Subaru Coronagraphic Extreme Adaptive Optics

SCExAO team

AO188, CHARIS, MEC, FIRST
VAMPIRES, RHEA, GLINT, SAPHIRA,
Kernel, vAPP/Leiden, MagAO-X teams

Presenter: Olivier Guyon

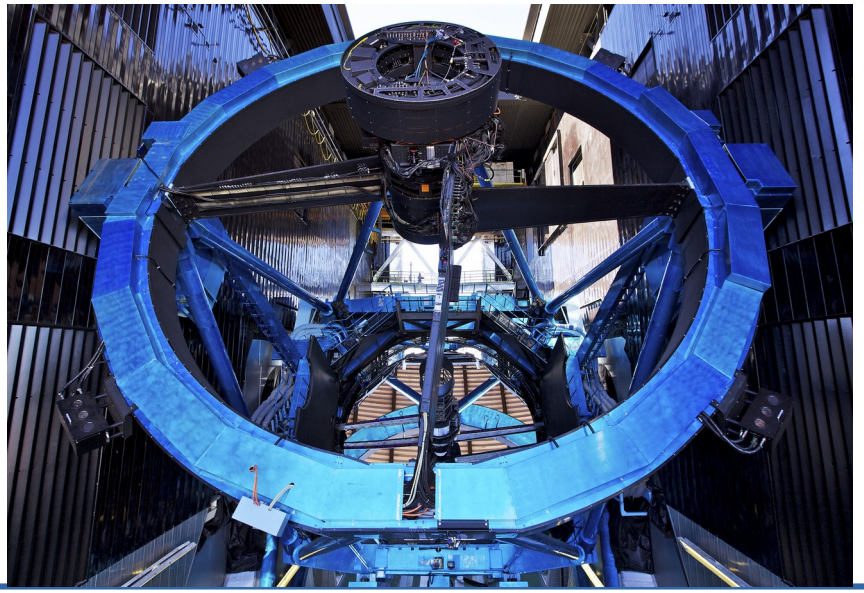
Subaru Telescope, National Astronomical Observatory of Japan, National Institutes for Natural Sciences (NINS)

Astrobiology Center, National Institutes for Natural Sciences (NINS)

University of Arizona


SERIOUSLY
BRILLIANT
MIND AT WORK
SCExAO
HIGH PRECISION DEVICES, INC.
HPD
DENALI Model 102 Cryostat

What is SCExAO ?



Science instrument in operation for high contrast imaging

CHARIS (Near-IR)
Princeton, US

VAMPIRES (visible)
Univ. of Sydney, Australia

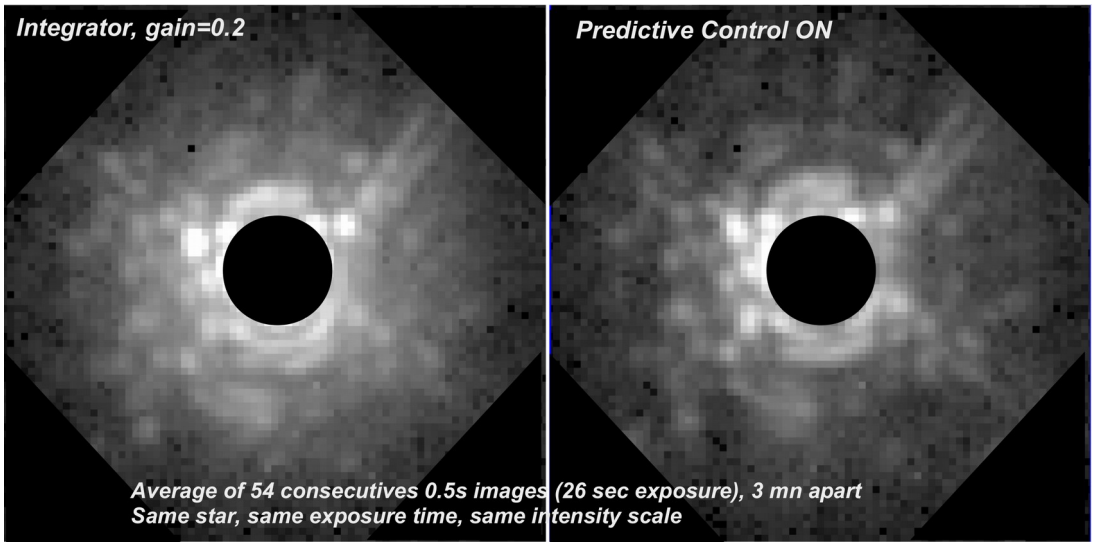
Development platform for on-sky validation of new technologies

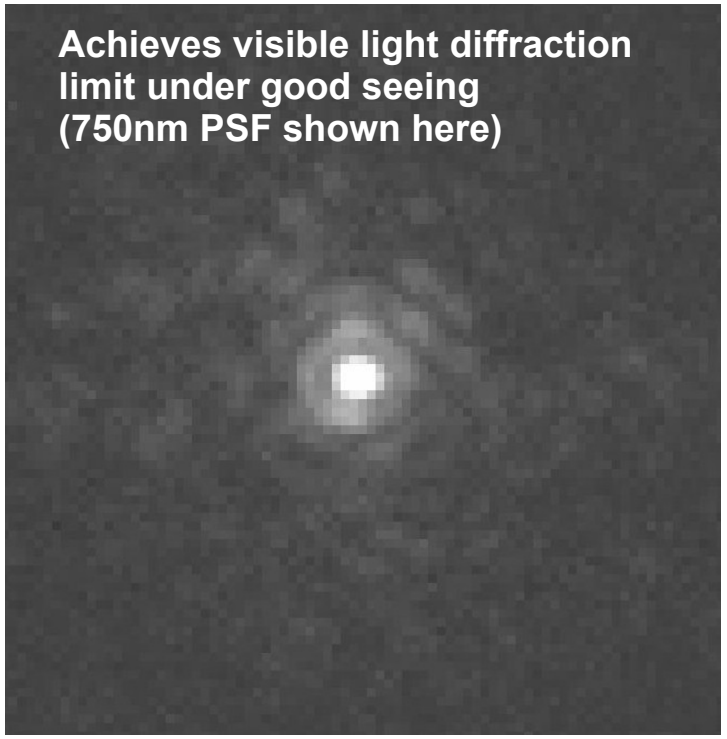
→ prototyping for imaging habitable planets with upcoming large telescopes

AO control loop

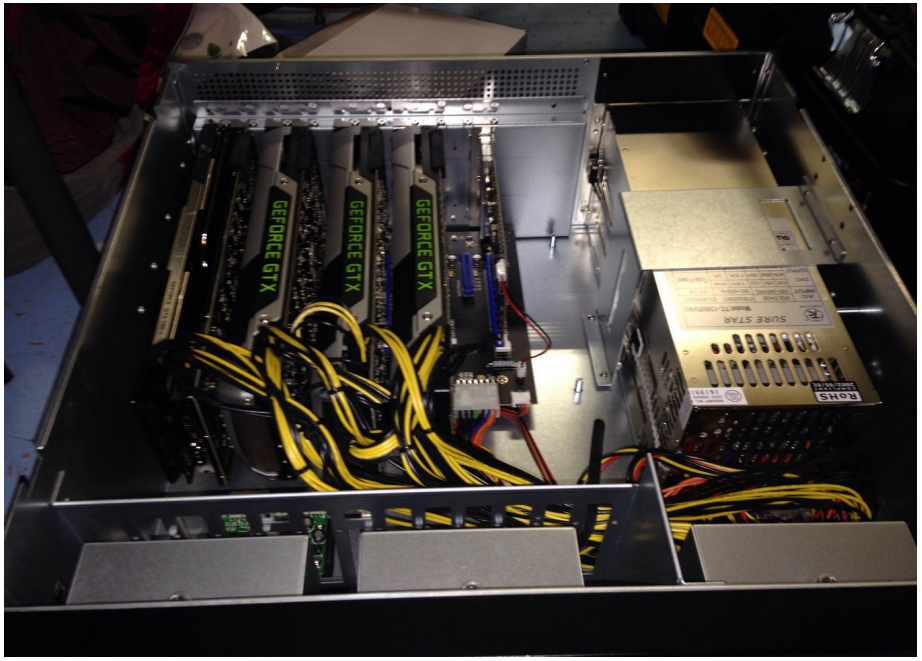
AO loop can run at 3.5 kHz (bright stars)
14,400 sensors → 2000 actuators

Includes predictive control





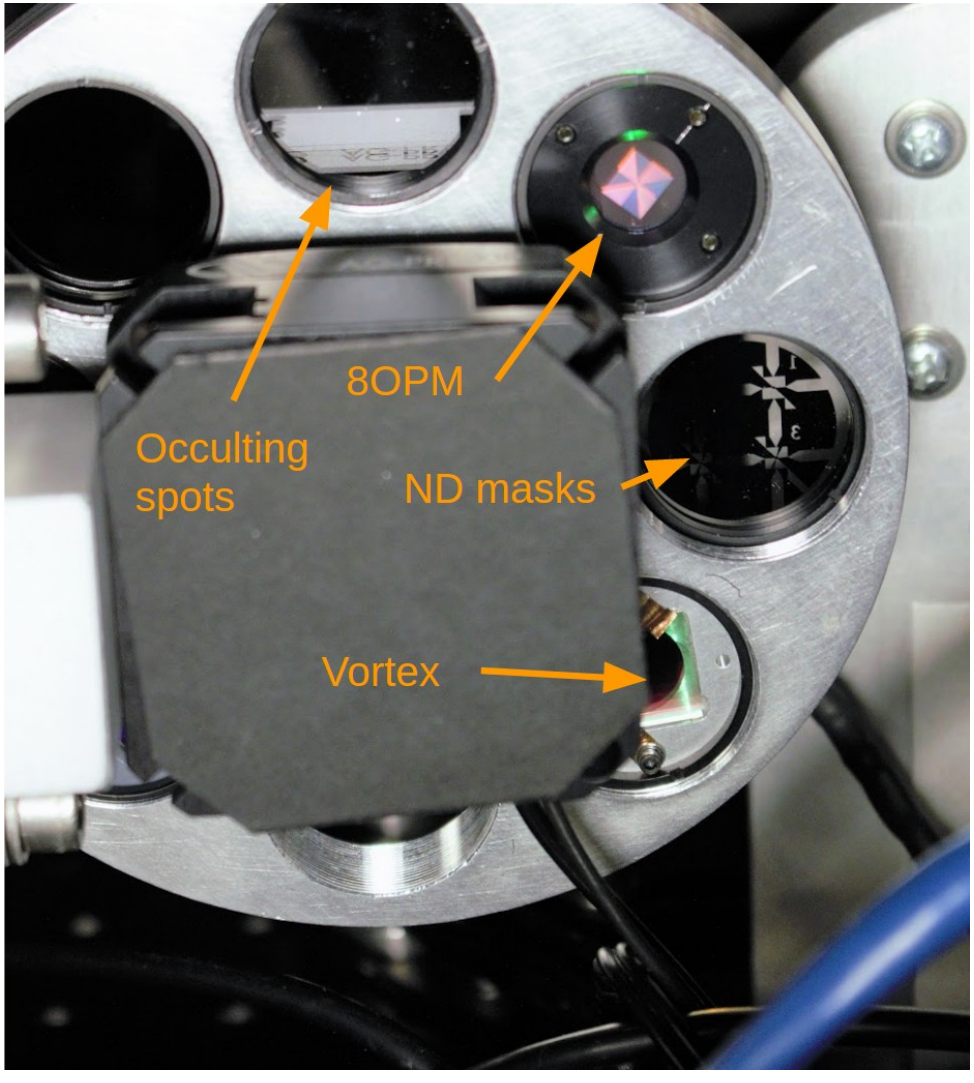
One of two GPU chassis

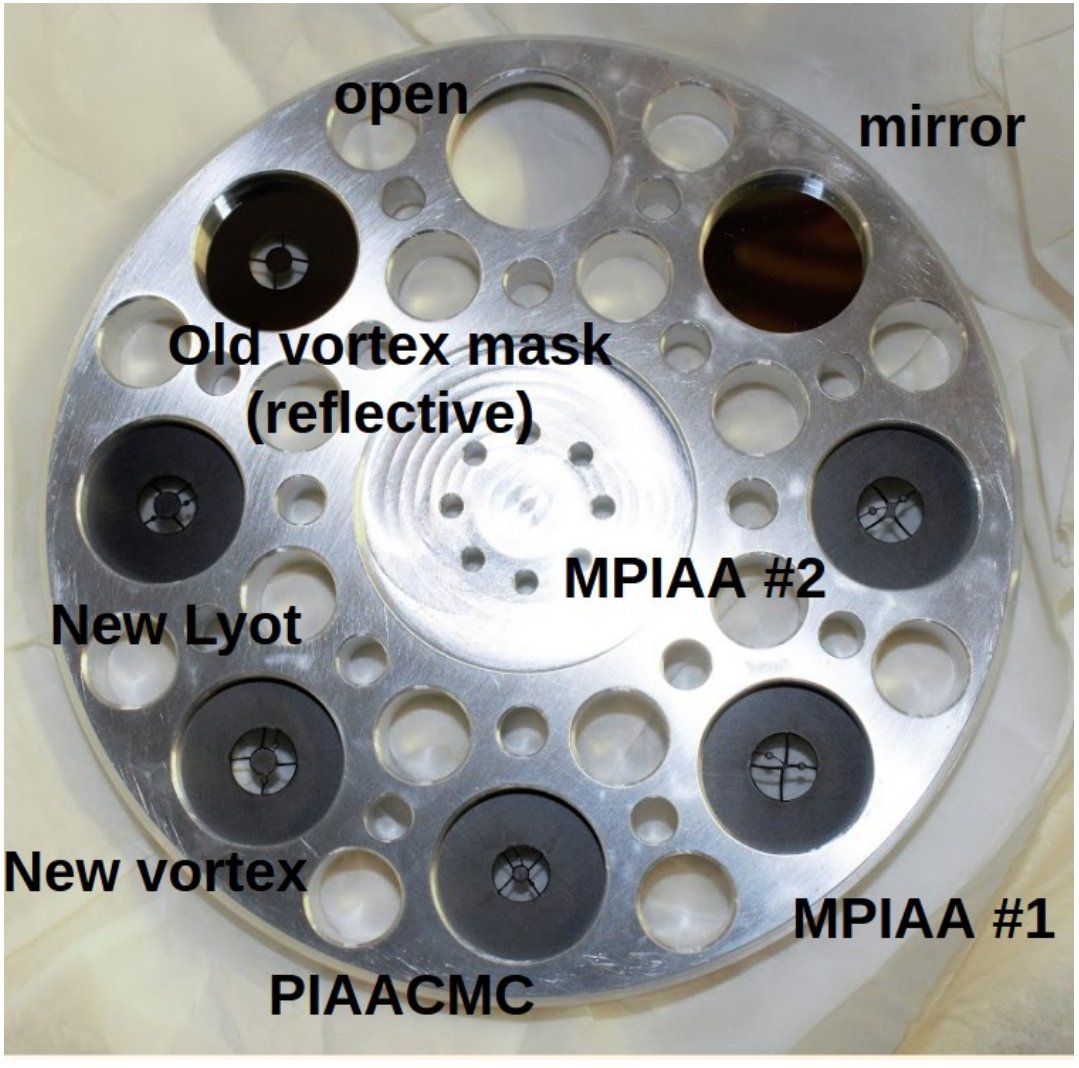


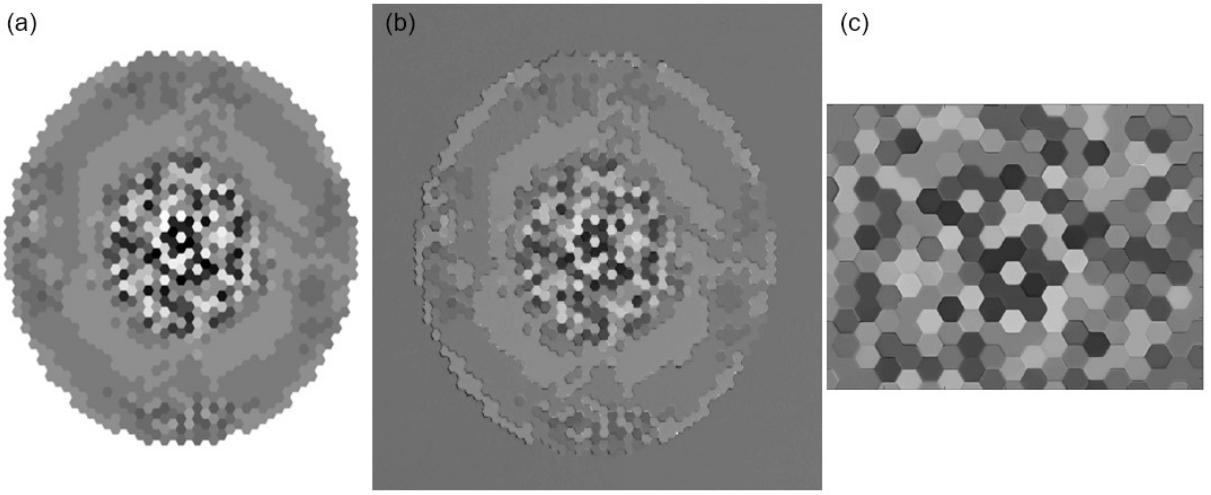
SCExAO uses >30,000 cores
Total RTC computing power >100 TFLOPS

Coronagraphy

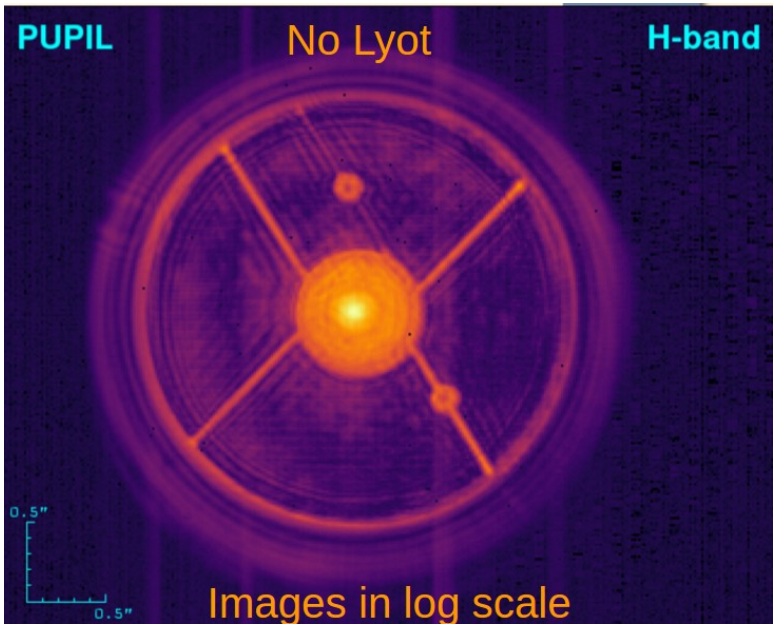
Coronagraphs:
- Vortex
- Lyot
- PIAACMC
- 8QPM
- Shaped Pupil
- vAPP

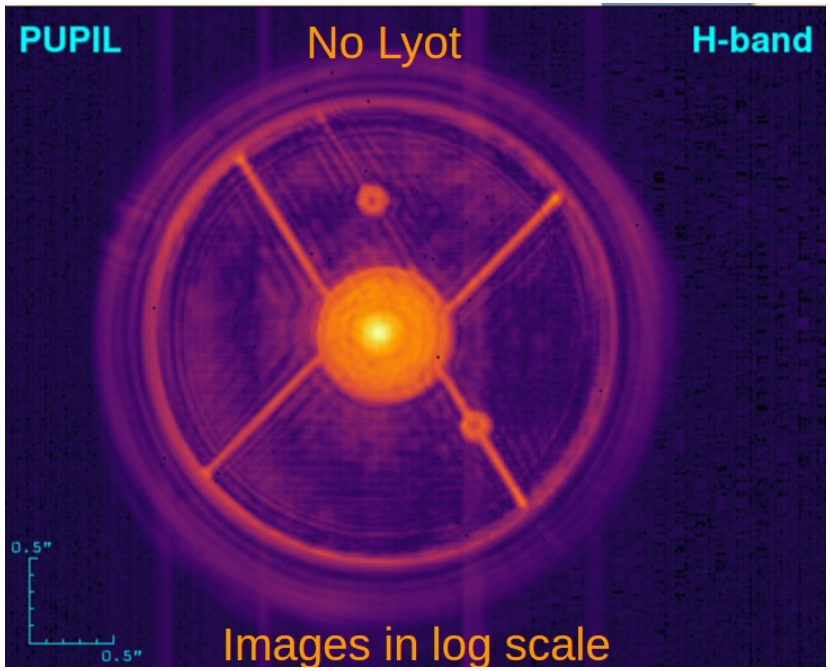




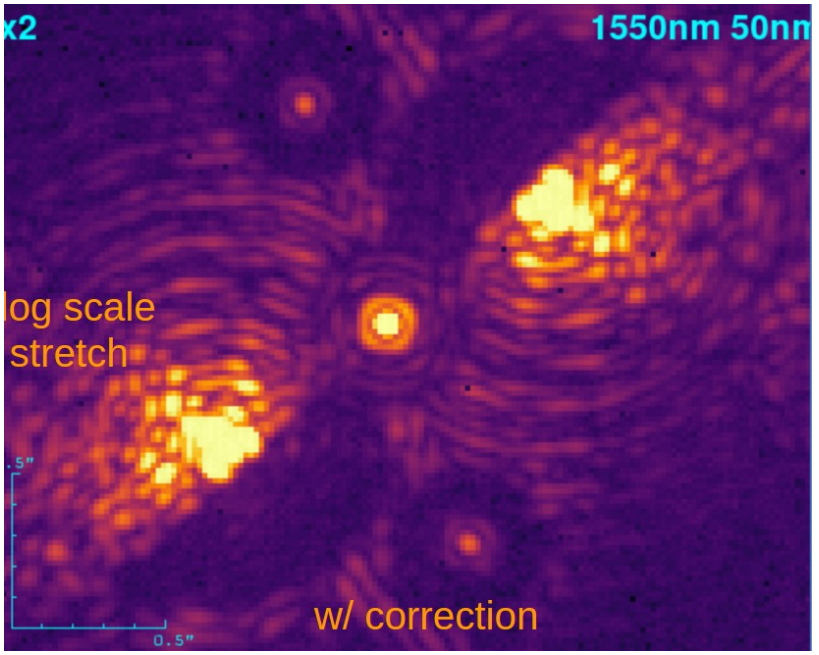


PIAACMC, Knight & Lozi, 2017





VVC, Lozi & JPL Vortex, 2017



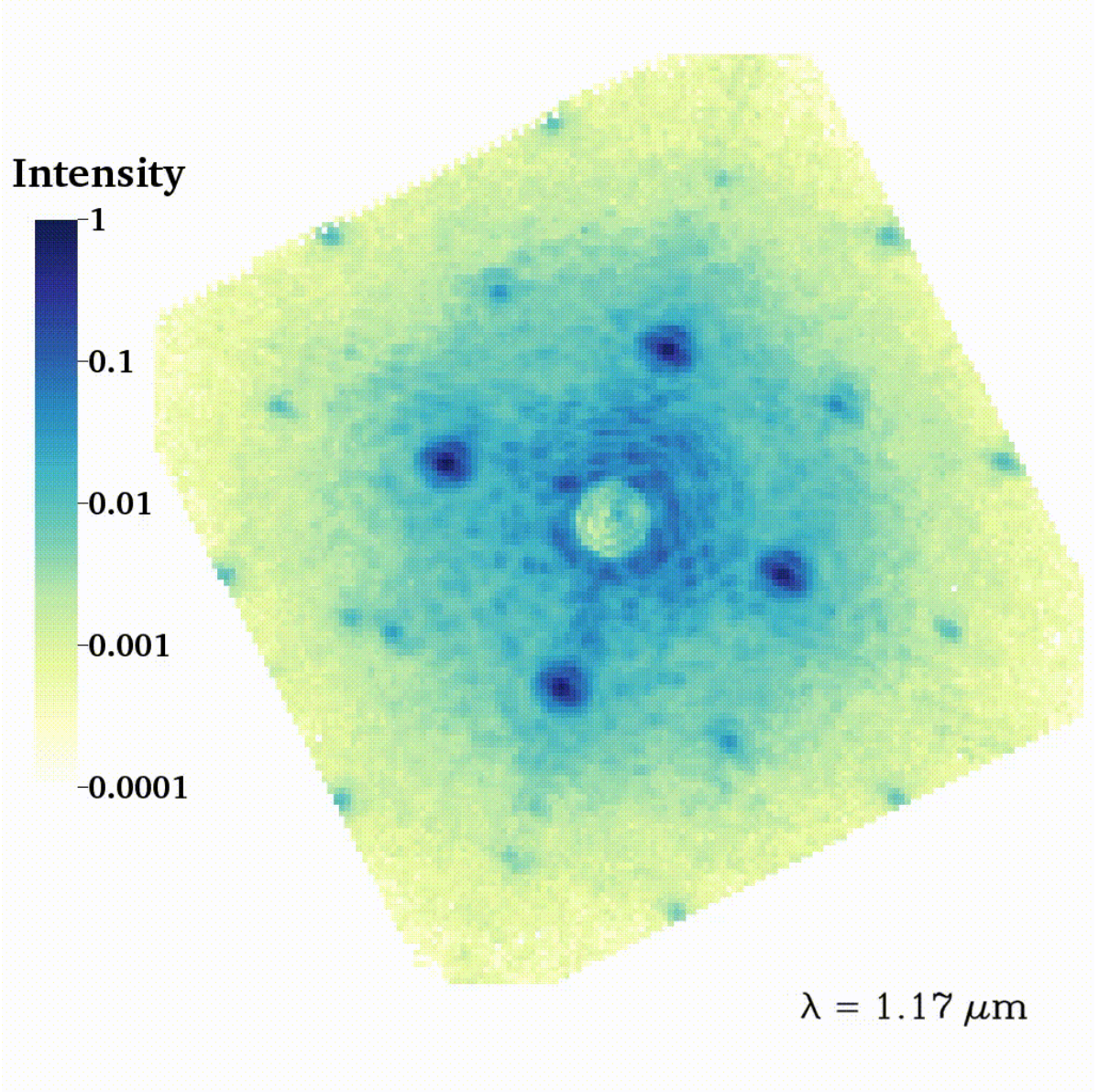
VAPP, Lozi & Leiden University, 2017

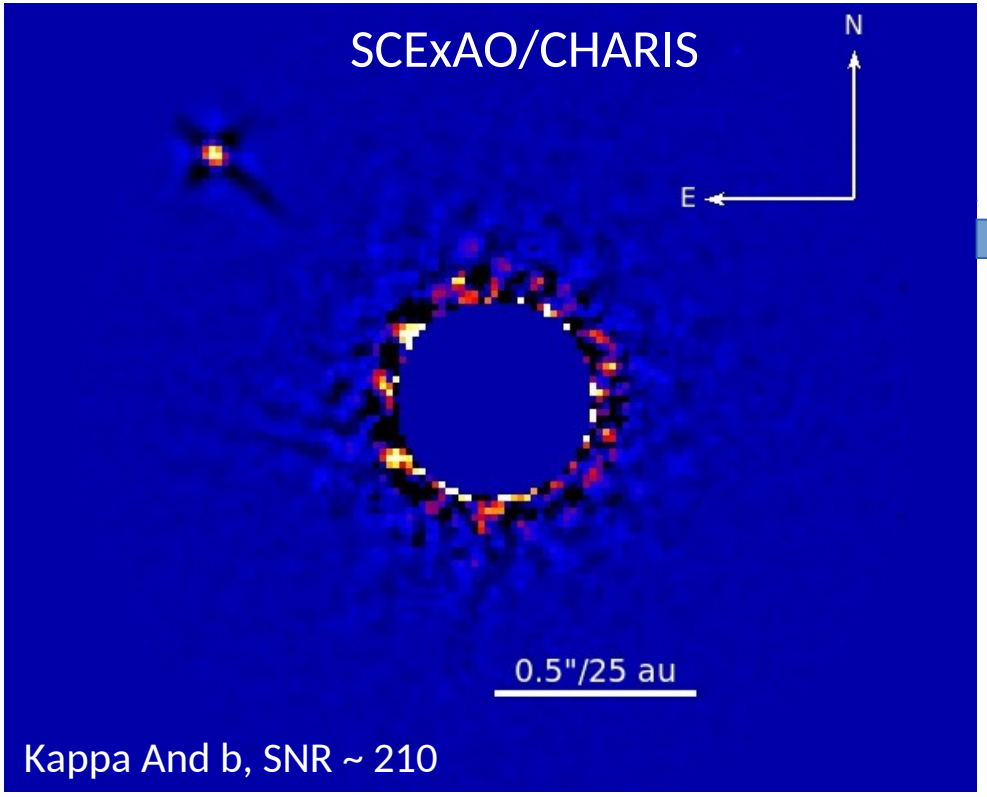
CHARIS

Near-IR IFU

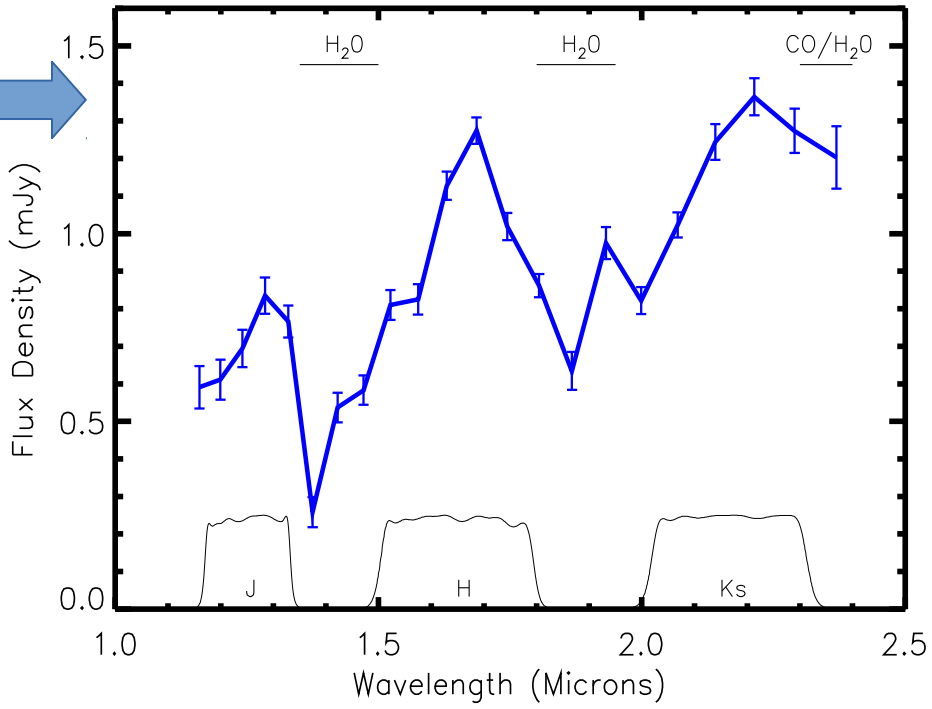
2” FOV
16.2mas / lenslet
J/H/K bands

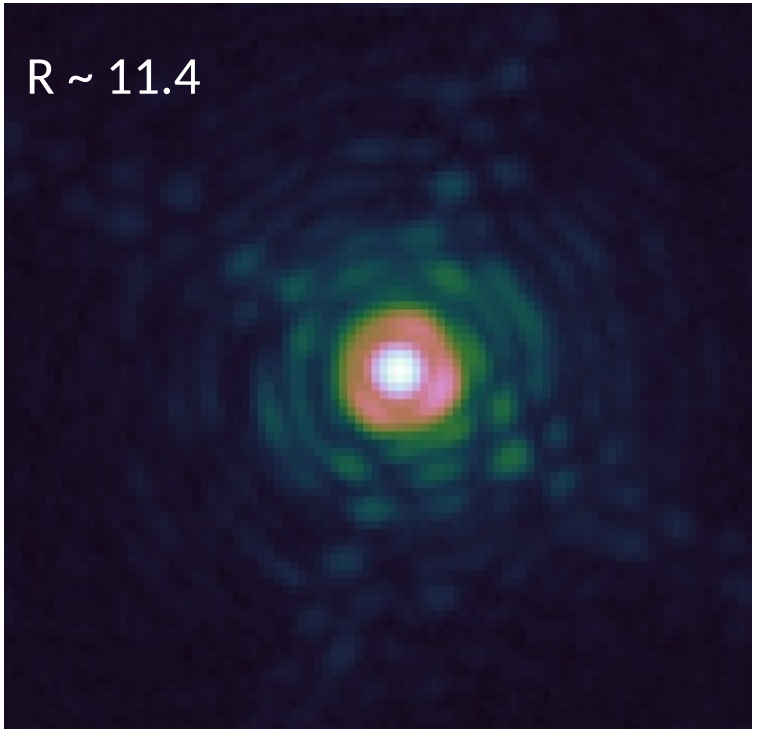
R=19 (low res, J+H+K)
R=70 (high res, J, H or K)

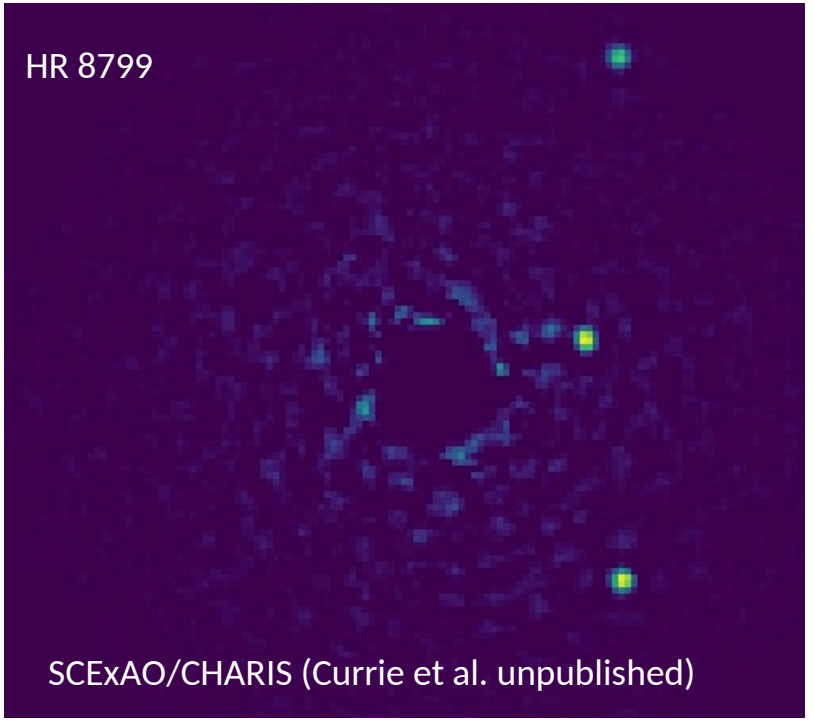


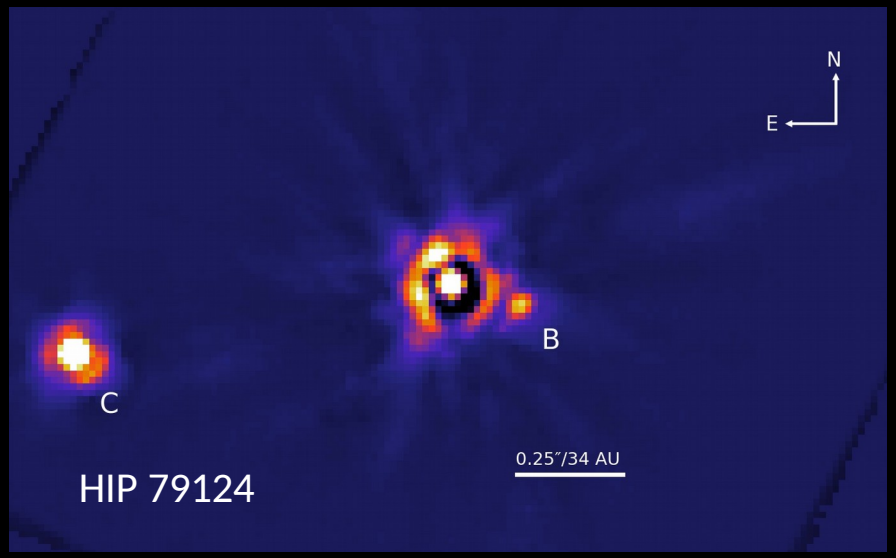


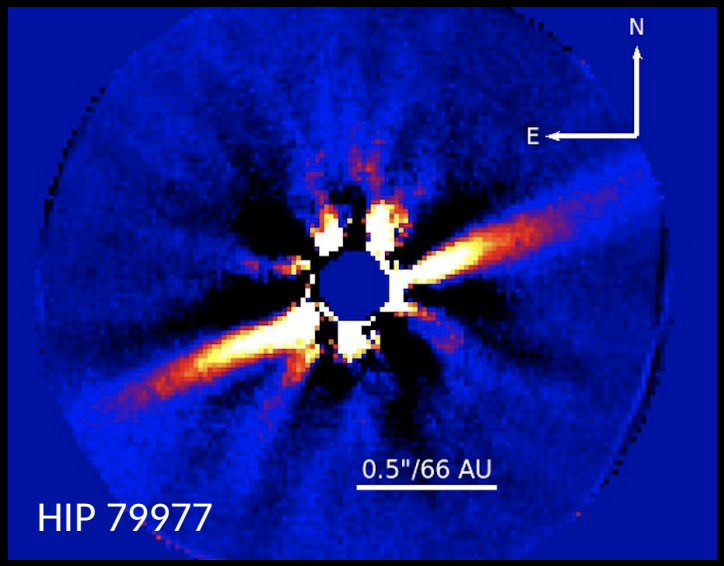
Sharply-peaked H band spectrum suggestive of low gravity ***(Currie et al. 2018, AJ, 156, 291)***

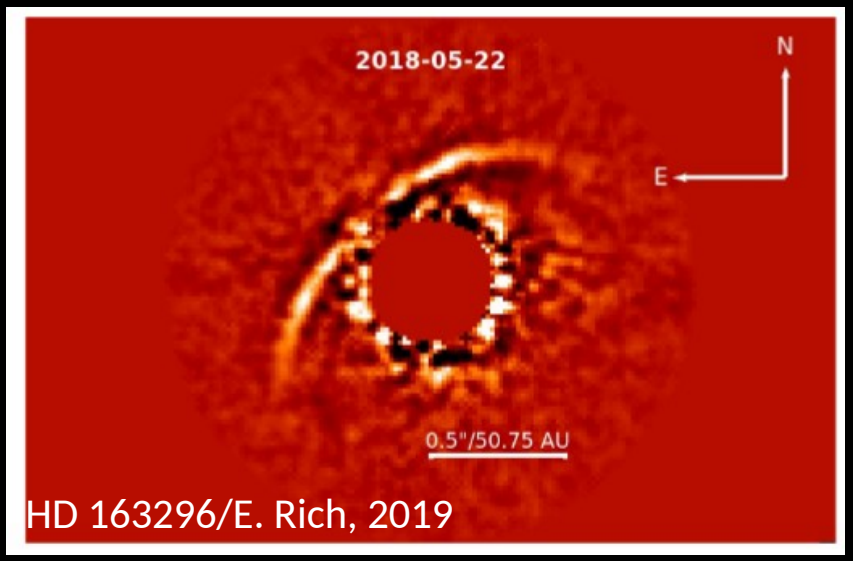


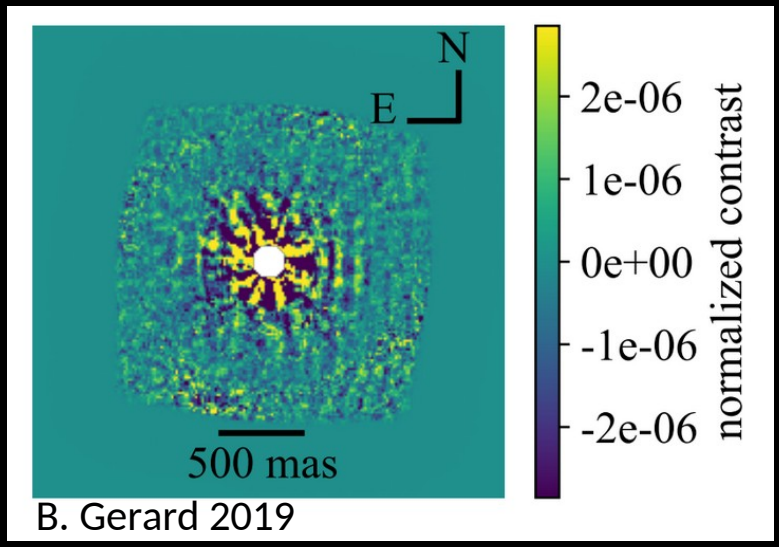





N
E
B
C
0.25″/34 AU
HIP 79124


N
E
0.5"/66 AU
HIP 79977


2018-05-22
N
E
0.5"/50.75 AU
HD 163296/E. Rich, 2019


N
E
500 mas
2e-06
1e-06
0e+00
-1e-06
-2e-06
normalized contrast
B. Gerard 2019

VAMPIRES

VISIBLE APERTURE MASKING POLARIMETRIC INTERFEROMETER FOR RESOLVING EXOPLANETARY SIGNATURES

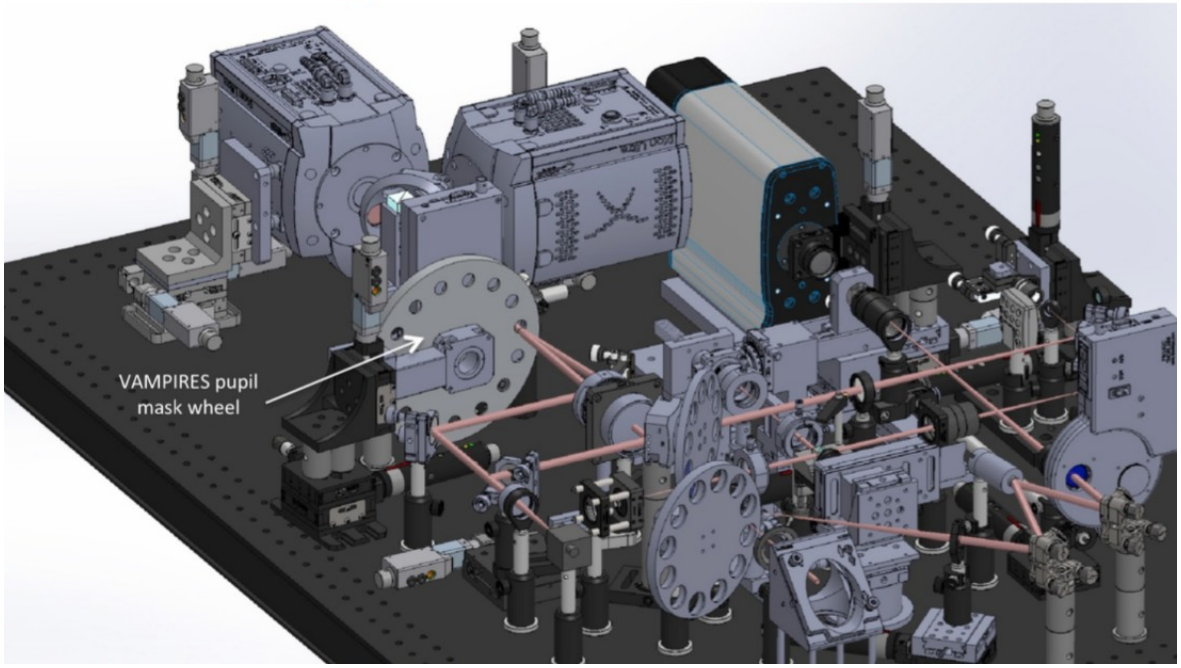
Dual EMCCD camera visible imaging.
512x512 pixel, 6mas/pix (3” FOV)

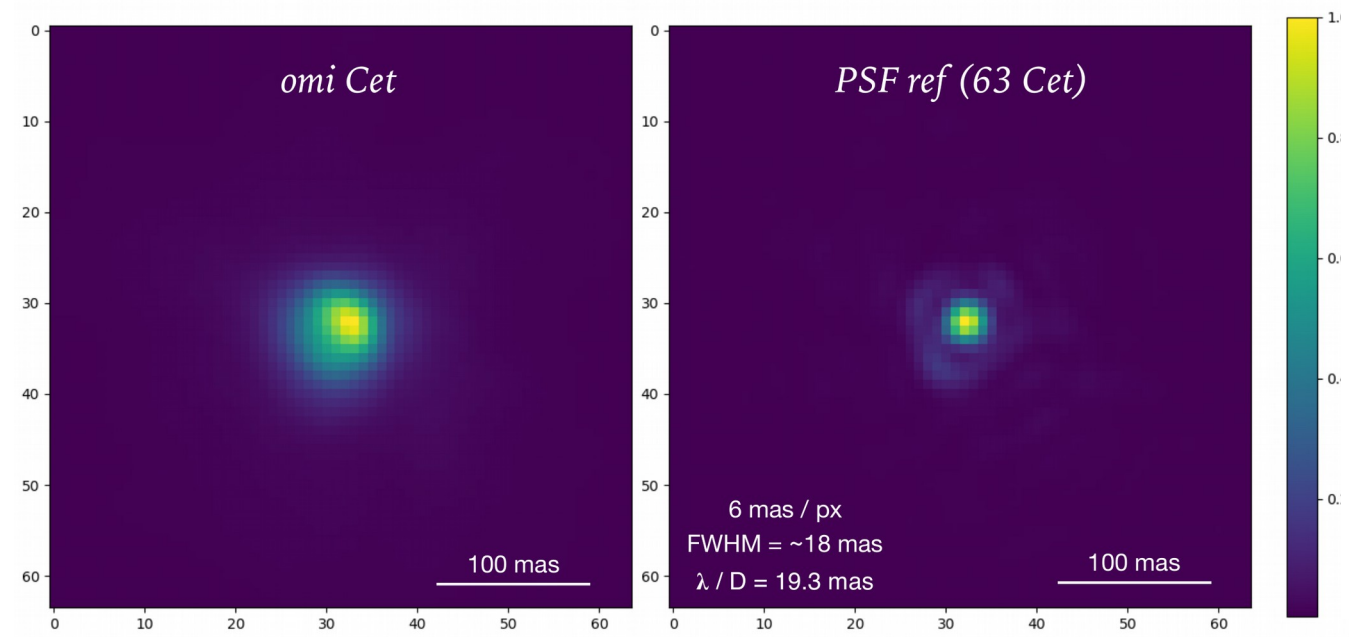
Fast frame imaging
35 Hz full frame, faster with small array

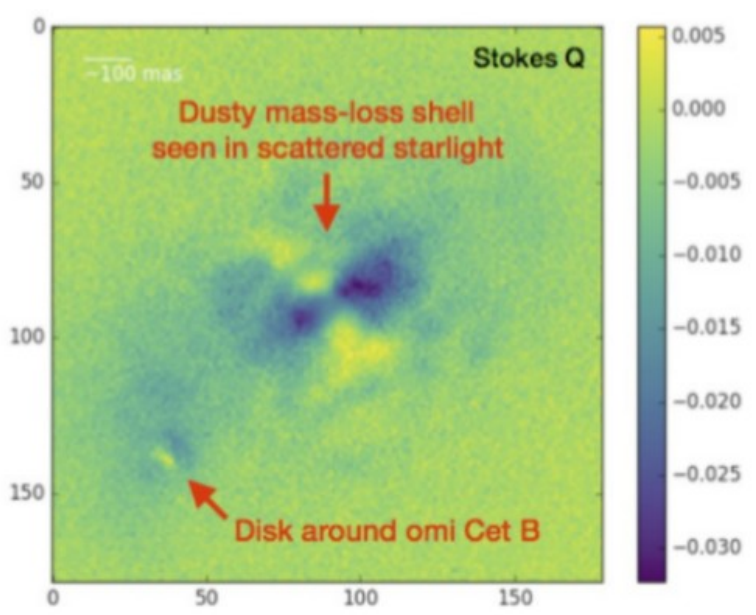
Simultaneous differential spectral imaging
Halpha emission

Simultaneous differential polarimetric imaging
Circumstellar disks

Aperture masking (+PDI)
High precision measurements beyond telescope diffraction limit







Observed 12/09/2017

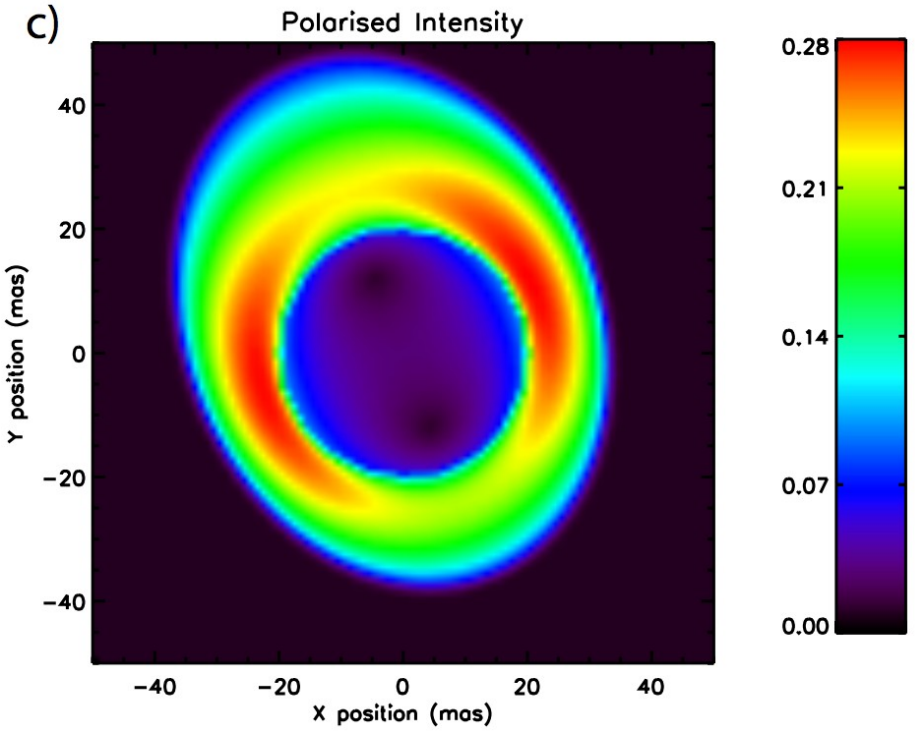
μ Cephei

Inner radius: 9.3 ± 0.2 mas (which is roughly R_{star})

Scattered-light fraction: 0.081 ± 0.002

PA of major axis: 28 ± 3.7 °

Aspect ratio: 1.24 ± 0.03



New & upcoming capabilities

Observing modes / instruments :

Speckle control → higher contrast
NearIR Polarimetry → disks imaging/characterization
High-Res spectroscopy →Exoplanet atmospheres
Interferometric imaging → ultra-high angular resolution

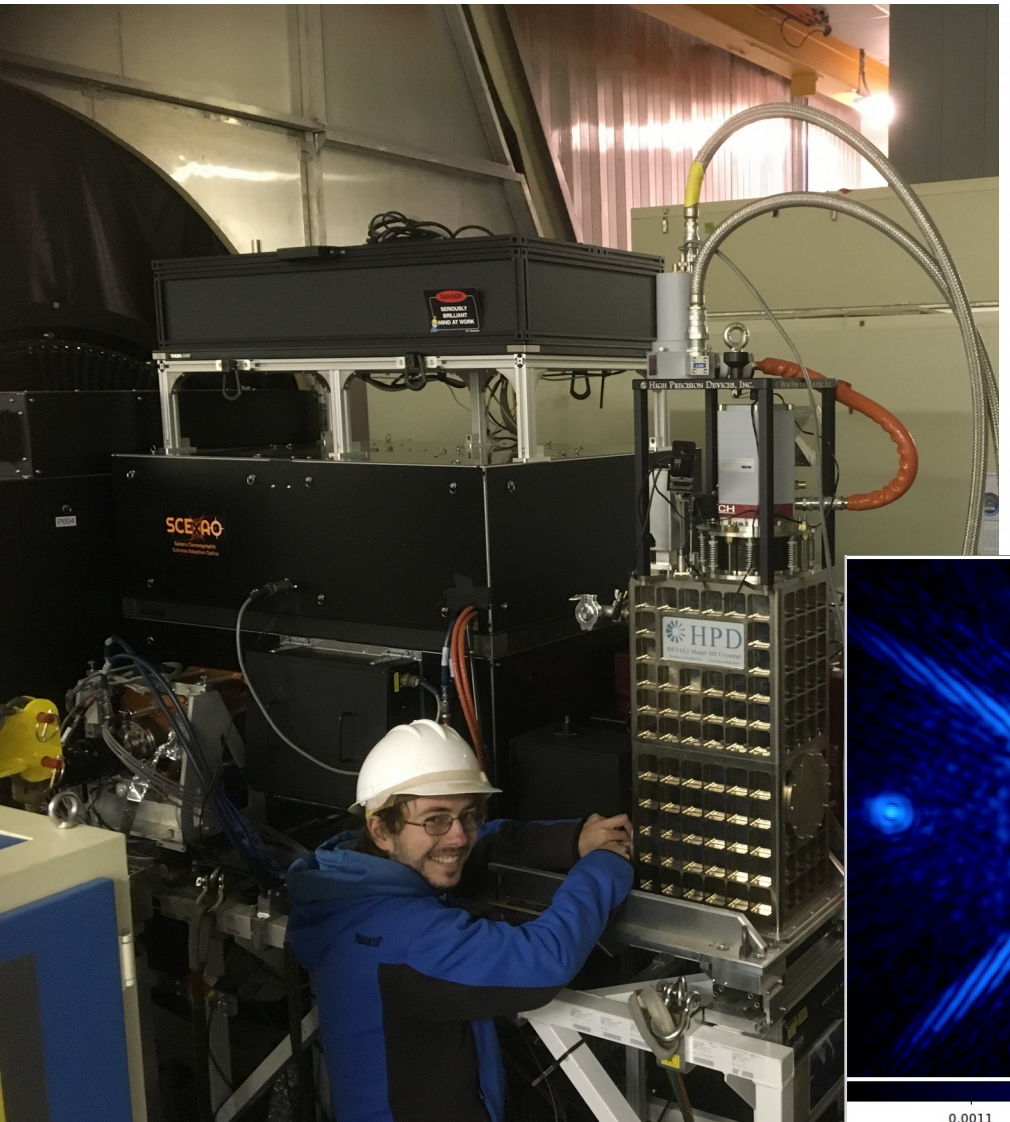
Software / data analysis:

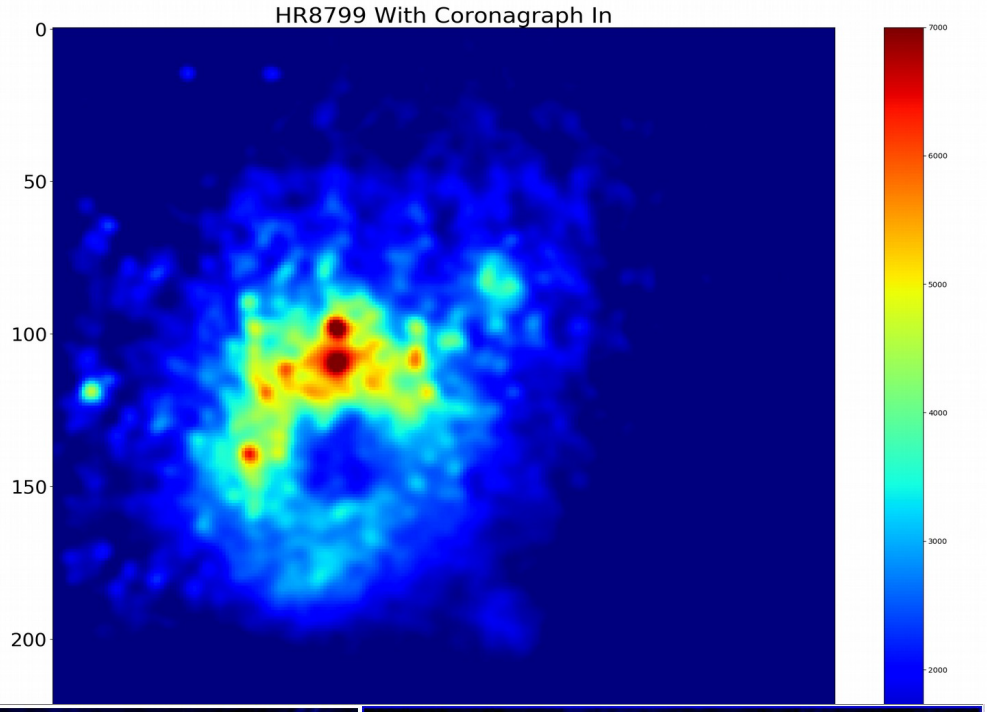
PSF calibration

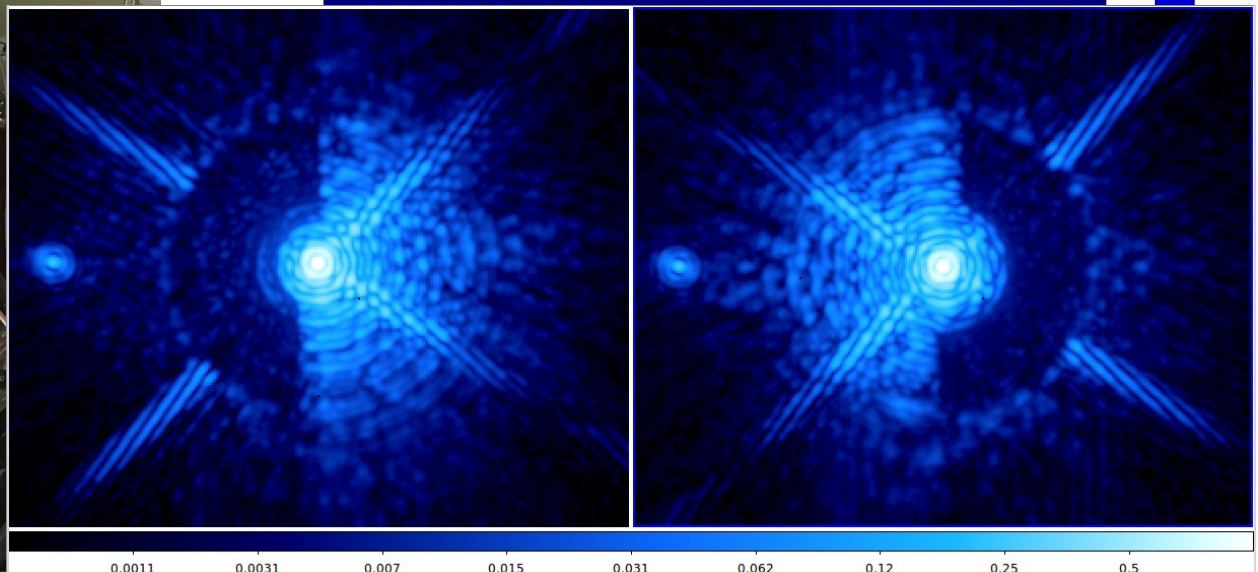
AO188 upgrades:

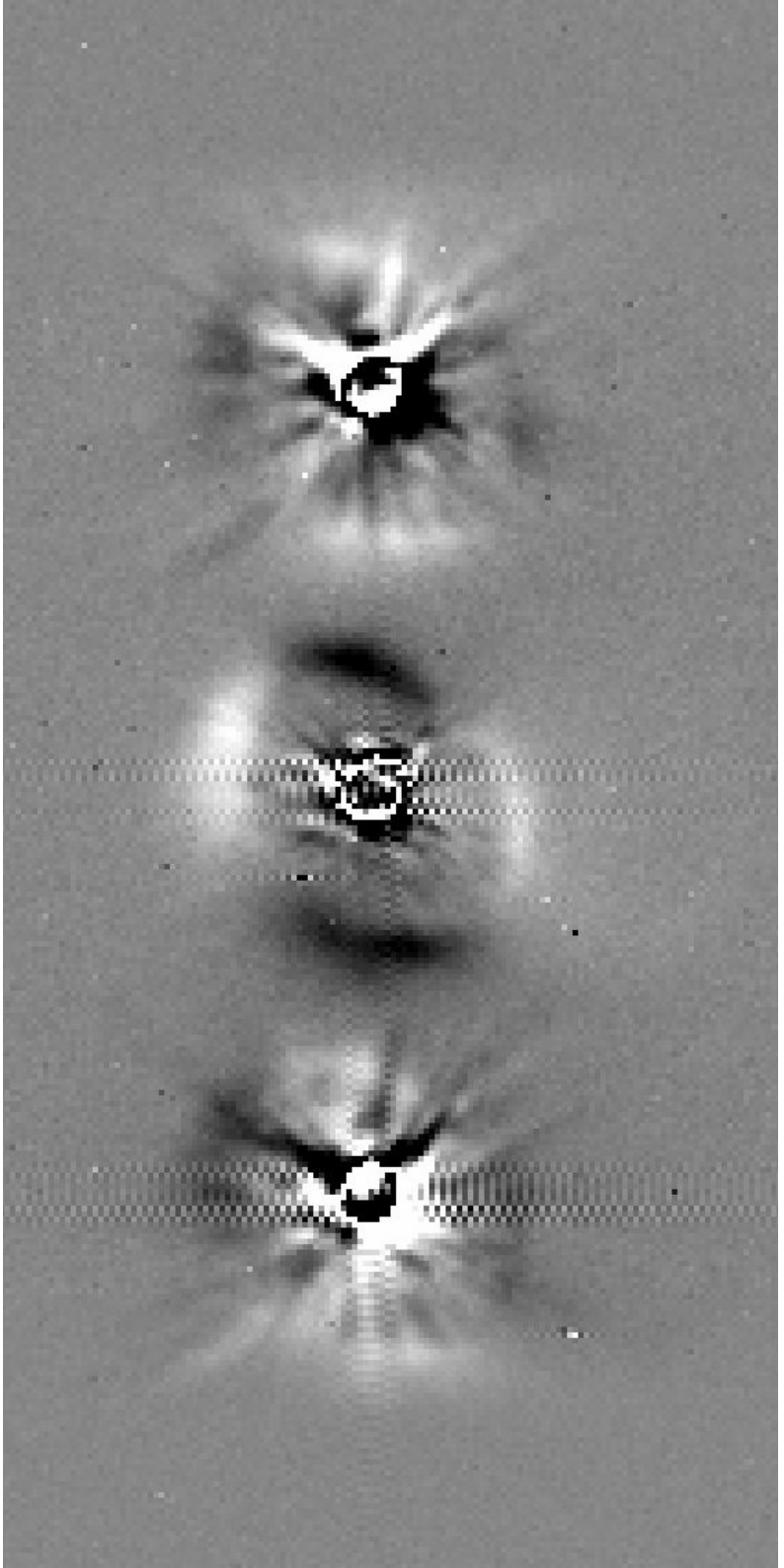
Beam switcher →easier operation
64x64 DM → higher performance overall
nearIR WFS → pushing limiting magnitude
Ultimate-START → LGS to push limiting magnitude

MKIDs camera [MEC, UCSB]
Optimized for fast speckle control









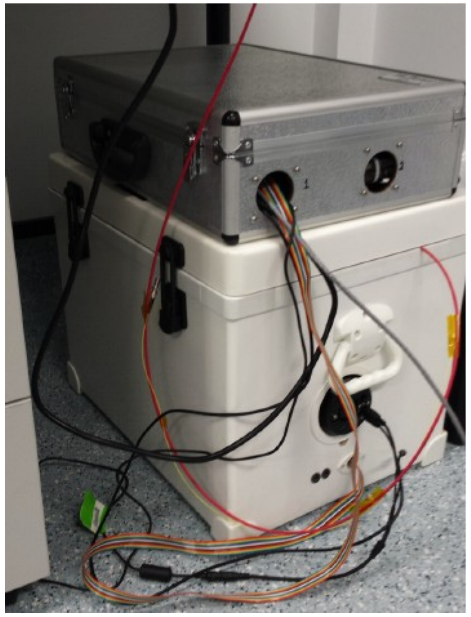
Near-IR polarimetry

Spectro-Polarimetry (CHARIS)
PDI mode feeding CHARIS

High speed PDI
Fast modulation with FLC

Both modes to be offered in S19B

Fiber-fed HR spectroscopy (R~70,000 to 100,000)



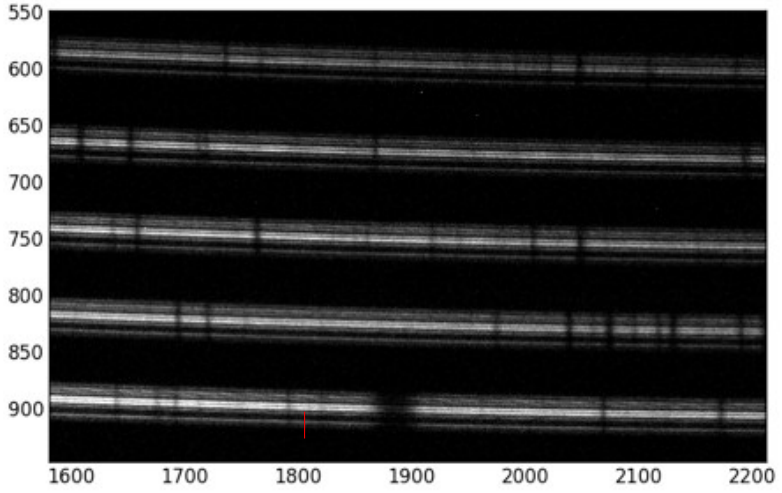
Visible

RHEA

Replicable High-resolution Exoplanet & Asteroseismology

(Michael Ireland, ANU
Christian Schwab, Macquarie Univ)

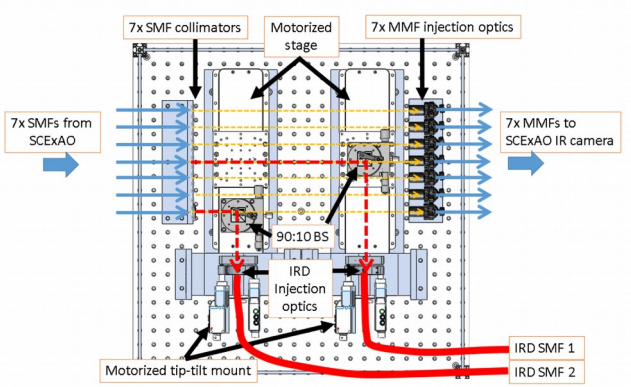
RHEA first light @ Subaru: Eps Vir (detail) Feb 2016

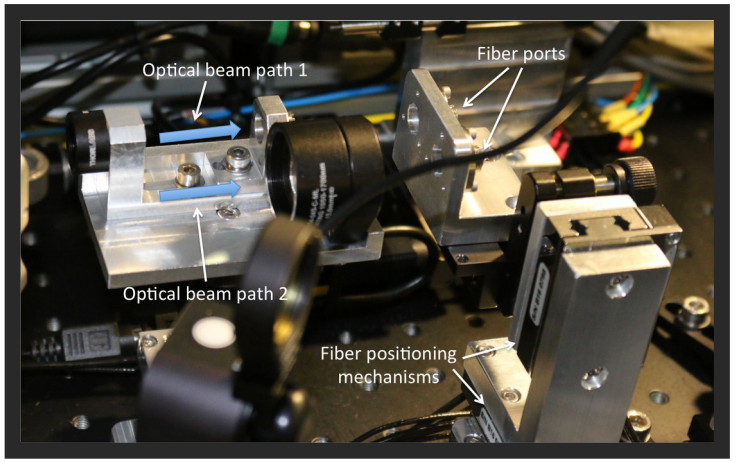


Near-IR

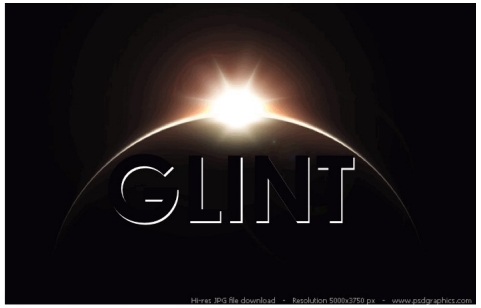
SCAHLET

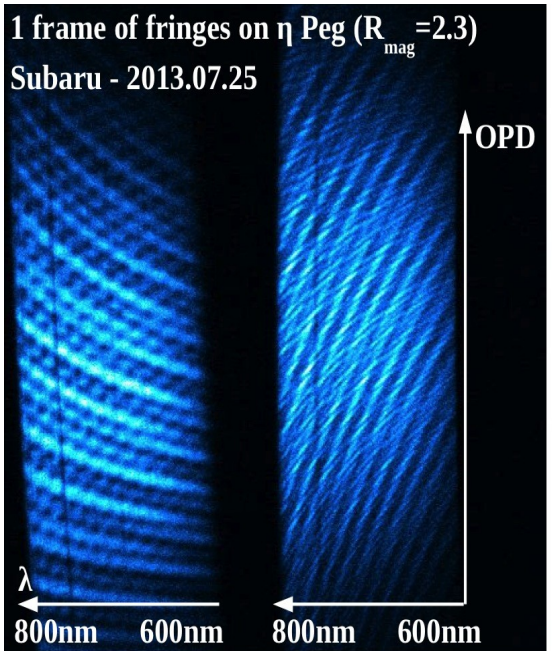
SCExAO→ IRD feed
T. Kotani, H. Kawahara

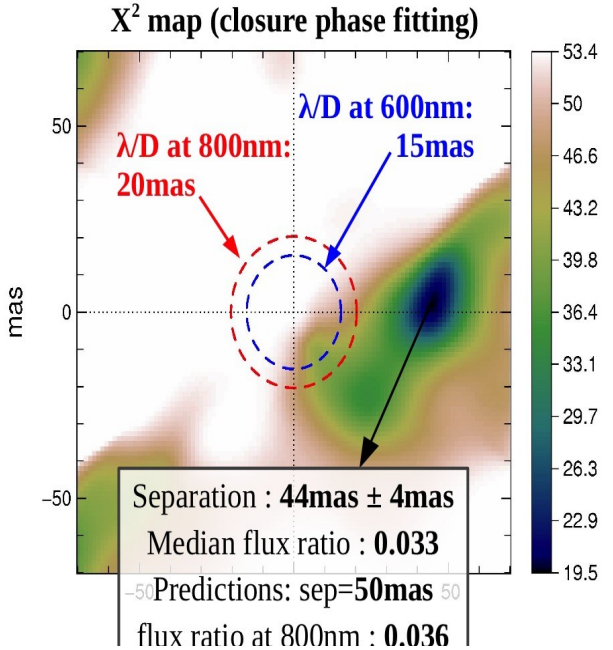


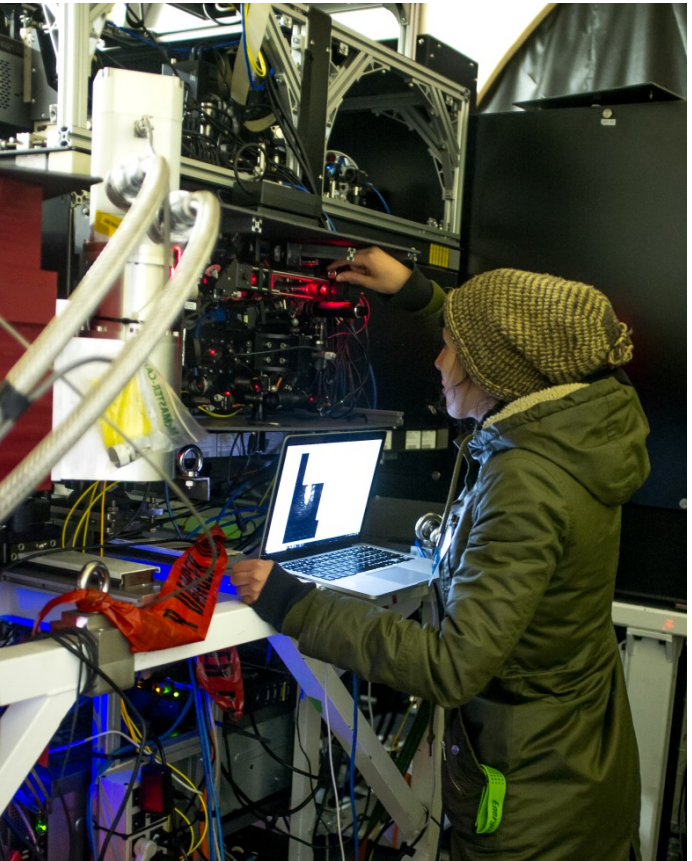


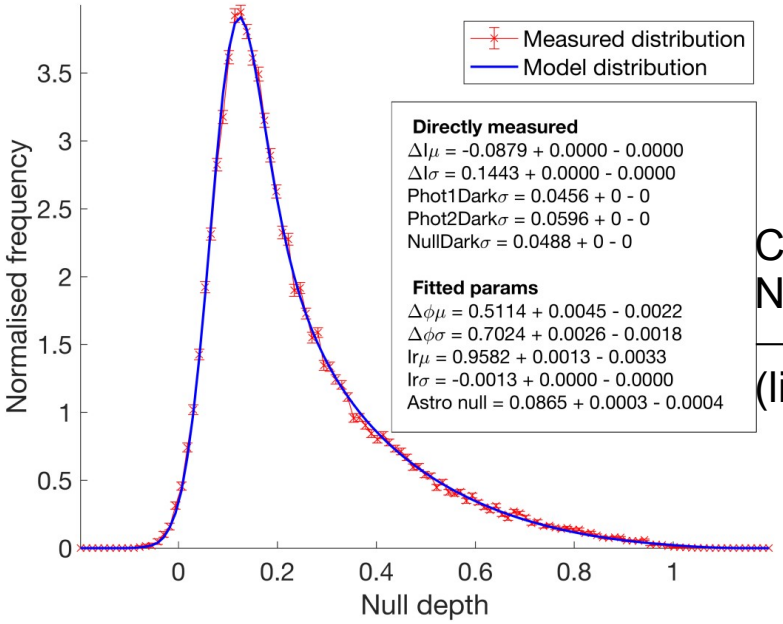
Interferometry: FIRST (vis) and GLINT (NIR)











Chi Cyg observed June 2017
Null depth= 0.0865 +- 0.0004
→ **diameter = 21.6 mas**
(literature values: 20-25 mas)

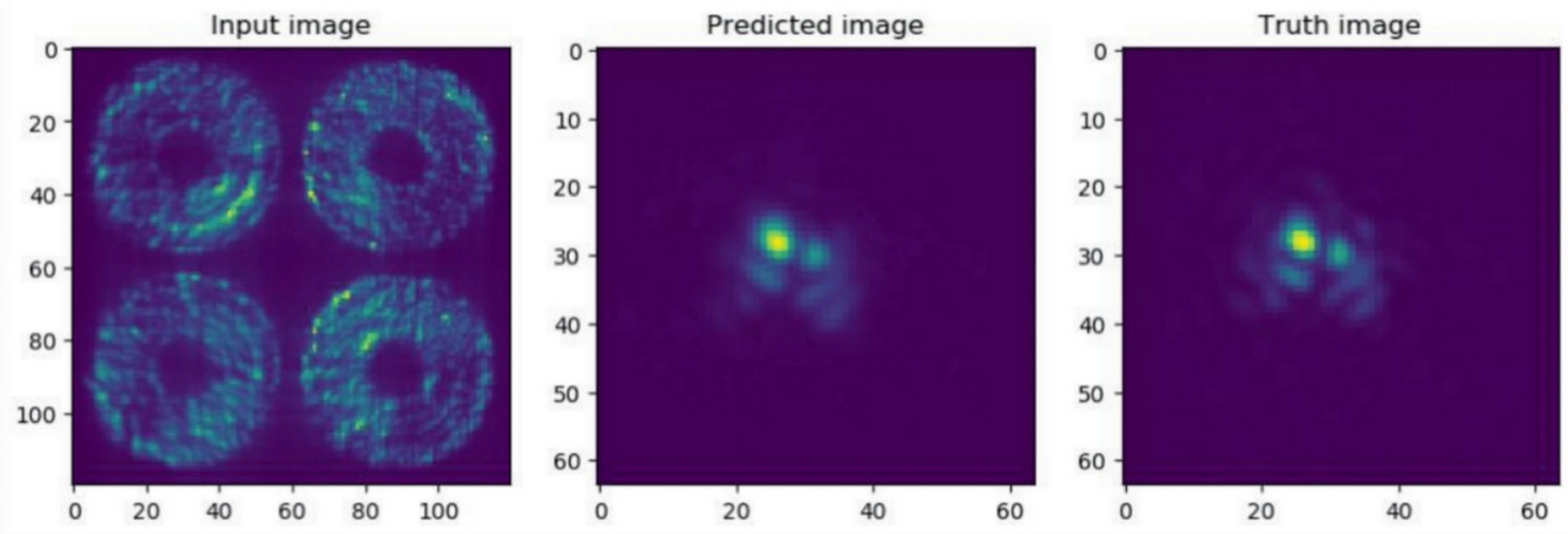
PSF calibration from real-time telemetry

→ it should be nearly impossible for speckles to “hide”

Two goals:
#1 improve **Wavefront control** sensitivity and accuracy
#2 provide real-time stellar PSF estimate for **PSF subtraction**

Promising… but realtime reconstruction of PSF from multiple WFSs is very challenging

Early work: PSF reconstruction using NN successfully estimates visible PSF (B. Norris, Univ. of Sydney)



CONCLUSIONS

SCExAO is a powerful platform for high contrast imaging in visible and NIR
Subaru science observations ↔ TMT exoplanet imaging prototyping

Current visible WFS affected by poor IRM2 reflectivity <600nm

Queue observing highly desirable (good/slow seeing)

SCExAO scientific productivity ramping up, but currently limited by :

Small pool of experienced observers
→ Advertising instrument performance

Perceived difficulty in reducing data
→ Improving data pipeline, Providing technical support

Limiting magnitude (mV~12)
→ NearIR WFS, LGS integration with ULTIMATE-START