SCExAO / Polarimetric Imaging with VAMPIRES & FAST-PDI

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OVERVIEW

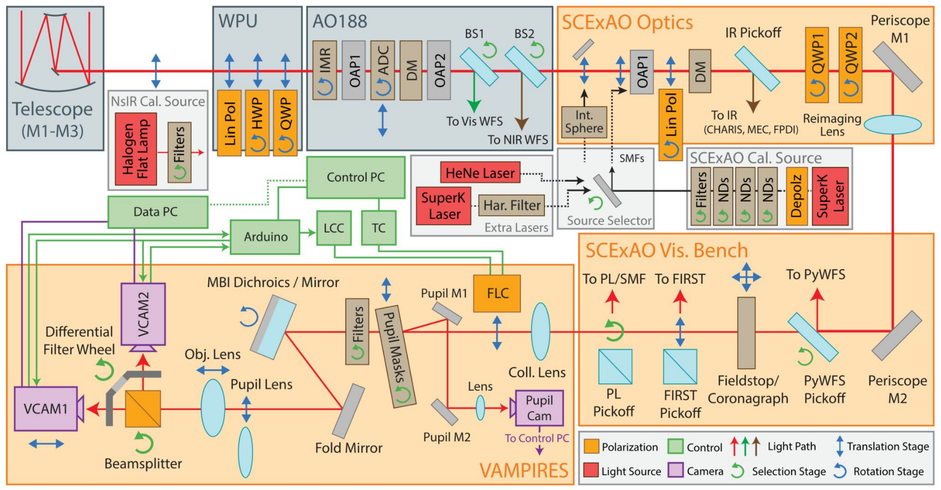
The Visible Aperture-Masking Polarimetric Imager/Interferometer for Resolving Exoplanet Signatures (VAMPIRES) is the visible-light (600-800nm) arm of SCExAO.

VAMPIRES is a coronagraphic dual-channel polarimeter that specializes in polarimetric observations, narrowband Halpha observations, and spectral differential imaging with its multiband imaging mode. The extreme AO correction provided by AO3k+SCExAO enables diffraction-limited observations even at visible wavelengths (peak on-sky Strehl ratio ~60%). Science cases for VAMPIRES include low-mass stellar companion direct imaging, circumstellar disks, stellar mass-loss shells and jets, and solar-system bodies. VAMPIRES can be used simultaneously with other modules (CHARIS, FASTPDI, FIRST-PL, etc.) and can perform simultaneous multi-instrument polarimetry alongside CHARIS and FAST-PDI.

The FAST-PDI module provides near-IR polarization differential imaging, complementing VAMPIRES-PDI, such that observers can take PDI measurements simultaneously from 600nm to 1.8um with the deep subtraction of non-polarized light provided by the camera's fast frame rates..

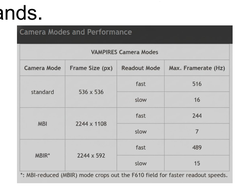
TECHNICAL IMPLEMENTATION

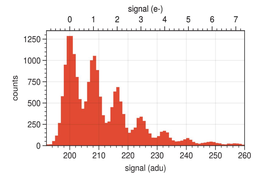
VAMPIRES is integrated within the SCExAO system, and optimized for polarization differential imaging at the diffraction limit. Full optical train (below) shows polarization modulation elements.



Fast, low noise detector

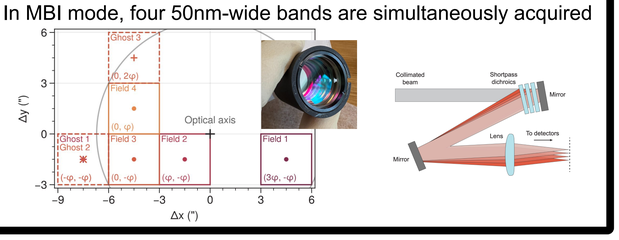
Two (2x) low-noise visible cameras, providing the sub-e- readout noise 0.2e- to 0.4e-).QE is 60% average in the VAMPIRES bands.





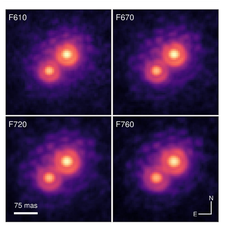
Multi-band Imaging (MBI)

In MBI mode, four 50nm-wide bands are simultaneously acquired



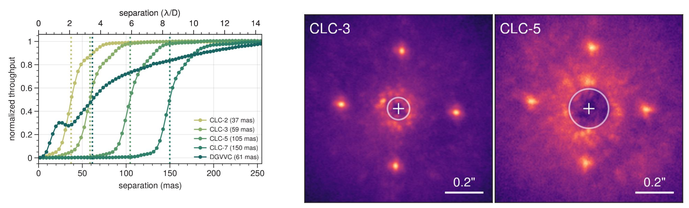
VAMPIRES' FIVE (5) MEASUREMENT MODES; CAN BE COMBINED

MBI



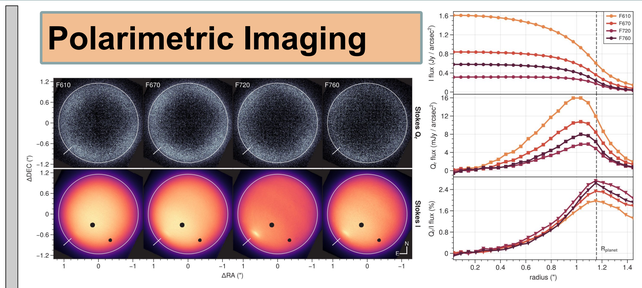
75mas binary (detail). Full frame is 3x3".

Coronagraphy



Selectable Lyot-type coronagraph masks (4 Lyot + vector vortex) . (left) Throughput curves for available masks. (right) Example on-sky frames.

Polarimetric Imaging

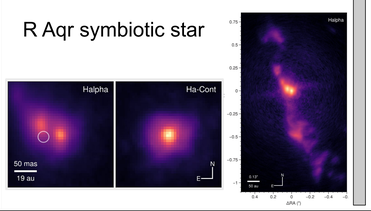


Neptune PDI: (left) Limb polarization; (right) Radial profiles show wavelength dependent intensity and scattering

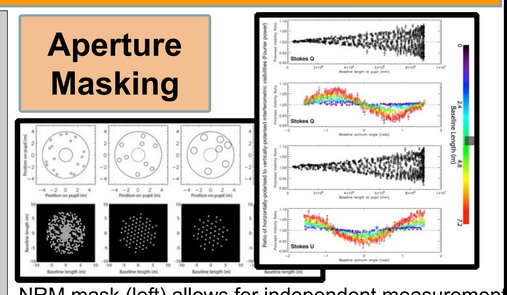
H-alpha

Simultaneous imaging of Ha and nearby continuum

R Aqr symbiotic star

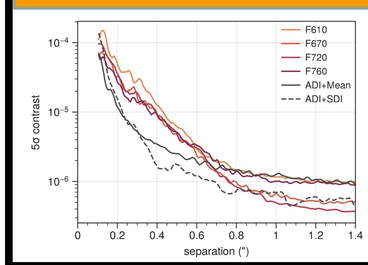


Aperture Masking



NRM mask (left) allows for independent measurement of baselines complex visibilities. (right) NRM+PDI

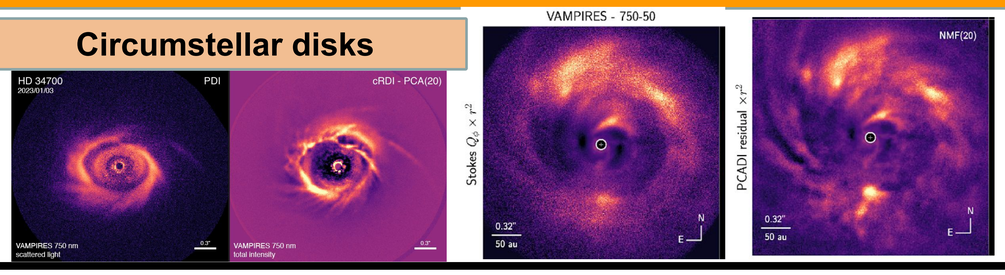
SCIENCE GOALS & CAPABILITIES



Stellar Companions

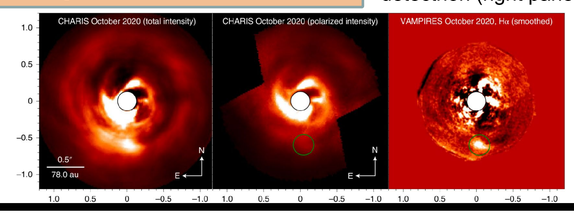
5σ throughput-corrected contrast curves from 60 minutes of data (mR=6, 10° PA rotation) in median conditions (seeing 0.5" ± 0.2")

Circumstellar disks



Exoplanet accretion

AB Aur b Halpha detection (right panel)



NIR Fast-PDI

FPDI can operate in parallel with VAMPIRES and/or CHARIS PDI.
FPDI no longer shares its NIR camera with AO3k's NIR WFS, so it can operate with NIR WFSing.

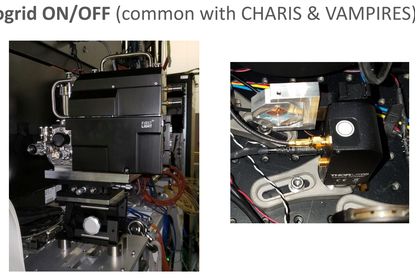
FPDI data uses a low-noise high frame rate NIR camera (Model: CRED1). Can be acquired with any combination of:

- **Non-PDI** or **PDI**
- **Single band** (Broadband possible but not recommended)
- **Full pupil** or **Coronagraph** (several options)

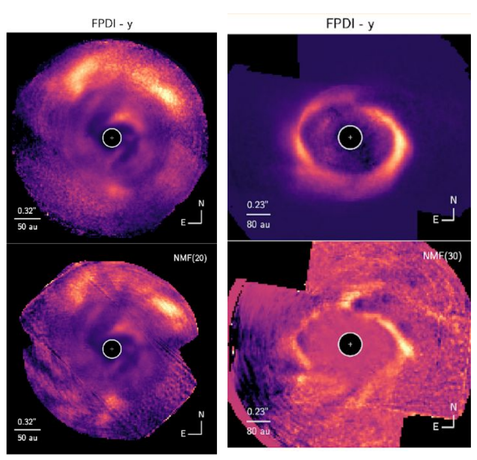
Camera Settings

- **Region of interest (ROI)** to trade FOV and frame rate in non-PDI (up to 4x4"), fixed in PDI (2x1", 3.5 kHz).
- **Integration time**
- **Detector gain (x1 to x121).** Highest gain values provide near photon counting performance, but reduced dynamical range and additional dark current.

Astrogrid ON/OFF (common with CHARIS & VAMPIRES)



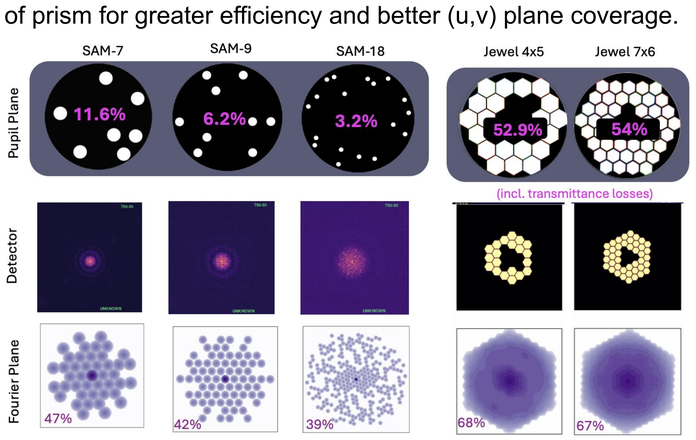
FPDI camera (left) and Wollaston prism (right)

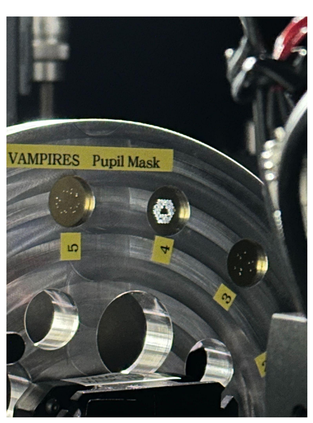


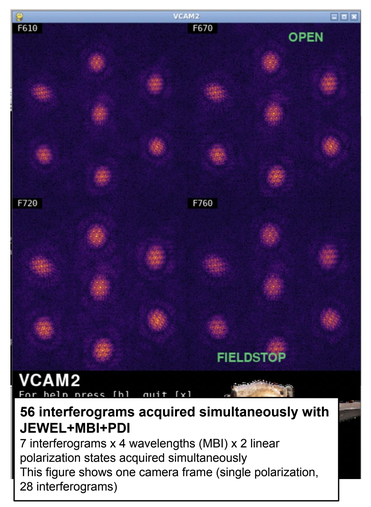
Example PDI data.
Left: AB Aur. Right: HD 34700
Top: PDI mode (polarized light)
Bottom: Total light

JEWEL MASK

JEWEL replaces the aperture masks (SAM-7, SAM-9, SAM-18) with a tiling of prism for greater efficiency and better (u,v) plane coverage.







56 interferograms acquired simultaneously with JEWEL+MBI+PDI
7 interferograms x 4 wavelengths (MBI) x 2 linear polarization states acquired simultaneously
This figure shows one camera frame (single polarization, 28 interferograms)

Acknowledgements

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