

Toward Directly Imaging Earth-like rocky planets with Focal Plane Wavefront Sensing: SPIDERS, a high-contrast imager pathfinder for the Subaru Observatory

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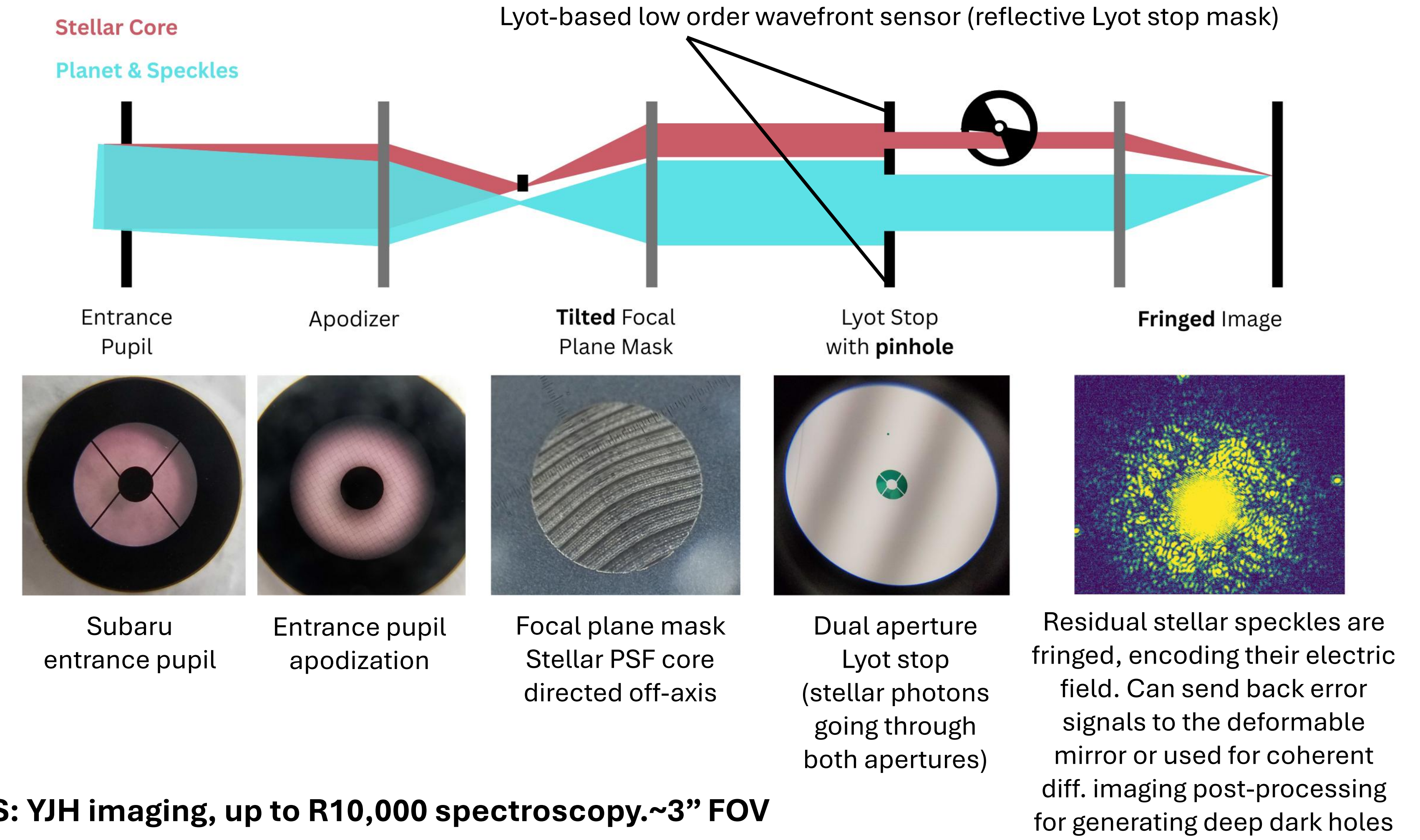
The quest to detect and characterize exoplanets and debris disks around nearby stars will be transformed in the coming years with the development of the next generation of high-contrast imagers. These new/upgraded instruments aim to achieve up to a 100x gain in sensitivity at small ~λ/D angular separations around bright stars. Over the past decade, significant R&D at the National Research Council of Canada has focused on developing focal-plane wavefront sensing techniques that enable measurements of the residual electric field directly in the science focal plane. These measurements can be used in closed loop with the instrument deformable mirror to create deep “dark holes” in the quasi-static dominated stellar halo, enabling the detection of faint disks and exoplanets. Using this approach, the science data can also be enhanced through coherent differential imaging, which leverages the coherence of the residual starlight to further suppress speckle noise in addition to standard techniques such as angular and spectral differential imaging. SPIDERS is a pathfinder instrument that aims to validate these new concepts at the Subaru observatory, performing on sky testing with the SCEXAO team.

SPIDERS at the Subaru Observatory!



SPIDERS installed at the Subaru Observatory. Team members: Adam Johnson, Olivier Lardière, Christian Marois, and William Thompson (in front of SPIDERS). With SCEXAO collaborator Julien Lozi. December 2025

SPIDERS coronagraphic FAST self-coherent camera focal plane wavefront sensing

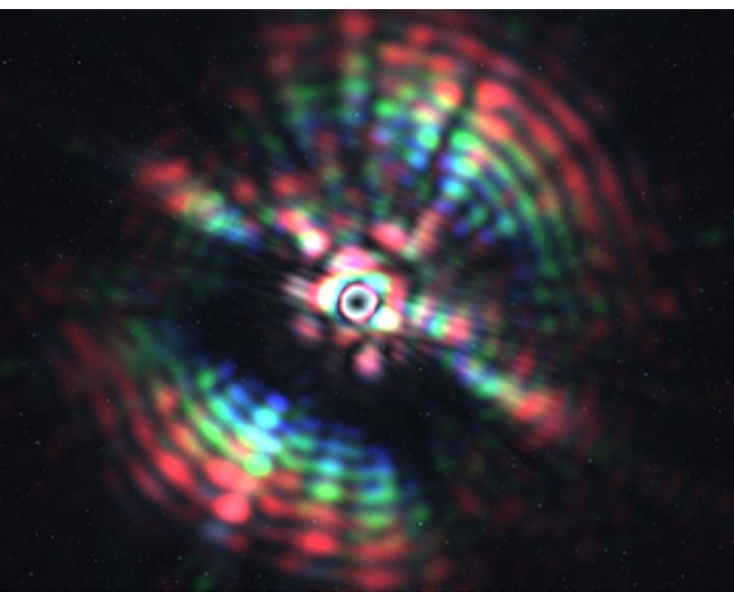


SPIDERS: YJH imaging, up to R10,000 spectroscopy. ~3" FOV

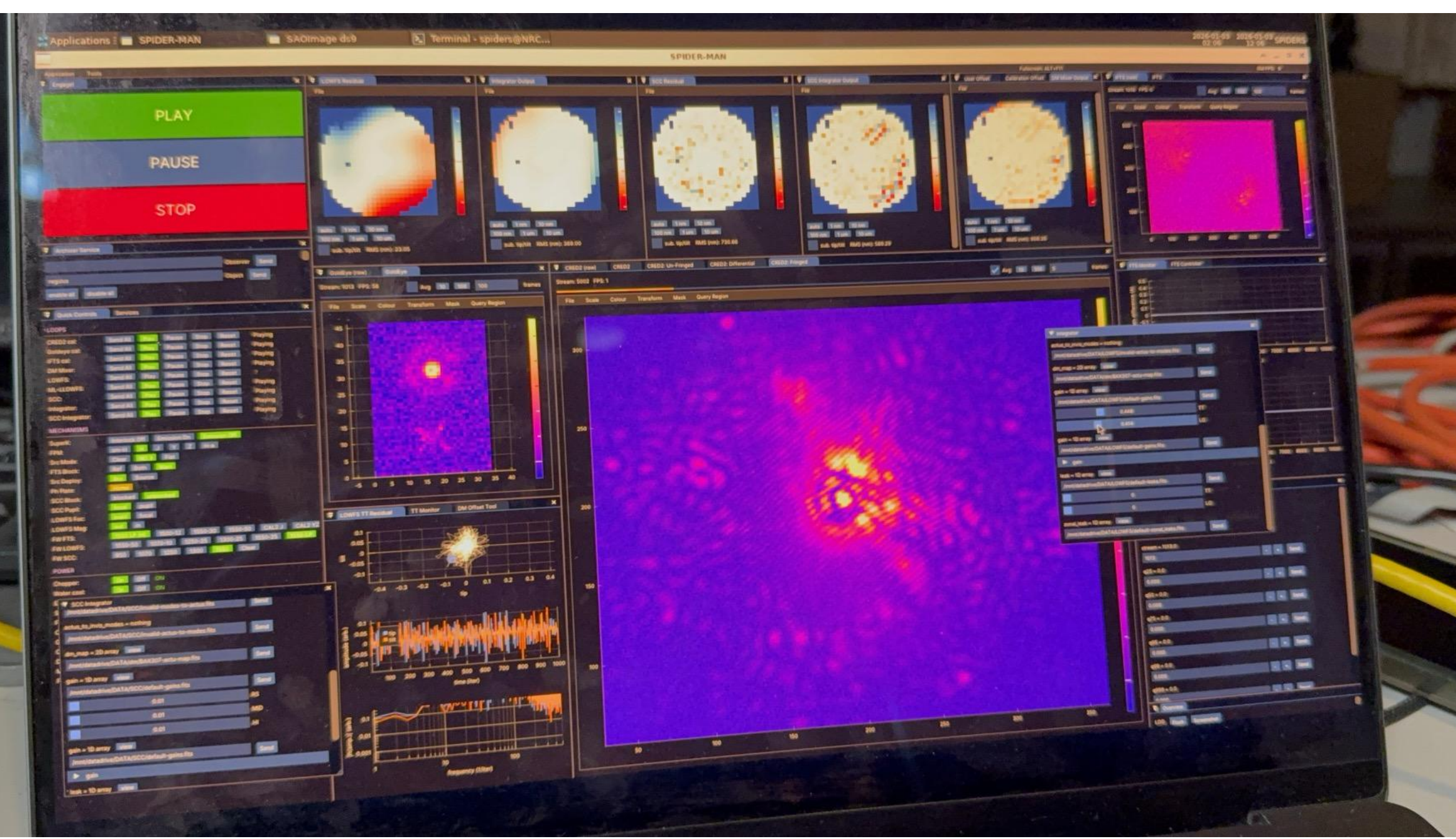
On sky R&D!

- Self-coherent camera high speed dark hole corrections
- Long integrations/stable loops
- Machine-learning based low order wavefront sensing
- Coherent differential imaging post-processing
- Imaging Fourier Transform Spectrograph operation on sky
- Wynne corrector (broadband 10%) dark hole (validated May 2026)

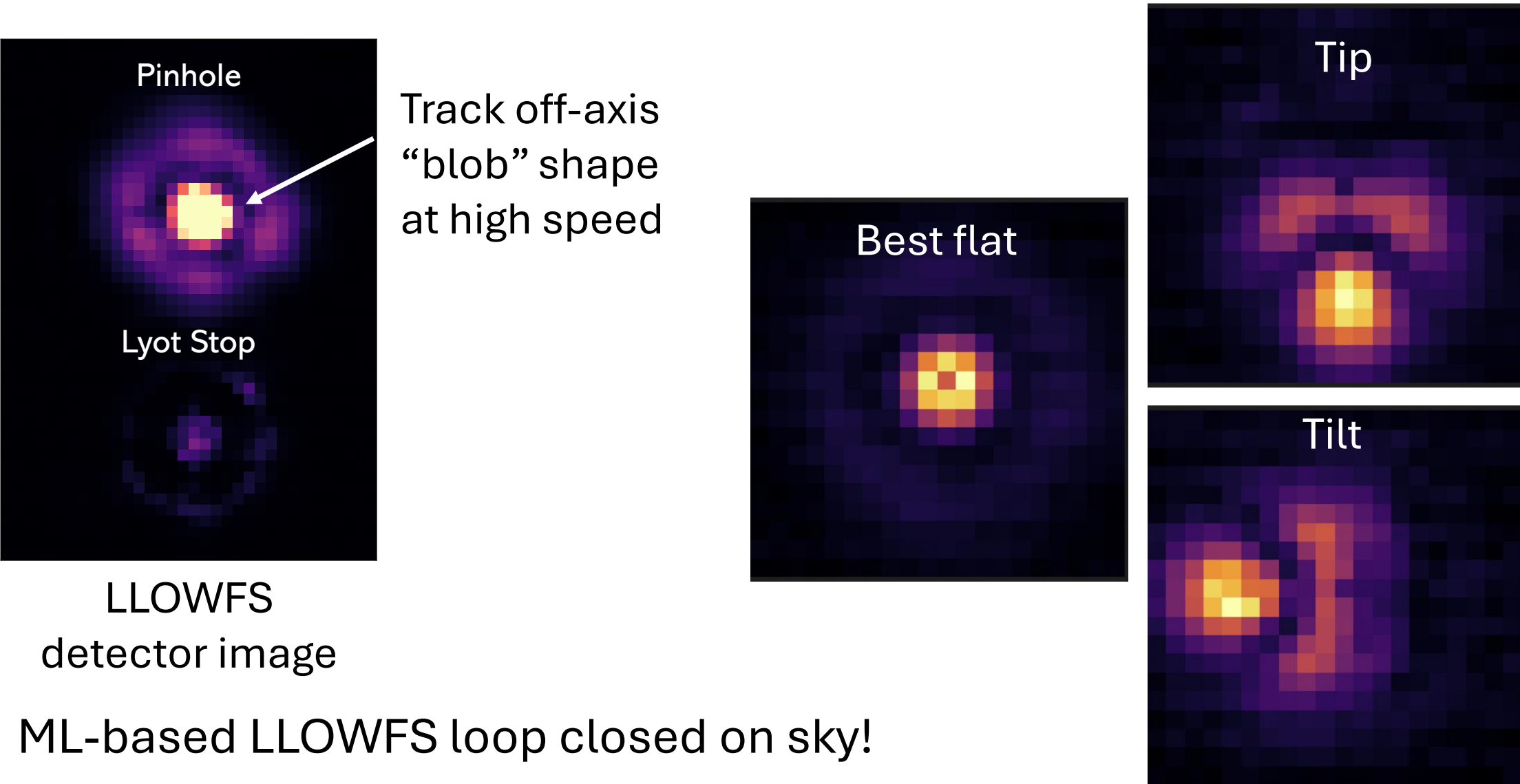
SPIDERS first dark hole on sky (December 2025),
World's first on sky high-speed focal plane wavefront sensing dark hole!



SPIDERS' imaging Fourier Transform Spectrograph polychromatic data cubes! (internal source)



Machine learning low order wavefront sensing (Andre Fogal Msc. thesis)



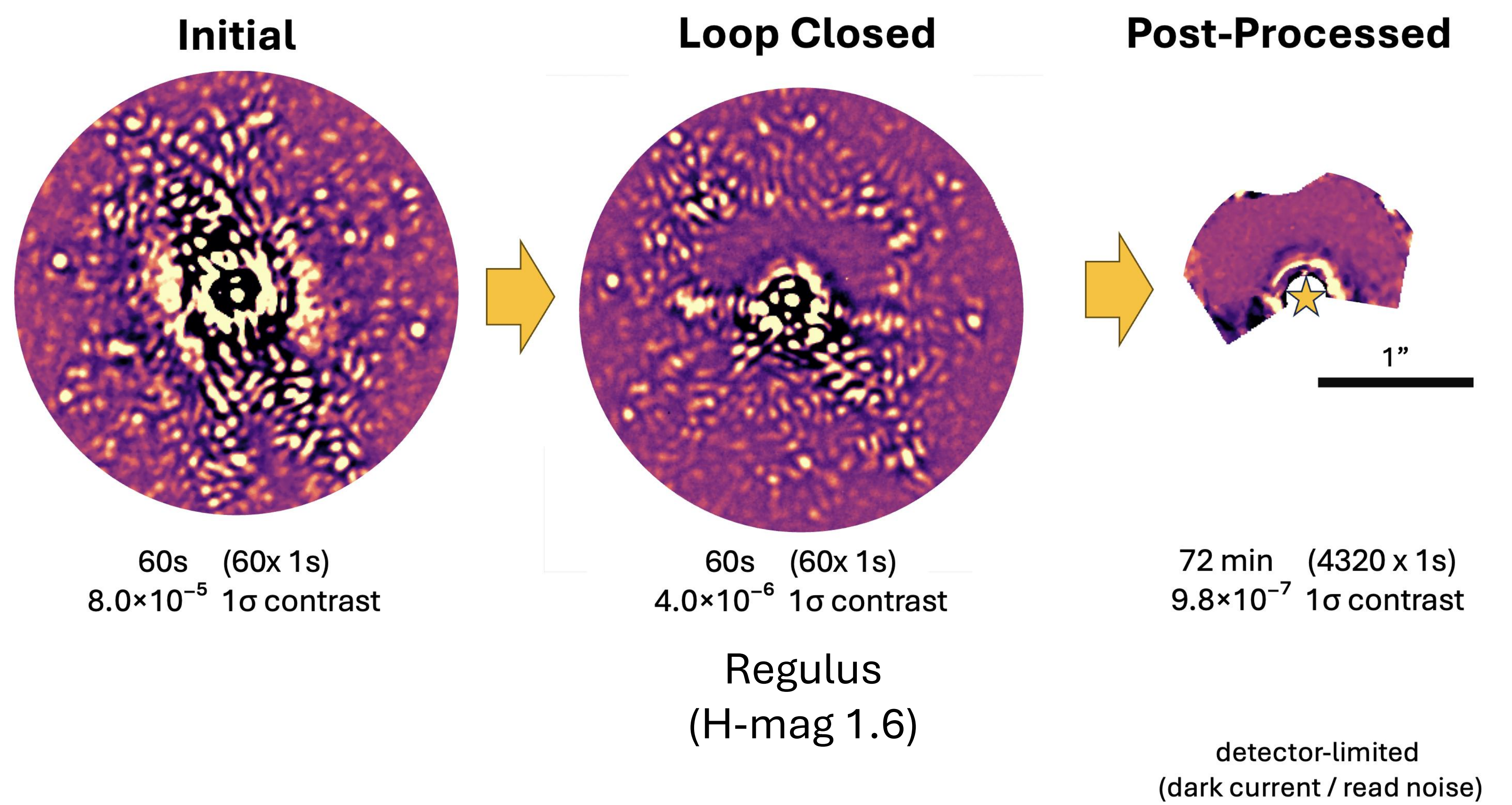
ML is dramatically increasing the sensor linearity range and crosstalk, for it to work on sky (up to -100/100 nm range)

Good performance at 100 Hz, 1 kHz even better!

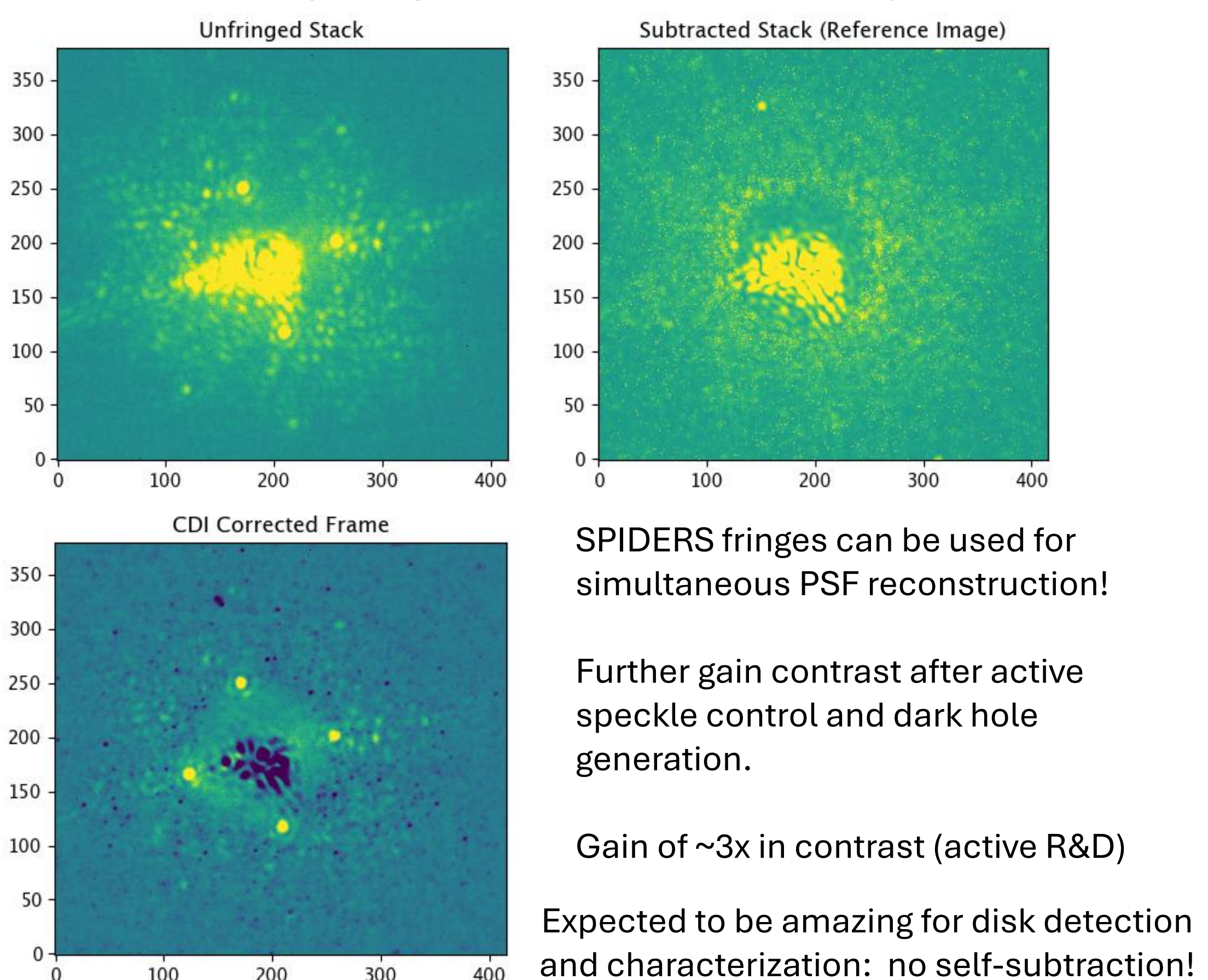
Low orders are evolving very fast behind AO3k

Seems to be correcting/helping to correct the low wind effect!

Closed loop 25Hz SCC focal plane WFS on sky, deep dark holes!



Coherent differential imaging (Kaitlyn Hessel Msc. thesis)

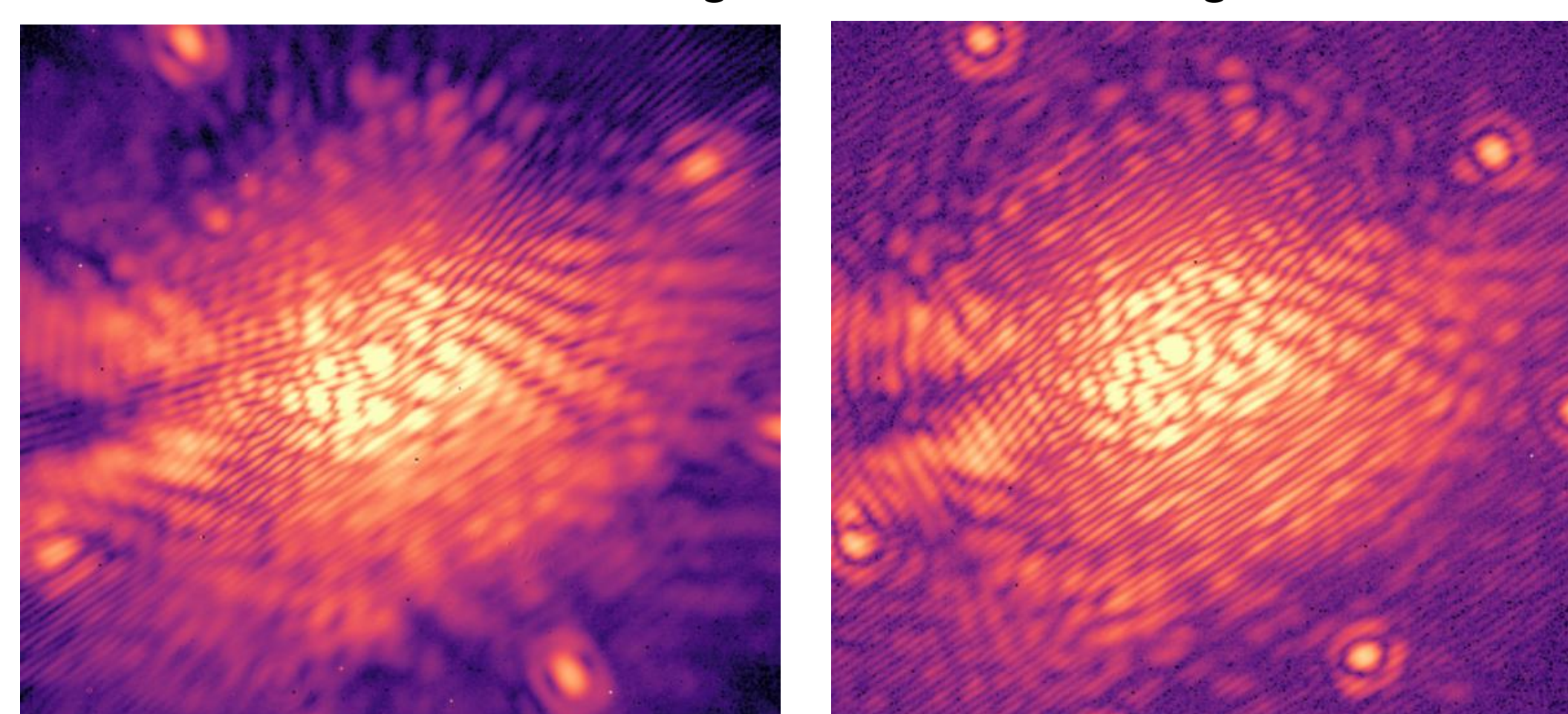


May/June 2026 Eng. run

Wynne Corrector successfully tested on sky!
(chromatic focal plane for achromatic speckle and fringe alignment)

Achieving 10% broadband focal plane wavefront sensing and post-processing!

Internal source images to demonstrate the gain

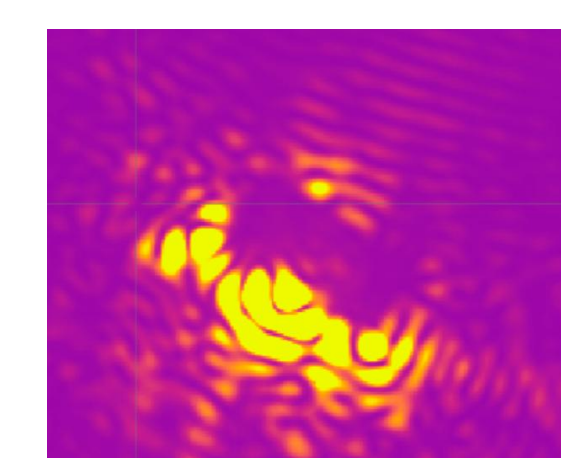


Original SPIDERS in a 10% bandpass Fringes are blurred due to the PSF magnification with wavelength

SPIDERS with a Wynne corrector The chromatic plate scale now generates achromatic speckles. Fringes are sharp all around the stellar PSF

SPIDERS' Future

- SPIDERS is shipping back to Canada
- ORCA-Quest funding secured, SPIDERS will extend to visible wavelengths (H-alpha and reflected light science)
- ~1 λ/D dark holes!
- Goal is <10E6 contrast 1 sigma < 0.3" in 1h
- DR4 Follow-ups



SPIDERS ~1 λ/D dark hole R&D using its internal source.

SPIDERS as a Visitor Instrument?

Interested in brown dwarfs, exoplanets, protoplanets, debris disks, reflected light exoplanet imaging?

We want to hear from you! We would like be to back and use it with the community!
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