Laser Guide Star Wavefront Sensor prototype for the E-ELT:

some results

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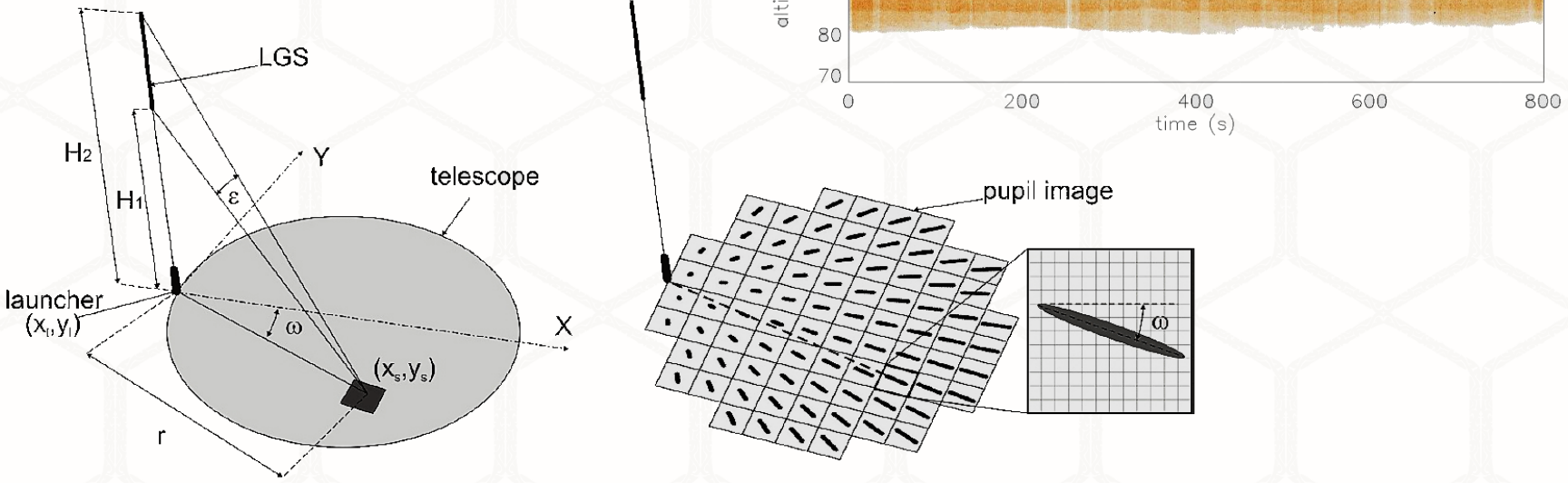
Main objectives

- Verify performance of LGS Shack Hartmann WFS under different working conditions (sampling, field of view, signal-to-noise ratio, algorithm type, Sodium profile features)
- Study low/medium order aberrations induced by Sodium layer coupled with spot truncation and other effects in the LGS WFS
- Verify the fidelity of numerical simulations that model the LGS image in the Shack Hartmann WFS sub-apertures



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Prototype scale

LGS 'seeing limited size'	Considering 1,5'' → 1.8 pixels FWHM
Pixel scale	0.83"/pixel
max FoV per Subaperture	19.9"
RON	15 e^-

Prototype configuration

Laser launcher from the telescope side

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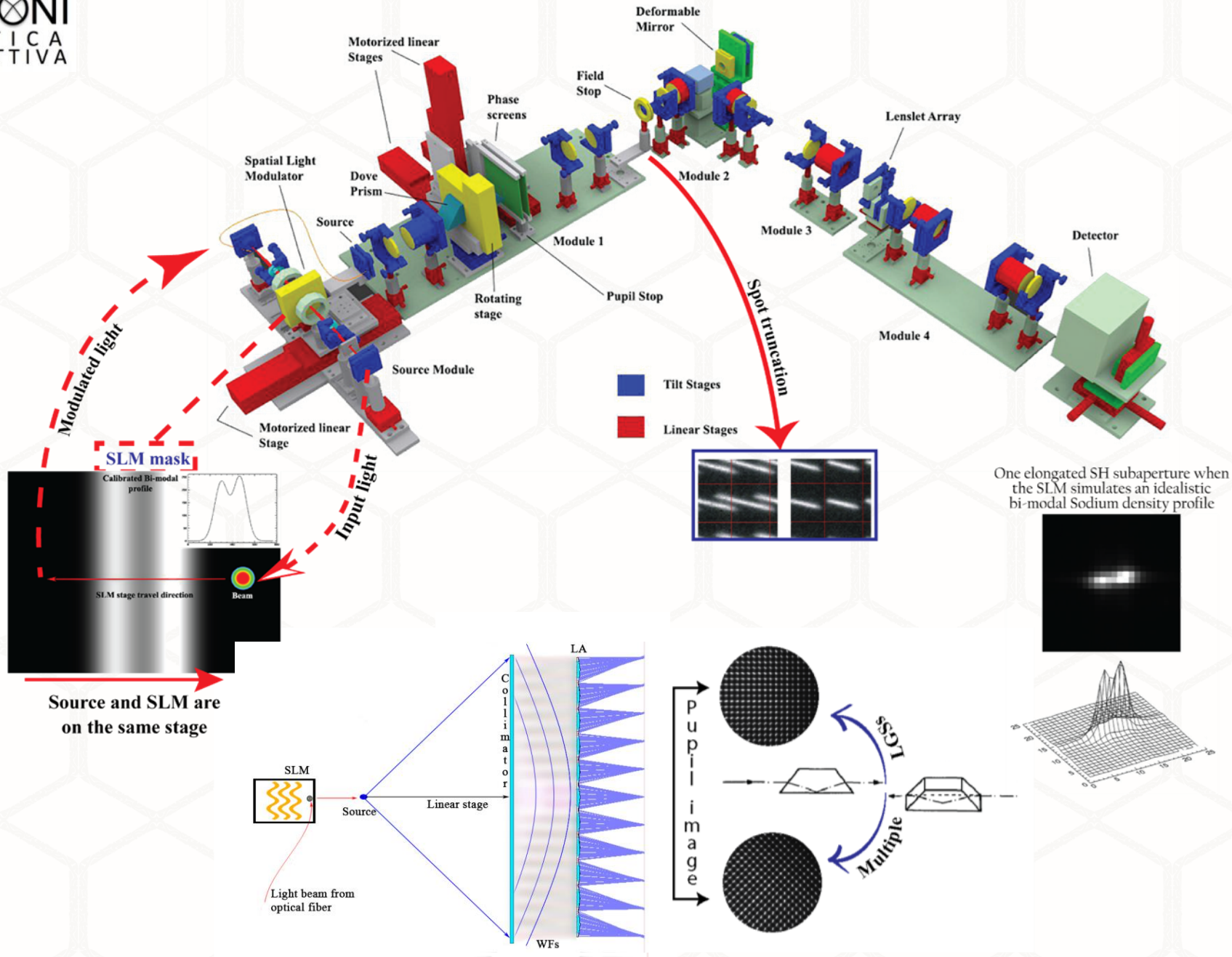
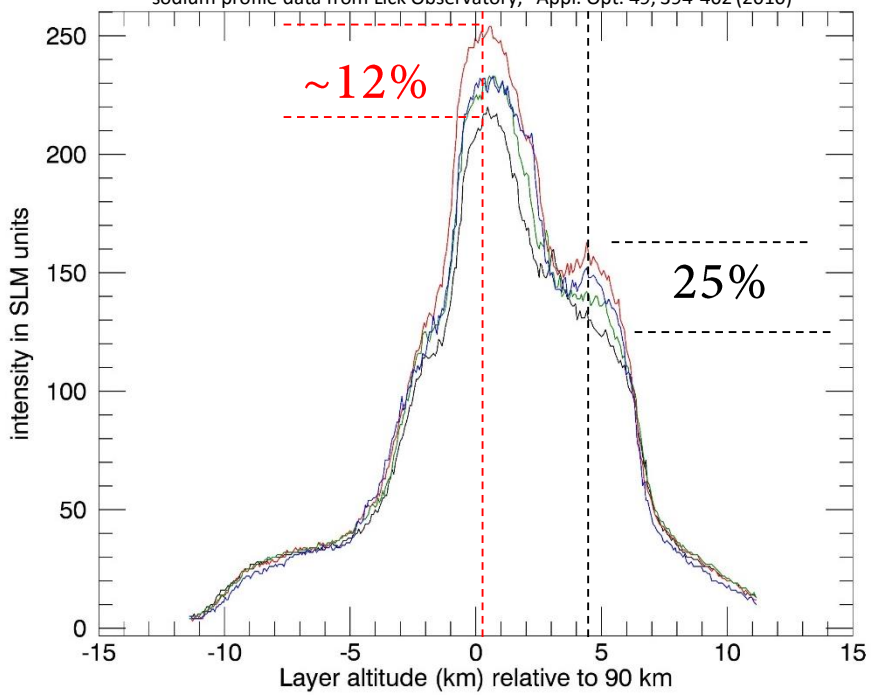
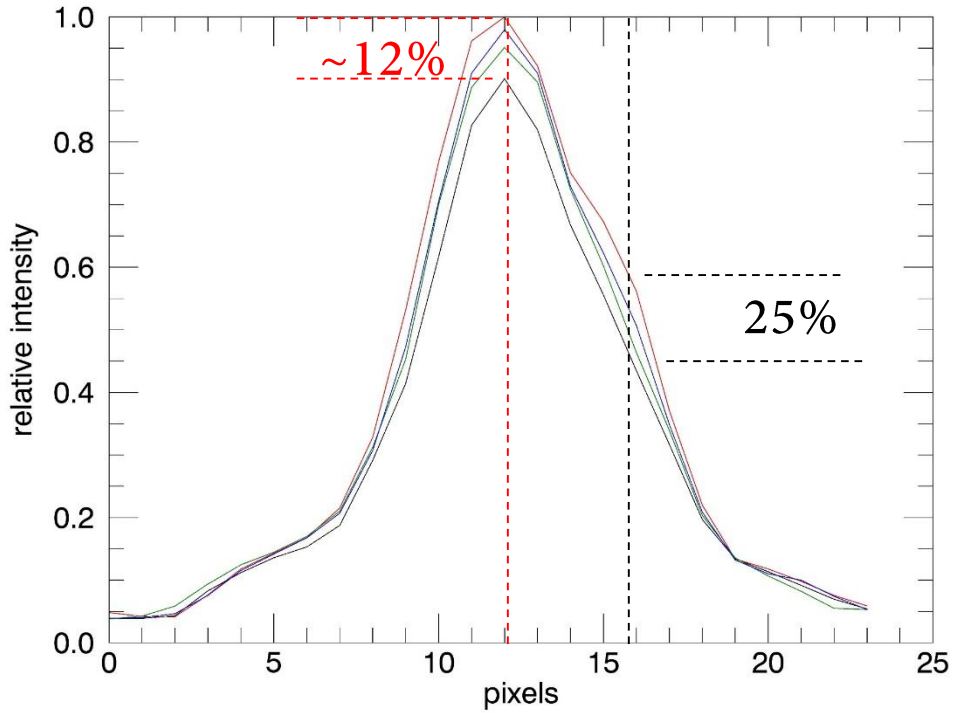


Accuracy of LGS image shapes on the SHWFS

SLM profile → Most elongated sub-aperture (high SNR)

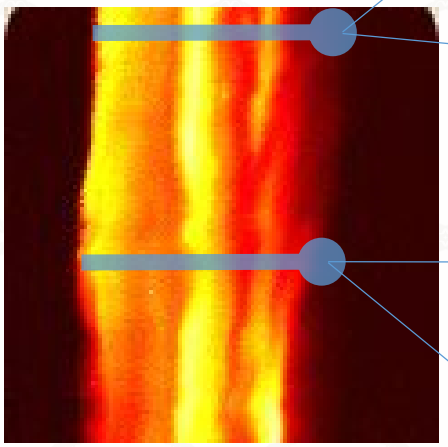
Sandrine J. Thomas, Donald Gavel, and Robert Kibrick, "Analysis of on-sky sodium profile data from Lick Observatory," Appl. Opt. 49, 394-402 (2010)

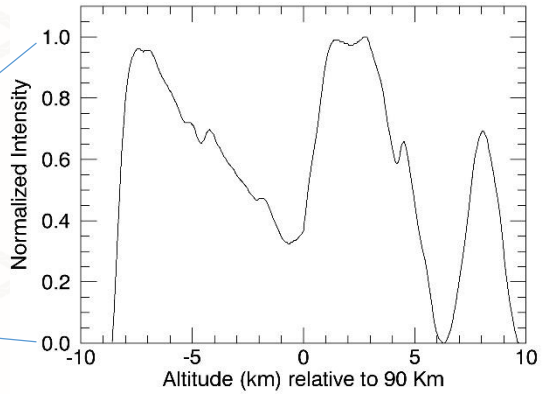


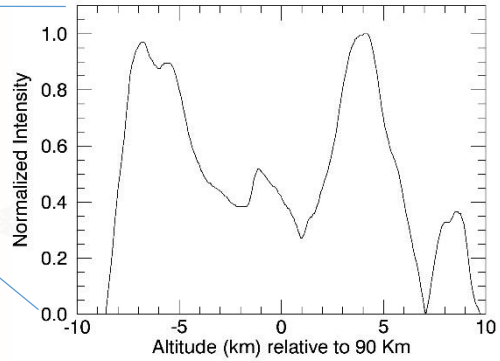


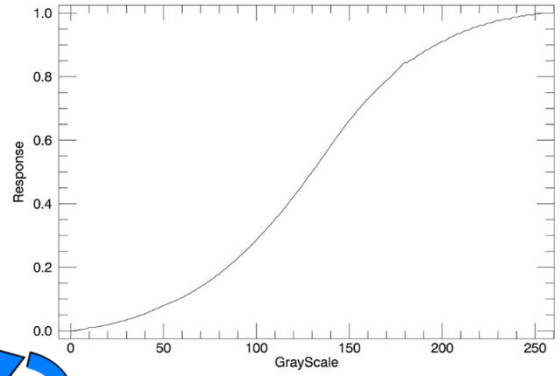
Most elongated sub-aperture : resolves Sodium profile intensity variations when ΔH > 2km

Case of real Sodium density profile









Pfrommer, T., P. Hickson, and C.-Y. She (2009), "*A large-aperture sodium fluorescence lidar with very high resolution for mesopause dynamics and adaptive optics studies*", *Geophys. Res. Lett.*, 36, L15831.

1) Chose Sodium density profile
2) Associate SLM pixels to layer altitudes according to perspective elongation
3) Calibrate by SLM curve response

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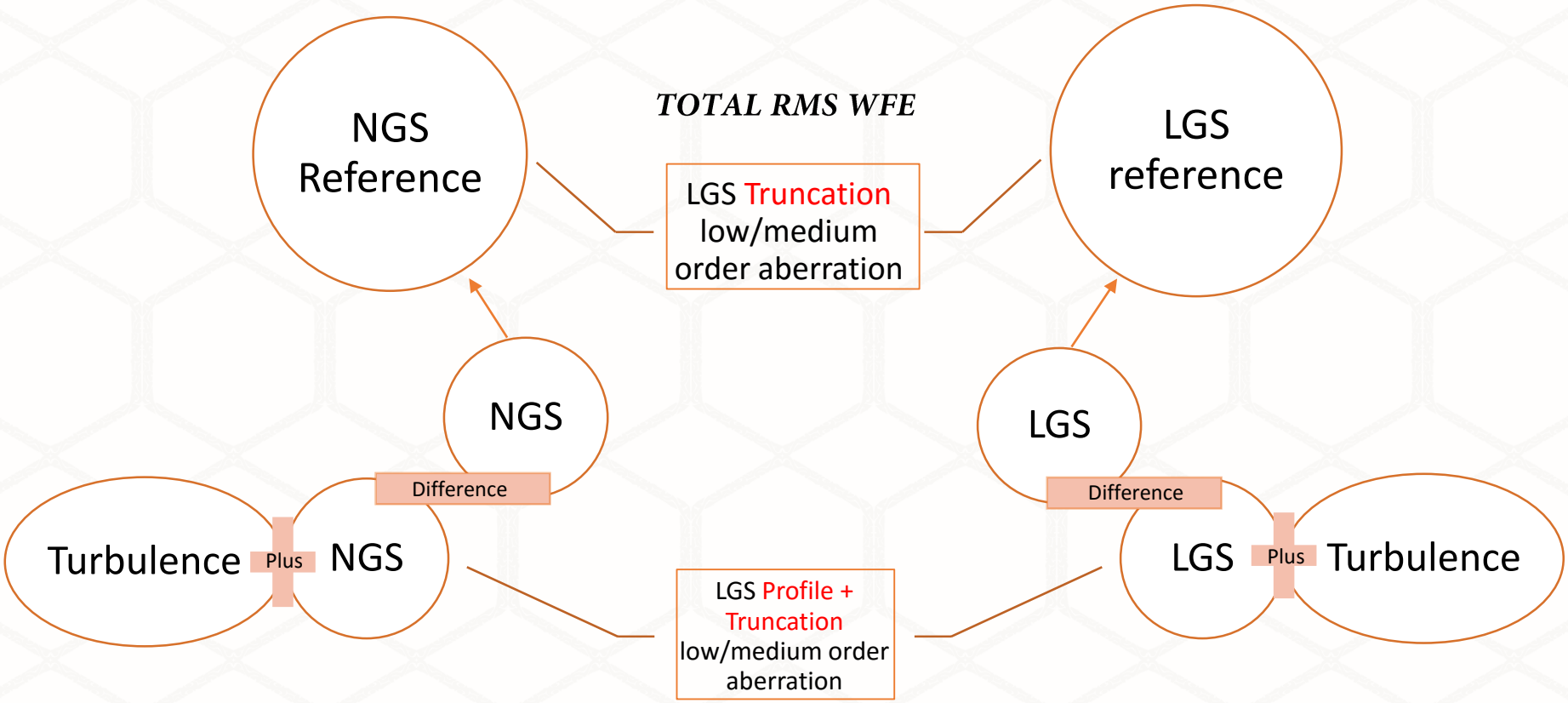
Perform first set of tests with realistic static Sodium density profiles

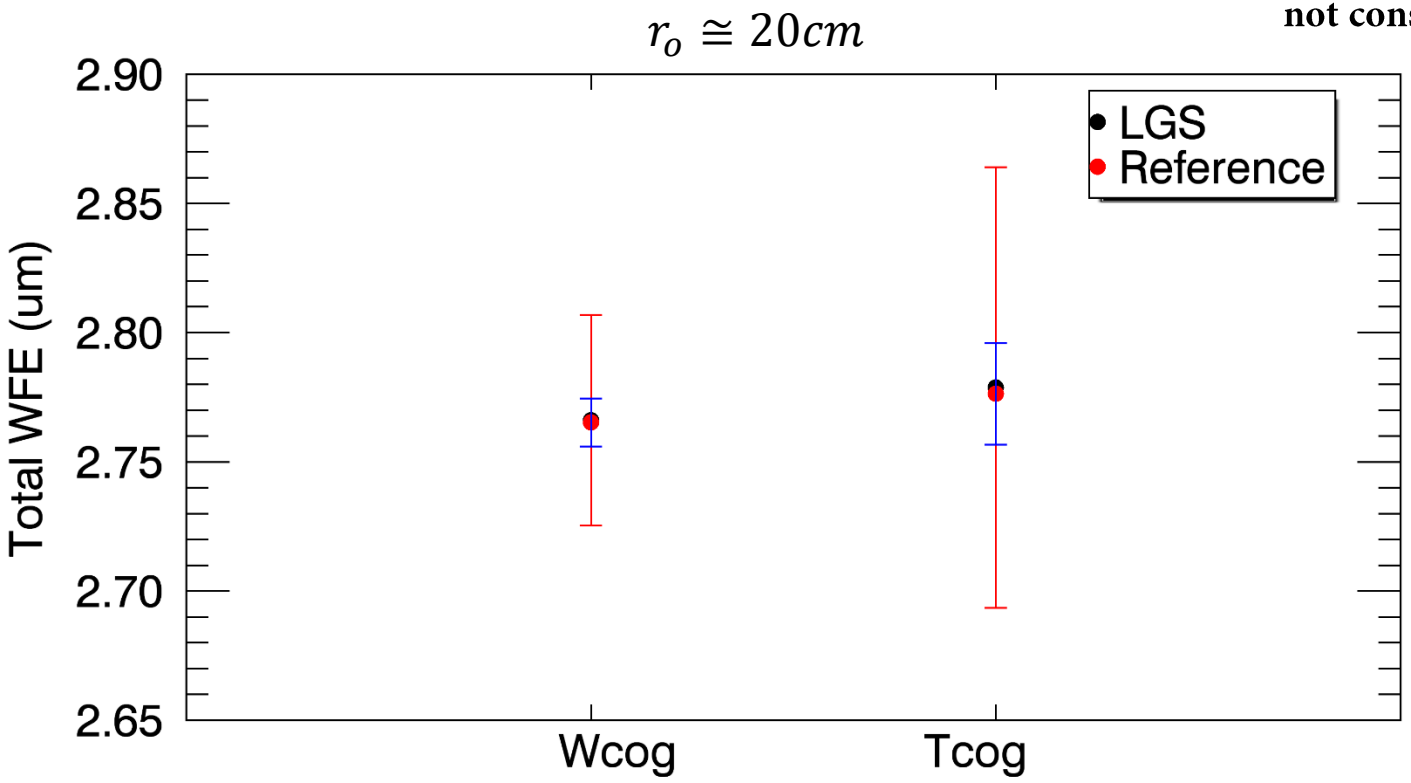
Truncated LGS images (~16" FoV) and 2 levels of atmospheric turbulence strength



Algorithm used : *WCoG and Threshold centroid*

Strong turbulence

Tip-Tilt & Defocus not considered

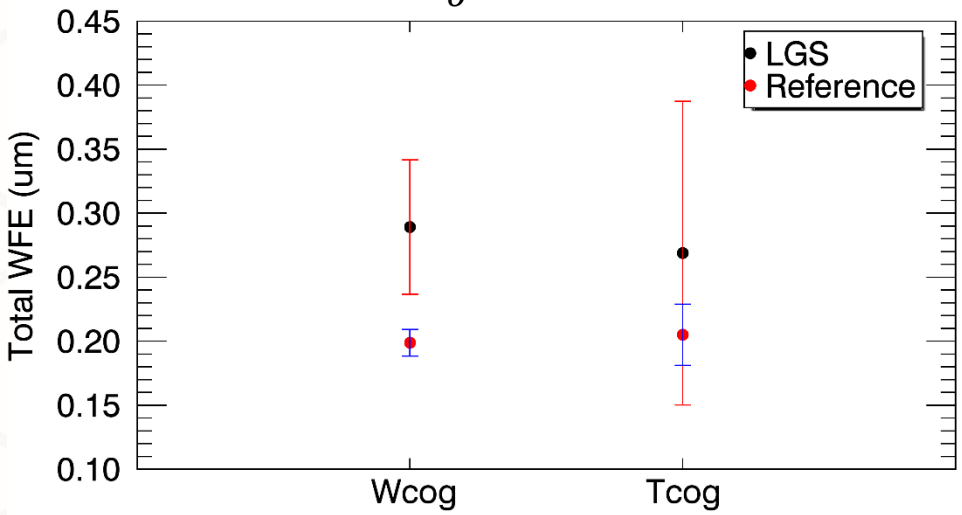


Effect of truncation not significant

WCoG more stable and reliable algorithm

Weak turbulence

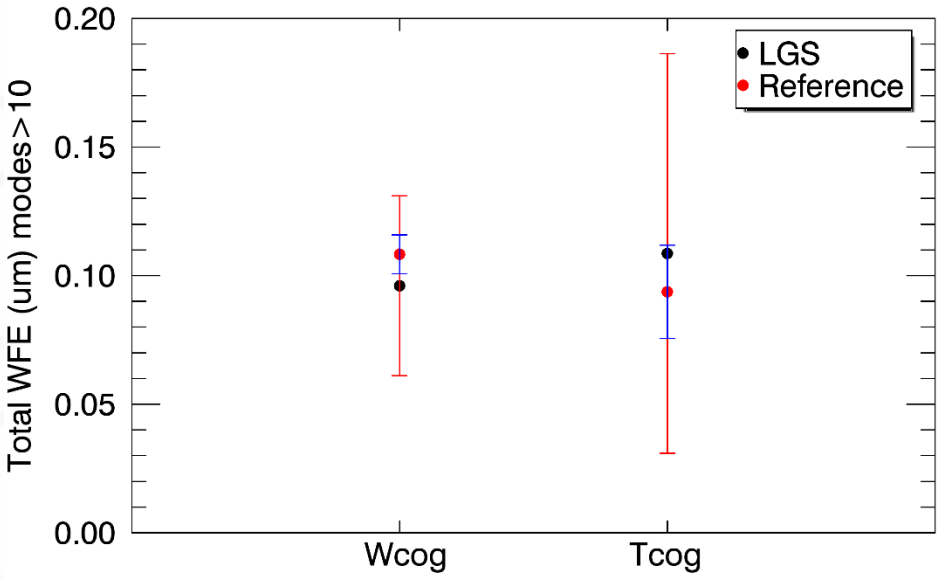
$r_o \cong 3\ m$



Tip-Tilt & Defocus not considered

Remove first

10 modes



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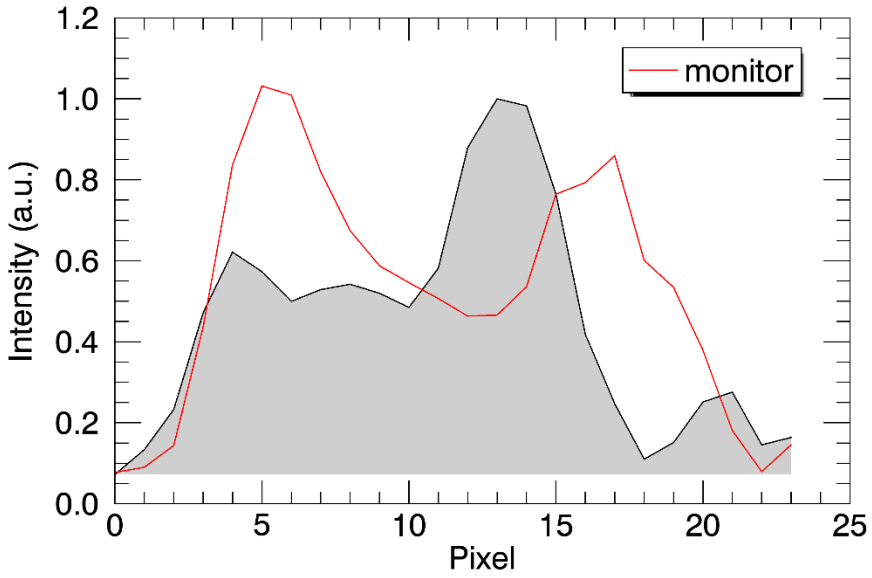
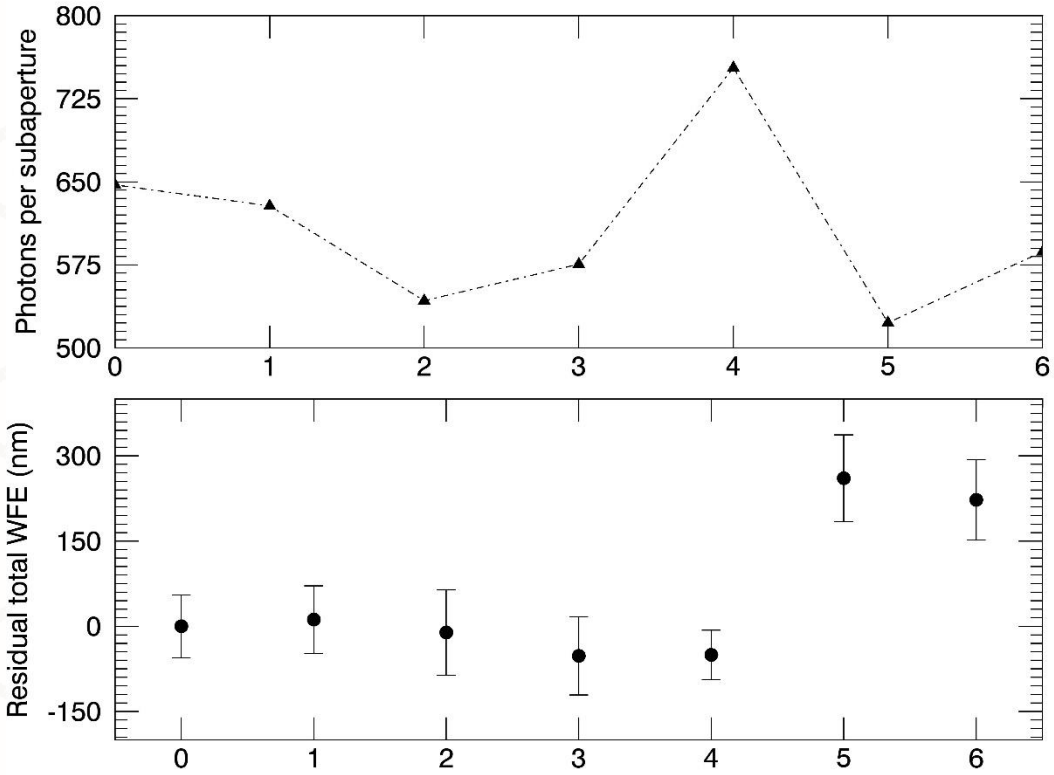
Real Sodium profile sequence to highlight the phase errors induced by the Sodium layer fluctuations

Test the idea to use the most elongated sub-aperture as a Sodium profile monitor. Such an 'in situ' tool could :

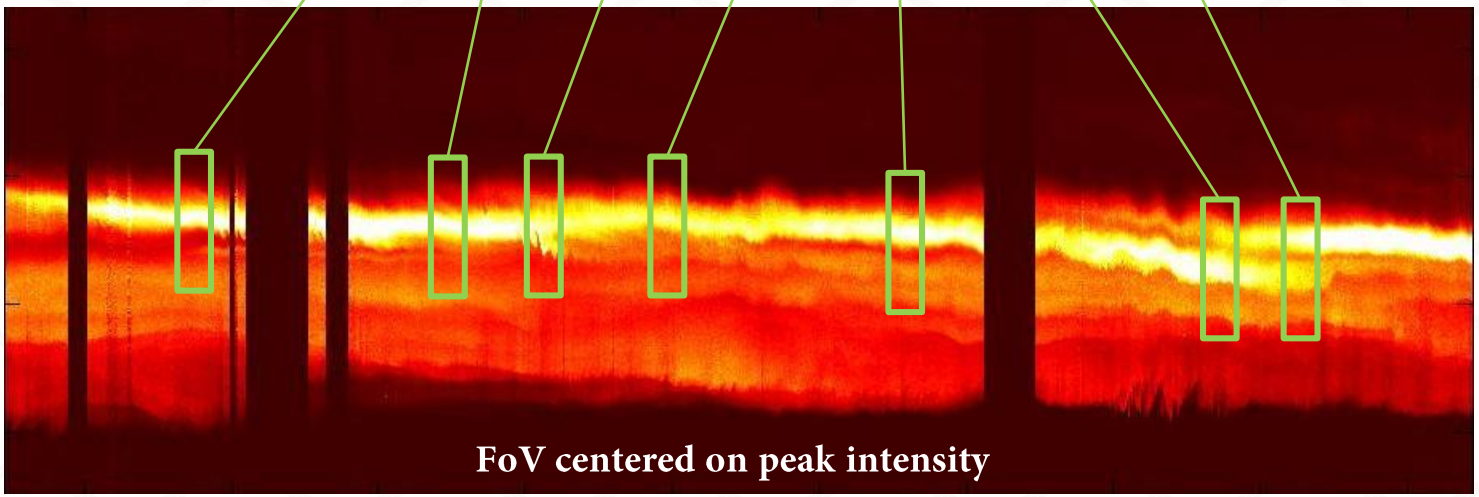
- prevent spurious aberrations, especially if a large spot truncation is foreseen.
- provide relevant sodium layer statistics that should correlate in a direct way with AO system performance at the telescope.

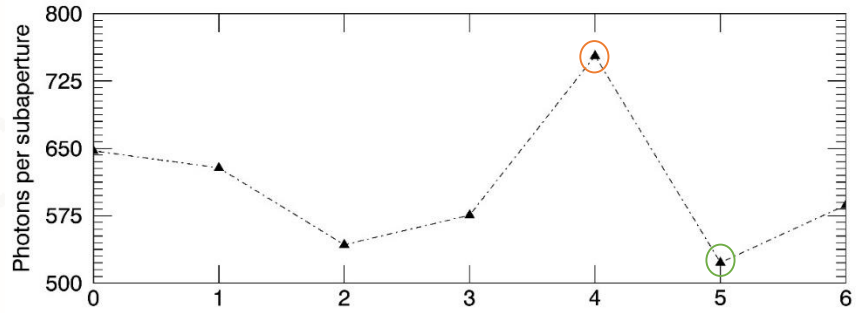


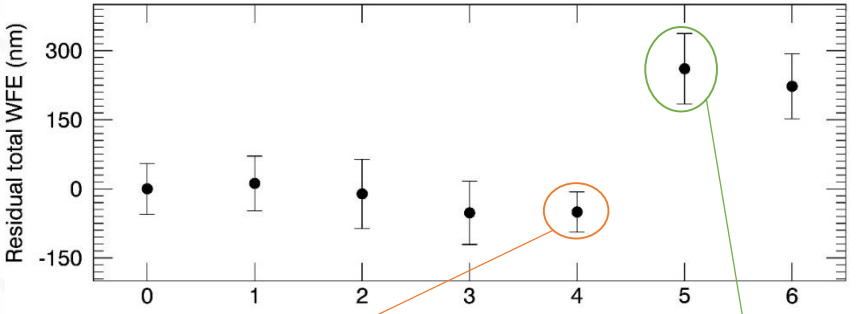
WGoC Algorithm

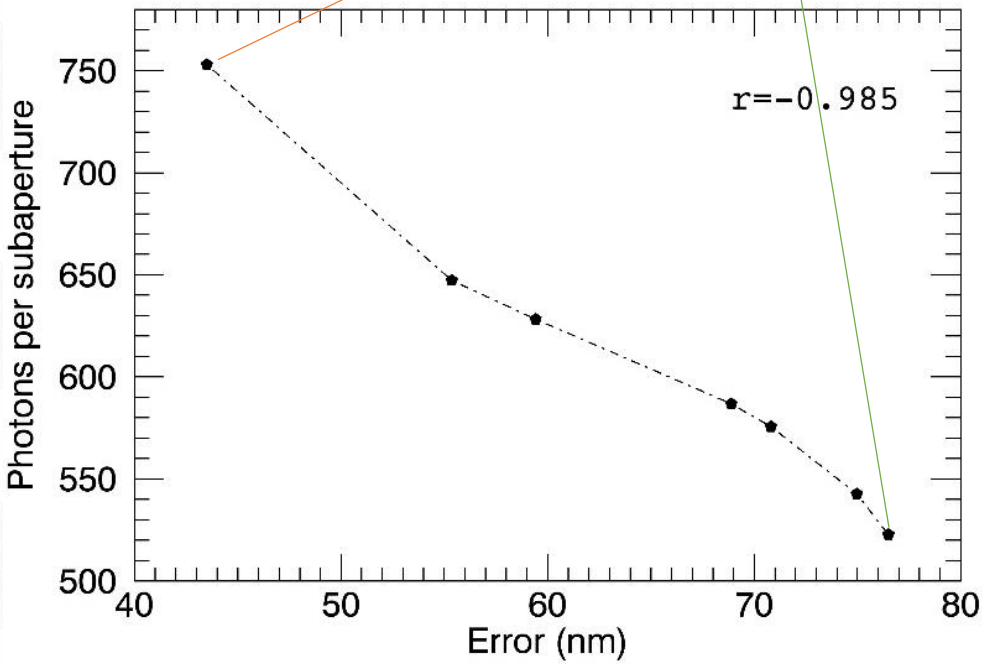


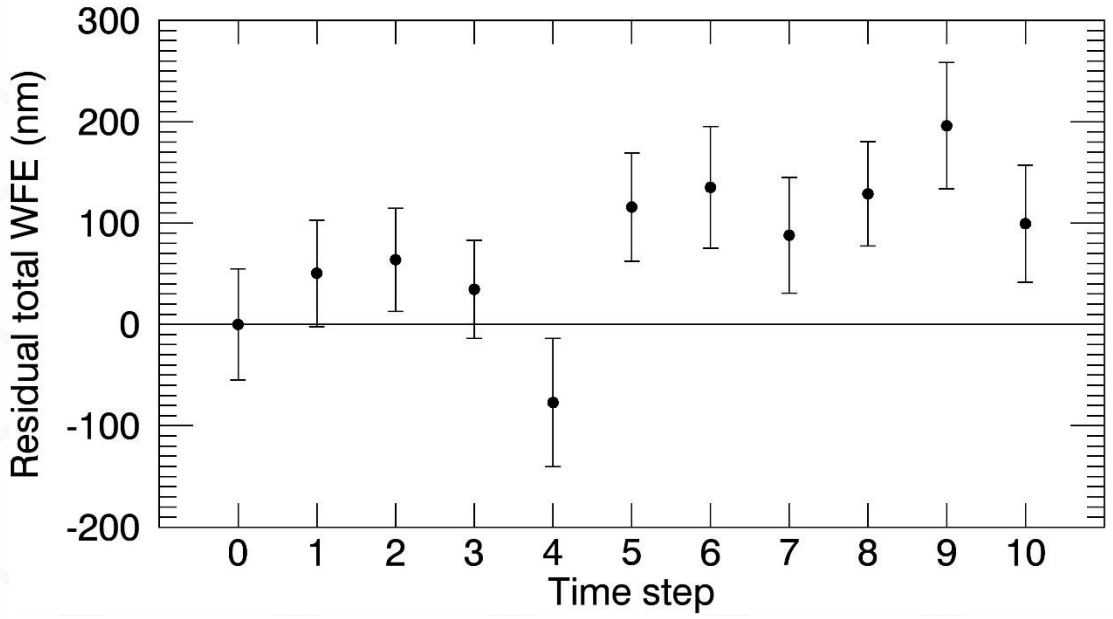
Tip-Tilt & Defocus not considered

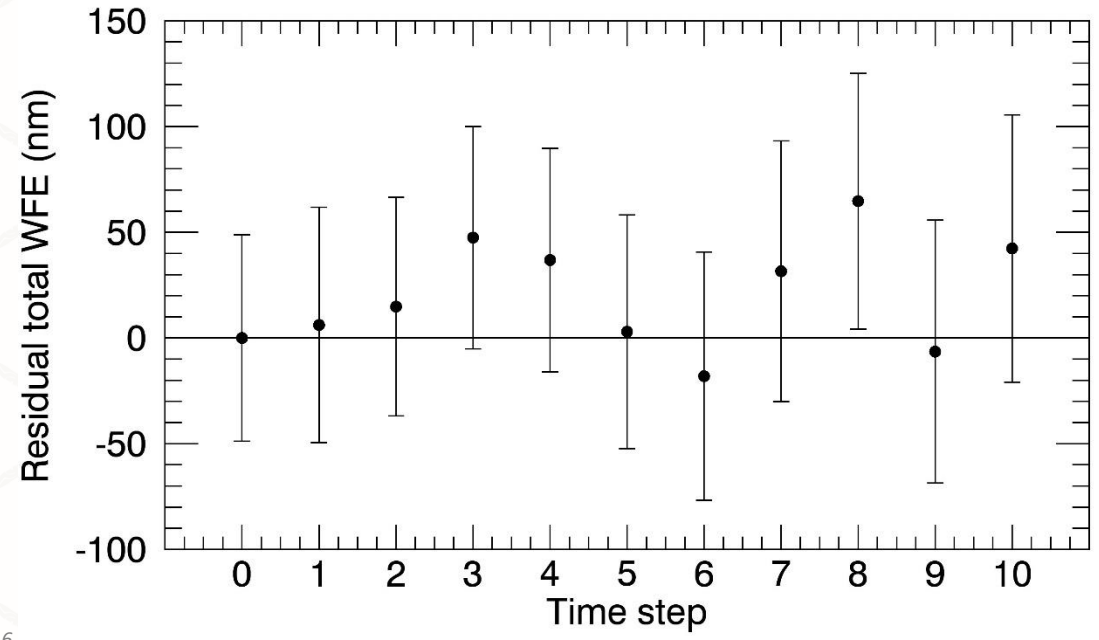



Photons per subaperture
800
725
650
575
500
0
1
2
3
4
5
6

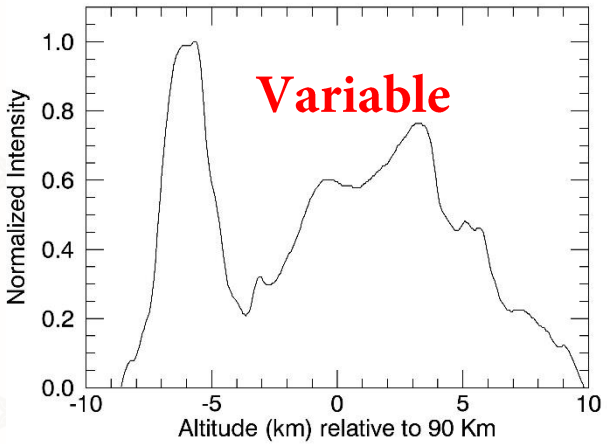

Residual total WFE (nm)
300
150
0
-150
0
1
2
3
4
5
6


r=-0.985
Photons per subaperture
750
700
650
600
550
500
40
50
60
70
80
Error (nm)

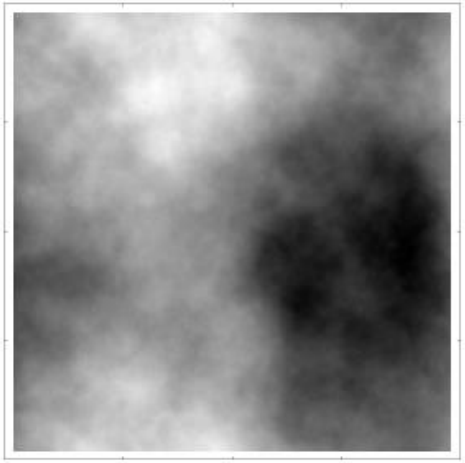




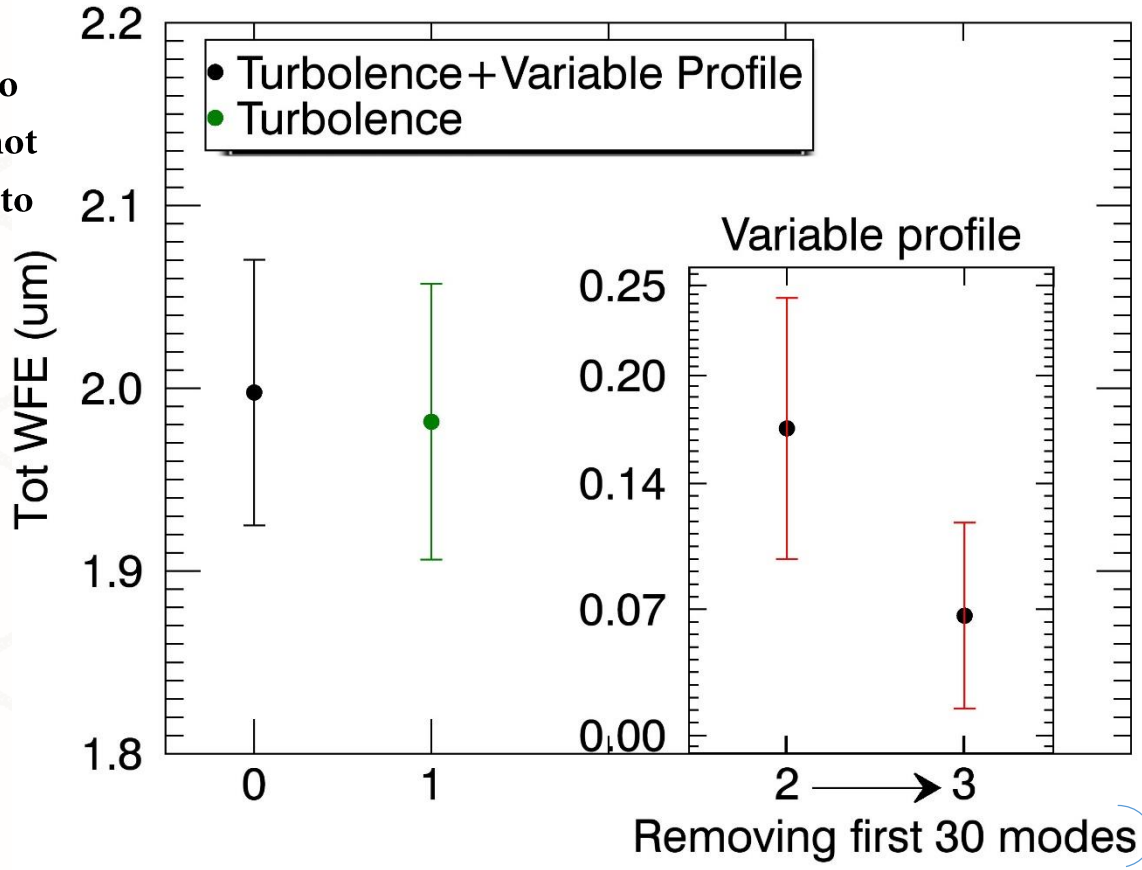
Use Sodium Monitor to avoid large spot truncation



Plus



Aberrations due to profile variations not significant respect to atmospheric turbulence



RMS WFE comparable to its error

Conclusion

- .*Strong turbulence*. When the AO loop starts, the low/medium order aberrations due to LGS image truncation and/or Sodium density variability are not significant.
- .*Weak turbulence*. Close to the AO loop convergence, LGS image truncation and/or Sodium density variability influence the WFS performance
- .*Sodium monitor*. Useful to mitigate the wavefront sensing risks but not sufficient to avoid a reference WFS, based on NGS, to measure the LGS spurious aberrations
- .*Near future*. Use the prototype to test the performance of Quad-cell (binning the detector) and Pyramid WFS (new optical channel)