Spatial Filtering with a PWS on High Order Testbench

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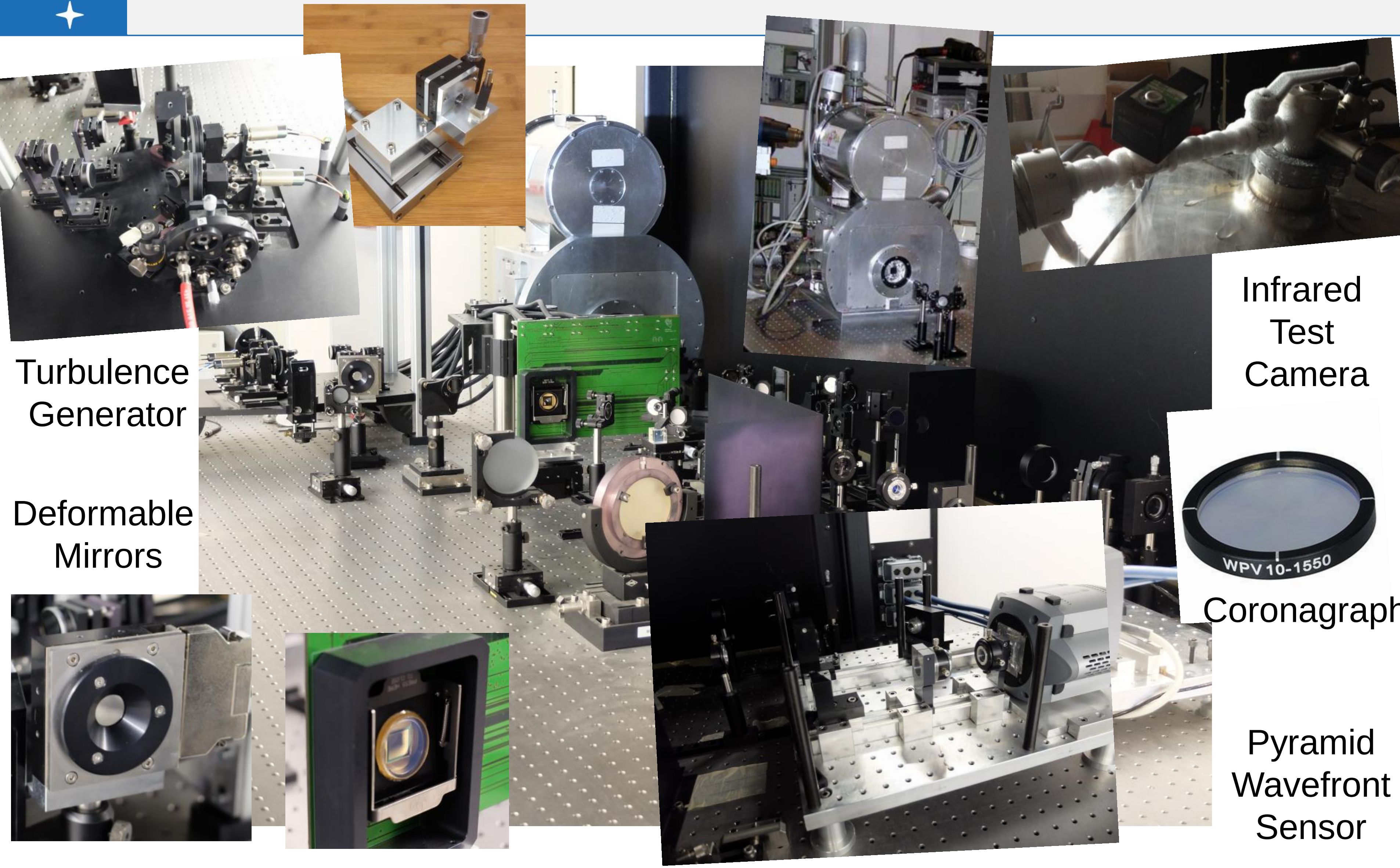
Personal Introduction

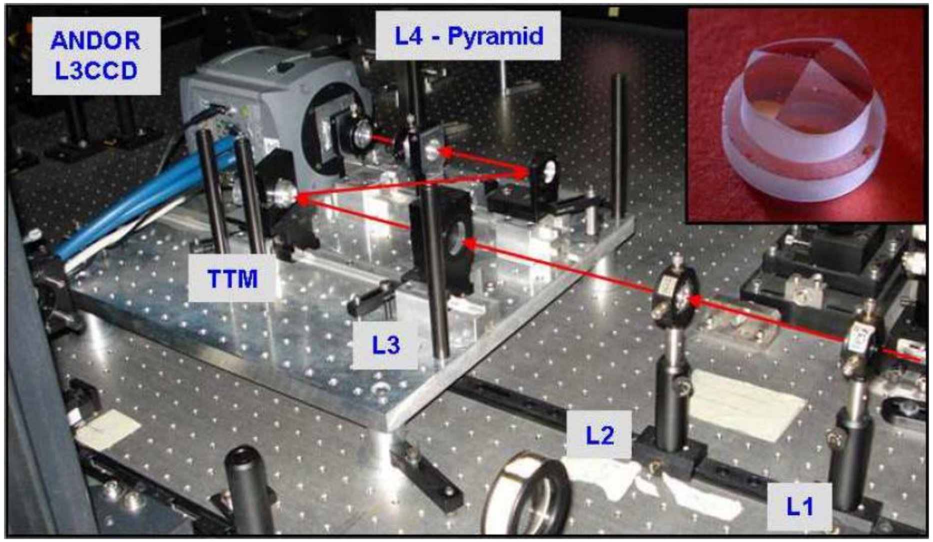
- July 2017 - Master thesis in Physics at Univ. of Munich (LMU) and ESO
  - “Adaptive Optics and High Contrast Imaging: Advancing the Direct Detection of Exoplanets”
- R&D Student for Planetary Camera and Spectrograph (aka EPICS)
  - Setup HOT bench
  - Optimize AO closed-loop
  - Study influence of spatial filtering on PWS

Outline

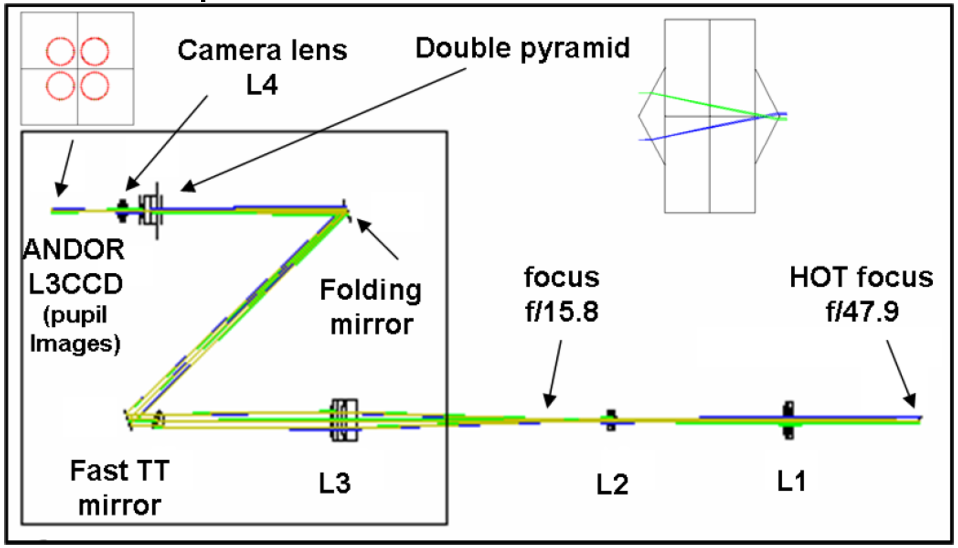
High Order Testbench (HOT)

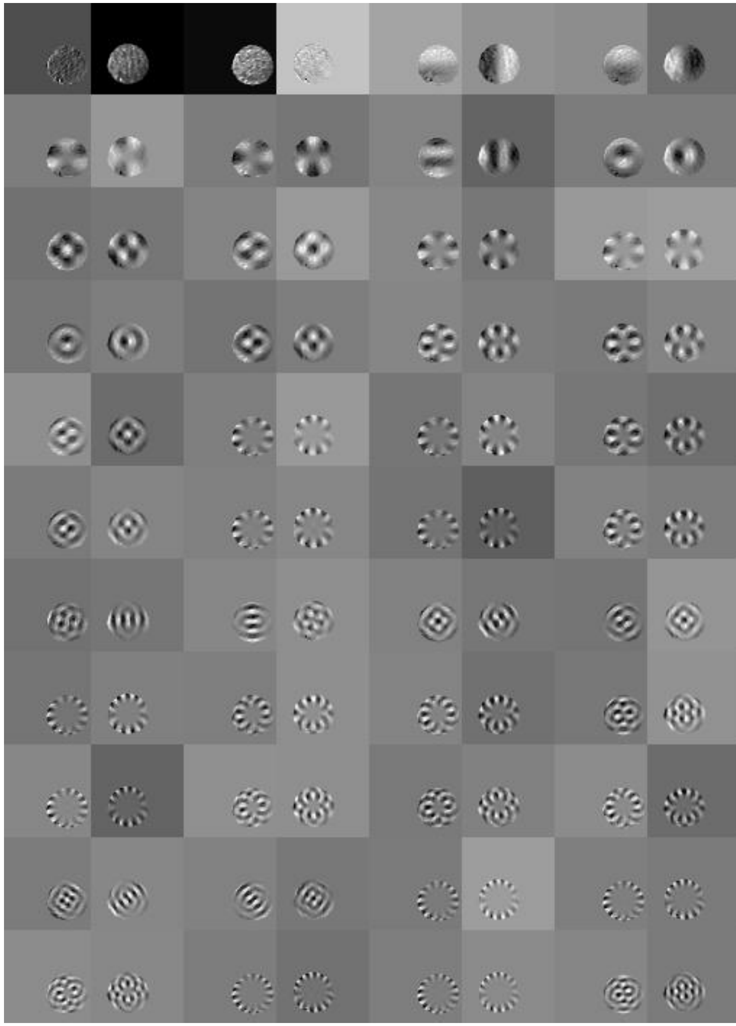


Pyramid Wavefront Sensor (PWS)

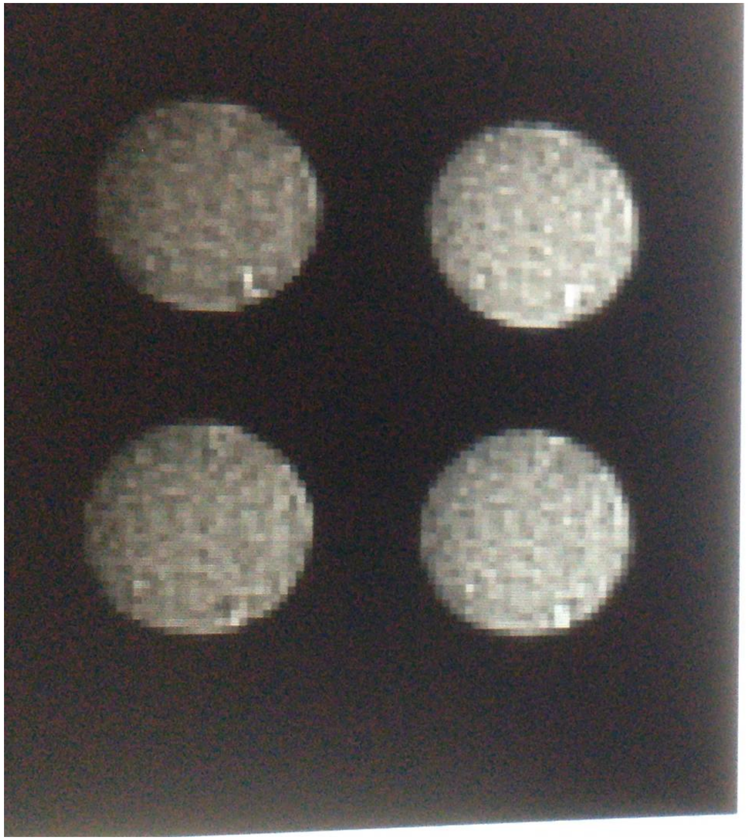


Aller Carpentier, 2011





Interaction Matrix



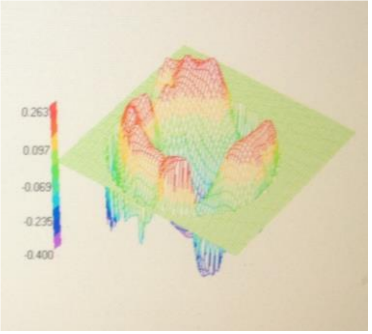
PWS Pupil plane =

$$a(x, y)\, \exp[i\ \phi(x, y)]$$

ITC Focal plane =

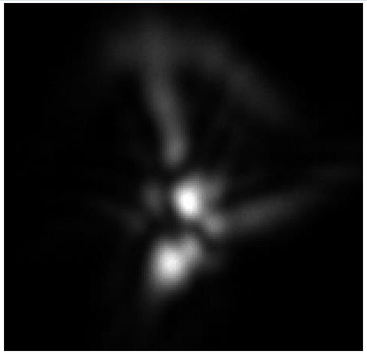
$$\mathcal{F}\{a(x, y)\, \exp[i\ \phi(x, y)]\}$$

Closed-loop Optimization

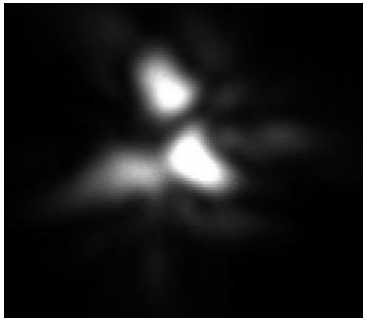


HASO

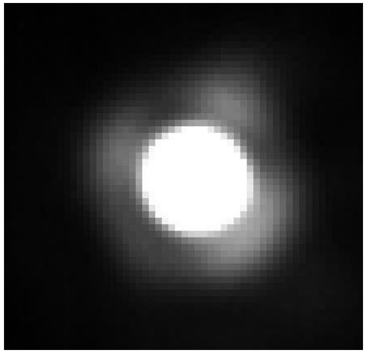
No DM
Correction



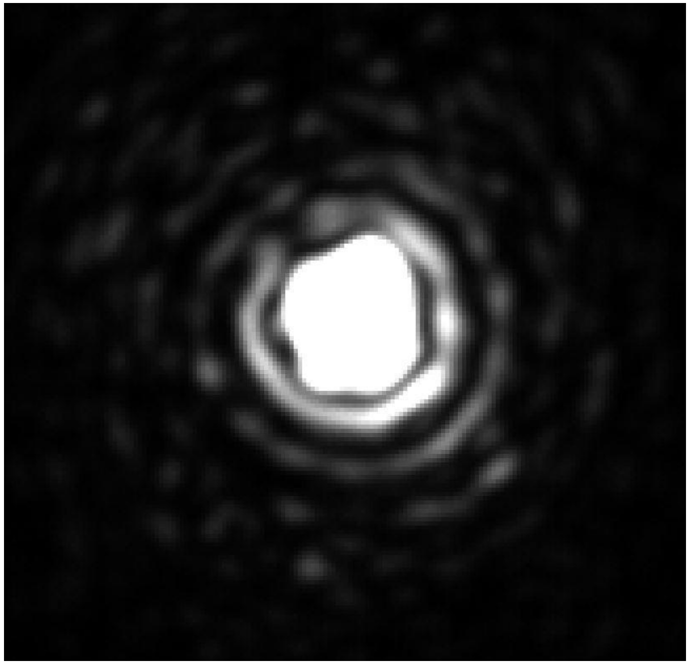
ALPAO
DM52 Static



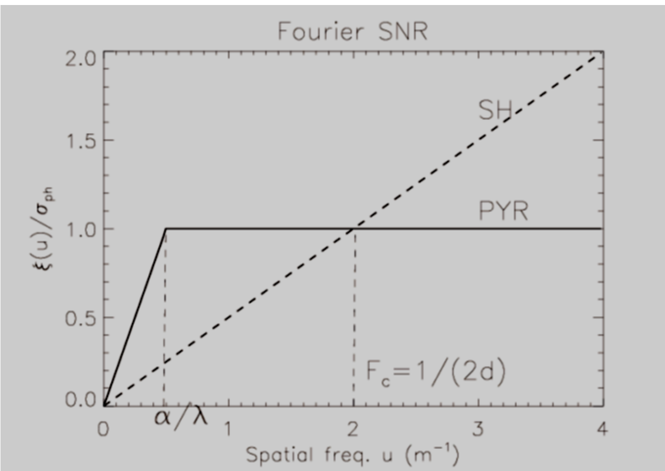
White light:
150 KL modes
No Turbulence
PSF center sat



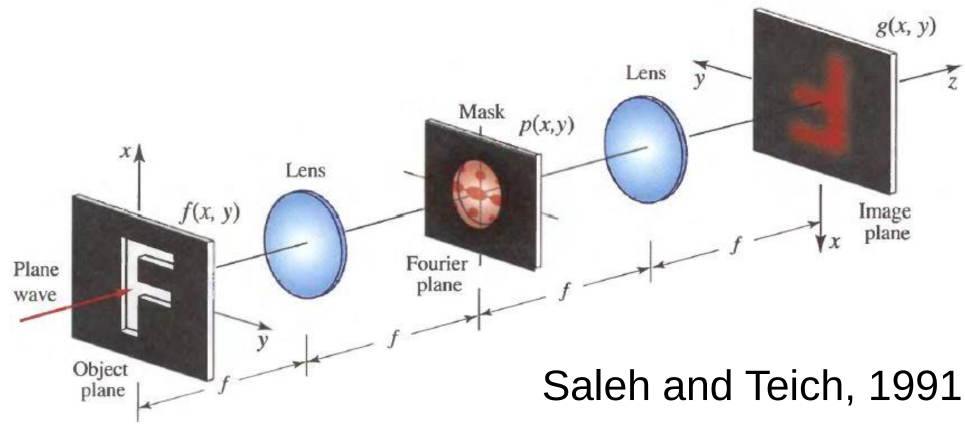
632 nm
150 KL modes
higher sat



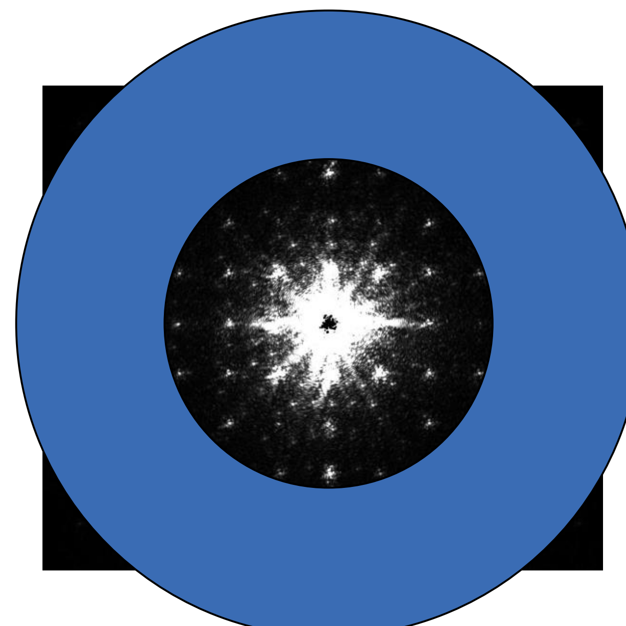
Aliasing and Spatial Filtering



Vérinaud et al., 2004



Saleh and Teich, 1991



Are PWS susceptible to aliasing?
Can a SF improve PWS performance?

Aperture Masks

- Cutoff frequency:

$$f_c = \frac{\lambda}{d} = f/\# \cdot N_{subap,\varnothing} \cdot \lambda_{sensing}$$

  - On HOT, $f_c \approx 1$ mm

- Procure aperture mask

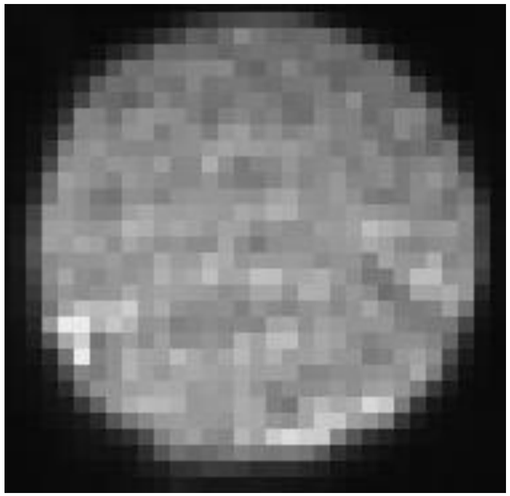
Thorlabs:

Zero aperture

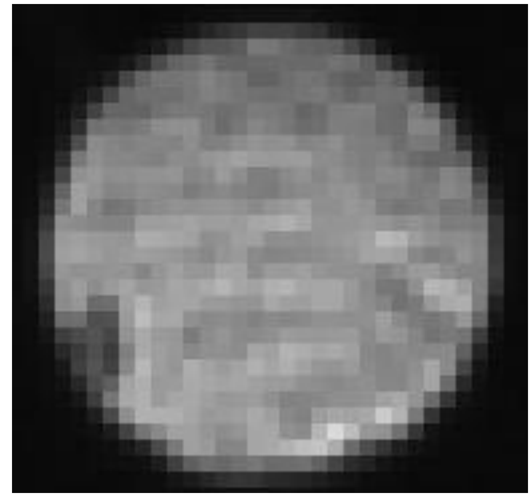
1 mm aperture

First Observations

No SF



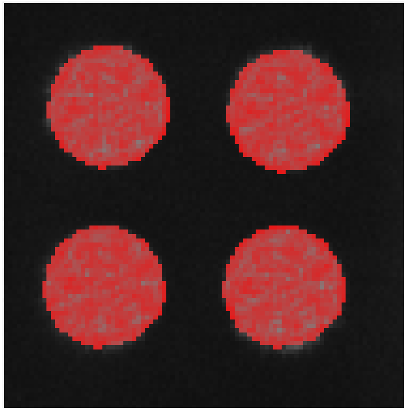
1.5 λ/d SF



- Light scattered from stuck actuators is blocked
- Slight smoothing of wavefront
  - PWS software: RMS wavefront error drops from 50 nm to 45 nm

Closed-Loop Integrations

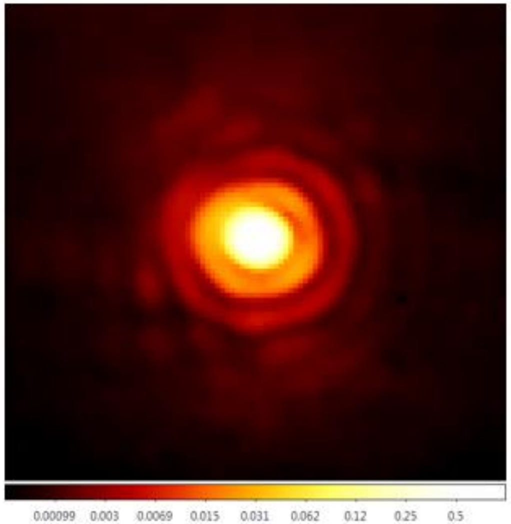
- Collect pupils and reconstruction matrices
  - Bypassing turbulence generator:
    - Acquire one set of pupils
    - Collect unique interaction matrix (300 K-L modes) for various spatial filter mask sizes (>1 λ/d)
    - PWS modulation at $6\ \lambda/d$

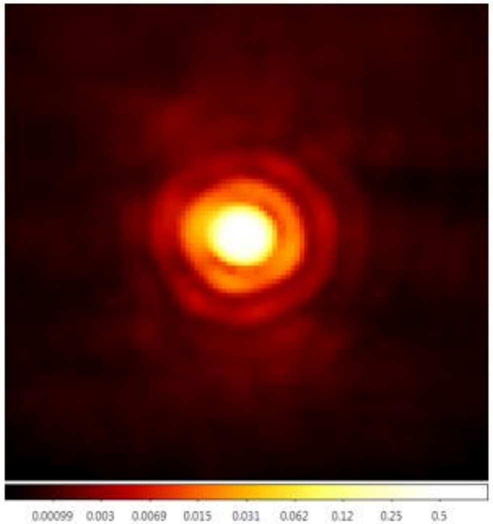


- Infrared PSFs in closed-loop
  - With turbulence:
    - 0.5" seeing phase screen (reduced low order aberrations)
    - H-band integrations

Strehl Ratio

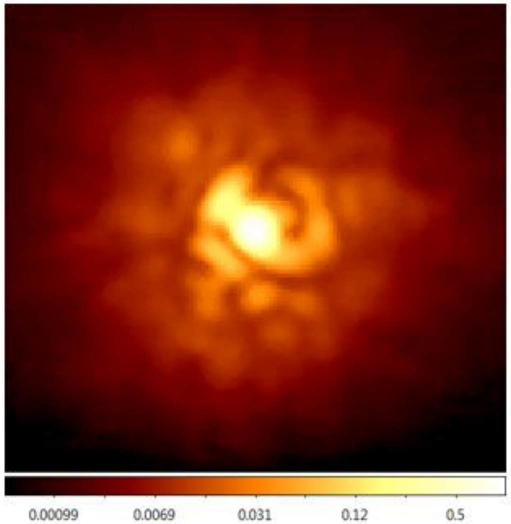
No SF





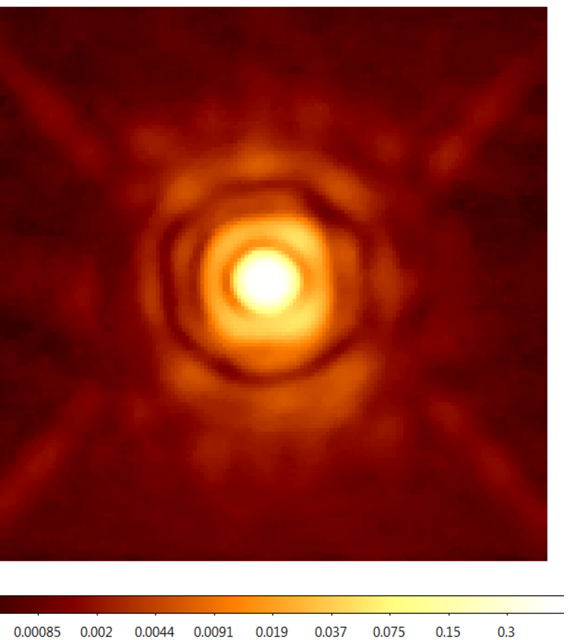
1.5 λ/d SF

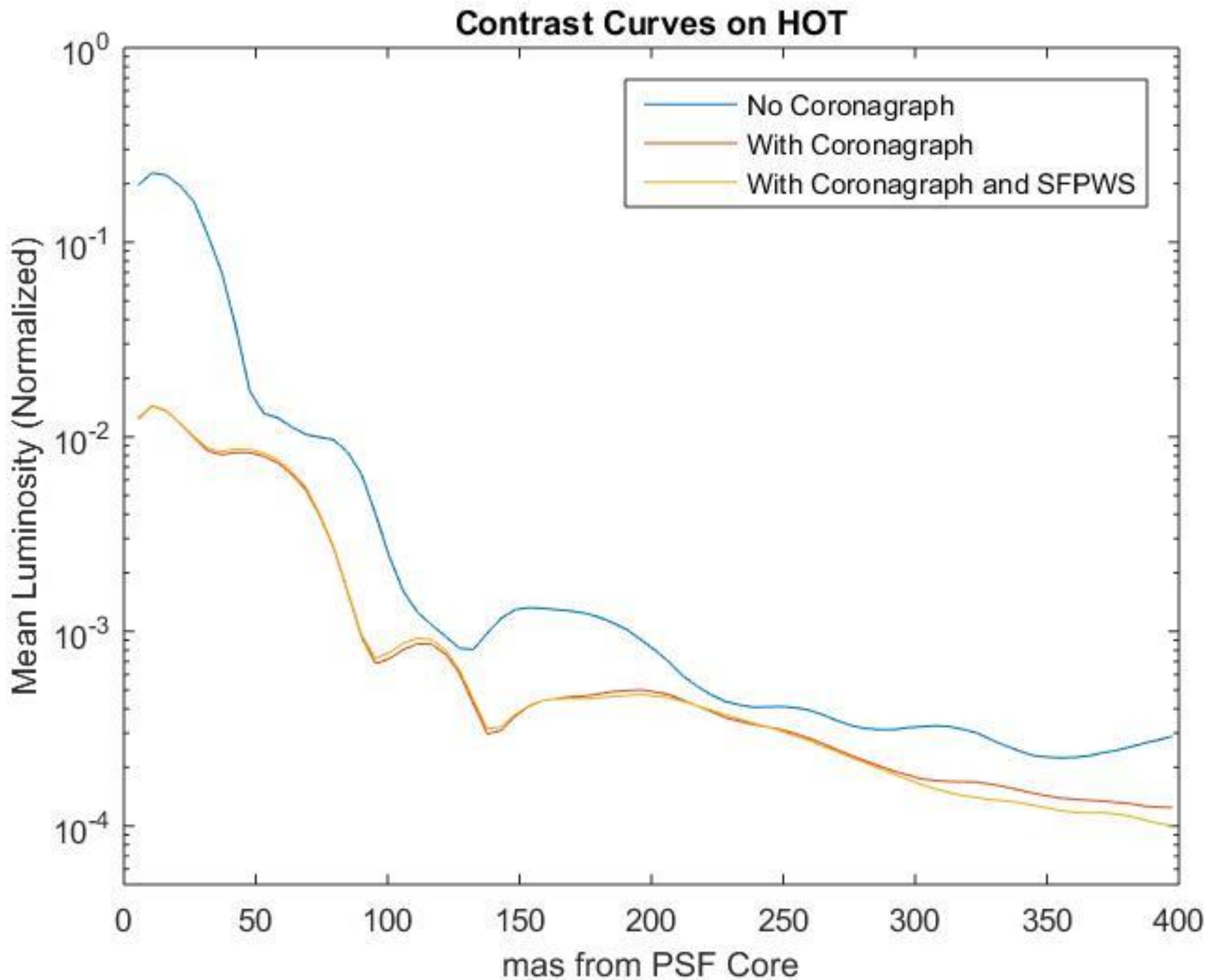
TT correction only
(reference)



SF size (λ/d)	**H-band SR**
1.5	71.8%
2	72.0%
3	70.9%
4	70.5%
No SF	70.6%
Tip-Tilt only	35.2%

Contrast Curves w/ Coronagraph



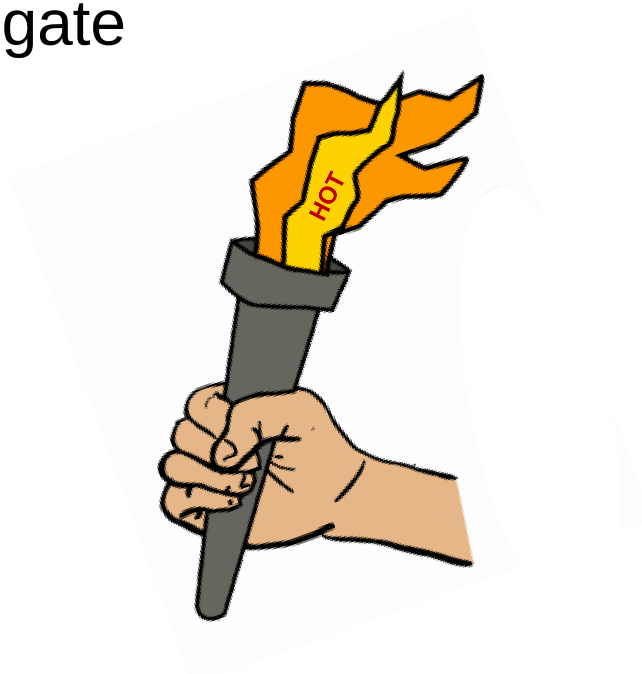


Conclusions

- HOT is fully prepared for performing experiments in next-gen XAO
  - Ease of use – takes only several minutes to close loop
- HOT PWS works well, but further optimization techniques to correct more modes.
- PWS design is robust against aliasing
  - Spatial filter produces negligible improvements in PWS performance
  - Agrees with simulations from Vérinaud et al., 2004, and Bond, 2017

Prospectives

- SFPWS improved performance in terms of sensitivity?
  - More elaborate: “dark wavefront sensing” tests on HOT
- Pass HOT torch onto PhD Student Nelly Cerpa Urra
  - Study and propose strategies to mitigate
    - Temporal bandwidth error (time-lag)
    - N-chromaticity
  - Test strategies on HOT



Thank you!

Questions?