Visible-light High Contrast Observations with SCExAO/VAMPIRES

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OVERVIEW

VAMPIRES operates in visible light (600-800nm), and operates at the diffraction limit thanks to AO3k+SCExAO wavefront correction. VAMPIRES supports imaging, aperture masking, polarimetry and coronagraphy. It is optimized for high contrast imaging and high angular resolution.

VAMPIRES operation modes can be combined (for example, coronagraphy, multi-band imaging and polarimetry), addressing a wide range of scientific needs.

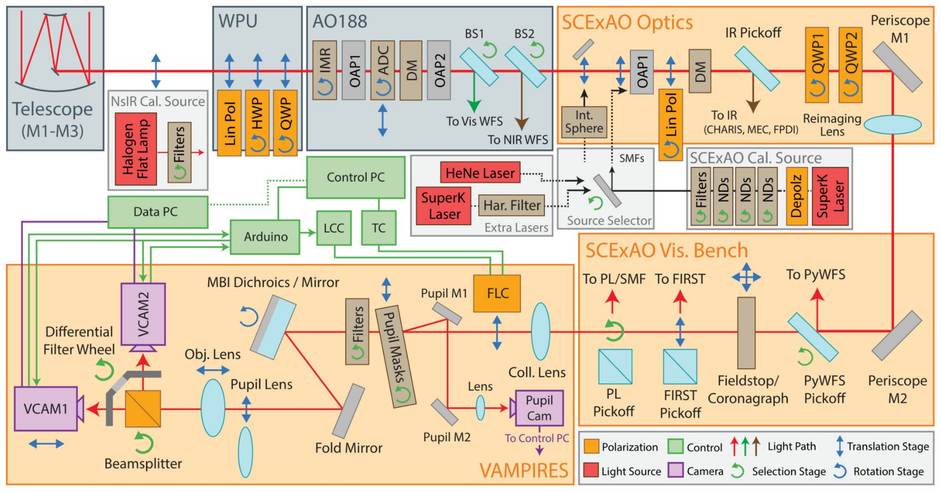
VAMPIRES operates simultaneously with SCExAO/CHARIS. Light is split within SCExAO between NIR (-> CHARIS, GLINT, MEC) and VIS (-> VAMPIRES, Pyramid WFS & FIRST-PL)

VAMPIRES was built by NAOJ/Subaru, Univ. of Sydney and University of Hawaii. The VAMPIRES team supporting instrument opration and data calibration/reduction spans multiple organizations.

STATUS: VAMPIRES in in science operation as a PI-type instrument.

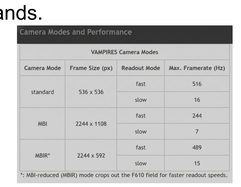
TECHNICAL IMPLEMENTATION

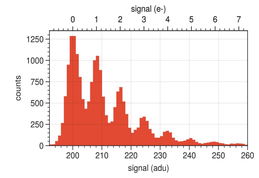
VAMPIRES is integrated within the SCExAO system, and optimized for polarization differential imaging at the diffraction limit. Full optical train (below) shows polarization modulation elements.



Fast, low noise detector

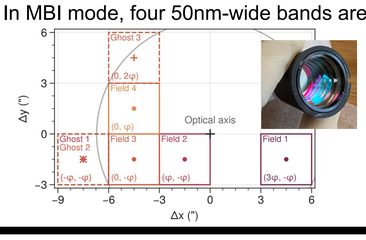
Two (2x) low-noise visible cameras, providing the sub-e- readout noise 0.2e- to 0.4e-).QE is 60% average in the VAMPIRES bands.

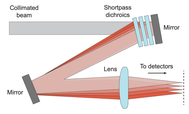




Multi-band Imaging (MBI)

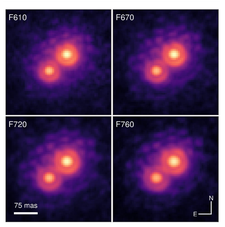
In MBI mode, four 50nm-wide bands are simultaneously acquired





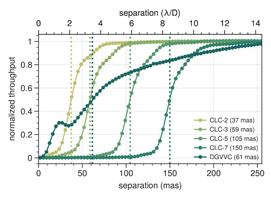
VAMPIRES' FIVE (5) MEASUREMENT MODES; CAN BE COMBINED

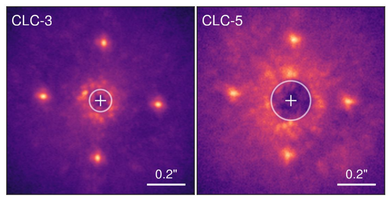
MBI



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

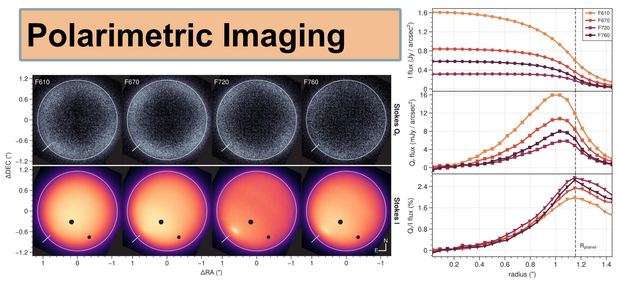
Coronagraphy





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

Polarimetric Imaging

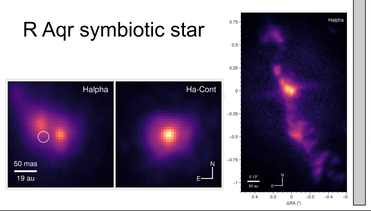


Neptune PDI: (left) Limb polarization; (right) Radial profiles show wavelength dependent intensity and scattering

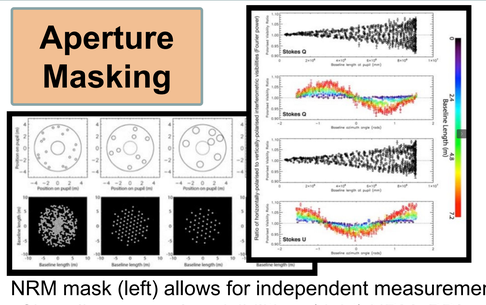
H-alpha

Simultaneous imaging of Ha and nearby continuum

R Aqr symbiotic star

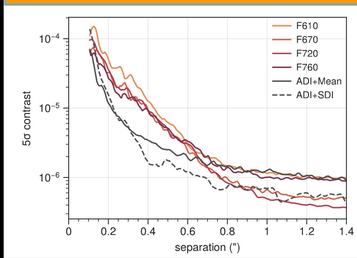


Aperture Masking



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

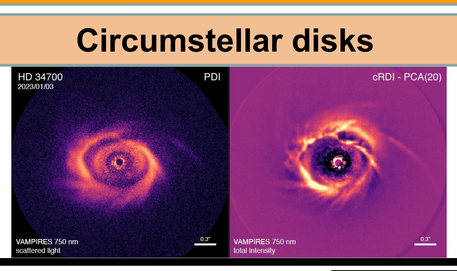
SCIENCE GOALS & CAPABILITIES

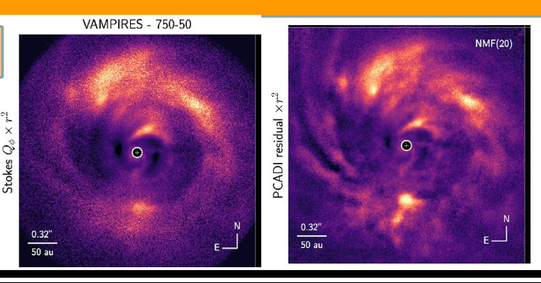


Stellar Companions

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

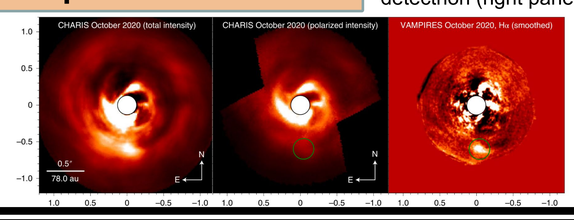
Circumstellar disks





Exoplanet accretion

AB Aur b Halpha detection (right panel)

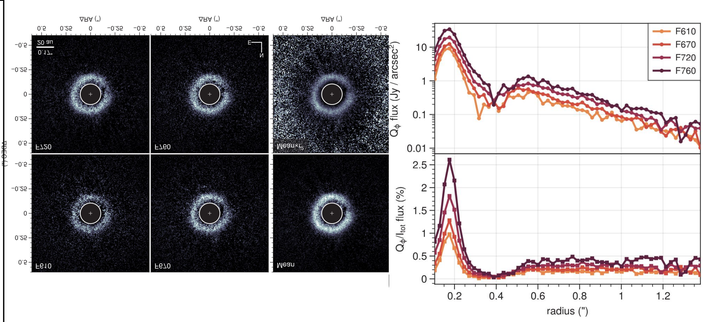


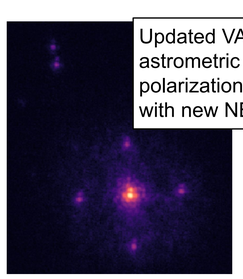
RECENT HIGHLIGHTS

Transitional Disk HD169142

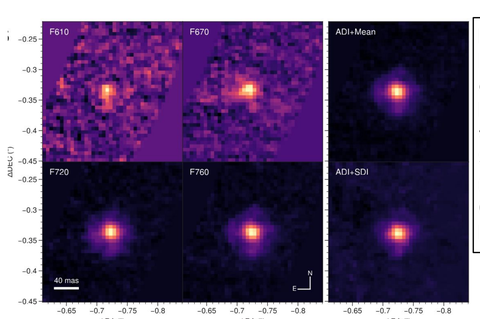
Wavelength-dependent scattering measured with MBI+PDI. Radial profiles show higher scattering at longer wavelength.

Temporal evolution: *"Dynamical Analysis of the HD 169142 Planet-Forming Disk: Twelve Years of High-Contrast Polarimetry"*, AJ, Lucas et al. 2025





Updated VAMPIRES astrometric and polarization calibration with new NBS



Measuring low-mass companion **HD1160 b** visible-light SED (separation 0.794") Lucas+ In prep

FUTURE PLANS

Coronagraphy

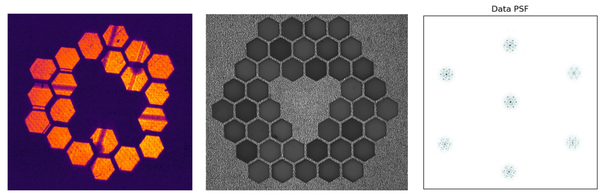
New masks: RAP for resilience to low-wind effect. Visible-light WFS with LOWFS and PL for improved contrast

PSF reconstruction

We are developing PSF reconstruction from WFS telemetry for deeper contrast. Also developing PDI and MBI optimized PSF reconstruction/subtraction algorithms.

Aperture Masking -> JEWELS

JEWELS replaces the aperture mask with a tiling of prism for greater efficiency and better (u,v) plane coverage. This will bring >10x boost in efficiency and sensitivity.



(Left) Jewel 4x5 mask currently installed on VAMPIRES. (Center) new Jewel 7x6. (Right) A rosette of Interferograms taken with a 633nm laser in an optical testbed illustrating the entire PSF of the new 7x6 mask.

Acknowledgements

We wish to recognize and acknowledge the significant cultural role and reverence that the summit of Maunakea has always had within the indigenous Hawaiian community. We are grateful and thank the community for the privilege to conduct observations from this mountain.
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