



Wavefront Sensor Comparison Testbed

Wavefront Sensing in the VLT/ELT Era V - AO Workshop Week II

13 – 15 October 2020

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AFRL/RDSS

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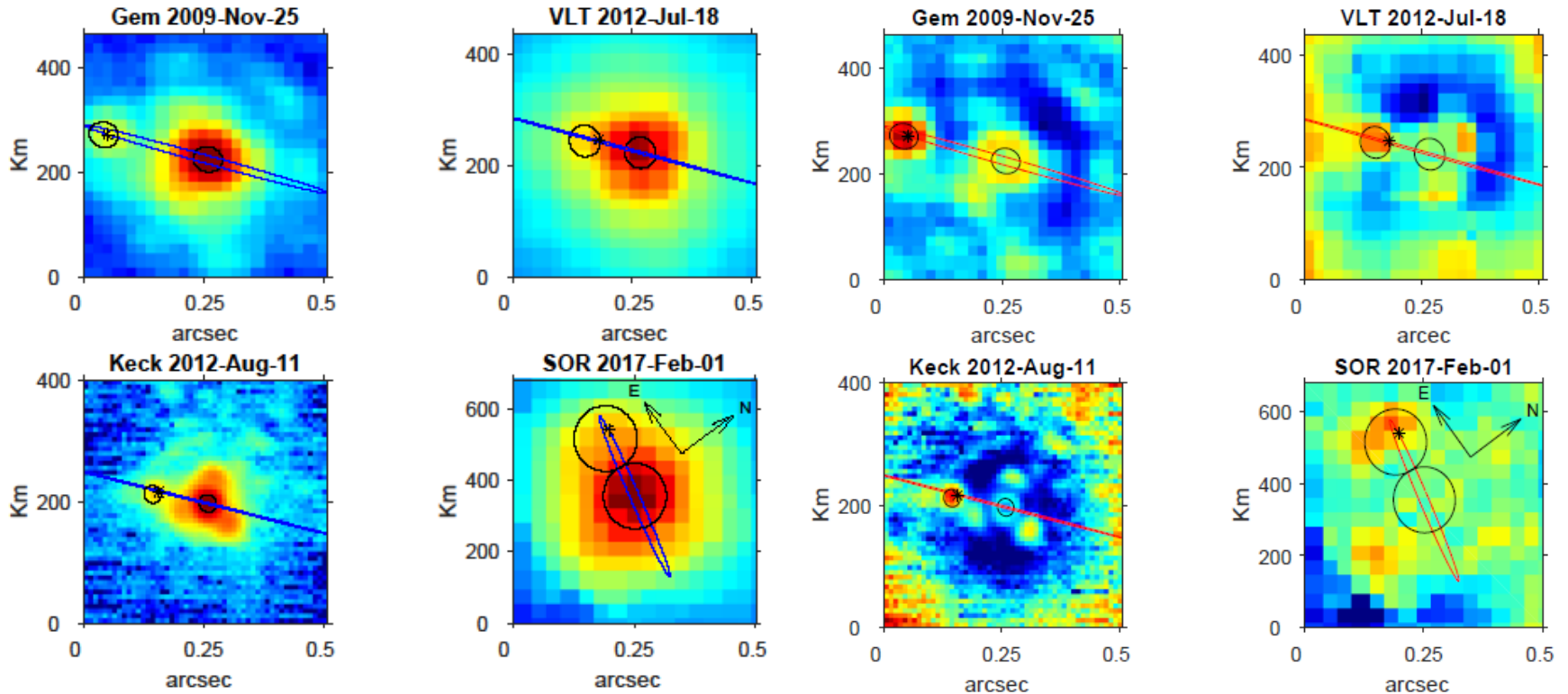
Michael Hart

Johanana Codona

Overview

- Comparing the performance of the SHWFS, nICWFS, PWFS4, PWFS3
- Theory
- Simulations
- Laboratory demonstration

Objective: moons around asteroids & other closely spaced objects

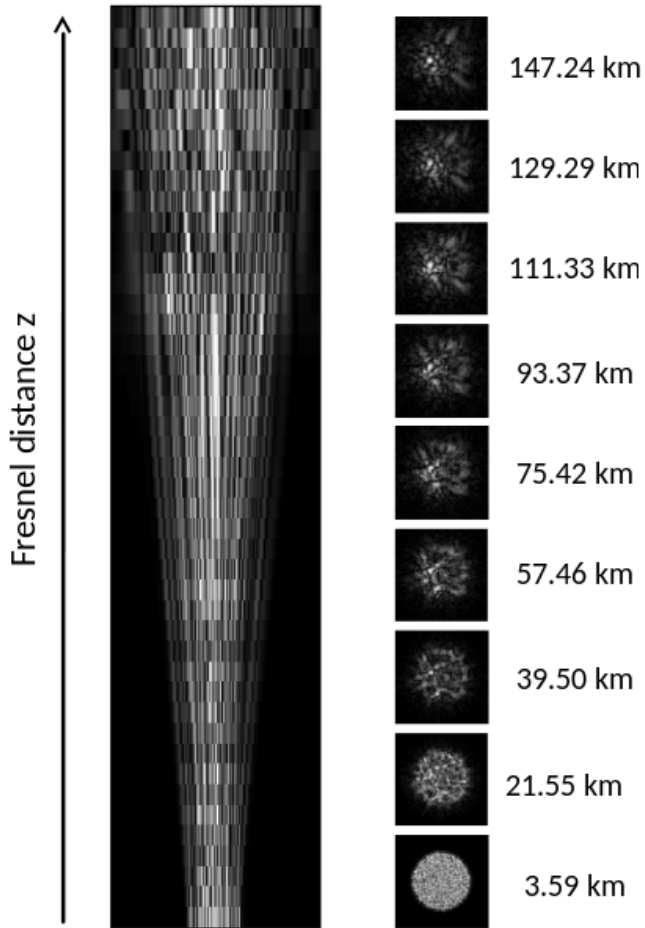


**SUBMITTED TO
ICARUS**

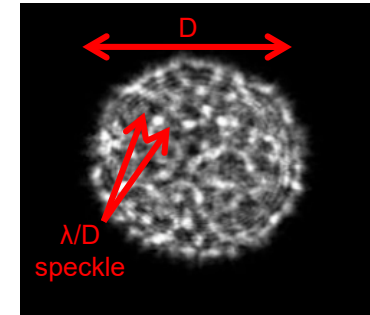
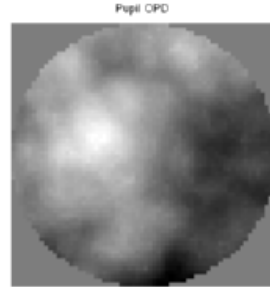
Roxanne $V = 13.0$ and its moon at $\Delta J = 3.0$; Notice the competing aberrations - LWE.
We want to obtain $\Delta J \geq 6.0$ at similar separations.

Drummond & Colleagues: The orbit of asteroid (317) Roxane's satellite Olympias from Gemini, Keck, VLT and the SOR

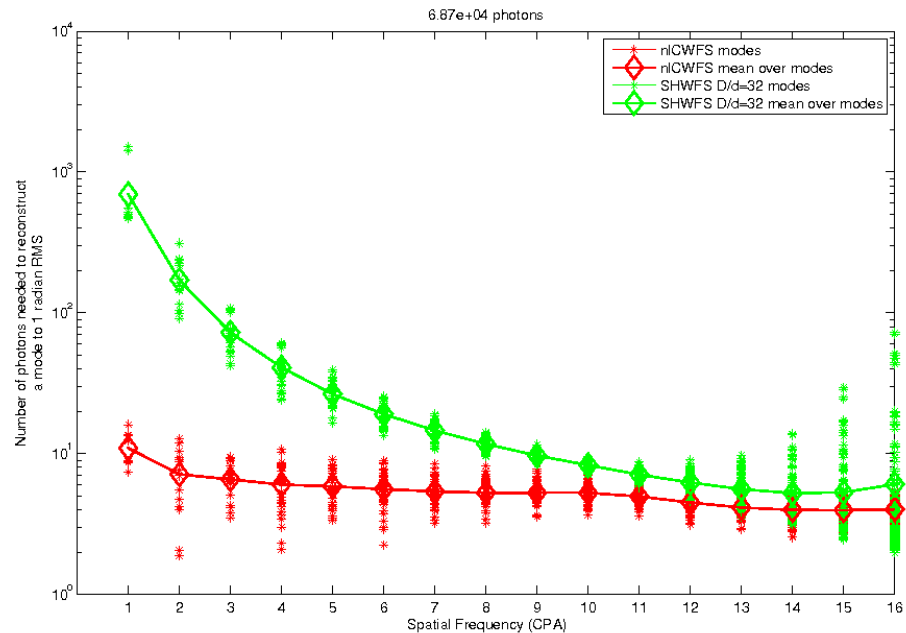
Nonlinear Curvature Wavefront Sensor



At the lowest order modes the SHWFS requires ~ 100 times more photons or a $\Delta m_v = 5$ to sense the mode.

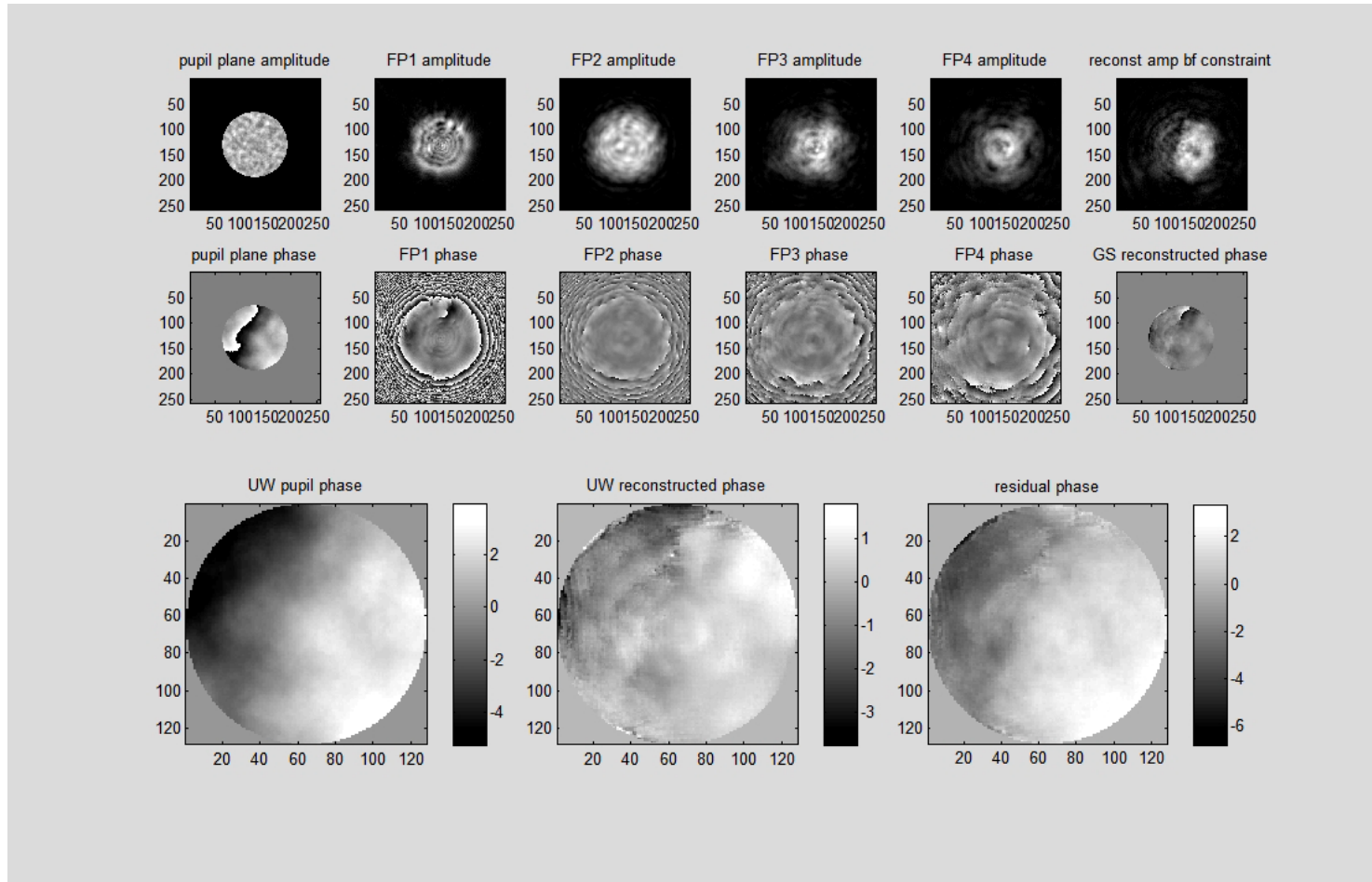


$(D/r_0)^2$ gain in Sensitivity for tip/tilt
 D^4 advantage for VLTs & ELTs



Mateen, "Development and verification of the non-linear Curvature Wavefront Sensor" Ph.D thesis, University of Arizona (2015)

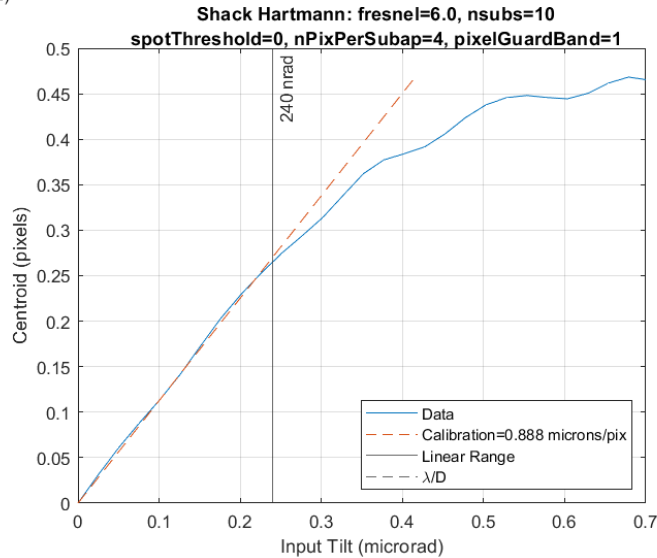
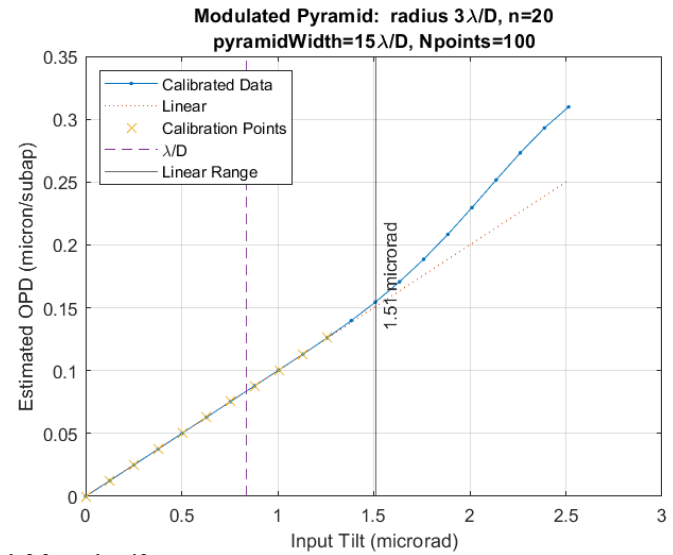
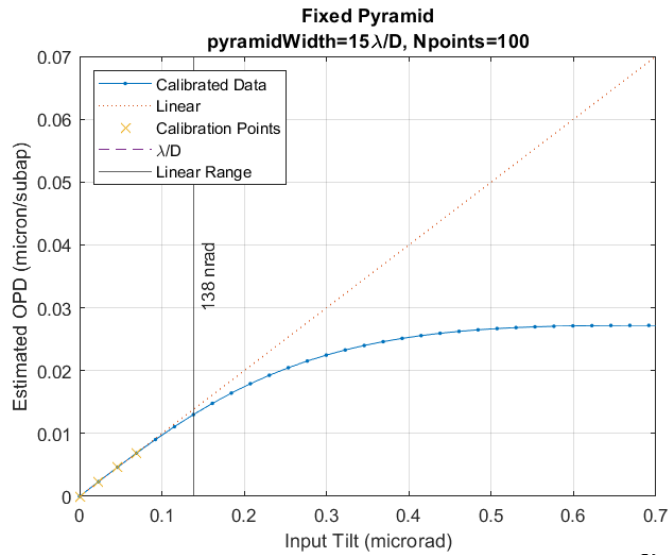
Gerchberg-Saxton based nICWFS Reconstruction



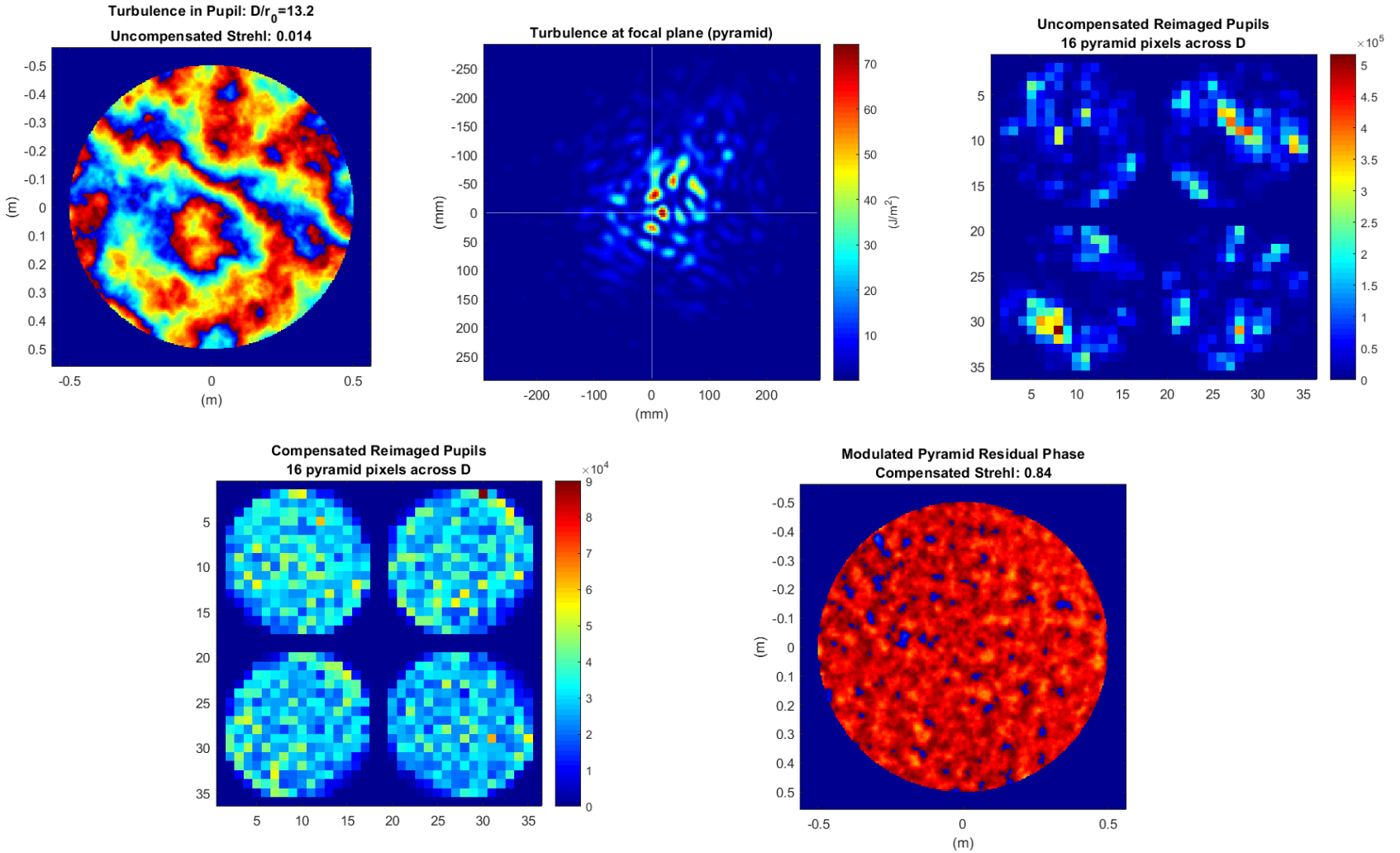
Faster reconstruction algorithm developed:

Codona et al. "A fast wavefront reconstructor for the nonlinear curvature wavefront sensor", Proc. SPIE 10703 (2018).

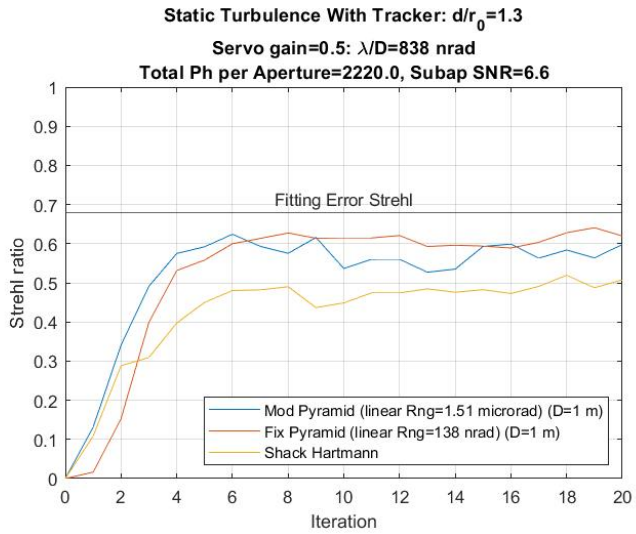
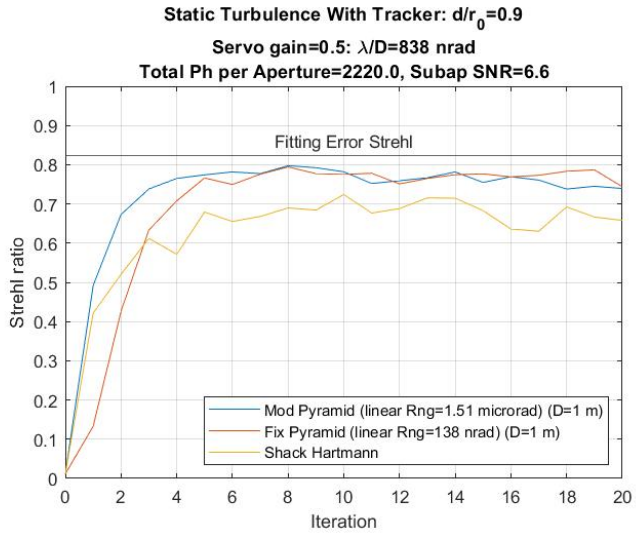
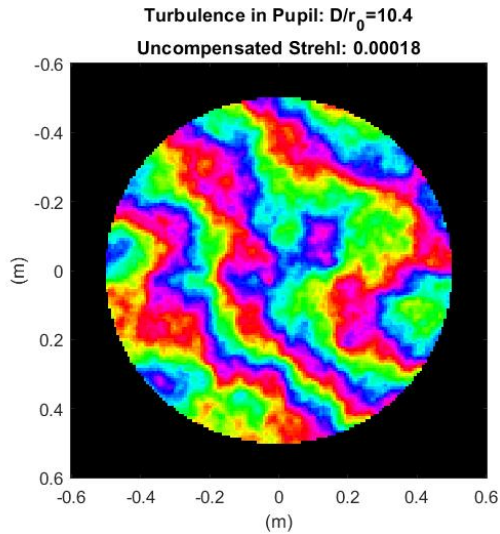
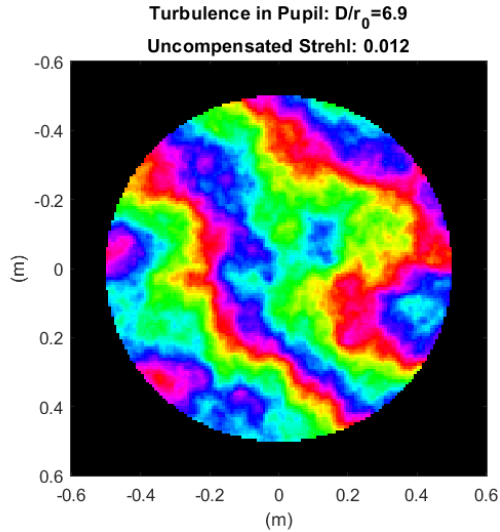
WFS Calibration Curves



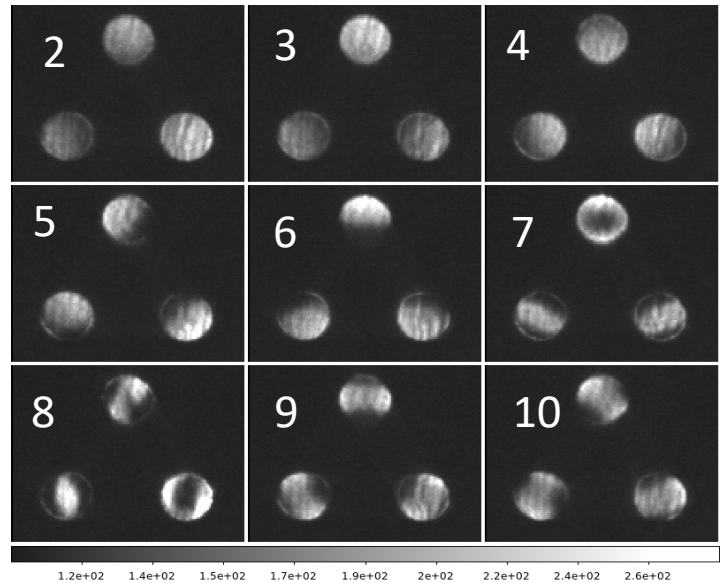
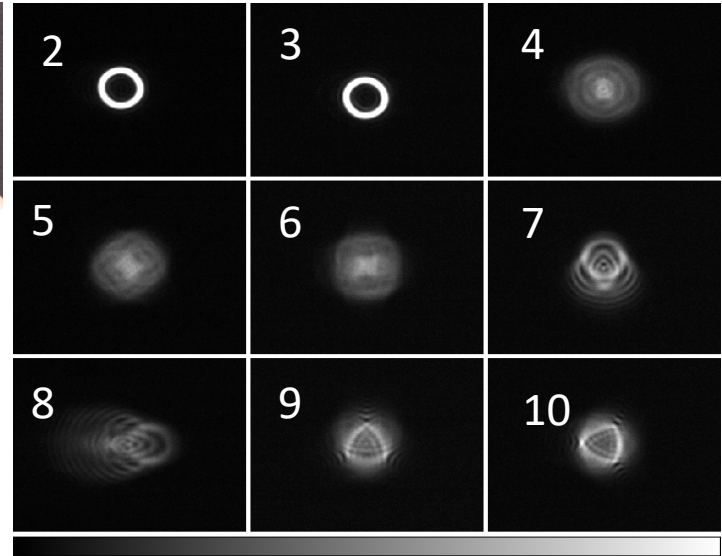
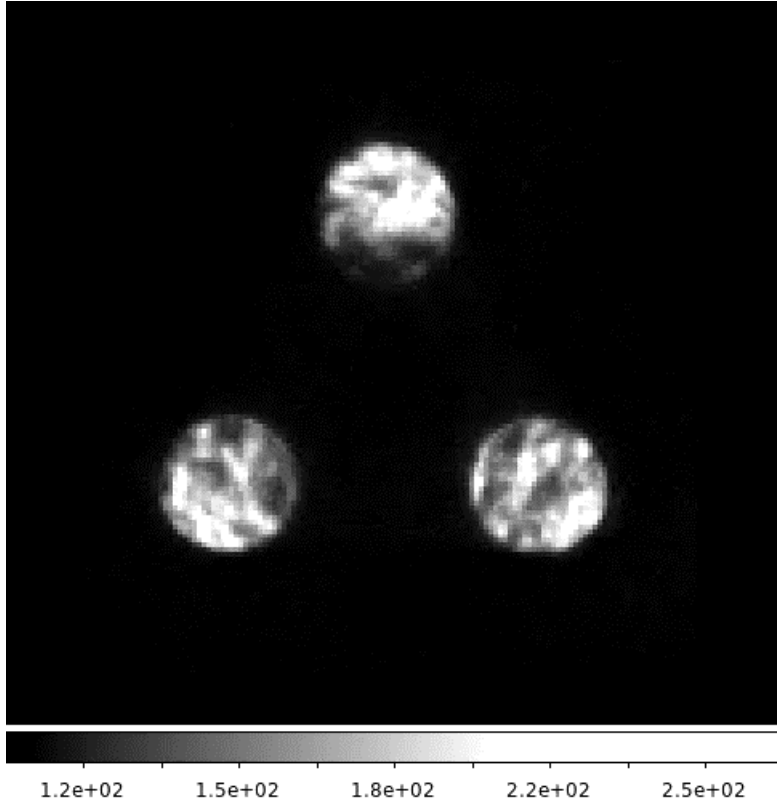
Pyramid Wavefront Sensor Simulation



Strehl Comparison

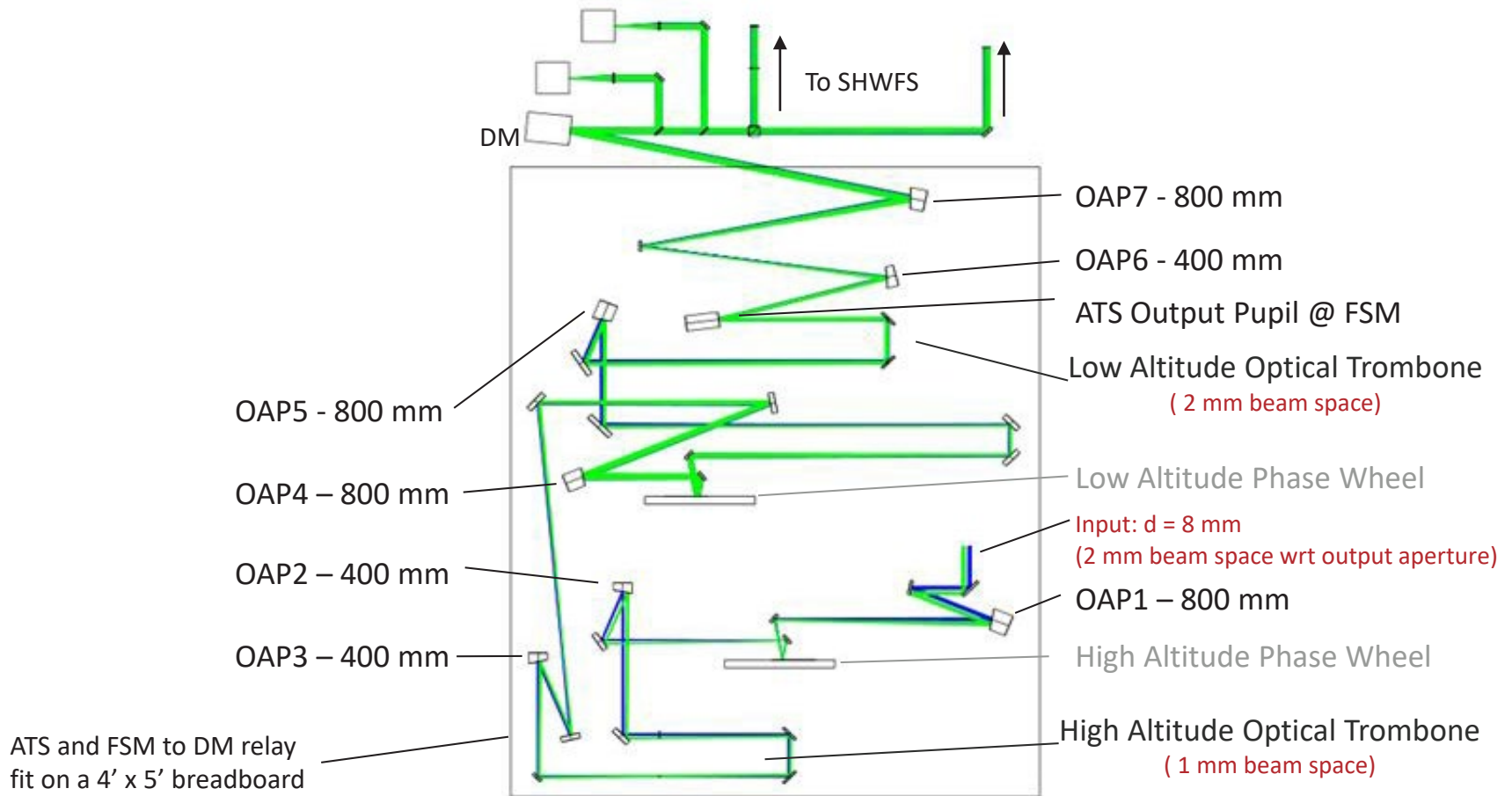


PWFS3 First Lab Results



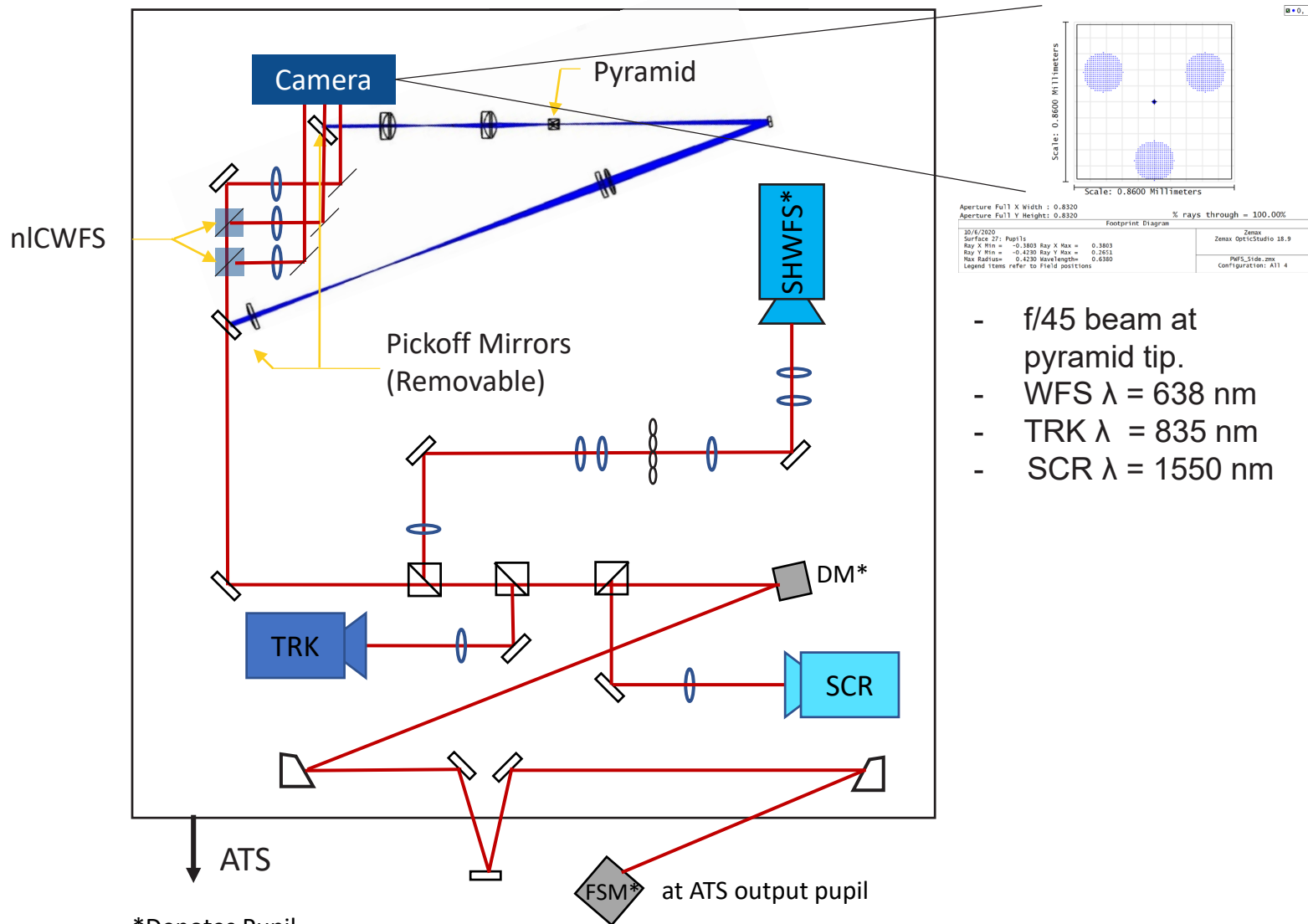
Courtesy University of Arizona & Hart Scientific Inc.

Atmospheric Turbulence Simulator Design



Phase wheel design is Guidestar Optical Systems Proprietary

WFS Comparison Testbed at Starfire Optical Range



- f/45 beam at pyramid tip.
- WFS $\lambda = 638 \text{ nm}$
- TRK $\lambda = 835 \text{ nm}$
- SCR $\lambda = 1550 \text{ nm}$

*Denotes Pupil

Simulated AO Control System

The screenshot displays the 'Simulated AO Control System' interface, which is divided into several functional areas:

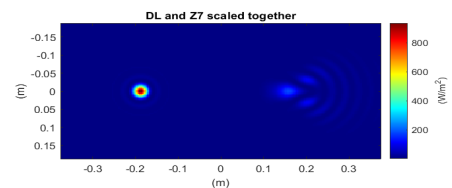
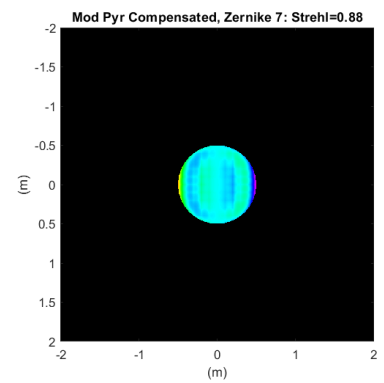
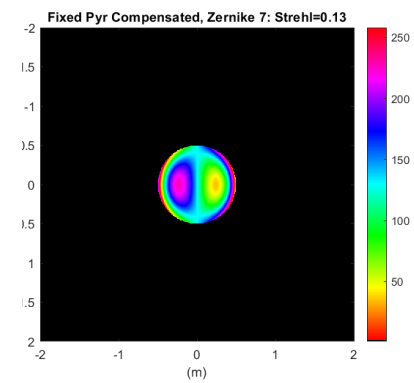
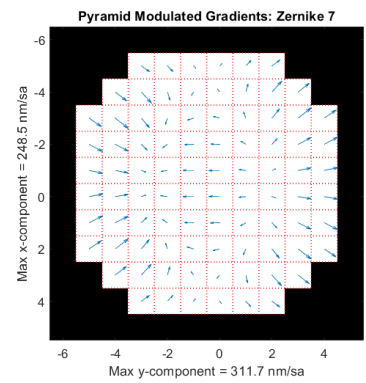
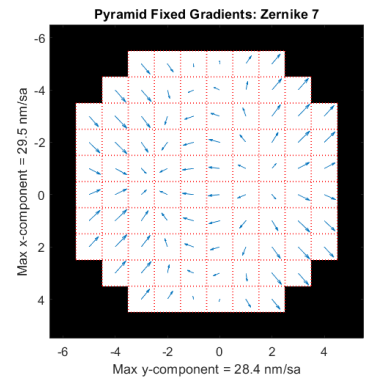
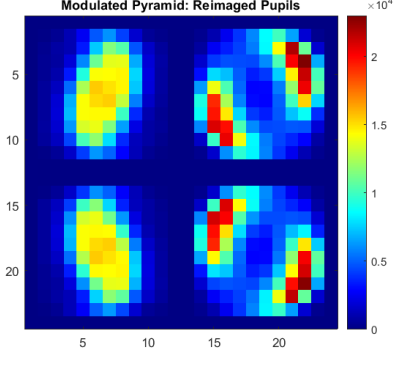
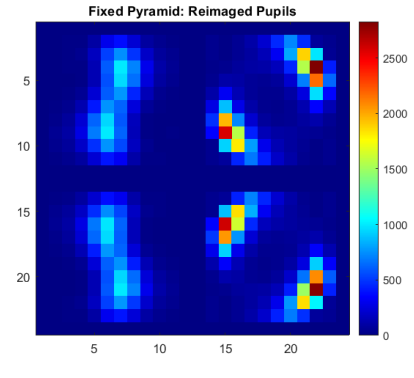
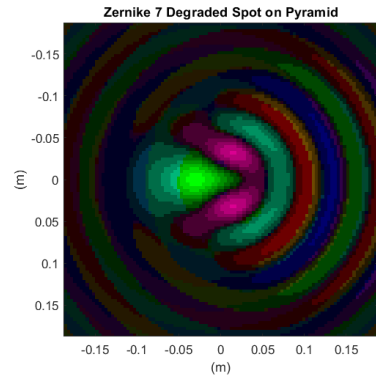
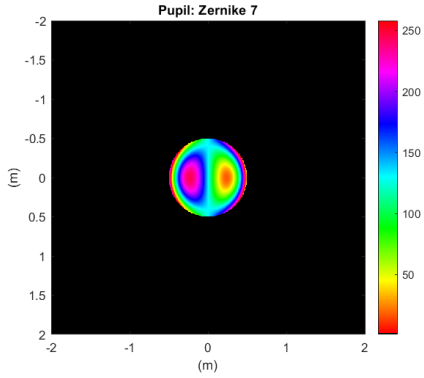
- Top Left Panel (Sensor Player 3.75.4):** Contains 'Data Capture' settings, including 'Data Mining' and 'DAS Maintenance' tabs. It shows a capture name 'scott1', a duration of 0.00000, and a frame rate of 20 Hz. Below this are exposure and gain controls.
- Top Right Panel (DM Control - V 1.0.0):** Features a large grid for mirror control. It includes fields for 'Mirror Type' (11: 144 Clean), 'Display Min' (-10201), and 'Display Max' (+11349). It also has 'Reference' (+00000), 'Gain x 10000' (10000), and 'Modifier' (+00000) settings.
- Right Panel (AO System):** Shows system status (Online/Offline), control tabs for Tilt, Phase, Servo, DM, and Cal. It includes a 'Loop Is Open' indicator and a 'Close Track Loop' button. Below are 'Corner Freq (Hz)' (0.0010) and 'Gain' (0.2700) settings.
- Bottom Left Panel:** Displays 'Required' and 'Desired' images for comparison, along with a 'Sensor PC' and 'Shutter' control.
- Bottom Right Panel:** Contains two 3D surface plots. The left one shows a flat surface, and the right one shows a textured surface representing the simulated AO wavefront.

Questions?

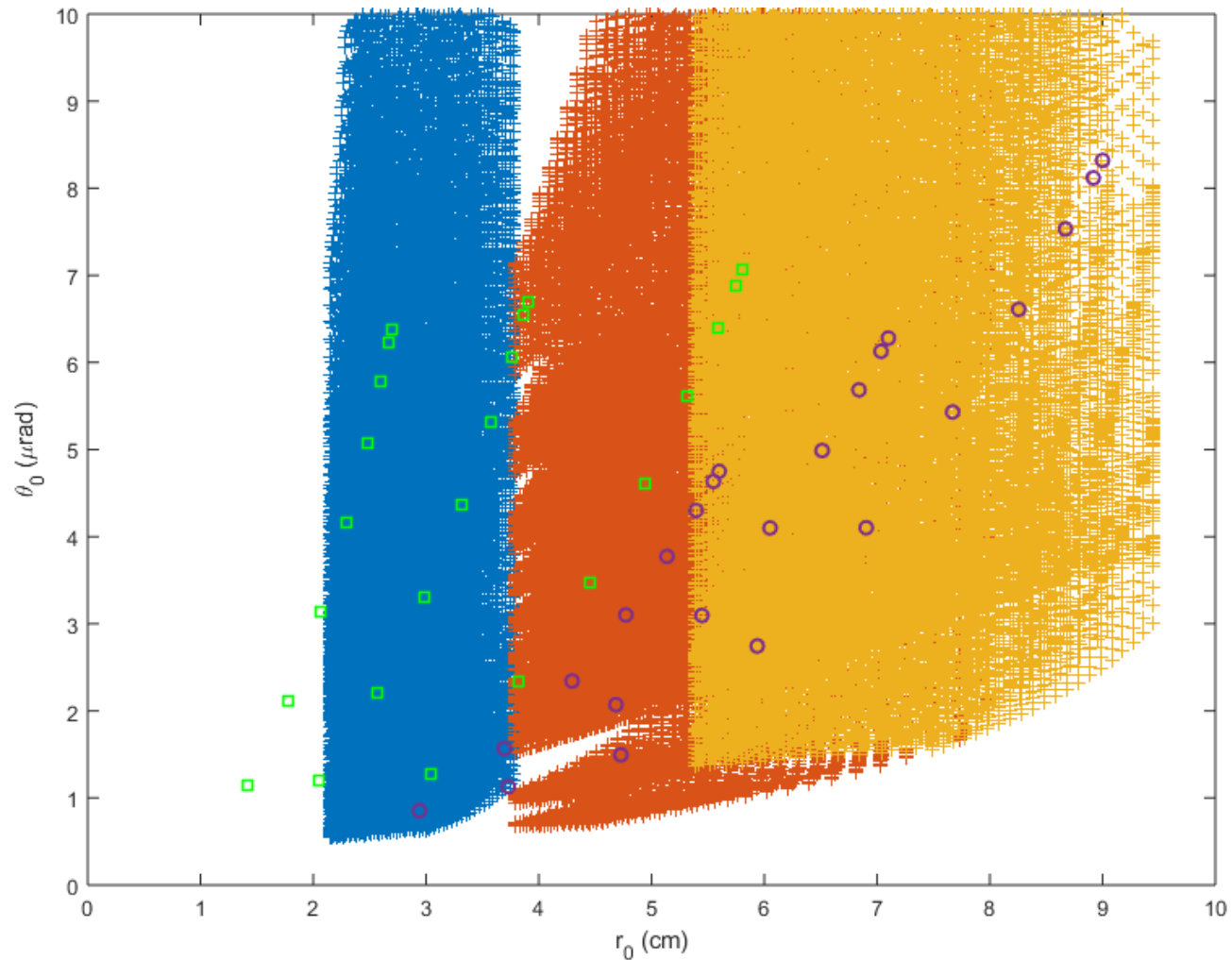
Backup Slides

Terry European (Deimos)

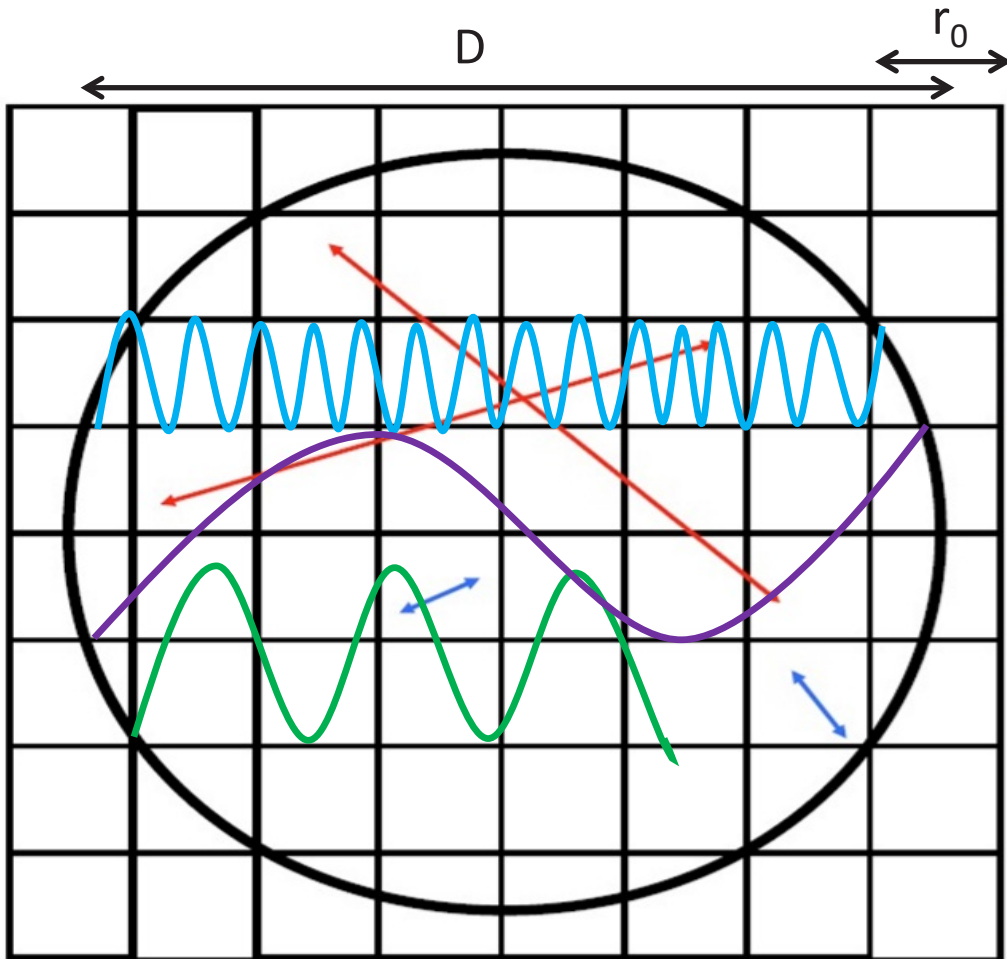
Zernike Test



Atmospheric Turbulence Simulator Range

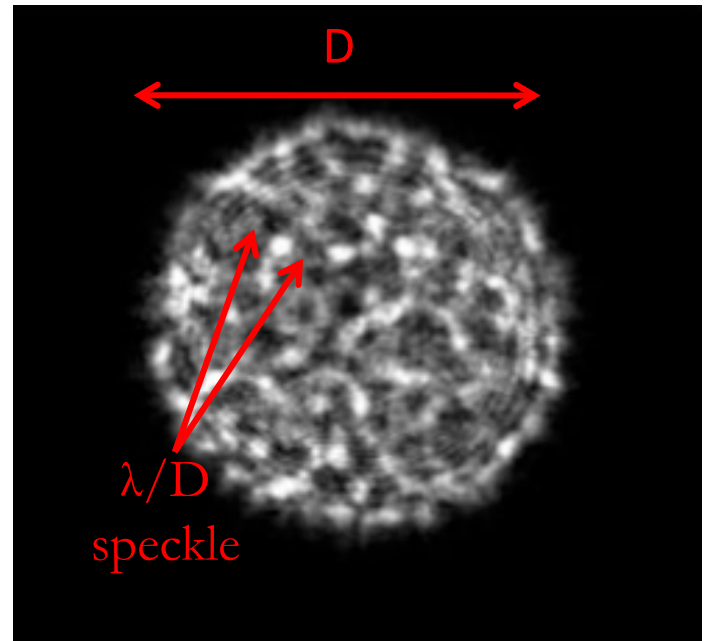


Extracting information from speckles



SH subapertures: Seeing limited (λ/r_0)

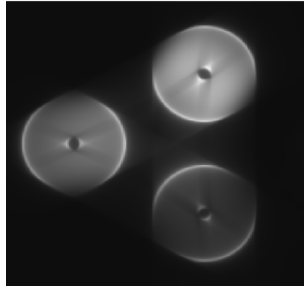
$(D/r_0)^2$ gain in Sensitivity for tip/tilt



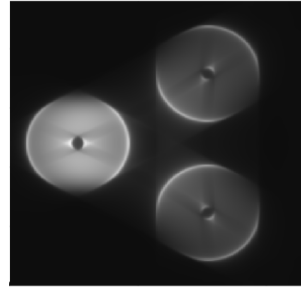
D^4 advantage for VLTs & ELTs

PWFS3 Simulations

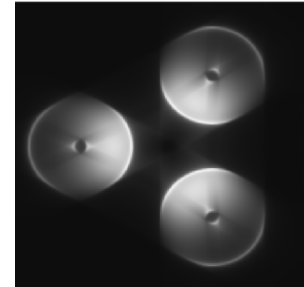
Modulated Zernike(1,1)



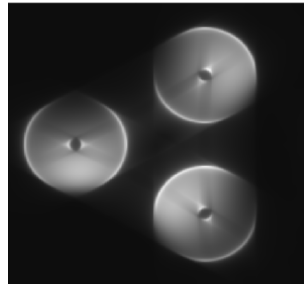
Modulated Zernike(1,-1)



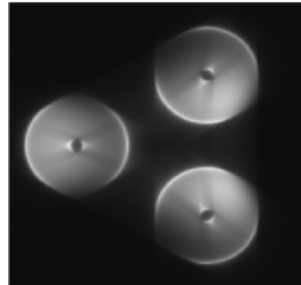
Modulated Zernike(2,0)



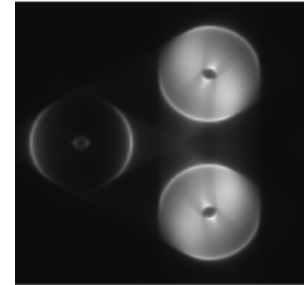
Modulated Zernike(2,-2)



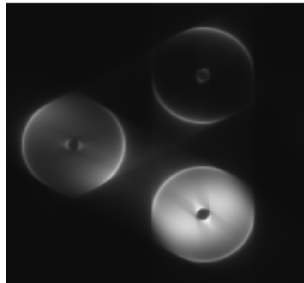
Modulated Zernike(2,2)



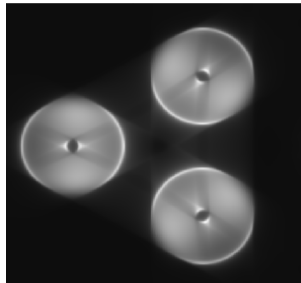
Modulated Zernike(3,-1)



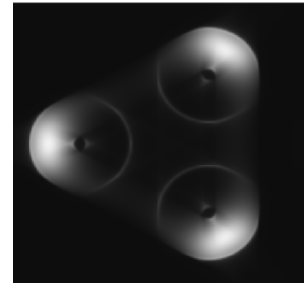
Modulated Zernike(3,1)



Modulated Zernike(3,-3)



Modulated Zernike(4,0)



Courtesy of Hart Scientific & University of Arizona