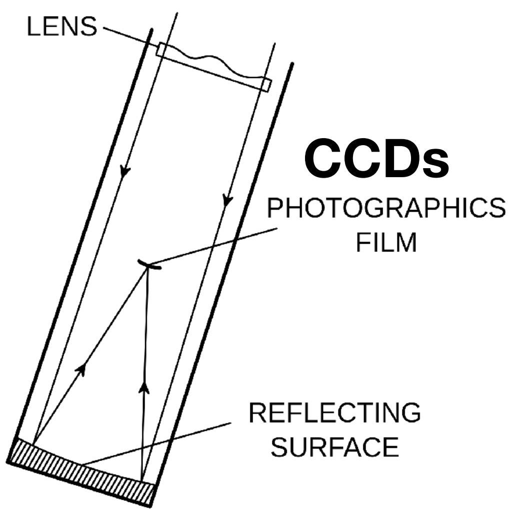
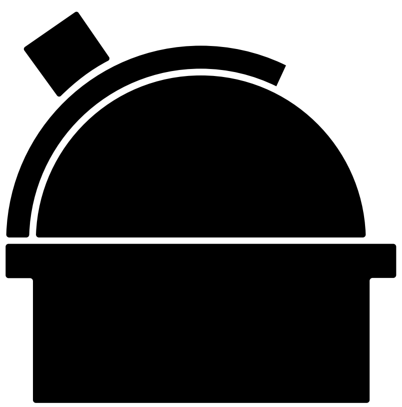
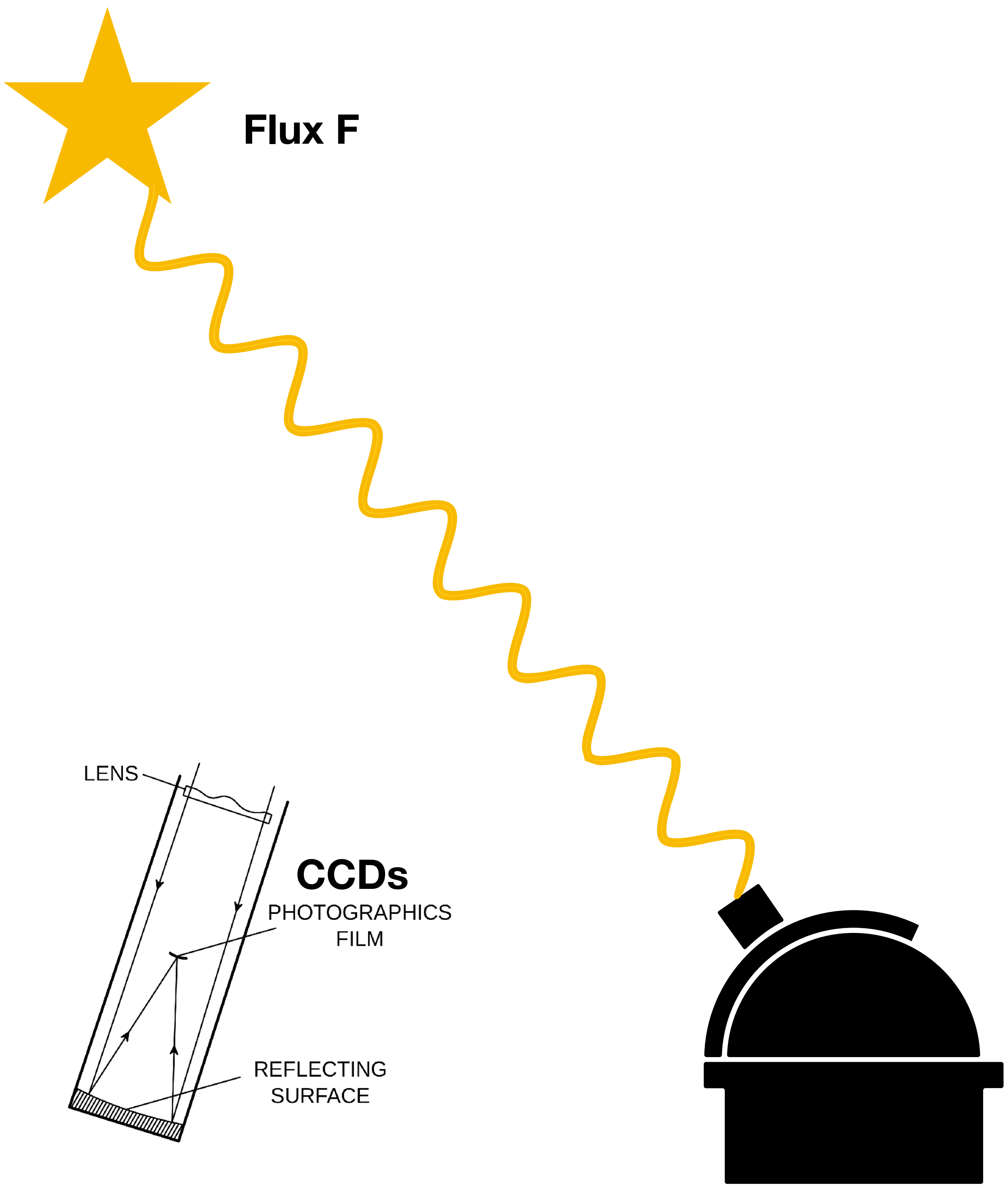
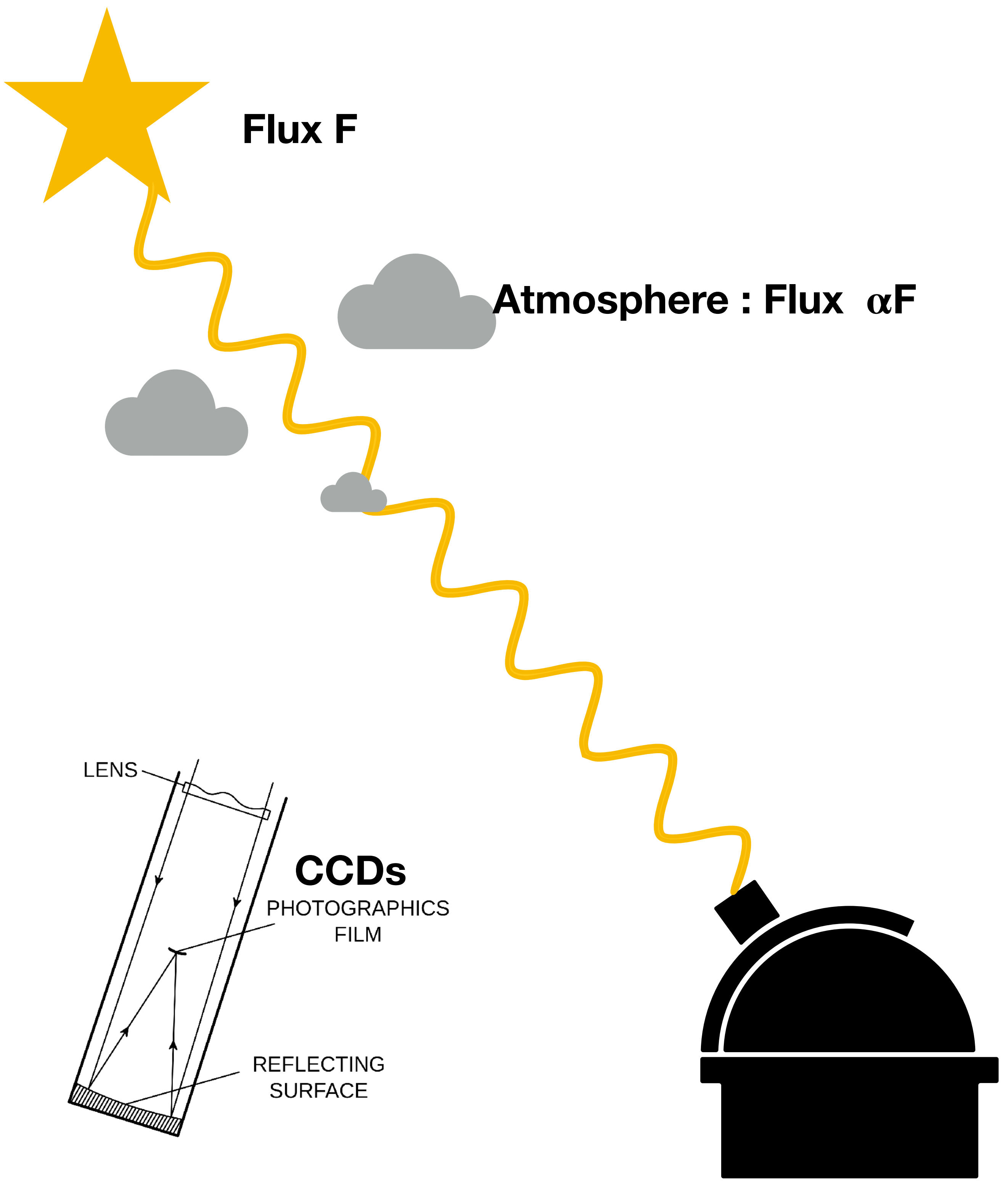
Flux F



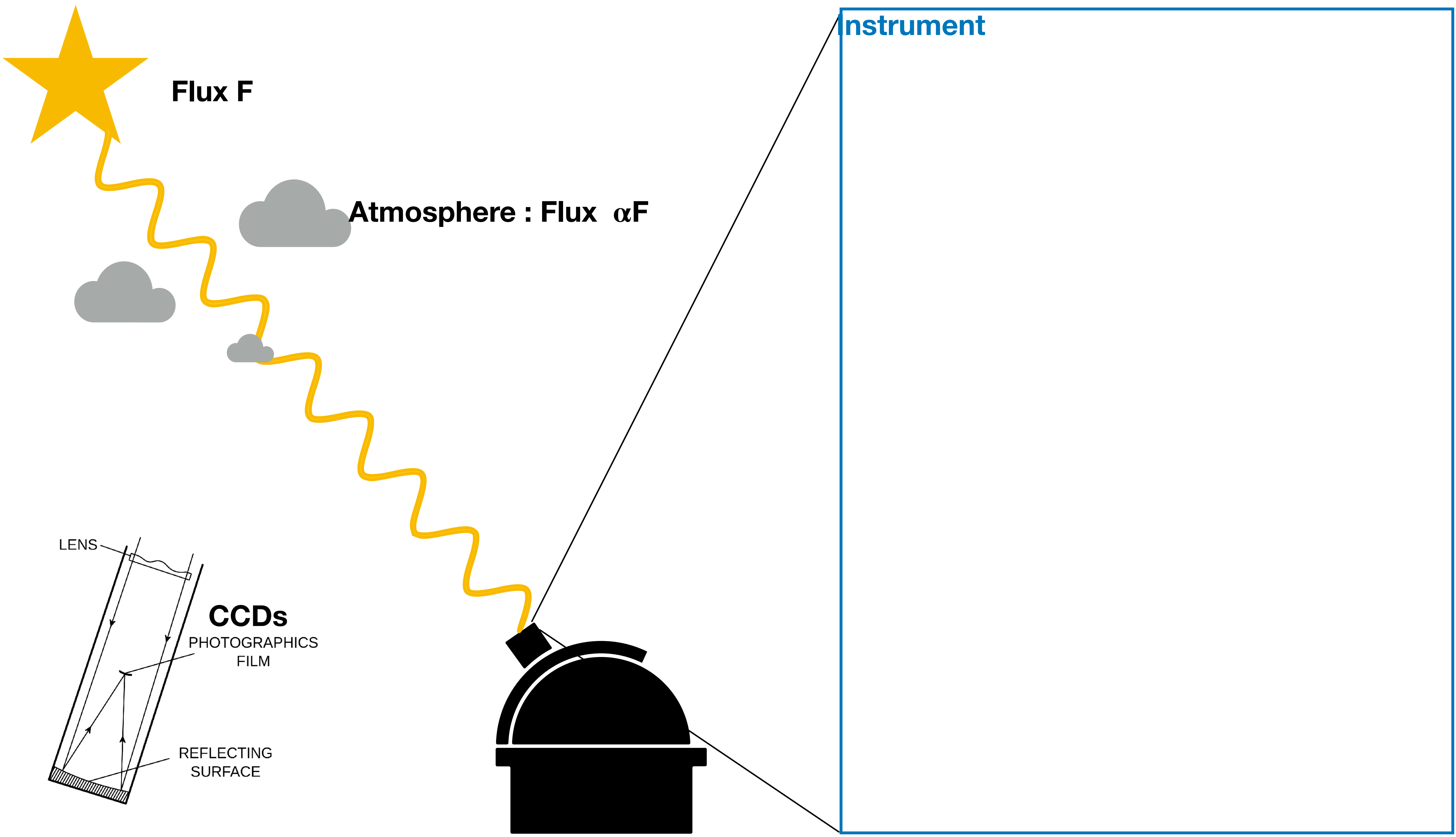
CCDs



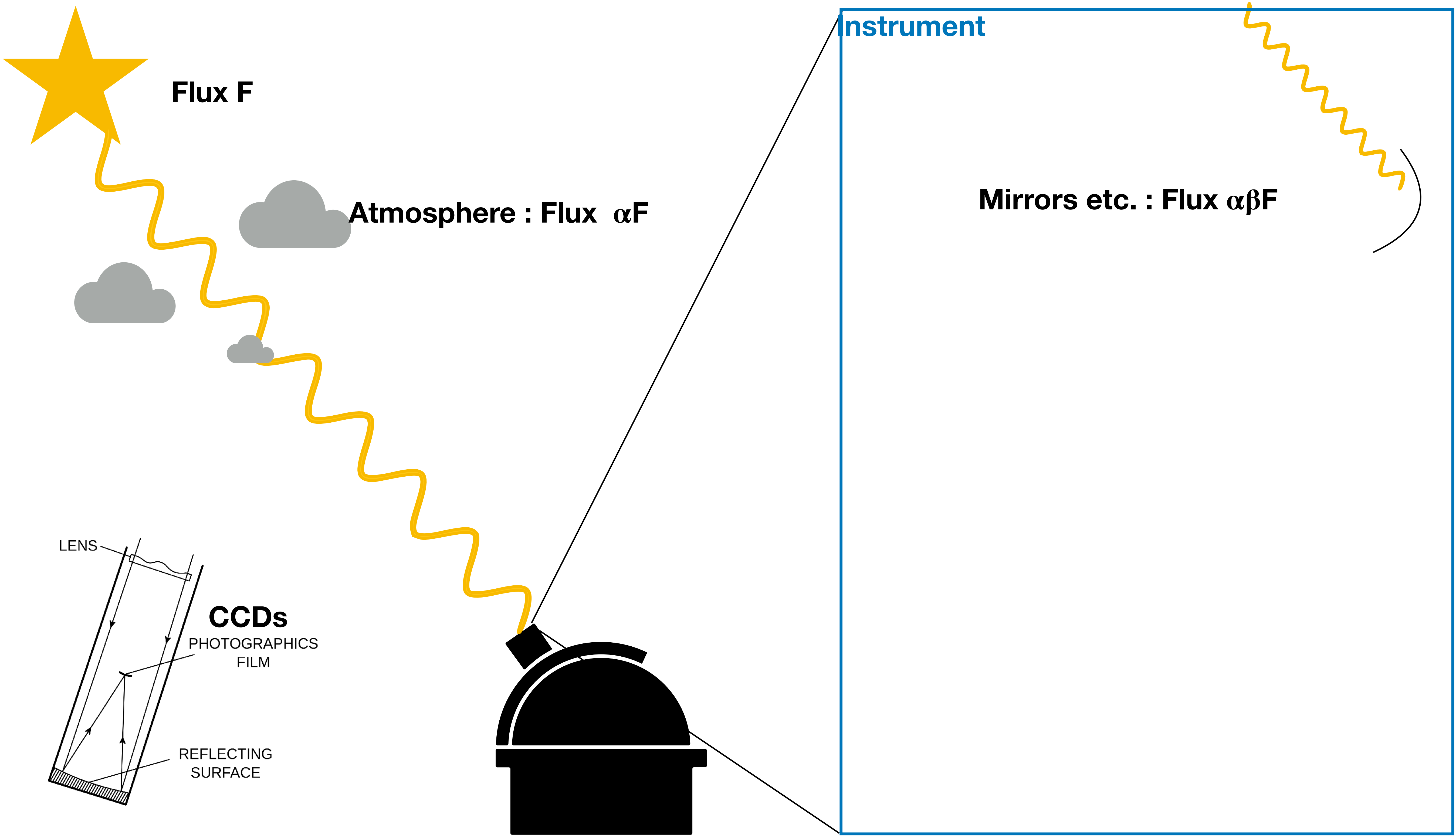

Flux F
LENS
CCDs
PHOTOGRAPHICS FILM
REFLECTING SURFACE

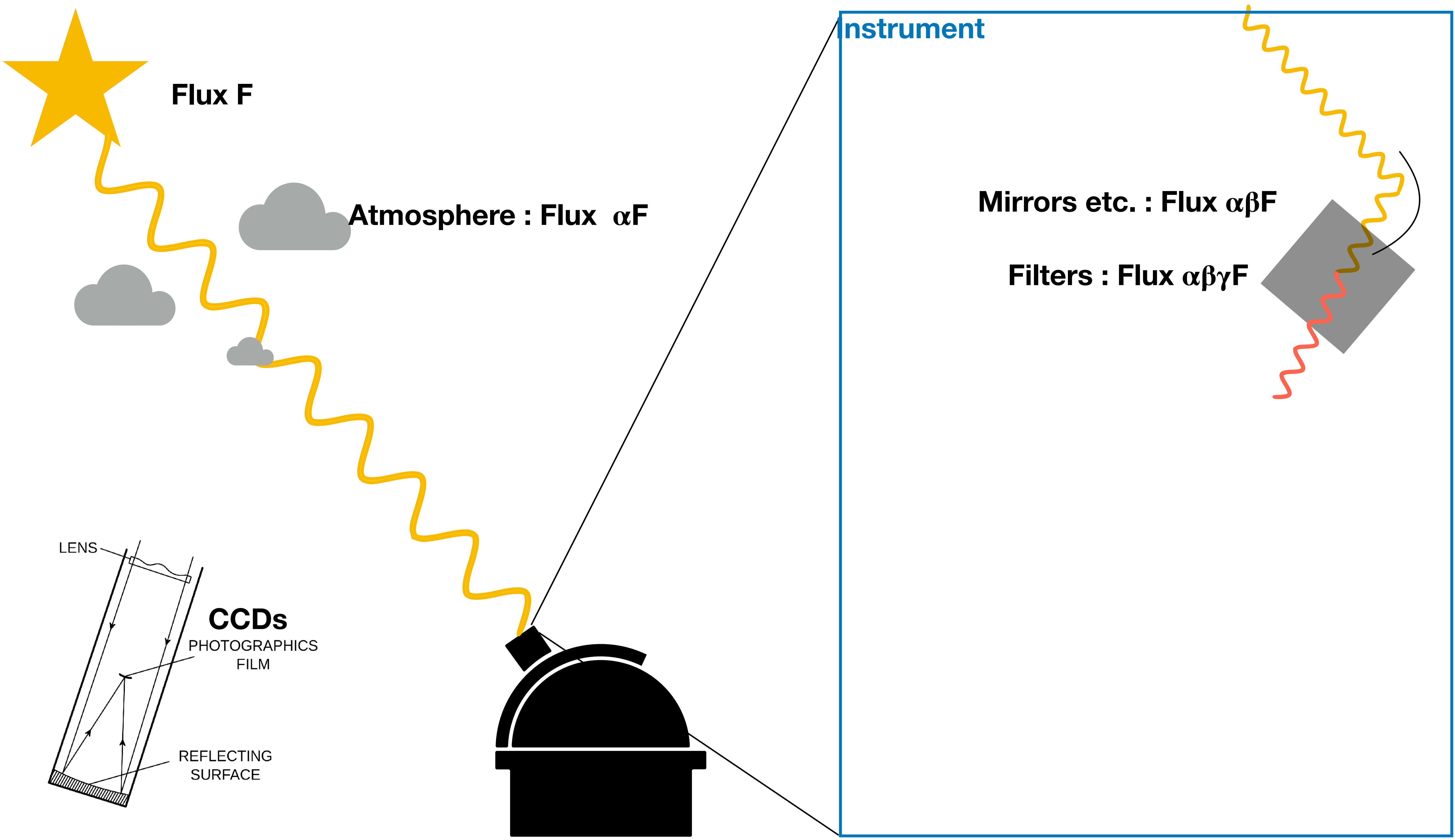


Flux F
Atmosphere : Flux αF
LENS
CCDs
PHOTOGRAPHICS FILM
REFLECTING SURFACE

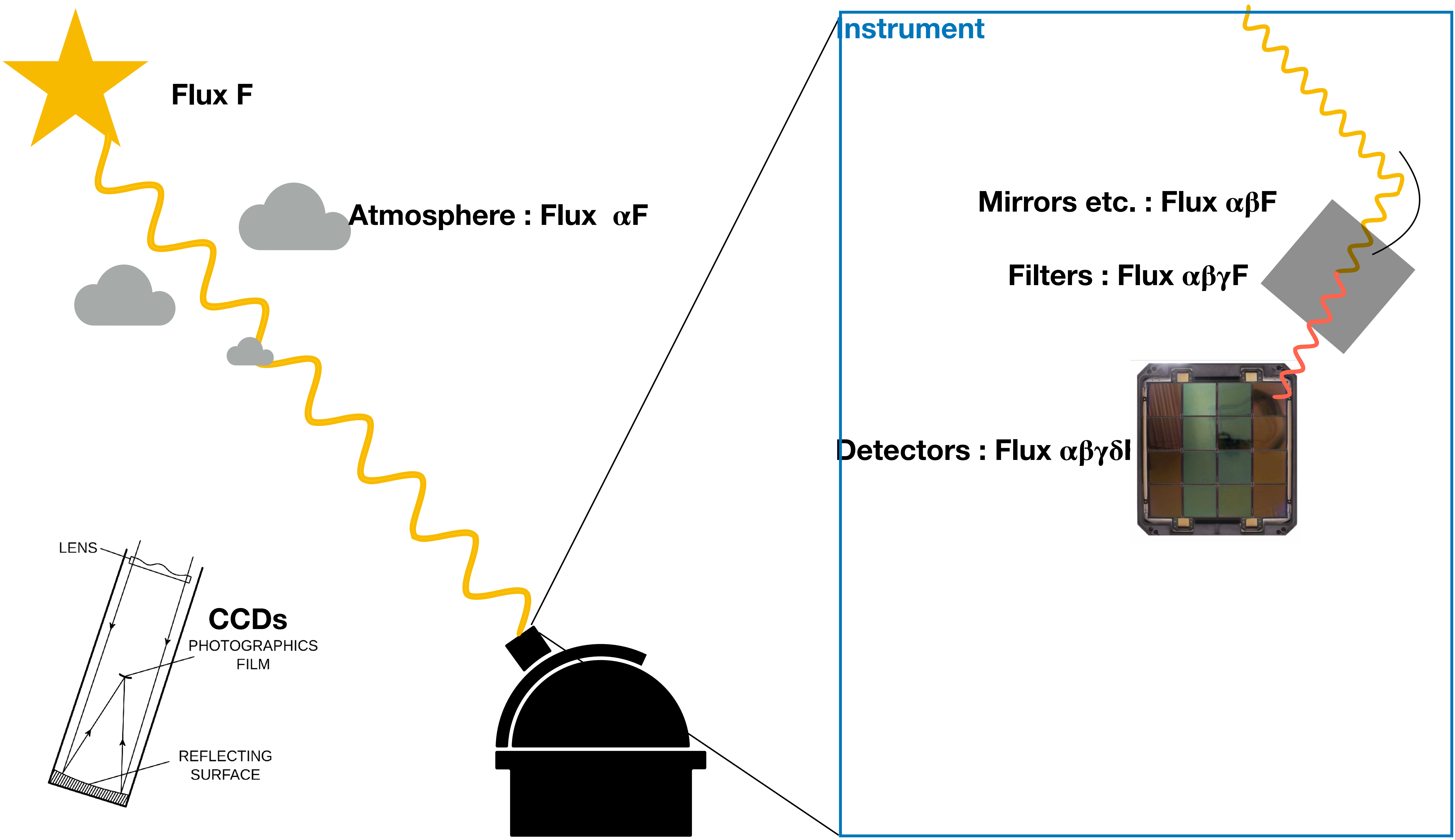


Flux F
Atmosphere : Flux αF
LENS
CCDs
PHOTOGRAPHICS
FILM
REFLECTING
SURFACE
Instrument

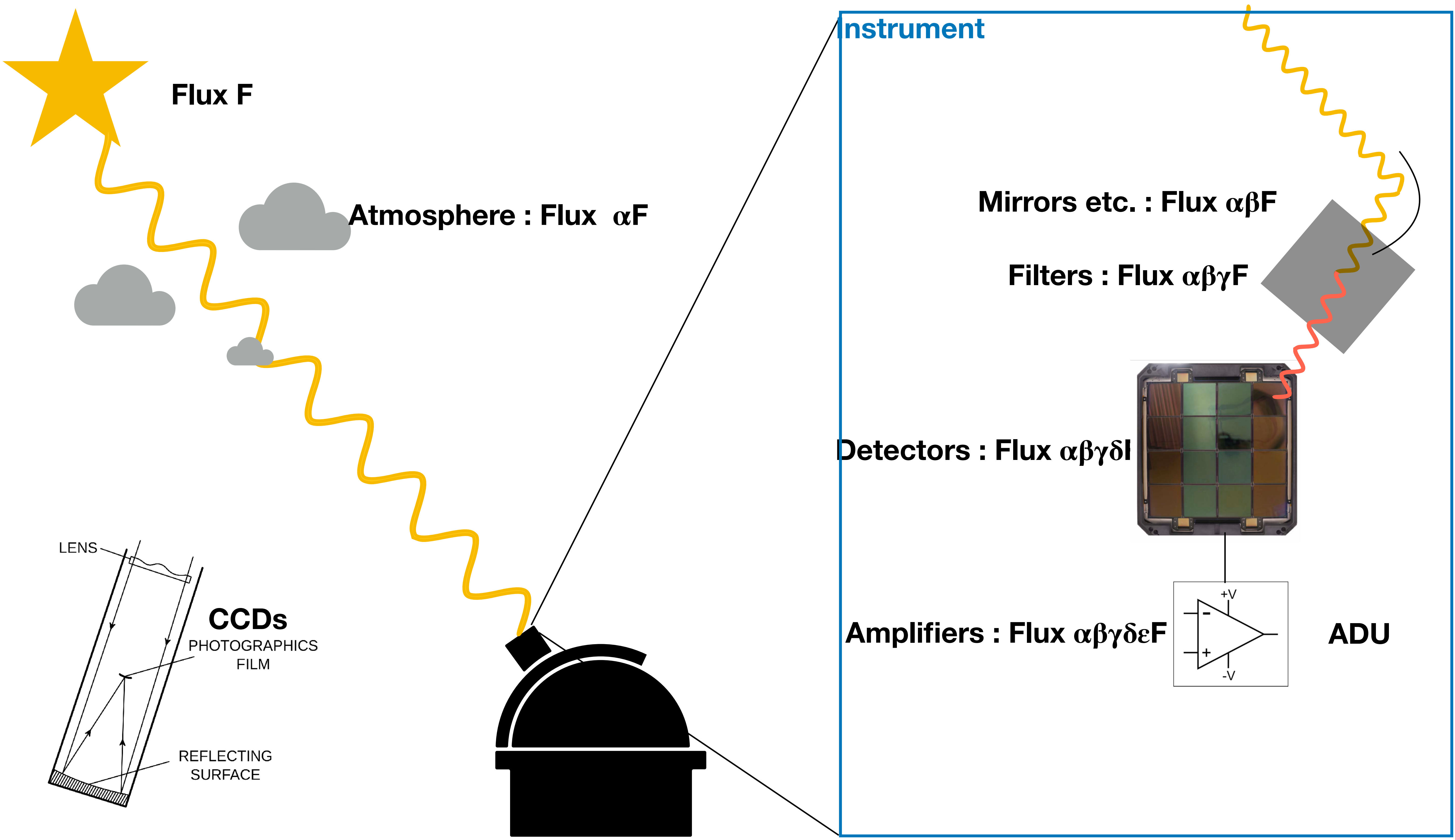

Flux F
Atmosphere : Flux αF
Instrument
Mirrors etc. : Flux αβF
LENS
CCDs
PHOTOGRAPHICS
FILM
REFLECTING
SURFACE



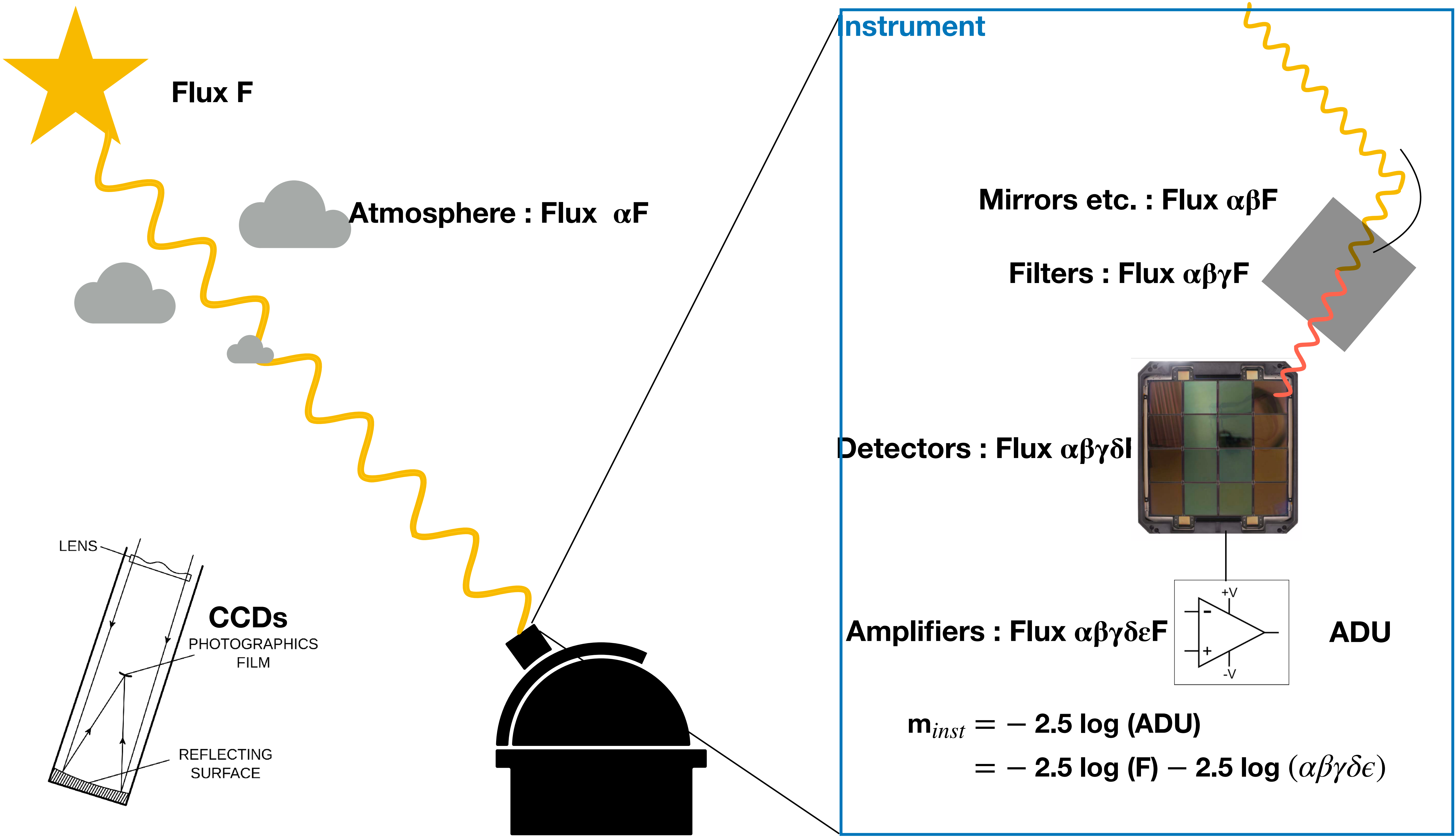
Flux F
Atmosphere : Flux αF
Instrument
Mirrors etc. : Flux αβF
Filters : Flux αβγF
LENS
CCDs
PHOTOGRAPHICS
FILM
REFLECTING
SURFACE



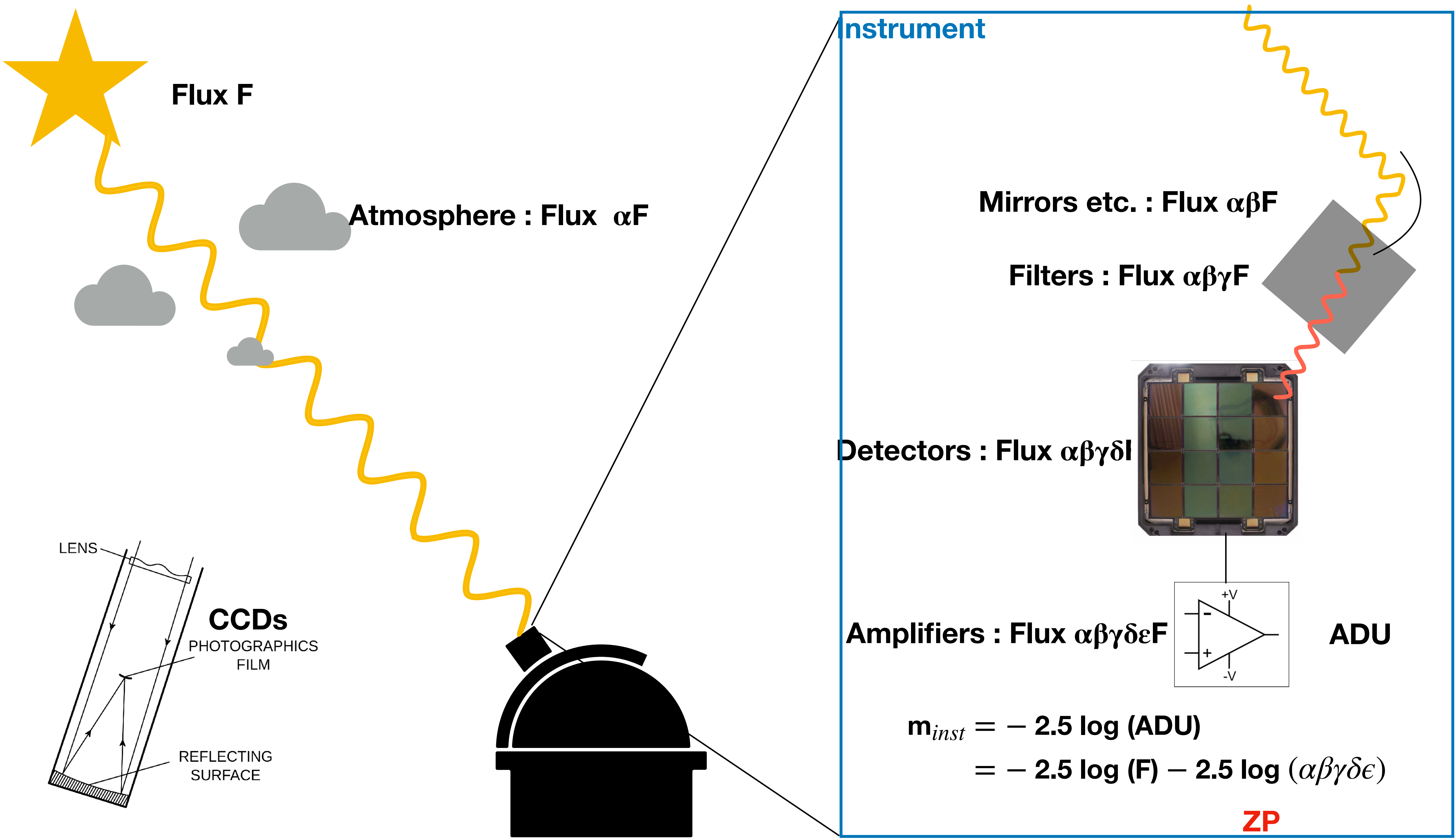
Flux F
Atmosphere : Flux αF
LENS
CCDs
PHOTOGRAPHICS
FILM
REFLECTING
SURFACE
Instrument
Mirrors etc. : Flux αβF
Filters : Flux αβγF
Detectors : Flux αβγδI

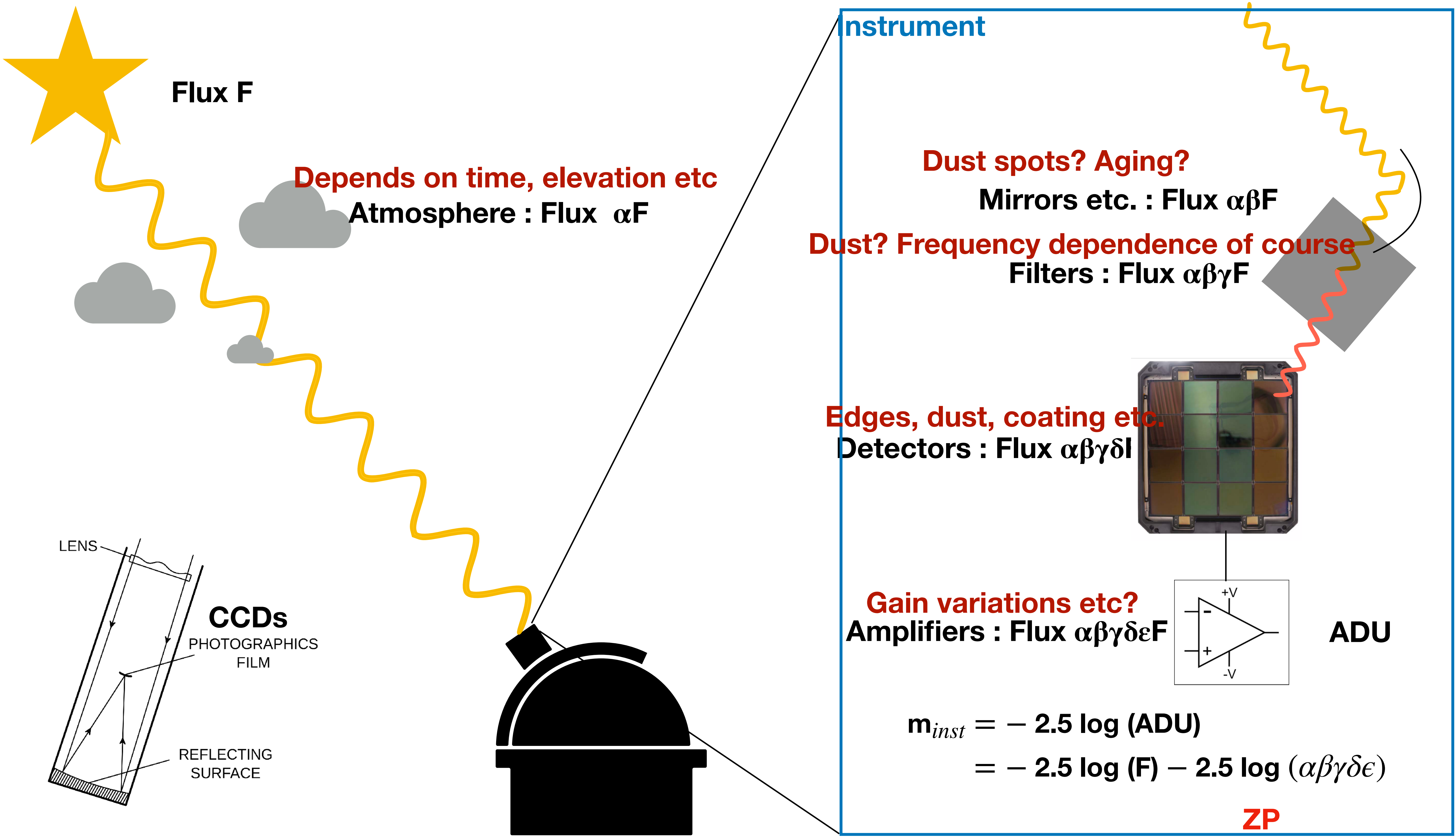


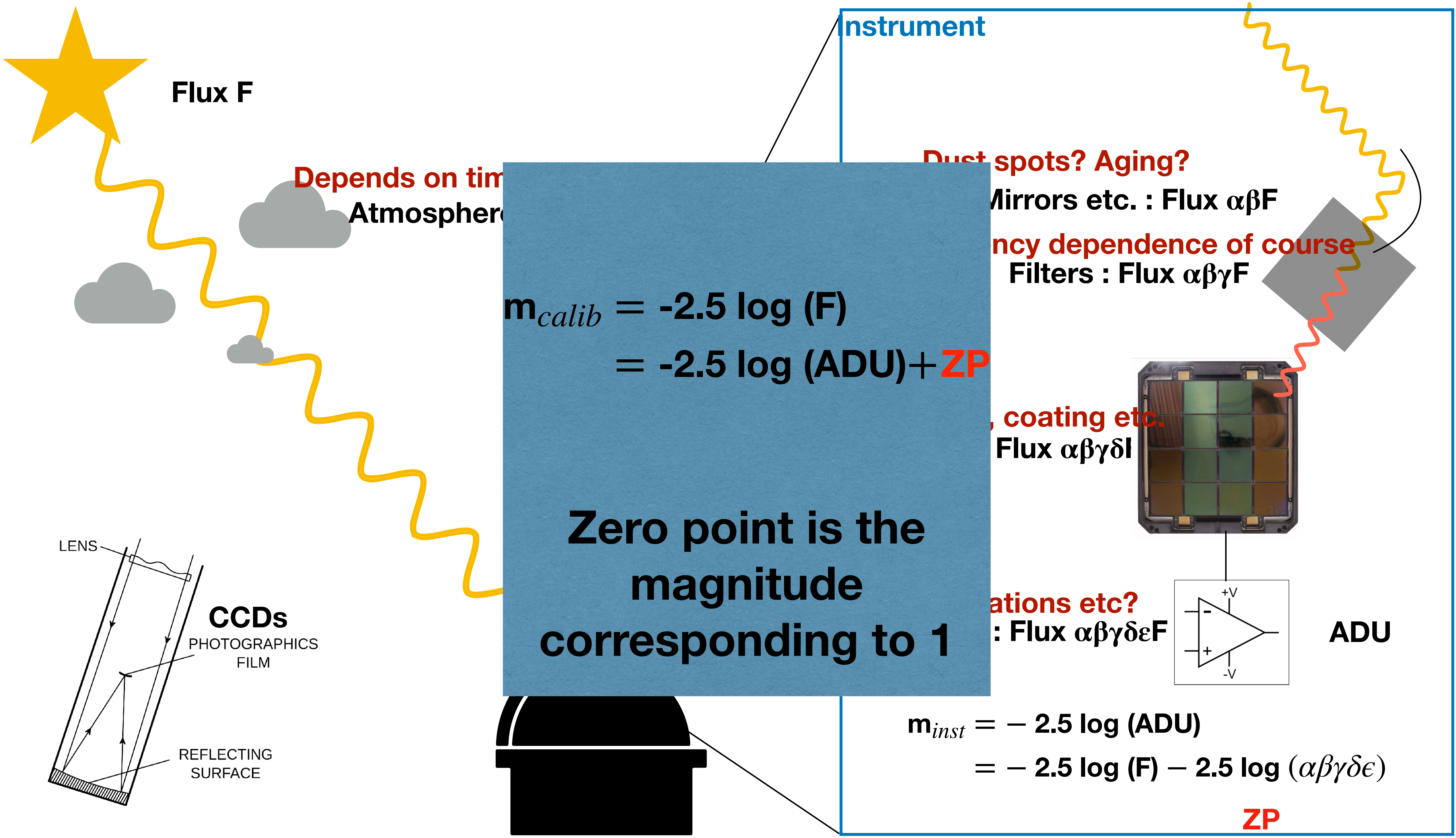
Flux F
Atmosphere : Flux αF
LENS
CCDs
PHOTOGRAPHICS
FILM
REFLECTING
SURFACE
Instrument
Mirrors etc. : Flux αβF
Filters : Flux αβγF
Detectors : Flux αβγδF
+V
-V
Amplifiers : Flux αβγδεF
ADU



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
ADU
$m_{inst} = -2.5 \log (ADU)$
$= -2.5 \log (F) - 2.5 \log (\alpha\beta\gamma\delta\epsilon)$

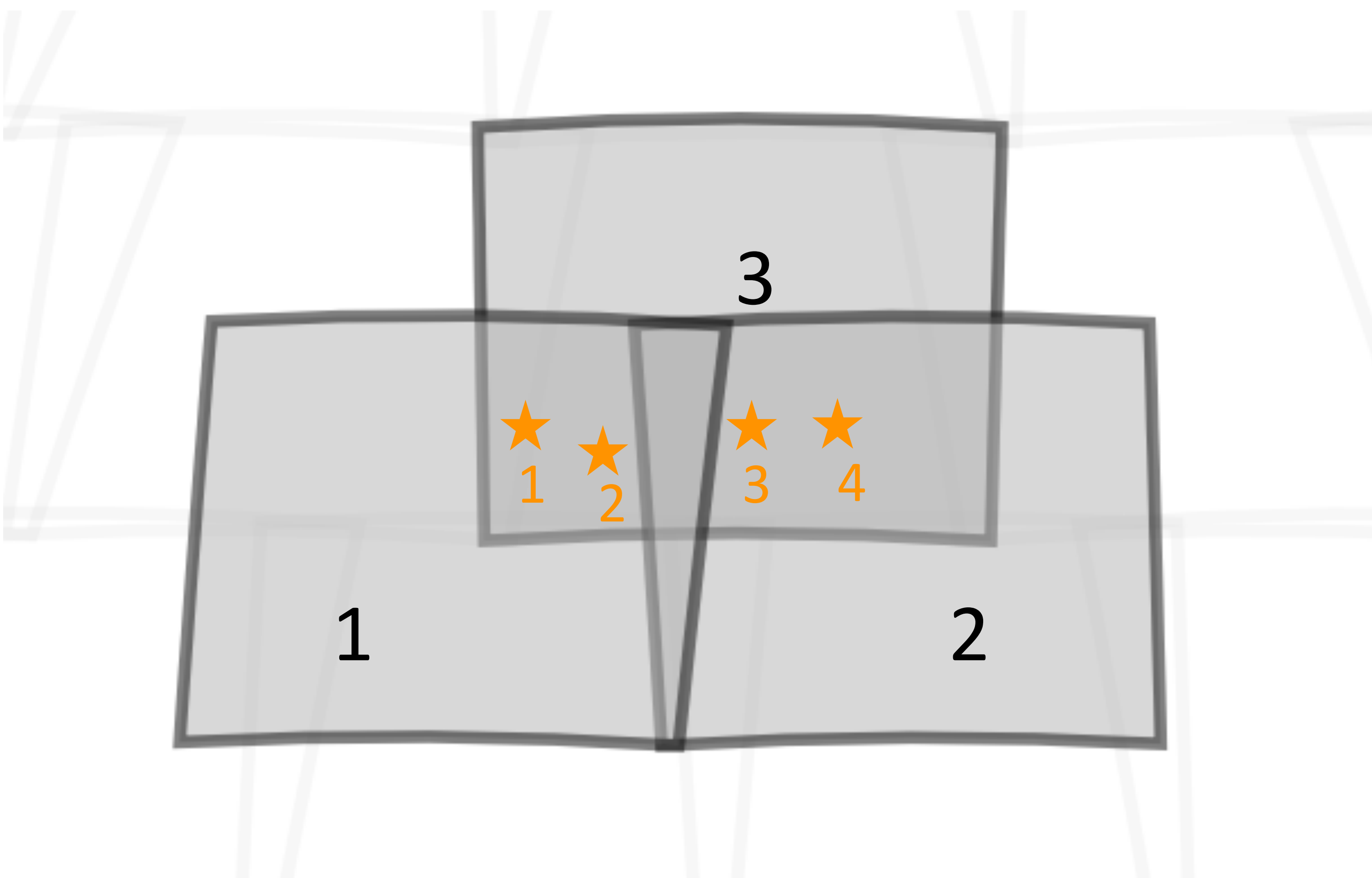

Flux F
Atmosphere : Flux αF
LENS
CCDs
PHOTOGRAPHICS FILM
REFLECTING SURFACE
Instrument
Mirrors etc. : Flux αβF
Filters : Flux αβγF
Detectors : Flux αβγδF
Amplifiers : Flux αβγδεF
+V
-V
ADU
$m_{inst} = -2.5 \log(ADU)$
$= -2.5 \log(F) - 2.5 \log(\alpha\beta\gamma\delta\epsilon)$
ZP


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? Frequency dependence of course
Filters : Flux αβγF
Edges, dust, coating etc.
Detectors : Flux αβγδI
Gain variations etc?
Amplifiers : Flux αβγδεF
+V
-V
ADU
$m_{inst} = -2.5 \log(\text{ADU})$
$= -2.5 \log(\text{F}) - 2.5 \log(\alpha\beta\gamma\delta\epsilon)$
ZP



Flux F
Depends on tim
Atmospher
Instrument
Dust spots? Aging?
Mirrors etc. : Flux αβF
ncy dependence of course
Filters : Flux αβγF
m_{calib} = -2.5 log (F)
= -2.5 log (ADU) + ZP
, coating etc.
Flux αβγδI
Zero point is the magnitude corresponding to 1
ations etc?
: Flux αβγδεF
+V
-V
ADU
LENS
CCDs
PHOTOGRAPHICS FILM
REFLECTING SURFACE
m_{inst} = − 2.5 log (ADU)
= − 2.5 log (F) − 2.5 log $(\alpha\beta\gamma\delta\epsilon)$
ZP

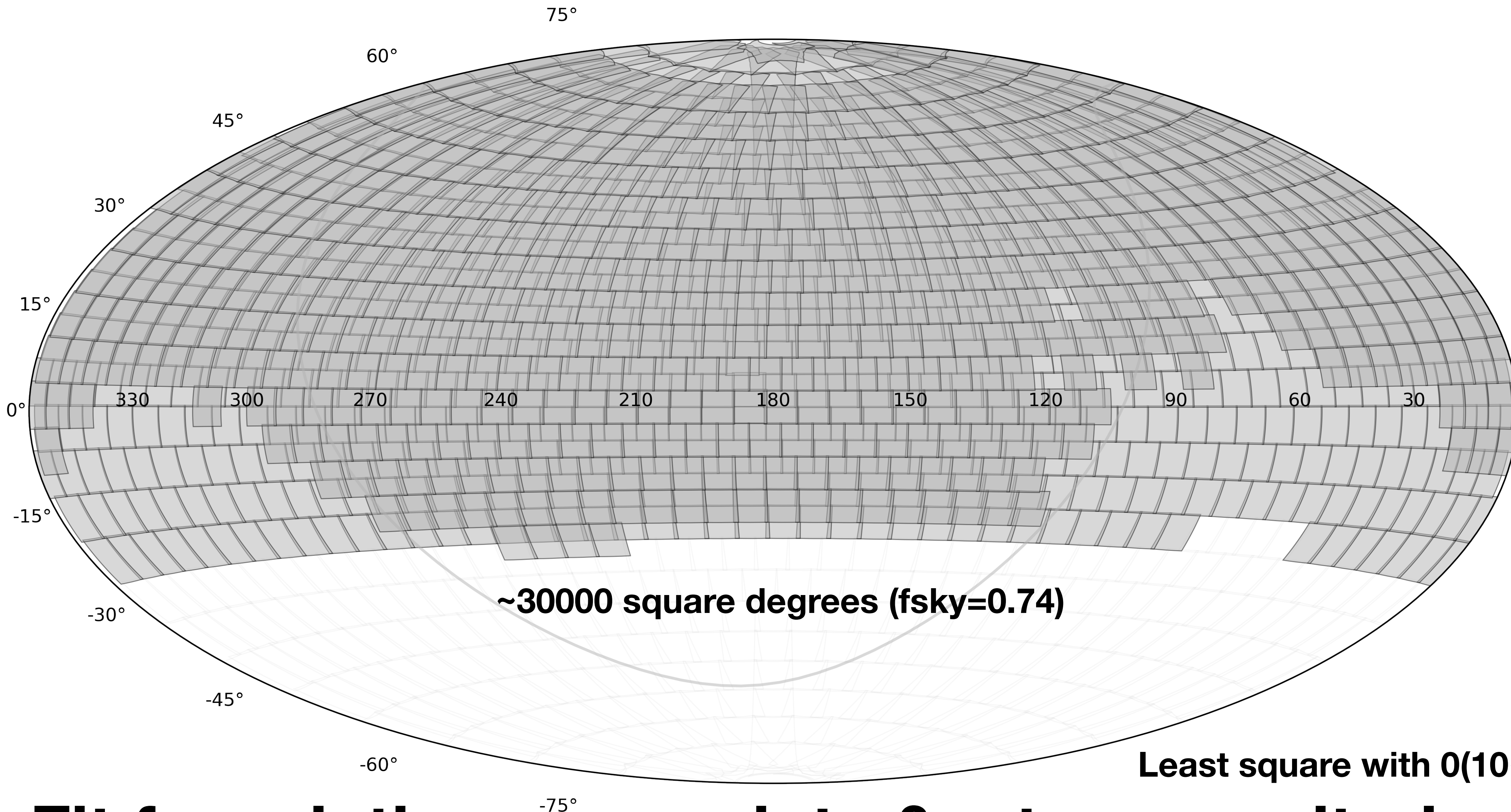
Ubercal method



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

Fit for relative zero points & star magnitudes

6 month: 2019-03 to 2019-08



Least square with 0(10^8) lines

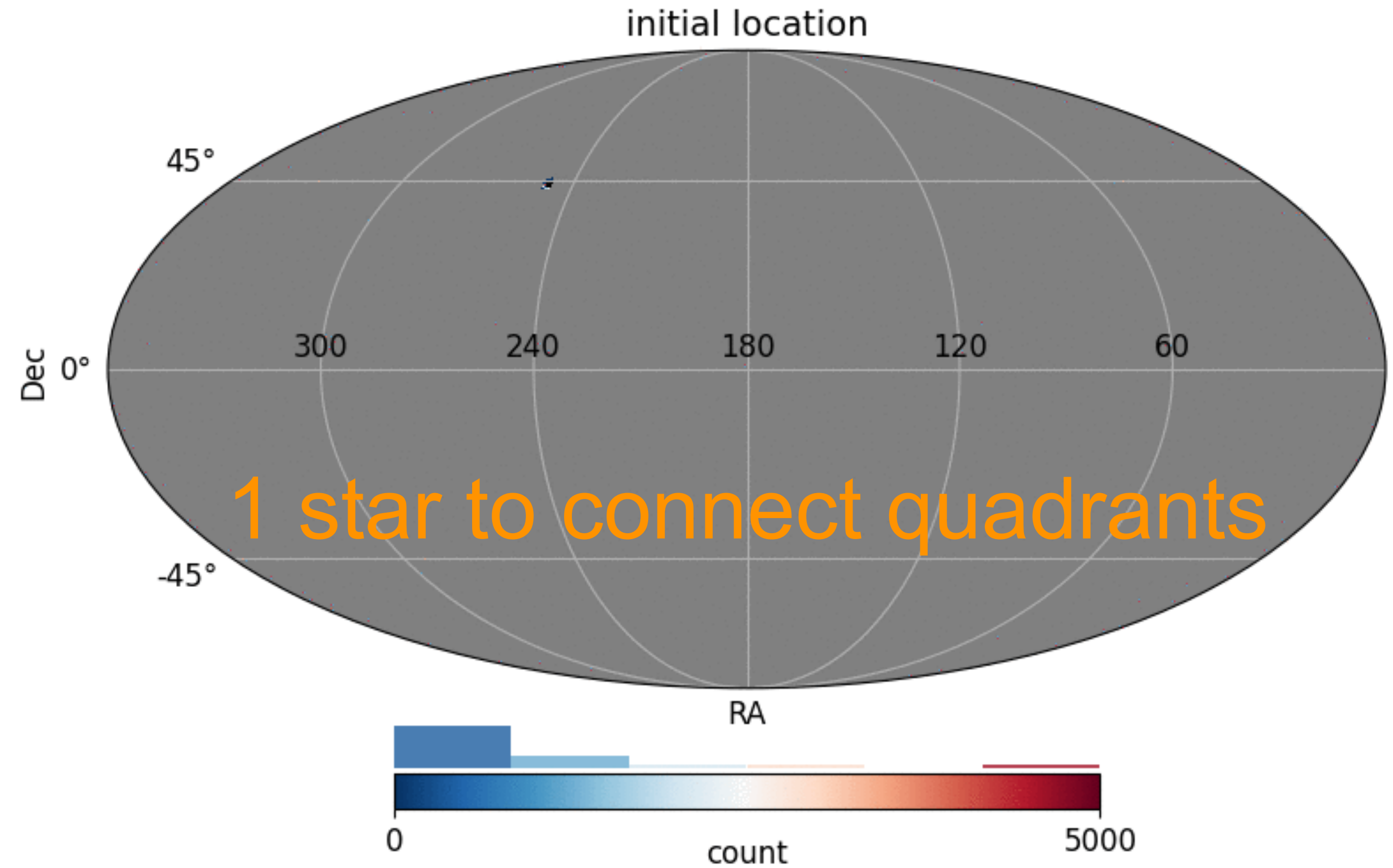
Fit for relative zero points & star magnitudes

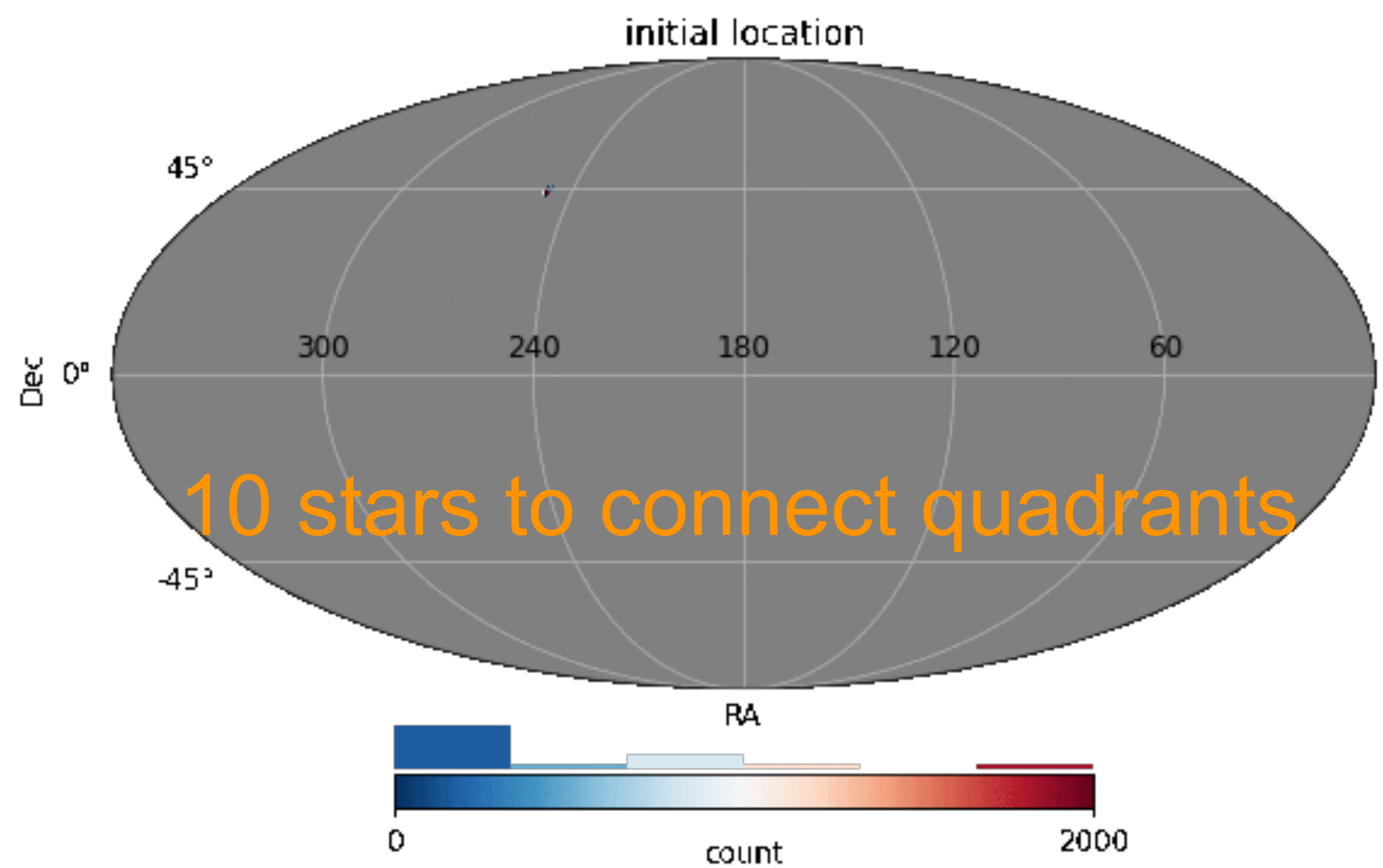
Connectivity

To perform ubercal we need common stars to « glue » exposures

(At a given scale: Focal plane/ quadrant/smaller? level)

Connectivity diffusion algorithm





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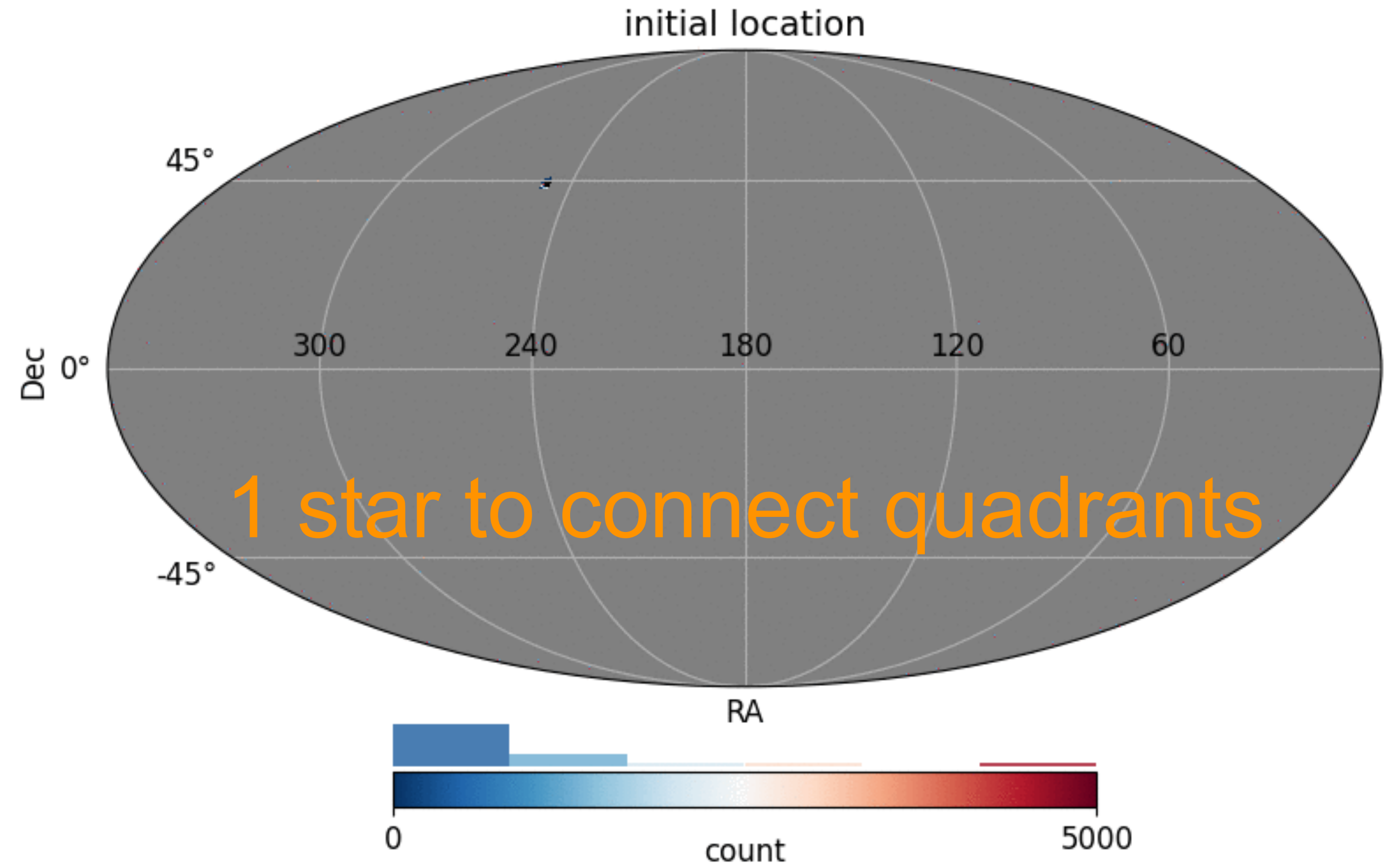

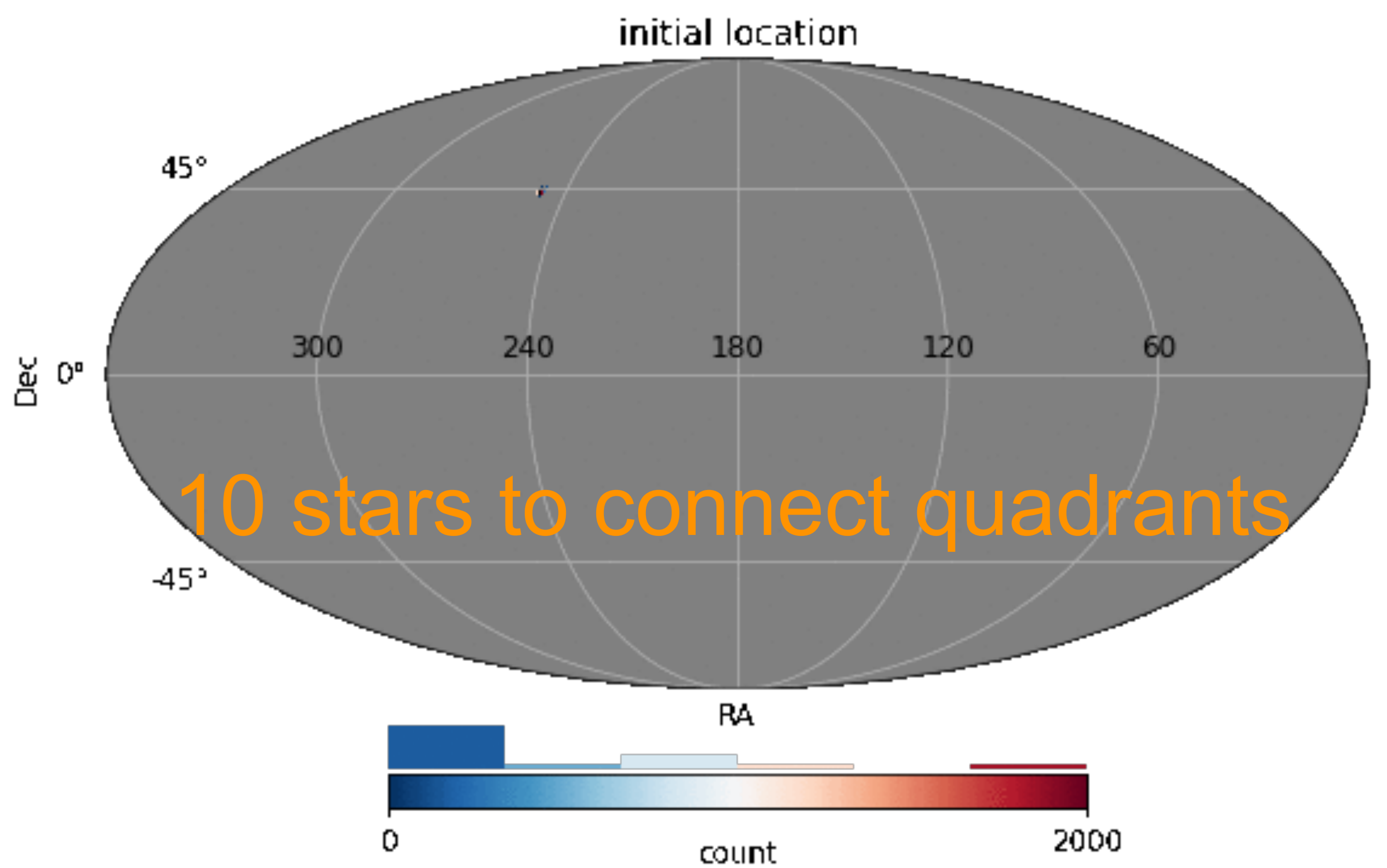

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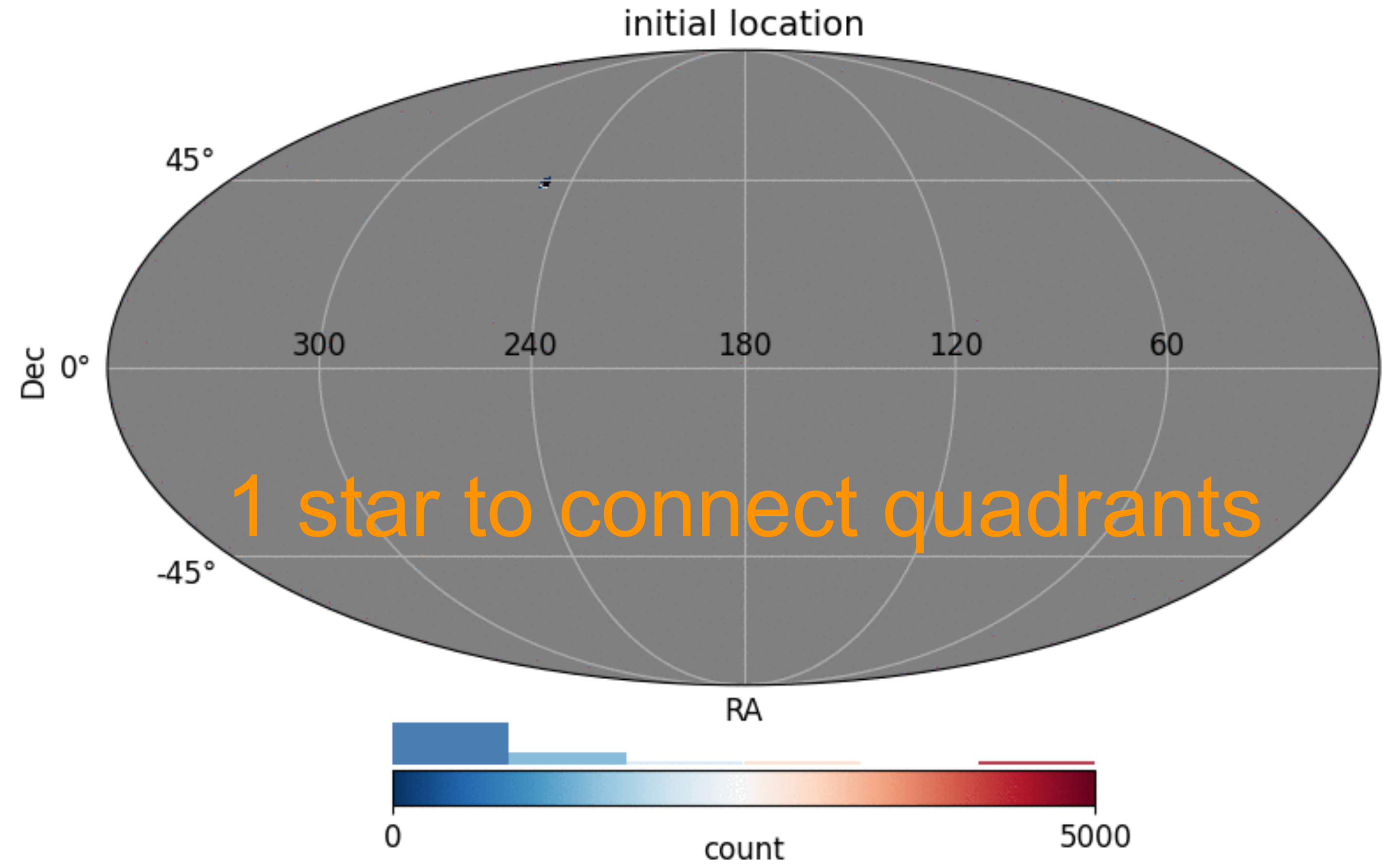
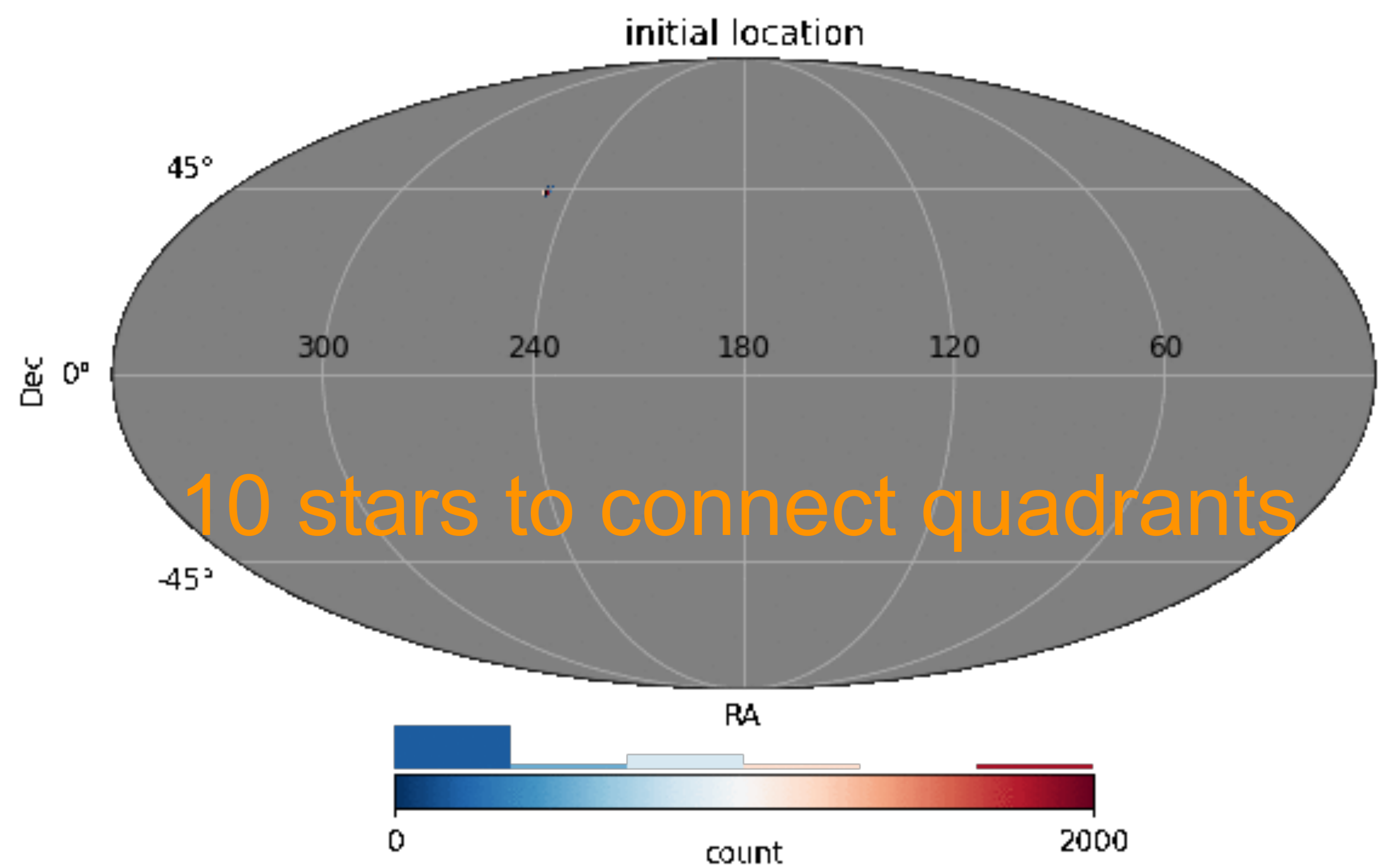
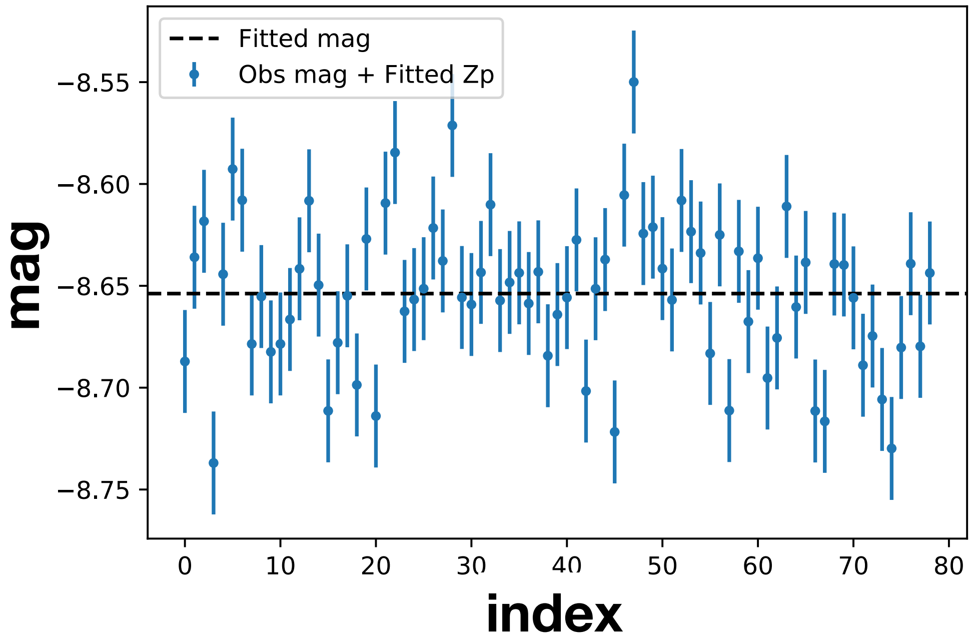
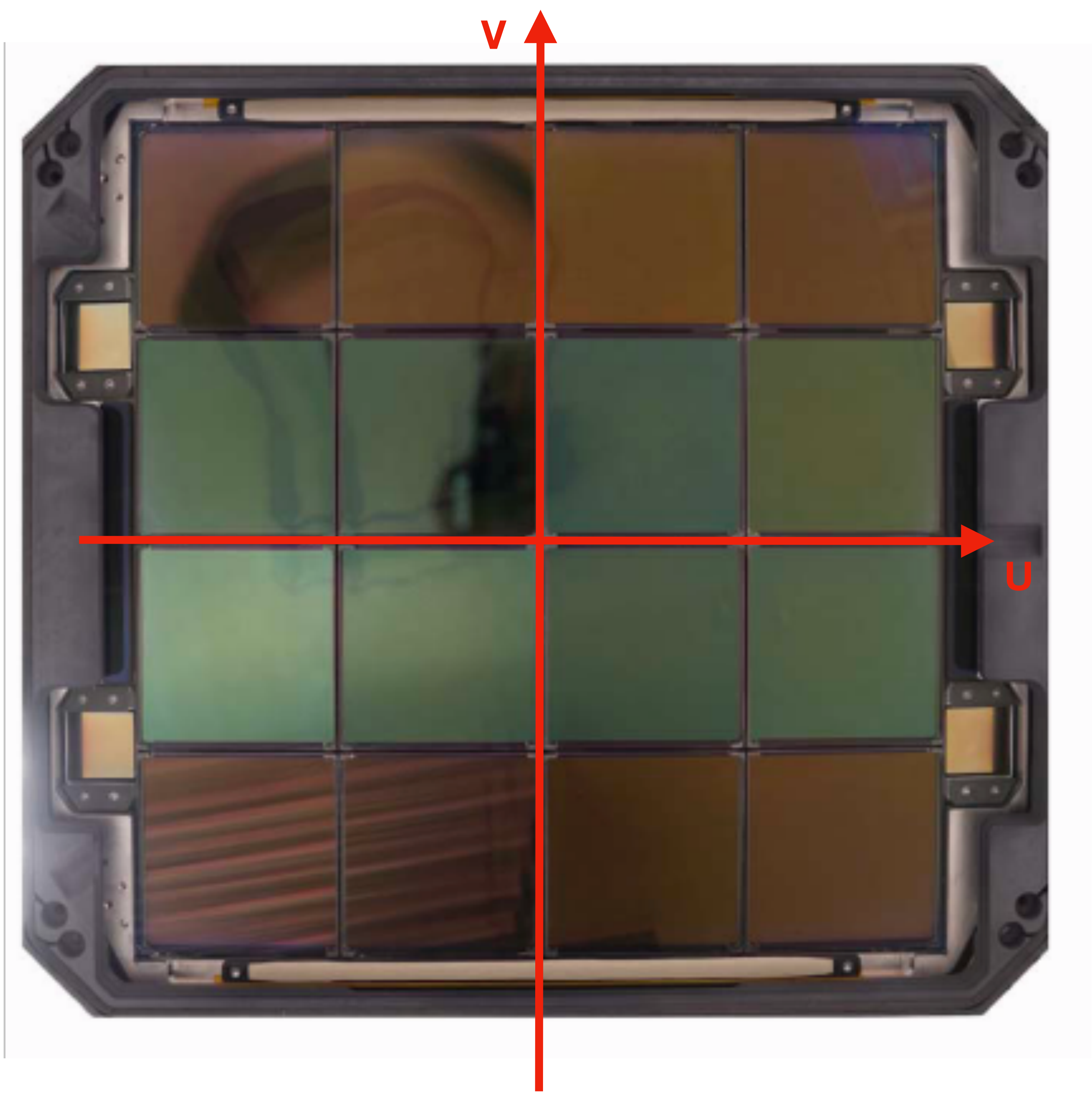




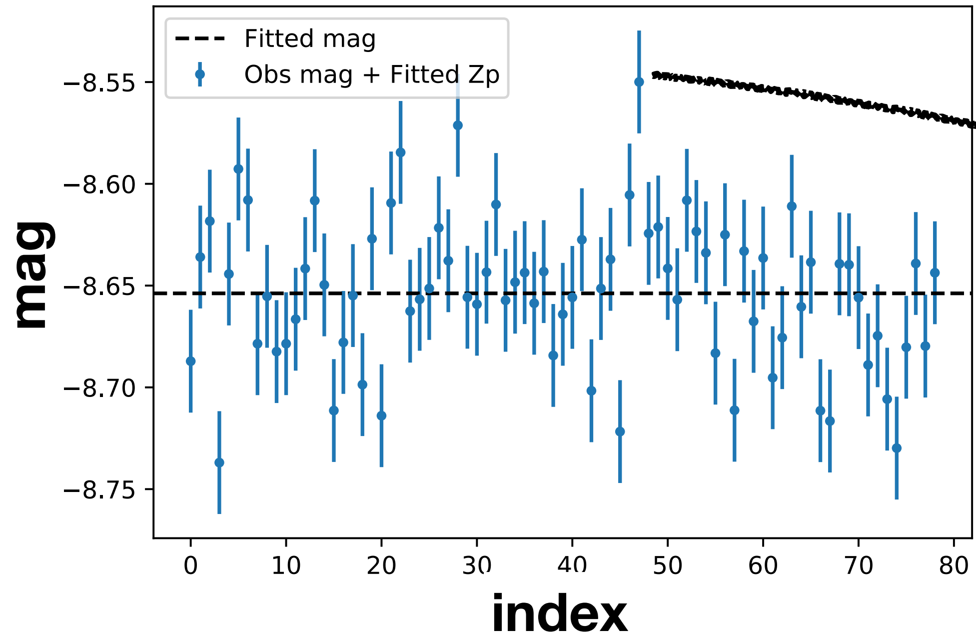
Result on one star (79 obs here)



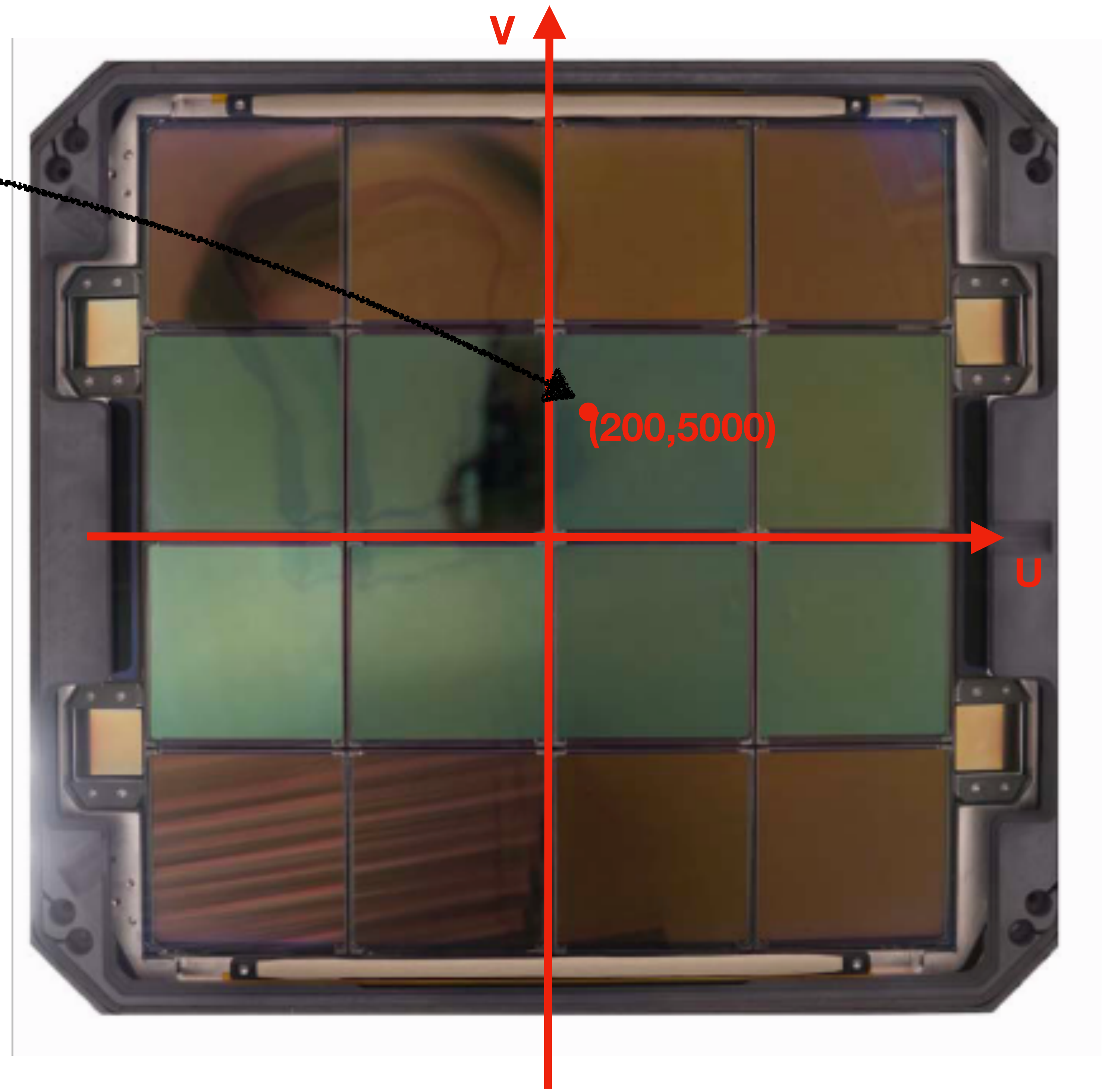
For each exposure, sources are observed at a specific position on the focal plane (uv coordinates)



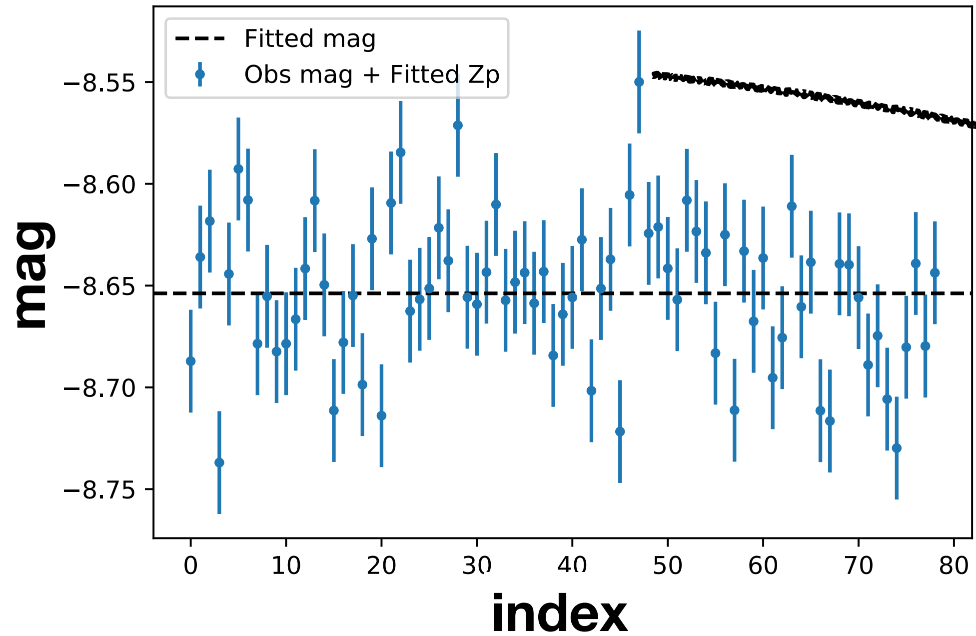
Result on one star (79 obs here)

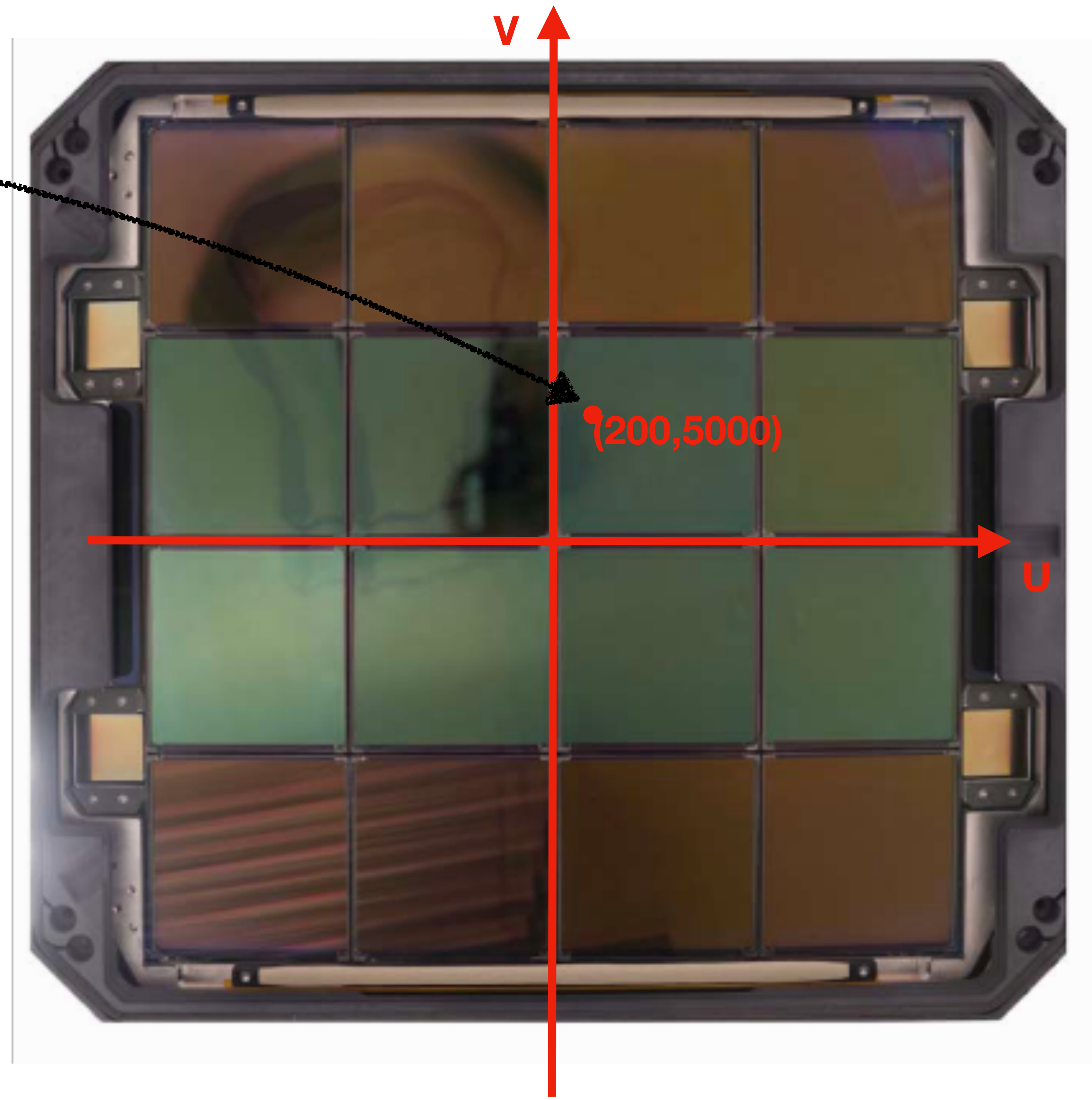


For each exposure, sources are observed at a specific position on the focal plane (uv coordinates)



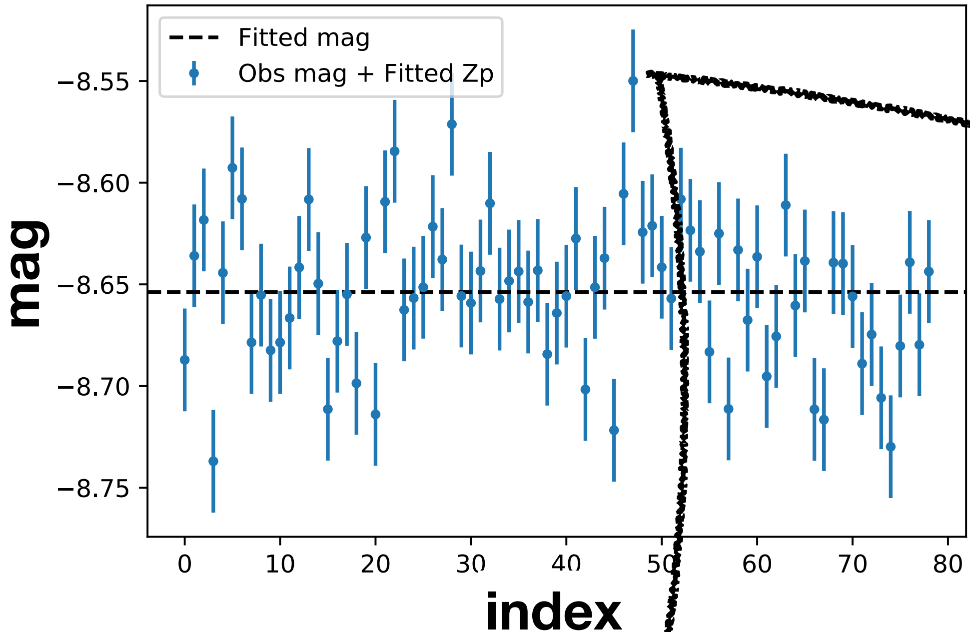
Result on one star (79 obs here)



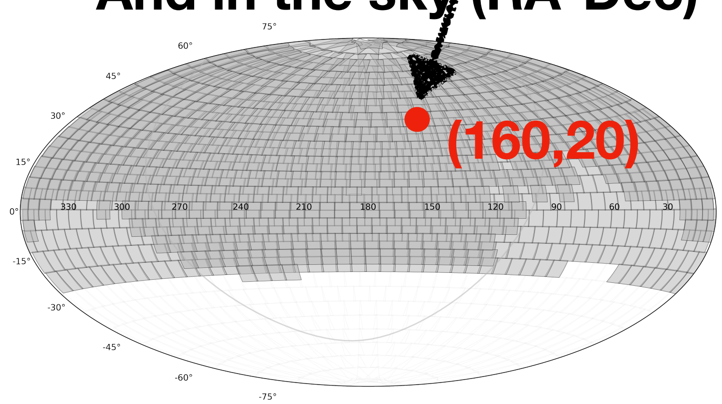


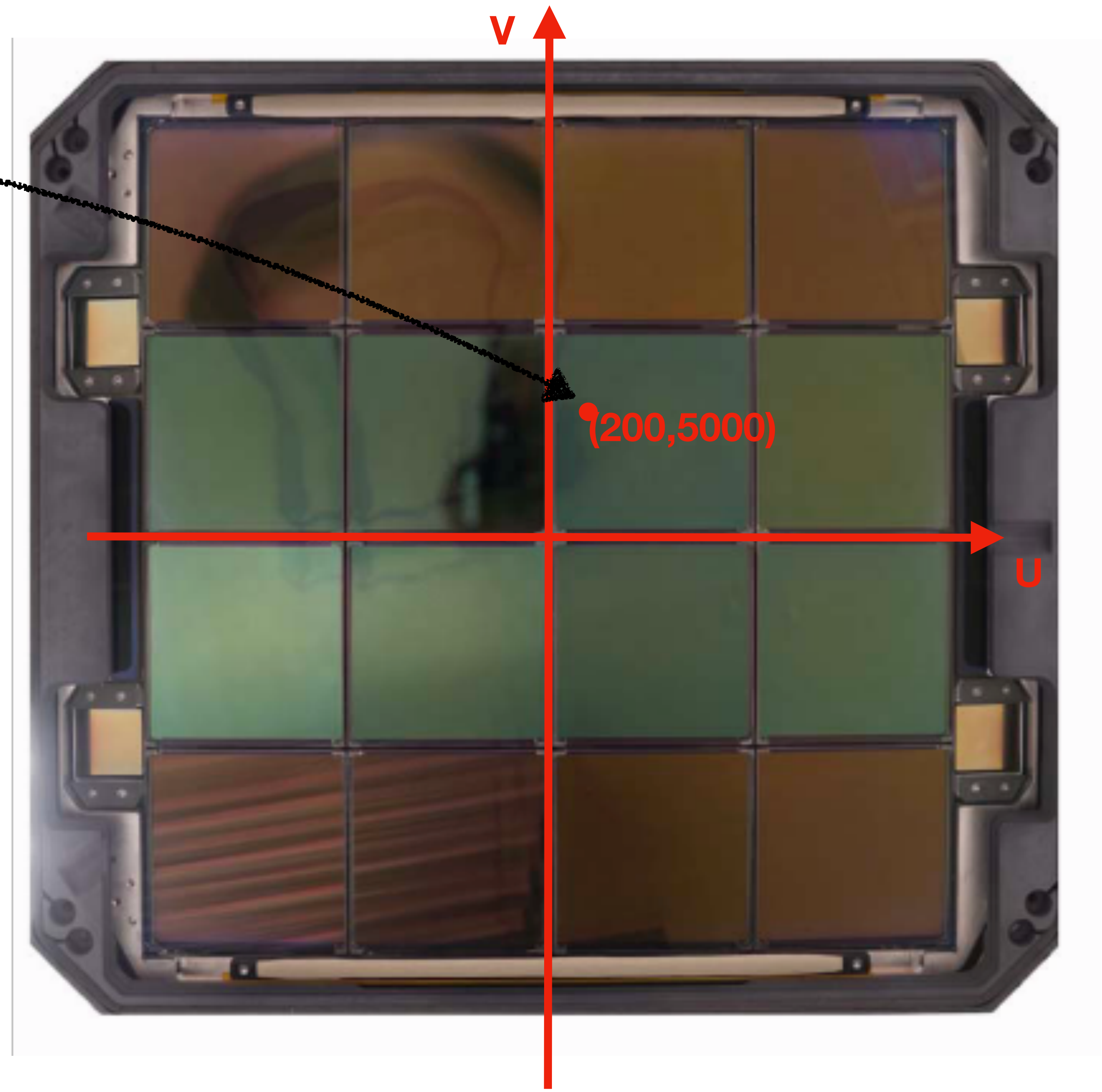
For each exposure, sources are observed at a specific position on the focal plane (uv coordinates)
And in the sky (RA-Dec)

Result on one star
(79 obs here)



For each exposure, sources are observed at a specific position on the focal plane (uv coordinates)
And in the sky (RA-Dec)

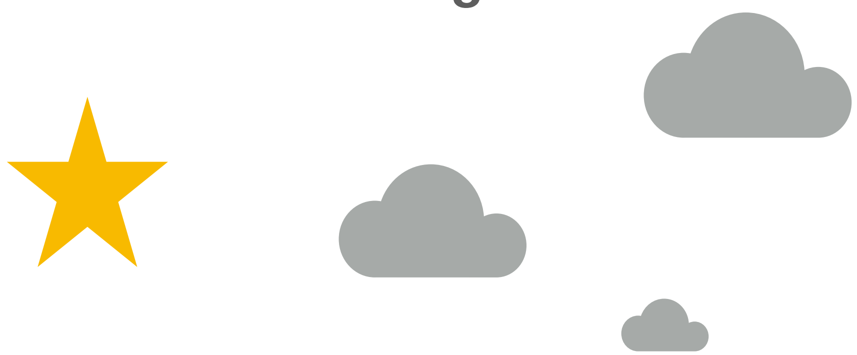




Our main output:
A calibrated catalog !

$$m_{obs} = m_{star} + ZP(t_{exposure})$$

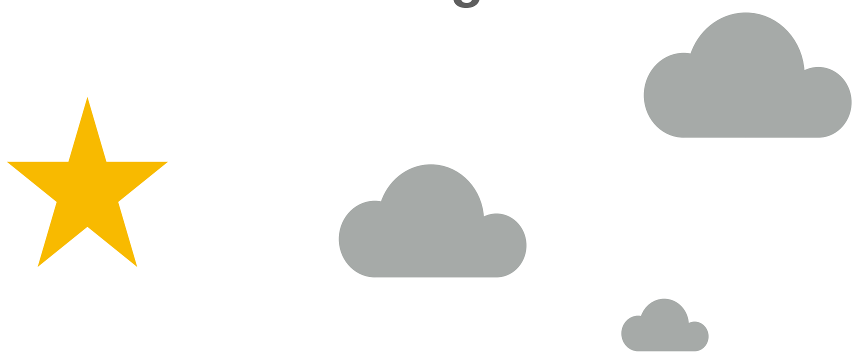
Fast change from clouds
Slow change from mirror aging?



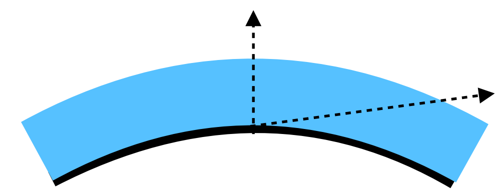
Our main output:
A calibrated catalog !

$$m_{obs} = m_{star} + ZP(t_{exposure}) + k(t_{night}) * \text{airmass} + \delta ZP(u, v)$$

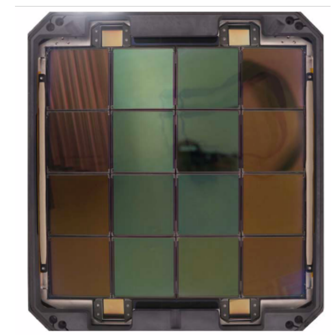
Fast change from clouds
Slow change from mirror aging?



Low elevation
=
Observing through
high airmass



Gain variability
CCD width variation
Dust spots
Fringing
Laser annealing



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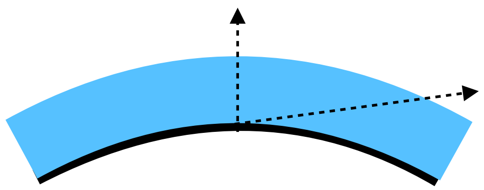

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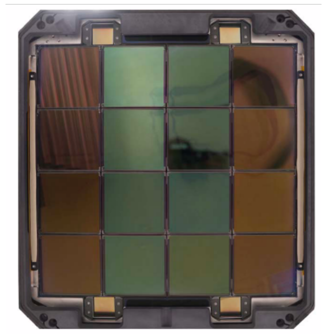
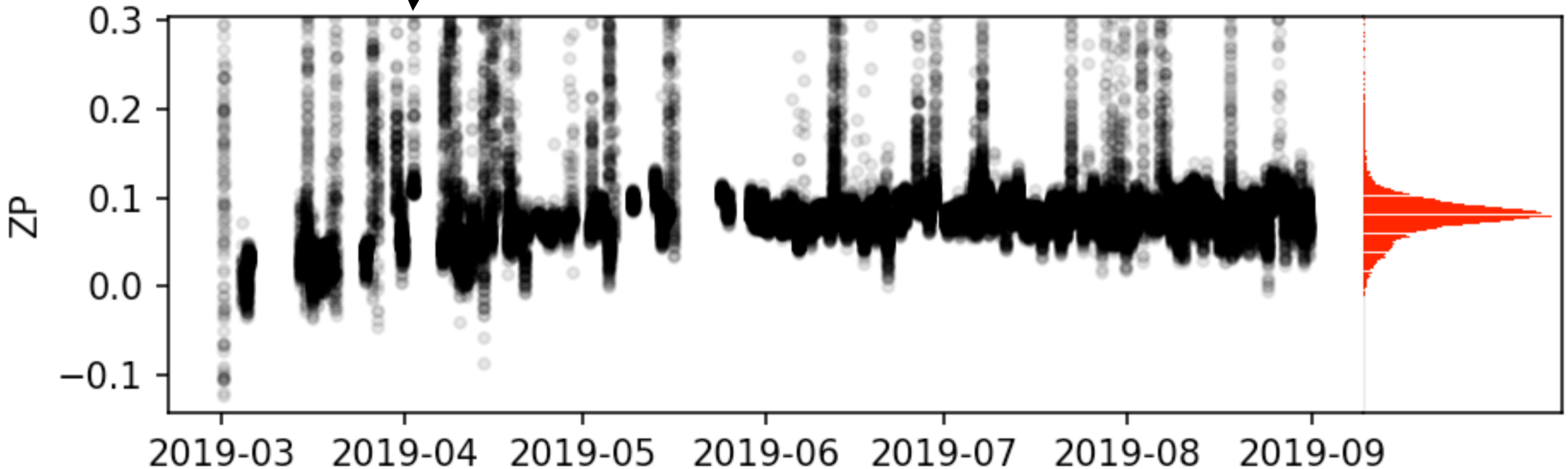


ztf-r



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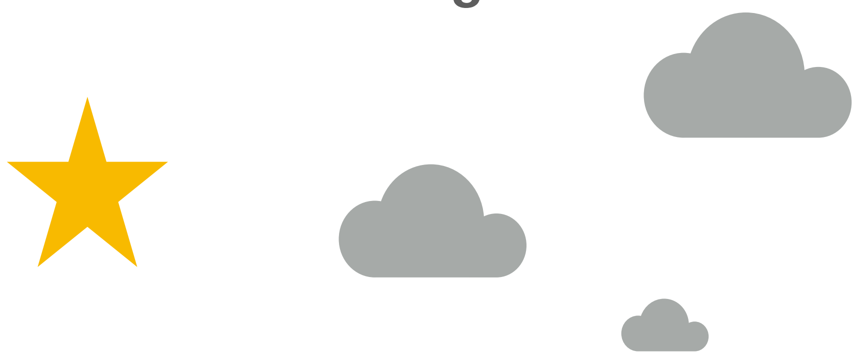

Low elevation
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Observing through
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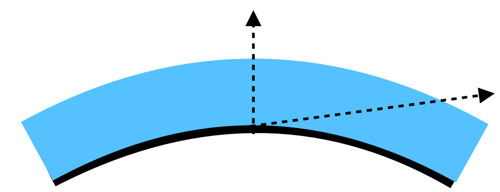

Gain variability
CCD width variation
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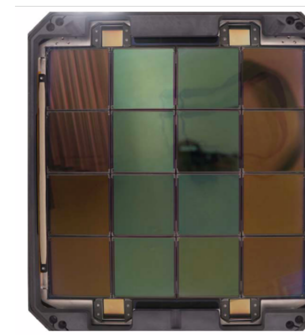

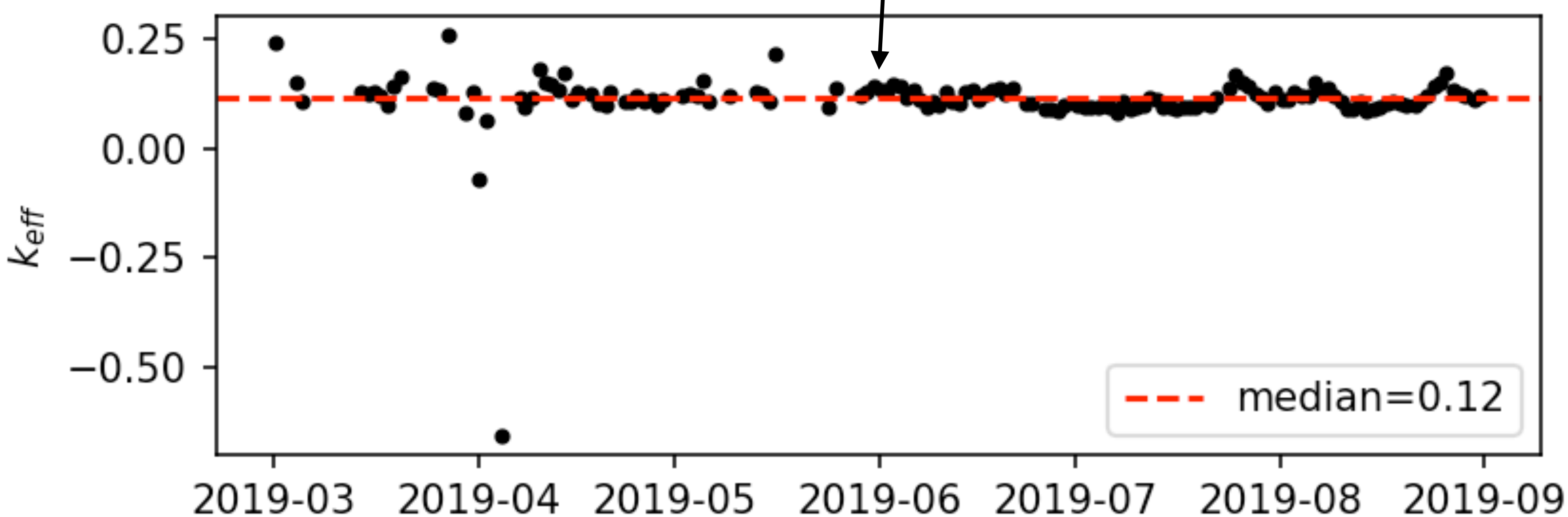

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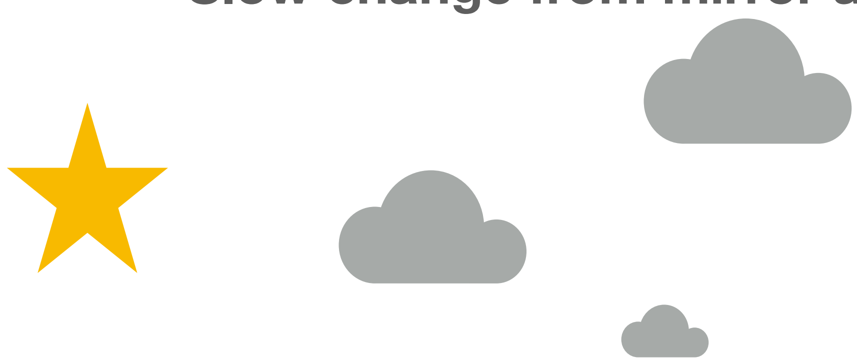
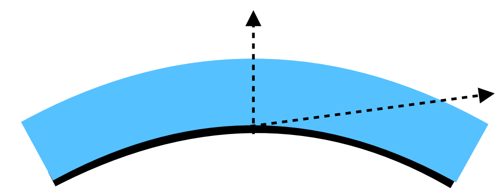


Low elevation
=
Observing through
high airmass



Gain variability
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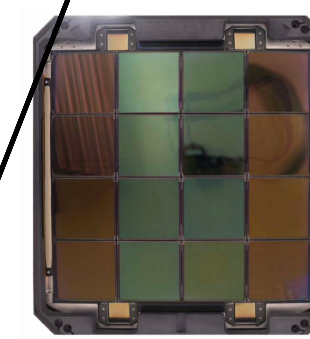
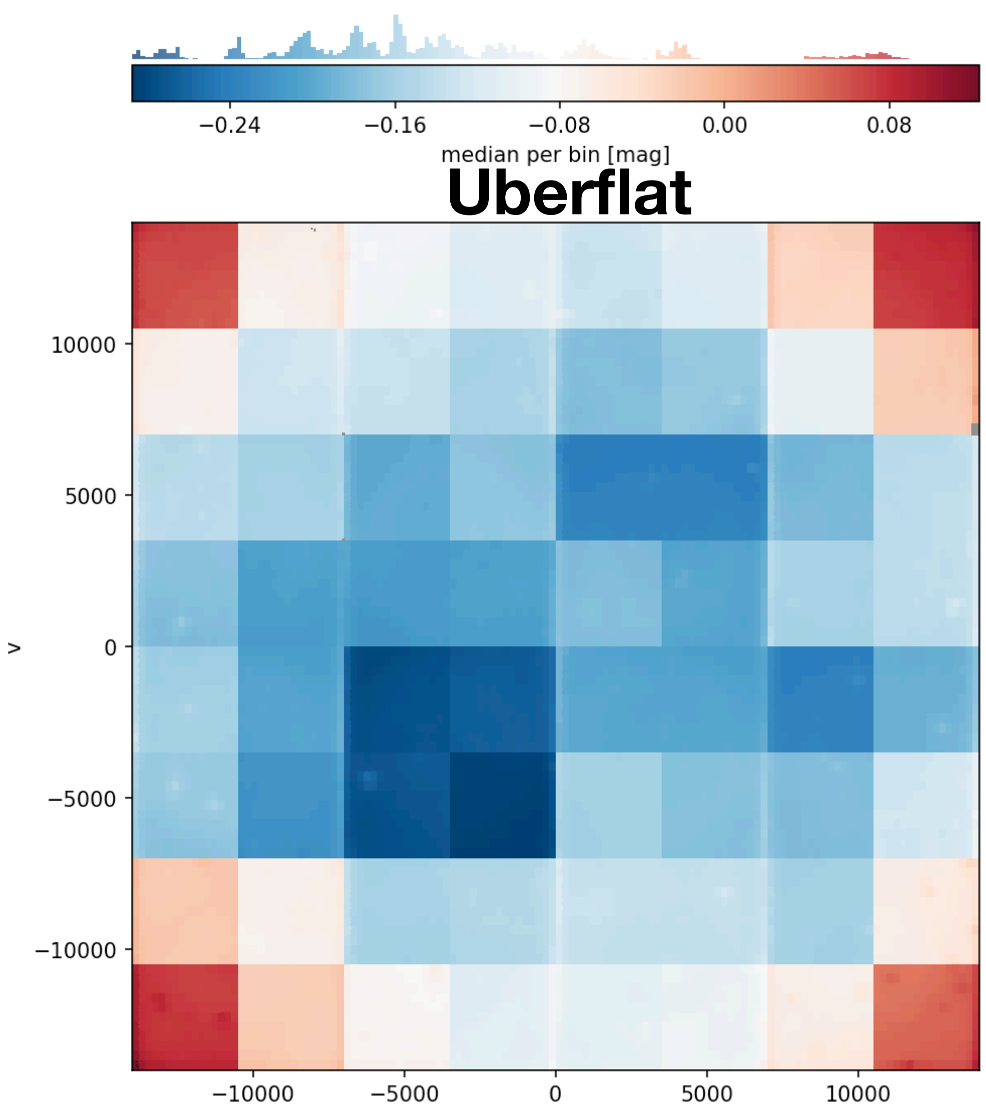
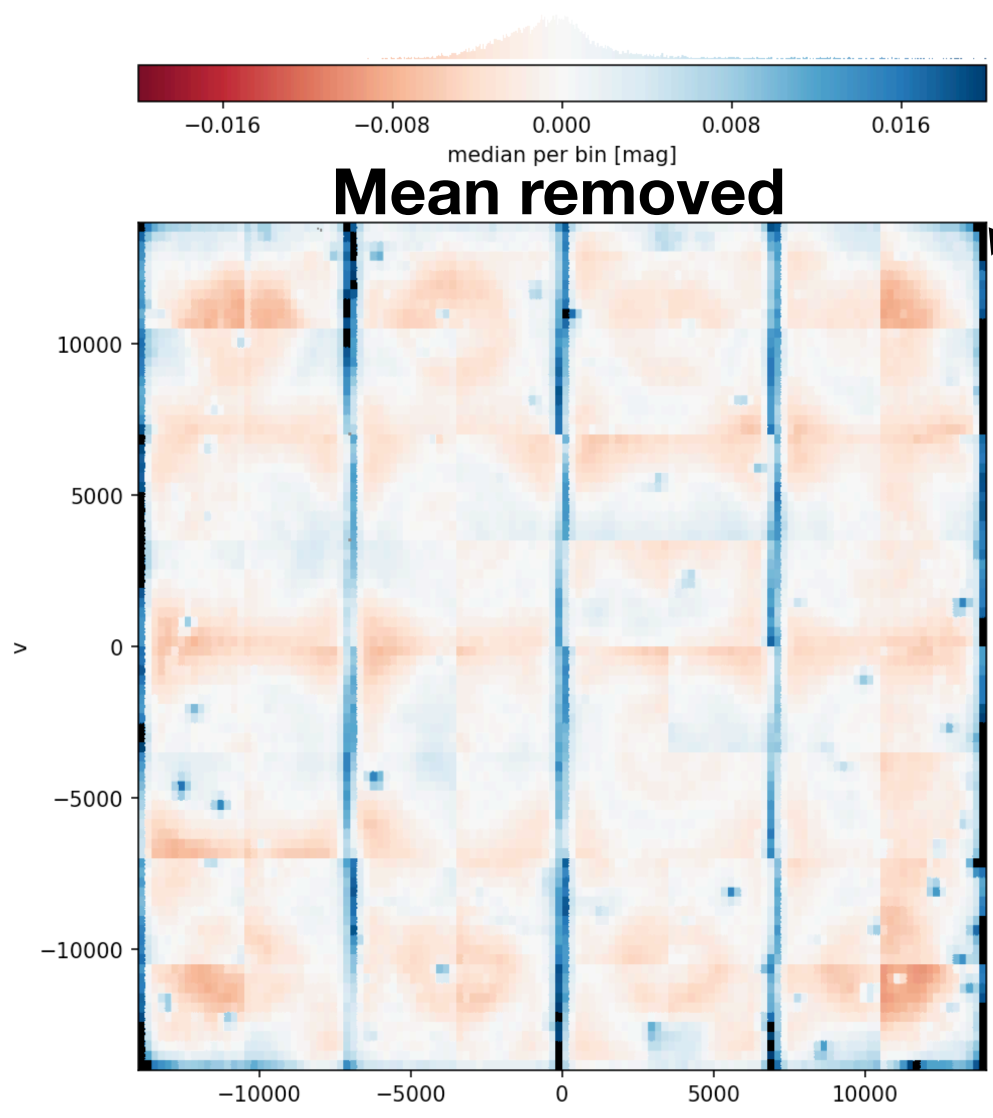
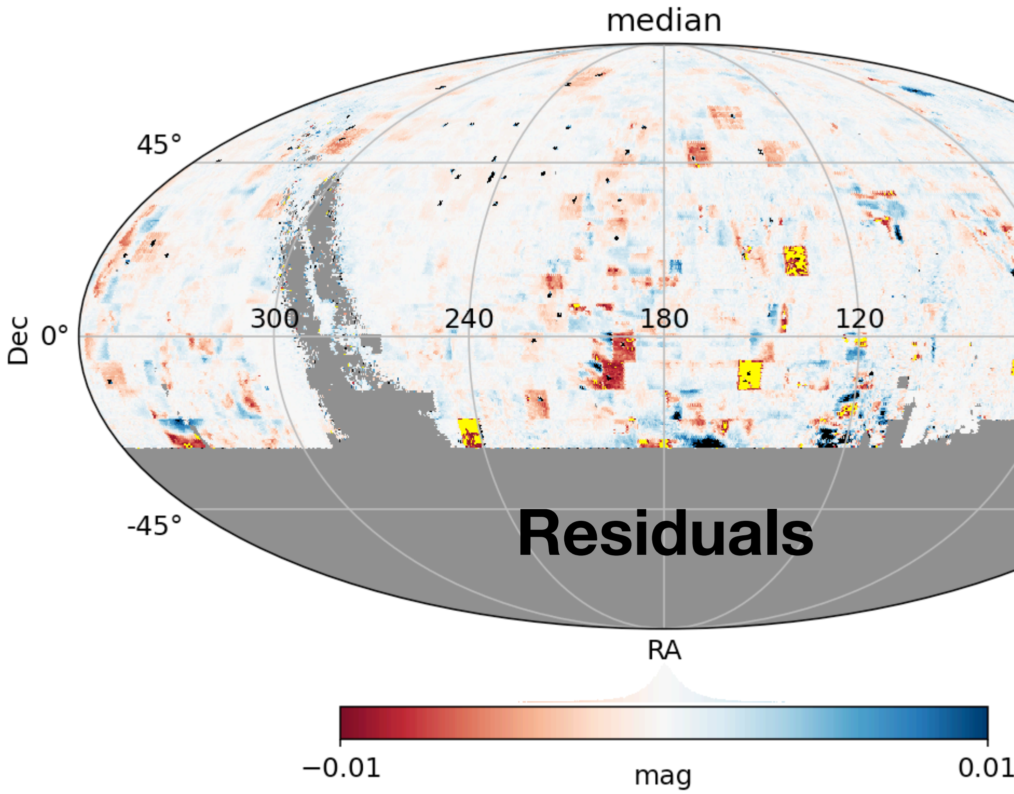
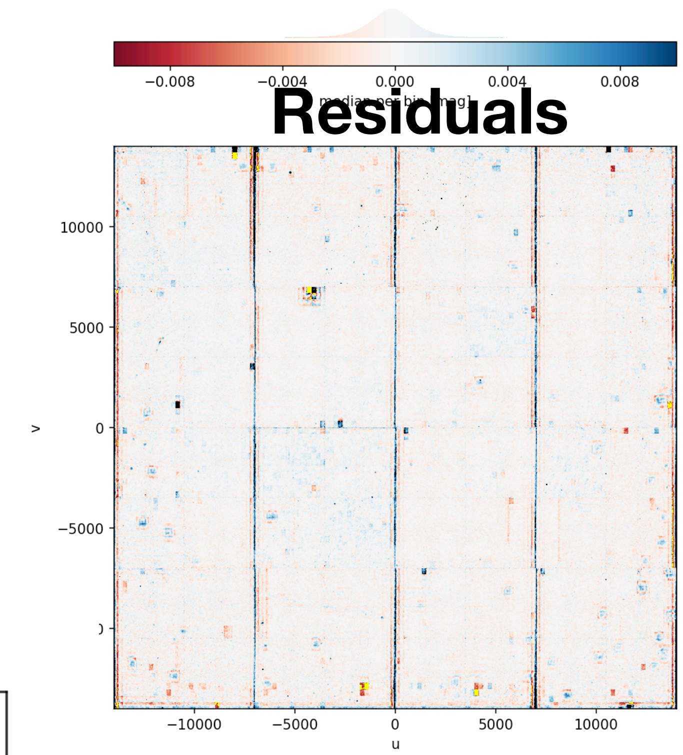




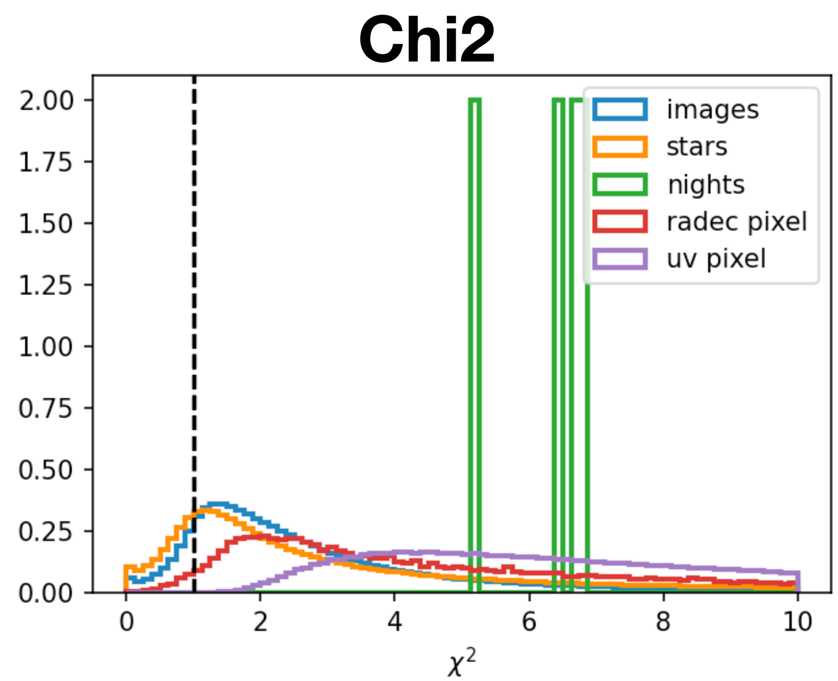


ztf-r

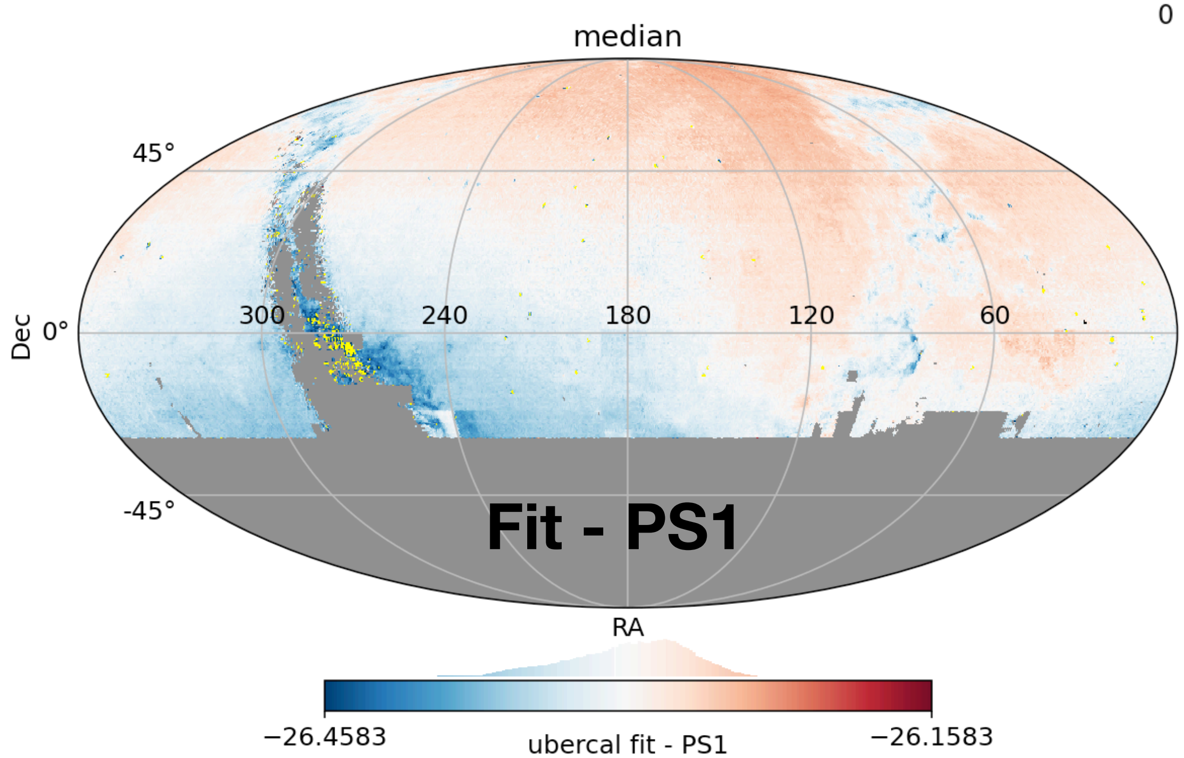




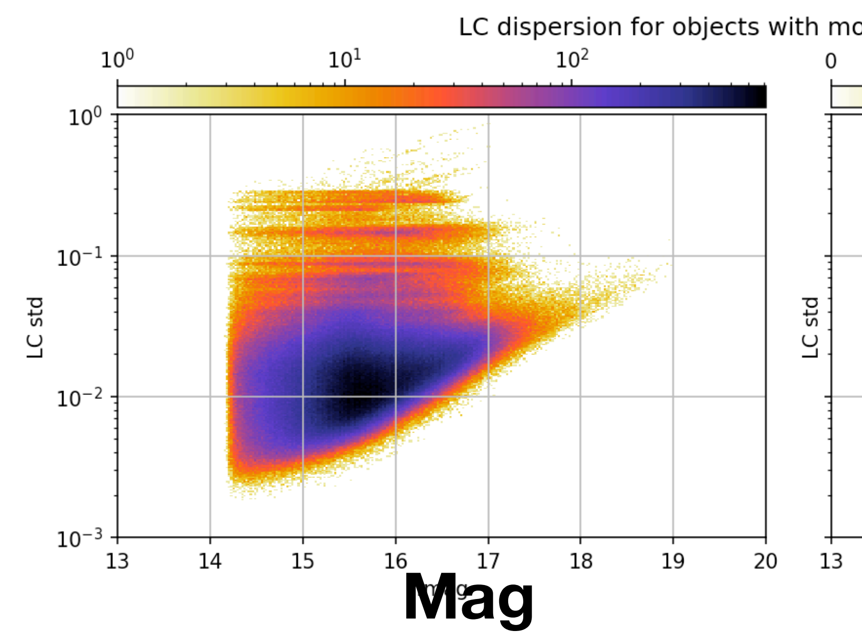
No cuts



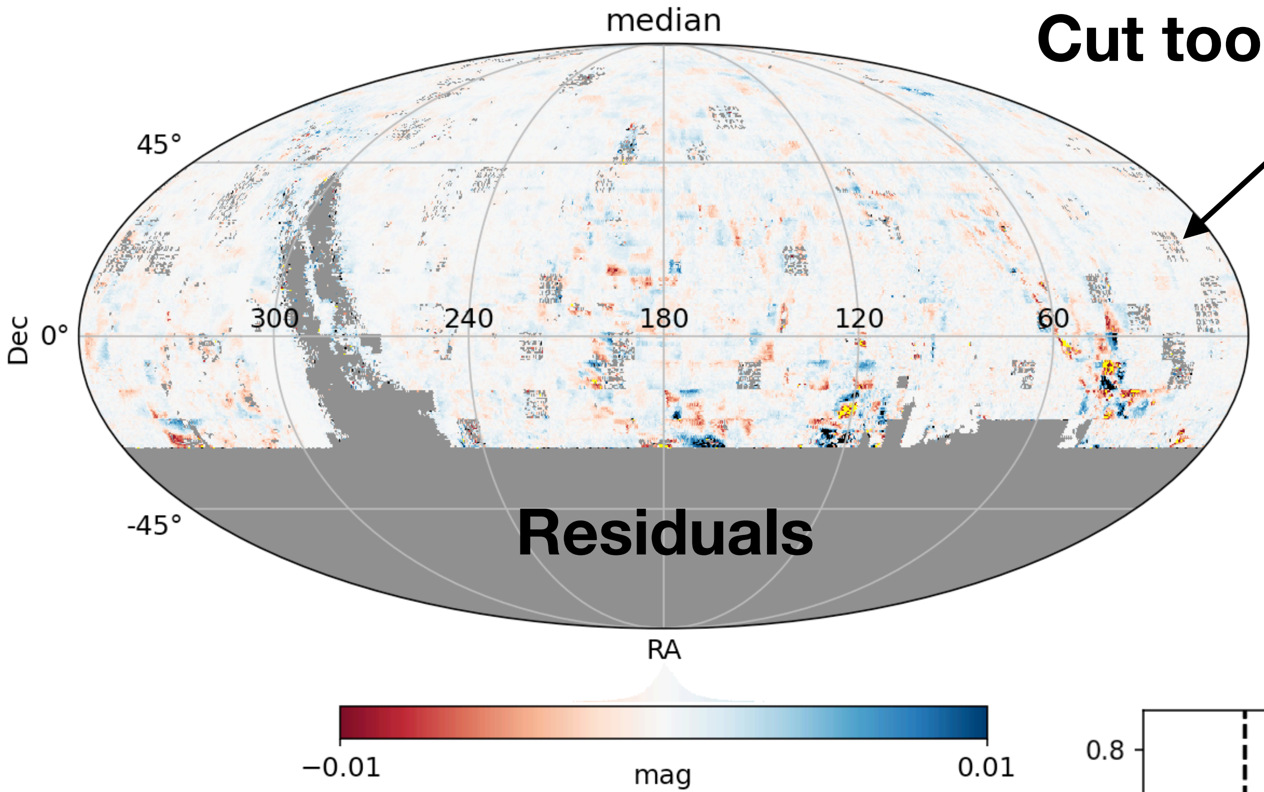
ztf-r

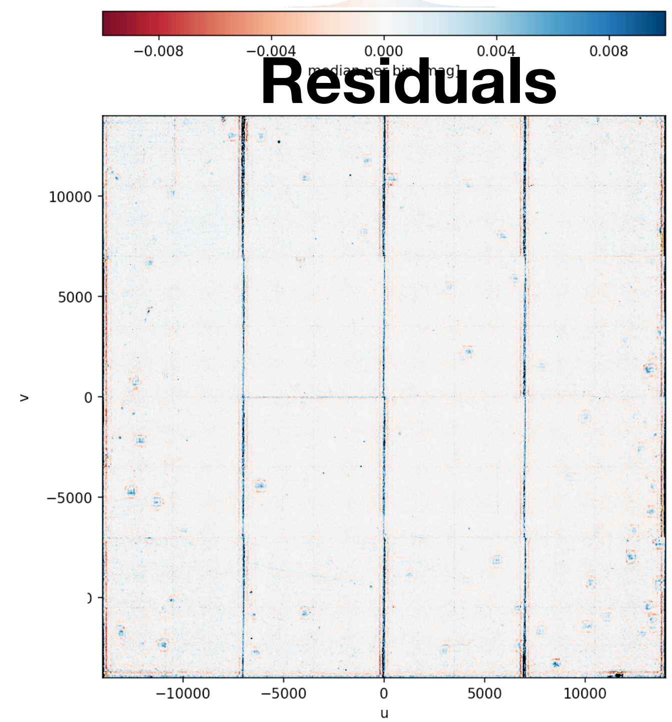


LC std

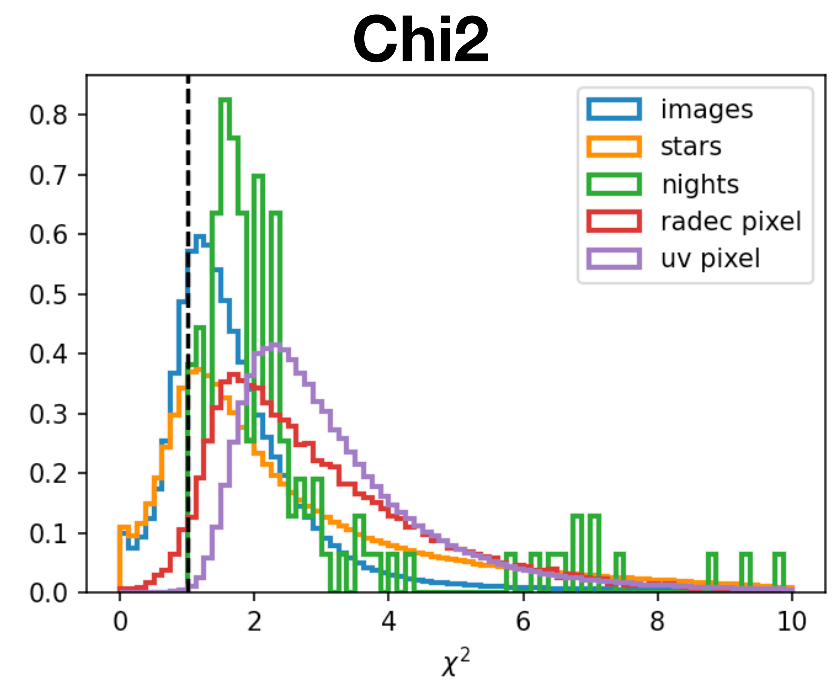


Cut too strong: holes

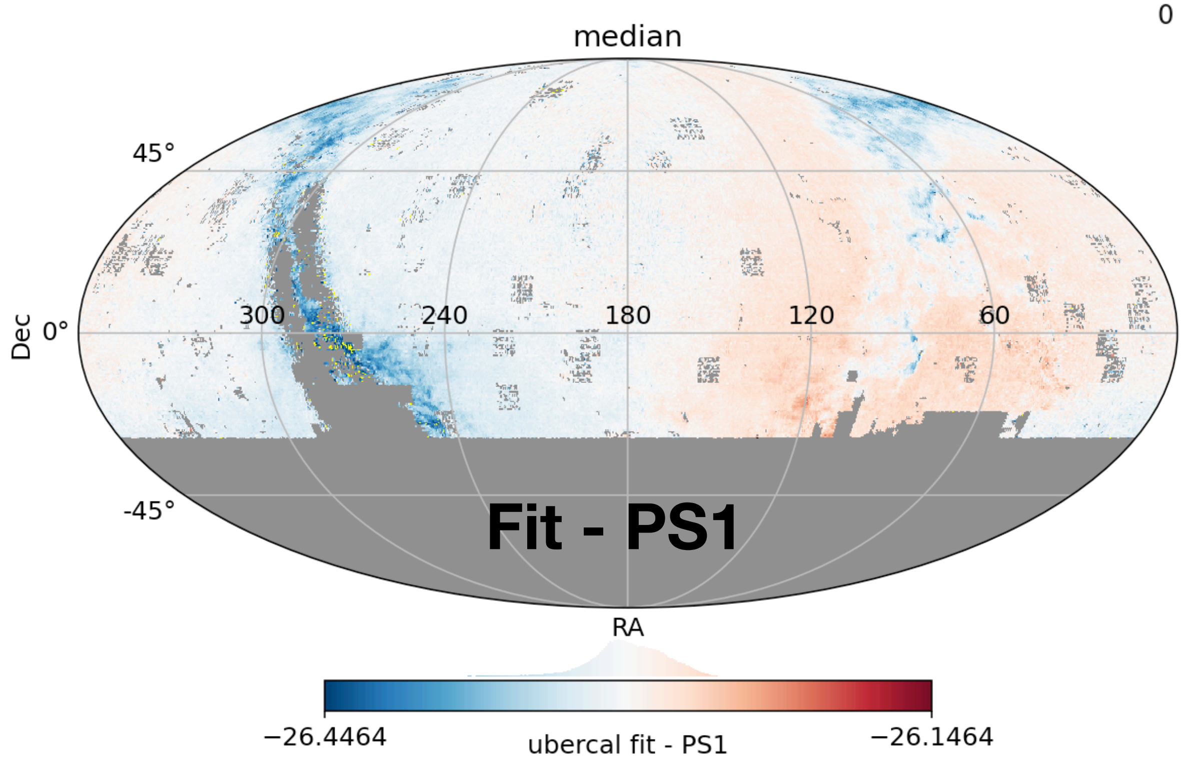




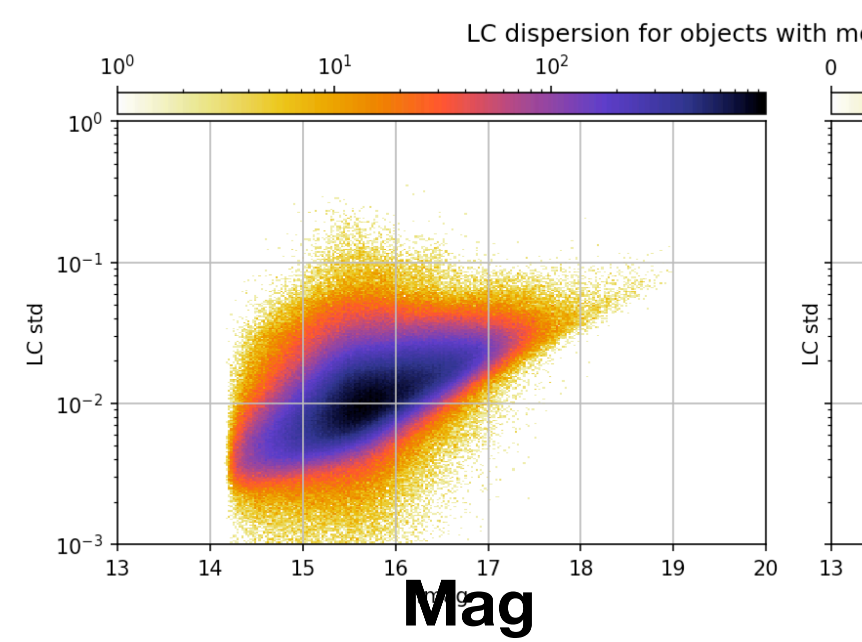
$$\chi^2_\star < 10$$

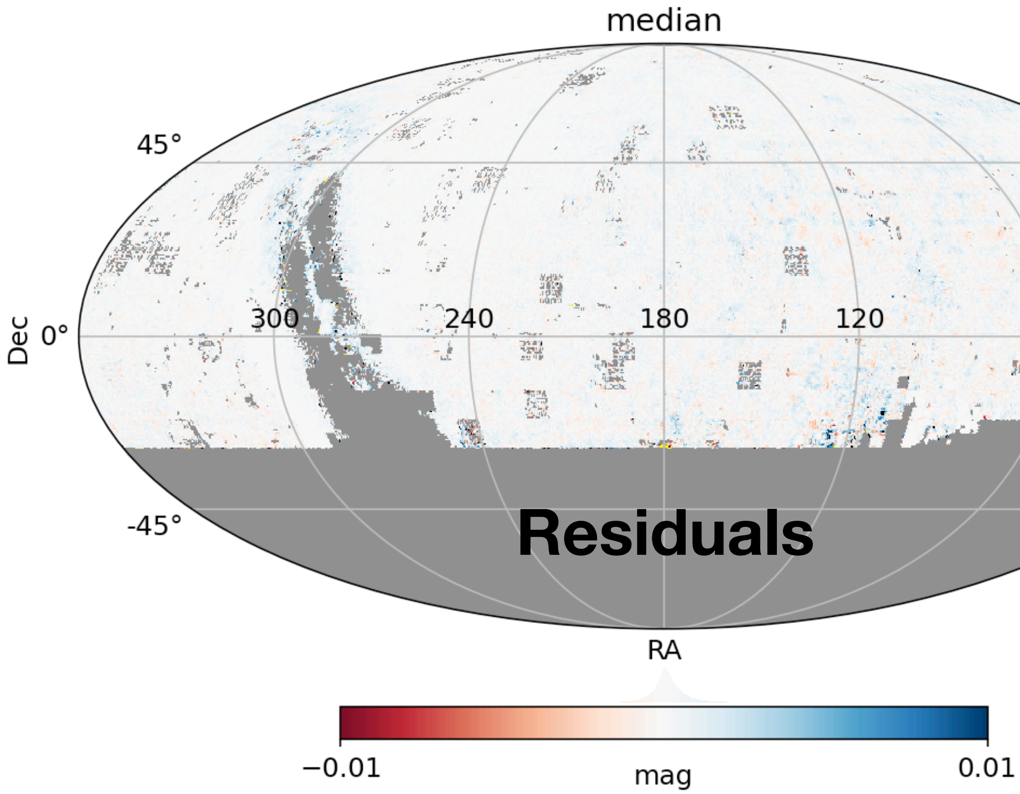


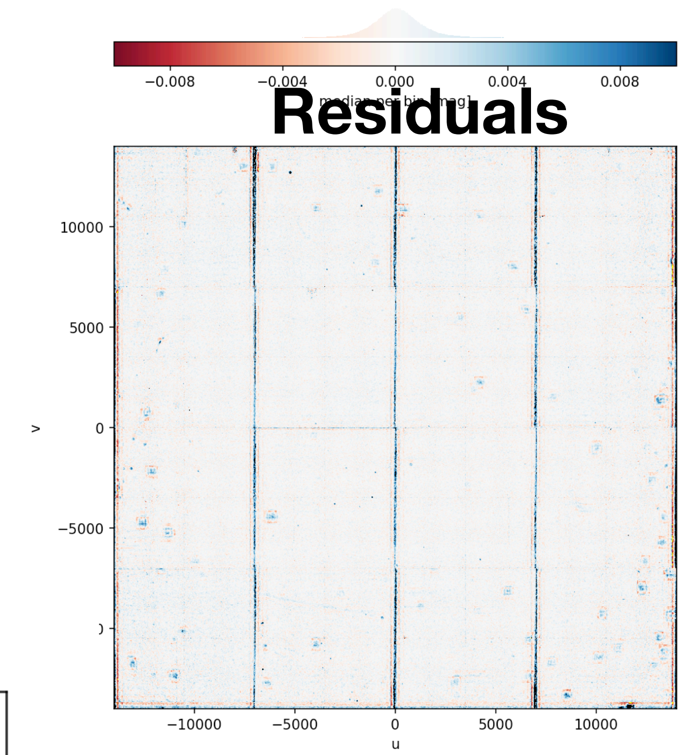
ztf-r



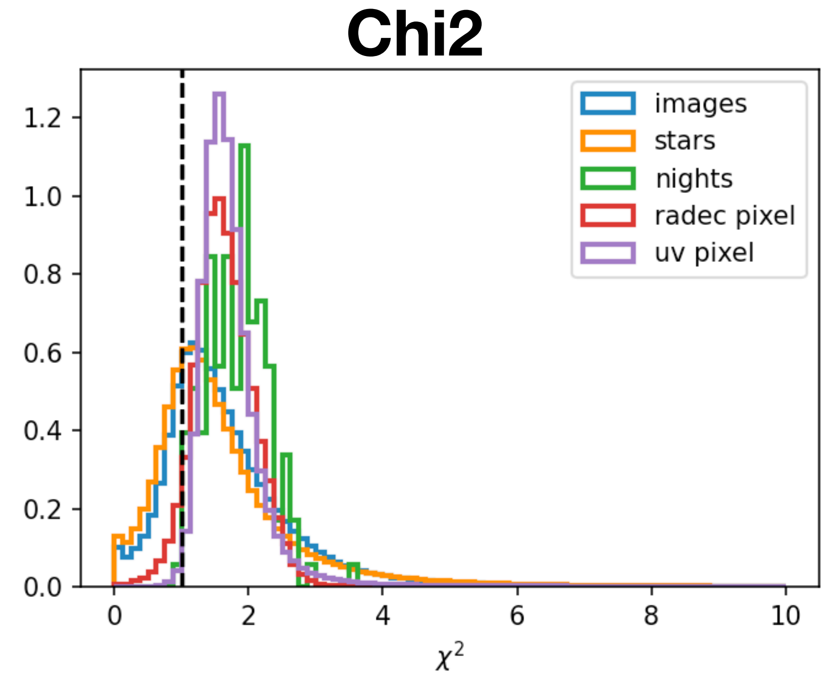
LC std



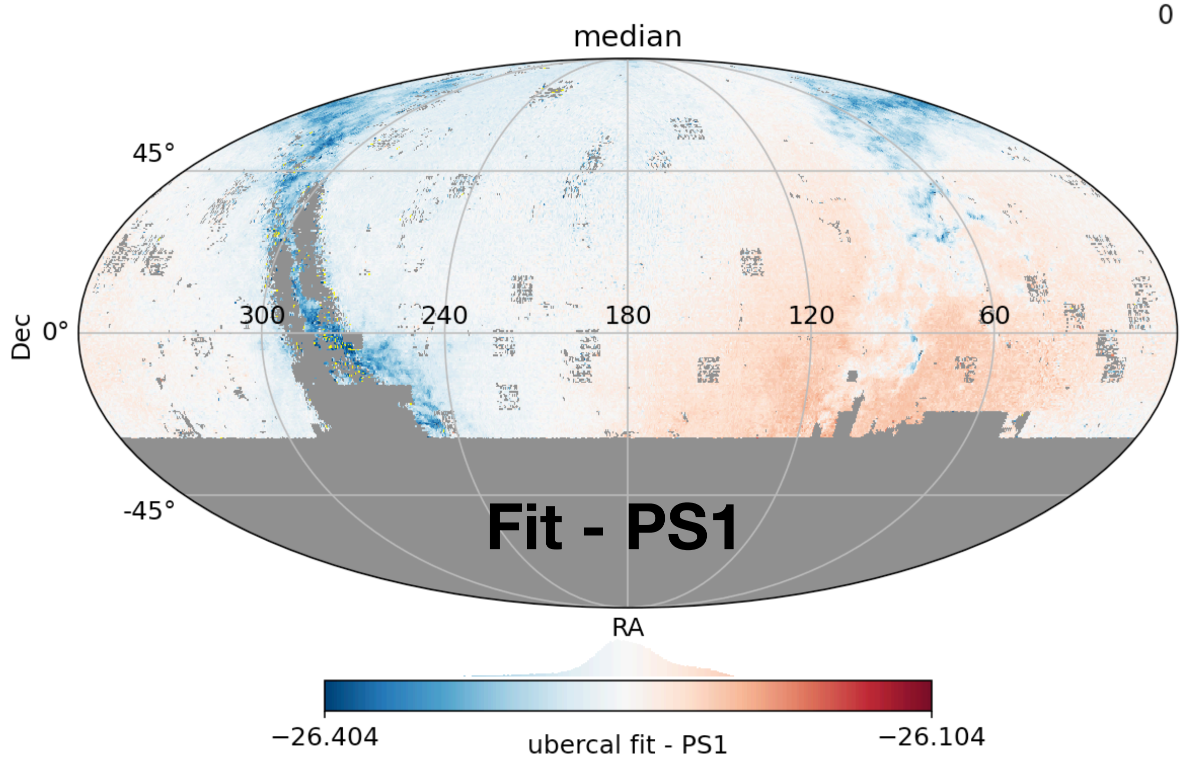


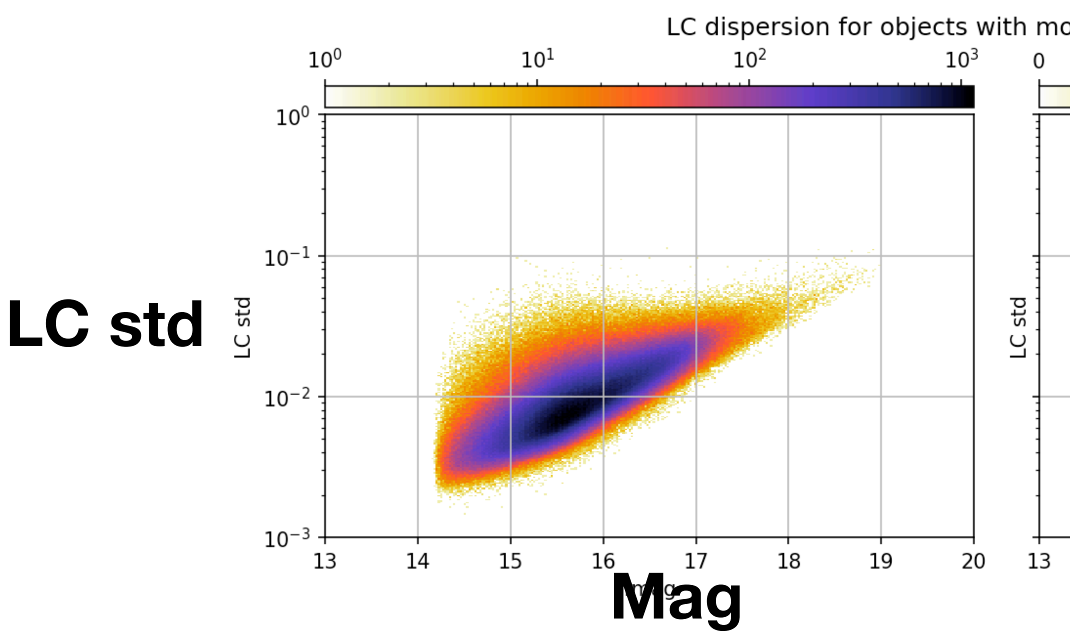


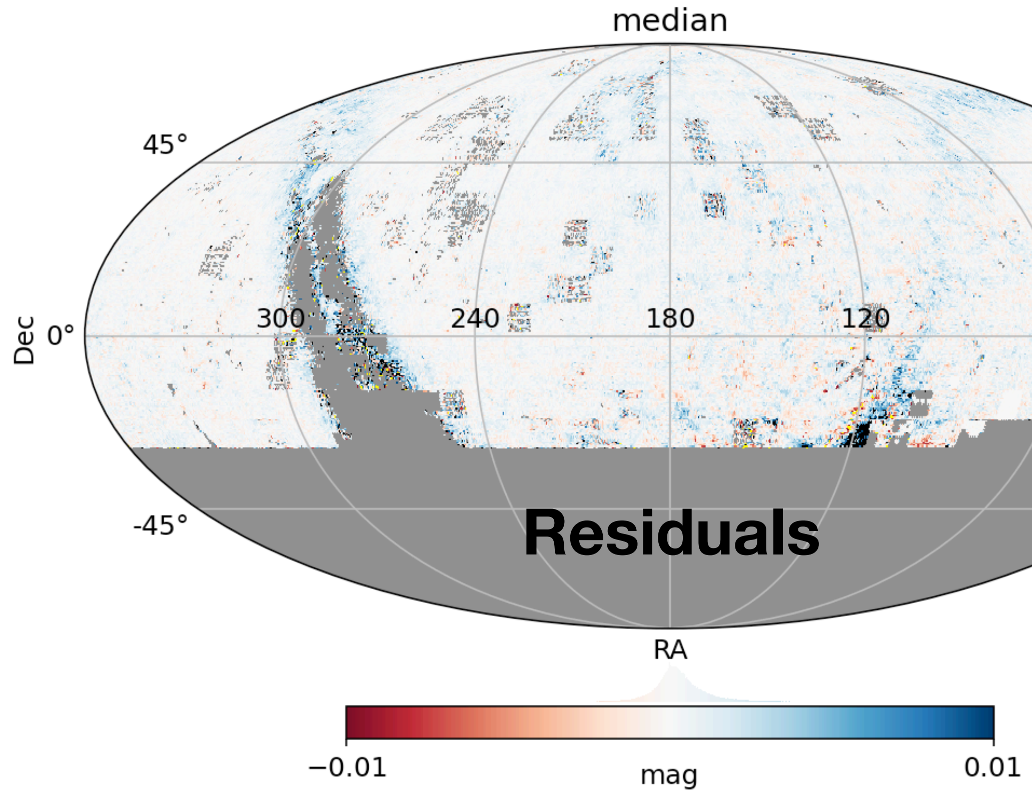
$$\chi^2_\star < 10 \; \& \; \chi^2_{\text{image}} < 6$$

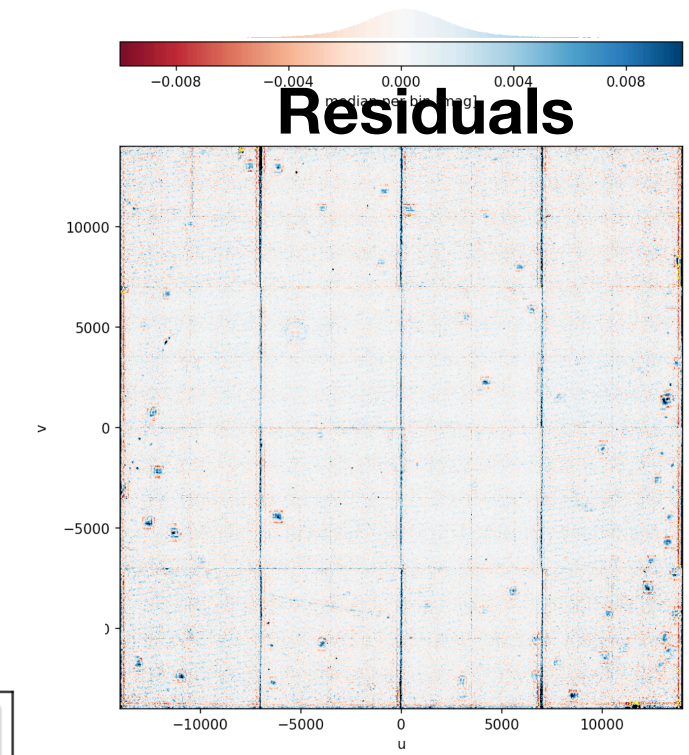


ztf-r

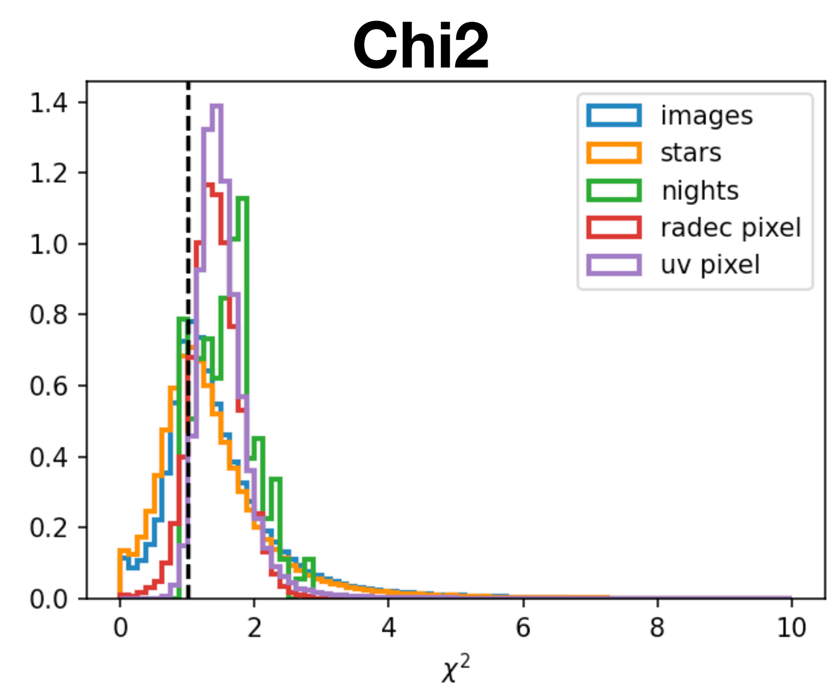




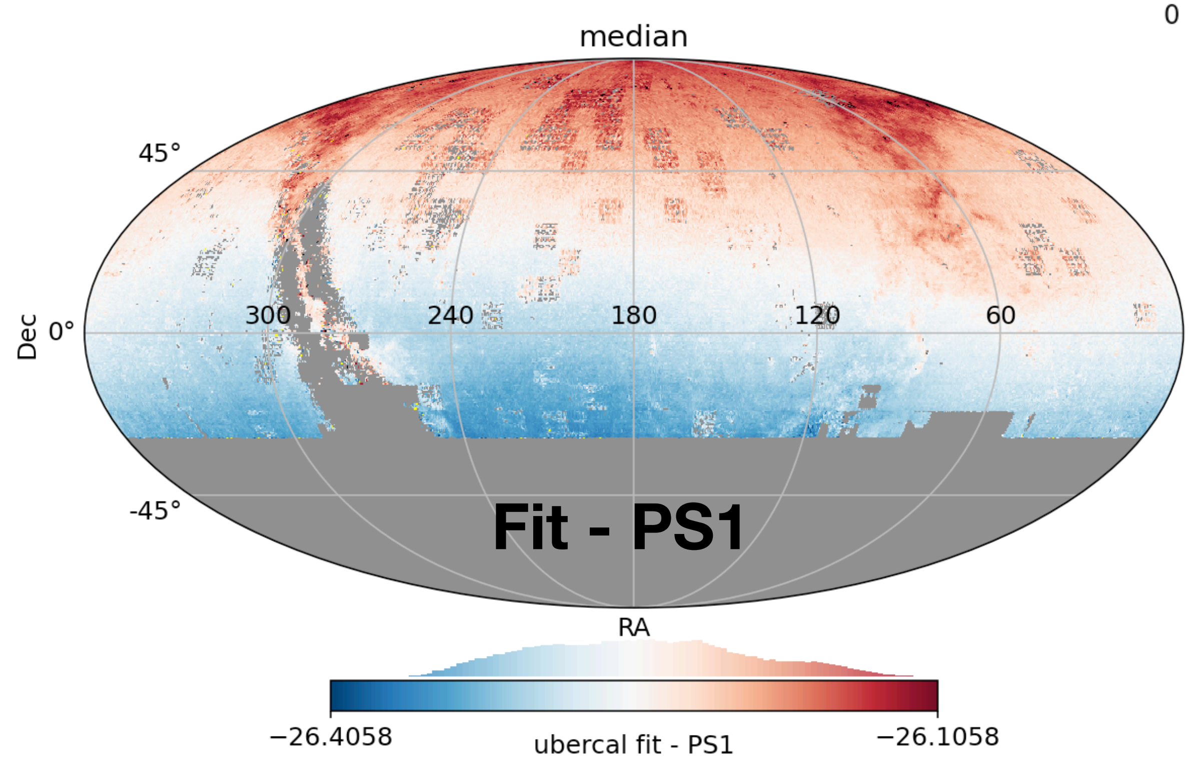


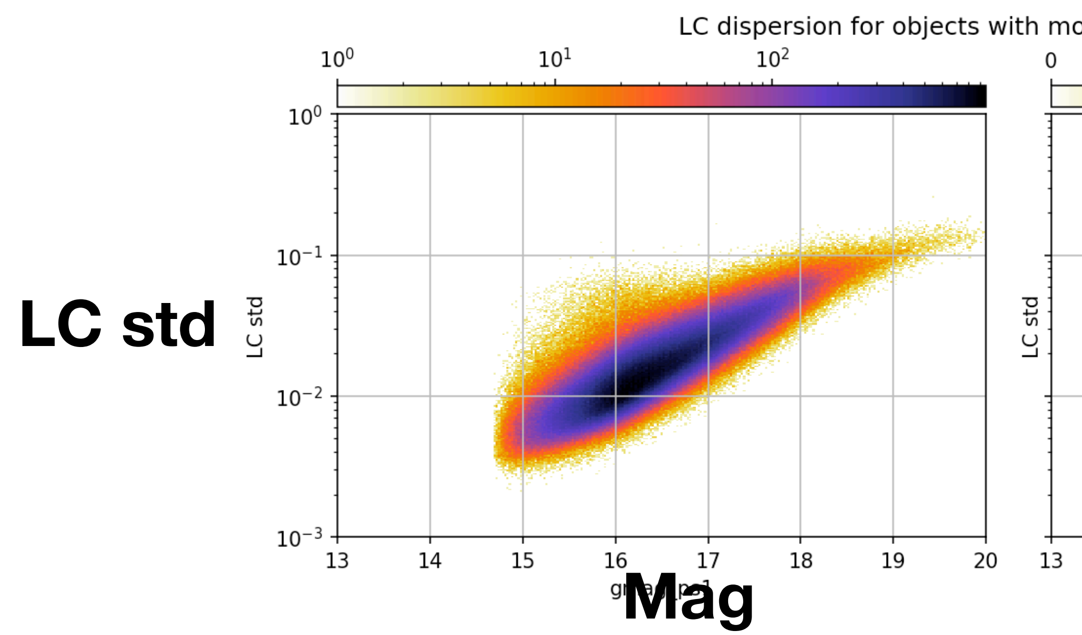


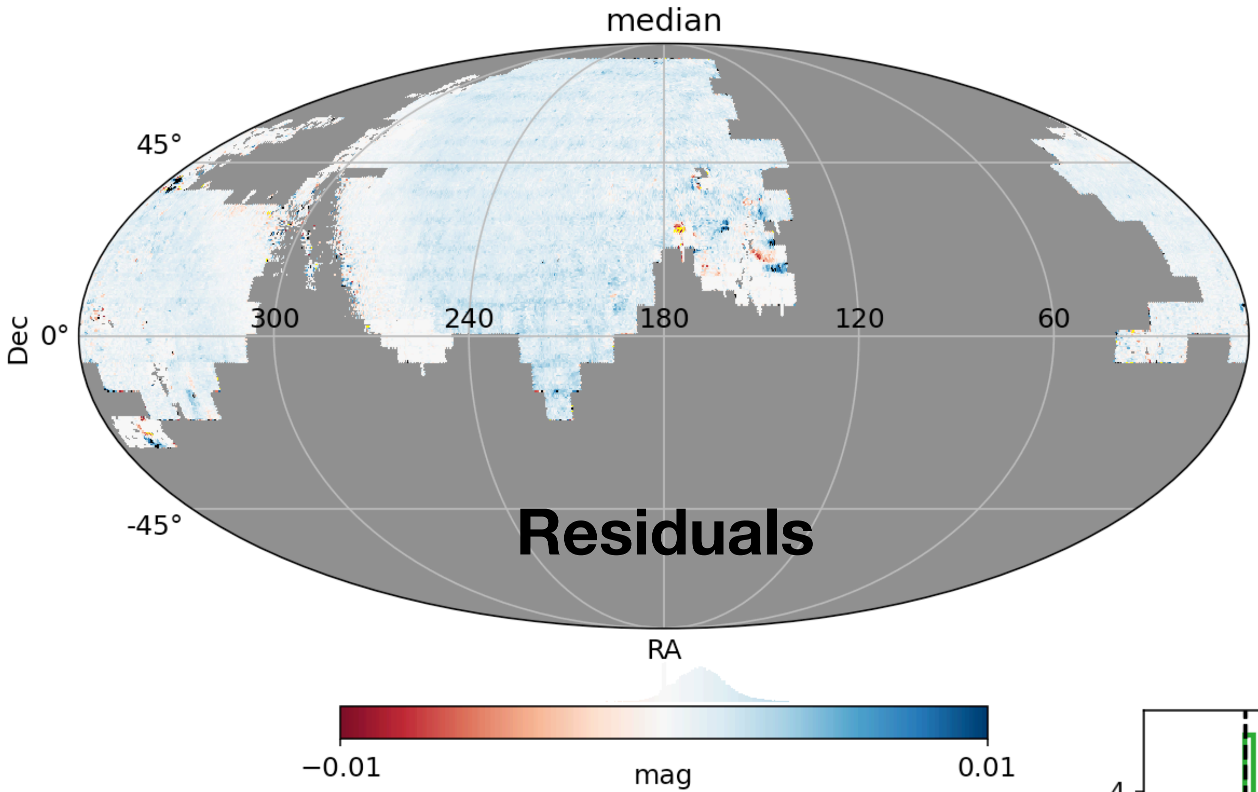
$\chi^2_\star < 10$ **&** $\chi^2_{\mathrm{image}} < 6$

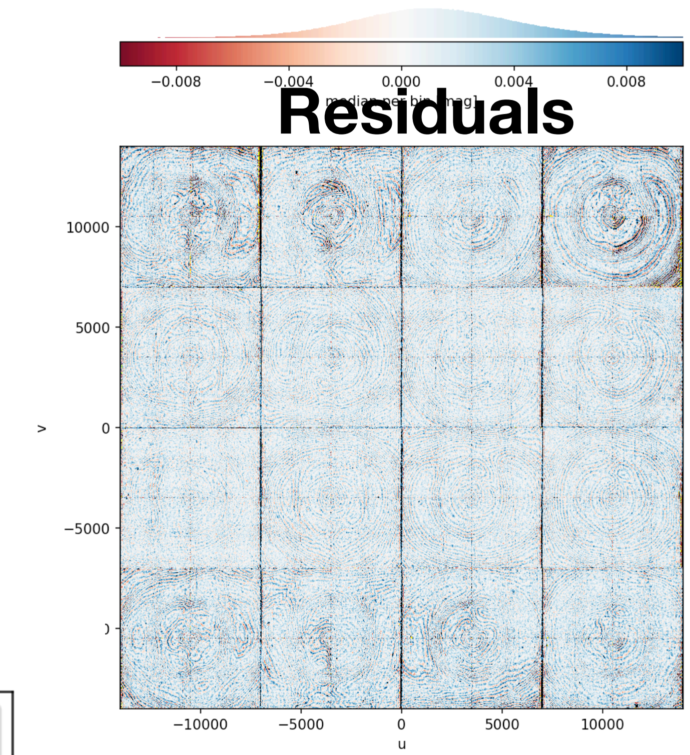


ztf-g

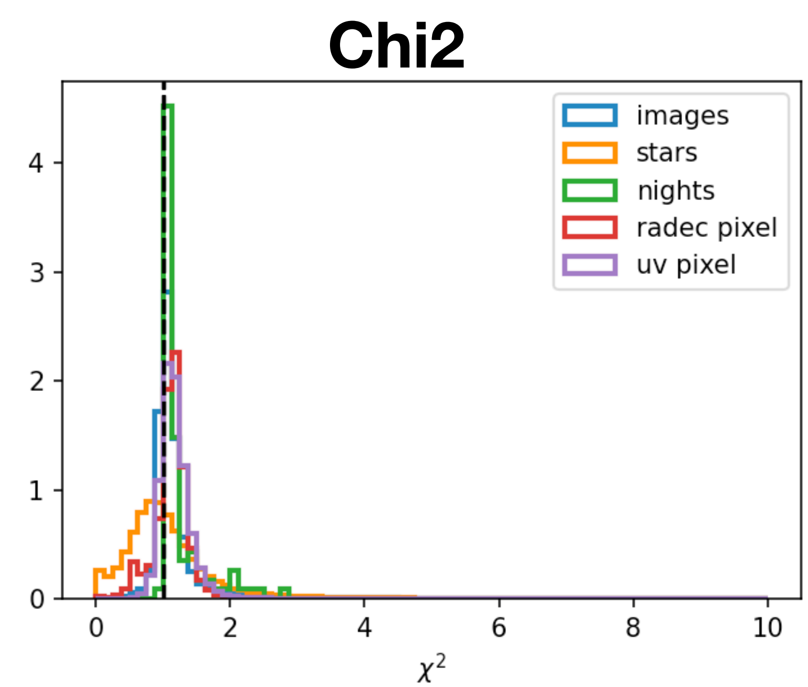




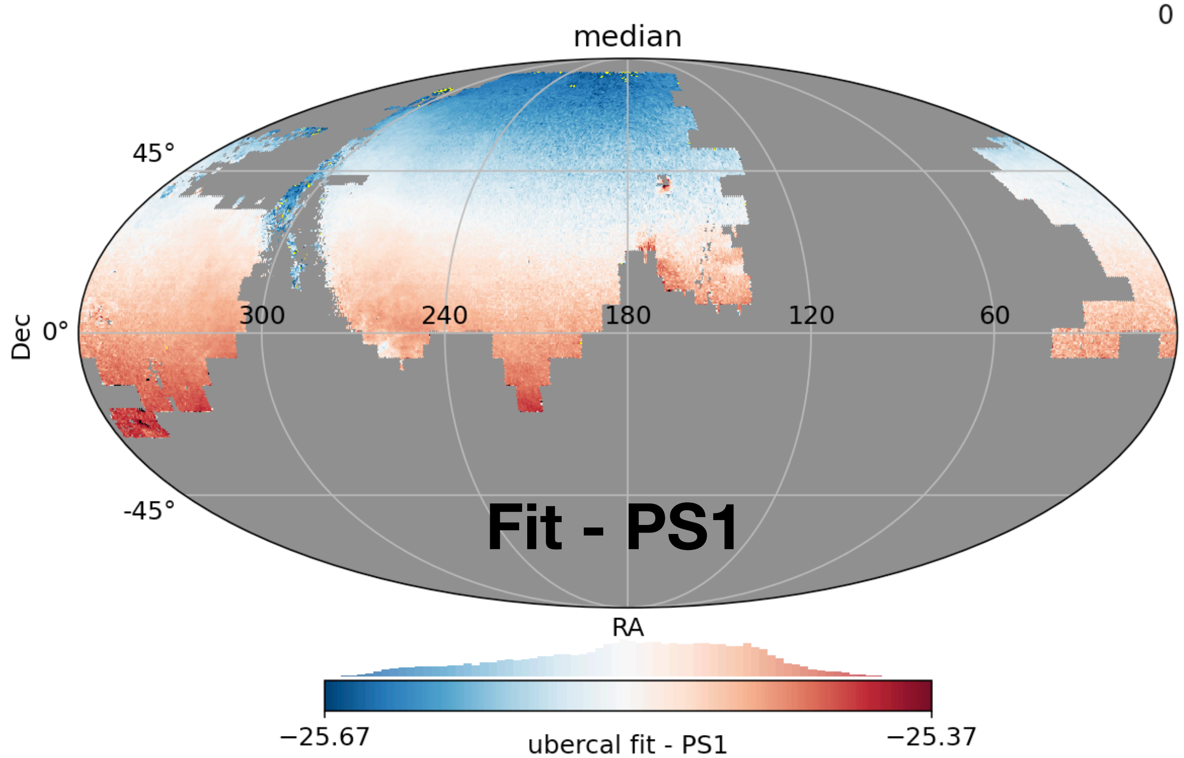




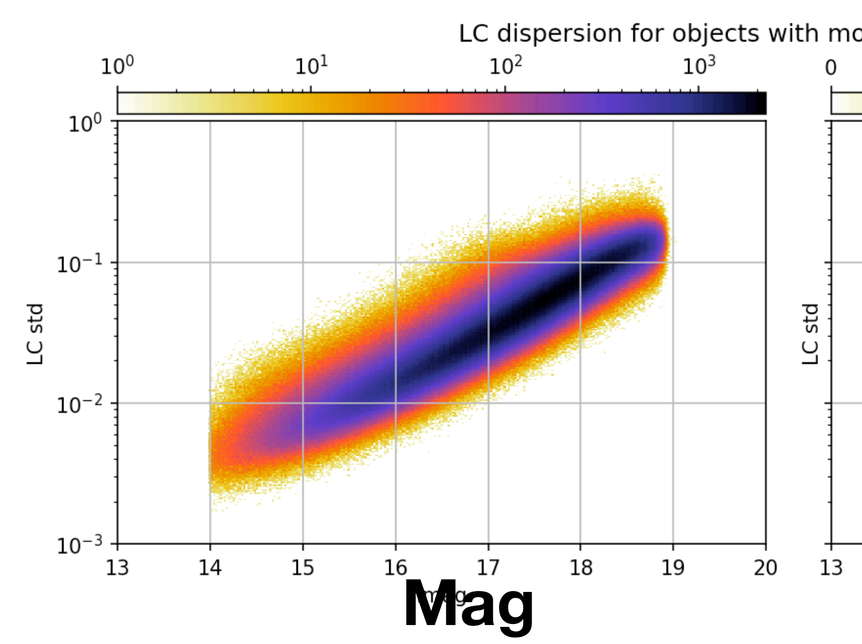
$$\chi^2_\star < 10 \; \& \; \chi^2_{\rm image} < 6$$



ztf-i

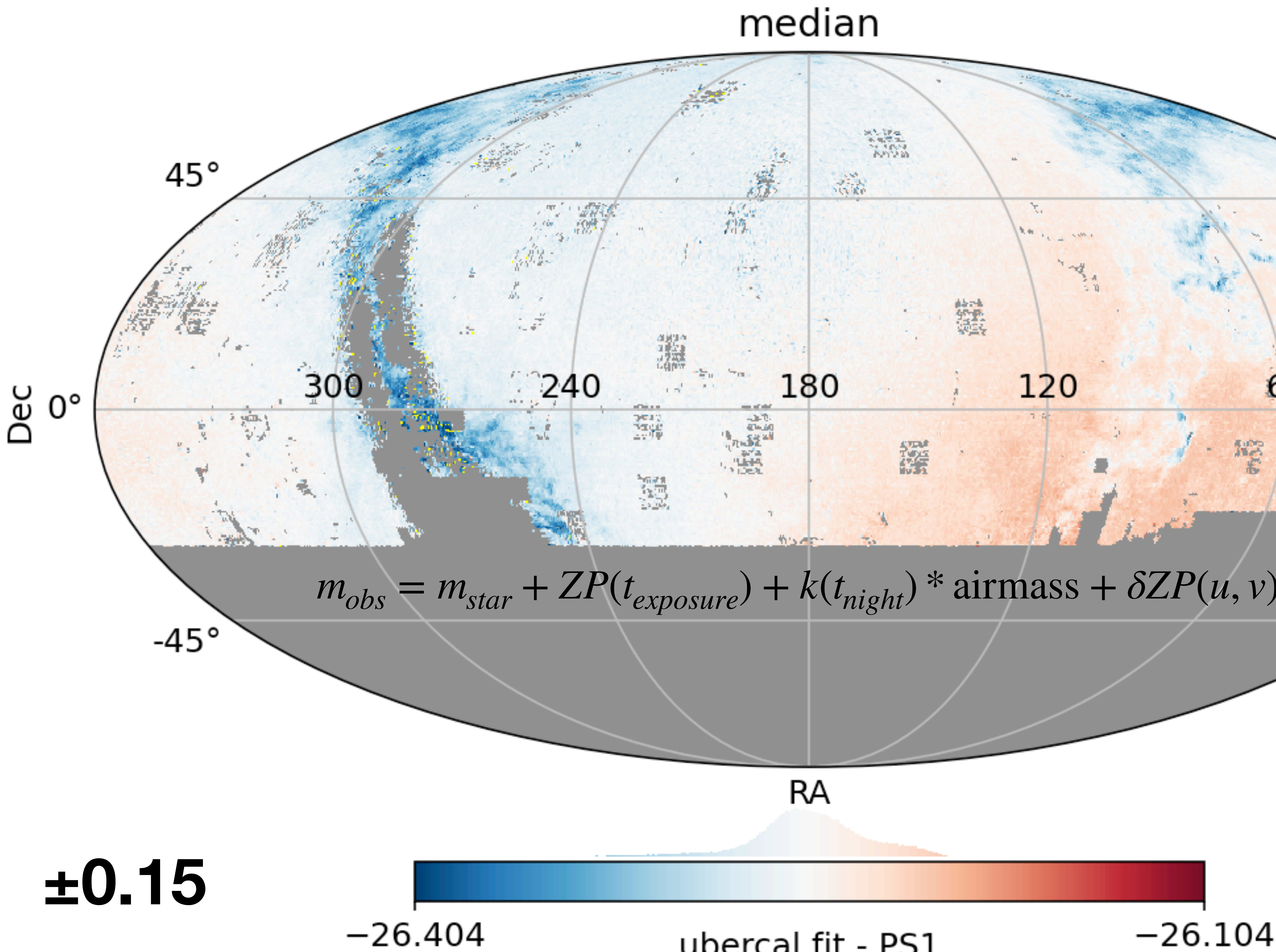


LC std



Full « auto » ubercal

ztf-r



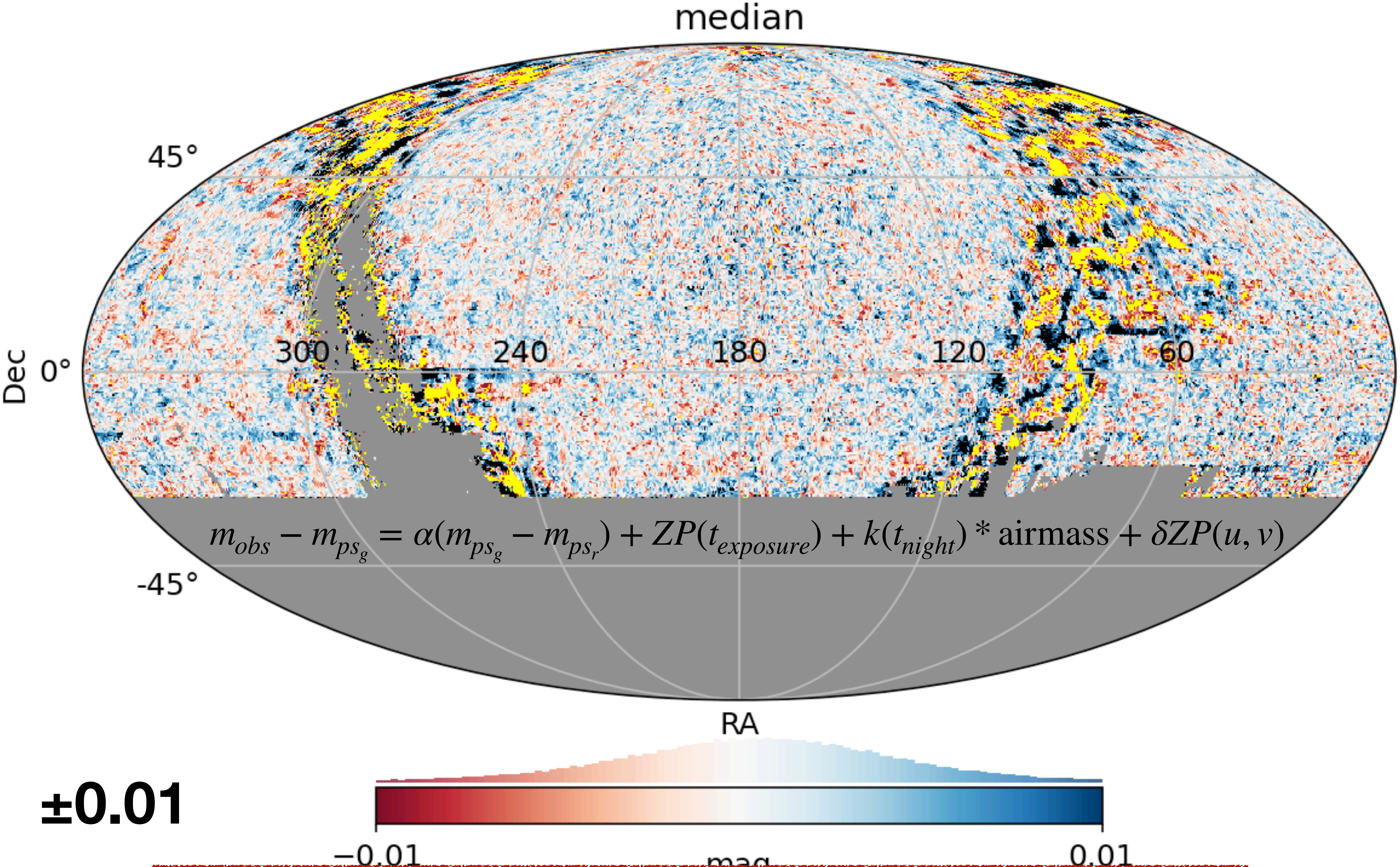
$$m_{obs} = m_{star} + ZP(t_{exposure}) + k(t_{night}) * \text{airmass} + \delta ZP(u, v)$$

±0.15

$$\chi^2_\star < 10 \ \& \ \chi^2_{\text{image}} < 6$$

PS1 anchored ubercal

Ztf-r

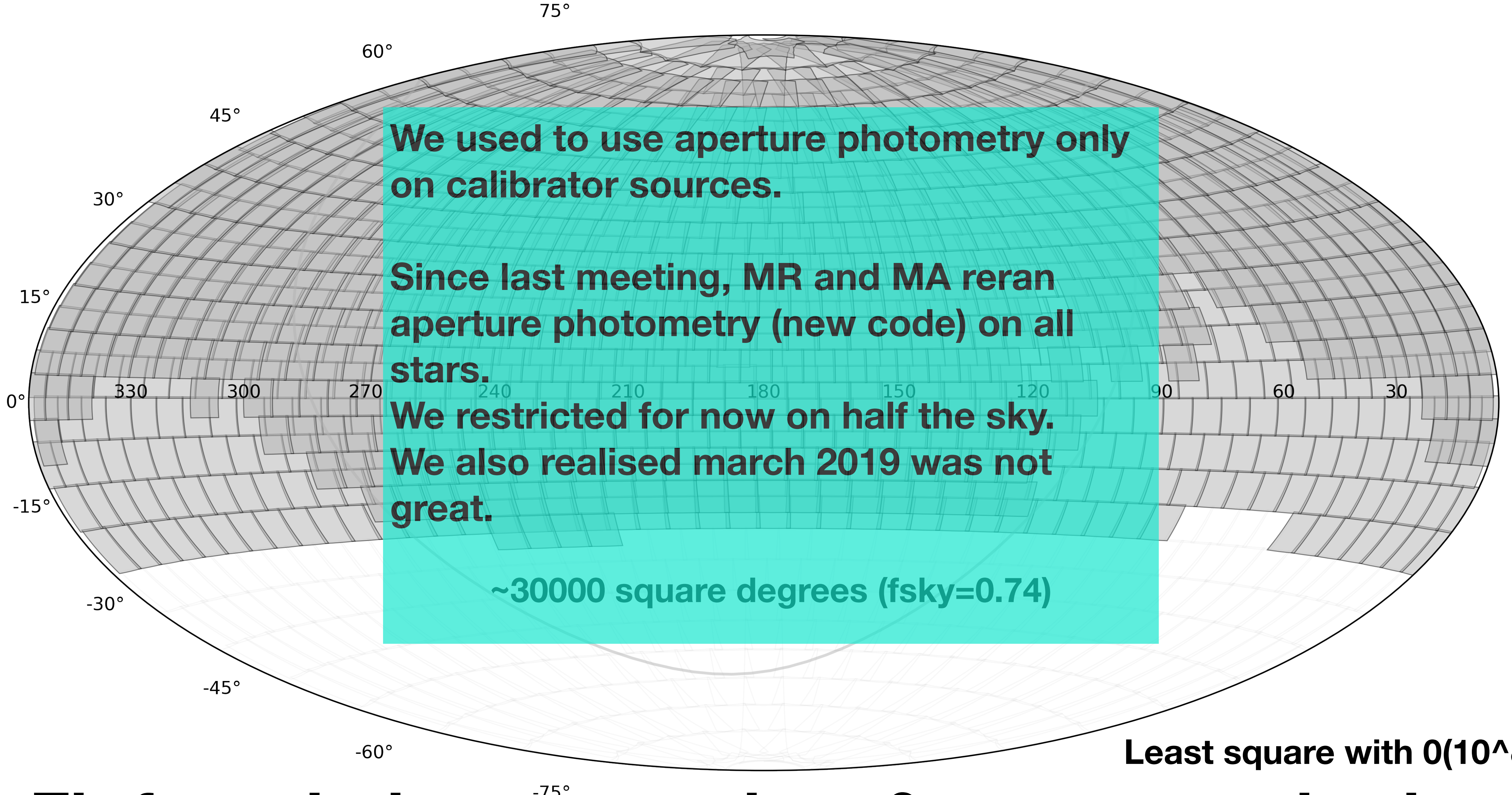


$$m_{obs} - m_{ps_g} = \alpha(m_{ps_g} - m_{ps_r}) + ZP(t_{exposure}) + k(t_{night}) * \text{airmass} + \delta ZP(u,v)$$

±0.01

$\chi^2_\star < 50$ **&** $\chi^2_{\text{image}} < 50$ **&** $\chi^2_\star < 10$ **&** $\chi^2_{\text{image}} < 10$

6 month: 2019-03 to 2019-08



We used to use aperture photometry only on calibrator sources.

Since last meeting, MR and MA reran aperture photometry (new code) on all stars.
We restricted for now on half the sky.
We also realised march 2019 was not great.

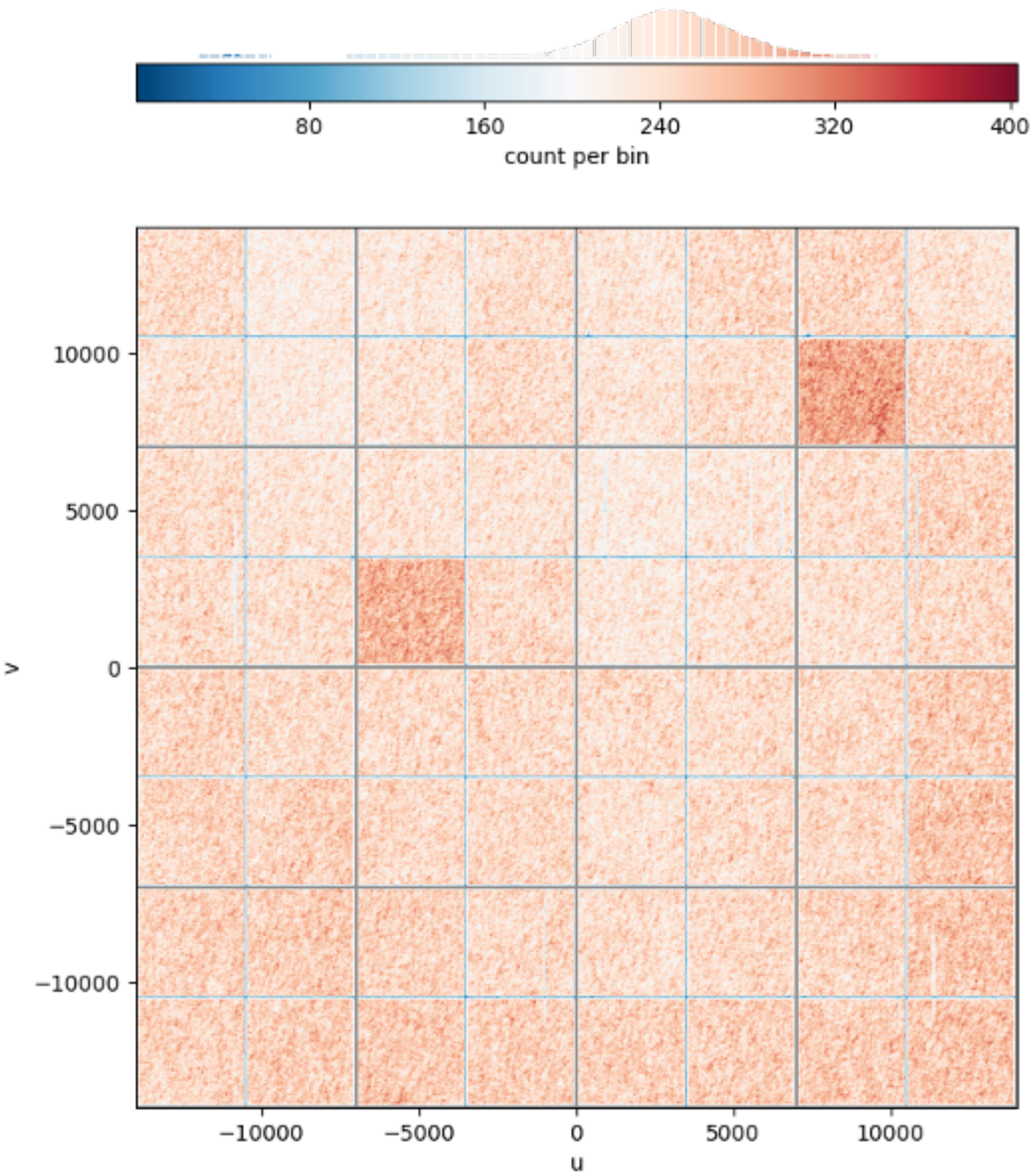
~30000 square degrees (fsky=0.74)

Least square with 0(10^8) lines

Fit for relative zero points & star magnitudes

CCD edge pixels

The edges of the CCDs (not the quadrants) have reflections?
cutting 32 pixel on the edge of the CCDs (+8 for y to make it square).
The images now have 3040 side.
This removes 1.66 % of the observations and 1.30 % of the stars



Here ztf-i, this is the count per 30pix superpixels. We see also an effect from the AP 10 pixel cut at image level. Should be fixed when we work with ccd images

catalog building

see p 32 of : https://irsa.ipac.caltech.edu/data/ZTF/docs/ztf_pipelines_deliverables.pdf

remove:

(g -i < 0.2)&(g>=18.0)& (g<=21.0)

(g -i < 2.771429 - 0.142857*.g)&(g>=14.5)& (g<=18)

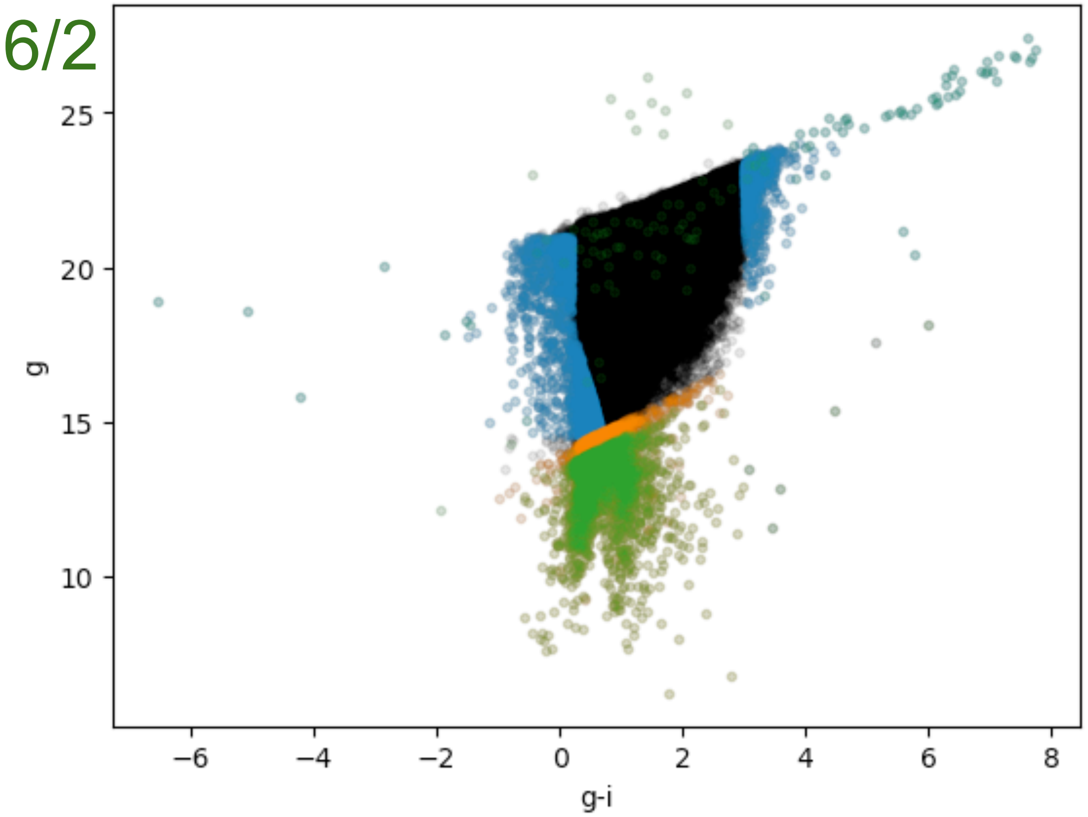
g-i>3

mag_err<1.086/2

mag_i>14

This removes more than 60% stars:

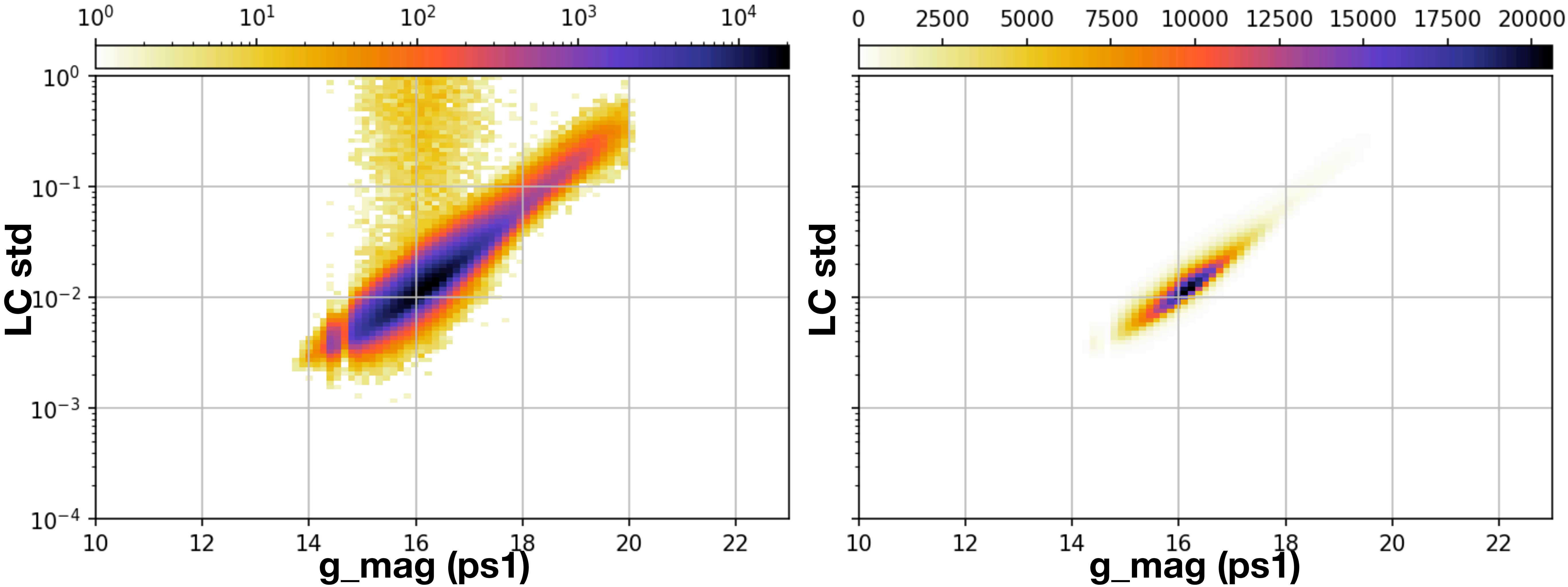
fid
1 0.388311
2 0.387851
3 0.381362



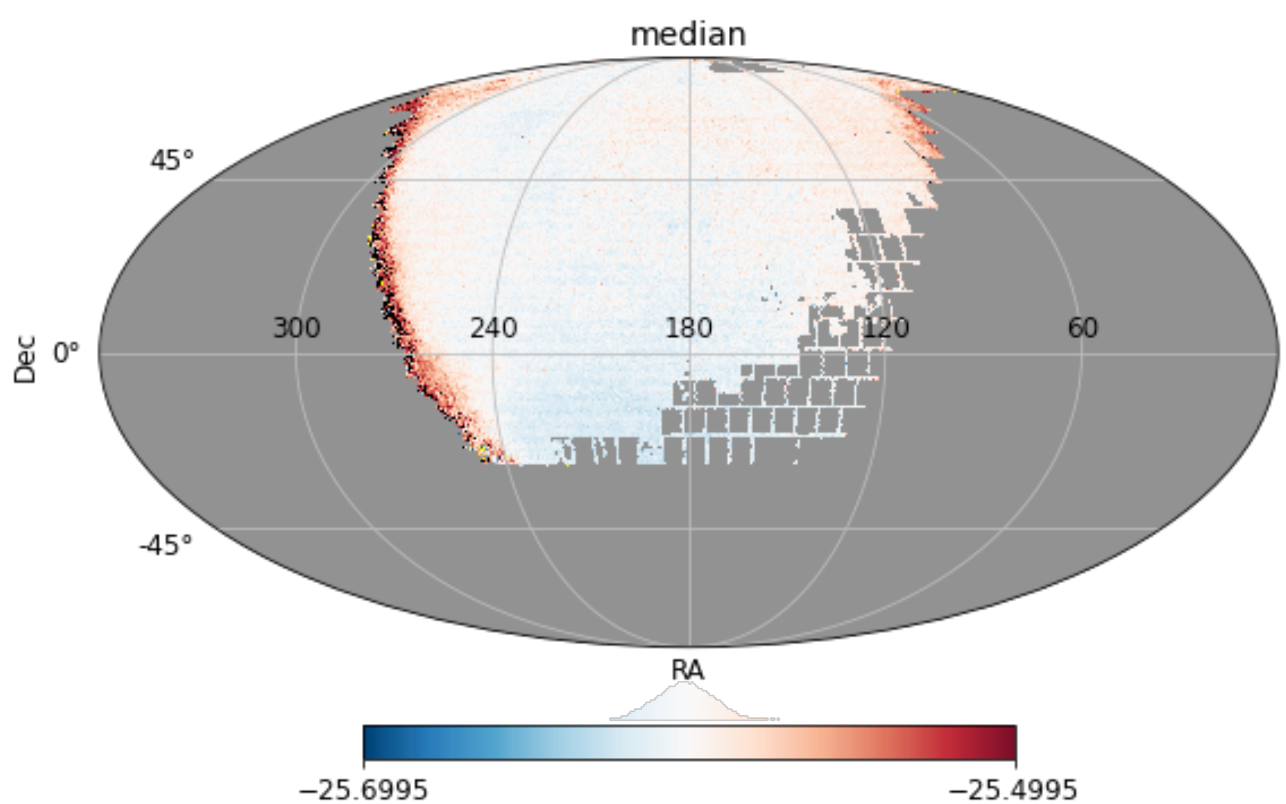
ZTF/Working_area/20230426_check_AP_output_and_produce_cat/20230428_clean_ps1.ipynb

1.3 Million stars

ztf-g

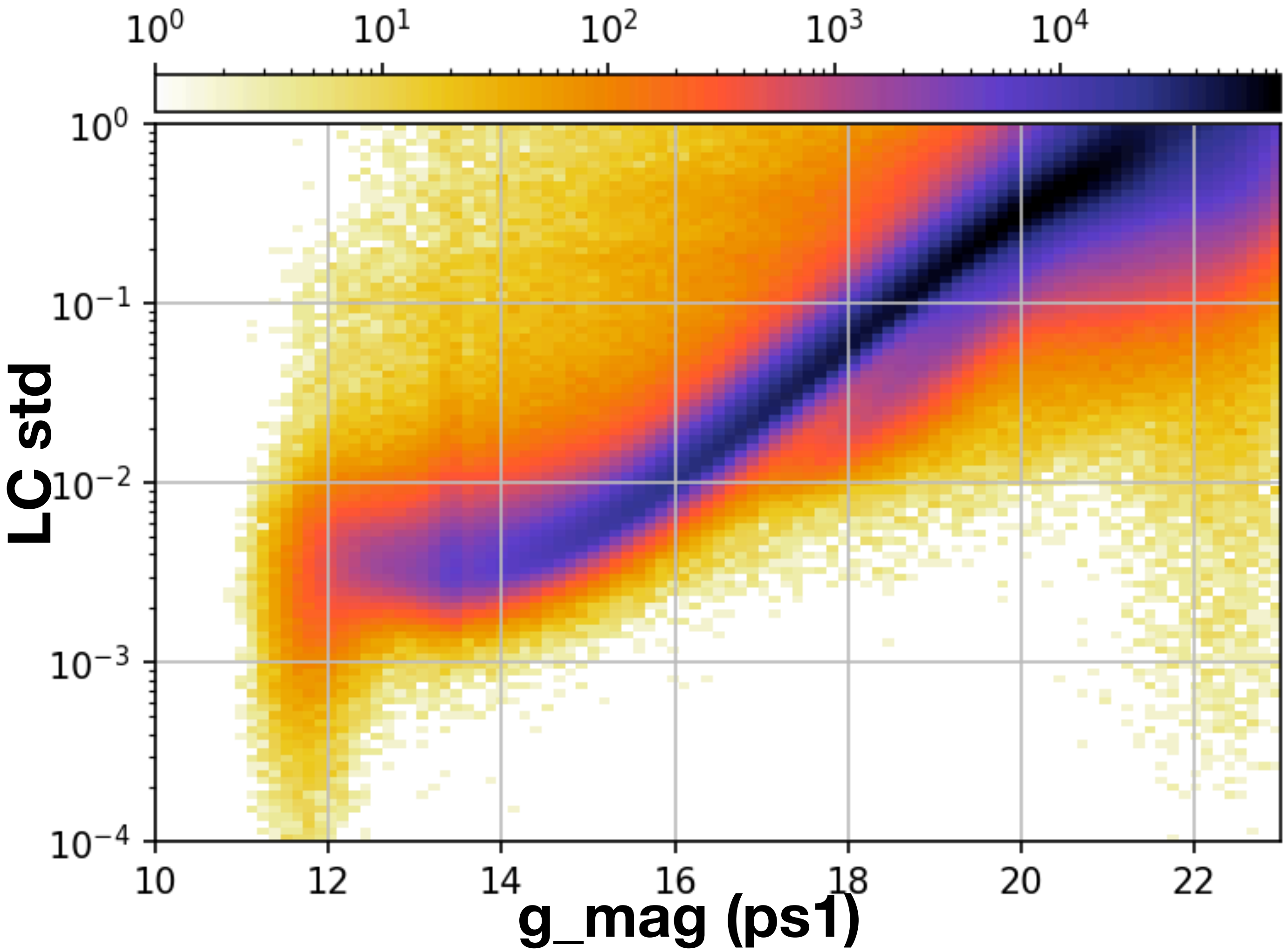


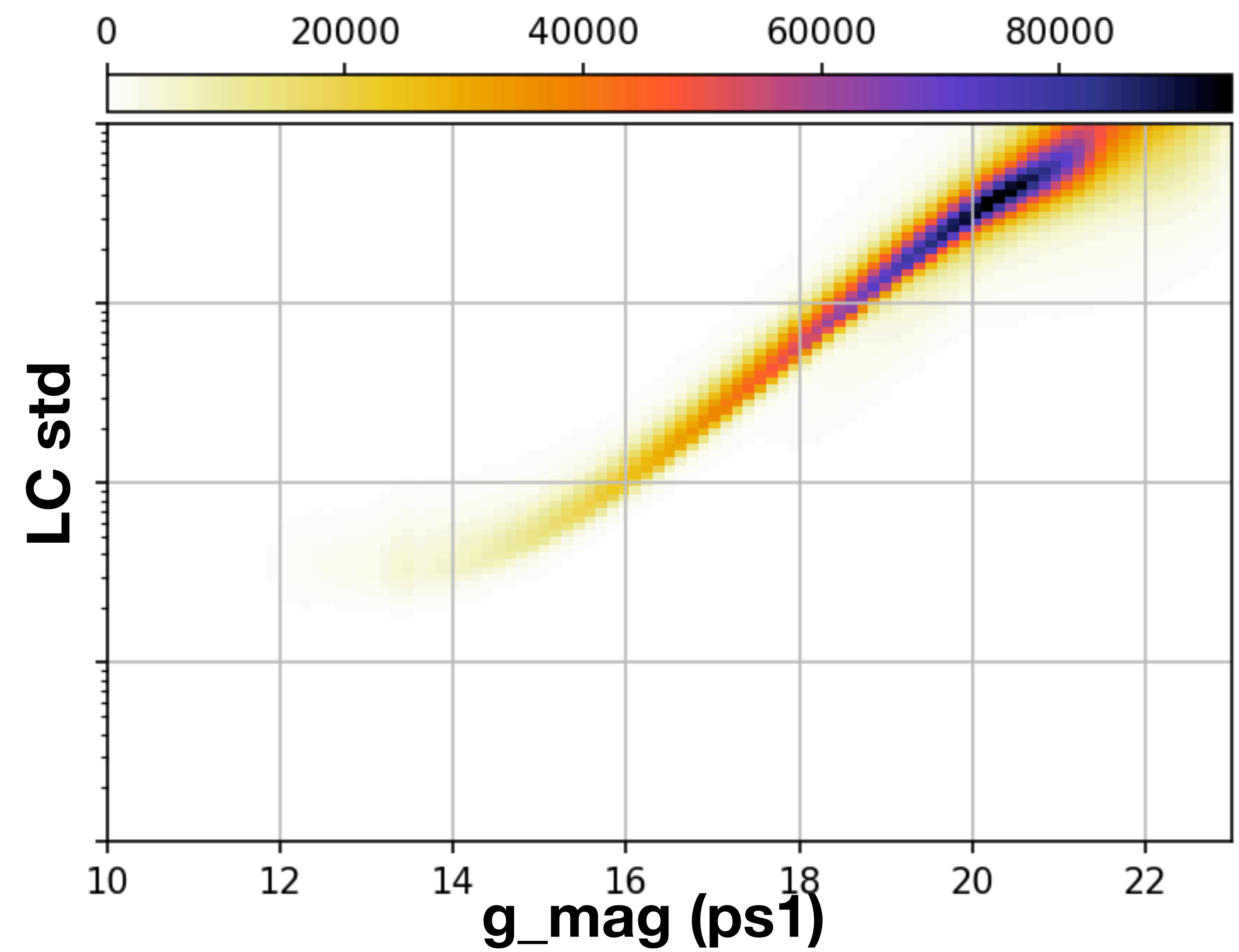
ubercal_mag - g (ps1)
n_obs>10



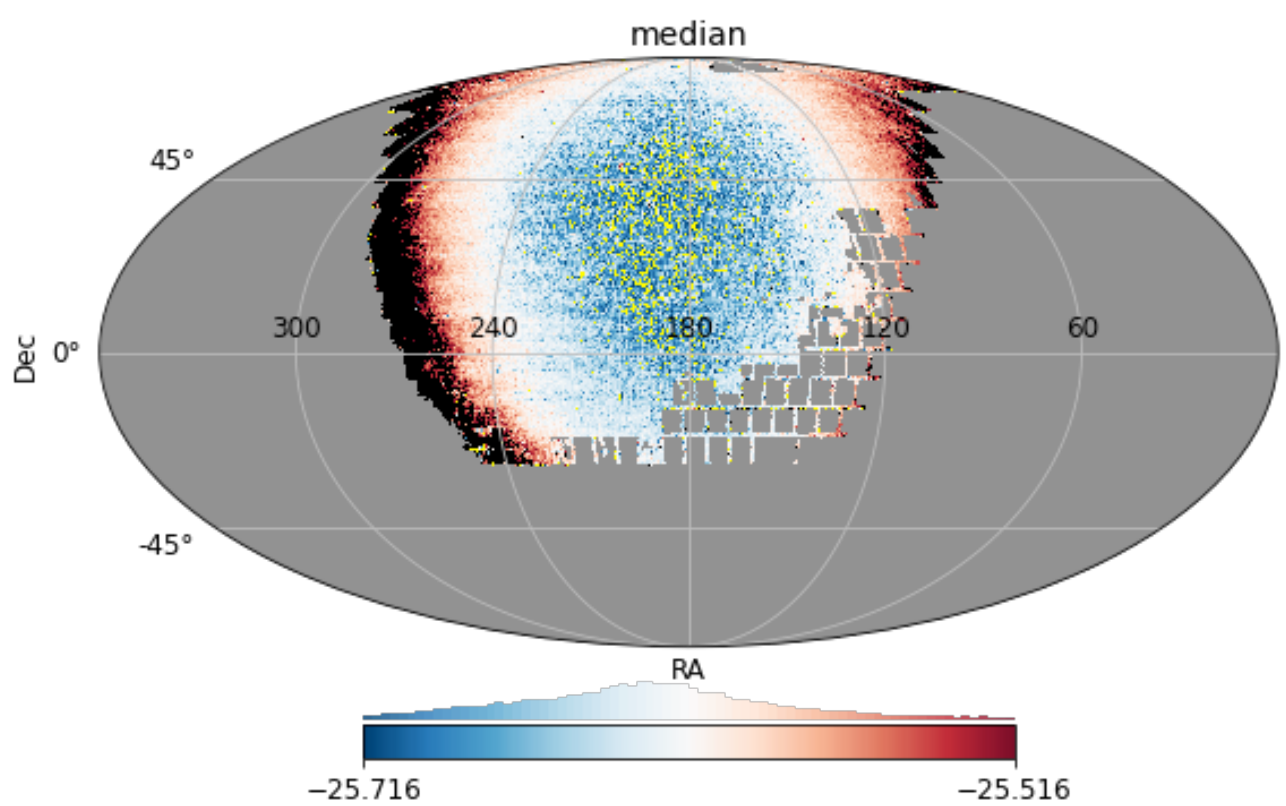
~30 Million stars

ztf-g



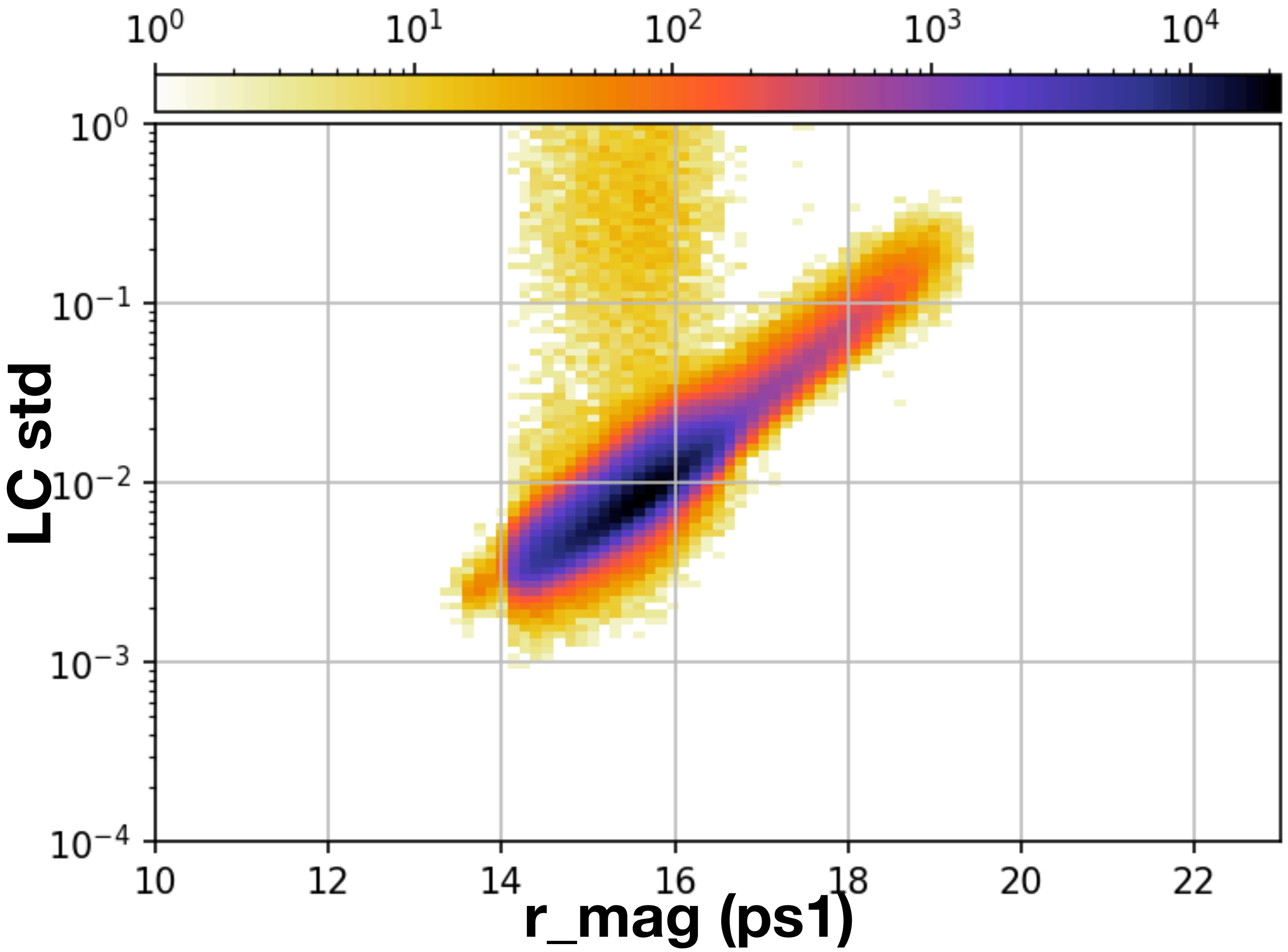


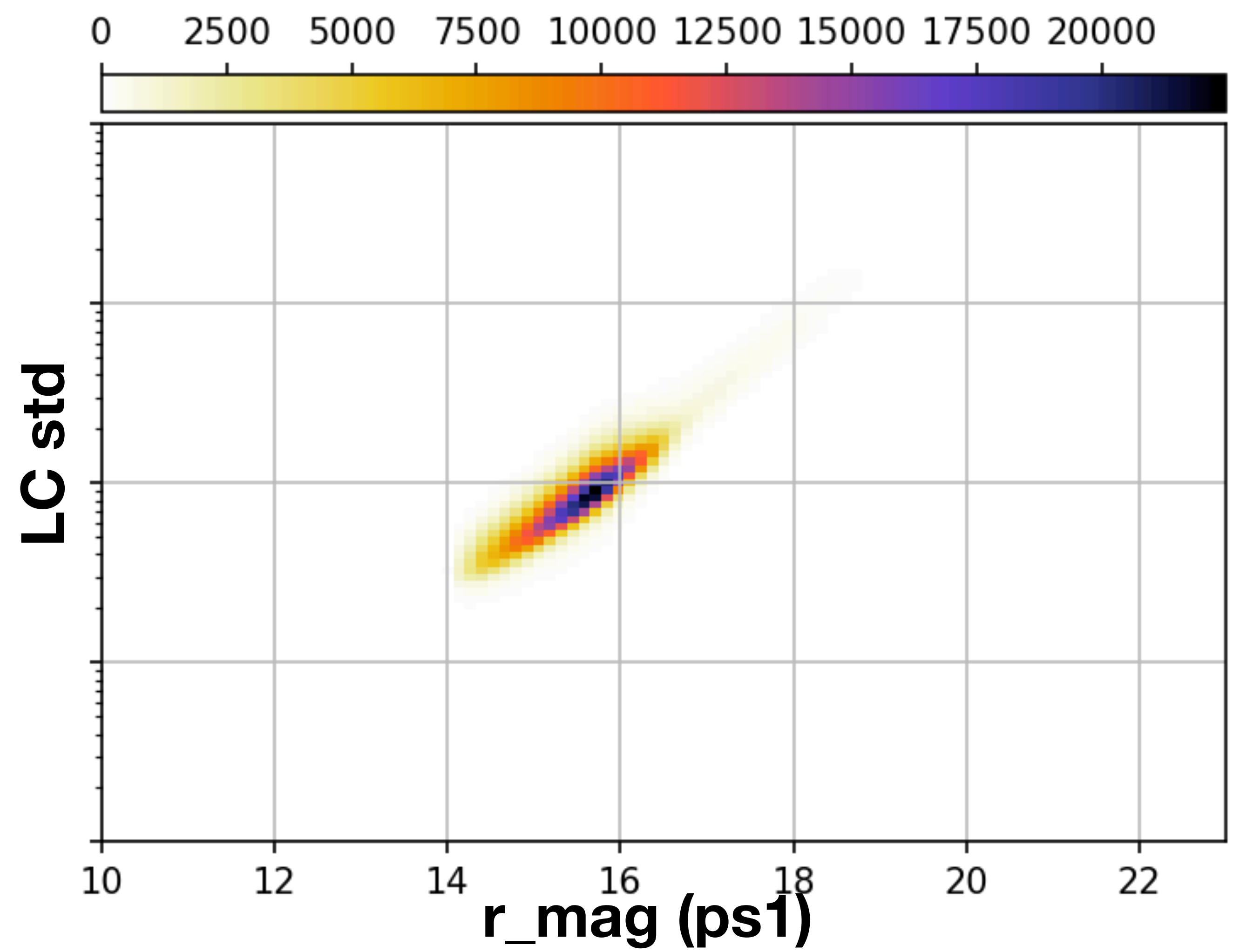
ubercal_mag - g (ps1)
n_obs>10



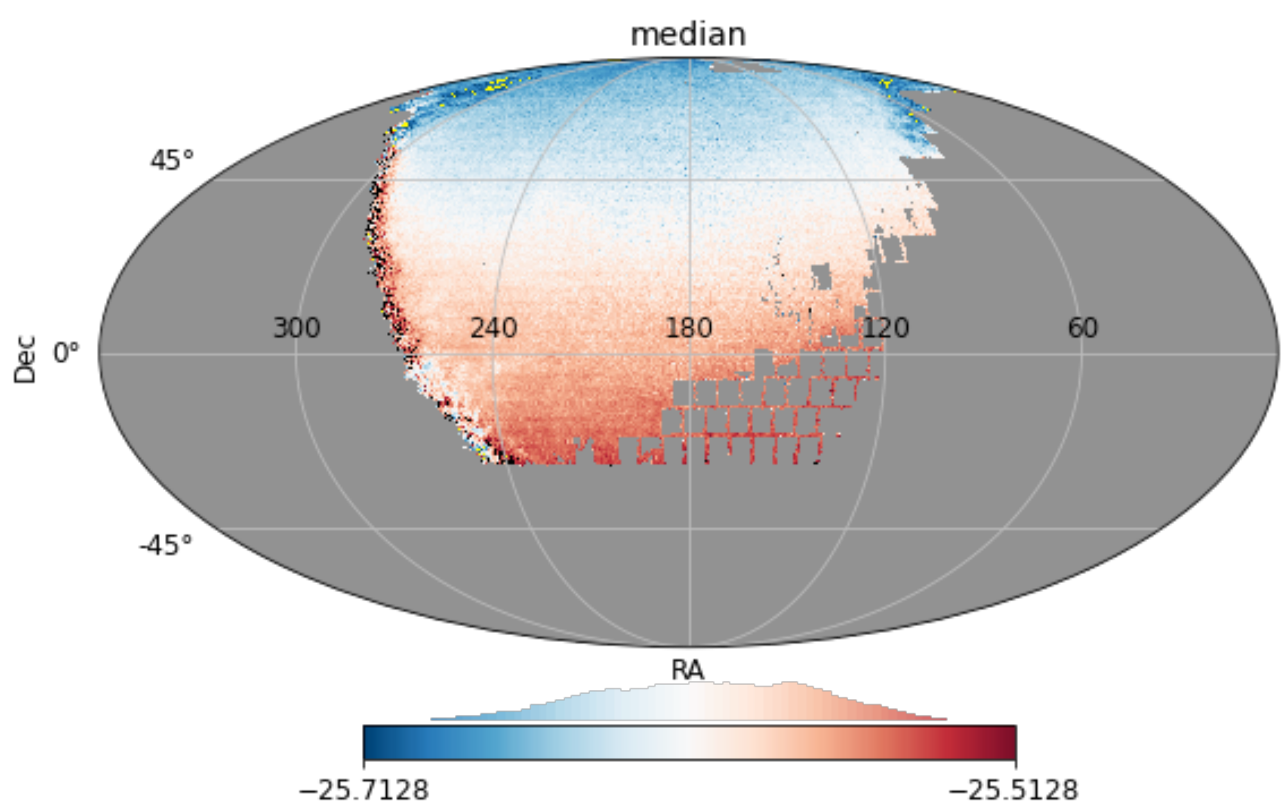
~30 Million stars

ztf-r



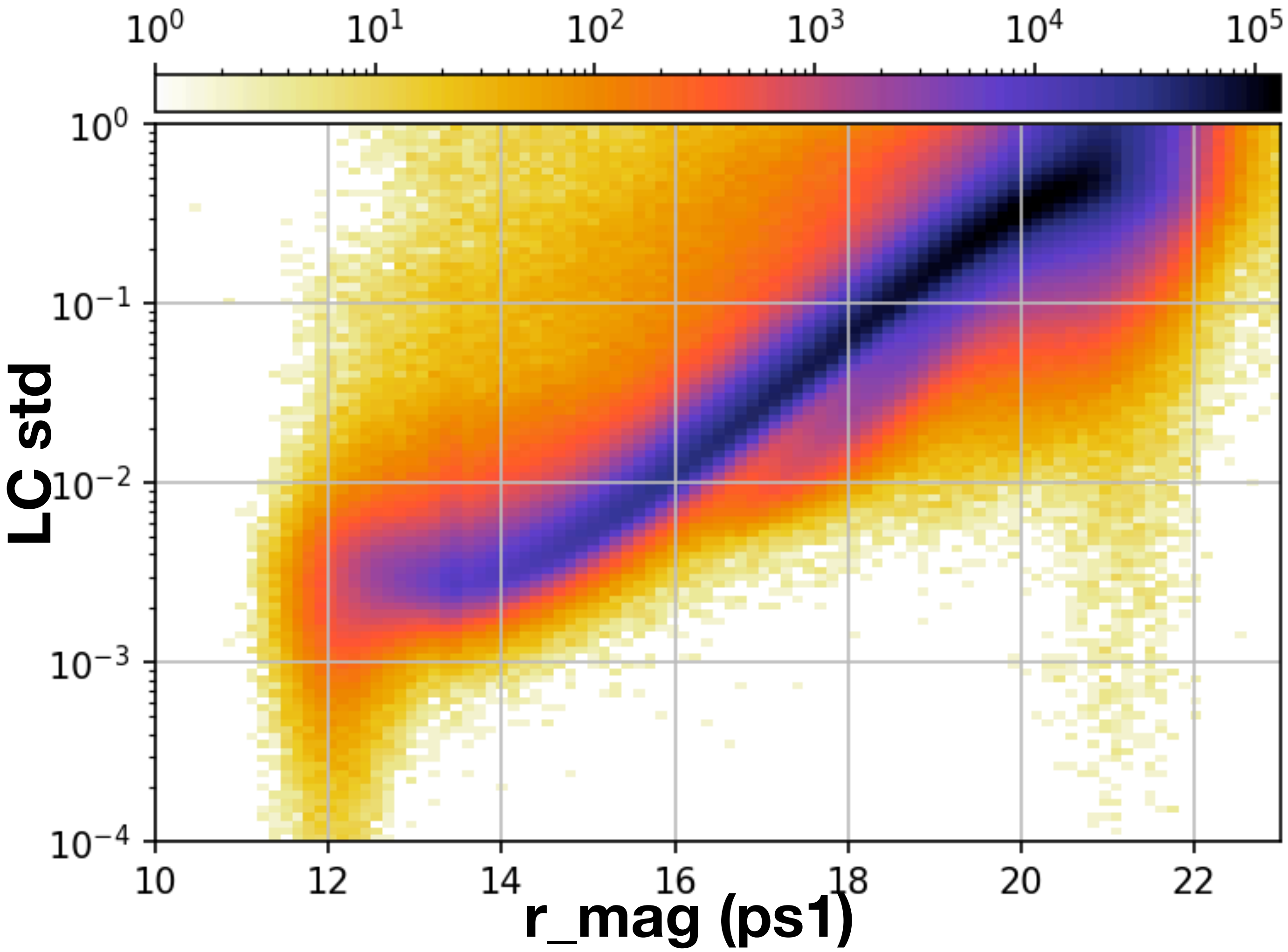


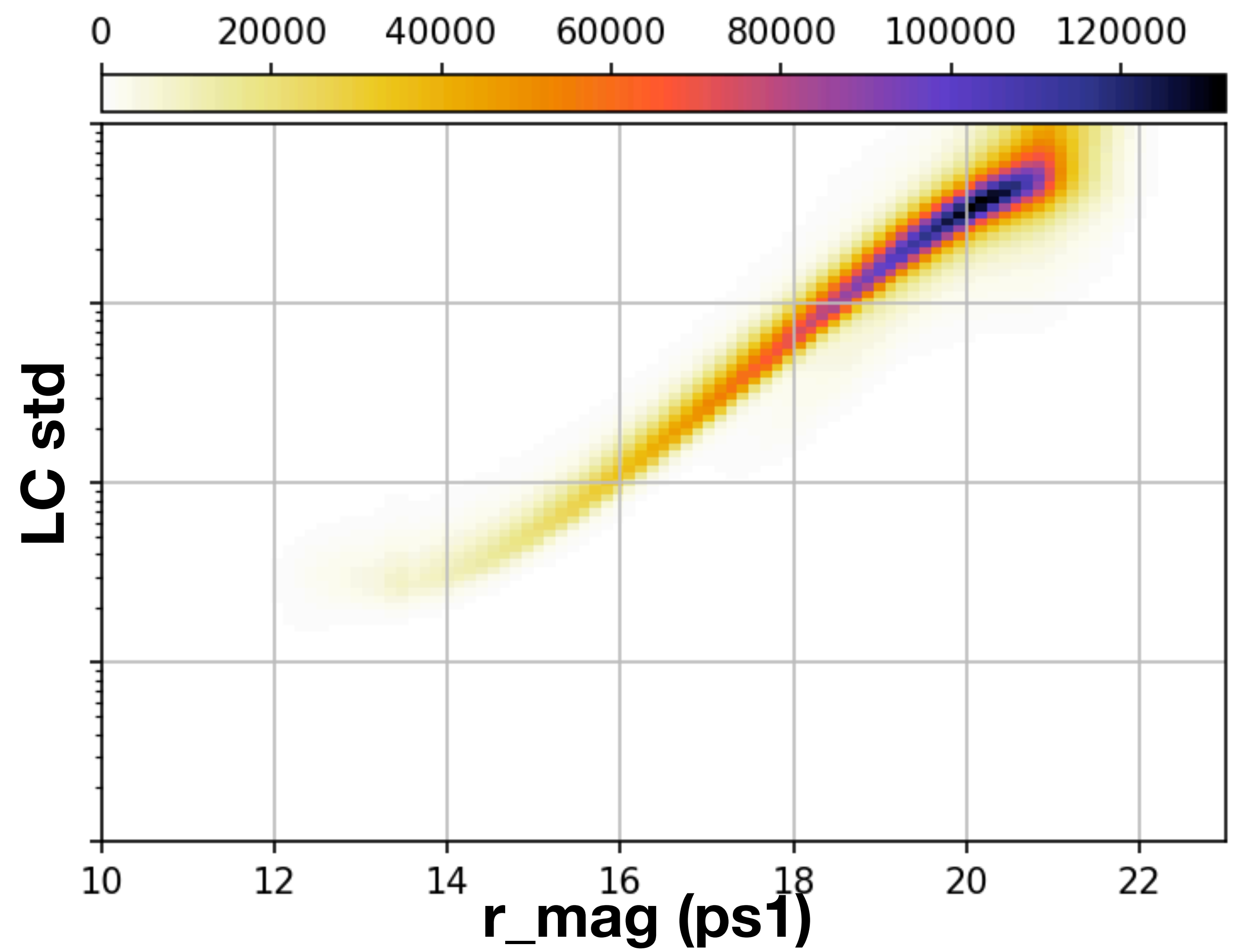
ubercal_mag - r (ps1)
n_obs>10



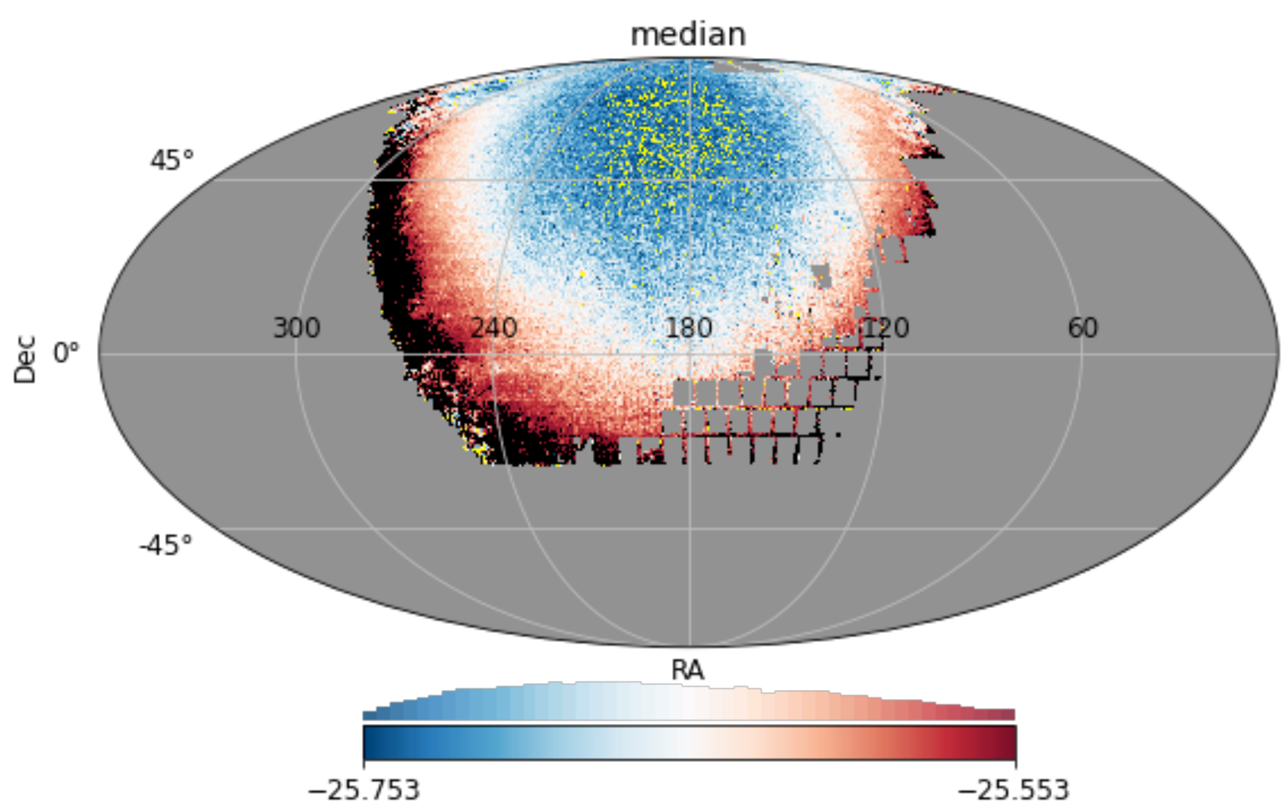
~30 Million stars

ztf-r



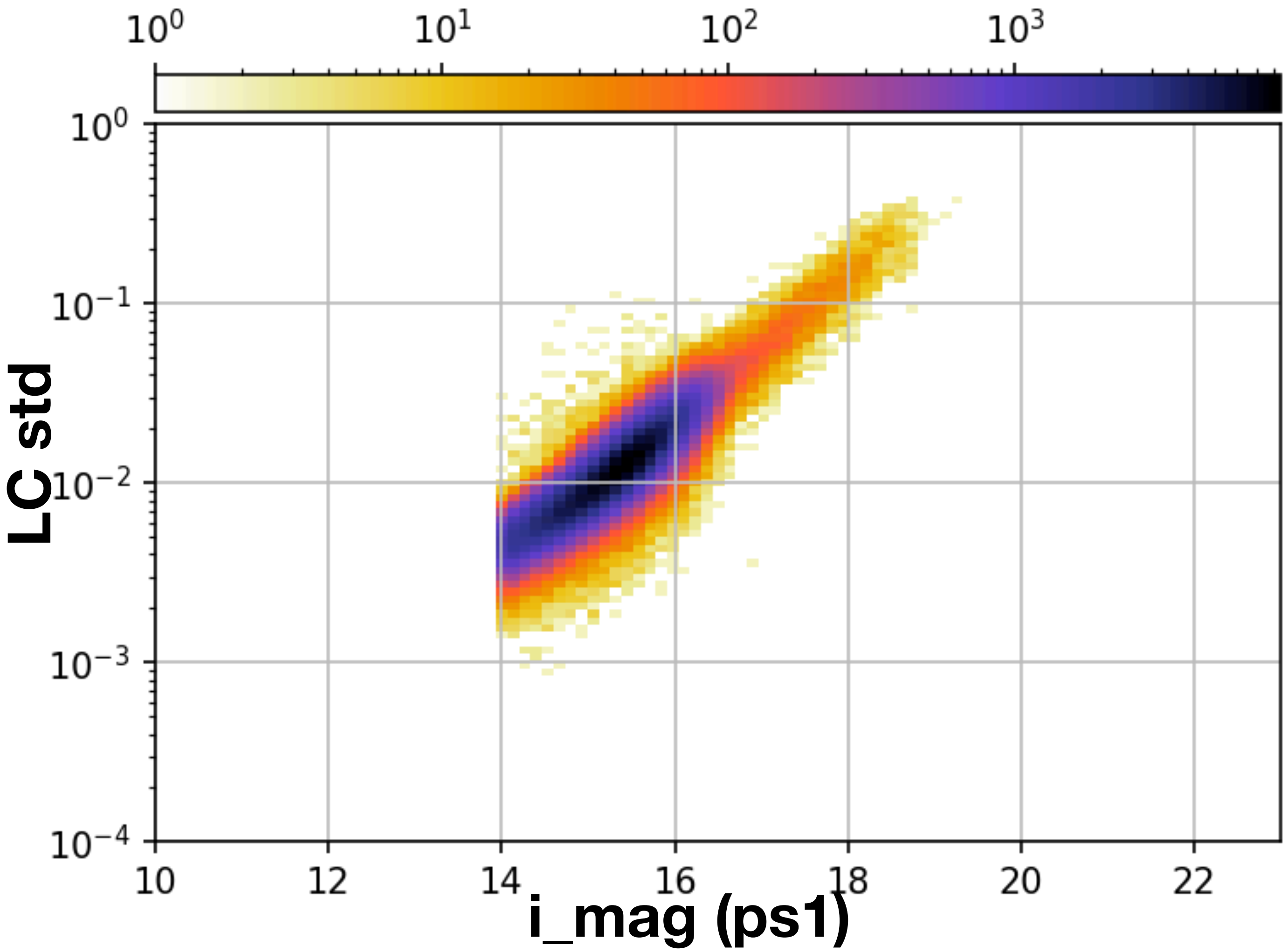


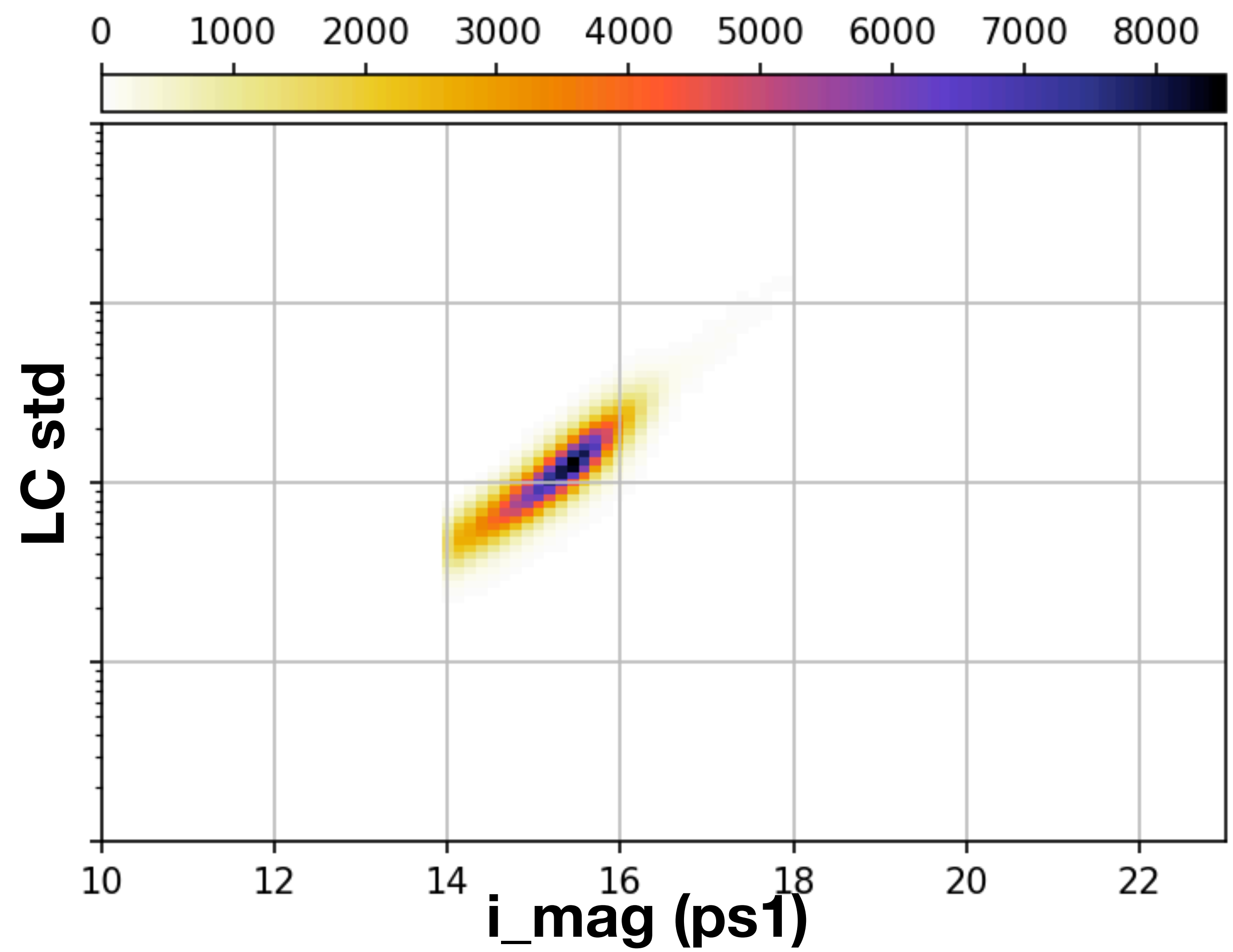
ubercal_mag - r (ps1)
n_obs>10



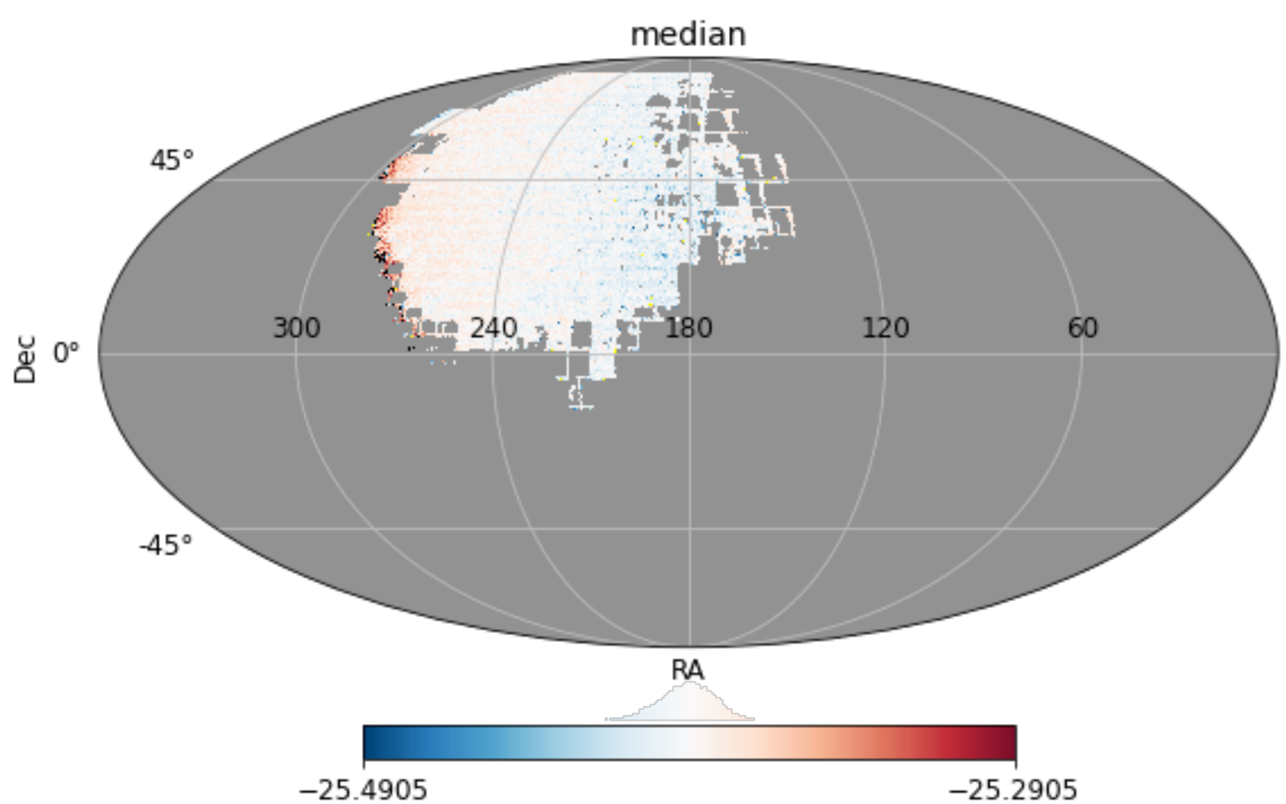
~30 Million stars

ztf-i



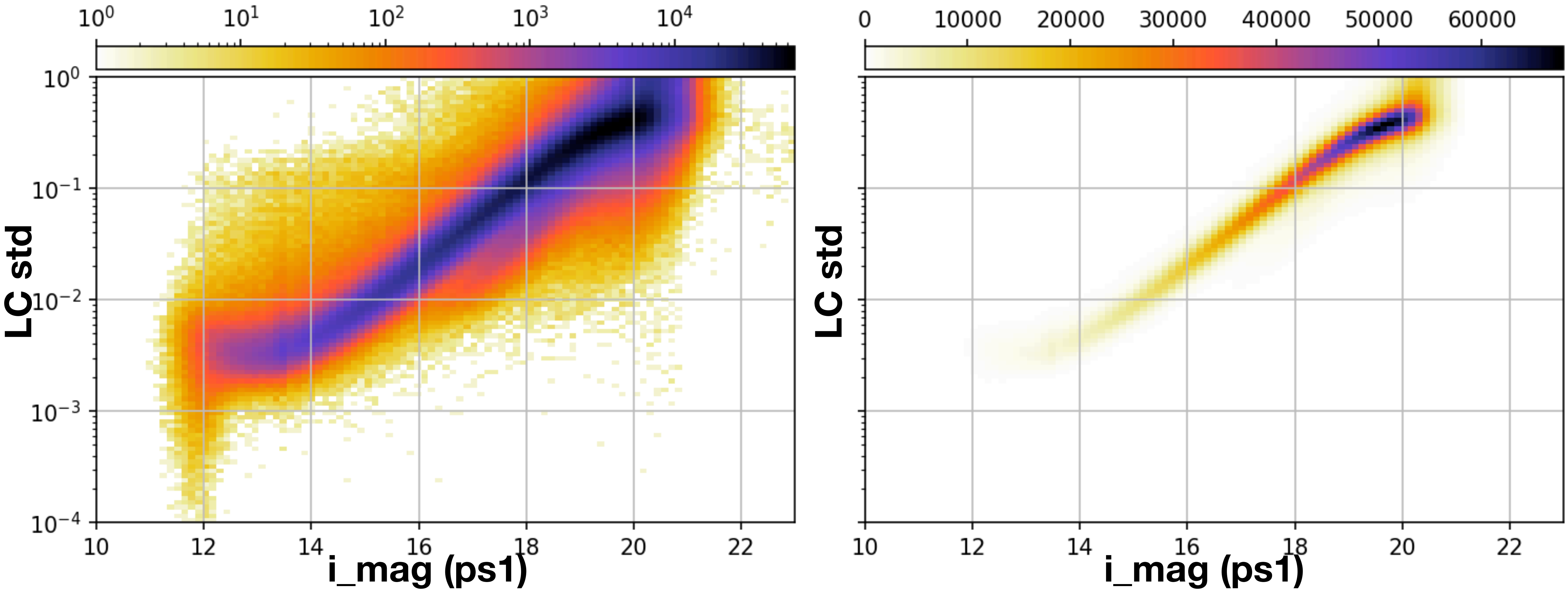


ubercal_mag - r (ps1)
n_obs>10

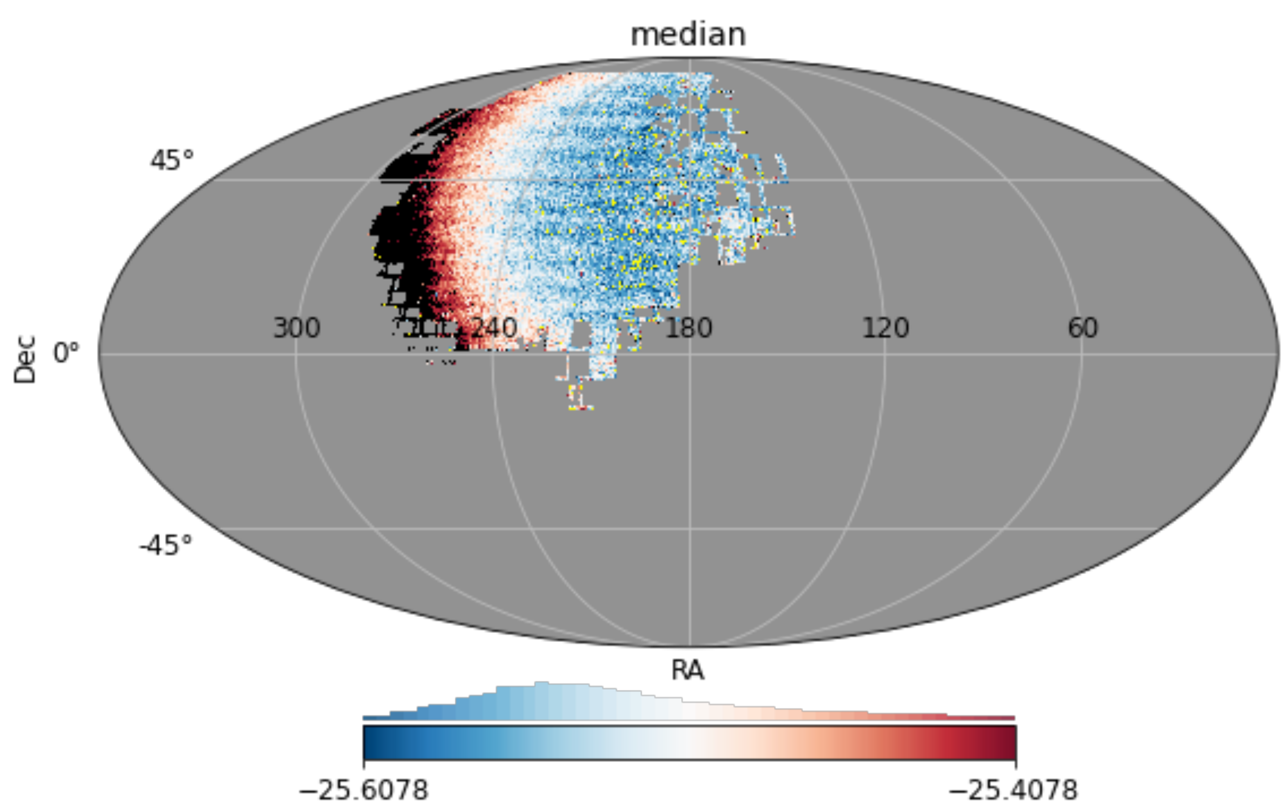


~30 Million stars

ztf-i



ubercal_mag - i (ps1)
n_obs>10



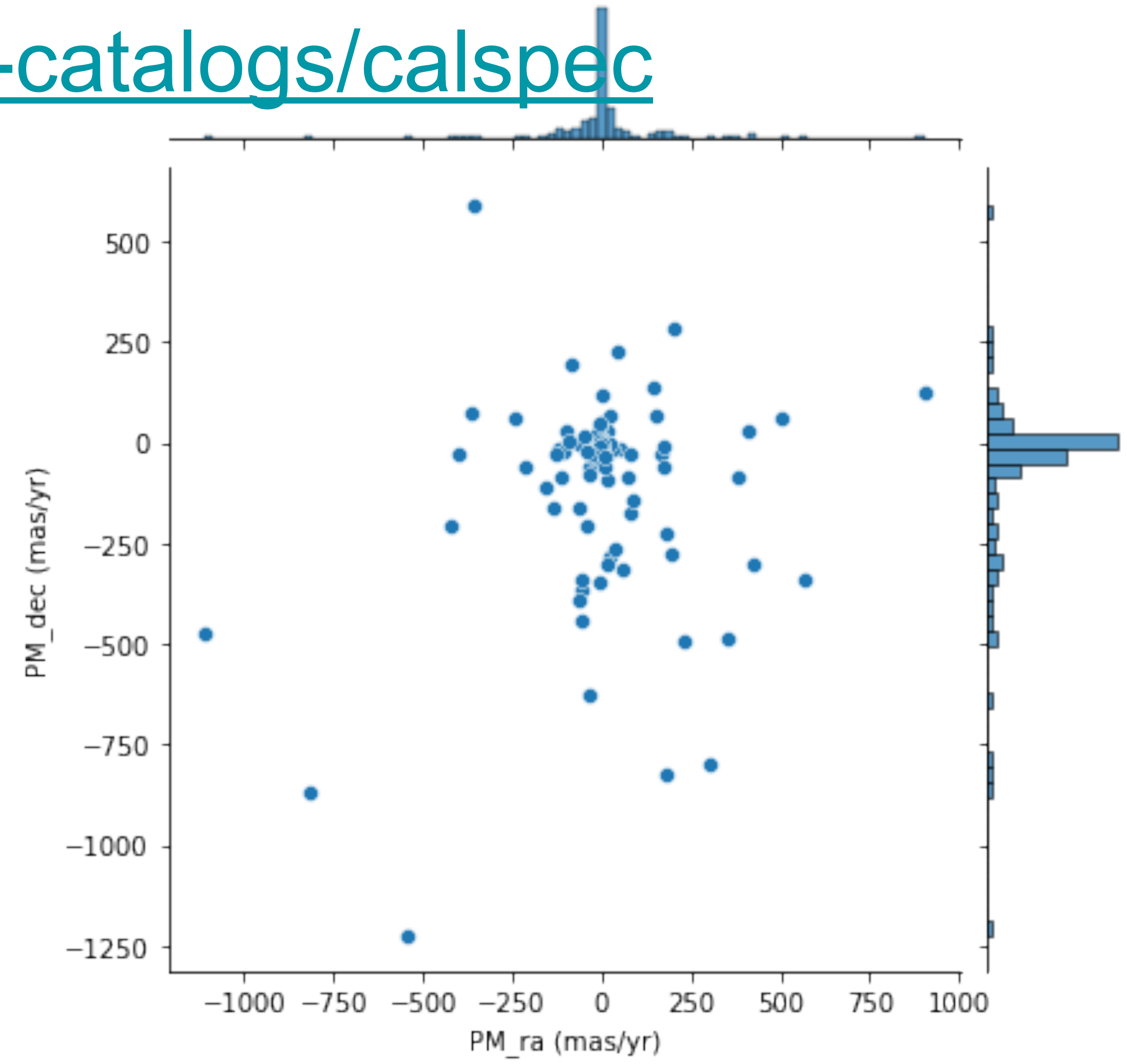
HST website has calspecs

https://www.stsci.edu/hst/instrumentation/reference-data-for-calibration-and-tools/astronomical-catalogs/calspec

No downloadable link?
Copy pasting html table kind of works

Not all Calspecs have proper motions reported, not all have magnitudes

Some have large speeds

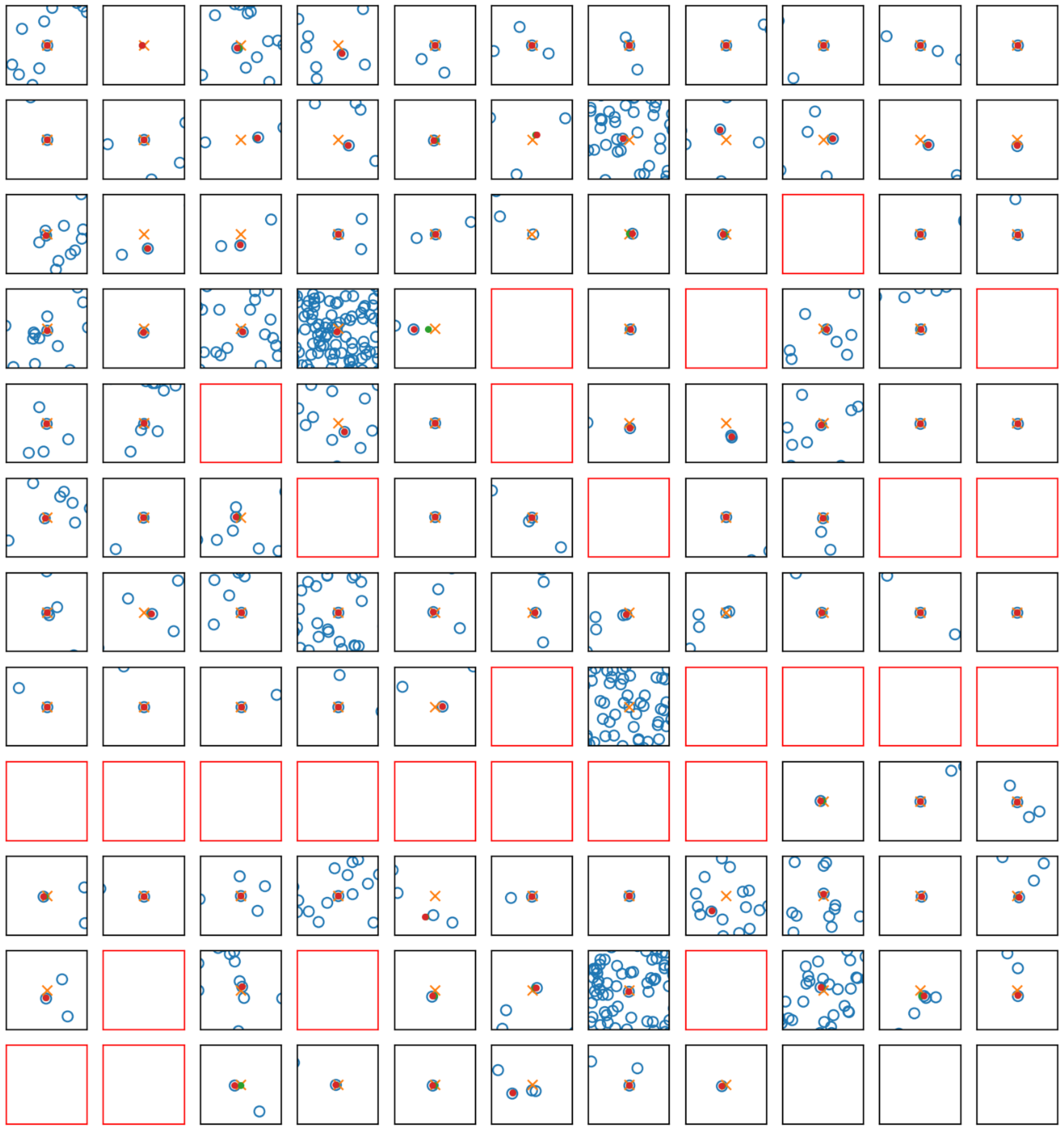


The columns have the unit comment (2000). We assume that this means J2000 and here we test if this means that the ra/dec reported takes into account propagating the PM to 2000.

It also seems like PM_ra is in fact PM_ra*cos(dec).

Gaia stars are in blue
yellow x is the ra/dec
green dot is moved (with cos added)
red dot is moved (without cos added)

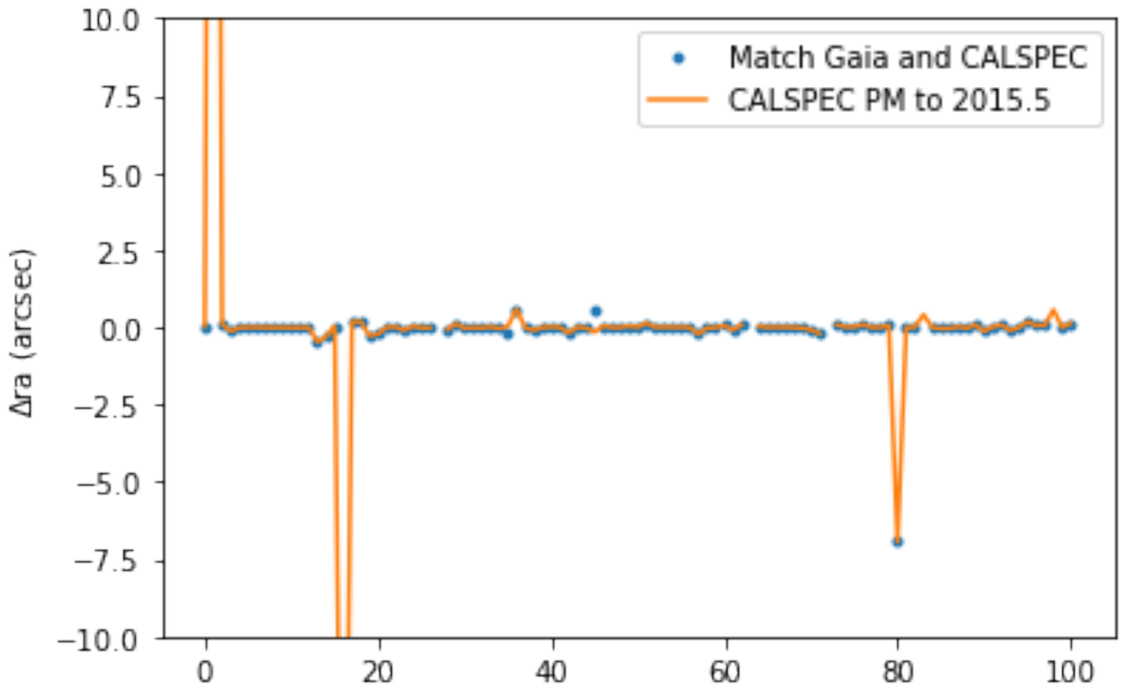
red squares are below dec of -30, skipped

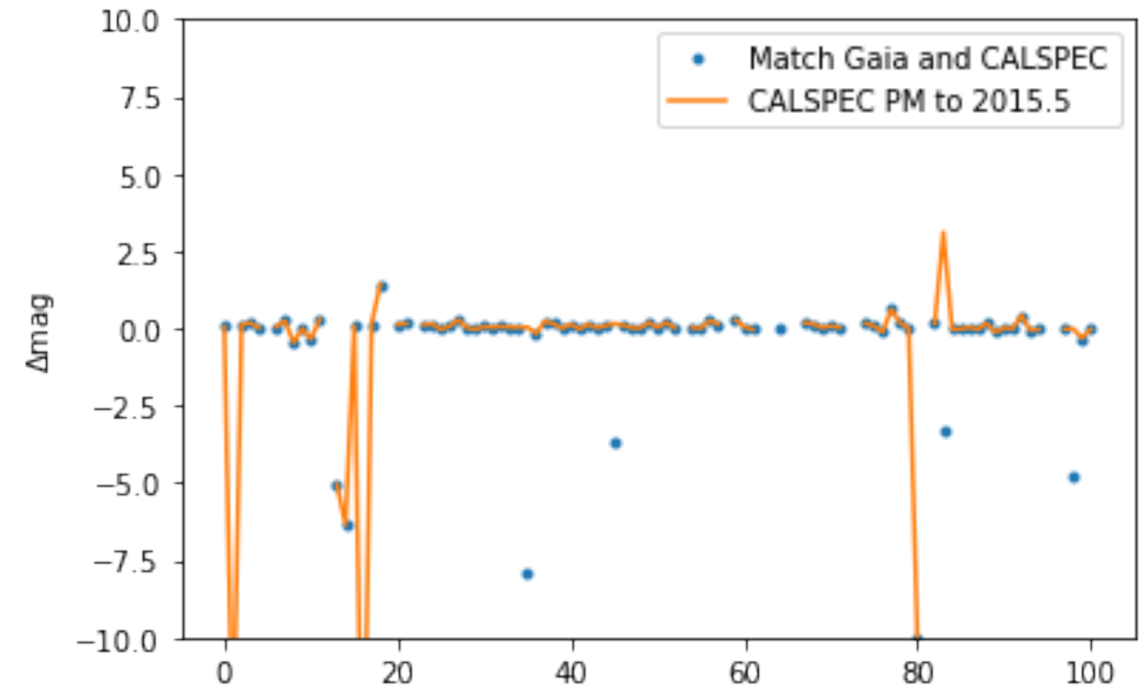


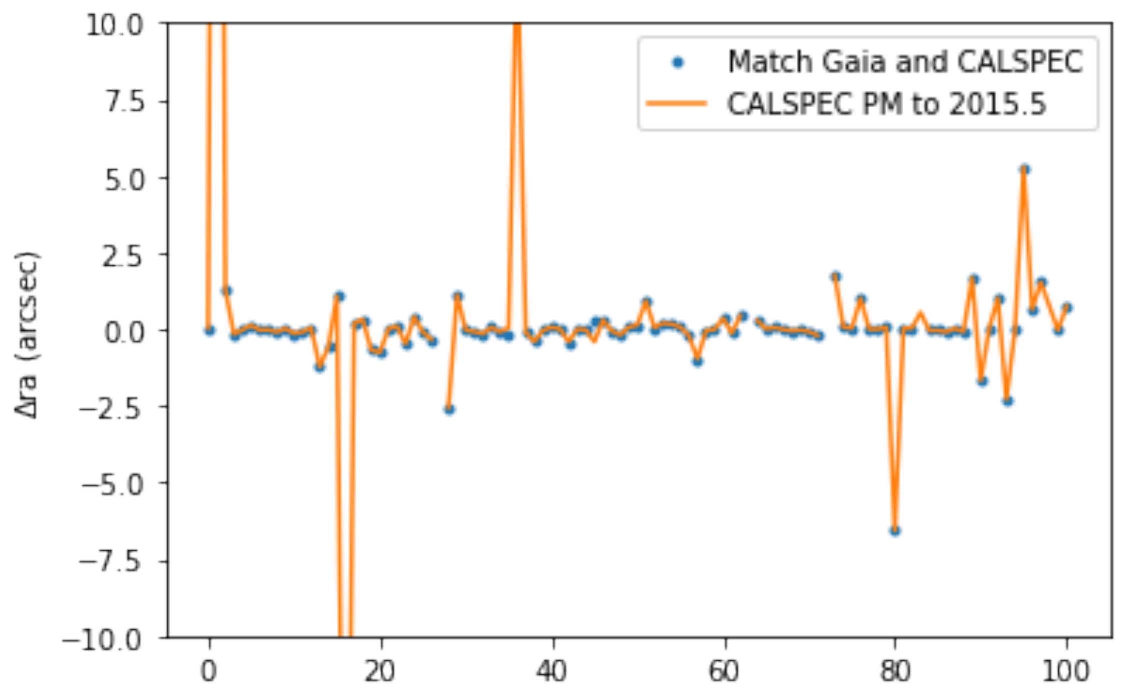
c_no_cos = SkyCoord(cal_pos.ra,cal_pos.dec, unit=(u.hour, u.deg), equinox='J2000',pm_ra_cosdec=cal_pos.PM_ra* u.mas/u.yr,pm_dec=cal_pos.PM_dec* u.mas/u.yr,obstime=Time("J2000"))

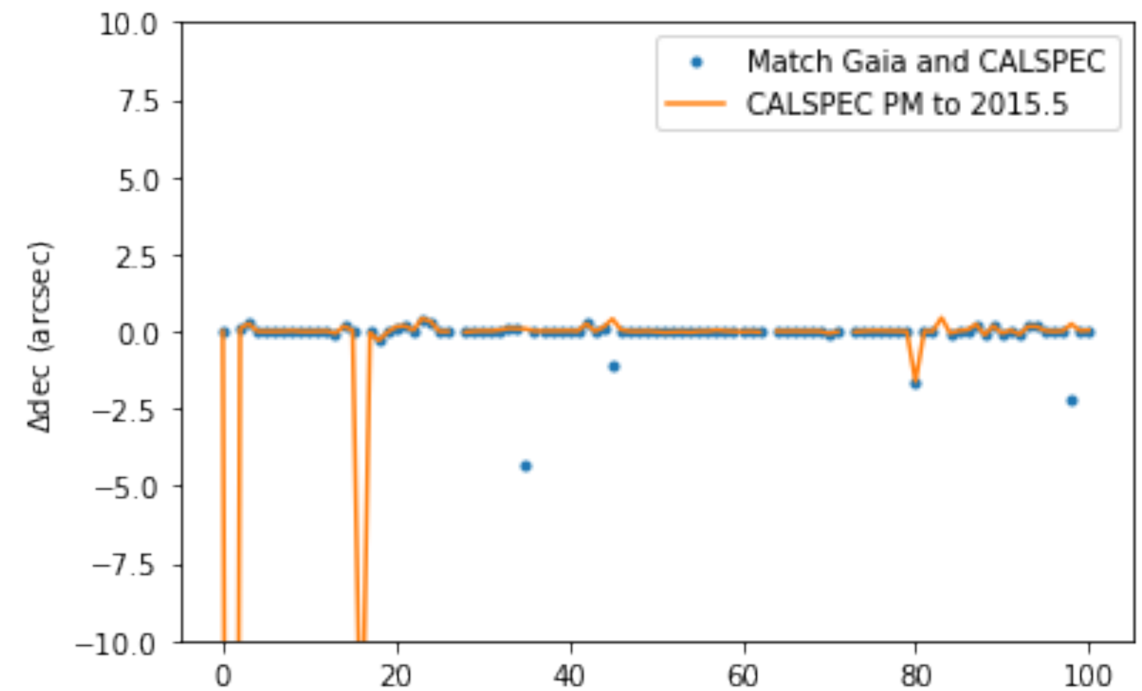
adding cos(dec) seems to give a worse match)

calspec after PM - gaia





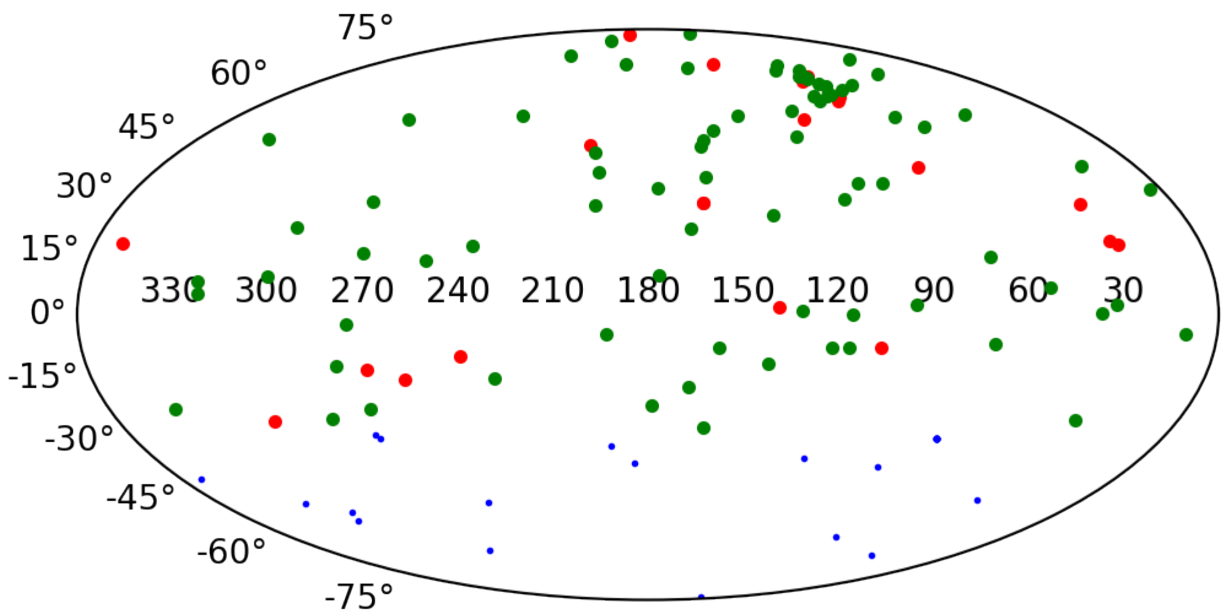


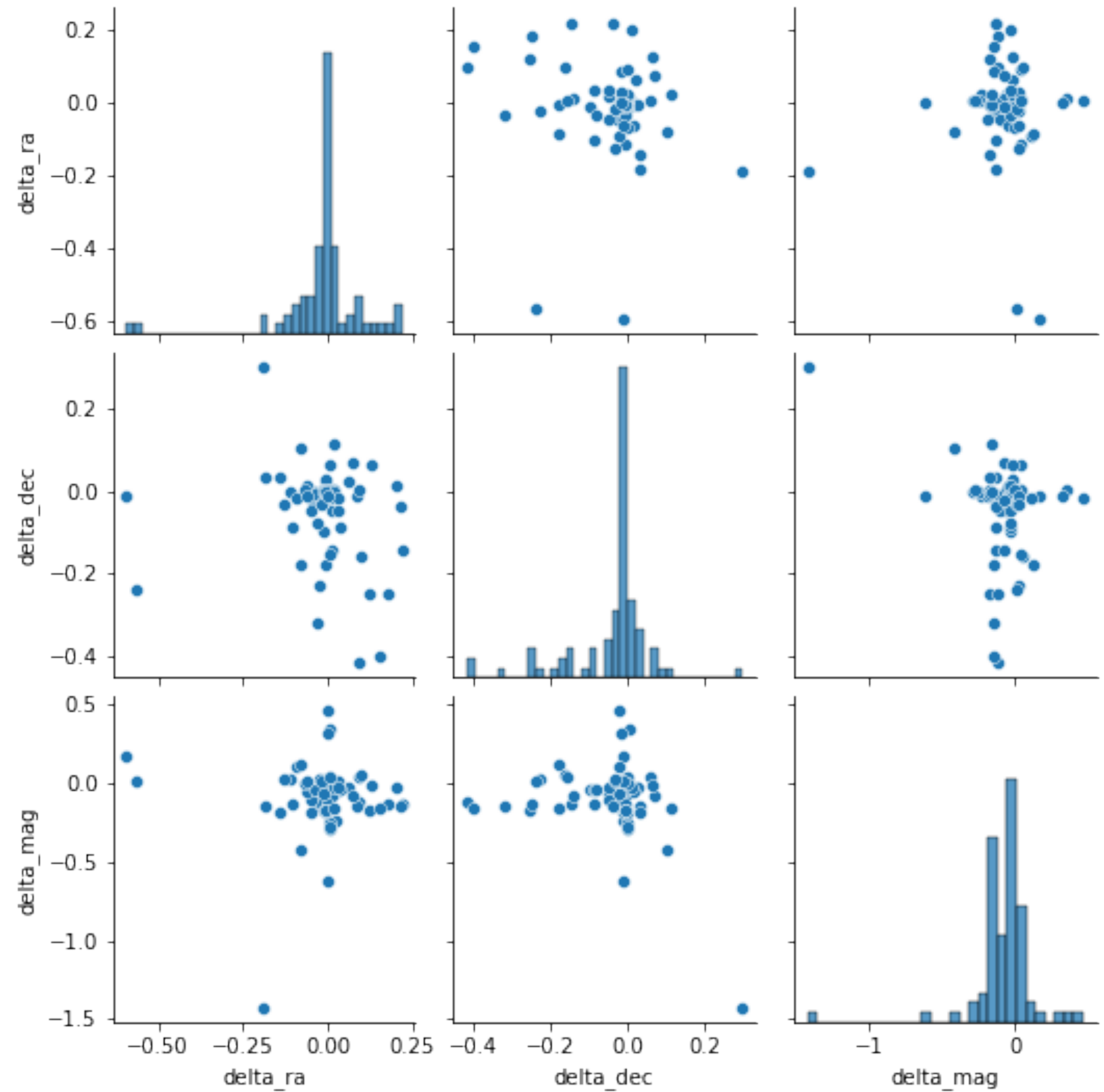


If we match with proper motion with PM_ra*cos(dec)

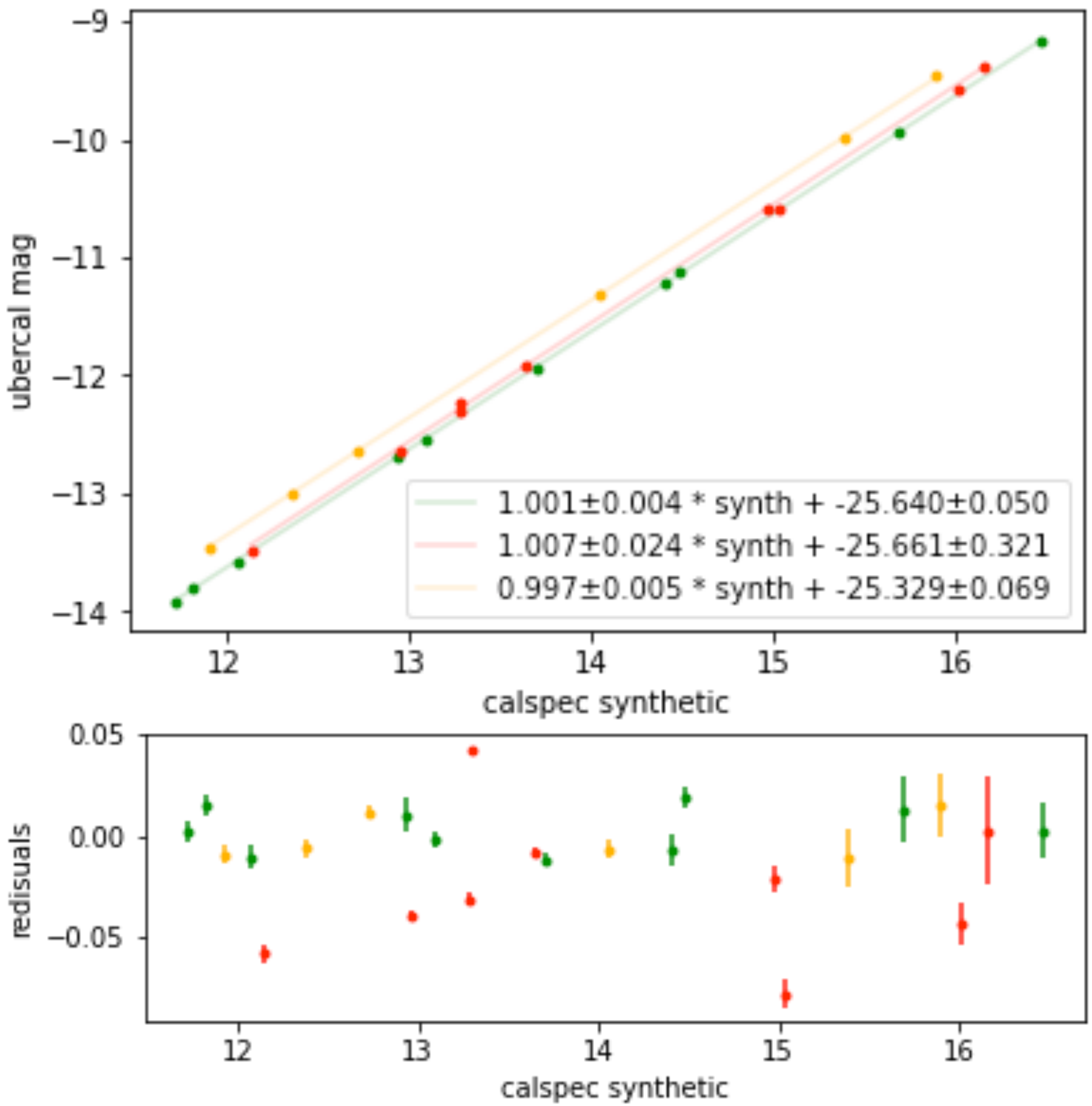
After selection,
abs(delta_ra)   < 2 arcsec
abs(delta_dec) < 2 arcsec
abs(delta_mag) < 2

We have 79 stars.

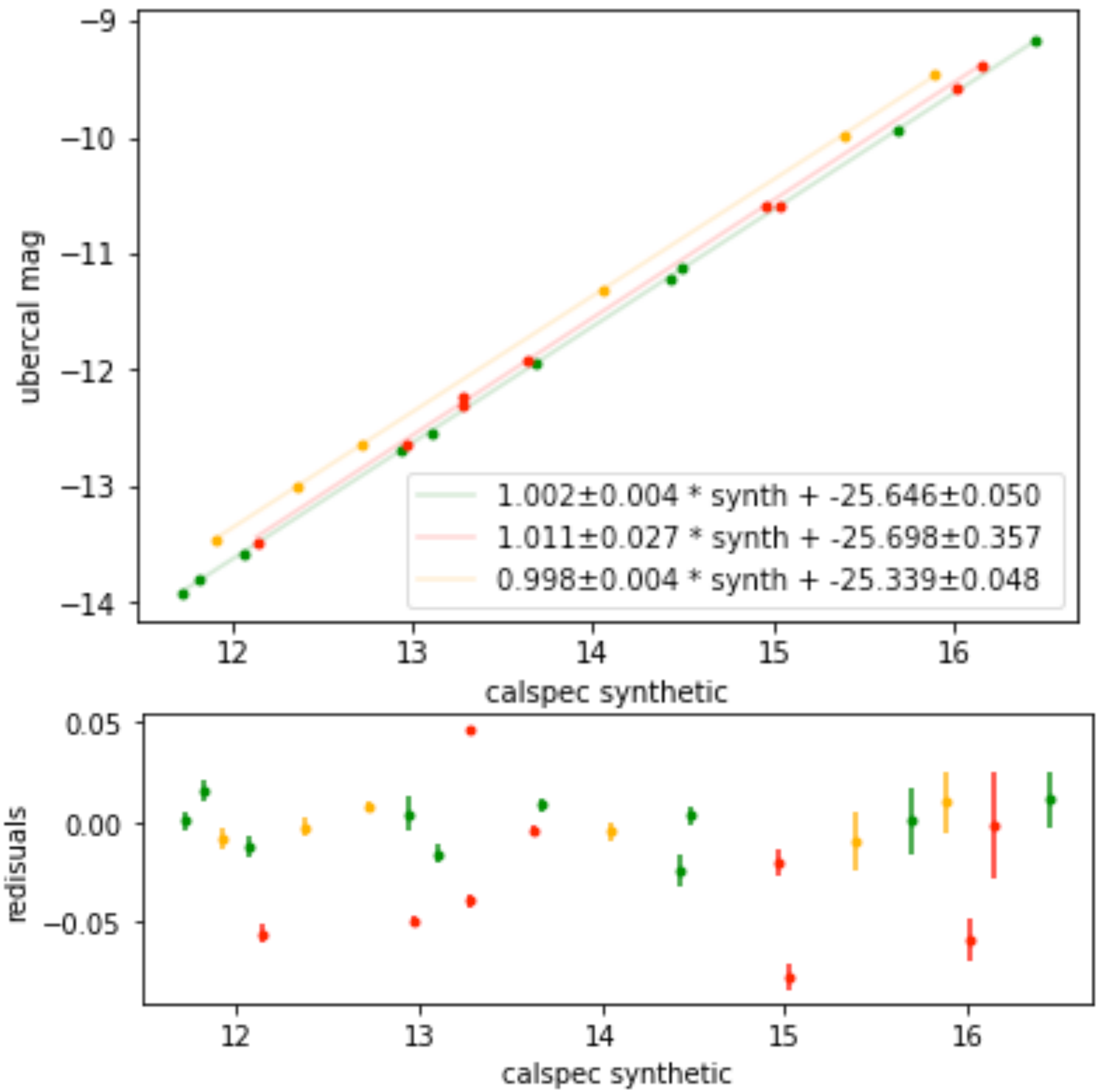




NO SHIFT



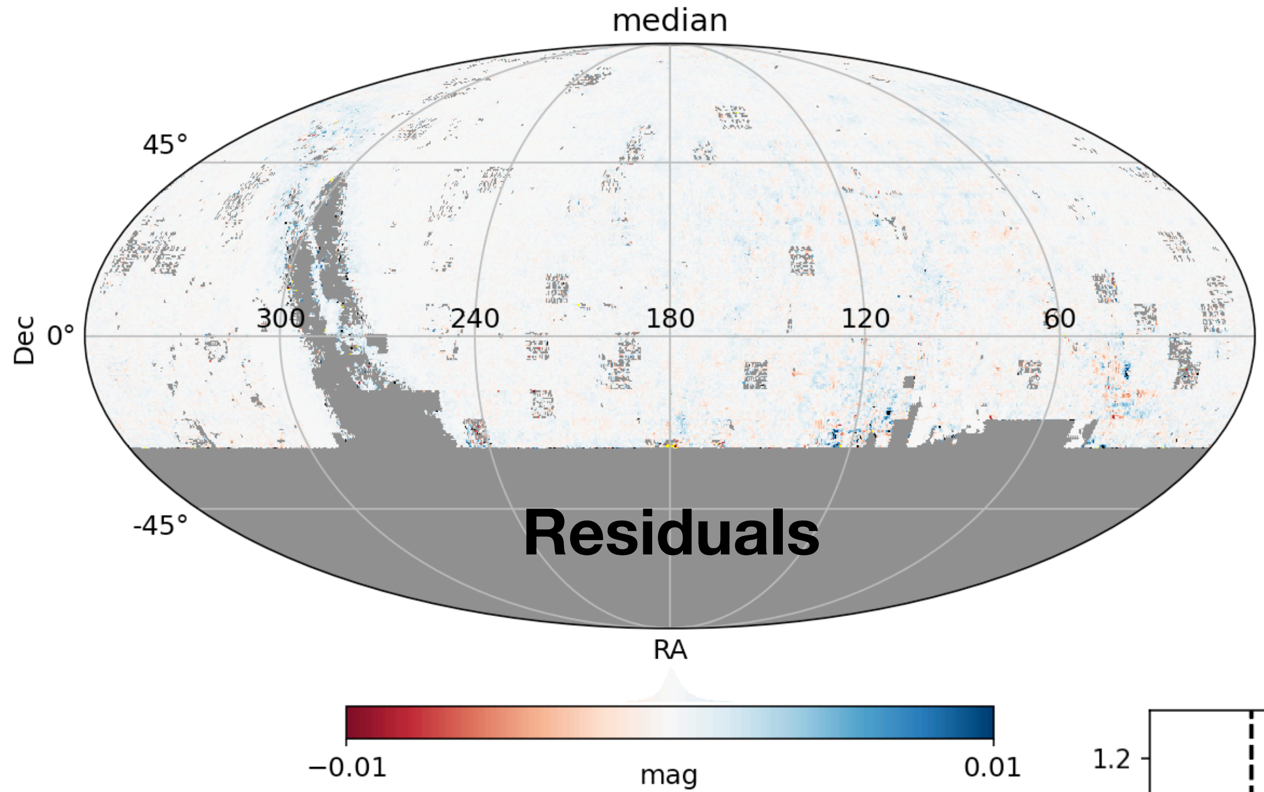
ubercal mag
1.001±0.004 * synth + -25.640±0.050
1.007±0.024 * synth + -25.661±0.321
0.997±0.005 * synth + -25.329±0.069
calspec synthetic
redisuals
calspec synthetic

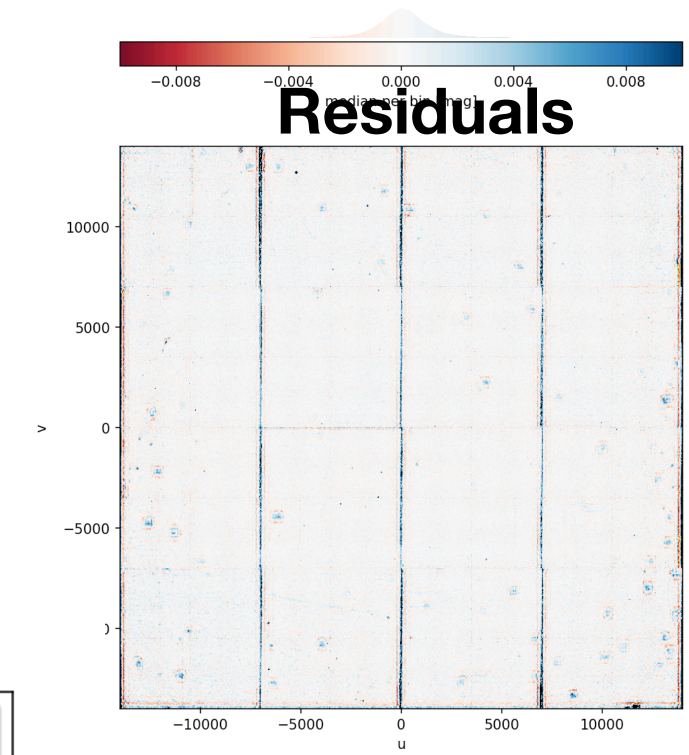


1.002±0.004 * synth + -25.646±0.050
1.011±0.027 * synth + -25.698±0.357
0.998±0.004 * synth + -25.339±0.048
ubercal mag
calspec synthetic
redisuals
calspec synthetic

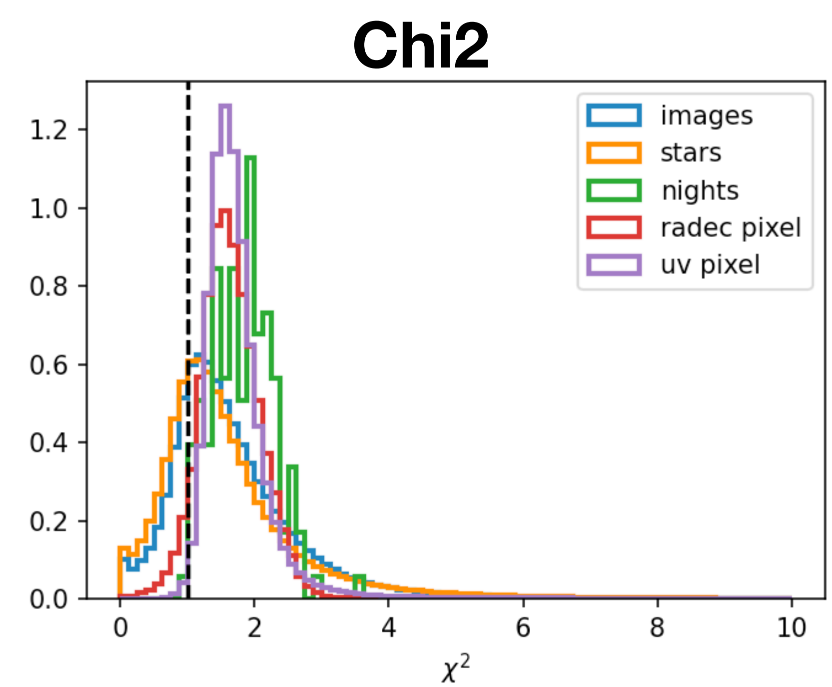
Slides from Damiano

https://docs.google.com/presentation/d/1n2KhaTVvFlVqmtc5PAbXvO1dudAXifQykPBk2KHz5Mo/edit#slide=id.g256cd799327_0_42

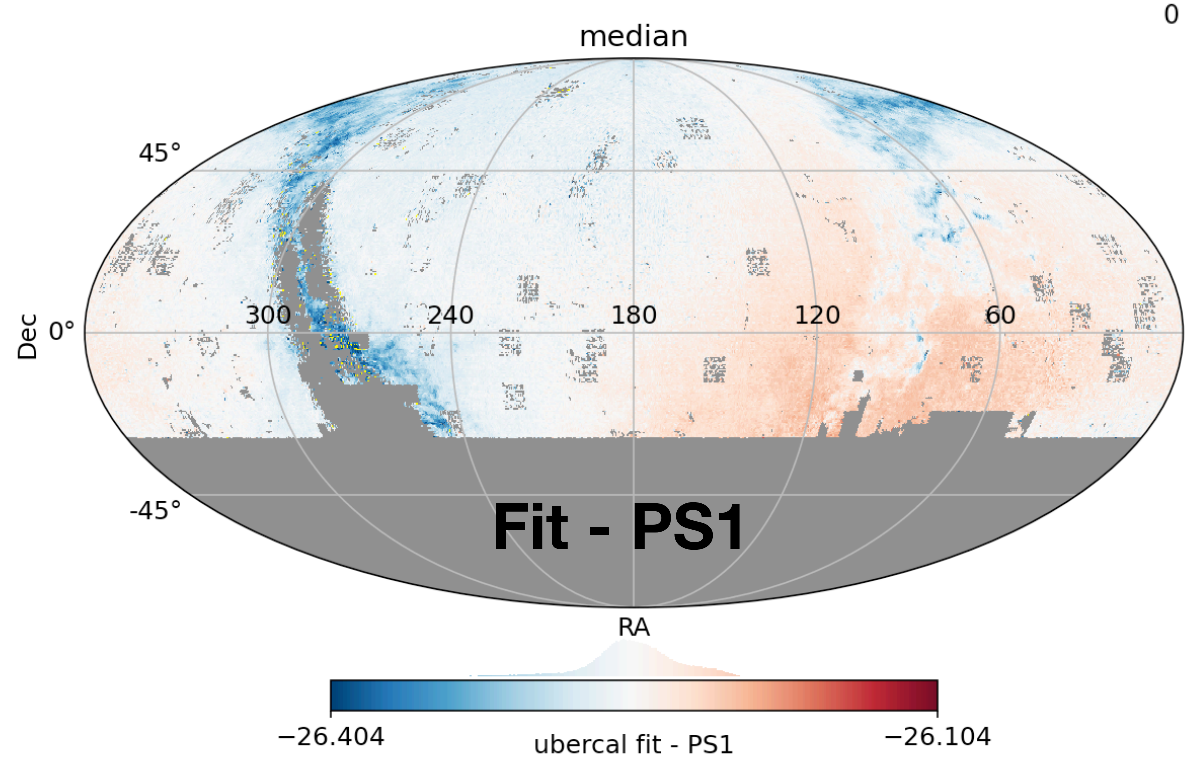




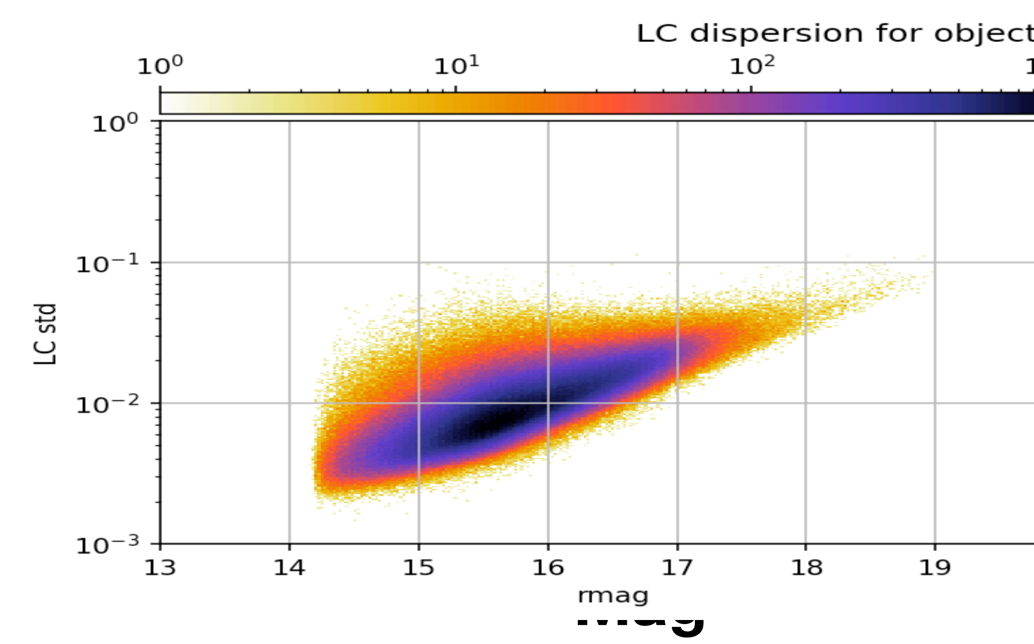
$$\chi^2_\star < 10 \;\&\; \chi^2_{\mathrm{image}} < 6$$

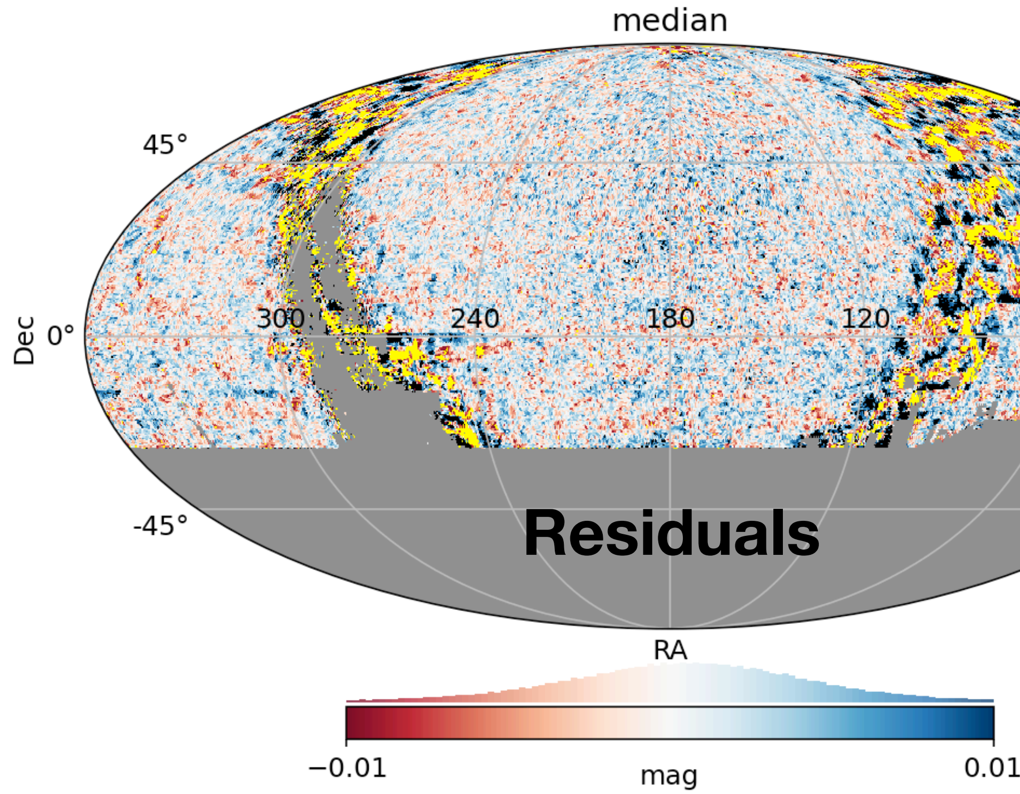


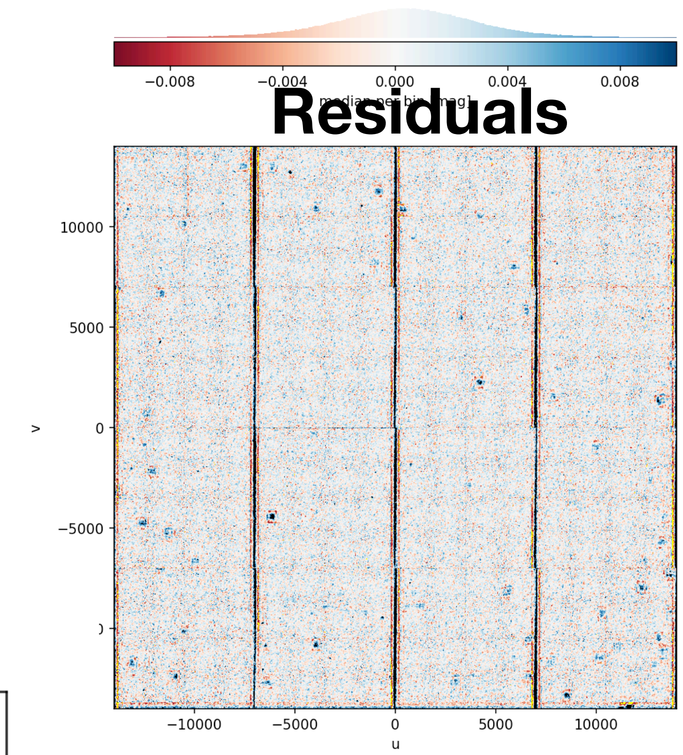
ztf-r



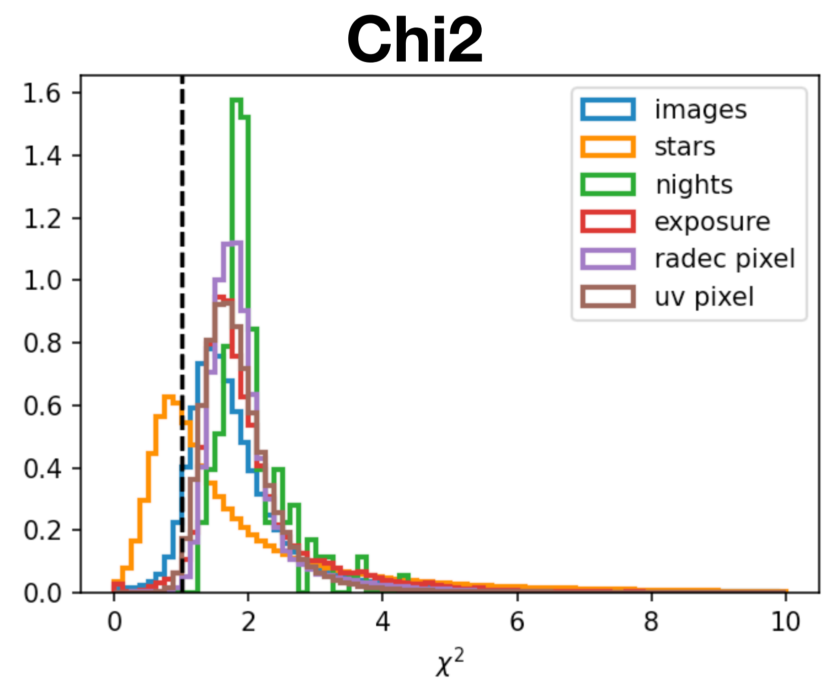
LC std



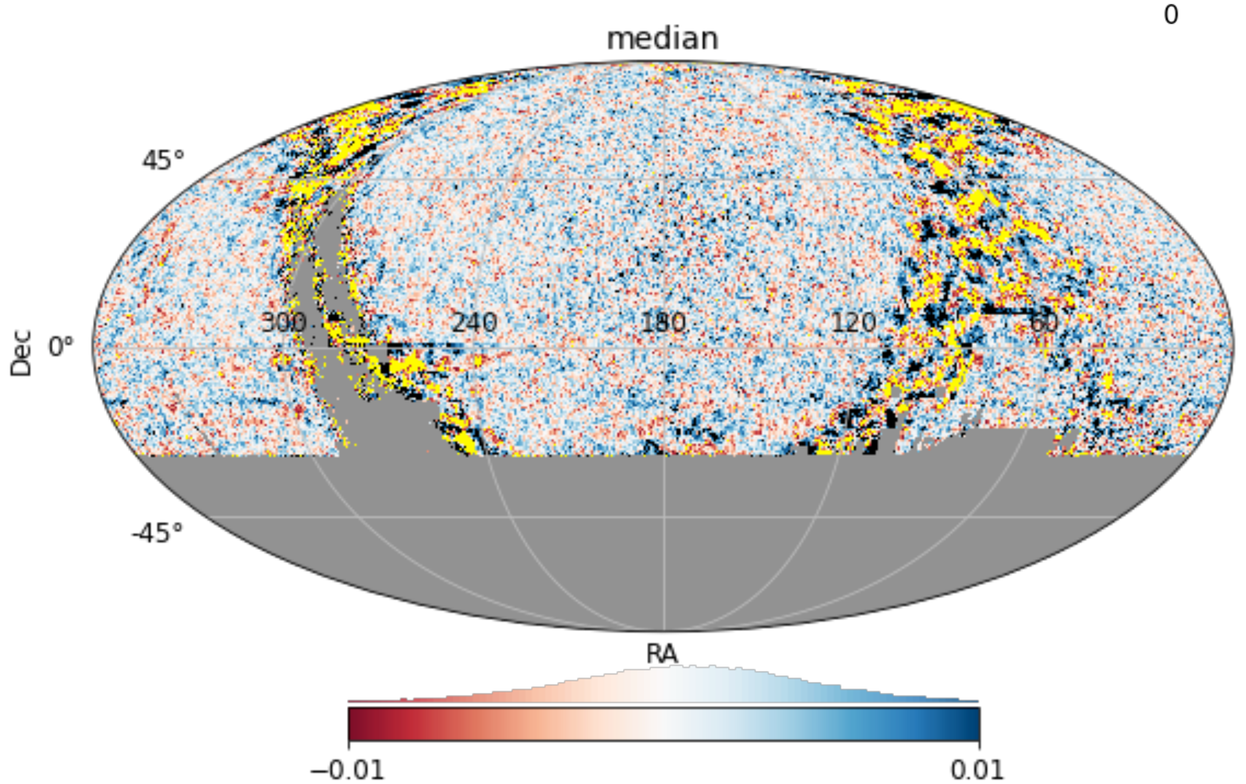




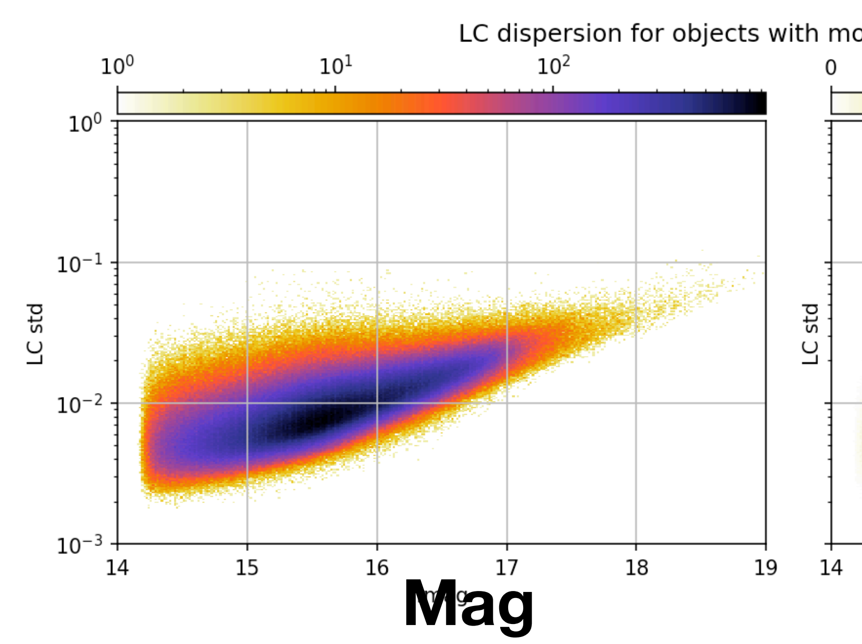
$\chi^2_\star < 10$ & $\chi^2_{\text{image}} < 6$

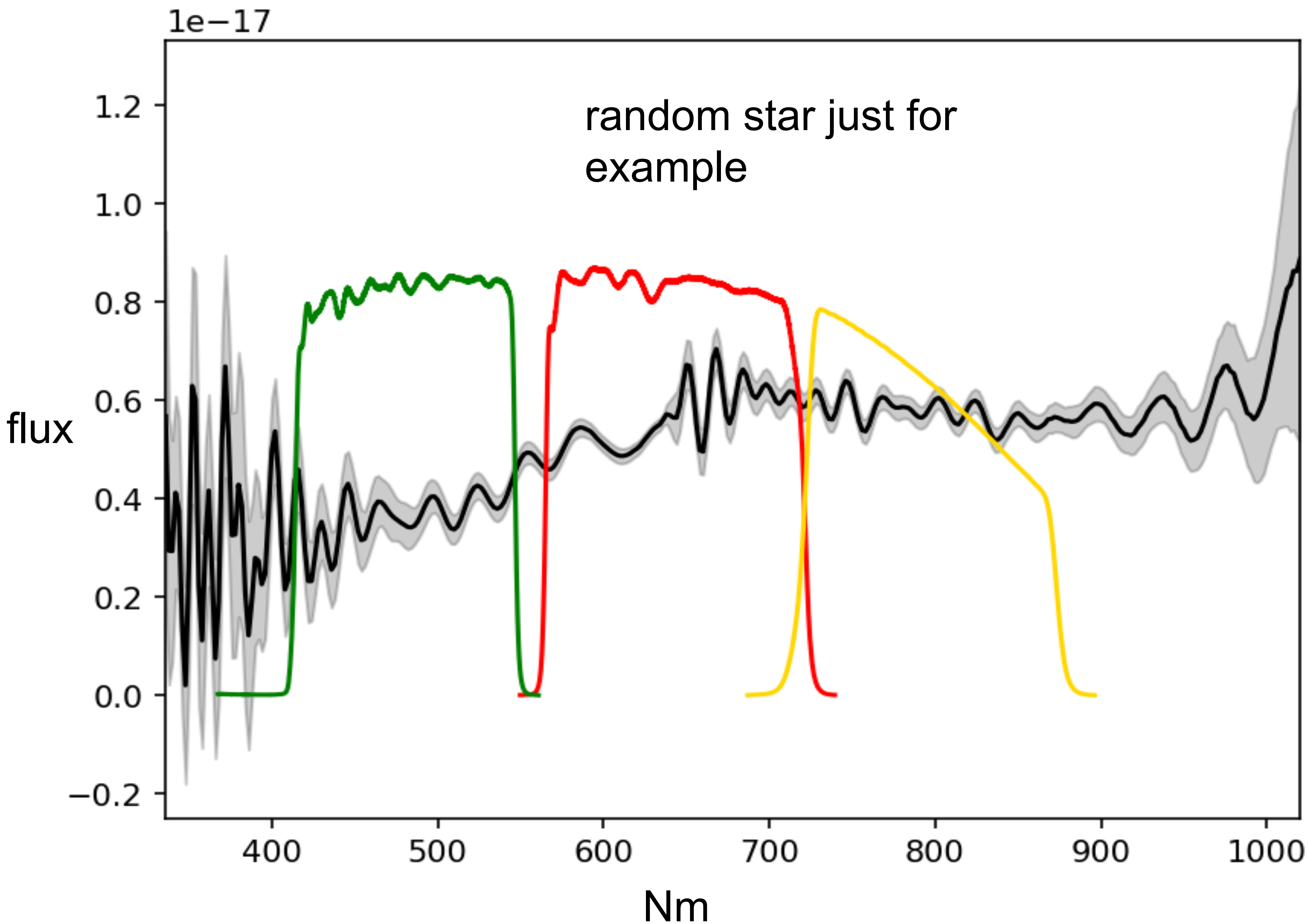


ztf-r

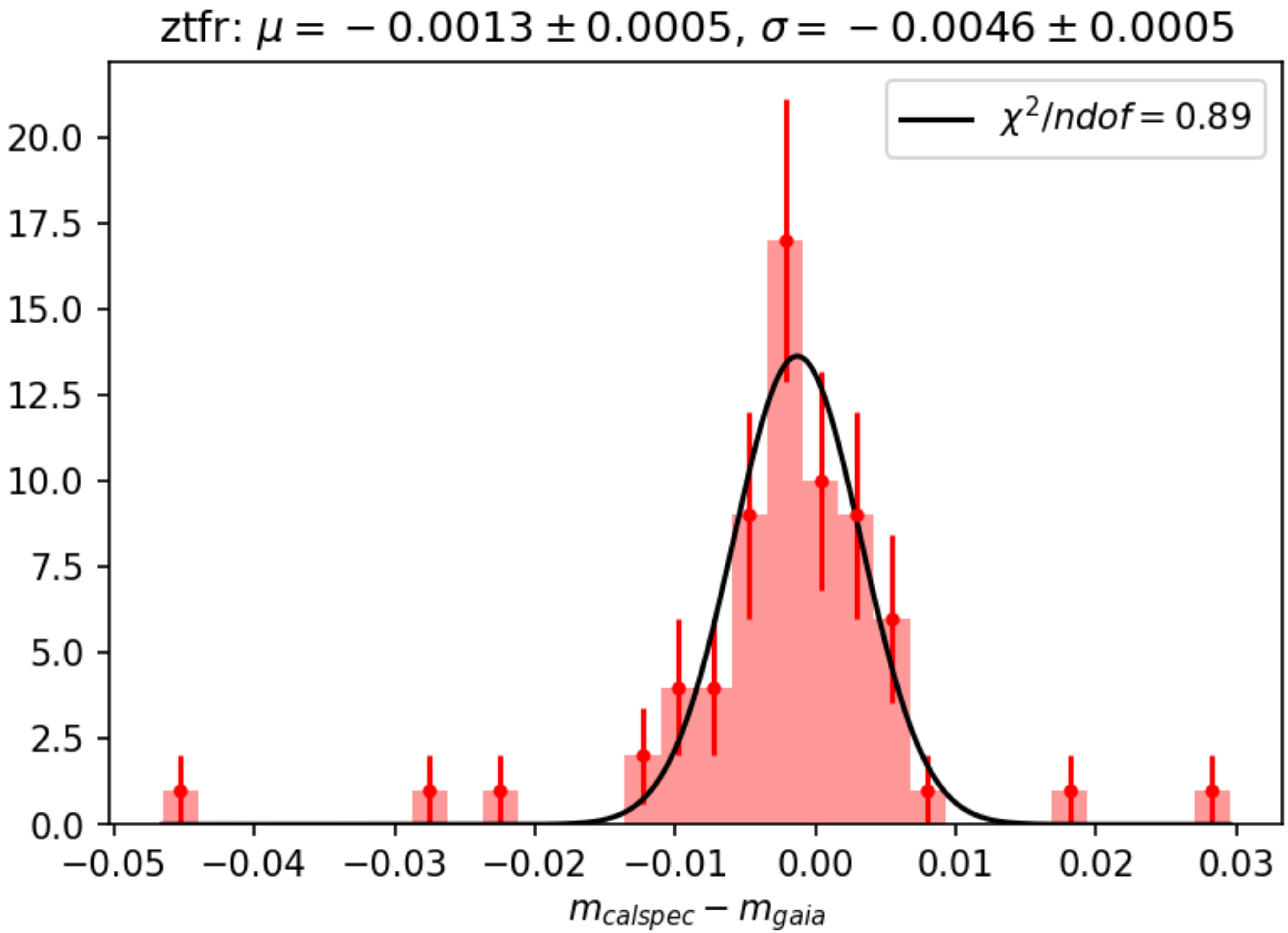


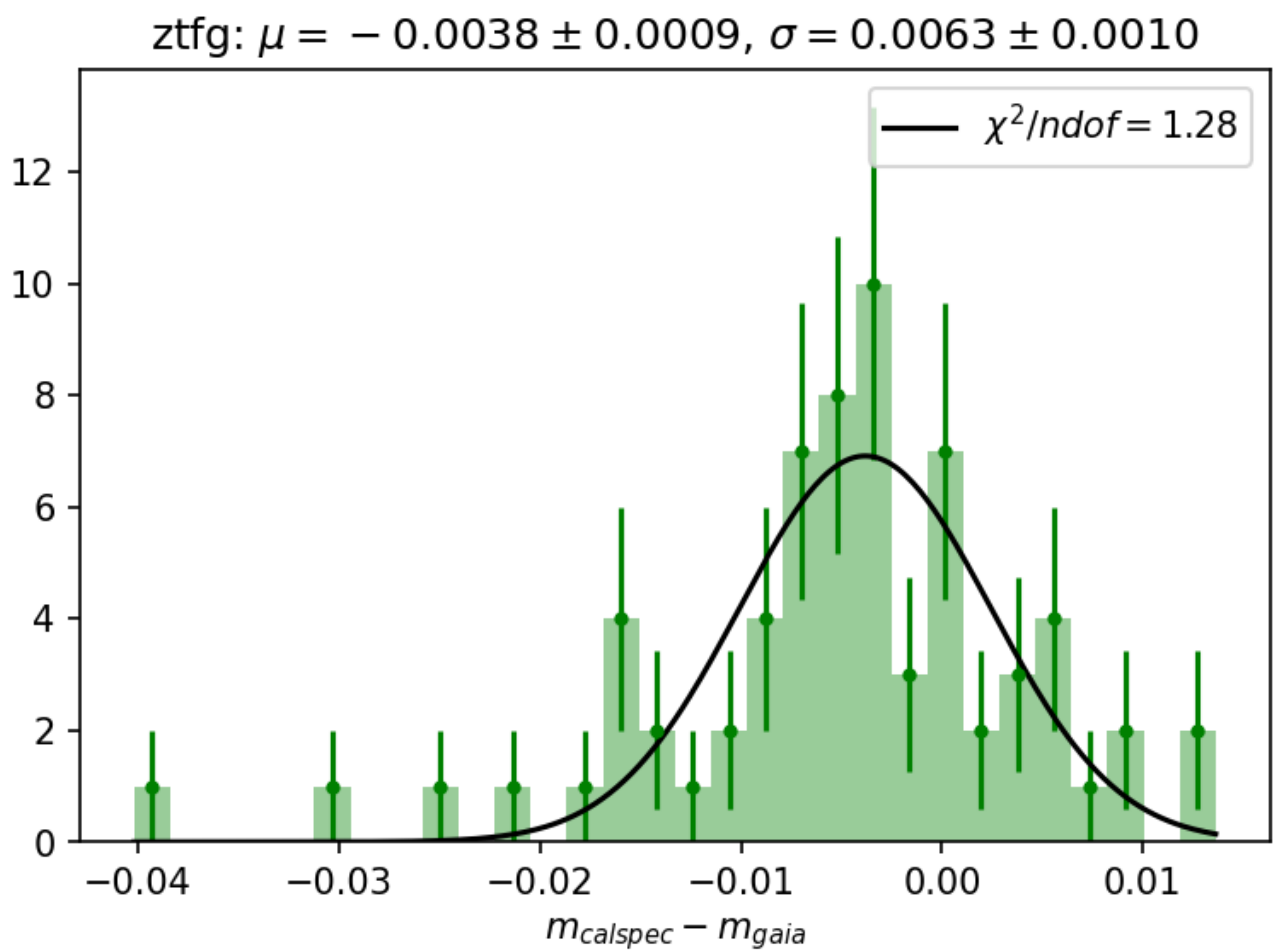
LC std



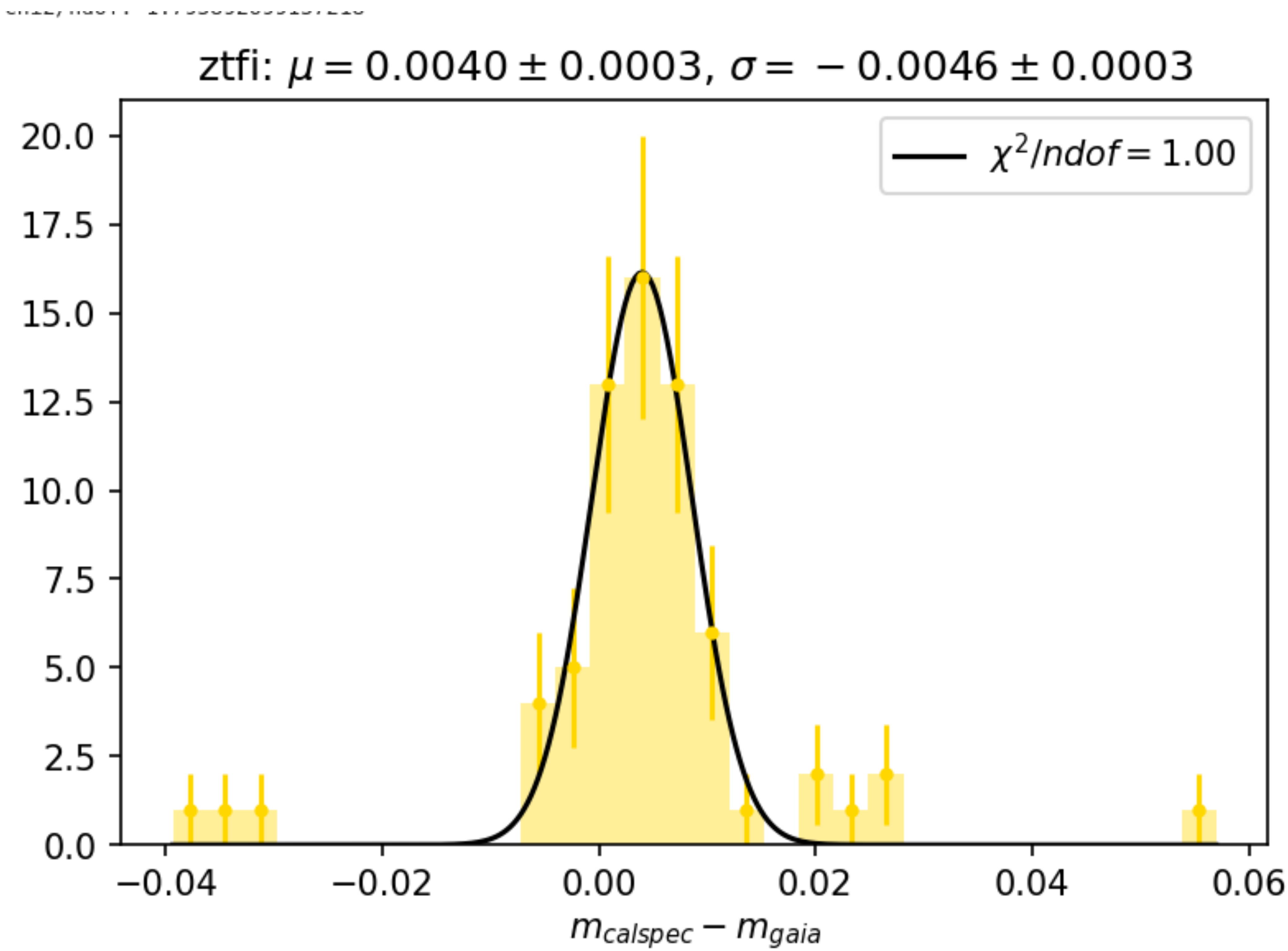


1e−17
random star just for
example
flux
Nm
1.2
1.0
0.8
0.6
0.4
0.2
0.0
−0.2
400
500
600
700
800
900
1000


ztfr: $\mu = -0.0013 \pm 0.0005$, $\sigma = -0.0046 \pm 0.0005$
$\chi^2/ndof = 0.89$
20.0
17.5
15.0
12.5
10.0
7.5
5.0
2.5
0.0
−0.05
−0.04
−0.03
−0.02
−0.01
0.00
0.01
0.02
0.03
$m_{calspec} - m_{gaia}$



ztfg: $\mu = -0.0038 \pm 0.0009$, $\sigma = 0.0063 \pm 0.0010$
$\chi^2/ndof = 1.28$
0
2
4
6
8
10
12
−0.04
−0.03
−0.02
−0.01
0.00
0.01
$m_{calspec} - m_{gaia}$


ztfi: $\mu = 0.0040 \pm 0.0003$, $\sigma = -0.0046 \pm 0.0003$
$\chi^2/ndof = 1.00$
0.0
2.5
5.0
7.5
10.0
12.5
15.0
17.5
20.0
−0.04
−0.02
0.00
0.02
0.04
0.06
$m_{calspec} - m_{gaia}$

Match with Ubercal Catalog

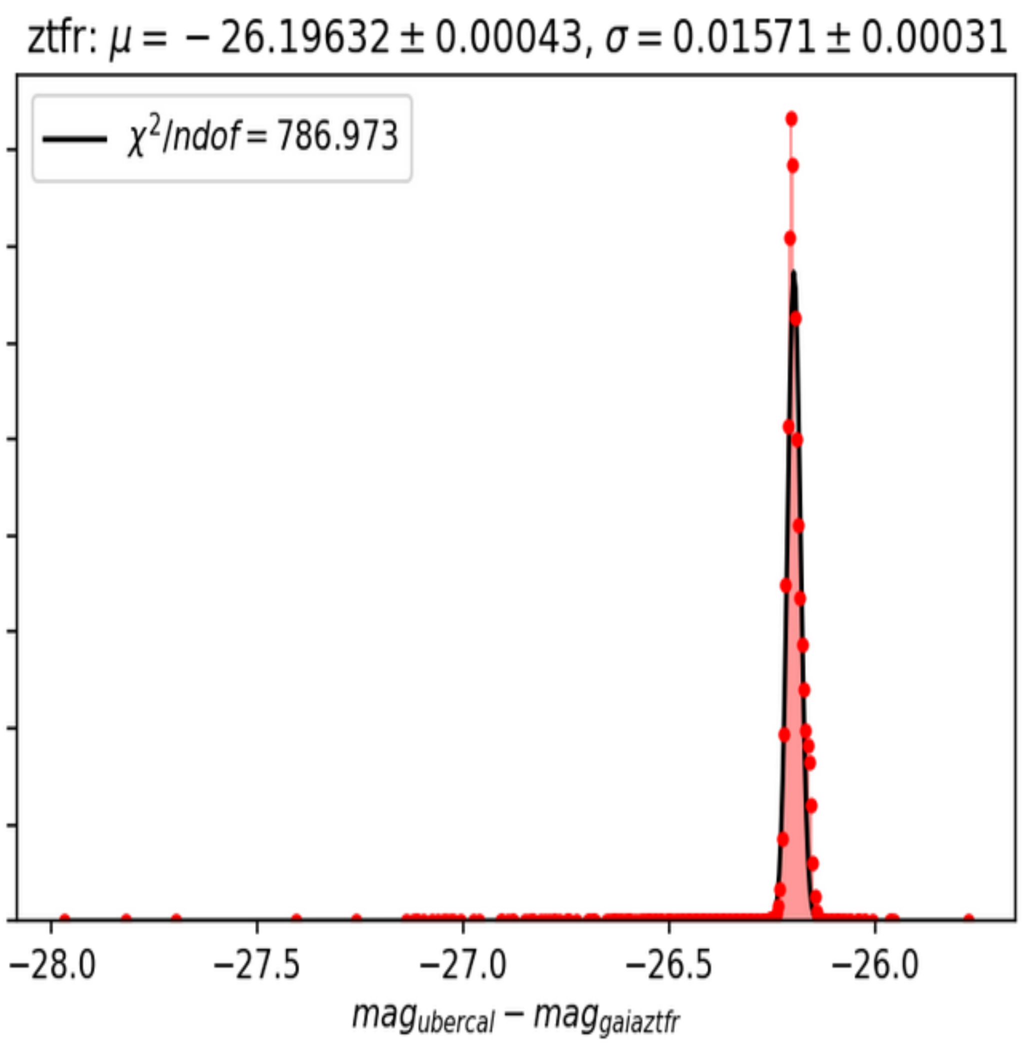
STARS Selection:

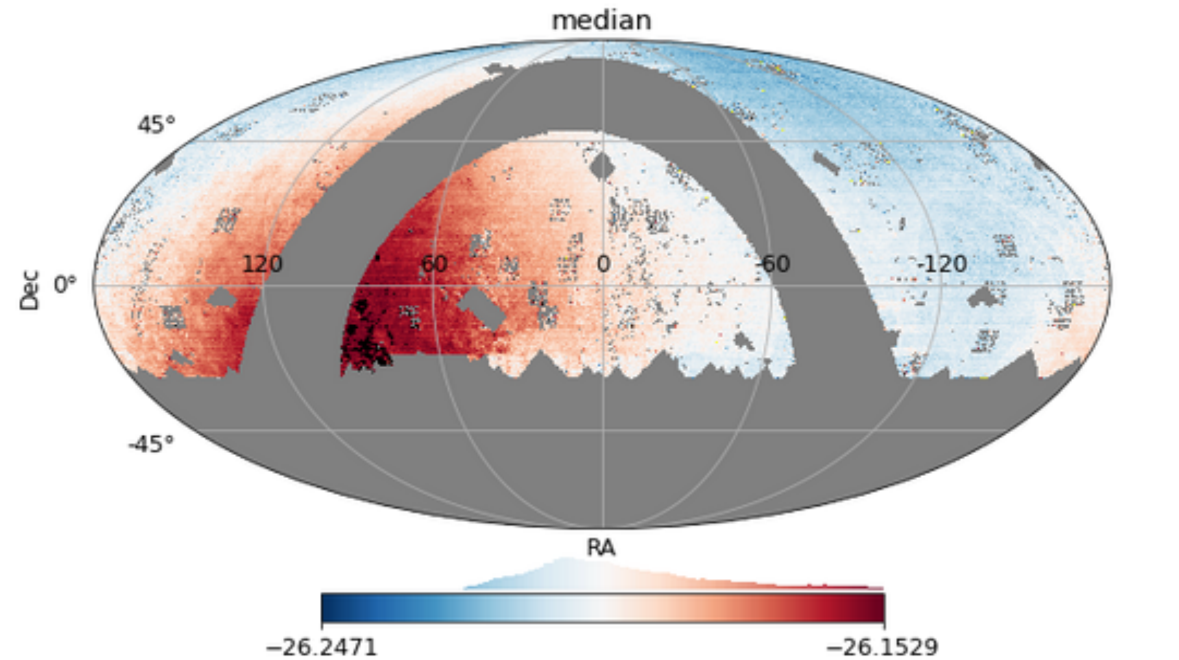
- Isolated stars (radius 20 arcsec)
- Constant stars (according to gaia flag)
- gaia ruwe flag (ruwe<1.4) (clean a sample from cases showing photocentric motions due to unresolved objects)
- gaia color_excess_factor C* < sigmaC* (sigmaC* std of C* distribution)
- processing mode 0 (gold sample)
- number of transit >15
- % of contaminated and blended transit <10%
- remove band of 30 degrees around galactic centre

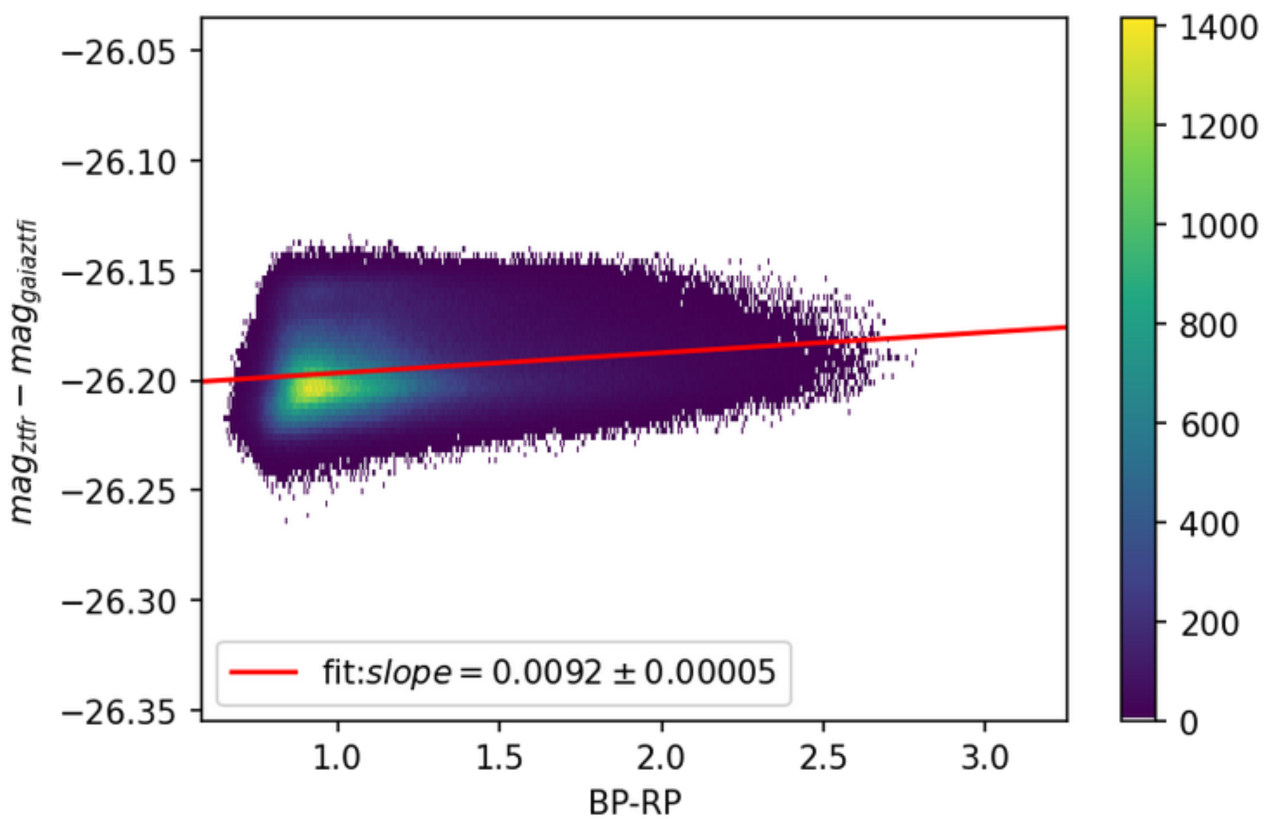
These selections do not change significantly the results

Each catalog has about 1.5-2 million stars

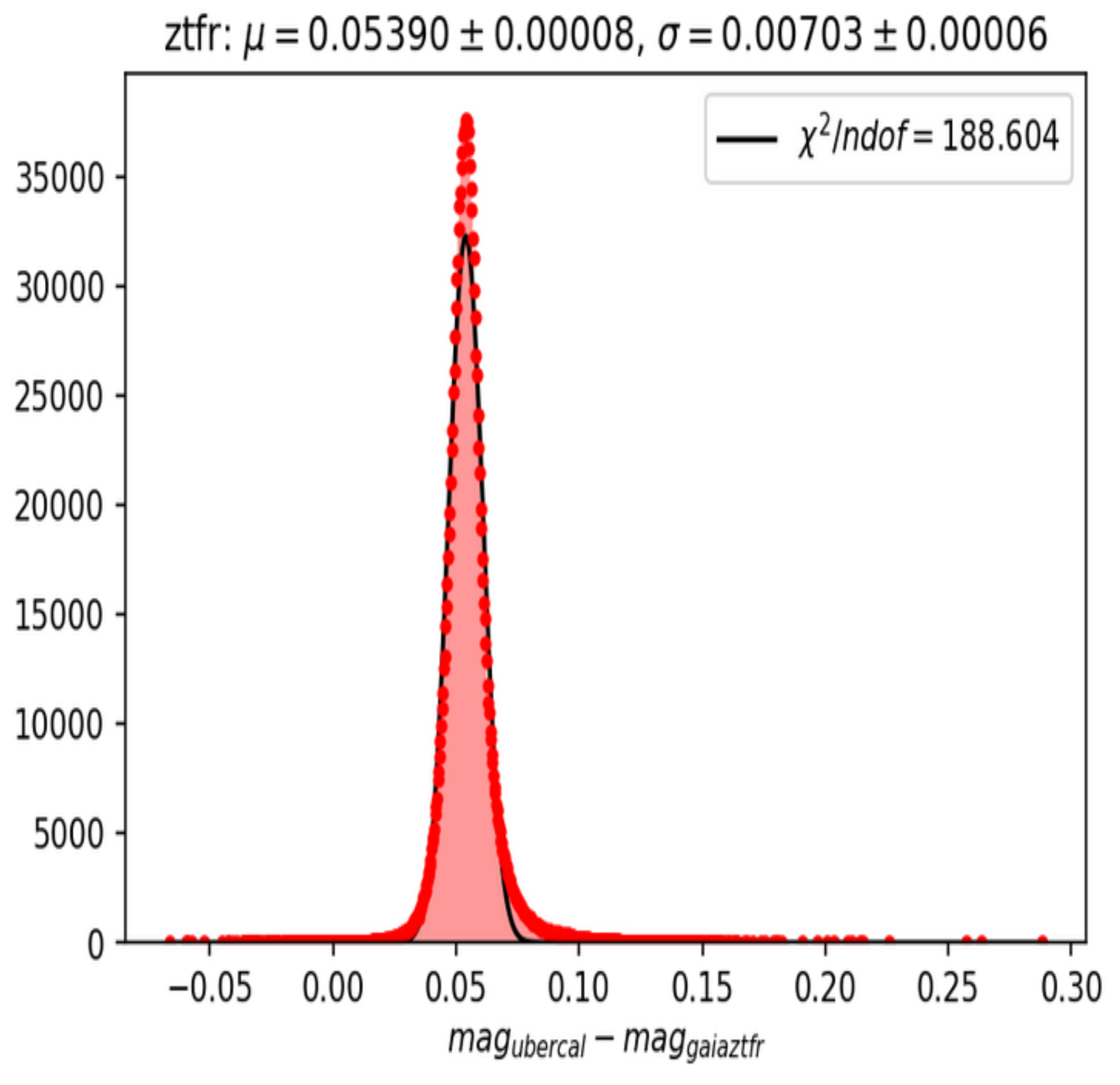
Self Ubercal

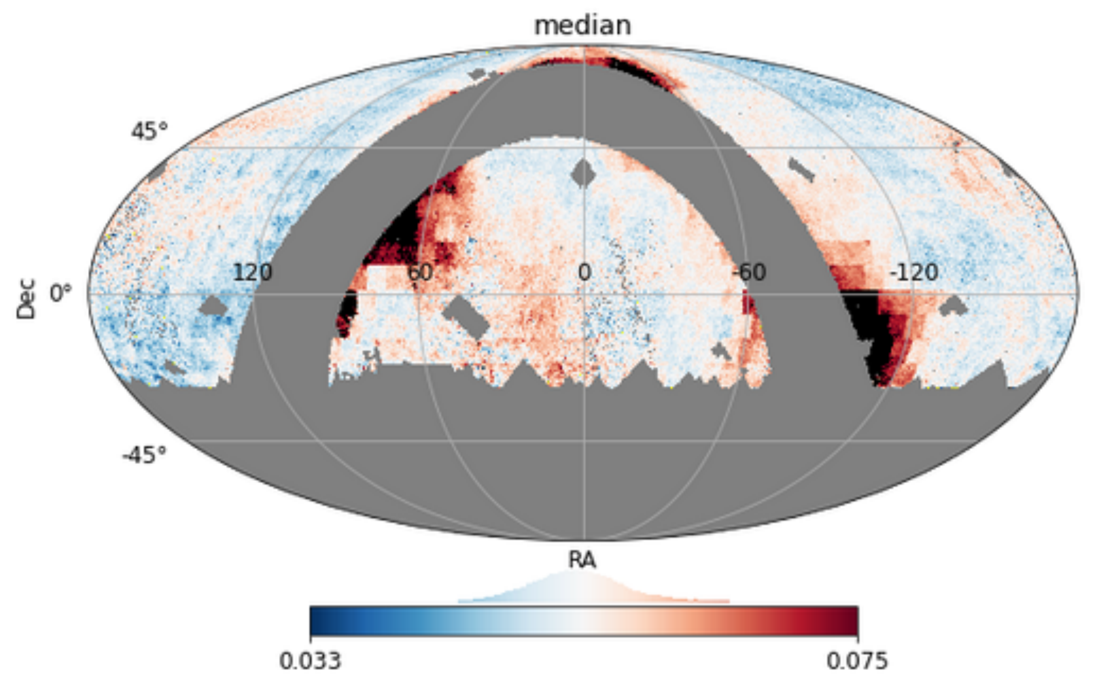


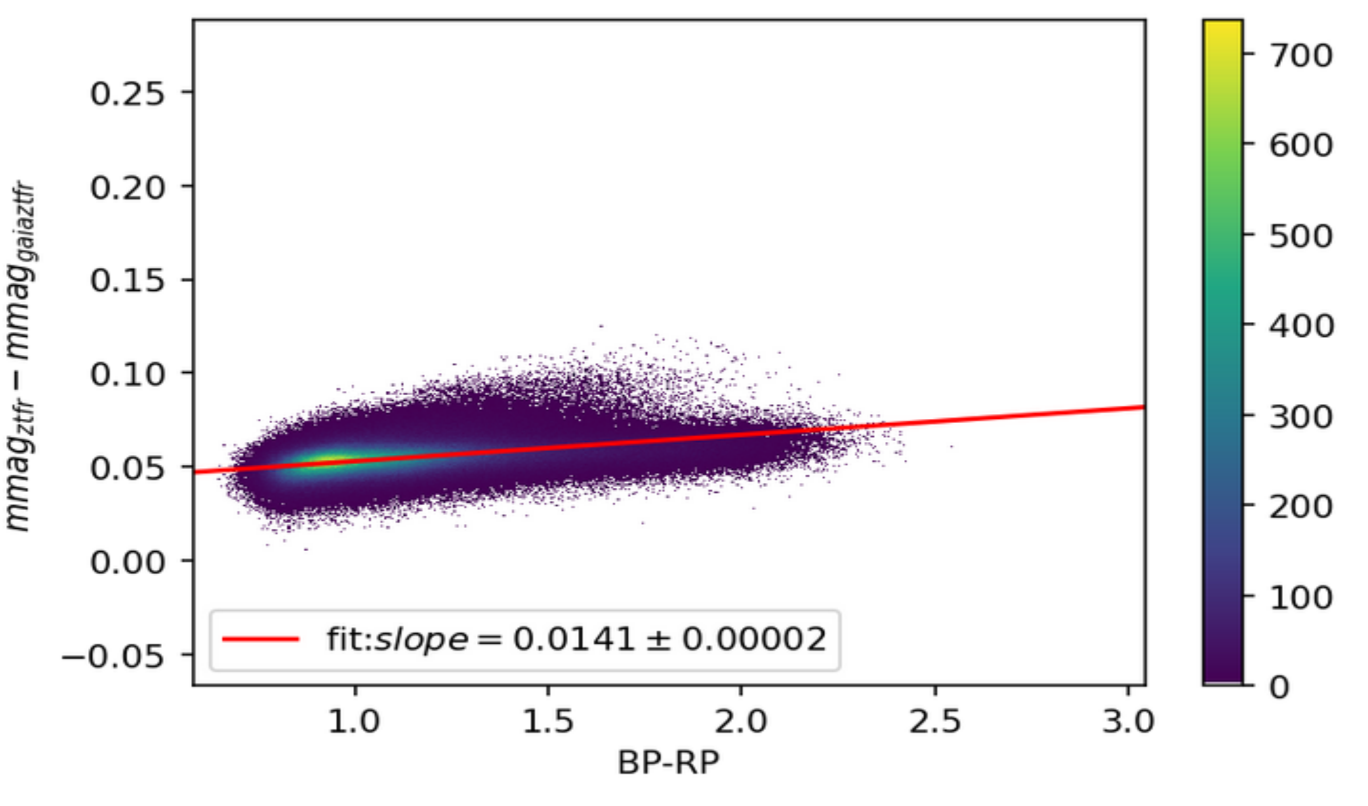


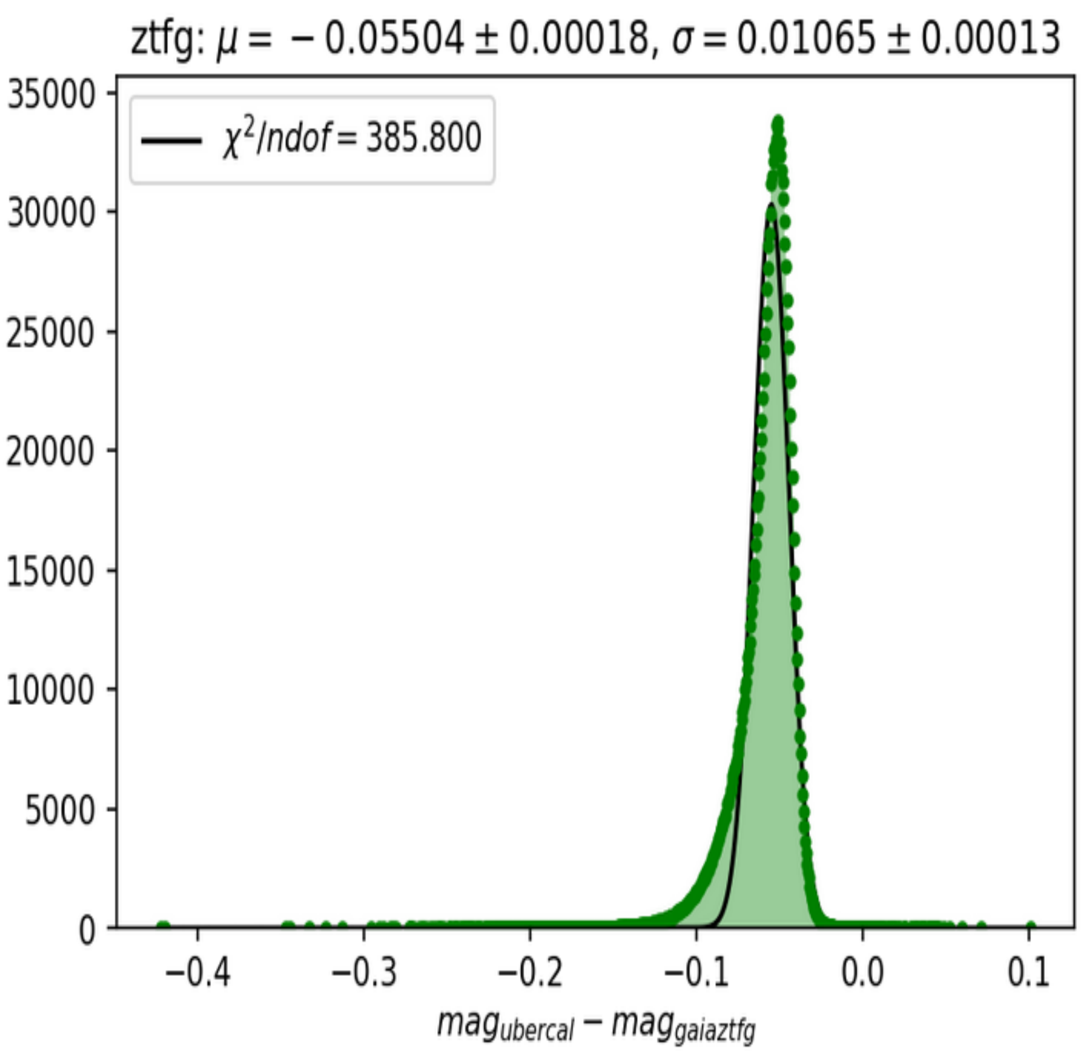


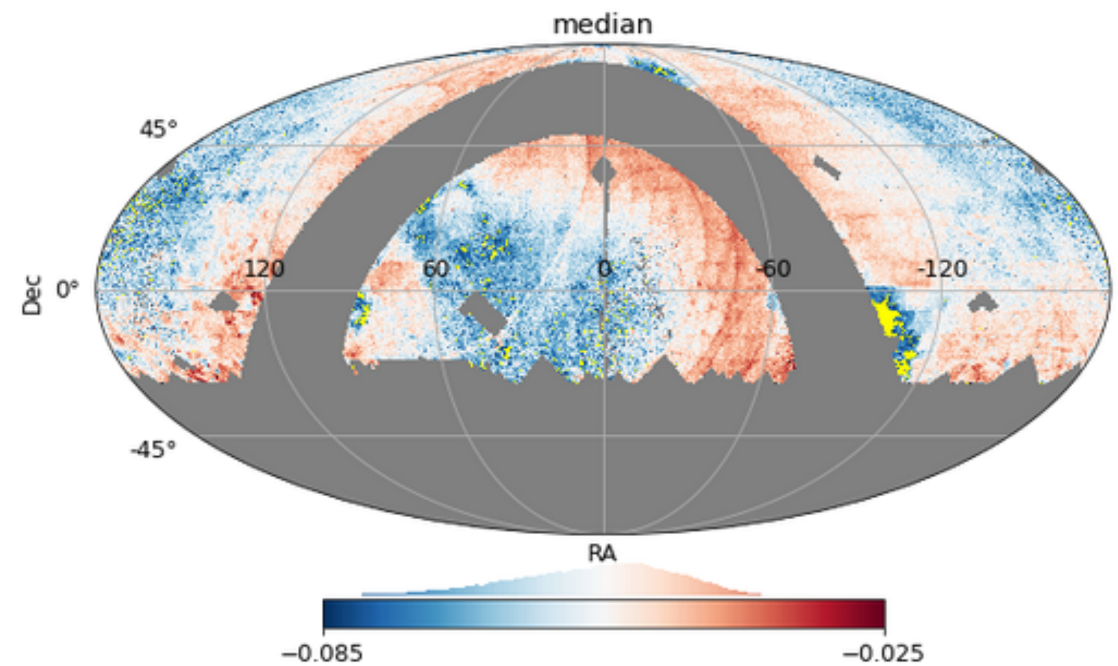
Ubercal

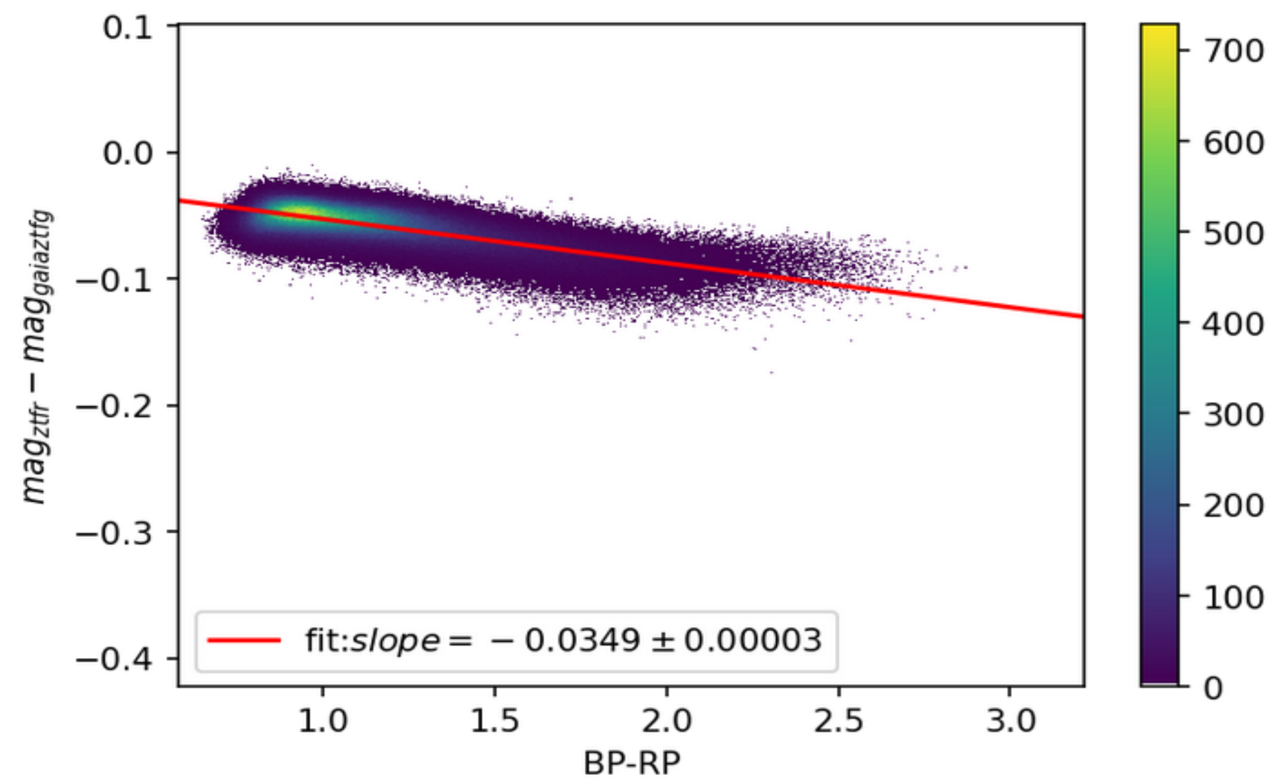

ztfr: $\mu = 0.05390 \pm 0.00008$, $\sigma = 0.00703 \pm 0.00006$
$\chi^2/ndof = 188.604$
35000
30000
25000
20000
15000
10000
5000
0
−0.05
0.00
0.05
0.10
0.15
0.20
0.25
0.30
$mag_{ubercal} - mag_{gaiaztfr}$

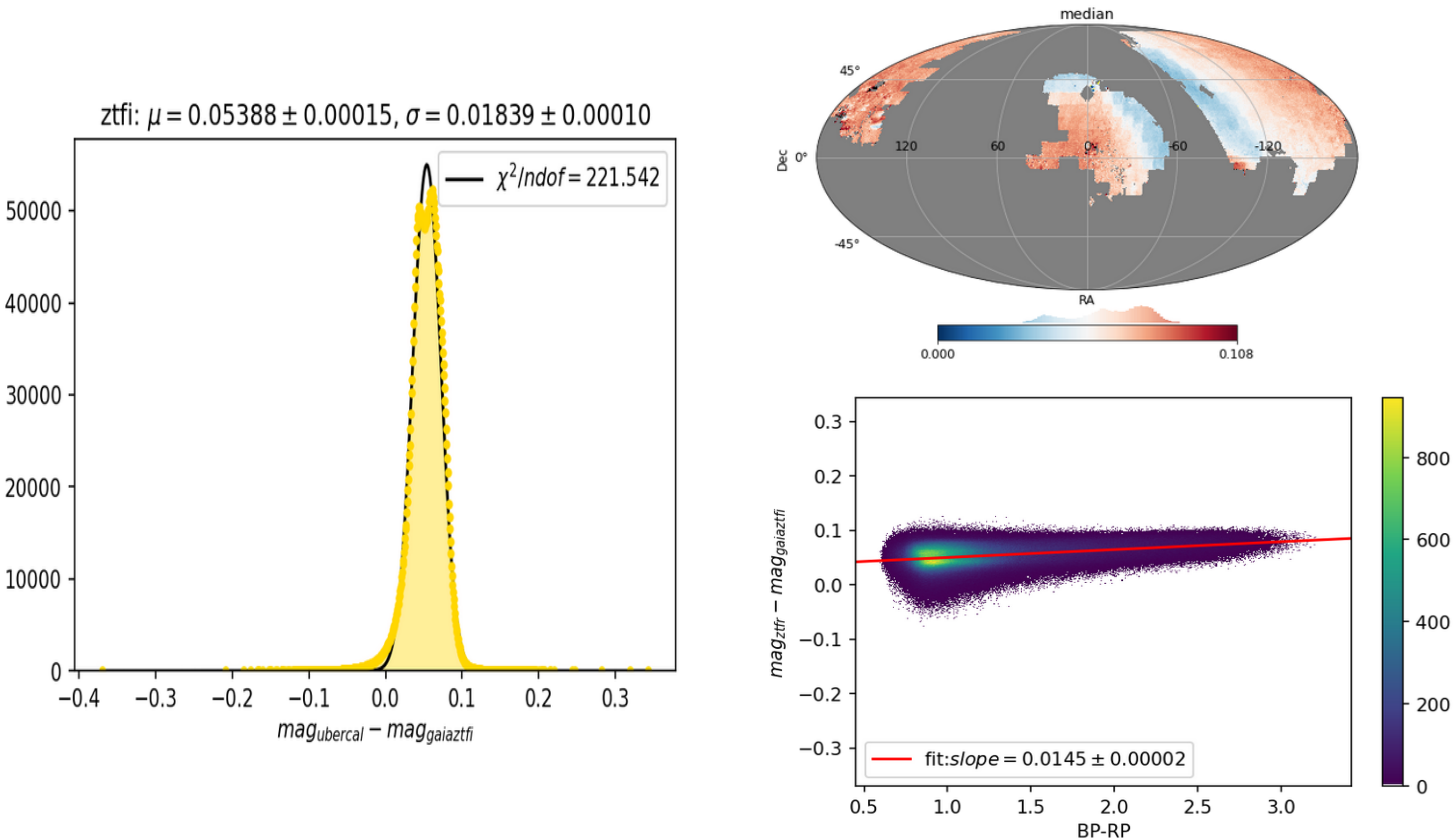

median
45°
0°
-45°
Dec
120
60
0
-60
-120
RA
0.033
0.075


0.25
0.20
0.15
0.10
0.05
0.00
−0.05
$mmag_{ztfr} - mmag_{gaiaztfr}$
fit: $slope = 0.0141 \pm 0.00002$
1.0
1.5
2.0
2.5
3.0
BP-RP
700
600
500
400
300
200
100
0


ztfg: $\mu = -0.05504 \pm 0.00018$, $\sigma = 0.01065 \pm 0.00013$
$\chi^2/ndof = 385.800$
35000
30000
25000
20000
15000
10000
5000
0
−0.4
−0.3
−0.2
−0.1
0.0
0.1
$mag_{ubercal} - mag_{gaiaztfg}$


median
45°
0°
−45°
Dec
120
60
0
-60
-120
RA
−0.085
−0.025


0.1
0.0
−0.1
−0.2
−0.3
−0.4
$mag_{ztfr} - mag_{gaiaztfg}$
1.0
1.5
2.0
2.5
3.0
BP-RP
fit: $slope = -0.0349 \pm 0.00003$
700
600
500
400
300
200
100
0

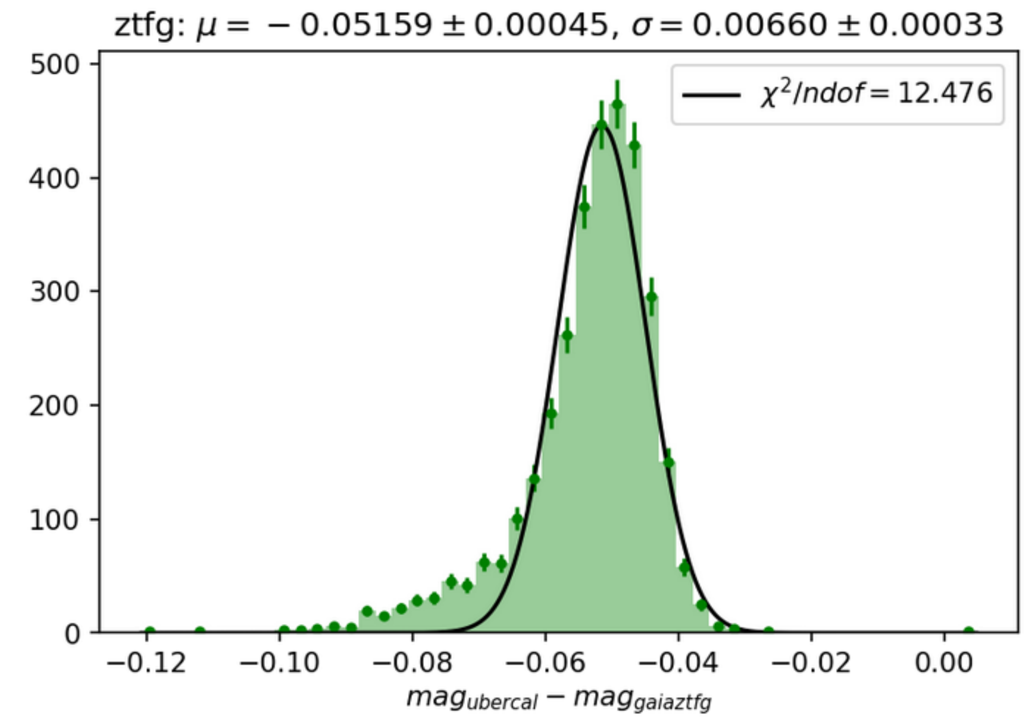

ztfi: $\mu = 0.05388 \pm 0.00015$, $\sigma = 0.01839 \pm 0.00010$
$\chi^2/ndof = 221.542$
50000
40000
30000
20000
10000
0
−0.4
−0.3
−0.2
−0.1
0.0
0.1
0.2
0.3
$mag_{ubercal} - mag_{gaiaztfi}$
median
45°
0°
-45°
Dec
120
60
0
-60
-120
RA
0.000
0.108
0.3
0.2
0.1
0.0
−0.1
−0.2
−0.3
$mag_{ztfr} - mag_{gaiaztfi}$
fit: $slope = 0.0145 \pm 0.00002$
0.5
1.0
1.5
2.0
2.5
3.0
BP-RP
800
600
400
200
0

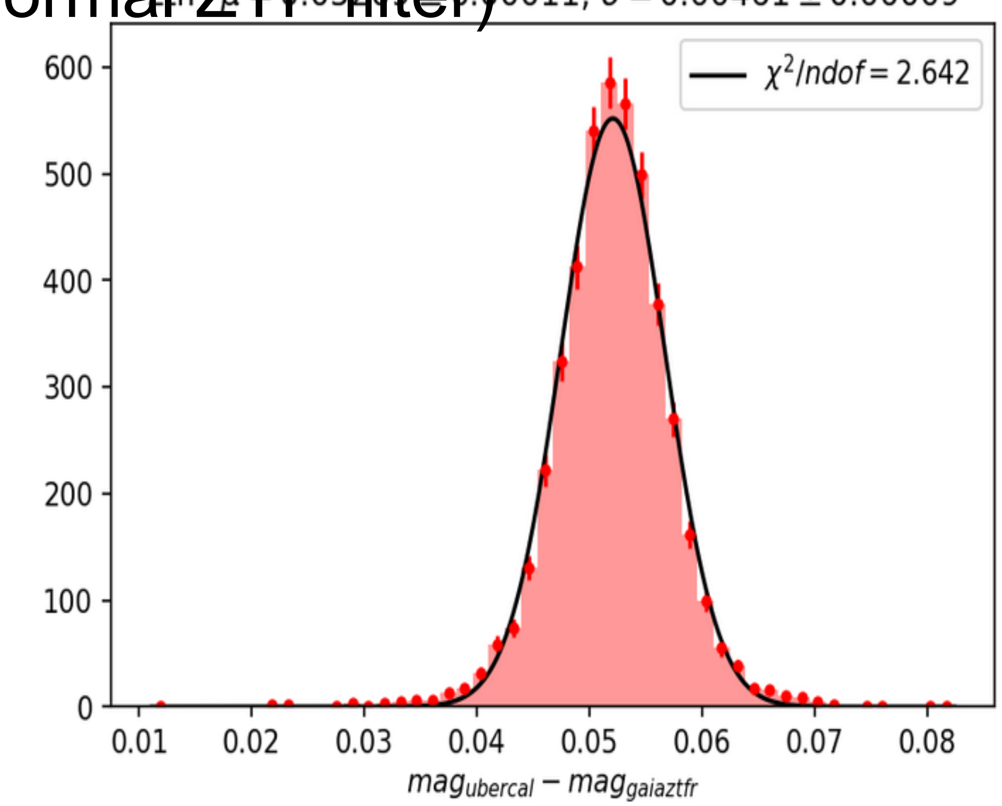
Field 600

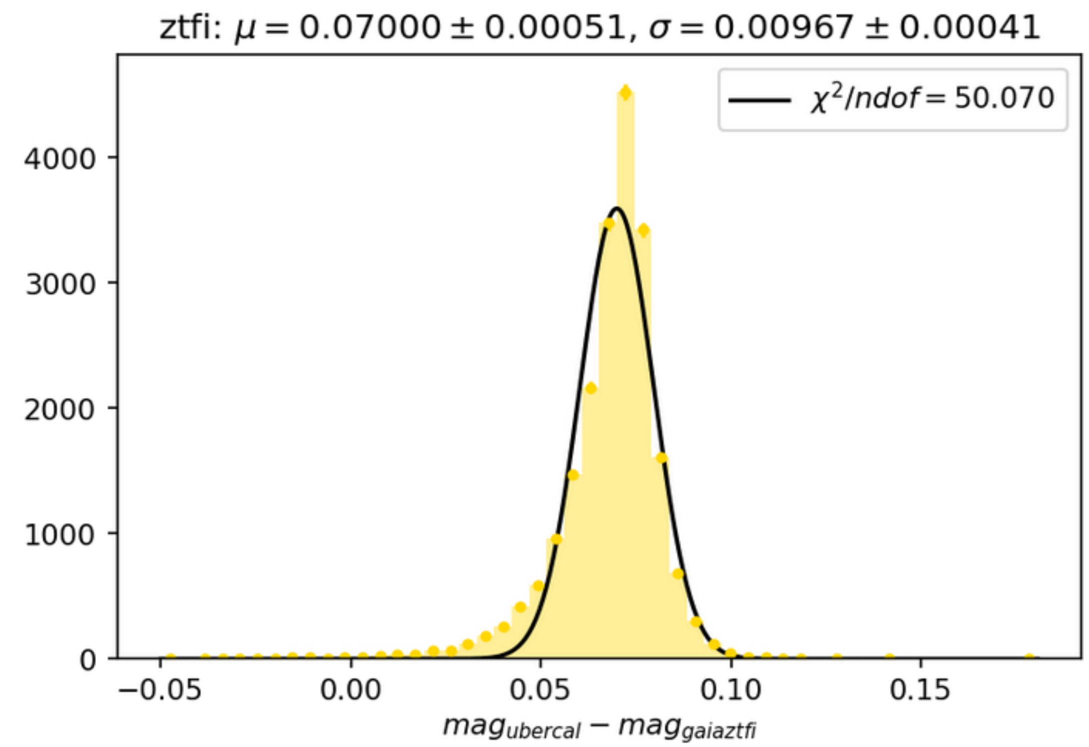
Filter shift estimation:

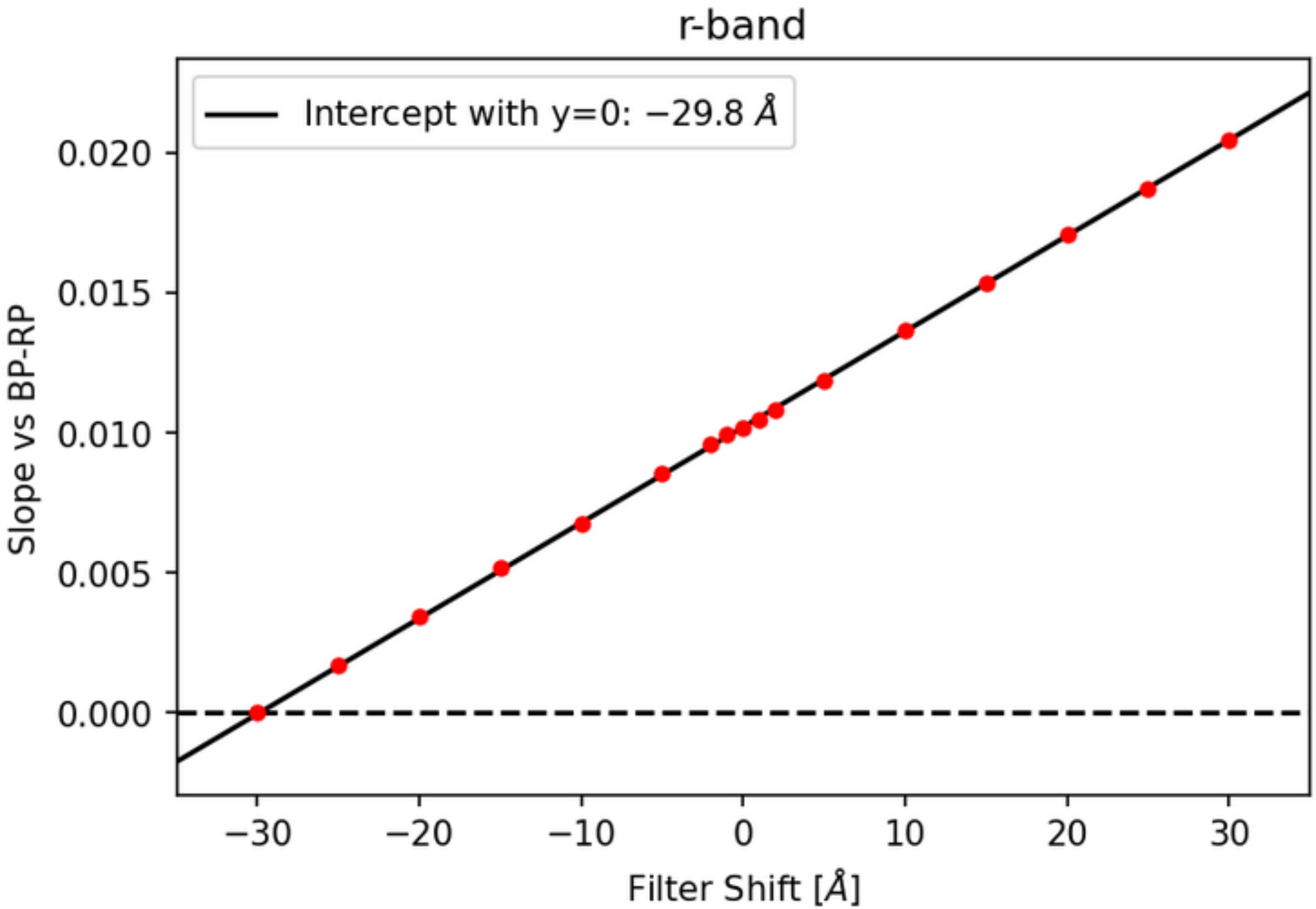
- computed ZTF mag from Gaia shifting the ZTF filter of arbitrary amount (between -30 and +30 Armstrong)
- Fitting the Slope vs BP-RP for each filter
- Fitting the Slope distribution as a function of the Shift and computing the required shift to have slope=0

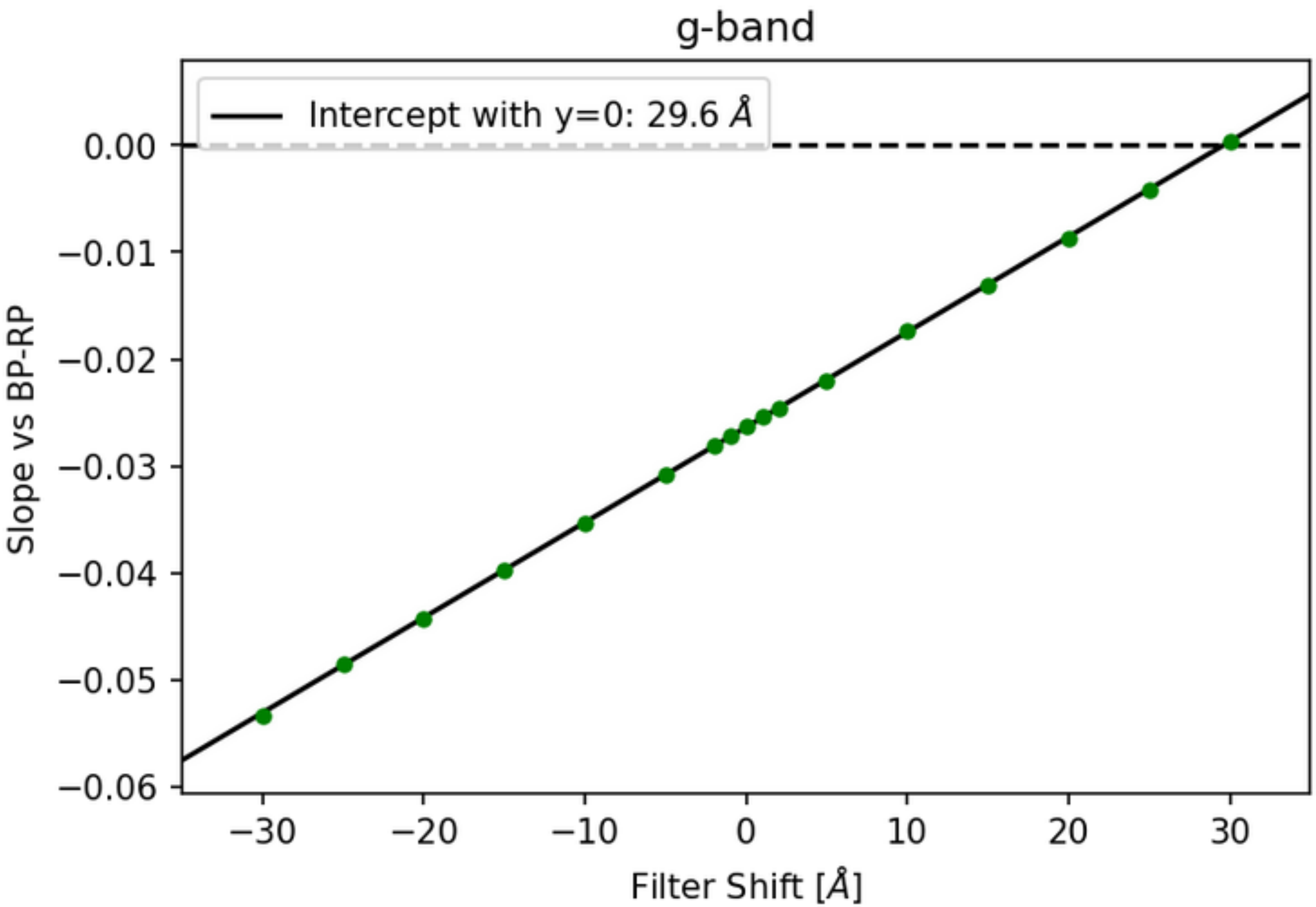
(the plots in the slide are computed with the normal ZTF filter)



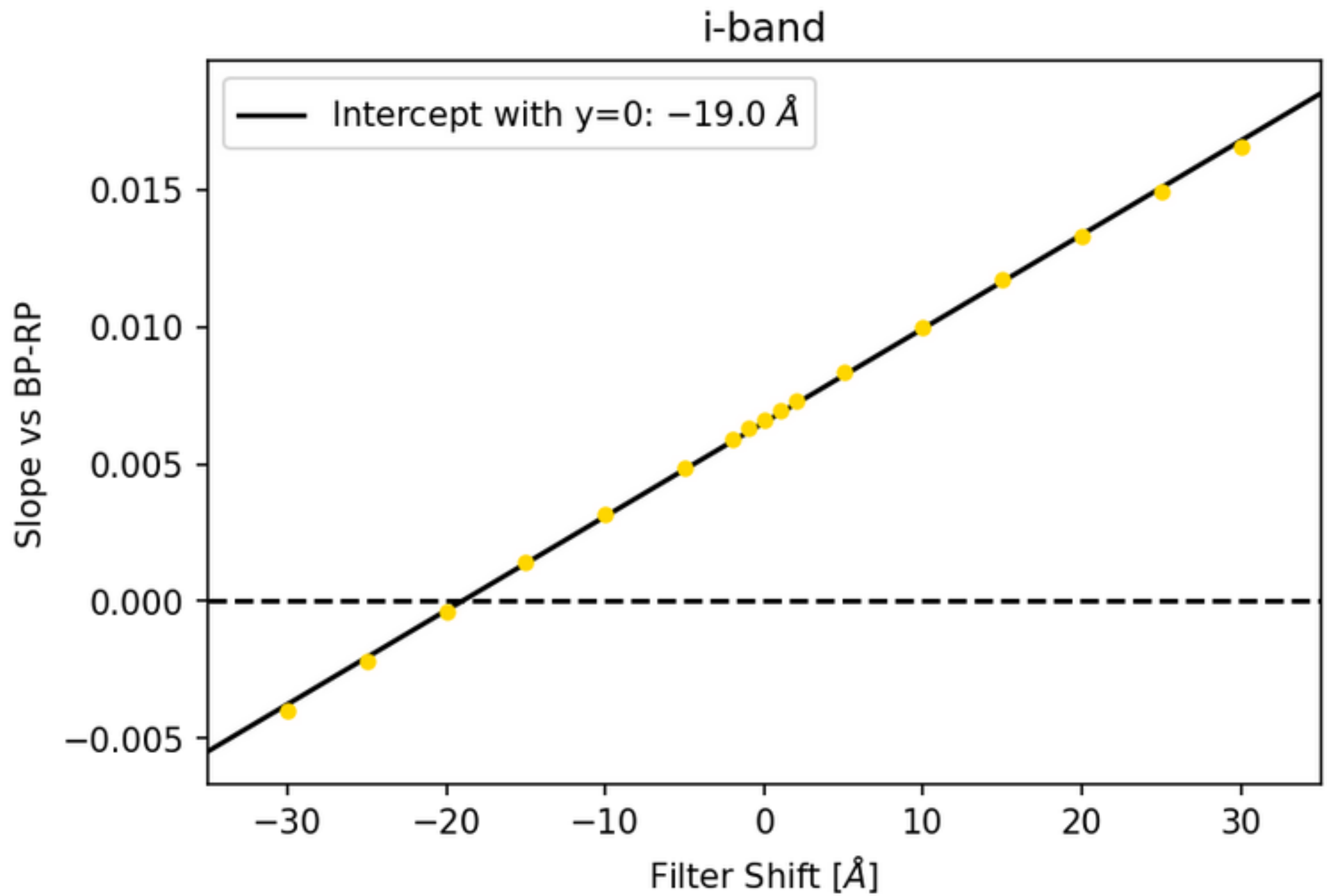





r-band
Intercept with y=0: −29.8 Å
Slope vs BP-RP
0.020
0.015
0.010
0.005
0.000
−30
−20
−10
0
10
20
30
Filter Shift [Å]



g-band
Intercept with y=0: 29.6 Å
0.00
−0.01
−0.02
−0.03
−0.04
−0.05
−0.06
Slope vs BP-RP
−30
−20
−10
0
10
20
30
Filter Shift [Å]



i-band
Intercept with y=0: −19.0 Å
0.015
0.010
0.005
0.000
−0.005
Slope vs BP-RP
−30
−20
−10
0
10
20
30
Filter Shift [Å]