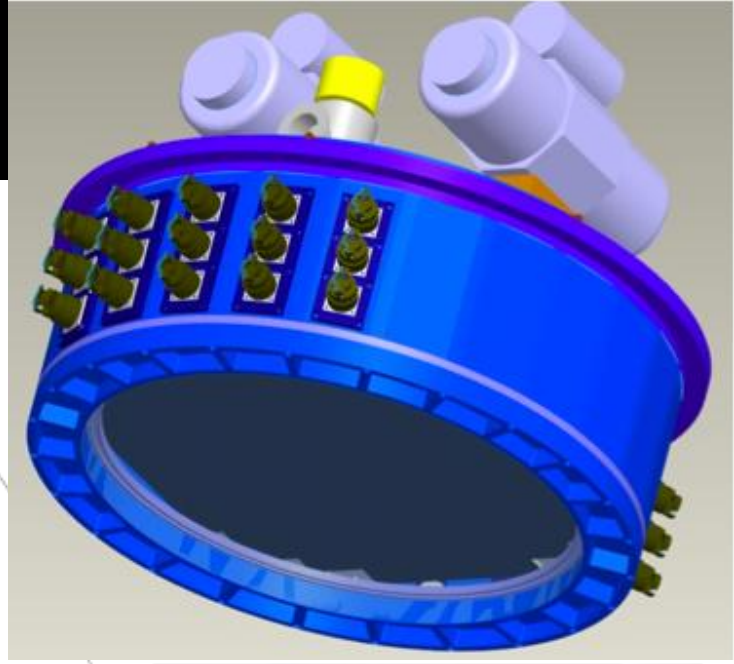
Designed IQ < 0.2 arcsec
Total FWHM ~0.32 arcsec

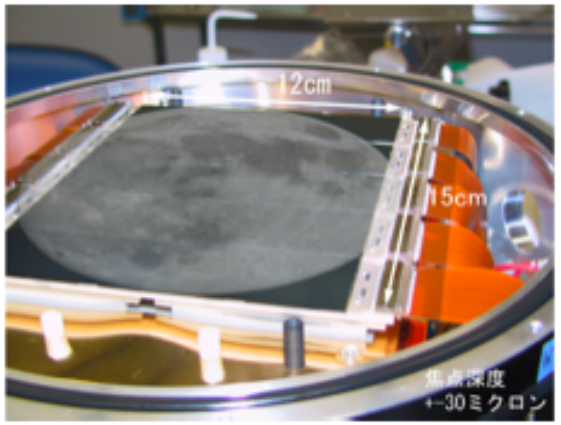




116 CCDs (HSC) vs. 10 (S-Cam)







SiC monolithic cold plate

3rd Generation Instruments

FMOS (2010~): FOV=φ30' , ●=0.9~1.8❍m, 400 x φ1.2" fiber

- Cooled (T=-55C) two spectrographs w/ OH supplession
- R=500 (1 time exp) & 2,200 (4 times exp)

IRCS-HRU (2012~): Additional High Spect. Resolution Unit

- ↖=1.4~5.5μm, ORION 2k x 2k InSb, w/ IR gas cell (NH_3)
- R~70,000 w/ Si Immersion Grating (*n*~3.4)

Subaru Coronagraphic ExAO (2010~)

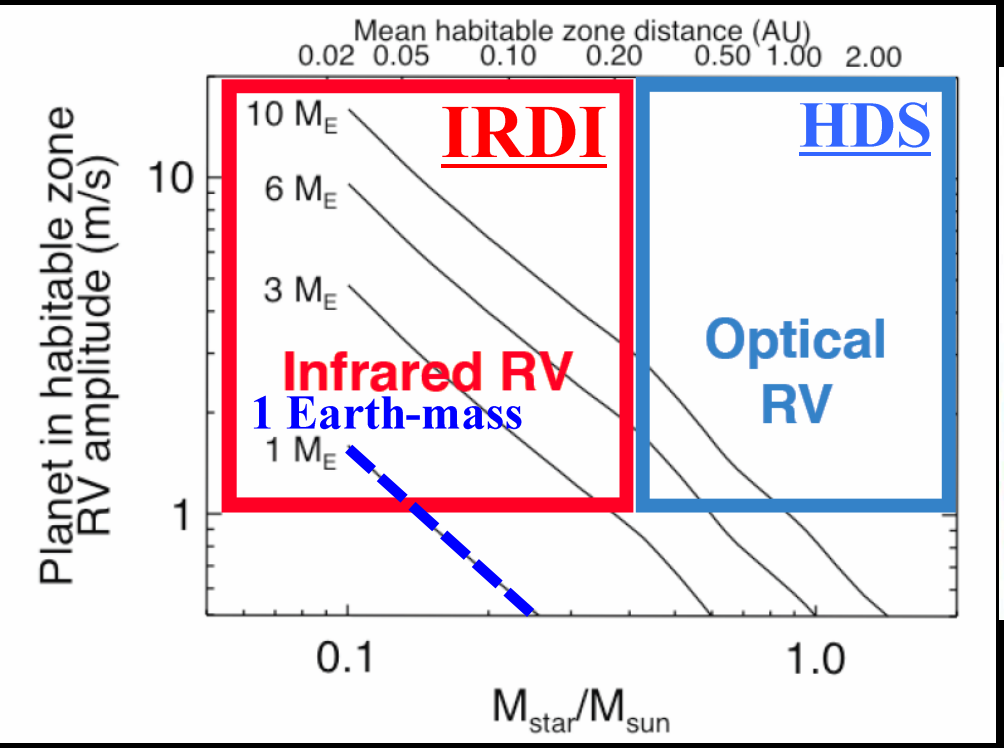
- PIAA Coronagraph, Coronagraphic WFS, MEMS(1024)→ <10E-7

Hyper Suprime Cam (from 2011)

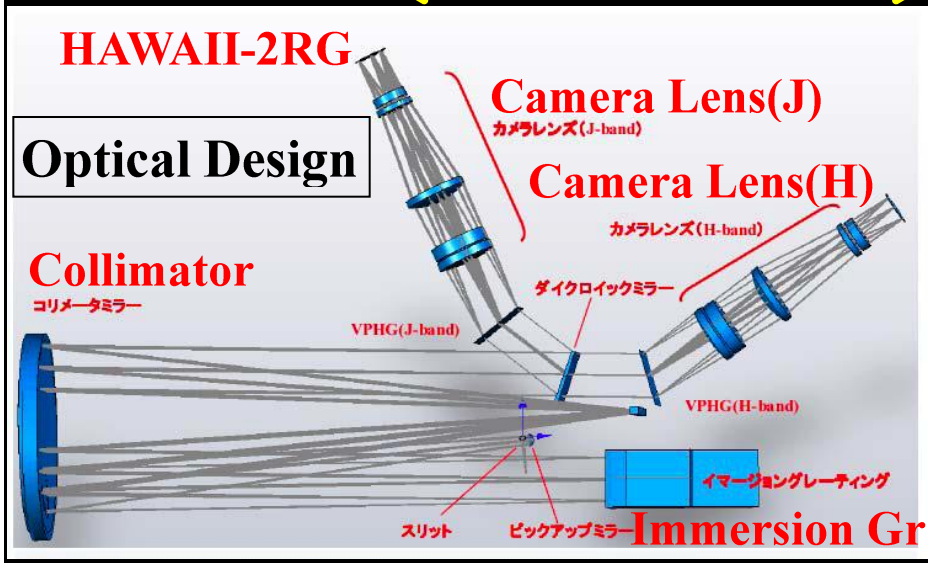
- FOV=φ1.5 deg , 116 2k x 4k FDCCD, ↖=0.4~1.1↗m
- 6 Filters (φ60cm): *Broad (g', r', i', etc.), Narrow*

IRD (IR Doppler Instrument) (2013~): Funded in FY2010

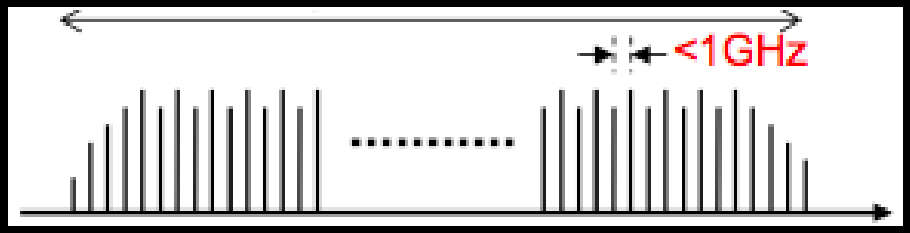
- ↖=1.1~1.7↗m, 2 x H2RG, w/ Frequency Comb (~1m/s)
- R=70,000 w/ ZnSe Imm. Grating (*n*~2.4), Fiber fed

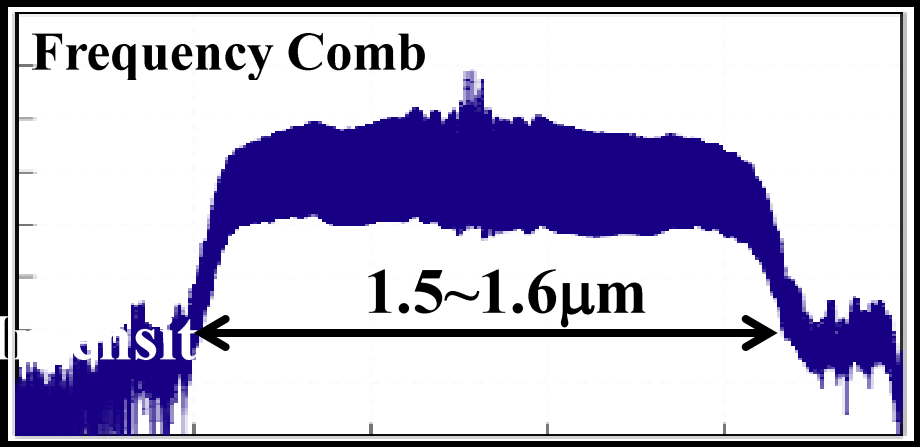


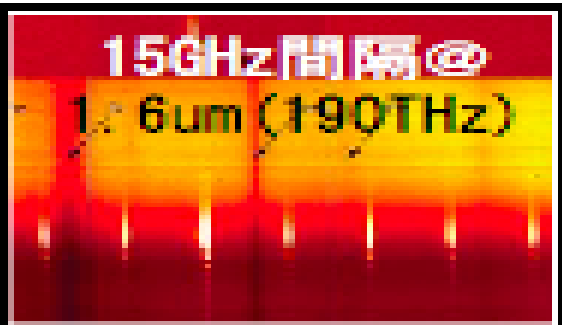
~50 cm



Frequency Comb

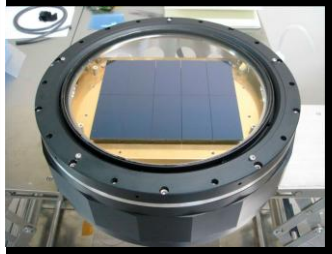






2nd Gen Instruments (2005~2009)

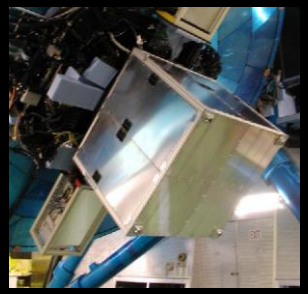
- *PF*
- *Nas*
- *Cass*

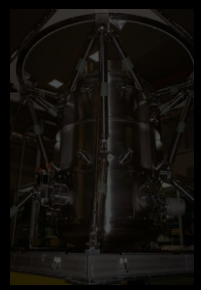


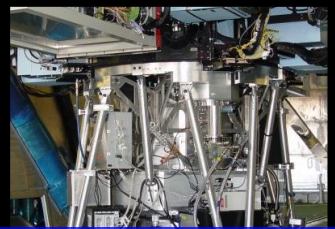
Suprime-Cam
(34'x27') **CCD upgraded (2008)**

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

HDS







FOCAS **(Kyoto 3DII)** **(CIAO)**

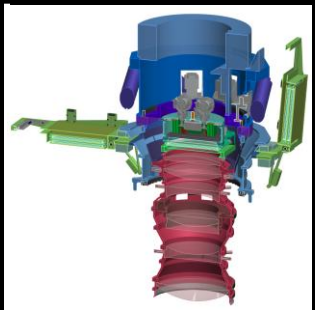
(4'x7' / 2005)
MOIRCS

COMICS

Optical **NIR (1~5μm)** **MIR (10~20μm)**

3rd Gen Instruments (2010~)

- *PF*
- *Nas*
- *Cass*



Hyper S-Cam
(φ1.5 deg / 2011~)

FMOS (2010)
(φ30' / JH)

HDS

Image Slicer mode

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

CCD upgraded (2010)

FOCAS (Kyoto 3DII)

MOIRCS

COMICS

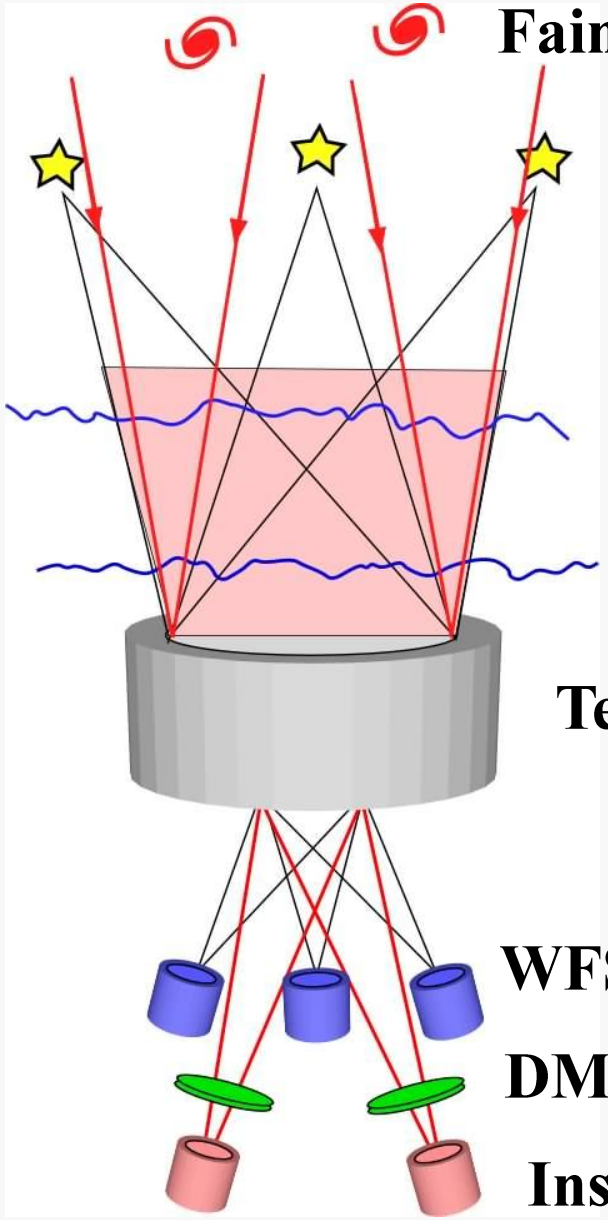
Optical **NIR** (1~5μm) **MIR** (10~20μm)

Future Instruments

RAVEN (from 2013): MOAO Demonstrator with IRCS @NsIR

- **Collaboration w/ UVic & HIA since 2009**
- **3 WFS for NGS (FOV=φ2’ , 2 DMs for Science targets）**

RAVEN: MOAO (Multi Object AO)



FOV:
-patrol: ~arcmin
-unit: ~arcsec

Tomographic wavefront reconstruction

Key Technologies

Open-loop control

Future Instruments (not fully funded)

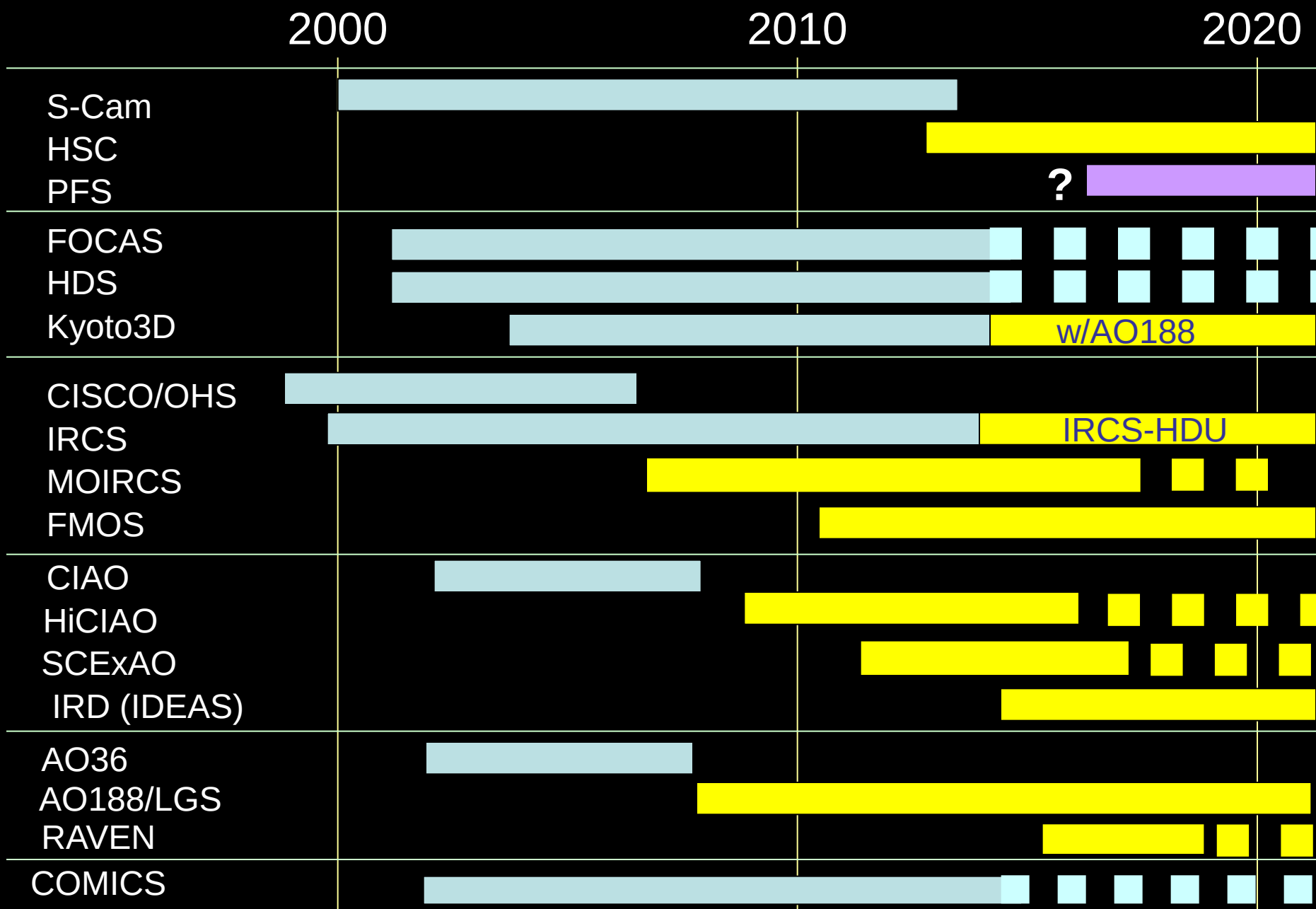
RAVEN (from 2013): MOAO Demonstrator with IRCS @NsIR

- **Collaboration w/ UVic & HIA since 2009**
- **3 WFS for NGS (FOV=φ2' , 2 DMs for Science targets**

PFS (from 201x): **WFMOS-like Multi-object spectrograph @PF**

- **SuMIRe (Subaru Measurements of Images and Redshifts)** led by U. Tokyo IPMU for HSC and PFS: **partially funded (~$15M)**
- **FOV~φ1.5 deg** , 2000 - 4000 **fiber, R=1,000~20,000,** ↖=0.4~1.1↗m
- Waiting for the community approval
- Specifications will be determined soon.

Subaru instrumentation



Possible PI-type Instruments

SWIIMS (2013?): **IR MOS for TAO**

- **FoV: 7' x 3.5' (=> 7.5' x 7.5')**
- **2-band simultaneously (0.9-1.4, 1.4-2.5um)**

TAO-MIR (2013?): **MIR imager/spectrograph for TAO**

- **Field stacker (simultaneous imaging of two independent filed for accurate differential photometry)**

SWIFT (from 201x): **IFS w/image slicer @Cs**

- **Optimized for 0.7-1.0 um**

MIR-HDS (from 201x):

- **Ge-immersion grating**

summary

- Strengthen Subaru's advantage
  - wide-field capability
  - good image quality
- Balancing between survey/narrow science instruments and general purpose instruments.
- Test-bed for future development (e.g. TMT instruments)

- **観測所として推進するべき方向は何か**
  - 広視野　＆　高解像度？
  - 多様なサイエンス要求への対応
  - サーベイ型の使い方をどこまで許容するか
  - 幅広いニーズへの対応、萌芽的研究をすばるでやるには
  - 観測所の強みを生かすには
  - 将来につながる種を育てるには
  - TMT
- **すばるの開発体制**
  - ハワイでどの規模までやるか
  - 三鷹の体制
  - 大学との連携
  - 海外との連携
  - TMTとの関係
- **装置開発予算の獲得方法**
  - 大型装置
  - 要素技術開発

Thank you.