NCPA Sensing with a ZELDA-WFS in the High-Contrast Subsystem of ELT-HARMONI

A. Carlotti, A. Hours, L. Jocou, T. Moulin and the rest of the High-Contrast team
IPAG - Univ. Grenoble Alpes

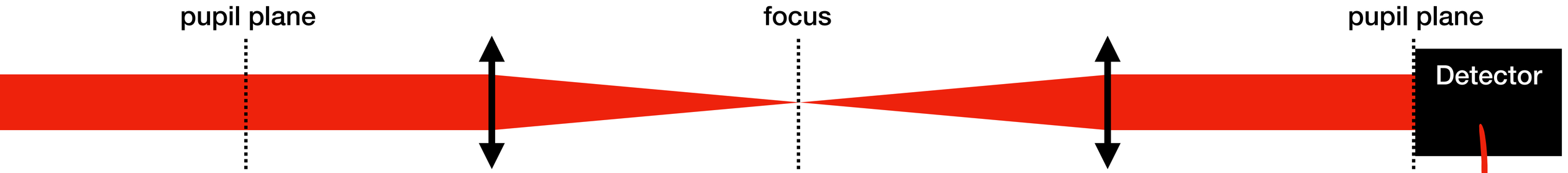
This project is funded by the European Research Council (ERC) under the European Union's Horizon 2020 research and innovation programme (grant agreement n°866001).

WFS2020 - 13th-15th October 2020

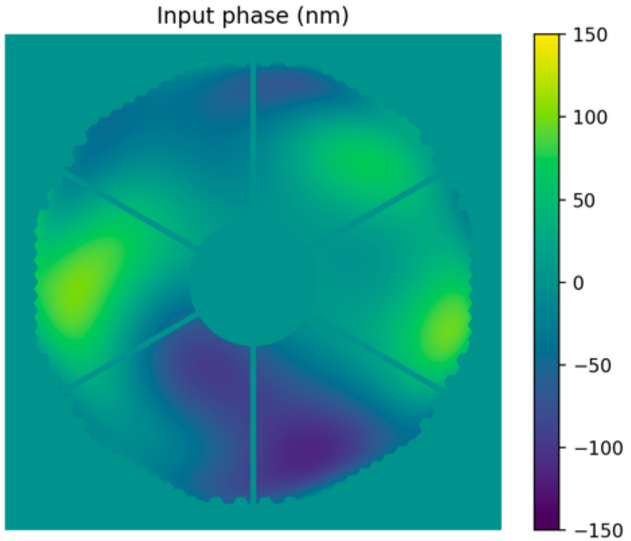
ZELDA: a high precision WFS for coronagraphy

See: N'Diaye et al. 2013, 2016 — Vigan et al. 2018, 2019

Nanometric precision — sensitive to piston errors (ex: LWE) — limited range (~60nm rms)

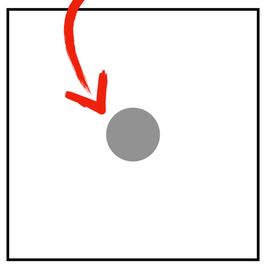


WF aberration

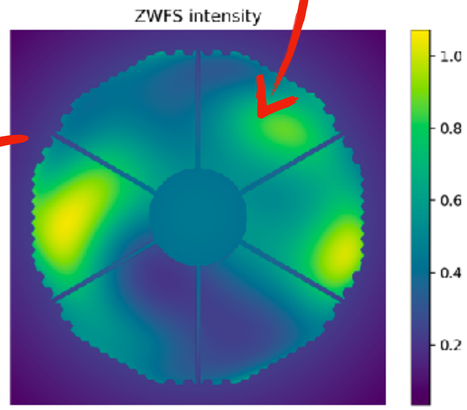


ZELDA mask

$\pi/2$ phase shift over ~1 λF/D disk

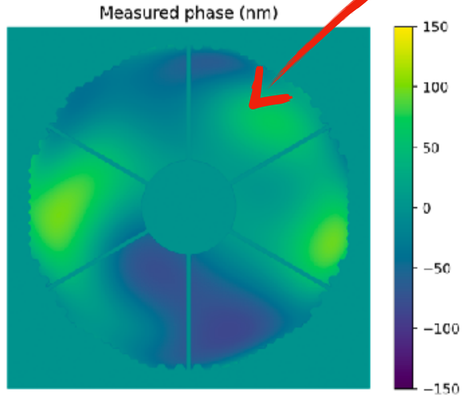


Intensity I



Retrieved WF:

$$\frac{I}{B^2} - \frac{P}{B} - 2\frac{B}{P} + 3$$



HARMONI High-Contrast (HC) Subsystem

See: Carlotti et al. 2018 — New SPIE papier end of 2020

ZWFS to calibrate NCPA & chromatic errors between SCAO and HC
(no dispersion correction before the HC subsystem)

Light from optical relay

To SCAO Subsystem < 1um

Pick-Off

High Contrast Bench

Apodizers (pupil plane)

Passive ADC

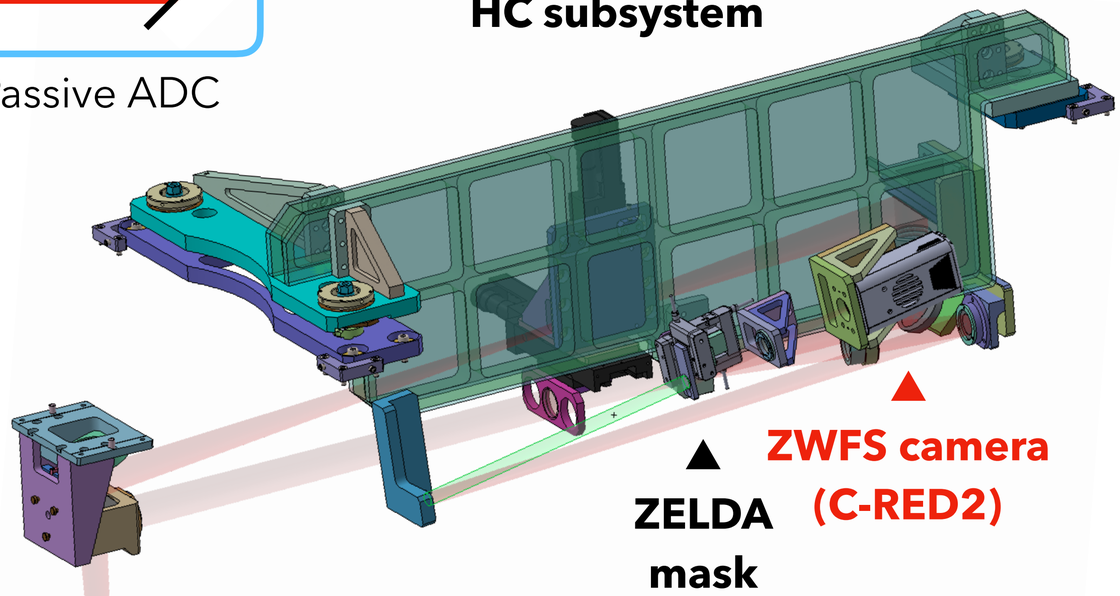
ZELDA WFS beam 1.15-1.2um

Science beam 1.25-2.45um

Focal plane masks

Towards IFS

3D view of the HC subsystem

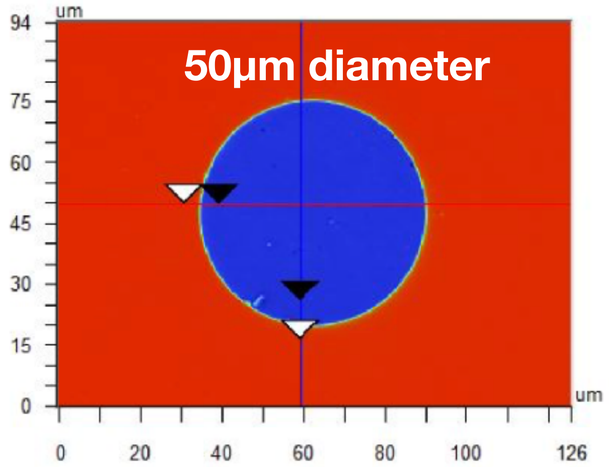


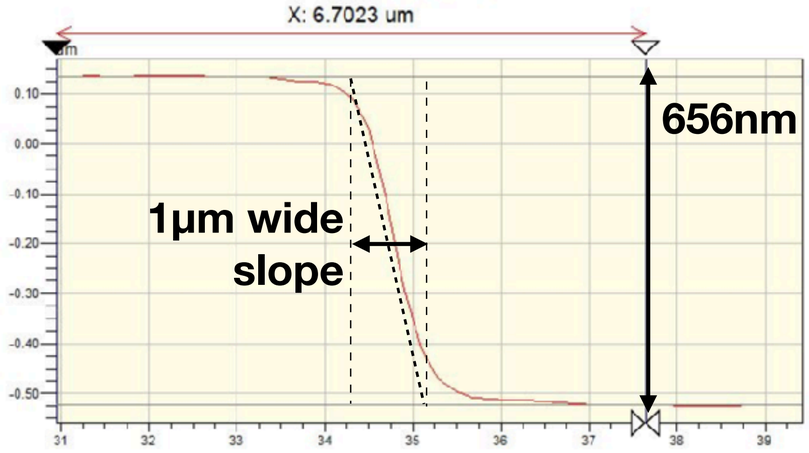
ZWFS camera (C-RED2)

ZELDA mask

Prototyping activities

ZELDA masks prototypes achieve their specifications

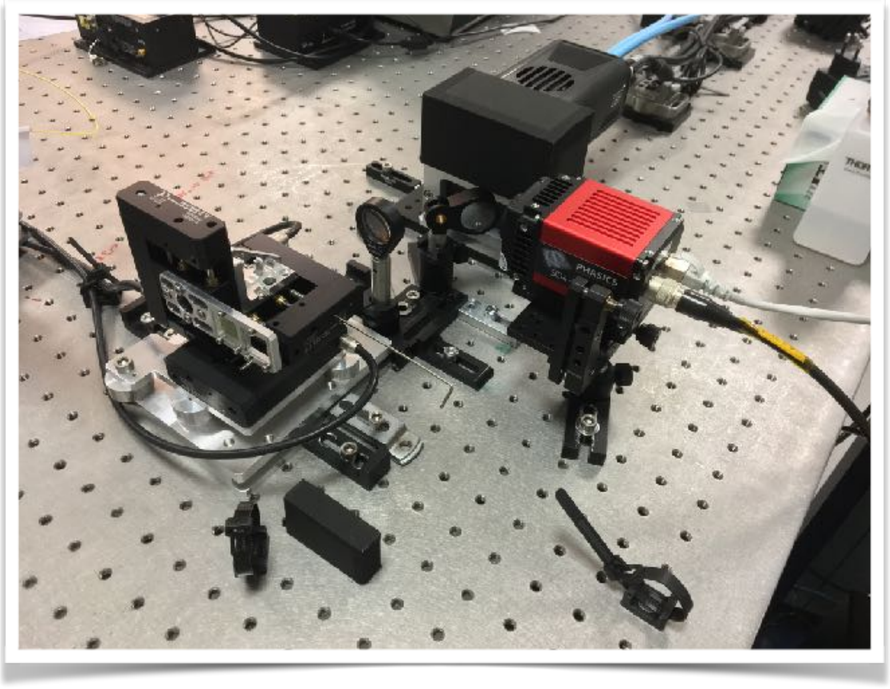




$$e = \frac{\lambda}{4\,(n-1)} \quad \text{with} \quad \lambda = 1.175\mu m \quad n(1.175) = 1.448$$

Bench built to validate ZWFS performance

1. Comparison with commercial high-res WFS
2. Replication of dispersion residuals
3. Replication of SCAO residuals (halo)



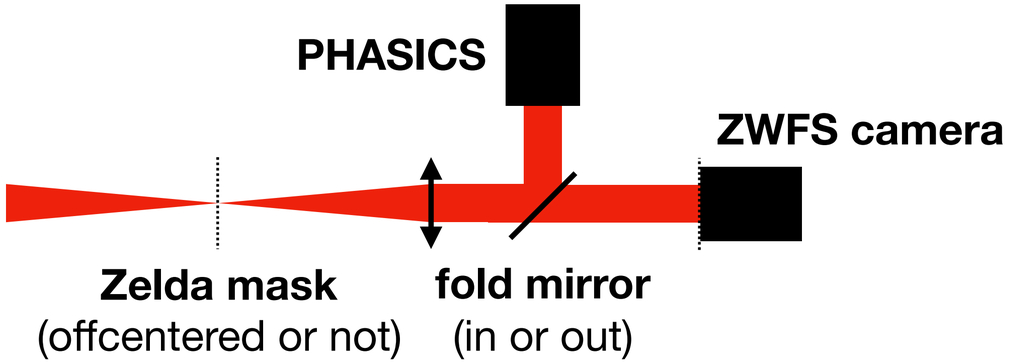
Prototyping activities

Good agreement between ZWFS and PHASICS sensor ; Some minor differences

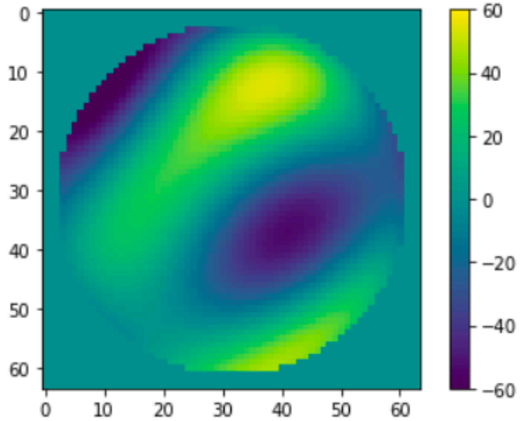
Sensors used alternatively

PHASICS: < 5nm systematic error & < 2nm precision

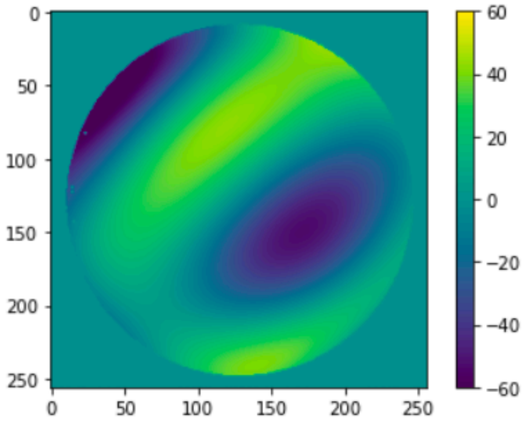
NCPA due to fold mirror: ~6nm rms



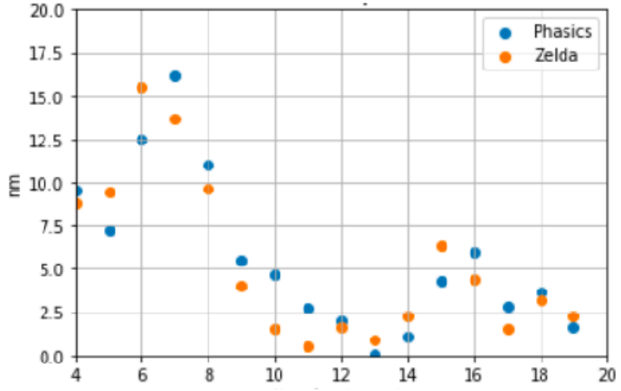
PHASICS: 25.1nm rms
(TT & focused removed)



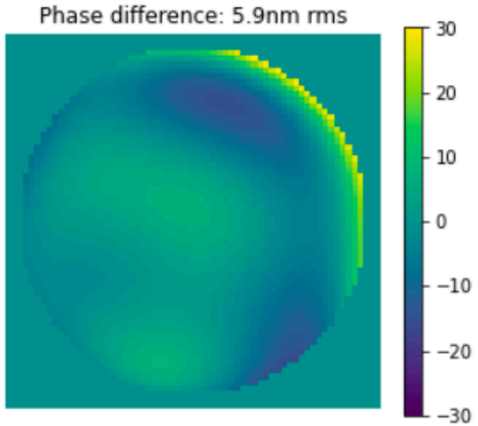
ZWFS data: 24.7nm rms
(TT & focused removed)



PHASICS vs ZWFS for first Zernike modes

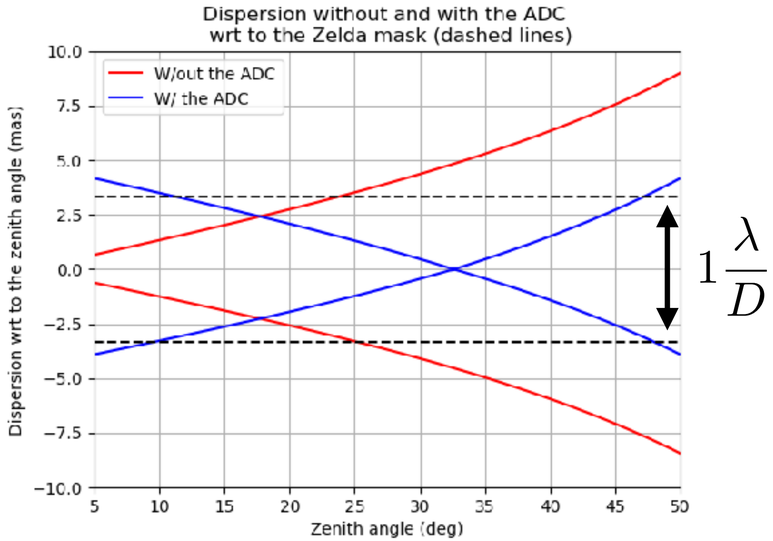


Difference: ~6nm rms



Next steps: Dispersion and SCAO residuals

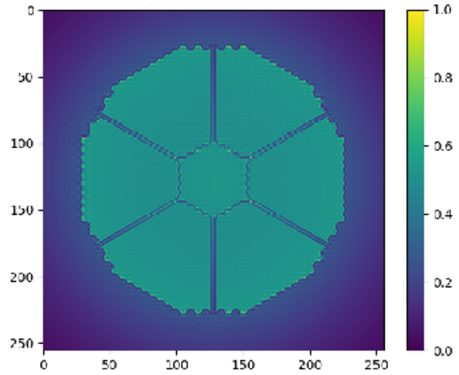
Dispersion induces a systematic phase that must be calibrated



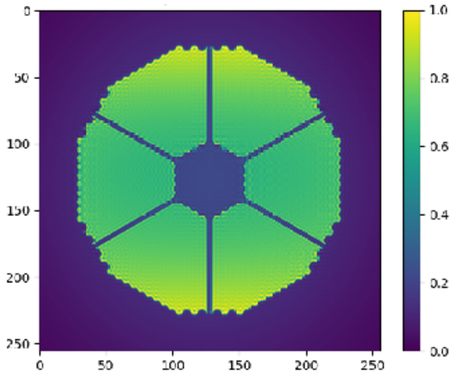
Full dispersion induces PSF shift up to ±1.5 λ/D at 50° ZD

Passive ADC limits this to ±0.7 λ/D at 5 and 50° ZD

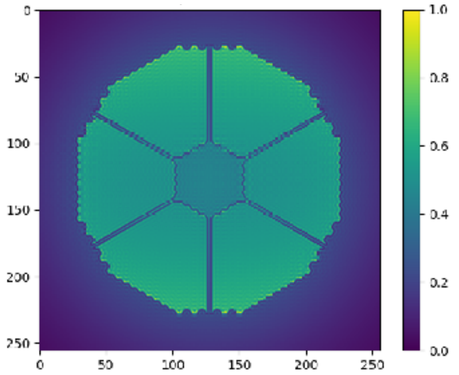
W/out dispersion



W/ dispersion (45° ZD)



W/ passive ADC (45° ZD)



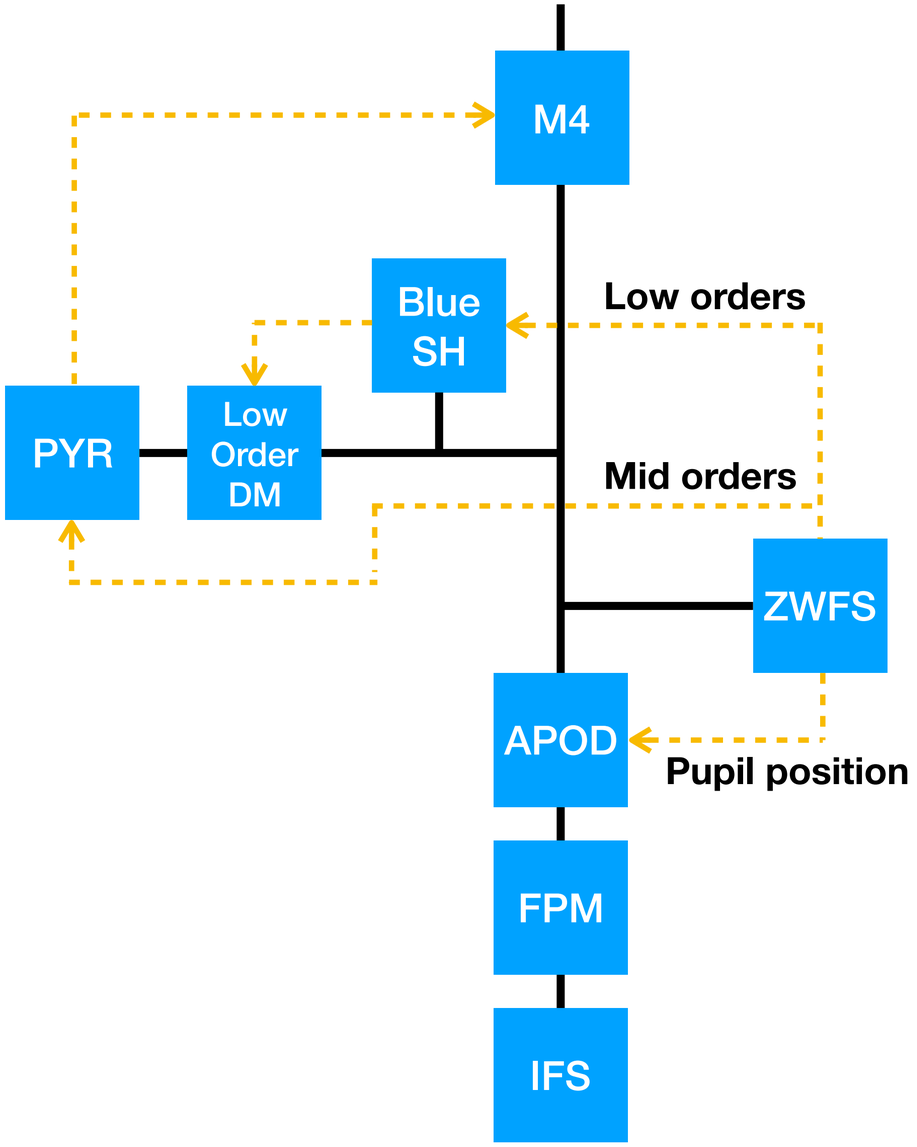
Next steps: replicate long exposure w/ SCAO residuals

Simulation data from HARMONI SCAO team at LAM (E. Choquet & J.-F. Sauvage)

‘Fast' SLM to induce the phase terms

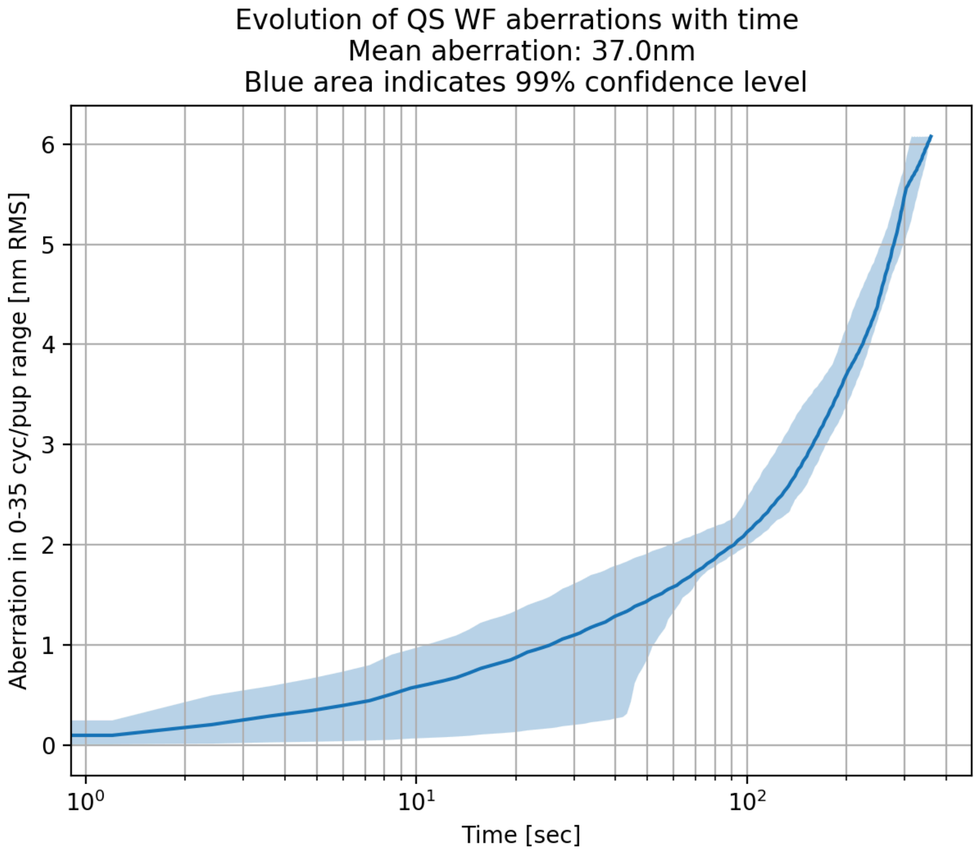
Thanks! Any question?

Closing the loop on ZWFS data



Evolution of quasi-static aberrations

Estimated evolution of quasi-static aberrations
2nm rms in 1min ; 5nm rms in 3min



Phase error vs. time
2nm rms for a 30sec observation with mag=8