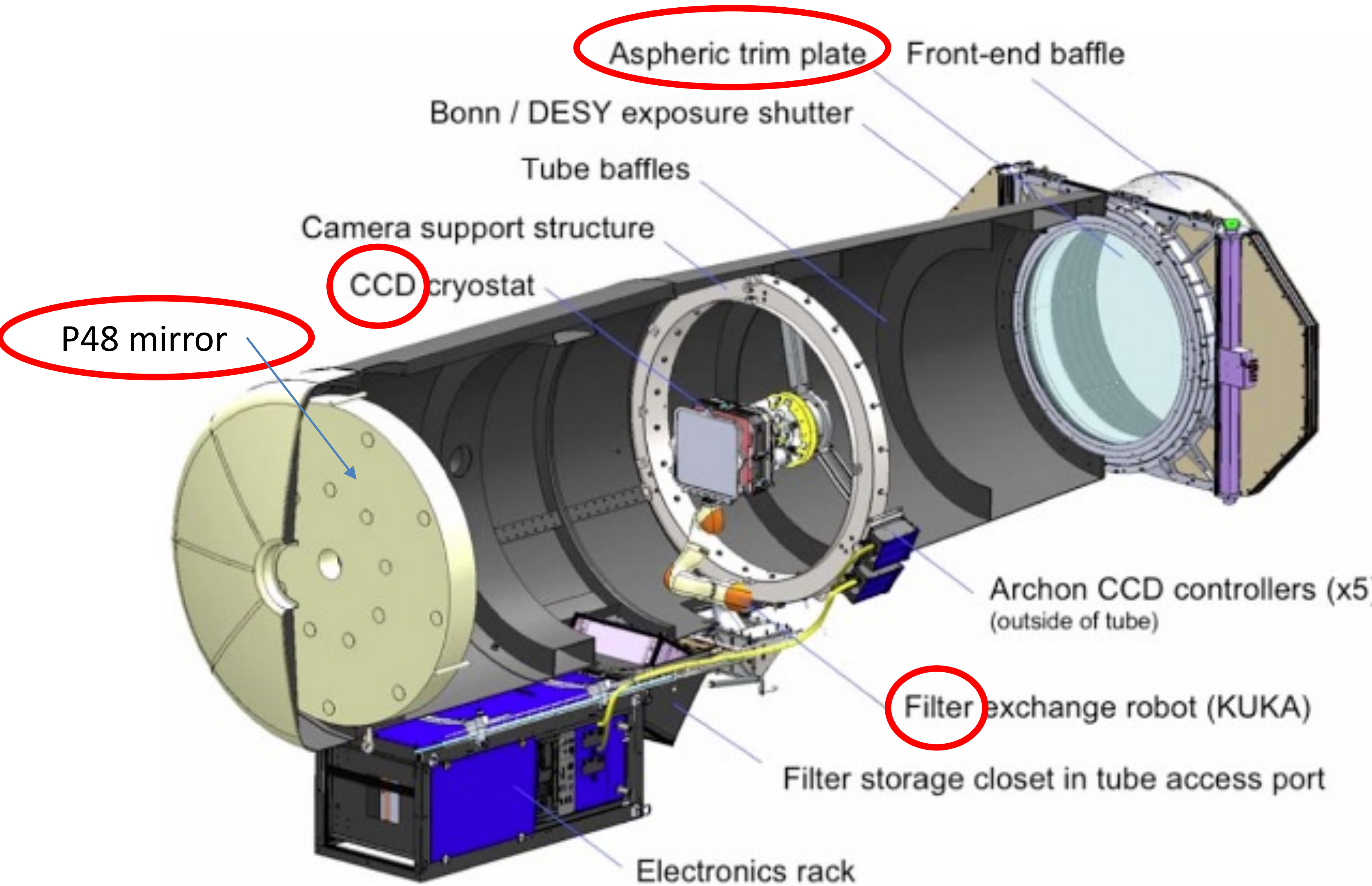
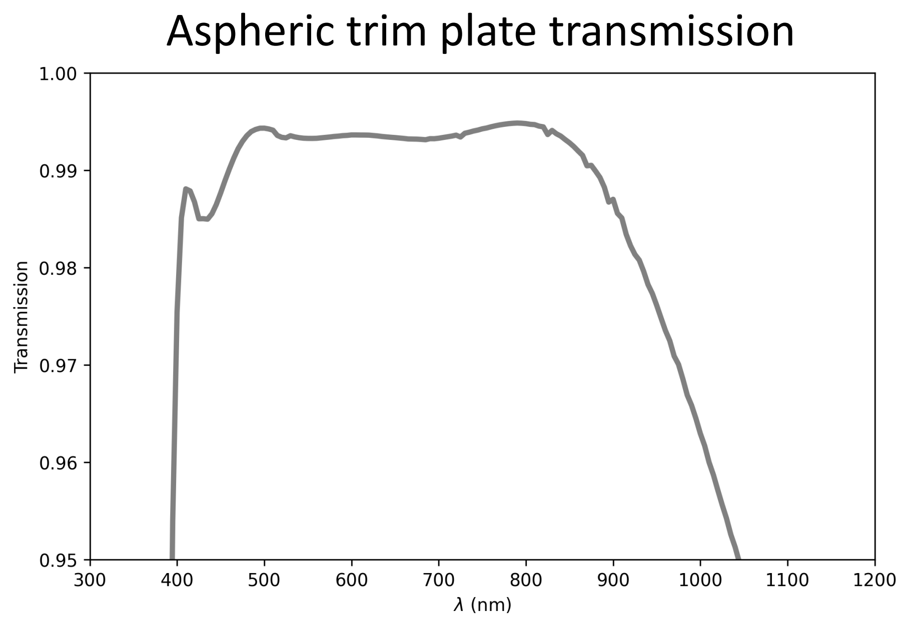
ZTF passbands

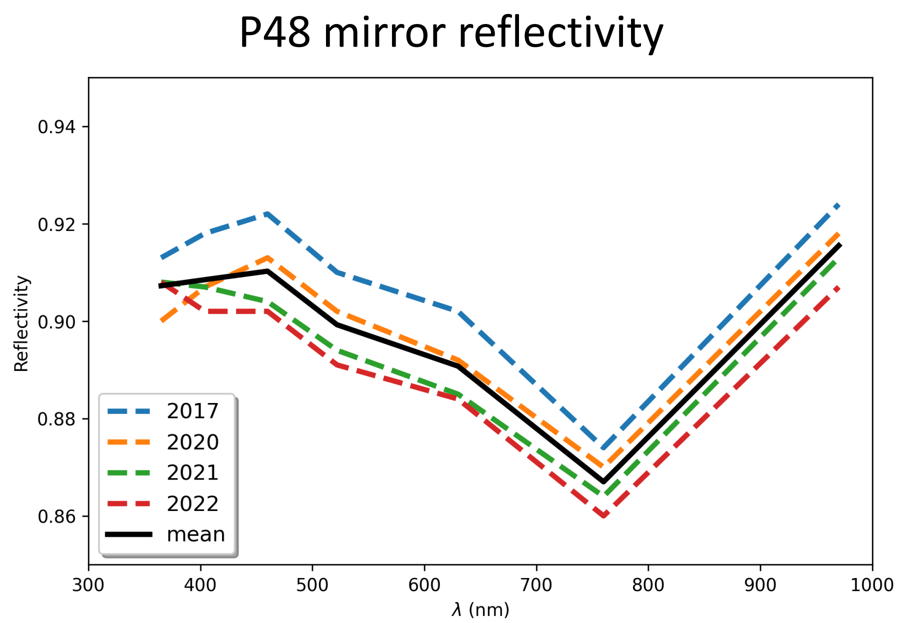
Philippe Rosnet, Chloé Barjou-Delayre
and Nicolas Regnault

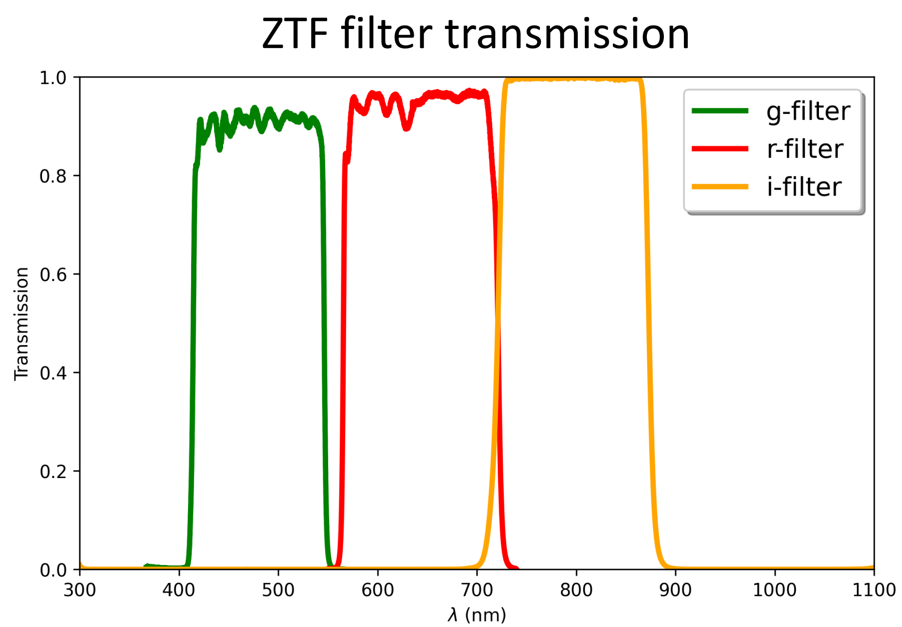
ZTF instrument: Schmidt-telescope

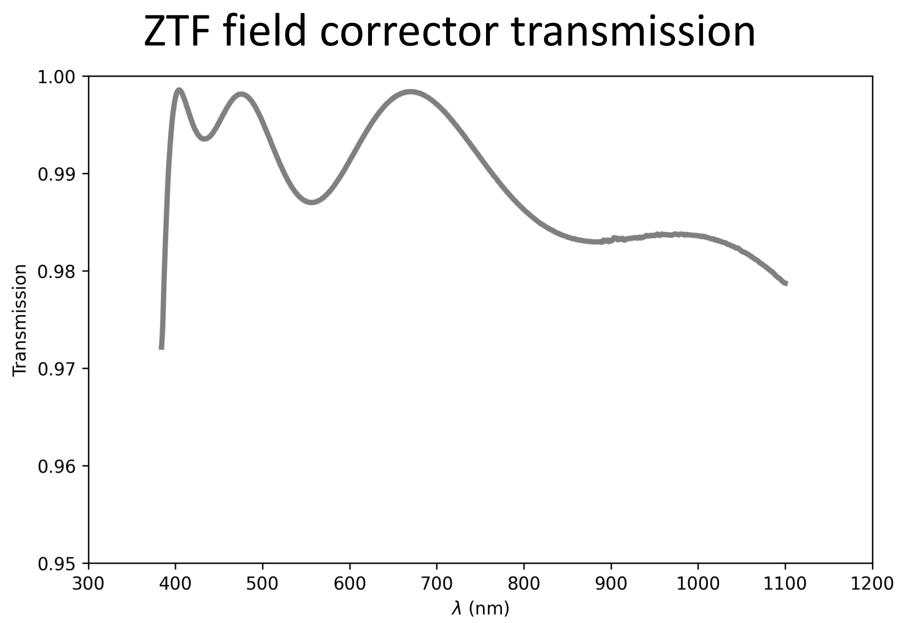


Instrument elements (1)



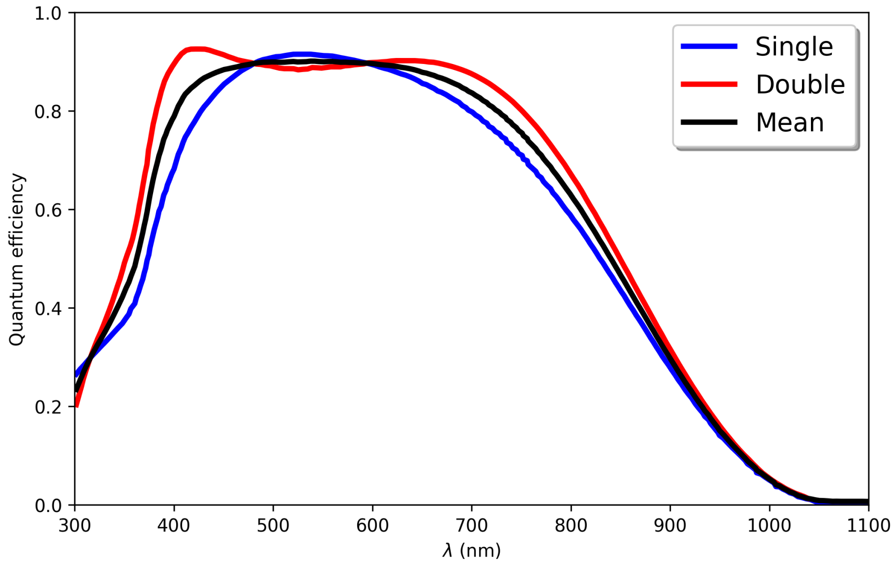


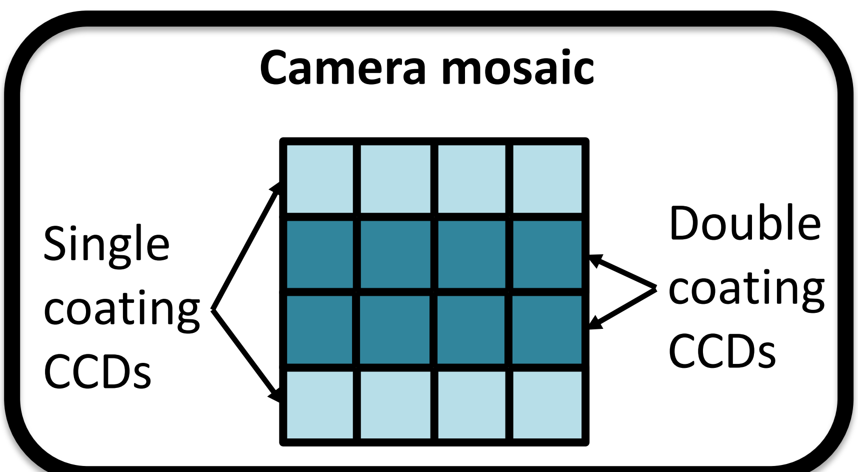




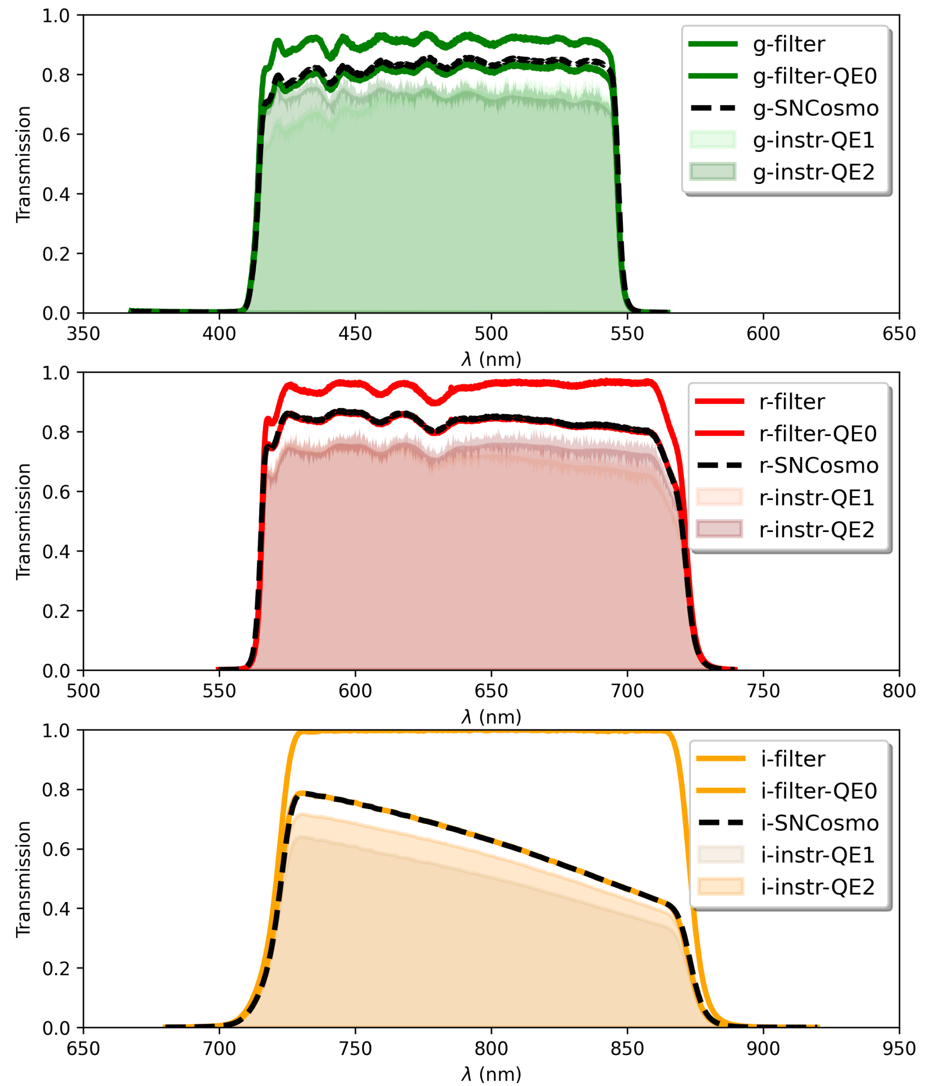
Instrument elements (2)

ZTF CCD quantum efficiency (QE)

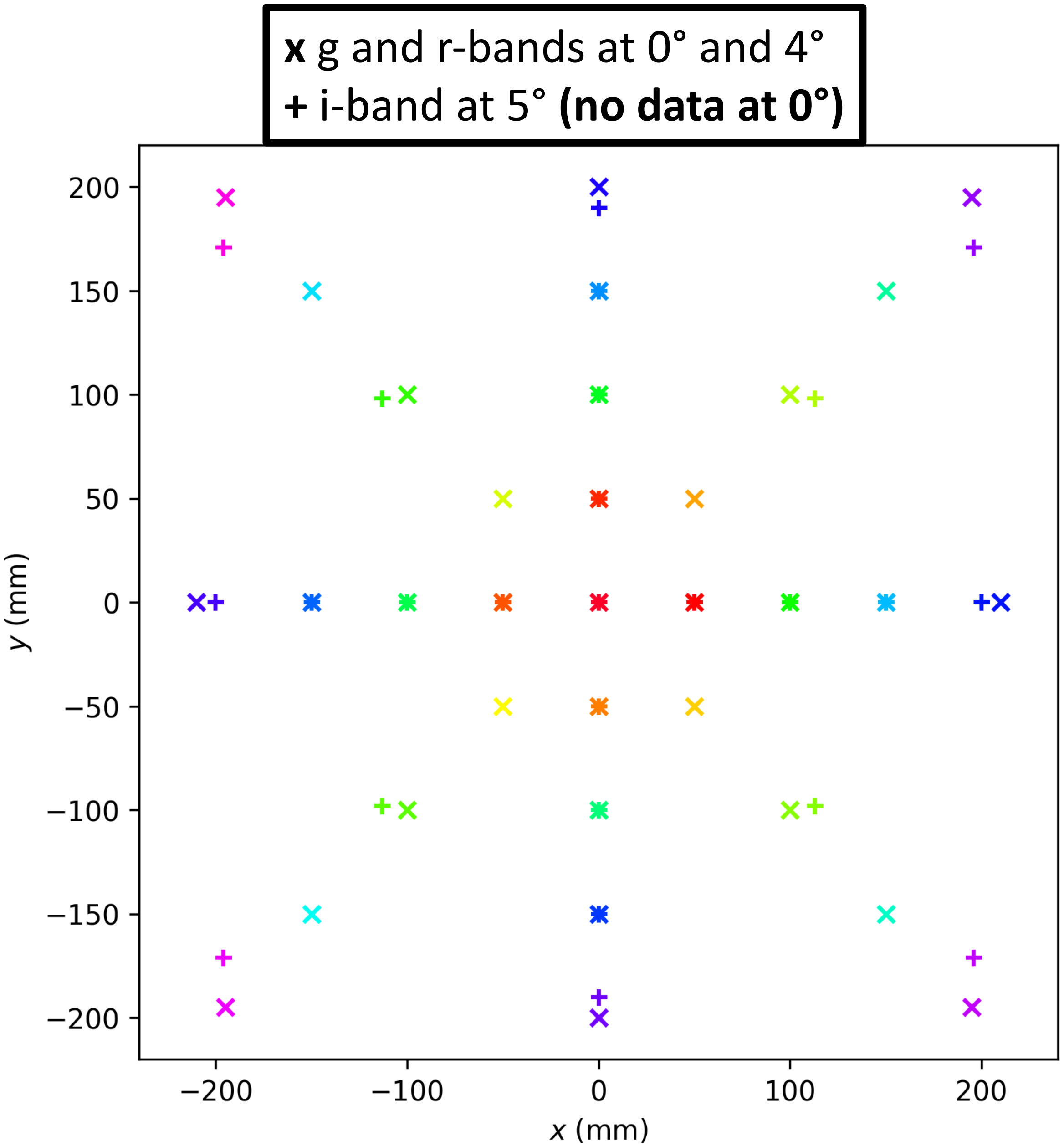




Full instrument model compared to SNCosmo inputs



ZTF filter characterization (Caltech)



Filter transmission dependency

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

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

- Determination of the **effective refracting index of filters**: shift of 0° data according to formula above to match 4° data by using as reference point the centre of the filter

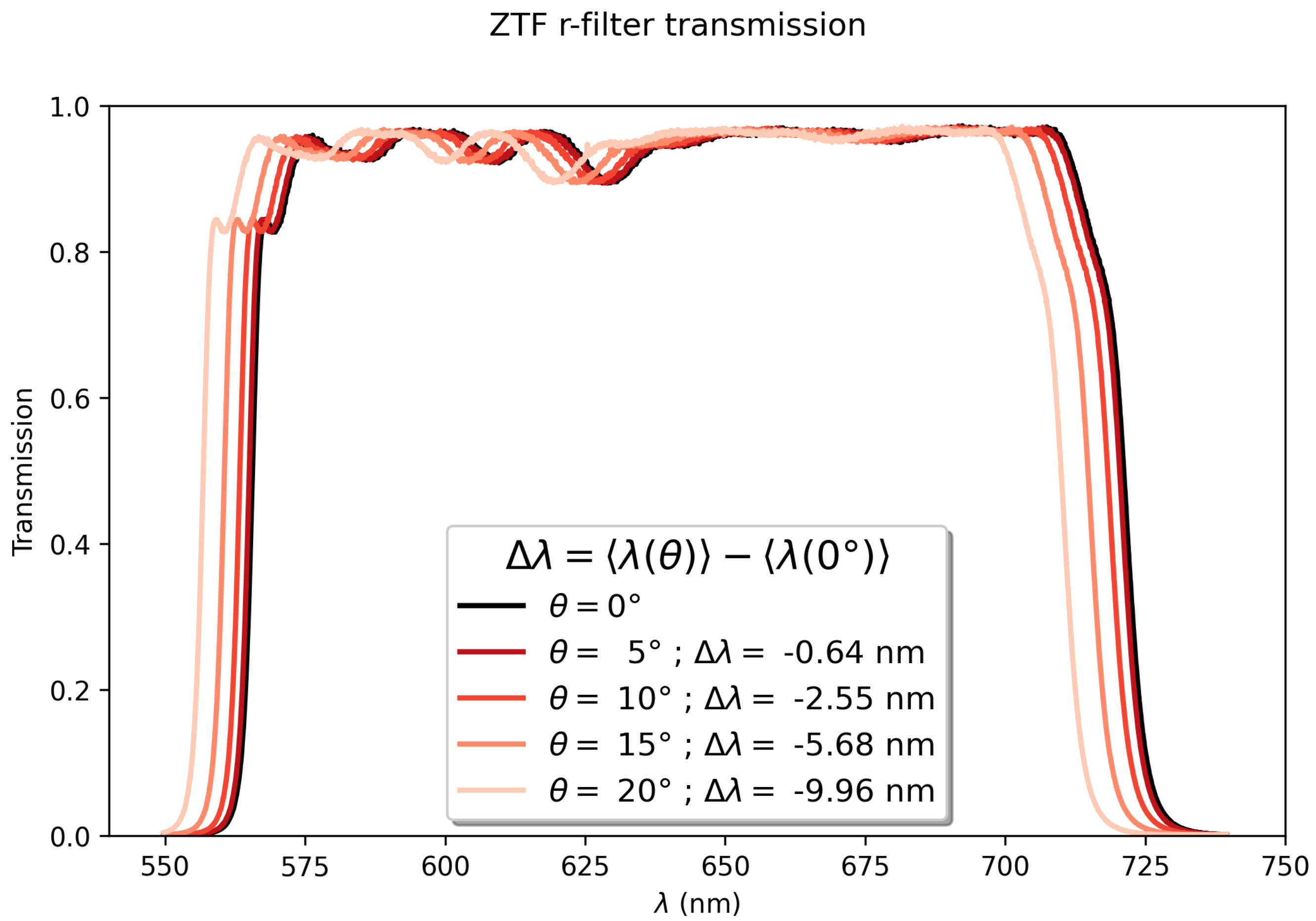
Instrument	g-band	r-band	i-band
SDSS	1.70	1.80	1.60
ZTF	**1.85**	**1.95**	**1.75**

Estimations Extrapolation

- Quantification of the filter transmission shift by computing the **1st moment** = mean value of filter transmission

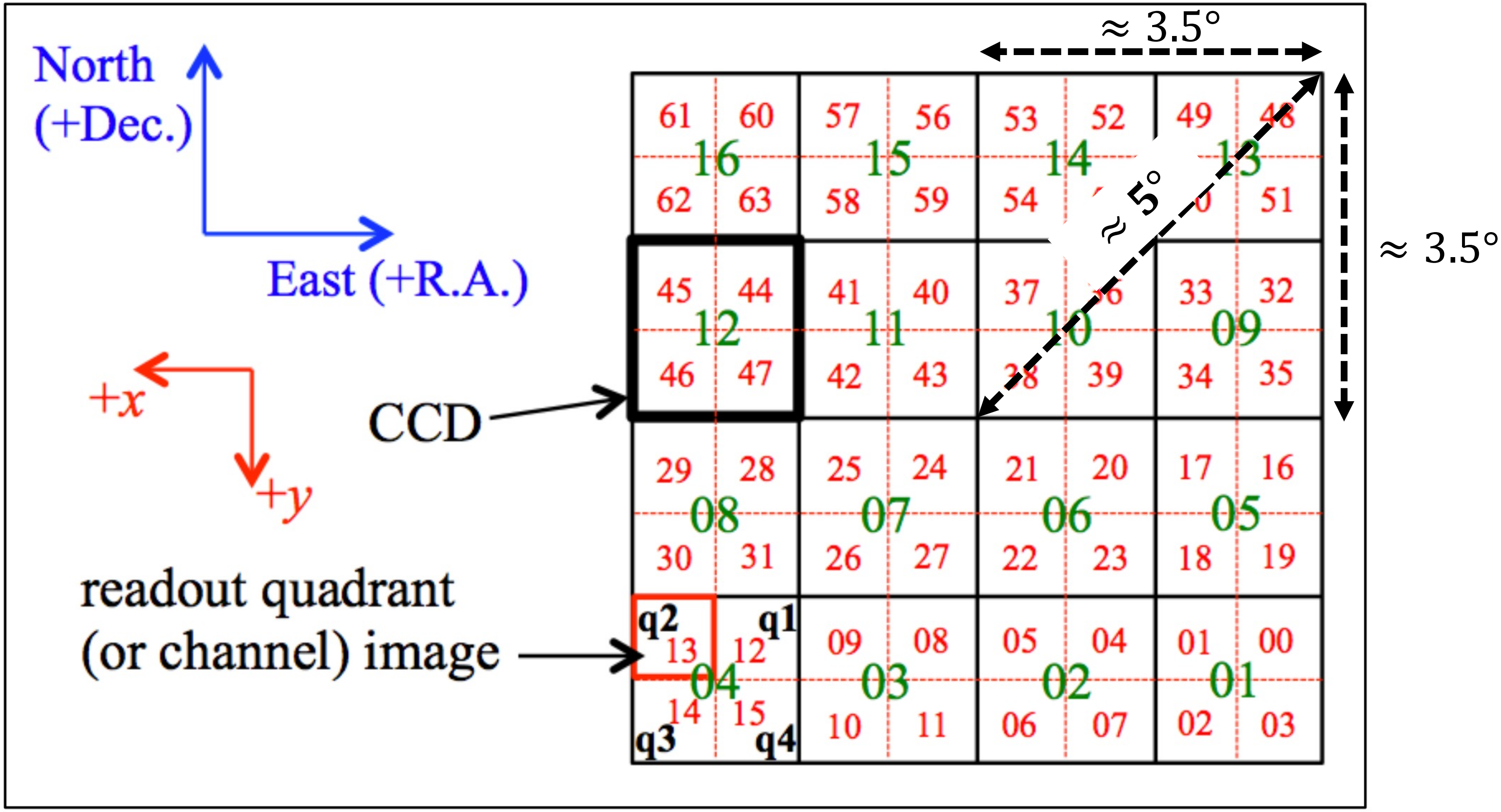
$$\langle\lambda\rangle = \frac{\int \lambda T(\lambda)\, d\lambda}{\int T(\lambda)\, d\lambda}$$

ZTF r-filter shift versus incident light angle



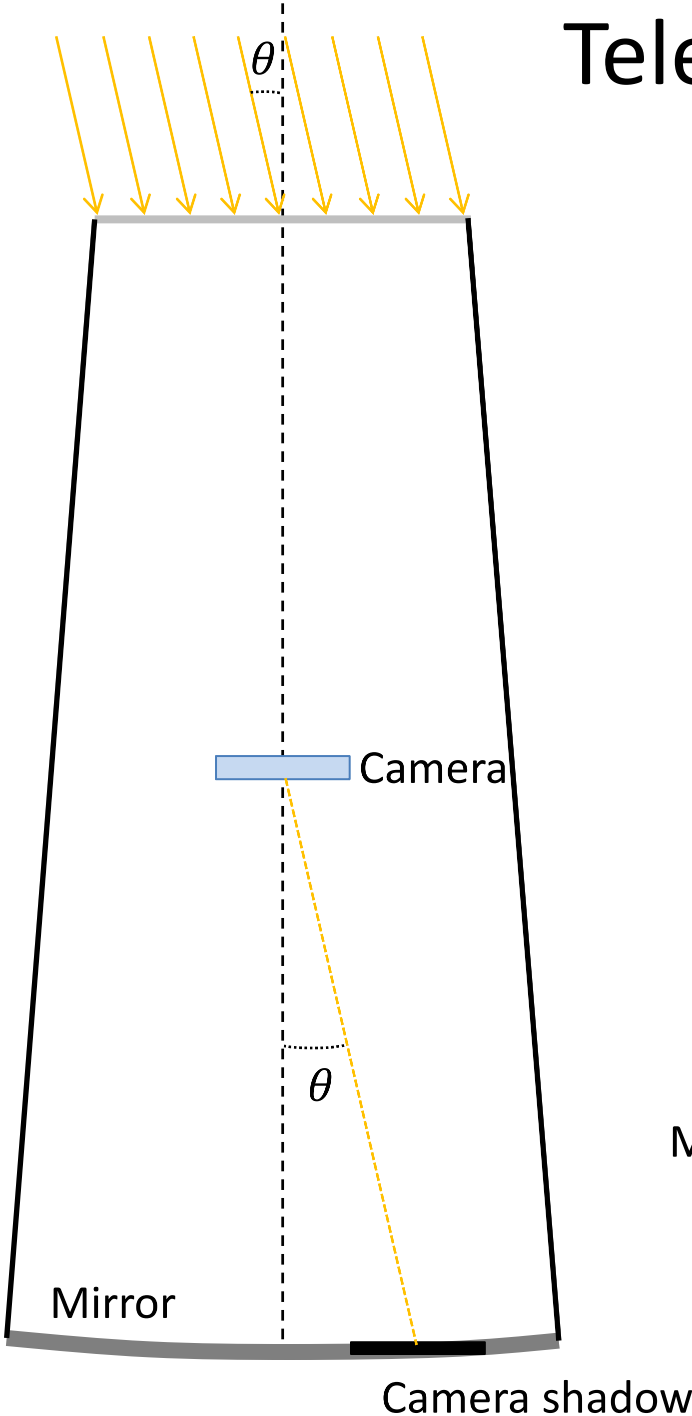
- The estimated refracting index $n_r \approx 1.95$ allows to predict the filter transmission at any light incident angle
- Question: **What is the real light incident angle on ZTF camera?**

ZTF camera



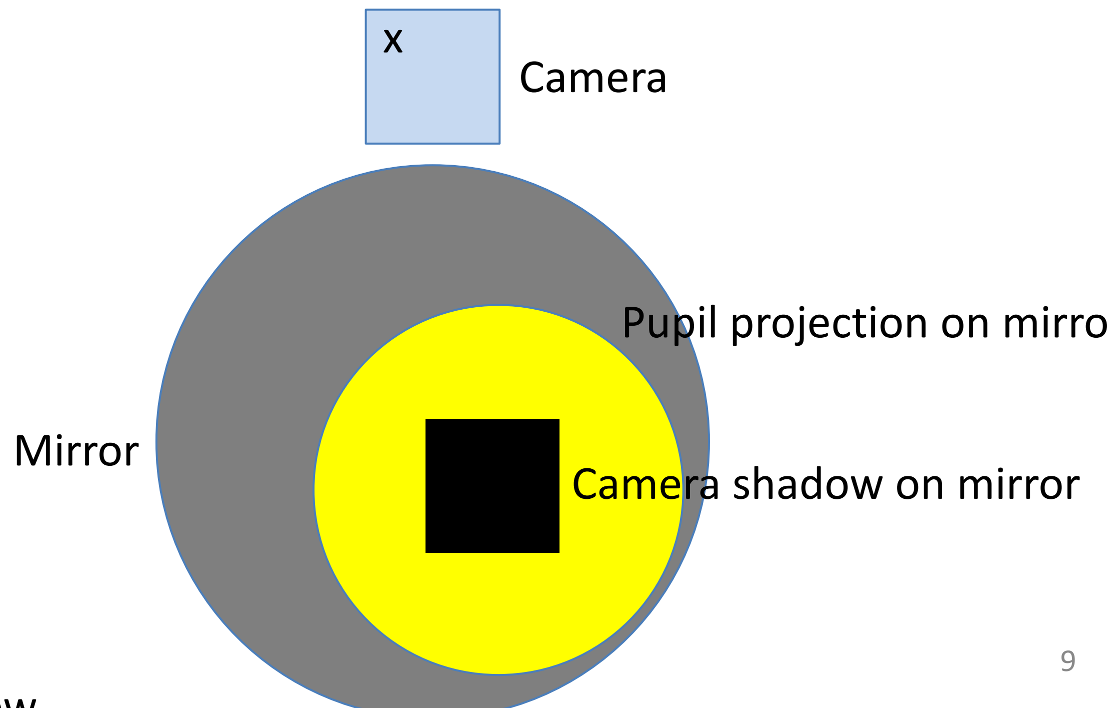
- Pixel size = 15 μm ≡ 1.01’’
- CCD = 6144 col × 6160 row ≡ 1.724° R.A. × 1.728° Dec.

Telescope model

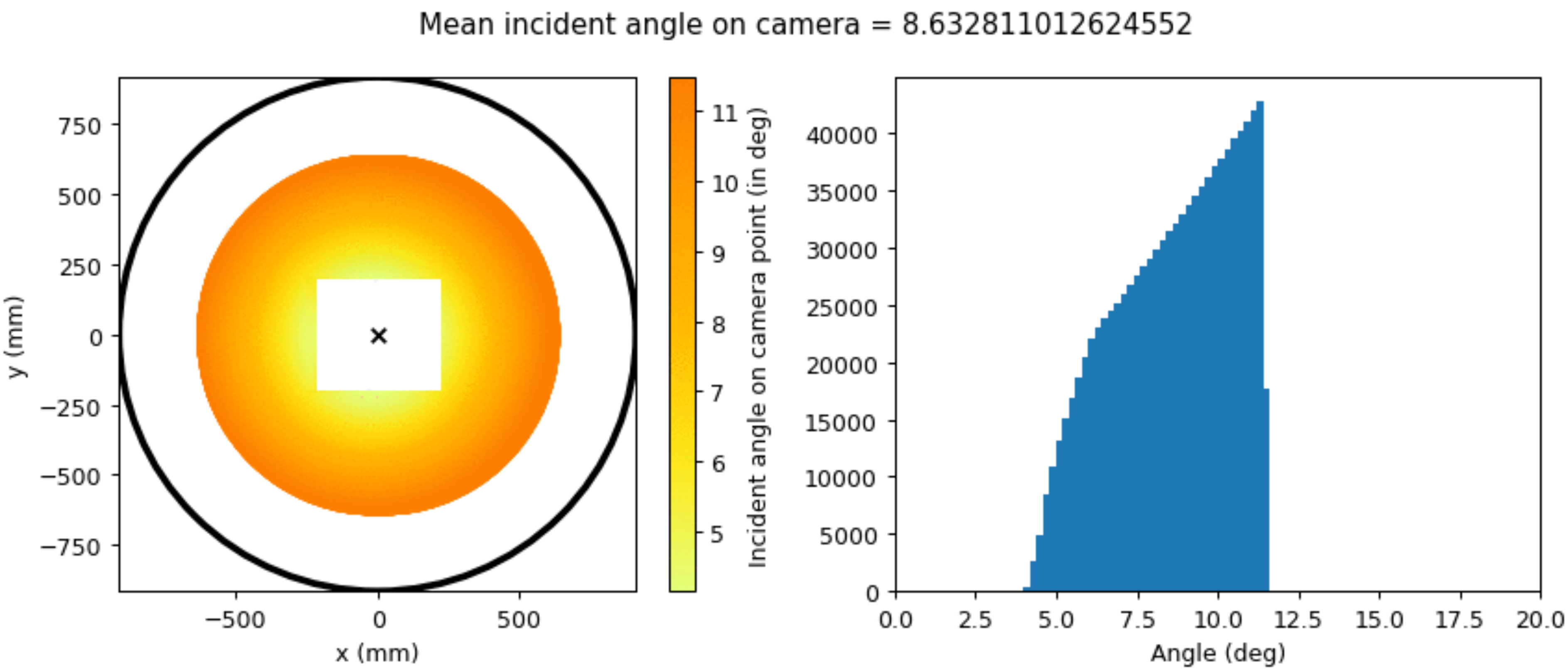


- Position (x) on camera correspond to light-rays from sky with incident angle θ

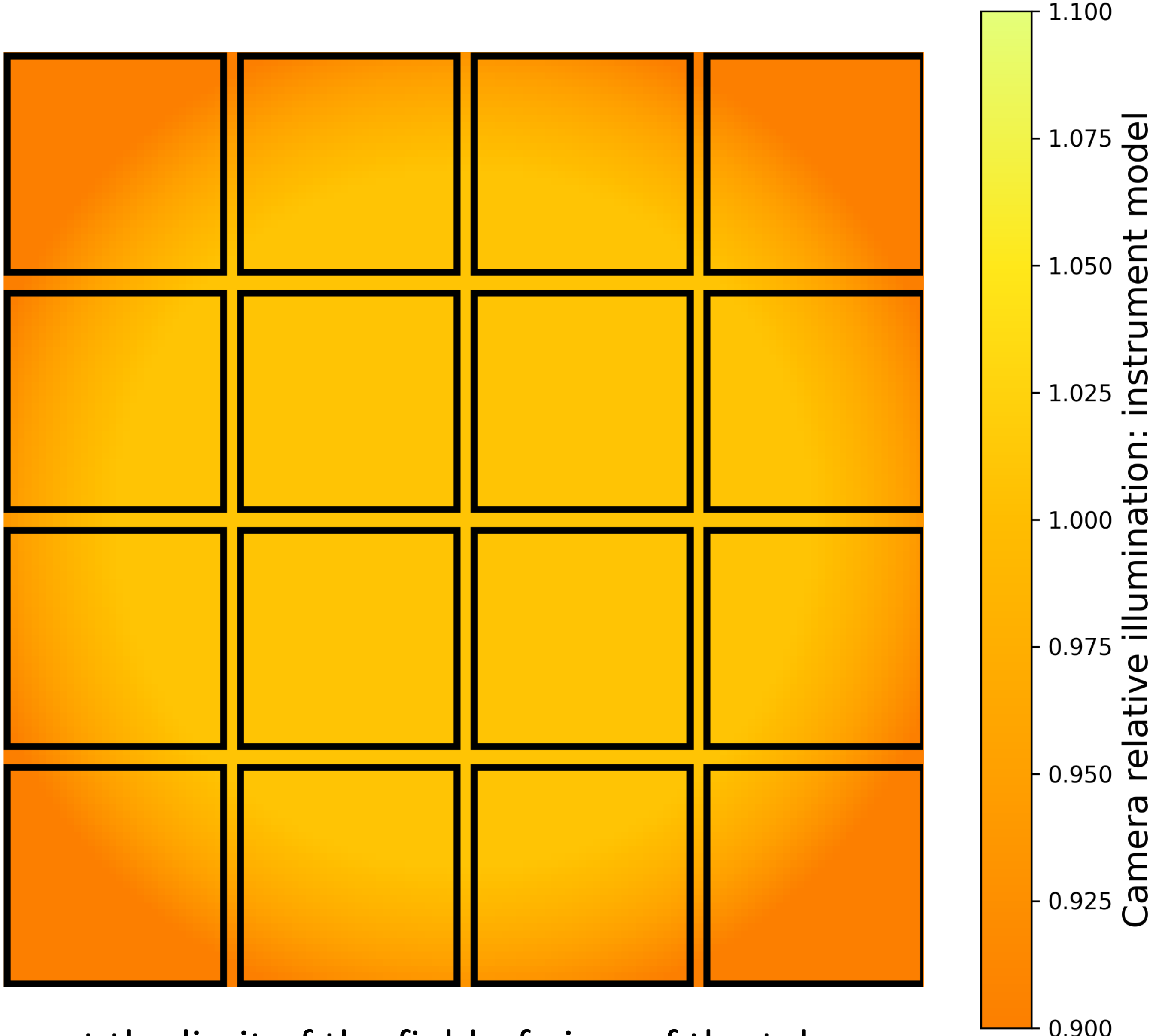
- <u>Hypothesis</u>: projection of pupil and camera on mirror according to incident angle θ (not realistic on scheme: $\theta_{max} \approx 5°$)



Model result versus incident angle

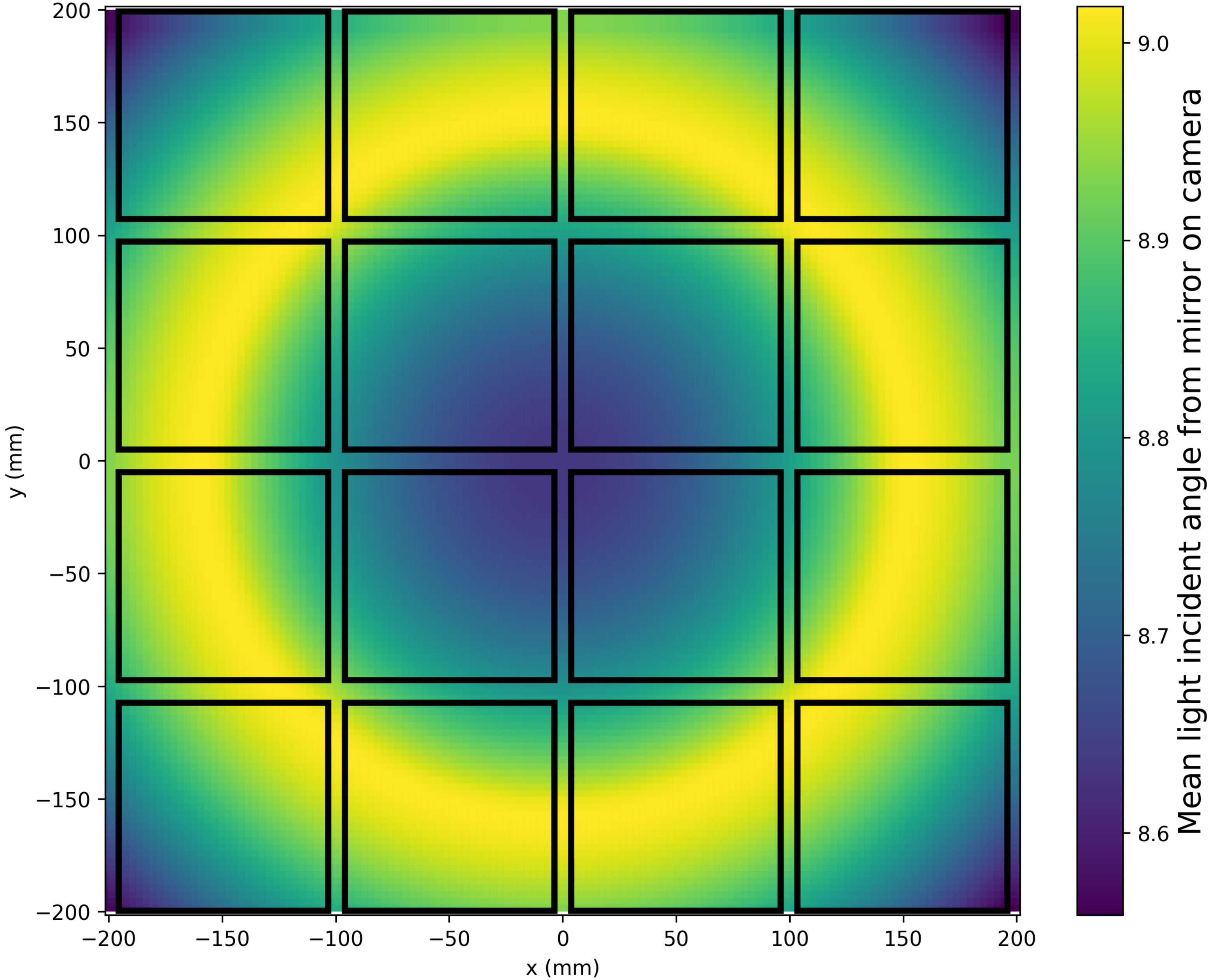


Model results: focal plane relative illumination

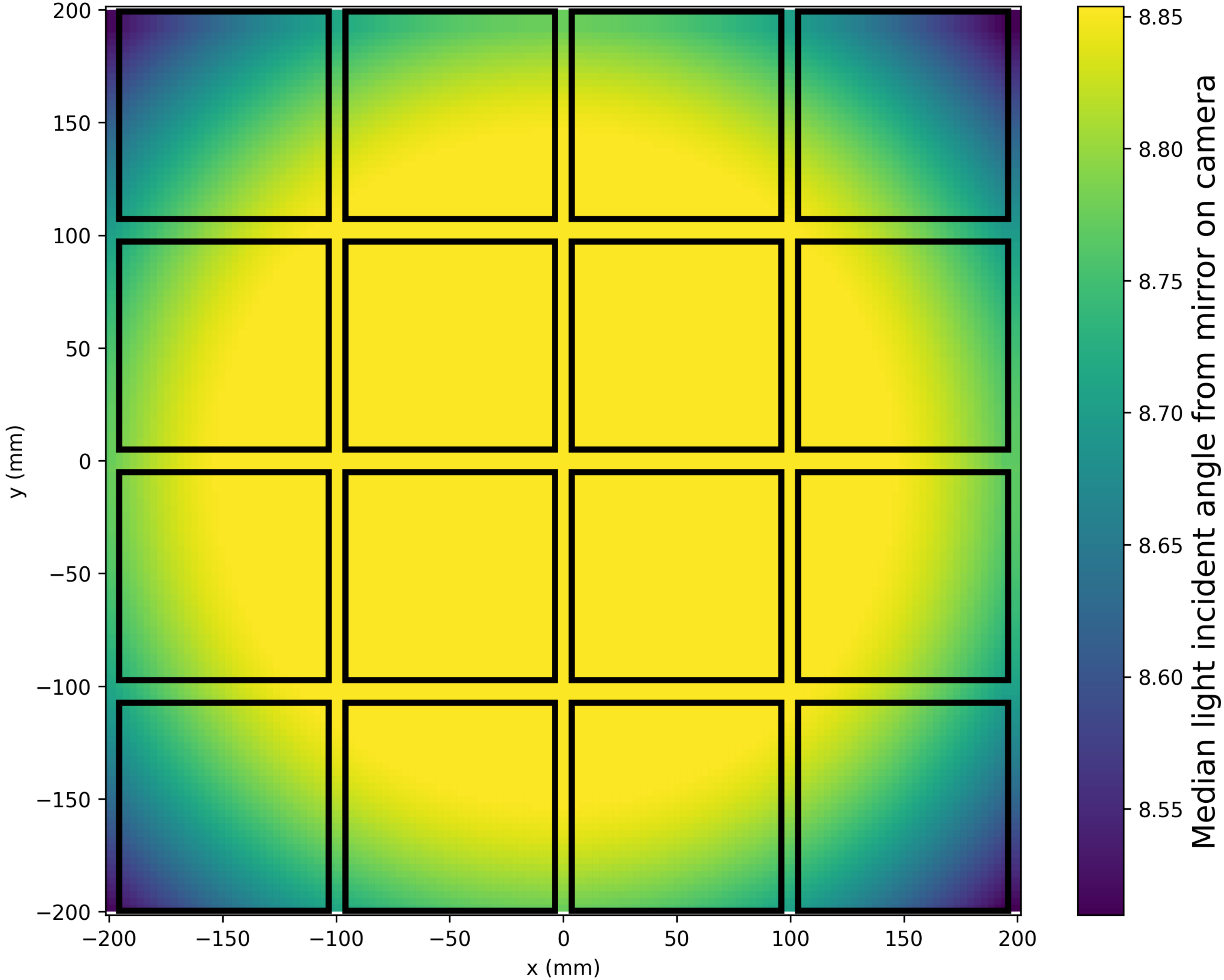


Camera at the limit of the field-of-view of the telescope

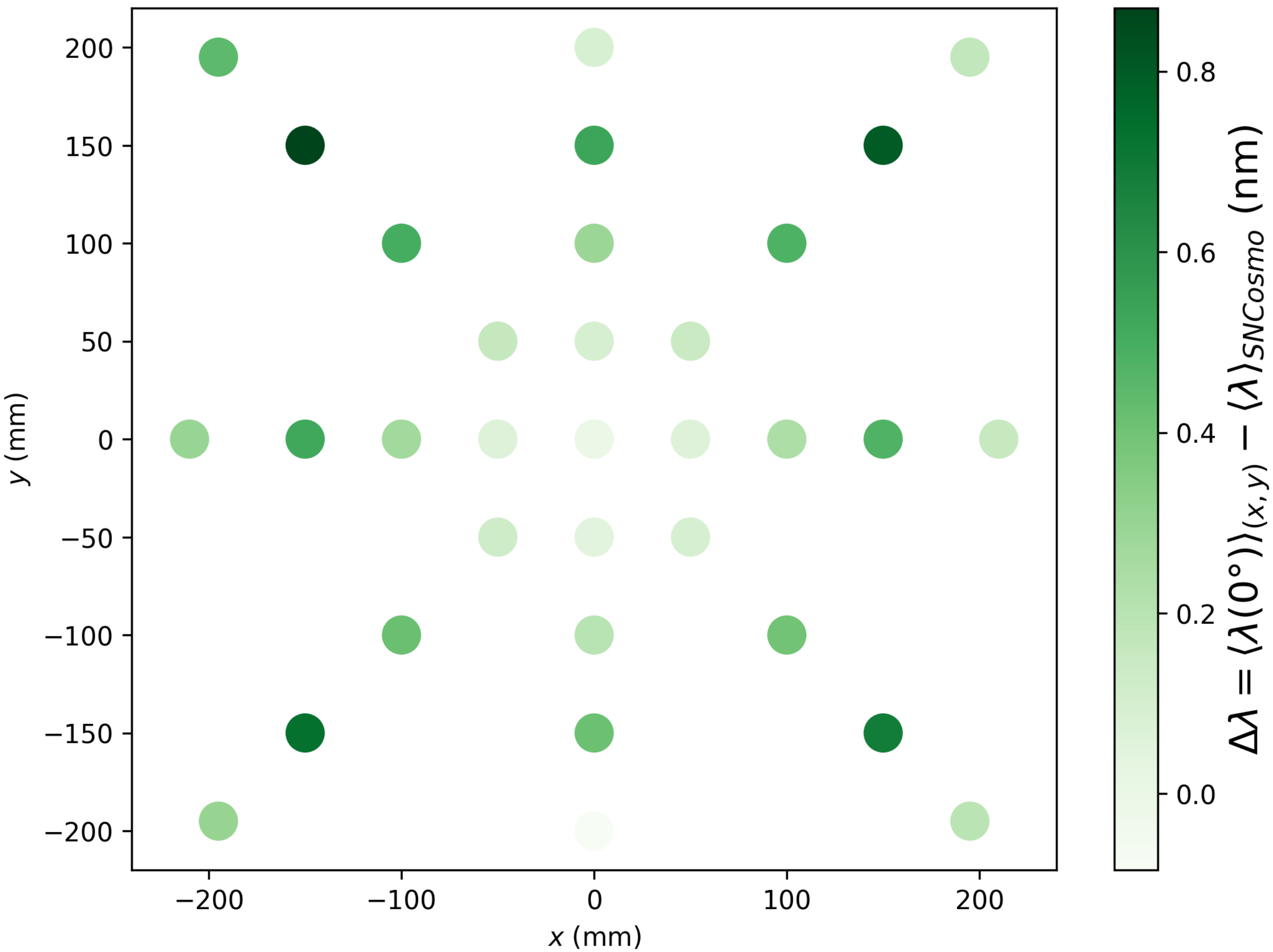
Model result: mean light incident angle on camera



Model result: median light incident angle on camera

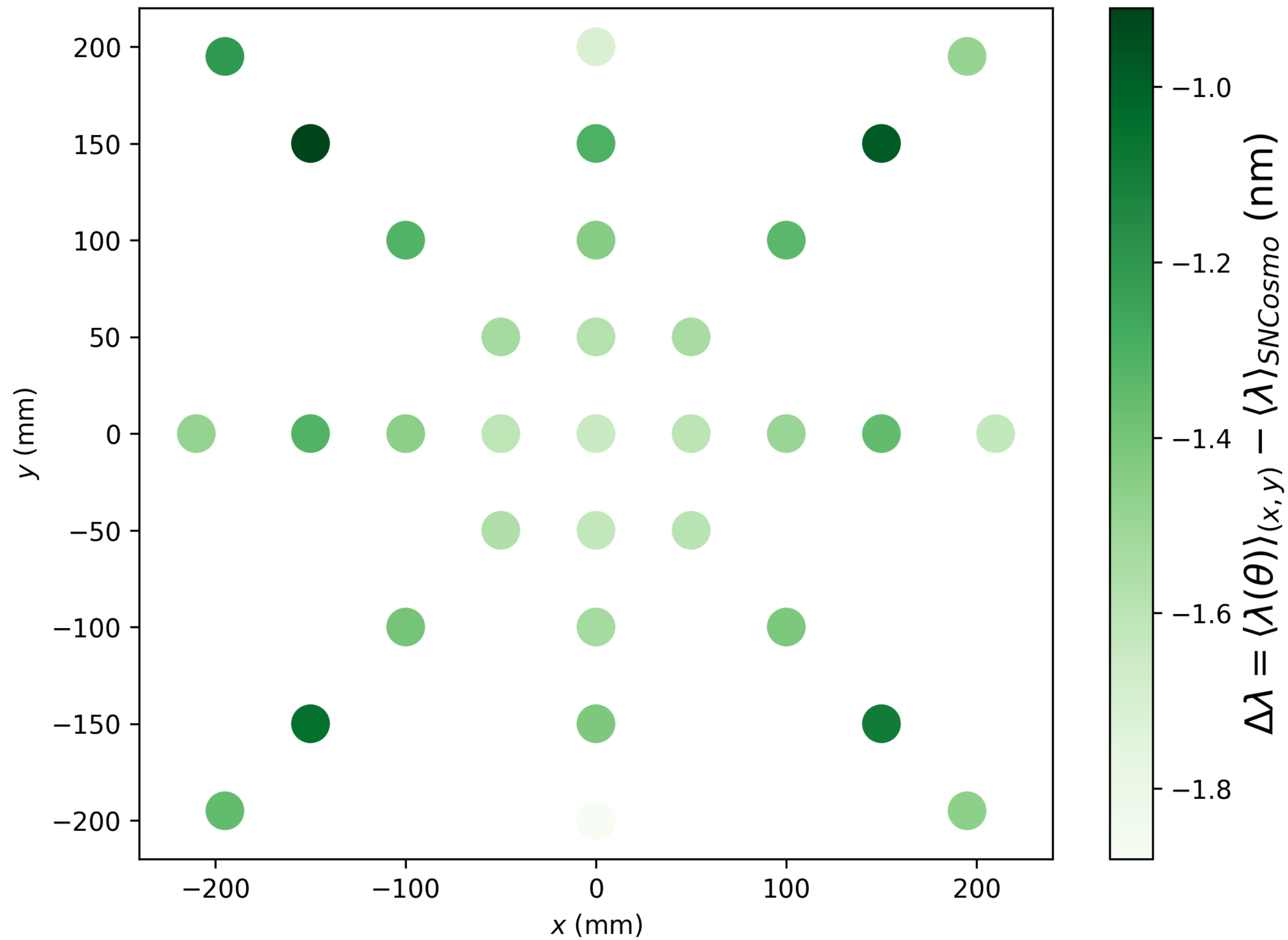


g-band: Caltech data



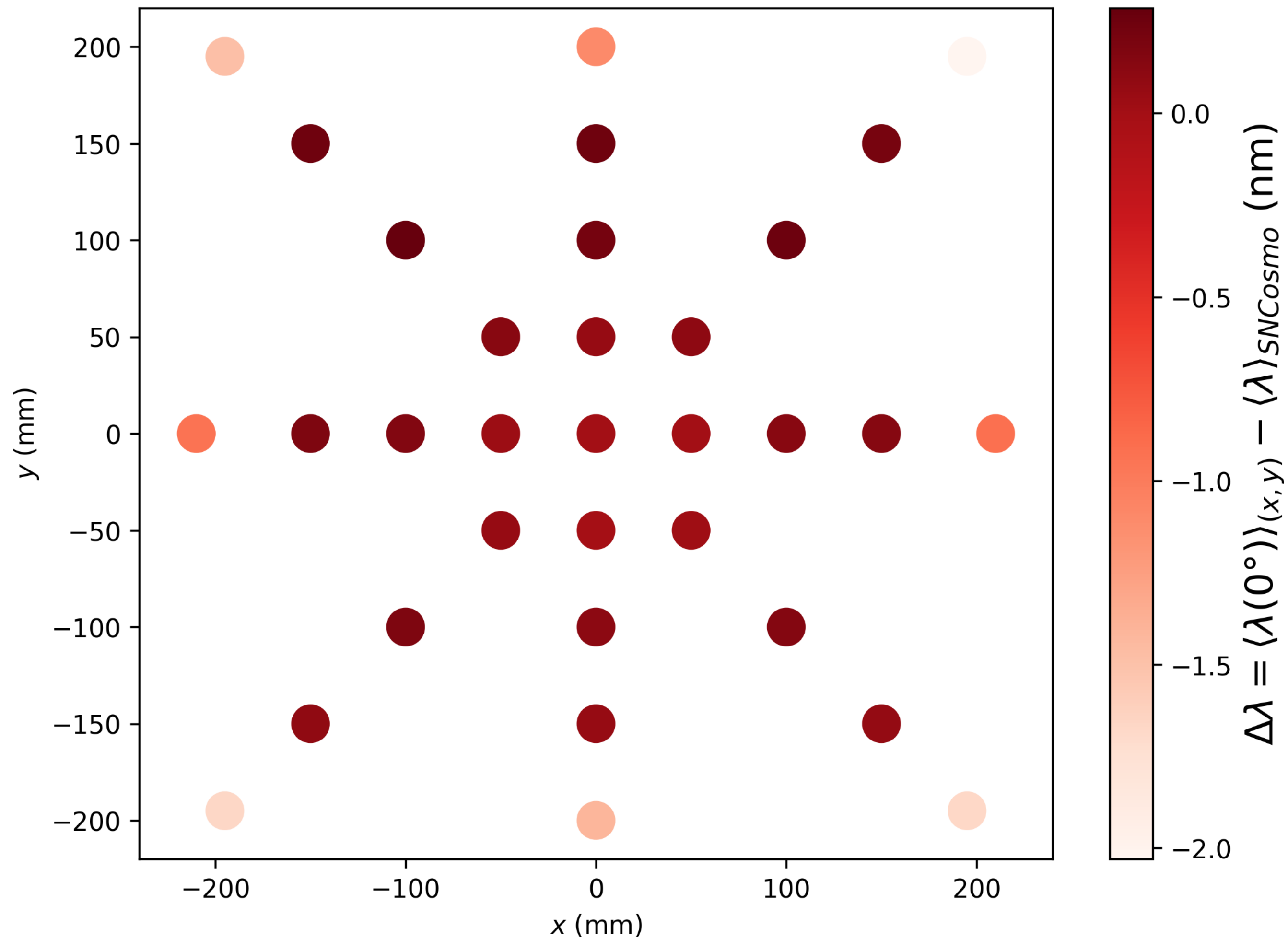
Filter transmission measured at 0° are compared to filter in SNCosmo

g-band: synthetic filter



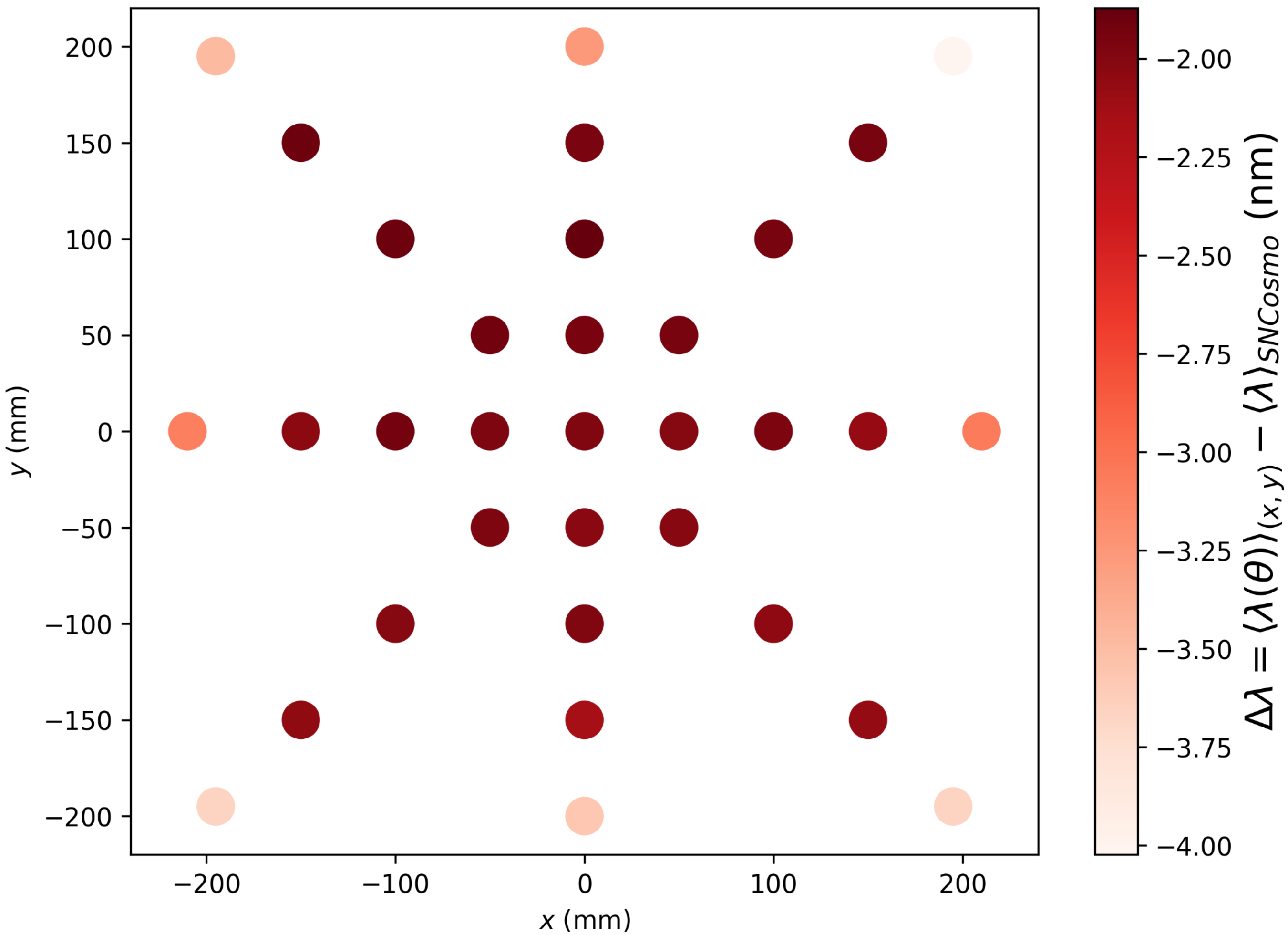
- **Synthetic filters compared to filter in SNCosmo**
- **First-moment mean shift = -1.74 nm**

r-band: Caltech data



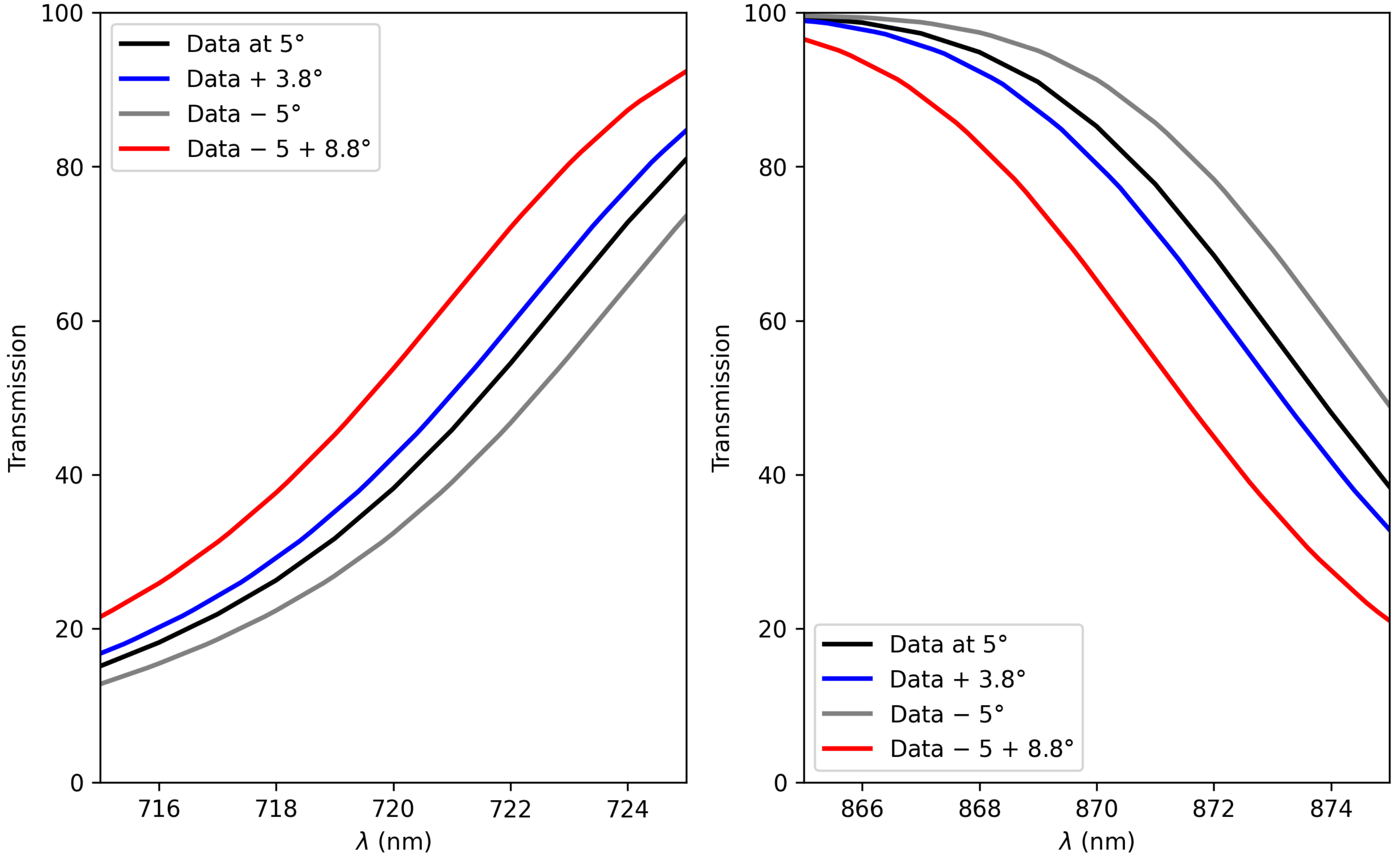
Filter transmission measured at 0° are compared to filter in SNCosmo

r-band: synthetic filter



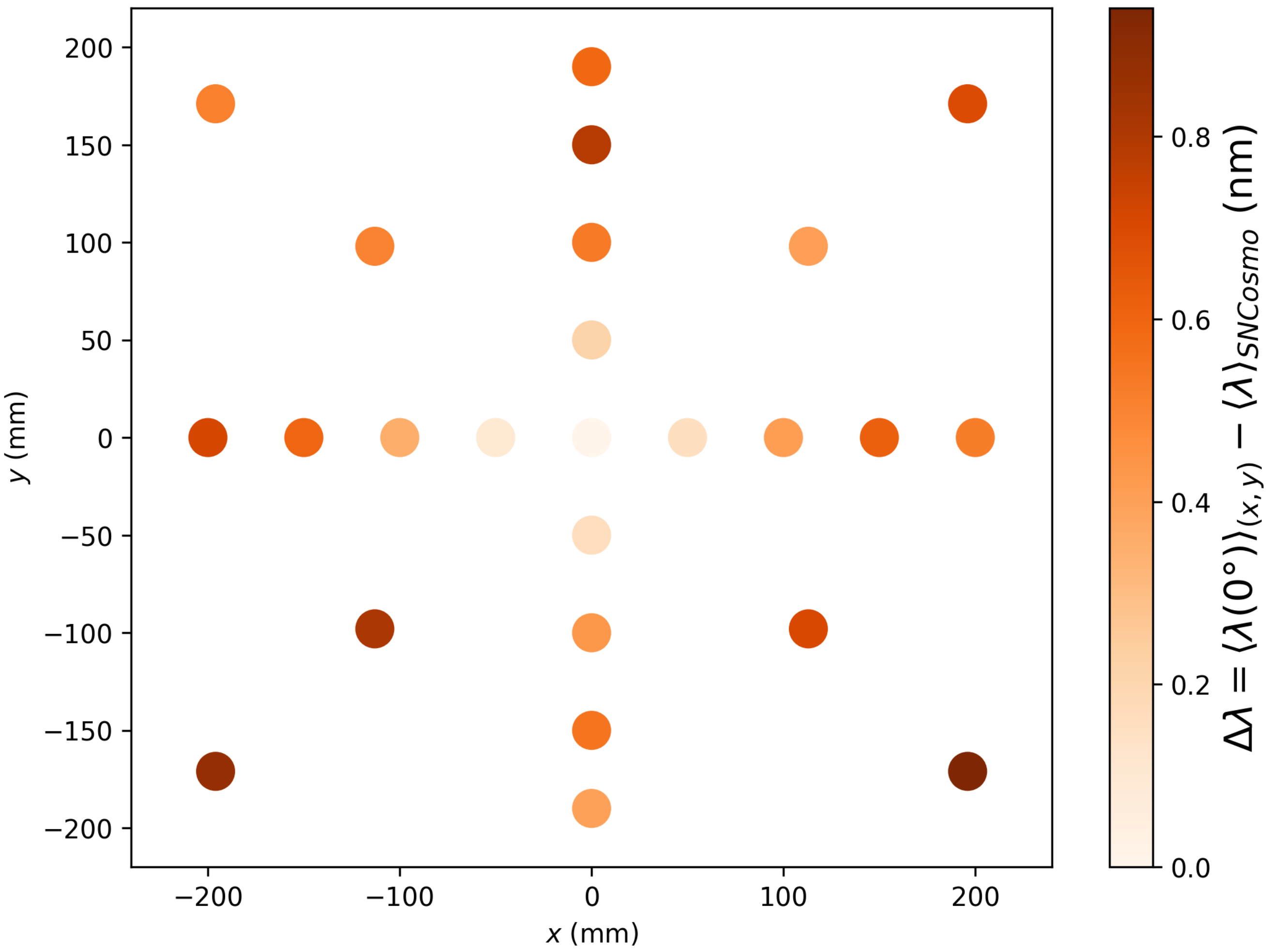
- **Synthetic filters compared to filter in SNCosmo**
- **First-moment mean shift = -2.10 nm**

ZTF i-filter: no measurement at 0°



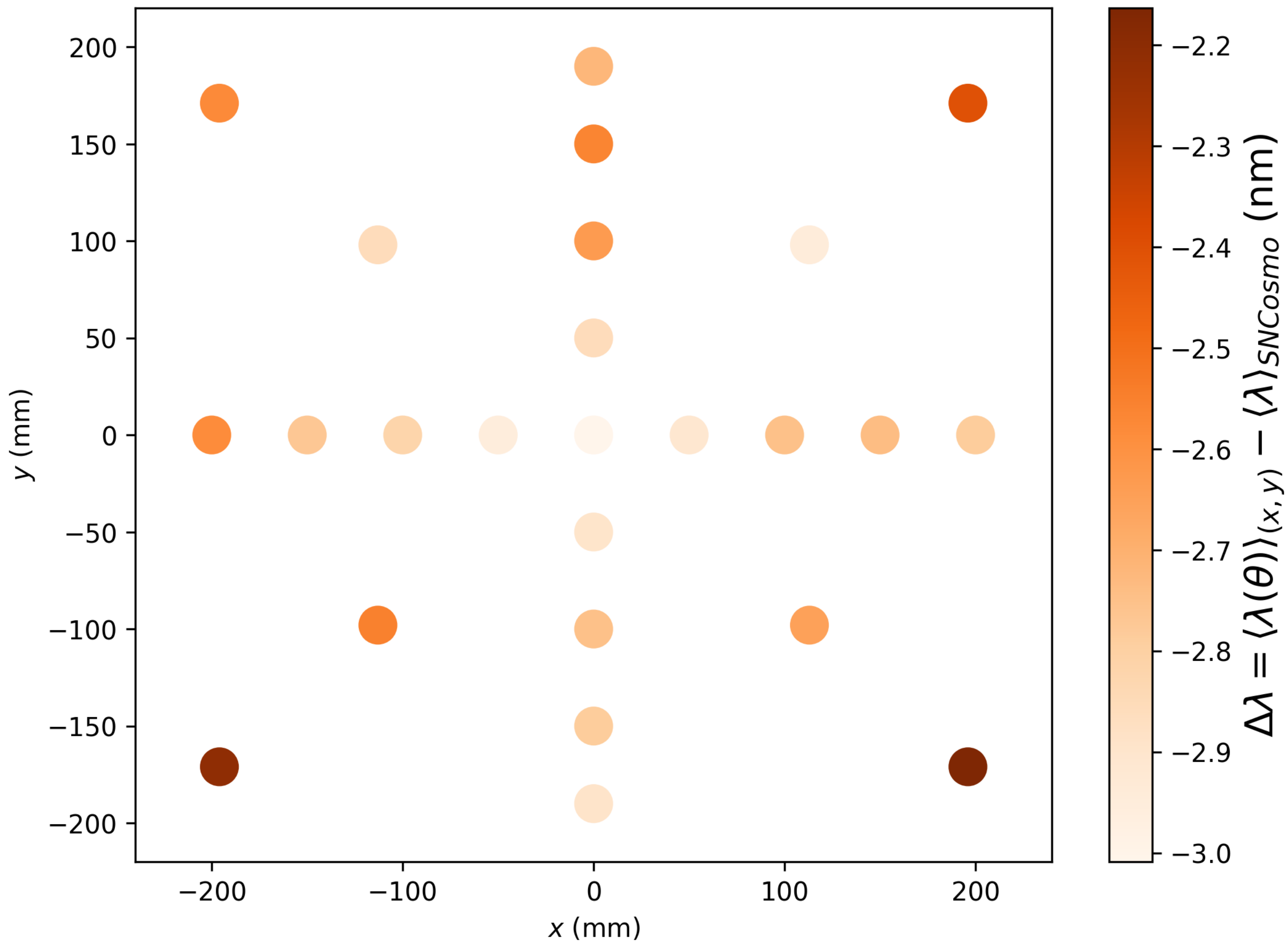
- First attempt (assuming linear behaviour): simple application of shift formula $5° \xrightarrow{+3.8°} 8.8°$
- **New extrapolation:** $\mathbf{5° \xrightarrow{-5°} 0° \xrightarrow{+8.8°} 8.8°}$

i-band: Caltech data



Filter transmission measured at 5° are compared to filter in SNCosmo

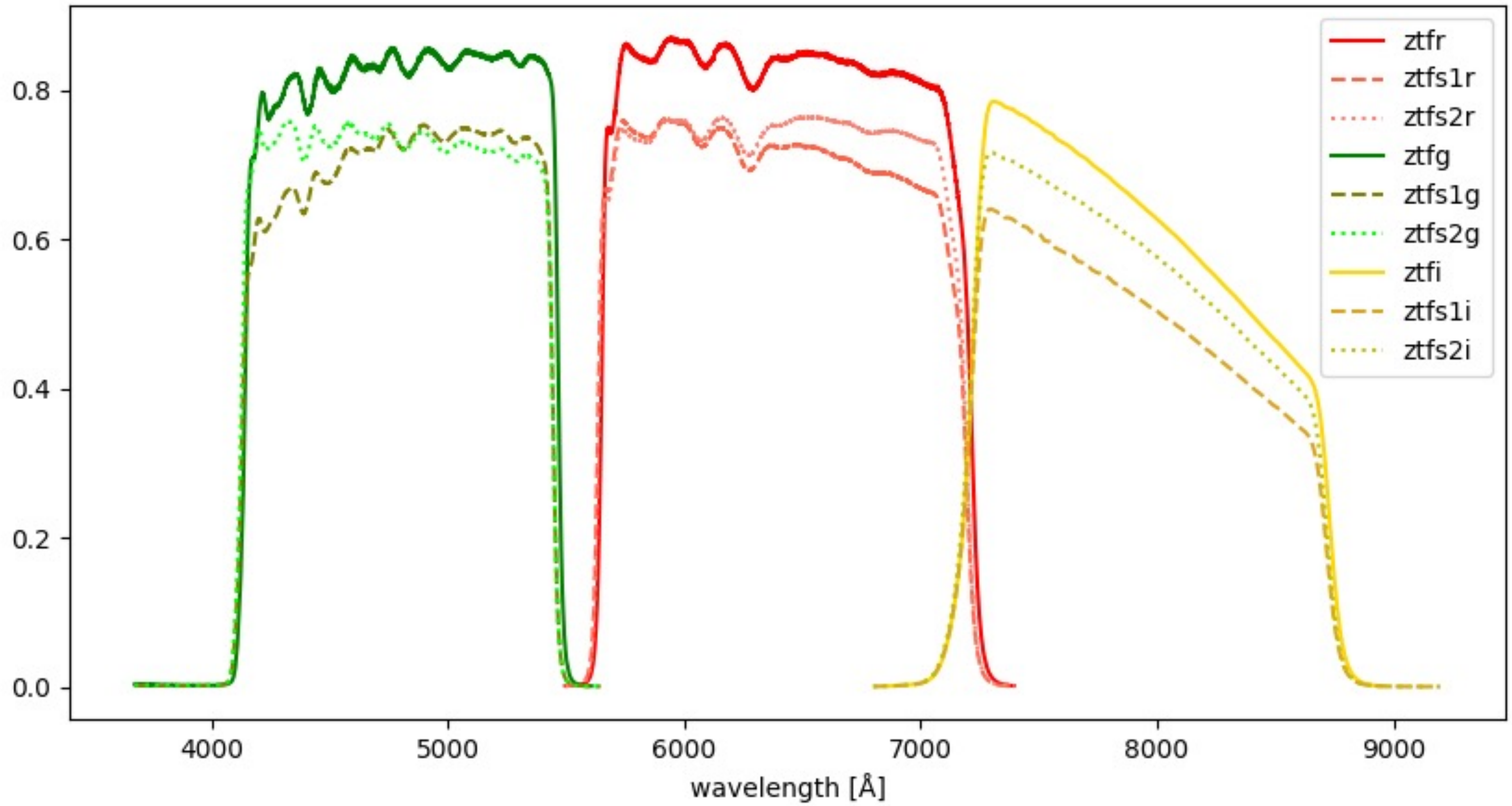
i-band: synthetic filter



- **Synthetic filters compared to filter in SNCosmo**
- **First-moment mean shift = -3.21 nm**

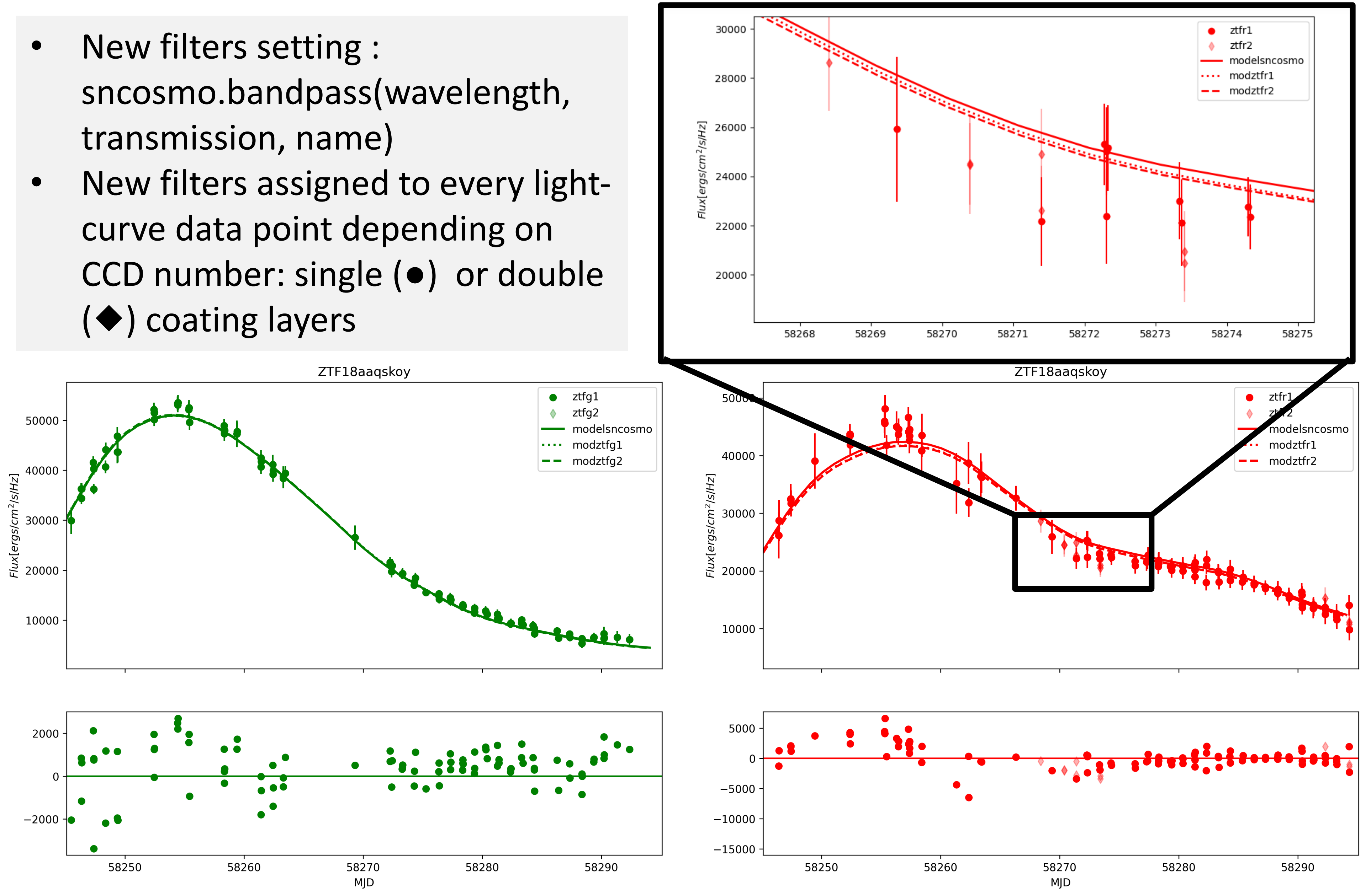
Chloé work: light-curve fit with new filters

New filters = optics + SNCosmo filters extrapolated at 8.8°
+ QE single/double layers



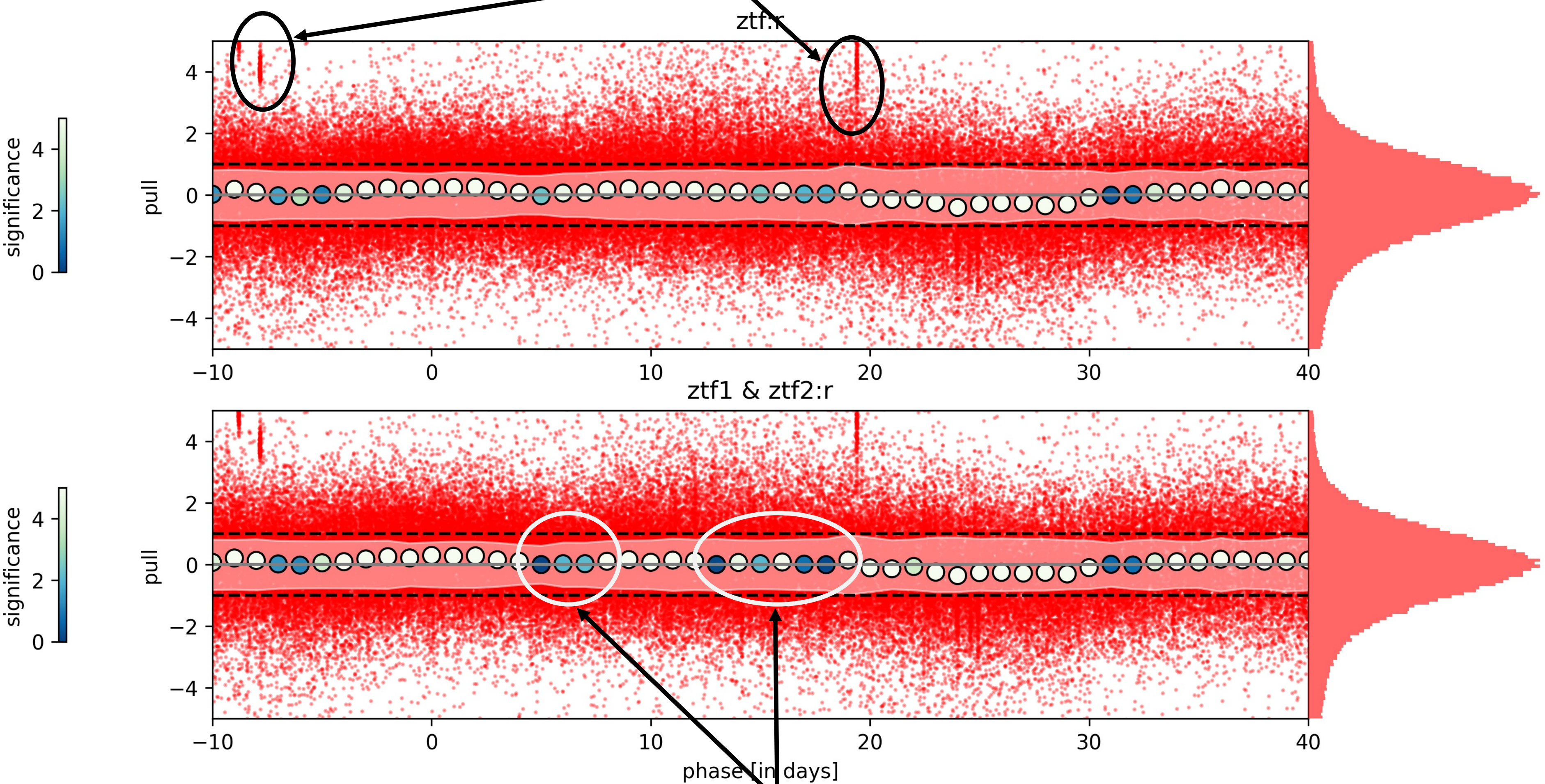
Chloé work: SNCosmo light-curve fitting

- New filters setting : sncosmo.bandpass(wavelength, transmission, name)
- New filters assigned to every light-curve data point depending on CCD number: single (●) or double (◆) coating layers



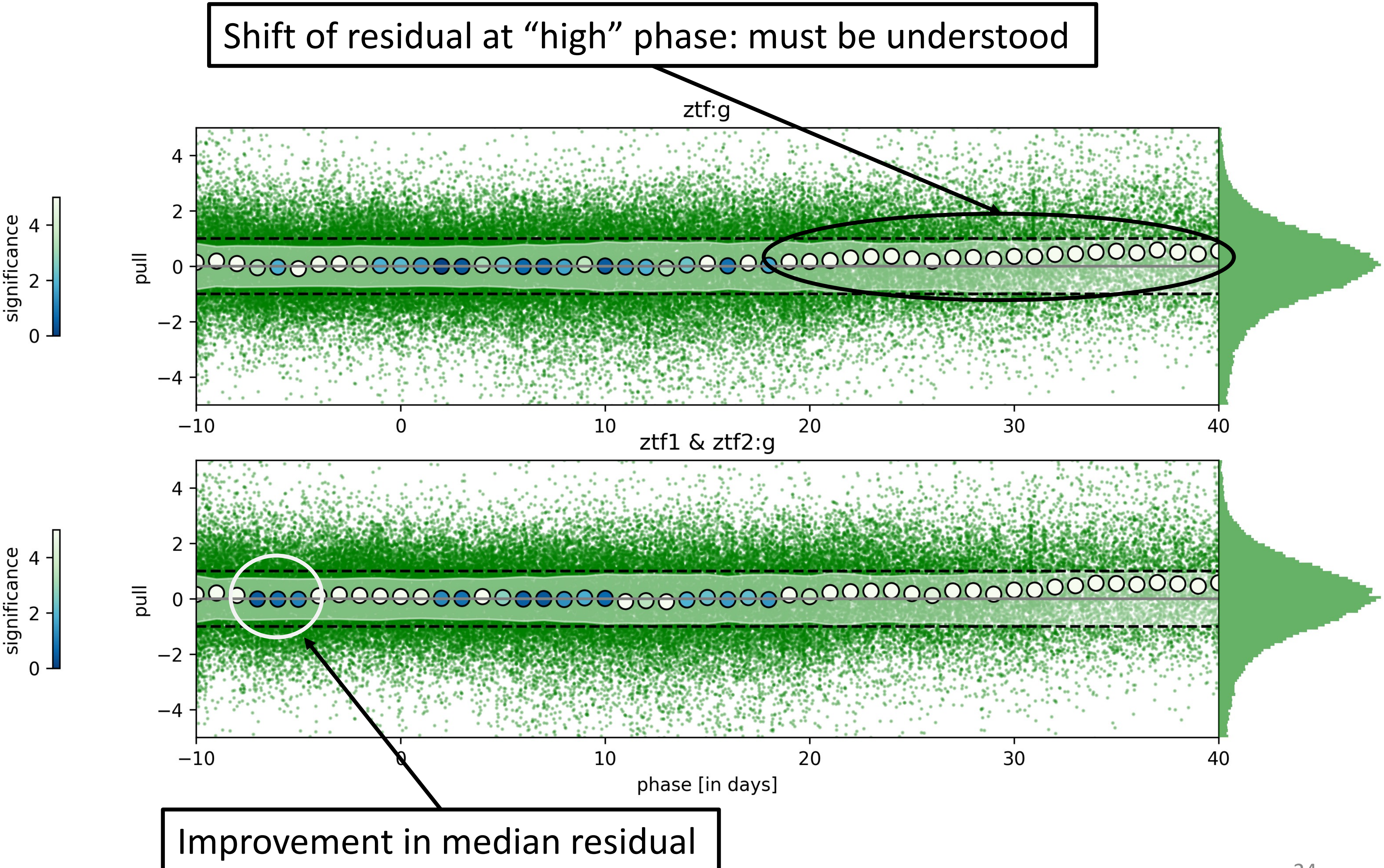
Chloé work: DR2 r-band light-curve residuals

Strange artefacts: only in r-band -> to be understood



Improvement in median residual in some parts of the light-curve

Chloé work: DR2 g-band light-curve residuals



Conclusions and next step

Conclusions

- Almost all pieces to build an instrument model
- First instrument card for SNCosmo (Nicolas)

instrument.cards

```
# mirror size (cm^2) = Schmidt trim plate pi*(124.4/2)^2
@MIRROR_AREA 12154.3

# transmission of the optics (Schmidt trim plate + CCD field correctors)
@OPTICS_TRANS ztf_optics_transmission.txt

# reflectivity of the mirror (P48)
@MIRROR_REFLECTIVITY ztf_mirror_reflectivity.txt

# atmospheric transmission (Almost unknown at Mont Palomar)
#@ATMOSPHERIC_TRANS modtran_maunakea_am12_pwv15_binned10ang.dat

# filters (radially varying filter transmission)
@RADIALLY_VARIABLE_FILTERS FilterWheel

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

# QE of individual CCD's (Single and double layer coating 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 (in as)
@PIX_SIZE 1.01
```

Next step: test with Gaia data

- Applied synthetic photometry to Gaia spectra
- Compare color indexes (g-r, r-I, g-i) to ZTF starflat data