FIRST-PL

Humu's Spin Orientation

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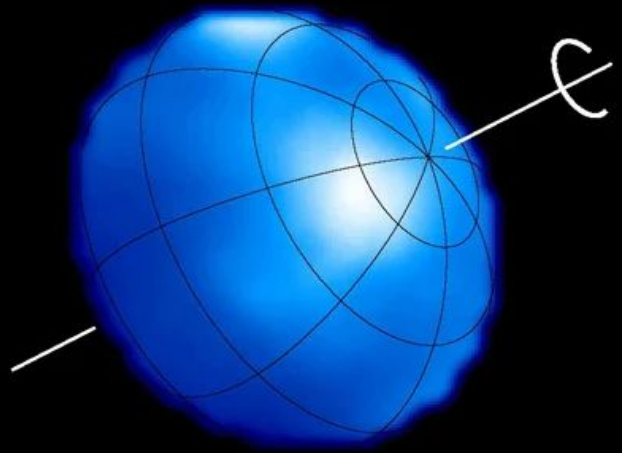
University of Hawaii



Monnier et al. 2007

Upcoming Telescopes

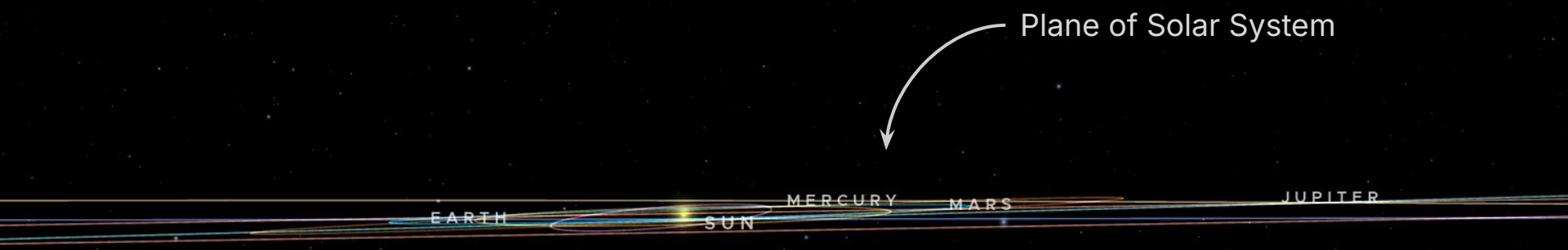
Target Earth-like planets around Sun-like stars

Habitable Worlds
OBSERVATORY

The Challenge: Constrain orbital geometry without direct detection

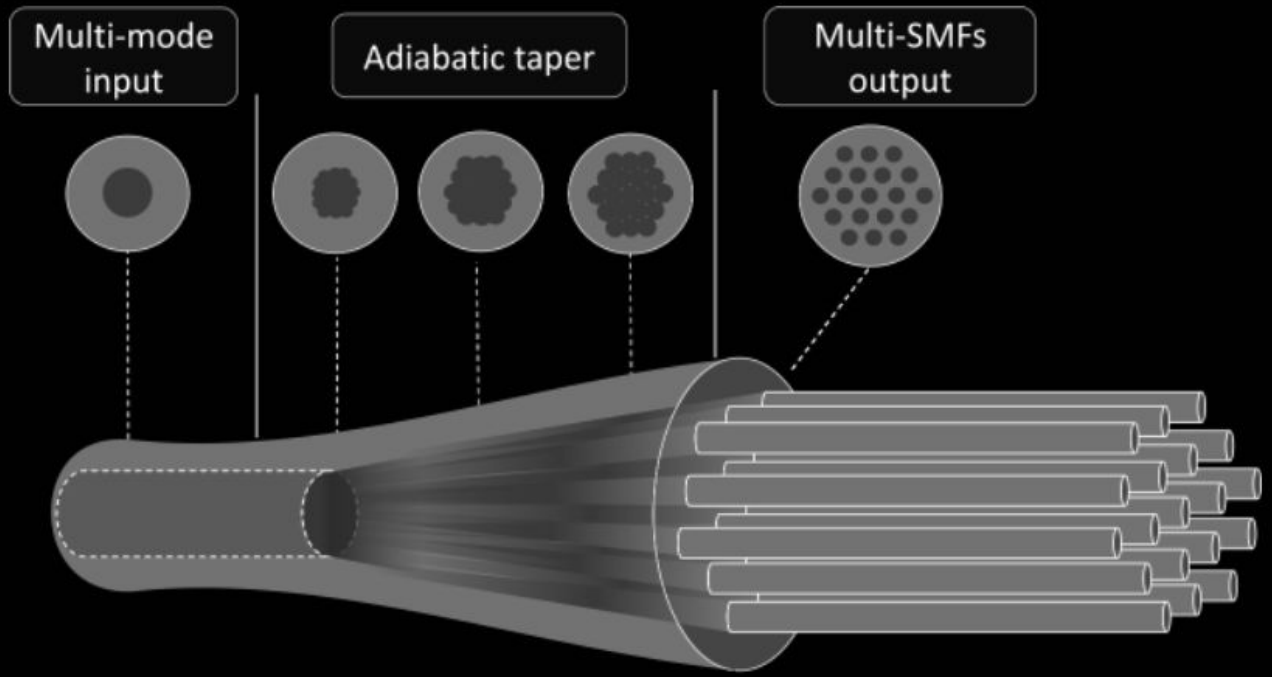
A Proxy for Orbital Geometry

Stellar spin orientation



NASA/JPL Caltech

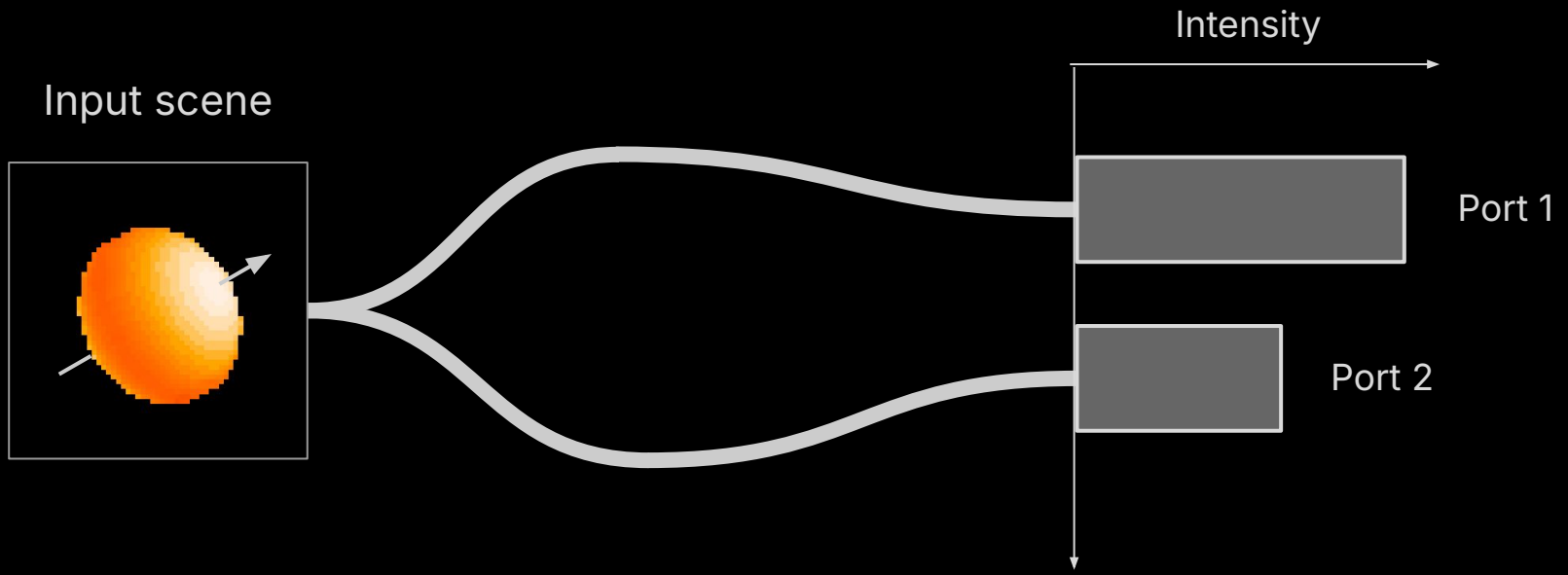
Photonic Lantern



Vievard et al 2024

Photonic Lantern

Sensitive to input scene and wavefront



Photonic Lantern

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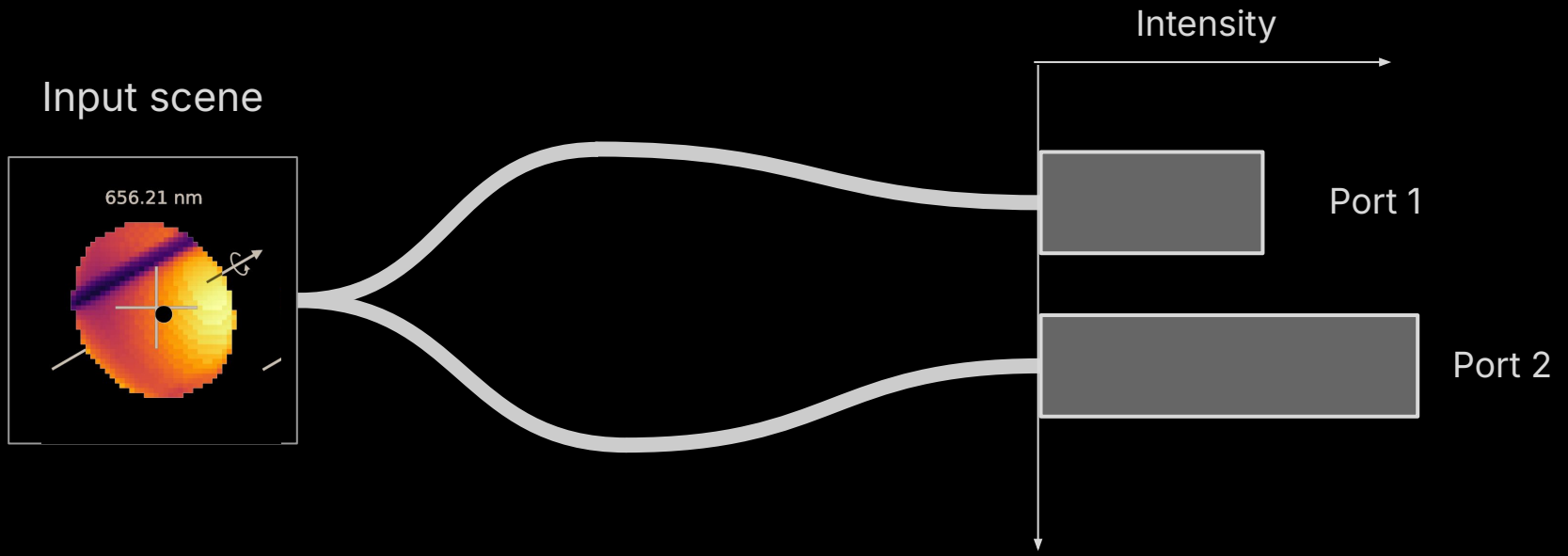
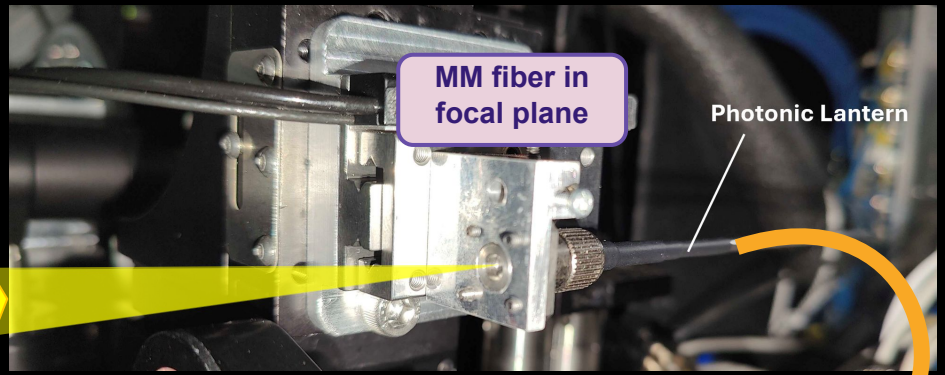


FIRST-PL

Located at Subaru Telescope

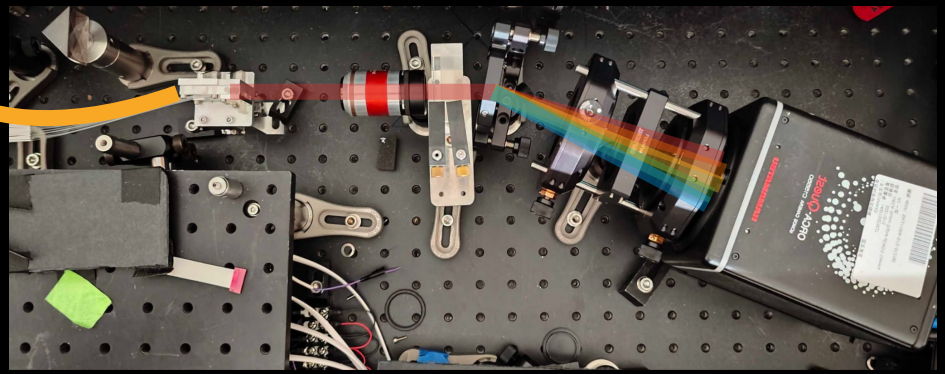
- Downstream of AO3k+SCExAO
- First on-sky open use PL
- 19 output ports
- R ~ 3000
- 620 < λ < 780 nm

See Also Poster P35



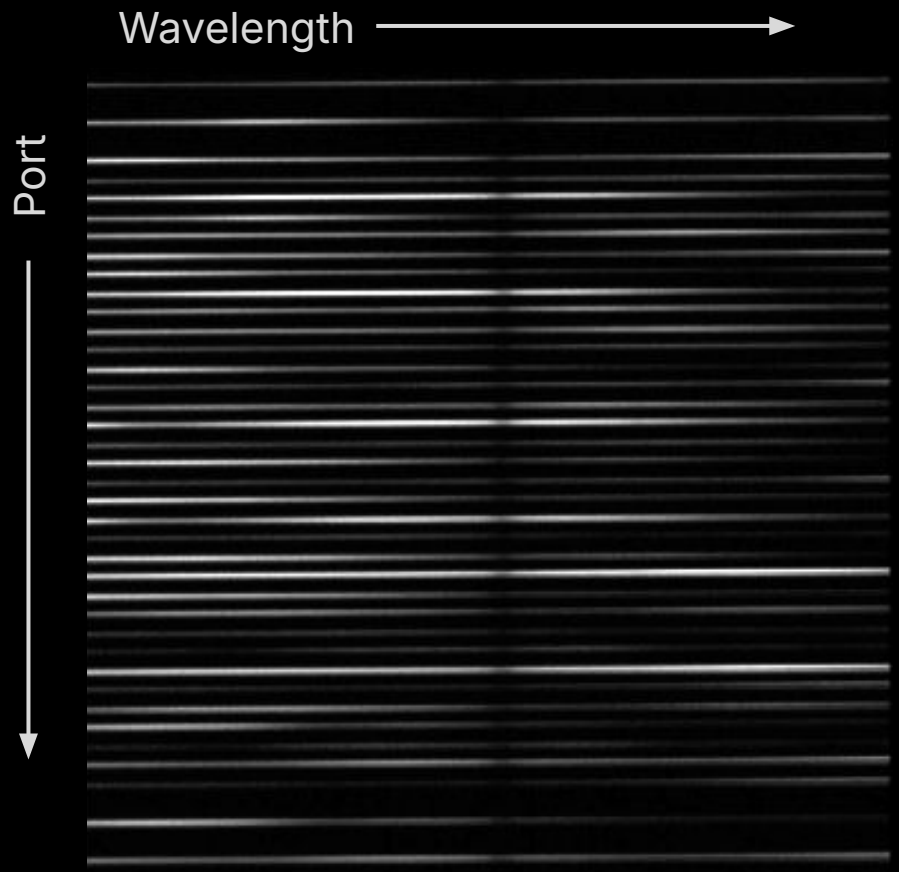
Credits: S. Vievard

Injection into the photonic lantern MM end



Credits: S. Vievard

FIRST Bench


Wavelength
Port

FIRST-PL Capabilities

1. Spectral Imaging

On-Axis

λ/D Spatial Resolution

FOV ~ 130 mas

contrast ~10

R mag (typical) = 11

Off-Axis

λ/D Spatial Resolution

FOV ~ 1000 mas

Contrast ~ 10^3

R mag (typical) = 6

2. Spectro-Astrometry

Image Moment Estimation

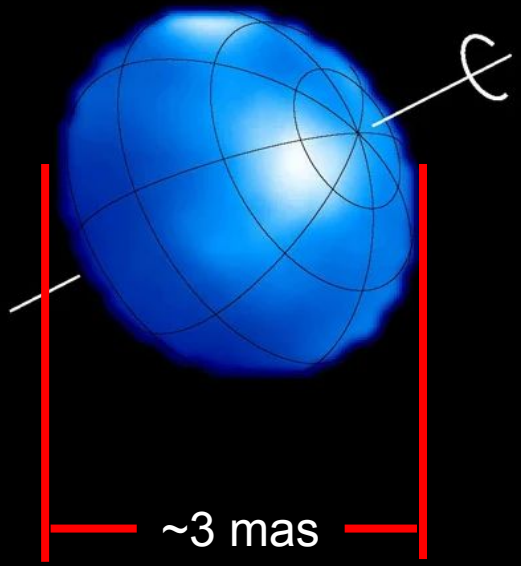
Velocity Resolution ~ 100 km/s

Centroid Precision ~50 μas

R mag (typical) = 4

Humu

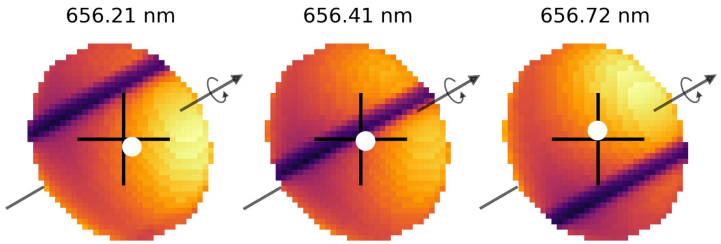
Monnier et al. 2007



>5x smaller than λ/D_{Subaru}

New Version of Spectro-Astrometry

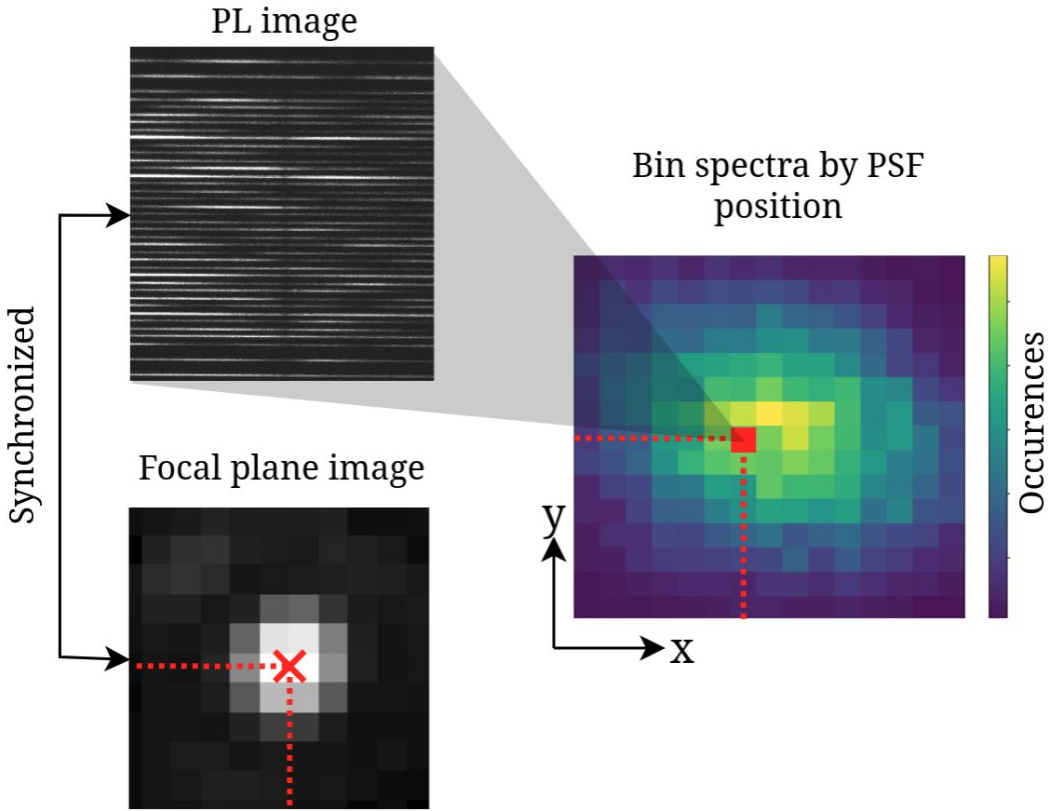
Simulated on-sky image of Humu



Method

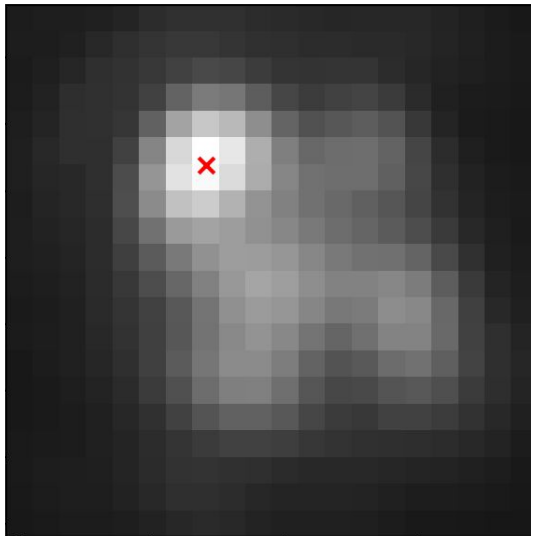
1. Measure PL response to a point source
2. Compare to observations of target
3. Compute centroid shifts as f′n of λ

Preparing the Data



Measure PL Response to the Input Field

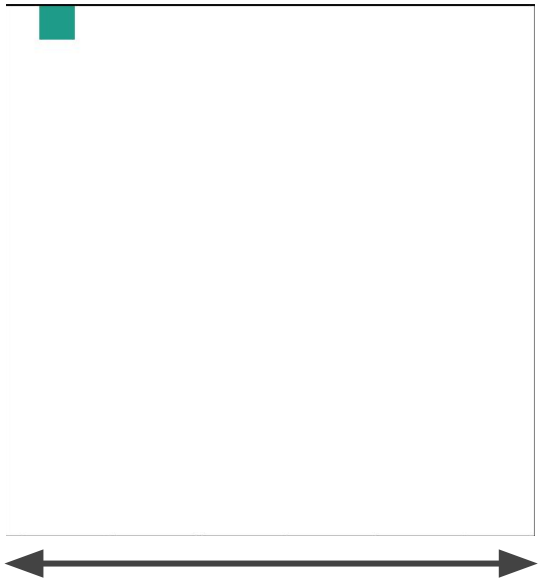
Average FP Image



Average PL Image

Port 3 Response

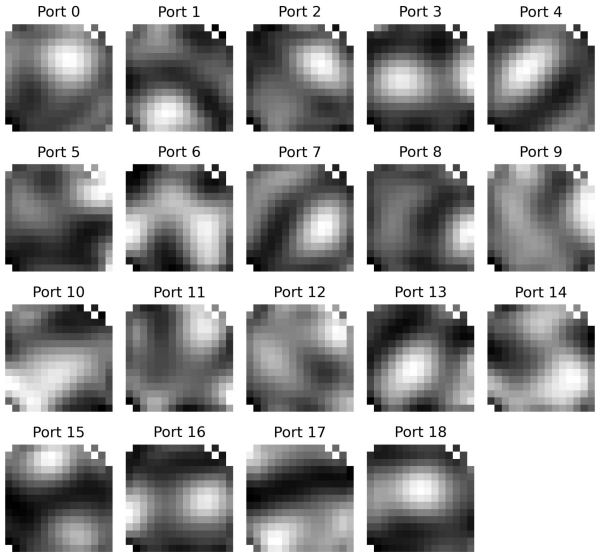
λ ≈ 656.46 nm



44 mas

Convolution Problem

Theoretical Response



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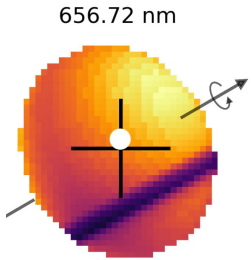

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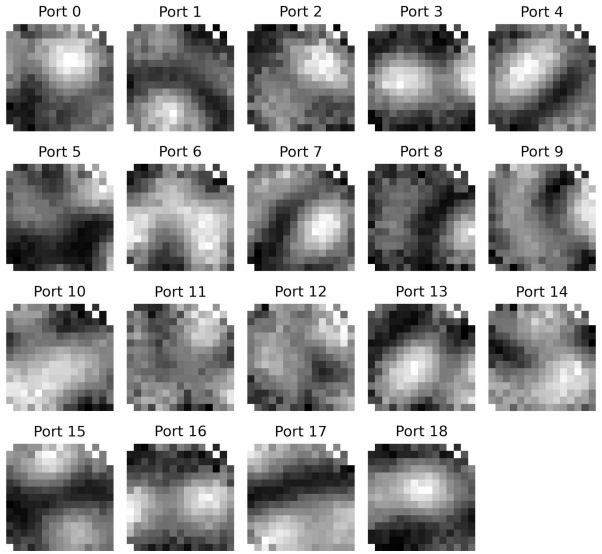
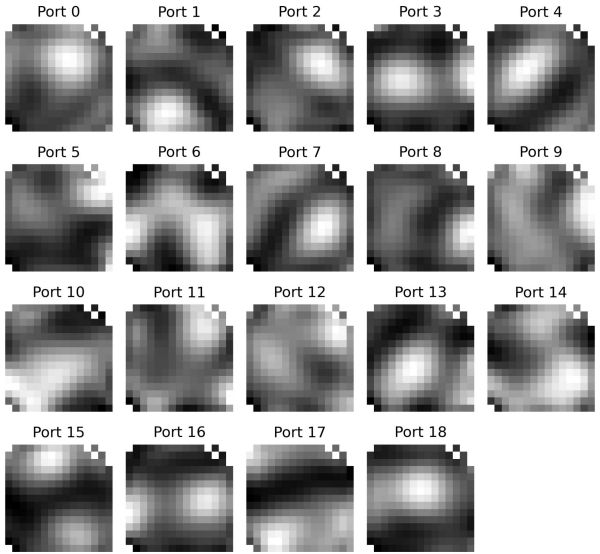
Observed Response



Convolution Problem

Theoretical Response



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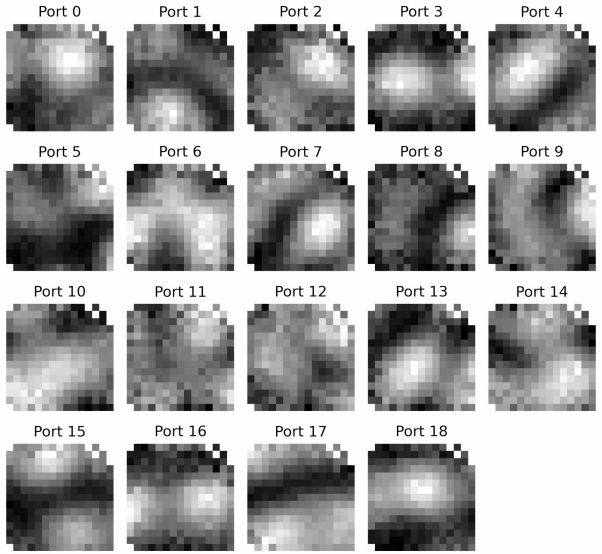
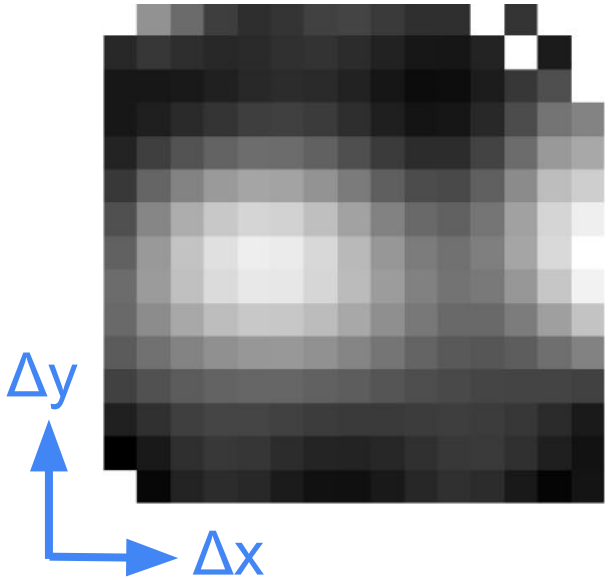
Observed Response



Deconvolution

Theoretical Response



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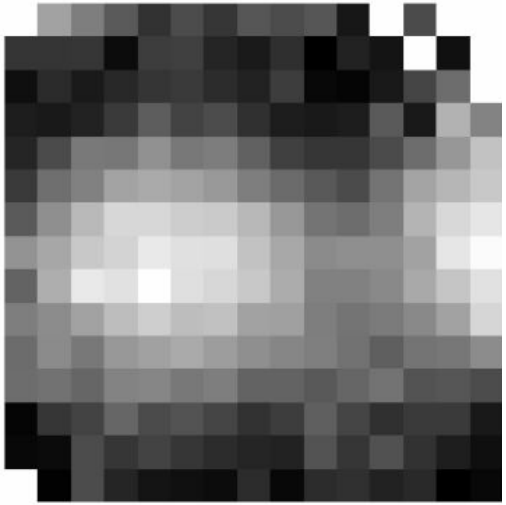
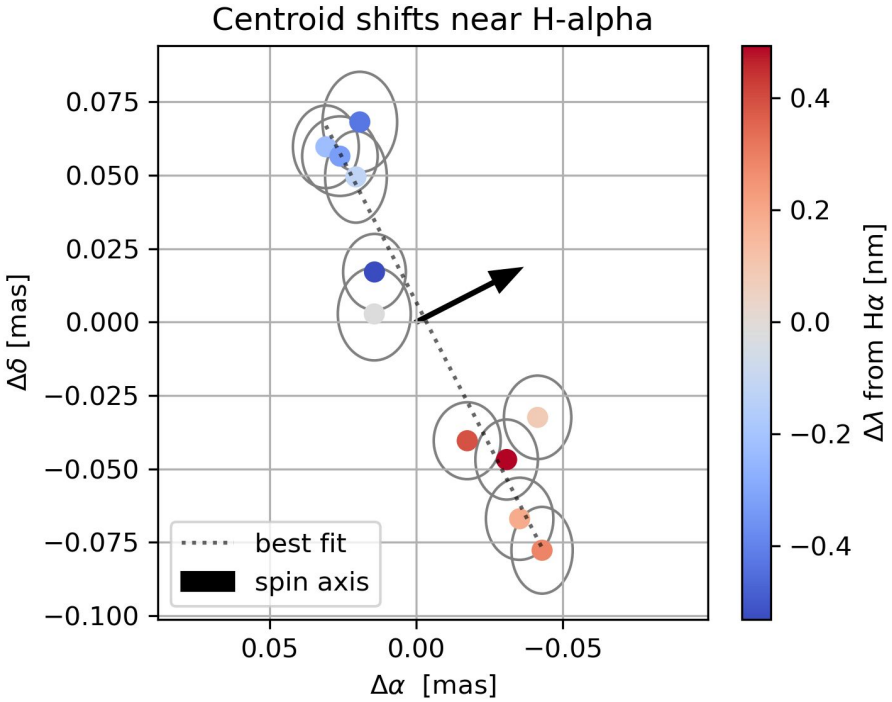
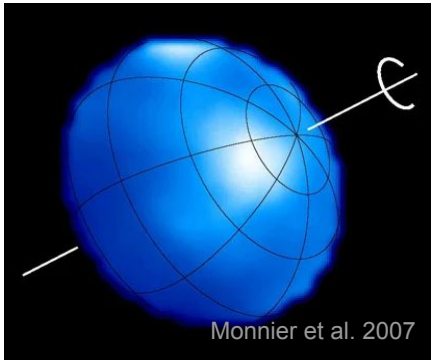
Observed Response

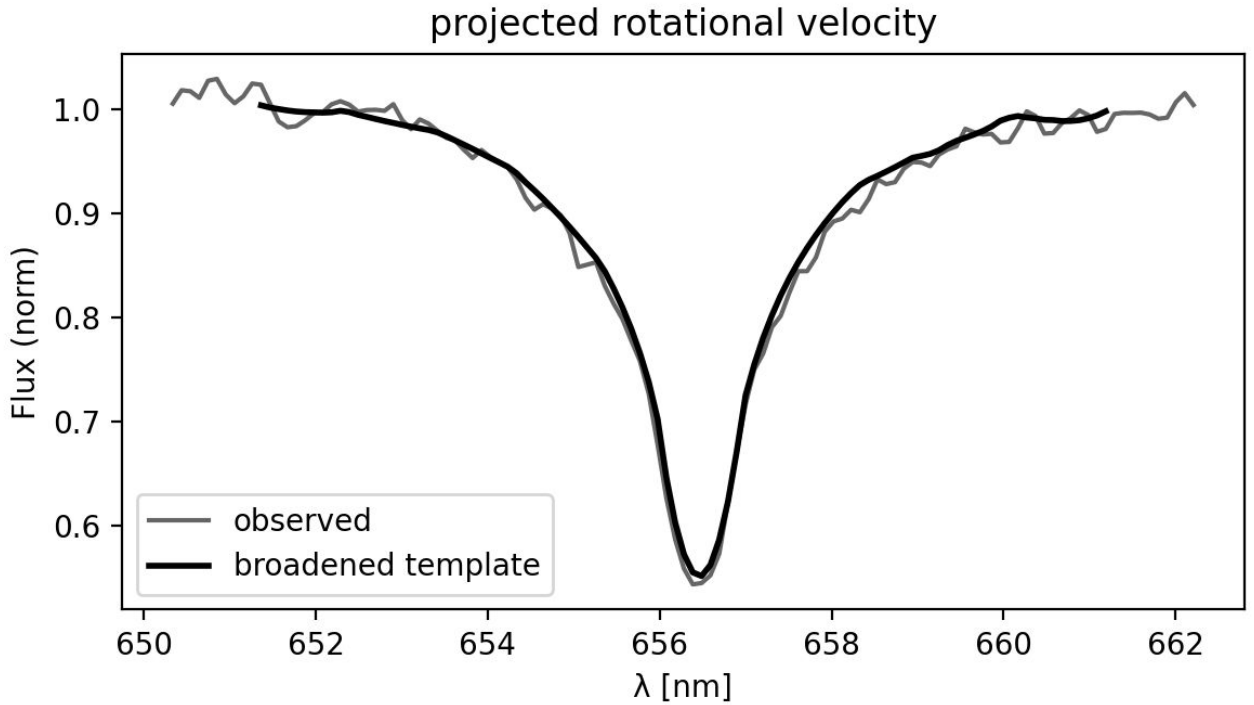


Spectro-astrometric Signal





Measure Inclination



Spin Orientation

Parameter	This Work	VLTI	CHARA
i (°)	**44.9 ± 4.1**	50.7 ± 1.2	57.2 ± 1.9
PA (°)	**-61.8 ± 2.8**	-58.9 ± 0.34	-61.8 ± 0.8
Baseline (m)	**8**	11 to 129	195 to 265

Future Work

Extend to Fainter Objects

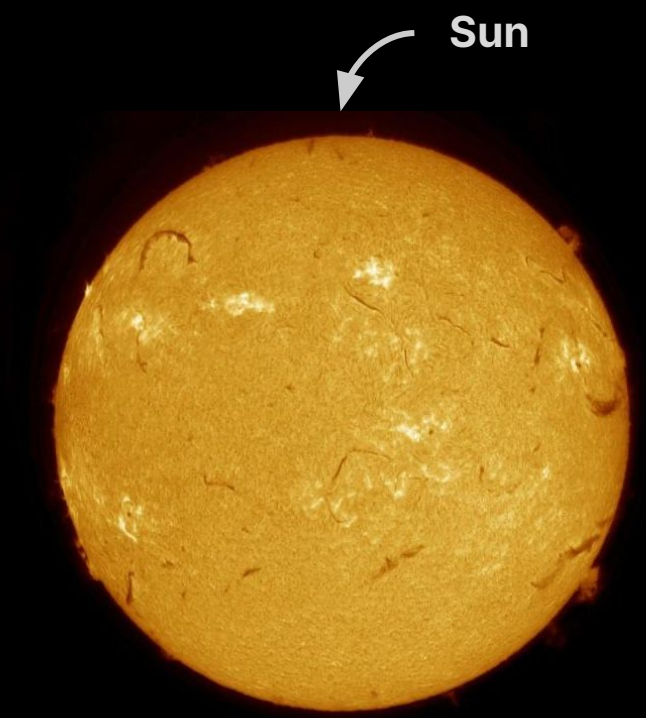
- Simulate signal of slower rotators
- Improve analysis to reach photon noise limit

Upgrade Spectrograph Resolution

- R ~ 3,000 → R ~ 60,000
- Target slower rotating stars

Measure Spin Orientation of Sun-like Stars

- Crucial for upcoming HWO and ELTs



Conclusion

PL's are great for spectro-astrometry

- 100 seconds integration time
- 3σ precision = 35 μas

Single Telescope Spin Measurement

Previously only possible using long-baseline interferometers

Unprecedented Surface Probing

Indirectly constrain exoplanet orbital geometry
Crucial for ELTs and HWO