Exoplanet & Circumstellar Disks Observations with SCExAO/CHARIS

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TEAMS: **CHARIS, AO3k, VAMPIRES**

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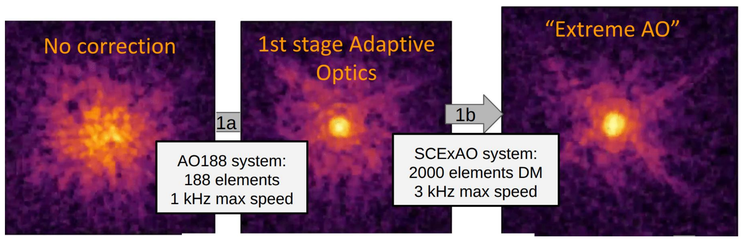
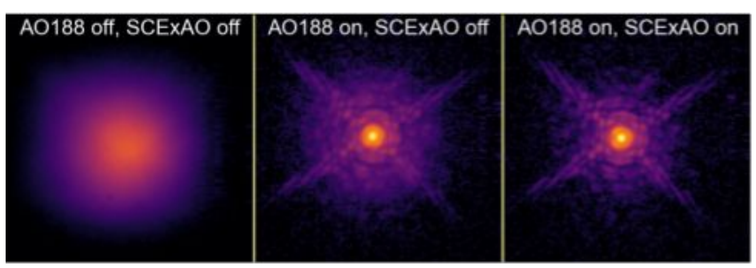
This poster serves as an introduction to the full SCExAO system and a review of CHARIS, its main science instrument. Other parts of the instrument are covered in posters P26 (VAMPIRES), P27 (Photonic Lantern), P28 (New technologies) and P29 (AO3k new modules).

WAVEFRONT CONTROL

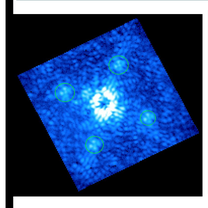
The SCExAO system combines high-performance "extreme" adaptive optics (AO) correction with instrument/modules optimize for high contrast imaging, spectroscopy and polarimetry.

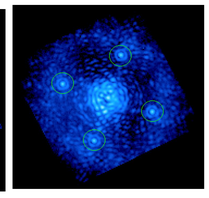




Real-time control performed by CACAO software developed in-house.

FUTURE PLANS & ACTIVITIES





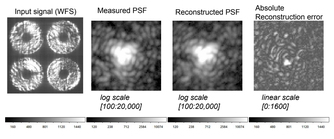
PSF splitting due to low-wind effect is impacting performance. 30-50% of coronagraphic data needs to be discarded -> we are exploring/testing WFS/C approaches to mitifate/solve this issue.

Improvements to AO correction

Predictive control
Automatic tuning
WFS reference updating

PSF reconstruction

Using vis / nir WFS
Algorithms in dev.



PSF reconstruction from on-sky images obtained with the VAMPIRES instrument at the Subaru Telescope. From left to right: Input (measured) WFS frame; Measured PSF; Reconstructed PSF; Residual reconstruction error (absolute value)
Credit: Seamus Duffy (SOKENDAI) & Takayuki Kotani (ABC)

Coronagraph system upgrades

Low-order WFS is being commissioned for auto-centering of PSF on mask
Better focal plane masks to leverage improved AO correction

User support for data analysis

Deployment of data analysis server at Hilo base

Detector Upgrade

Exploring upgrade from H2RG to ImAPD for lower RON and higher frame rate
-> enabled better PSF subtraction
-> Key to focal-plane WFS/C upgrades

Acknowledgements

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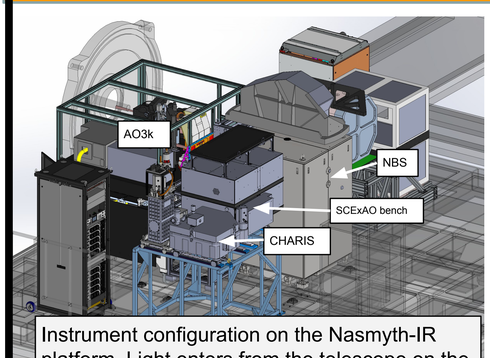
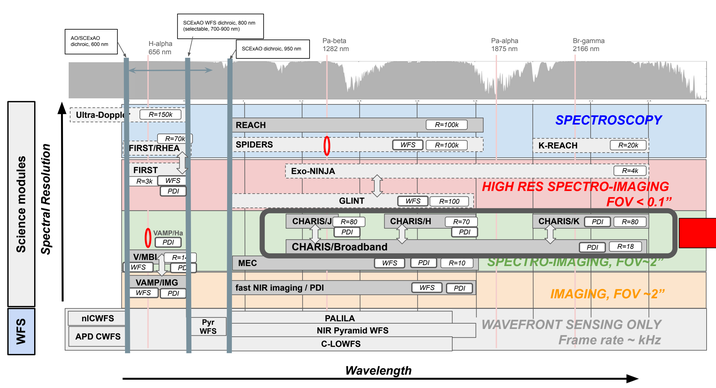
INTRODUCTION TO SCExAO & CHARIS

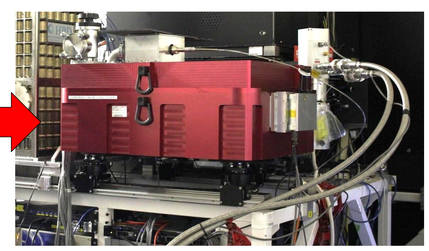


Instrument configuration on the Nasmyth-IR platform. Light enters from the telescope on the left. AO3k performs the initial AO correction. Light is then sent to SCExAO for 2nd-stage AO correction and starlight suppression, before entering CHARIS

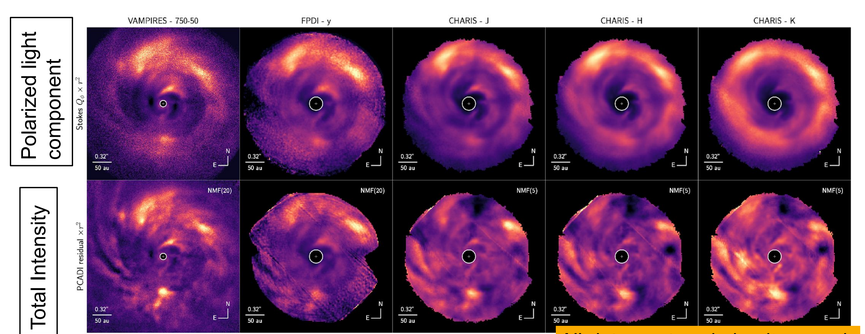


Current and future instrument modules, as a function of wavelength (x-axis) and spectral resolution (y-axis). Many modules can operate simultaneously. See posters P26, P27, P28 and P29 for details.

CHARIS



CHARIS is the main SCExAO science instrument, operating in nearIR at spectral resolution ranging from 20 to 70.
FOV 2.07" x 2.07%



All data captured *simultaneously*

SCExAO provides a broad range of measurement capabilities to study exoplanet and disks.
In this example, the AB Aur disk was observed from visible to NIR.
From left to right:

- VAMPIRES @ 750nm (one of 4 bands available)
- fast-PDI in y band
- CHARIS in J, H and K bands (raw data has 20 bands)

Each of the 3 instruments was used in PDI mode: PDI shown at the top, total intensity in the bpttpm
All measurements obtained with coronagraph.

CHARIS MODES

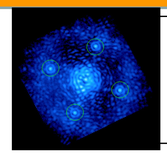
Spectroscopy

LOW RESOLUTION MODE:

- R~19, J+H+K Band
- 65-70% instrument throughput
- 10-15% from atmosphere to detector

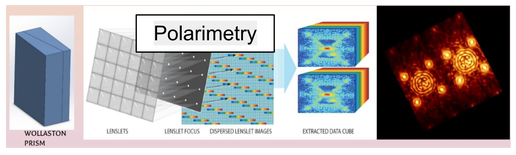
HIGH RESOLUTION MODE:

- R~70-90: J, H, and K Bands
- 55-60% instrument throughput
- ~15% from atmosphere to detector

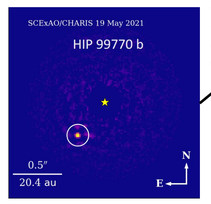


Coronagraphy

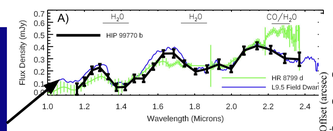
- Selectable Lyot focal plane mask
- Optional astrogrid for PSF referencing

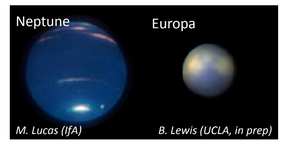


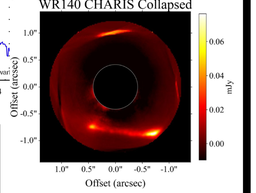
CHARIS SCIENCE MEASUREMENTS



Currie et al. Science (2023)







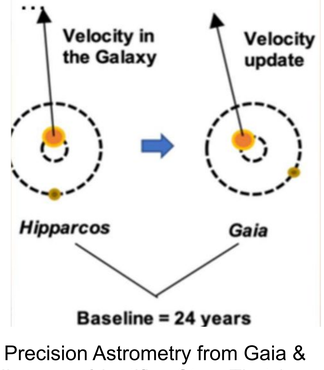
R. Lau, ApJ, 2023

CHARIS RECENT HIGHLIGHTS: OASIS INTENSIVE SURVEY

Example discoveries from the Observing Accelerators with SCExAO Imaging Survey (OASIS)

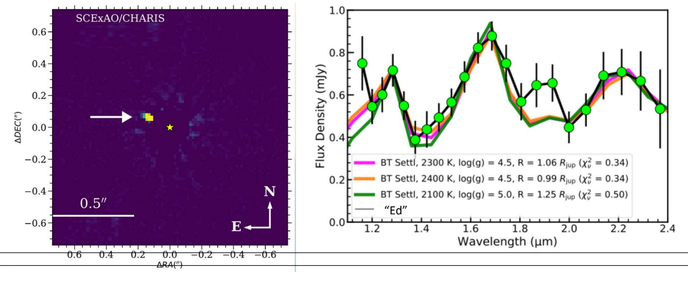
Thayne Currie, Survey Principal Investigator (Subaru/U. Texas-Antonio)
Masayuki Kuzuhara, Survey Co-PI (NAOJ)

Survey targets accelerating stars (significantly more efficient than blind surveys)



- Precision Astrometry from Gaia & Hipparcos Identifies Stars That Are Being Gravitationally Accelerated by An Unseen Companion
- Target accelerating stars that are young enough to have imageable planets

A new planet discovery



Orbits a very young A star that has never been the subject of a planet search before
~3--4 lambda/D separation!
~2100-2400 K, M/L transition object

Mass: ~17.6 Mj
Mass ratio ~9e-3
(similar to HR 8799 cde, HIP 99770 b)
sma ~ 25 au, ecc ~ 0.4

A brown dwarf companion suitable for Roman Coronagraph Technology Demonstration

El Morsy et al. 2025, ApJ Letters, under minor revision