Traveling Collimated Beam Projector

Latest campaigns results

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What is a CBP ? (and why)

- Cosmology with type Ia supernovae : **need accurate fluxes and colors measurements**
- Instrumental uncertainties : **dominants for dark energy parameters estimation (1%)**

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CBP (Collimated Beam Projector) → instrument shooting monochromatic light with controlled flux and wavelength (per mil level)

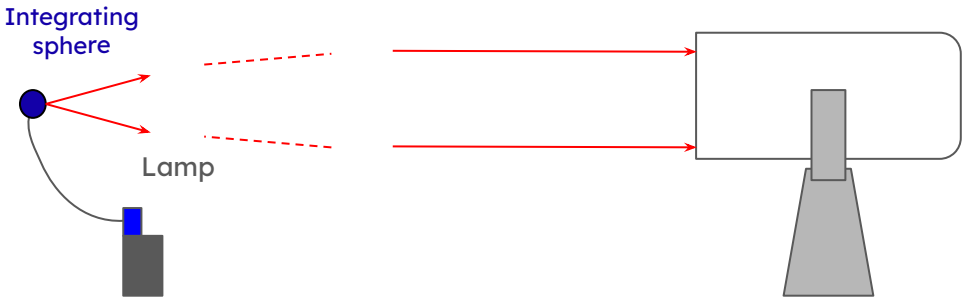
→ Can be used as an artificial star

→ Powerful calibration tool to measure any telescope transmission (optical and filters)

→ **Goal : Low the instrumental uncertainties from 1% to 0.1%**

Different setups

1) Shoot light inside the instrument with a long distance monochromatic source (artificial star)



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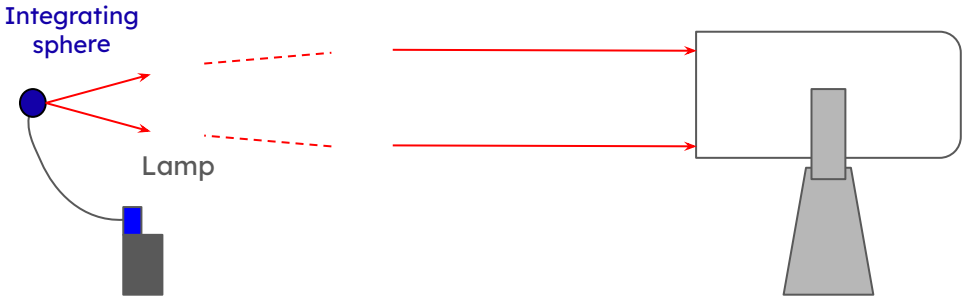
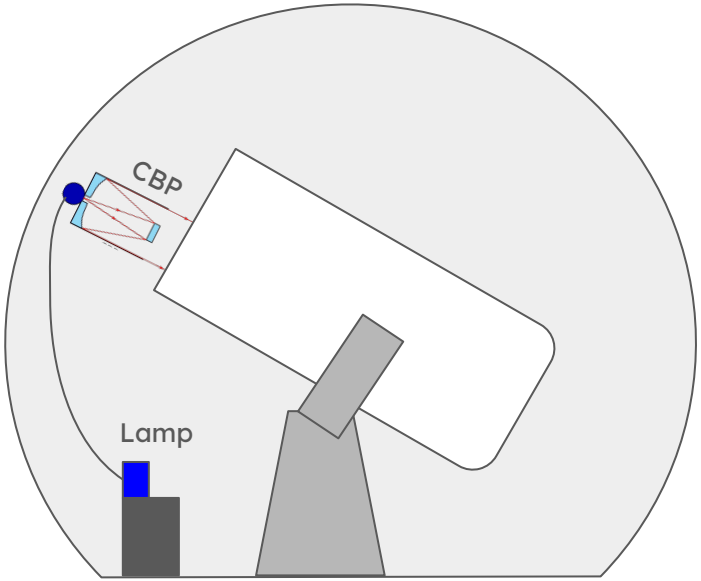
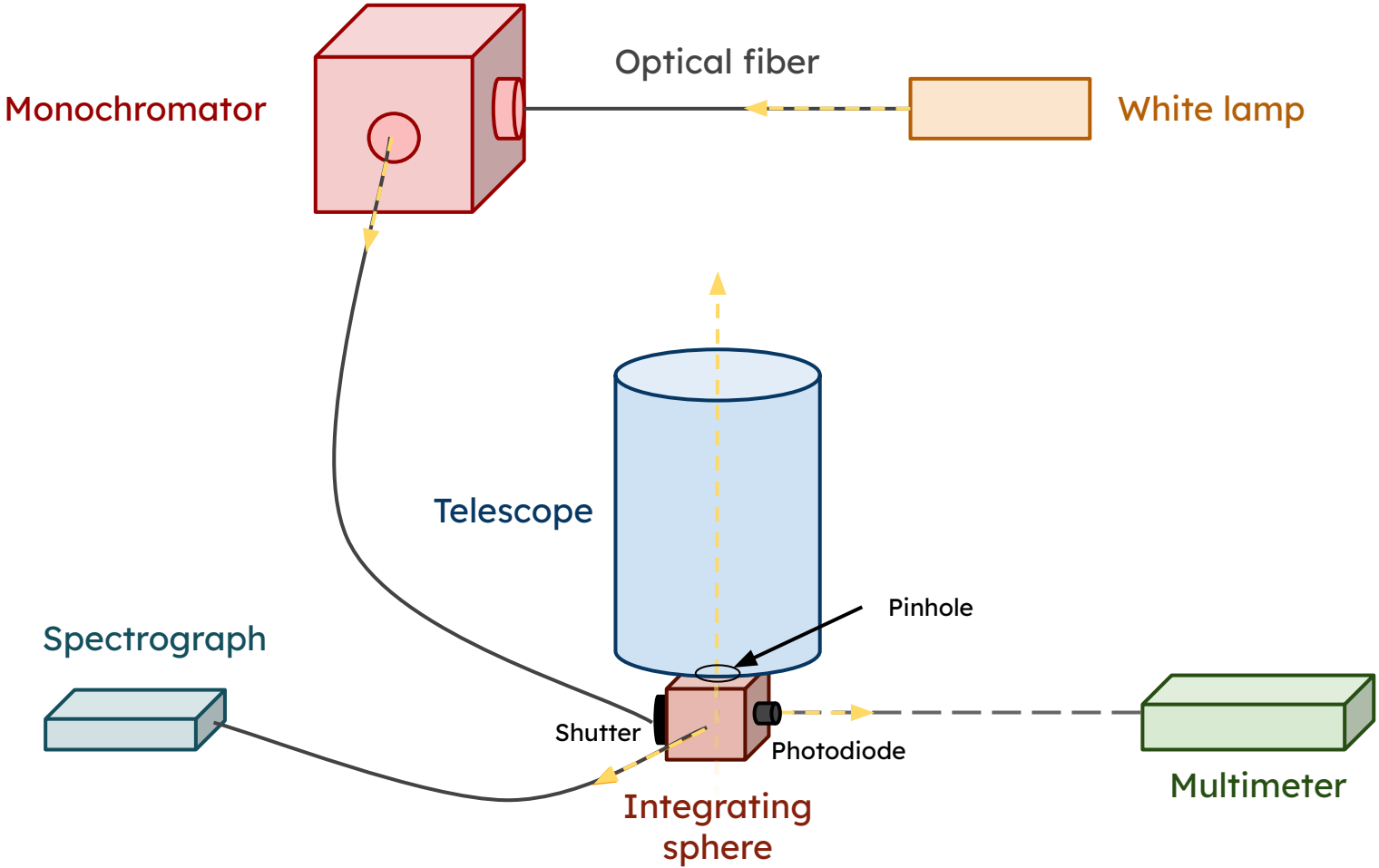
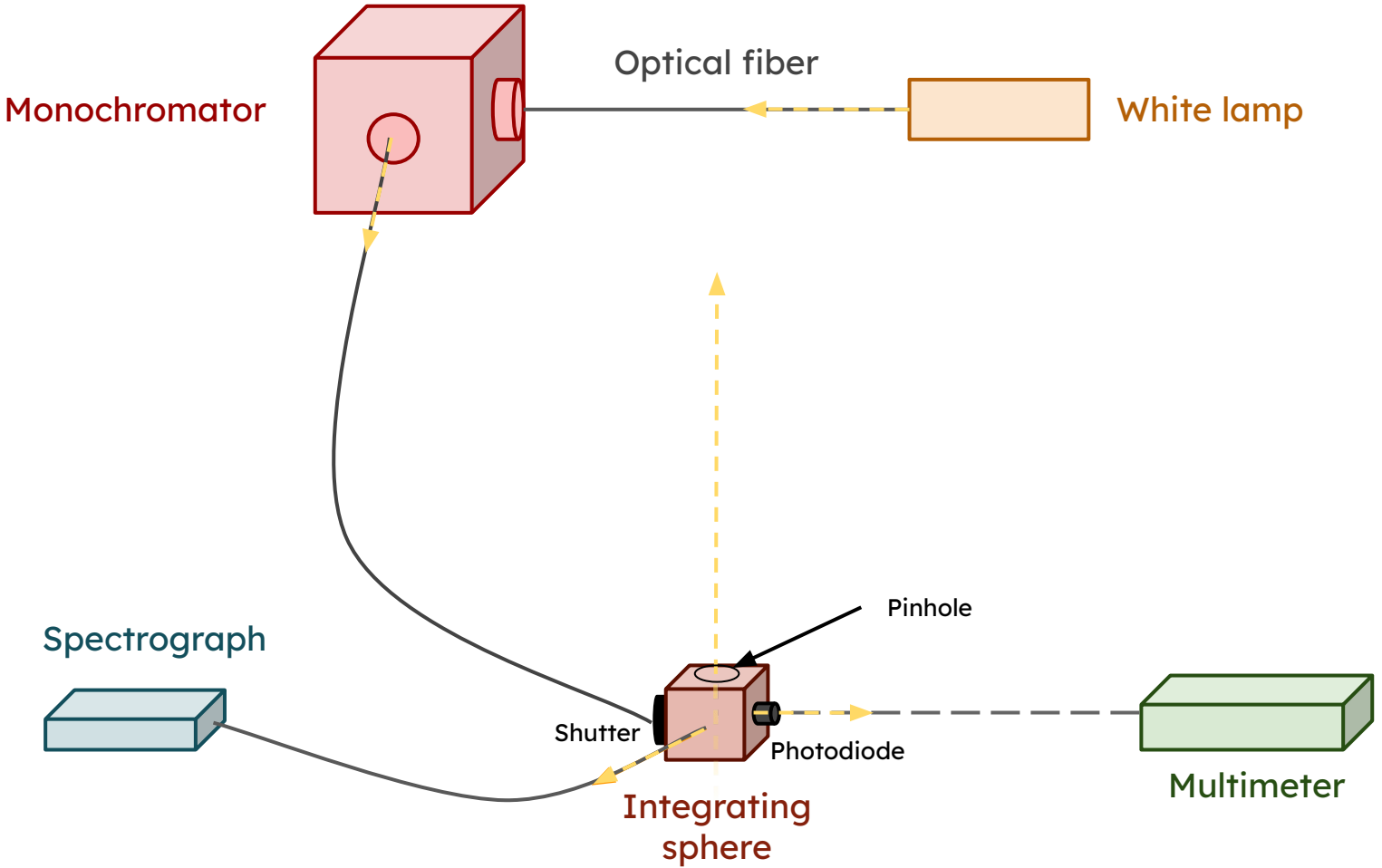


2) Shoot a monochromatic parallel light beam inside the instrument to calibrate




Monochromator
Optical fiber
White lamp
Telescope
Pinhole
Spectrograph
Shutter
Photodiode
Multimeter
Integrating sphere


Monochromator
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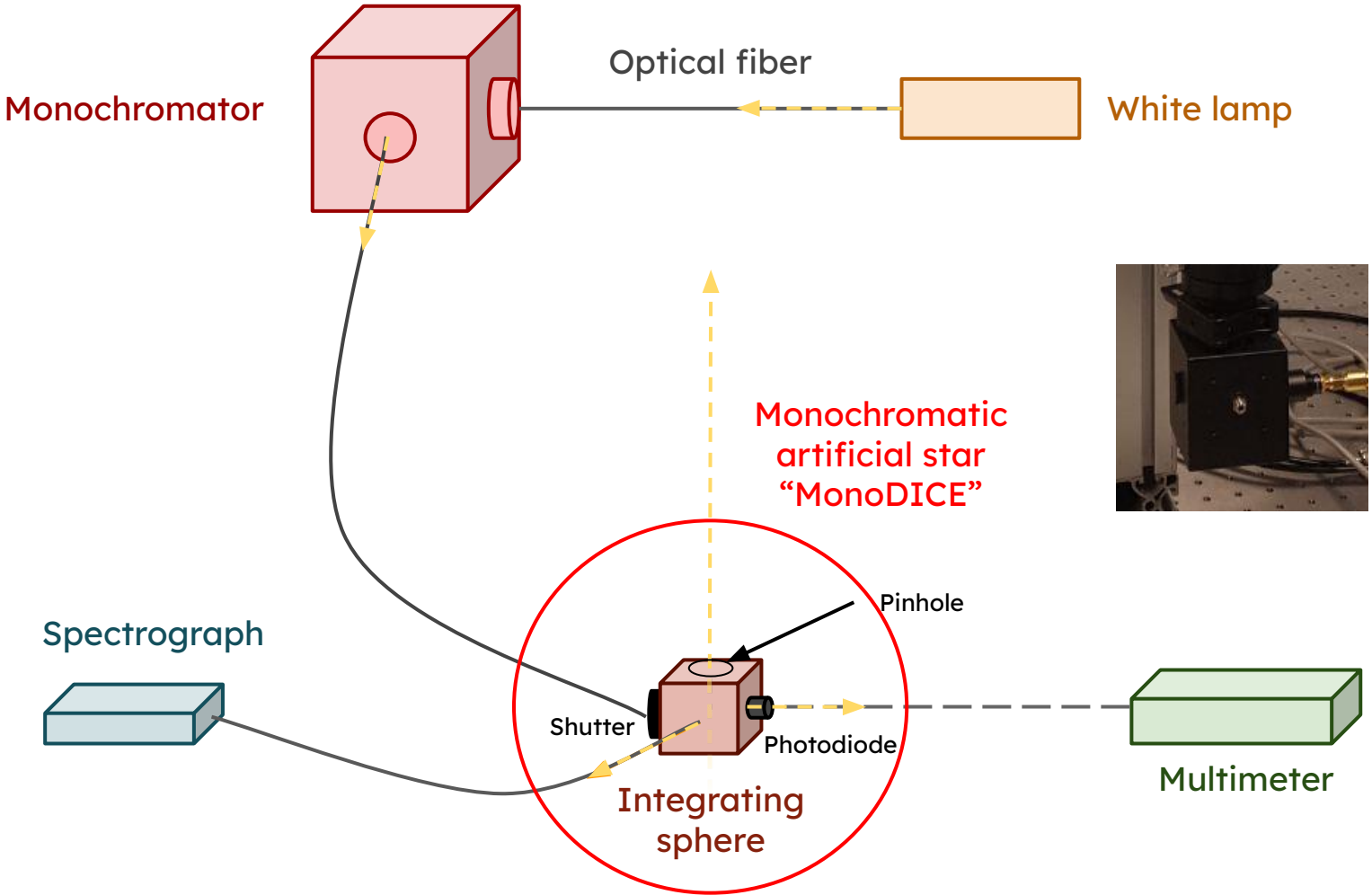
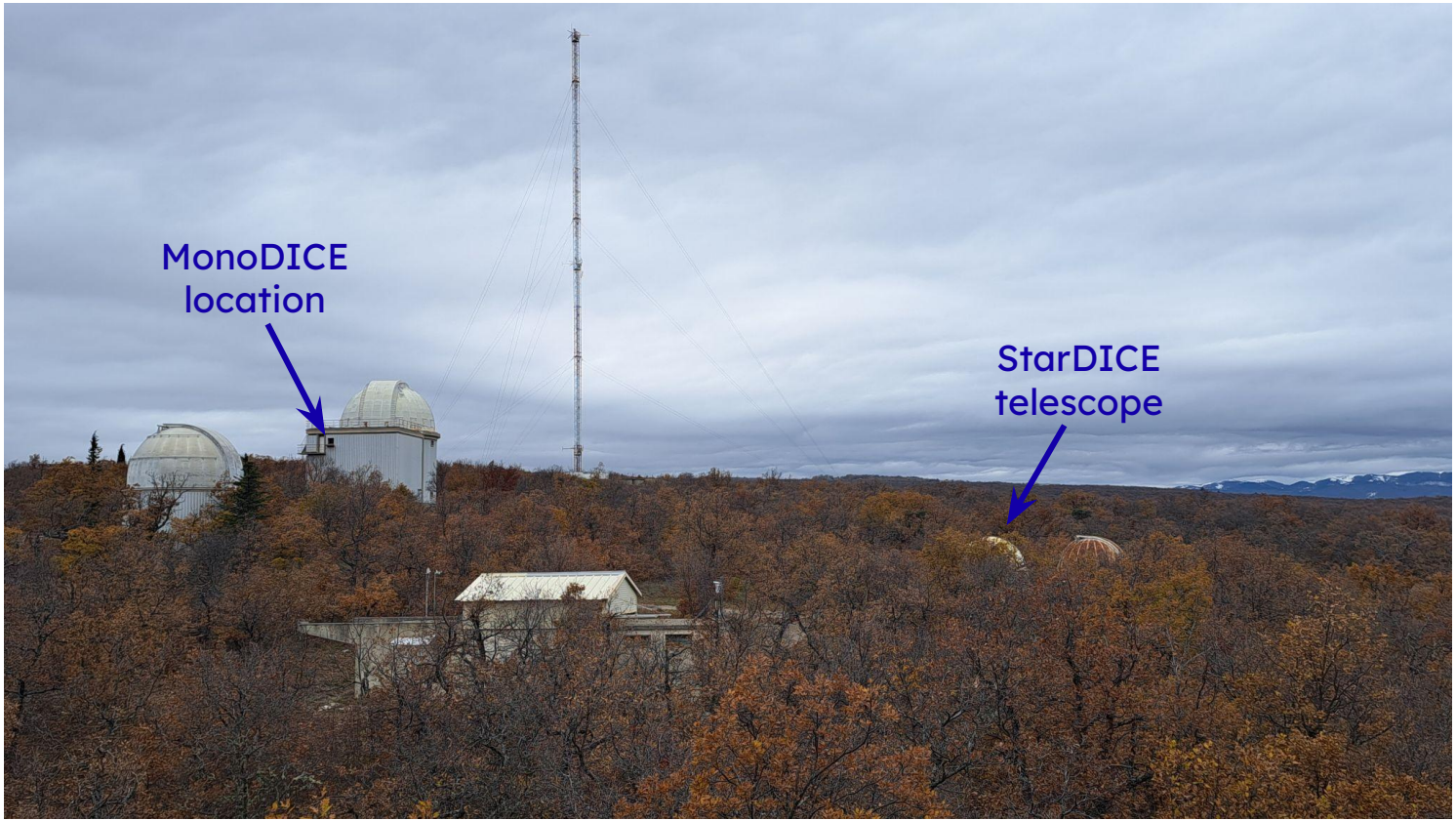

Monochromator
Optical fiber
White lamp
Monochromatic
artificial star
“MonoDICE”
Spectrograph
Pinhole
Shutter
Photodiode
Integrating
sphere
Multimeter

MonoDICE @ OHP

MonoDICE observed by the StarDICE telescope



MonoDICE observed by the StarDICE telescope

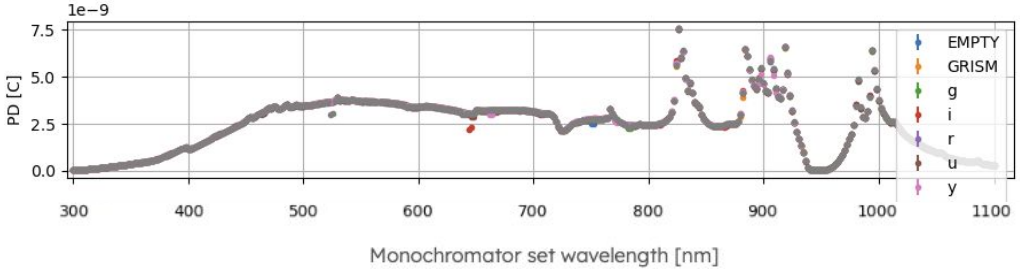
Main settings :

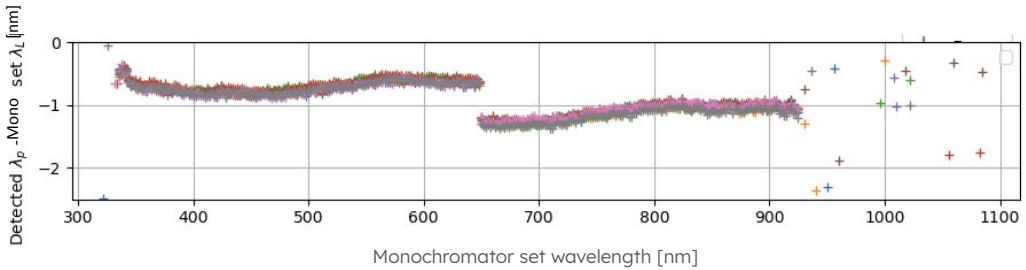
- Observations 3-4 days after new moon
- Monochromator resolution 1nm FWHM
- 1mm output pinhole = 1 StarDICE pixel
- StarDICE: 4s exposure
- MonoDICE: 2s exposure within StarDICE exp, 115m away from StarDICE

Summary of 1 night with 7 scans

7 filter scans from 300 - 1100 nm with 2nm steps (~1h15)

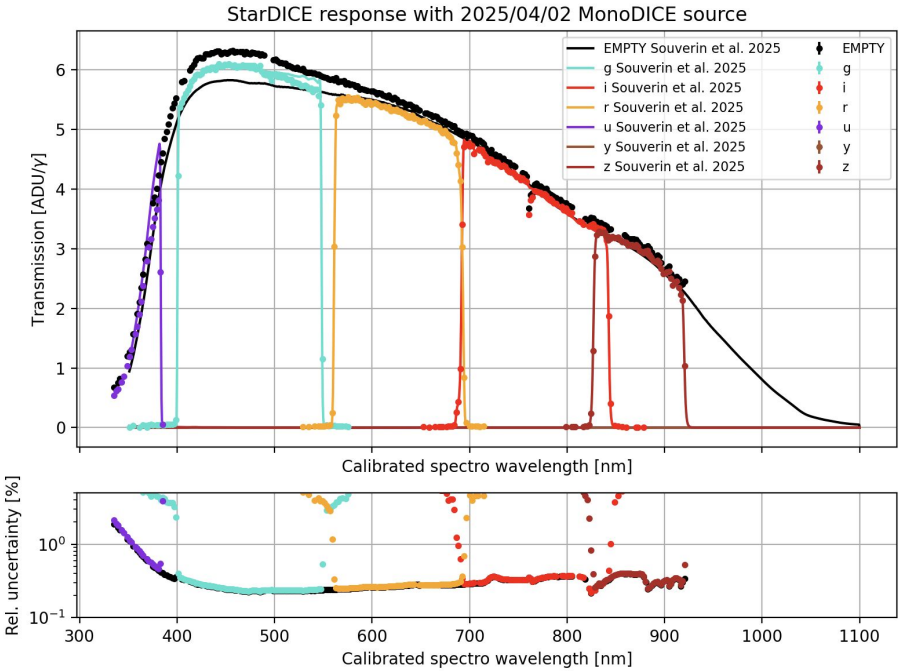
- very good lamp stability
- very good monochromator repeatability
- low lamp flux around 950nm
- low spectro QE after 900nm



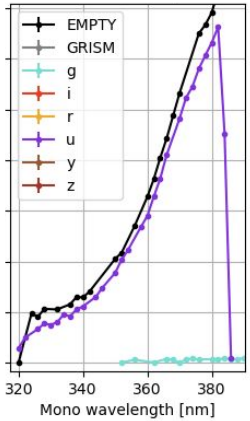


StarDICE filters transmission measurement

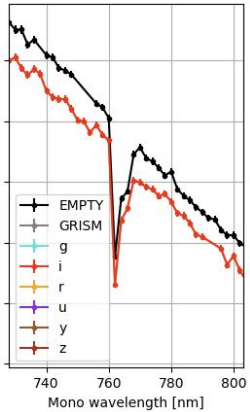
0.2 - 0.4% transmission uncertainty with 1 scan from 400 to 900nm



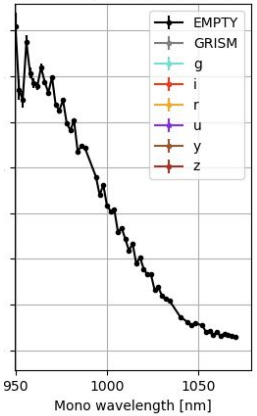
u-band at 320nm



O_2 line



Fringing in near-IR



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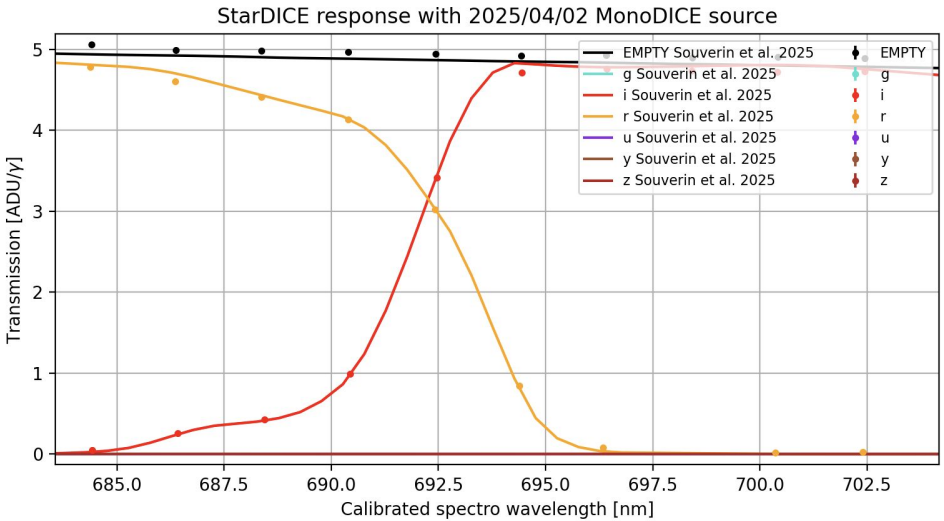

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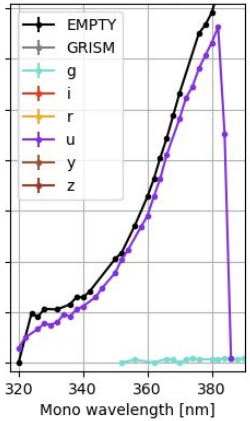

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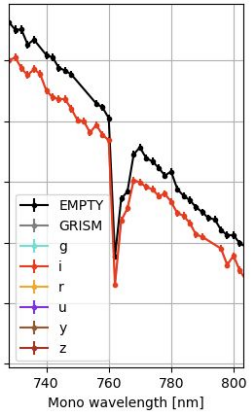

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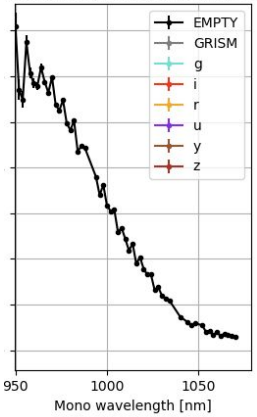
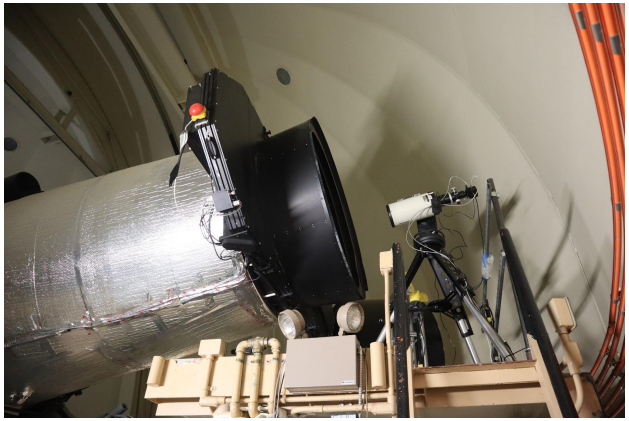


TCBP @ ZTF

Installation and main settings

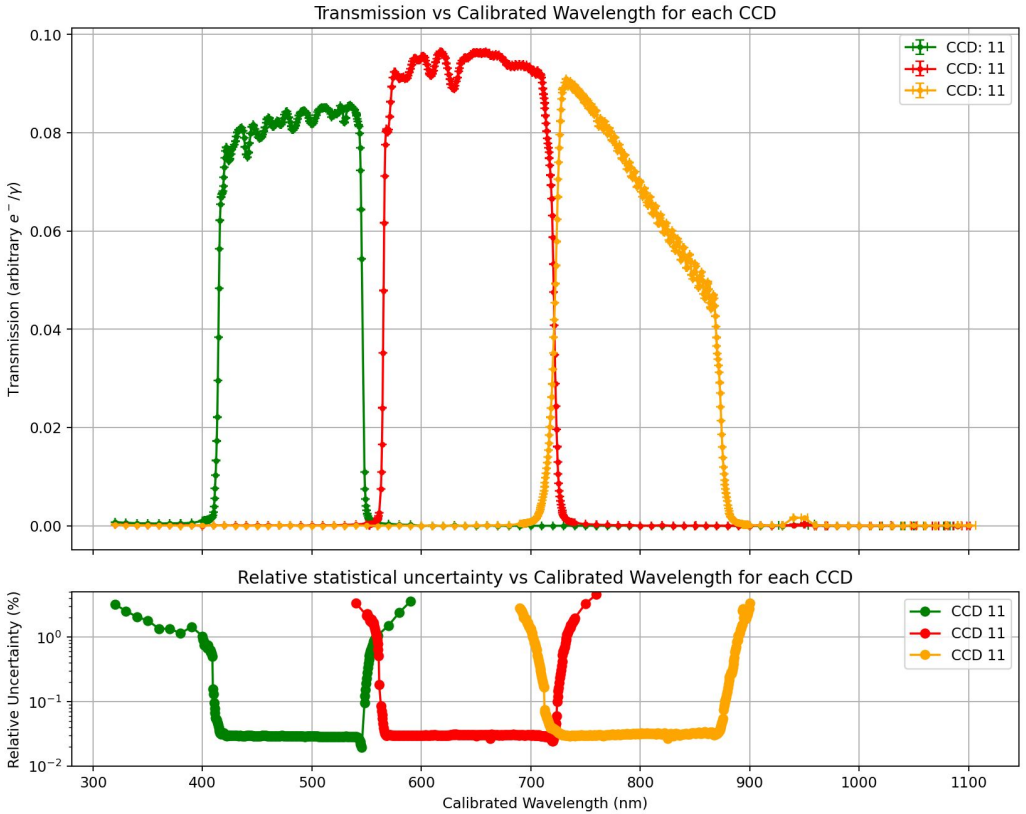


Settings :

- 200um pinhole = ~ 30 pixels spot on ZTF camera
- 1 nm FWHM spectra
- Around 5 to 10s exposures per spot
- Focus at infinity (best effort basis…)

First results (one spot strategy) : fine filter scan

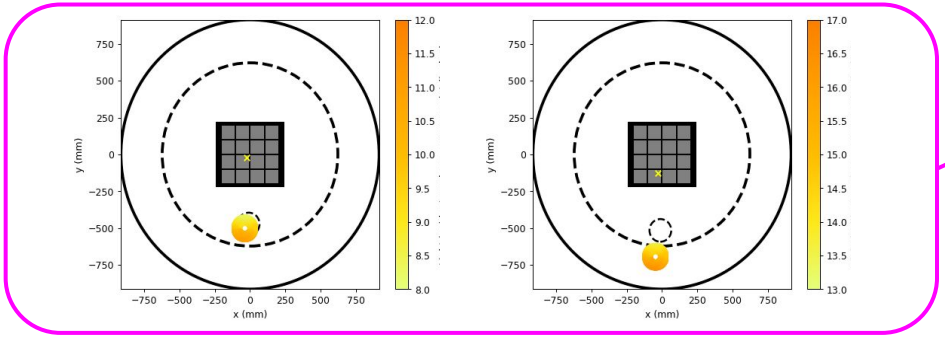
- 3 filters scanned in one day with fine steps in CCD11
- subpermil statistical uncertainties
- normalisation issue needing investigations

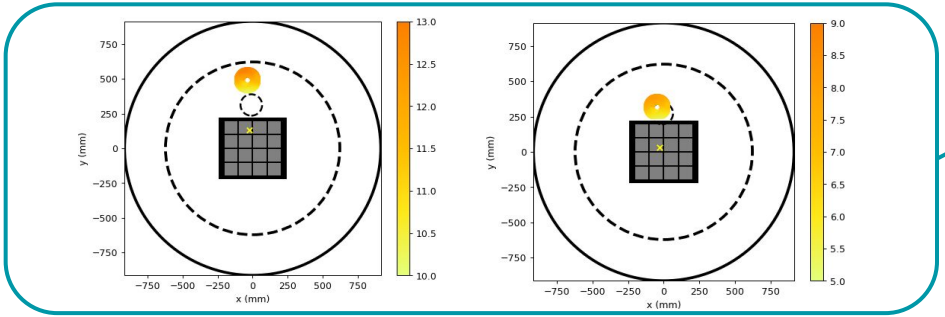


Multispot strategy

Scan 8 CCDs for each wavelength during runs in 4 different positions on the mirror :

- positions 1,2,3 (top) : CCDs 09-16
- position 4 (bottom) : CCDs 01-08

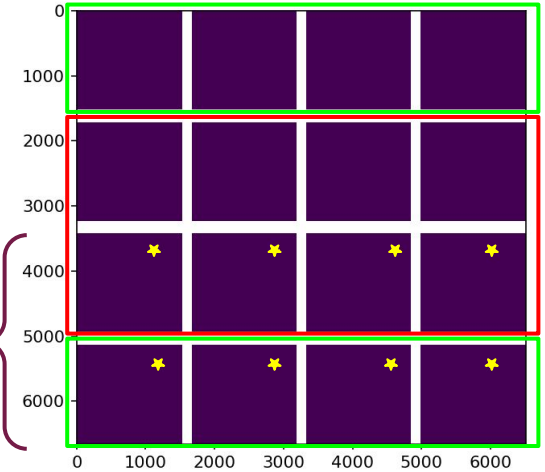




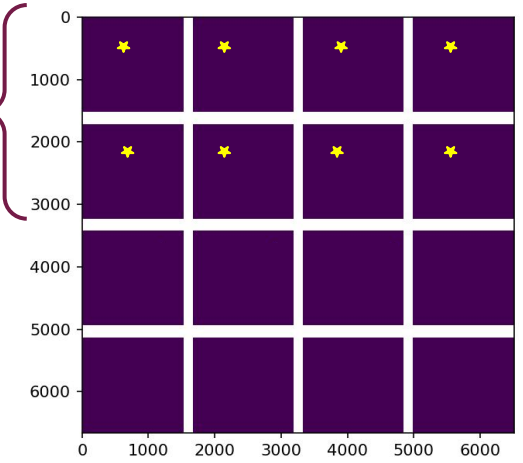
Single coating

Double coating

CCD 09-16



CCD 01-08



Multispot strategy

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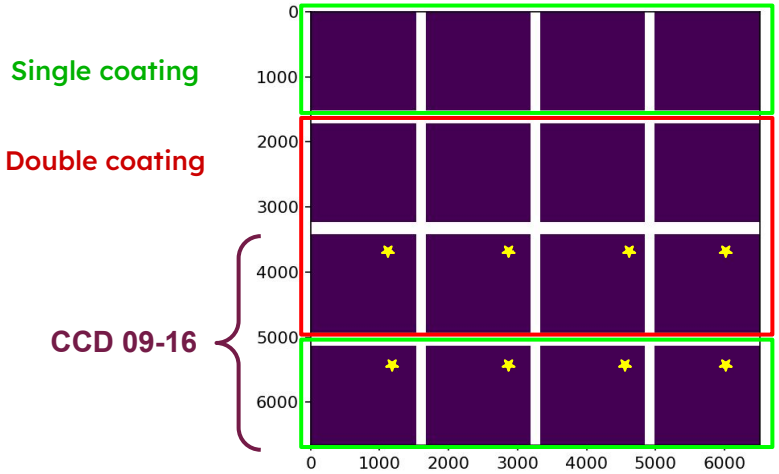
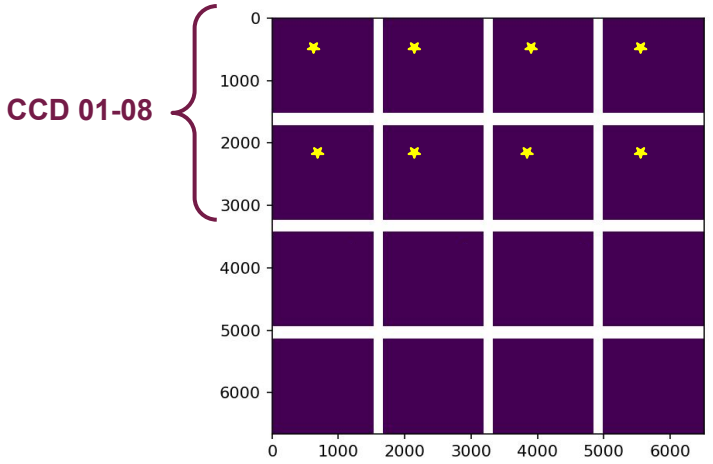
- position 4 (bottom) : CCDs 01-08

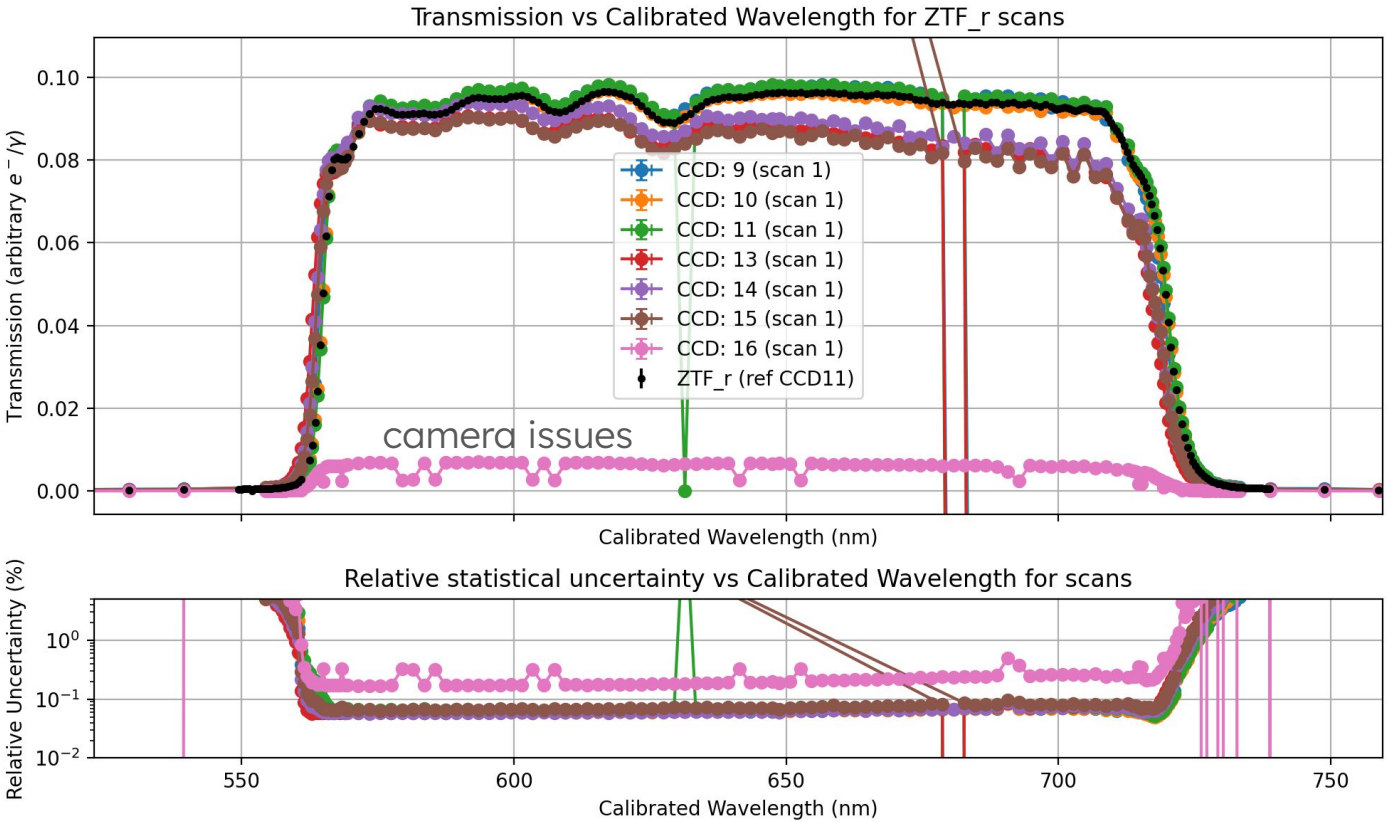
- double & single coating flavors in one scan
- allows the measurement of each CCD quantum efficiency
- at least positions 1, 2, 4 for each filters (+ empty) → **the full focal plane is scanned at 3 (or 4) different incident angles on the mirror**





Multispot results : r band

- 2 CCD families
- But still internal dispersion between them
- Fringing more pronounced for CCDs 13-16 (single coating)



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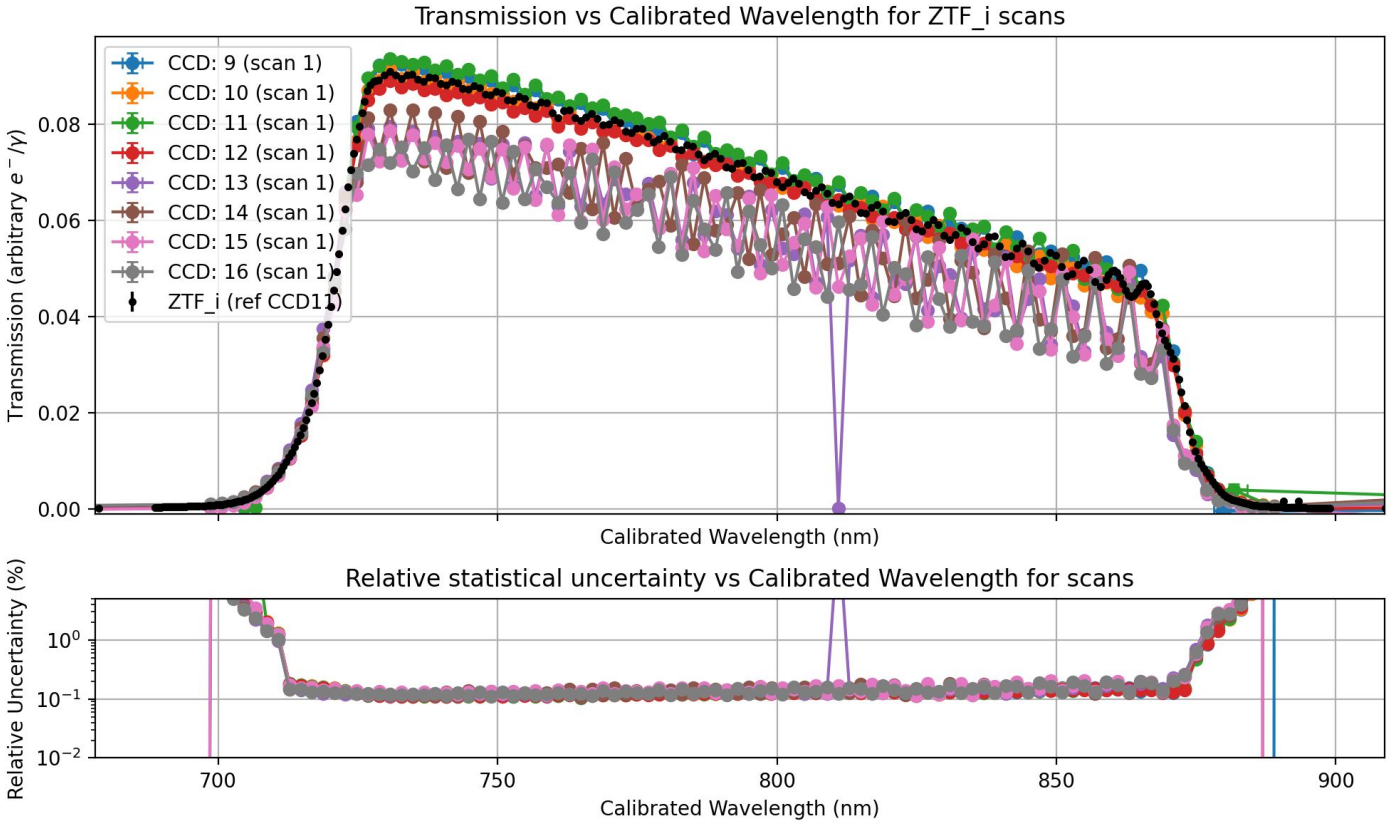
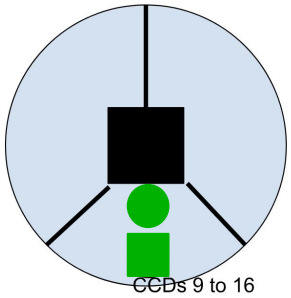
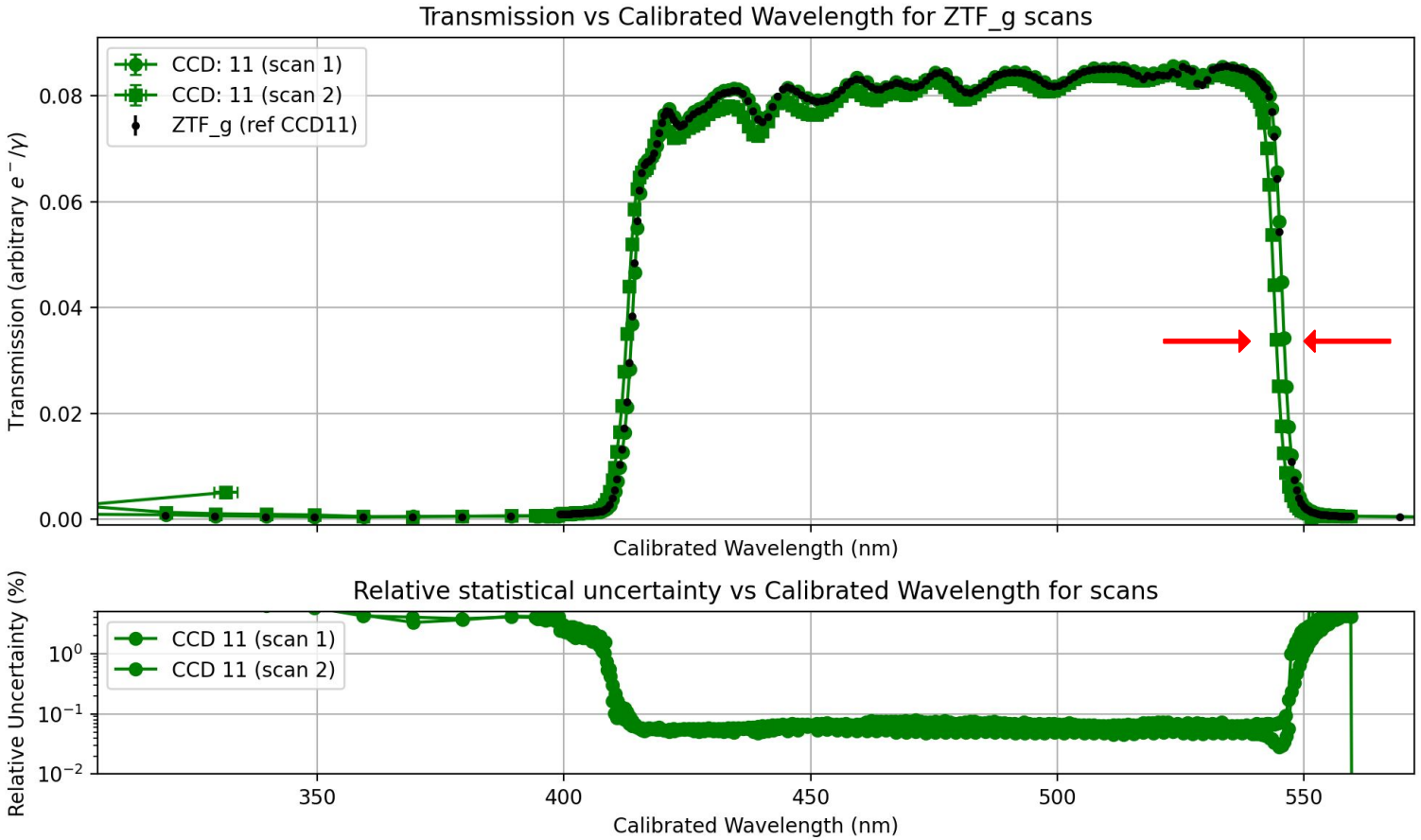
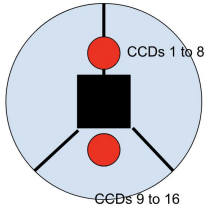


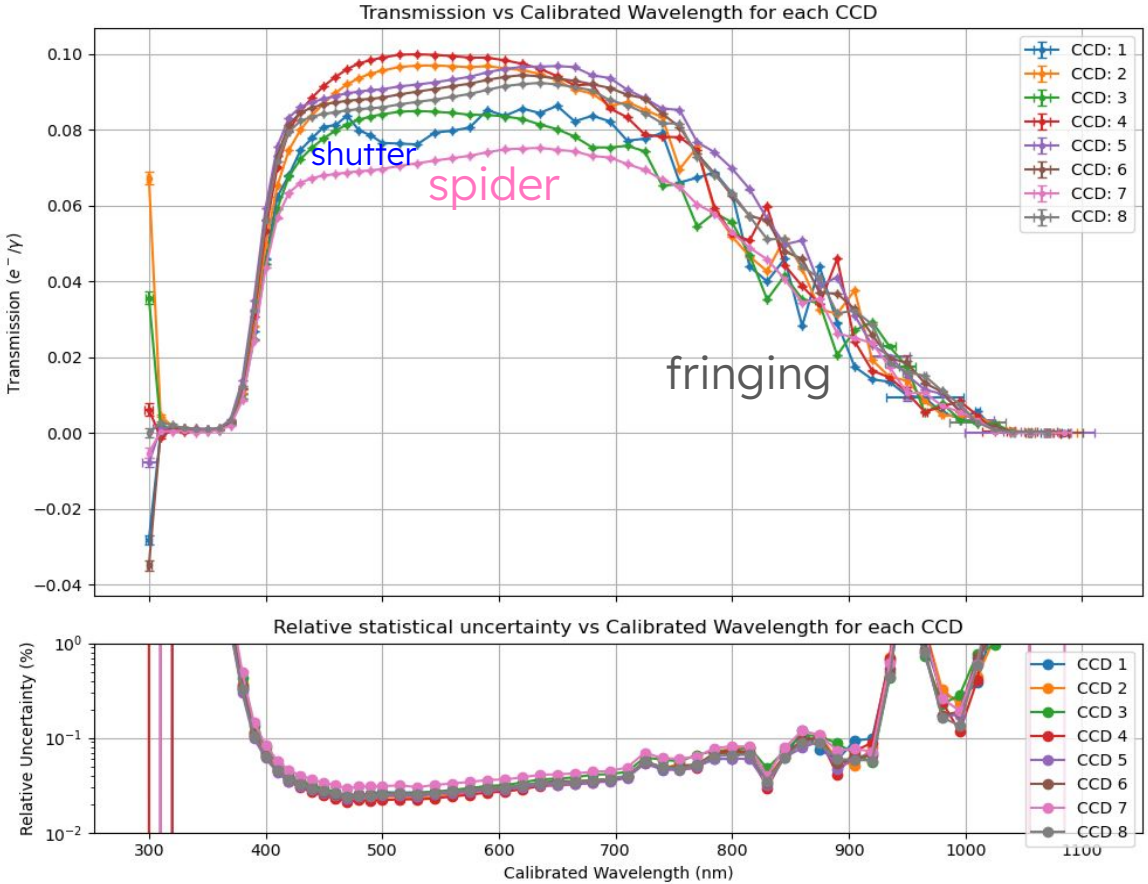
Filter shifts preliminary results



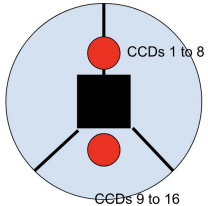


CCD QEs


CCDs 1 to 8
CCDs 9 to 16


Transmission vs Calibrated Wavelength for each CCD
Transmission (e^-/γ)
shutter
spider
fringing
CCD: 1
CCD: 2
CCD: 3
CCD: 4
CCD: 5
CCD: 6
CCD: 7
CCD: 8
Relative statistical uncertainty vs Calibrated Wavelength for each CCD
Relative Uncertainty (%)
Calibrated Wavelength (nm)
CCD 1
CCD 2
CCD 3
CCD 4
CCD 5
CCD 6
CCD 7
CCD 8

CCD QEs


CCDs 1 to 8
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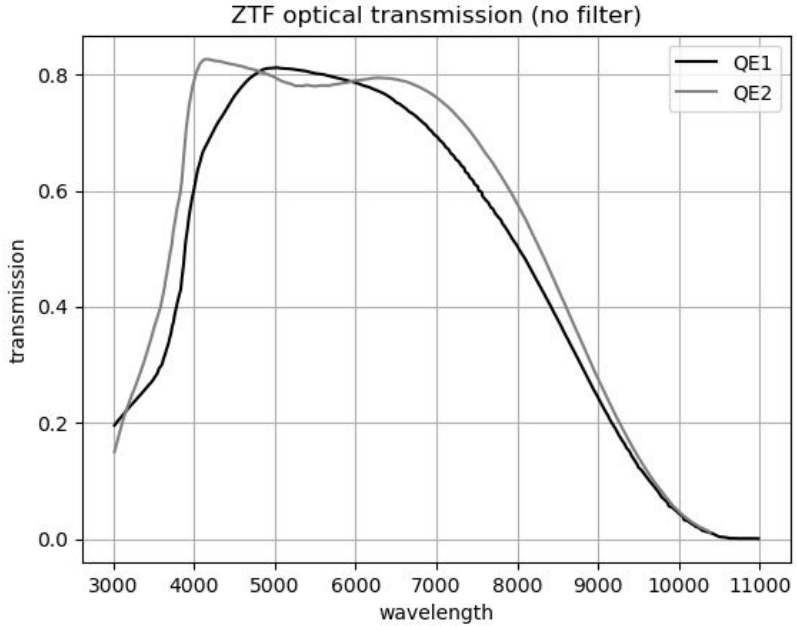
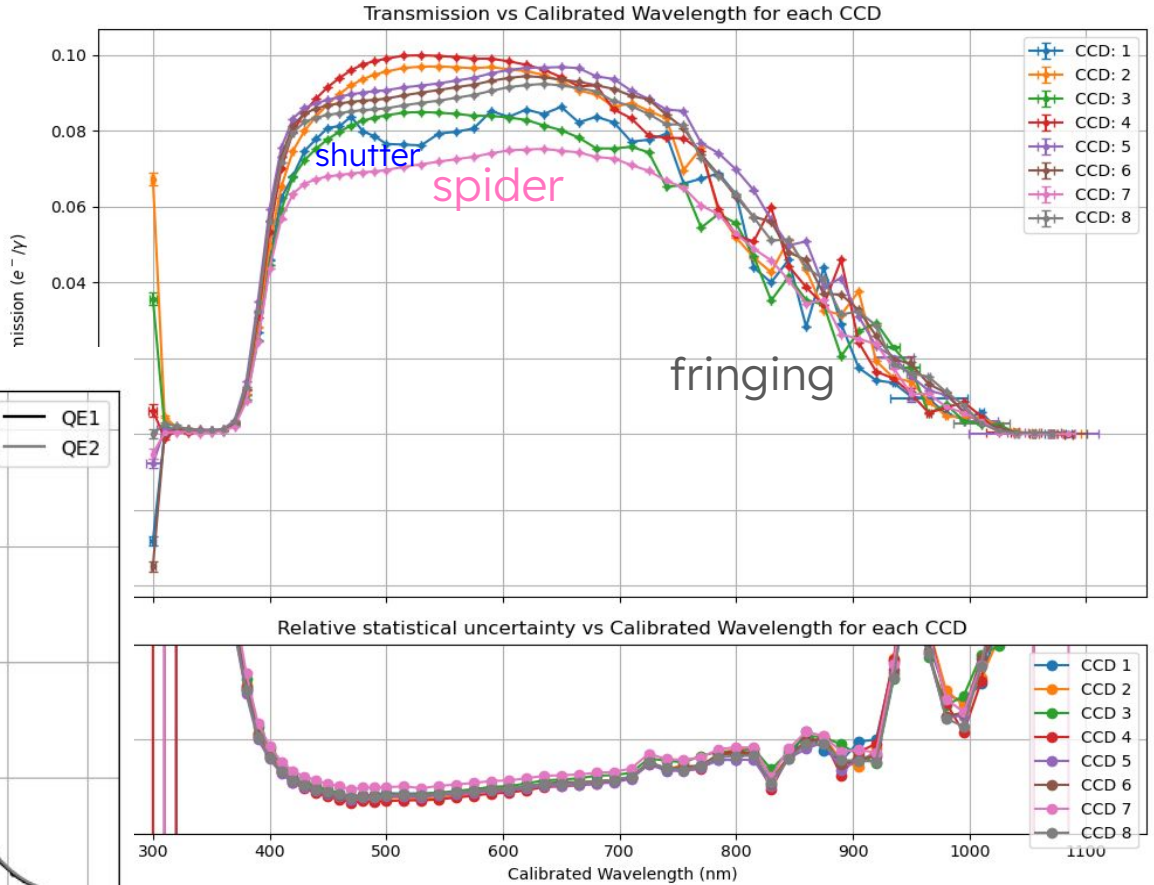

ZTF optical transmission (no filter)
QE1
QE2
transmission
wavelength
0.0
0.2
0.4
0.6
0.8
3000
4000
5000
6000
7000
8000
9000
10000
11000


Transmission vs Calibrated Wavelength for each CCD
shutter
spider
fringing
CCD: 1
CCD: 2
CCD: 3
CCD: 4
CCD: 5
CCD: 6
CCD: 7
CCD: 8
0.04
0.06
0.08
0.10
Relative statistical uncertainty vs Calibrated Wavelength for each CCD
CCD 1
CCD 2
CCD 3
CCD 4
CCD 5
CCD 6
CCD 7
CCD 8
300
400
500
600
700
800
900
1000
Calibrated Wavelength (nm)

What’s next ?

Next steps

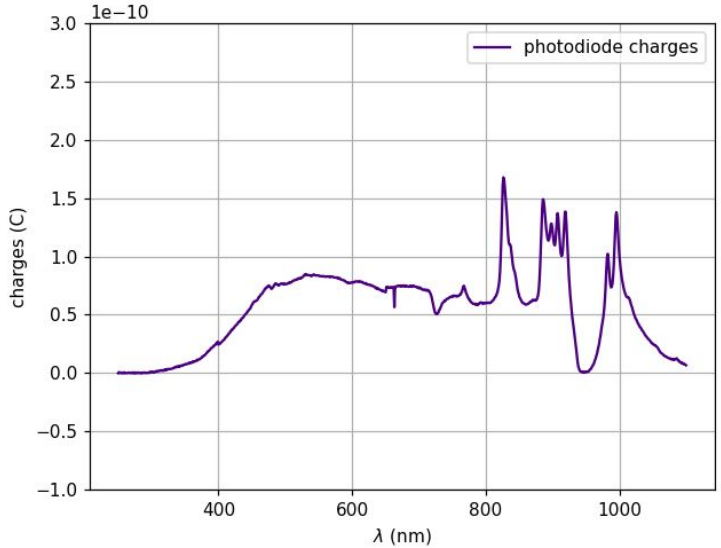
- **MonoDICE @ OHP** (~autumn 2025) : Second campaign on StarDICE
- **MonoDICE @ CEA** (~autumn 2025) : Calibration of CTA's NectarCAM
- **MonoDICE @ Palomar** (2026 ?) : Second campaign on ZTF with MonoDICE (located far away from the telescope)
- **TCBP @ Cerro Pachón** (2026 ?) : Measurement of AuxTel transmission

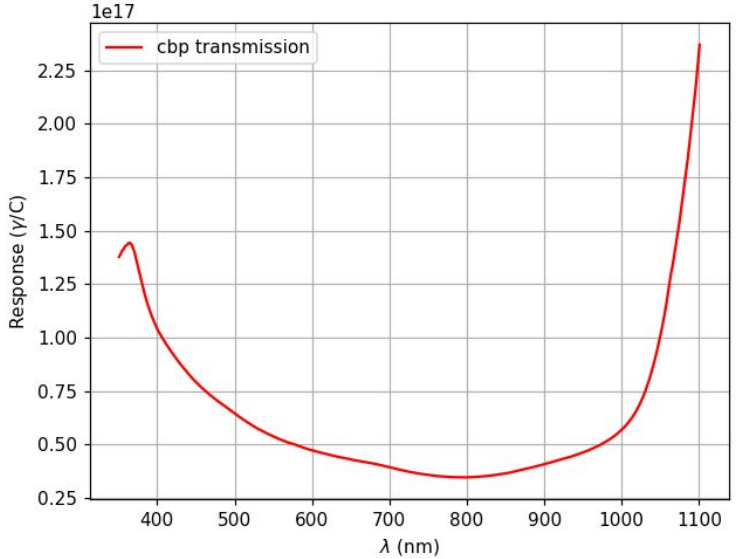
Thank you !

Backups

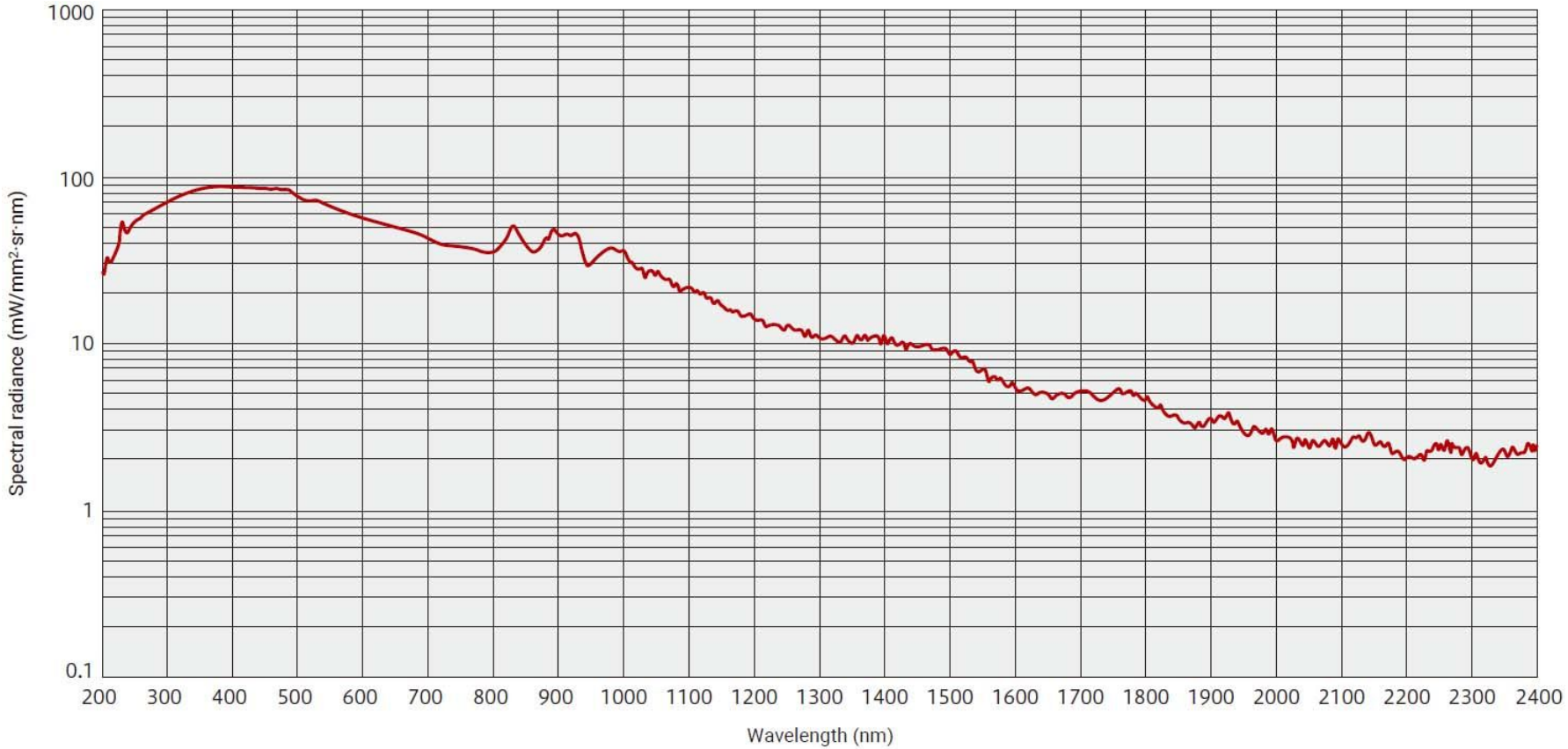
CBP transmission

$$R_{\text{tel}} = \frac{Q_{\text{ccd}}}{Q_{\text{phot}} \times R_{\text{CBP}}}$$



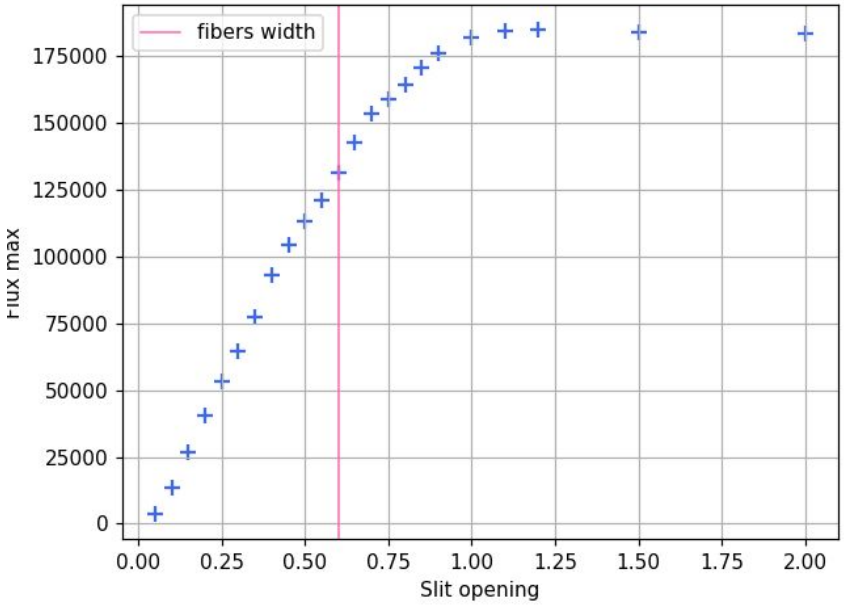


LDLS spectral radiance

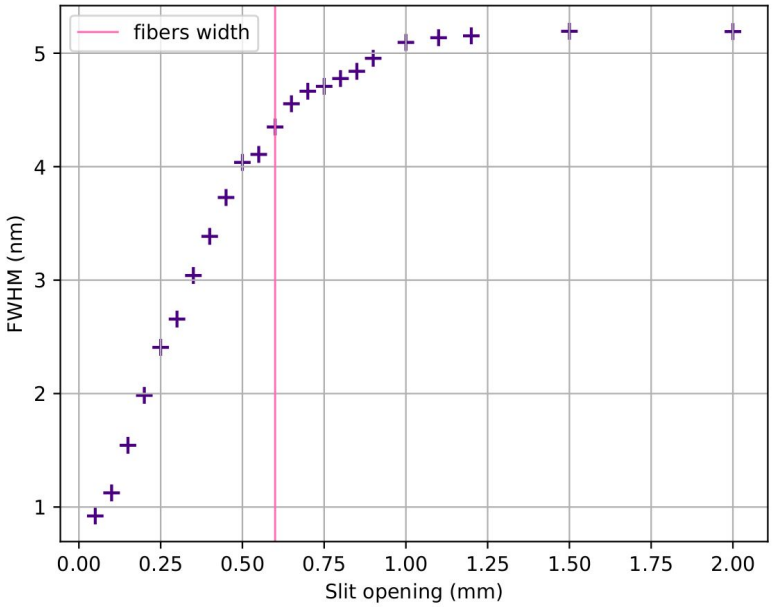


Monochromator resolution (500nm)

Peak's maximal flux **VS** slit opening

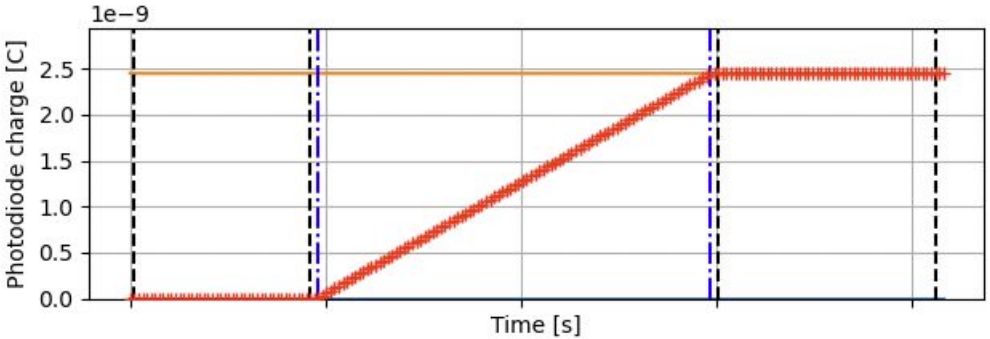


Peak's FWHM **VS** slit opening



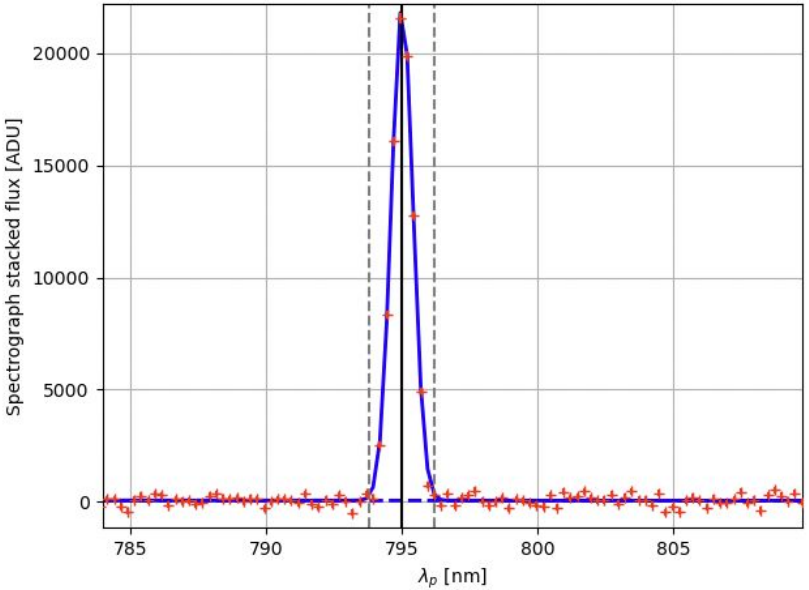
MonoDICE @ OHP : raw data

Photodiode charge measurement



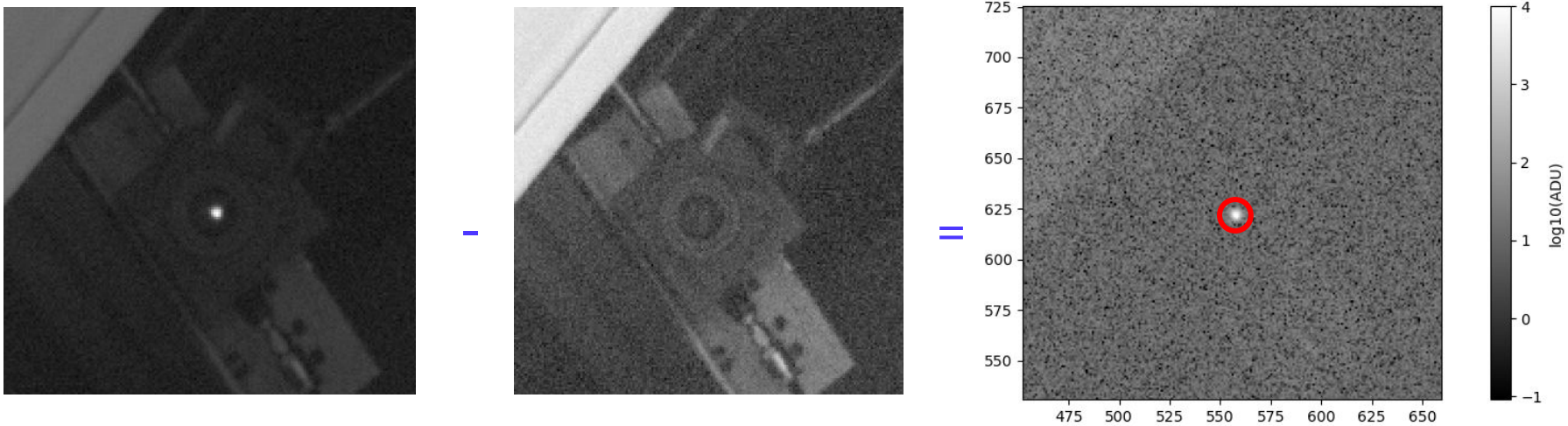
2.45 +/- 1.194e-05 nC with t1=0.964s, t2=2.972s **(dt=2.008s)**

Spectrograph measured flux



MonoDICE @ OHP : raw data

Aperture photometry (radius=5.60 pix)

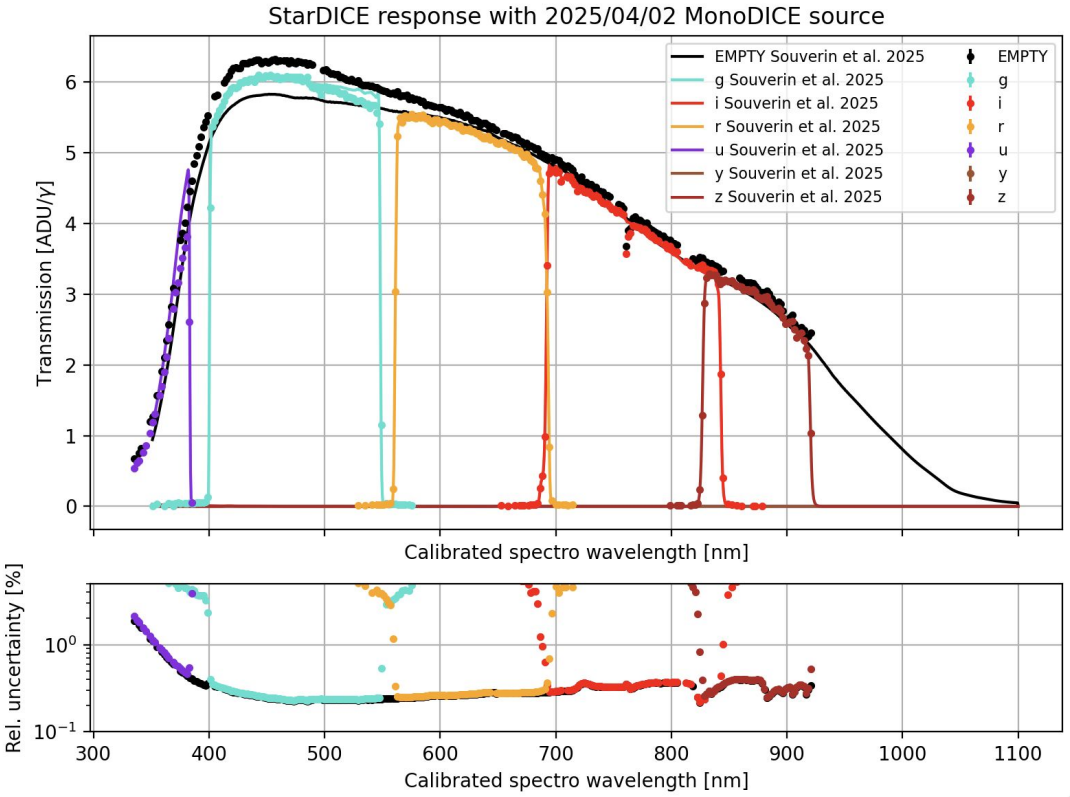


Not forced (yet)

MonoDICE @ OHP : Comparison to CBP-laser measurements

4 radial measurements with the laser CBP combined via pupil stitching:

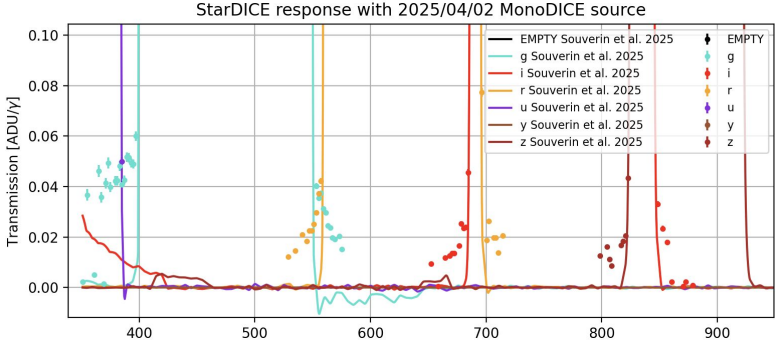
- normalized by its mean (naive tentative to normalize monodice measurements using monodice distance, pinhole and photodiode sizes…)
- no spectro measurements below 340nm and after 920nm
- overall shape discrepancy can be due to Thorlabs photodiode QE given by vendor

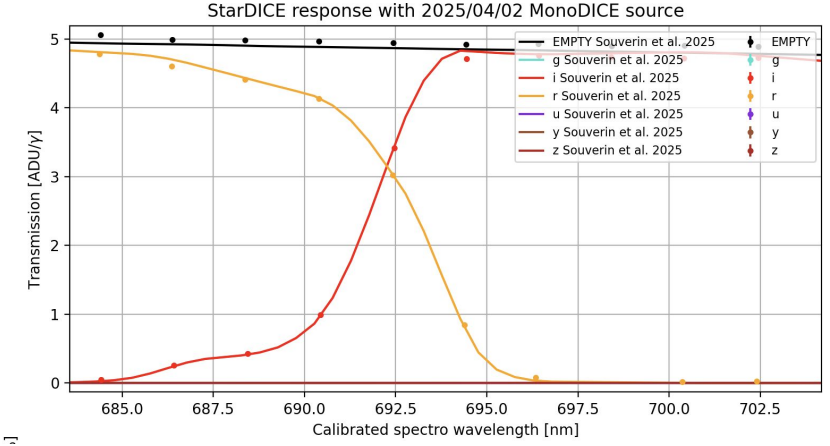


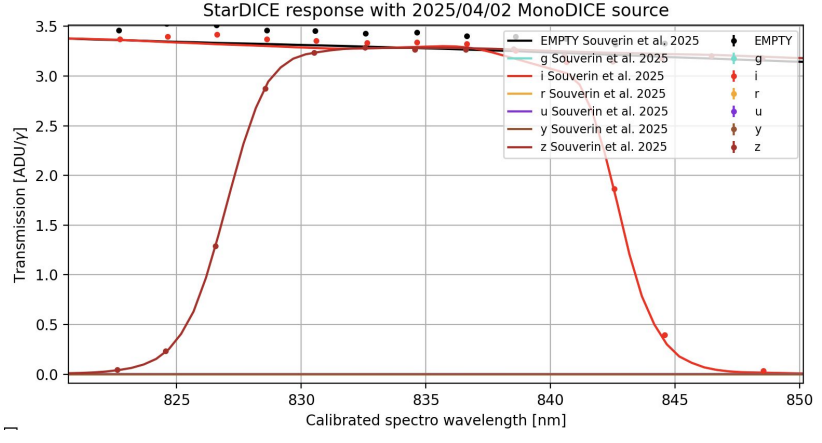
MonoDICE @ OHP : Comparison to CBP-laser measurements

4 radial measurements with the laser CBP combined via pupil stitching:

- filter edges match better than 0.1nm in the red, maybe 0.3nm in the blue but filter edges are very sharp there (need to deconvolve by monodice 1nm wide spectrum?)
- filter foots not at zero

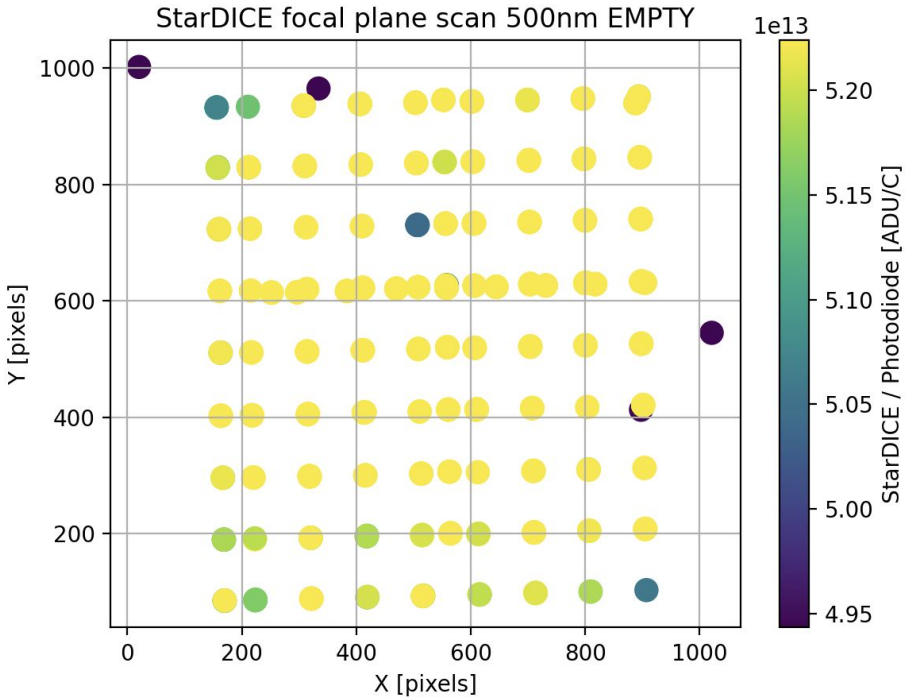




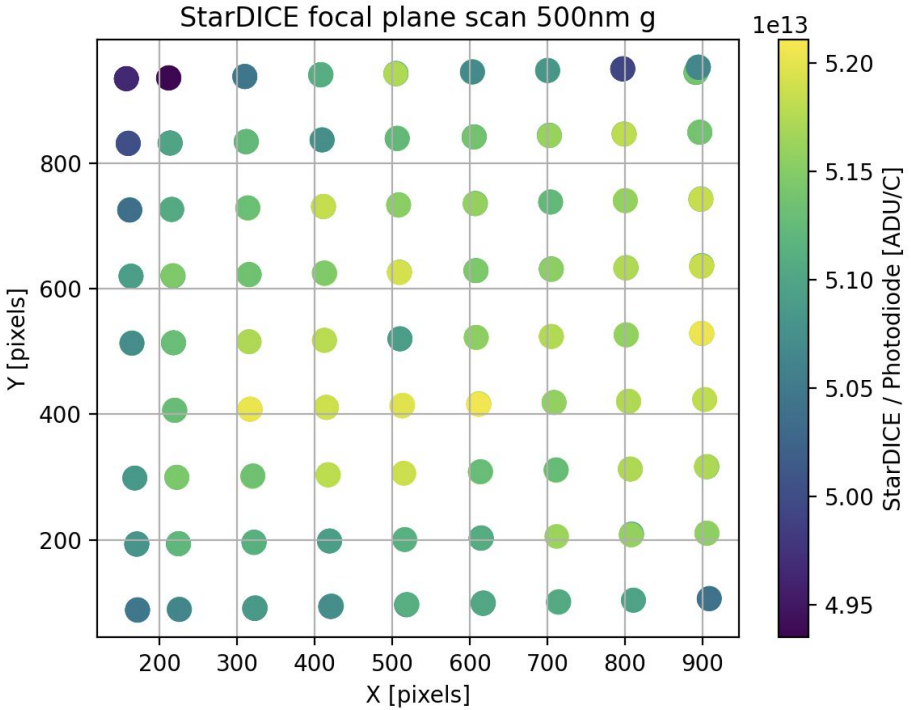


MonoDICE @ OHP : Focal plane and filter scans at 500nm

No filter



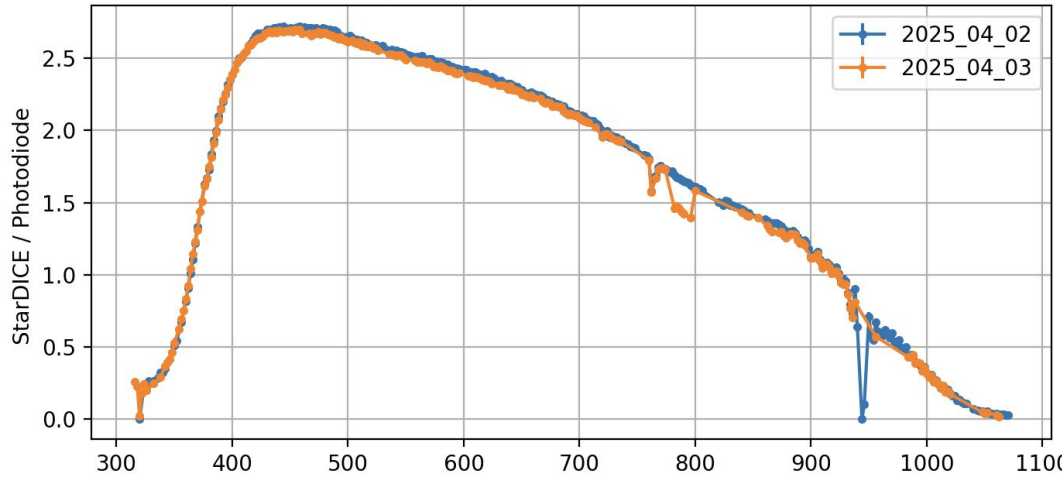
g filter

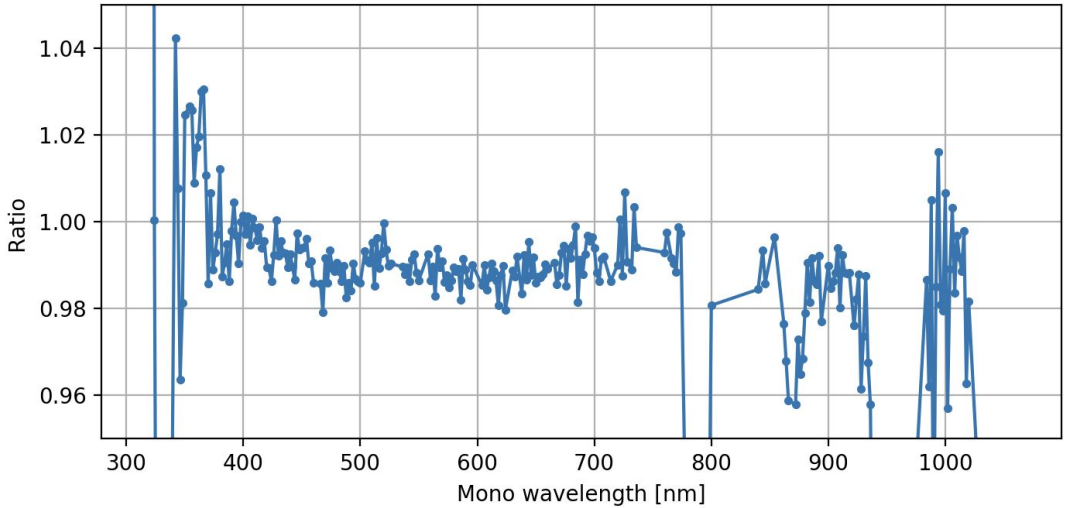


MonoDICE @ OHP : Repeatability

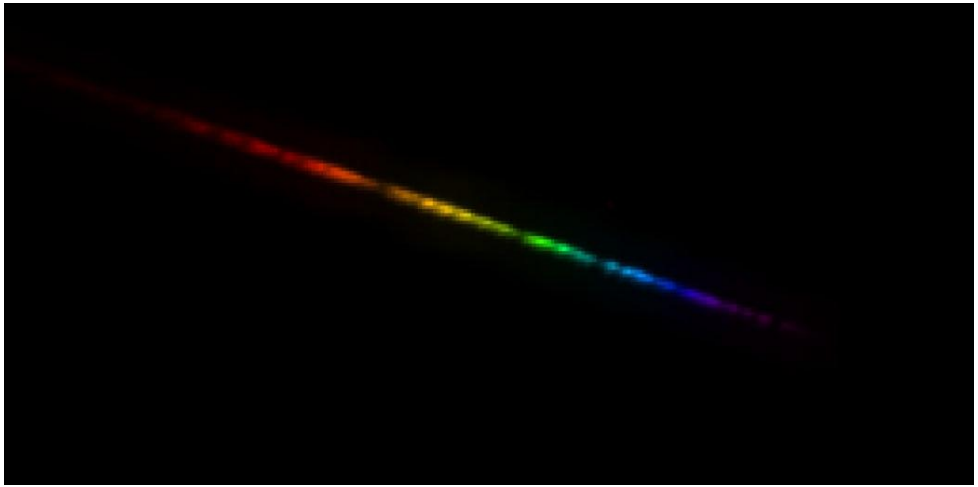
Comparison of two consecutive nights on EMPTY transmission:

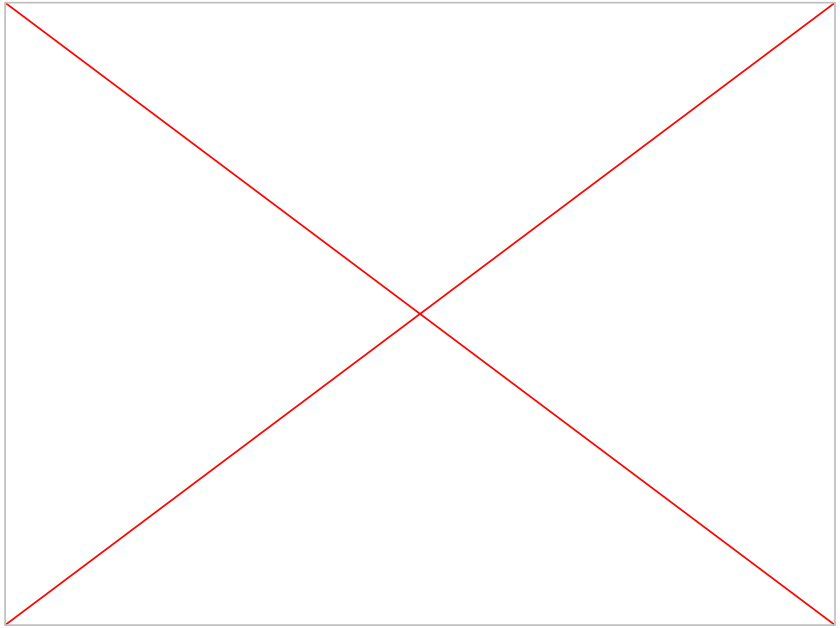
- overall shape OK
- 1% discrepancy to investigate (background, aperture corrections)





MonoDICE @ OHP : PSF characterization using StarDICE GRISM

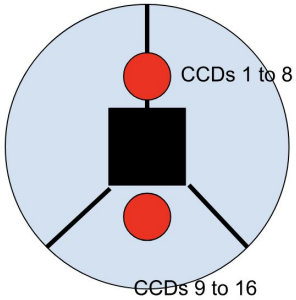


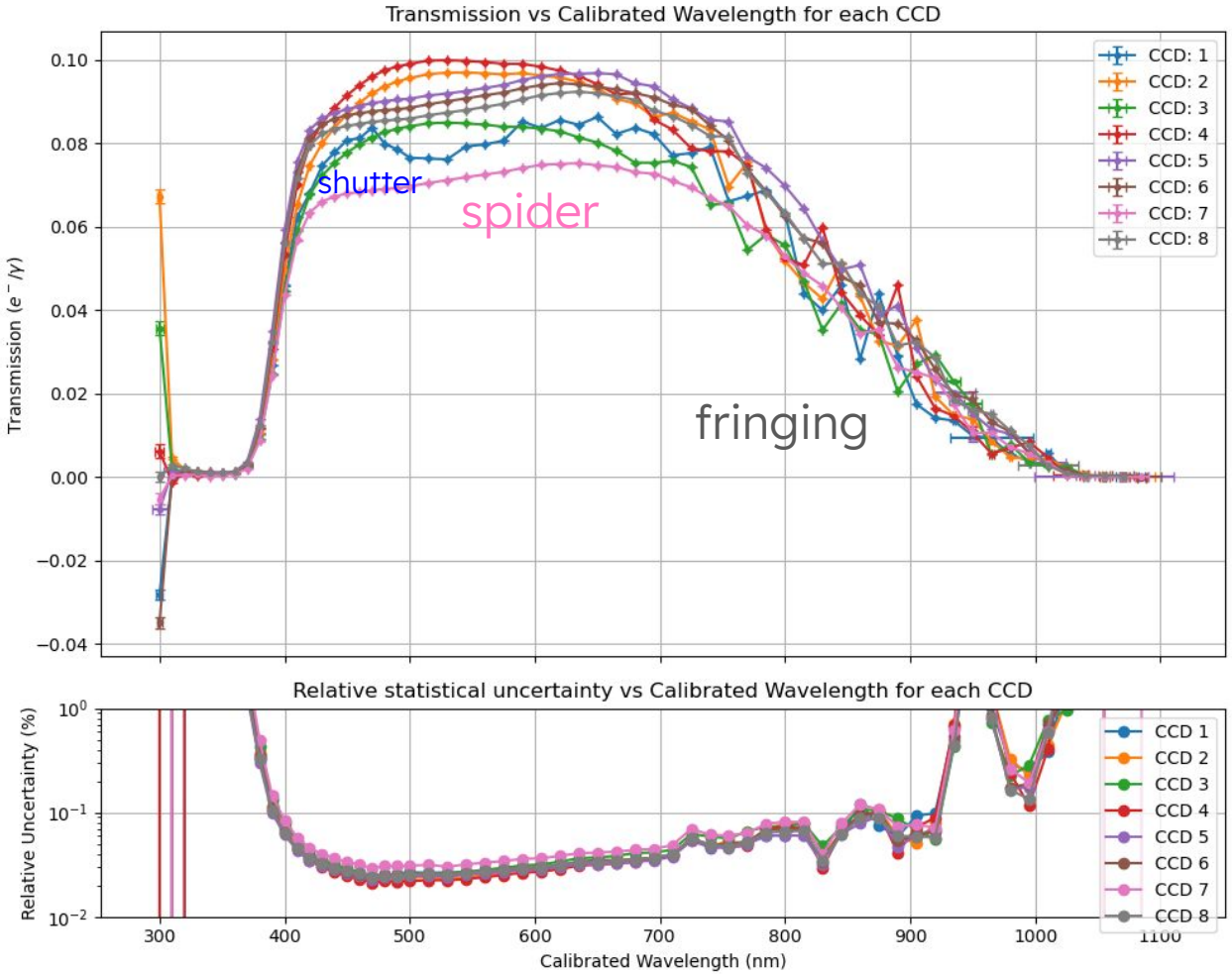


TCBP @ ZTF data set summary

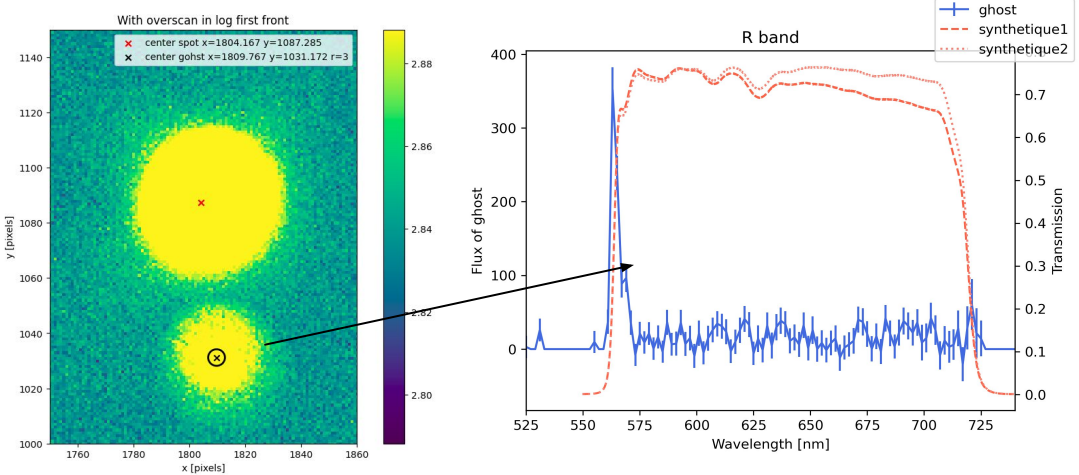
	Filter	g	r	i	empty
CCD 11	1 nm steps	One scan	Two scans	One scan	
CCD 11	Optimized steps	One scan	One scan	One scan	
CCD 09-16	Multispot pos1	One scan	One scan	One scan	One scan
CCD 09-16	Multispot pos2	One scan	One scan	Two scans	One scan
CCD 09-16	Multispot pos3		One scan (well sampled to see fringing)	One scan	
CCD 01-08	Multispot pos4	One scan	One scan	One scan	One scan

TCBP @ ZTF : CCD QEs

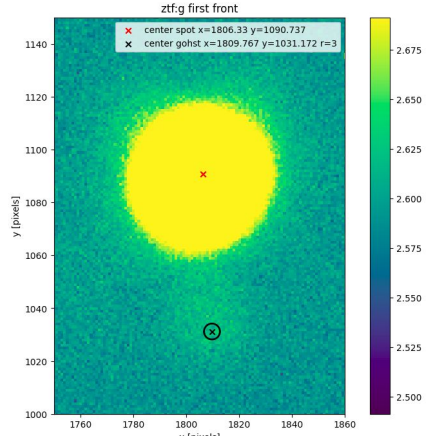


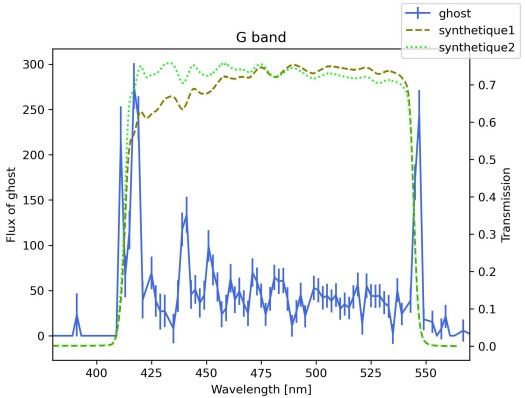


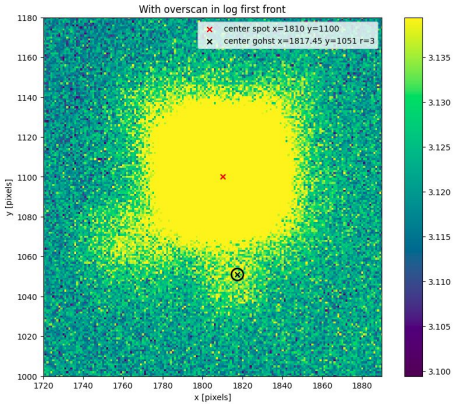
TCBP @ ZTF : Ghosts

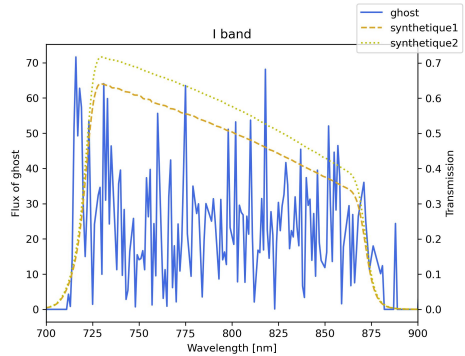


- One ghost in the first edge in the r-band
- One ghost in each edge of the g band
- In all the i band

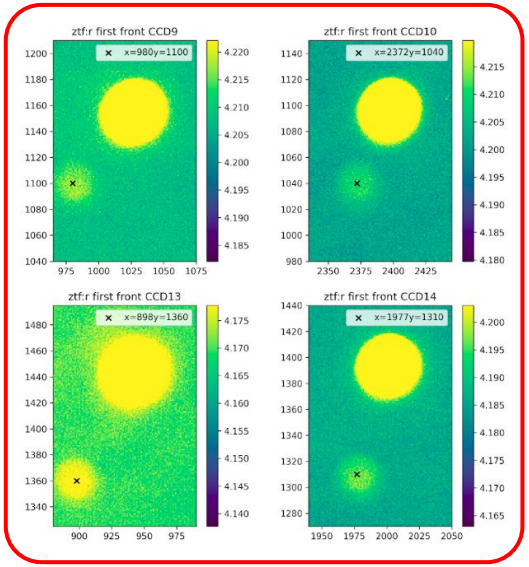




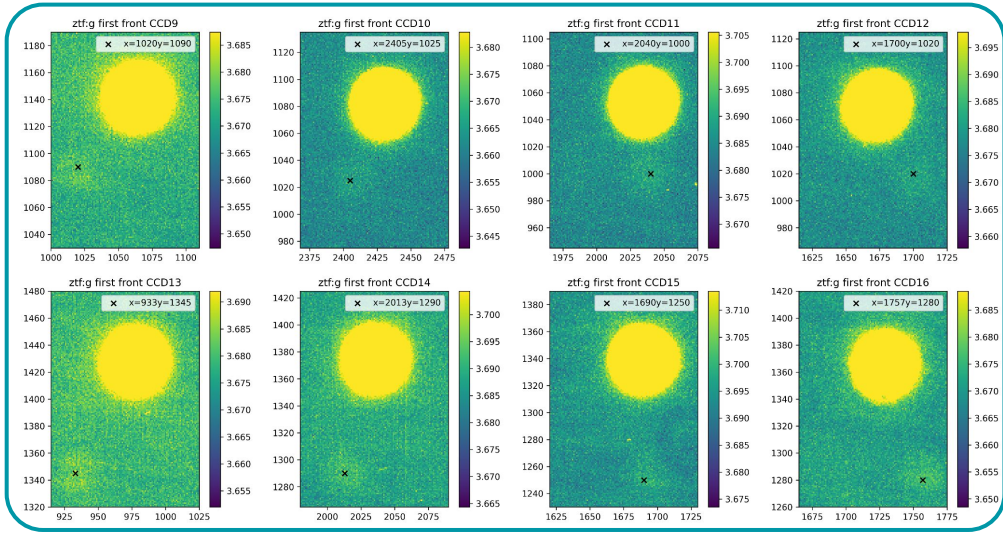


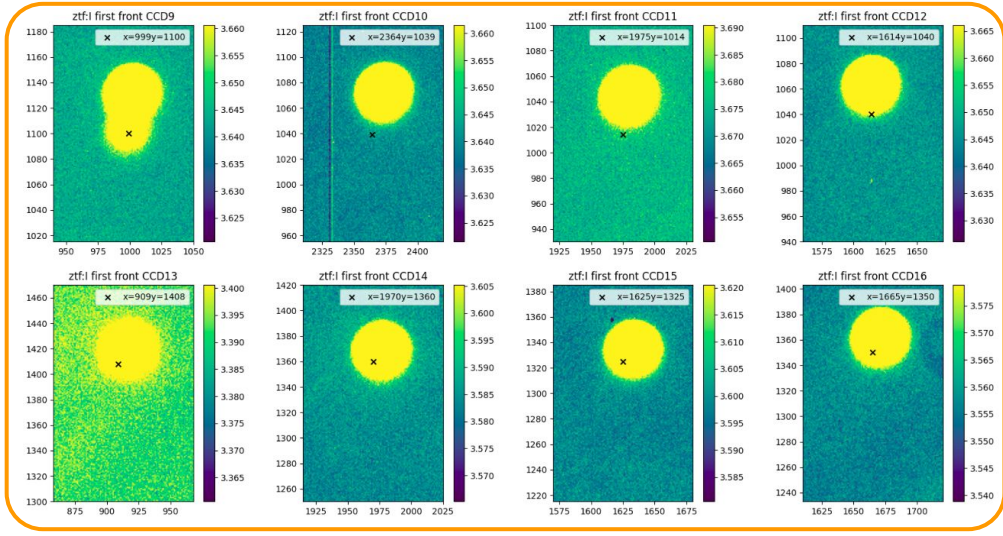


TCBP @ ZTF : Ghosts

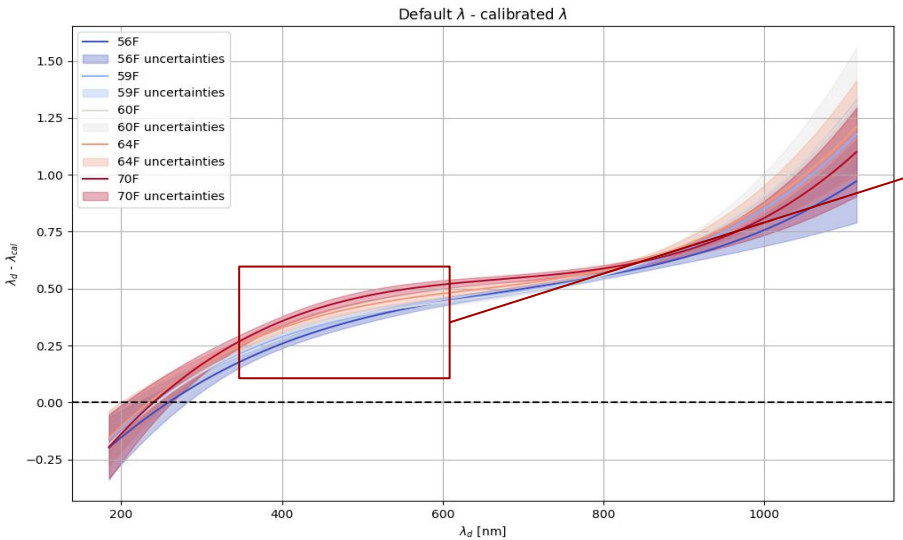


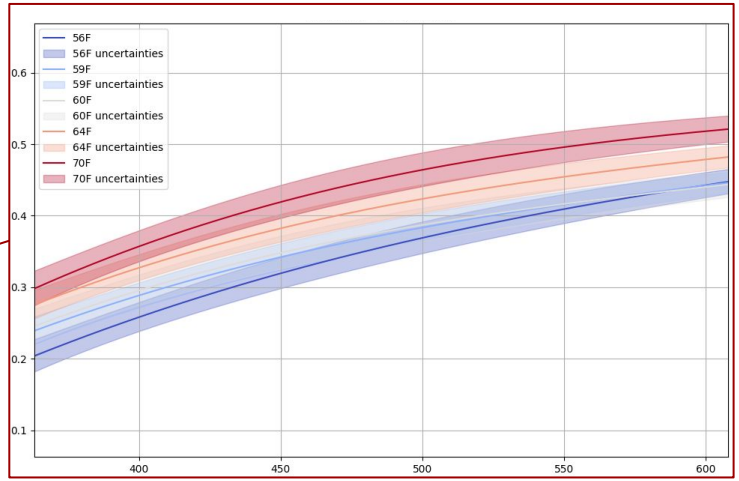
- r band : only CCD9,10,13,14. Ghost farther away from the spot for single coating.
- g band : lower intensity but at different locations as a function of the CCD.
- i band : ghost merging with the spot ?



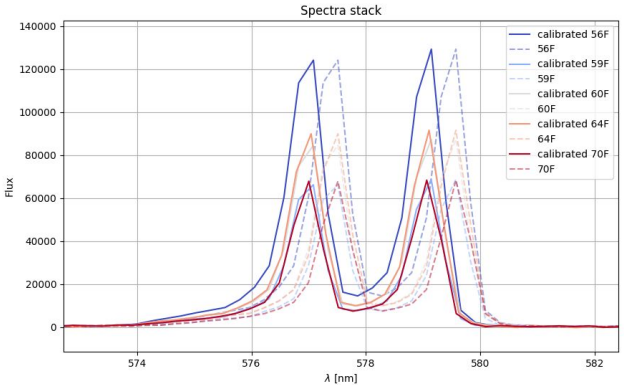


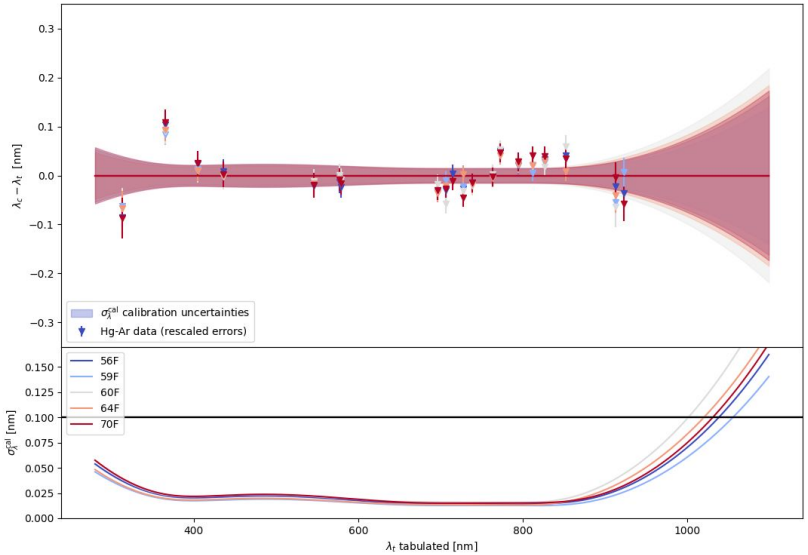
TCBP @ ZTF : Spectro calibration





Temperature dependency





calib uncertainty < 1Å !