IN2P3

Institut national de physique nucléaire
et de physique des particules

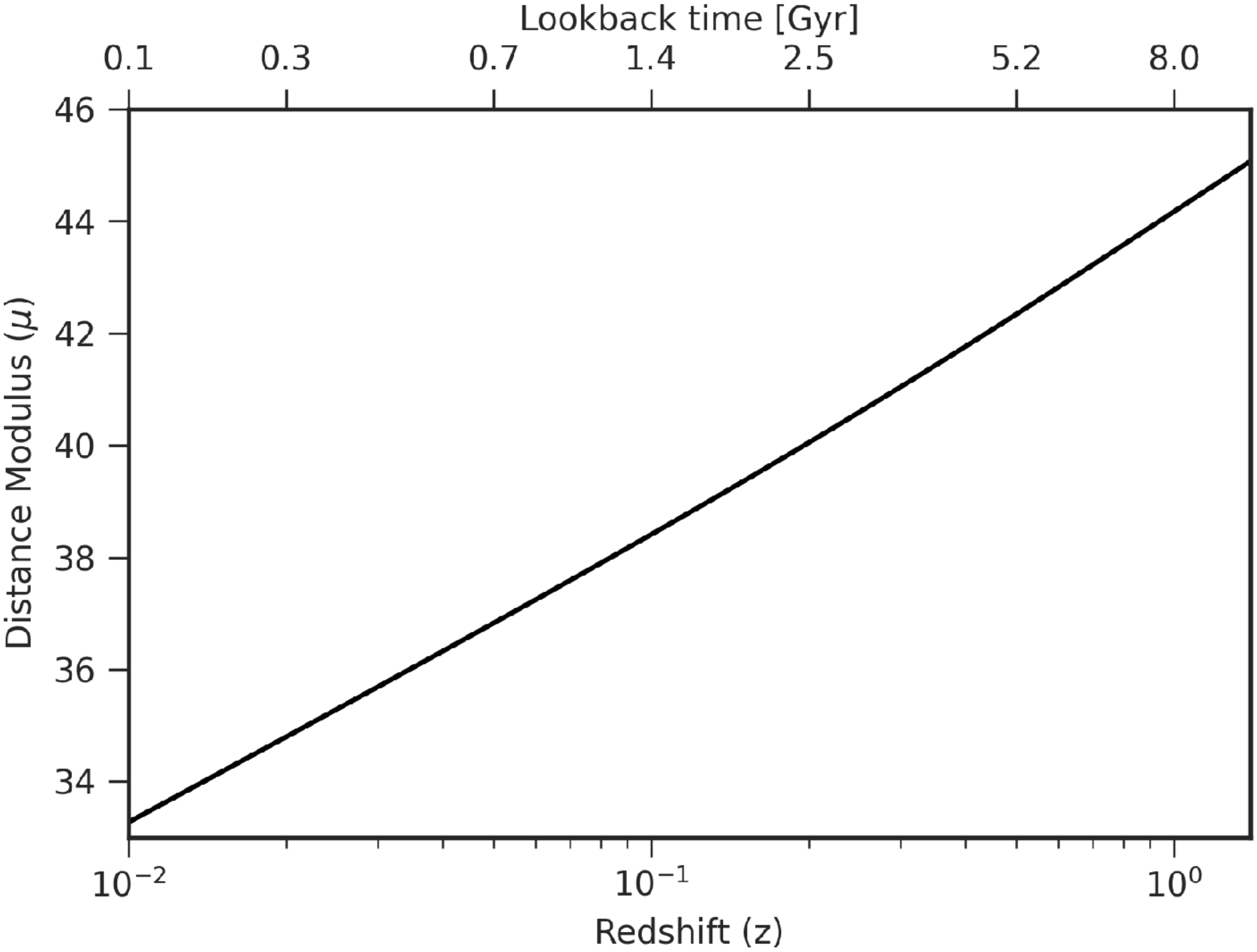
funded by anr

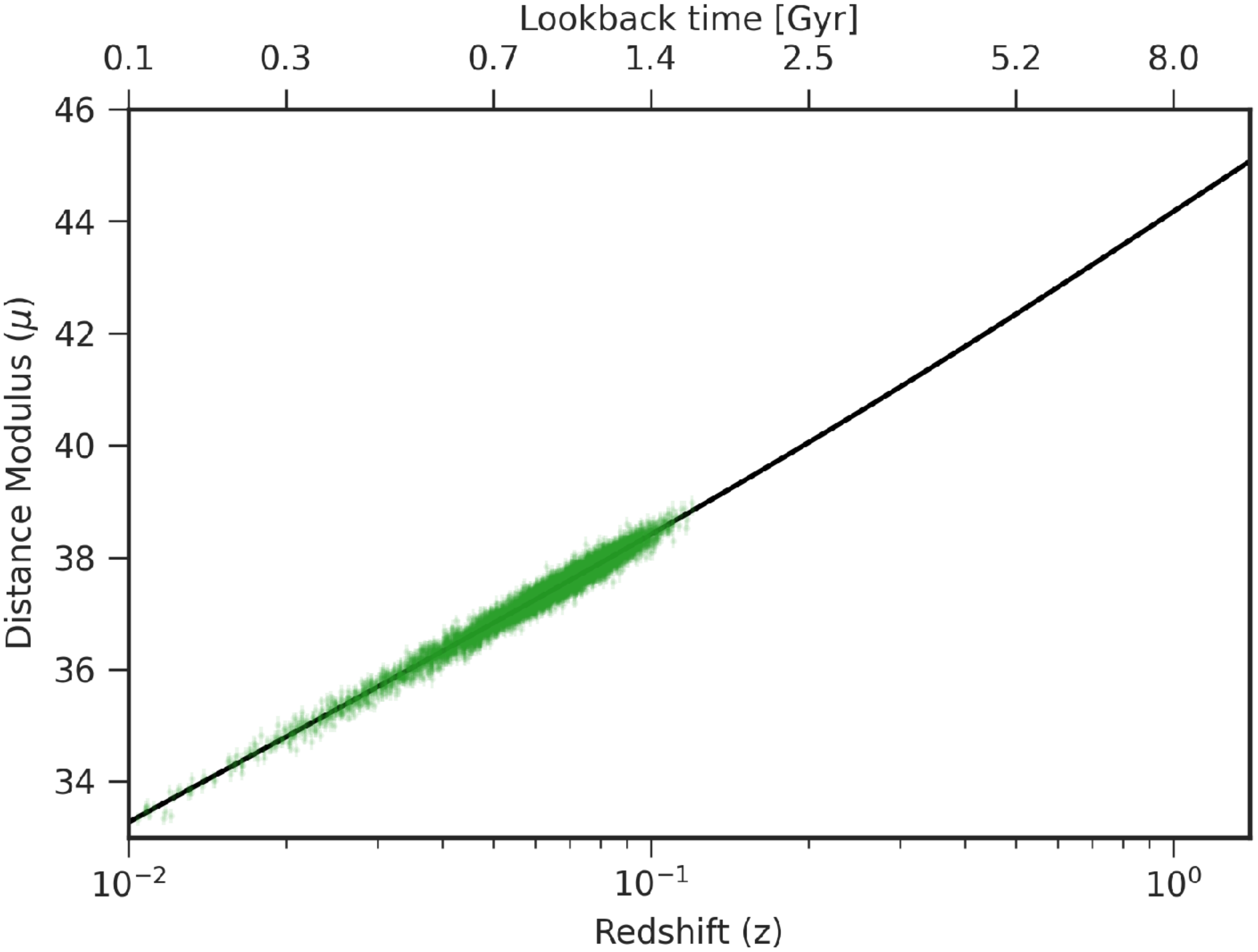
Update on the new ZTF calibration pipeline

Benjamin Racine, with slides from many people

May 17th 2022

Rubin France meeting, Annecy


Lookback time [Gyr]
0.1
0.3
0.7
1.4
2.5
5.2
8.0
46
44
42
40
38
36
34
Distance Modulus (μ)
10^{-2}
10^{-1}
10^{0}
Redshift (z)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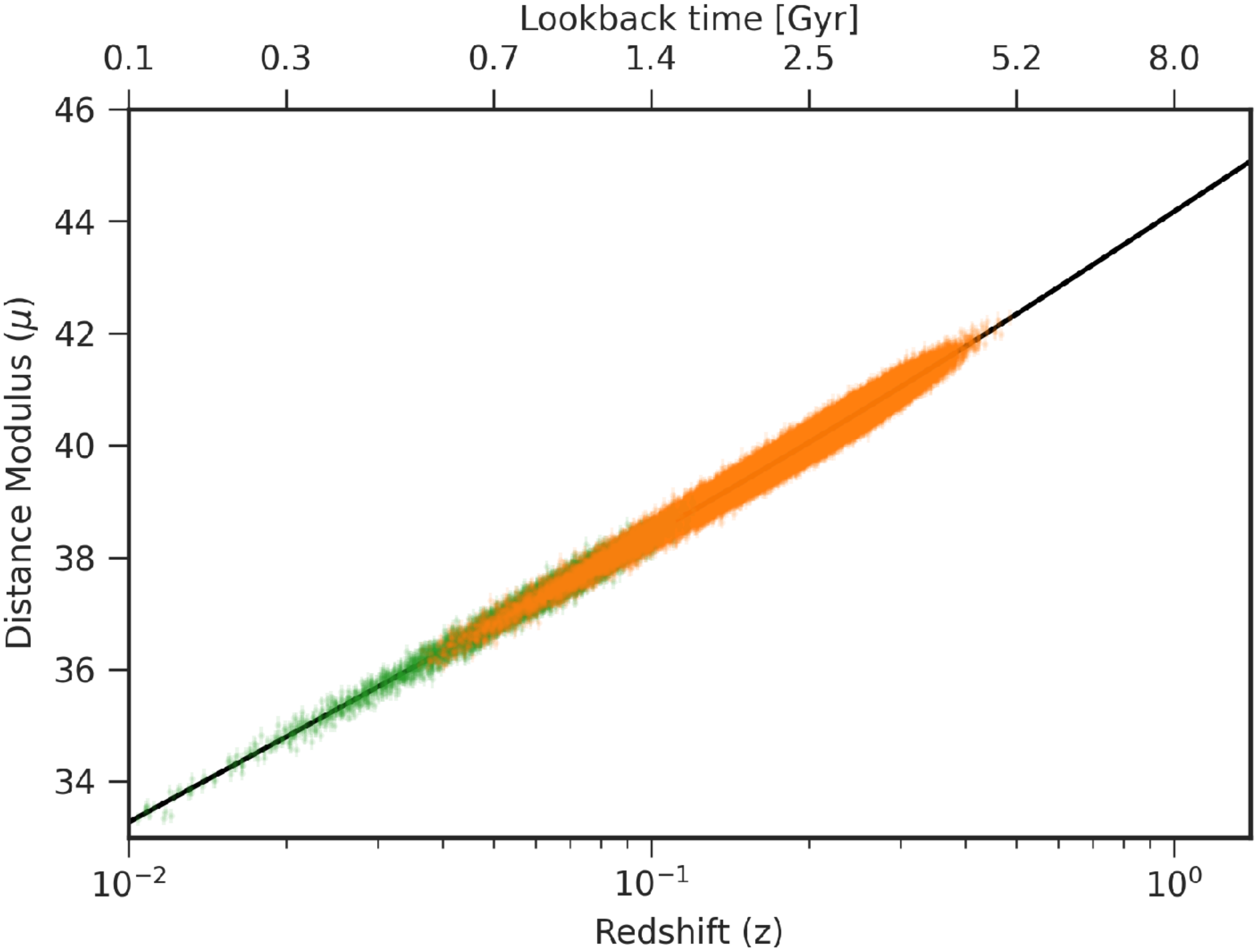
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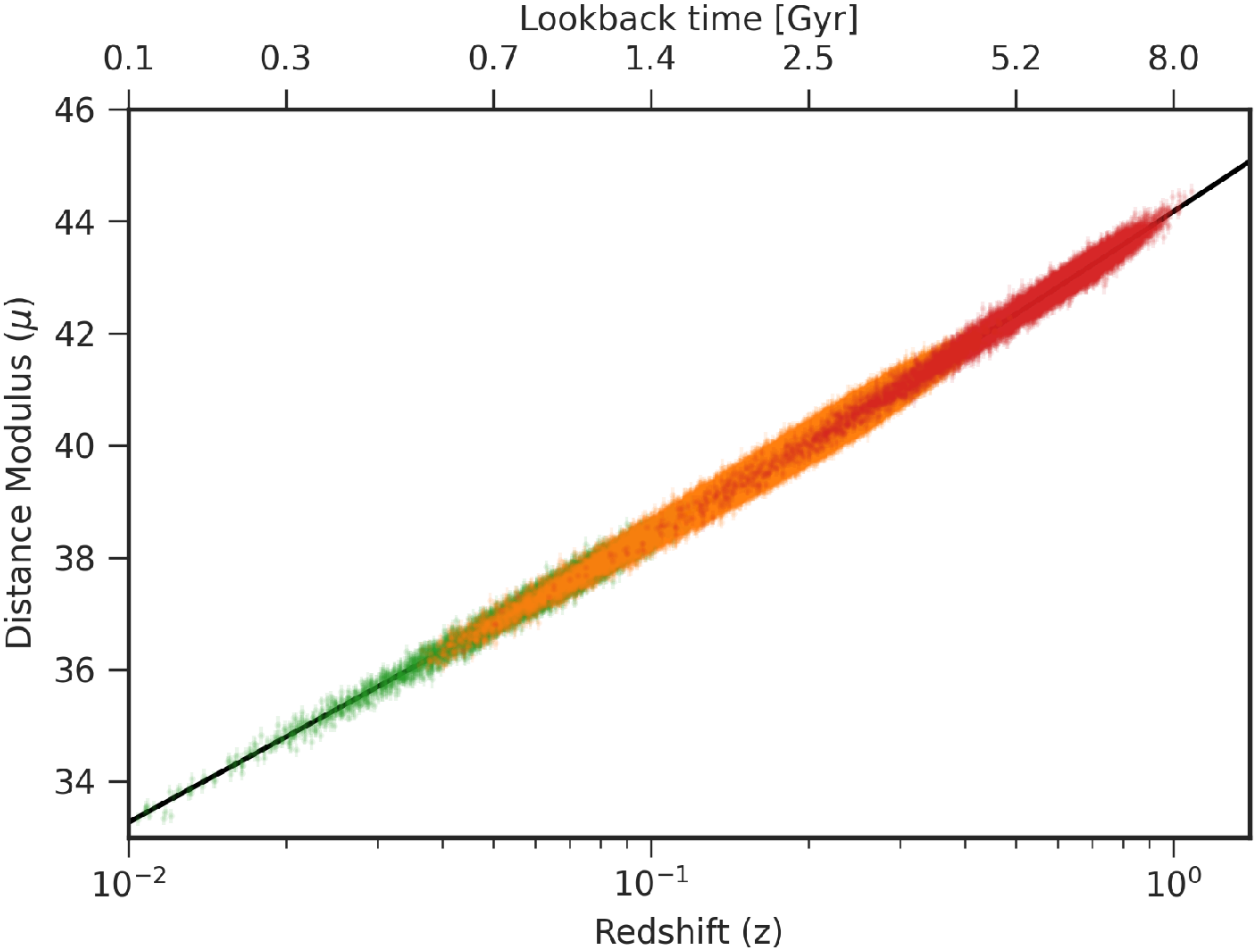

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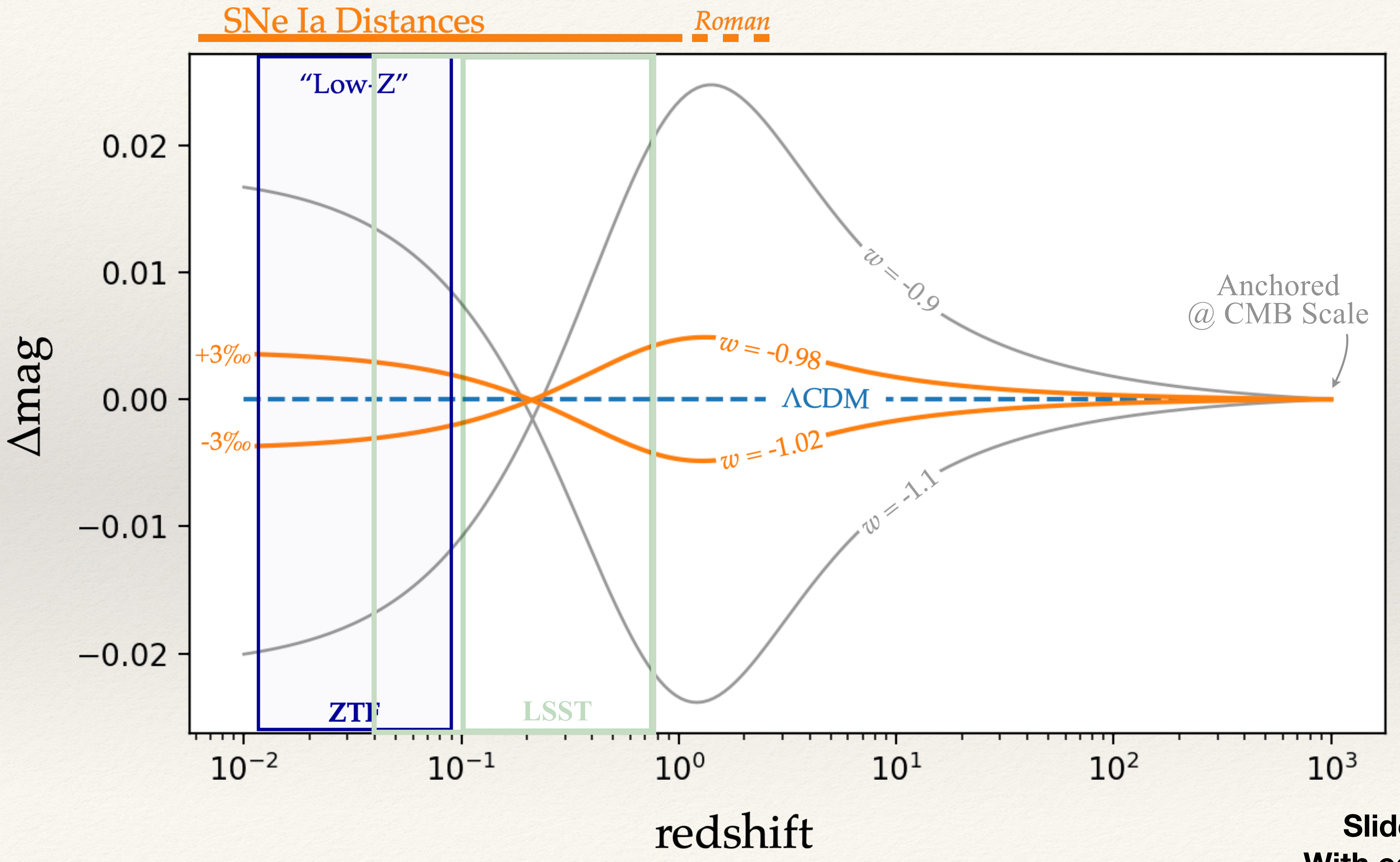
10^{-1}
10^{0}
Redshift (z)

Exotic form of Dark Energy | *Stats & Precision*



SNe Ia
→ Δmag=15%

See talk from M. Ginolin

O(5000) SNe Ia
→ Δmag= 0.2%

Photometric Accuracy
→ Δmag= 0.1%

Slide from M. Rigault
With edit from P. Antilogus

Calibration Goals

- Goal #1
  - Band intercalibration at 0.1%
  - (Absolute scale unimportant)
- Goal #2
  - Uniformity at 0.1% on focal plane
  - Uniformity at a few 0.1% on full survey footprint
  - **Deliverable:** g,r,I catalog anchored on CALSPEC/DICE

CALSPEC
DICE

StarFlats
Ubercal

Adapted form N. Regnault

Calibration Goals

- Goal #1
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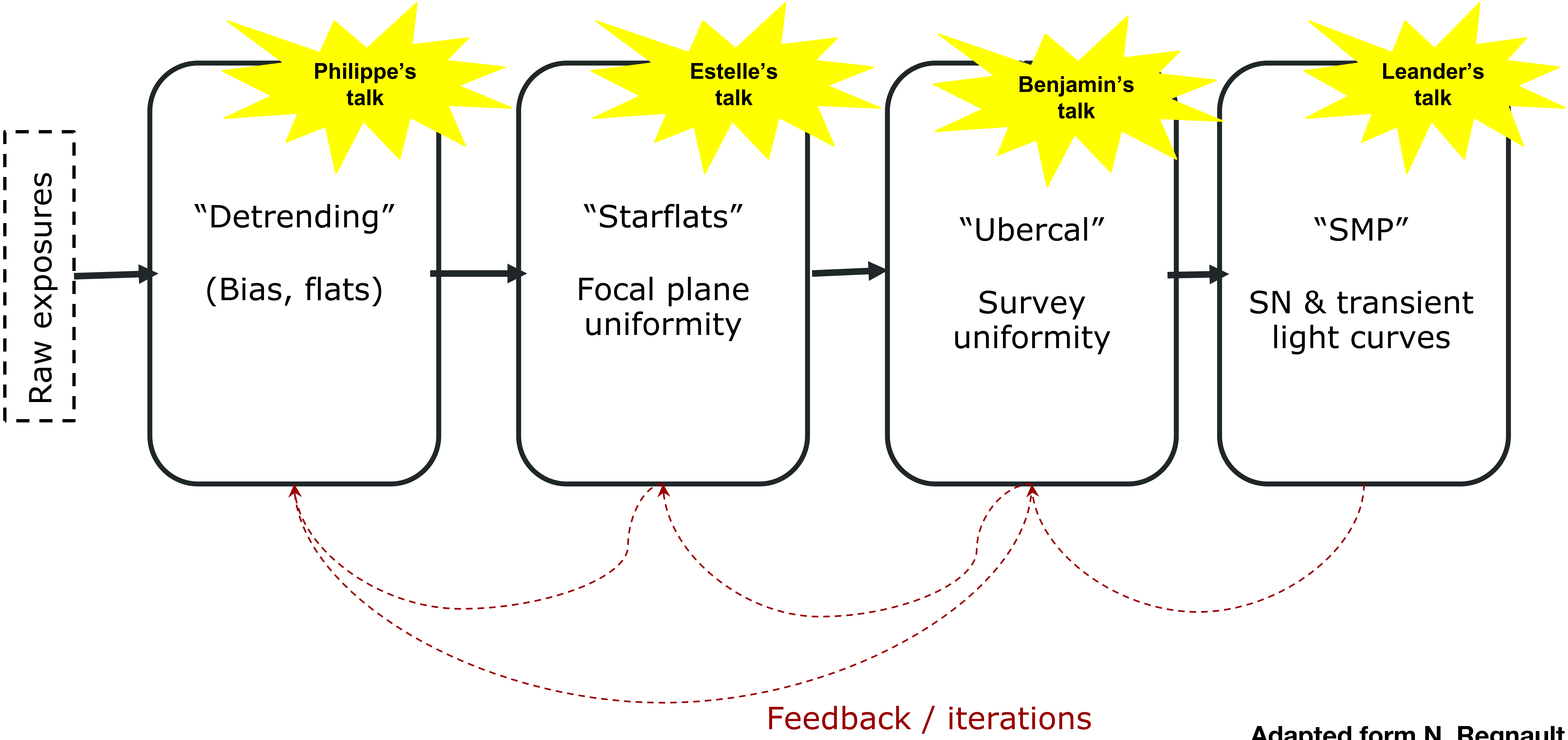
  - **Deliverable:** g,r,I catalog anchored on CALSPEC/DICE
- Goal #3
  - Anchor the SN light curves to this calibration at 0.1%
  - *We use the field stars as calibrators*
  - Need an estimator which can run (1) on the supernovae (2) on the field stars

CALSPEC
DICE

StarFlats
Ubercal

Scene
modeling

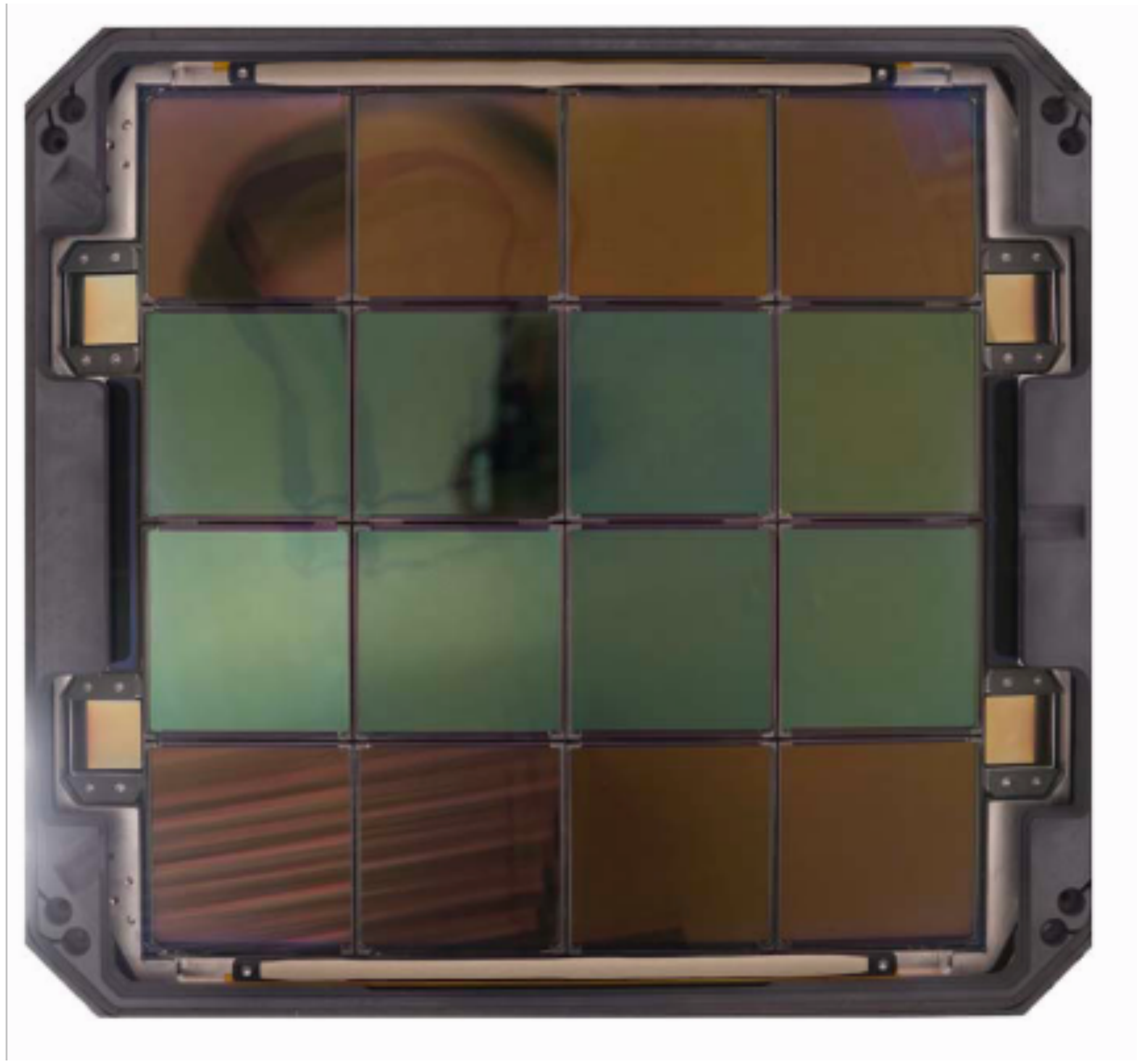
Adapted form N. Regnault

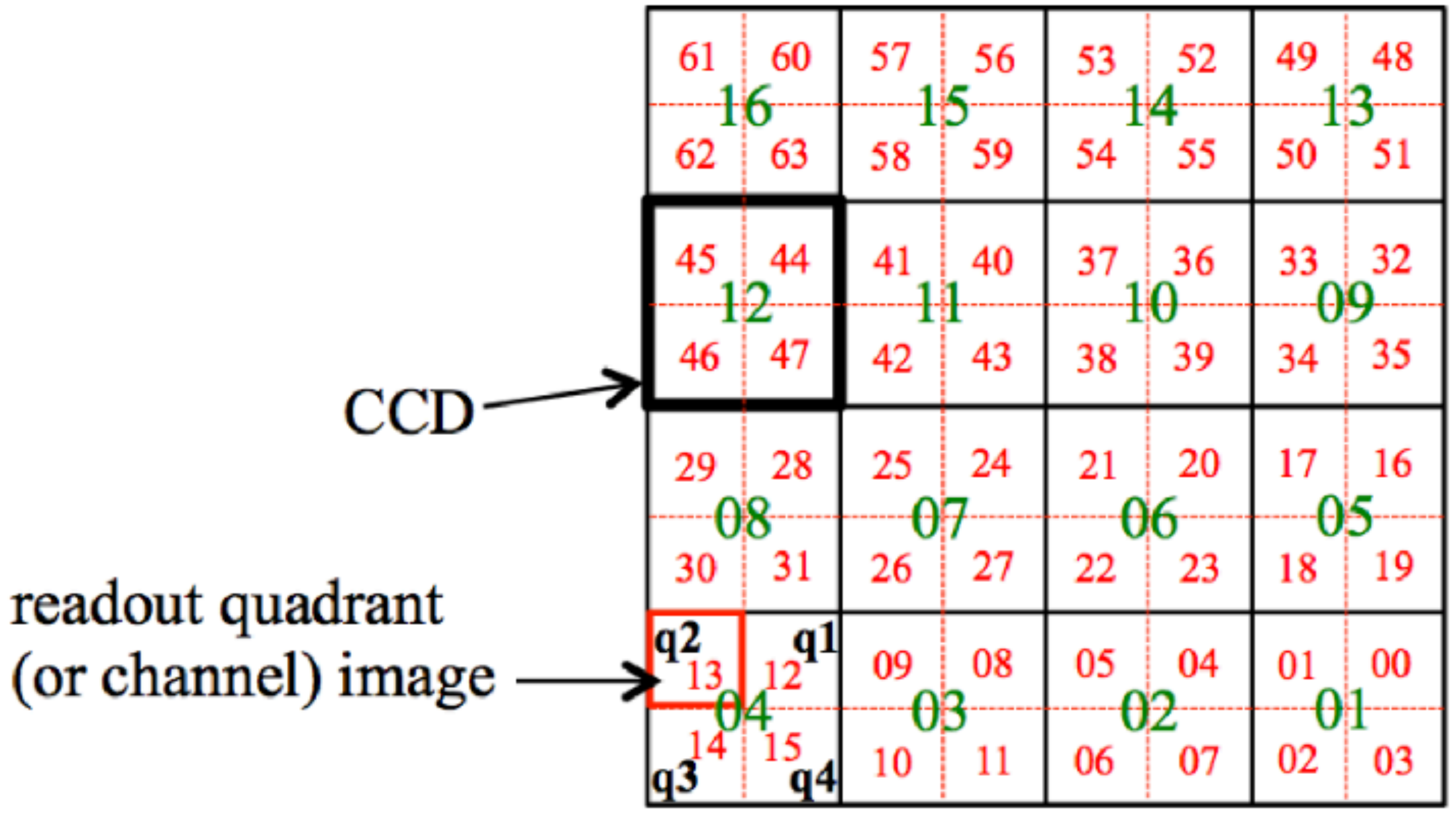


Adapted form N. Regnault

Bias & Flat fielding

Philippe Rosnet & Philippe Gris

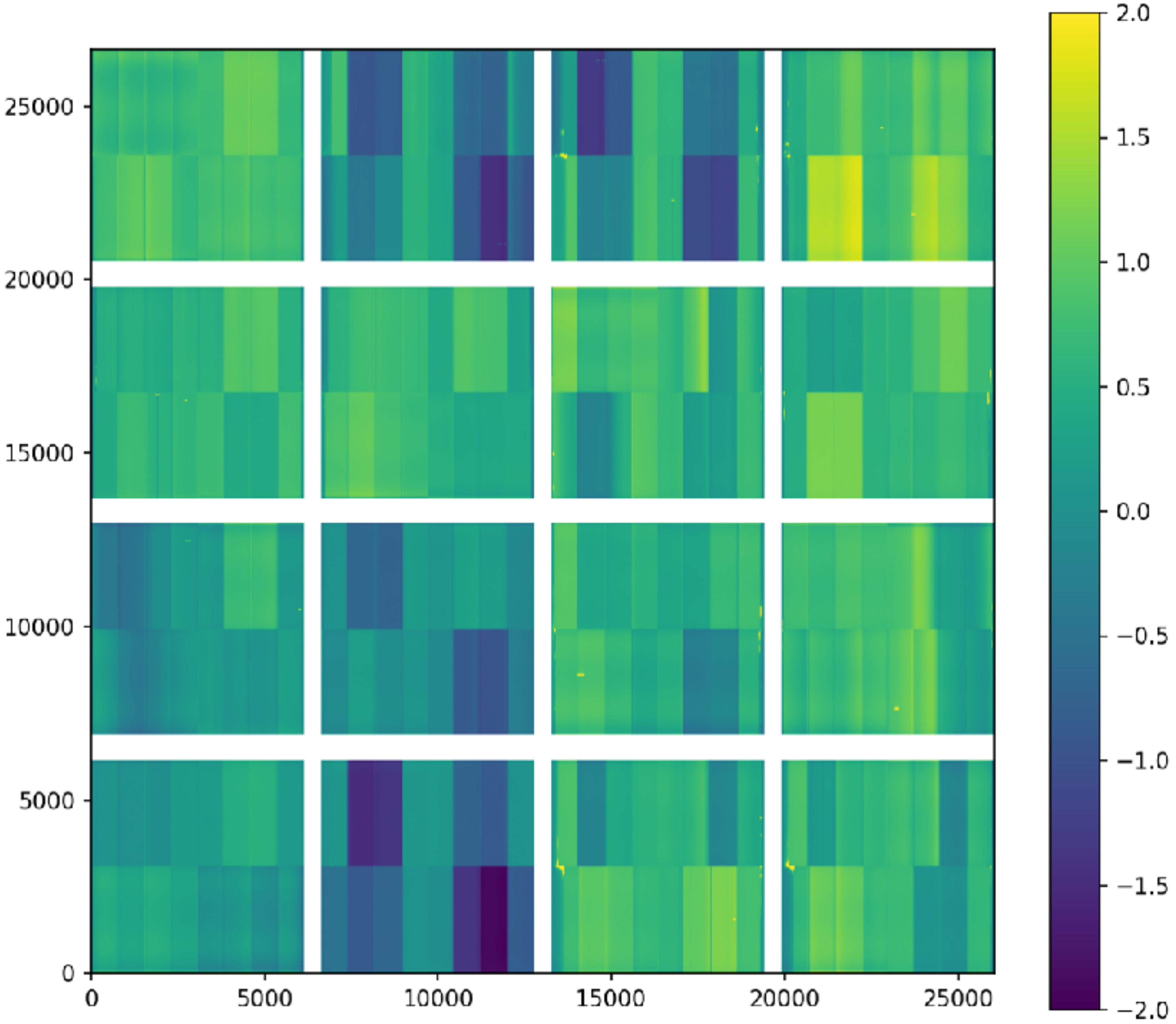




$$\frac{\text{Raw image} - \text{Bias image}}{\text{Flat image}} = \text{Science image}$$

Adapted from P. Rosnet

Bias & Flat fielding

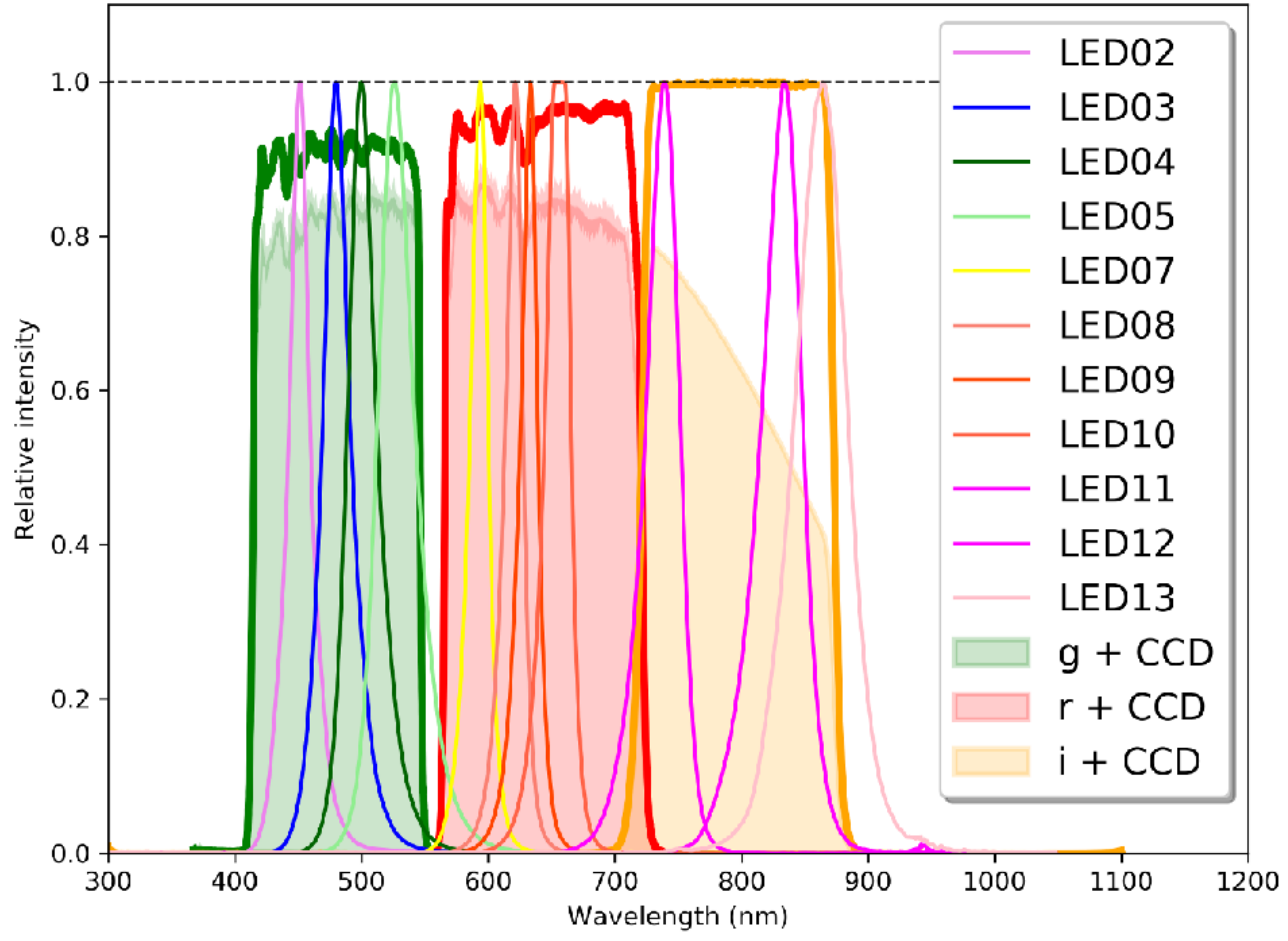


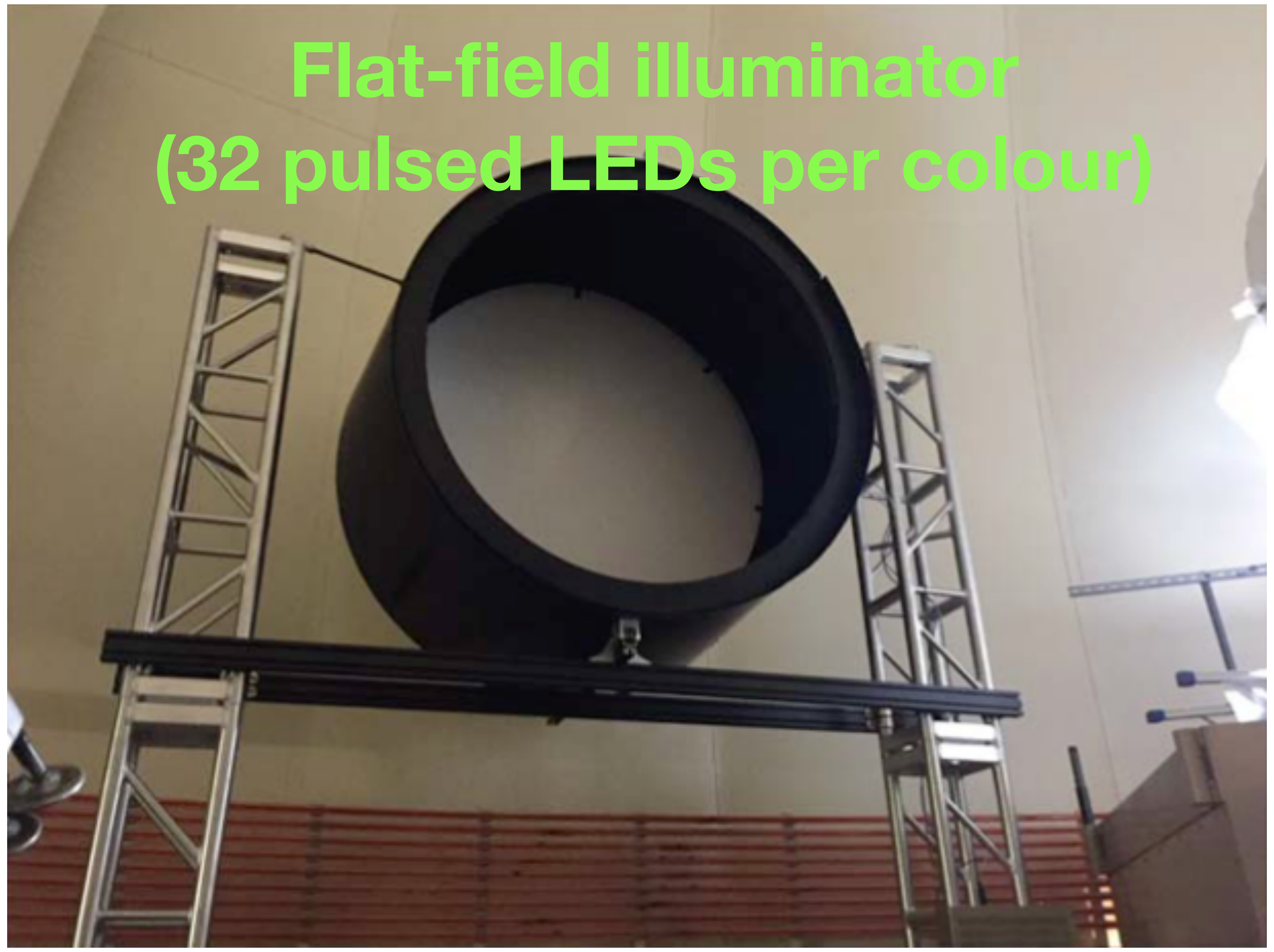
- Master-bias (20 days) stable at the level of 0.01 ADU
- Outlier < 0.6%
- Full study of 2019 on-going

$$\frac{\text{Raw image} - \text{Bias image}}{\text{Flat image}} = \text{Science image}$$

Adapted from P. Rosnet

Bias & Flat fielding

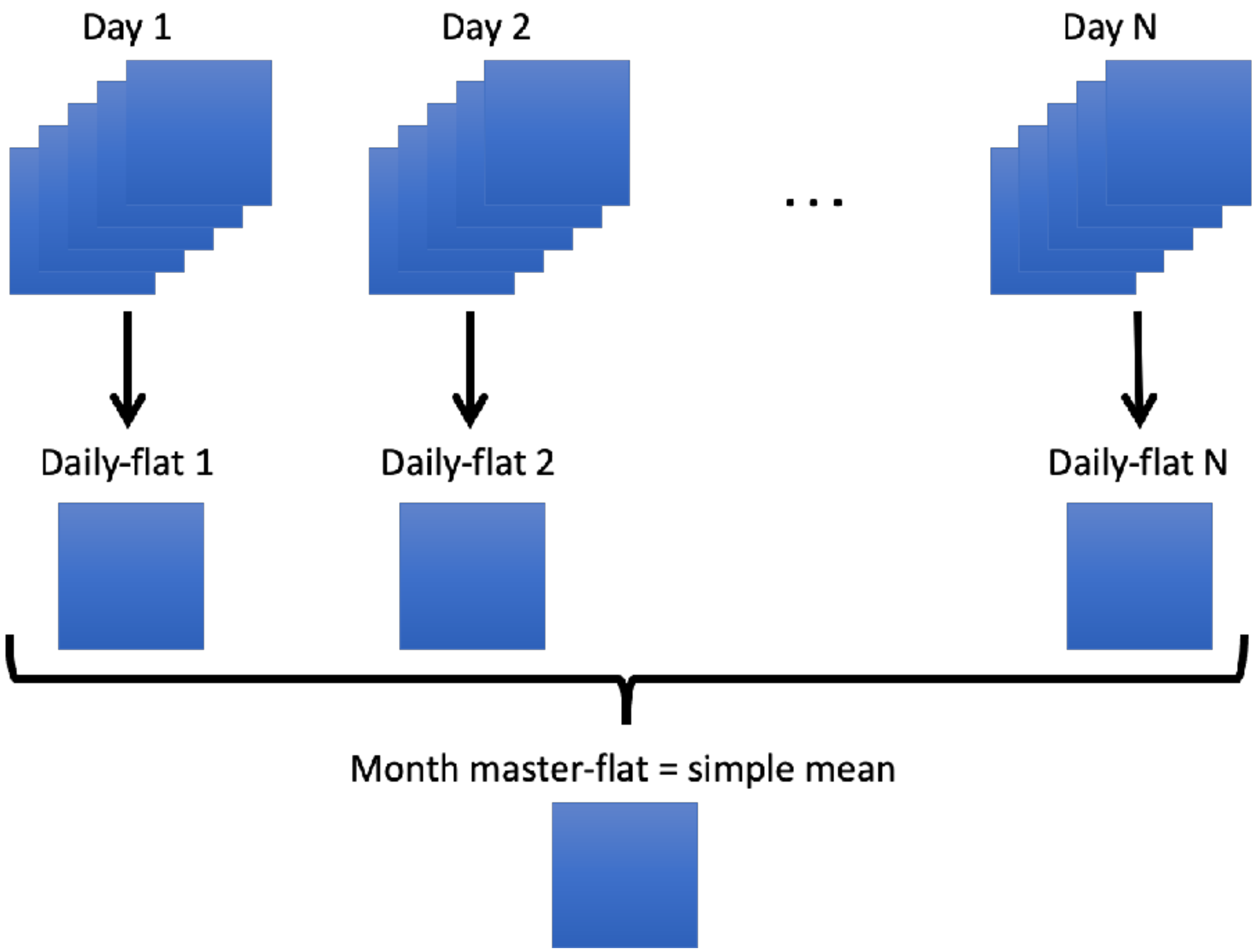




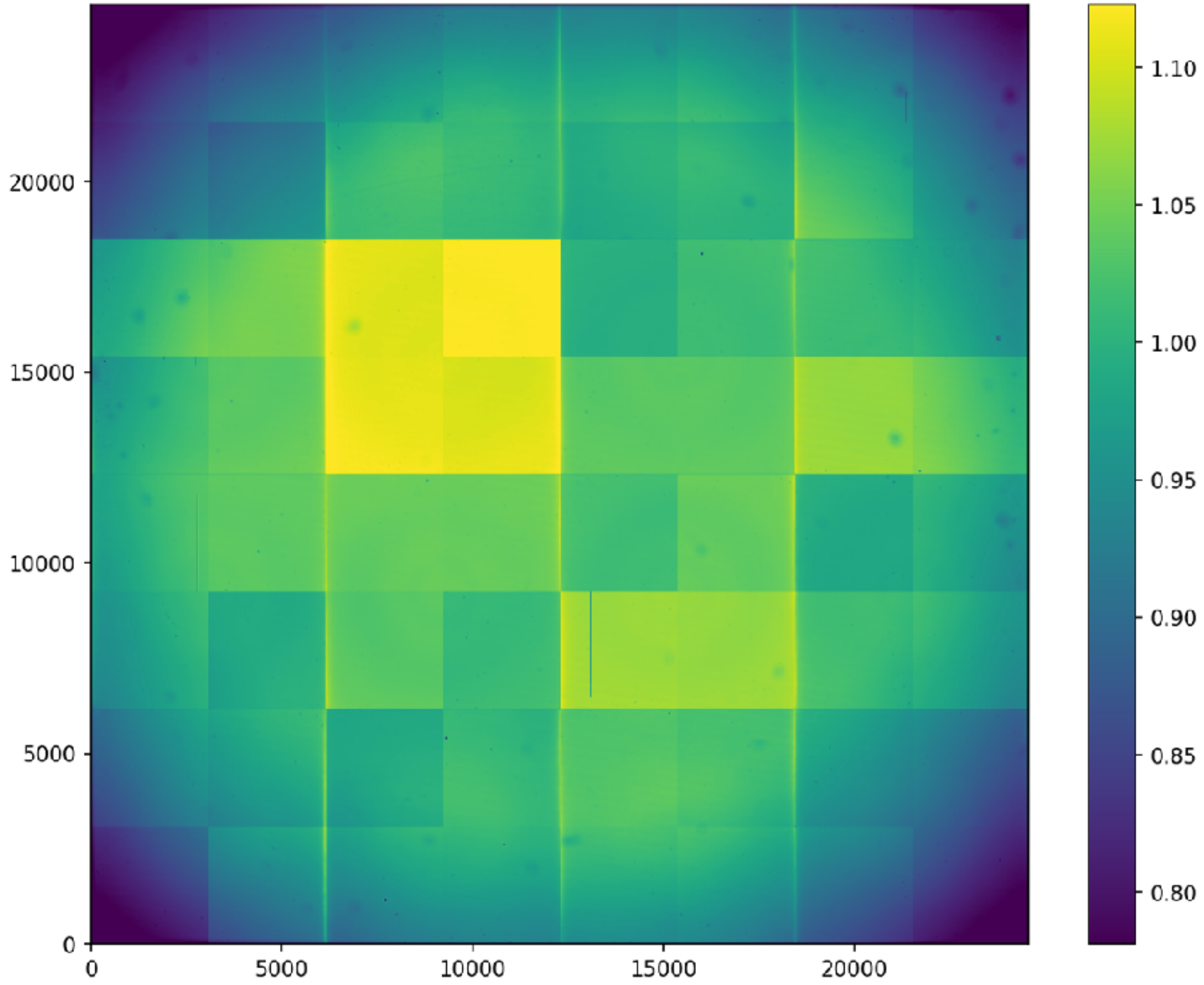
$$\frac{\text{Raw image} - \text{Bias image}}{\text{Flat image}} = \text{Science image}$$

Adapted from P. Rosnet

Master-flat processing



LED09 - January 2019



Adapted from P. Rosnet

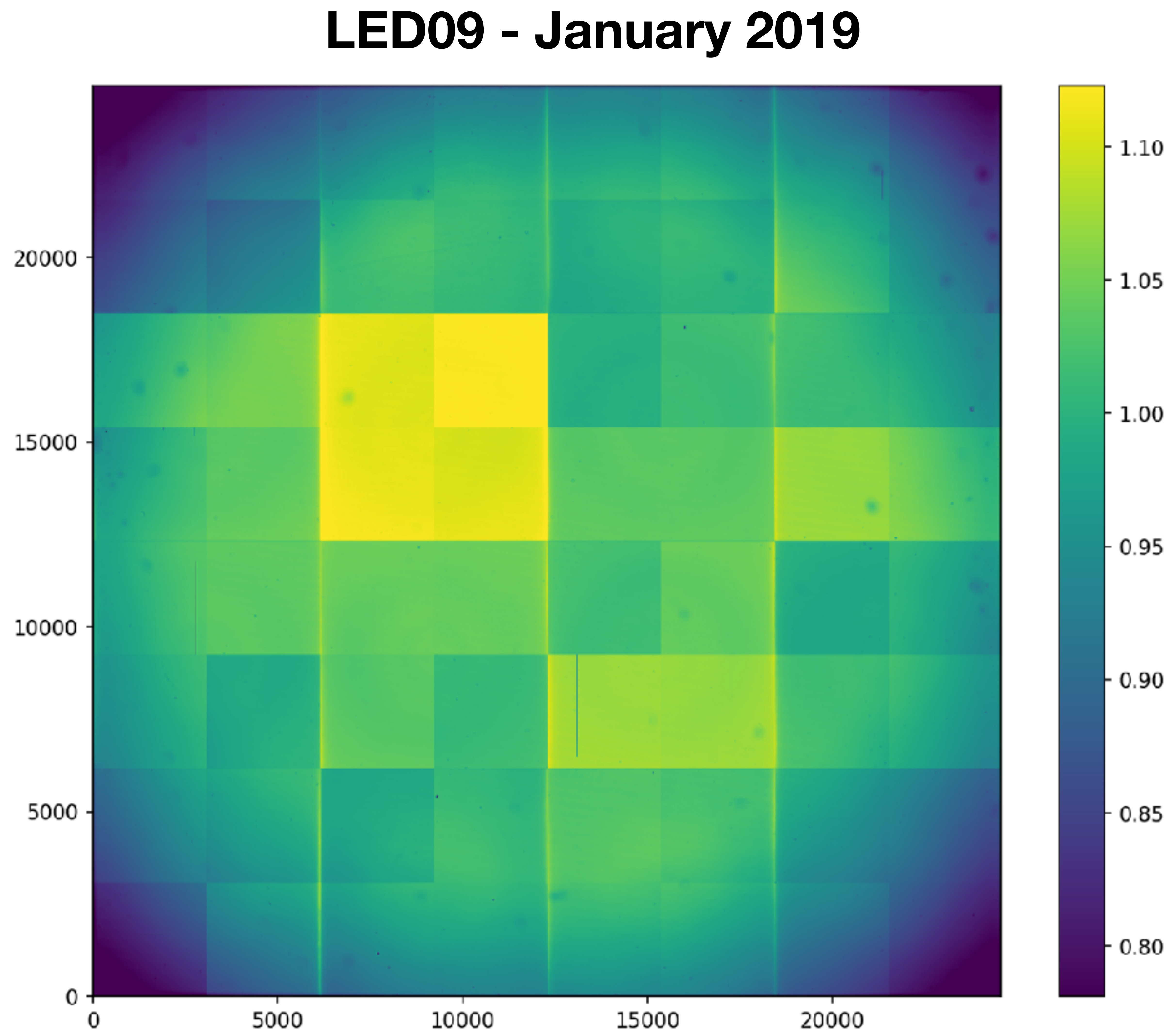
Master-flat processing

<u>Conclusions of preliminary study of master-flat</u>

- Flat-field **stability better than 0.1%** for every LEDs
- Better stability of flat-fielding when performed **at CCD level** versus mosaic level

<u>Next step</u>

- Identification of period between interventions
- **Processing master-bias and master-flat per period**
- Test the new flat fielding procedure using starflats



Adapted from P. Rosnet

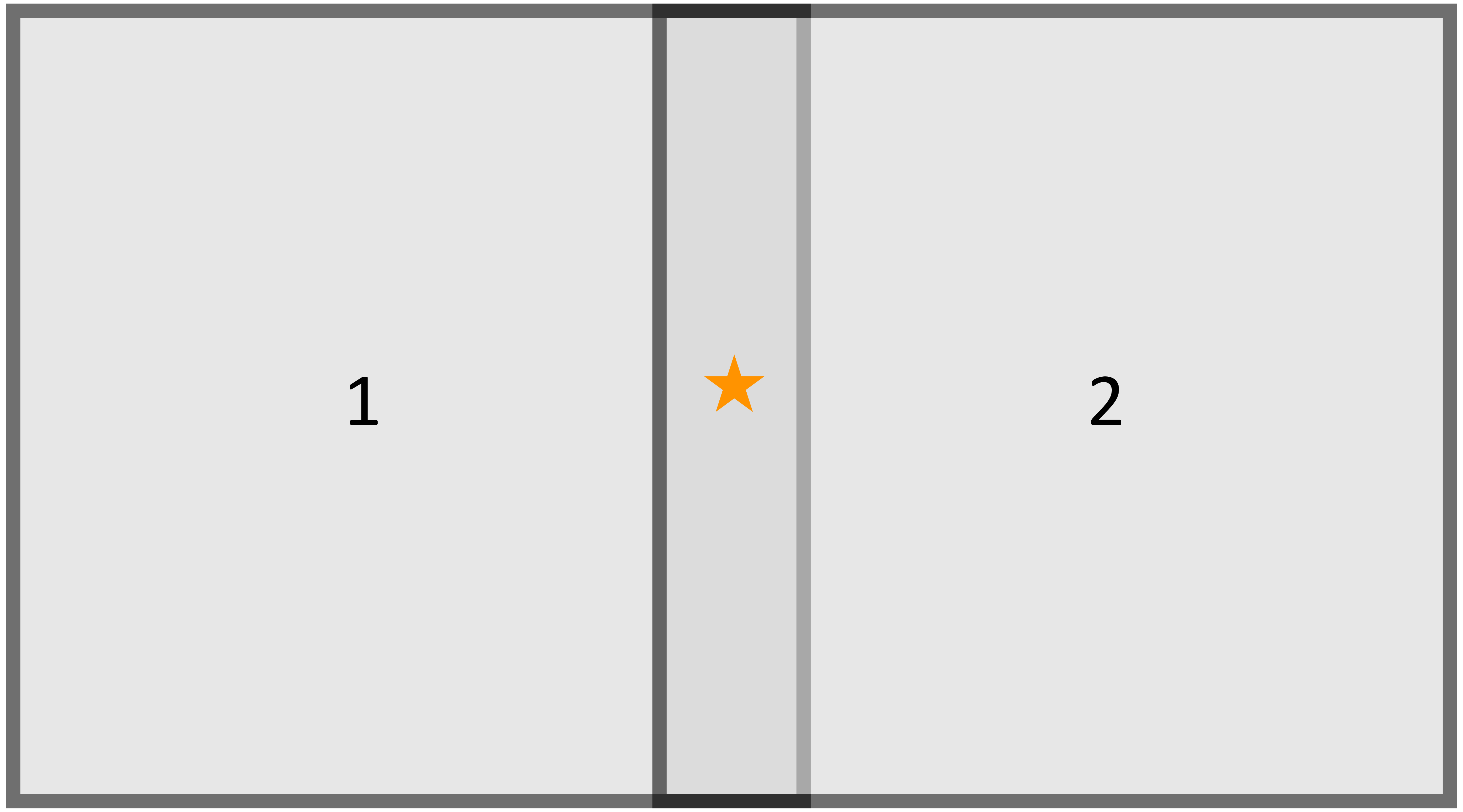
Ubercal

Benjamin Racine, Fabrice Feinstein
+ Julian Bautista, Mickael Rigault, Bastien Carreres, Dominique Fouchez


Flux F
Atmosphere : Flux αF
LENS
CCDs
PHOTOGRAPHICS
FILM
REFLECTING
SURFACE
Instrument
Mirrors etc. : Flux αβF
Filters : Flux αβγF
Detectors : Flux αβγδF
Amplifiers : Flux αβγδεF
+V
-V
Signal
measured
in ADU
$m_{meas} = -2.5 \log (F_{meas})$
$= -2.5 \log (F) - 2.5 \log (\alpha\beta\gamma\delta\epsilon)$
ZP


+ Frequency dependence
Flux F
Depends on time, elevation, etc
Atmosphere : Flux αF
LENS
CCDs
PHOTOGRAPHICS
FILM
REFLECTING
SURFACE
Instrument
Dust spots? Aging?
Mirrors etc. : Flux αβF
Dust?
Filters : Flux αβγF
Edges, dust, coating etc.
Detectors : Flux αβγδF
Gain variations etc?
Amplifiers : Flux αβγδεF
+V
-V
Signal
measured
in ADU
$m_{meas} = -2.5 \log (F_{meas})$
$= -2.5 \log (F) - 2.5 \log (\alpha\beta\gamma\delta\epsilon)$
ZP

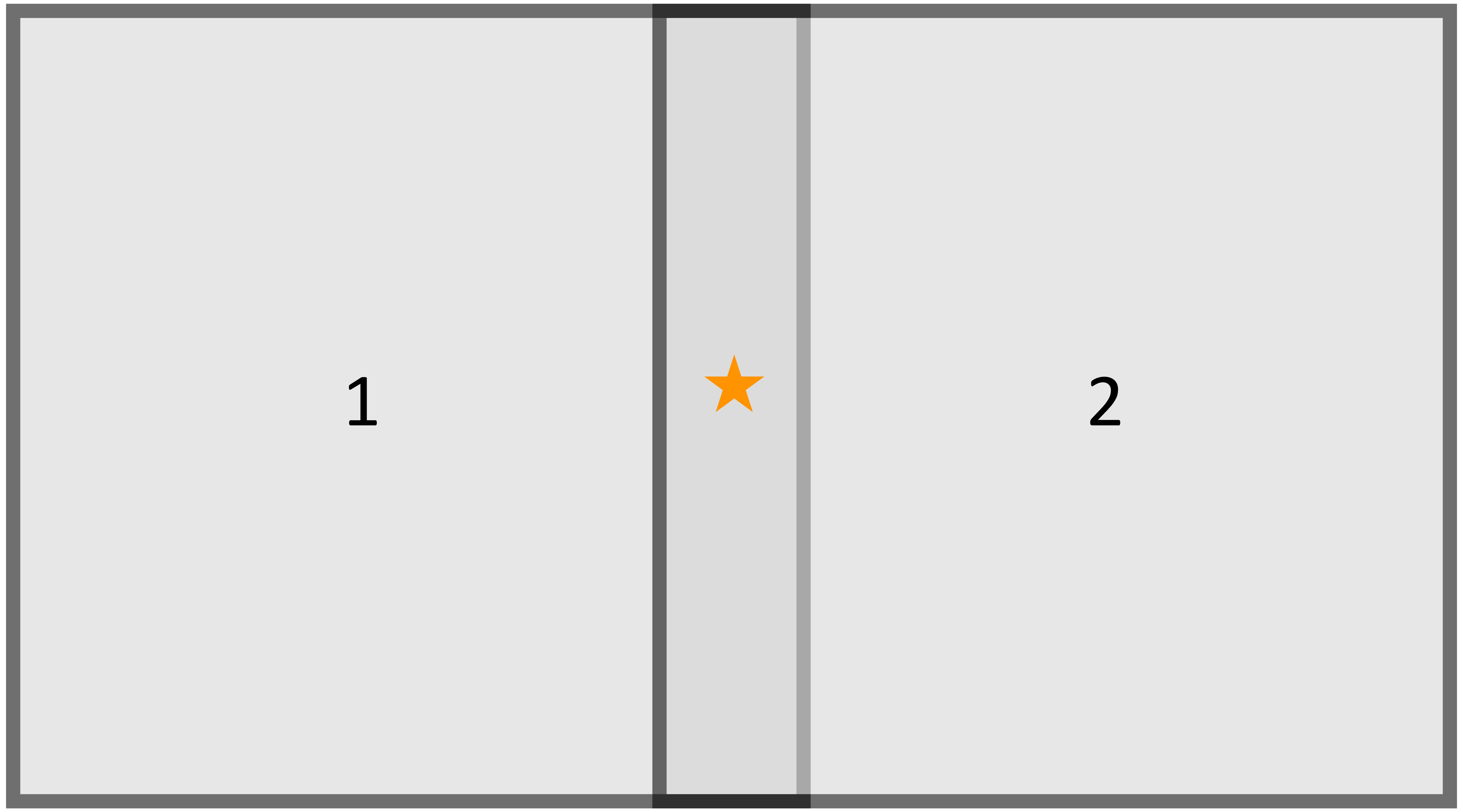
Ubercal method



$$m_1 + ZP_1 = m_{11}^{obs}$$

$$m_1 + ZP_2 = m_{12}^{obs}$$

Ubercal method

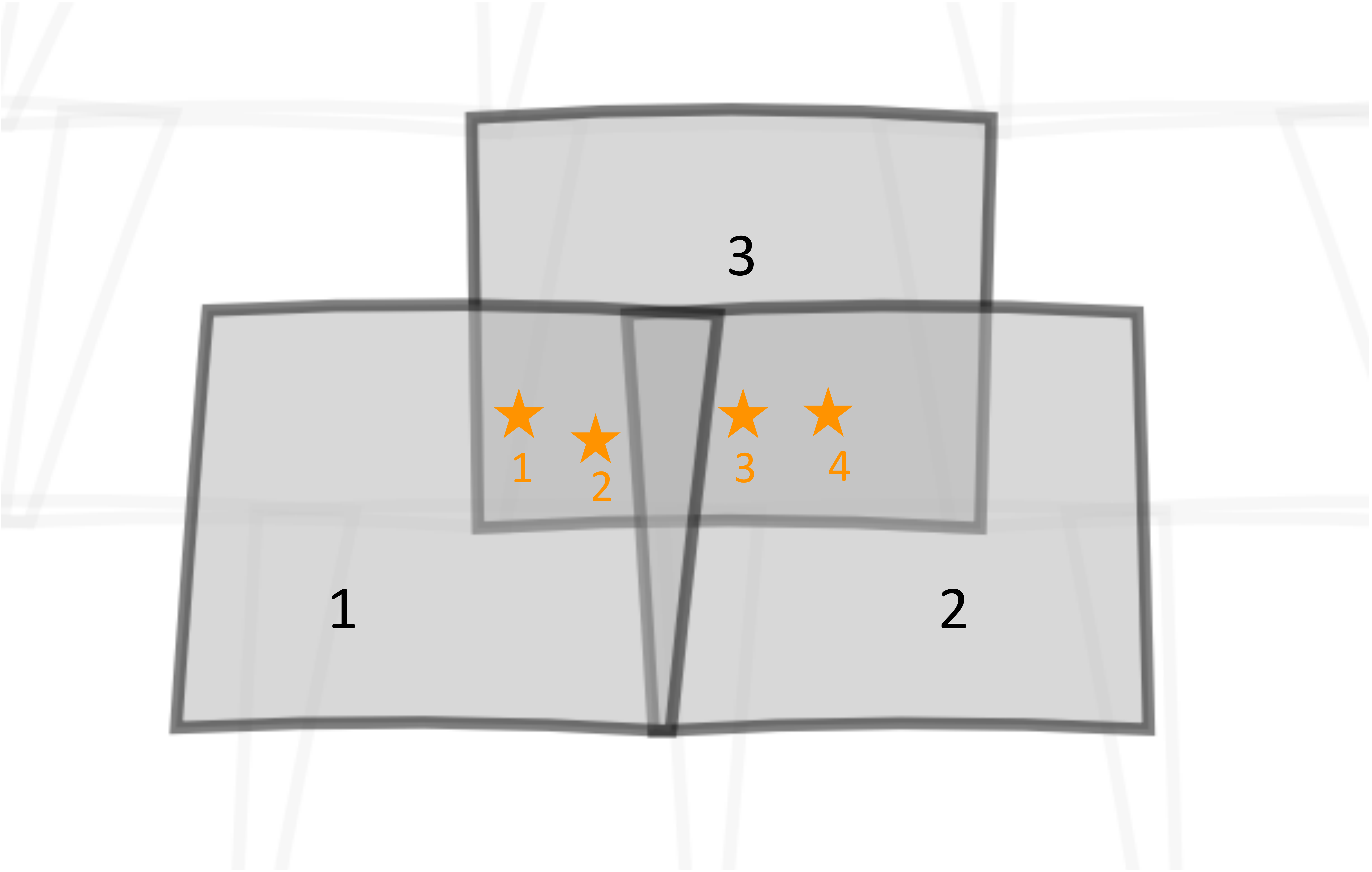


$$m_1 + 0 = m_{11}^{obs}$$

$$m_1 + \Delta ZP_2 = m_{12}^{obs}$$

Fit for relative zero points & star magnitudes

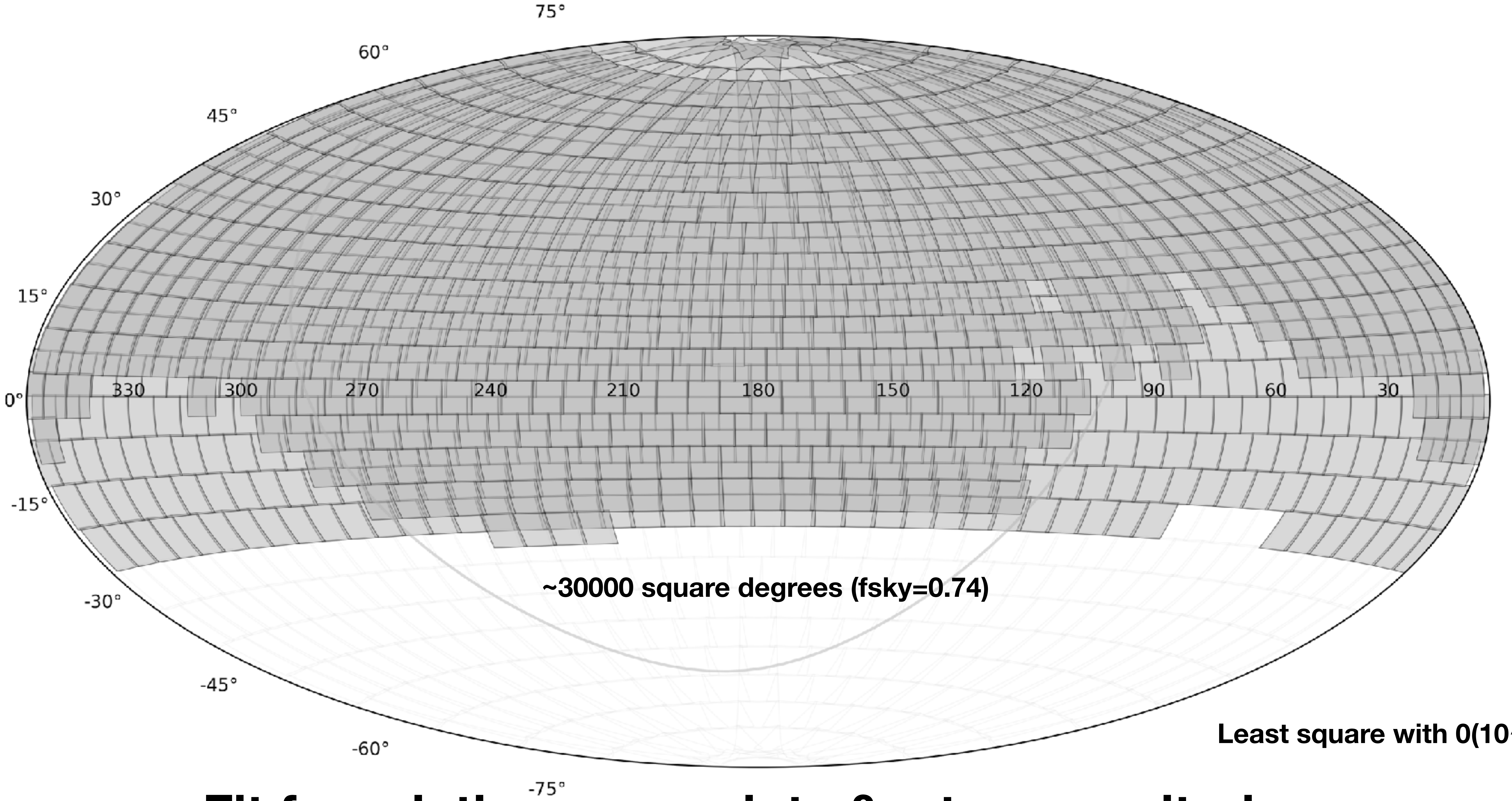
Ubercal method



$$m_1 + 0 = m_{11}^{obs}$$
$$m_2 + 0 = m_{21}^{obs}$$
$$m_3 + \Delta ZP_2 = m_{32}^{obs}$$
$$m_4 + \Delta ZP_2 = m_{42}^{obs}$$
$$m_1 + \Delta ZP_3 = m_{13}^{obs}$$
$$m_2 + \Delta ZP_3 = m_{23}^{obs}$$
$$m_3 + \Delta ZP_3 = m_{33}^{obs}$$
$$m_4 + \Delta ZP_3 = m_{43}^{obs}$$

Fit for relative zero points & star magnitudes

6 month: 2019-03 to 2019-08



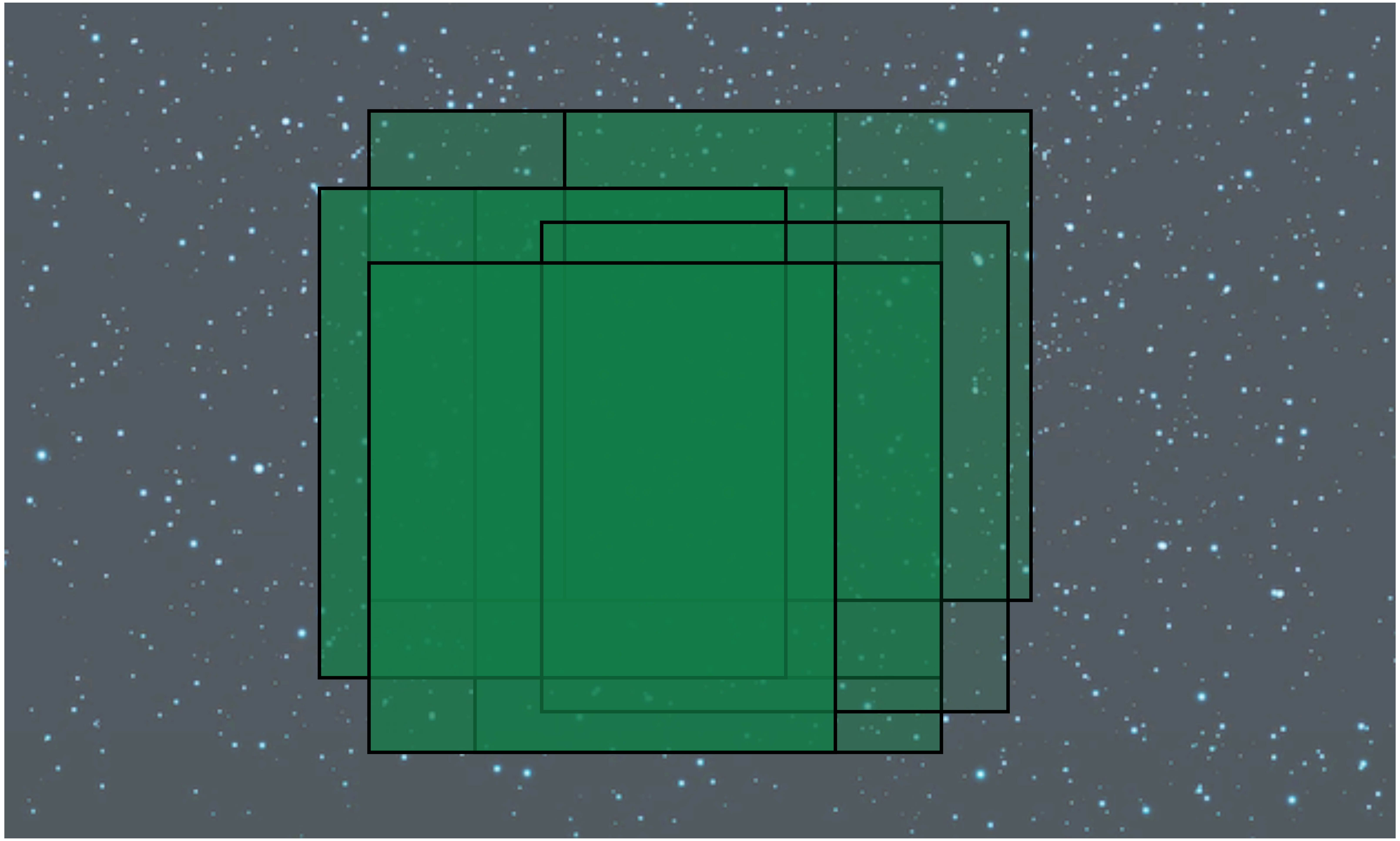
Least square with 0(10^8) lines

Fit for relative zero points & star magnitudes

Starflats (aparté)

Estelle Robert, Nicolas Regnault

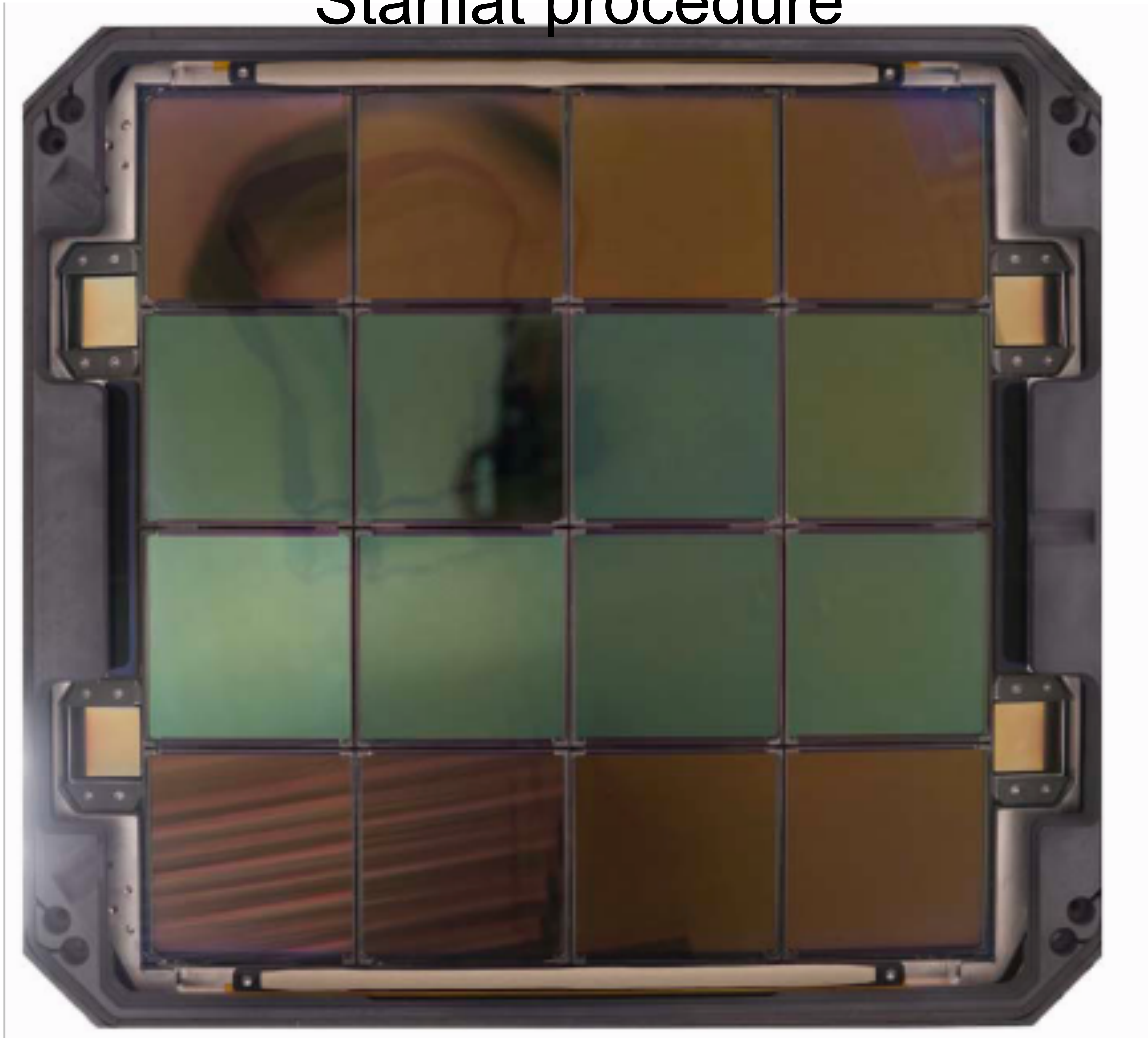
Starflat procedure



Adapted form E. Robert

Starflat procedure

We see large quadrant to quadrant gain variations



Starflat procedure

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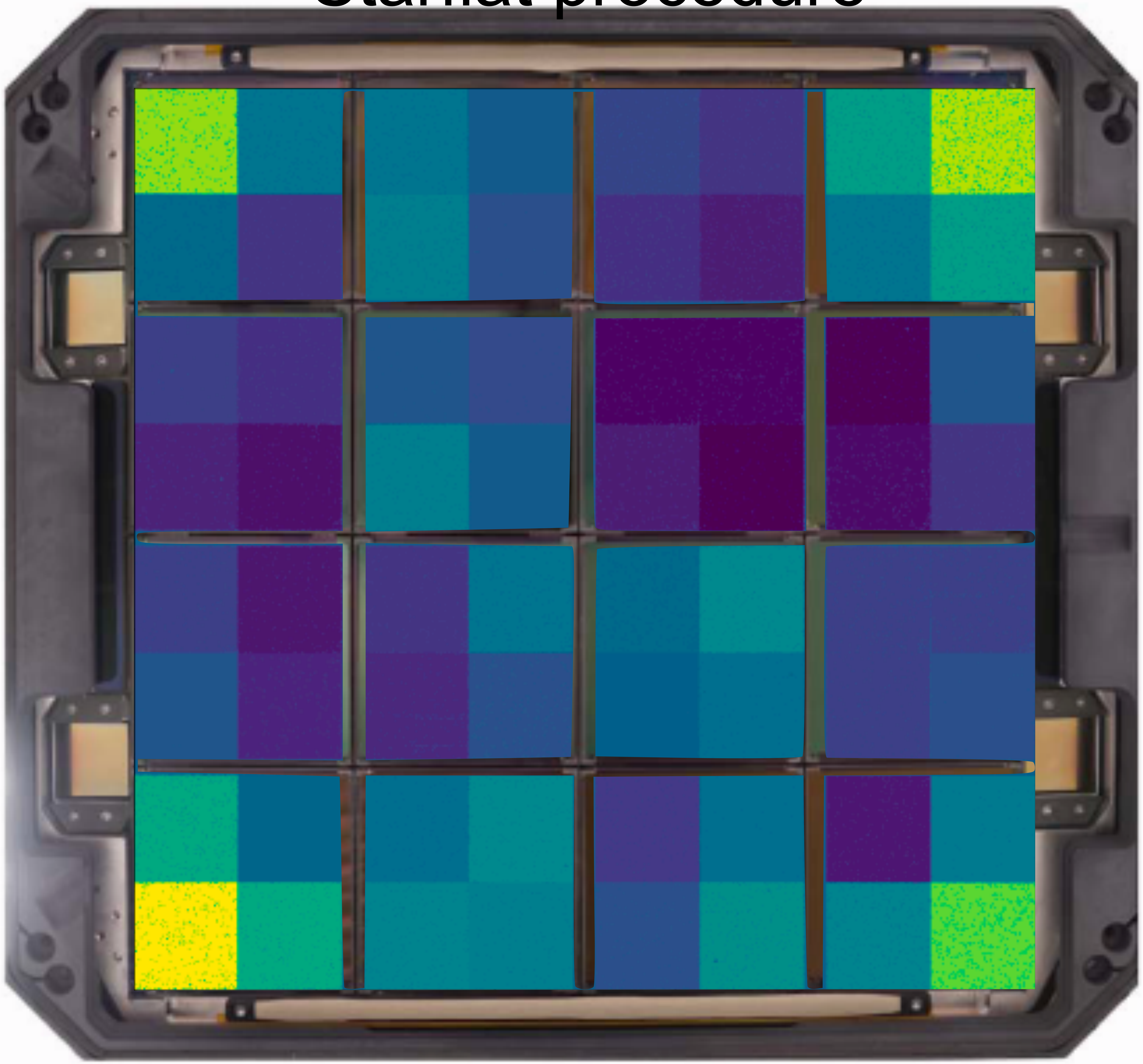
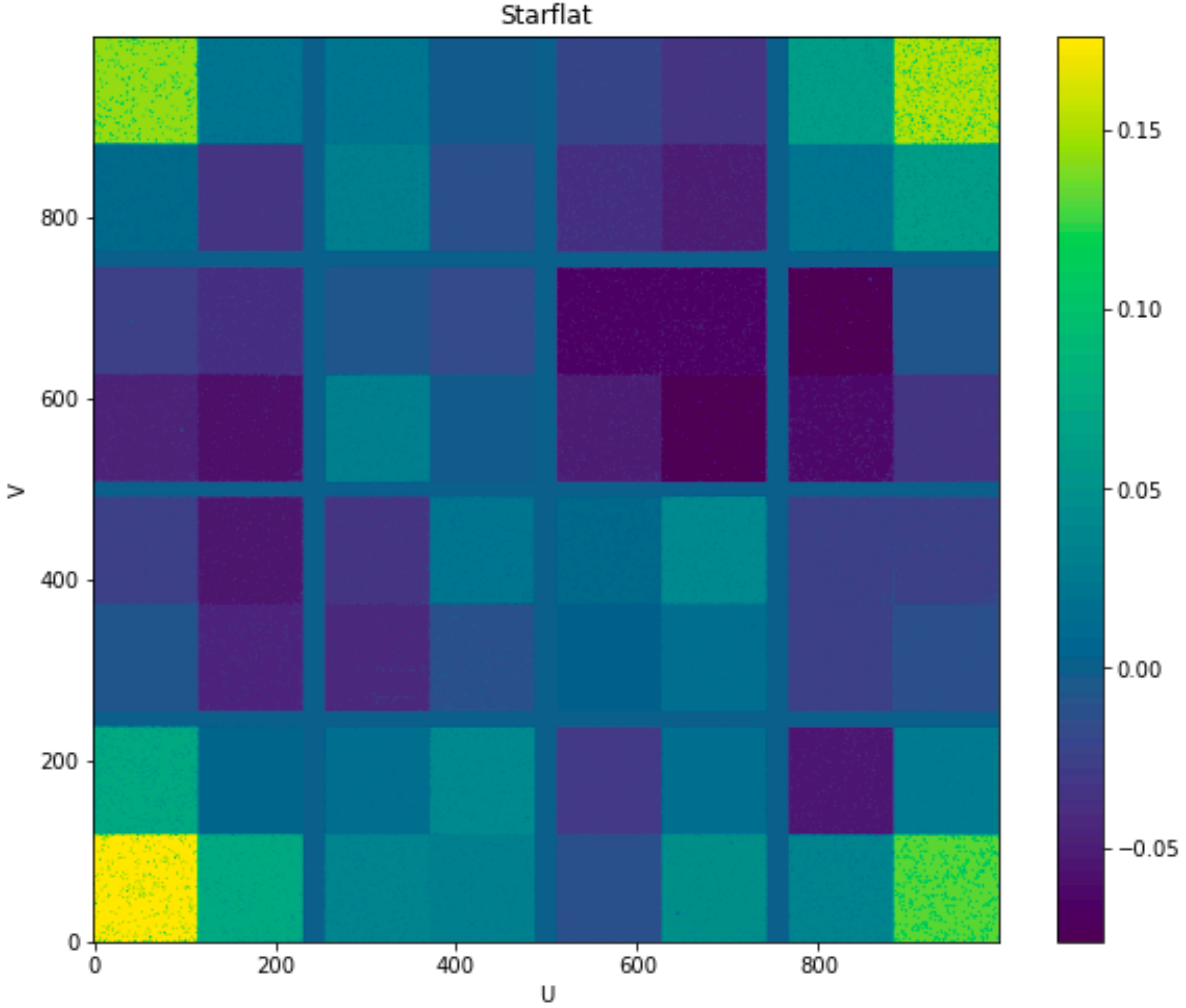


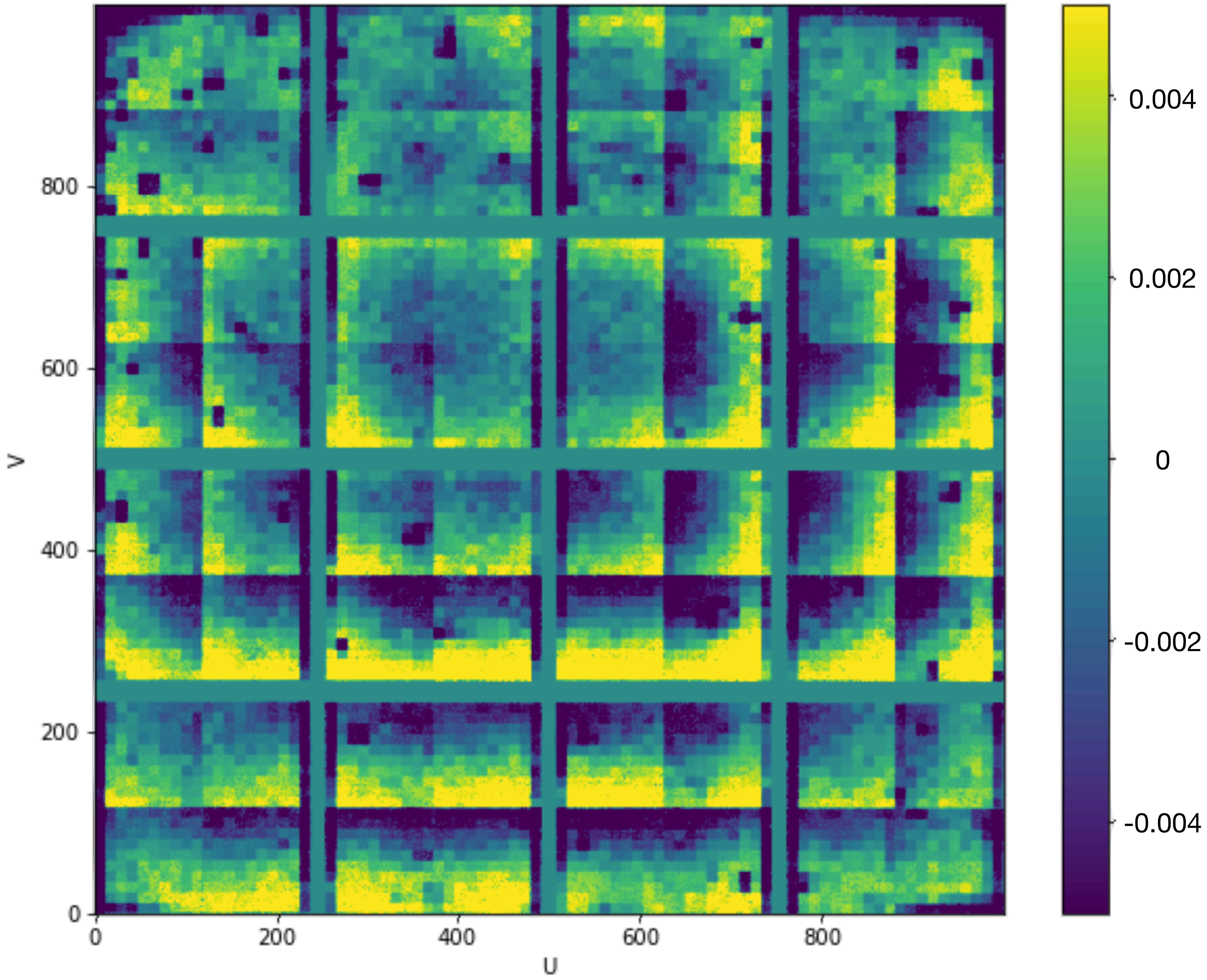
Starflat procedure



We see large quadrant to quadrant gain variations

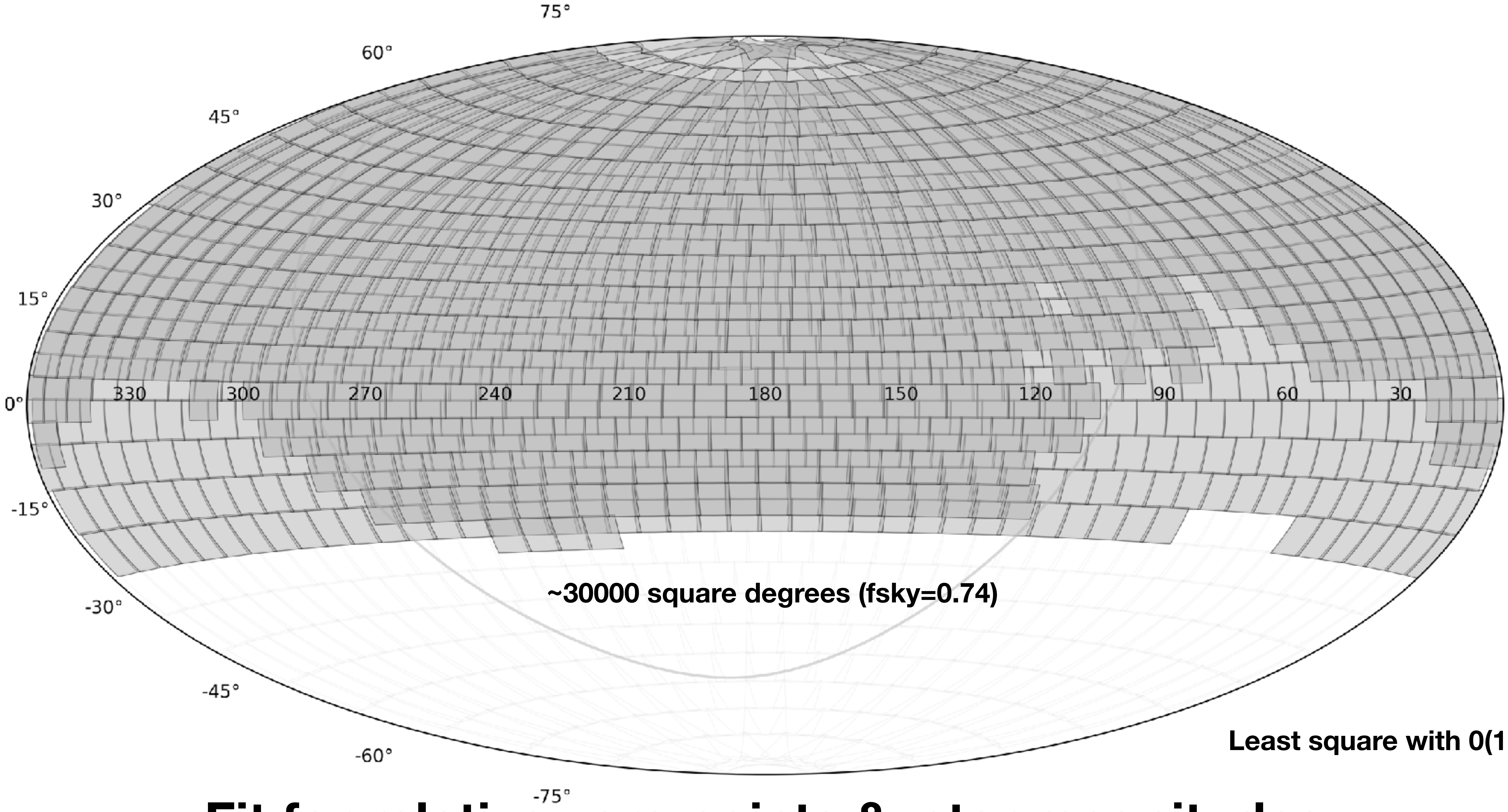
Starflat procedure

Gain subtracted



Back to ubercal

6 month: 2019-03 to 2019-08

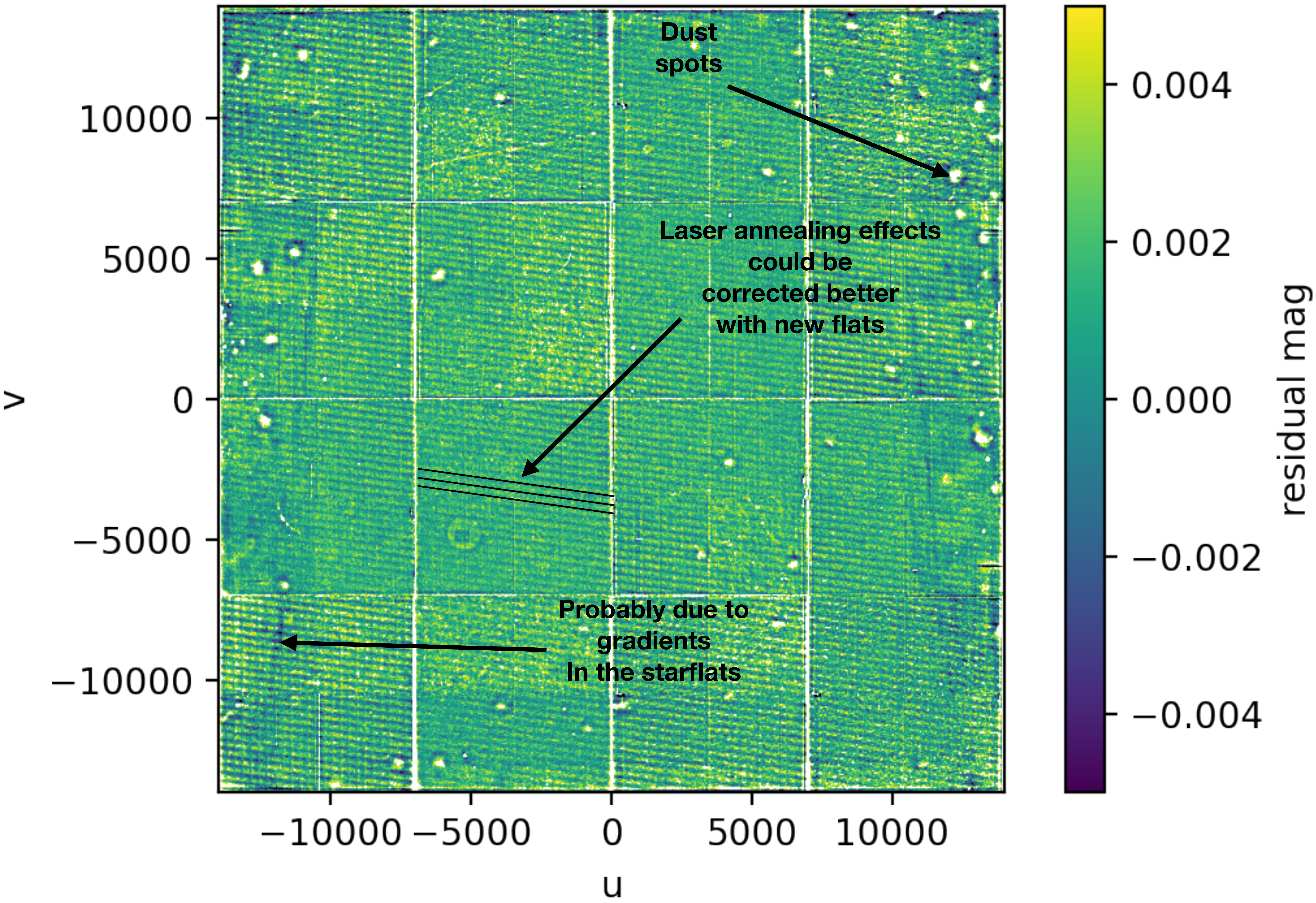


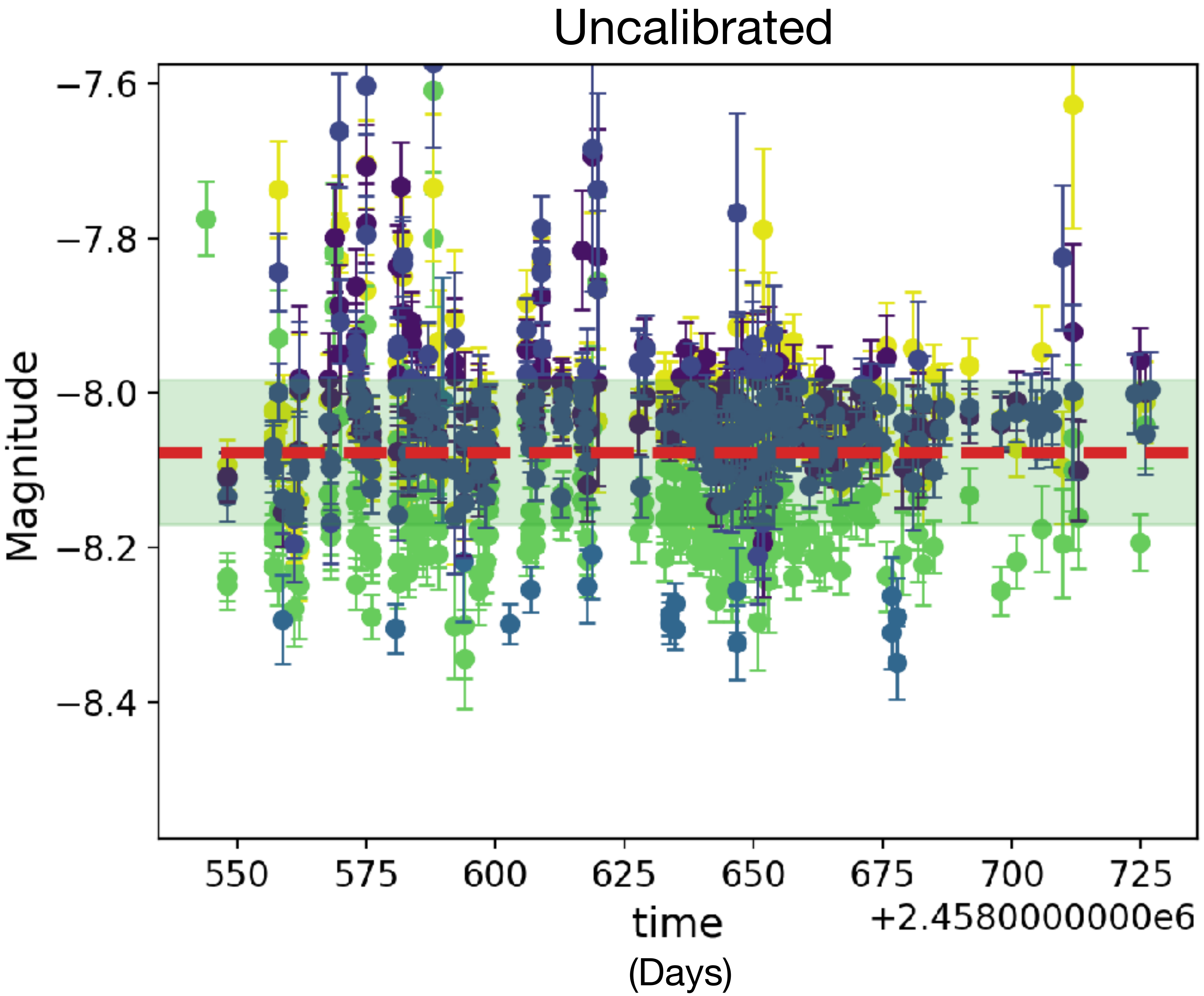
Least square with 0(10^8) lines

Fit for relative zero points & star magnitudes

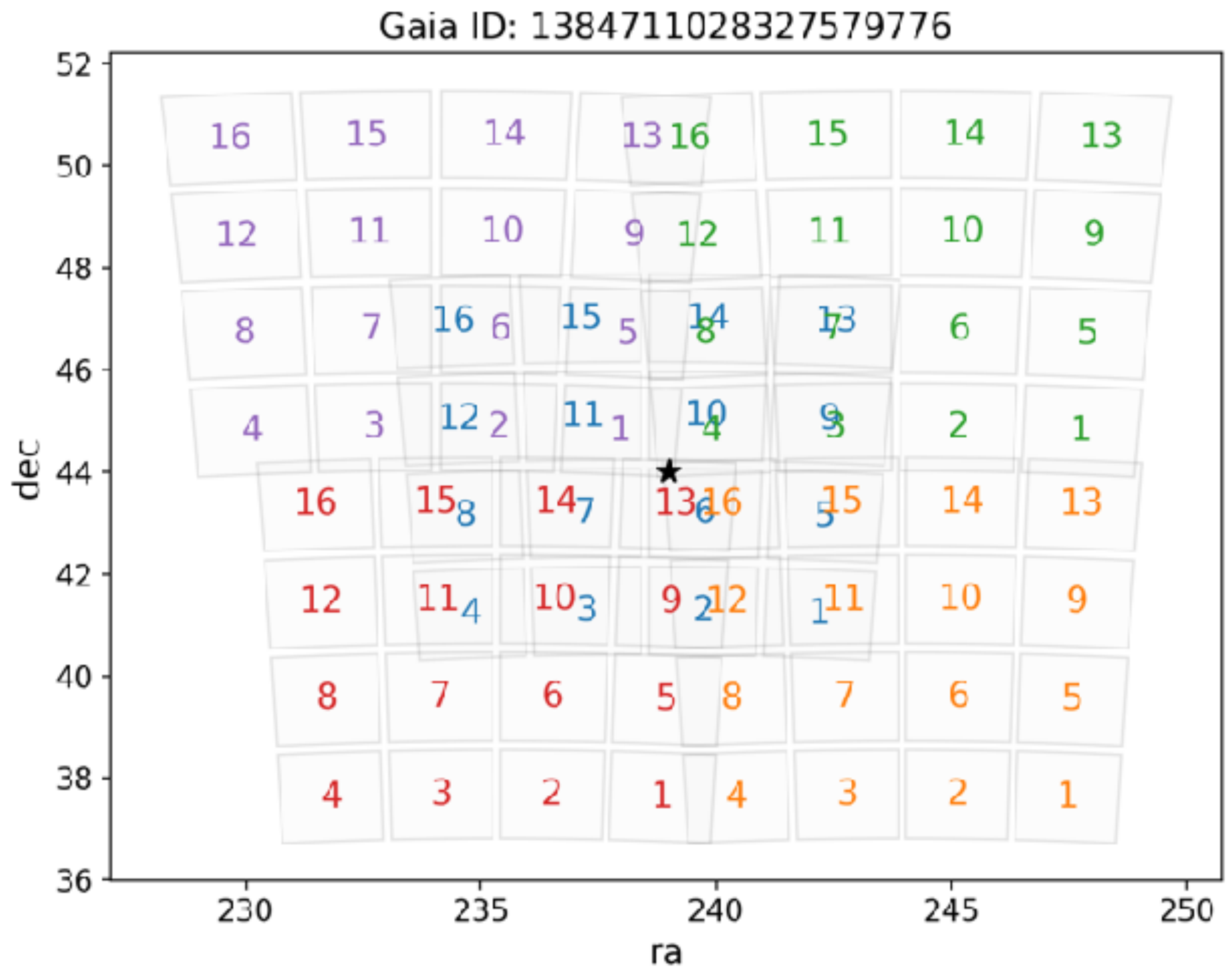
ZTF-g

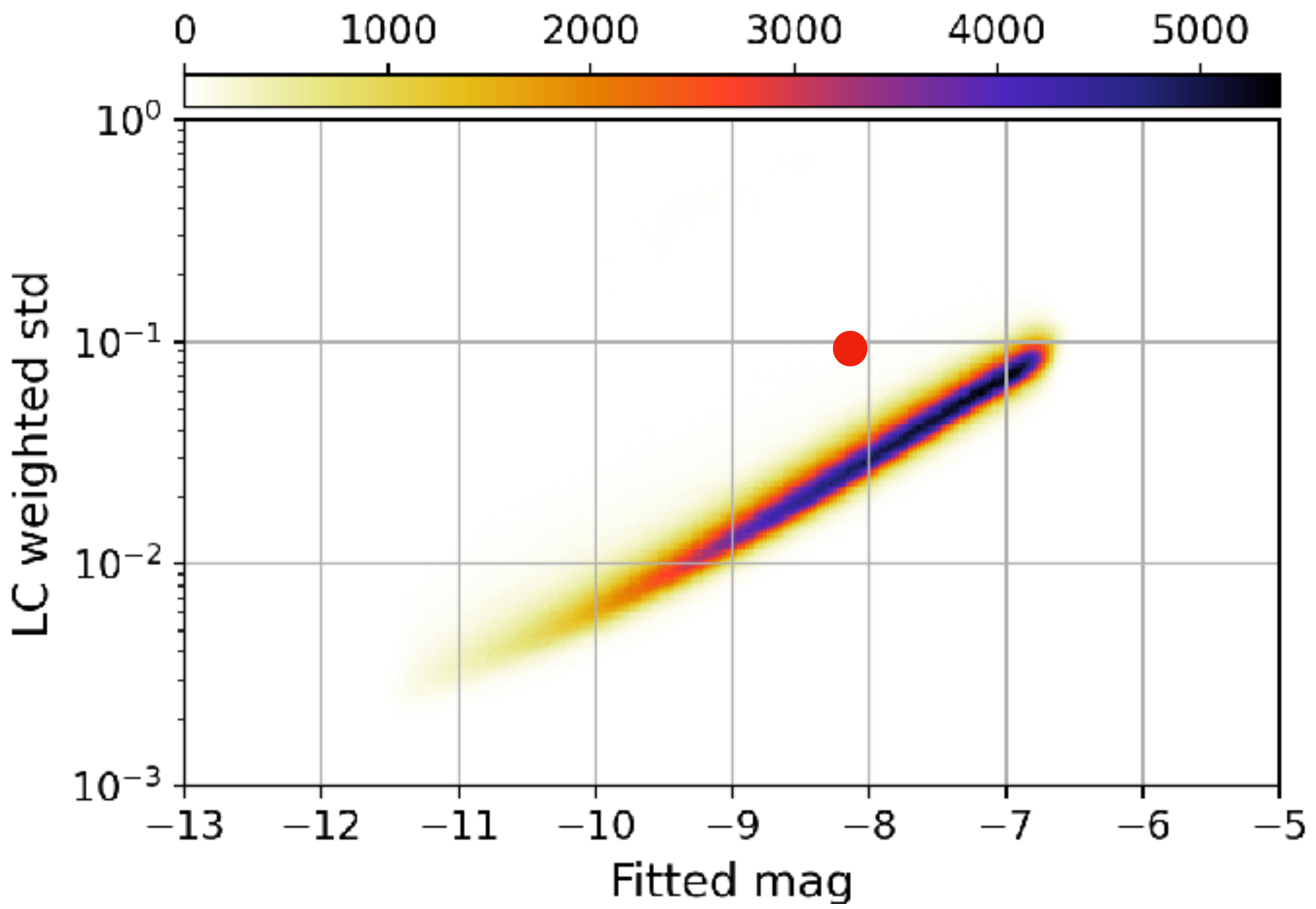
Fit
1 zero point
per quadrant
per time of exposure
(if 2nd pointing)
With starflat correction



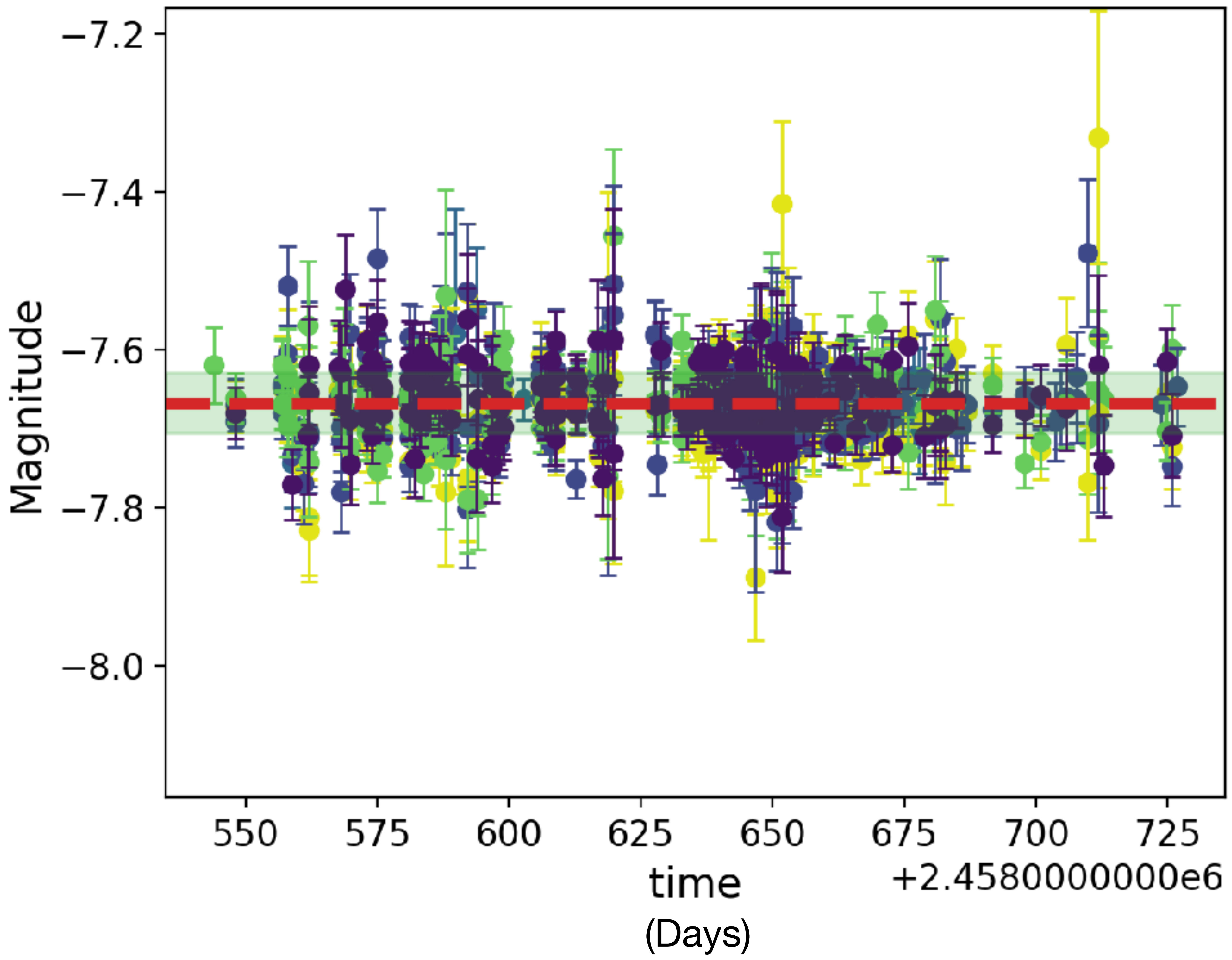

Uncalibrated
Magnitude
−7.6
−7.8
−8.0
−8.2
−8.4
550
575
600
625
650
675
700
725
time
+2.4580000000e6
(Days)

std=0.093

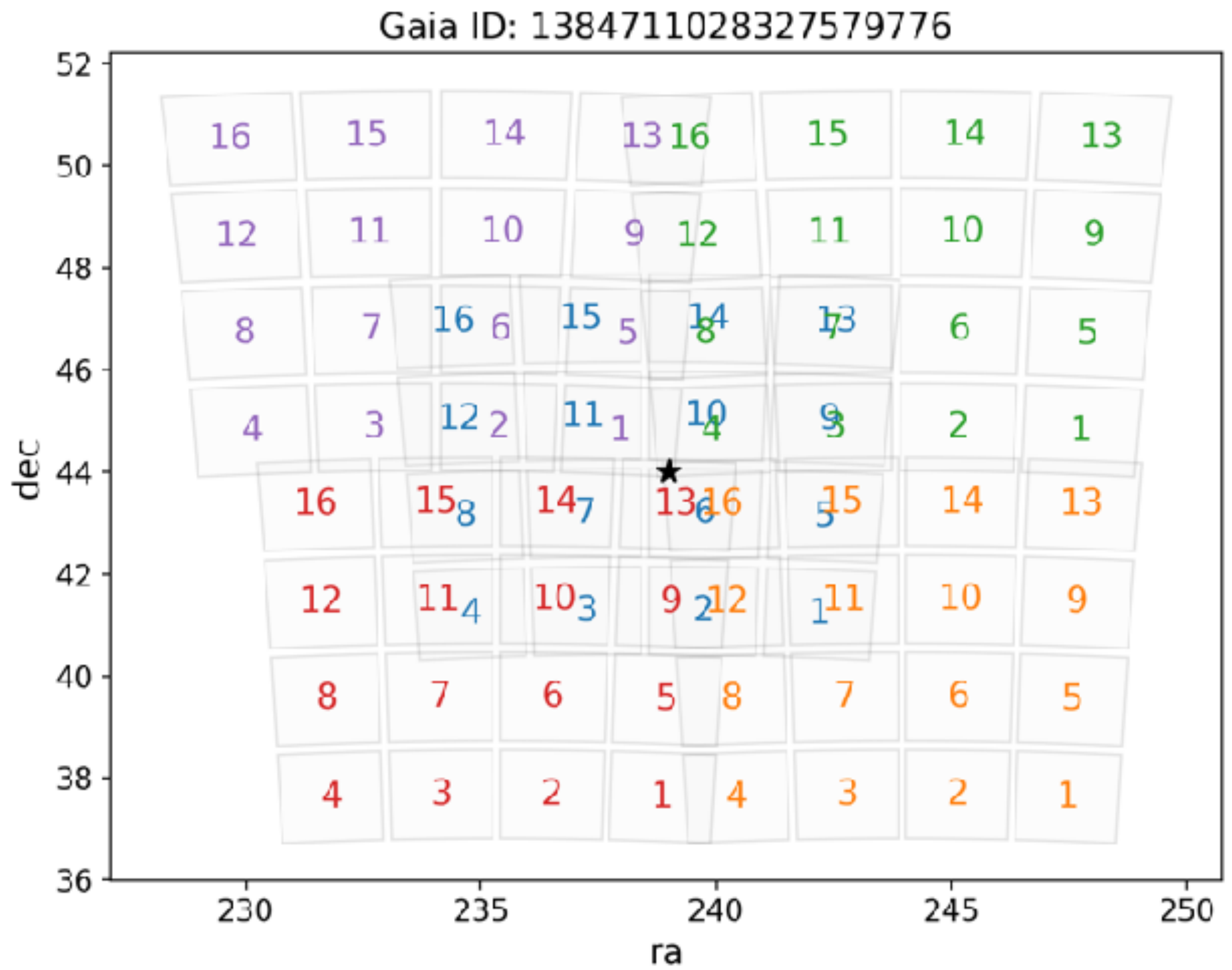

Gaia ID: 1384711028327579776
dec
ra
52
50
48
46
44
42
40
38
36
230
235
240
245
250

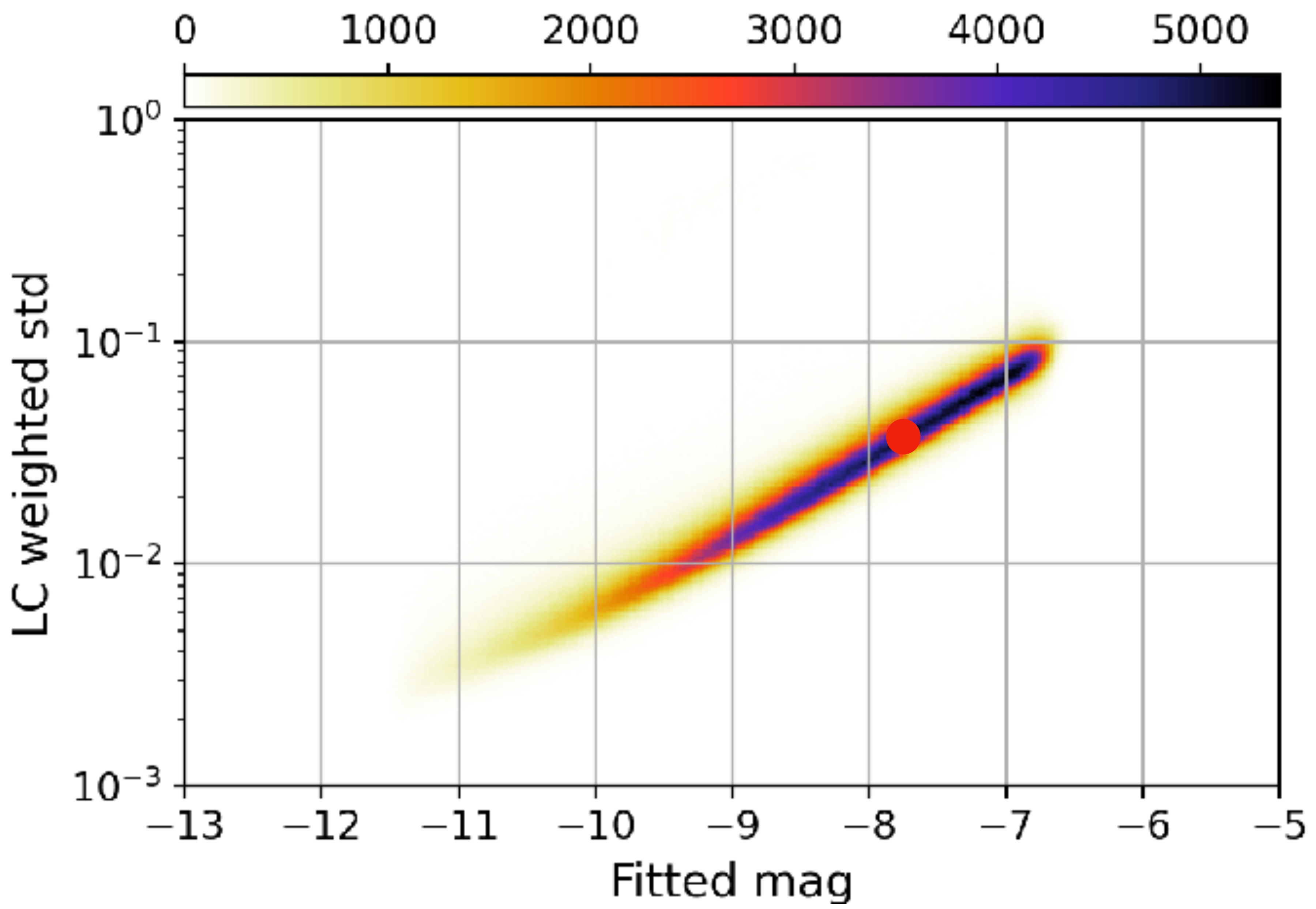

0
1000
2000
3000
4000
5000
LC weighted std
Fitted mag
10^0
10^{-1}
10^{-2}
10^{-3}
−13
−12
−11
−10
−9
−8
−7
−6
−5

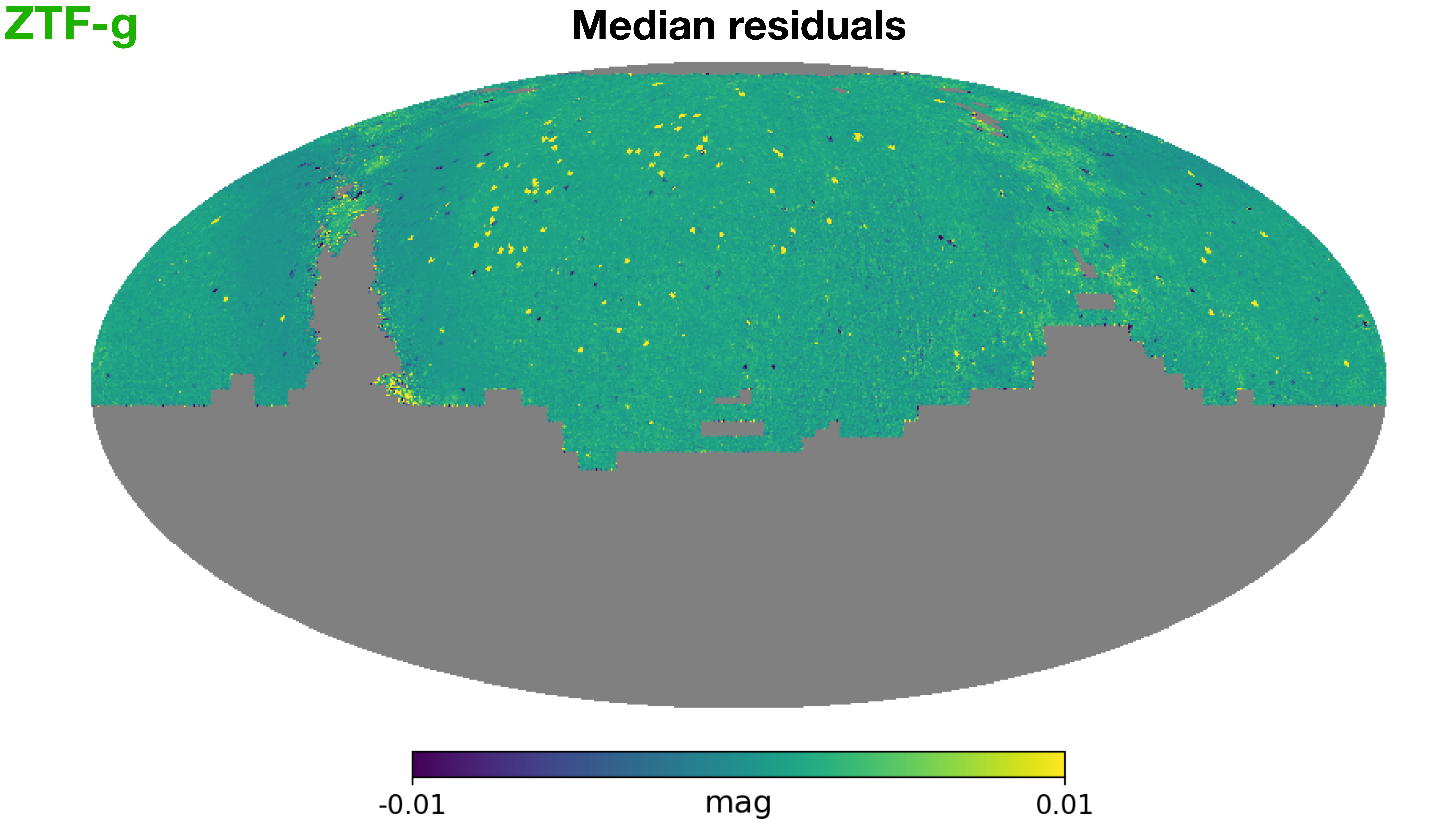
Ubercal with 1 ZP per quadrant + starflats



std=0.0383





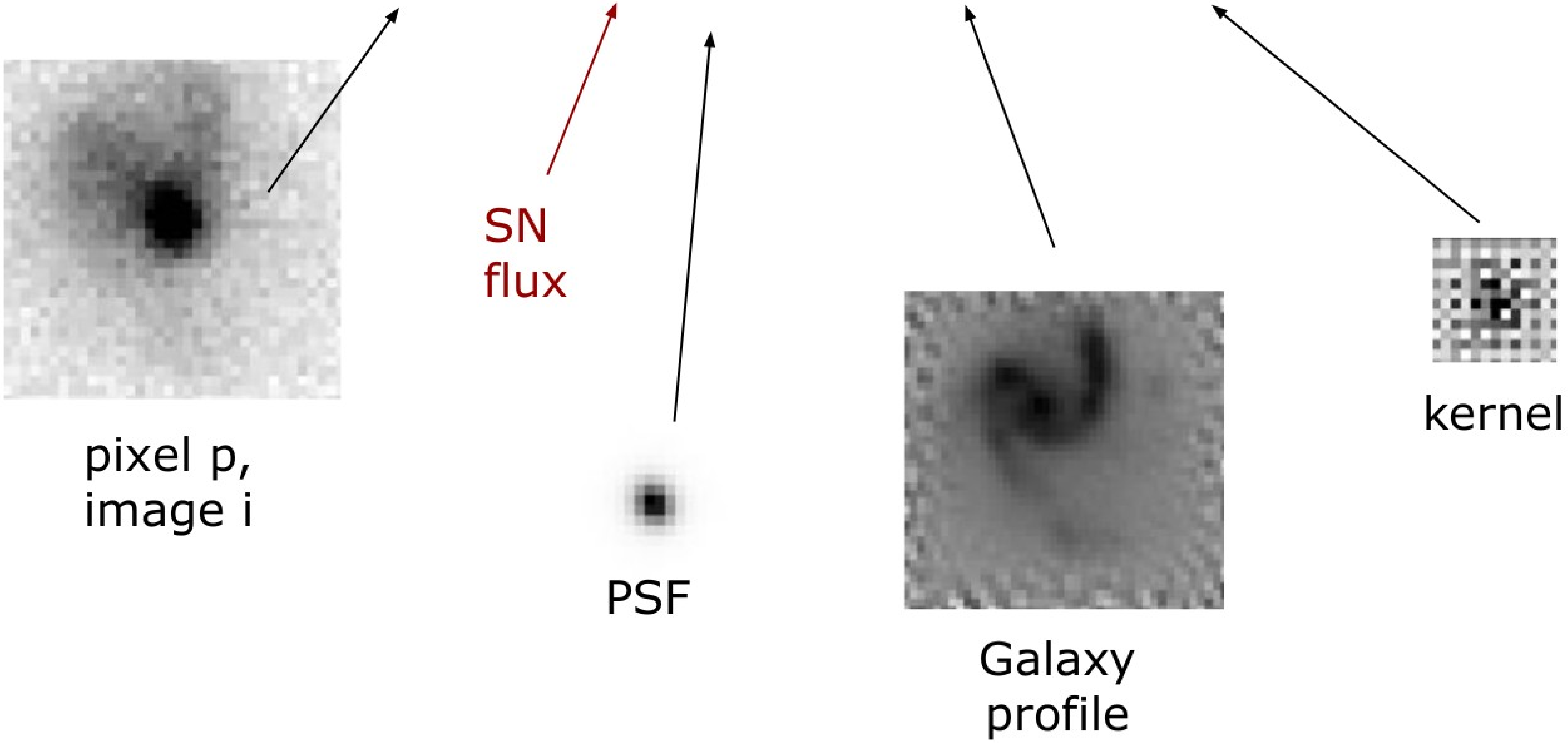

ZTF-g
Median residuals
-0.01
mag
0.01

Scene modeling

Leander Lacroix, Nicolas Regnault

Scene modeling

$$I_i = f_i P_i + \mathrm{Gal} \otimes K_i$$



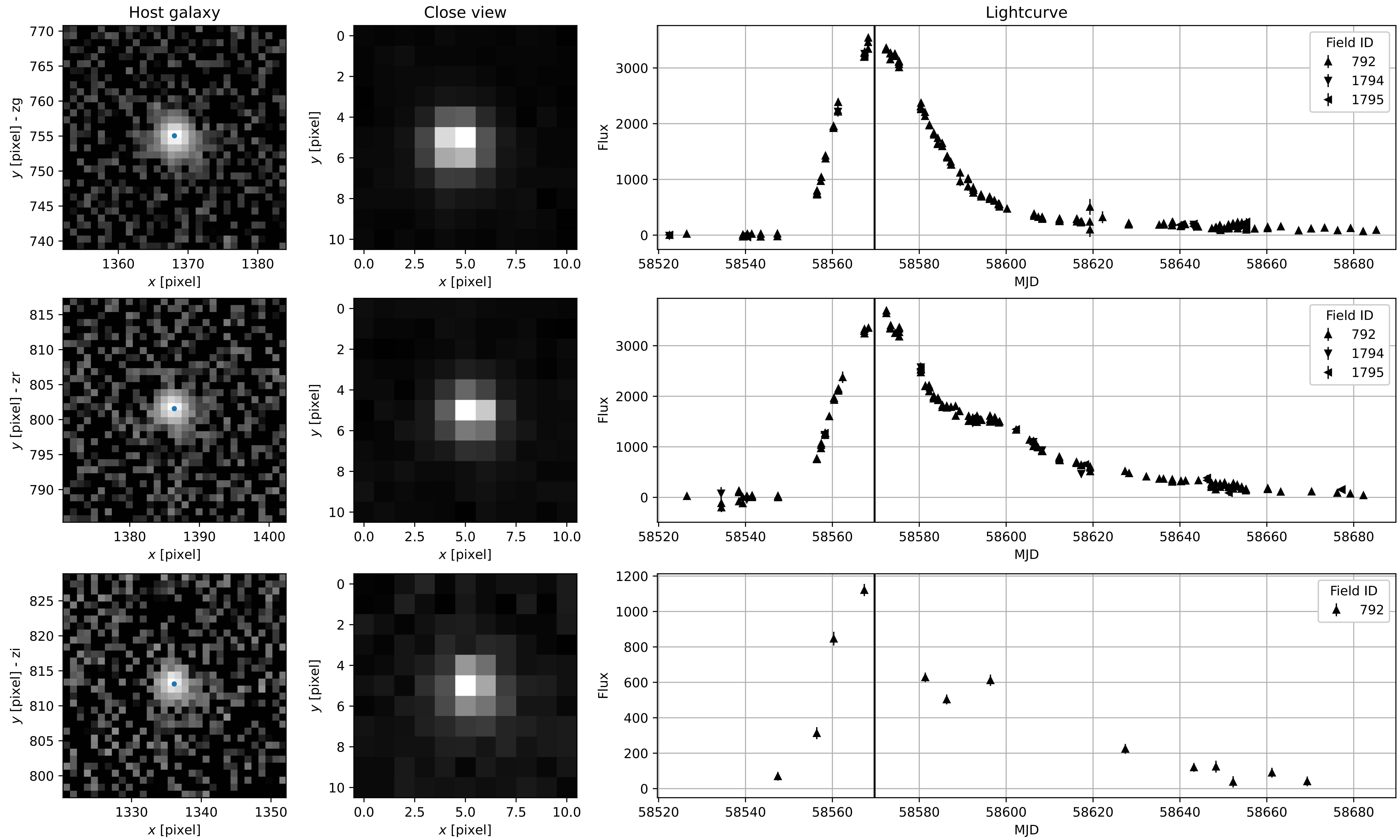
Scene modeling

$$I_{i,p} = \alpha_i P_i(x_p - \varphi_i(x_{\mathrm{SN}}))f_i + \alpha_i G_p(\varphi_i^{-1}(x_p)) \otimes K_i$$

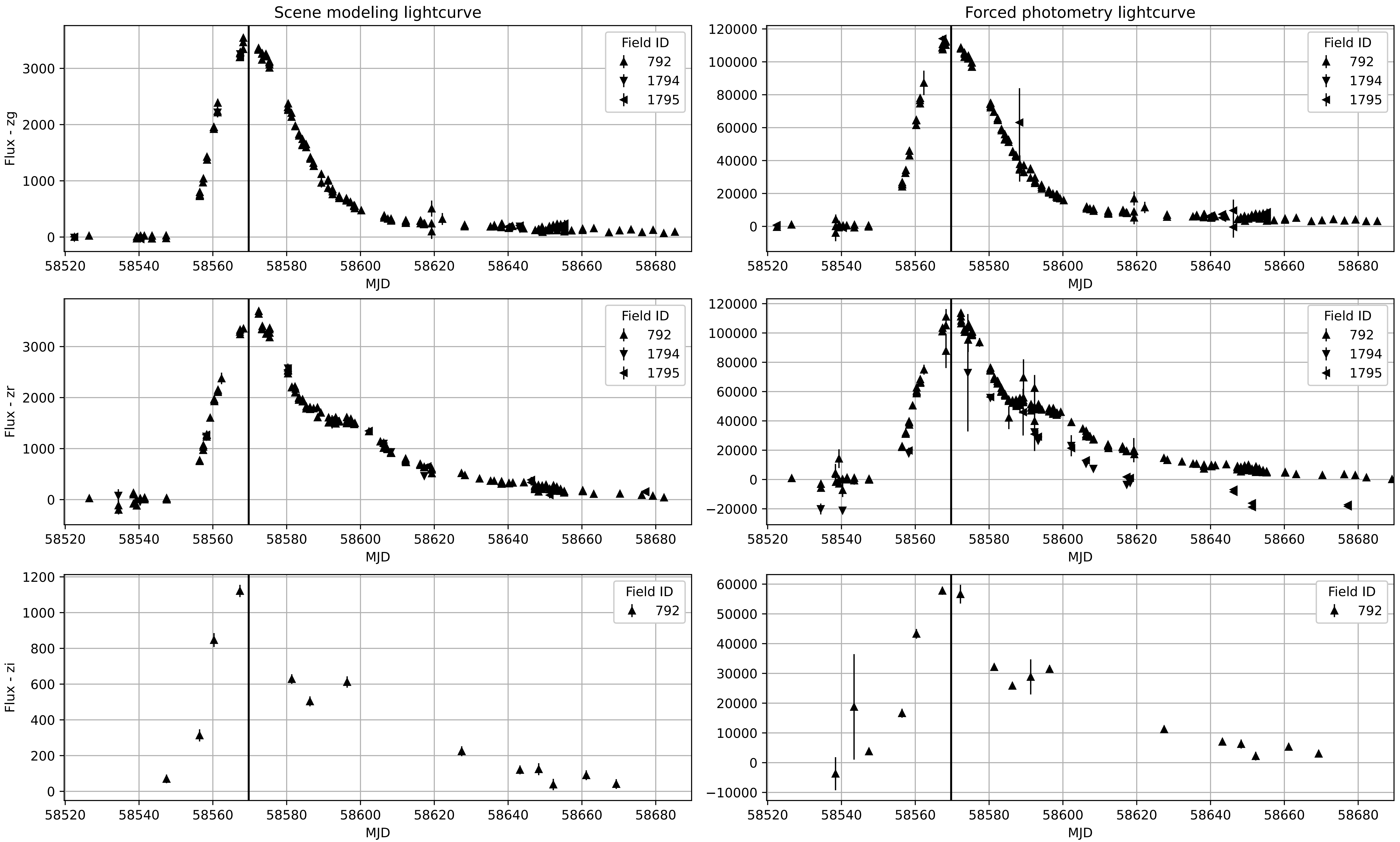
- Fit by Least Square

$$V = \begin{pmatrix} f_1 & \dots & f_n & x_{\mathrm{SN},1} & x_{\mathrm{SN},2} & G_1 & \dots & G_N \end{pmatrix}$$

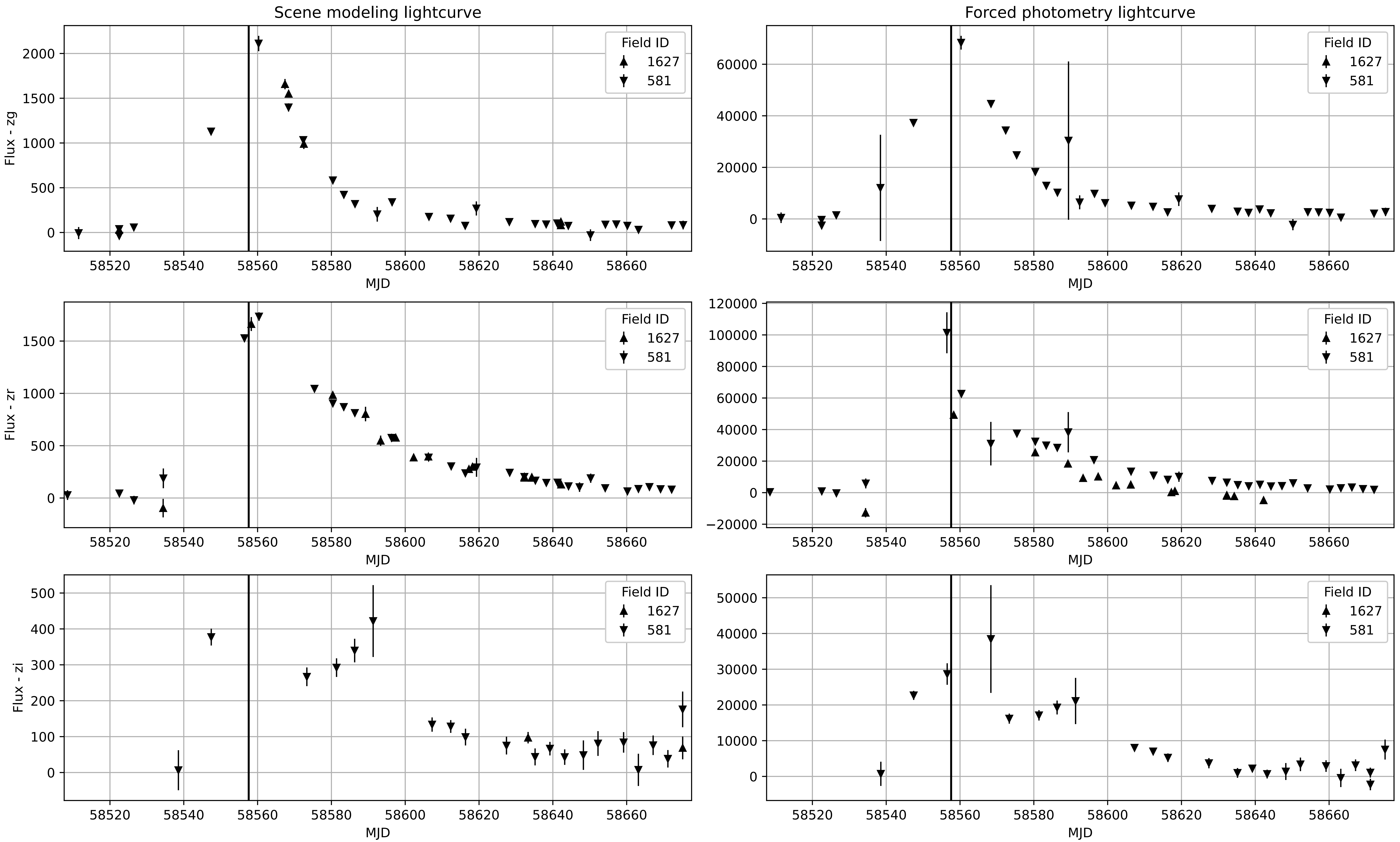
ZTF19aamhhae



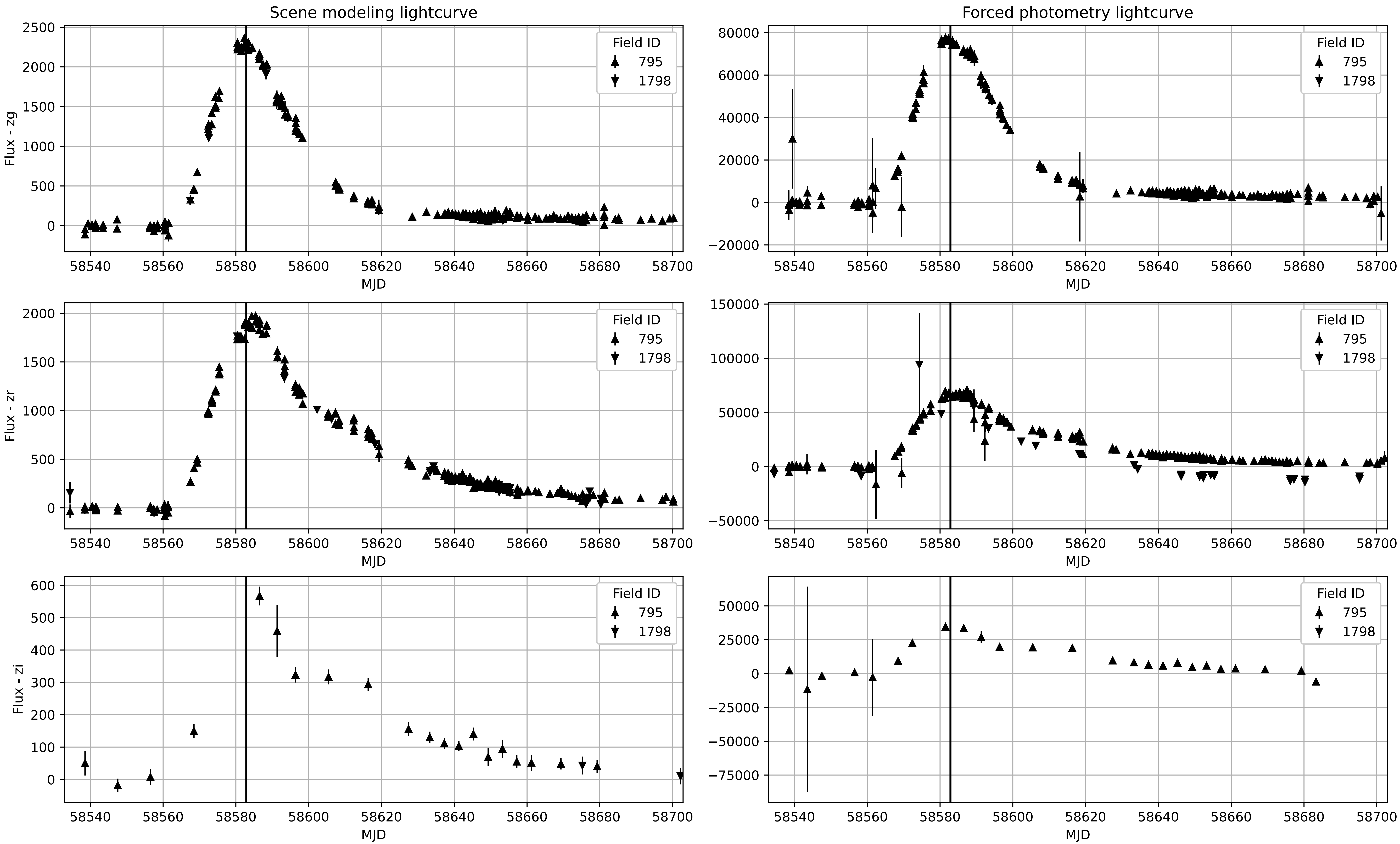
ZTF19aamhhae



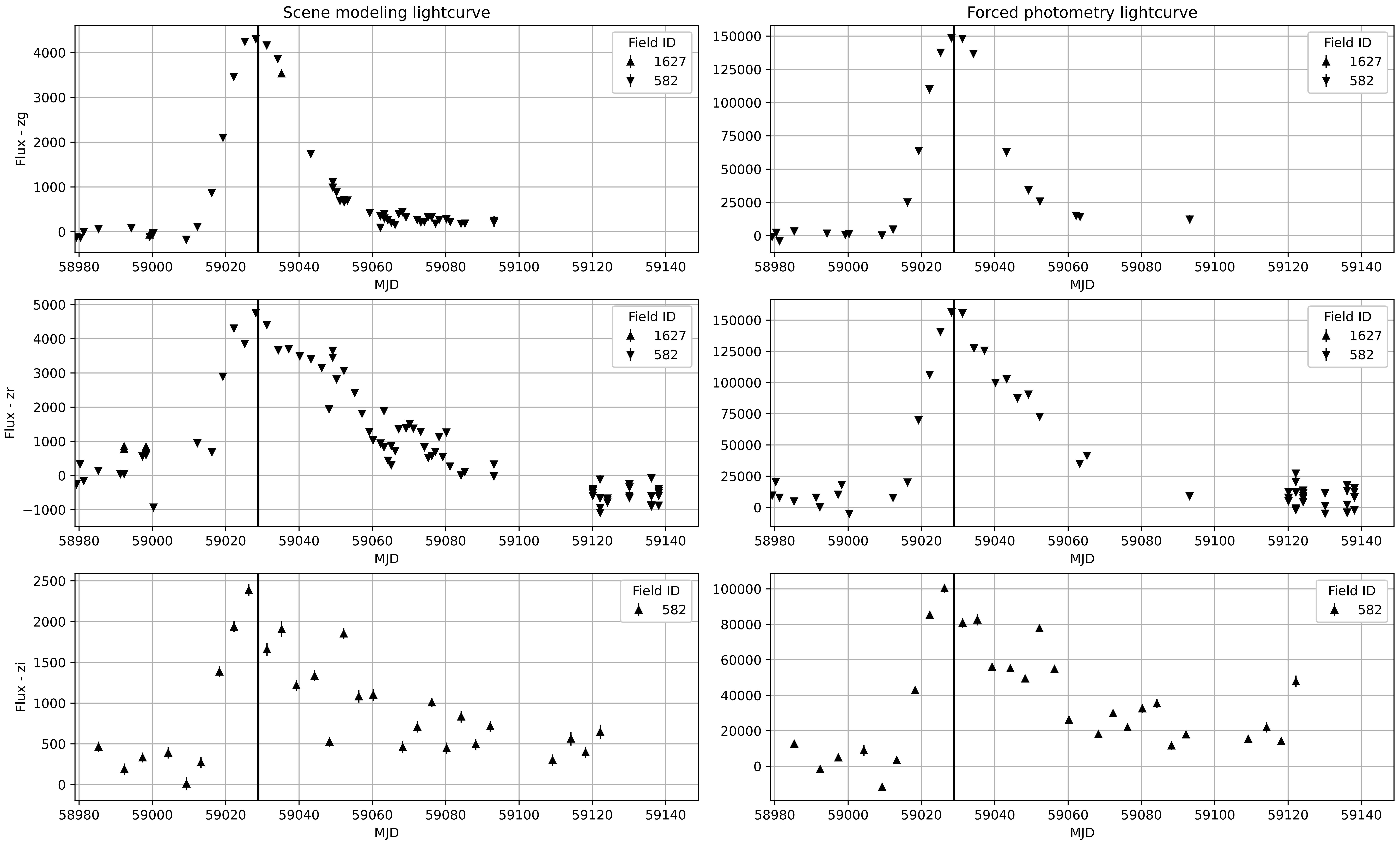
ZTF19aalzmmt

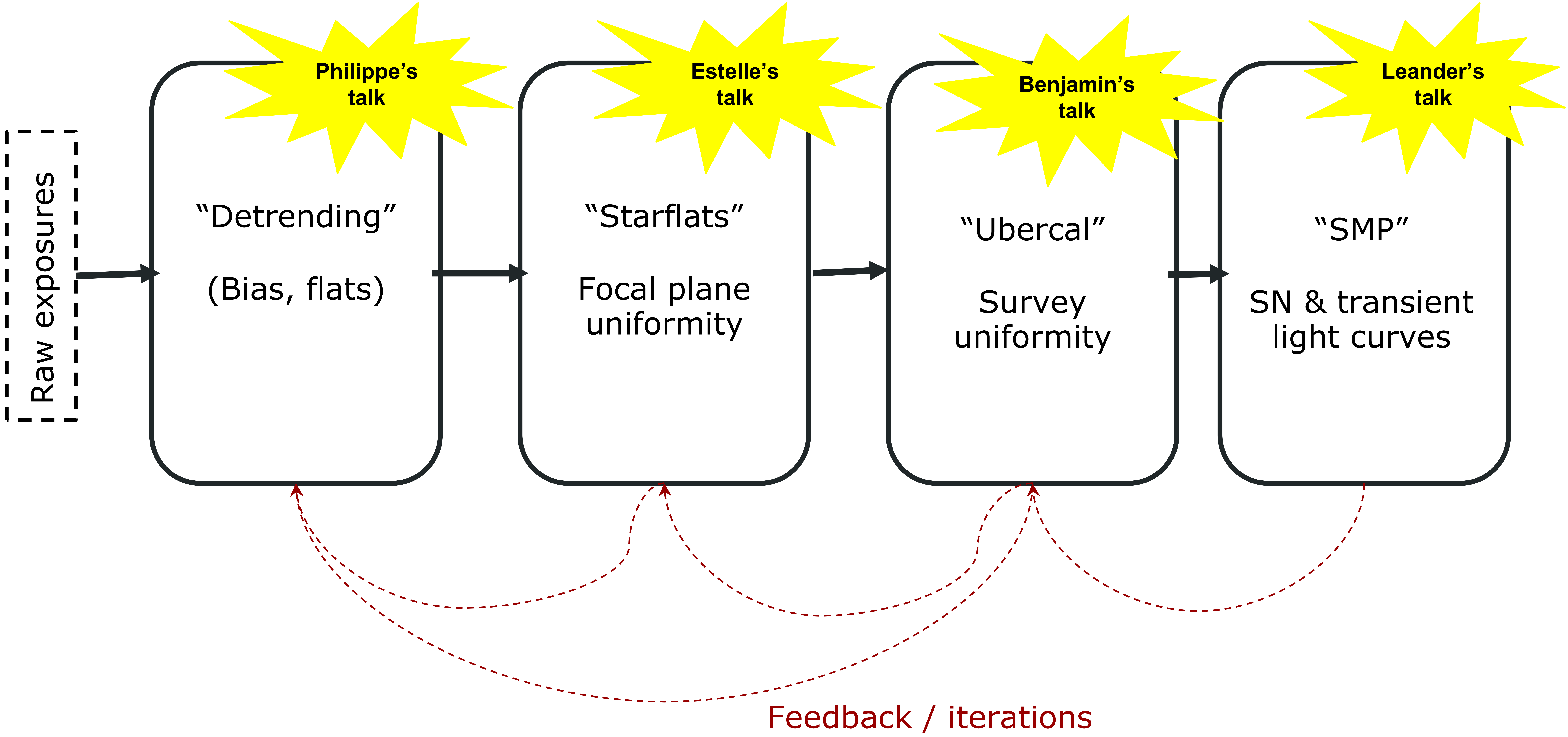


ZTF19aanircs



ZTF19aamdmcs




Raw exposures
Philippe's talk
"Detrending"
(Bias, flats)
Estelle's talk
"Starflats"
Focal plane uniformity
Benjamin's talk
"Ubercal"
Survey uniformity
Leander's talk
"SMP"
SN & transient light curves
Feedback / iterations