

# Extreme-AO and diffraction-limited AO @ Subaru

**Olivier Guyon**

*Subaru Telescope*

*NINS Astrobiology Center (Japan)*

*University of Arizona*



**GOPIRA 2023**

# AO Systems: Image Quality vs. Field of View

<b>GLAO</b> Ground-Layer AO <i>Single DM conjugated near ground for maximum FOV</i> <i>Multiple LGS</i>	<b>MCAO</b> Multi-Conjugate AO <i>Multiple DMs for large FOV</i> <i>Multiple LGS</i>	<b>LTAO</b> Laser Tomography AO <i>Single DM</i> <i>Multiple LGS for volumetric turbulence reconstruction</i>	<b>ExAO</b> Extreme AO <i>High-order DMs for optimal correction</i> <i>Single bright NGS</i>
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Field of View

~ 10'

~ 1'

~ 10"

~ 1"

Image quality

*~2x better than seeing*

*Diffraction-limited*

*Diffraction-limited*

*High Contrast*

~0.25" @ nearIR

~0.050" @ nearIR

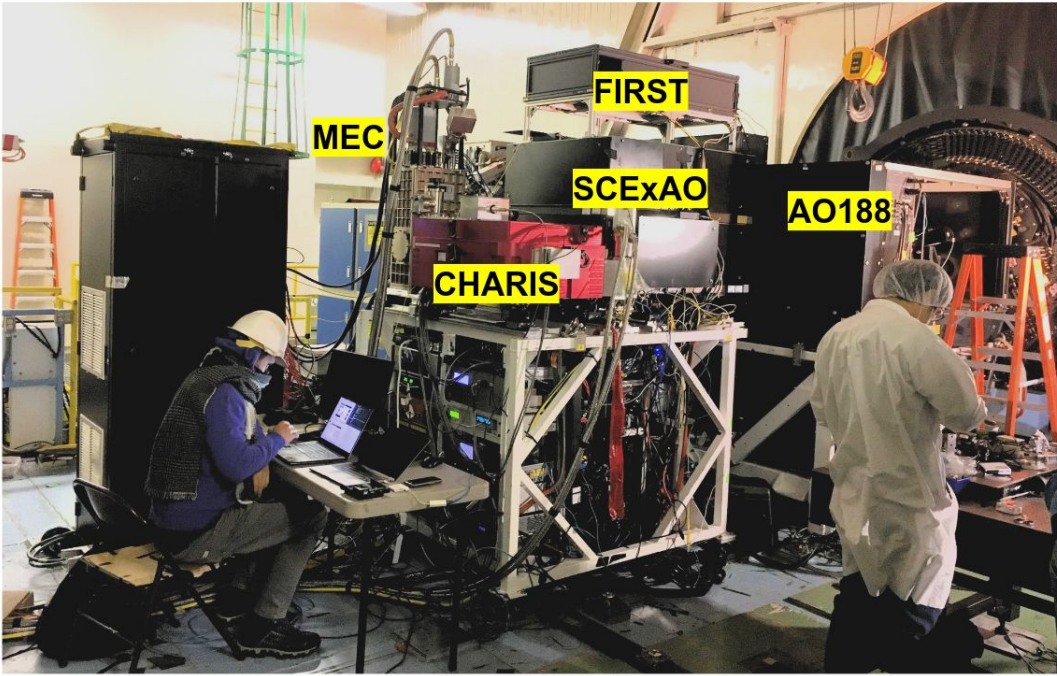
~0.050" @ nearIR

~0.040" @ nearIR

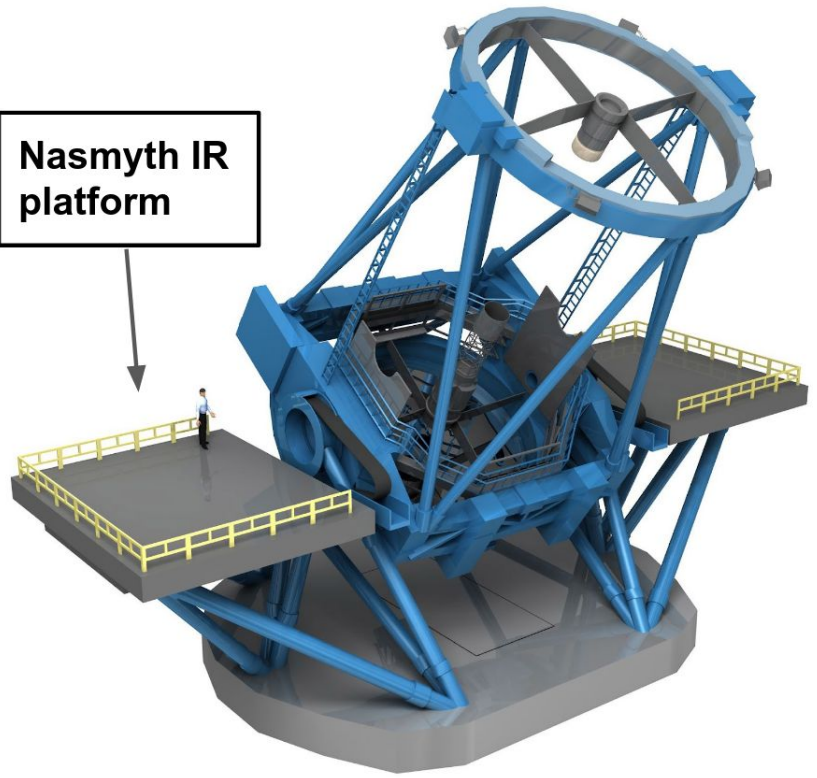
~0.020" @ VIS  
(~30" FOV)

~0.020" @ VIS

~0.020" @ VIS



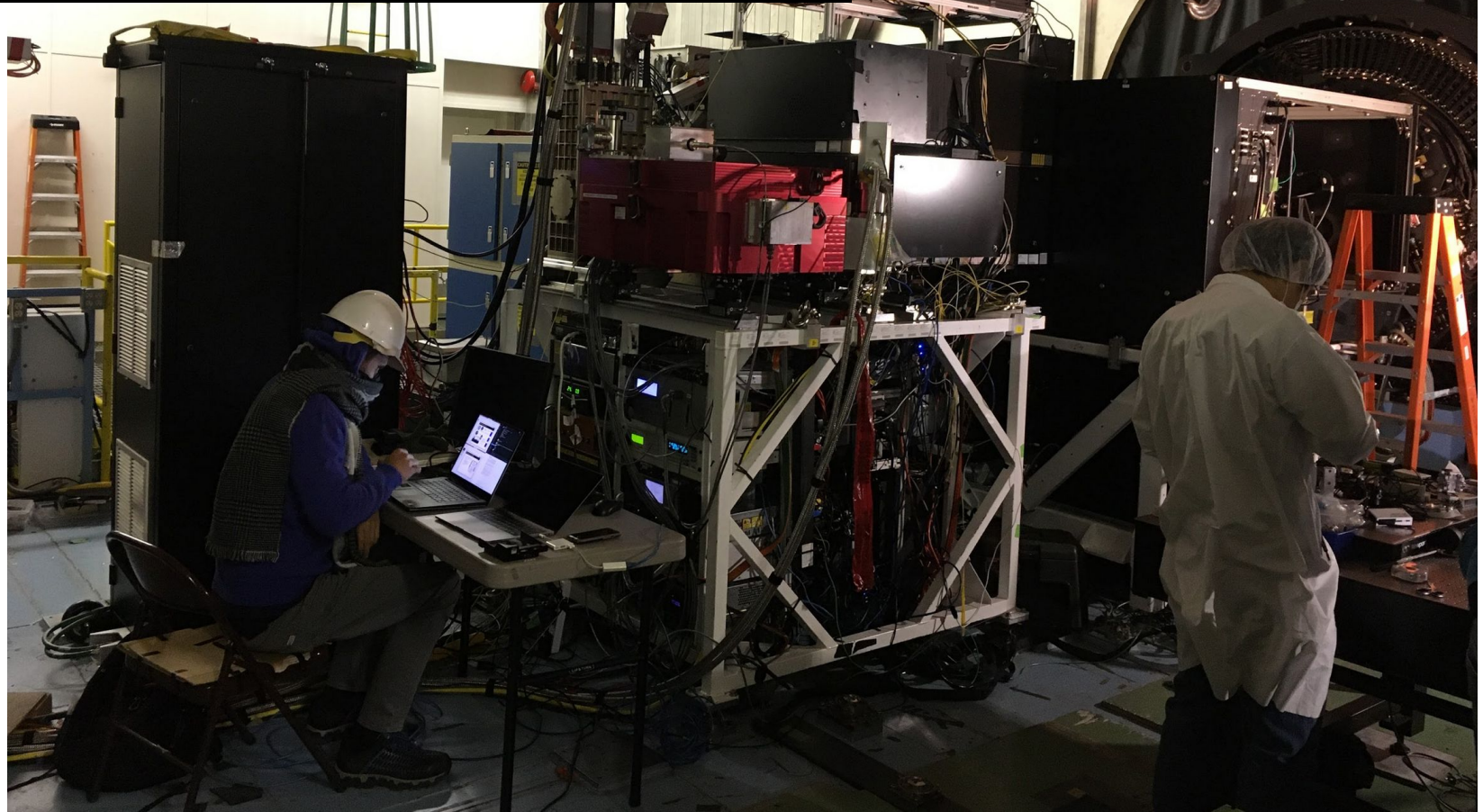
Nasmyth IR platform





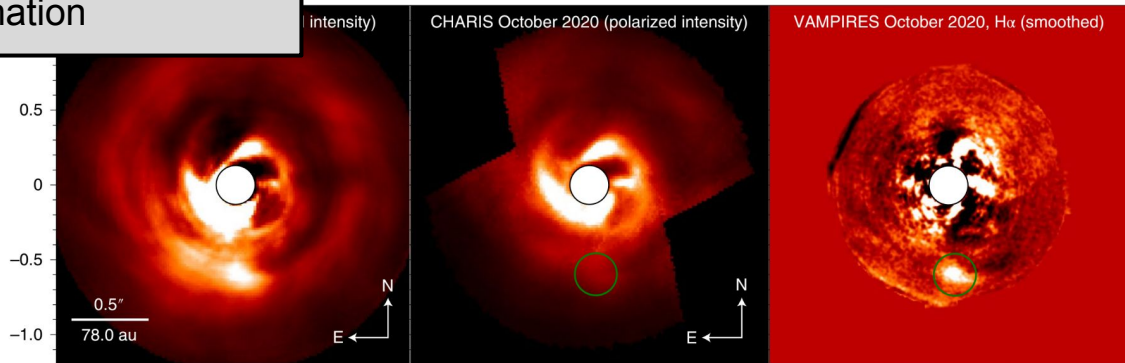
Subaru Coronagraphic Extreme Adaptive Optics

すばるコロナグラフ極限補償光学装置



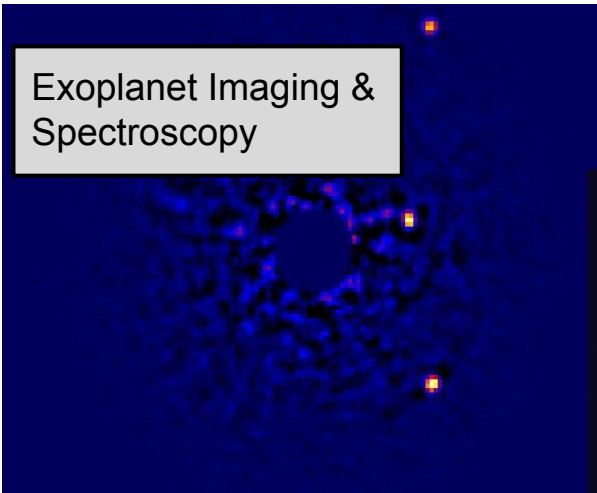
# Key Science

## Disks & planet formation



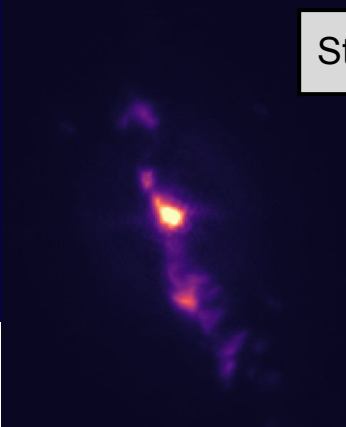
"Images of embedded Jovian planet formation at a wide separation around AB Aurigae", *Currie et al. 2022*

## Exoplanet Imaging & Spectroscopy

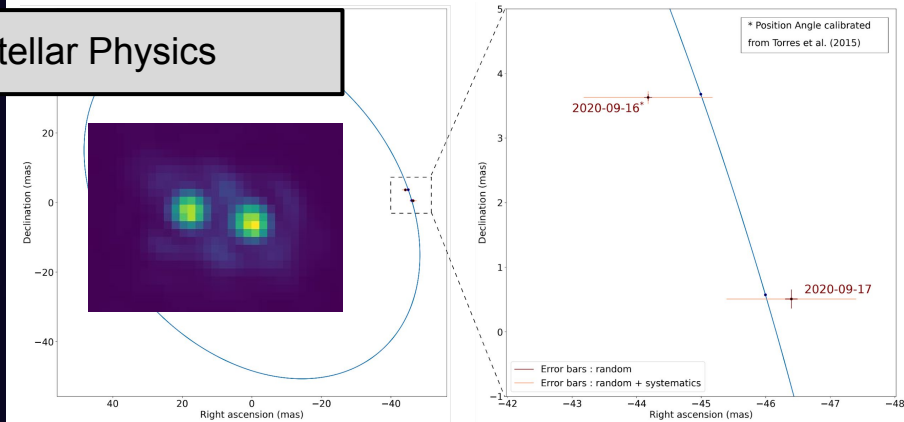


Inner 3 planets in HR8799 system

## Stellar Physics



R Aquarii mass loss in Halpha (Miles Lucas, UH)

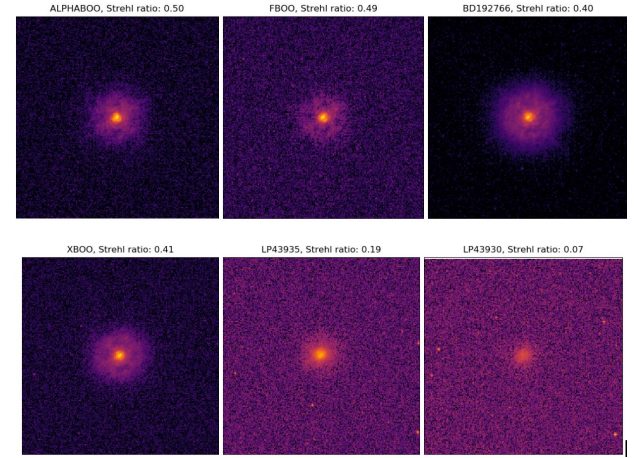


"Single-aperture spectro-interferometry in the visible at the Subaru telescope with FIRST: First on-sky demonstration on Keho' oea ( $\alpha$  Lyrae) and Hokulei ( $\alpha$  Aurigae)", *Vievard et al. 2023*

# Recent (2023) Upgrades

Visible light (VAMPIRES): new cameras, coronagraphs & multiband imaging

NearIR wavefront sensor for AO188



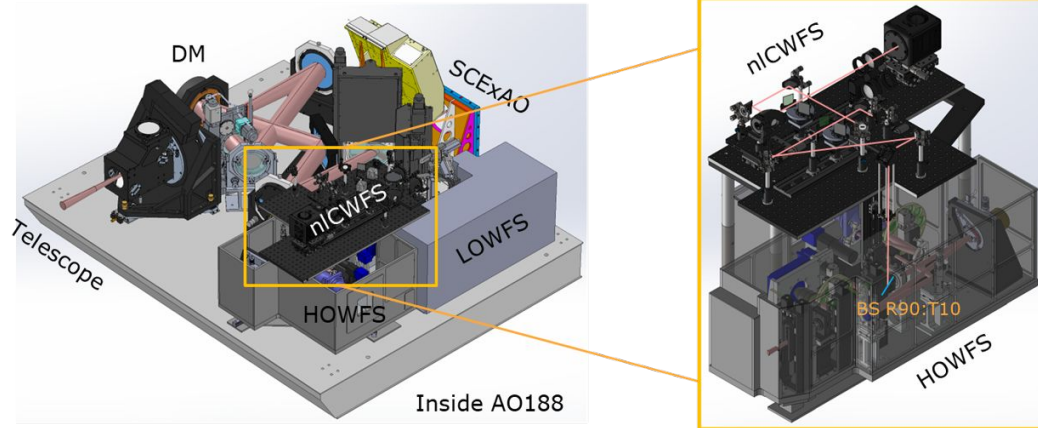
Near-IR WFS (Lozi et. al 2023)

# 2024 Upgrades

AO188 upgrade to 3000-actuators (AO3k)

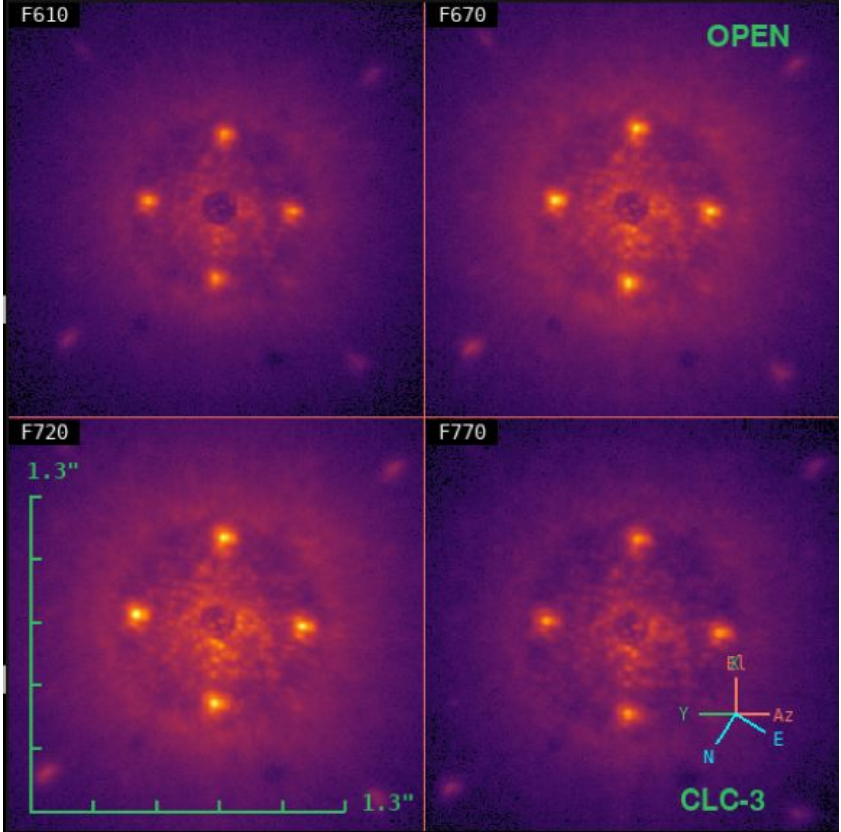
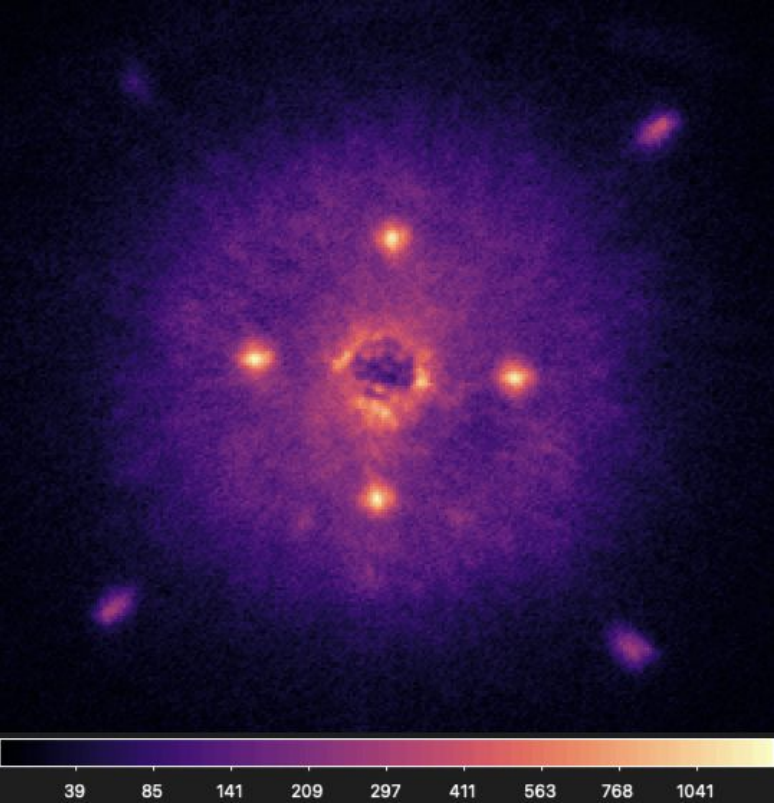
New high-order visible WFS

Photonic nulling & spectro-imaging



High order visible WFS (Ahn et. al 2023)

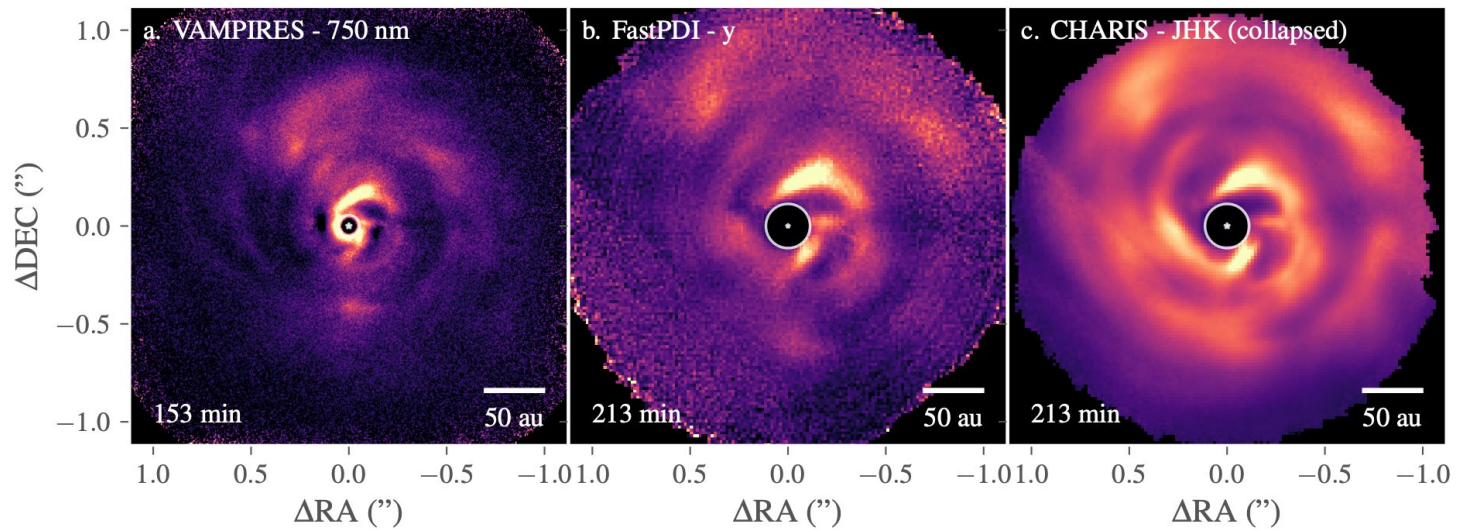
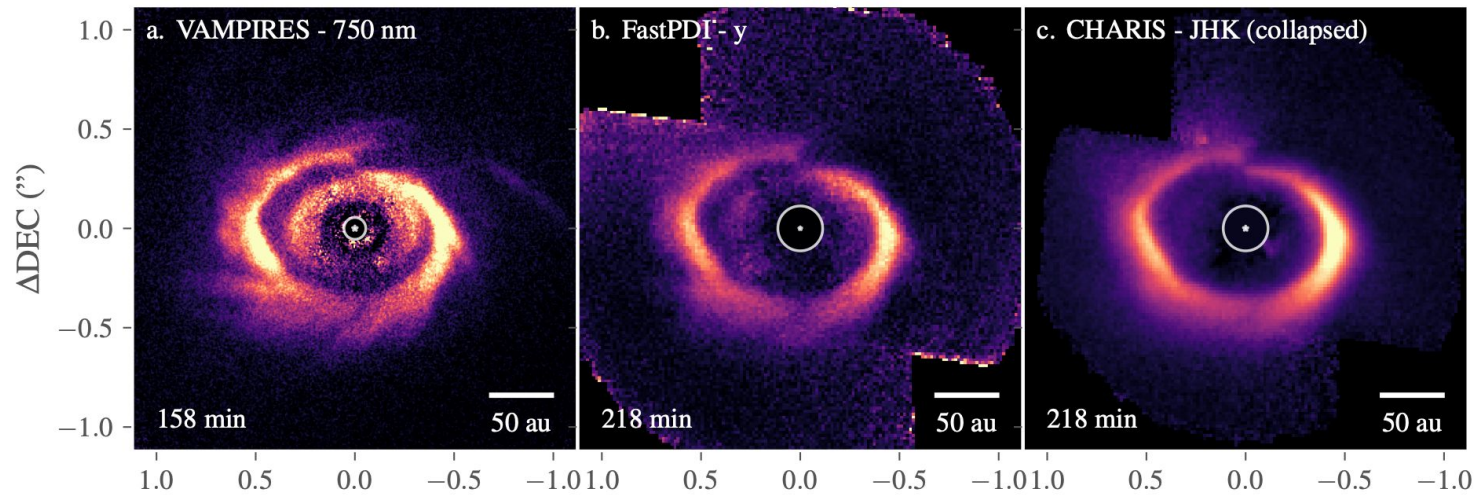
# Visible Imaging with VAMPIRES



## VCAM1

For help press [h], quit [x]  
crop = [ 756 2995 632 1735]  
t= 100.051 ms / fps= 10  
trigger: INT / readout: SLOW  
l,h=( 187, 4714) mu= 214





Data reduction:  
Miles Lucas, UH



# AO Systems: Science Capabilities

## GLAO

### Ground-Layer AO

*Single DM conjugated near ground for maximum FOV  
Multiple LGS*

## MCAO

### Multi-Conjugate AO

*Multiple DMs for large FOV  
Multiple LGS*

## LTAO

### Laser Tomography AO

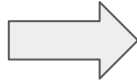
*Single DM  
Multiple LGS for volumetric turbulence reconstruction*

## ExAO

### Extreme AO

*High-order DMs for optimal correction  
Single bright NGS*

Extragalactic & galactic, surveys (see previous presentation on ULTIMATE)



Follow-up of individual objects

Diffraction-limited imaging (~50mas in nearIR, ~20mas in VIS)

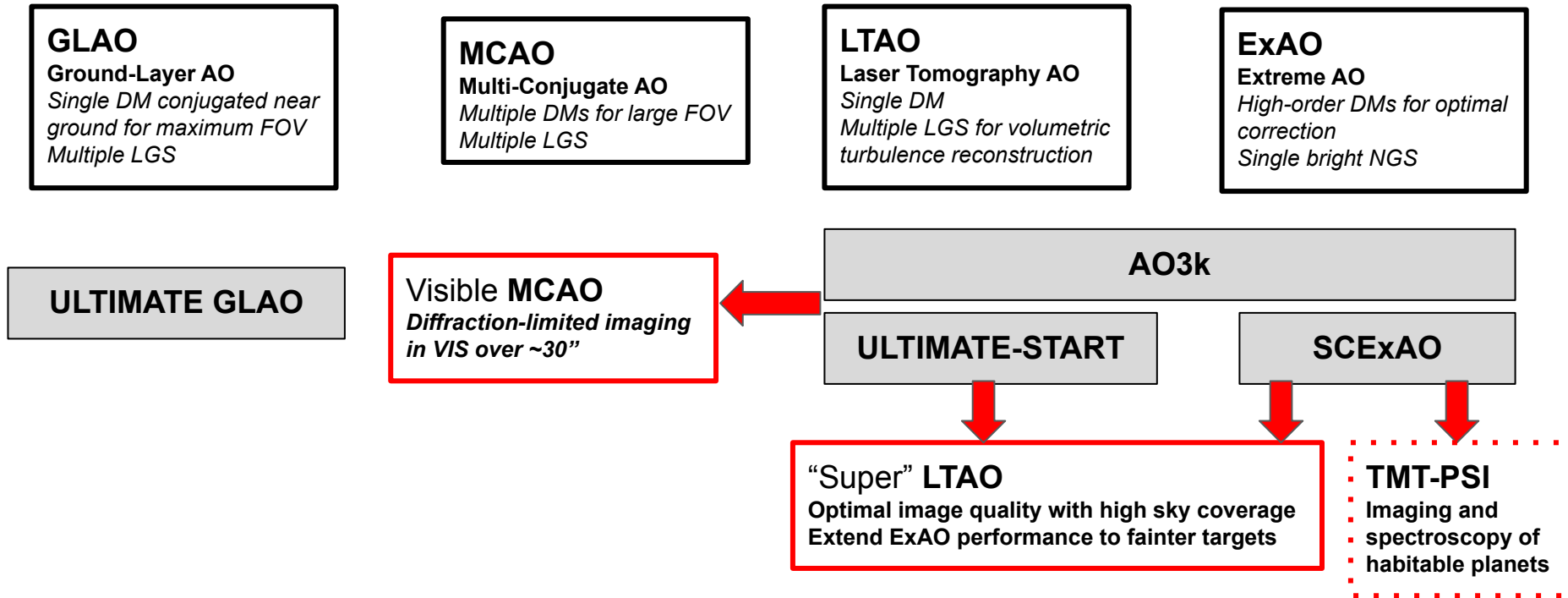
Optimal point-source sensitivity thanks to diffraction-limited angular resolution

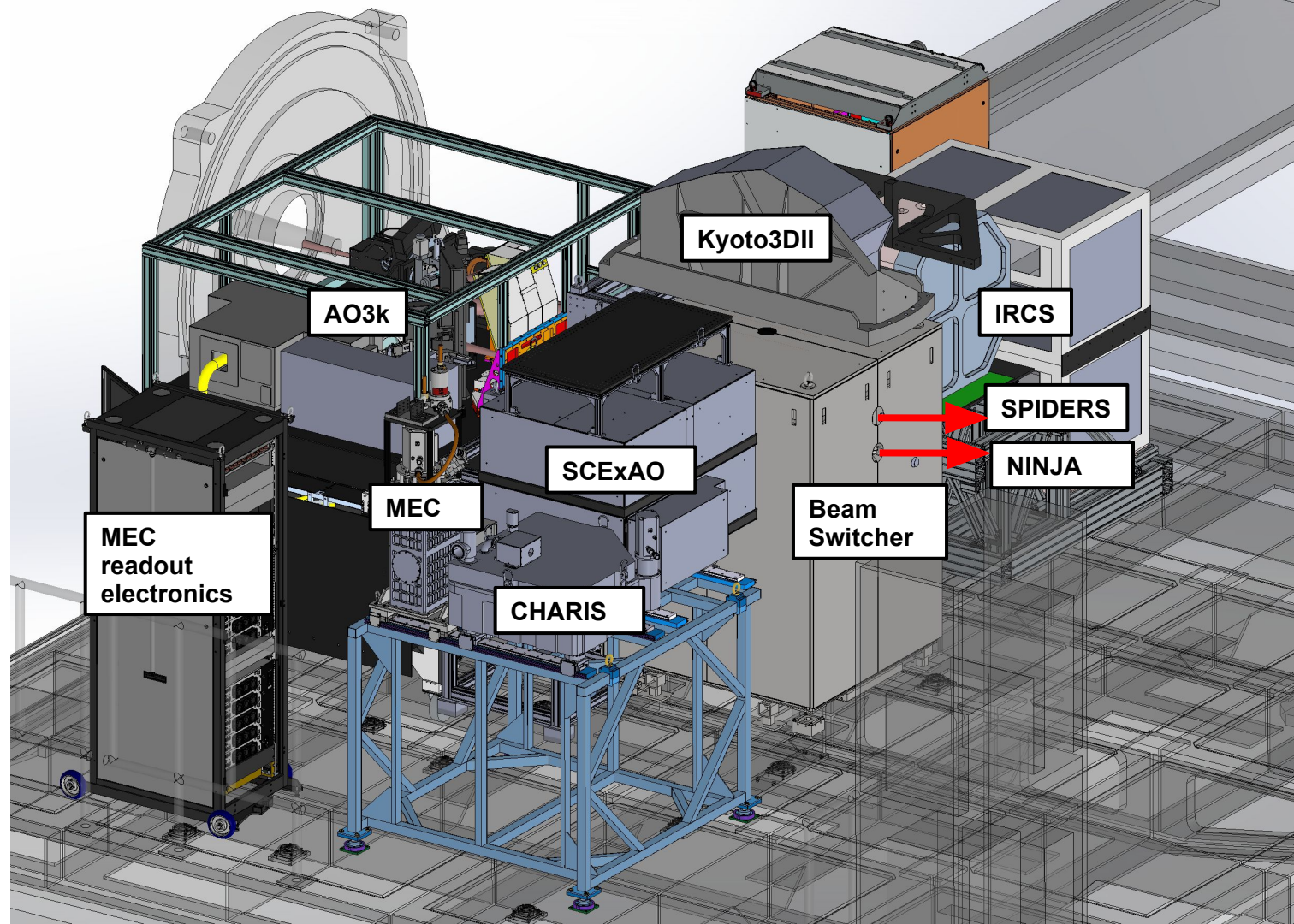
Optimal image quality in VIS & NIR, high contrast imaging

Exoplanets & Star formation

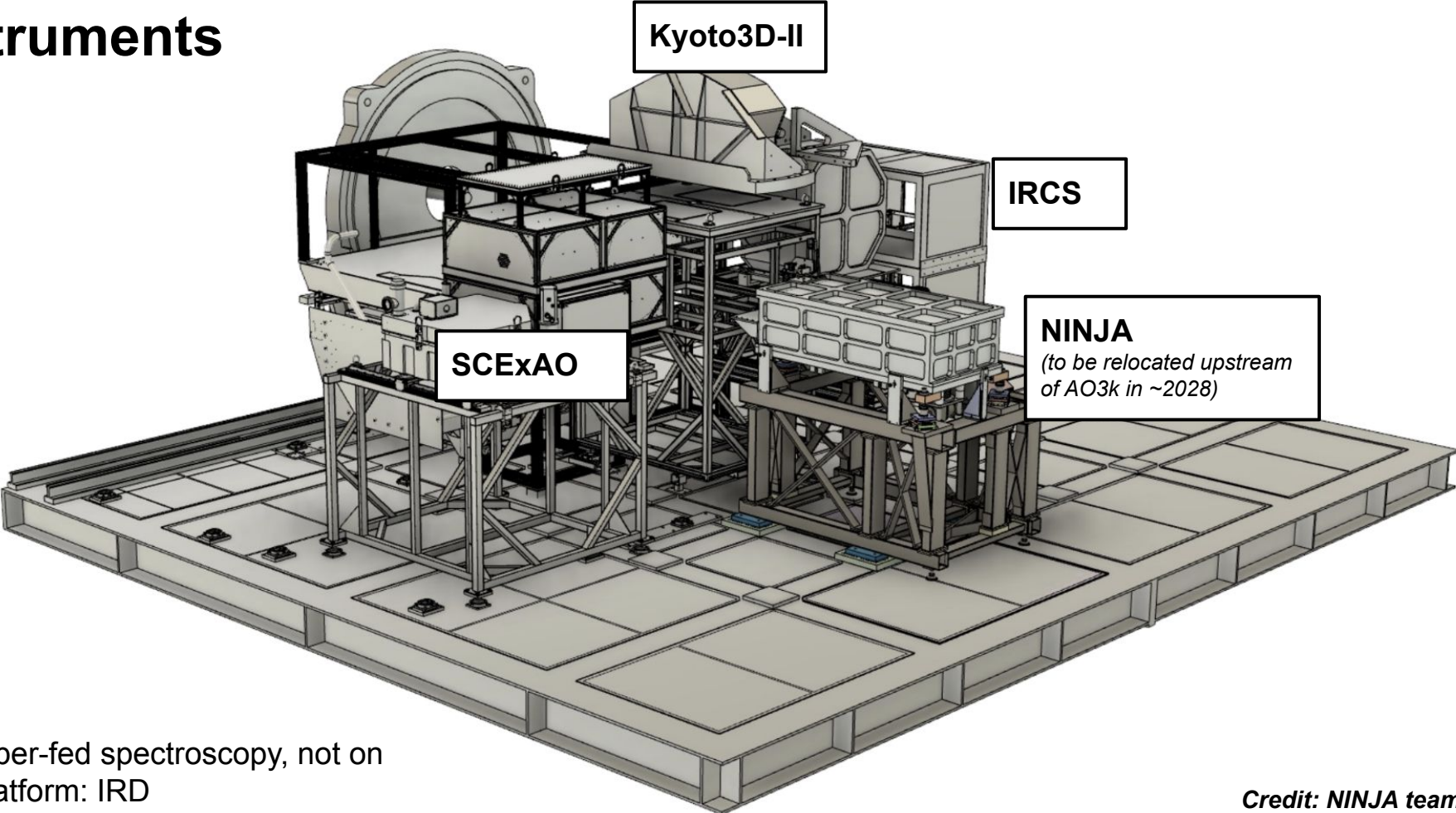
*Requires bright (m~12) NGS*

# AO @ Subaru & Possible Future Development Paths for narrow-field AO





# Instruments



**Kyoto3D-II**

**IRCS**

**SCExAO**

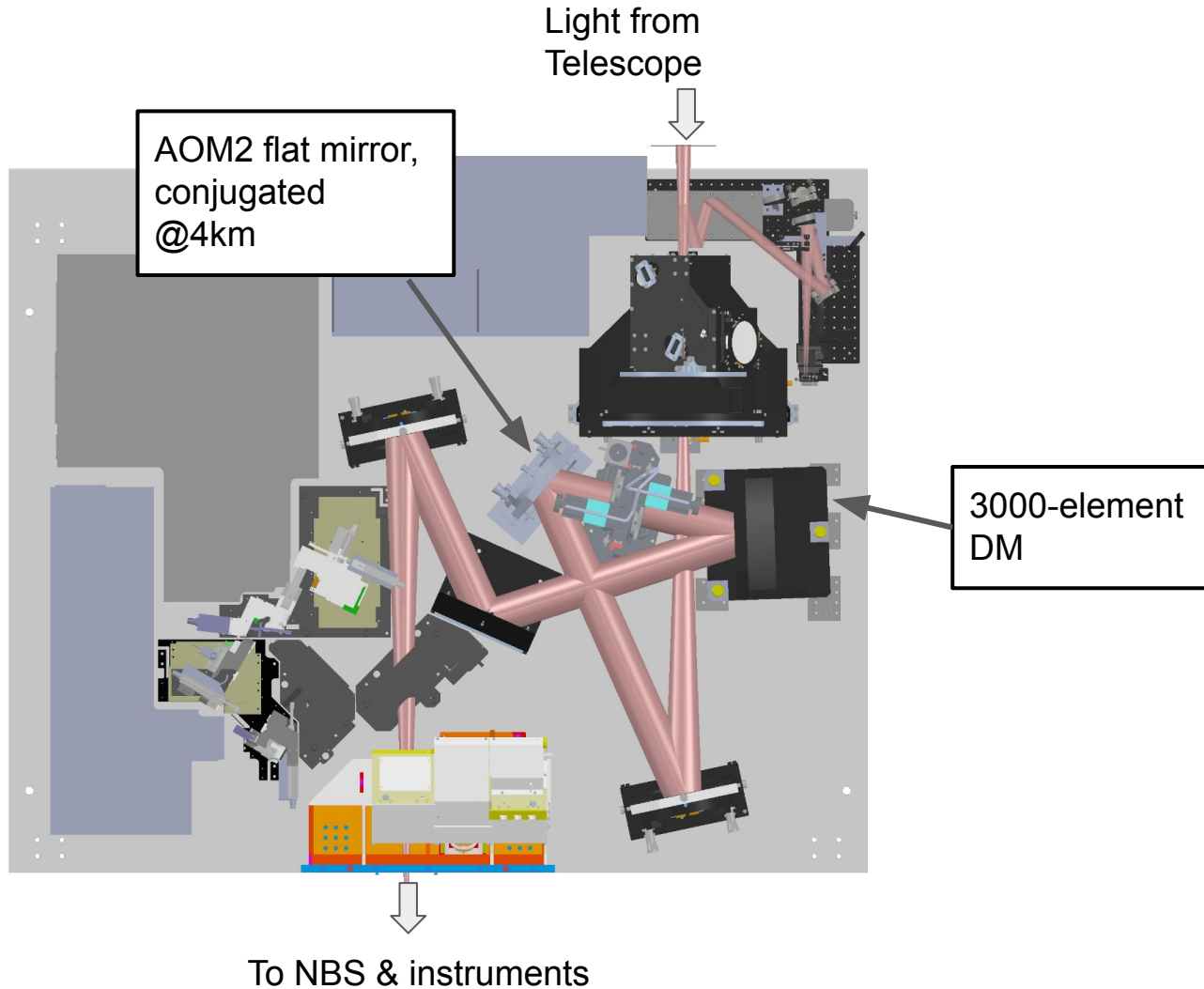
**NINJA**  
*(to be relocated upstream  
of AO3k in ~2028)*

Fiber-fed spectroscopy, not on  
platform: IRD

*Credit: NINJA team*

# AO3k bench

Upgrade path to MCAO system:  
Replace AOM2 flat mirror with  
new deformable mirror



# Conclusions

Subaru Telescope now providing world-leading extreme-AO, delivering high contrast diffraction limited imaging in visible and nearIR.

Upgrades are extending diffraction limited imaging performance to fainter targets (AO3k, LTAO, nearIR WFS).

Wider field of view high quality diffraction-limited performance in visible light is possible with MCAO.

***“Wide” field optical imaging and spectroscopy instrumentation opportunities should be discussed and planned.***