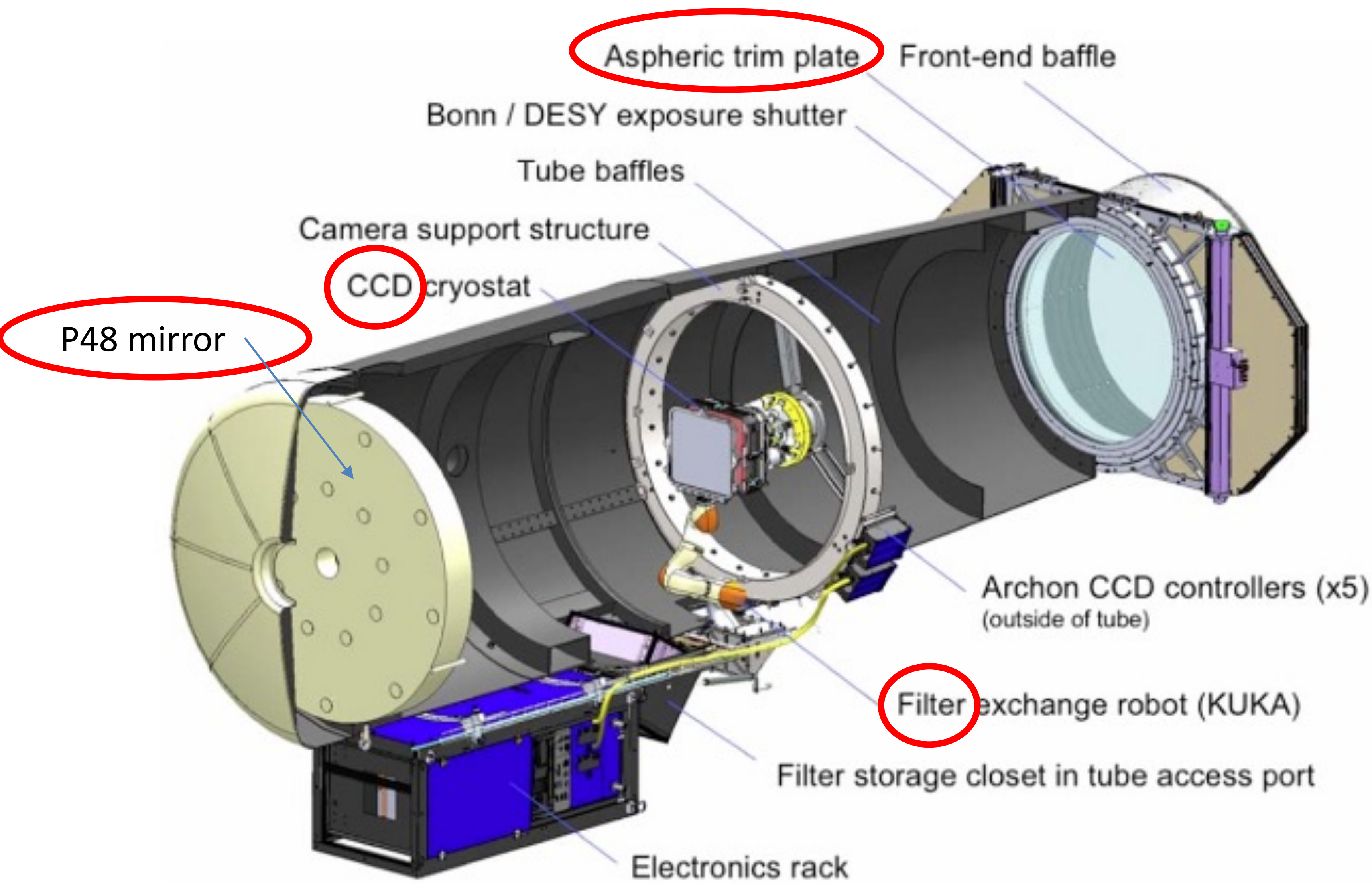
ZTF-France meeting, LPC, 11-12 September 2023

Instrument model

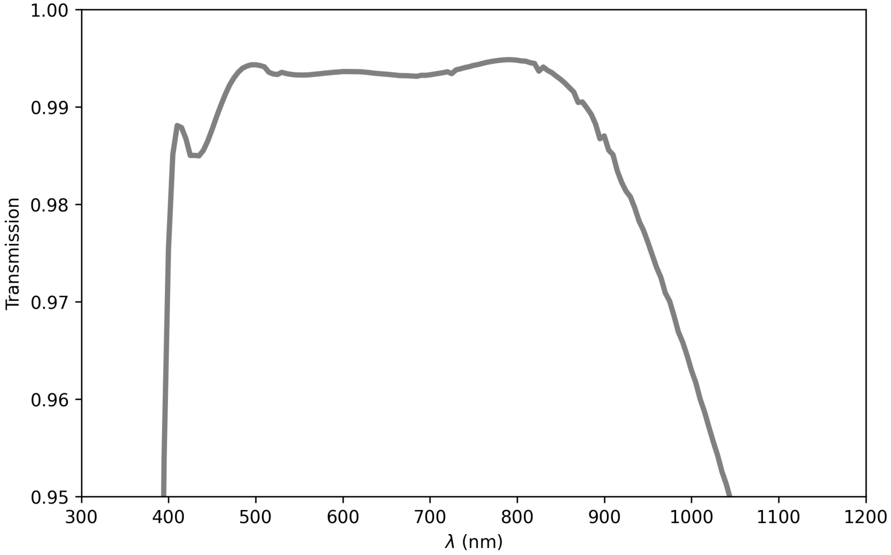
Philippe Rosnet
Laboratoire de Physique de Clermont
Université Clermont Auvergne – CNRS/IN2P3

ZTF instrument

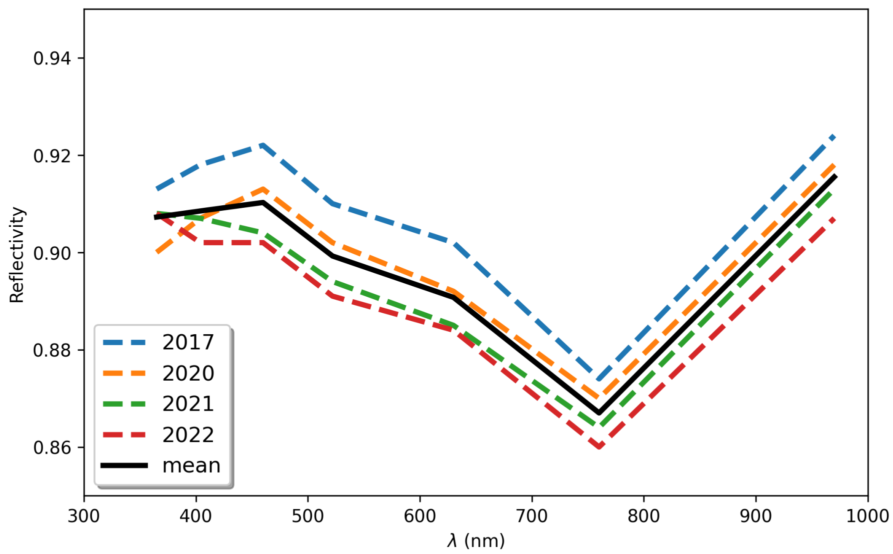


Instrument elements (1)

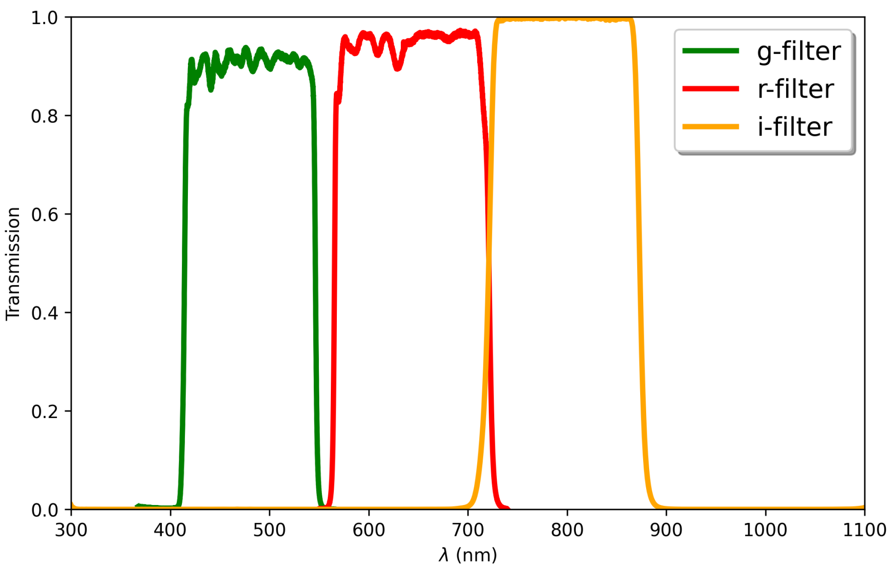
Aspheric trim plate transmission



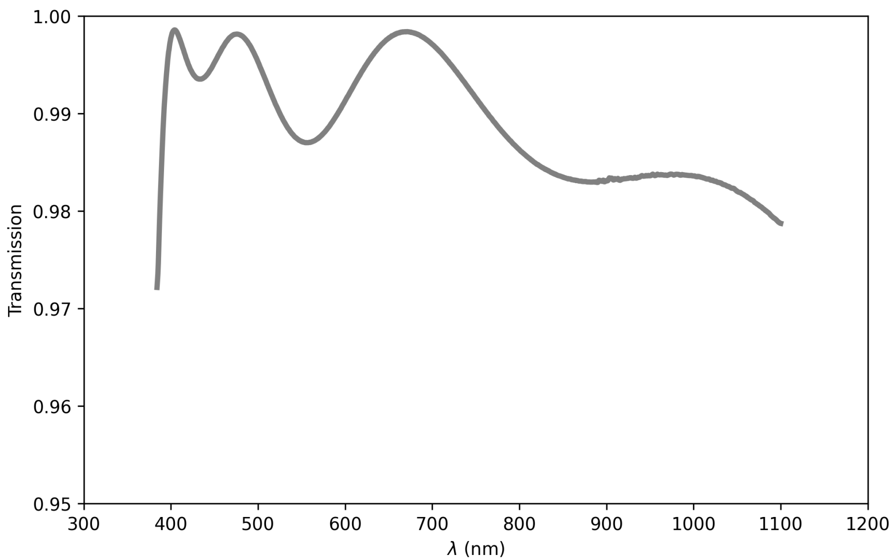
P48 mirror reflectivity



ZTF filter transmission

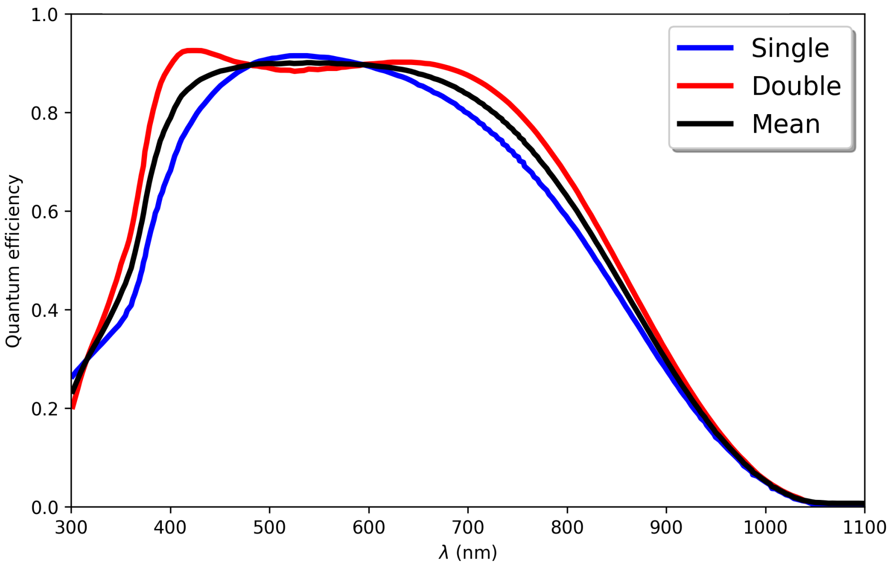


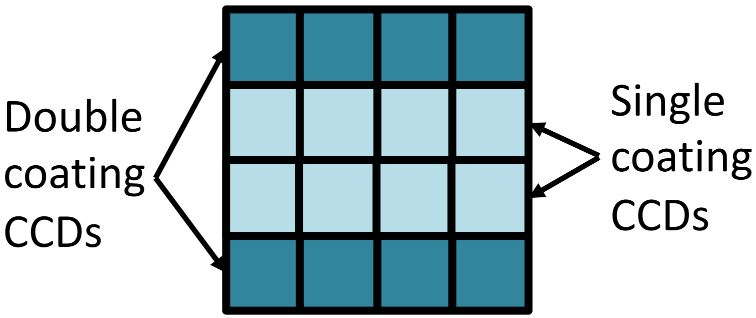
ZTF field corrector transmission



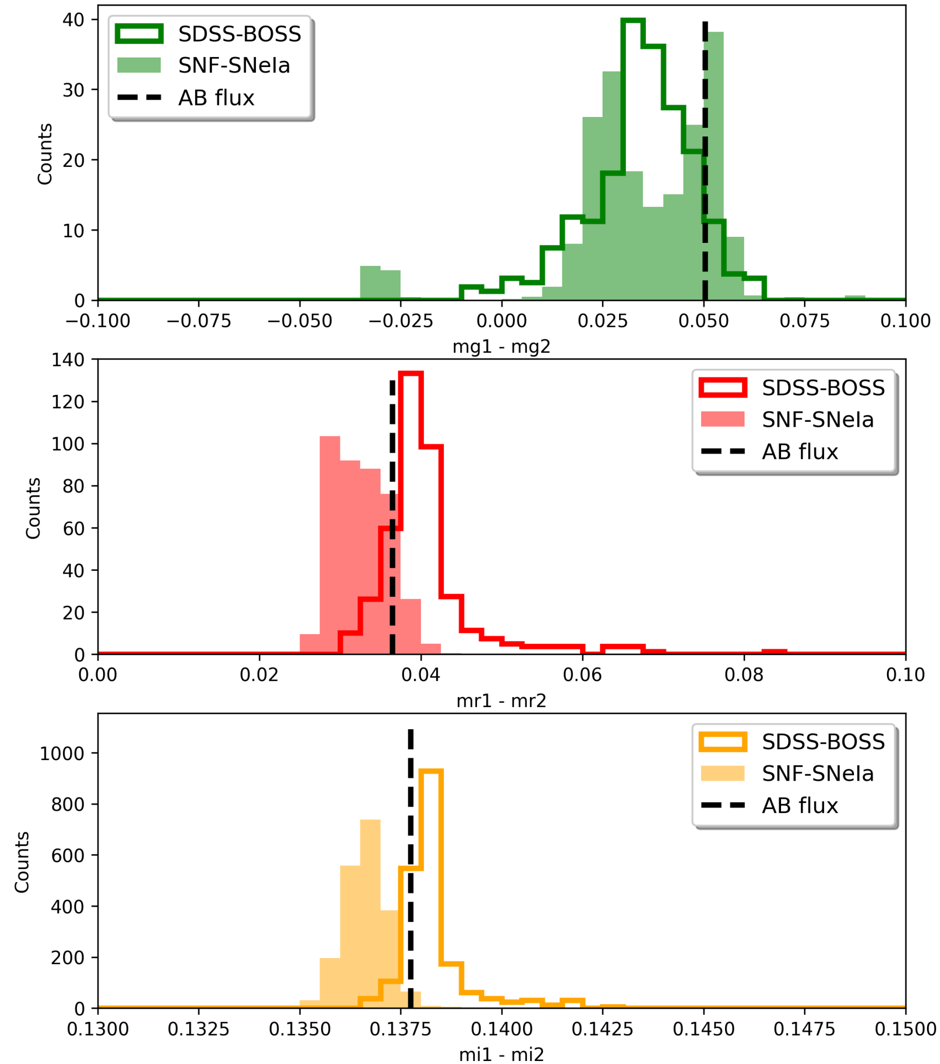
Instrument elements (2)

ZTF CCD quantum efficiency (QE)





Colour effect due to single versus double coating CCD's estimated on spectra

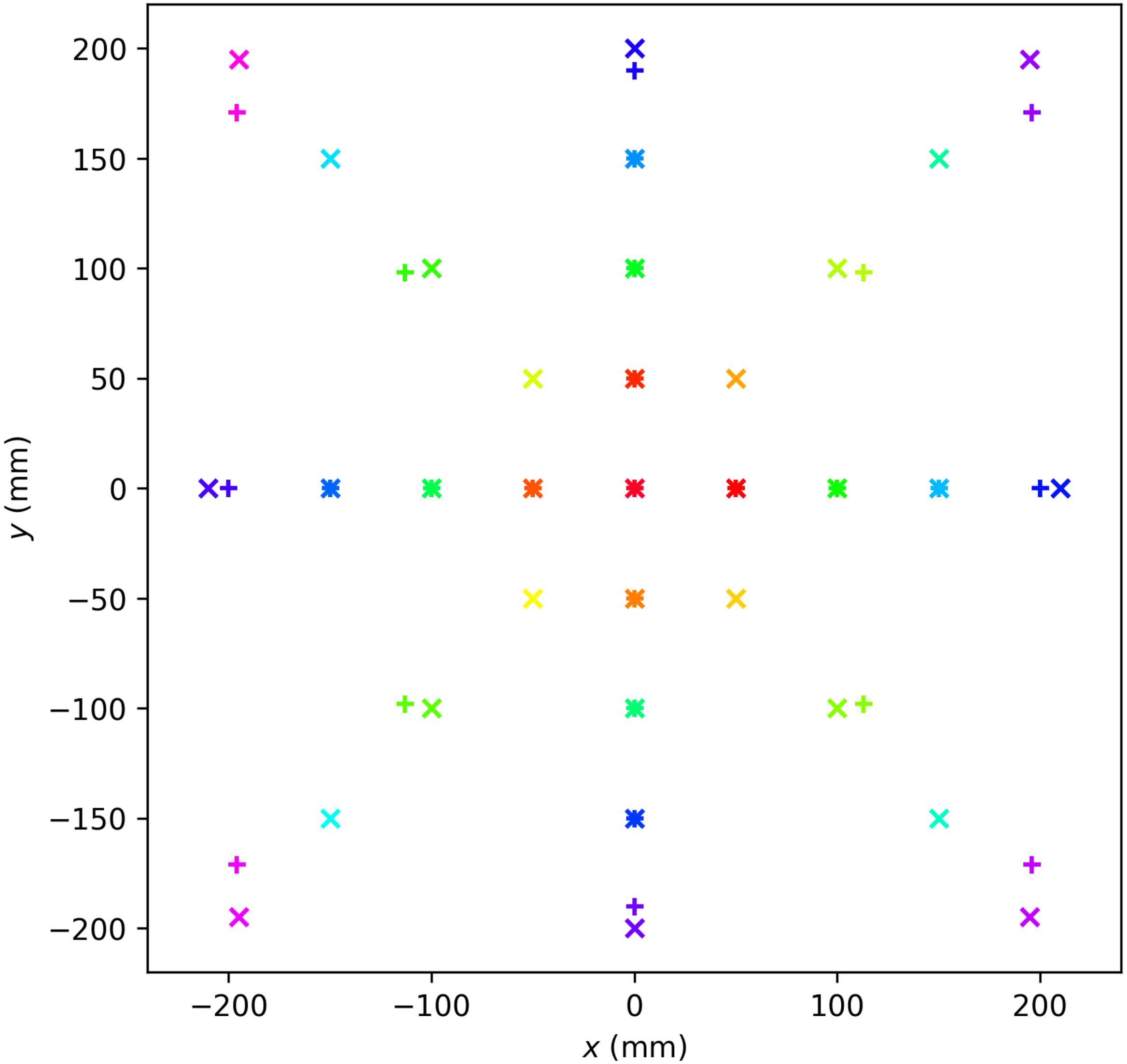


Why an instrument model ?

1. Mean QE in SNCosmo ➜ bias in SNe Ia magnitude estimation
2. Filter in SNCosmo at normal incident angle ➜ is it the realistic ?

ZTF filter position measurements

x g and r-bands at 0° and 4°
+ i-band at 5° (0° data ???)



Filter transmission dependency

- Approximate **angular dependence of interference filter transmission** (arXiv:0908.3808)

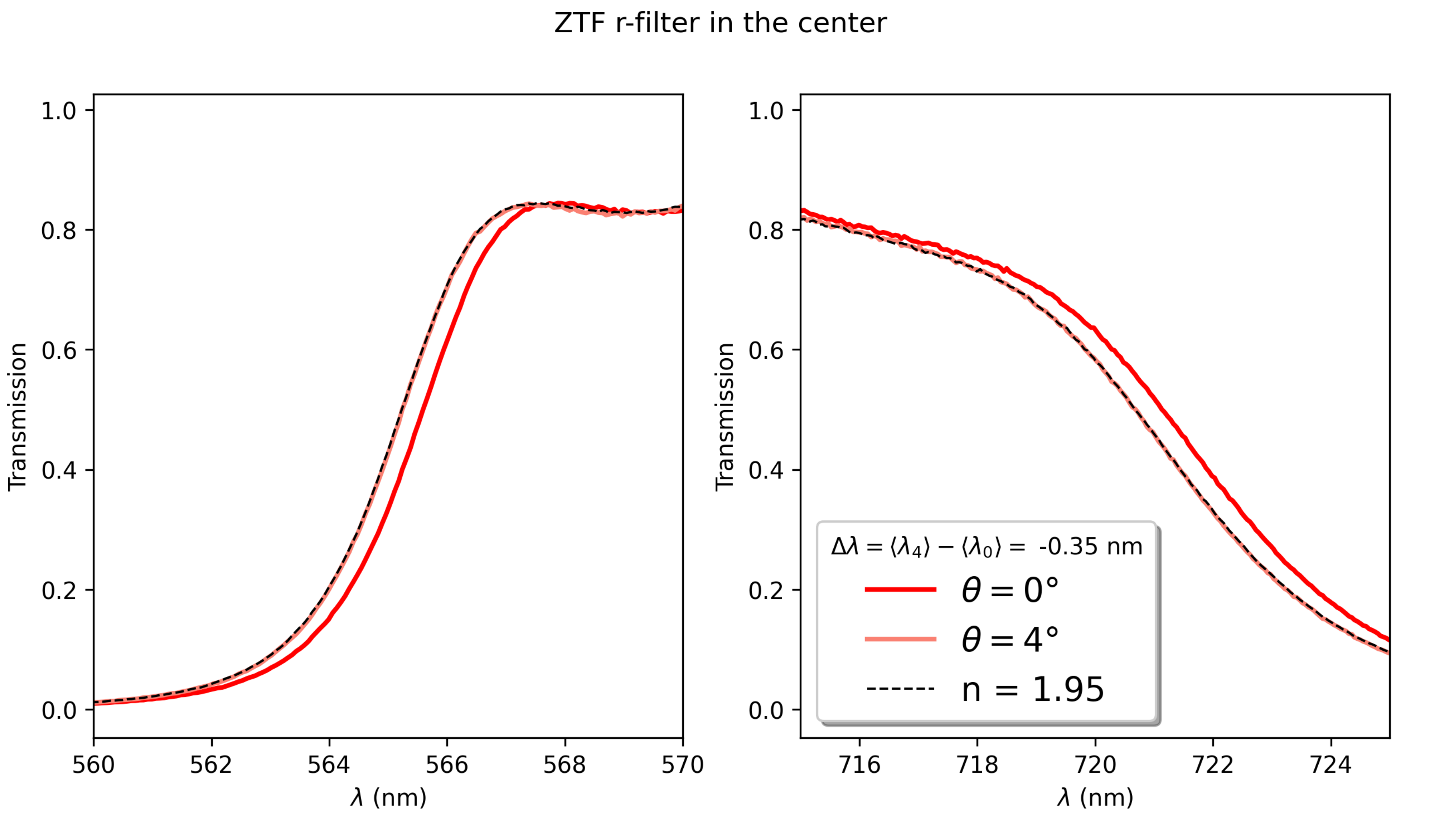
$$T(\lambda,\theta) = T(\lambda\left(\left[1-\frac{\sin^2\theta}{n^2}\right]^{-1/2},\theta = 0\right)$$

- Determination of the **refracting index of filters**: shift of 0° data filter according to formula above to match 4° data by using as reference point the centre of the filter
  - $n_g \approx 1.85$
  - $n_r \approx 1.95$

- Characterization of optical uniformity by studying of **1st moment** of filter transmission

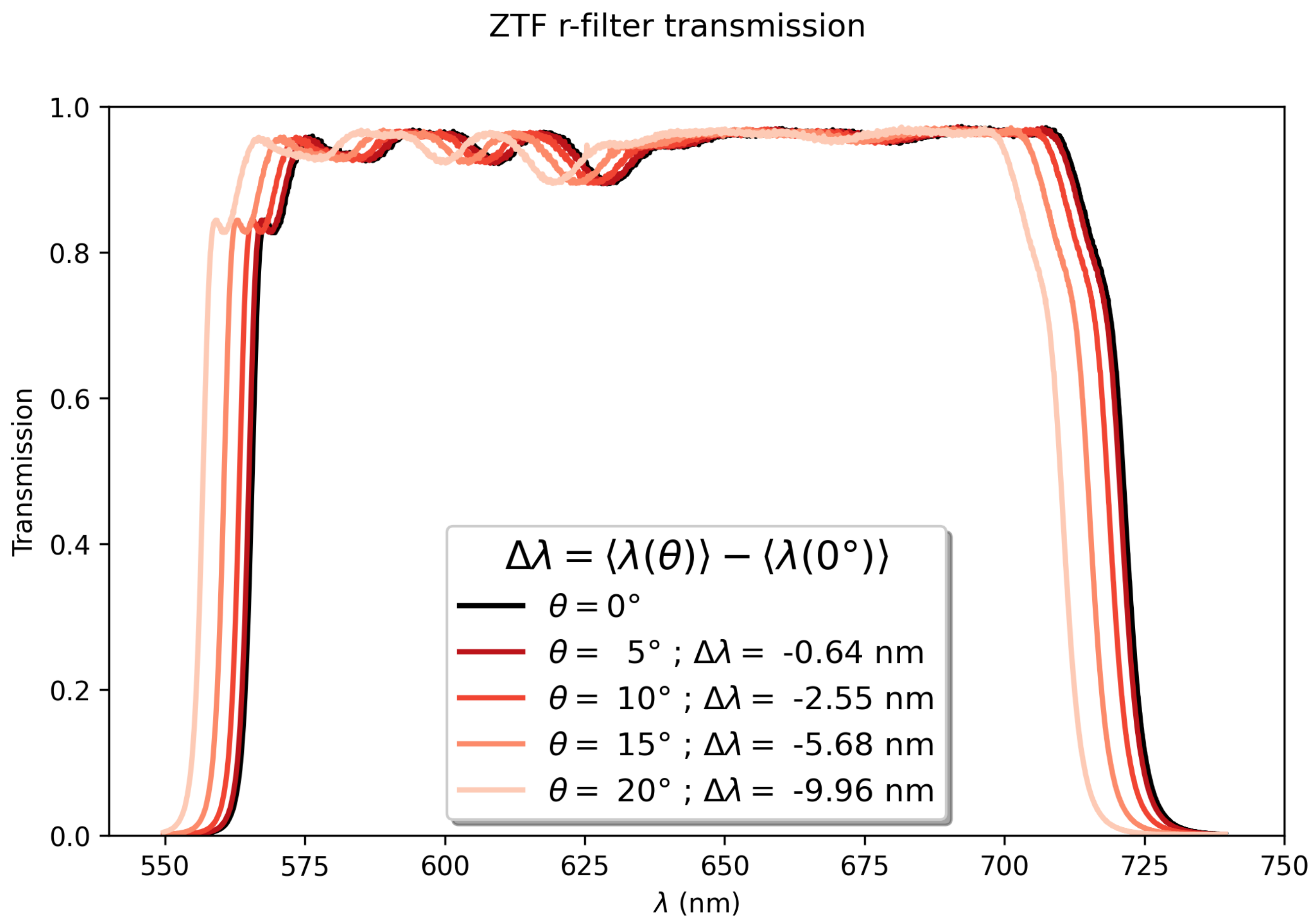
$$\langle\lambda\rangle = \frac{\int \lambda T\,(\lambda)\,d\lambda}{\int T(\lambda)\,d\lambda}$$

ZTF r-filter refracting index



Measured transmission at $\theta = 0°$ is extrapolated to $\theta = 4°$ with an adjustment of refracting index $n_g \approx 1.95$ to match measured transmission at $\theta = 4°$

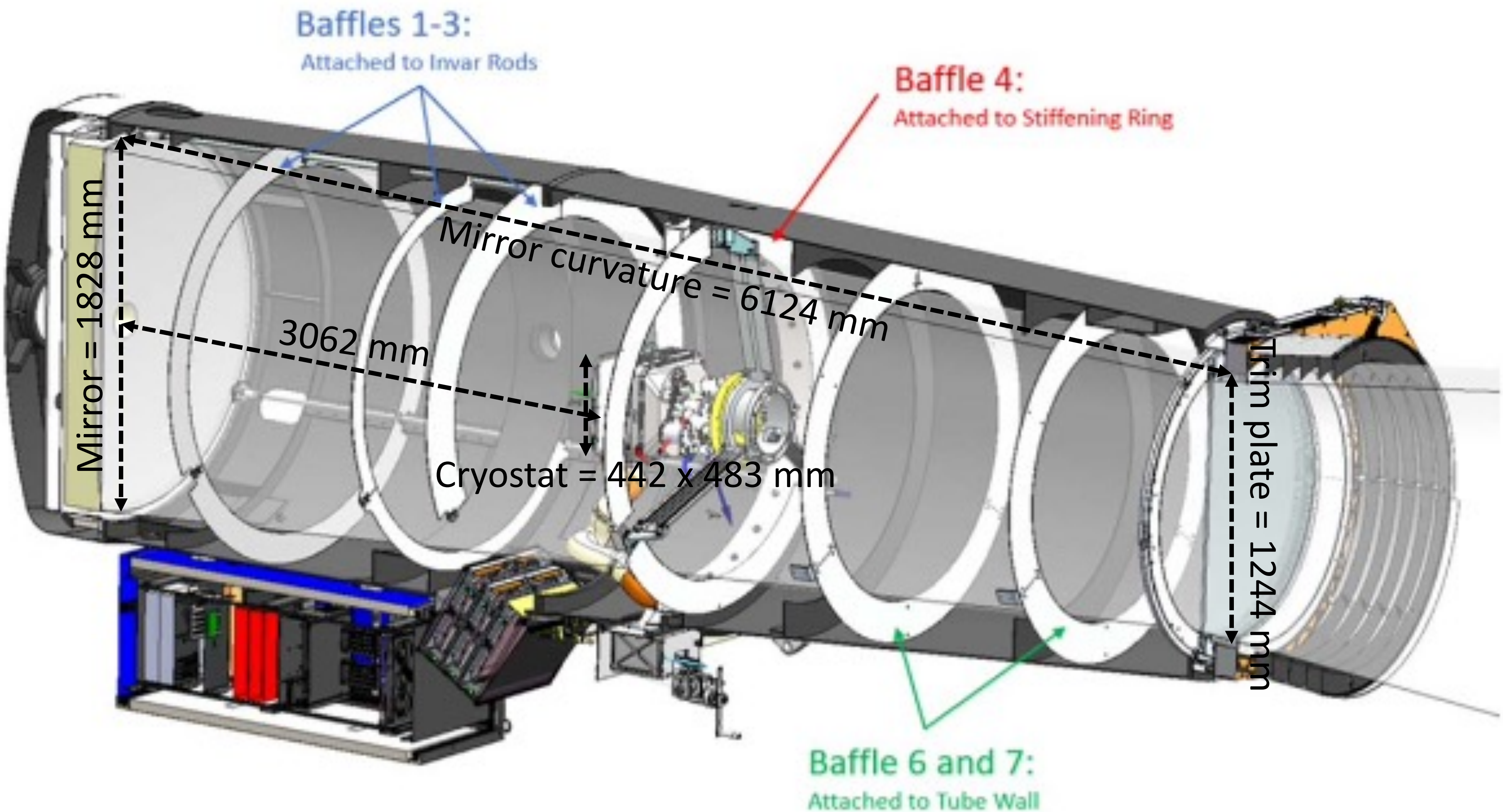
ZTF r-filter shift versus incident light angle



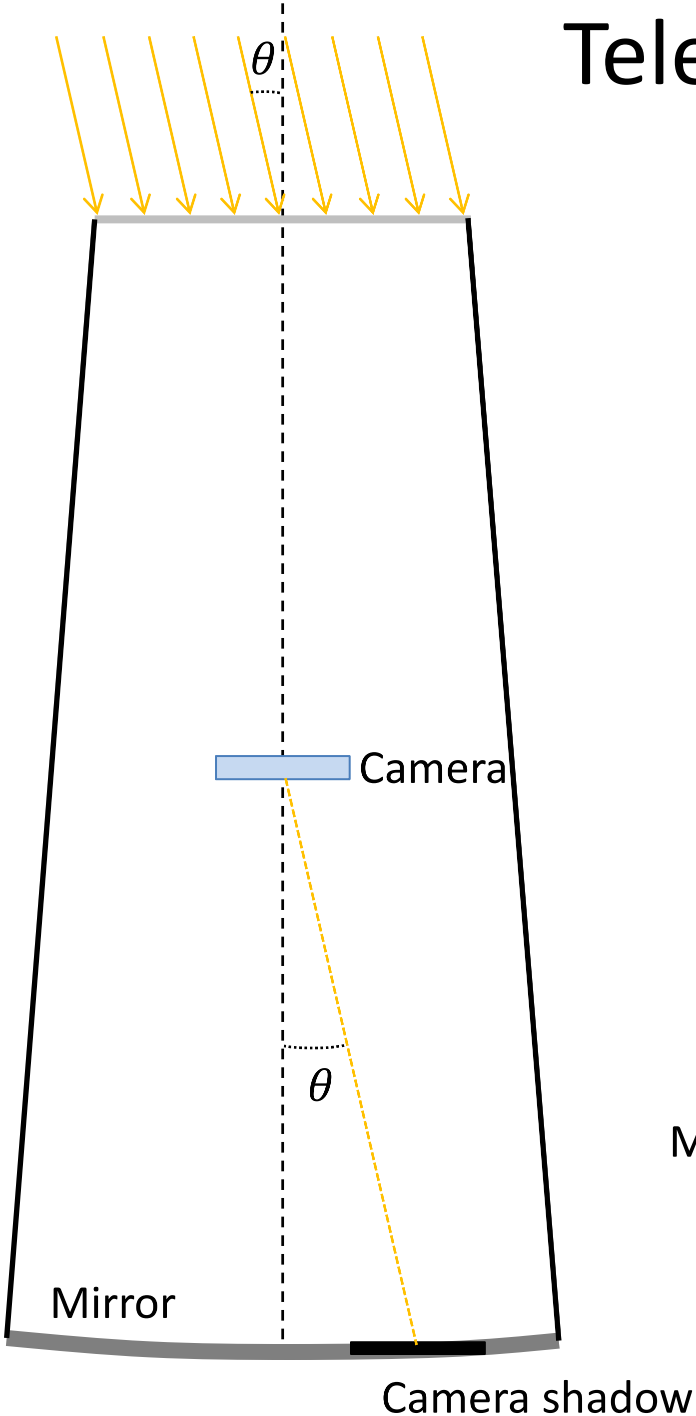
Measured transmission at $\theta = 0°$ is extrapolated to $\theta = 4°$ with an adjustment of refracting index $n_g \approx 1.95$ to match measured transmission at $\theta = 4°$

Telescope scheme

arXiv:2008.04923

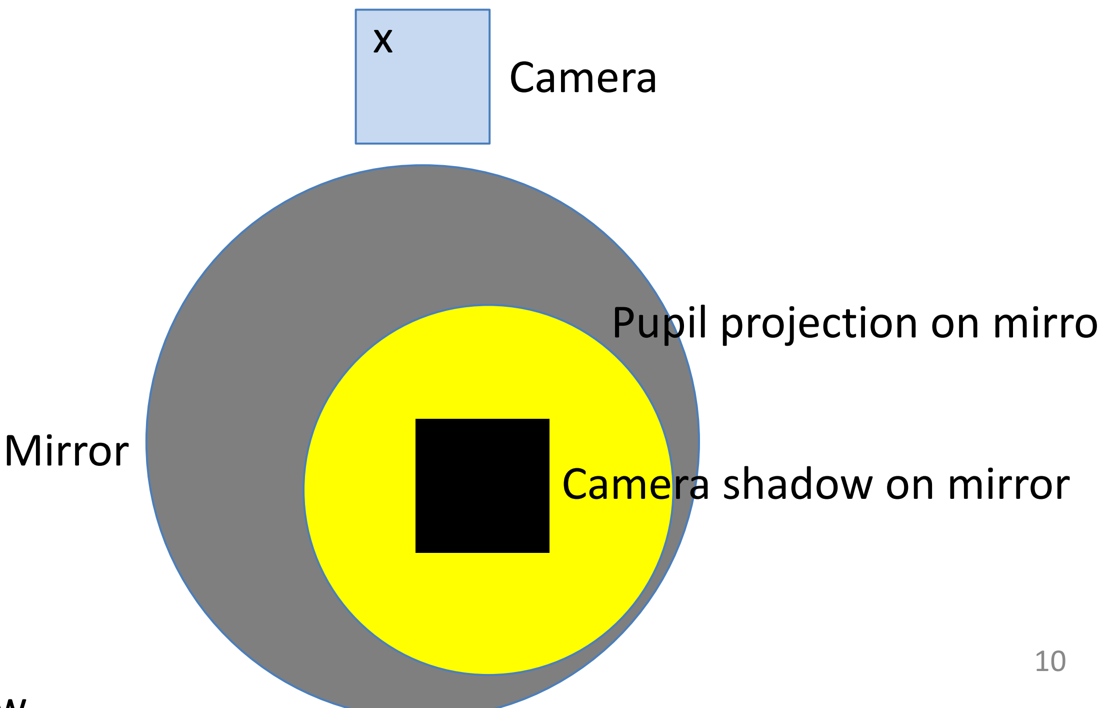


Telescope model

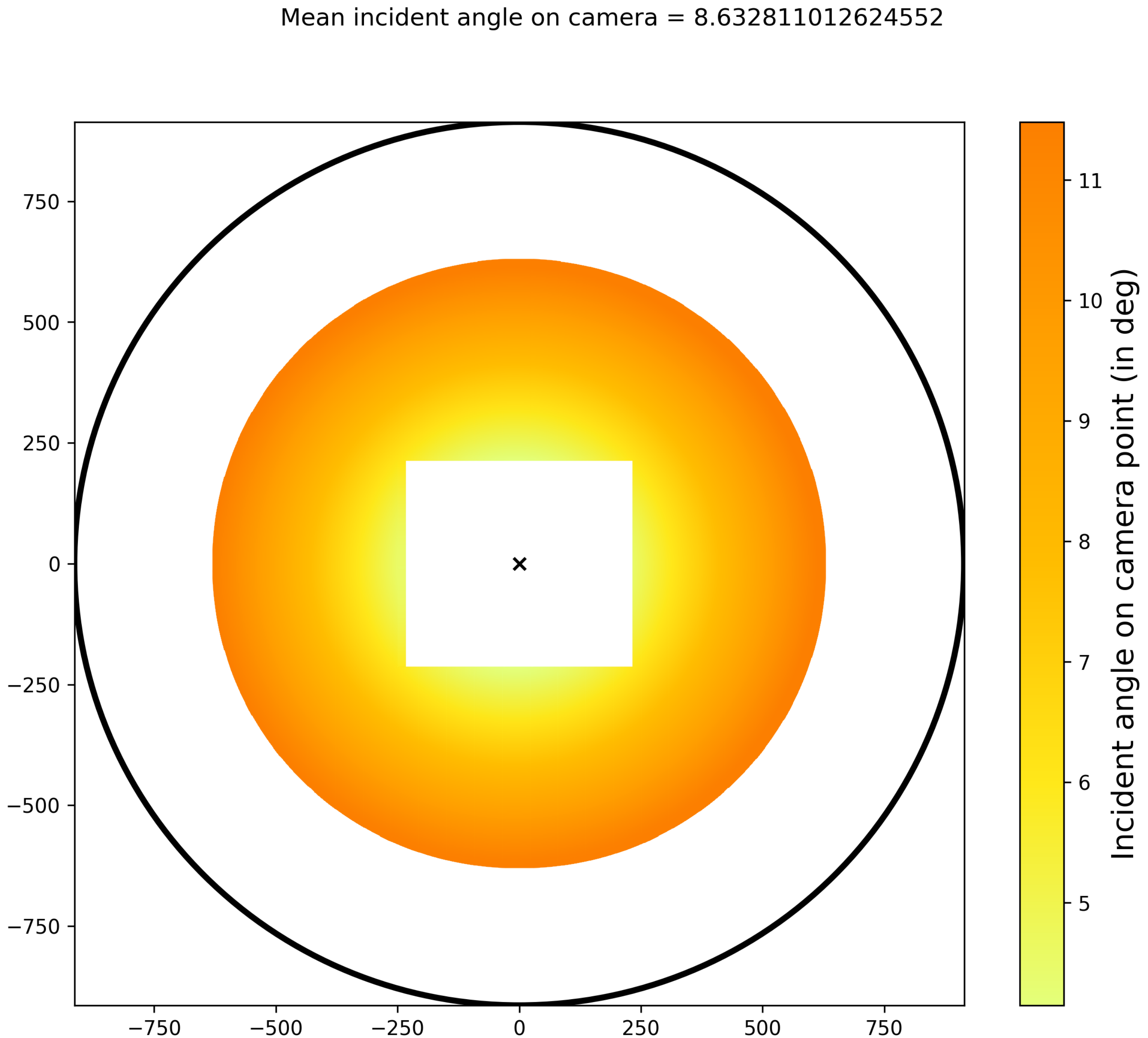


- Position (x) on camera correspond to light-rays from sky with incident angle θ

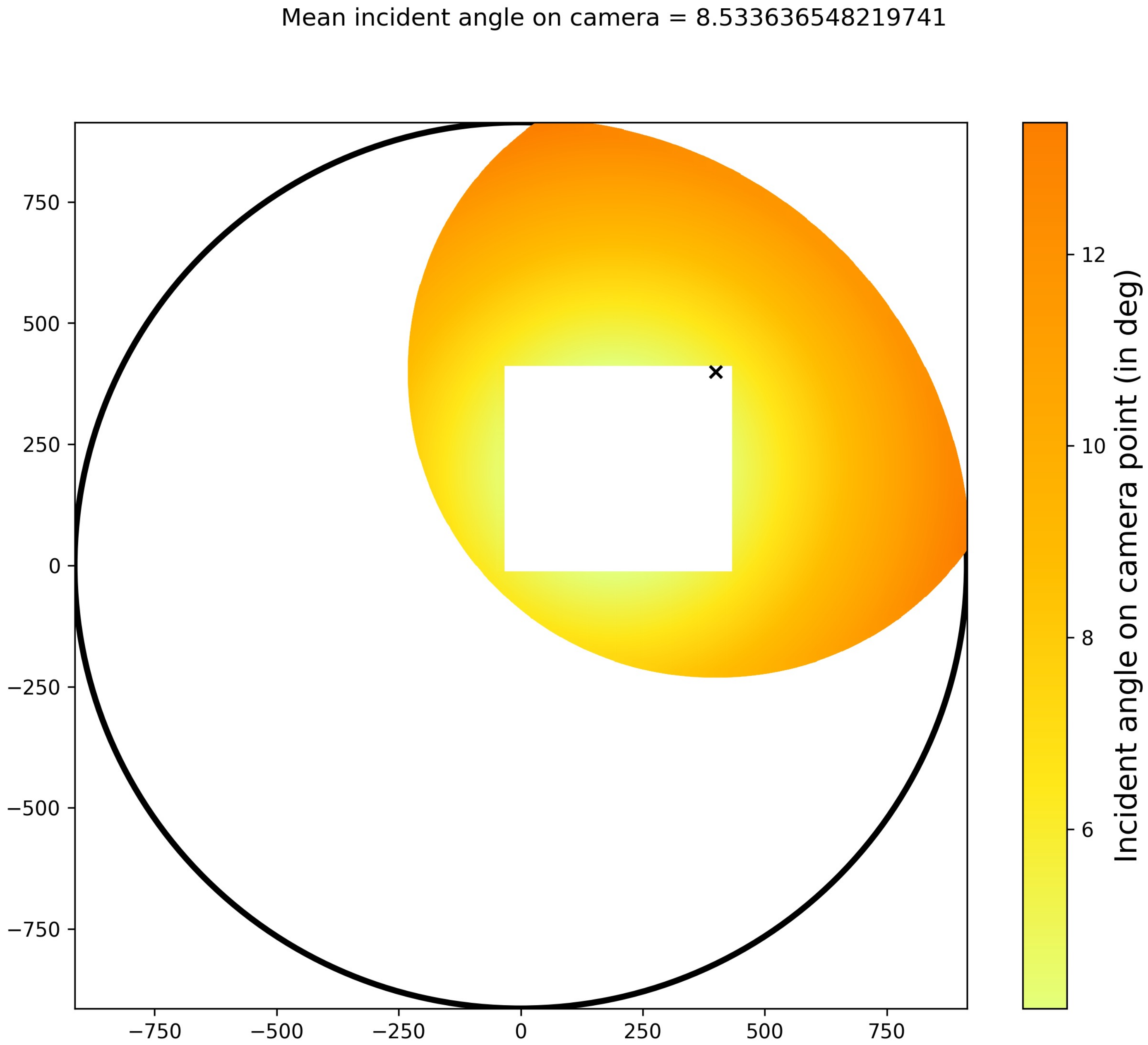
- <u>Hypothesis</u>: projection of pupil and camera on mirror according to incident angle θ (not realistic on scheme: $\theta_{max} \approx \sqrt{47/2} = 4.8°$)



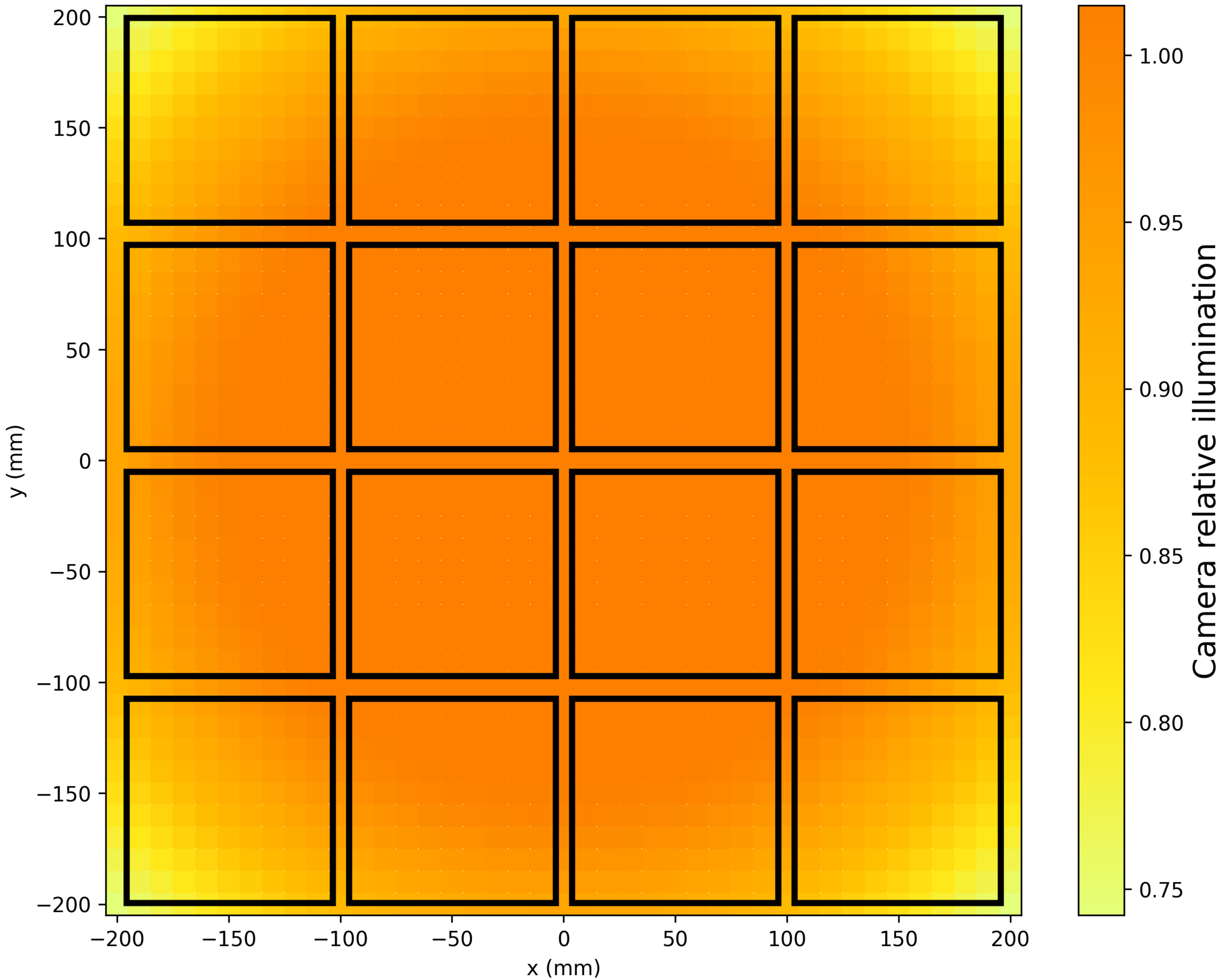
Model implementation: normal incident angle



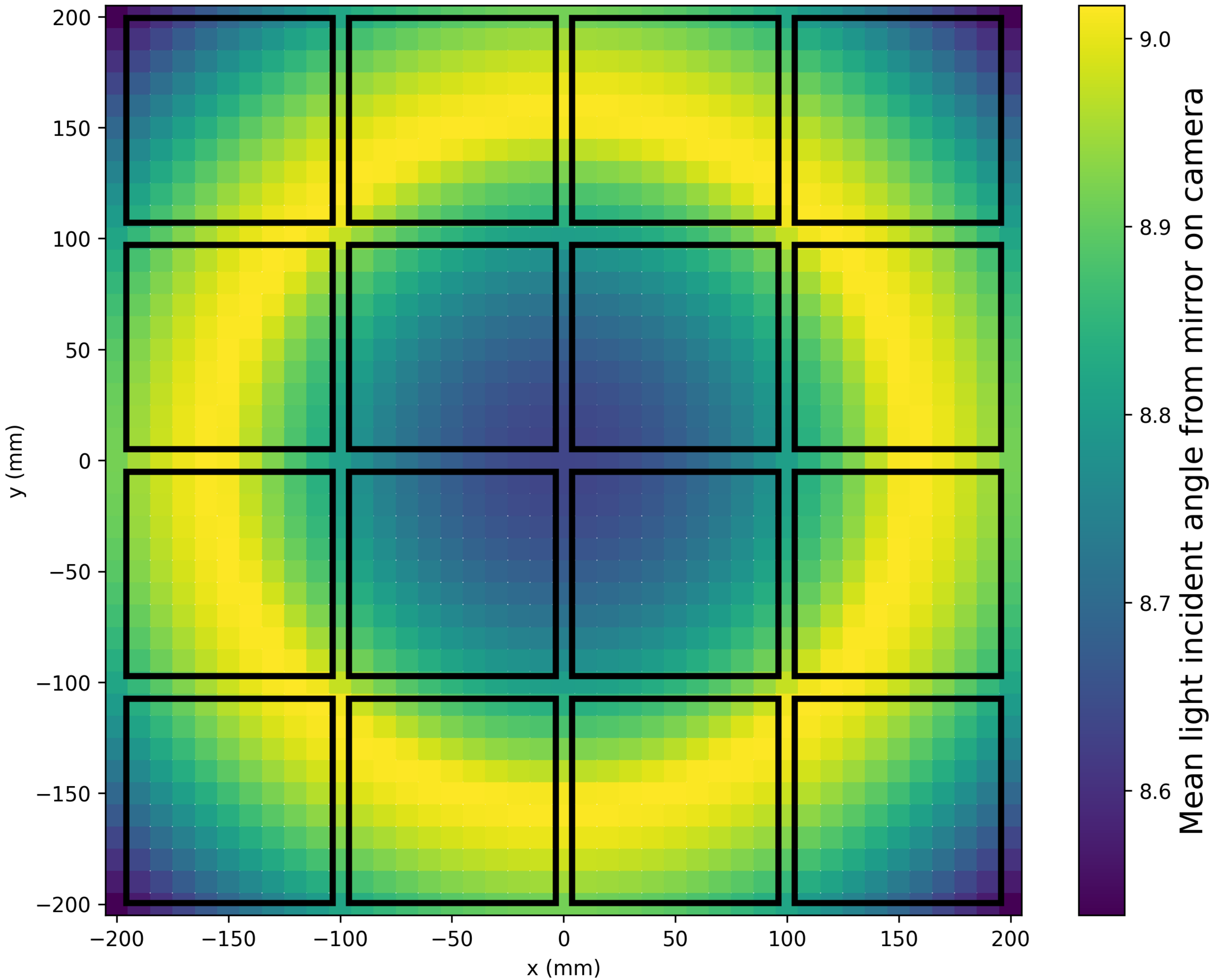
Model implementation: max. incident angle



Model results: focal plane illumination



Model result: mean incident angle on camera



Conclusions and next steps

Conclusions

- Almost all pieces to build an instrument model : i-band 0° data missing
- Photometric bias expected due to
    - Different QE versus CCD types
    - Different mean light incident angle on filter versus position
- Refracting index of g and r-bands determined from Caltech data filter characterization

Next steps

- Build filter transmission over focal plan by extrapolating Caltech measurements with light incident angle dependency
- Define an instrument model in SNCosmo (Nicolas)

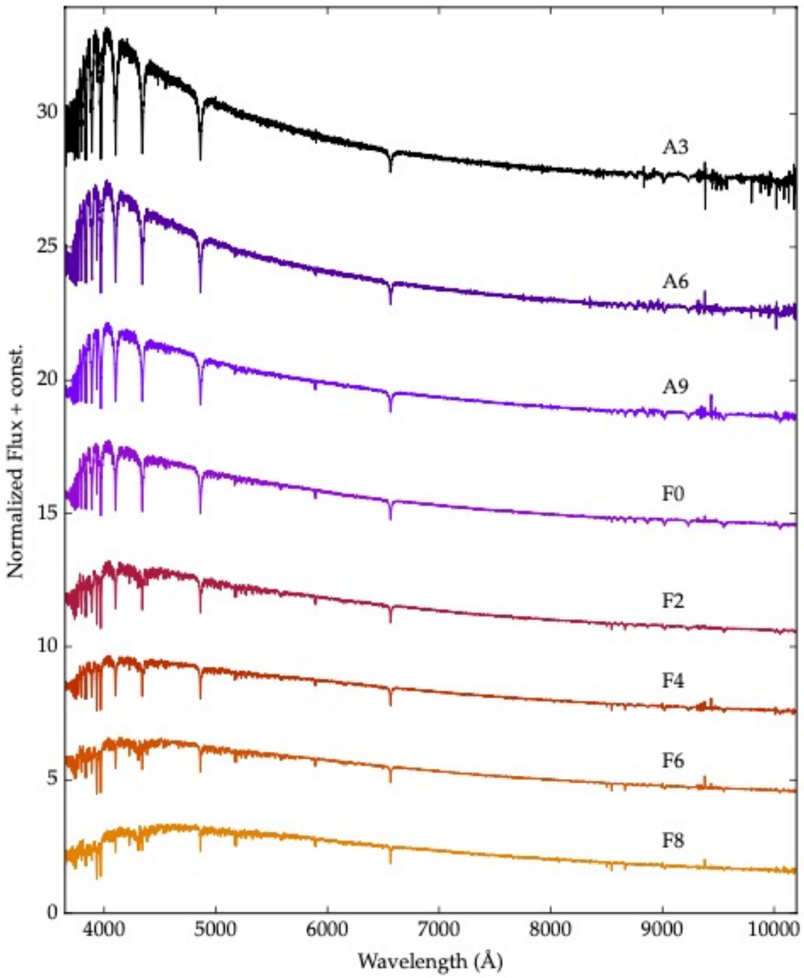
instrument.cards

```
@MIRROR_AREA 510430.

# transmission of the optics
@OPTICS_TRANS ztf_optics_transmission.txt

# reflectivity of the mirror
@MIRROR_REFLECTIVITY ztf_mirror_reflectivity.txt

# atmospheric transmission
#@ATMOSPHERIC_TRANS modtran_maunakea_am12_pwv15_binned10ang.dat

# filters
@RADIALLY_VARIABLE_FILTERS FilterWheel

# QE of CCD's
#@QE qe_ccd_hsc.txt

# QE of individual CCD's
@QE_PER_CCD ztf_qe_ccd_1_2_3_4_13_14_15_16.txt ztf_qe_ccd_5_6_7_8_9_10_11_12.txt

# pixel size
@PIX_SIZE 1.01" OR 15 µm ???
```

Set of SEDs

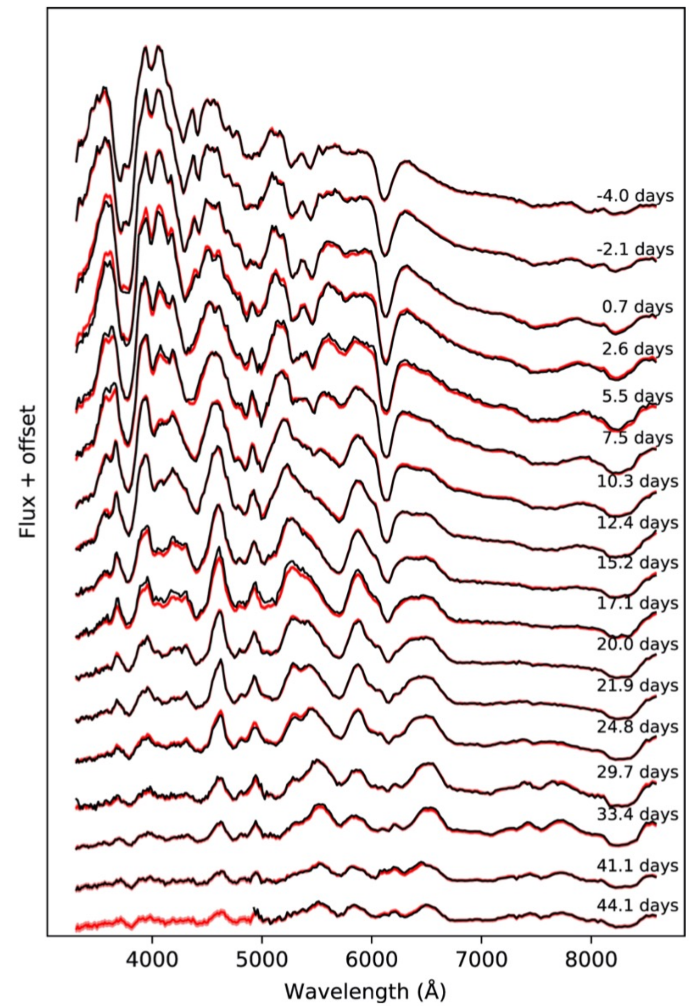
SDSS-BOSS stellar templates

- 322 spectra
- All star type



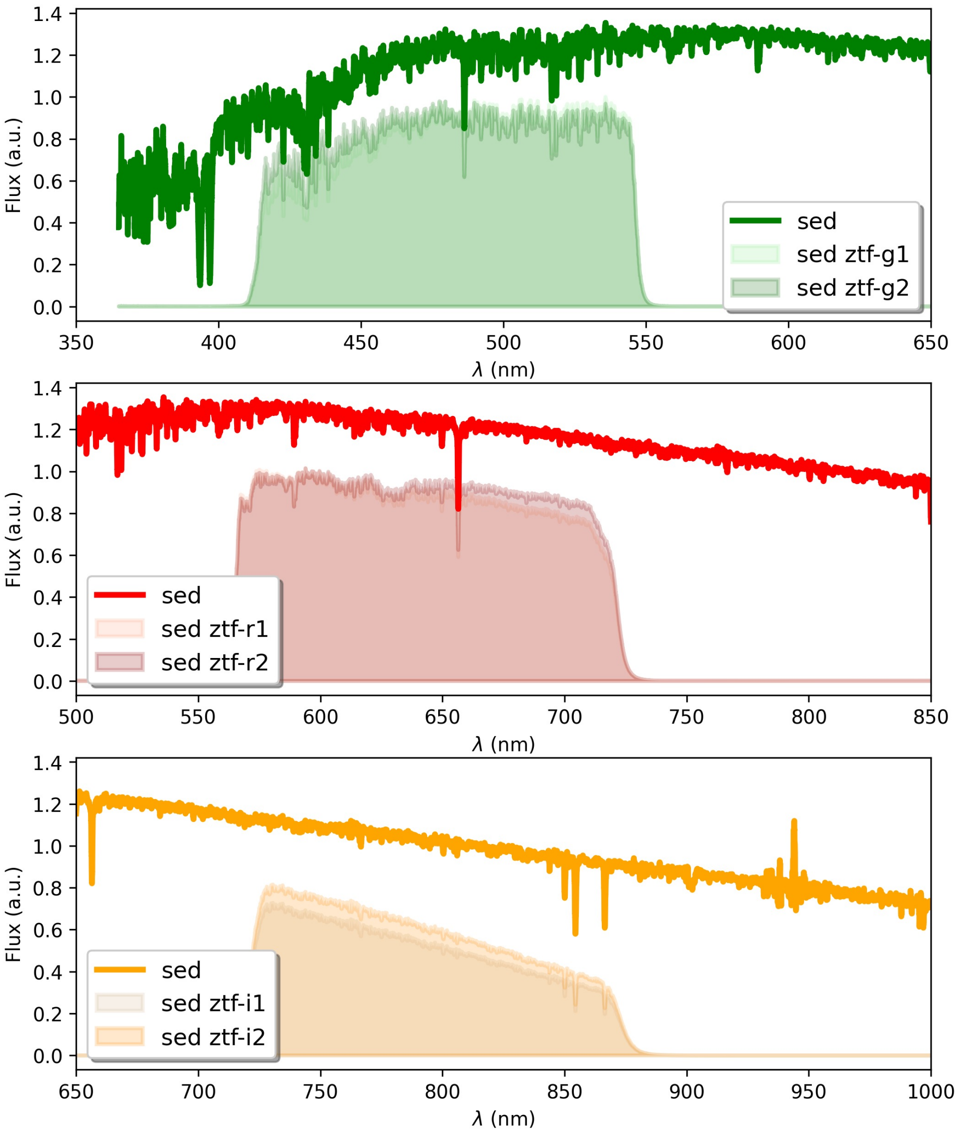
SN factory

- 172 SNe la time series
- More than 2000 spectra

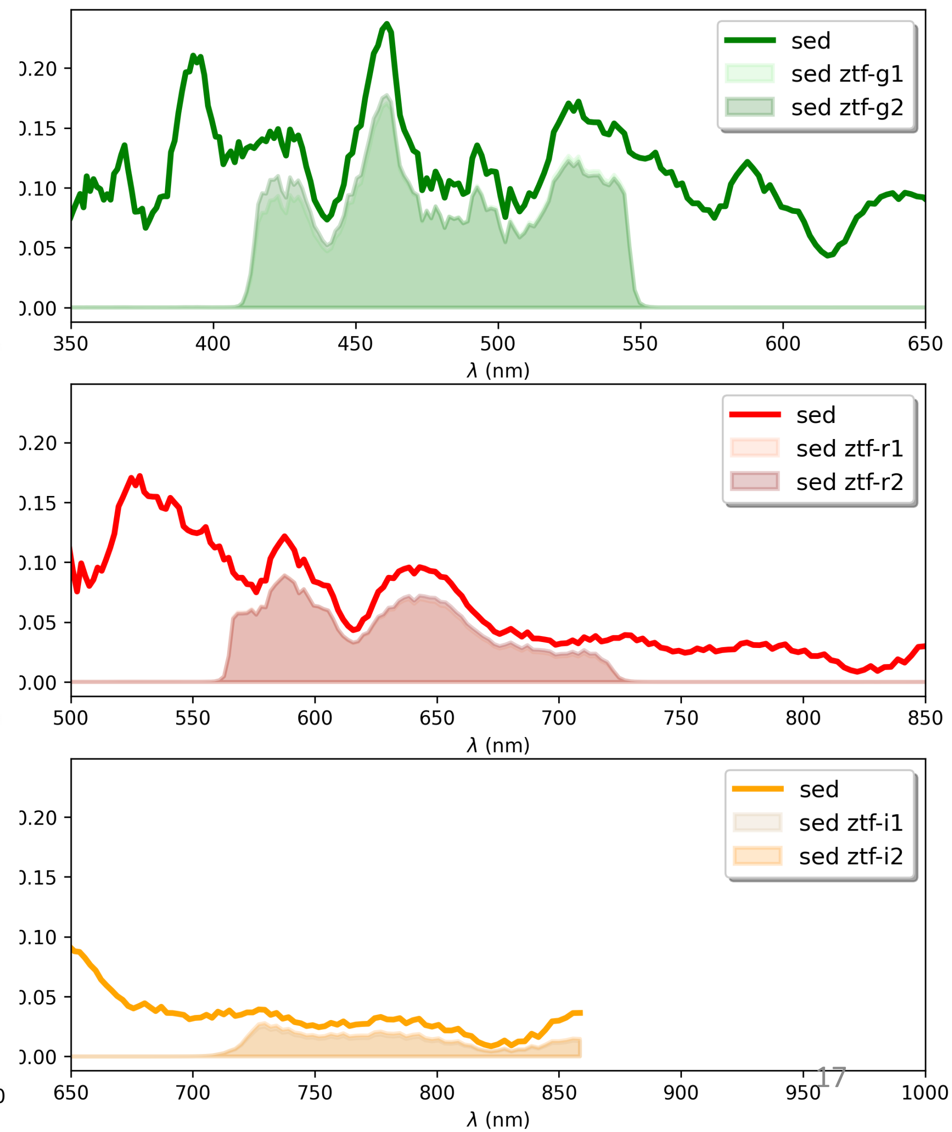


SEDs through ZTF

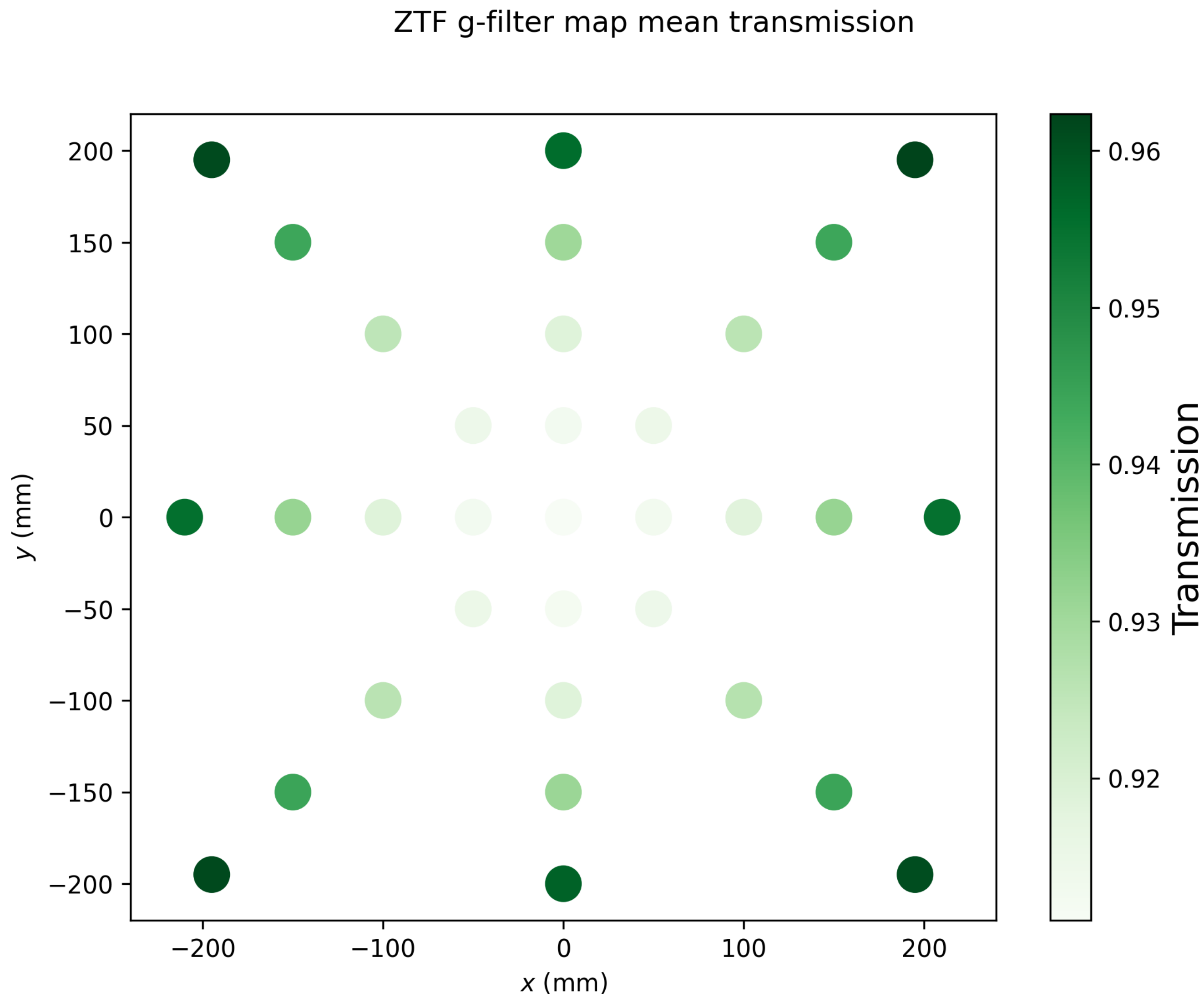
K2_-0.5_Giant.fits



Train_SN26_7.dat

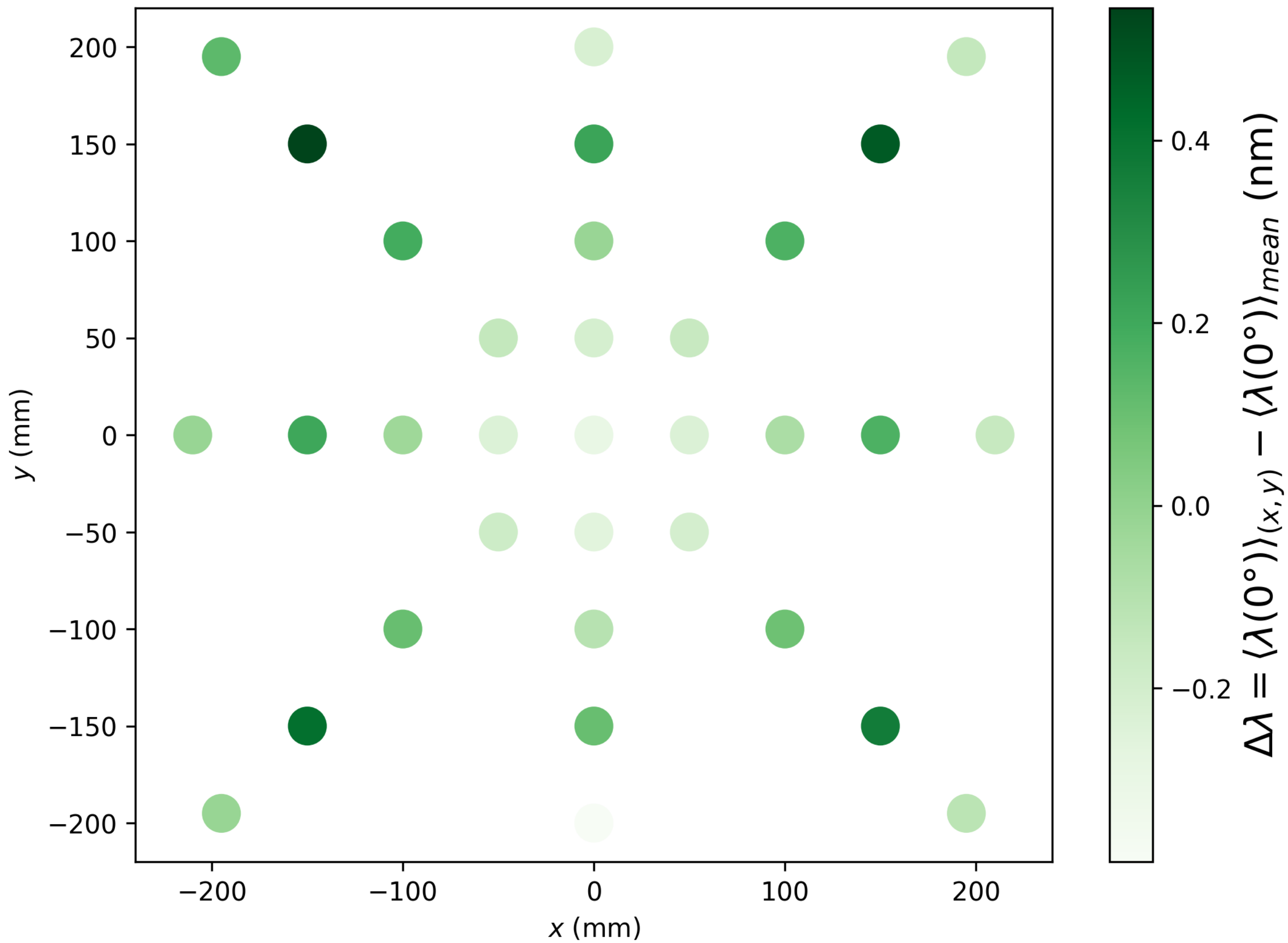


ZTF g-filter mean transmission at 0°



Mean value of filter transmission in the band-pass: $430 < \lambda < 530$ nm

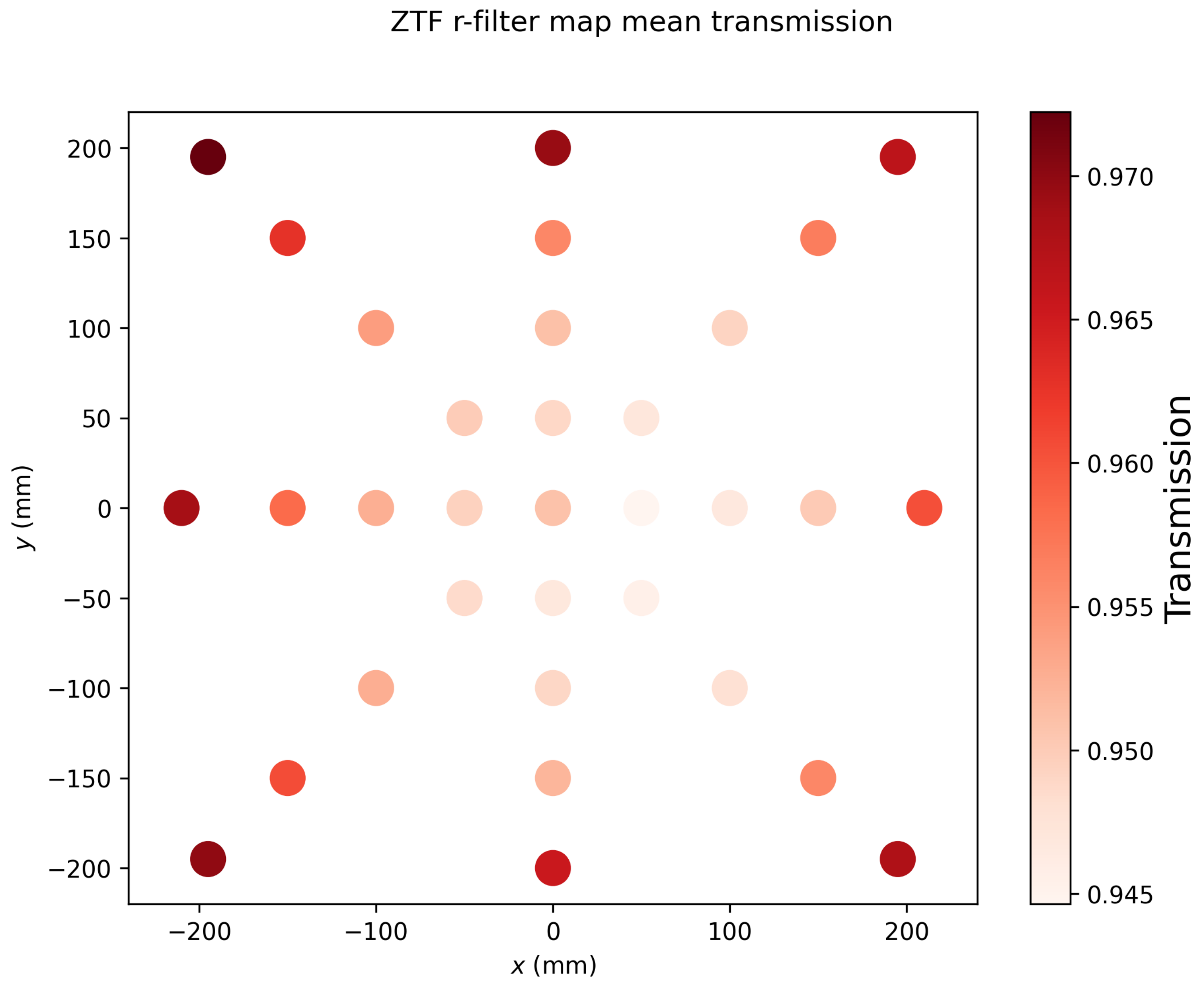
First-moment variation of g-filter measurements at 0°



First-moment of each filter point $\langle\lambda(0°)\rangle_{(x,y)}$ is compared to first-moment of mean transmission average over filter $\langle\lambda(0°)\rangle_{\text{mean}}$

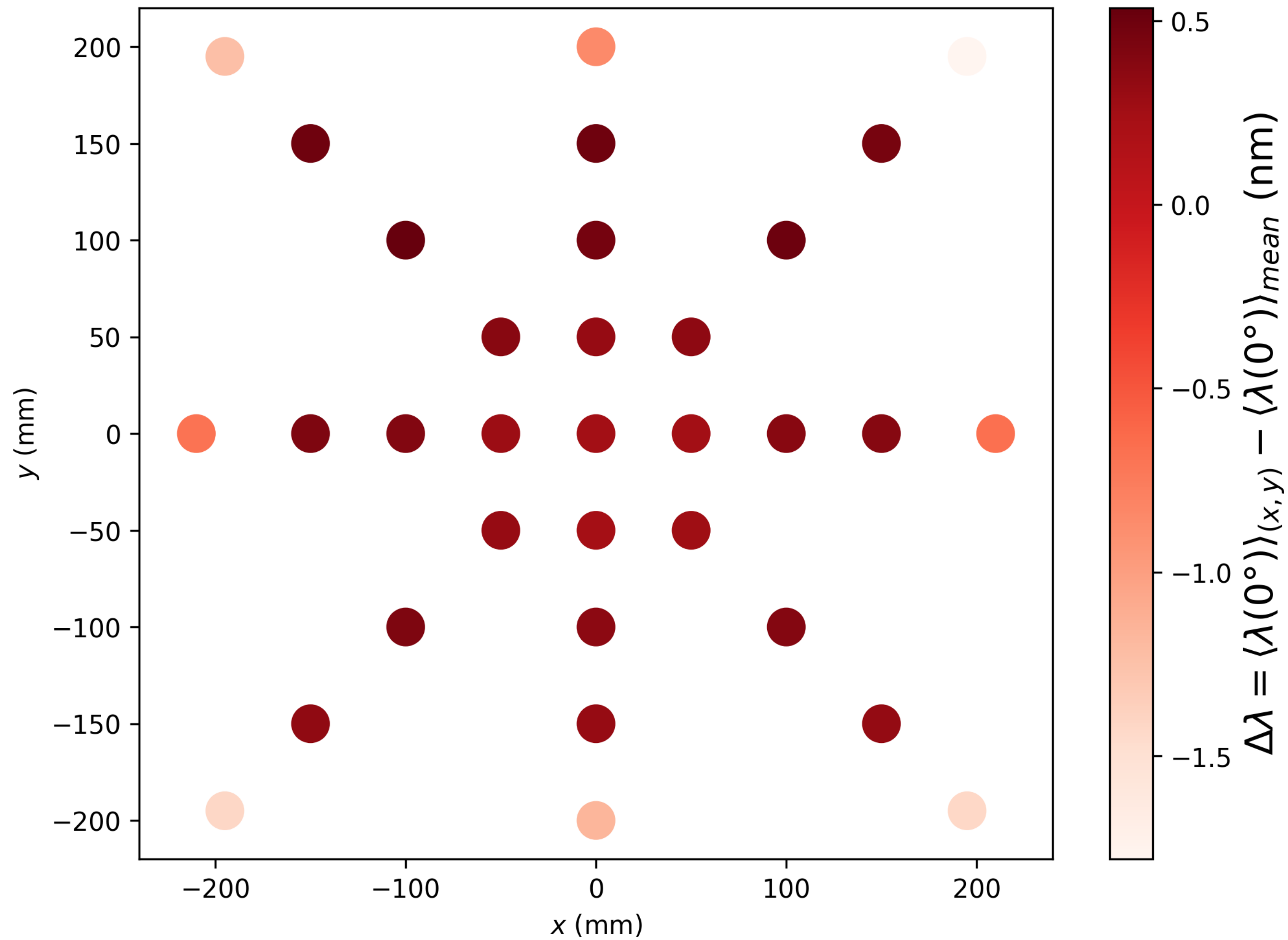
- intrinsic dispersion of the filter $\Delta\langle\lambda\rangle \approx 0.94\ \text{nm}$

ZTF r-filter mean transmission at 0°



Mean value of filter transmission in the band-pass: $580 < \lambda < 700$ nm

First-moment variation of r-filter measurements at 0°



First-moment of each filter point $\langle\lambda(0°)\rangle_{(x,y)}$ is compared to first-moment of mean transmission average over filter $\langle\lambda(0°)\rangle_{\text{mean}}$

- intrinsic dispersion of the filter $\Delta\langle\lambda\rangle \approx 2.32$ nm