

# 2D point spread function characterization for Prime Focus Spectrograph

N. Caplar, J. Meyers, R. Lupton, J. Gunn, PFS collaboration



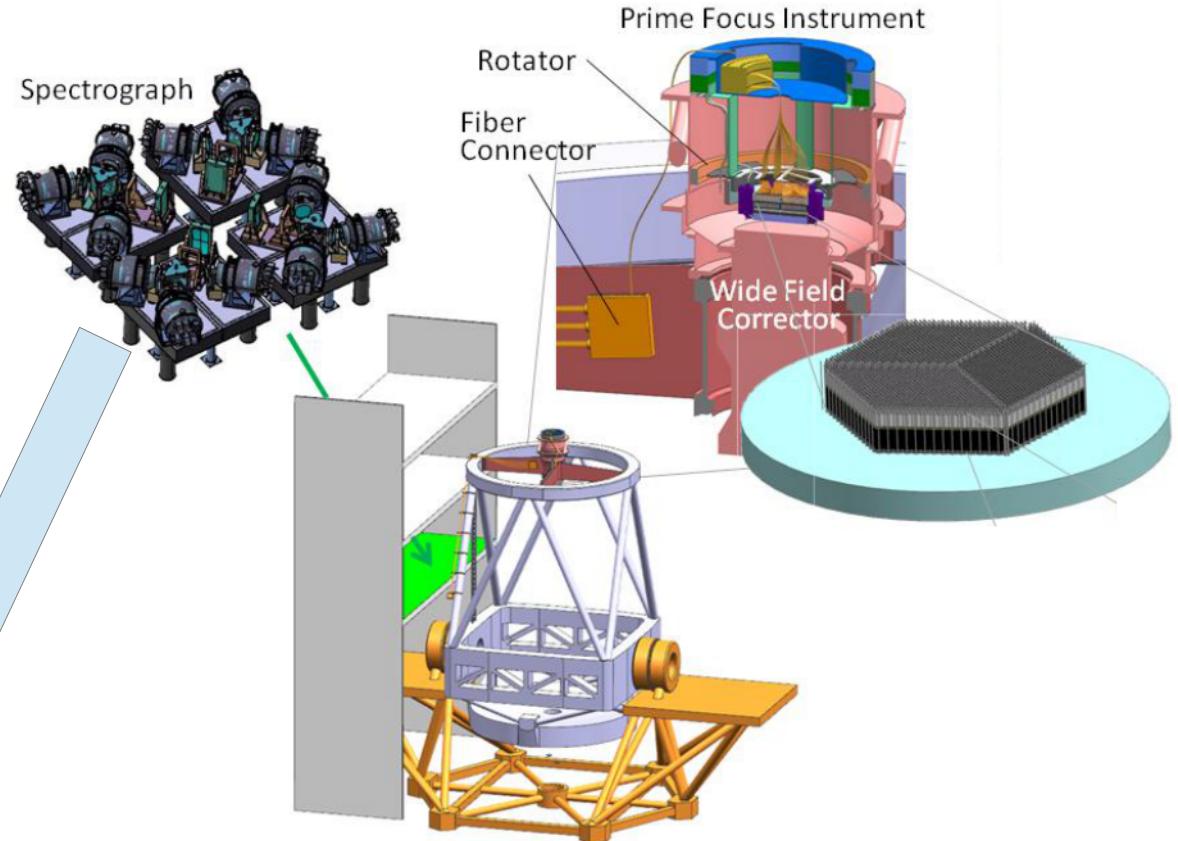
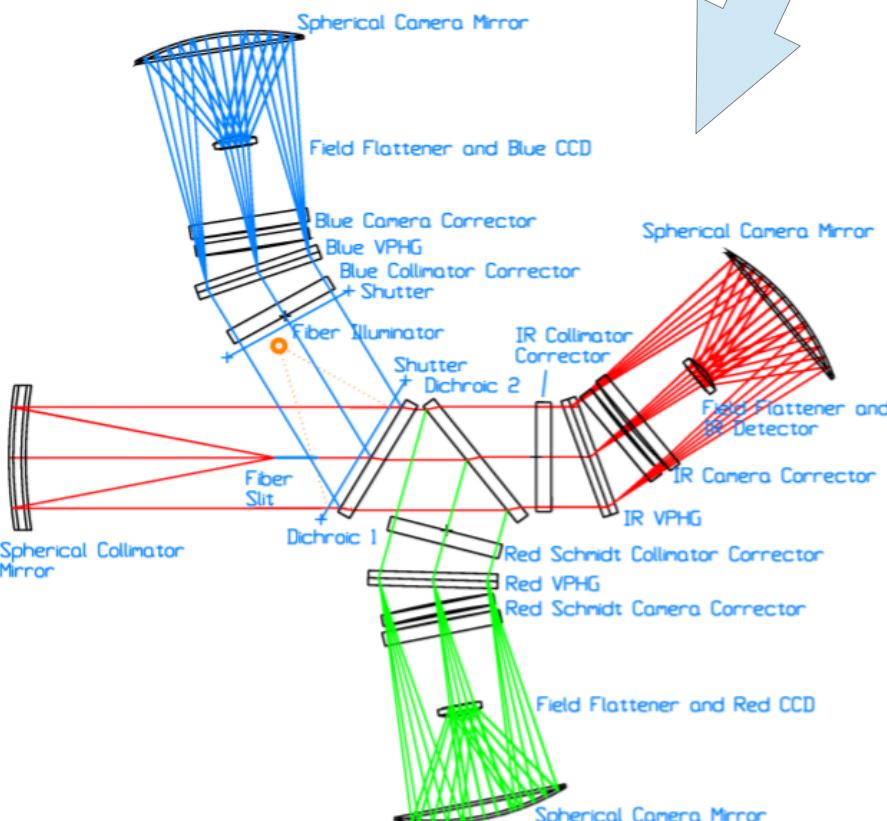
PRINCETON  
UNIVERSITY



To be installed on Subaru telescope

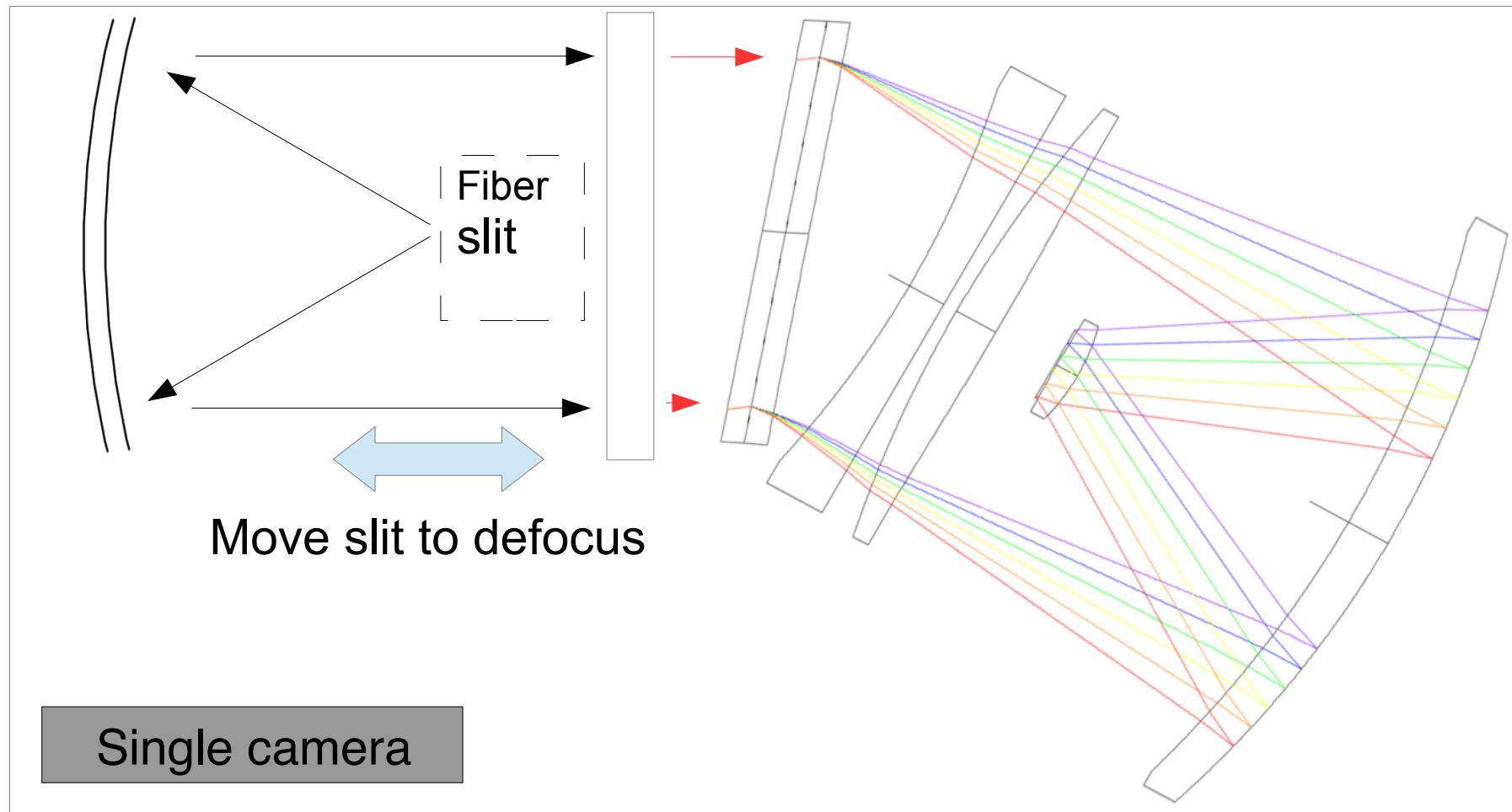
Science drivers are:

- cosmology
- galactic archeology
- galaxy/AGN evolution



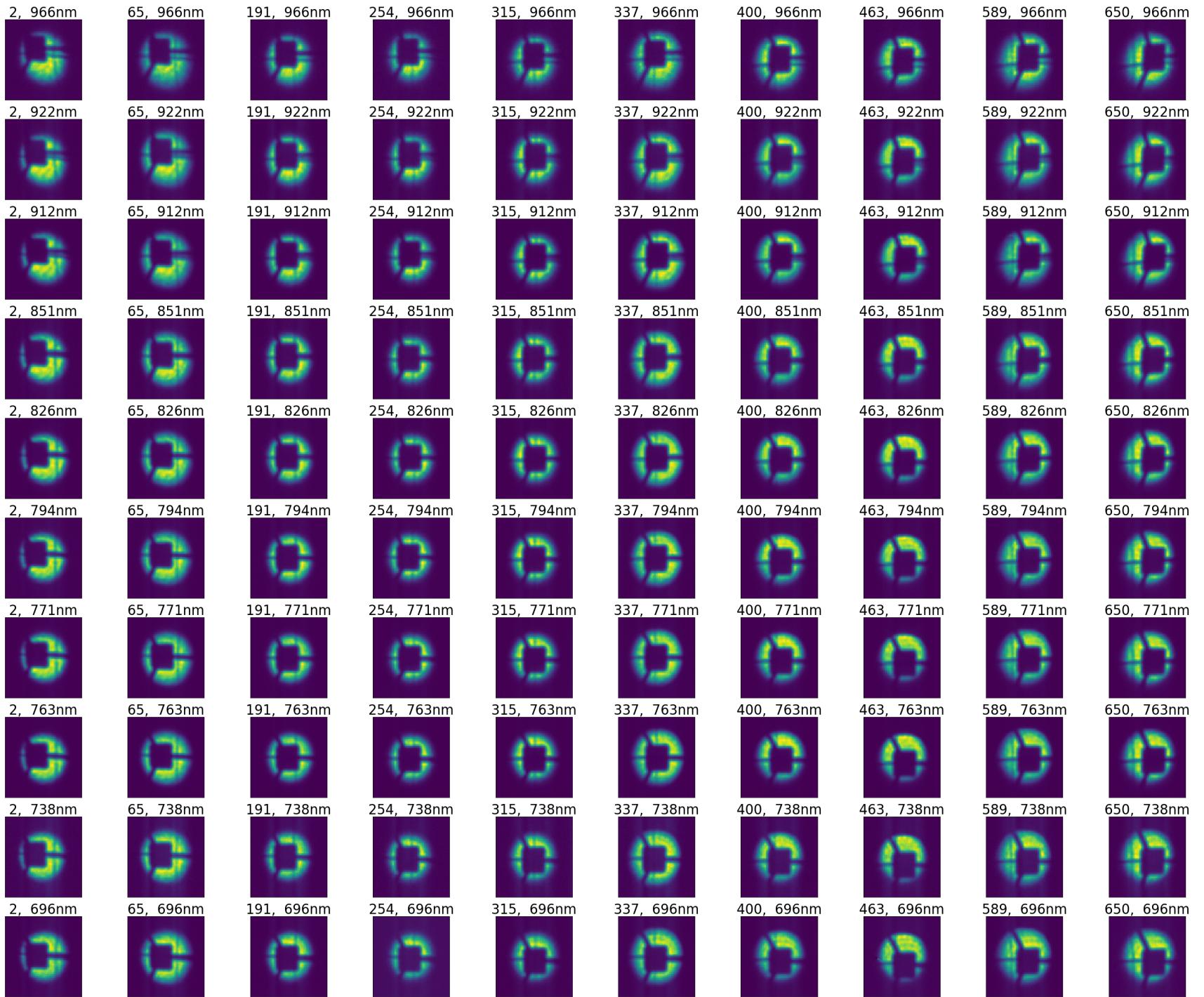
- Commissioning start: 2019
- Fiber spectrograph (2400 fibers)
- Wavelength range: 0.38 to 1.28  $\mu\text{m}$

- 3 components to the PSF
- Telescope pupil illumination
  - Focal ratio degradation in the fibres
  - Spectrograph cameras



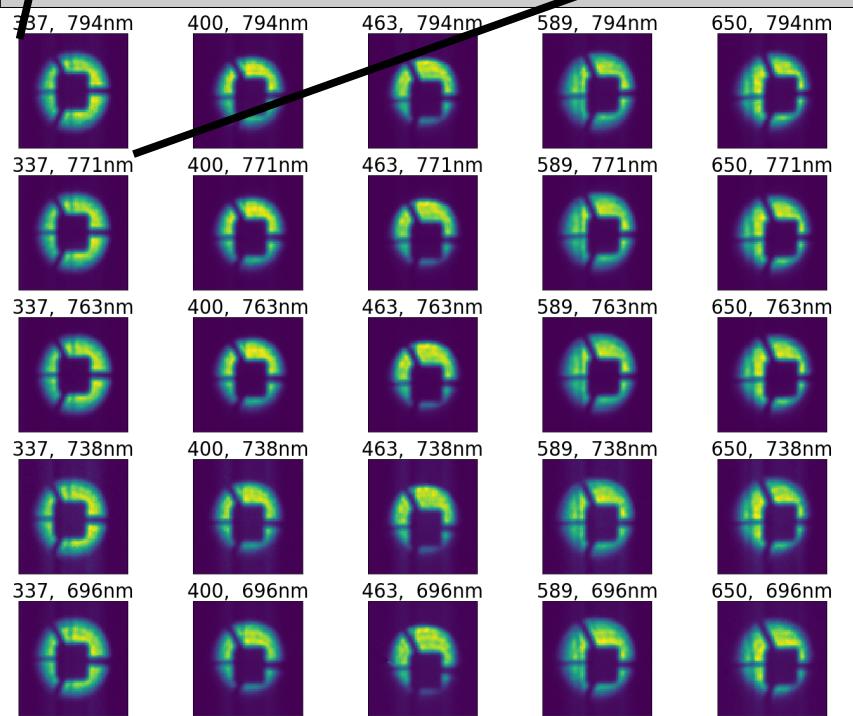
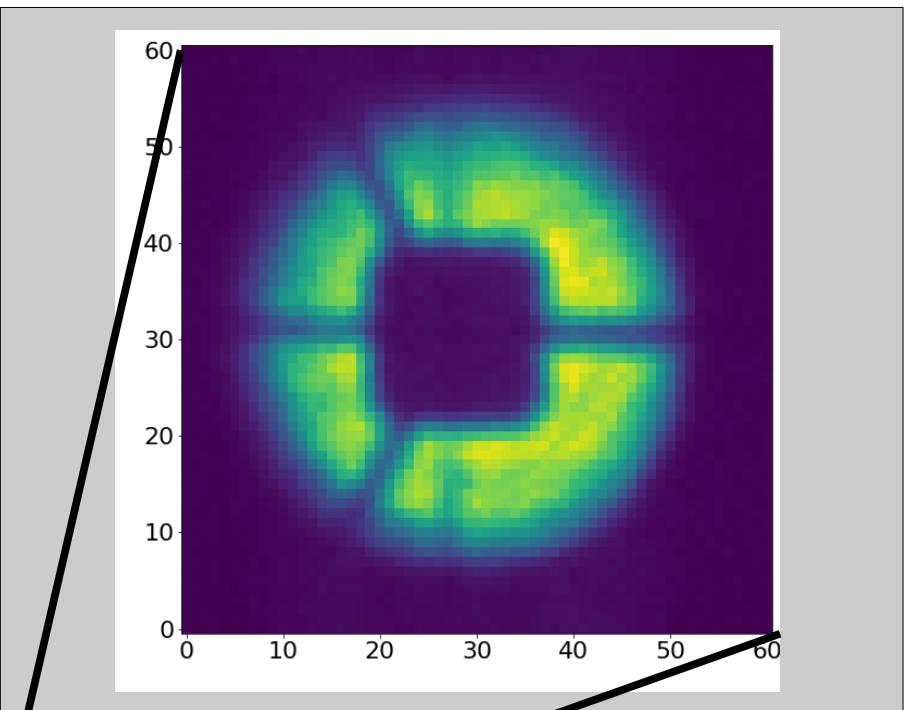
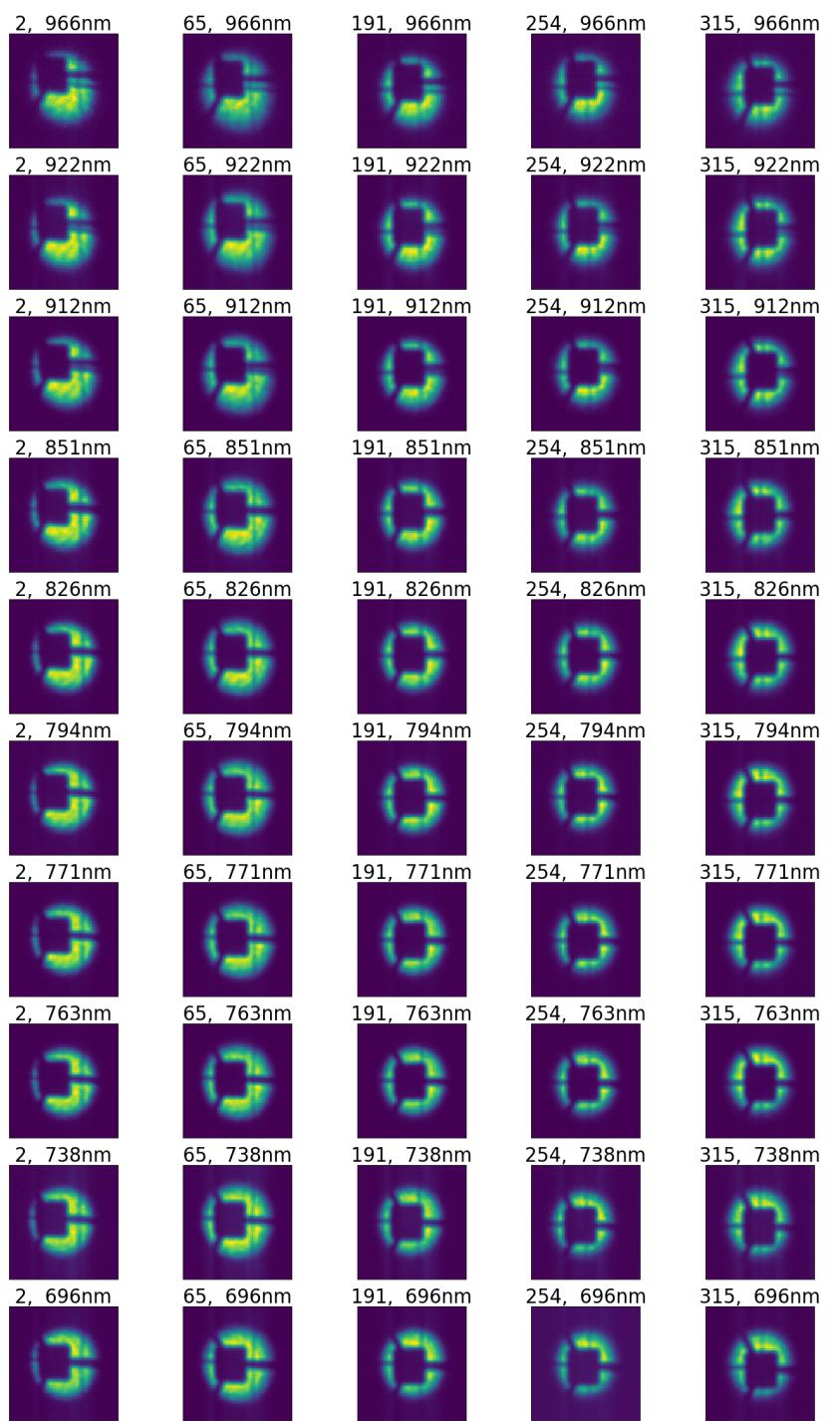
- Separate these 3 components (vignetting, fibers & camera) causing aberrations in the PSF by working in wavefront space
- We aim to characterize contribution of camera imperfections to PSF by modelling optical performance using defocussed data
- Data taken from the first assembled camera at Laboratoire d'Astrophysique de Marseille
- Let's look at it!

Wavelength

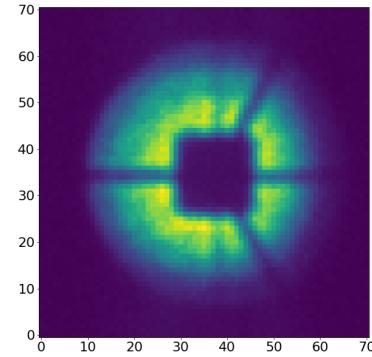


Different fibers

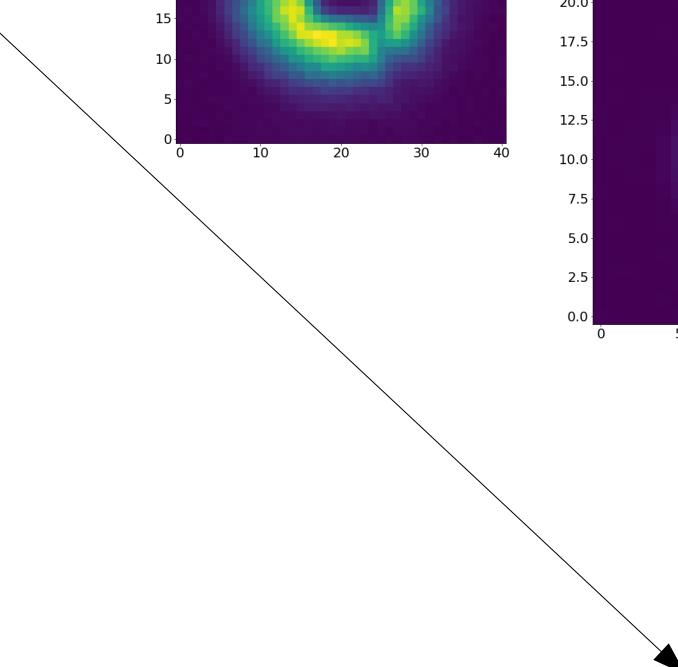
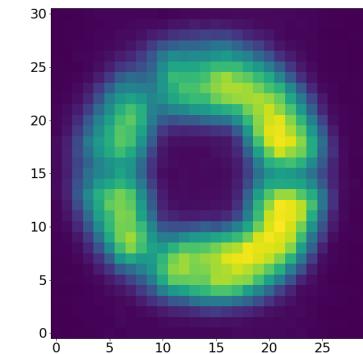
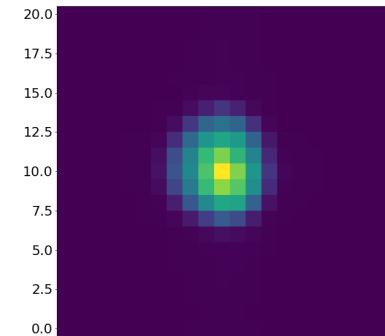
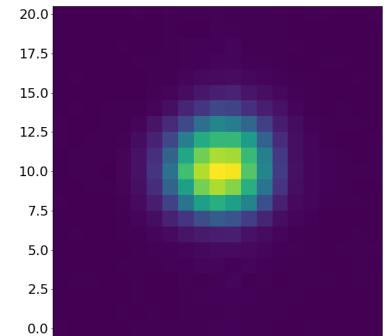
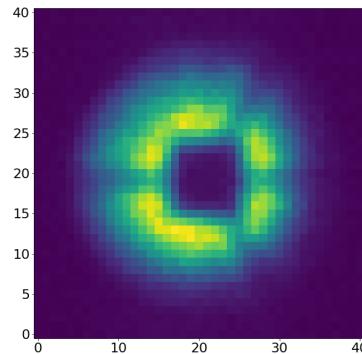
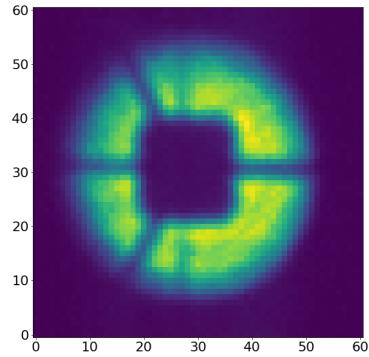
Wavelength



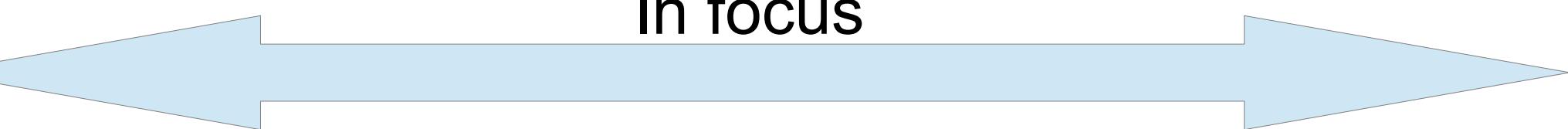
Different fibers



- We have even more information!
- We have taken images at different values of defocus
- Follow wavefront aberrations as a function of defocus



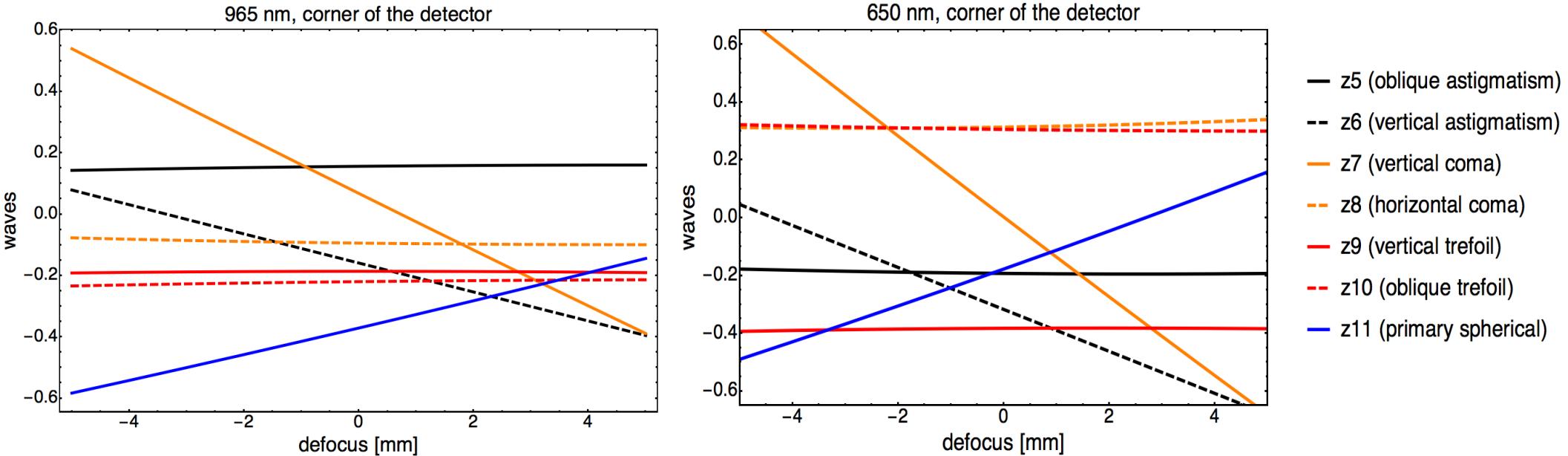
More defocused



In focus

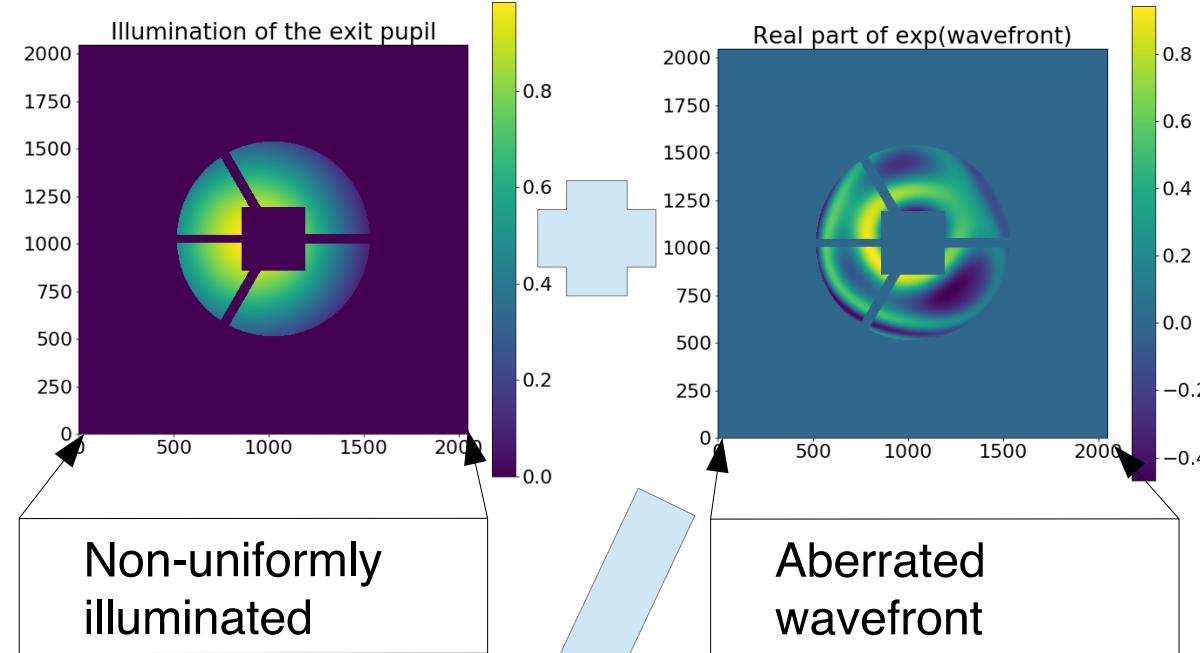
More defocused





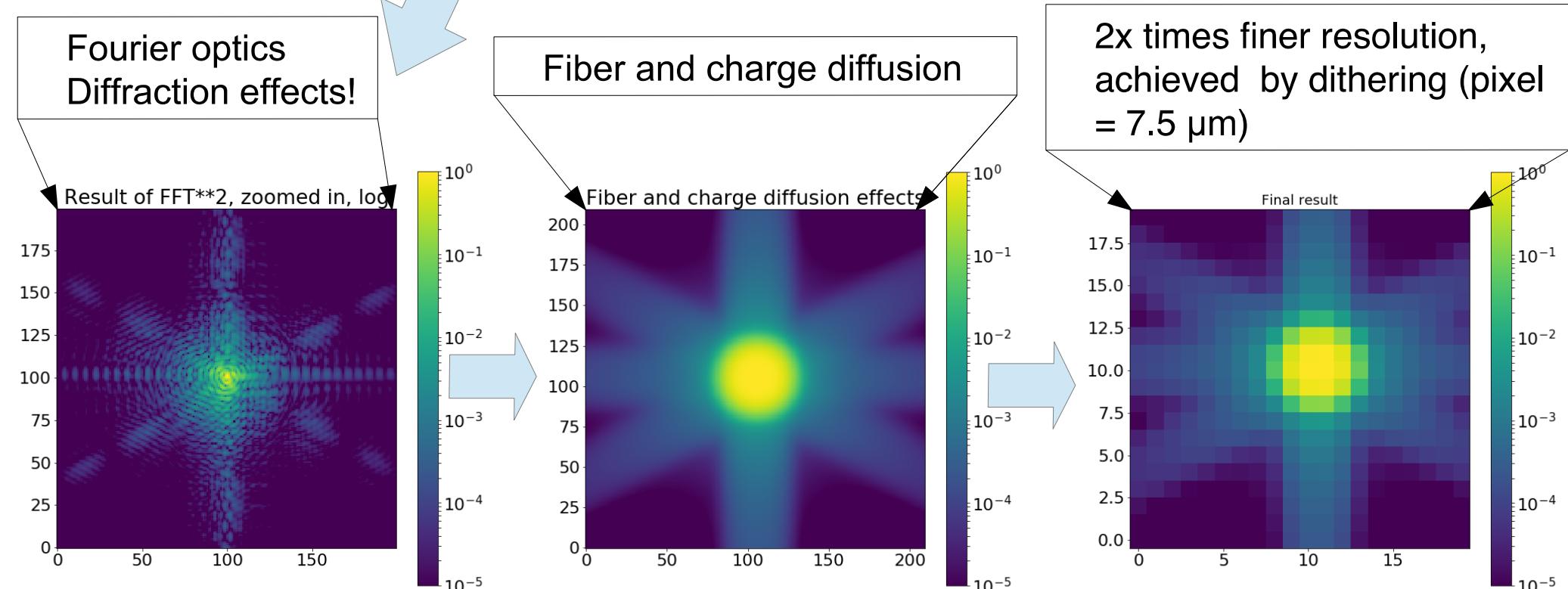
## Example from Zemax modelling

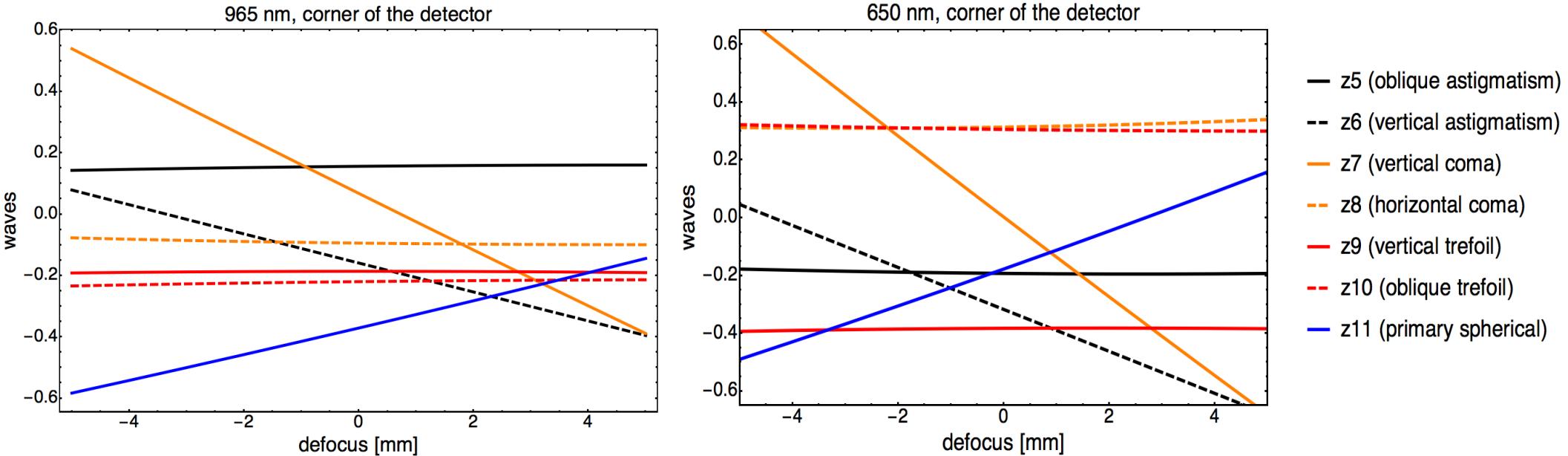
- We wish to deduce/reproduce these curves from the data
- Model wavefront aberrations at each position in the detector



We have been developing a model to simulate PSF based on our experience in HSC project

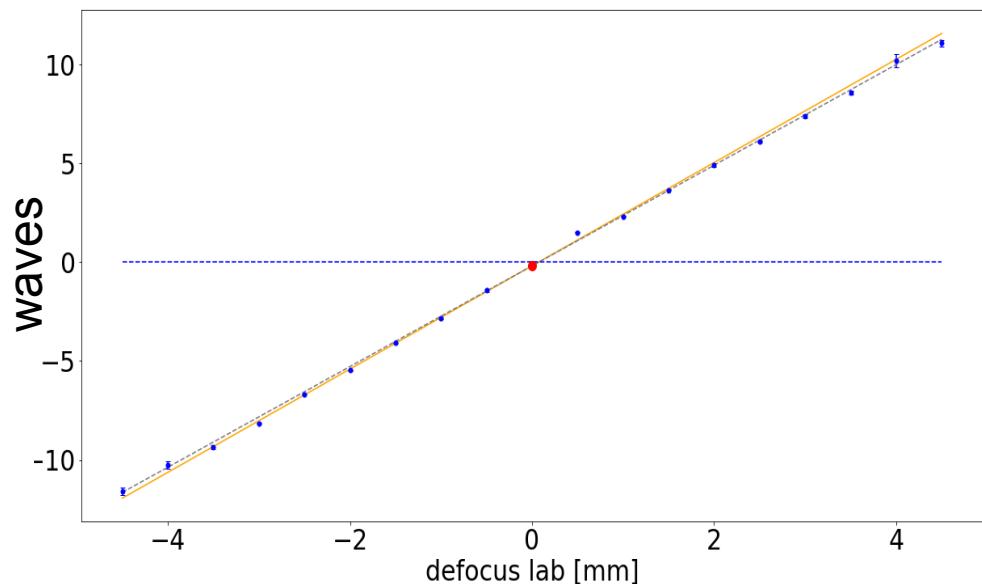
- Non-uniform illumination of the pupil
- Wavefront aberrations
- Fourier optics
- Finite size of fiber
- Charge diffusion



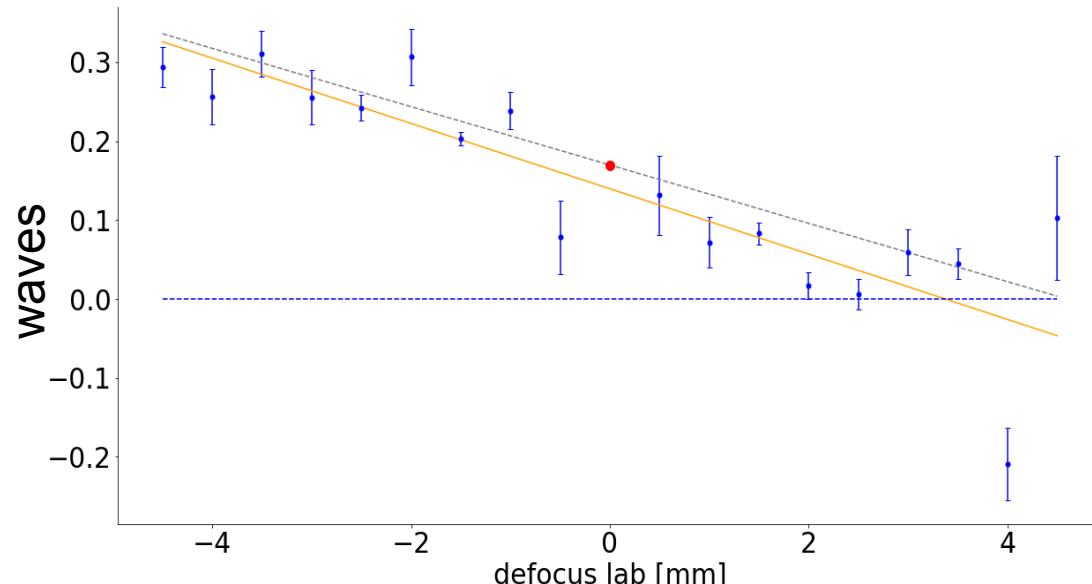


Example from early modelling of the experimental data below  
(not the same spot and Zernike coefficients as above!)

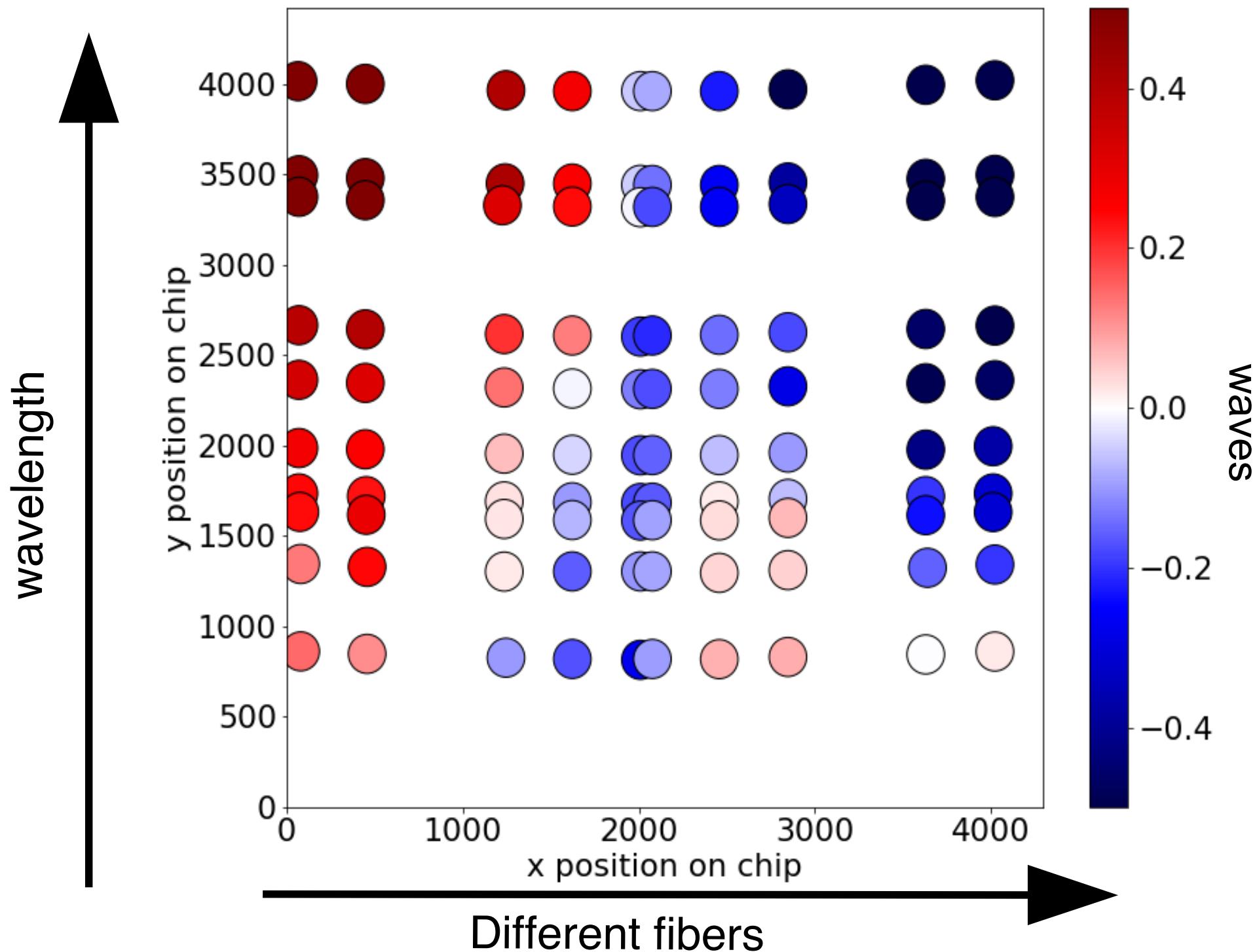
Z4 - defocus

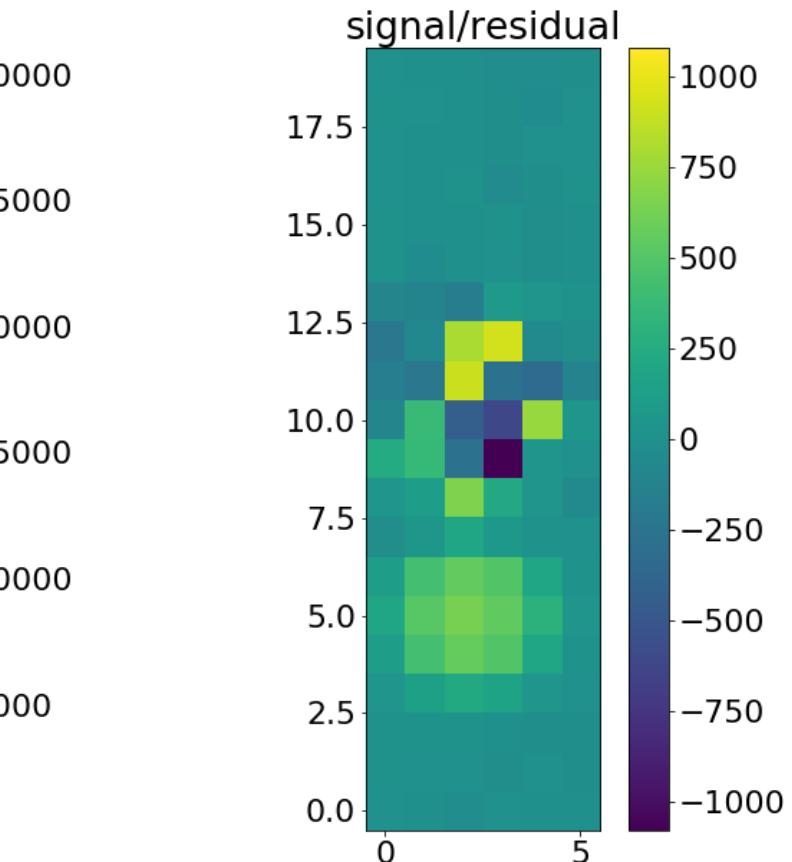
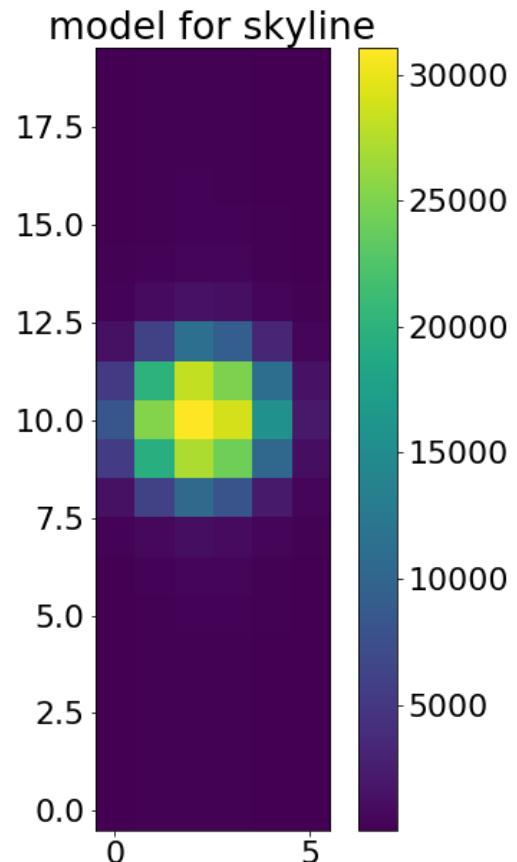
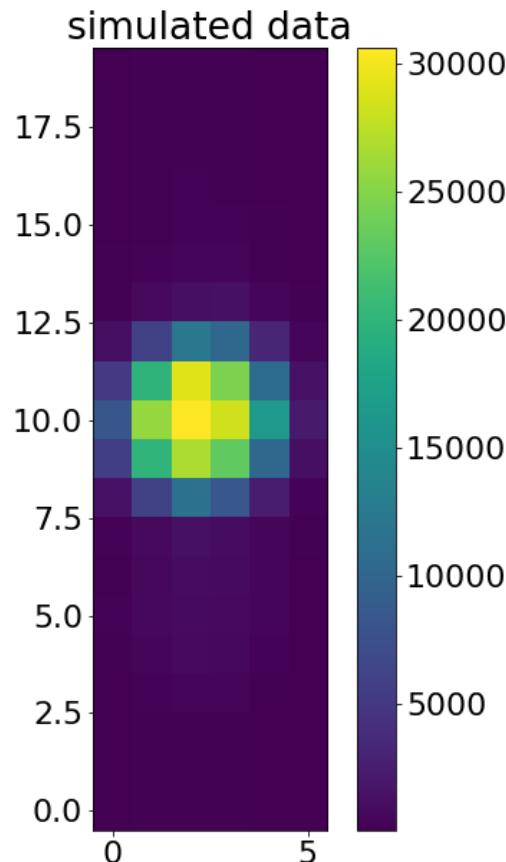


Z8 – horizontal coma



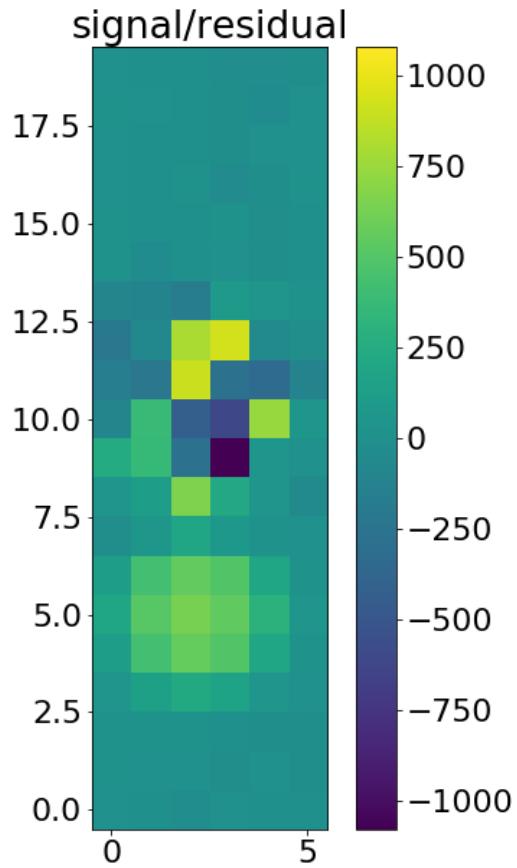
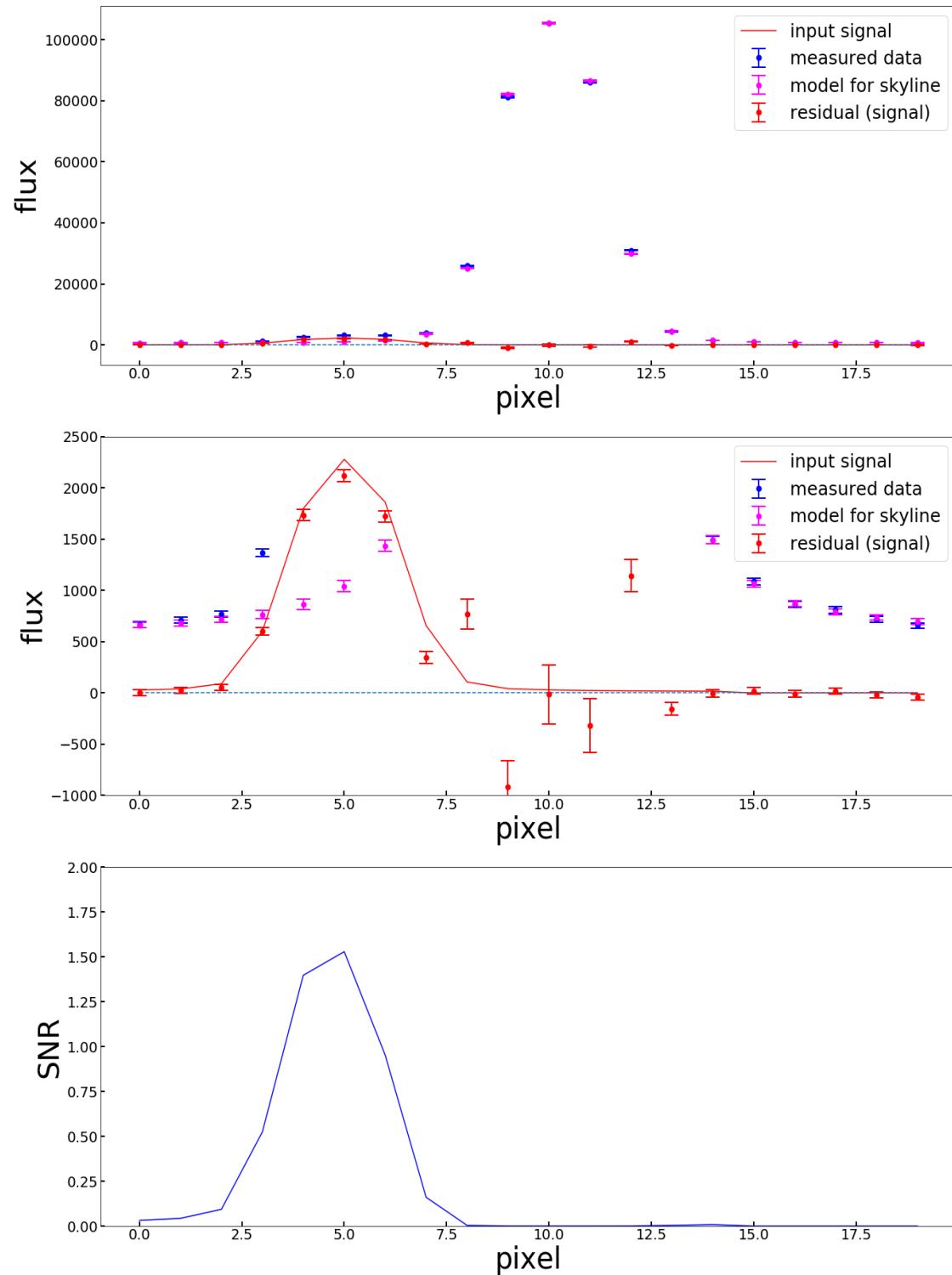
# Example: Z5 – oblique astigmatism





**Example of the desired behaviour:**

- Modelled the skyline
- Subtract by the model
- Proceed with "optimal extraction" or similar 1D technique



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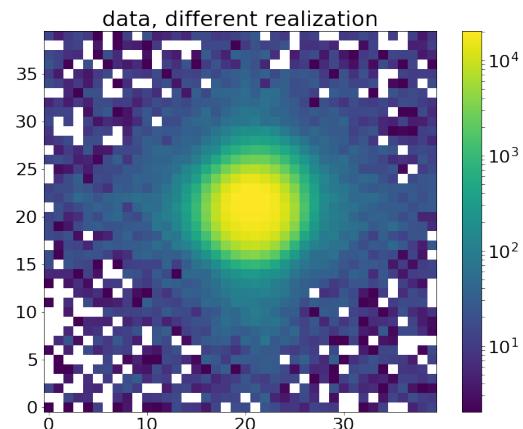
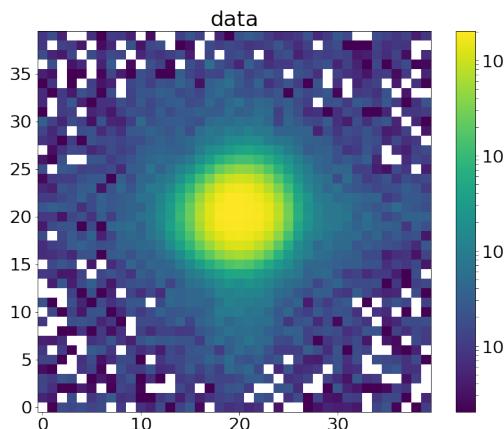
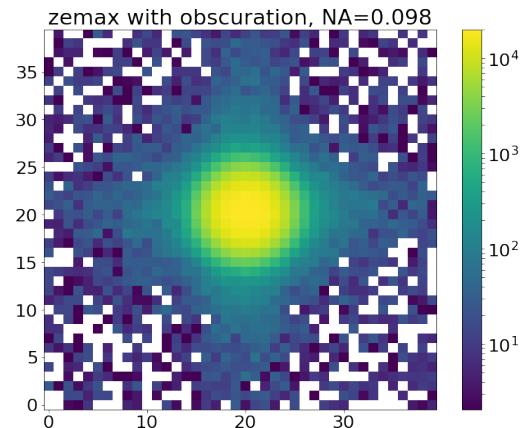
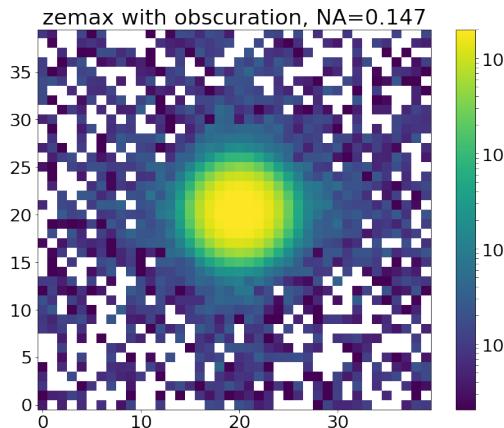
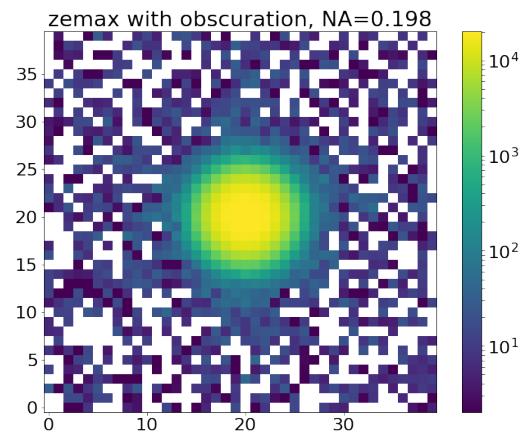
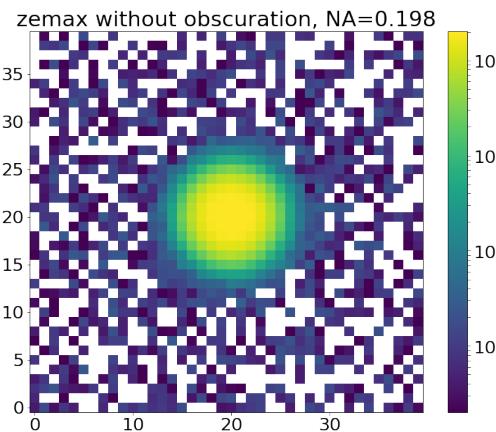
# Where are we now; what am I thinking about

2 main issues at the moment:

- Stronger wings of the PSF than expected
- For some wavelengths, even stronger vertical component of the PSF

Diffraction effects are stronger than expected:

- Non-uniform illumination?
- Effective numerical aperture is smaller?



# Where are we now; what am I thinking about

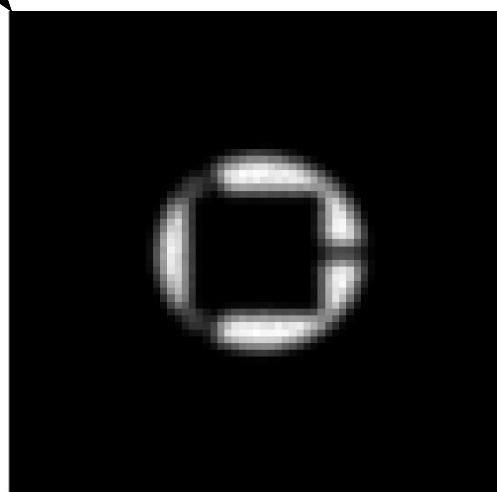
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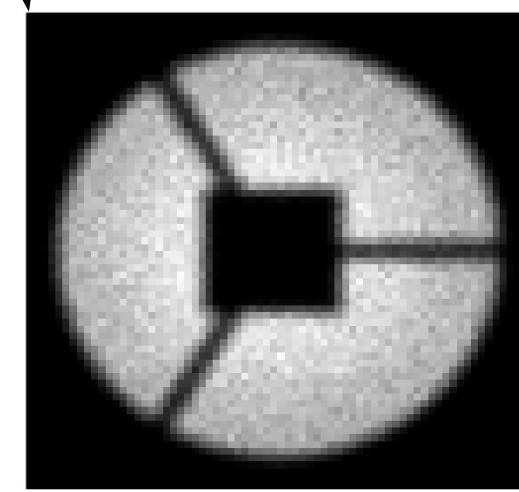
Diffraction effects are stronger than expected:

- Non-uniform illumination?
- Effective numerical aperture is smaller?
- Unlikely, given the defocused image analysis...

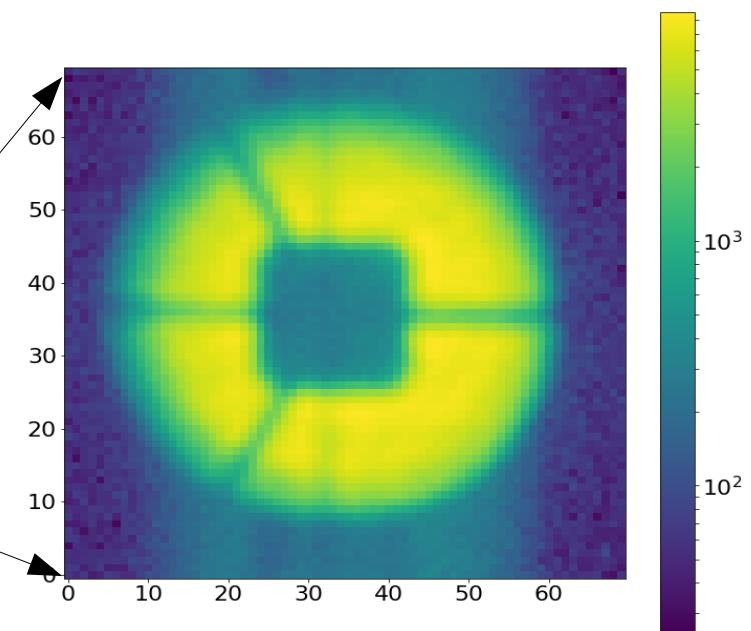
Defocused image that creates enough wings in focused data



Expected defocused image



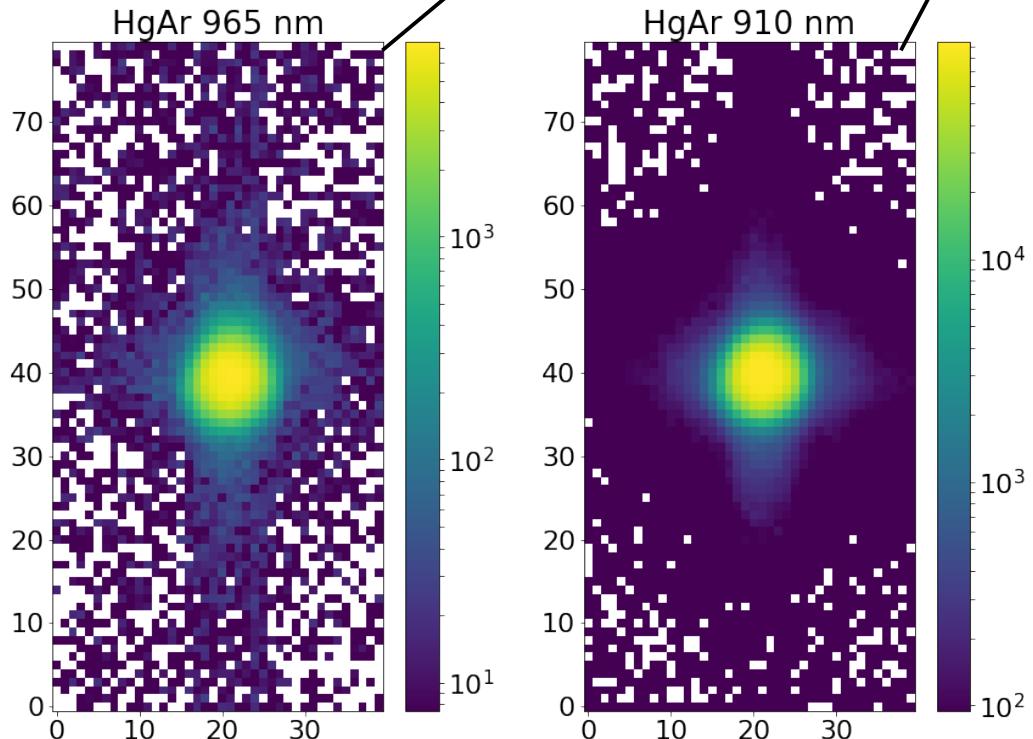
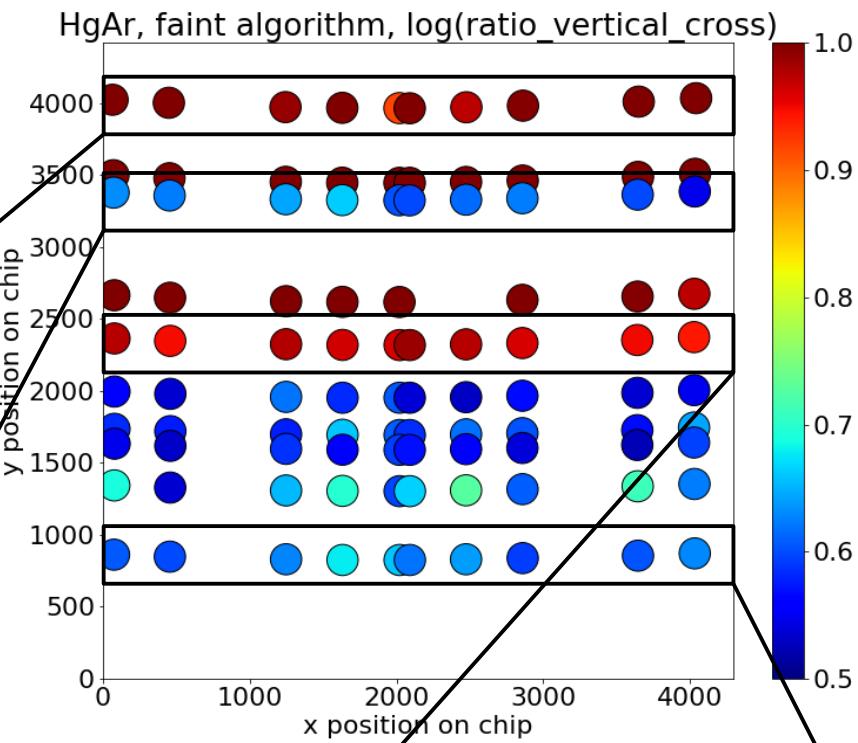
Actual data



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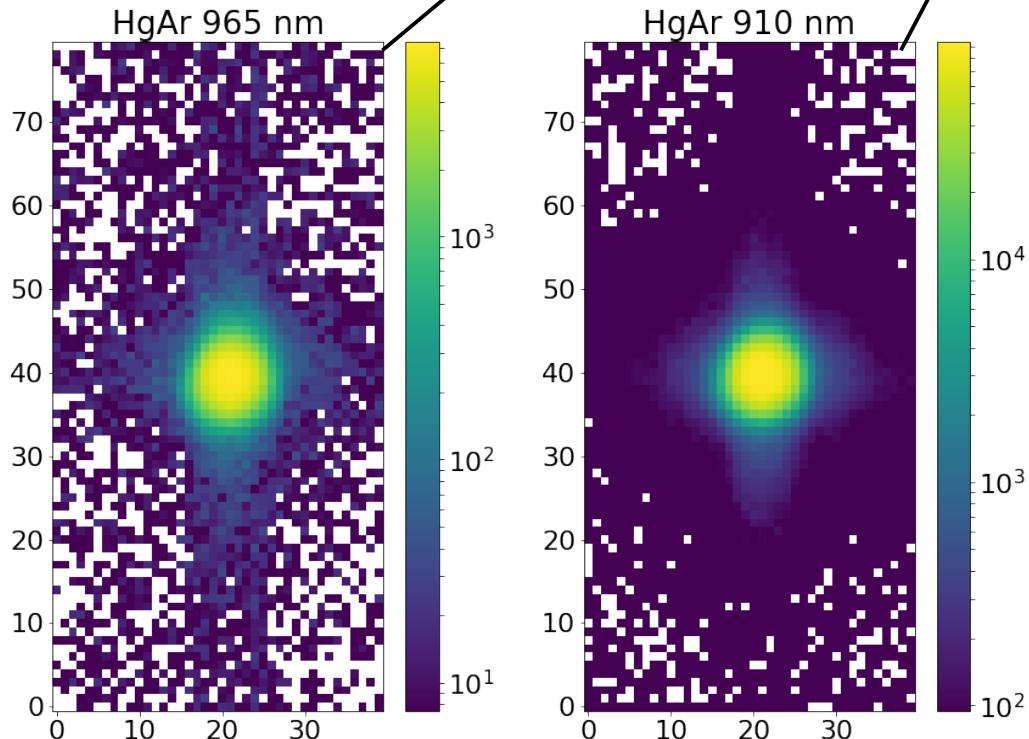
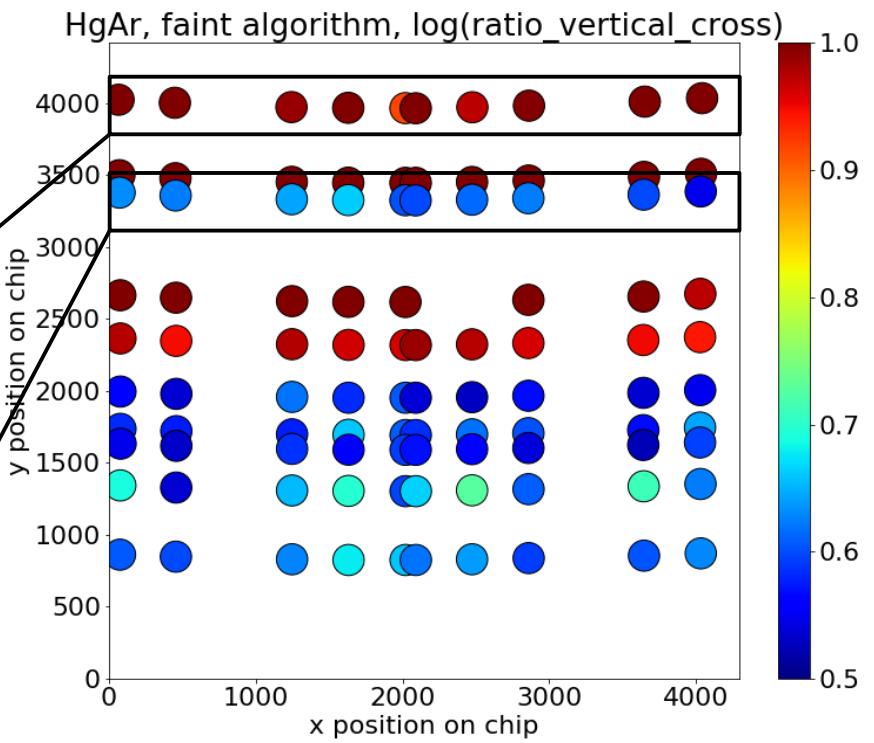
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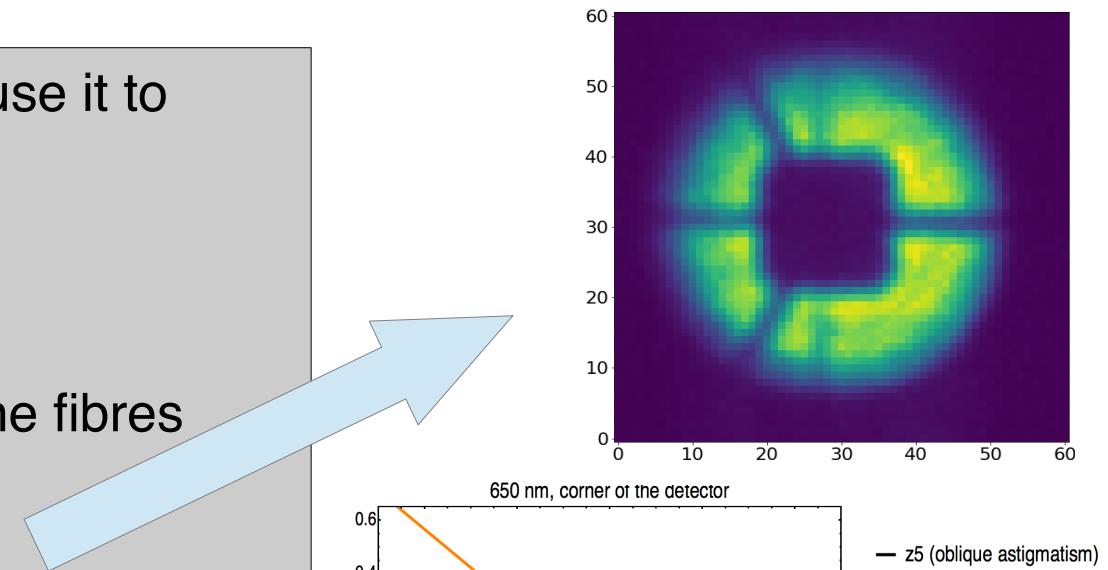


Most probable solutions for these issues:

- Incompetent Post-doc has wrongly modelled something and underestimated diffraction effects
- Extra power in the vertical wings due to grating

# Summary

- We want to predict PSF and use it to subtract wings of the skylines
- 3 components to the PSF
  - Telescope pupil illumination
  - Focal ratio degradation in the fibres
  - Spectrograph cameras
- Characterize contribution of camera imperfections to PSF by modelling optical performance using defocussed data



- We are developing code to analyse and determine wavefront aberrations from the data taken at the optical bench
- Local challenges
  - Possibly stronger wings than expected
  - Extra power in vertical direction at some wavelengths

