

2D point spread function characterization for Prime Focus Spectrograph

Neven Caplar



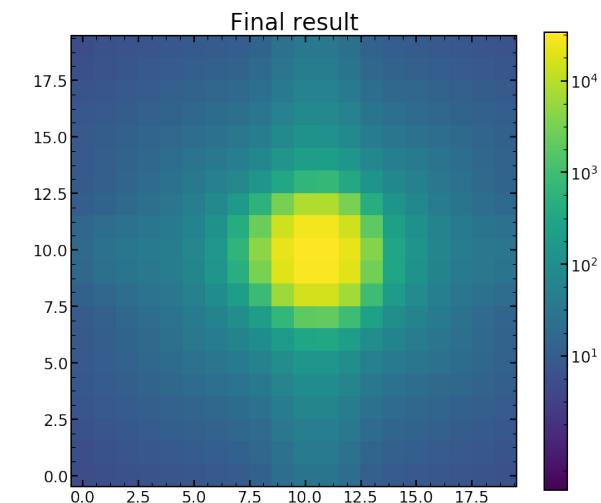
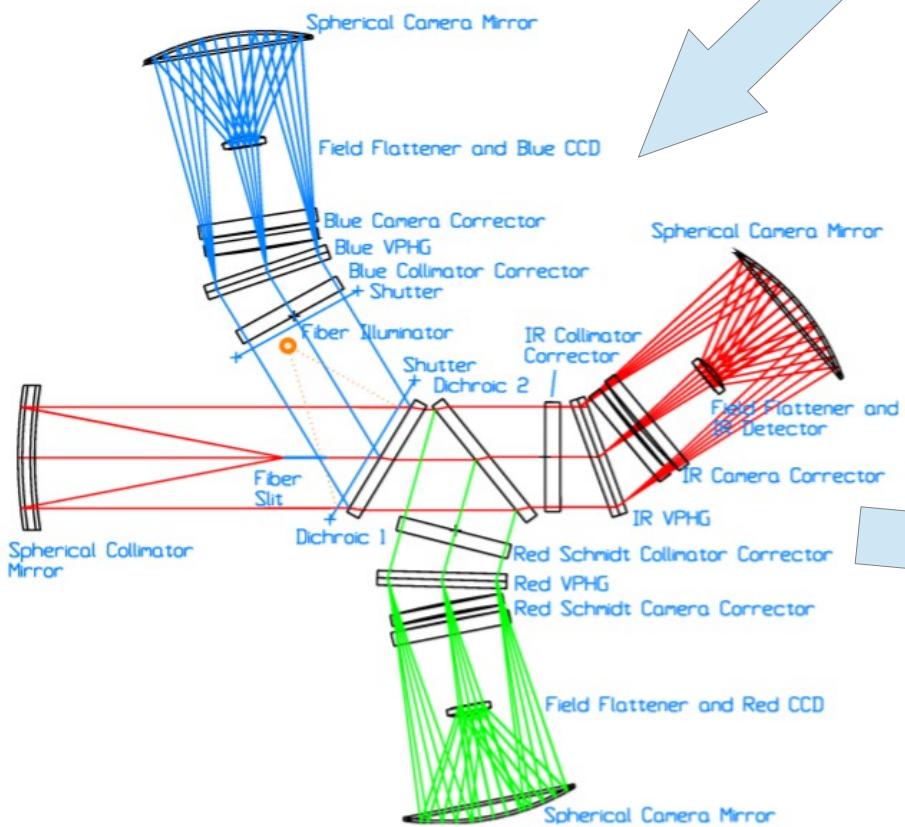
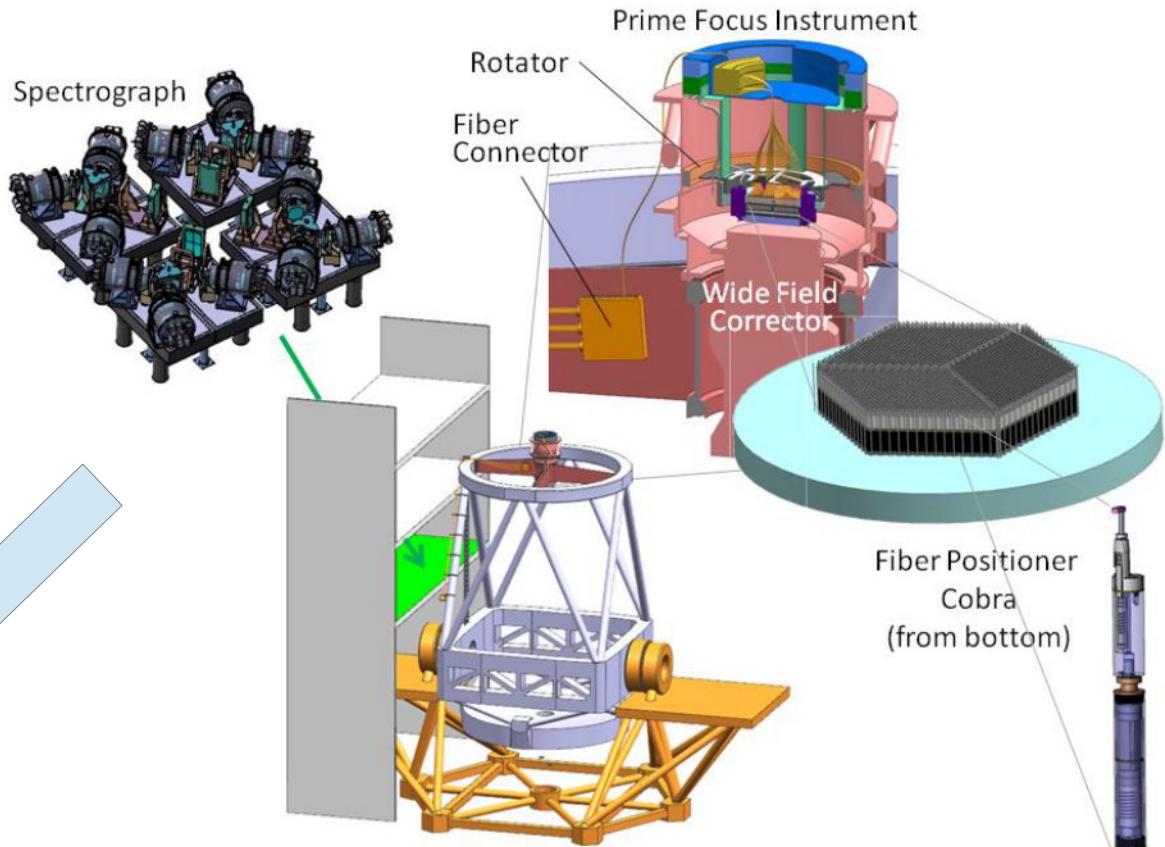
PRINCETON
UNIVERSITY



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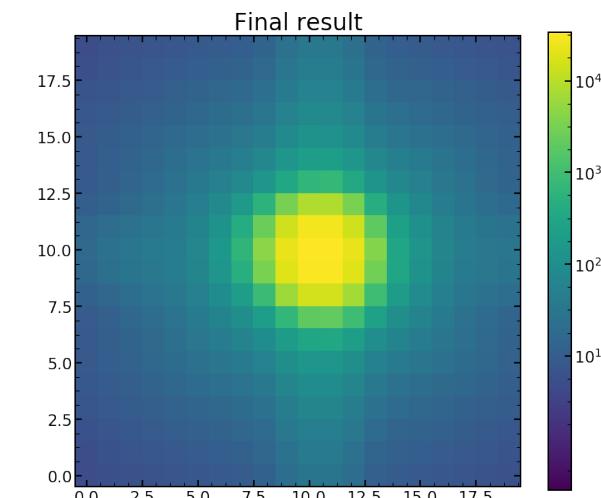
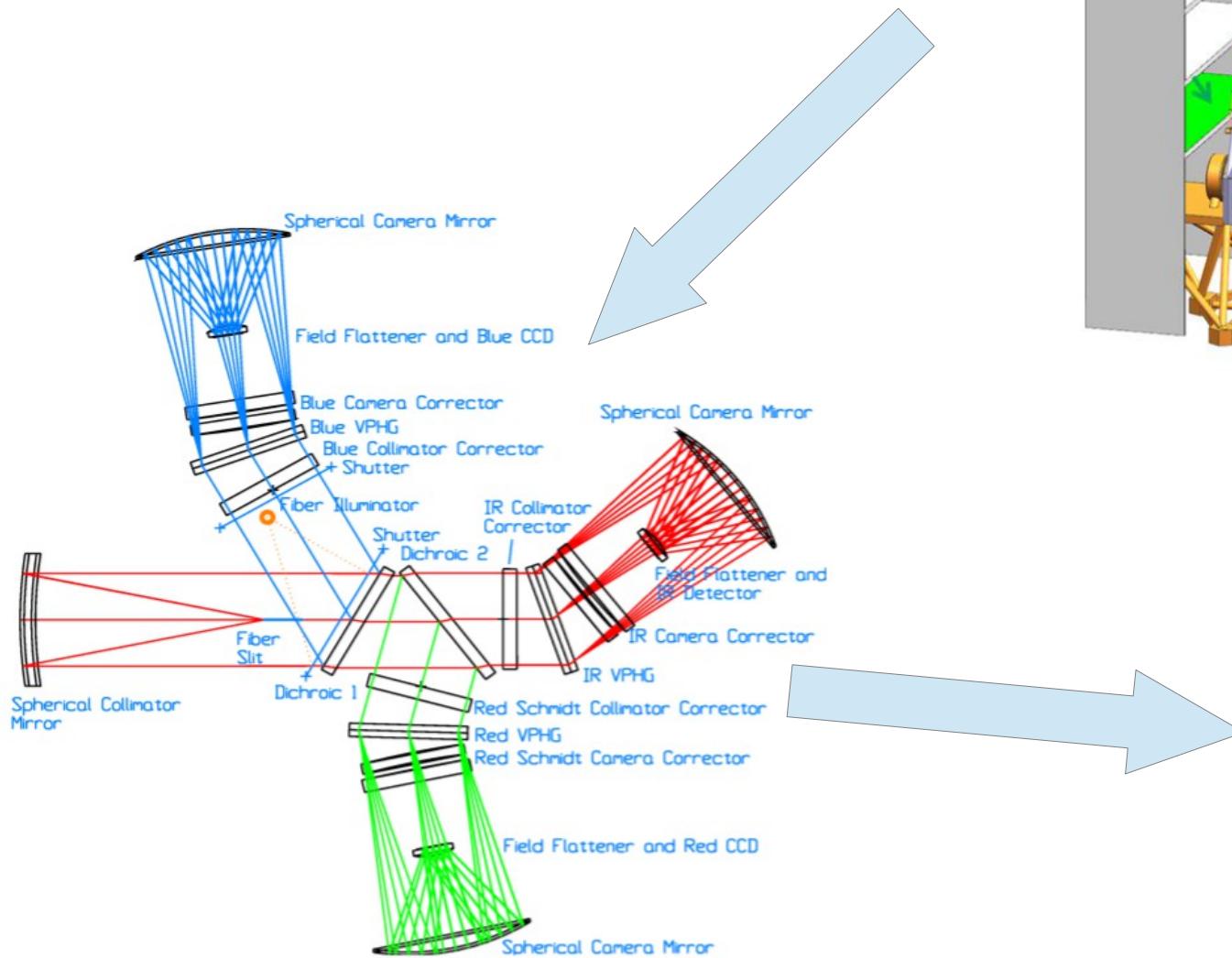
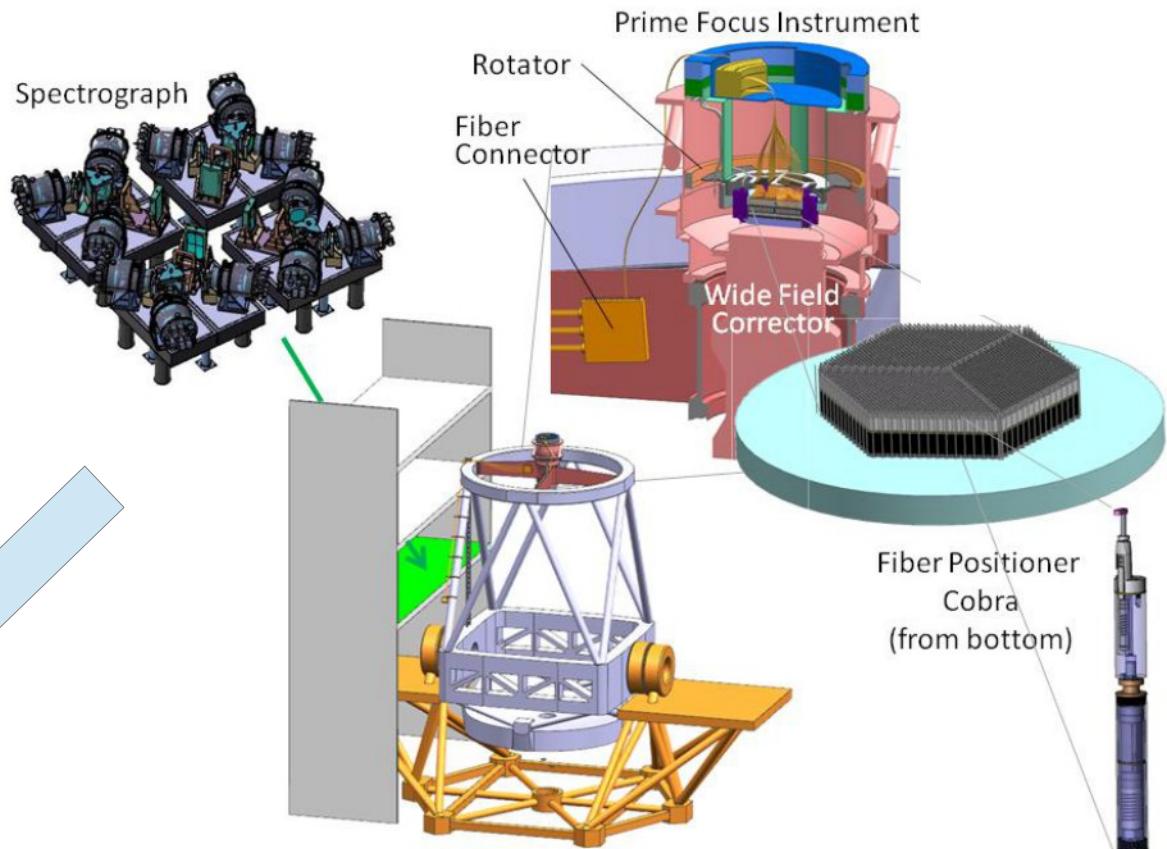
- Overview of the spectrograph
- Sky subtraction
 - 2d point-spread function algorithm
 - Analysis of defocused images
 - Behavior of wavefront
- Some interesting topics/problems (optional)
 - Overlap
 - Wings

- 2394 fibers on 8.2 meter Subaru Telescope
- 360 nm – 1260 nm
- 1.6 to 2.7 Angstrom resolution
- Start of commissioning: Oct 2021



3 components to the PSF

- Telescope pupil illumination
- Focal ratio degradation in the fibres
- Spectrograph cameras



3 components to the PSF

- Telescope pupil

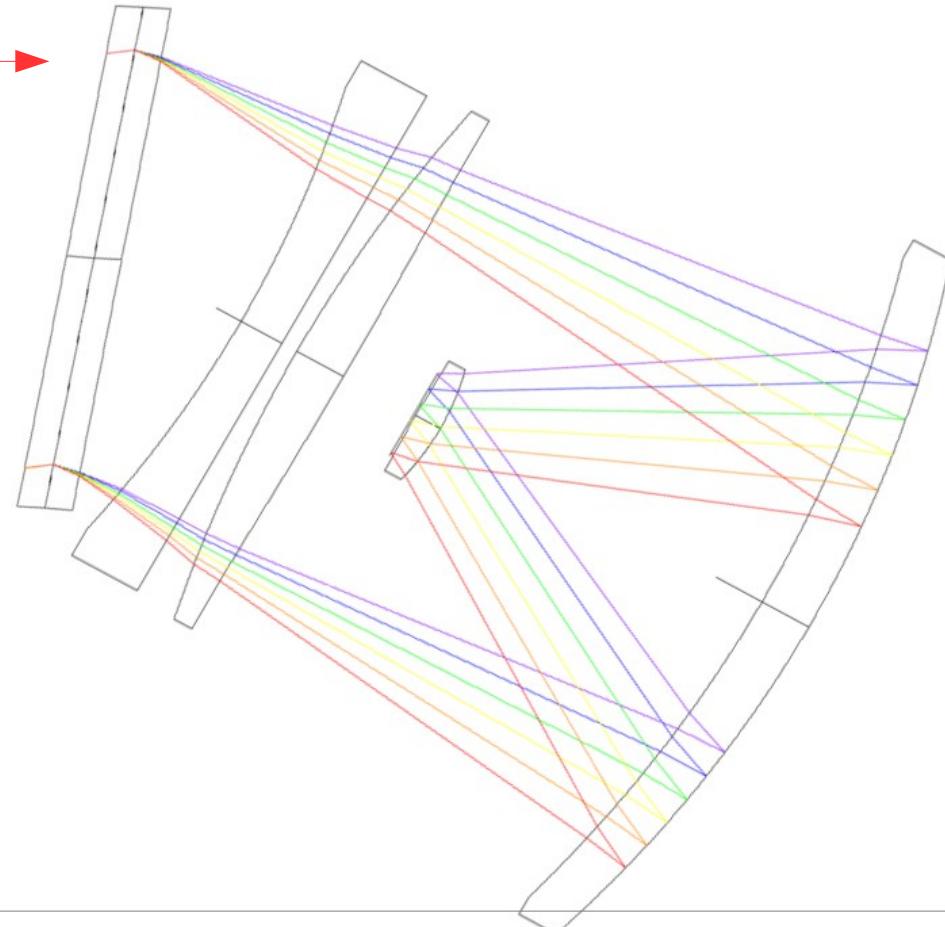
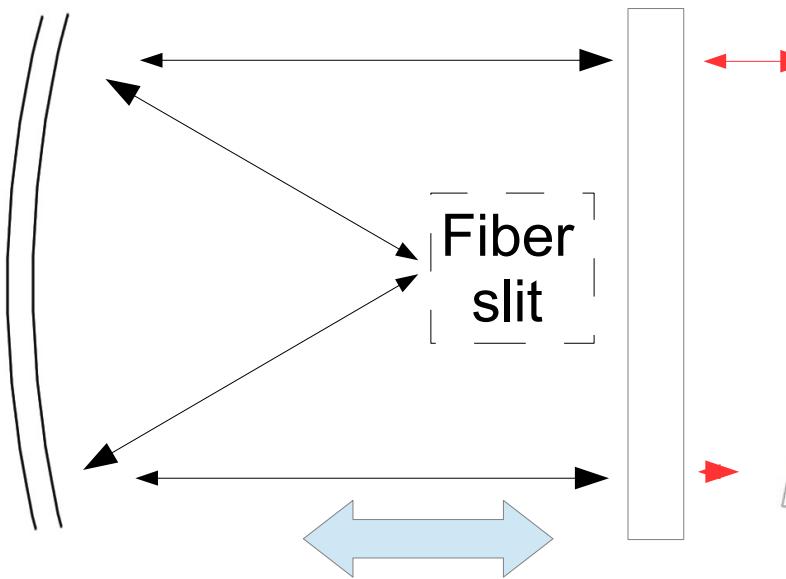
- illumination

- Focal ratio degradation

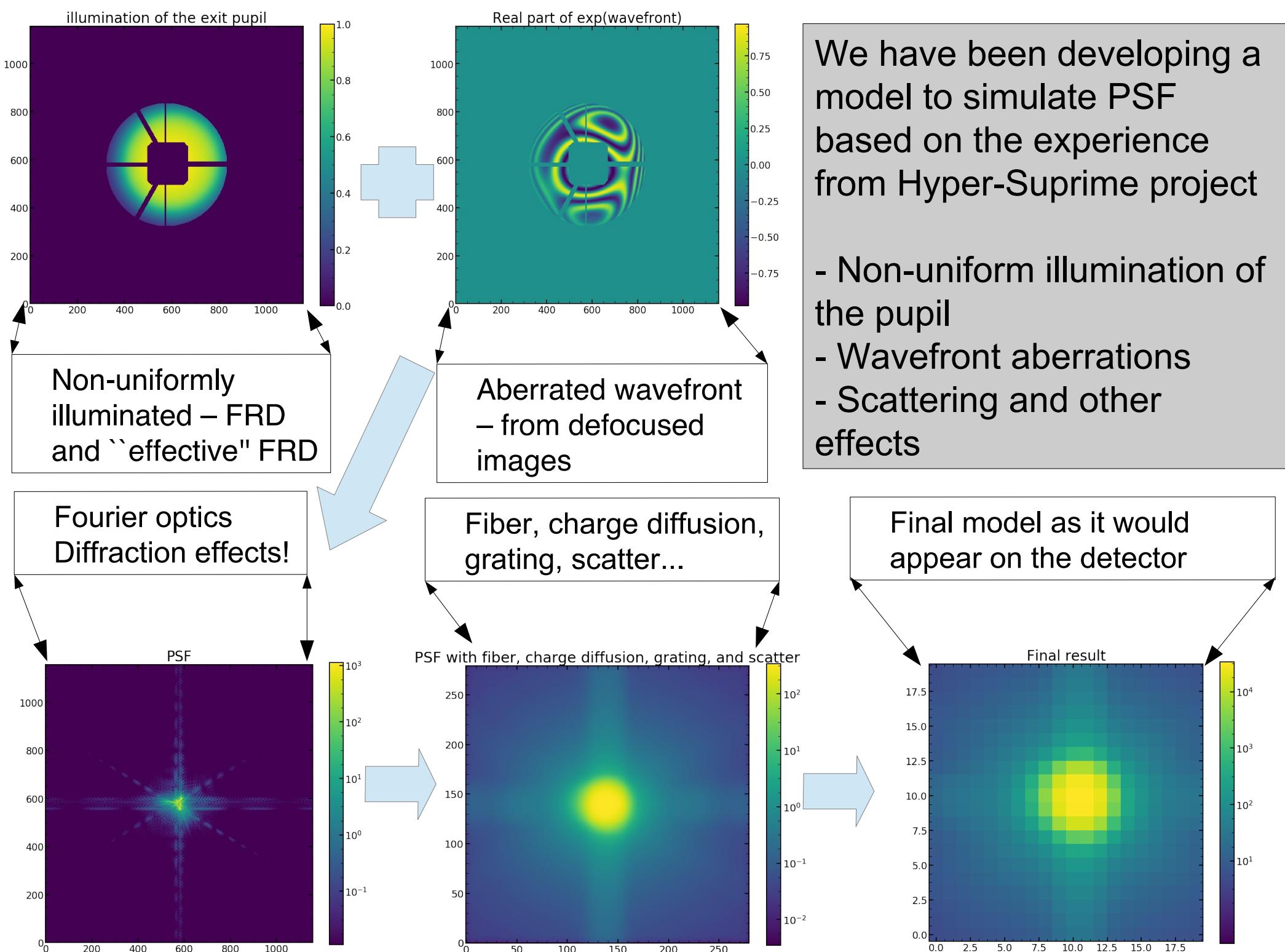
- in the fibres

- Spectrograph cameras

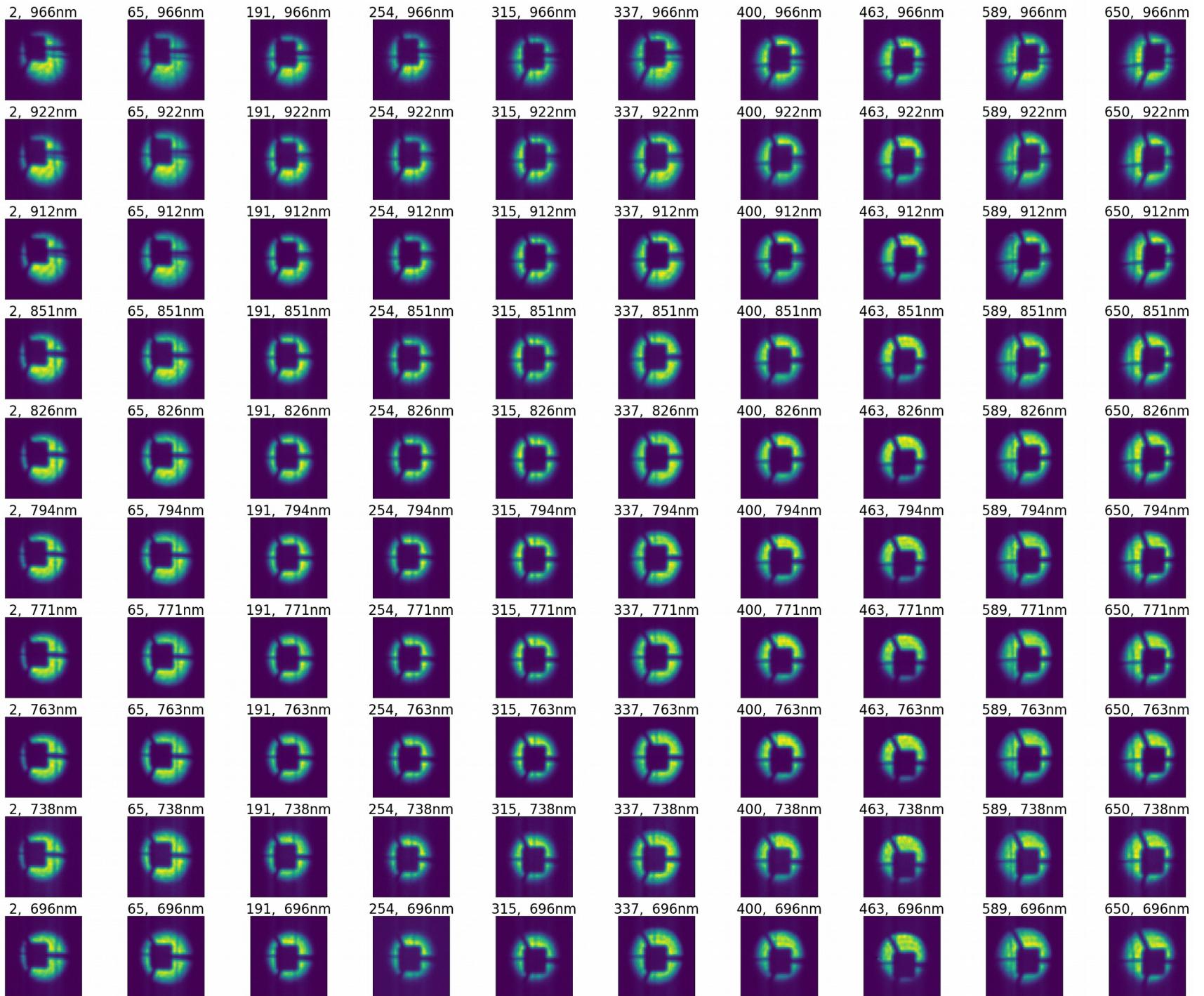
- Separate these 3 components (vignetting, fibers & camera) causing aberrations in the PSF by working in wavefront space
- We aim to characterize contribution of camera imperfections to PSF by modelling optical performance using defocussed data



Single camera

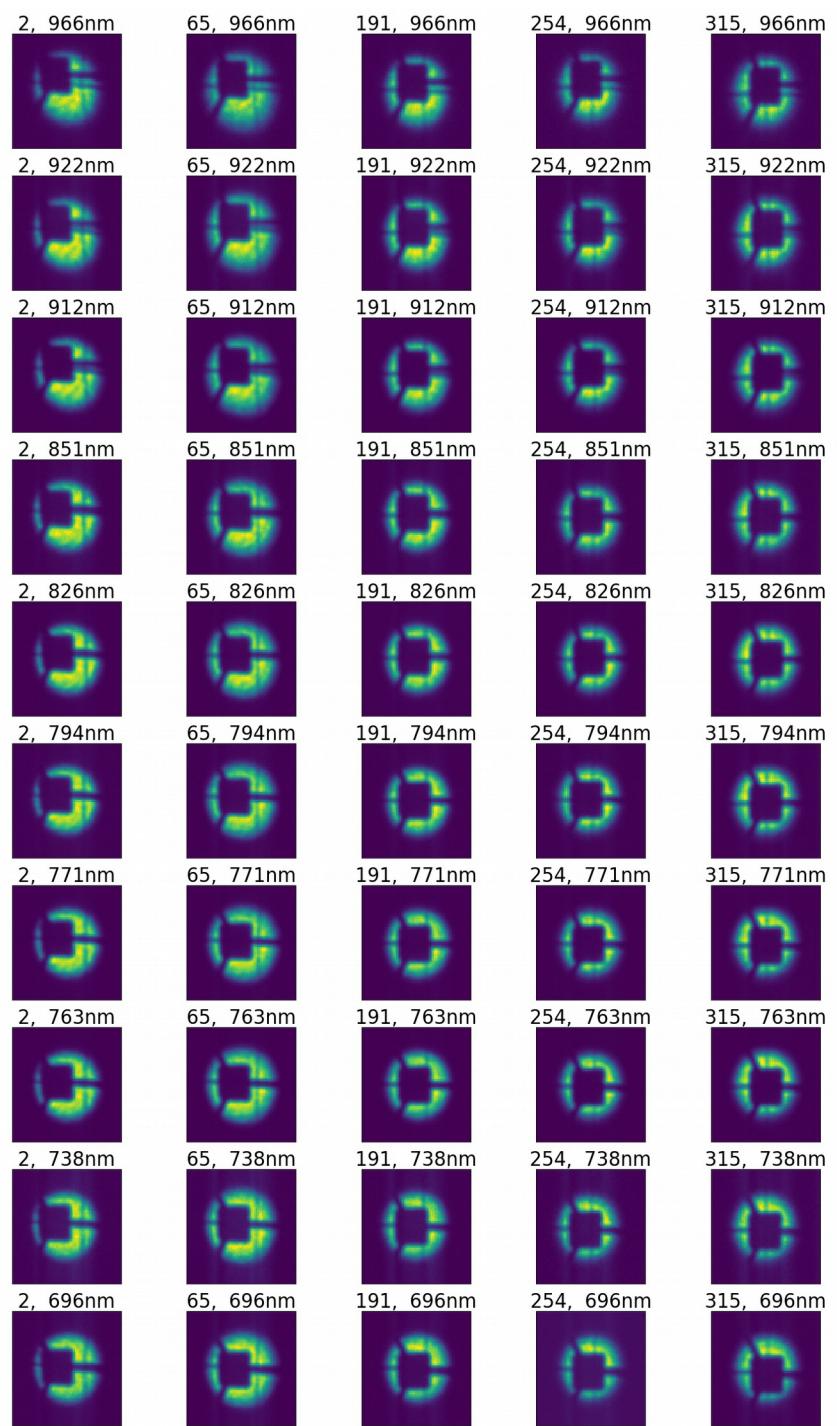


Wavelength

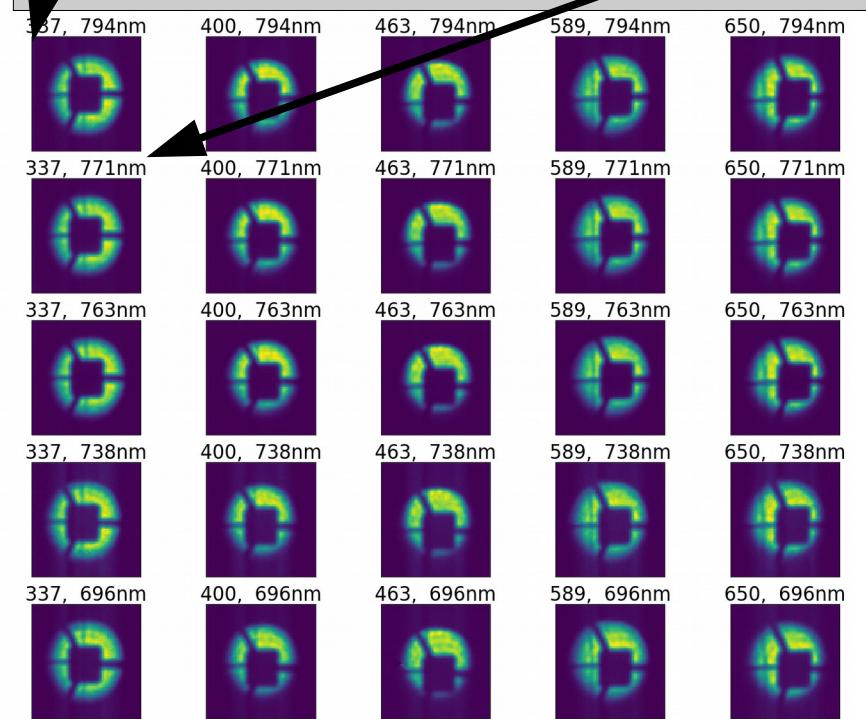
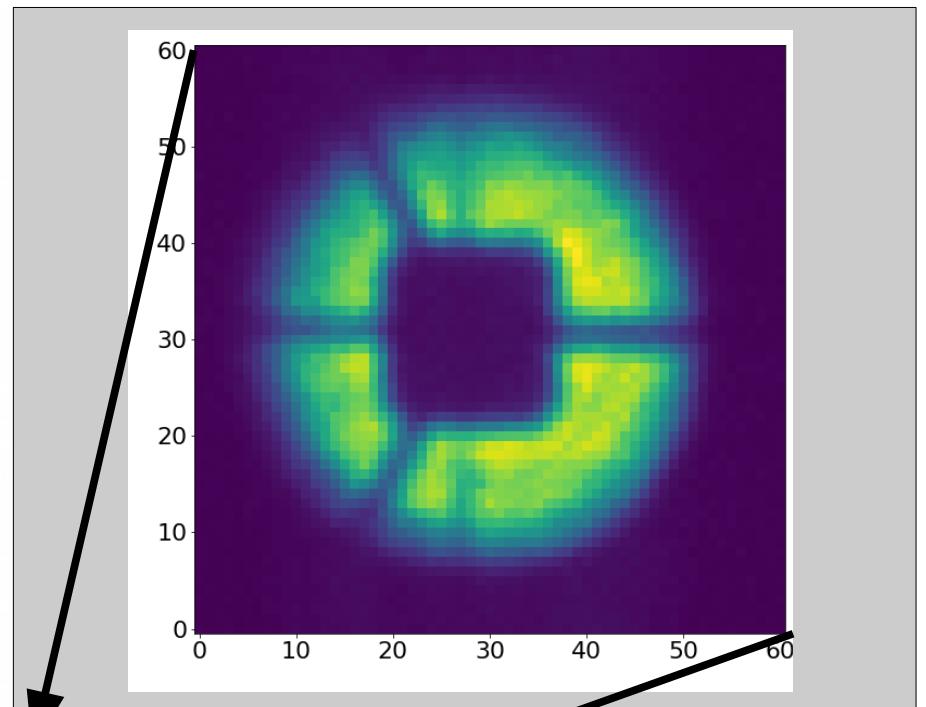


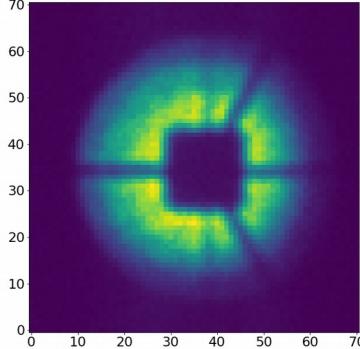
Different fibers

Wavelength



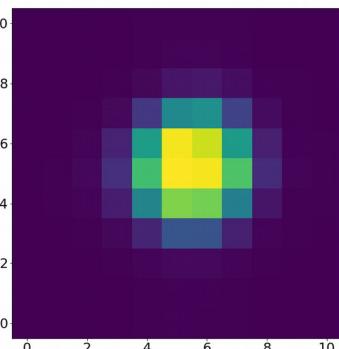
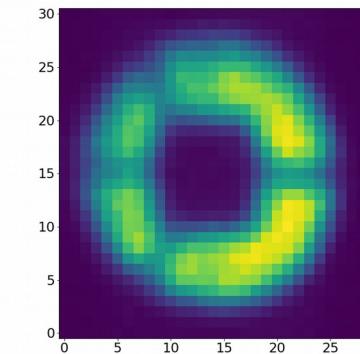
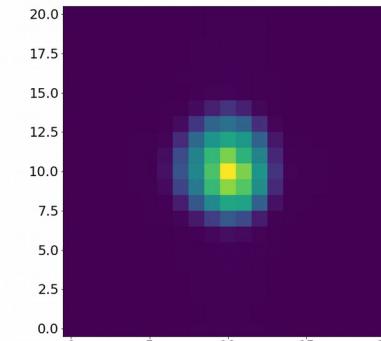
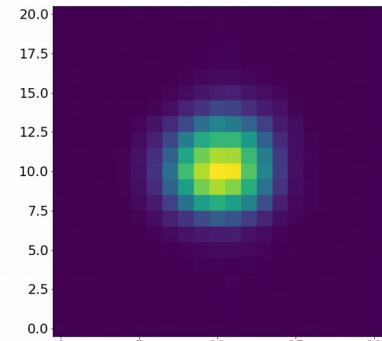
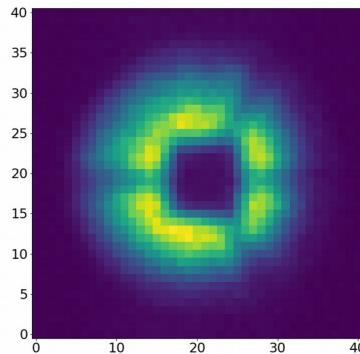
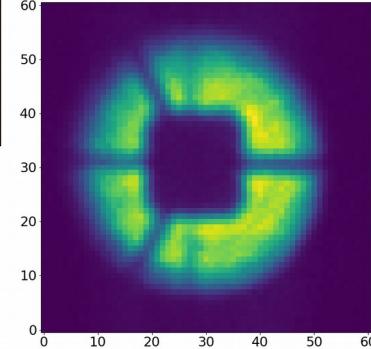
Different fibers





How to decouple the illumination and the wavefront aberrations?

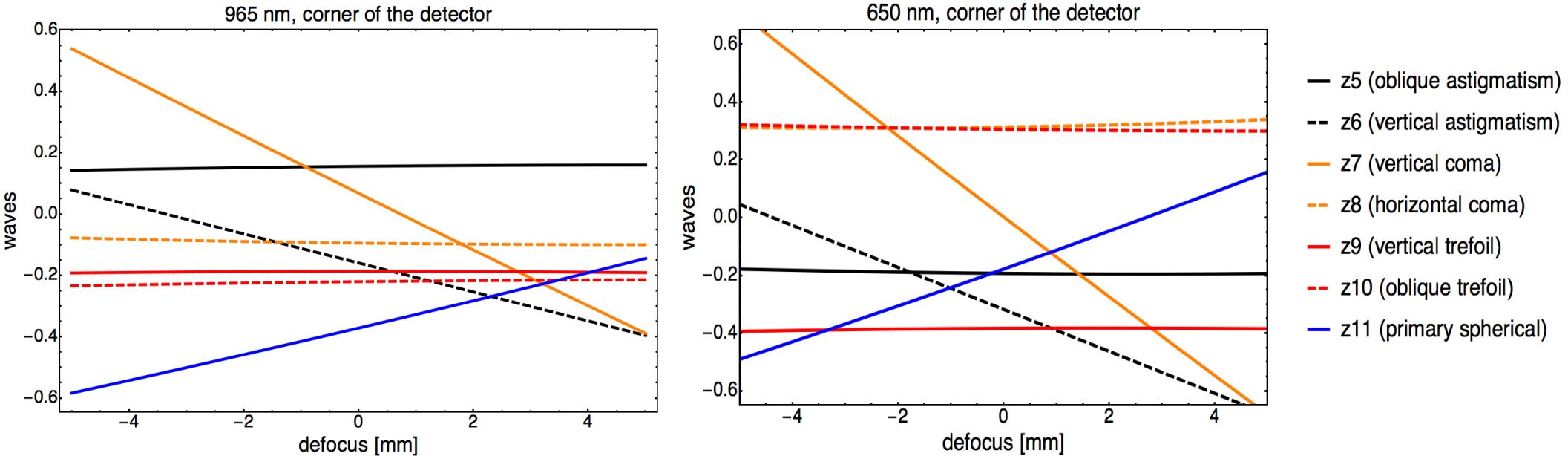
- Images at different value of defocus
- Follow wavefront aberrations as a function of defocus



More defocused

In focus

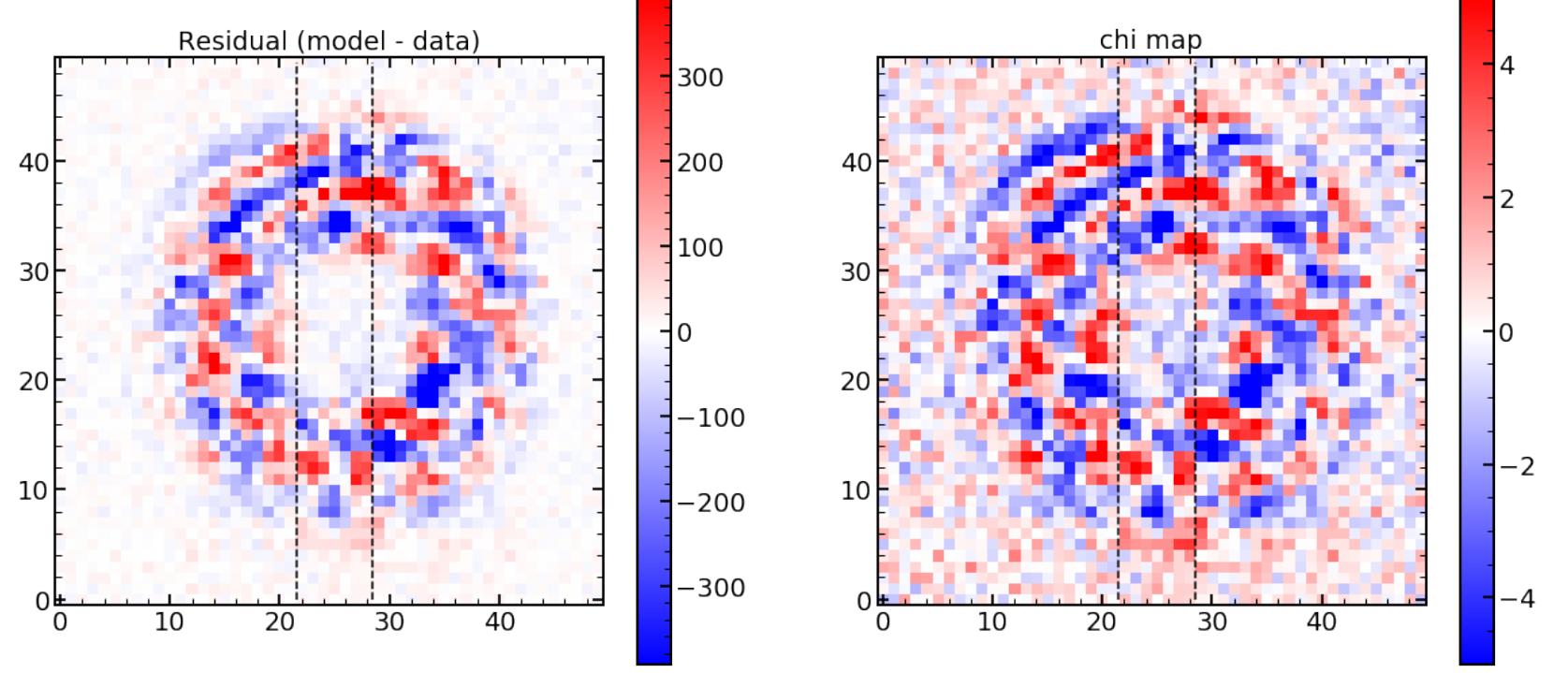
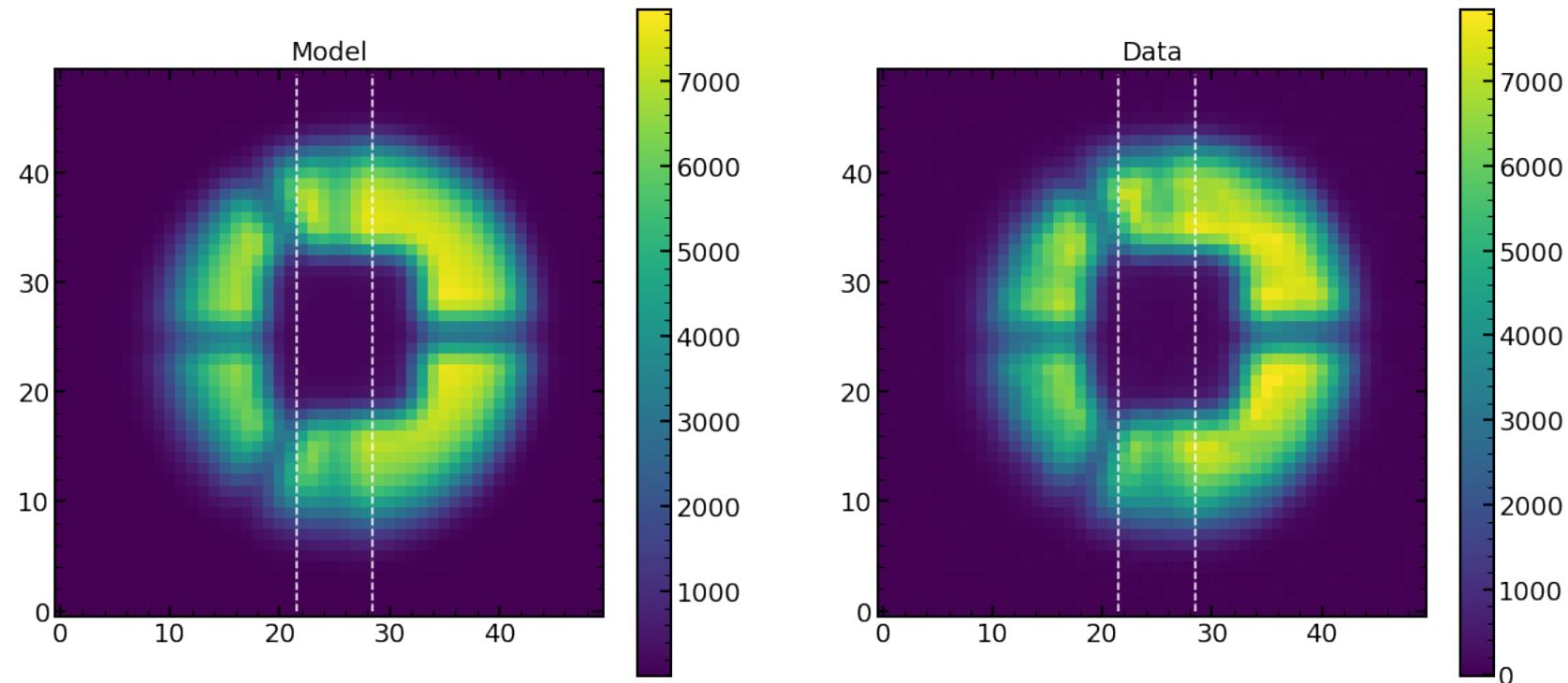
More defocused



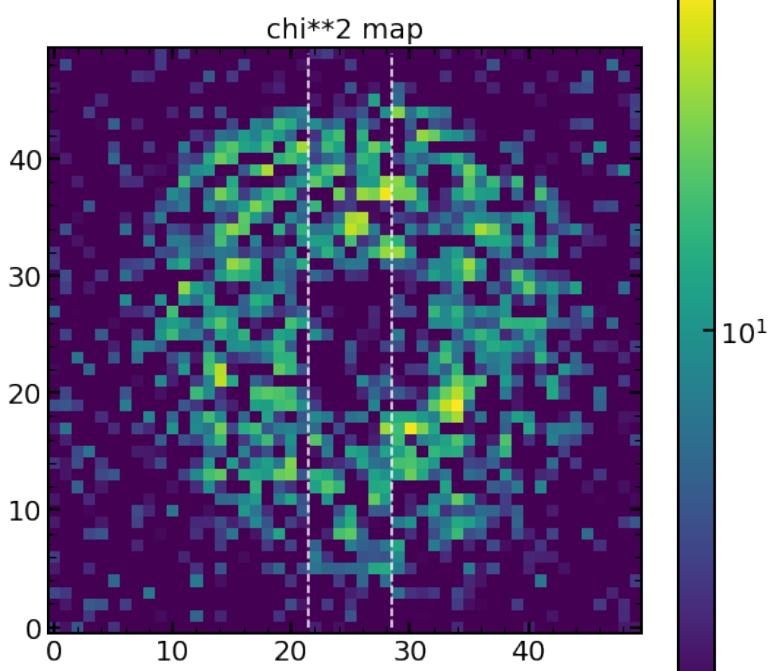
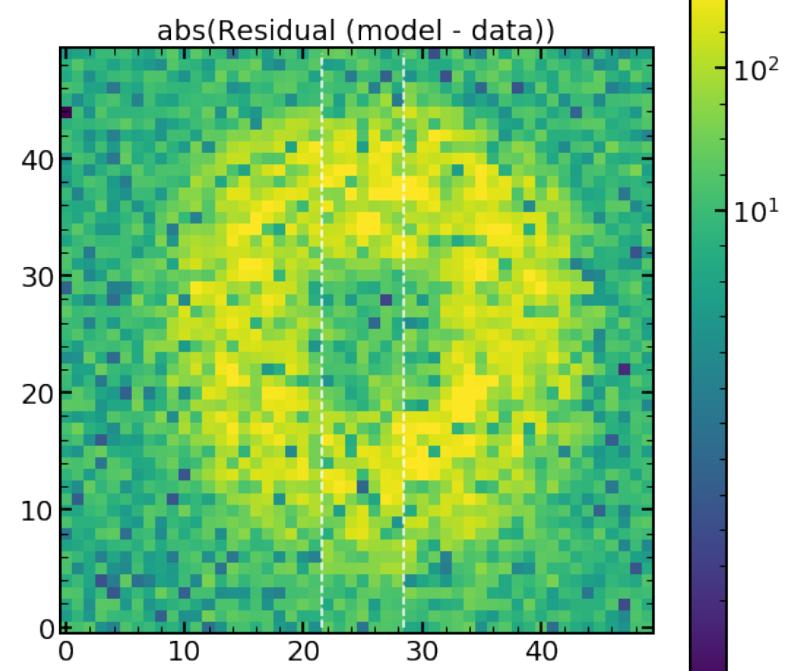
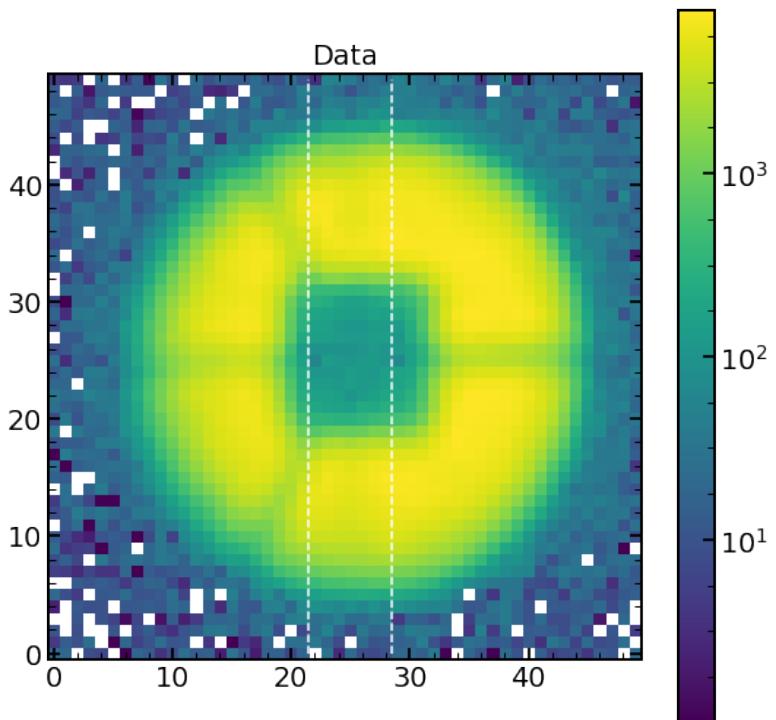
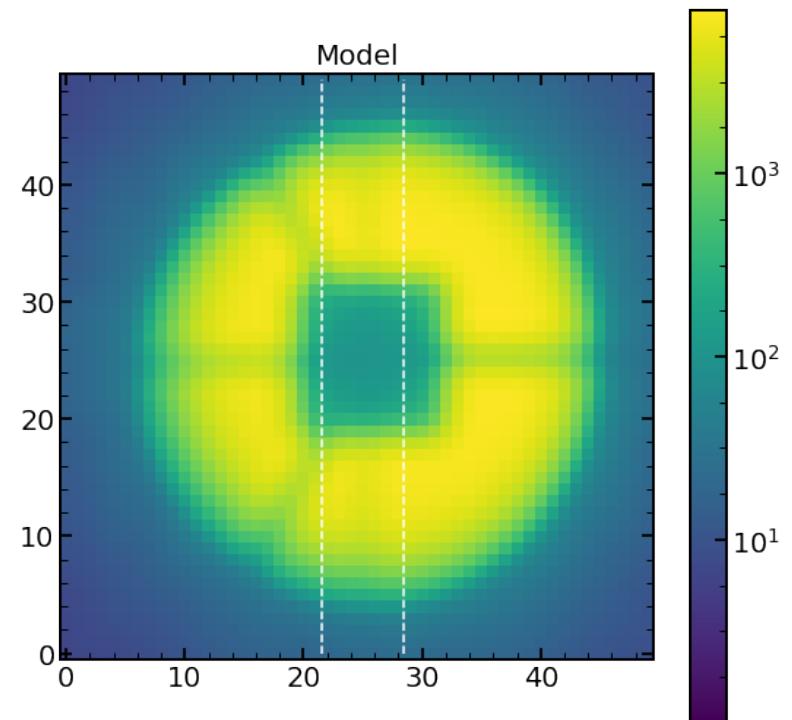
Wavefront aberrations as function of defocus (Zemax)

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

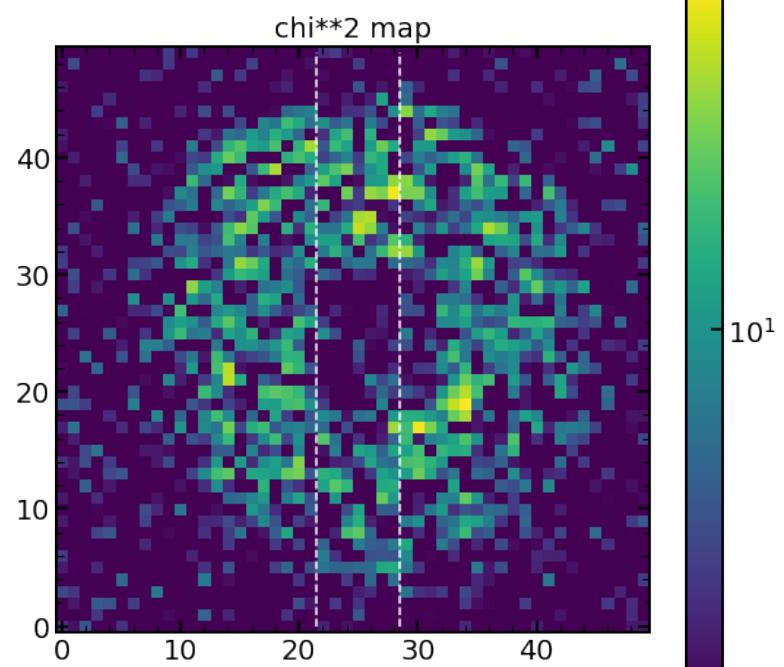
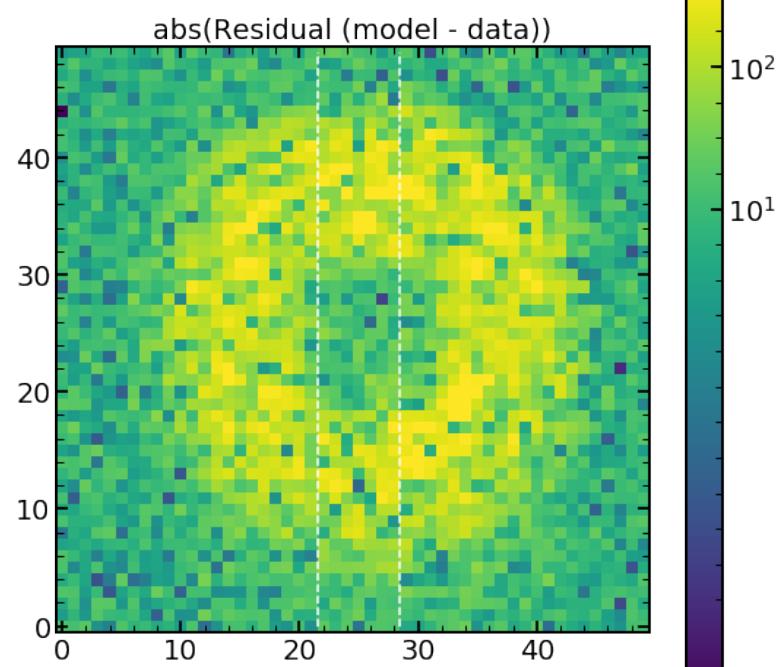
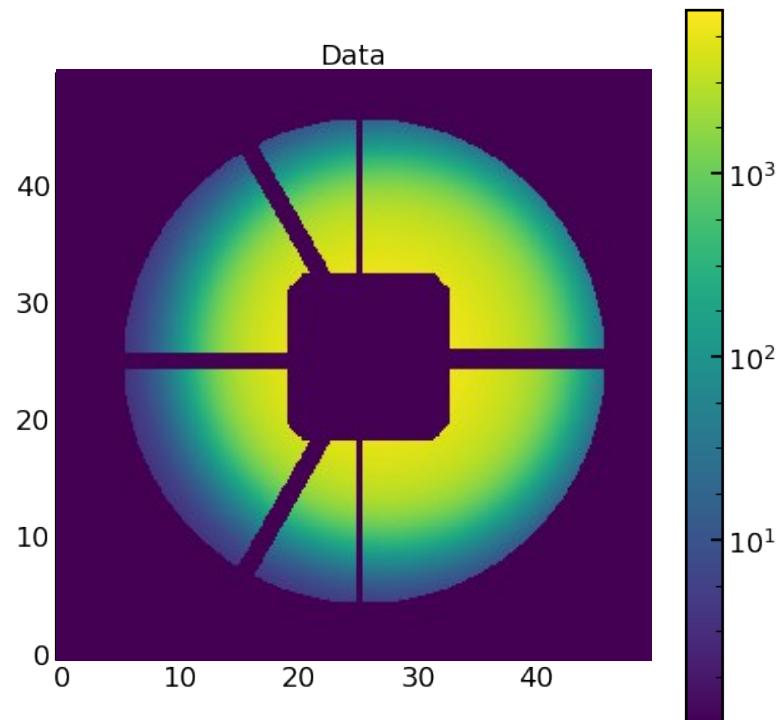
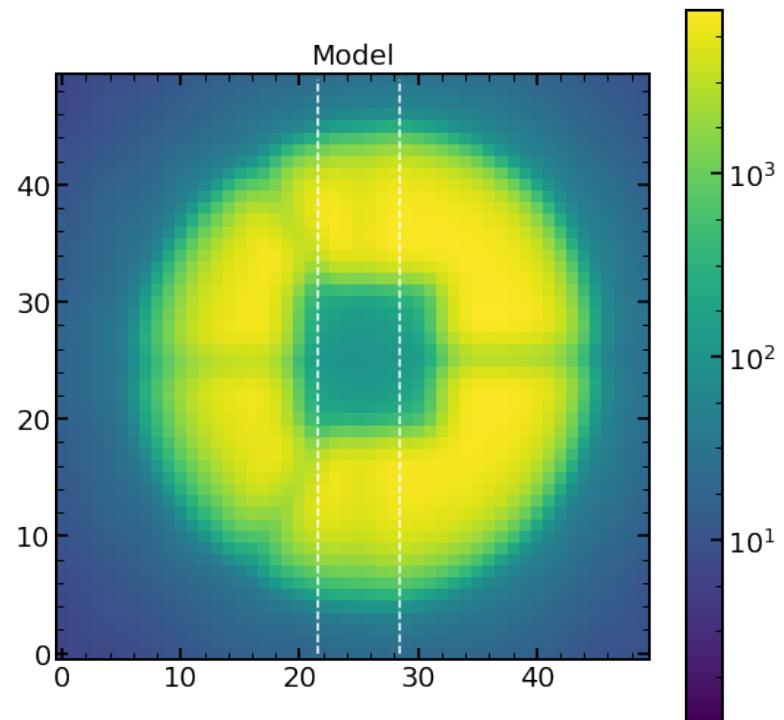
Defocused data, example with linear scaling

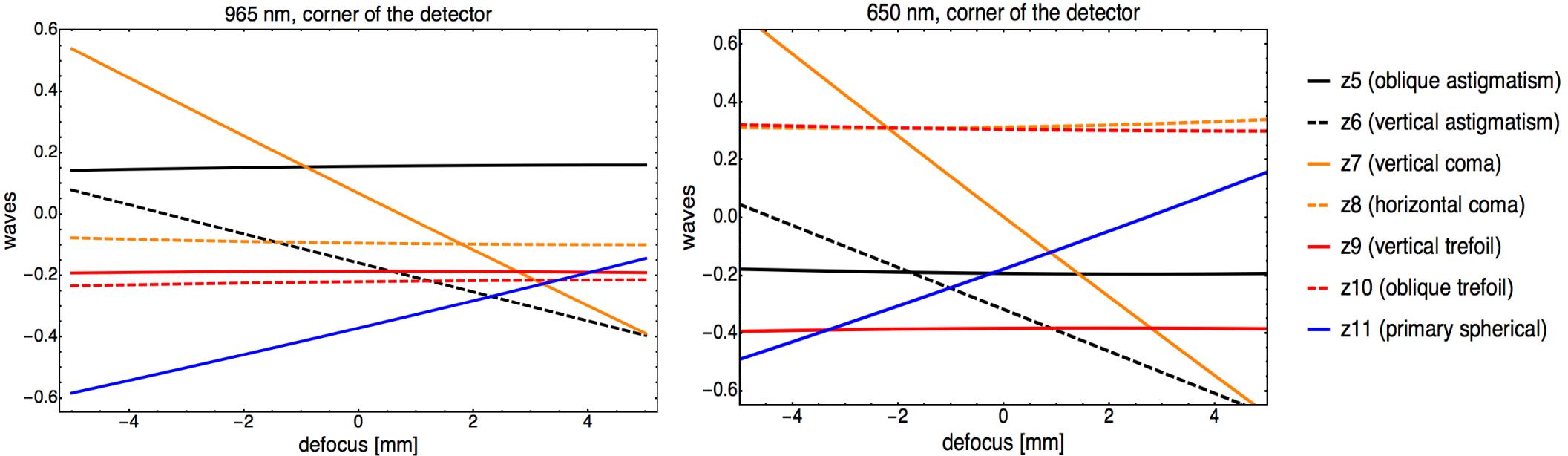


Defocused
data,
example with
log scaling

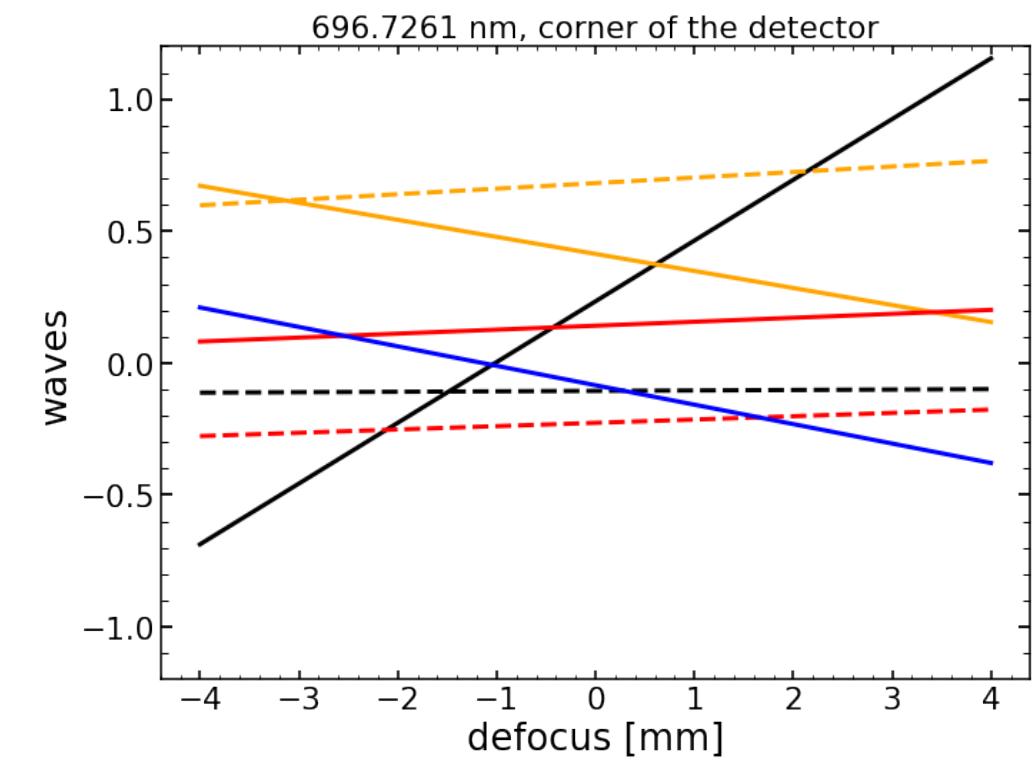
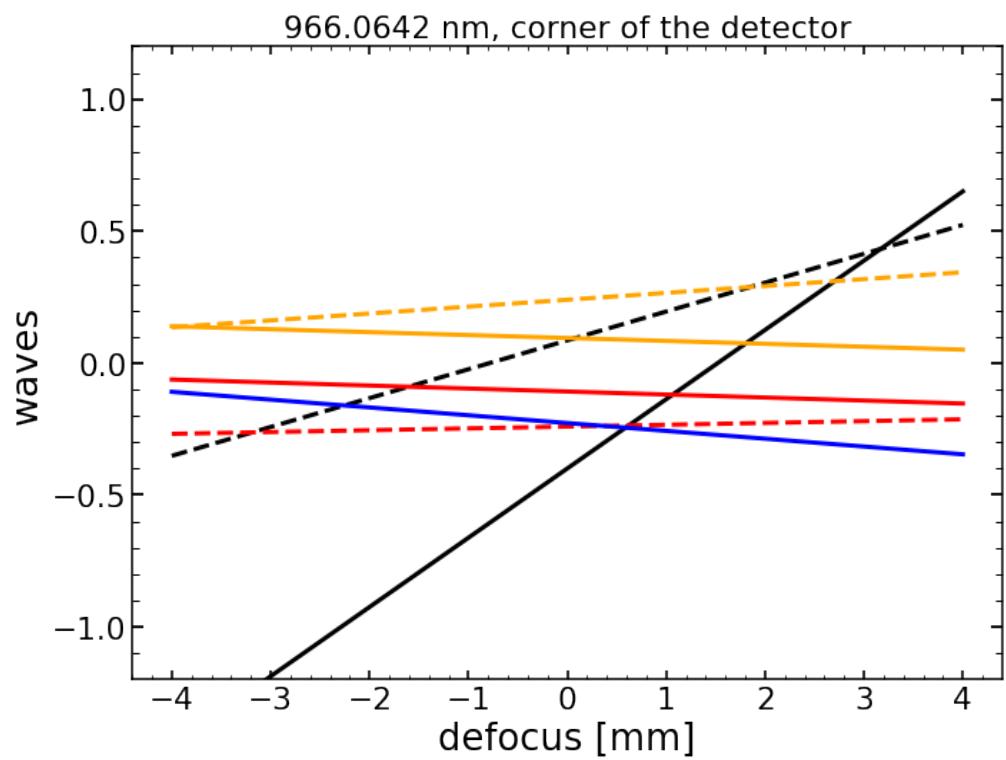


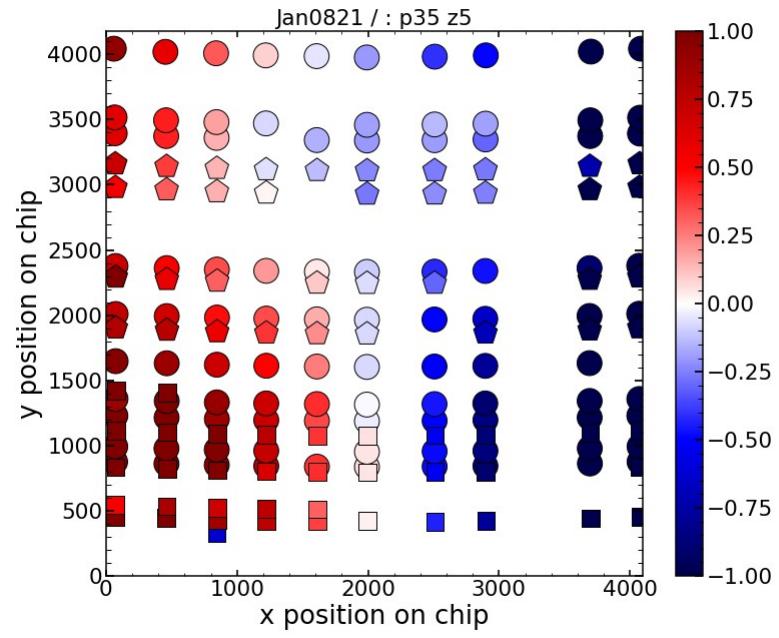
Defocused
data,
example with
log scaling



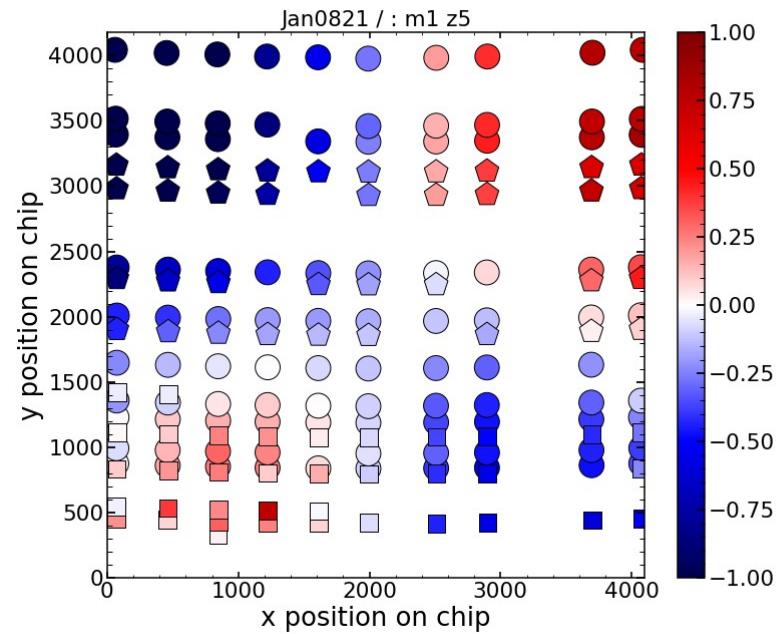
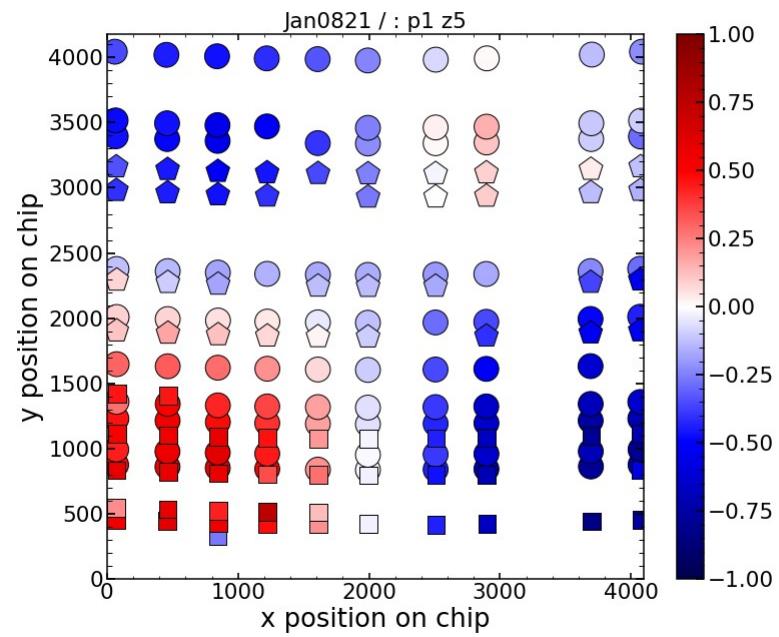
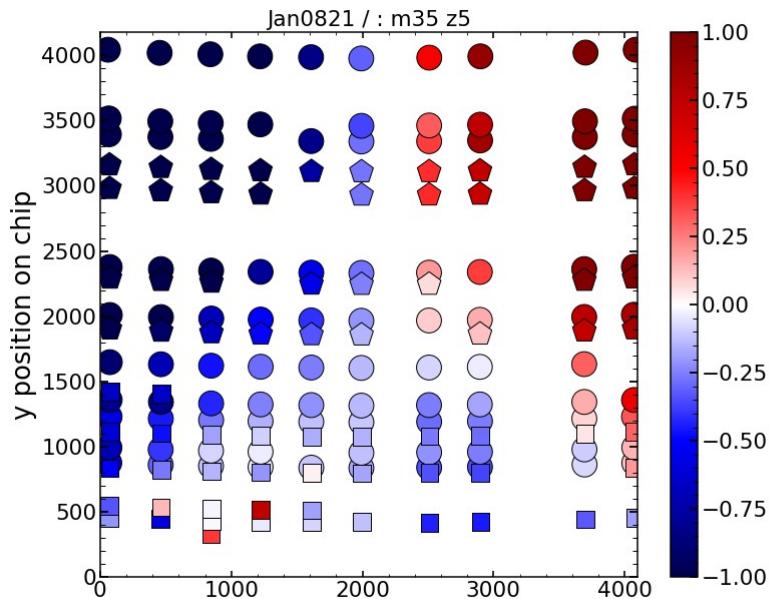


- Example from modelling of the experimental data below
(not exactly the same location as above, but observe large difference)



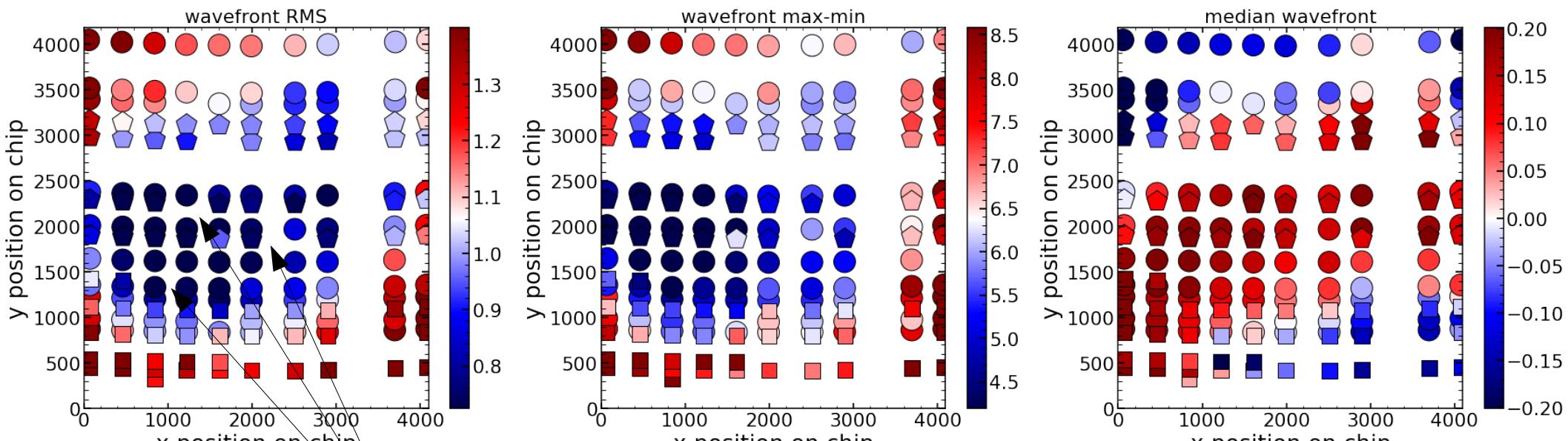


Change of single component
(oblique astigmatism)



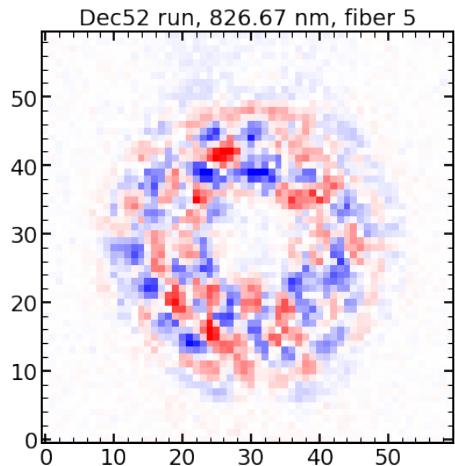
Changing defocus

Wavefront rms across the detector

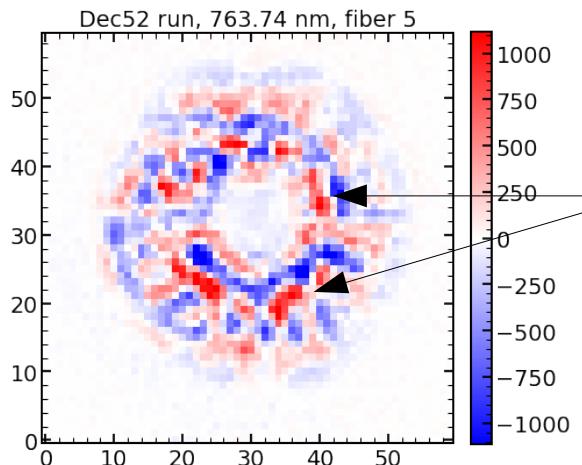
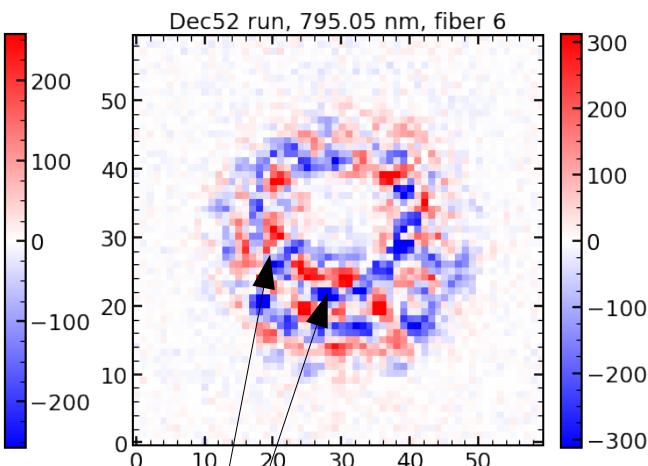
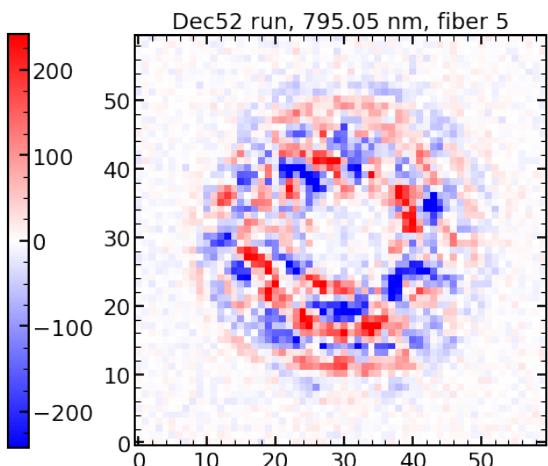
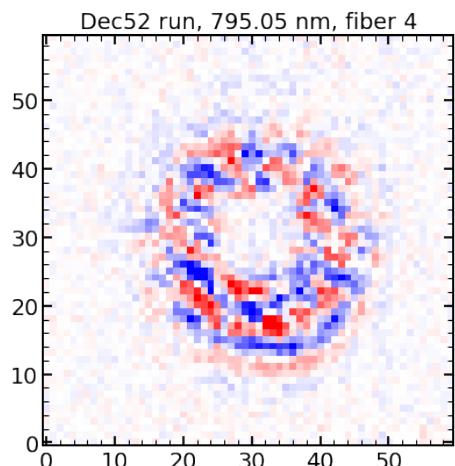


Not in the center of the detector –
probably because it was centered from
available data

Residuals of fits to the data - defocus



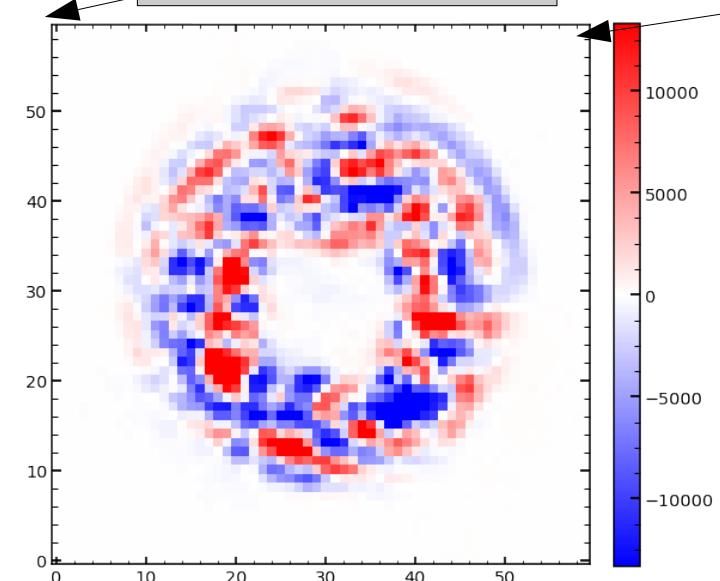
Residuals scaled to
5% of the maximal flux
in the data



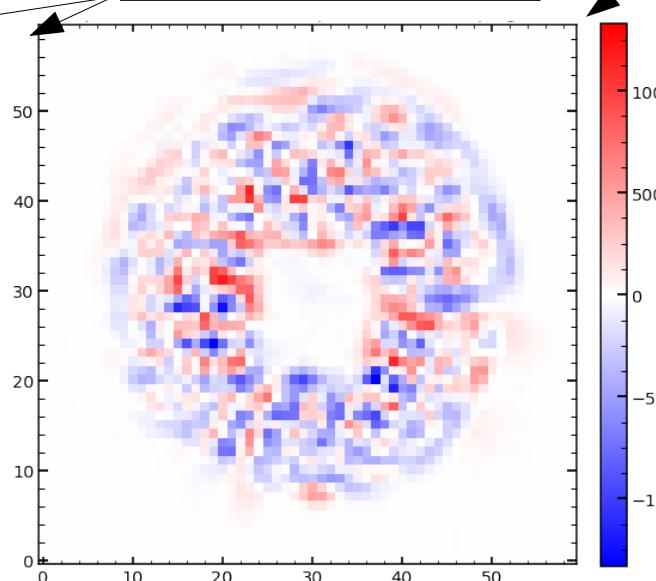
Speckles – can be
"removed" by fitting
higher order
wavefront
abberations

Direct Fits

Up to z22

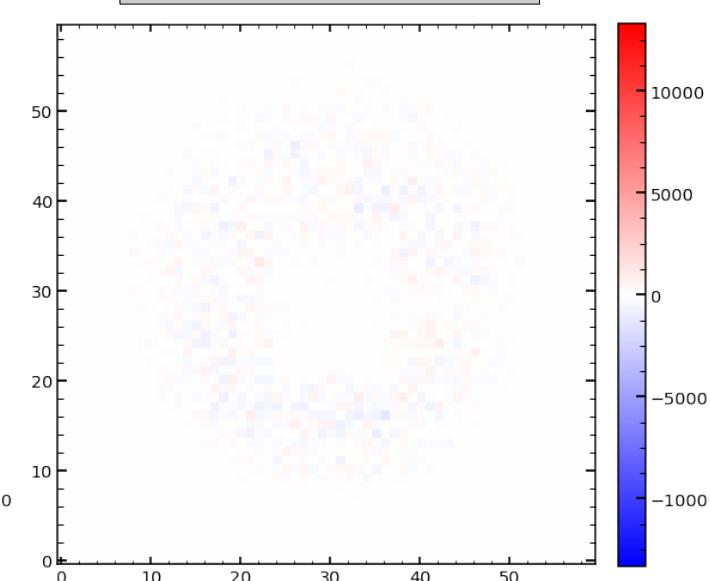


Up to z254



Residuals scaled to
5% of the maximal flux
in the data

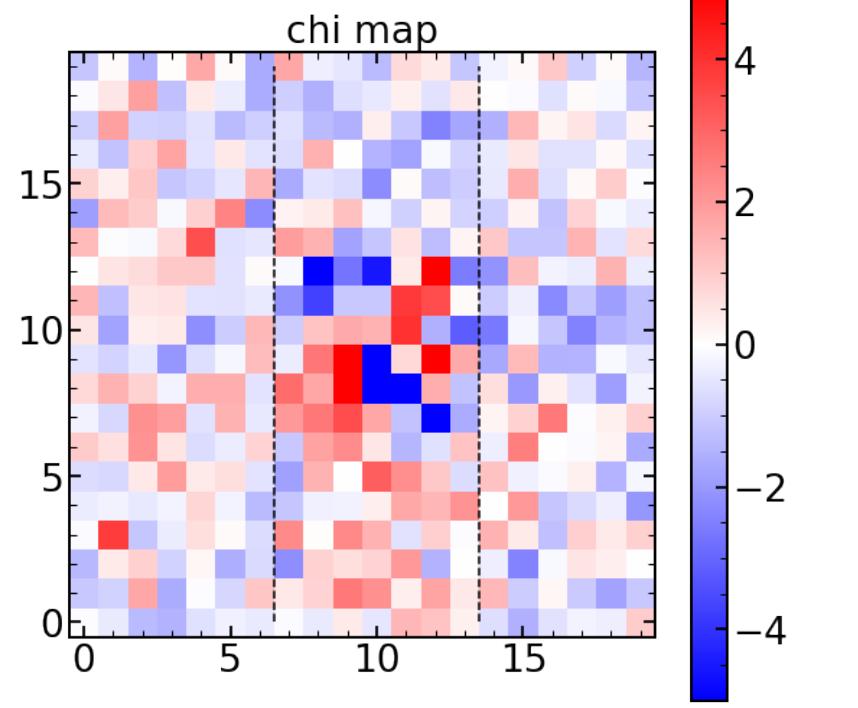
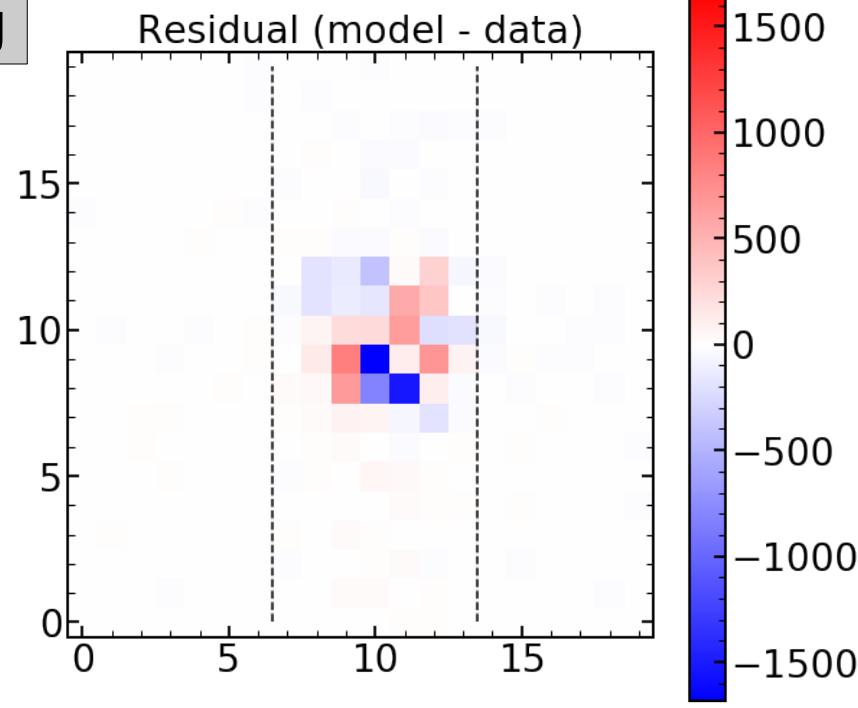
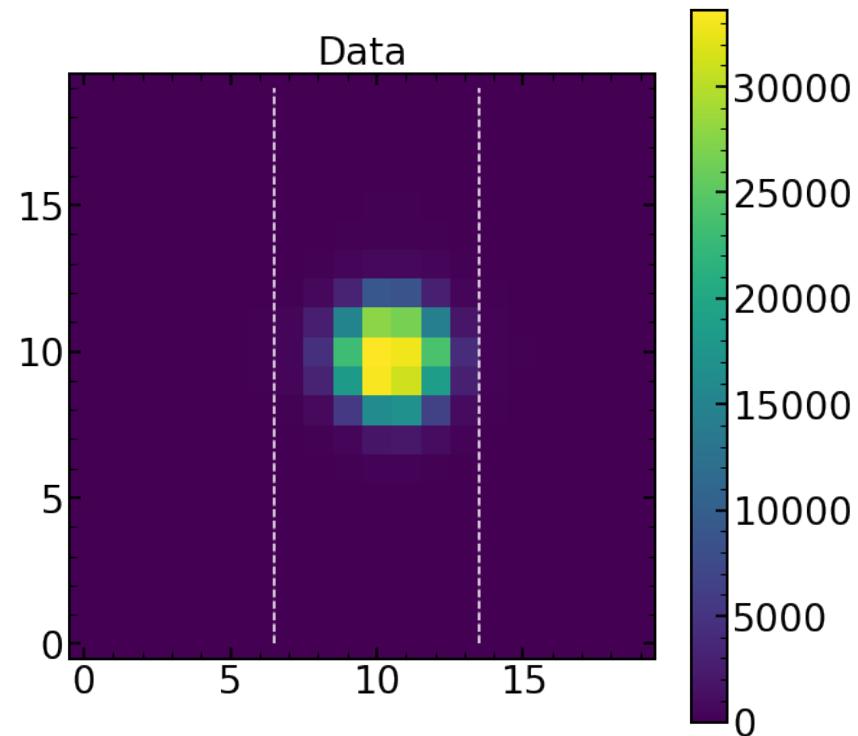
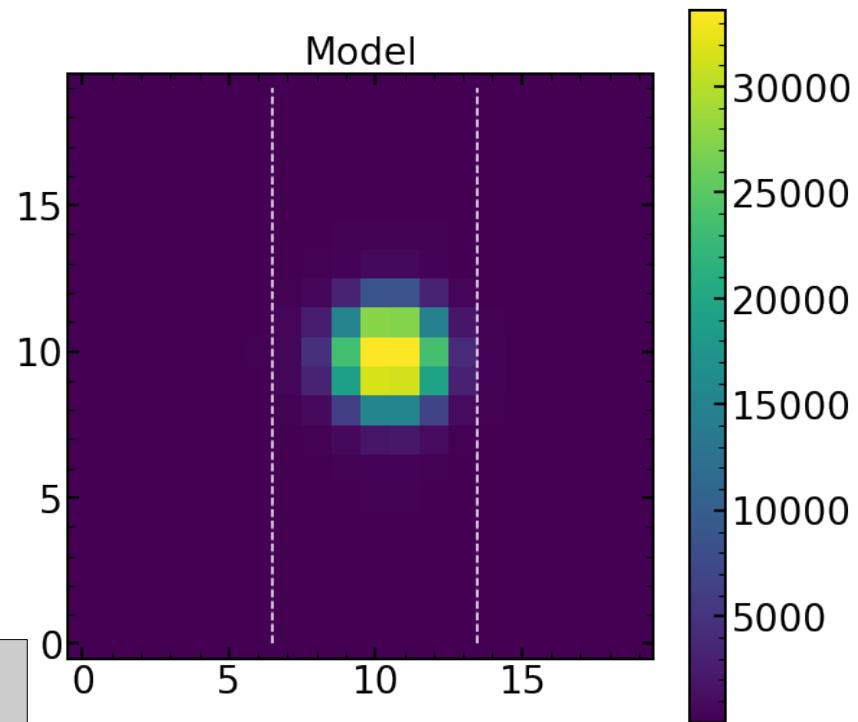
Perfection

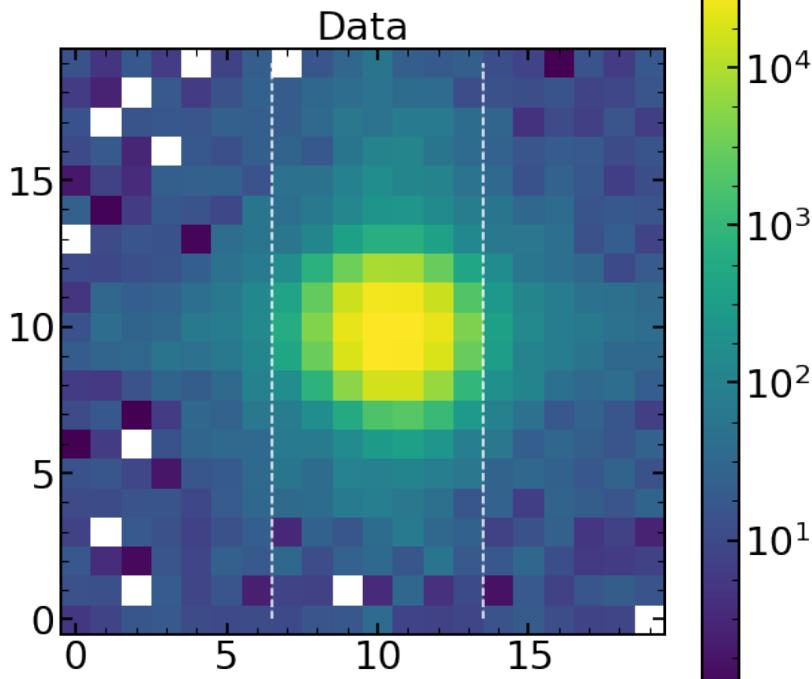
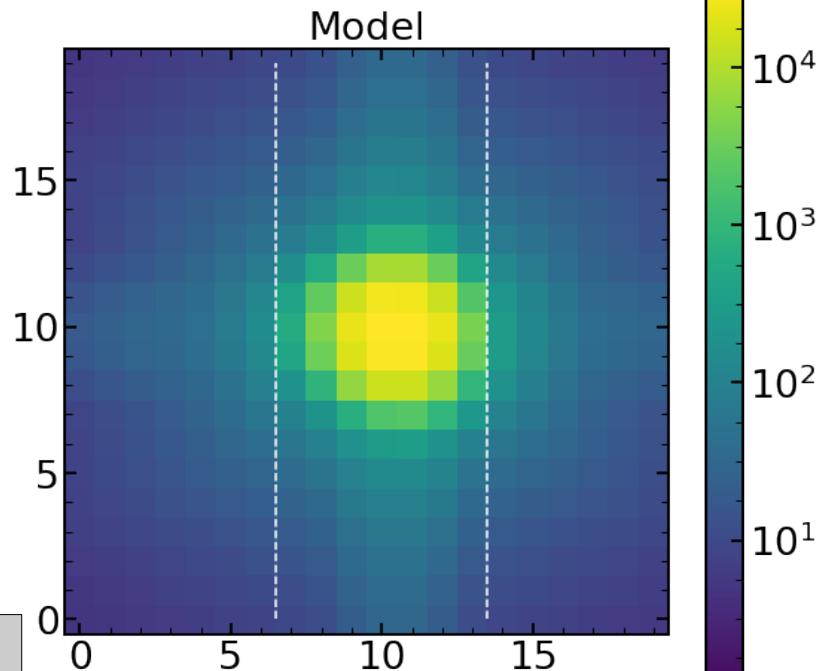


High order
aberrations do not
vary as a position of
the detector? (if they
come from glass
imperfections)

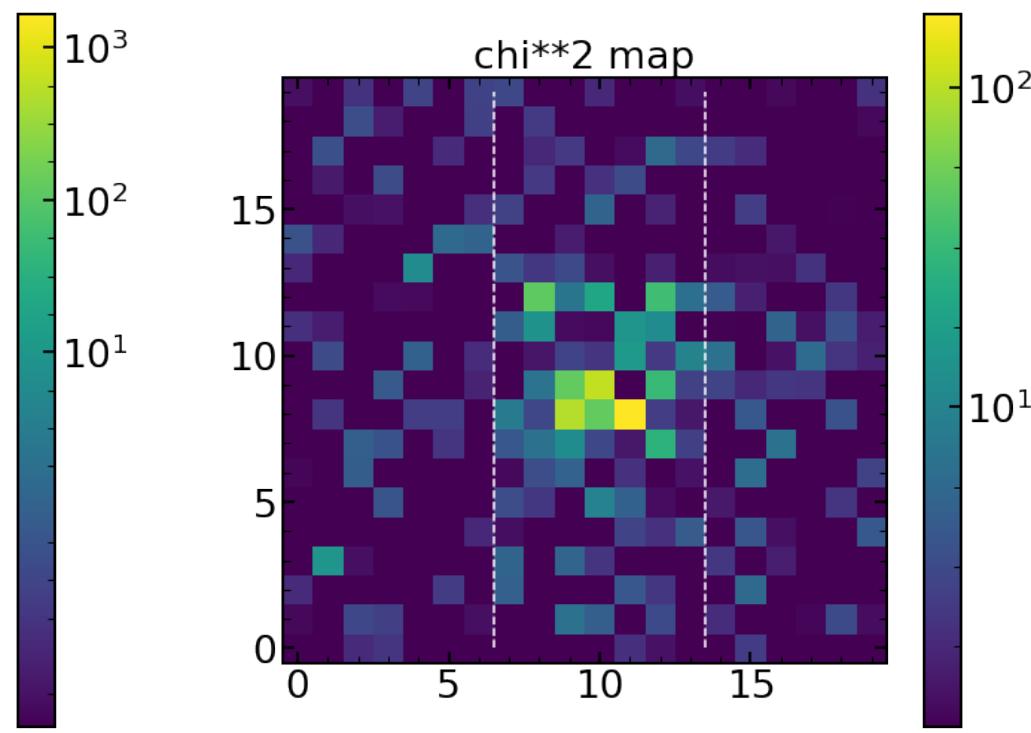
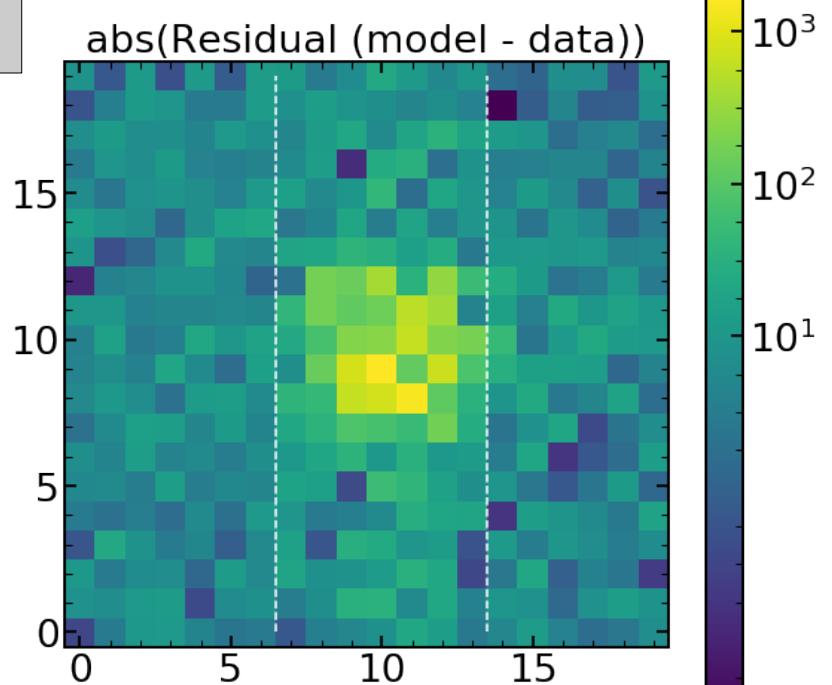
Speckles – can be
``removed" by fitting
higher order
wavefront
abberations

Focused
data,
example with
linear scaling



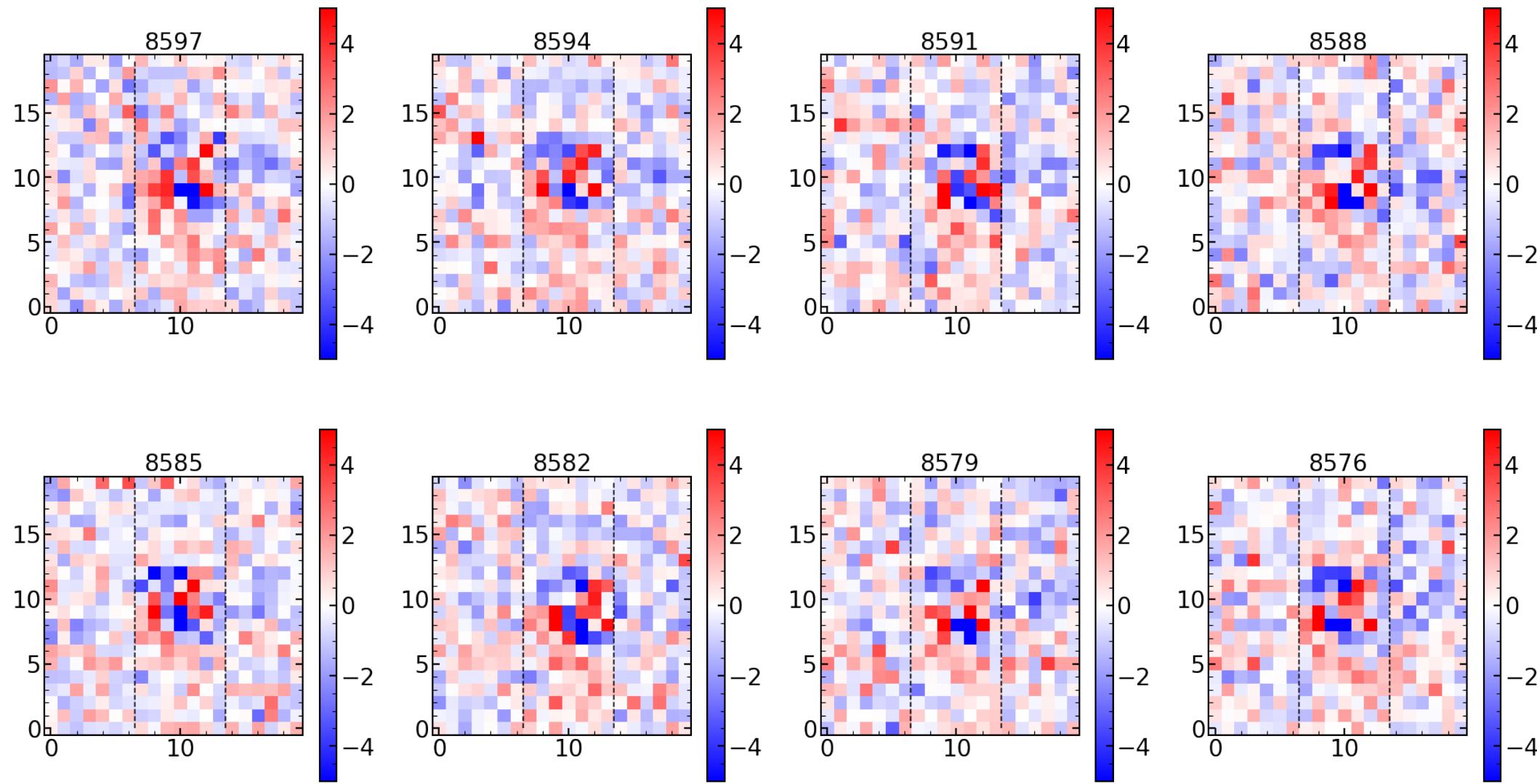


Focused
data,
example with
log scaling



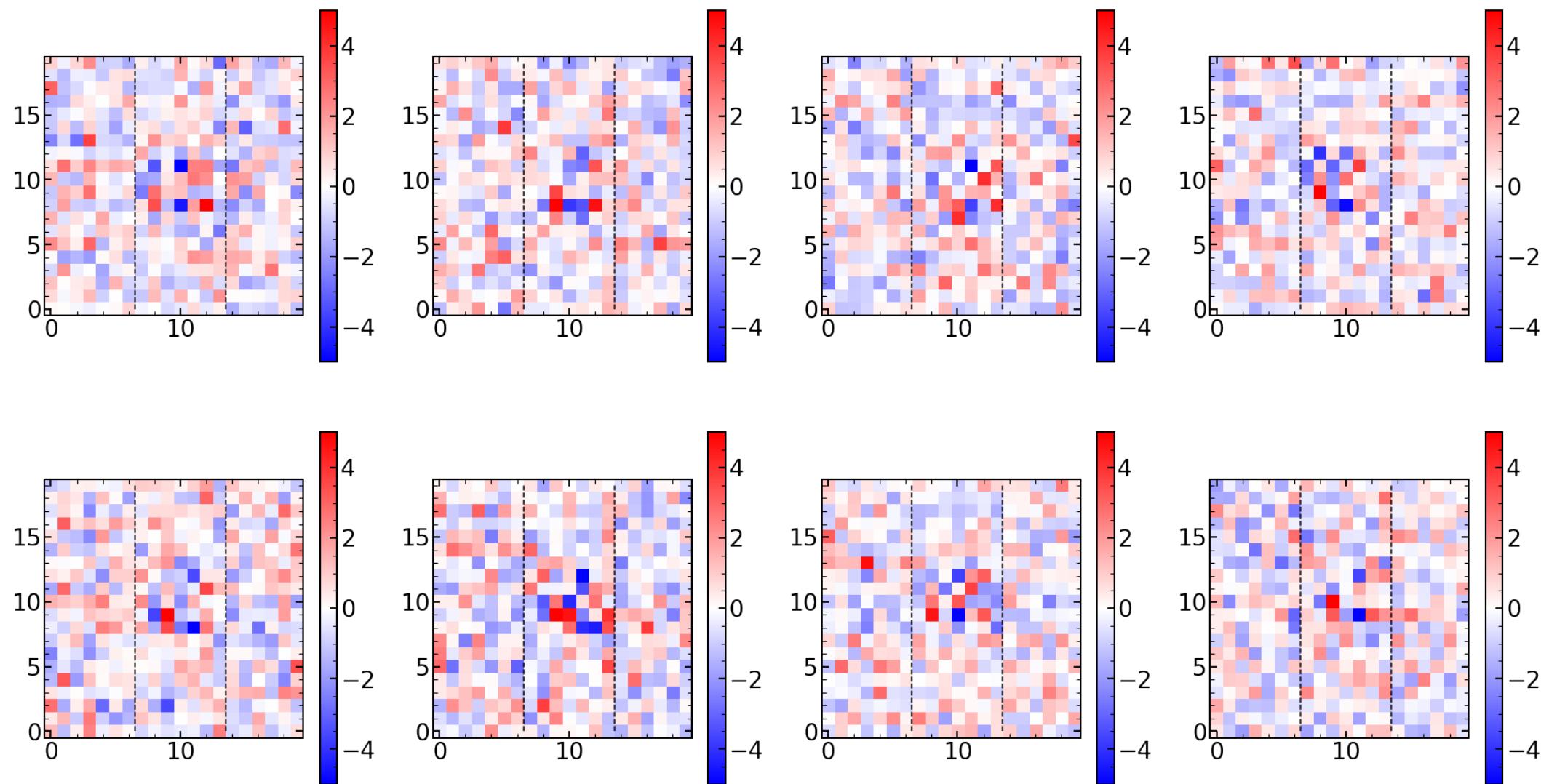
Residuals in the focused data, 8 different dithering positions

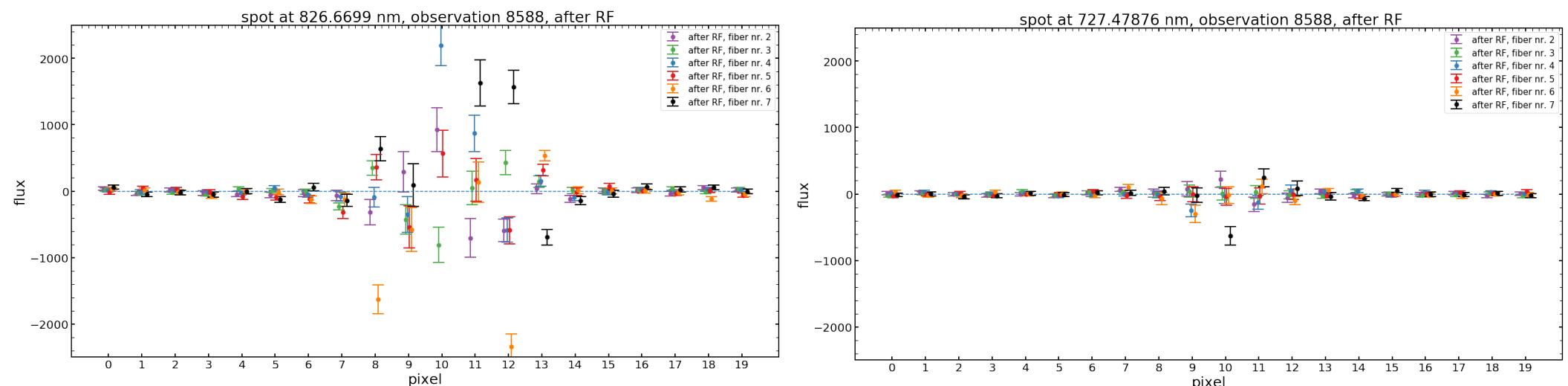
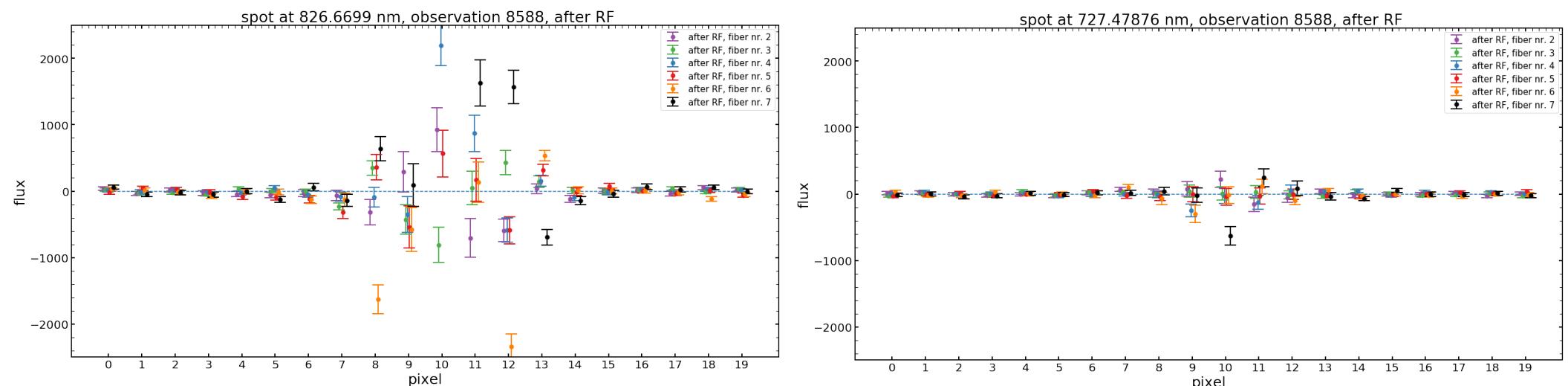
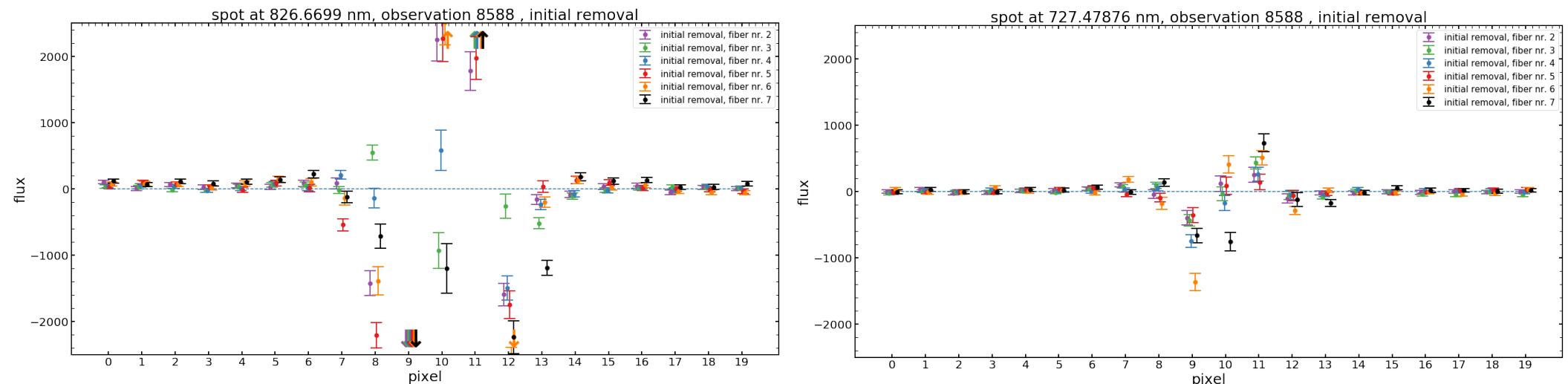
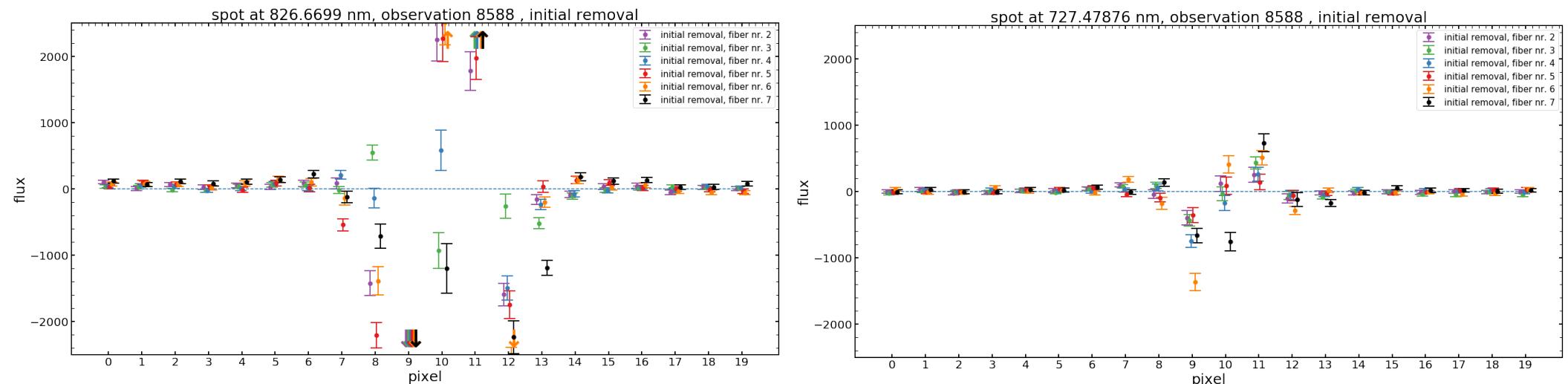
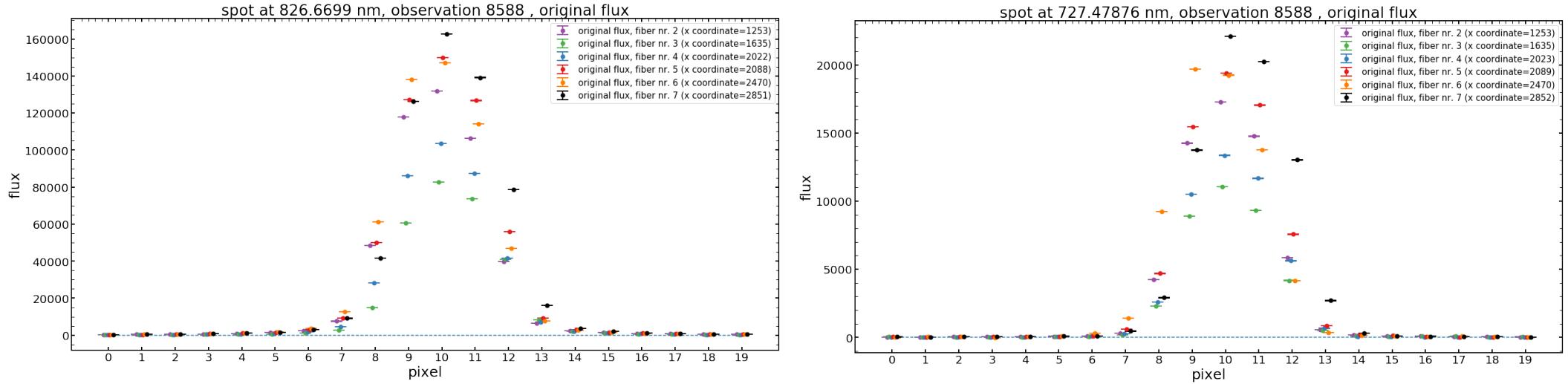
Residuals, up to Zernike 22 and Jan 15 modifications to centering



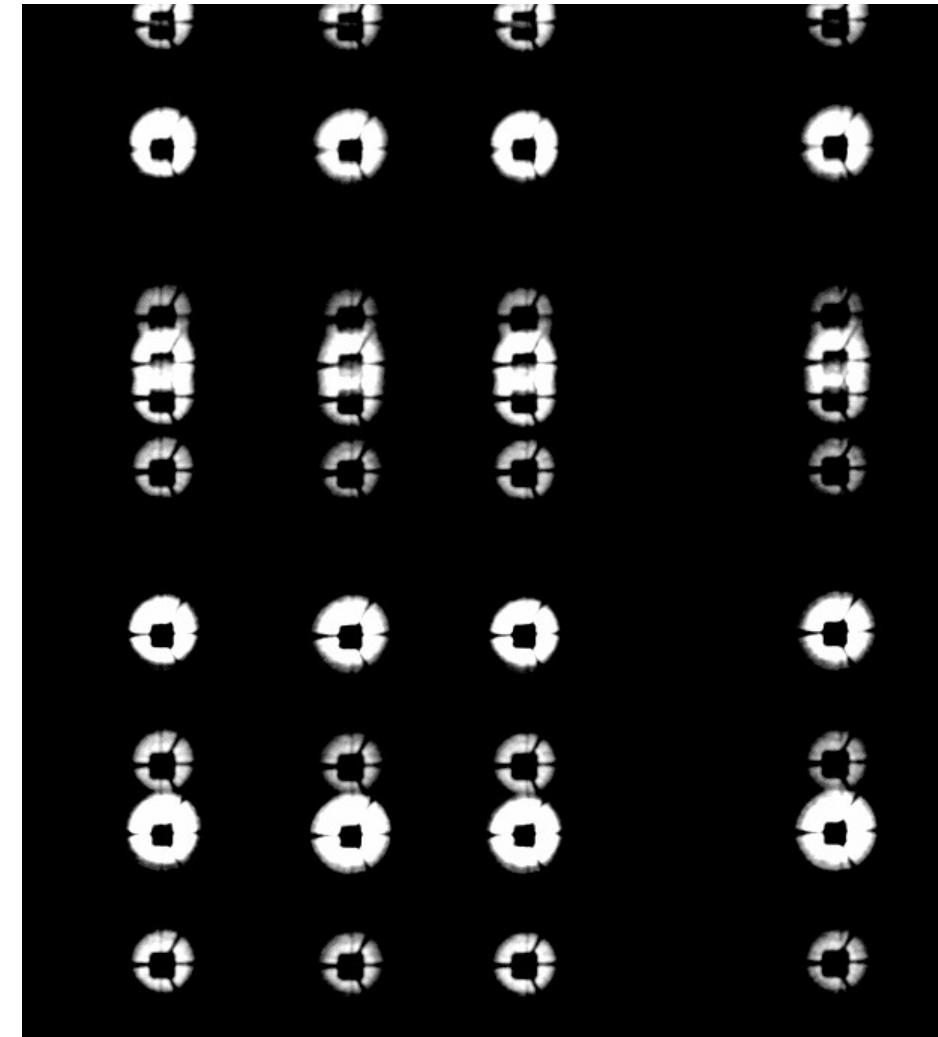
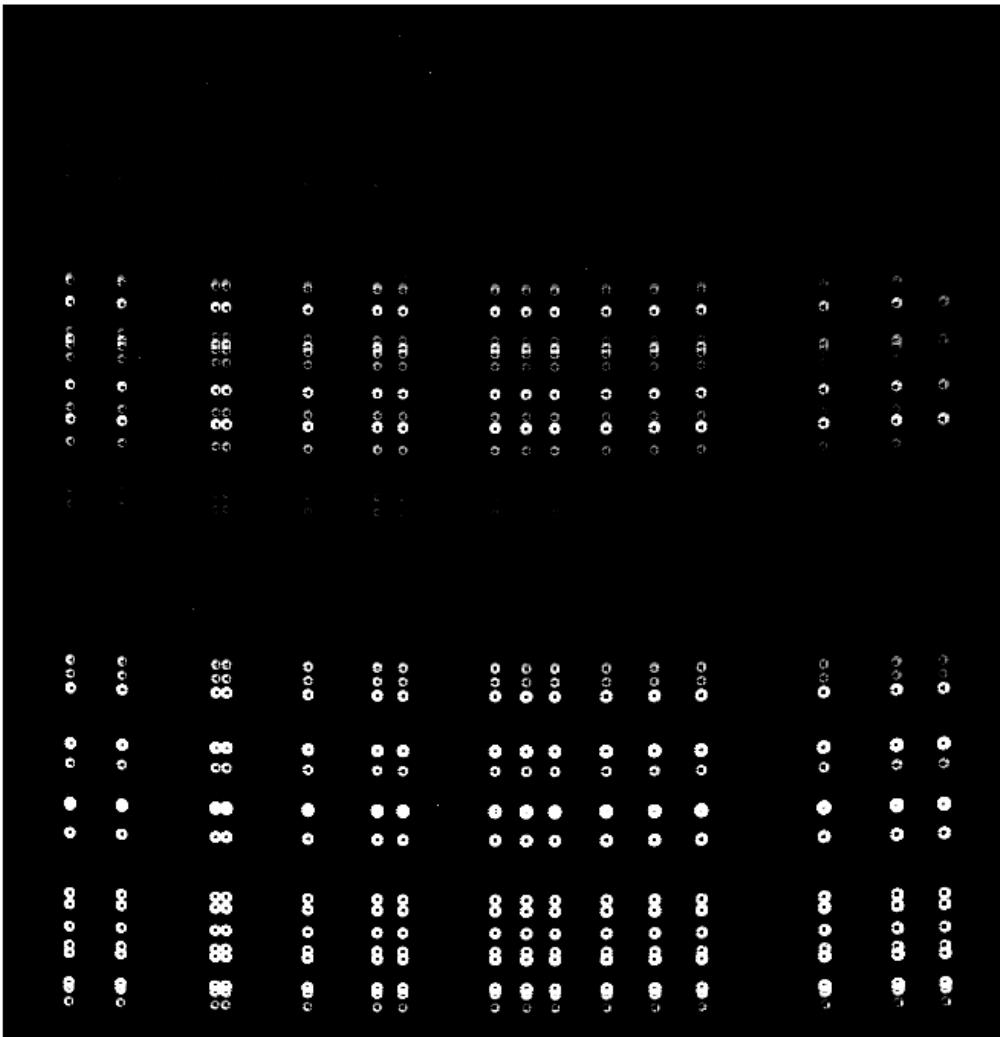
Residuals in the focused data, 8 different dithering positions, after Random forest cleaning applied

up to Zernike 22, Jan 15 modifications to centering, and Random Forest postprocessing



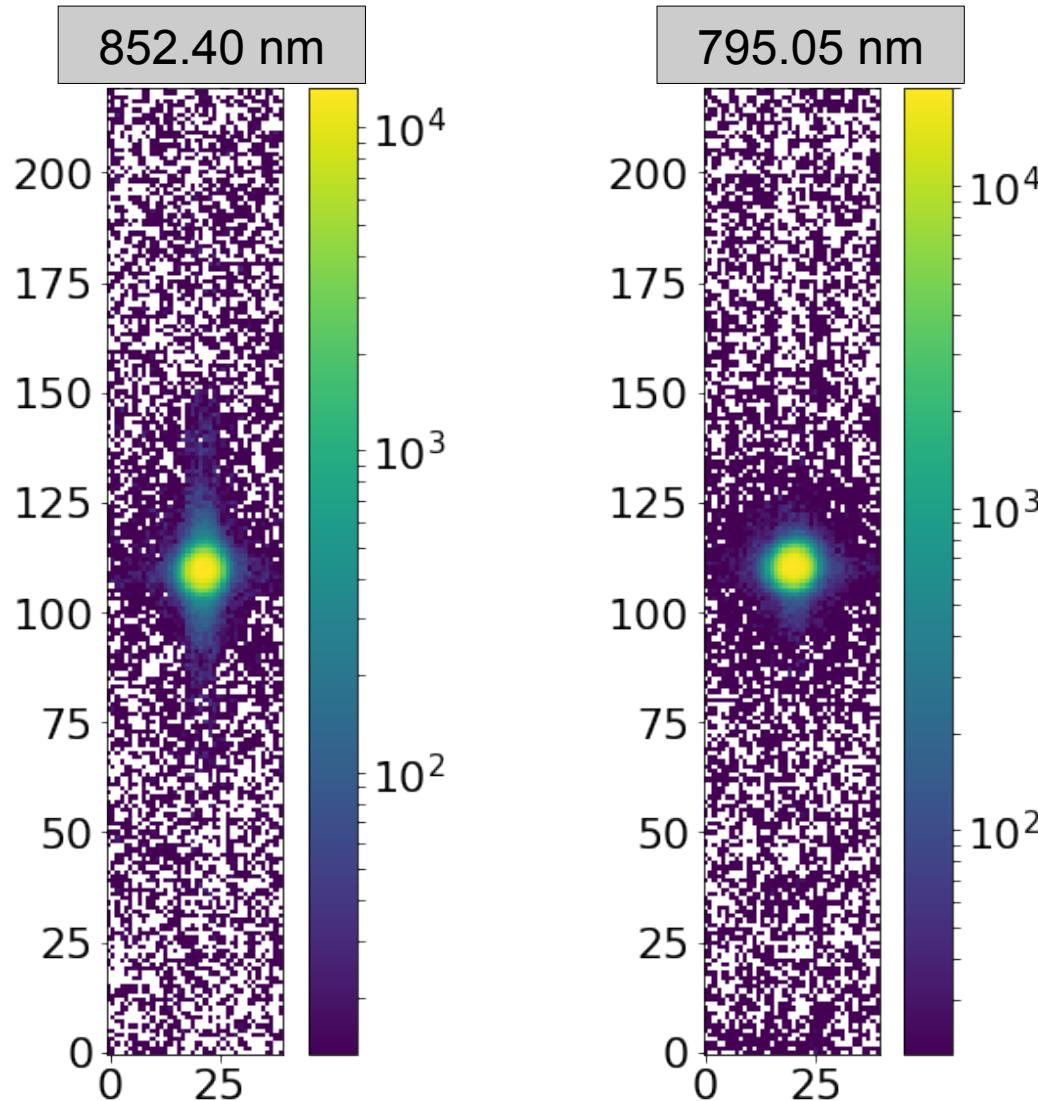
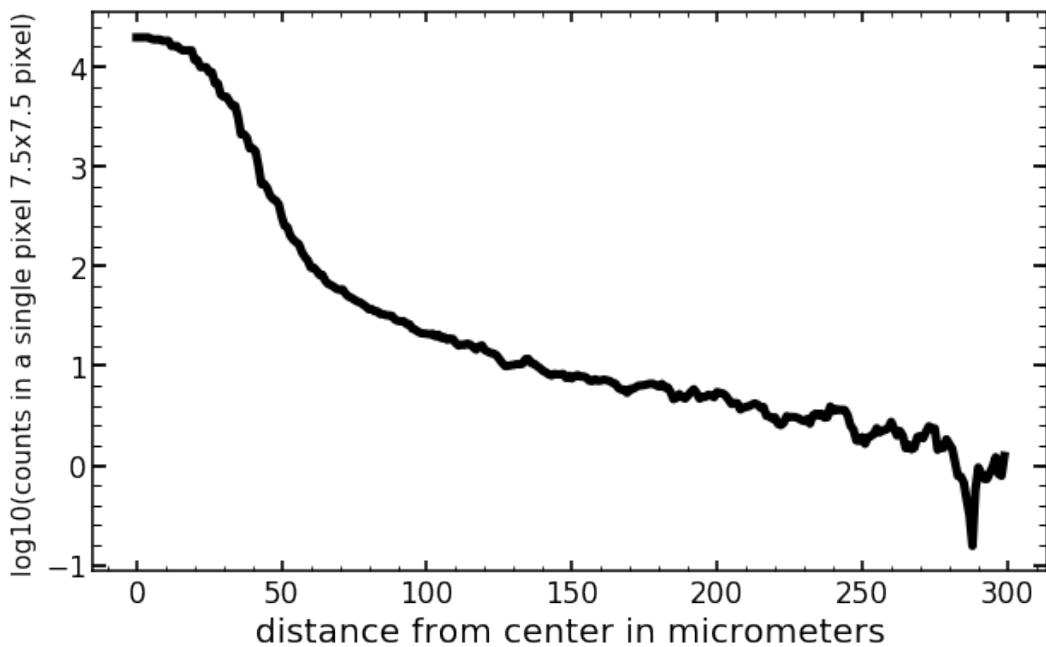
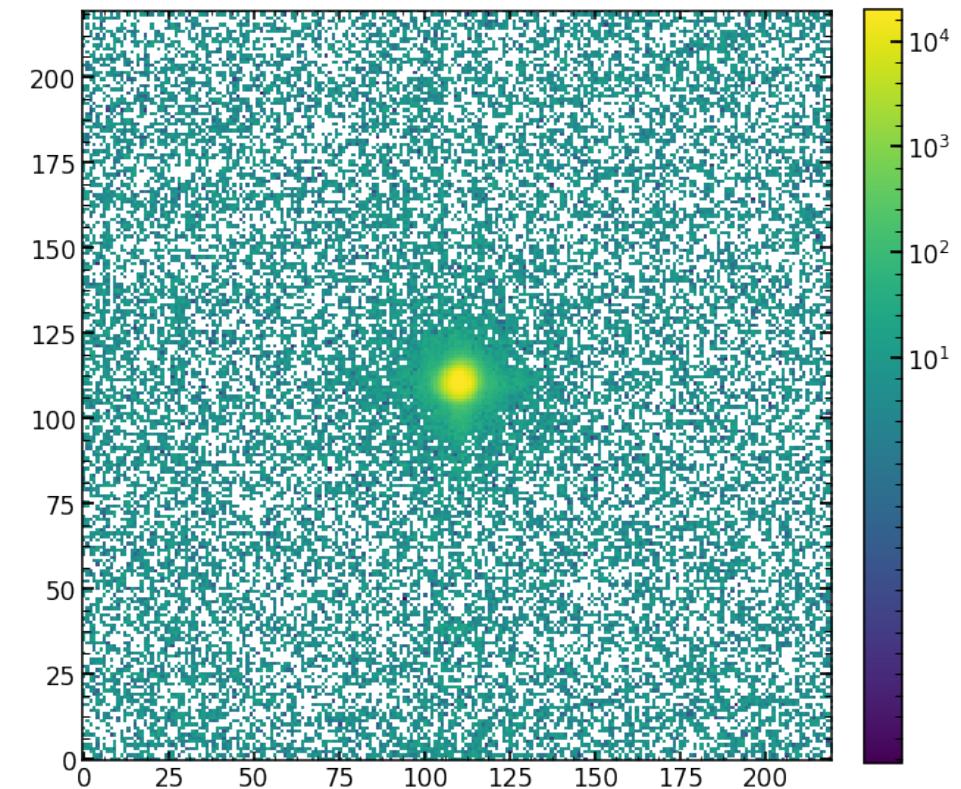


Selected topics – Overlap of spots



Partially mitigated by algorithm improvement, creating two identical
models with an offset and adding them together

Selected topics - wings



Additional possible topics:

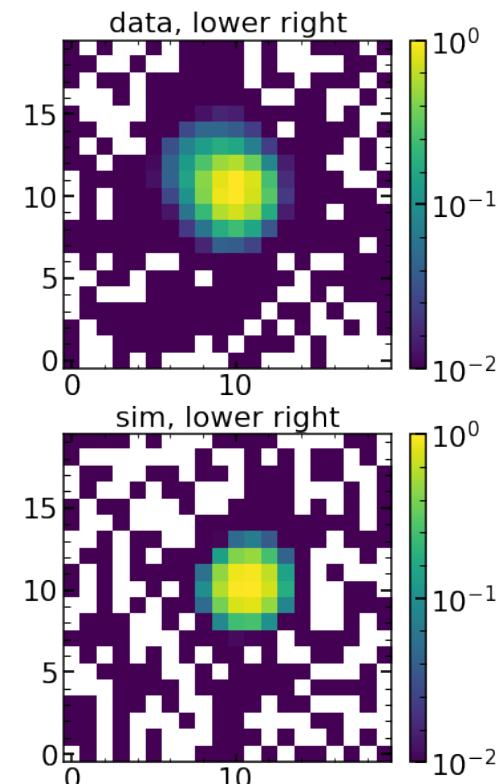
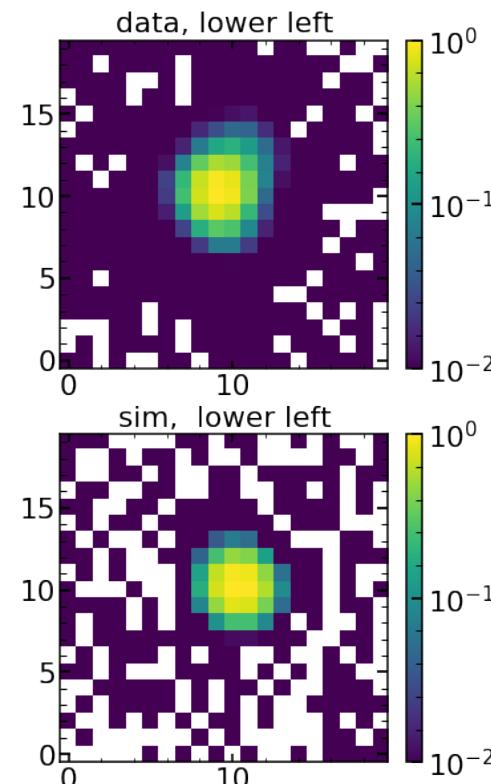
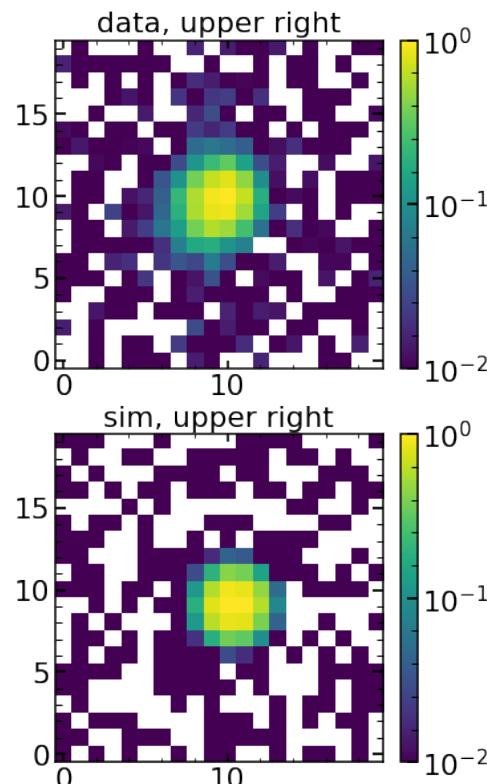
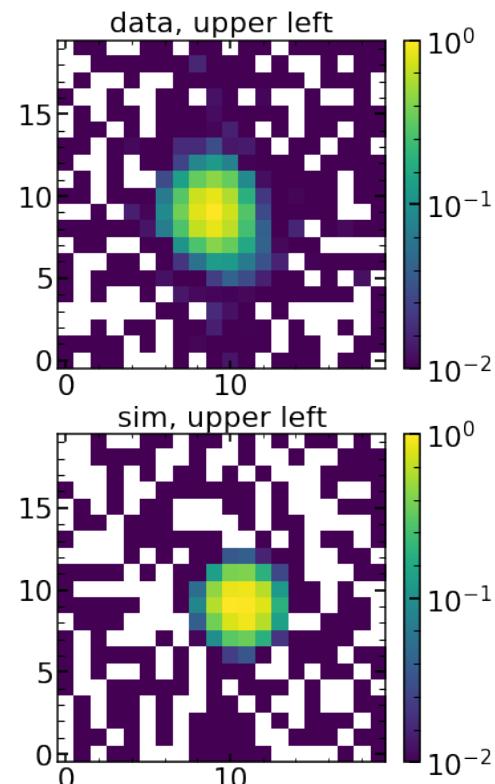
- dithering problems
- attenuator, shutter and flux control
- FRD and different collimator F-ratios

Summary

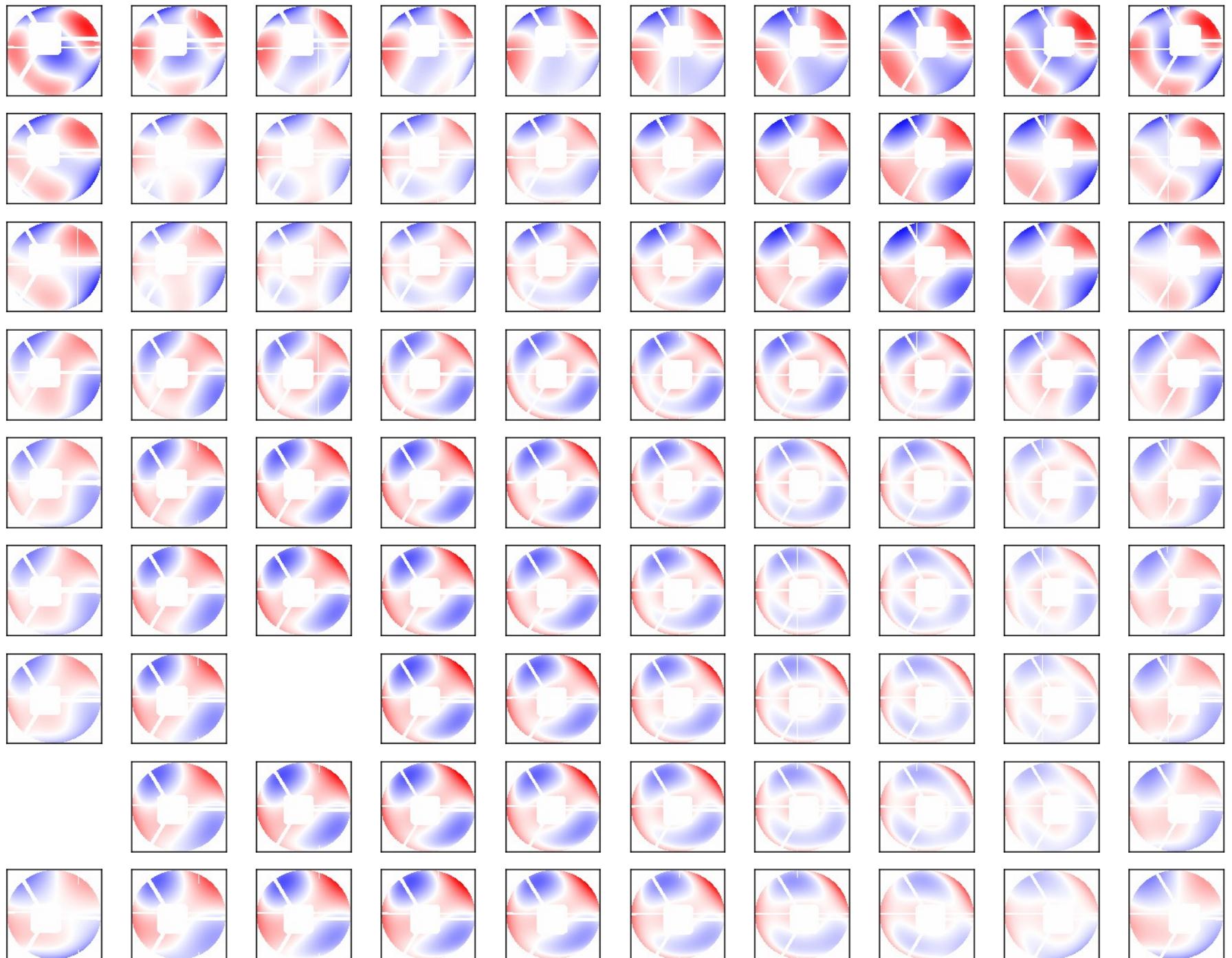
- Prime Focus Spectrograph – 2394 fibers, 380nm-1260nm, to be installed on Subaru
- 3 components of the point spread function
 - Telescope pupil illumination
 - Focal ratio degradation in the fibres
 - Spectrograph cameras
- Characterize contribution of camera imperfections to the point spread function by modelling optical performance using defocused data
- Defocused images on both sides of focus allow to decouple the illumination and the wavefront aberrations
- github.com/nevencaplar/Presentations/BerkleyLab_PFS_Jan21_2021

Extra slides

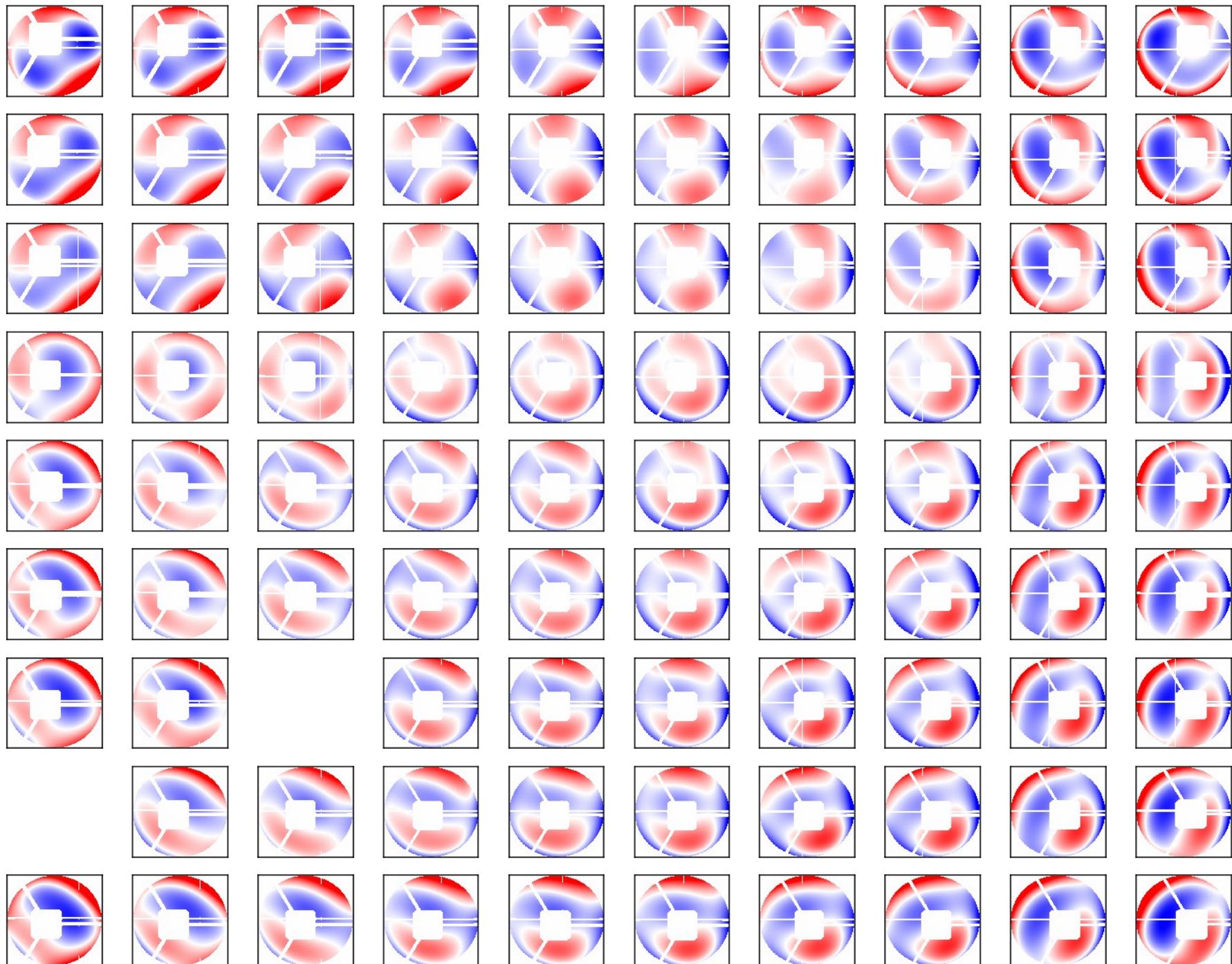
Zemax & real data



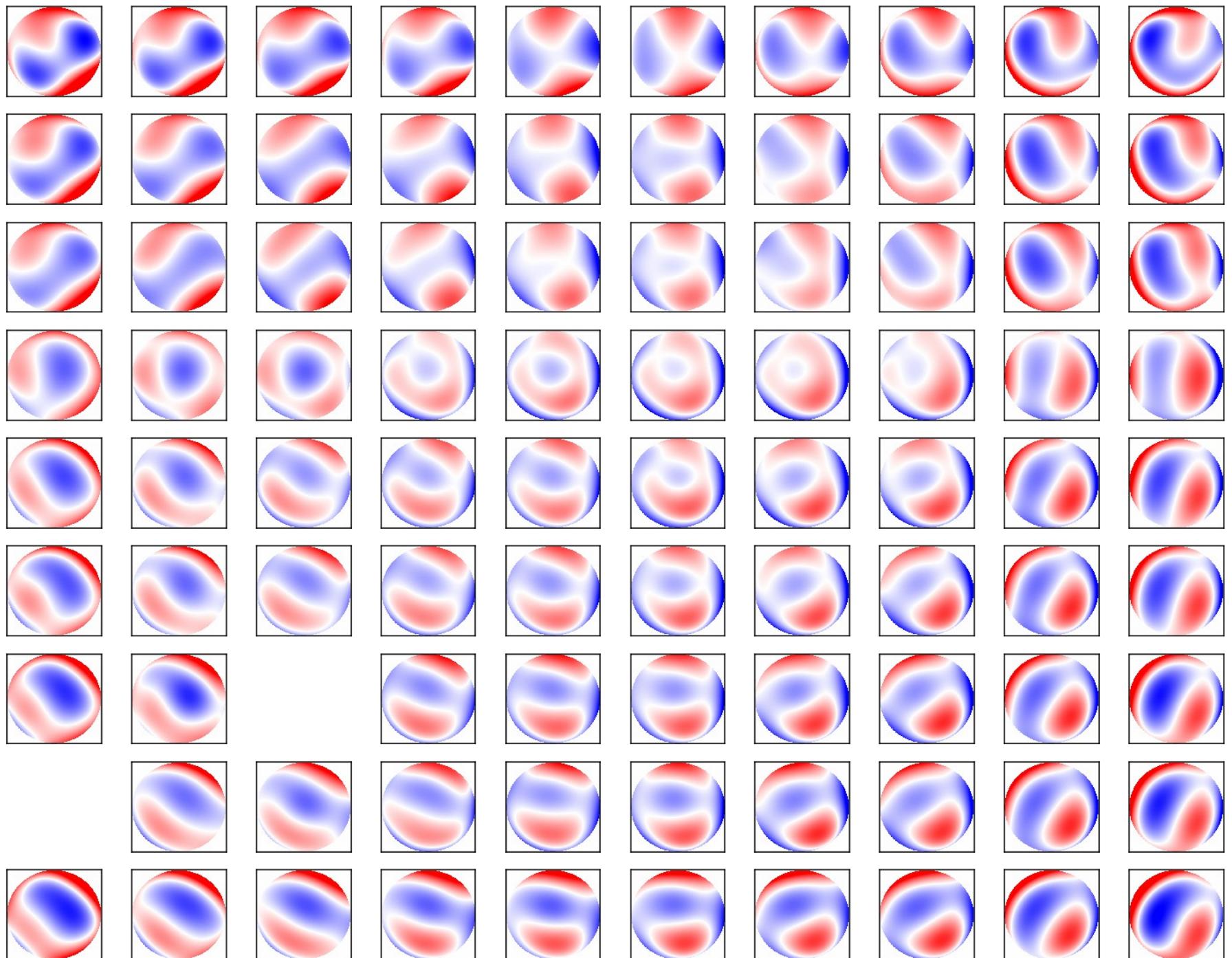
wavefront



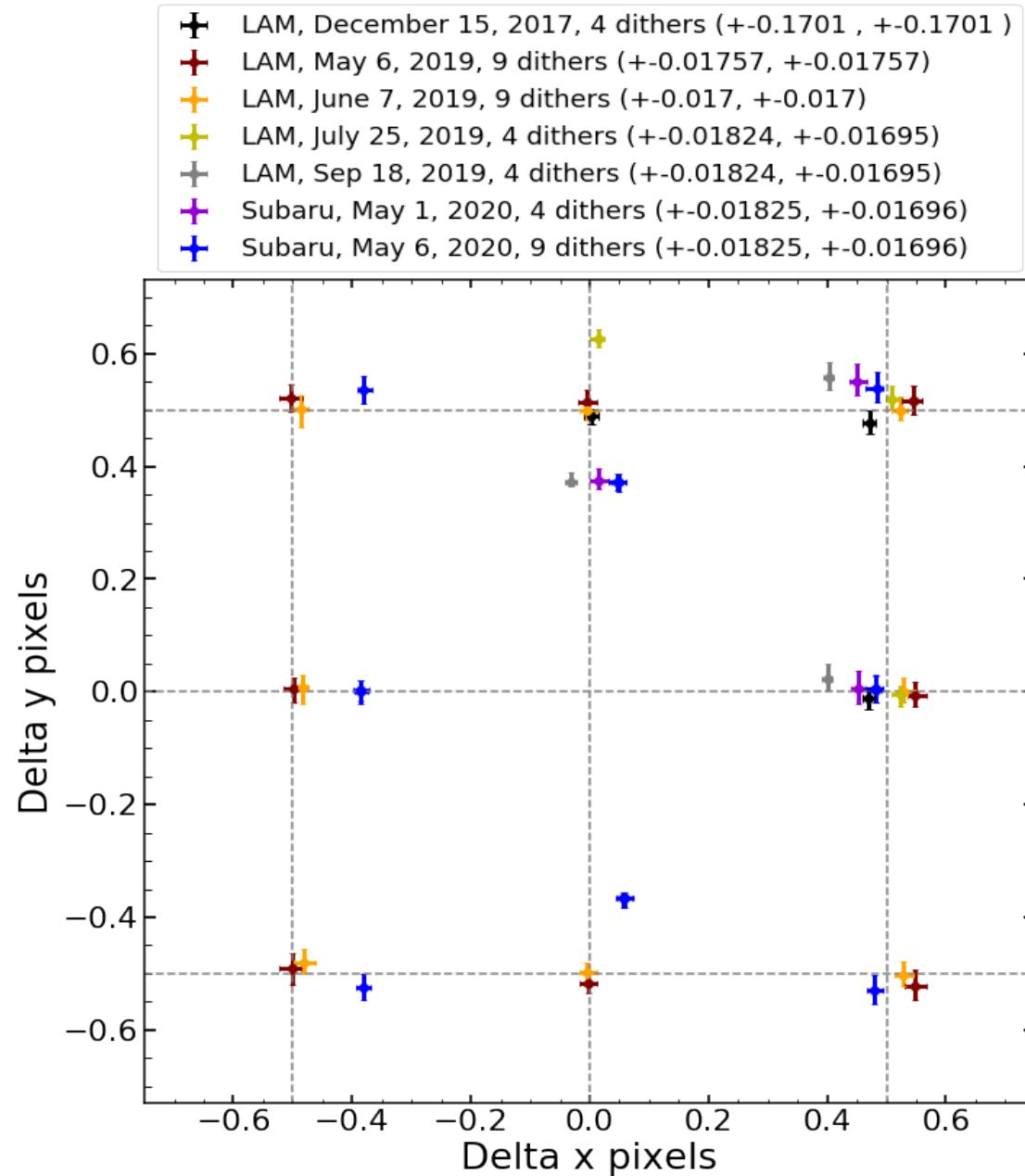
wavefront



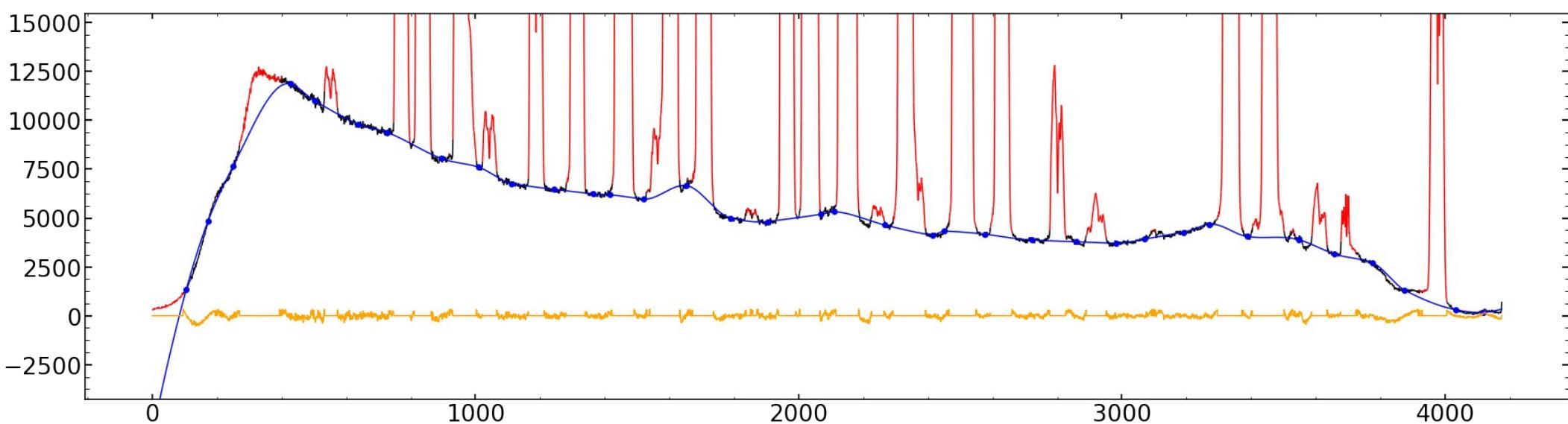
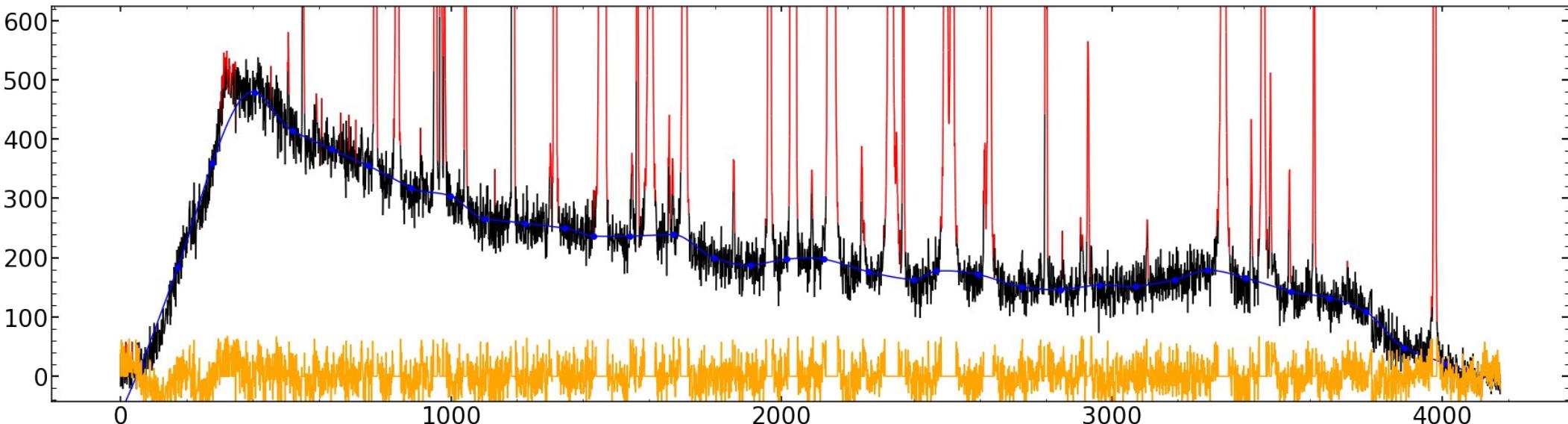
wavefront



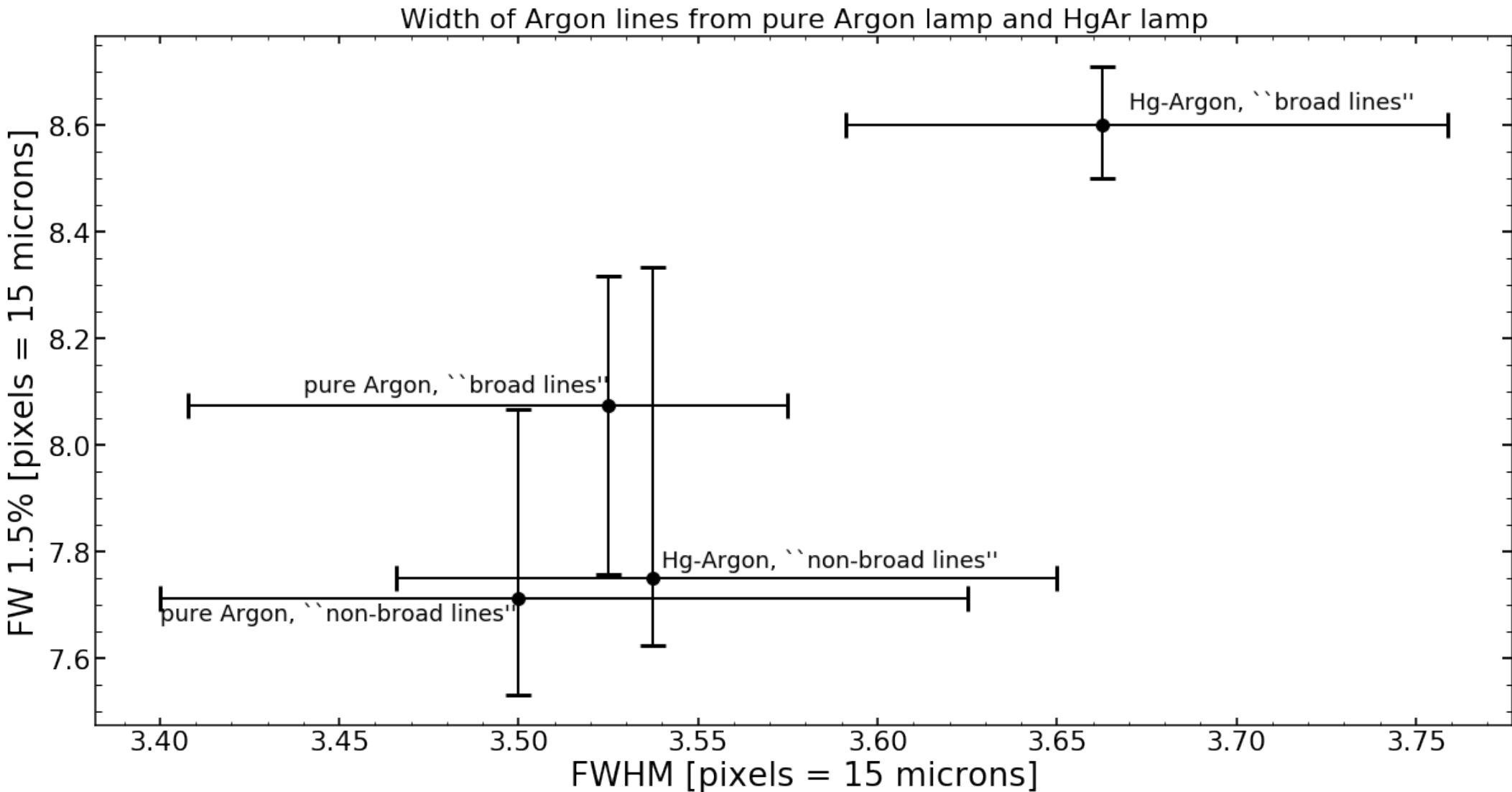
Dithering



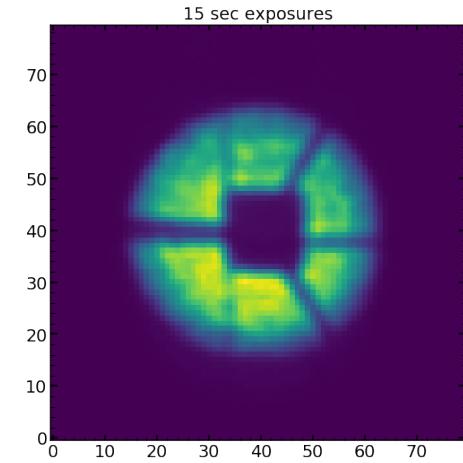
HgAr continuum



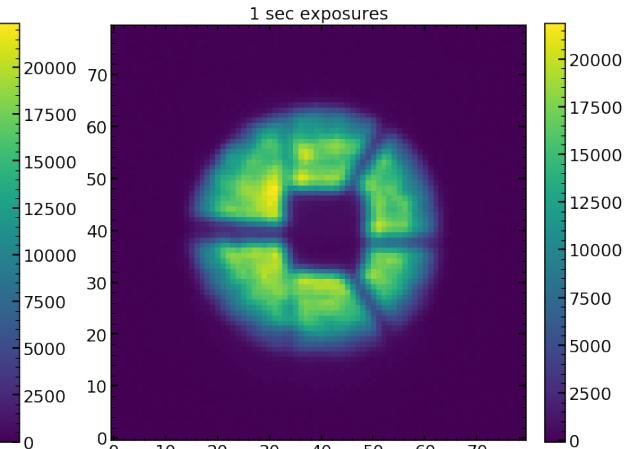
Broad lines of HgAr



15 sec exposures

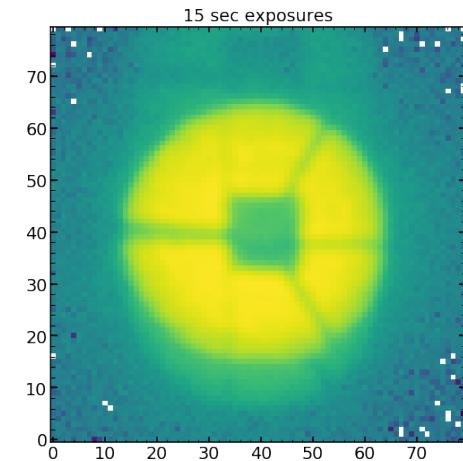


1 sec exposures

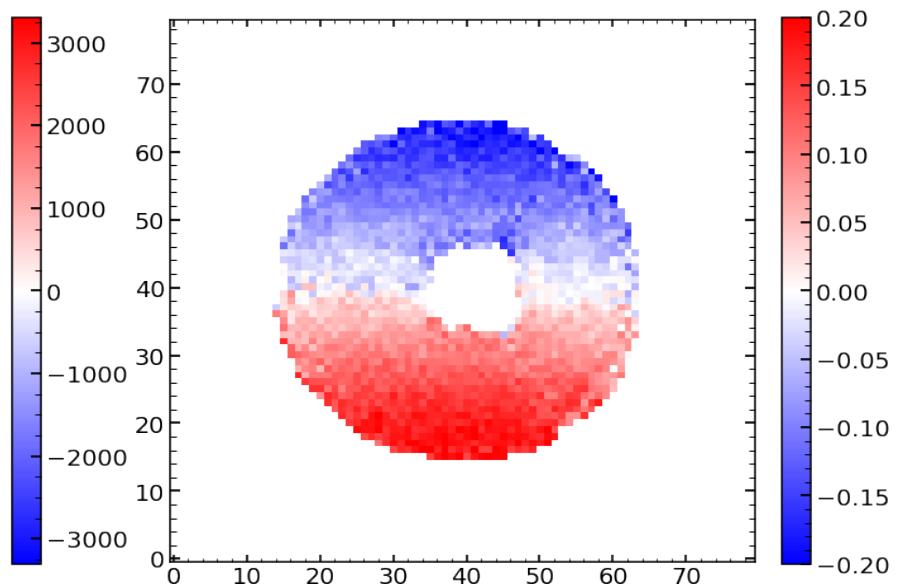
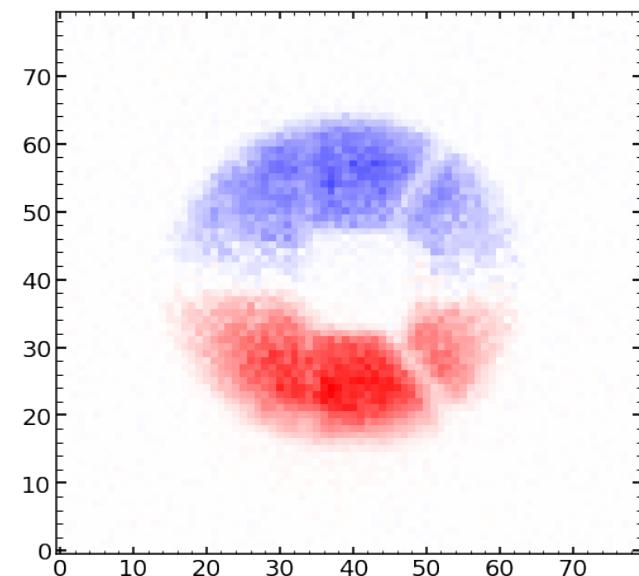
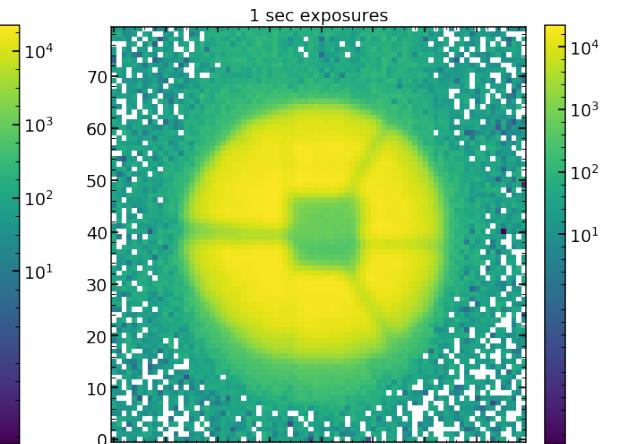


Shutter and flux control

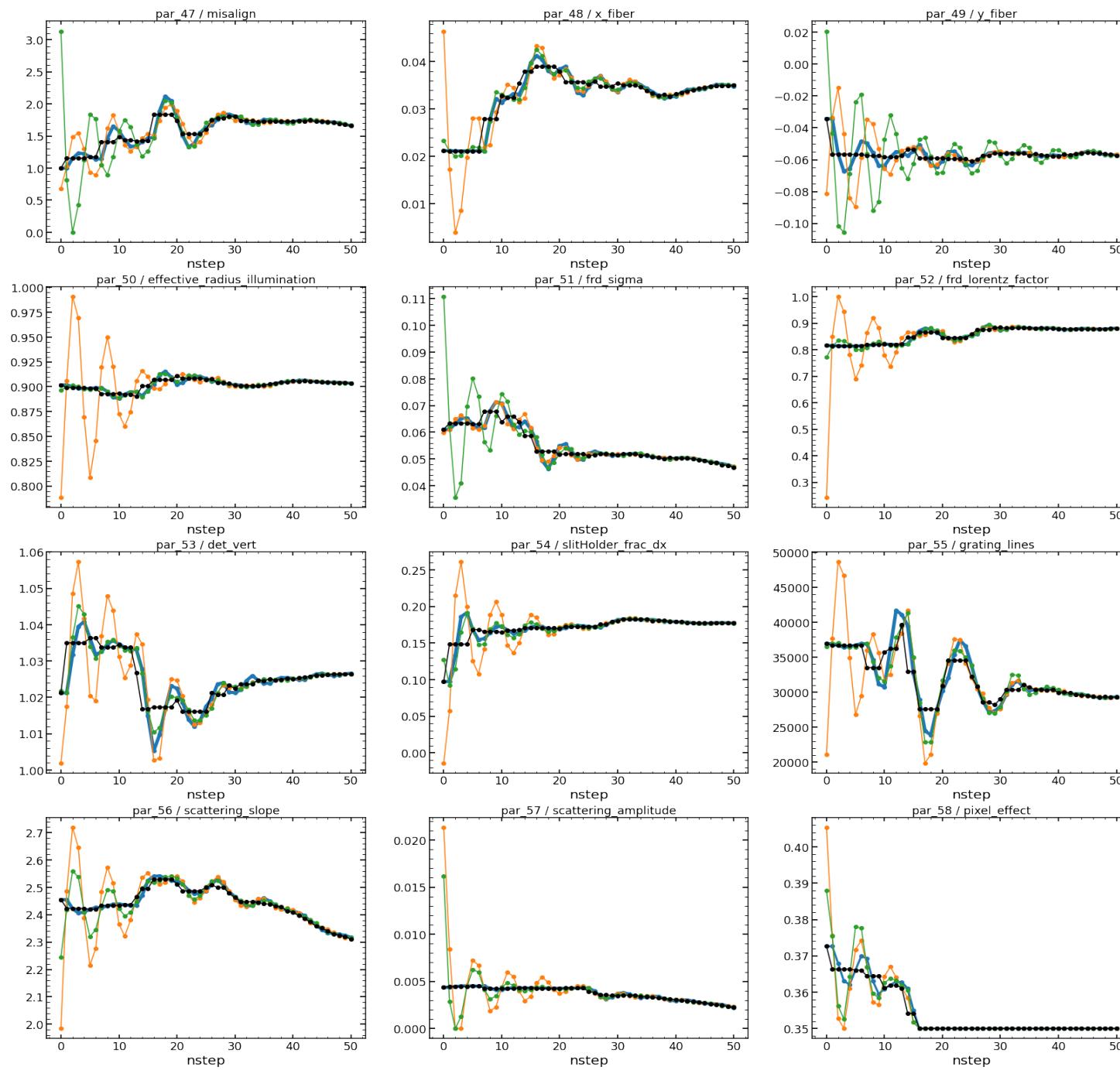
15 sec exposures



1 sec exposures

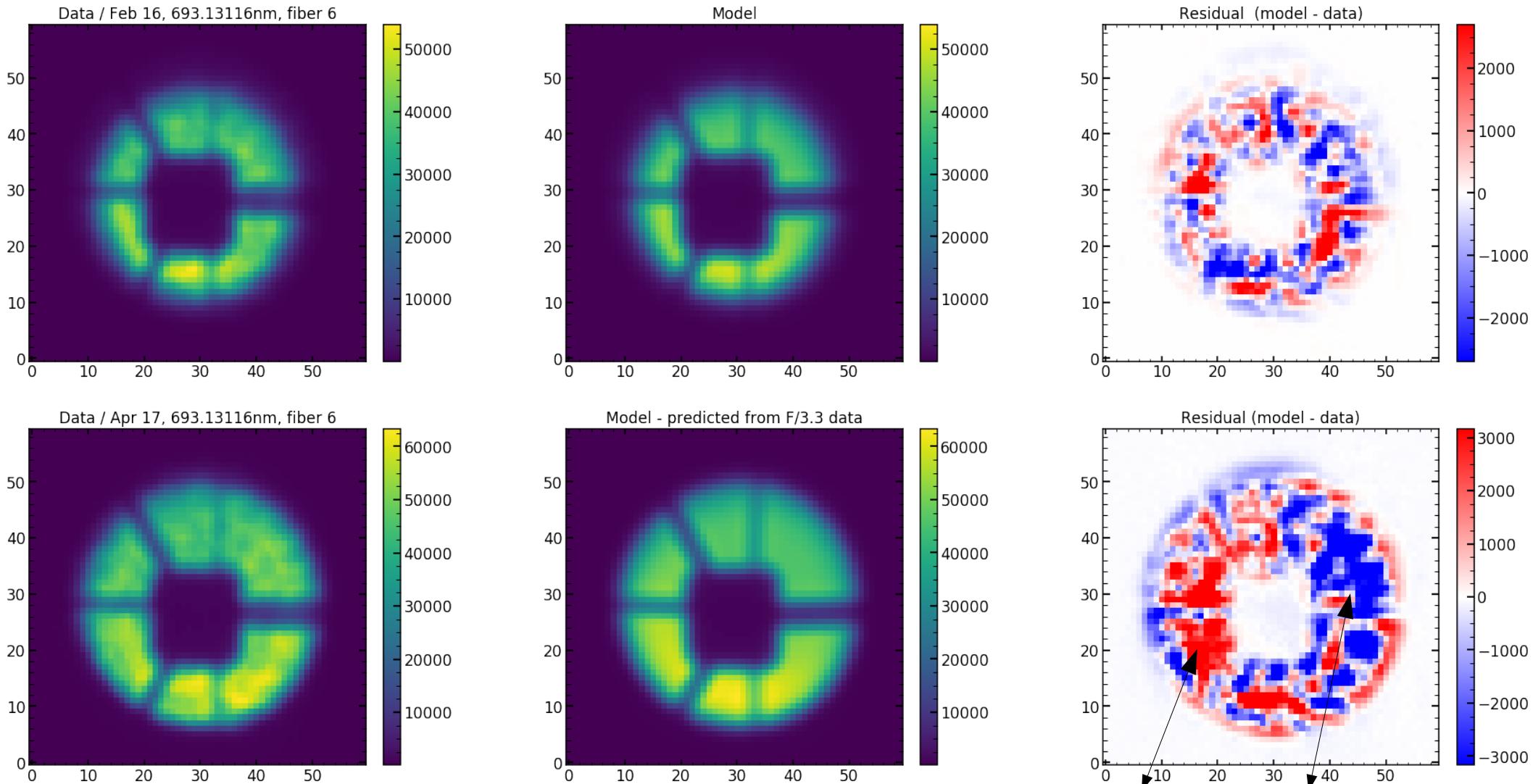


Parameter fitting



Different stops

a) only illumination of the full pupil gives full information



b) experiment for the quality of the approach

Mistakes in the non-illuminated region!