StarDICE transmission model

StarDICE workshop

LPNHE, 29 novembre 2023

STARDICE

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Synthesizing the full-pupil effective transmission from CBP measurements

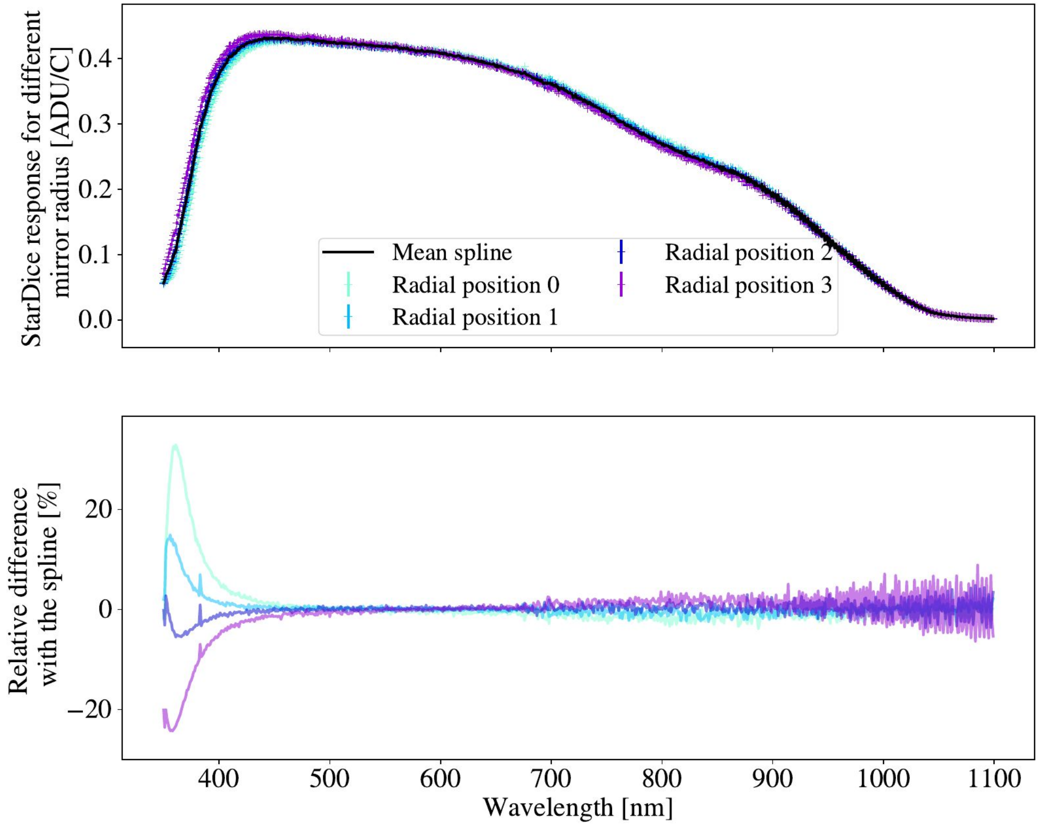
The transmission of the StarDICE telescope is a fonction of the position in the primary mirror

Part of it was expected

- The transmission of interference filter depends on the angle of incidence
- To first order the transmission is shifted towards the blue as :

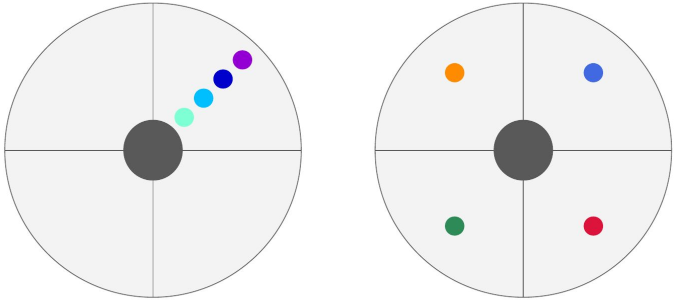
$$T(\lambda, \theta) = \mathcal{T}\left(\frac{\lambda}{\sqrt{1 - (\sin(\theta)/n_{\text{eff}})^2}}\right)$$

Part of it was not



The CBP samples a small fraction of the mirror

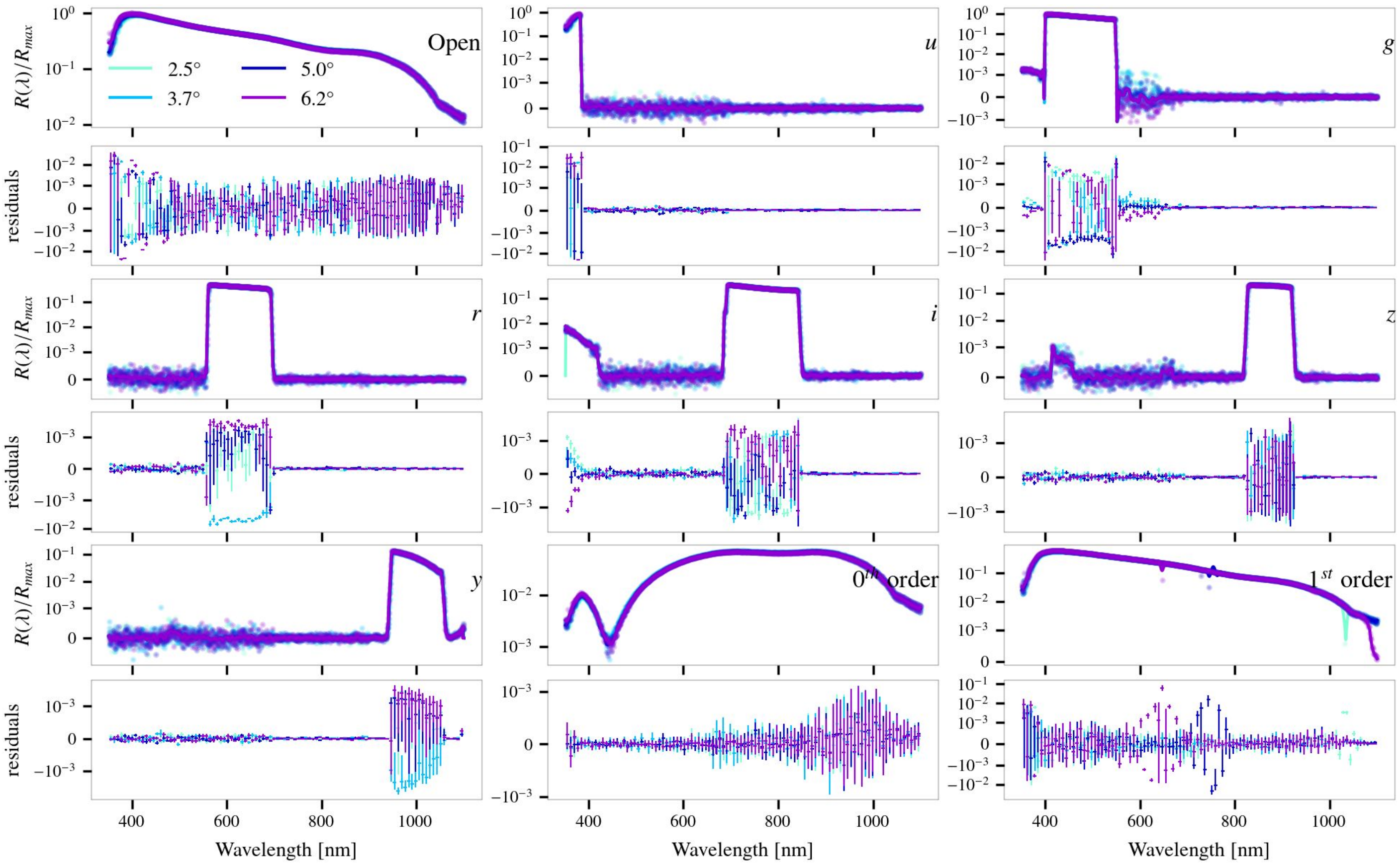
- We sampled 8 mirror positions



- The proposition is to build a “radial” model on the 4 roughly aligned samples
- Check the consistency with the 4 “random” positions
- Integrate the radial model on the pupil area to build a synthetic transmission curve for the full-pupill StarDICE telescope

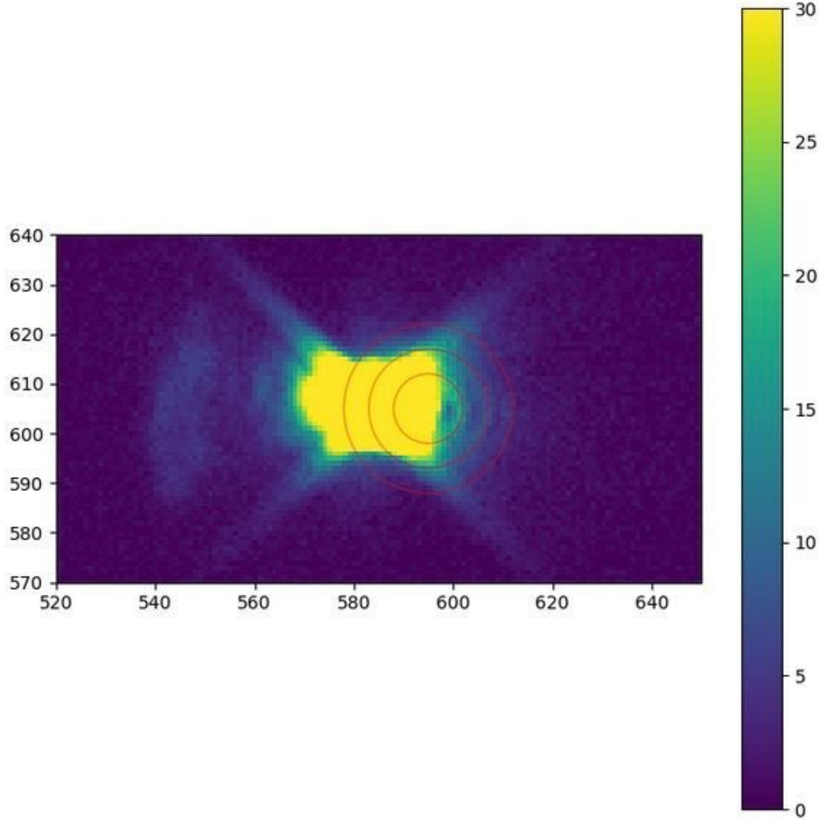
- The model needs to be an analytical parametric function of wavelength and radius so that it can be integrated
- Radial model components:
  - Smooth open transmission:
    - 2D third-order B-spline basis
    - 70 wavelength nodes regularly spaced between 350-1100nm
    - 2 nodes in angles between 1.97° and 7.24°
  - Filter transmission:
    - angle dependence: $T(\lambda, \theta) = \mathcal{T}\left(\frac{\lambda}{\sqrt{1 - (\sin(\theta)/n_{\mathrm{eff}})^2}}\right)$
    - 1D piece-wise linear function of wavelength
  - Smooth grating transmission
    - Same model as the open transmission

Model and model residuals



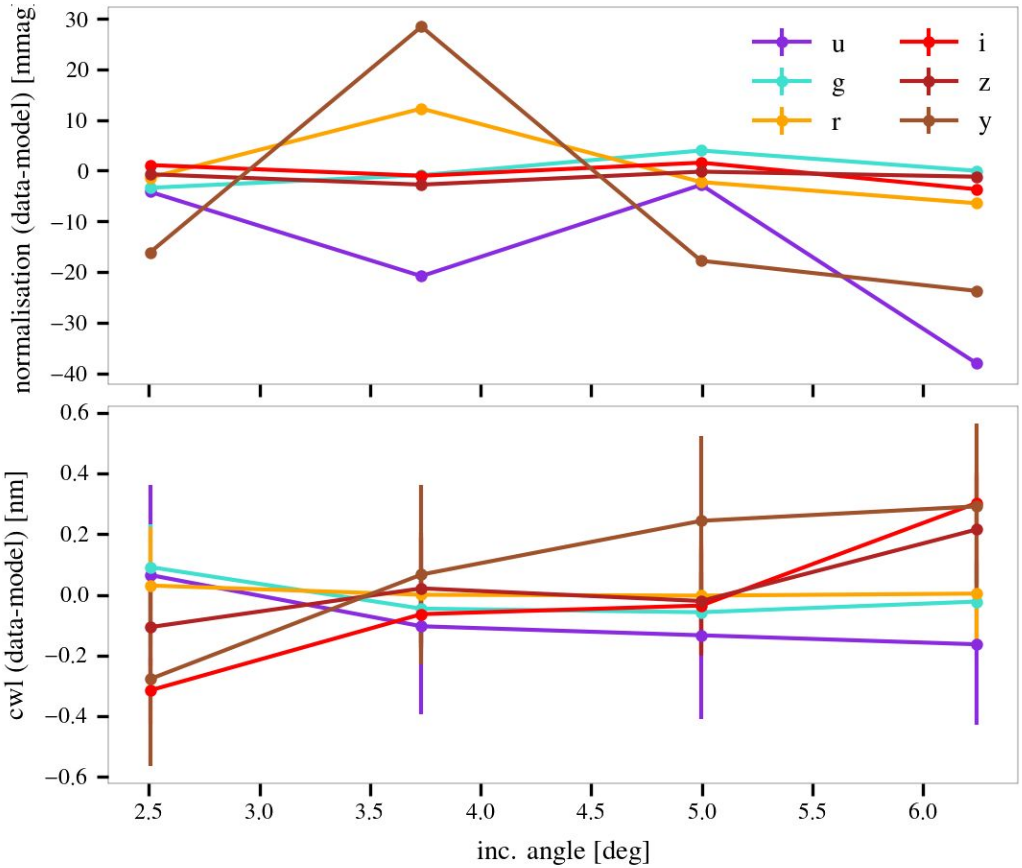
- New results on the DR4
- The model requires a bit of tuning to describe the edges
- A few more outliers in DR4 needs cleaning
- main feature in the residuals : random gray changes in the filter passbands as a function of position

A more detailed look at the passband change in r



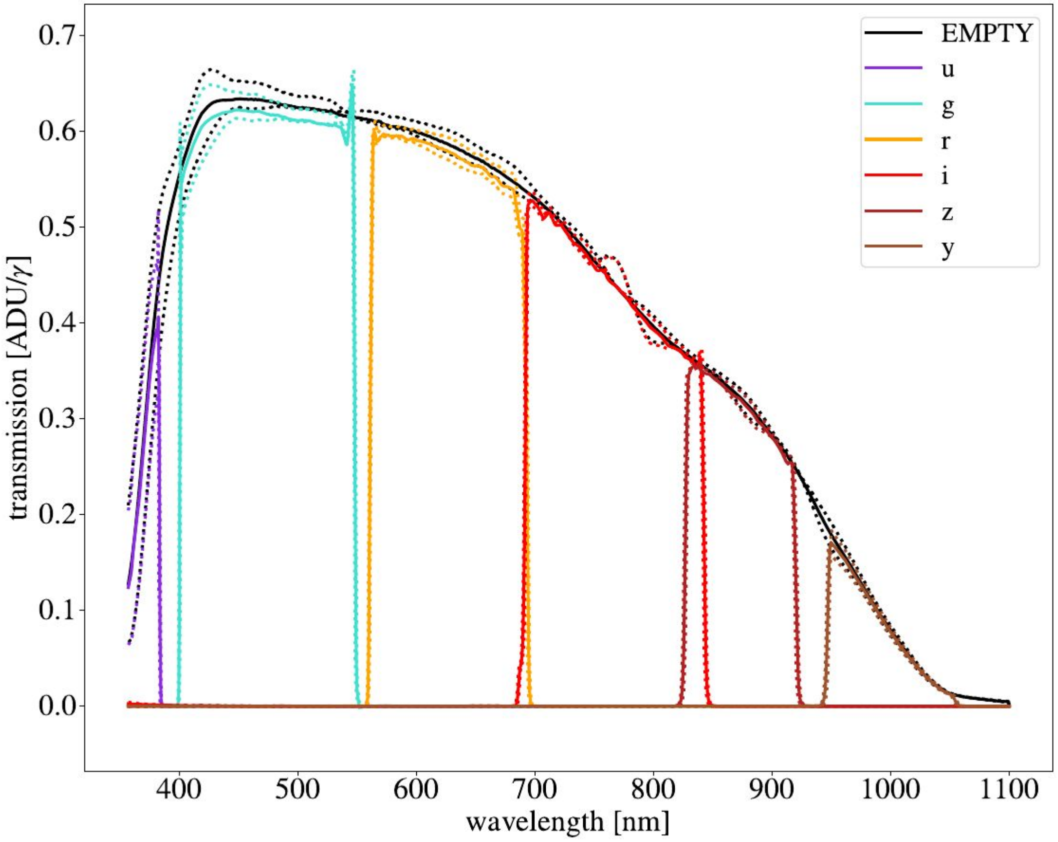
- The area of the spot formed on the filters by the CBP beam is about 12mm²
- Stacking images corresponding to the 3.7° measurement reveals a diffraction pattern compatible with the beam intercepting a dust particle of diameter 200-300 μm
- Such a particle would cause an occultation of .3-.6% of the beam
- Inherent noise in such sampled-based measurements

Summary of Model/measures differences



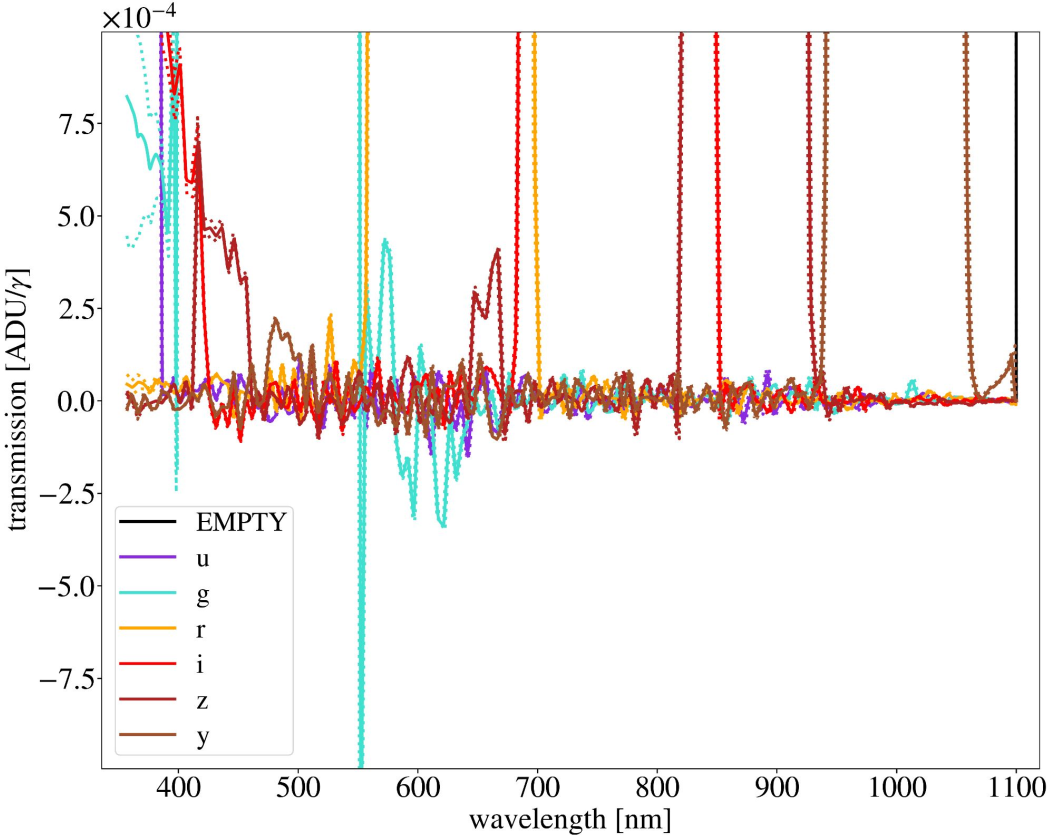
- The dispersion of passbands normalisations wrt the mean model is 12mmag
- Averaging 4 samples we expect the resulting uncertainty to be of the order of 6mmag
- The dispersion of passbands central wavelength wrt the blueshift model is 0.15nm
- The result were a bit better in the DR3 so part of is likely related to the remaining outliers disturbing the fit and edges problems

Synthesized full-pupil passbands



- Apart from the cleaning of ringing due to outliers and edge mismatch: pretty darn good
- We miss the blue edge of the u-band filter
- The noise on out-of-band is well below 10^{-3}

Synthesized full-pupil passbands



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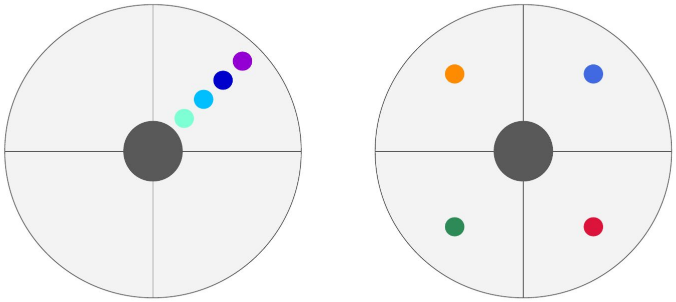
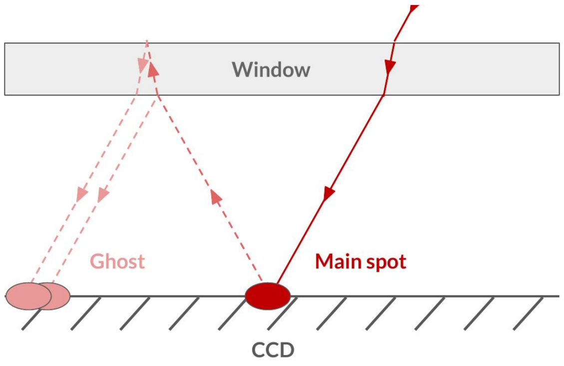
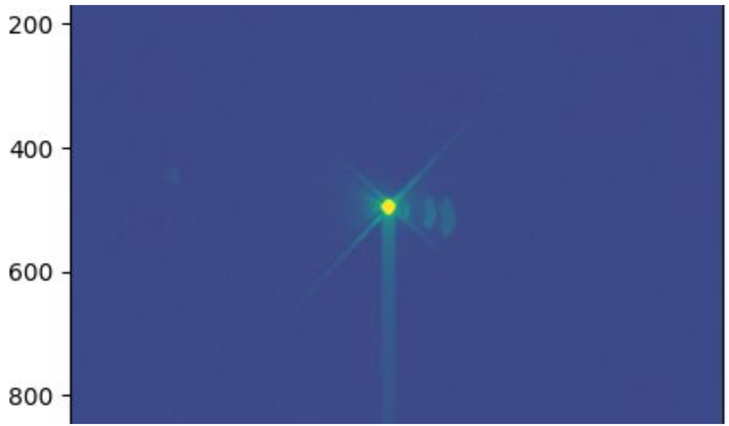
Going beyond those results

Four more samples are available



- That could be interesting because 4 more samples decrease the “dust noise”
- Making use of them requires a bit more work because their location must be inferred from the data
- We can use of the window ghosts for this purpose

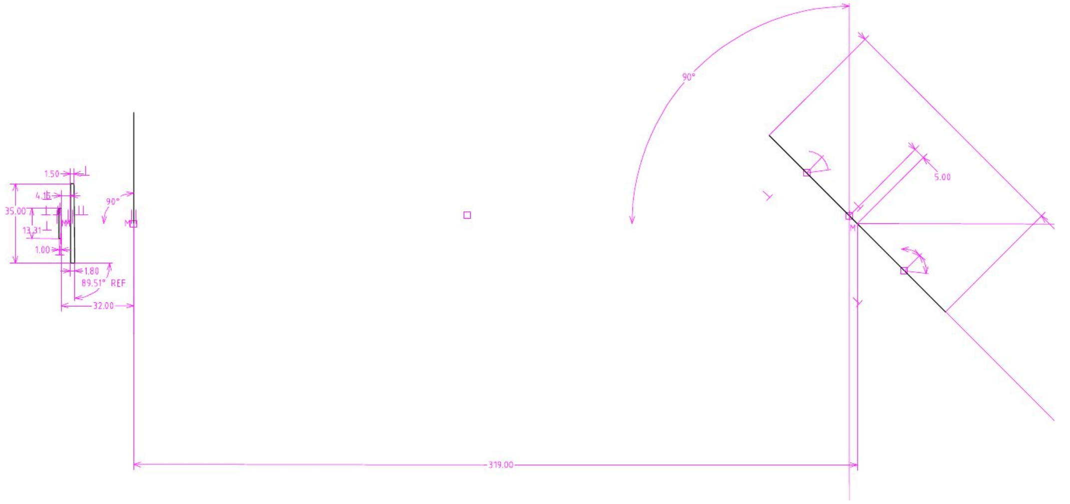




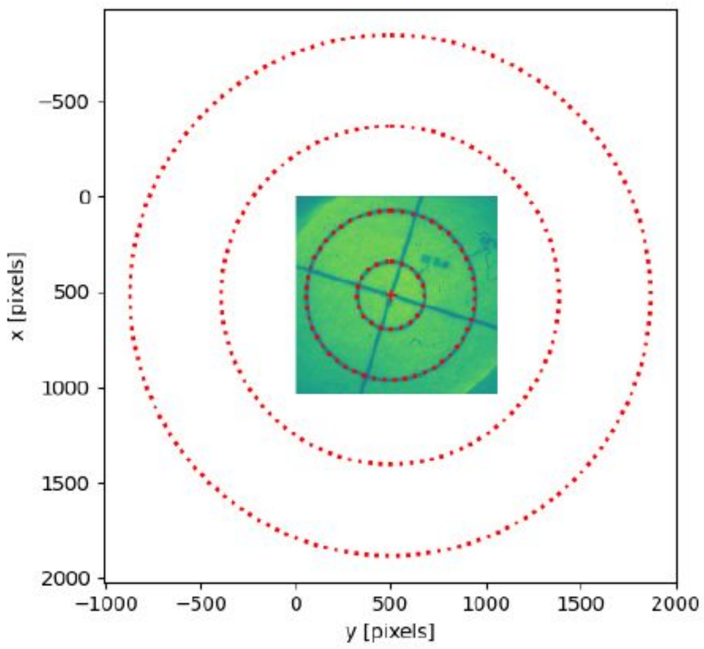
Towards a physical model of the optics

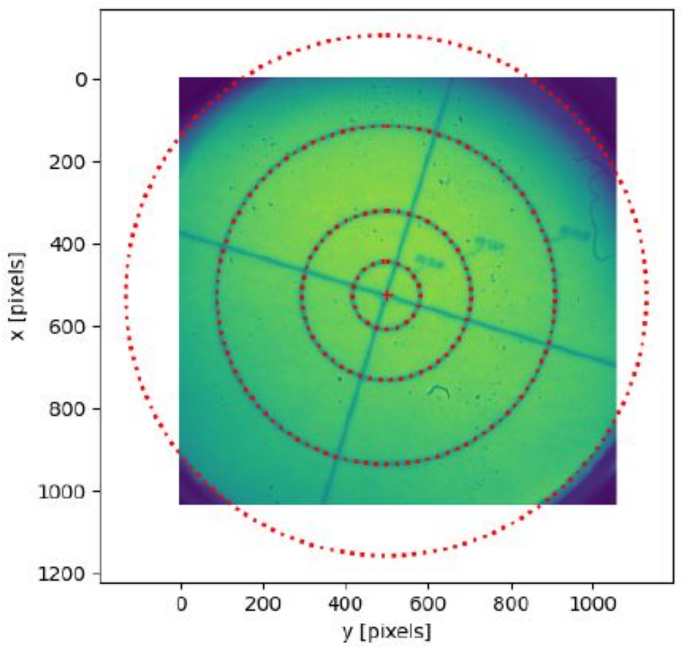
Take advantage of pinhole images of the telescope and of a target to:

- Characterize the pinhole imaging
  - ccd-pinhole distance
  - focuser axis alignment
- Fit the unknown telescope quantity
  - secondary position relative to the primary vertex
  - secondary-camera alignment
  - secondary diameter
  - primary diameter
- Check that the window is properly positioned by synthetizing ghost images
- Infer the CBP-StarDICE position from ghost images thanks to the model

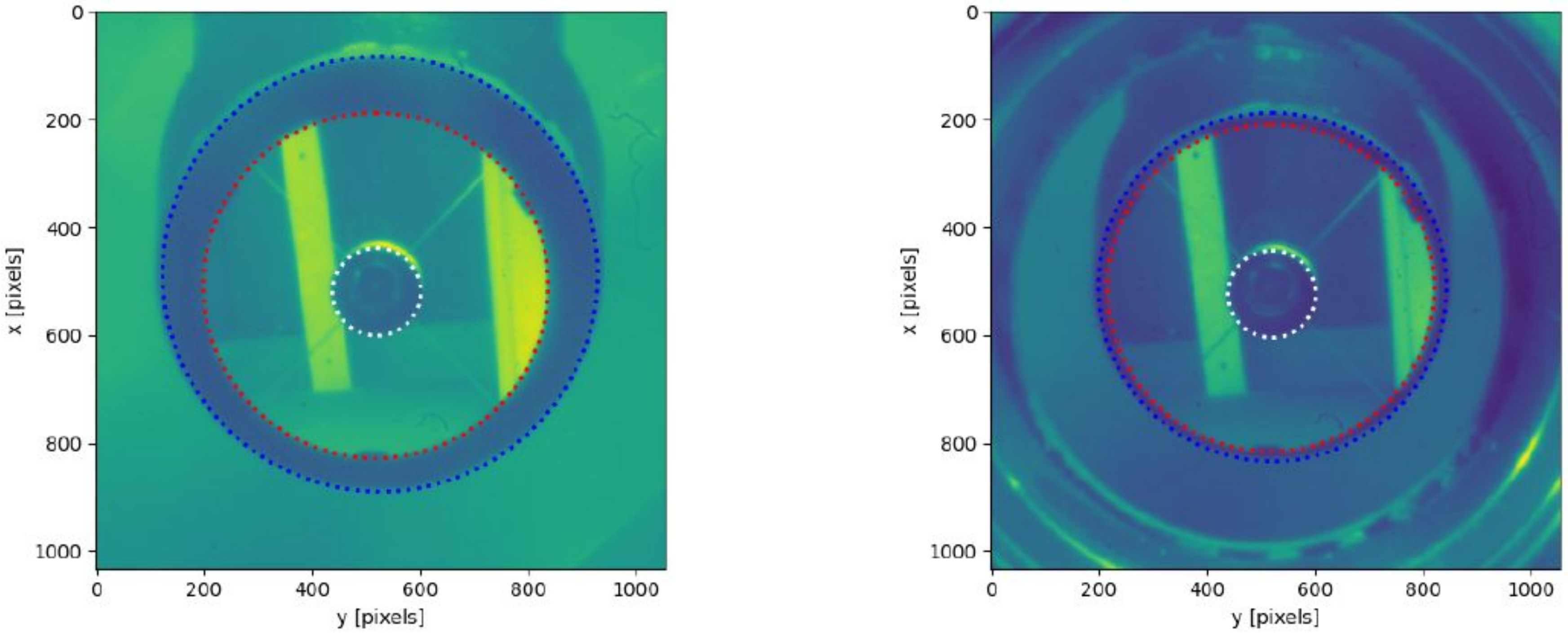


Processing pinhole images of the mire

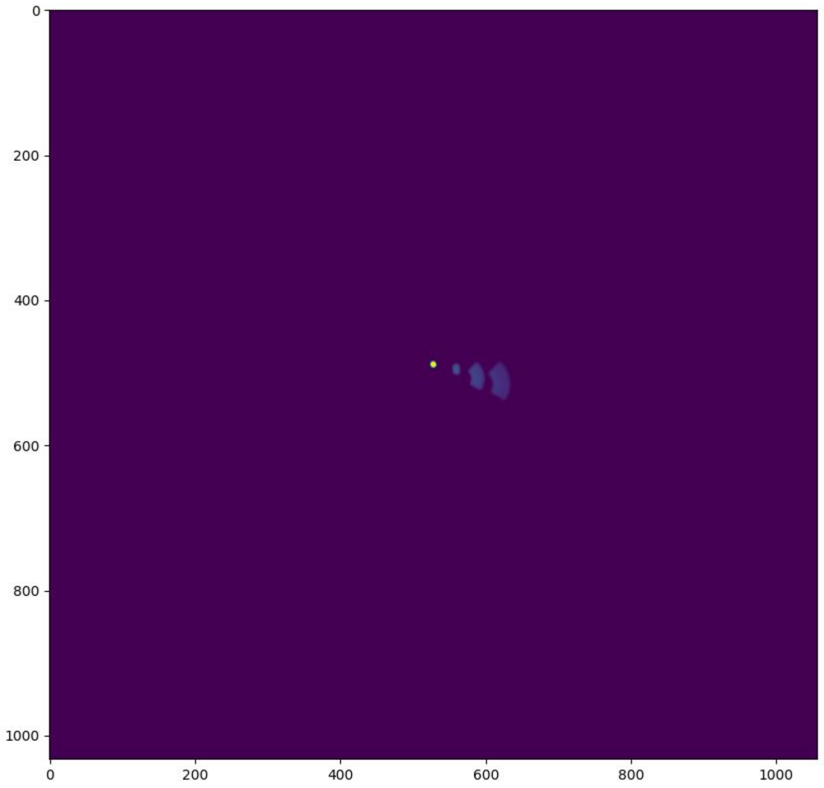




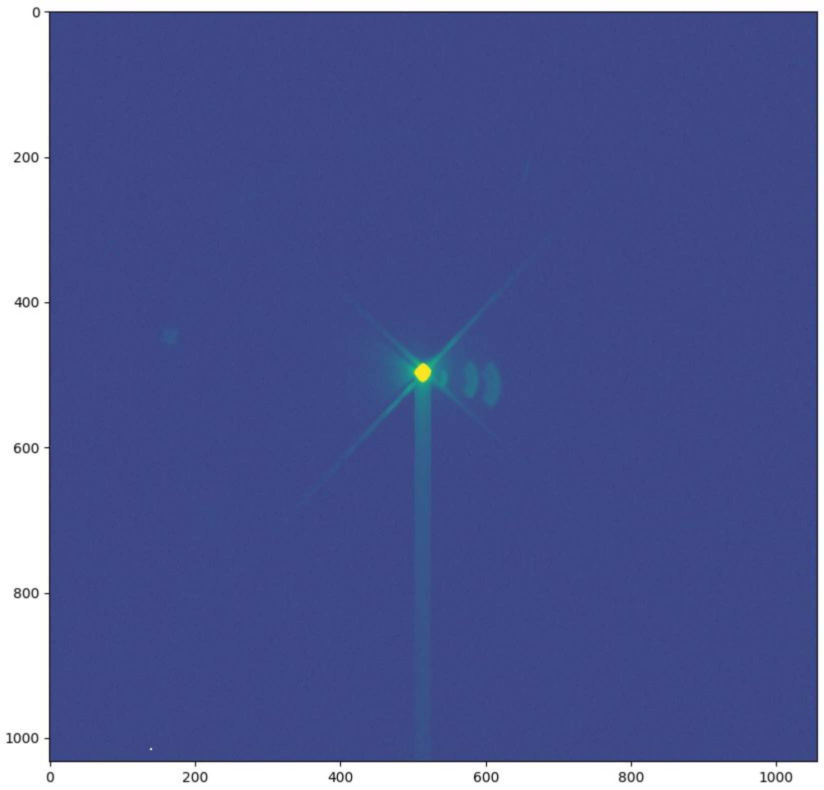
Processing pinhole images of the telescope



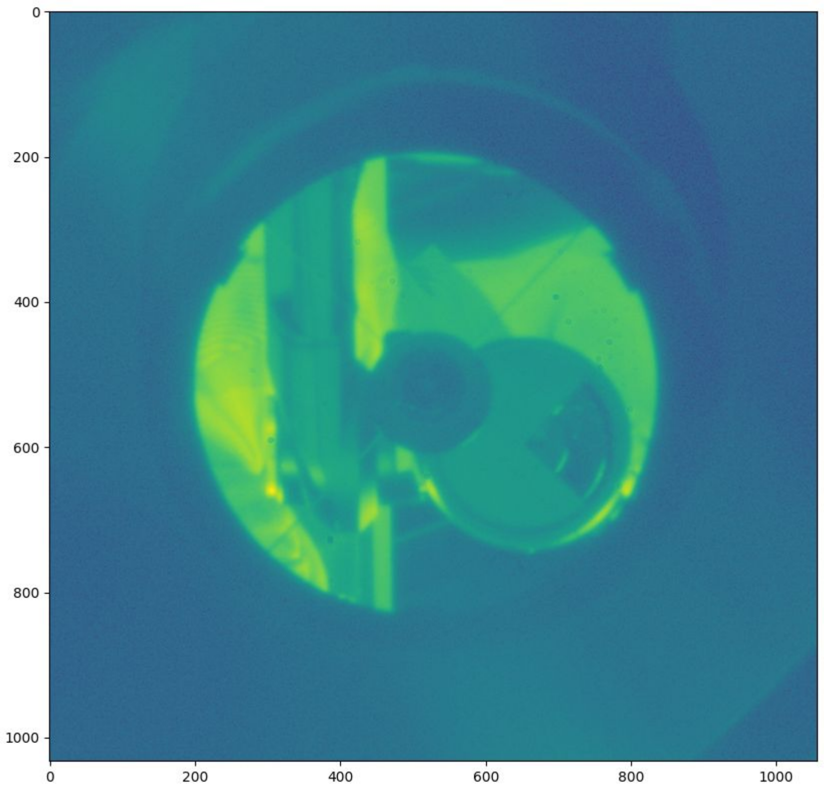
Synthetic ghost image



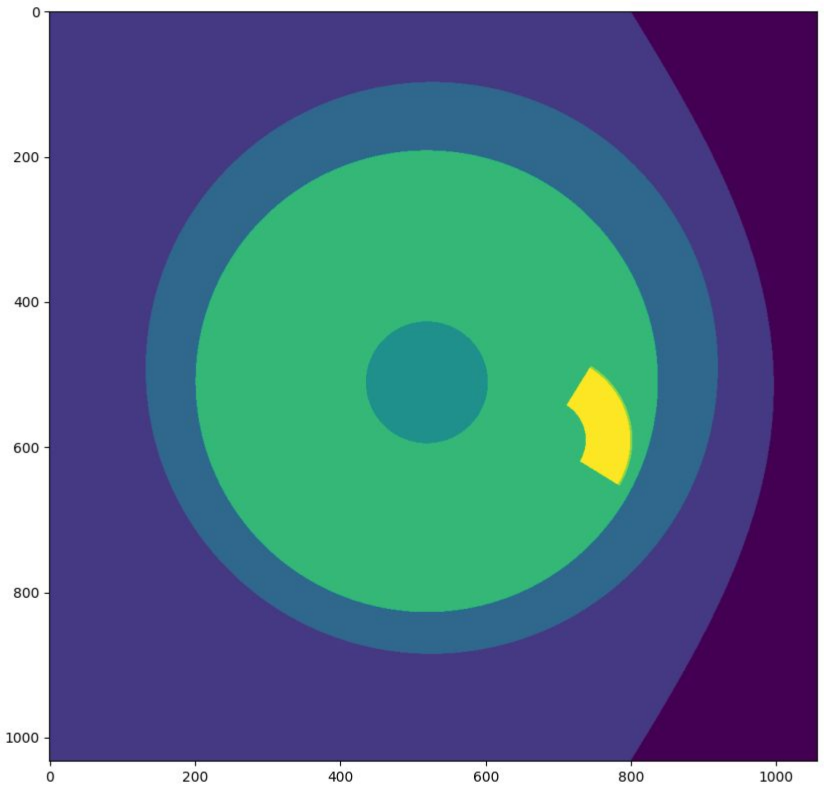
Real image



Looking now at pinhole image



Synthetic pinhole images



Conclusion

- A bit more cleaning and the CBP results are ready for publication
  - ~5mmag uncertainty on passband normalization
  - 0.1nm uncertainty on central wavelength
- We have a very promising path to build a complete physical model of the optics and baffling but that will come after the publication
  - Tuning of the CBP/StarDICE relative positioning and orientation is likely what is missing to describe correctly the ghosts/alignment images and unlock the analysis of the 4 remaining samples
  - The resulting optical model could be used also to predict the vignetting, the plate-scale distortion… and therefore reproduce the flat-field pattern