

# 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

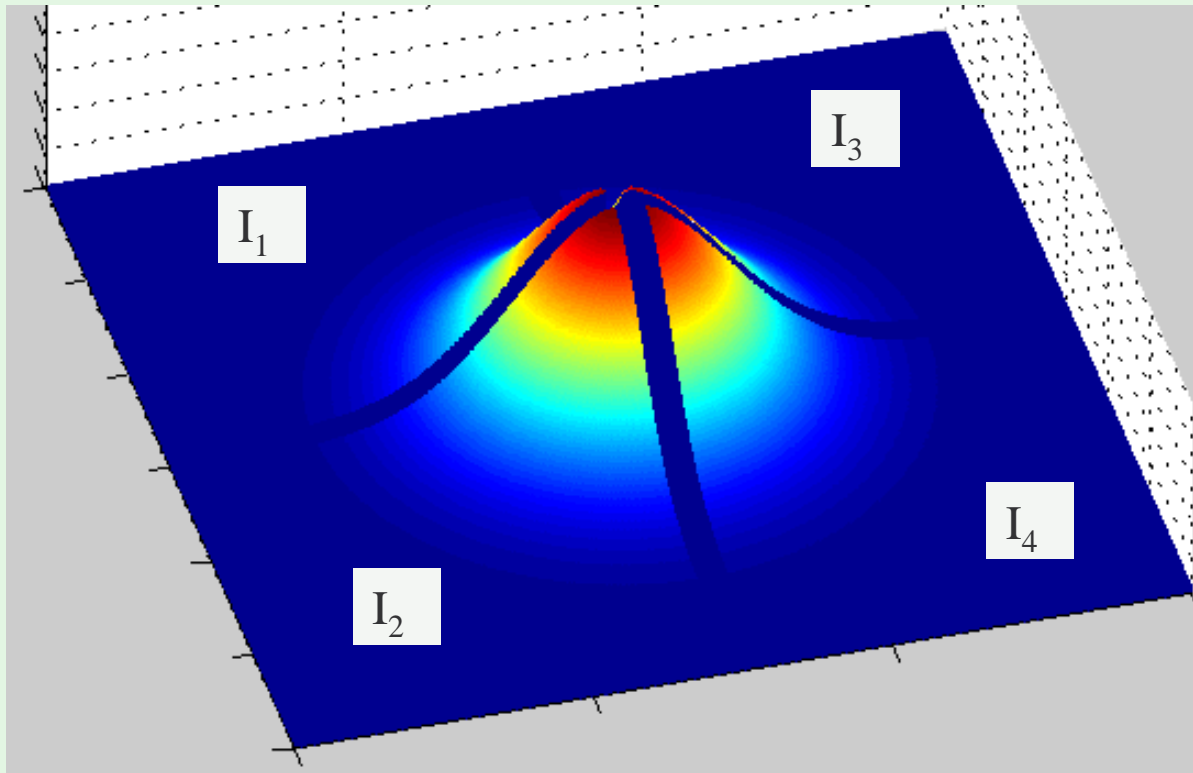
# Why AO characterization?

- ☞ 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  $2 \times 2$  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.

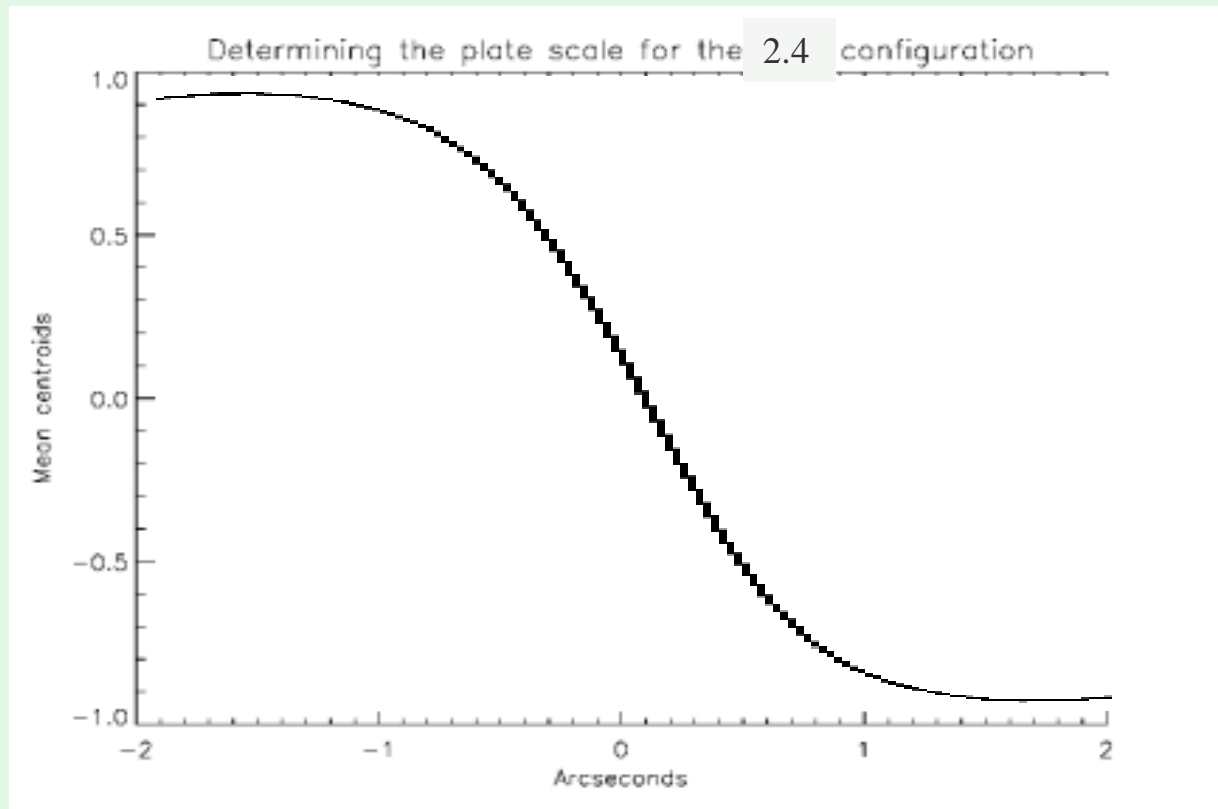
☞ Spot sizes

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.
- B** Suspect that the reducer optics defocuses and shifts the spots!

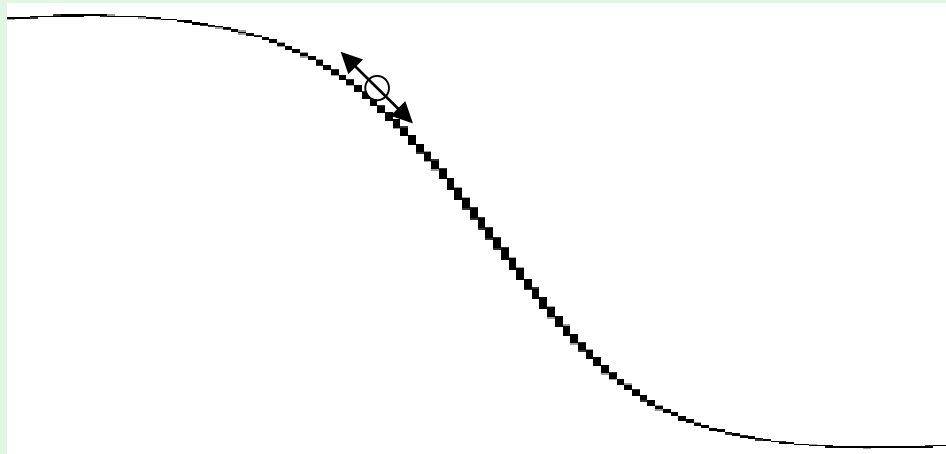
# Optical quality of lenslets

- ☞ 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
<b>2.4</b>	<b>X</b>	<b>-0.32</b>	<b>0.29</b>	<b>0.12</b>
<b>2.4</b>	<b>Y</b>	<b>-0.21</b>	<b>0.26</b>	<b>0.09</b>

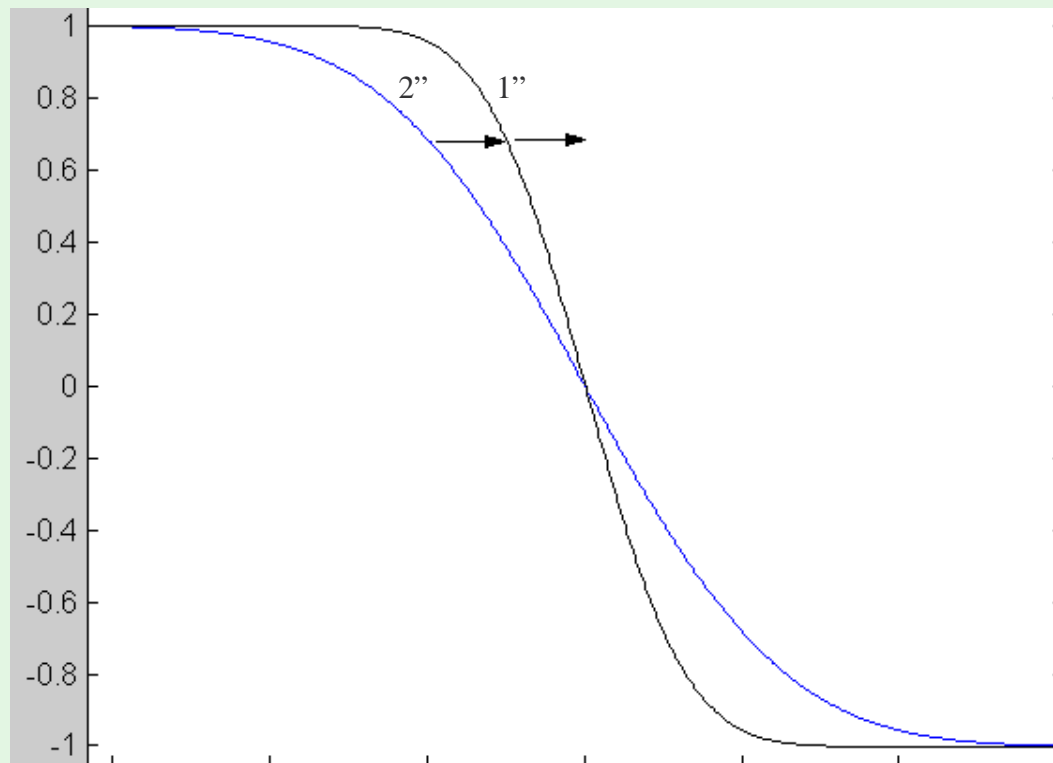
# Effect of off-centered spots

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



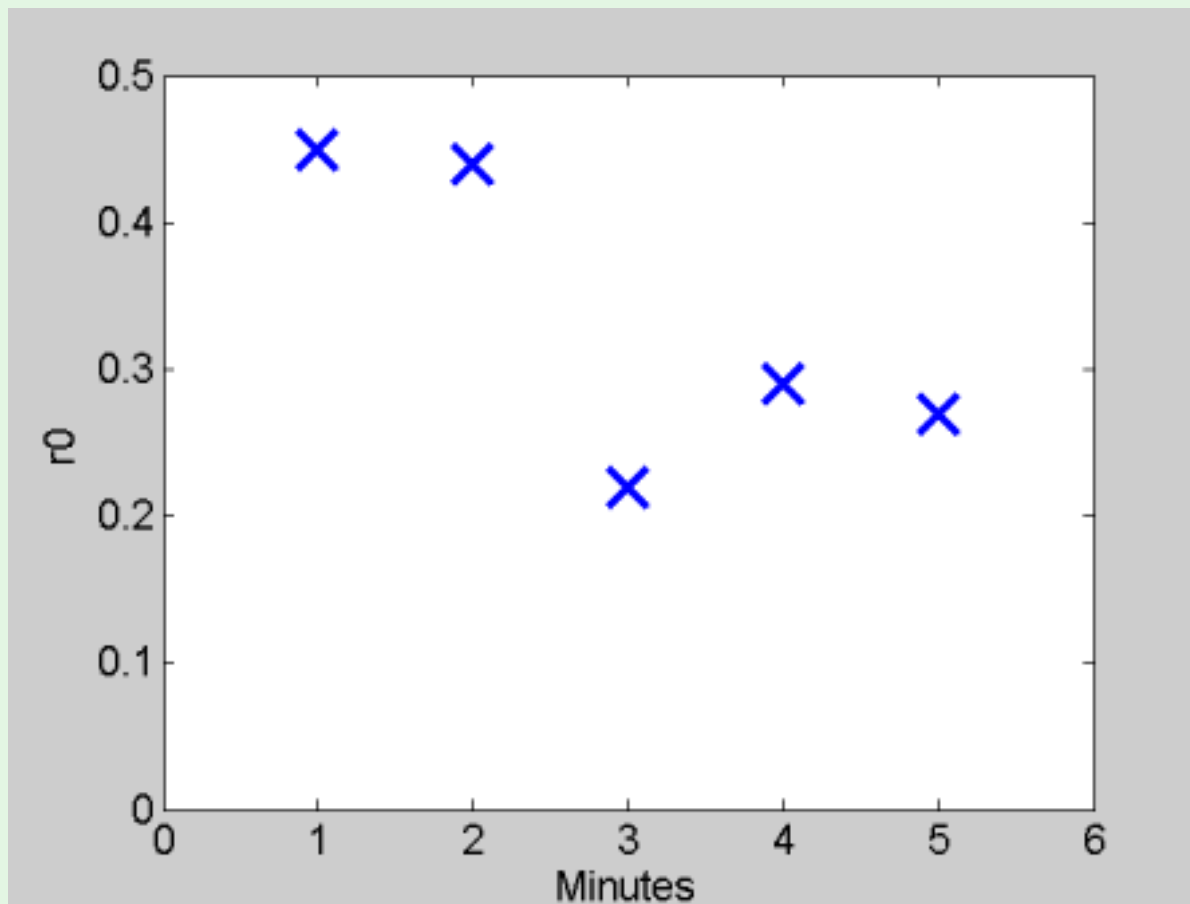
☞ If spot size doubles due to turbulence,

- 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.

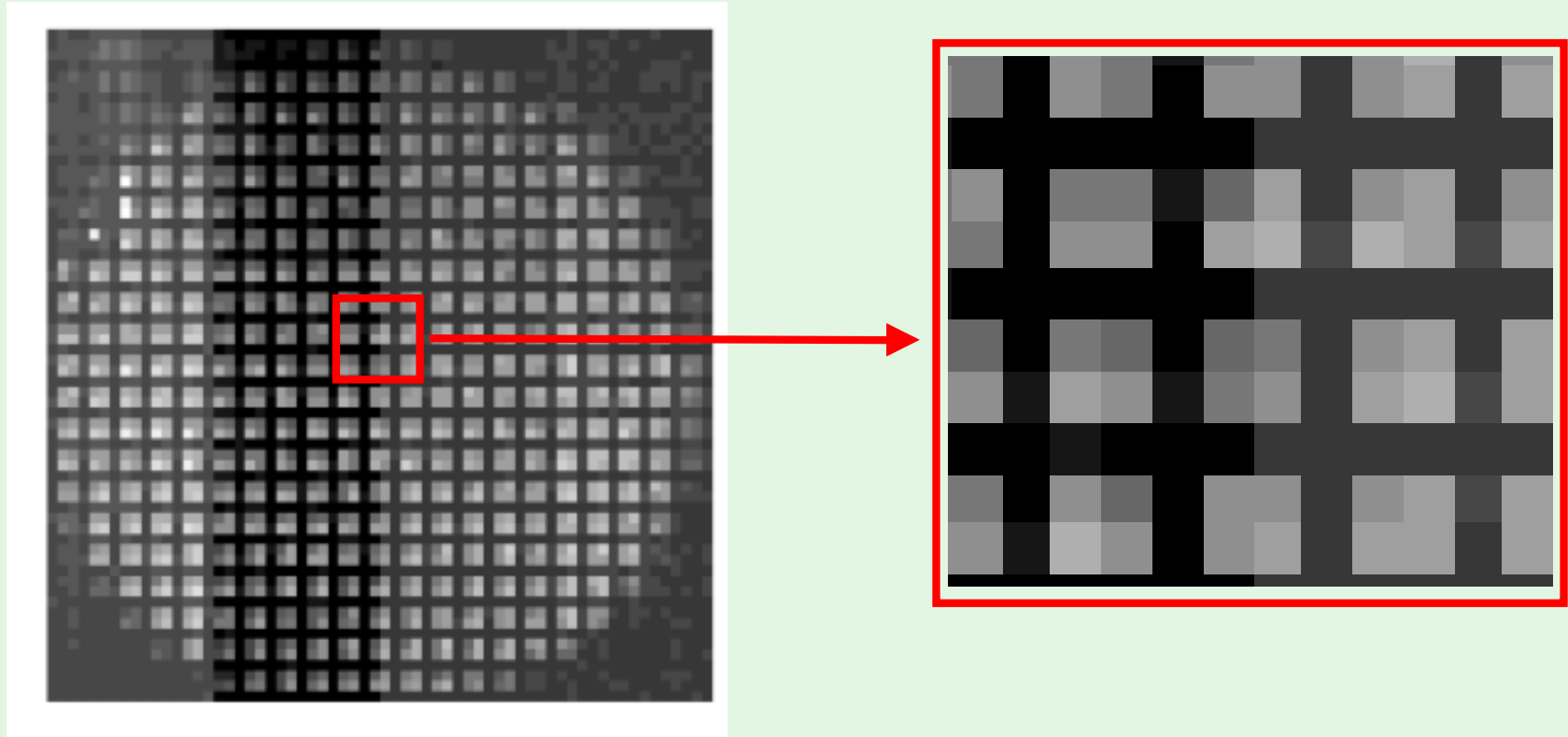
- ☞ Introduces error if the spot size changes. The spot size changes on every time scale!
- ☞ This is a consequence of turbulence being fractal in nature.



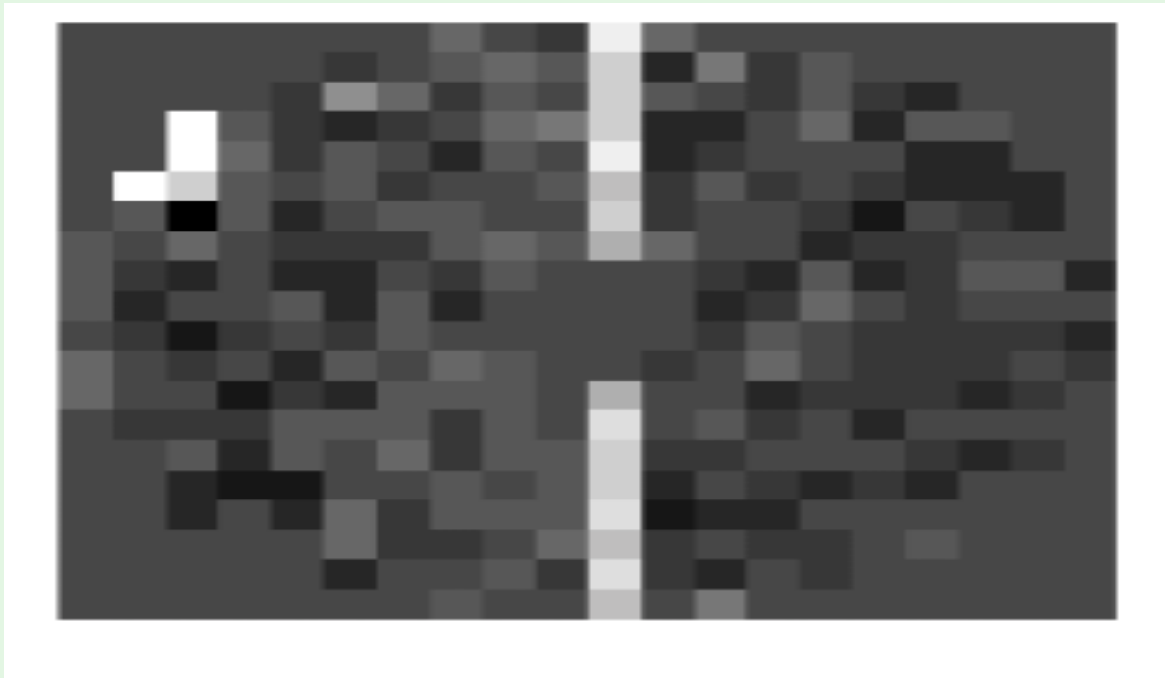
Courtesy M. Schoeck

# 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.

