Characterization of a wave-front sensor and reconstructor

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Introduction

- Characterization of an AO system
- The wave-front sensor
- The wave-front reconstructor

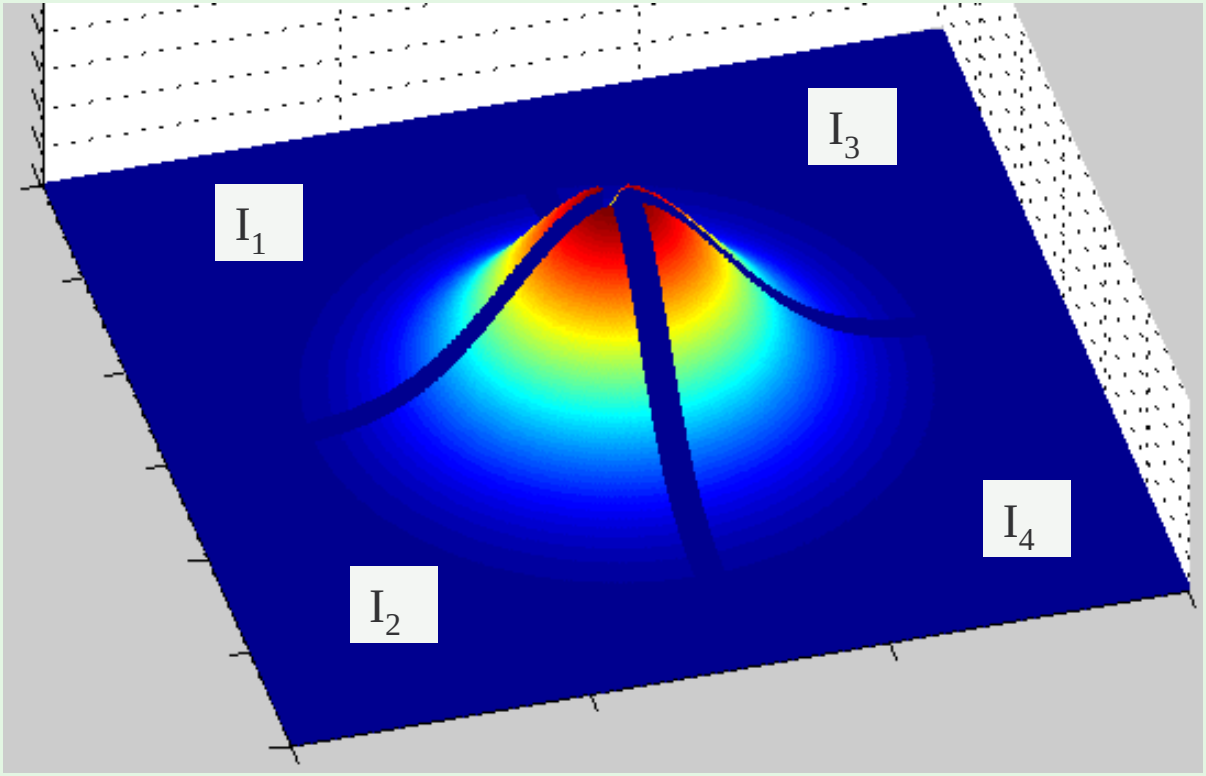
Why AO characterization?

- Traditionally, AO performance is evaluated using
  - Simple analytic formulae.
  - Monte-Carlo simulations using a simple model.
- The images obtained are not as good as these models predict.
- Want to understand the sources of error better.
- This will hopefully lead to AO systems with better images!

SH WFS with Quad Cells

- Intensity detected using a 2×2 array
- The centroid is given by

$$S_x = \frac{I_1 + I_2 - I_3 - I_4}{I_1 + I_2 + I_3 + I_4}$$



Finding the spot size

- A light source is scanned across the focal plane of the telescope.
- The average centroids are measured and the transfer curve is computed.
- This procedure is also used to find the best focus of the wave-front sensor.

Spot sizes

- Diffraction-limited spots are 0.20” FWHM.

- Spot sizes

Pixel size	FWHM	Diffusion	FWHM
Arcsec	Arcsec	Pixels	Arcsec
1.98	1.29	0.34	0.62
0.76	0.52	0.34	0.26
0.45	0.39	0.34	0.23

- There is diffusion in the CCD. This is modeled as a convolution by a Gaussian with a FWHM of 0.34 pixels.

Transfer curve

- There is a non-linear relationship between the centroid and the displacement of the spot.
- Sensitivity is inversely proportional to spot size.

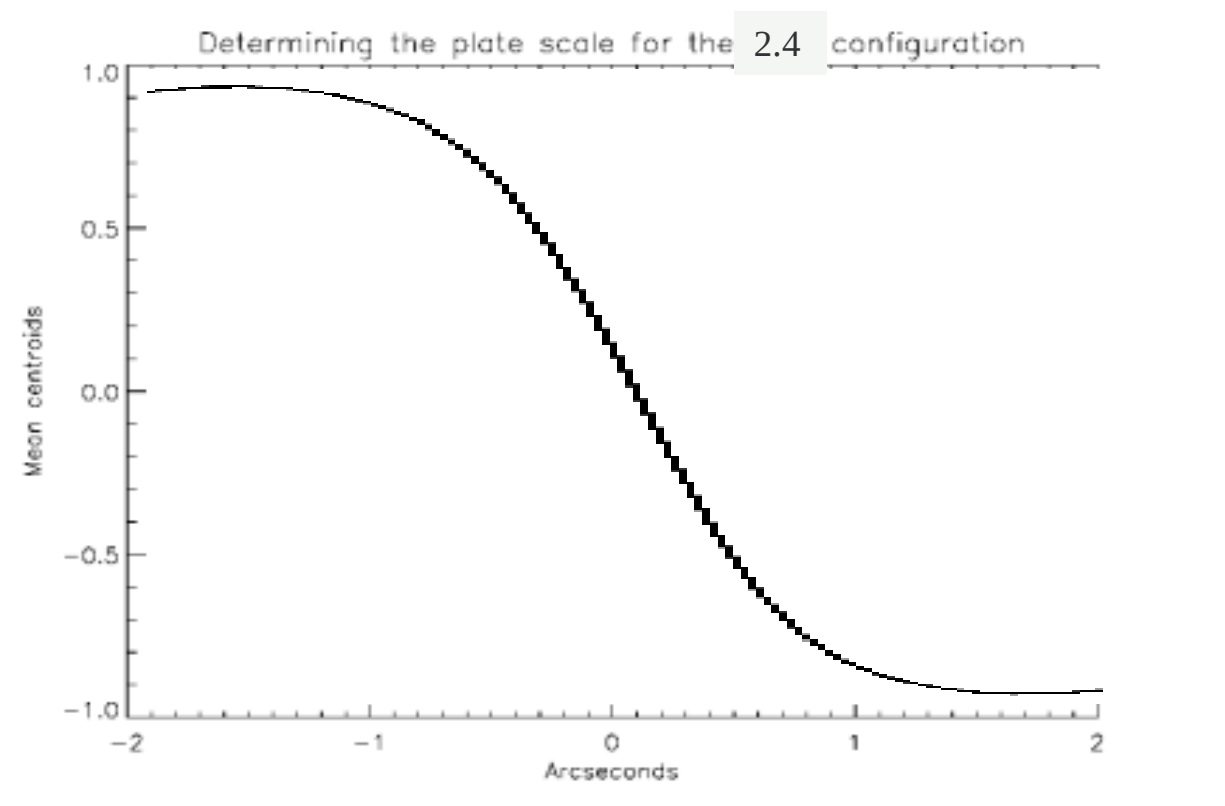


Plate scale

- The plate scales differ from the specifications.
  - 1.98” instead of 2.44” per pixel
  - 0.80” instead of 0.98” per pixel
  - 0.45” instead of 0.62” per pixel

- This is due to the effective focal length of the lenslets getting longer.
- The optimum distance to the CCD increases.
- There is defocus on the wave-front sensor when it is placed at its nominal focus.

- Suspect that the reducer optics defocuses and shifts the spots!

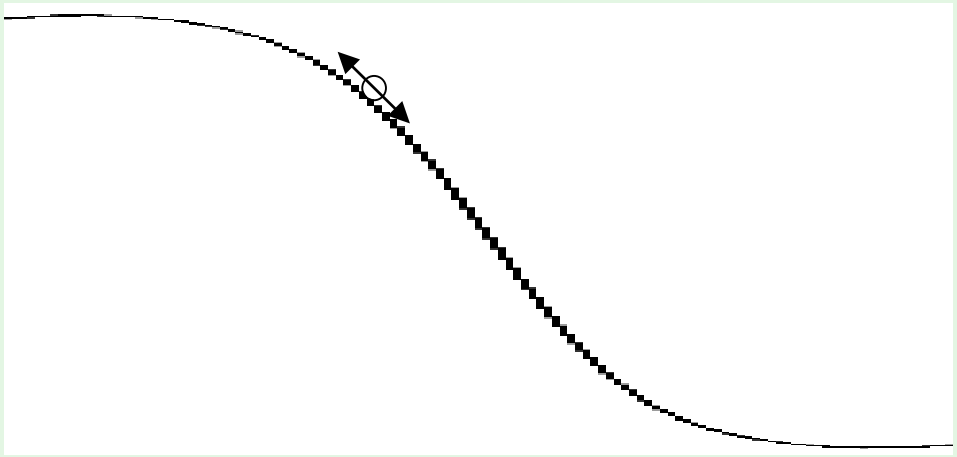
Optical quality of lenslets

- We would like the spots to be centered on the cross-hairs of the quad-cells.
  - Remove any DC slopes from the centroids
  - Remove focus by moving the wave-front sensor
- Any residual centroids are probably due to the lenslets.

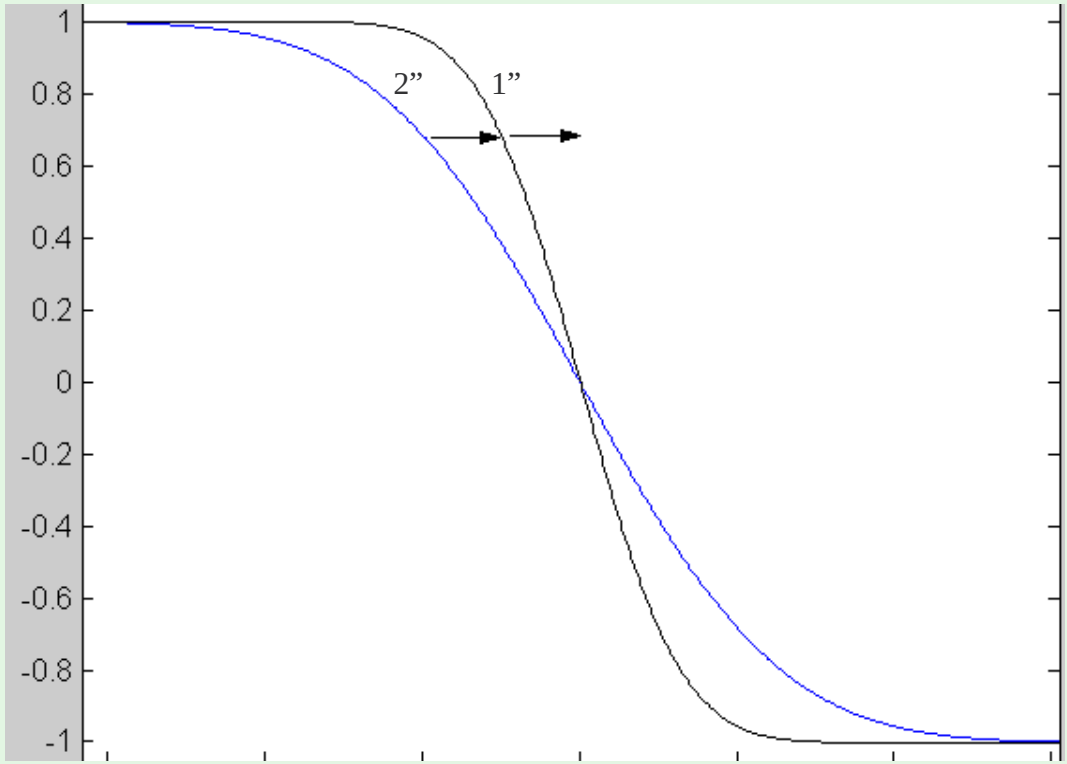
Lenslet		Min	Max	Std. dev.
0.6	X	-0.63	0.55	0.19
0.6	Y	-0.50	0.60	0.16
1.0	X	-0.32	0.55	0.13
1.0	Y	-0.52	0.50	0.13
2.4	**X**	**-0.32**	**0.29**	**0.12**
2.4	**Y**	**-0.21**	**0.26**	**0.09**

Effect of off-centered spots

- Spots are off center because of the lenslets and non-common-path aberrations.
- Results is operating in the different part of the transfer curve.

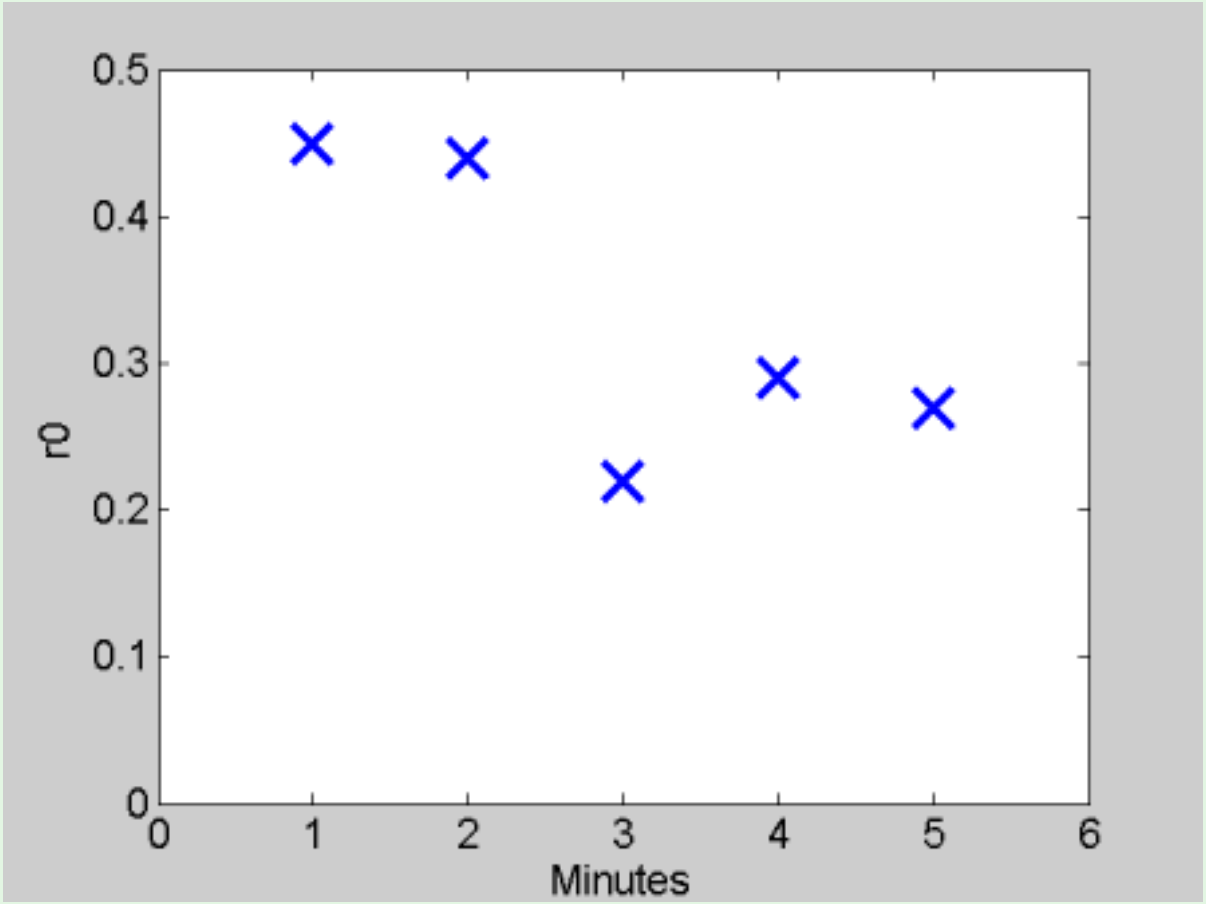


- If spot size doubles due to turbulence,
  - wave-front slope estimates are doubled
  - all the non-common path aberrations and lenslet registration errors are passed through the AO system



- If the spots are made big, there is a decrease in signal-to-noise ratio.

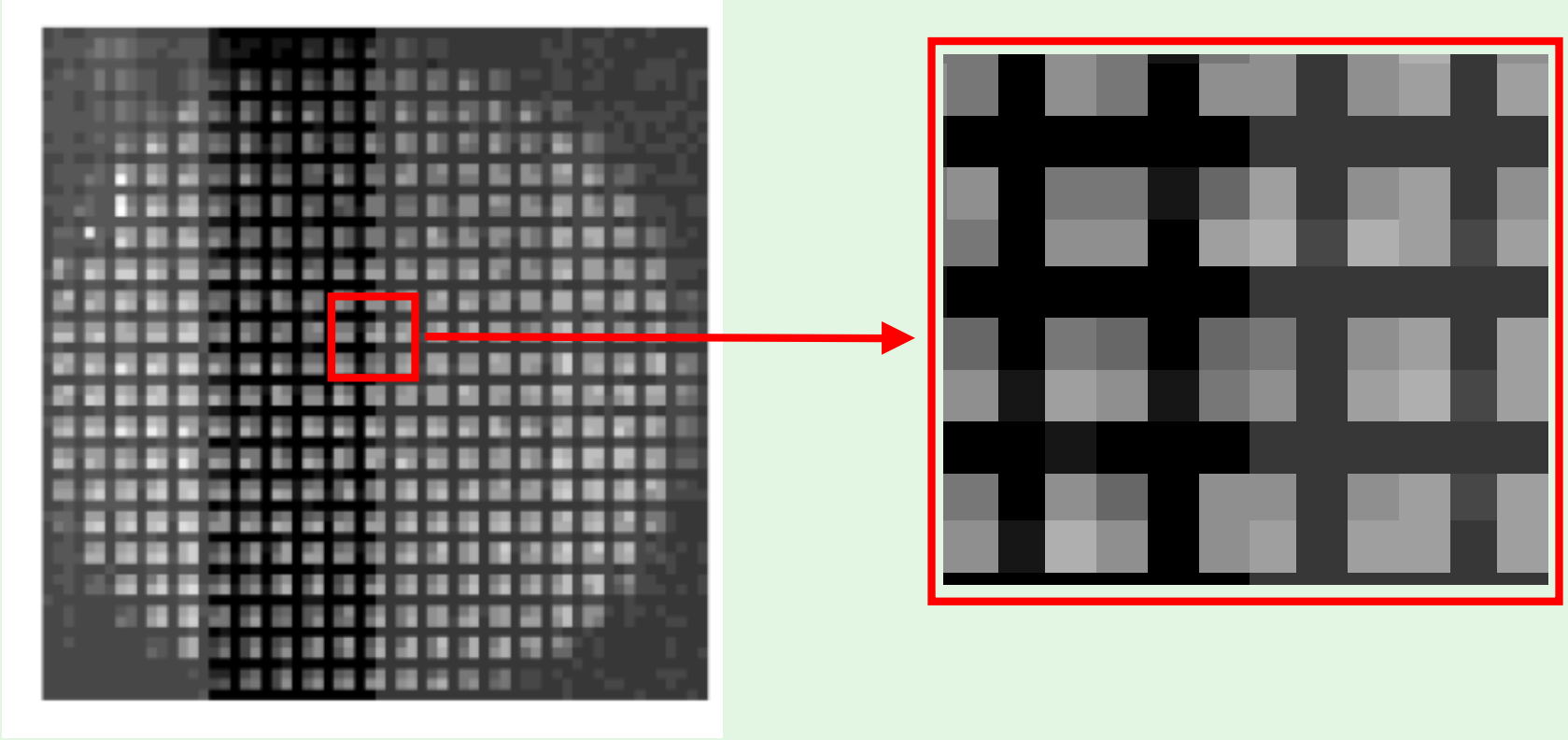
- Introduces error if the spot size changes. The spot size changes on every time scale!
- This is a consequence of turbulence being fractal in nature.



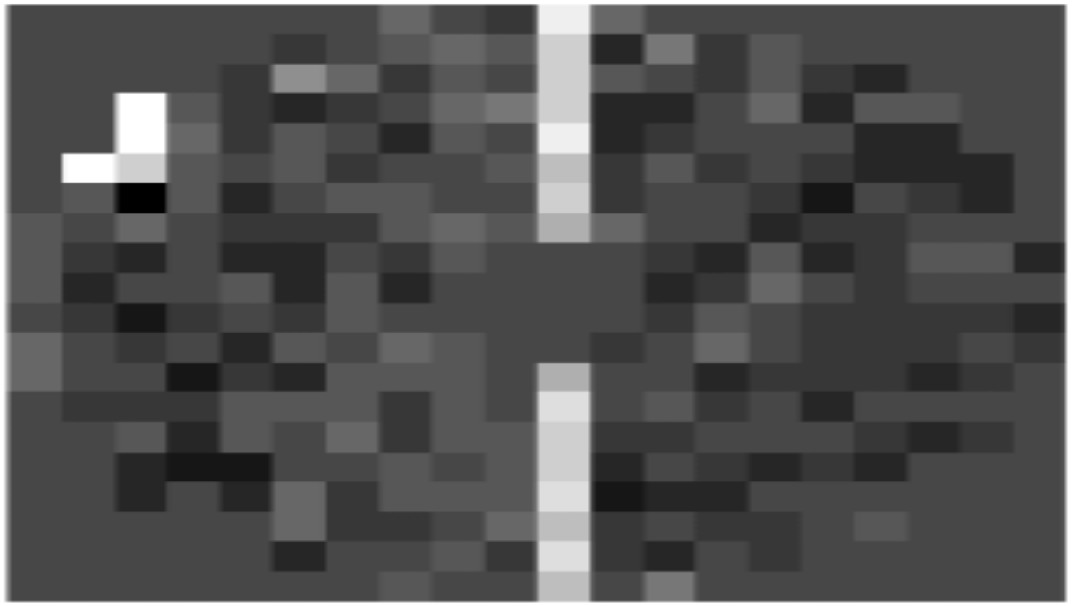
Courtesy M. Schoeck

Amplifier gains

- The CCD has four image amplifiers.



- This leads to differences between the centroids at low and high photon counts



Difference in centroids with no turbulence

- Which results in artefacts in the images.