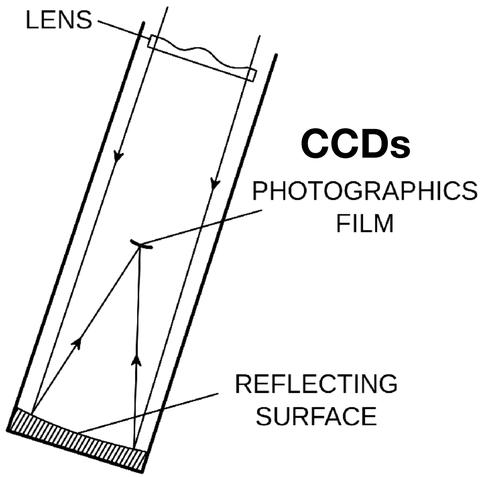
Update on Ubercal

Benjamin Racine & Fabrice Feinstein

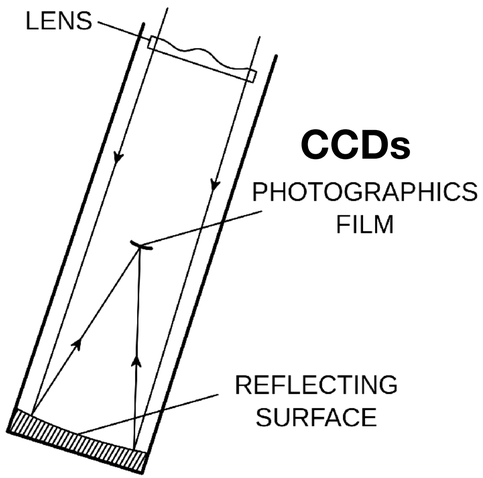
January 19th, 2022

Flux F

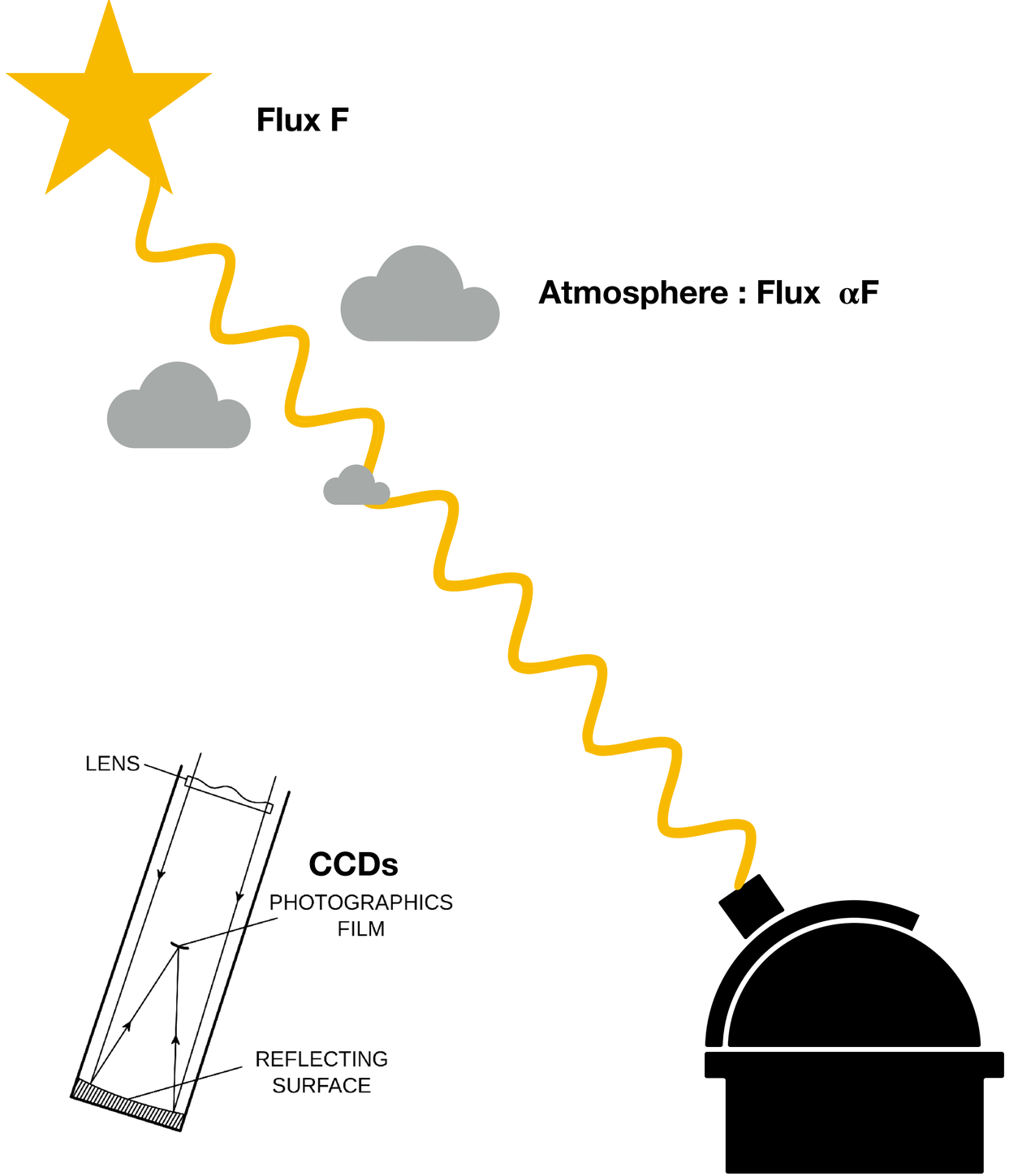


CCDs

Flux F

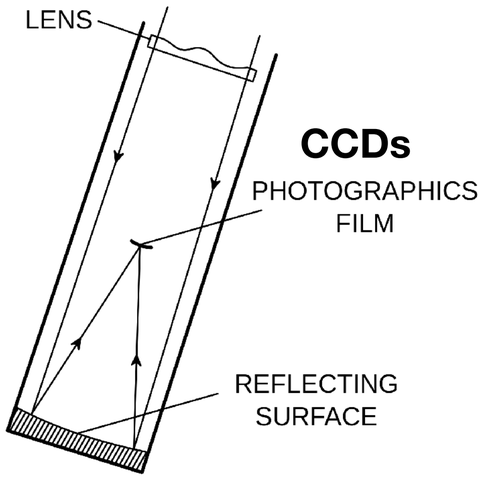


CCDs


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

Flux F

Atmosphere : Flux αF



CCDs

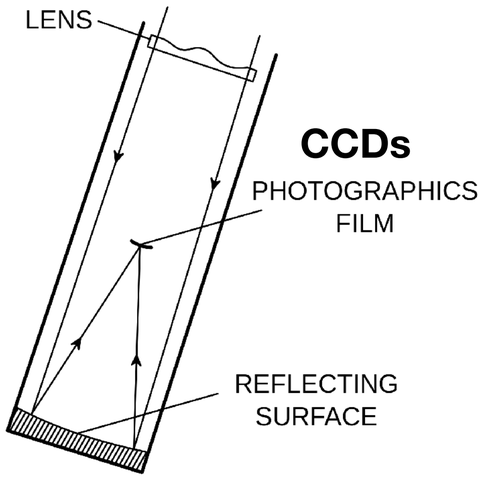
Instrument

Flux F

Atmosphere : Flux αF

Instrument

Mirrors etc. : Flux $\alpha\beta F$



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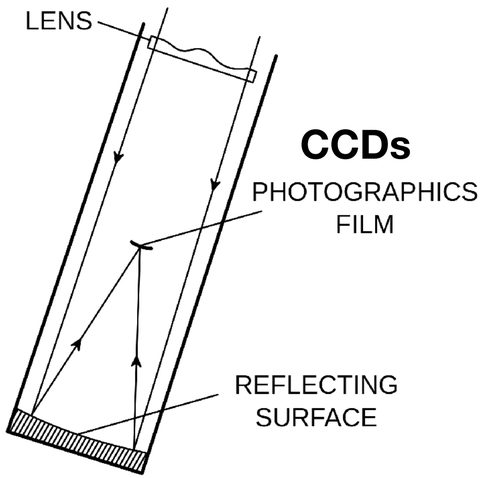
Atmosphere : Flux αF

Instrument

Mirrors etc. : Flux $\alpha\beta F$

Filters : Flux $\alpha\beta\gamma F$



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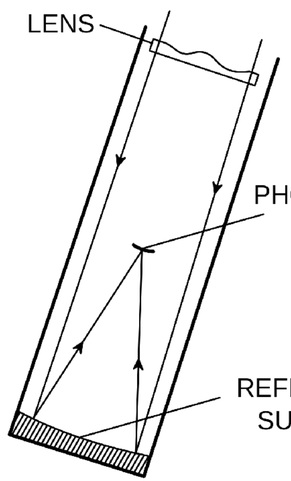
Atmosphere : Flux αF



CCDs

Instrument

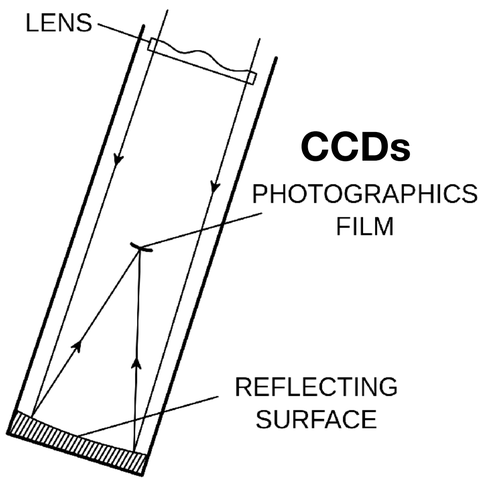
Mirrors etc. : Flux $\alpha\beta F$

Filters : Flux $\alpha\beta\gamma F$

Detectors : Flux $\alpha\beta\gamma\delta F$

Flux F

Atmosphere : Flux αF



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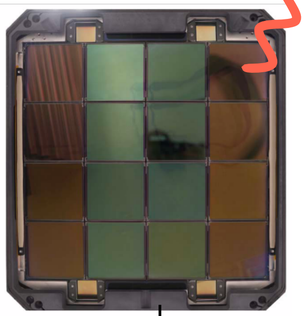
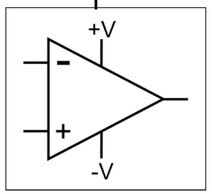
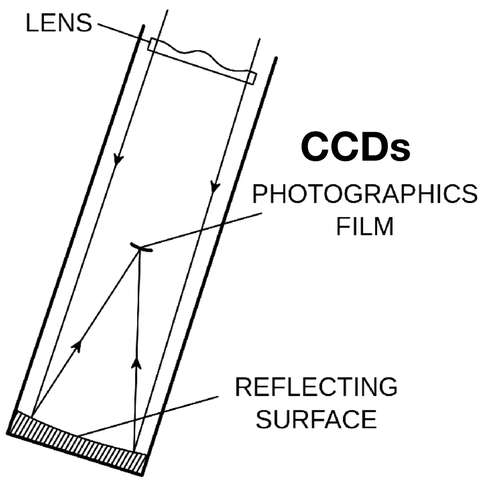


Amplifiers : Flux $\alpha\beta\gamma\delta\varepsilon F$



Flux F

Atmosphere : Flux αF



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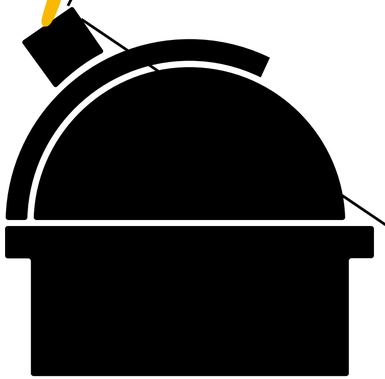

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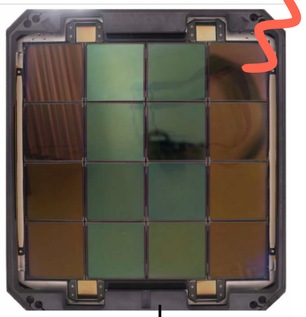
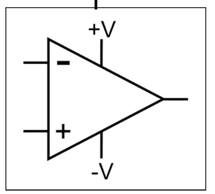


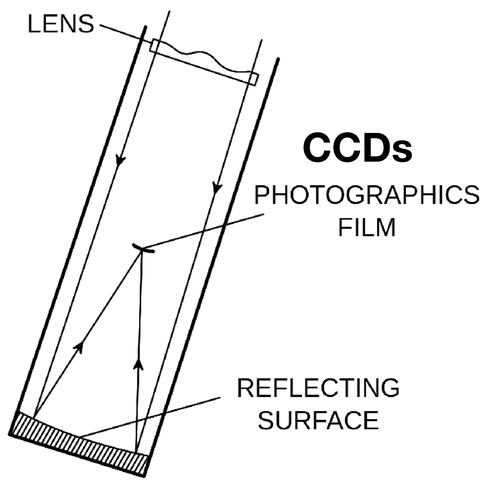
Amplifiers : Flux $\alpha\beta\gamma\delta\varepsilon F$

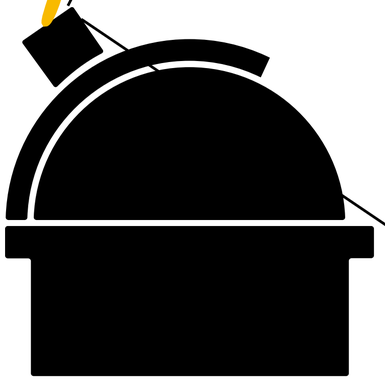


Signal measured in ADU

Flux F

Atmosphere : Flux αF





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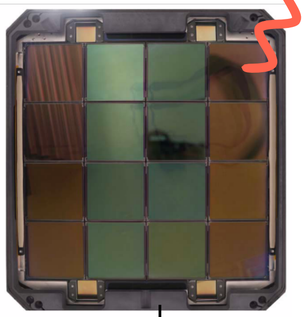

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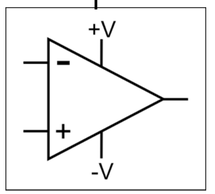
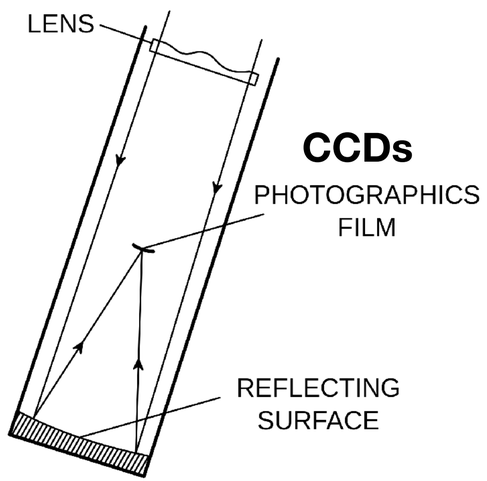


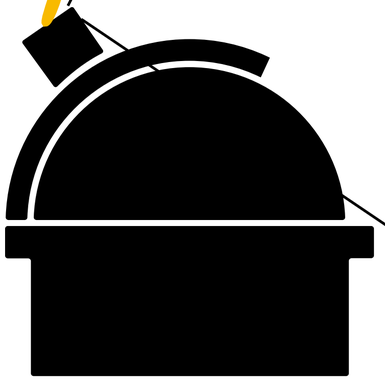
Signal measured in ADU

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

Flux F

Atmosphere : Flux αF





Instrument

Mirrors etc. : Flux $\alpha\beta F$

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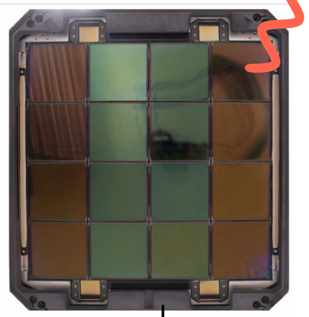
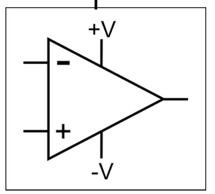


Detectors : Flux $\alpha\beta\gamma\delta F$



Amplifiers : Flux $\alpha\beta\gamma\delta\varepsilon F$

Signal measured in ADU

$$m_{meas} = -2.5 \log (F_{meas})$$

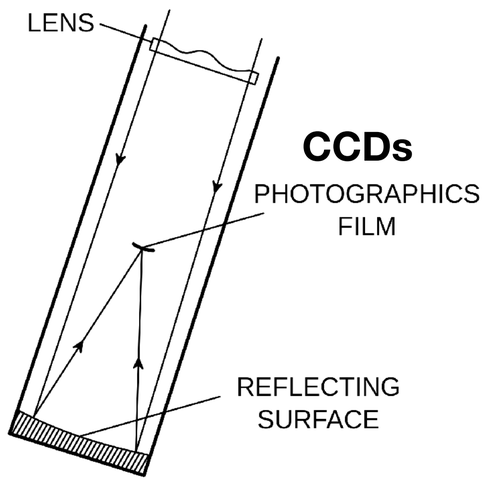
$$= -2.5 \log (F) - 2.5 \log (\alpha\beta\gamma\delta\epsilon)$$

ZP

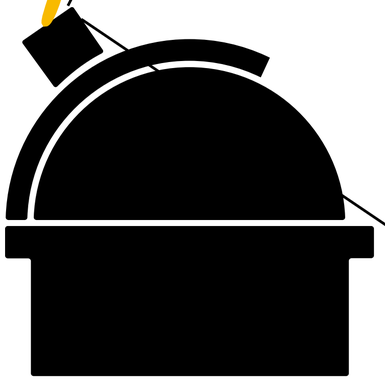
Flux F

Depends on time, elevation etc

Atmosphere : Flux αF



CCDs



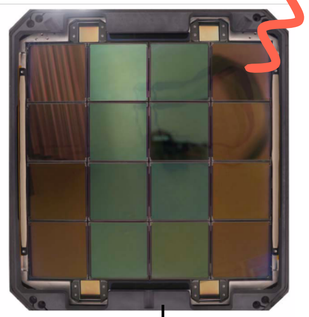
Instrument

Dust spots? Aging?

Mirrors etc. : Flux $\alpha\beta F$

Dust? Frequency dependence of course

Filters : Flux $\alpha\beta\gamma F$

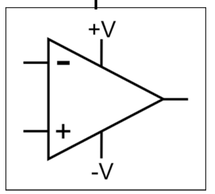


Edges, dust, coating etc.

Detectors : Flux $\alpha\beta\gamma\delta F$

Gain variations etc?

Amplifiers : Flux $\alpha\beta\gamma\delta\varepsilon F$



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ZP

Flux F

Depends on tim

Atmospher

Instrument

Dust spots? Aging?

Mirrors etc. : Flux $\alpha\beta F$

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Filters : Flux $\alpha\beta\gamma F$

, coating etc.

Flux $\alpha\beta\gamma\delta F$

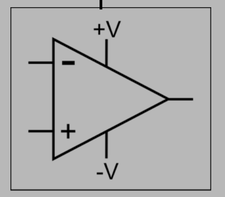
ations etc?

: Flux $\alpha\beta\gamma\delta\varepsilon F$

$$m_{calib} = -2.5 \log (F)$$
$$= -2.5 \log (F_{meas}) + ZP$$

in ADU/s

The zeropoint is the magnitude corresponding to a flux of 1 ADU/s



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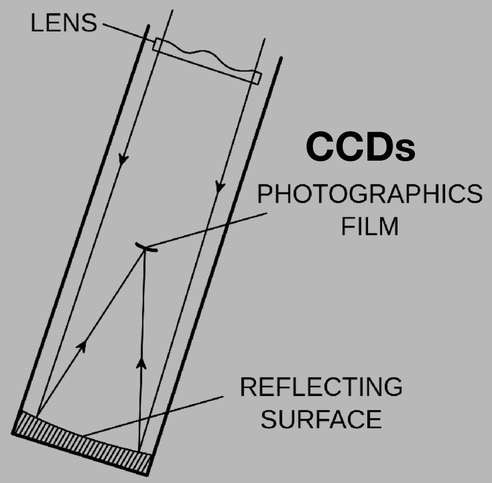

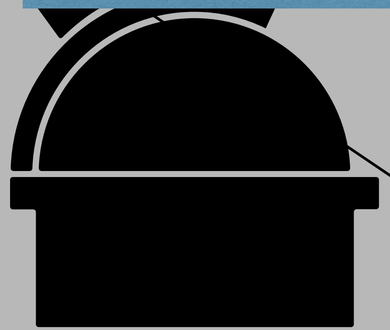

$$m_{meas} = -2.5 \log (F_{meas})$$
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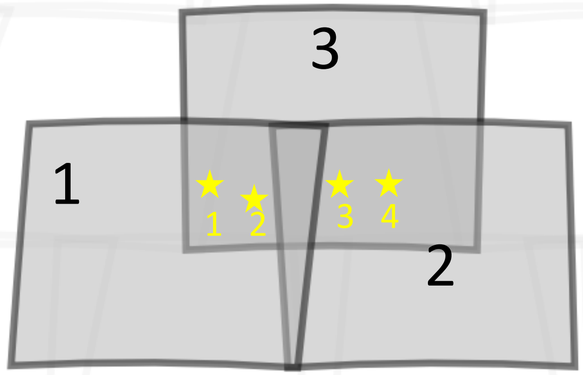
ZP

⚠️ **ubercal mags are relative**



Ubercal method

$$m_{i_{star}} + ZP_{j_{field}} = m^{obs}_{i_{star},\, j_{field}}$$

$$\begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 & 1 & 0 \\ 1 & 0 & 0 & 0 & 0 & 1 \\ 0 & 1 & 0 & 0 & 0 & 1 \\ 0 & 0 & 1 & 0 & 0 & 1 \\ 0 & 0 & 0 & 1 & 0 & 1 \end{bmatrix} \cdot \begin{bmatrix} m_1 \\ m_2 \\ m_3 \\ m_4 \\ \Delta ZP_2 \\ \Delta ZP_3 \end{bmatrix} = \begin{bmatrix} m^{obs}_{11} \\ m^{obs}_{21} \\ m^{obs}_{32} \\ m^{obs}_{42} \\ m^{obs}_{13} \\ m^{obs}_{23} \\ m^{obs}_{33} \\ m^{obs}_{43} \end{bmatrix}$$

$$A_{8x6} \cdot X_{6x1} = B_{8x1}$$

system of 8 equations :

$A\,X = B$

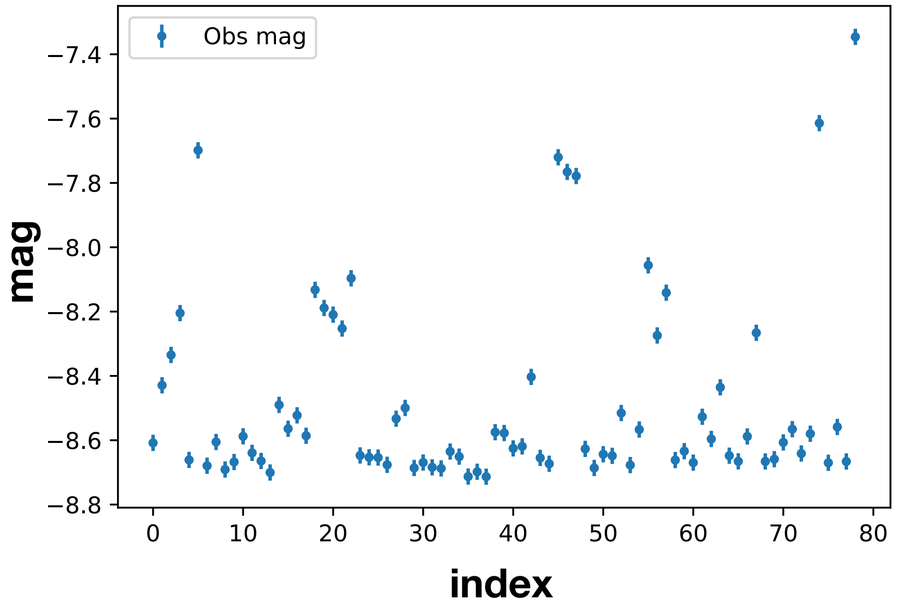
<u>least square fit</u> :

$A^t\,C\,A\,X = A^t\,C\,B$

C : diagonal matrix with weights of $m_{i,\,j}$ measurements

Covariance of parameters given by: $[A^t\,C\,A]^{-1}$

Result on one star (79 obs here)



⚠️ **ubercal mags are relative**

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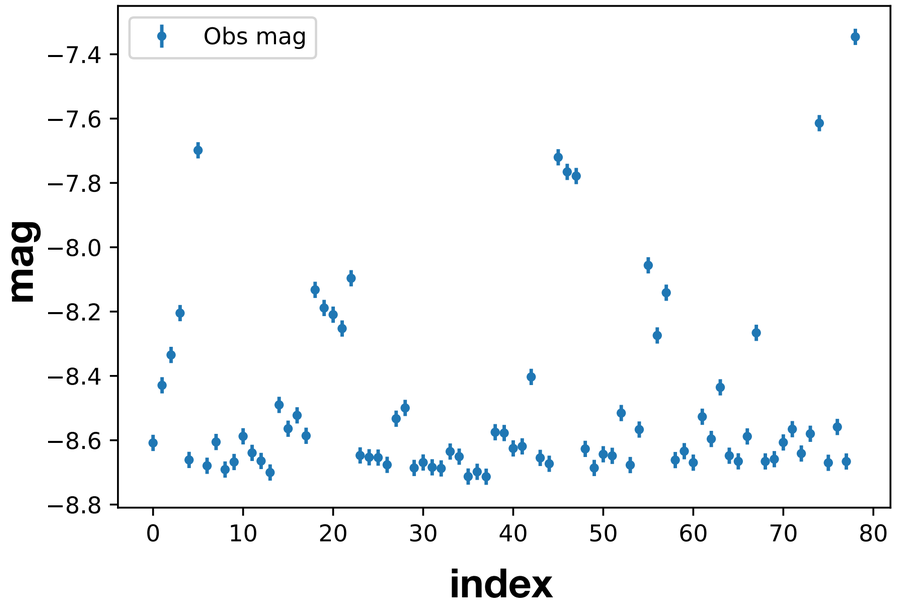

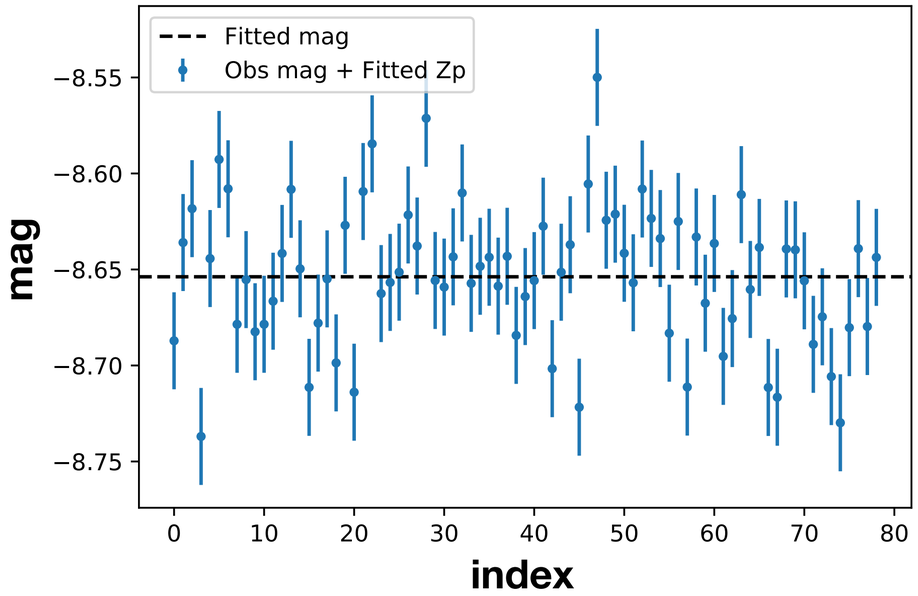

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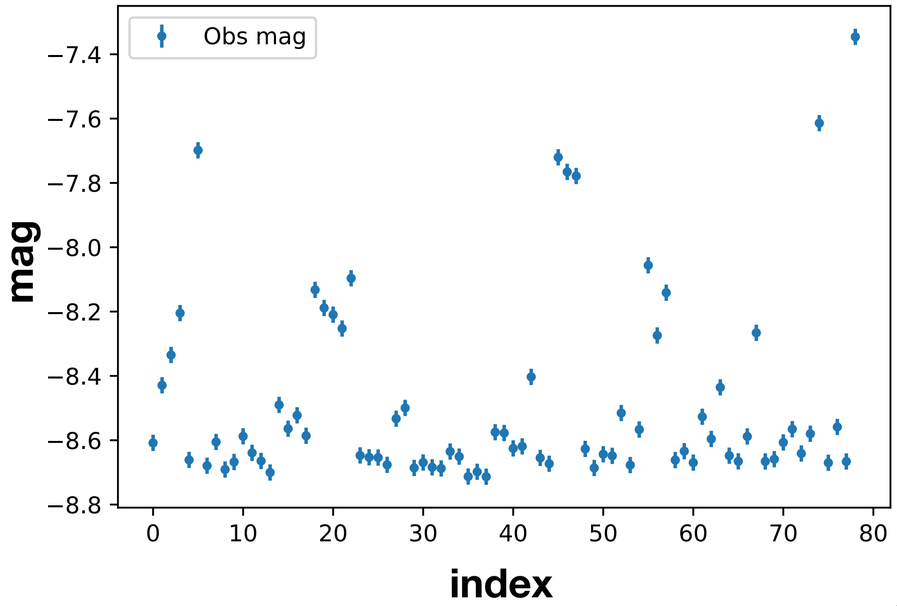
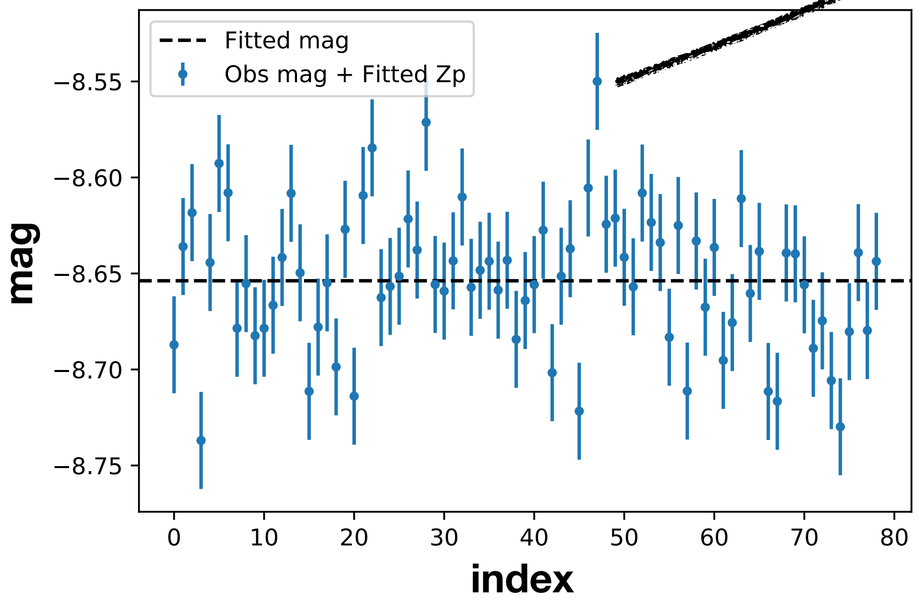
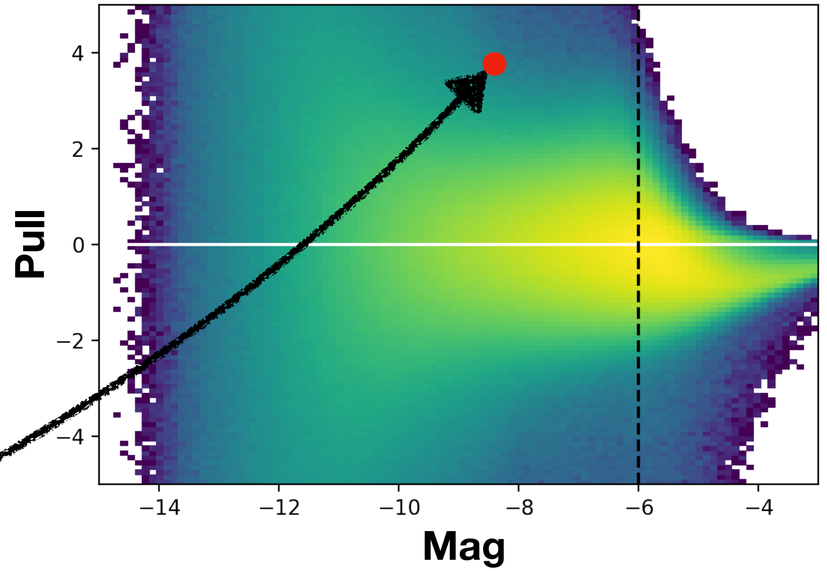




Result on all stars



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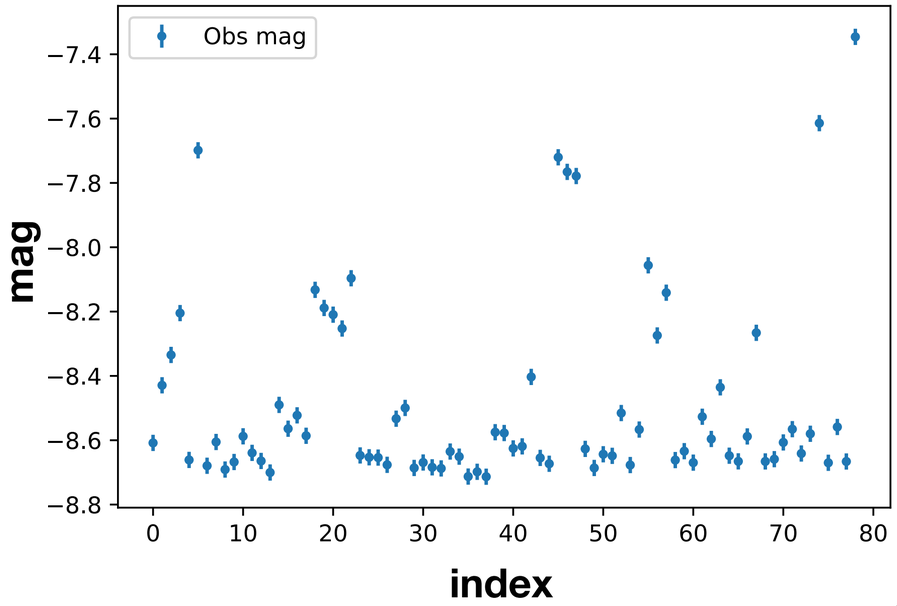

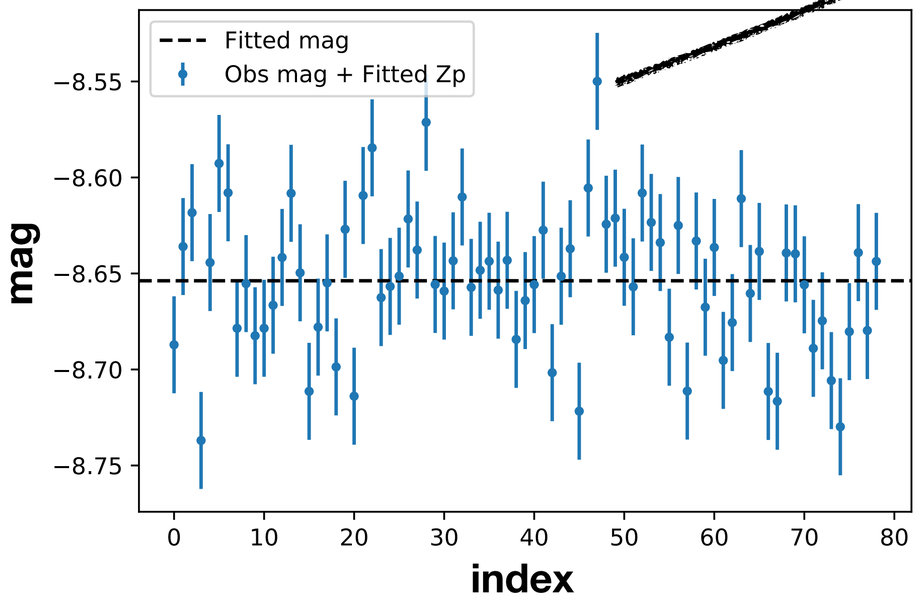

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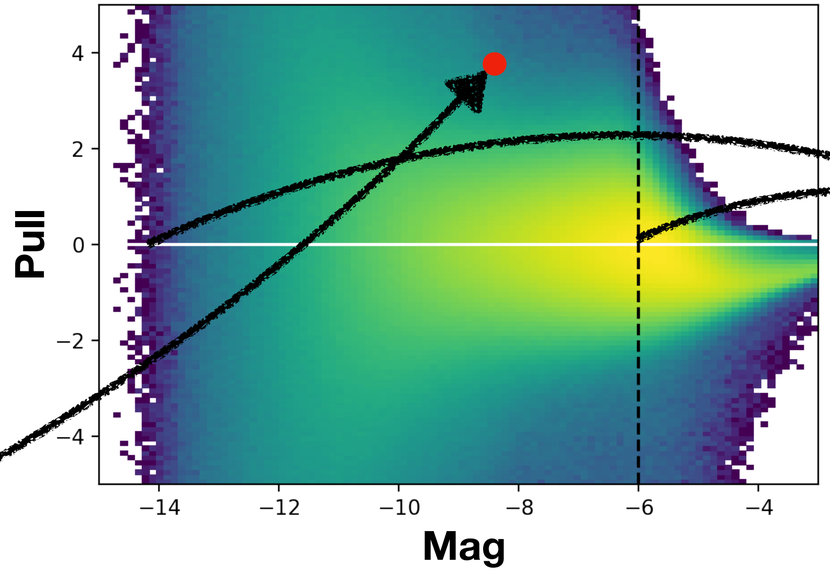

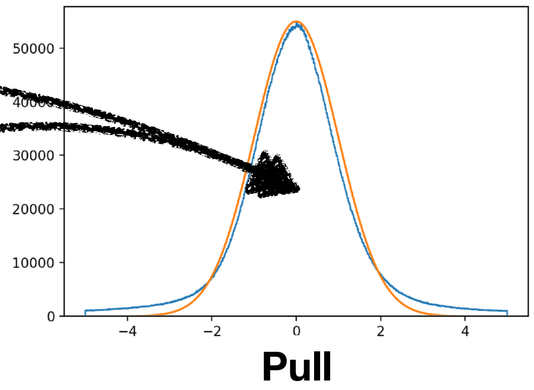

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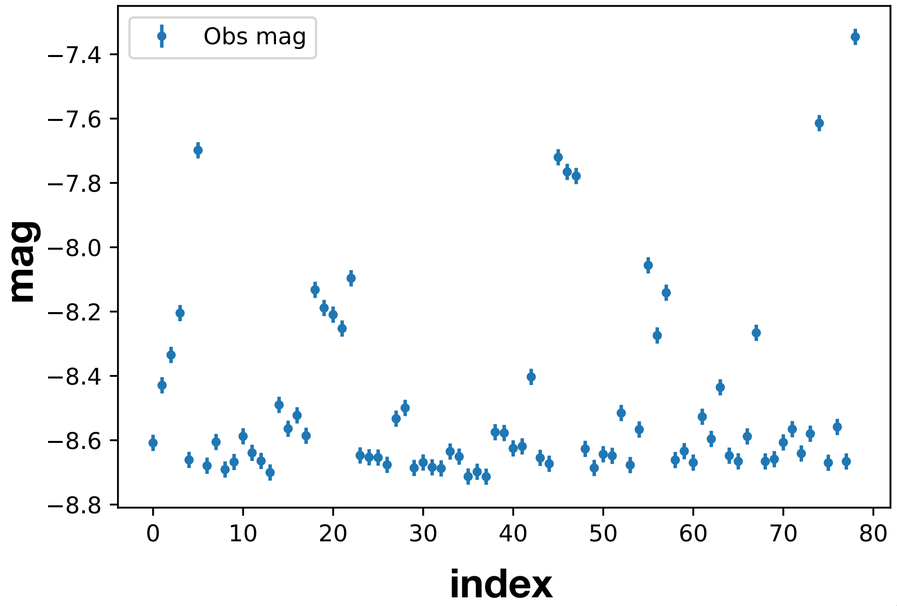

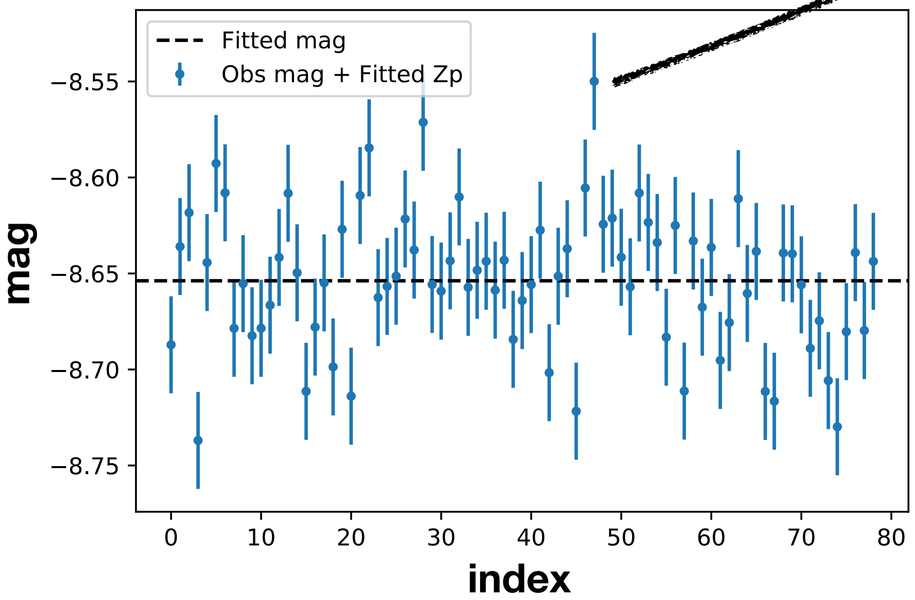

std=0.036

Result on all stars

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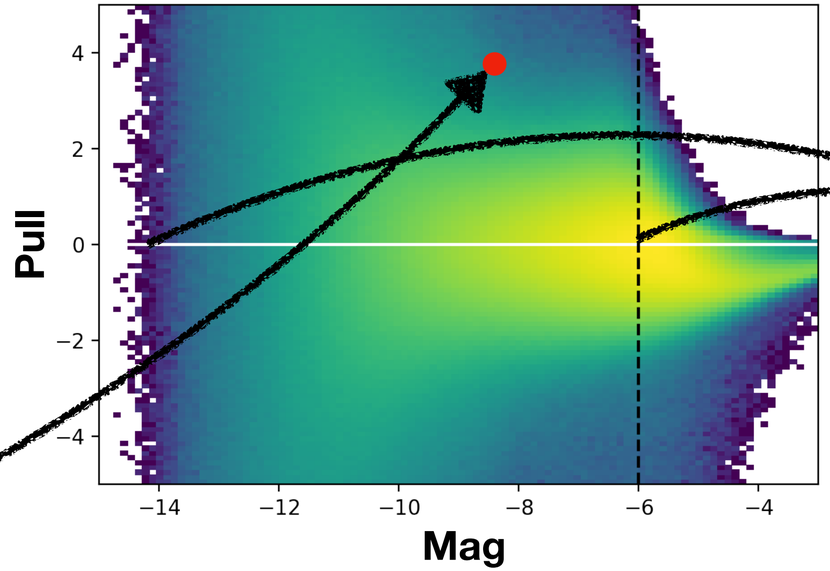
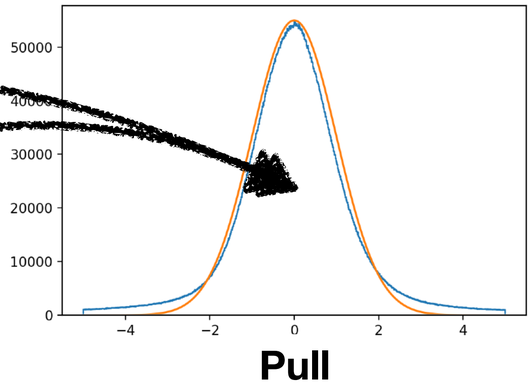


Data vs $\mathcal{N}(0,1)$



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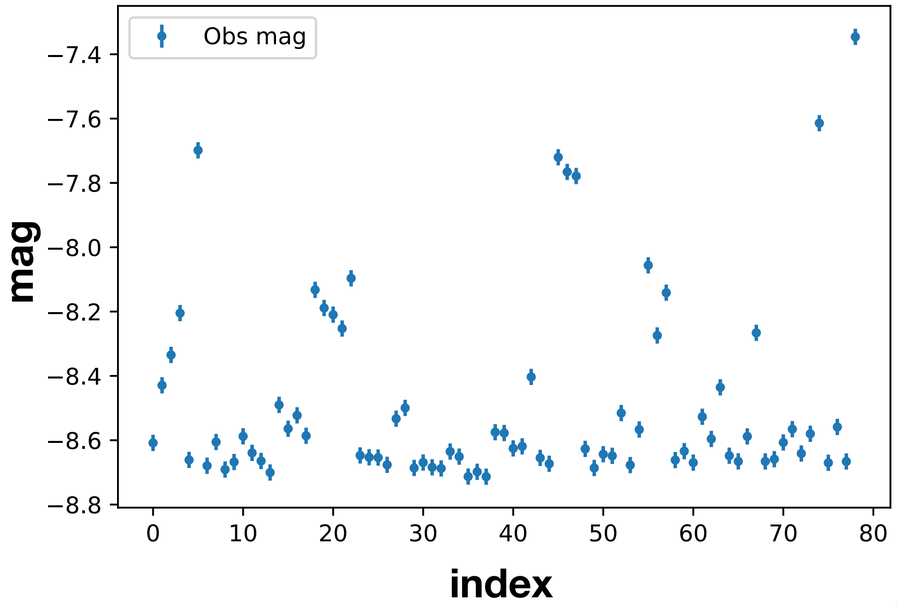

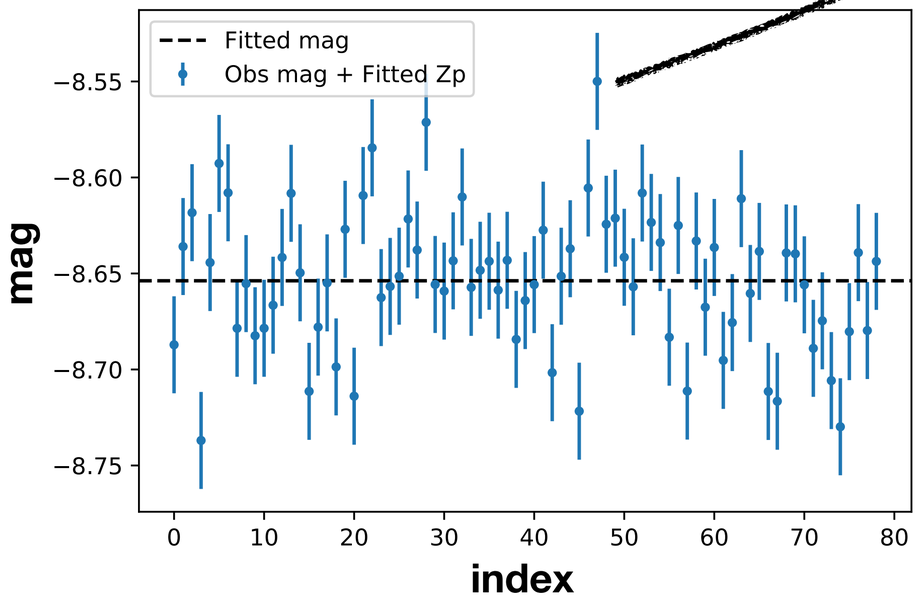

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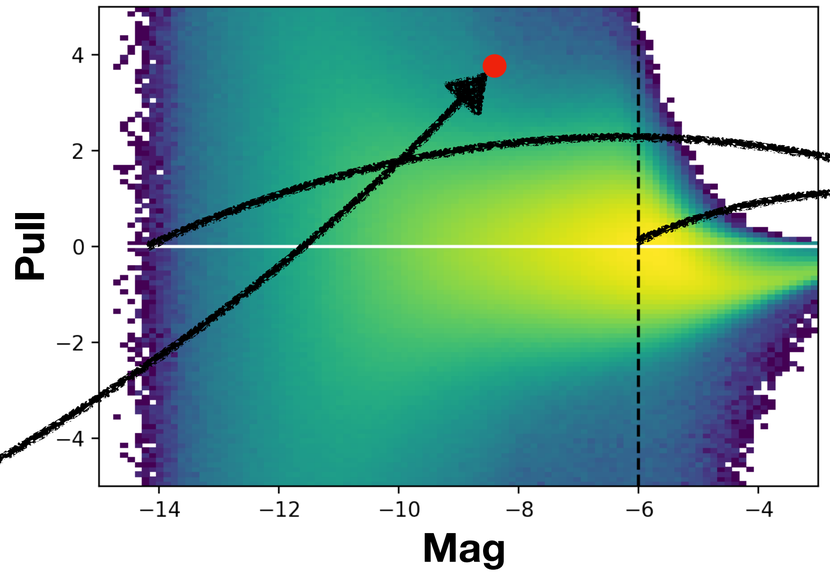
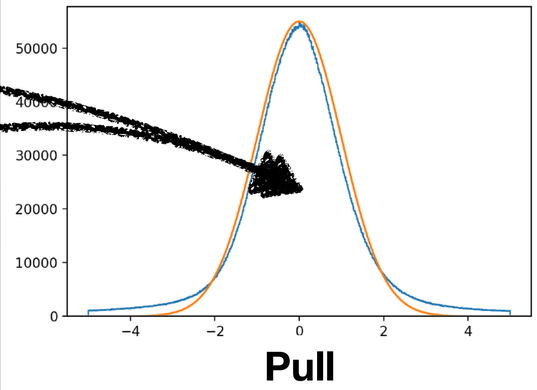
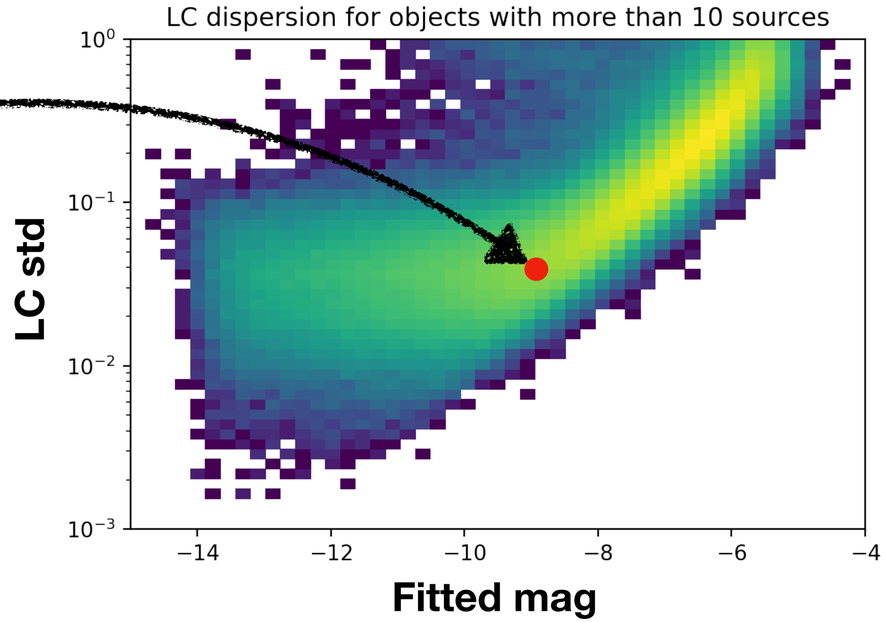
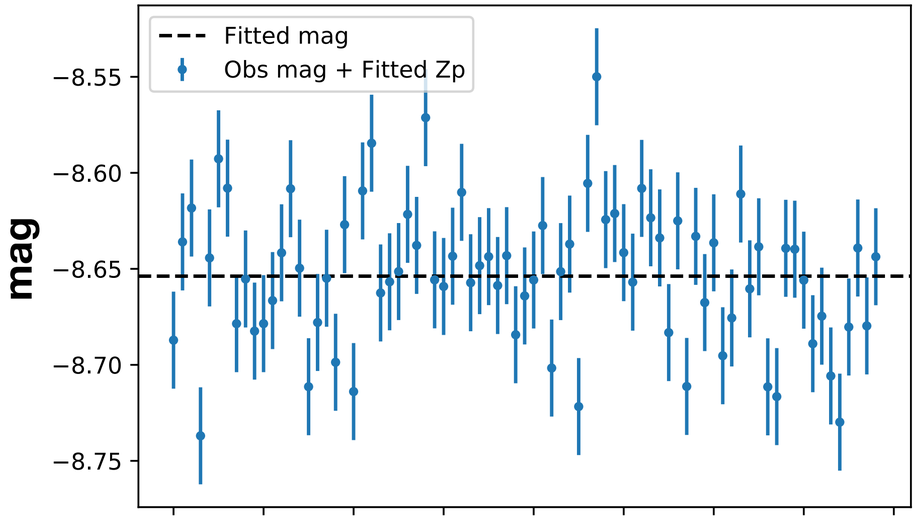


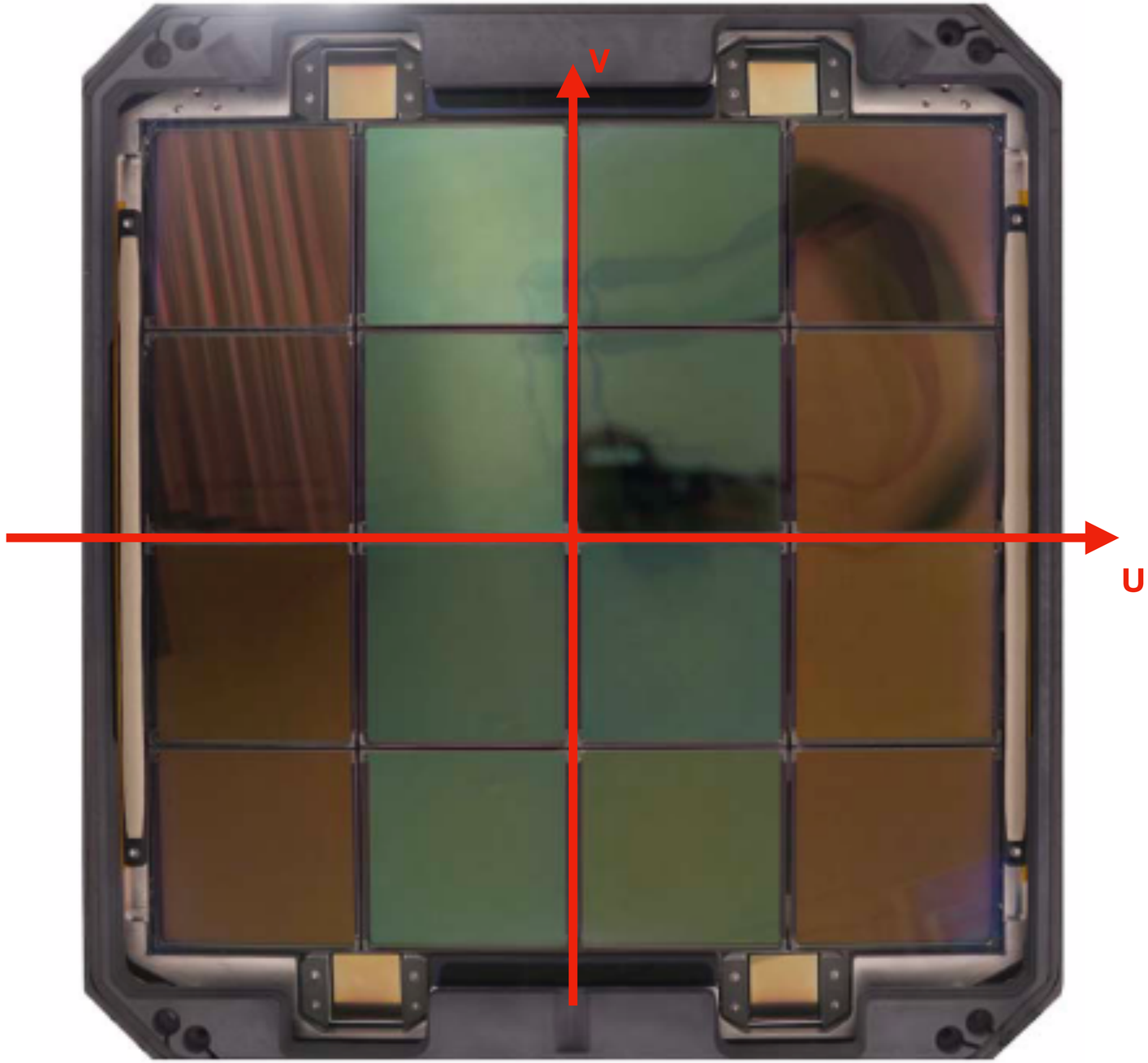




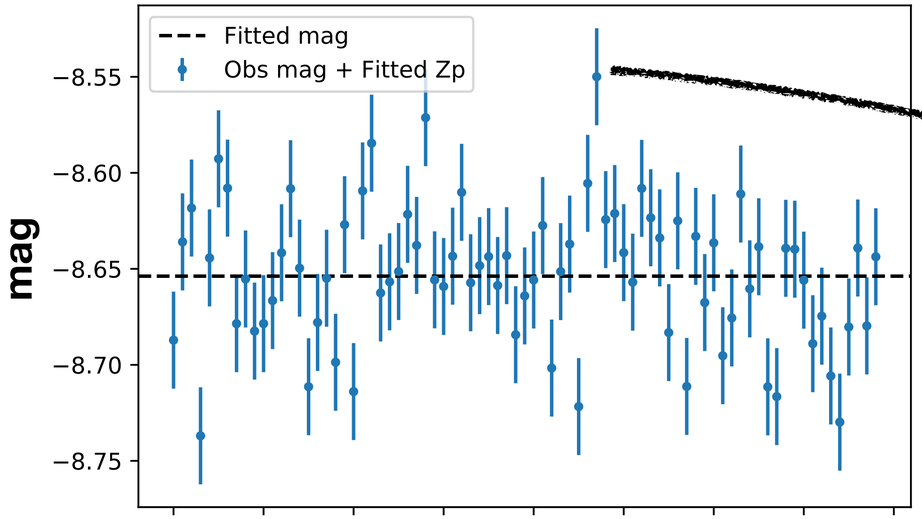
Result on one star (79 obs here)



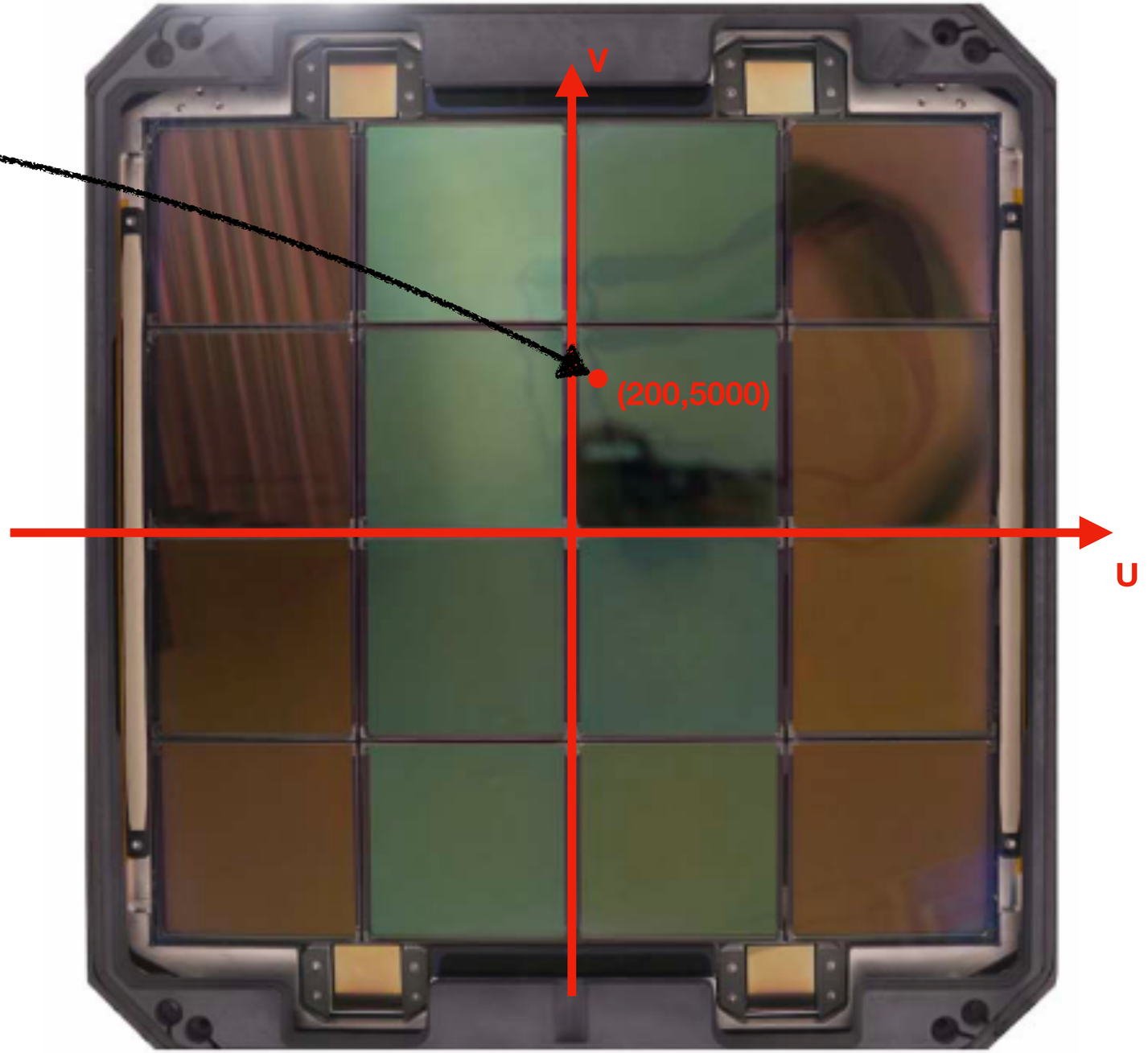
For each exposure, sources are observed at a specific position on the focal plane (uv coordinates)



Result on one star (79 obs here)

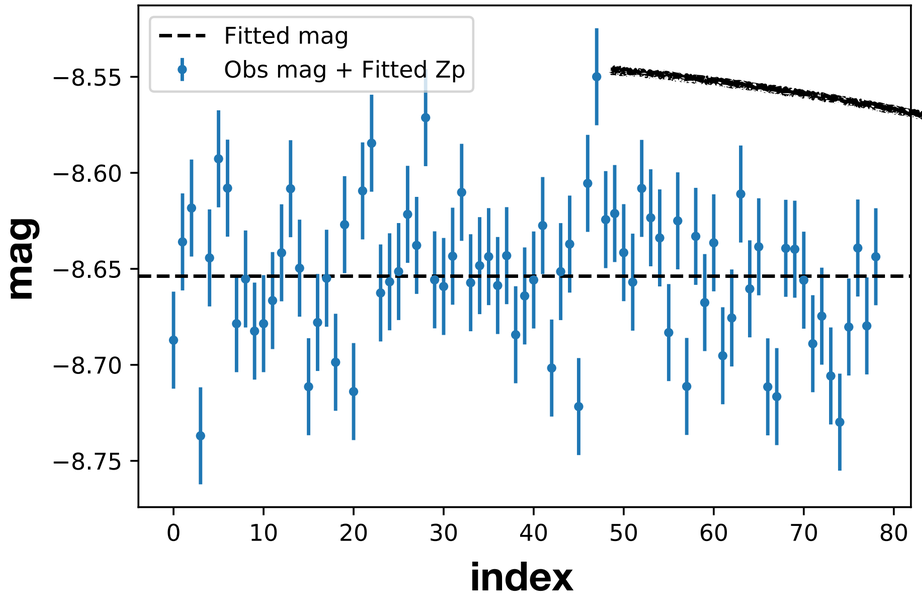


For each exposure, sources are observed at a specific position on the focal plane (uv coordinates)

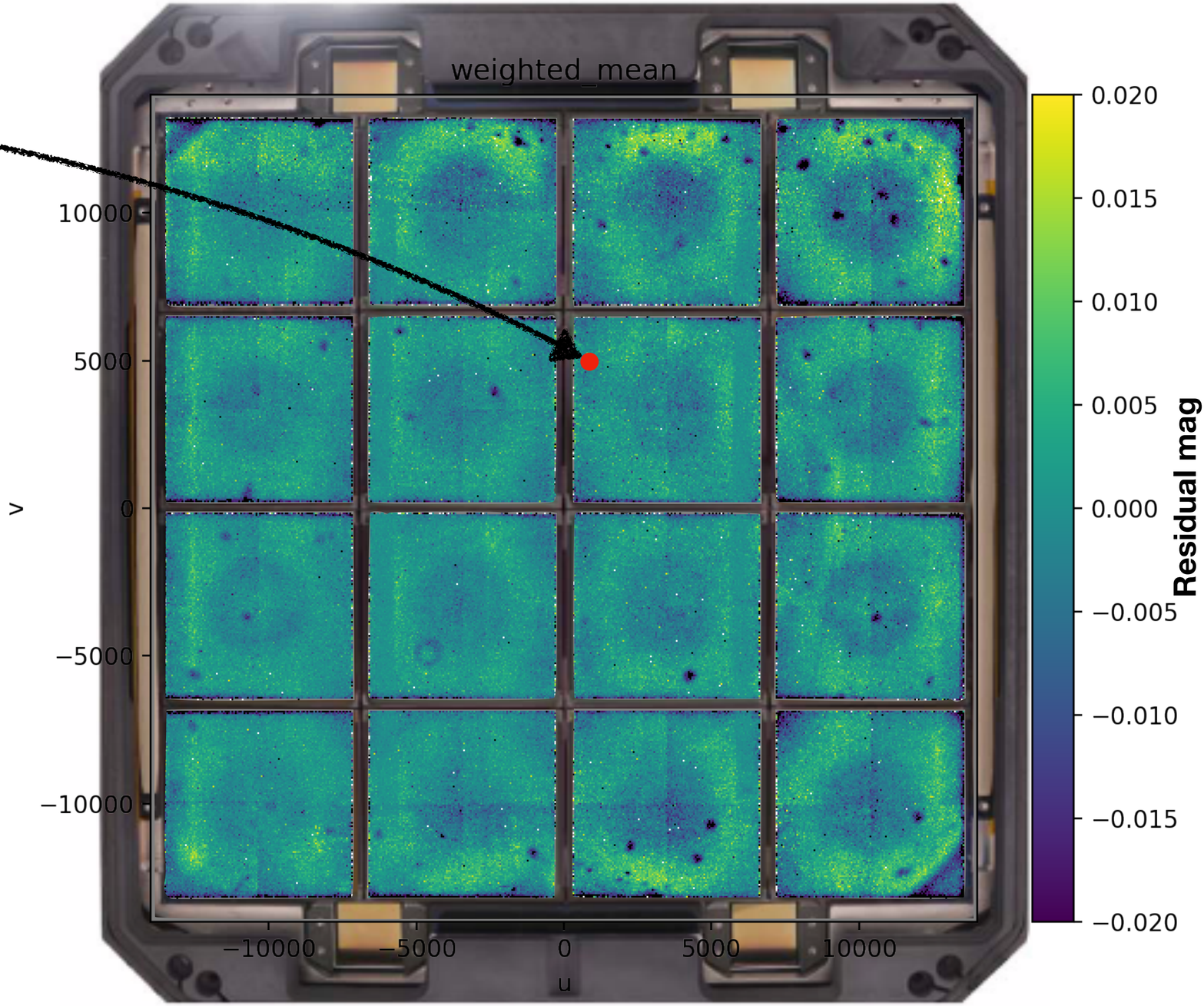


Residual mag

Result on one star (79 obs here)



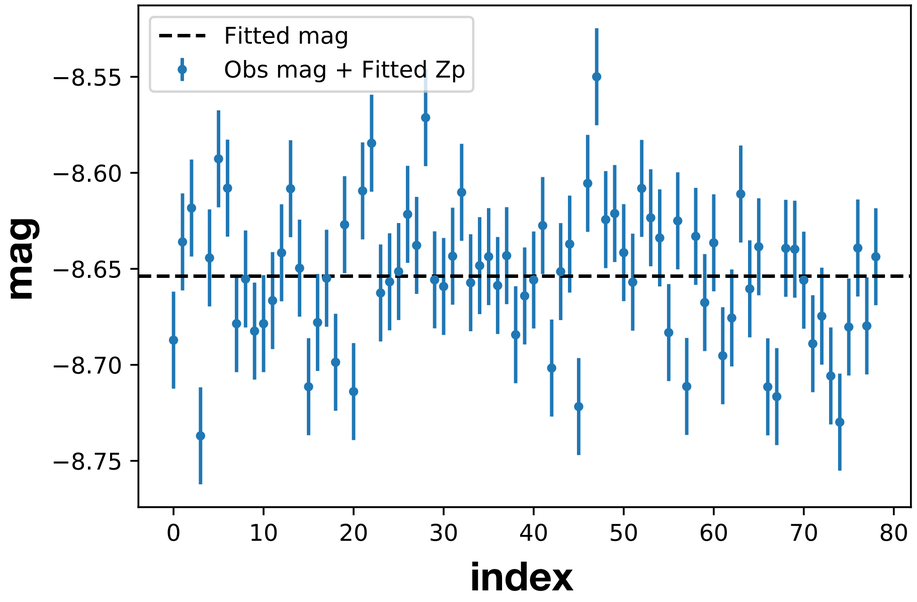
Result on all stars



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

We can then bin in uv each observation's residual and plot the weighted mean

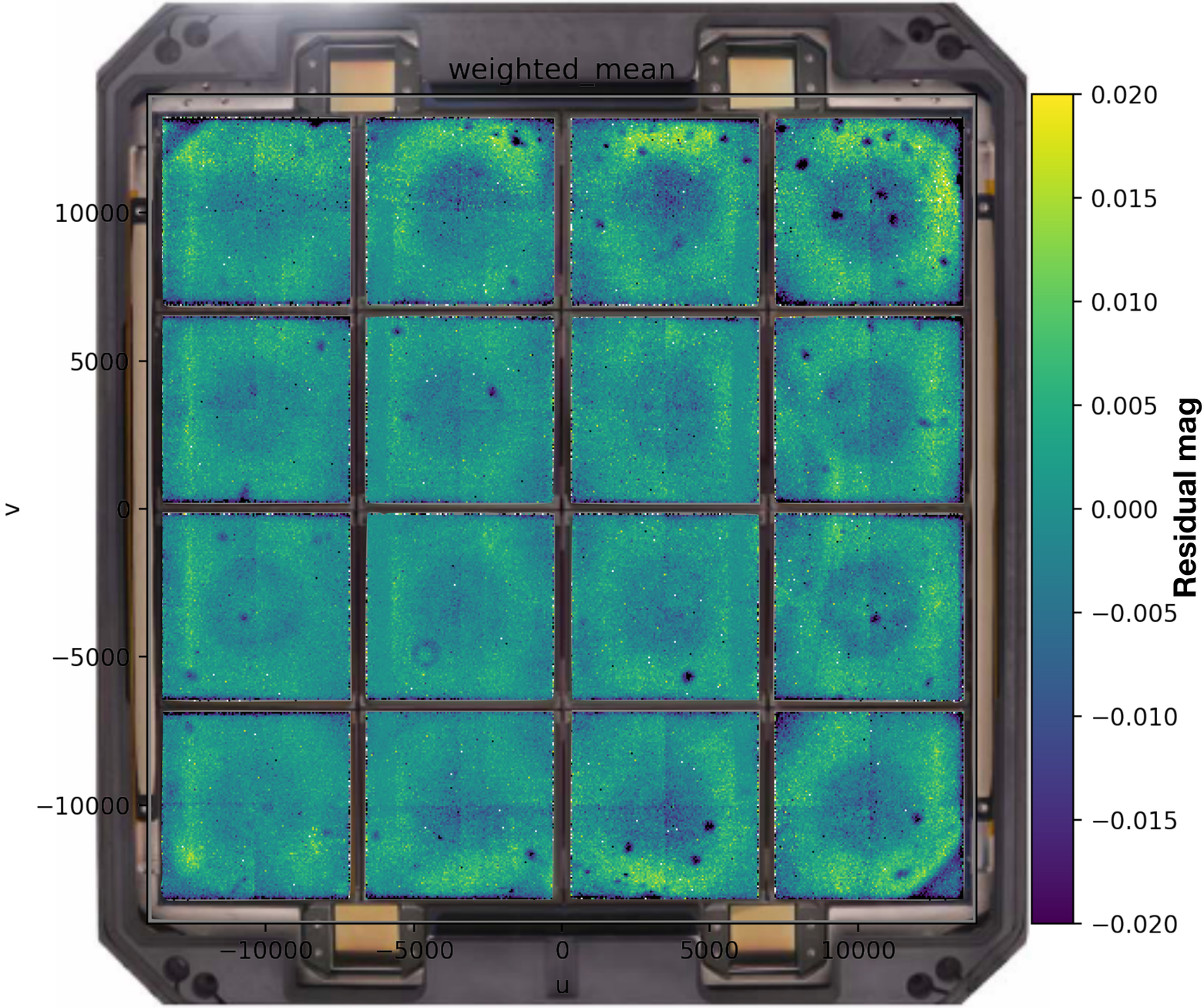
Result on one star (79 obs here)



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

We can then bin in uv each observation's residual and plot the weighted mean

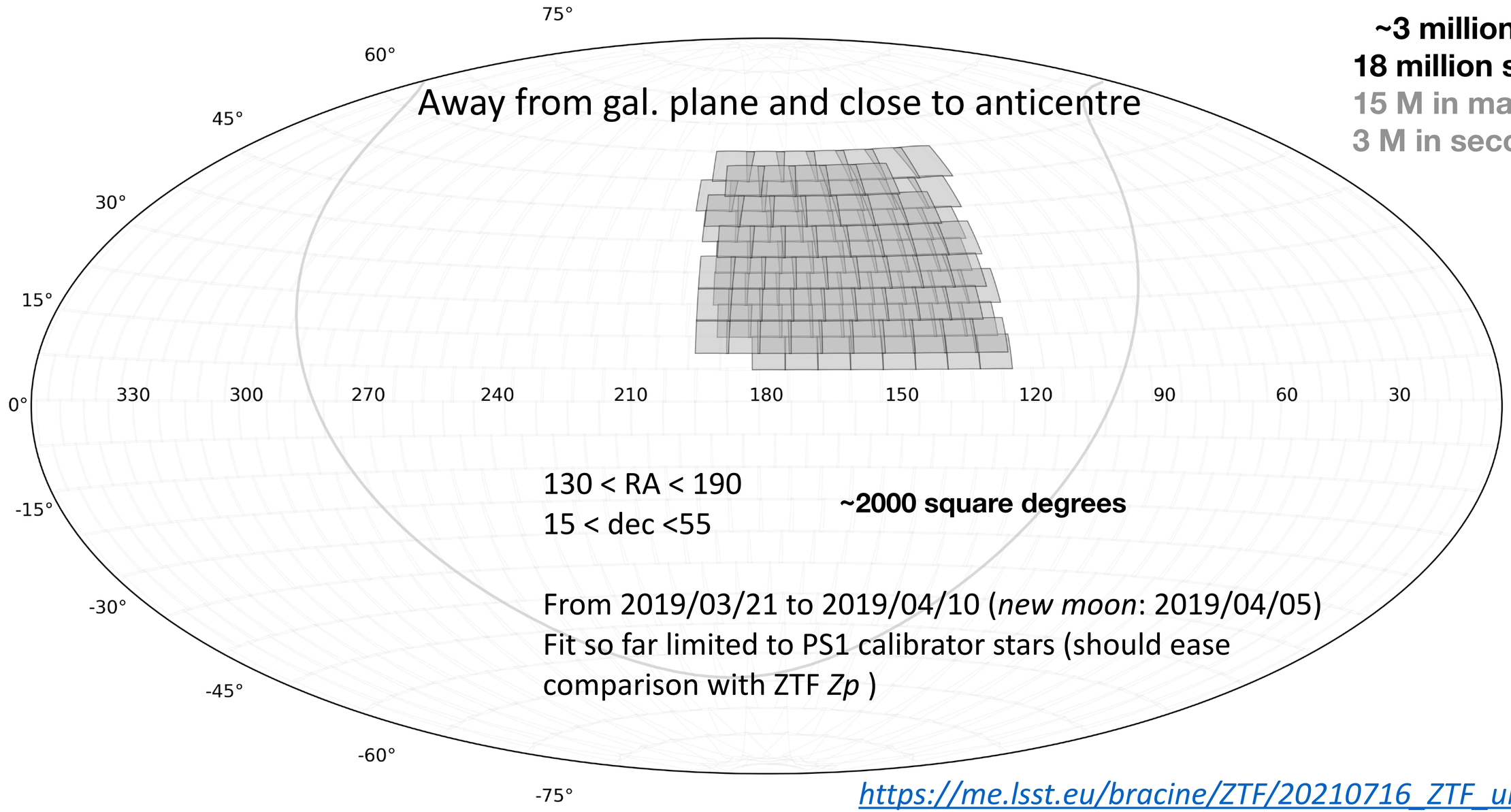
Result on all stars



Test case

Estelle provided a catalog with
PSF and aperture photometry
with starflat correction for AP

~3 million stars
18 million sources
15 M in main grid
3 M in secondary



Away from gal. plane and close to anticentre

130 < RA < 190
15 < dec <55

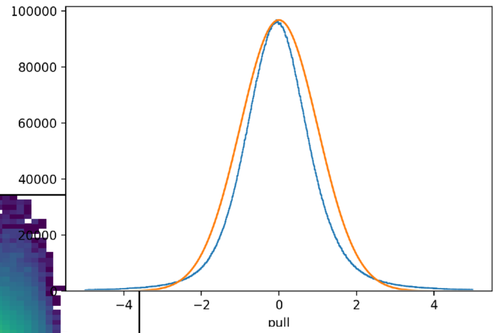
~2000 square degrees

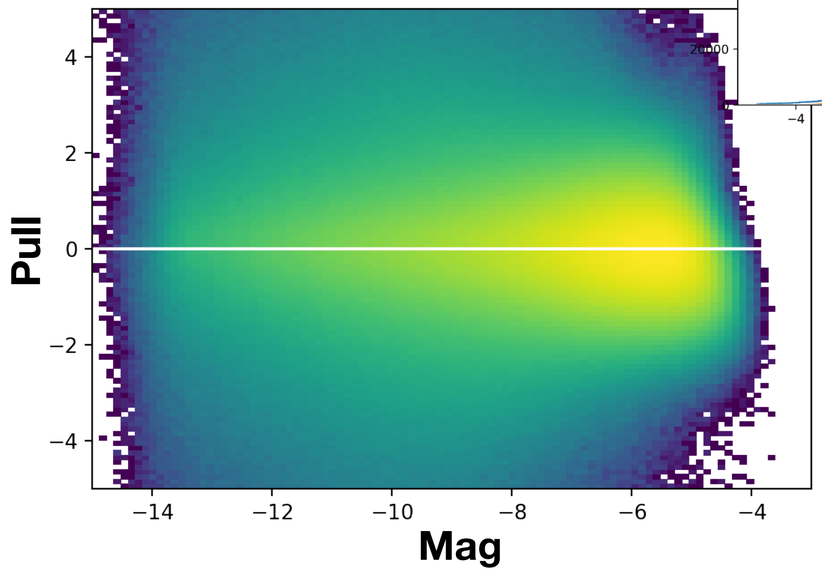
From 2019/03/21 to 2019/04/10 (*new moon*: 2019/04/05)
Fit so far limited to PS1 calibrator stars (should ease comparison with ZTF *Zp*)

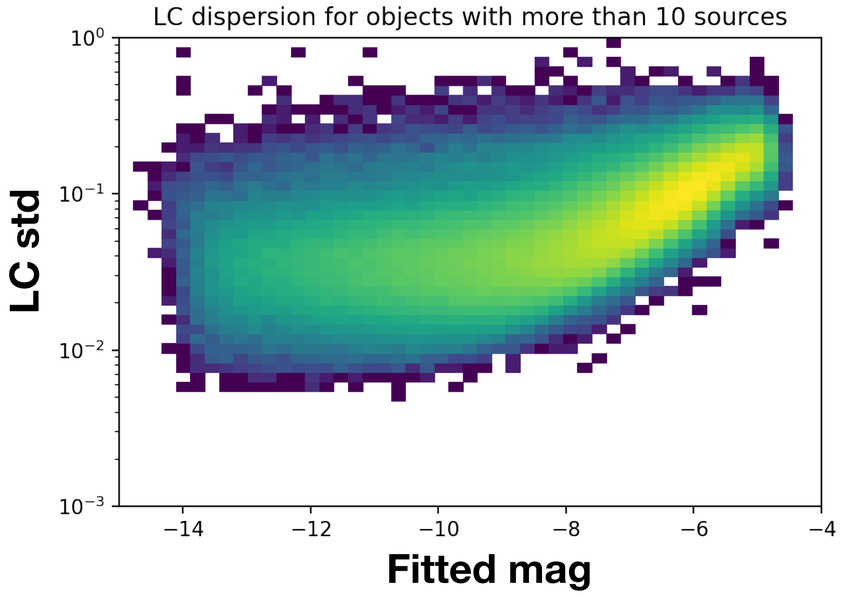
https://me.lsst.eu/bracine/ZTF/20210716_ZTF_ubercal_first_try/

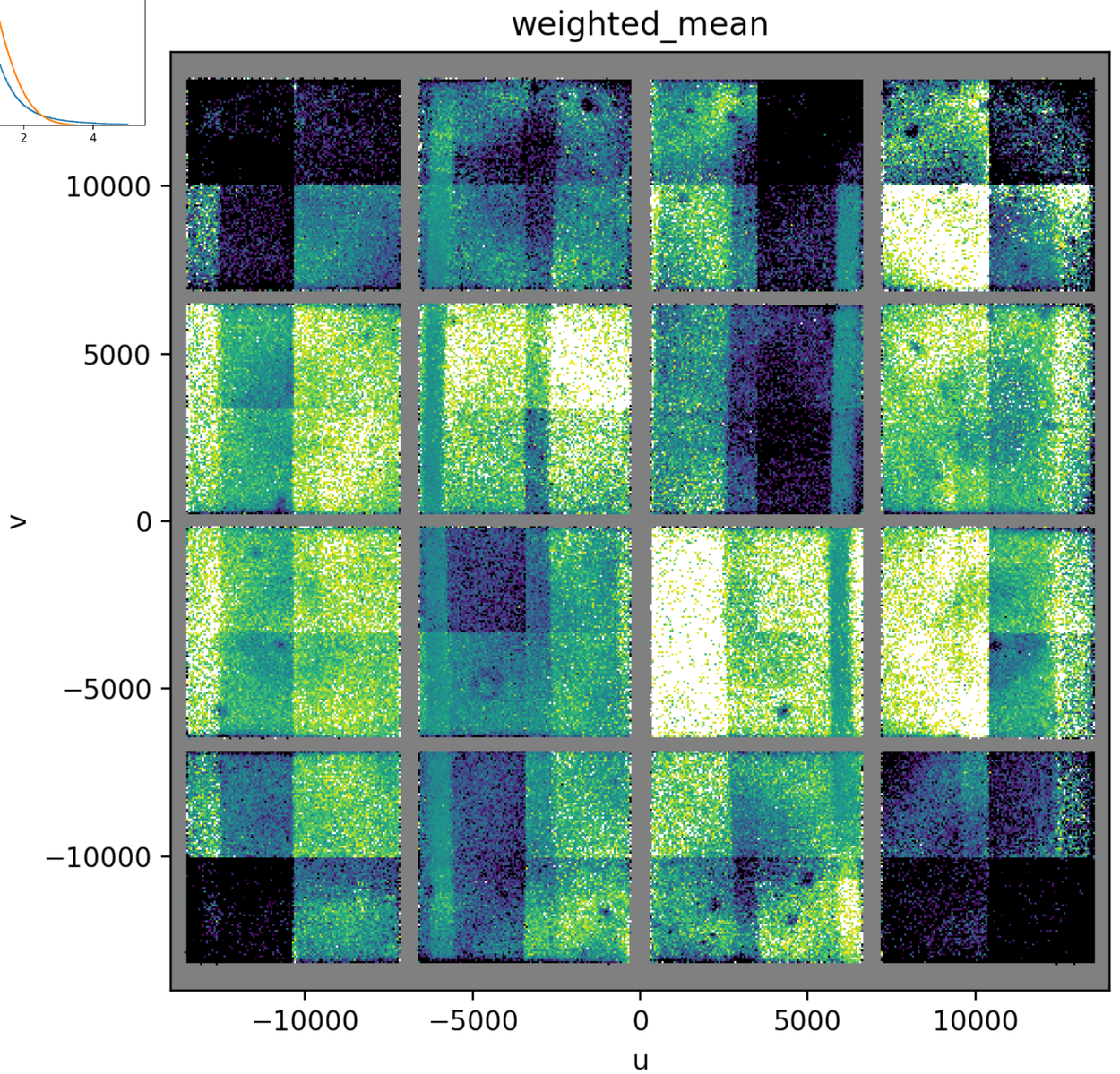
⚠️ **ubercal mags are relative**

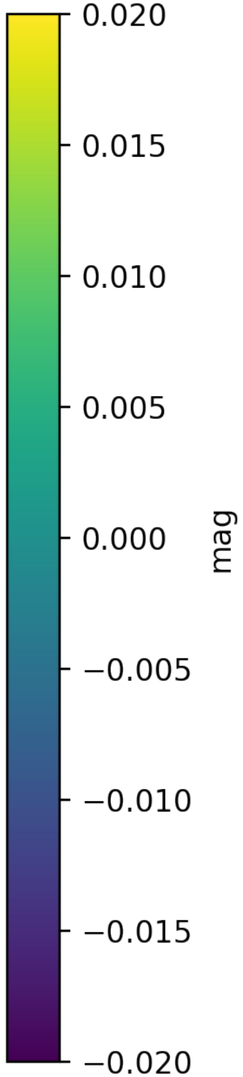
1 zero point per exposure
PSF photometry





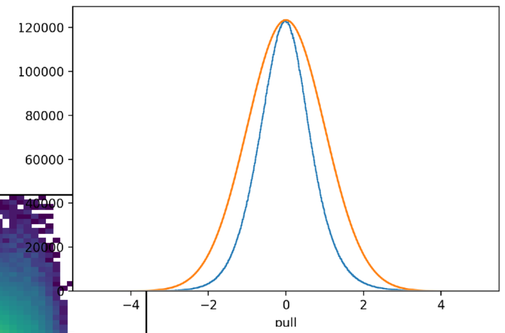


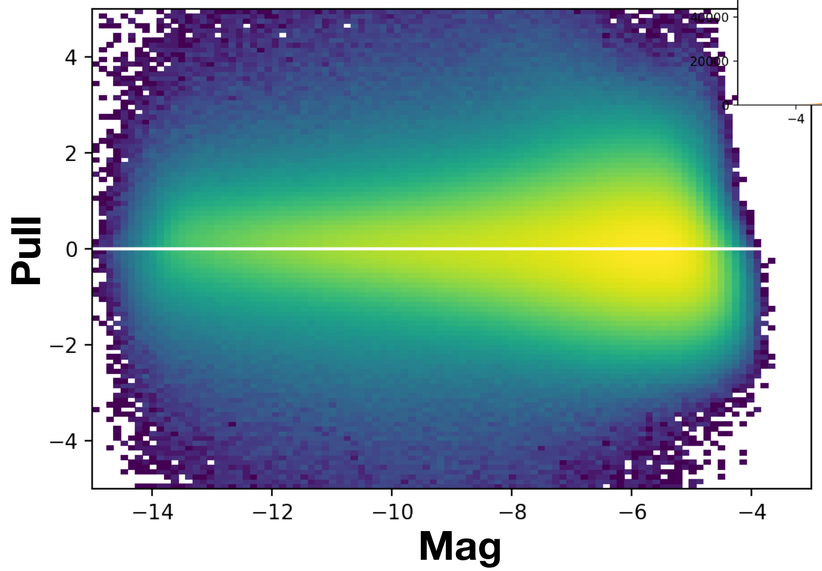


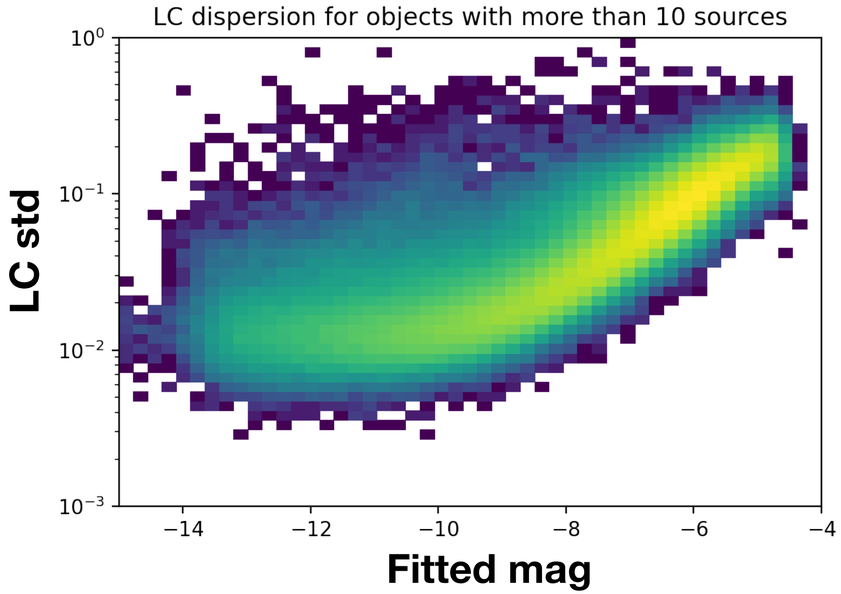


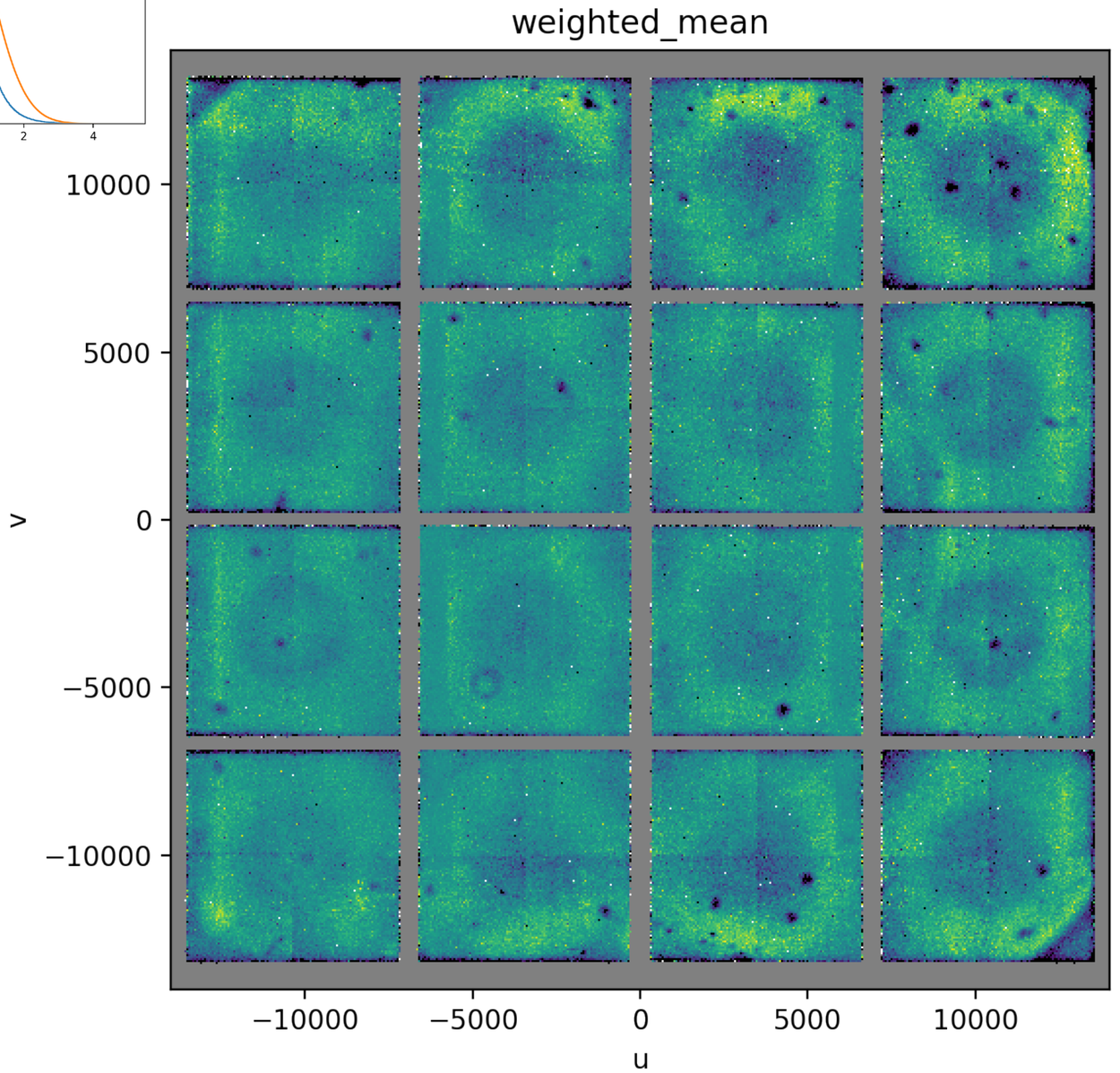
⚠️ **ubercal mags are relative**

1 zero point per quadrant
PSF photometry



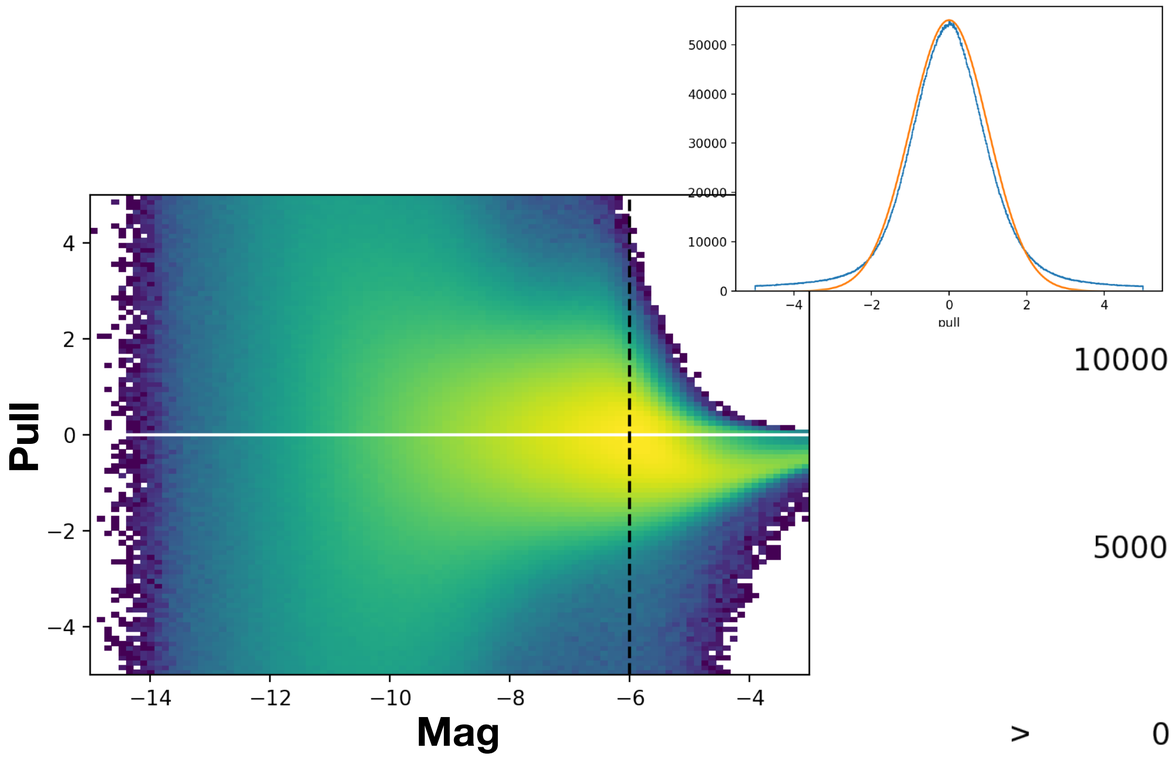


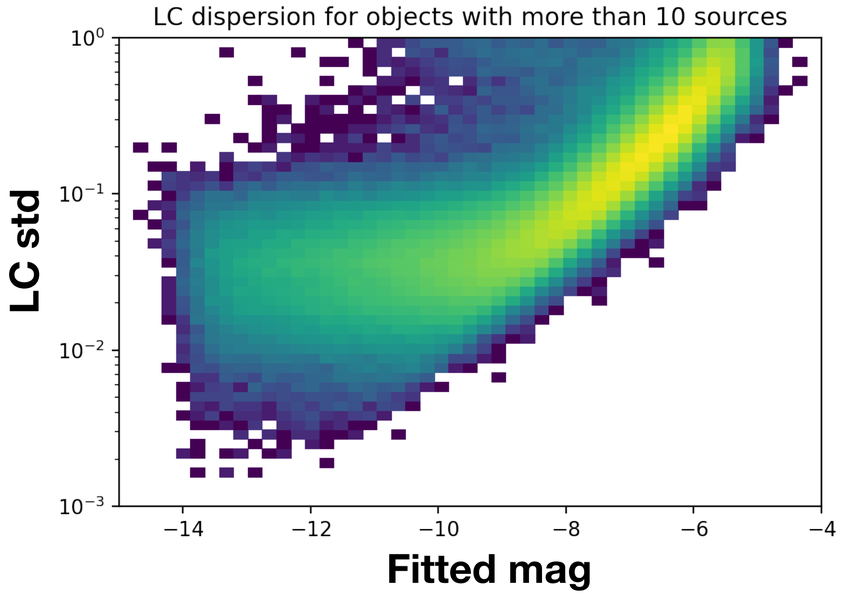


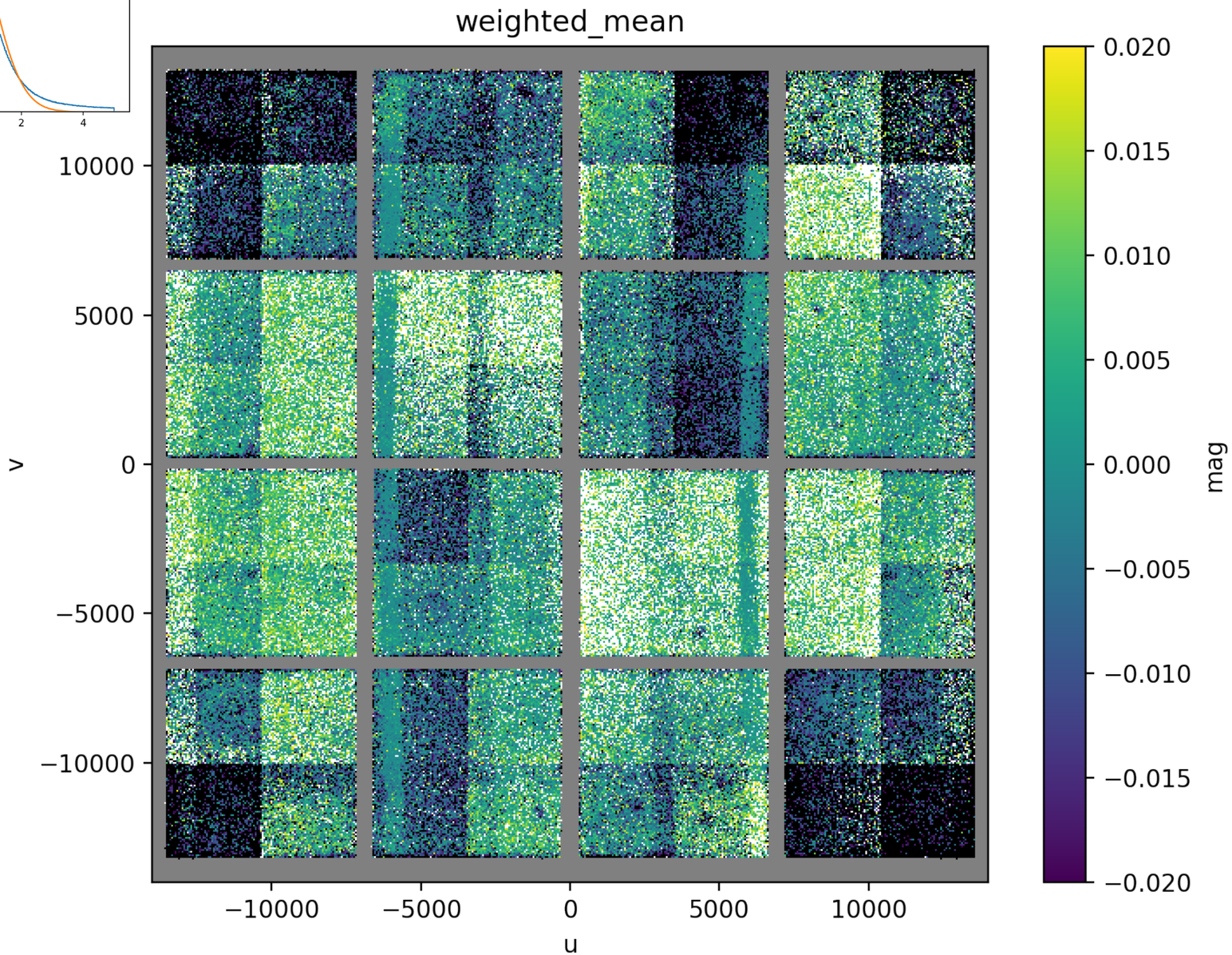


⚠️ **ubercal mags are relative**

1 zero point per exposure
Aperture photometry

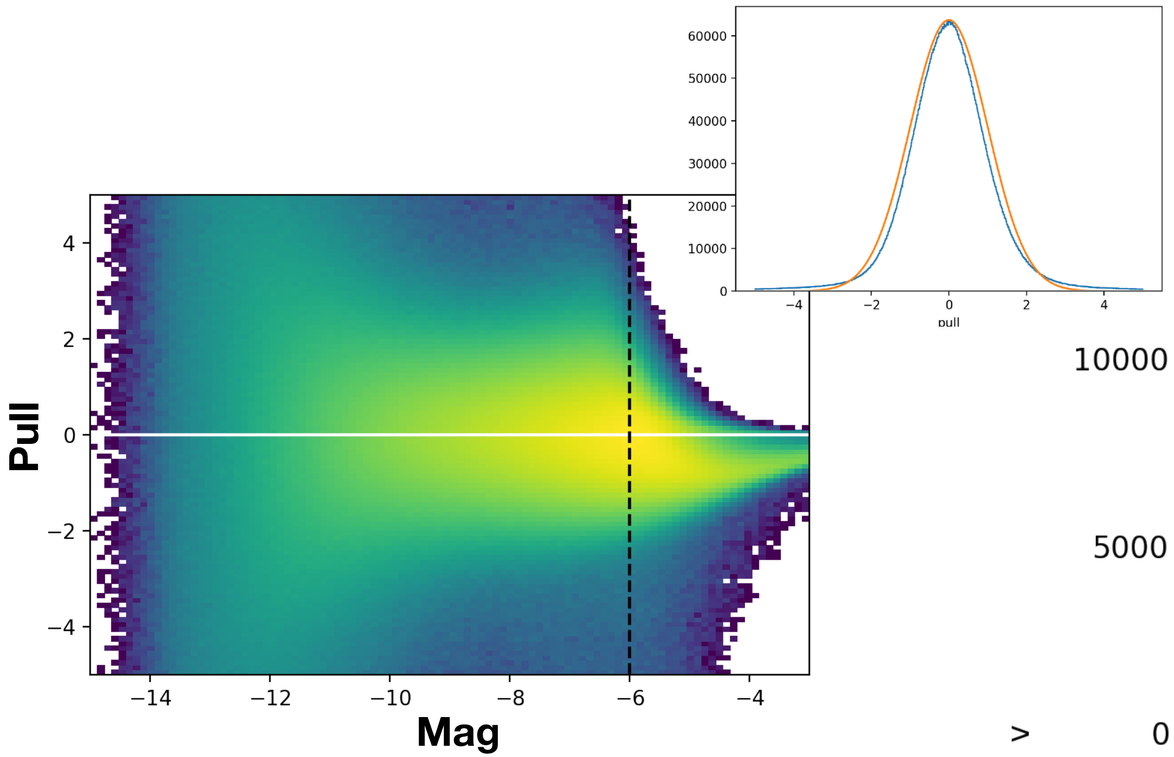


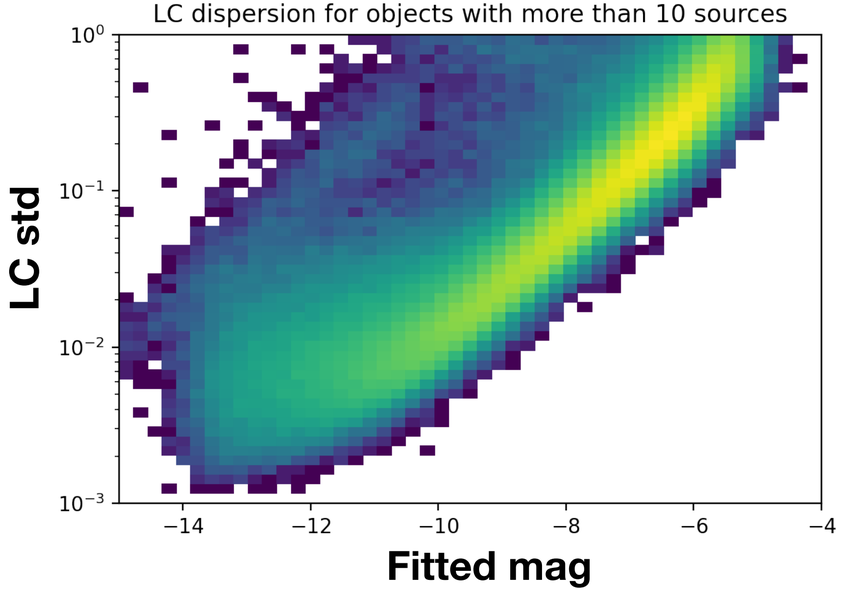


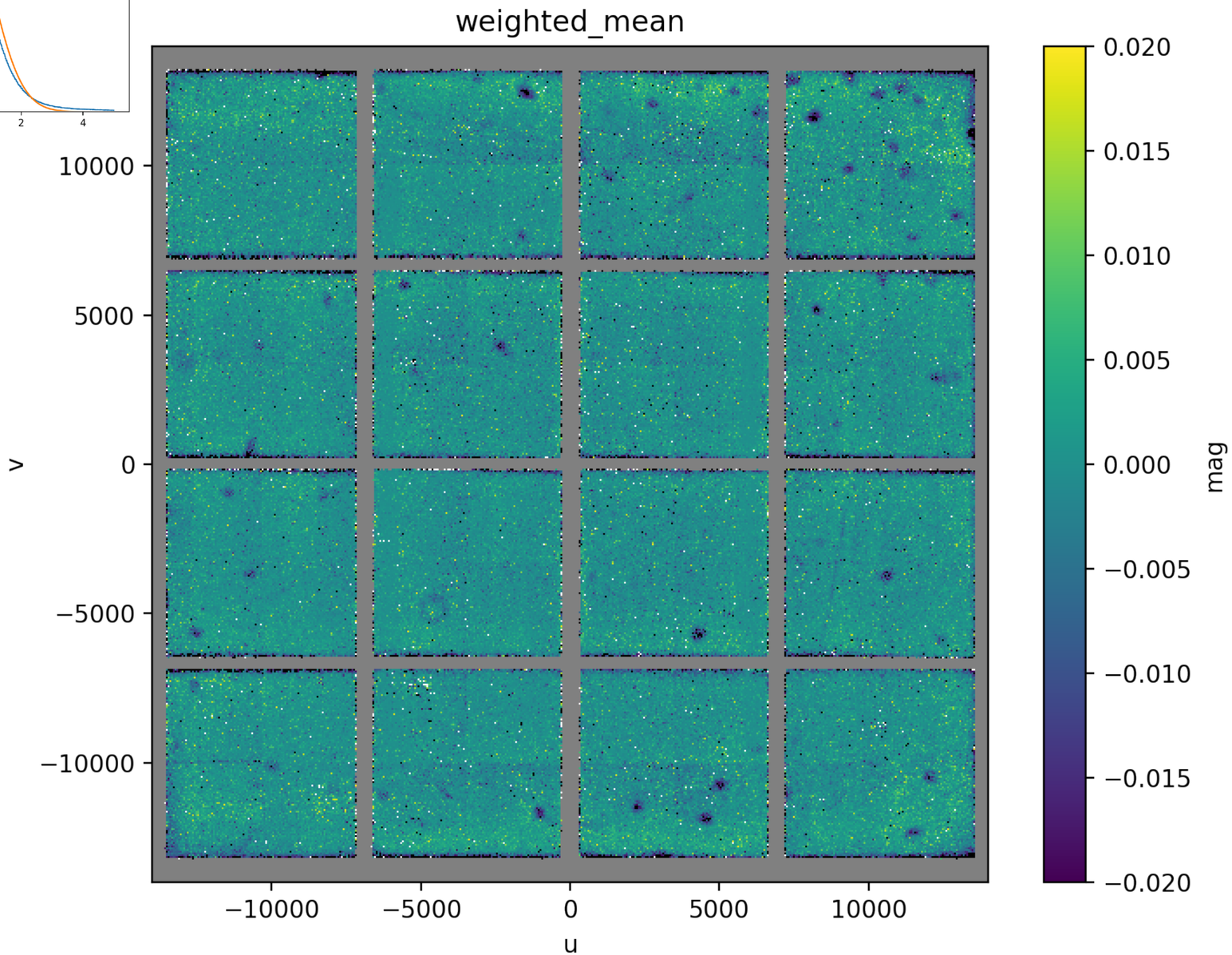


⚠️ **ubercal mags are relative**

1 zero point per quadrant
Aperture photometry







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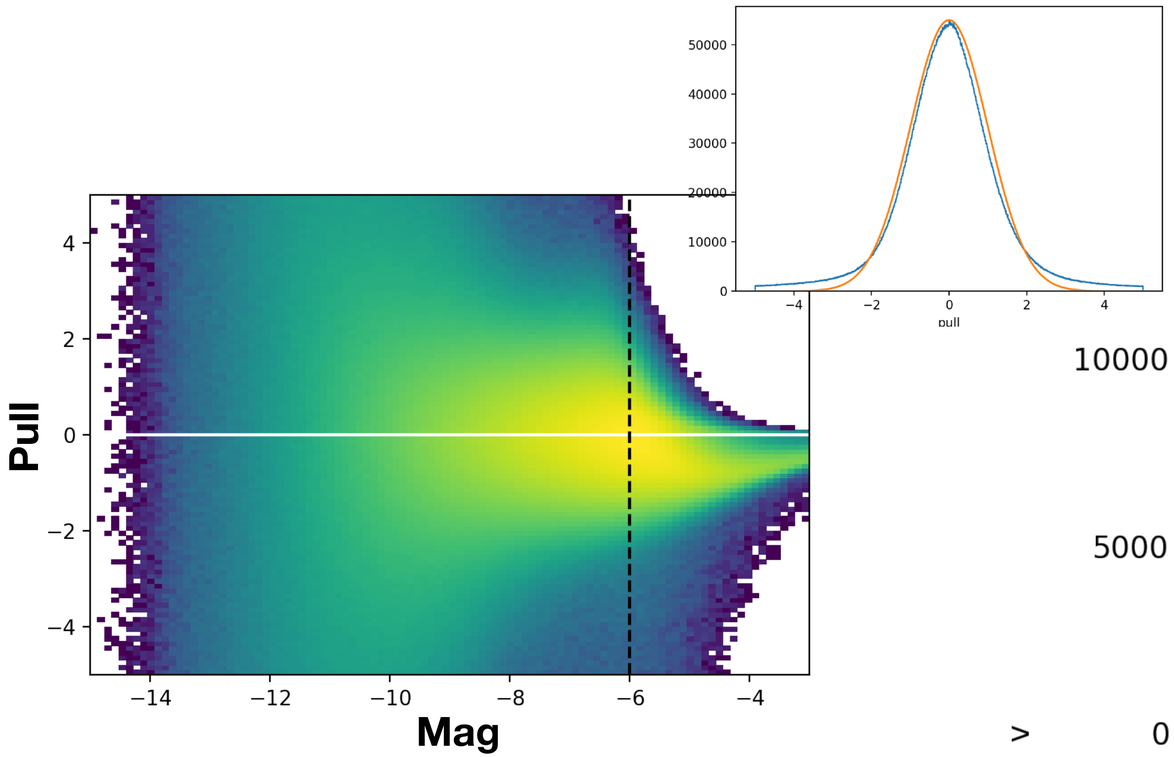
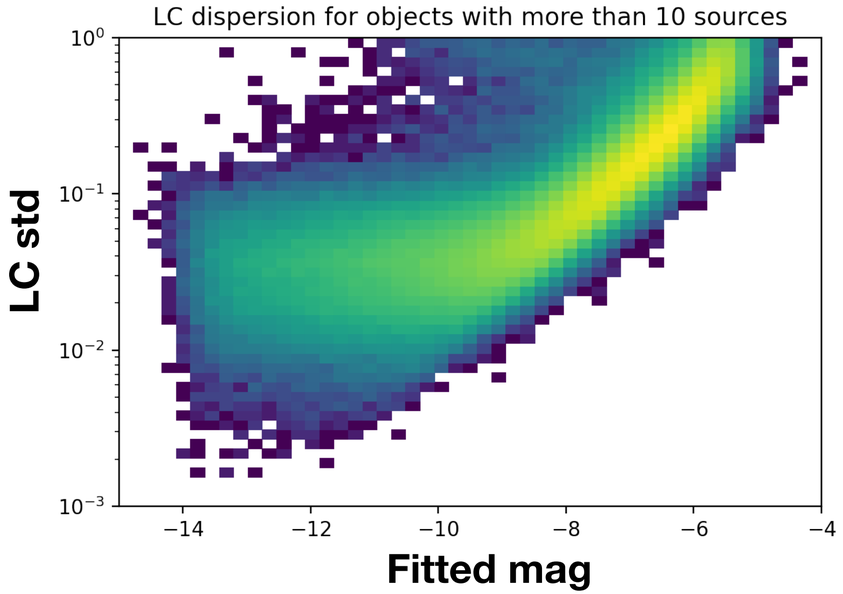
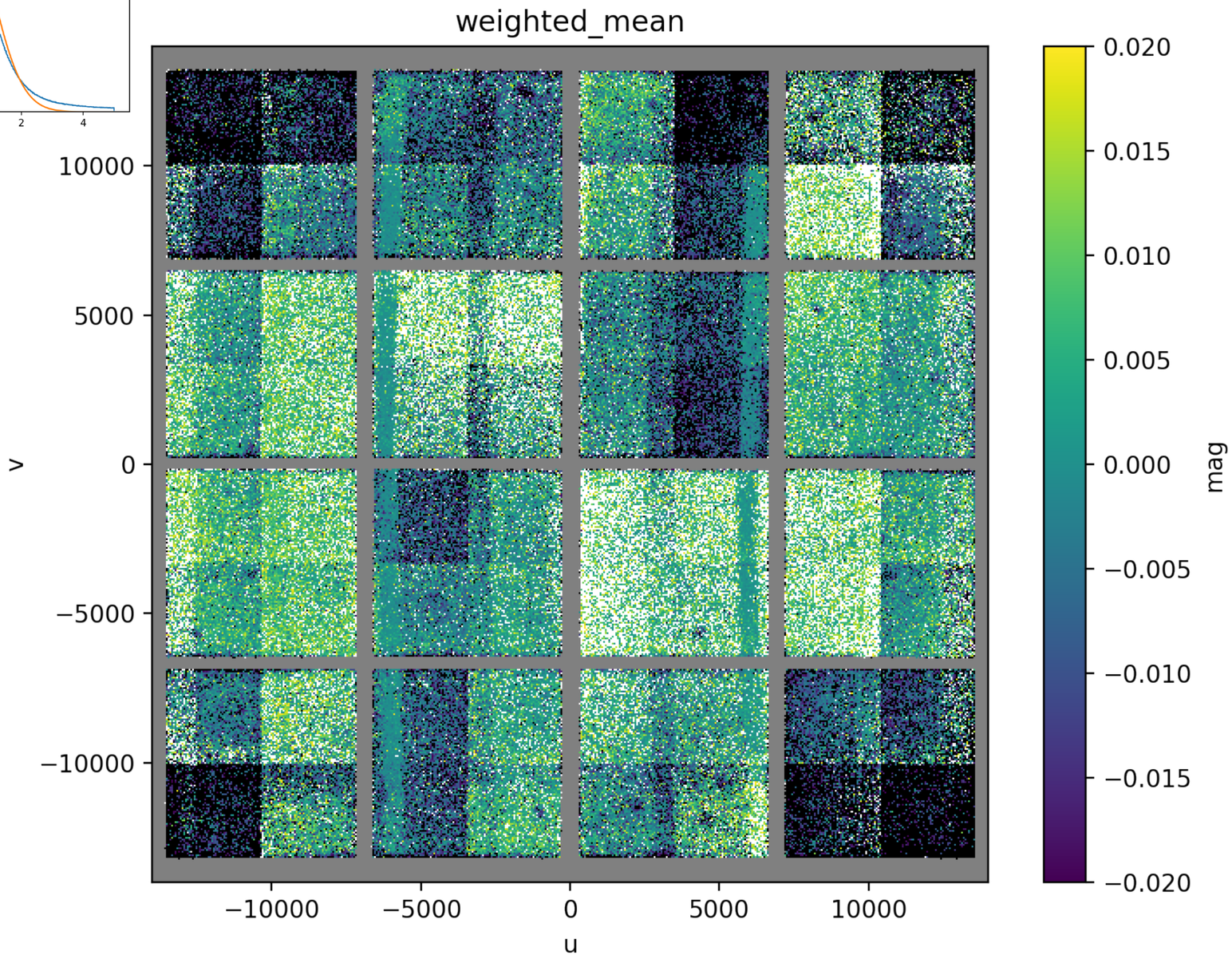
1 zero point per exposure
Aperture photometry

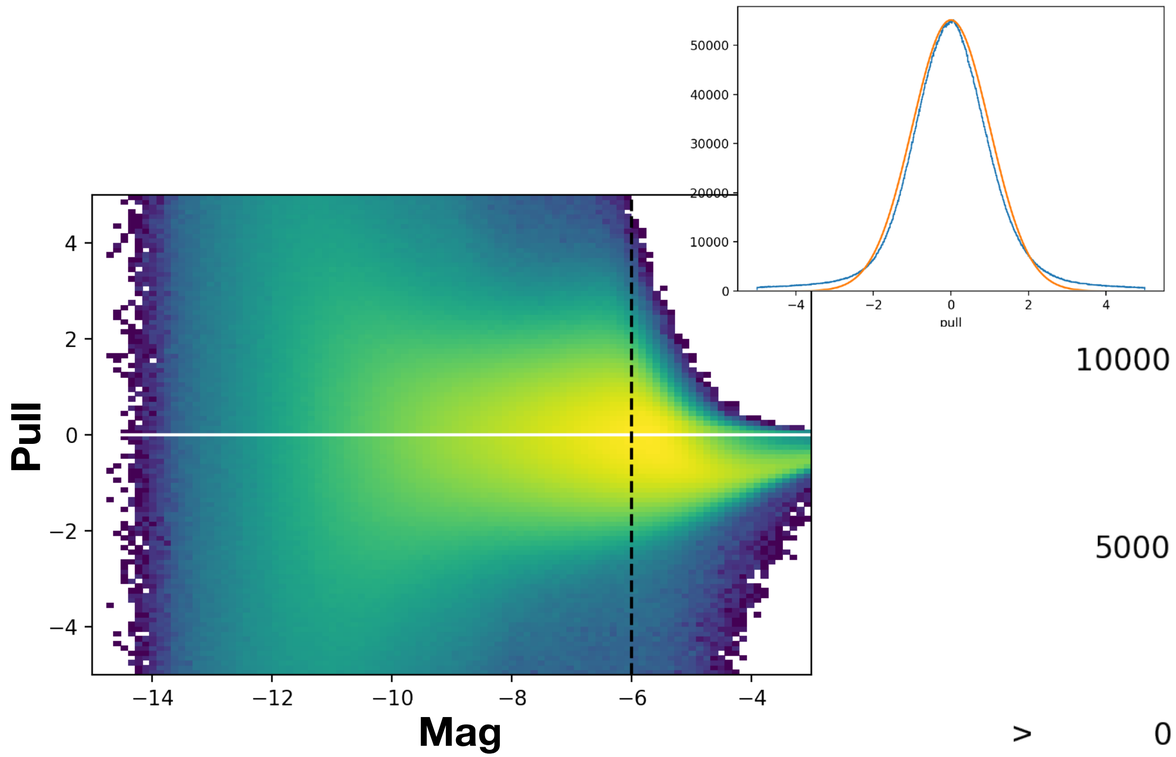


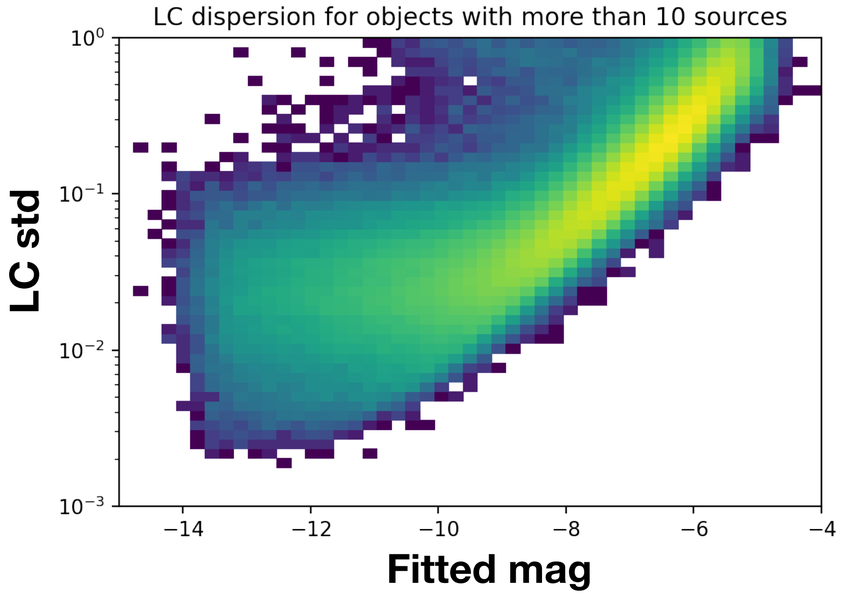


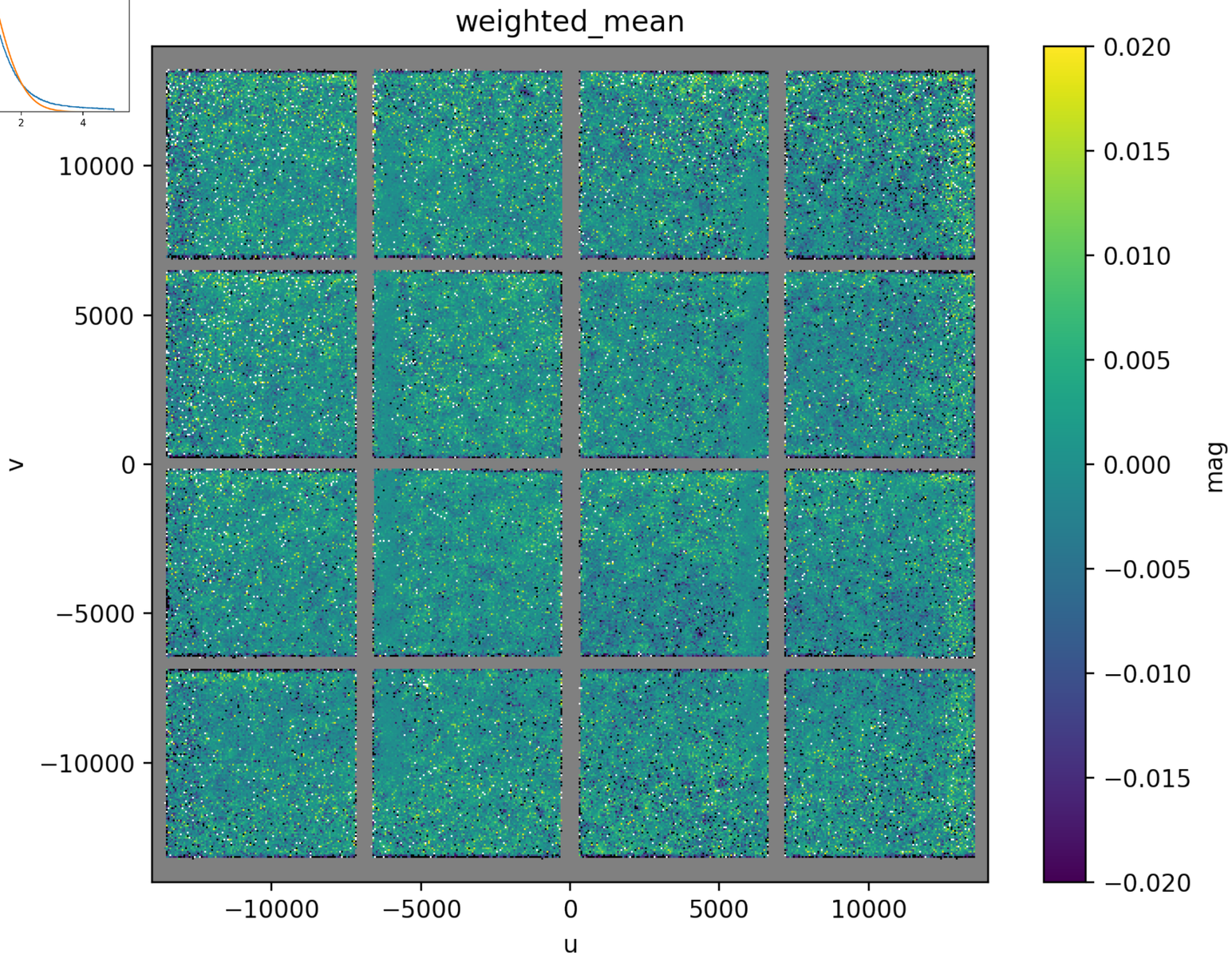


⚠️ **ubercal mags are relative**

1 zero point per exposure
Aperture photometry
with starflat correction







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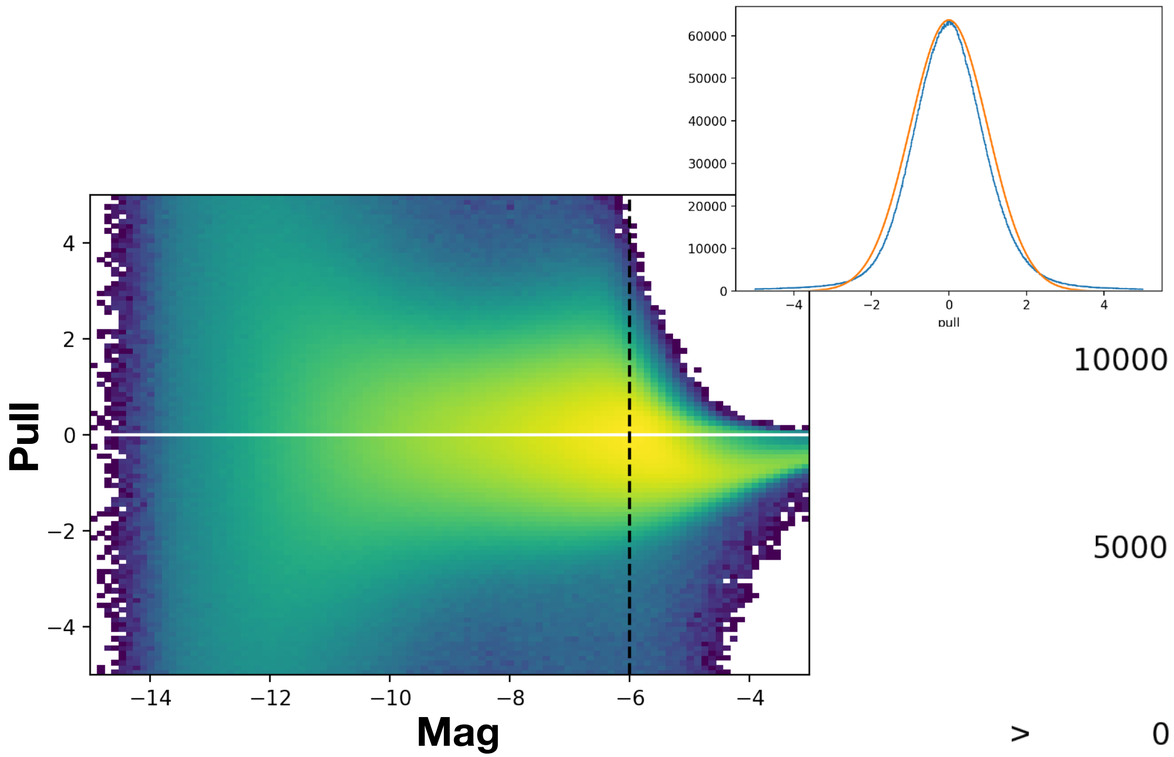
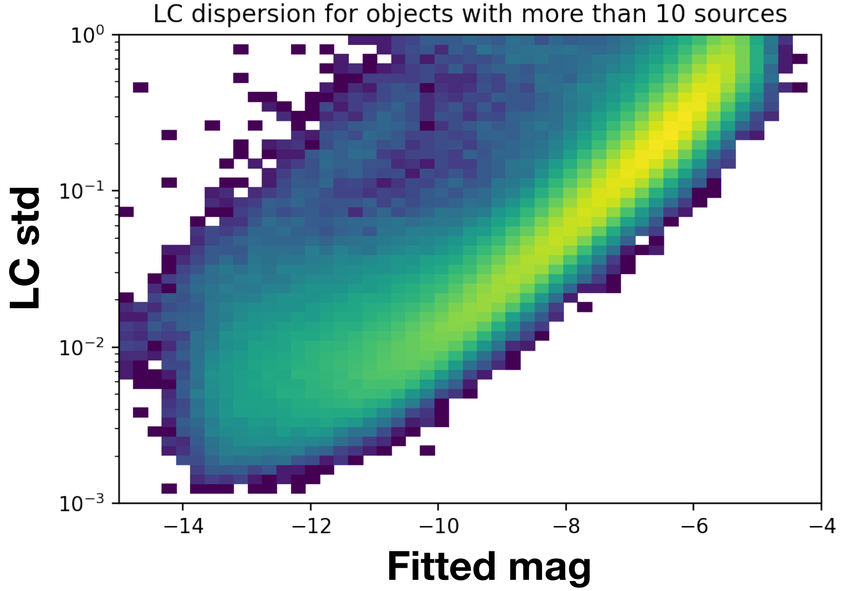
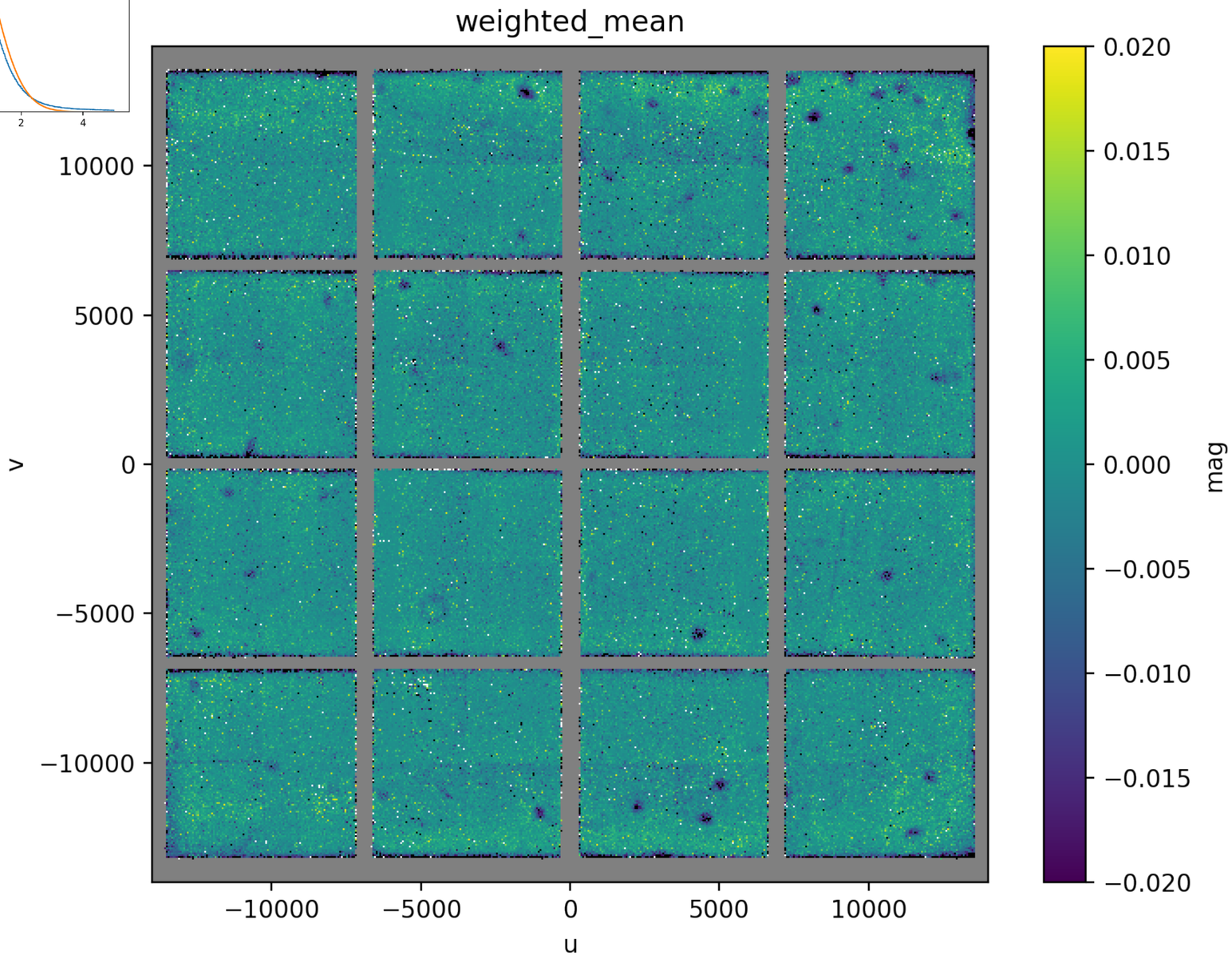
Aperture photometry







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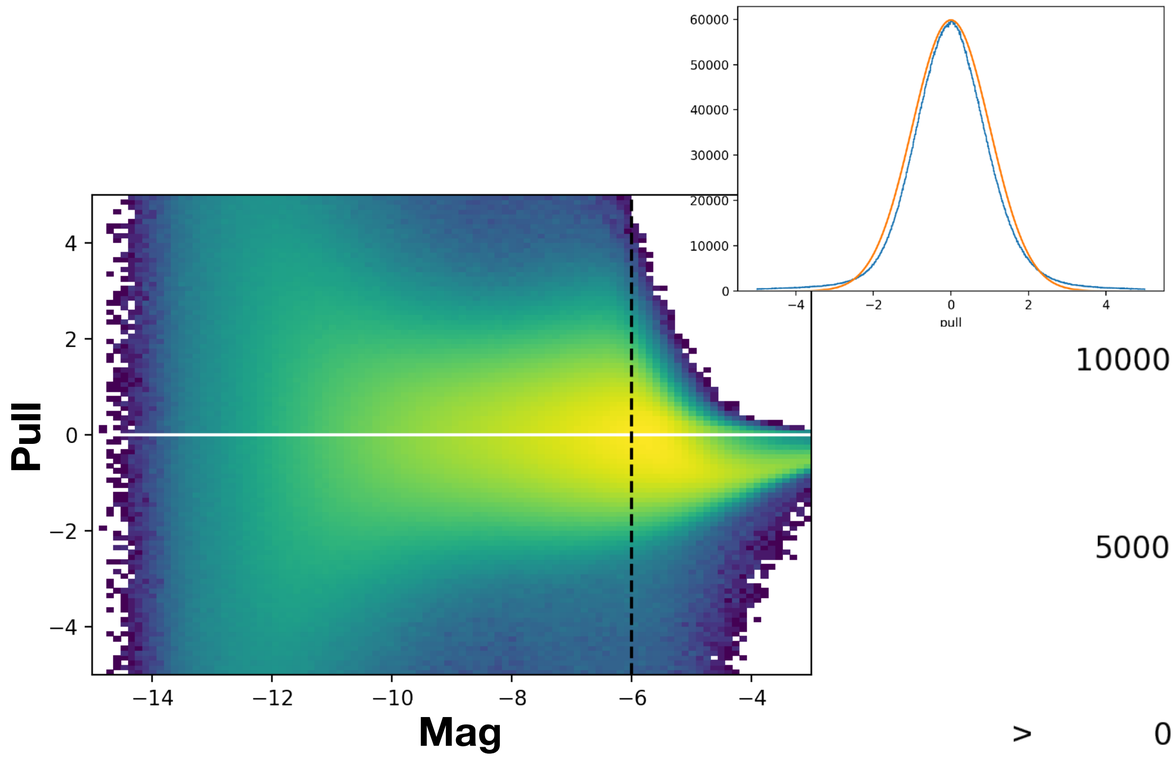
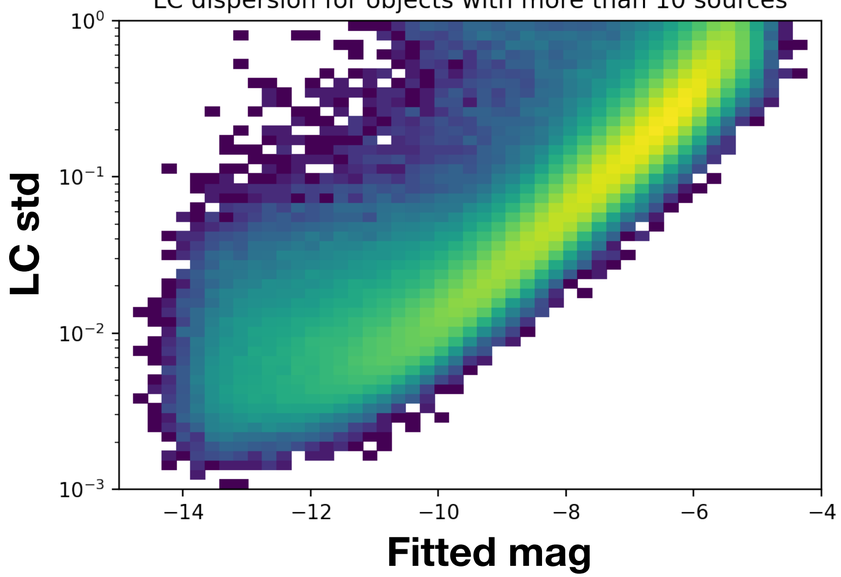
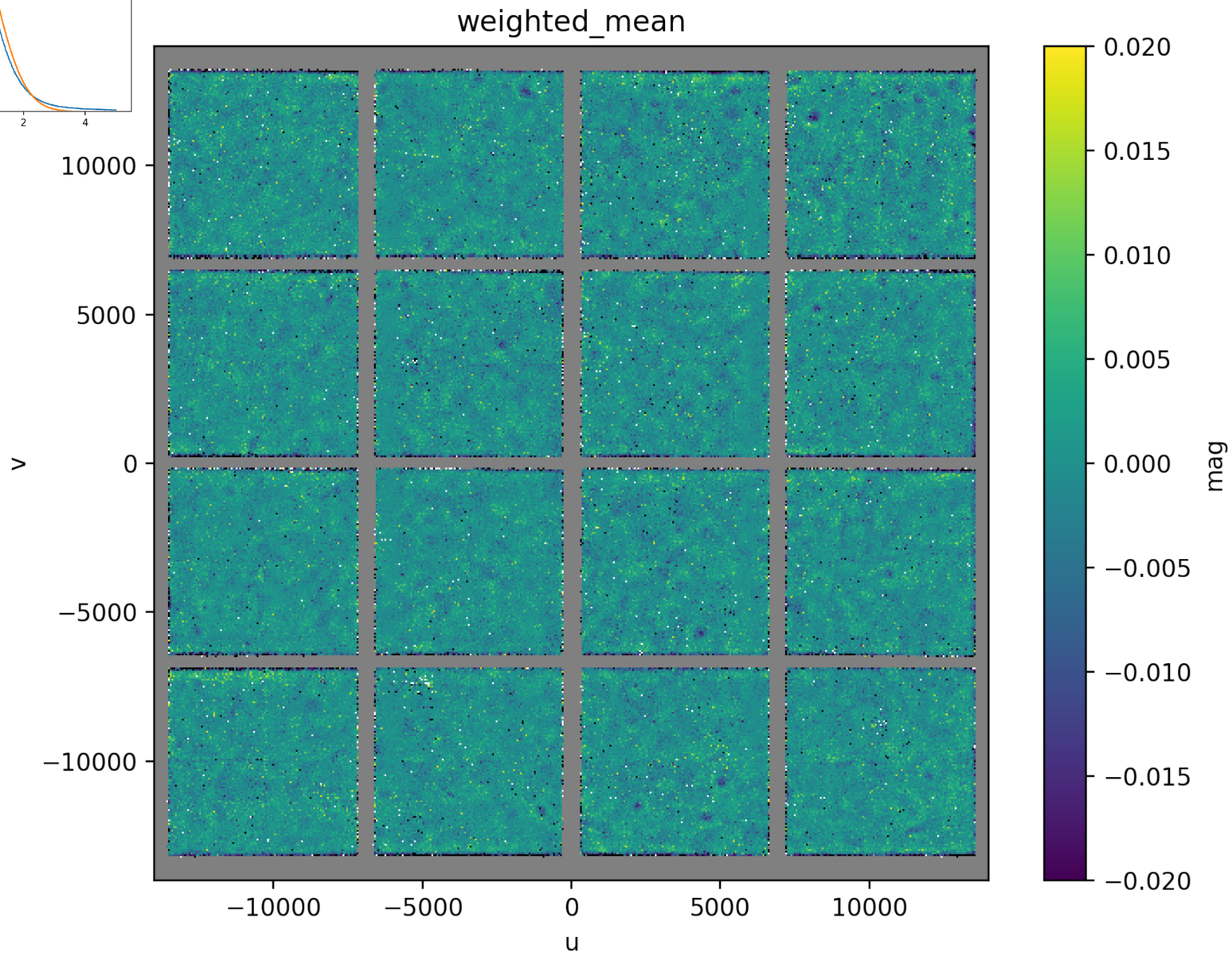
1 zero point per quadrant
Aperture photometry
with starflat correction

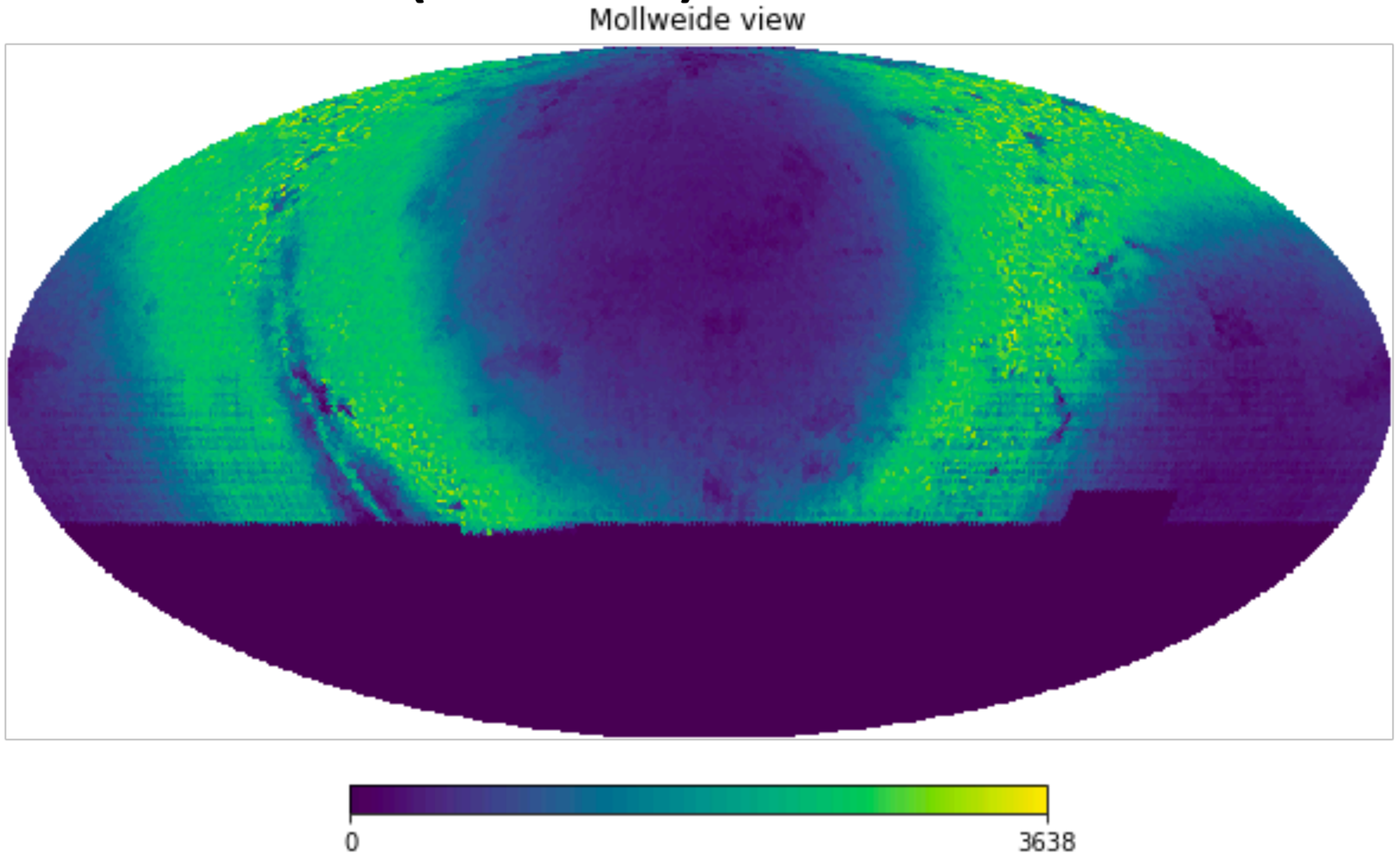






Next: data from March to August 2019 all bands (here r)

~30000 square degrees
After some filtering:
50 million stars
4 billion « sources »



Next: data from March to August 2019 all bands (here r)

~30000 square degrees
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50 million stars
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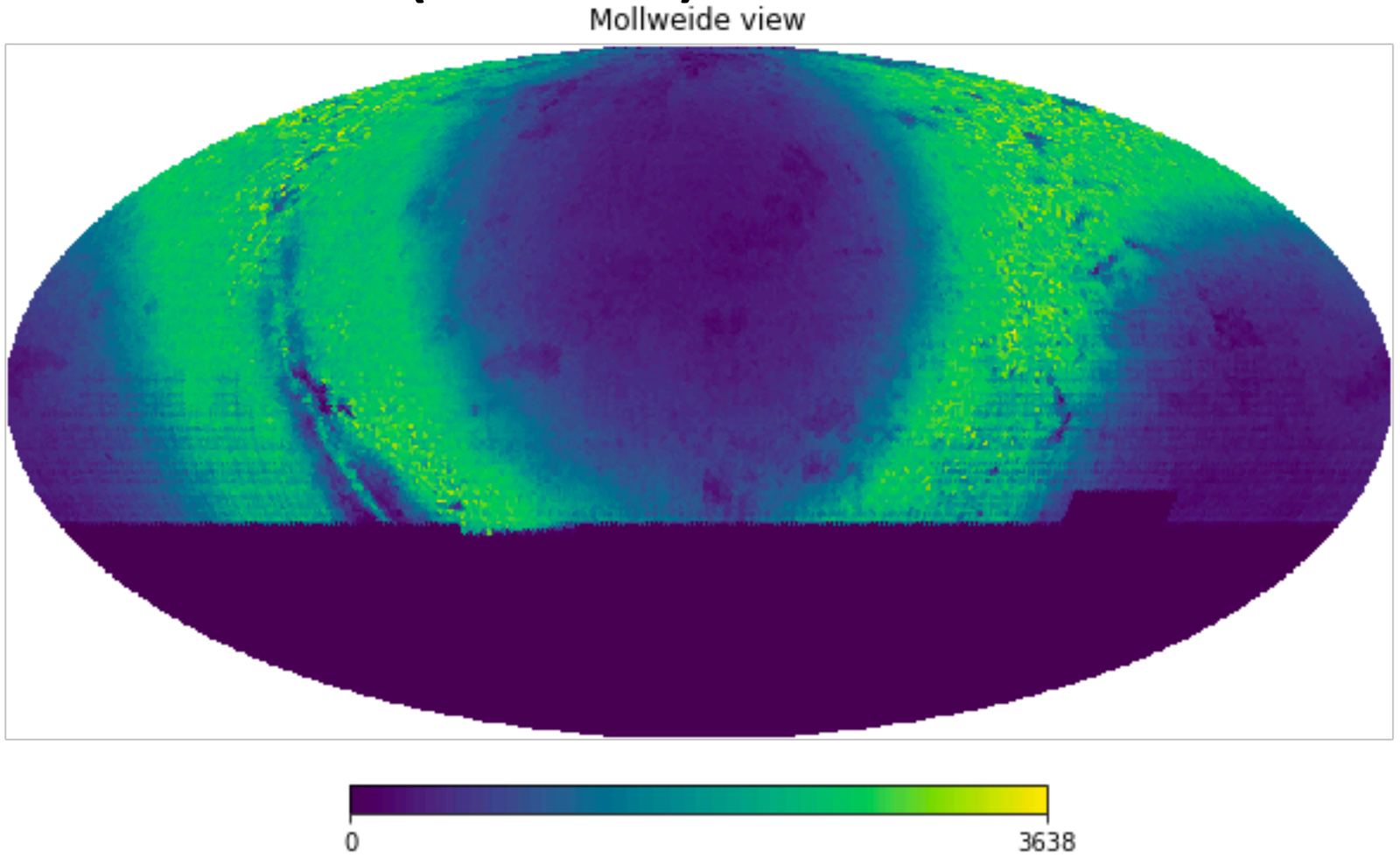
Reduced to 250 million sources by downsampling galactic plane (~100 per square degrees)



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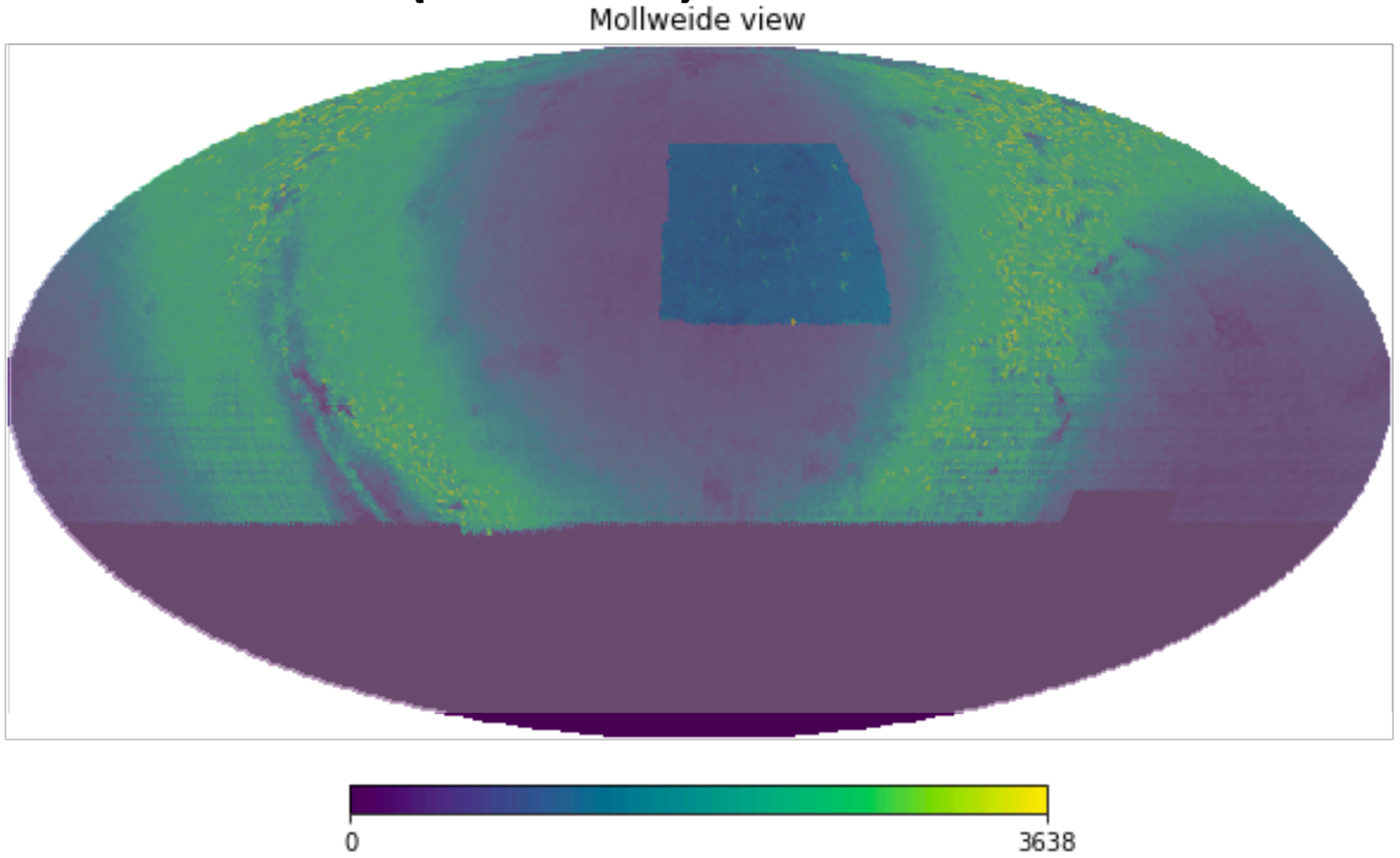

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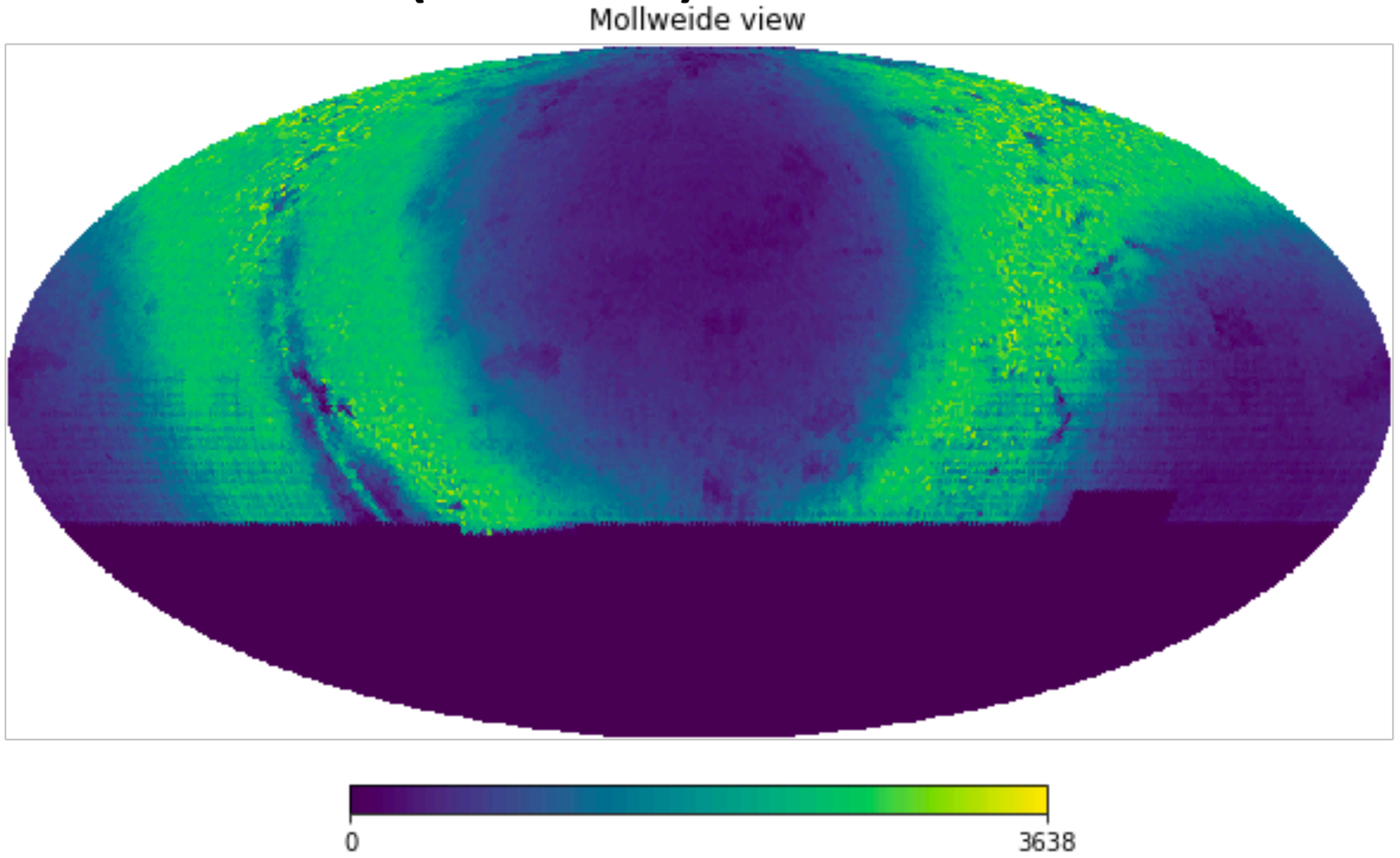

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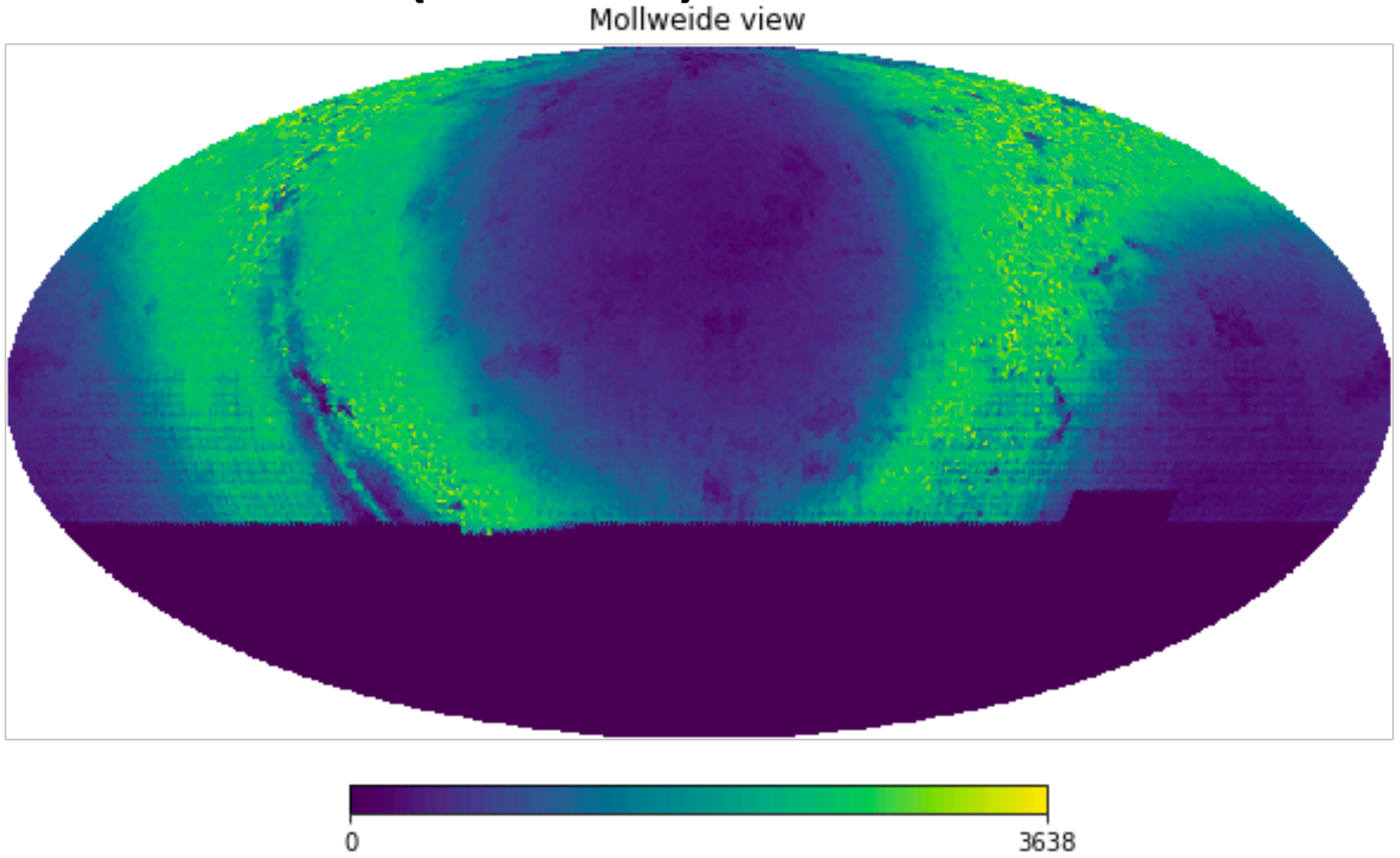
1 zero point per exposure PSF photometry



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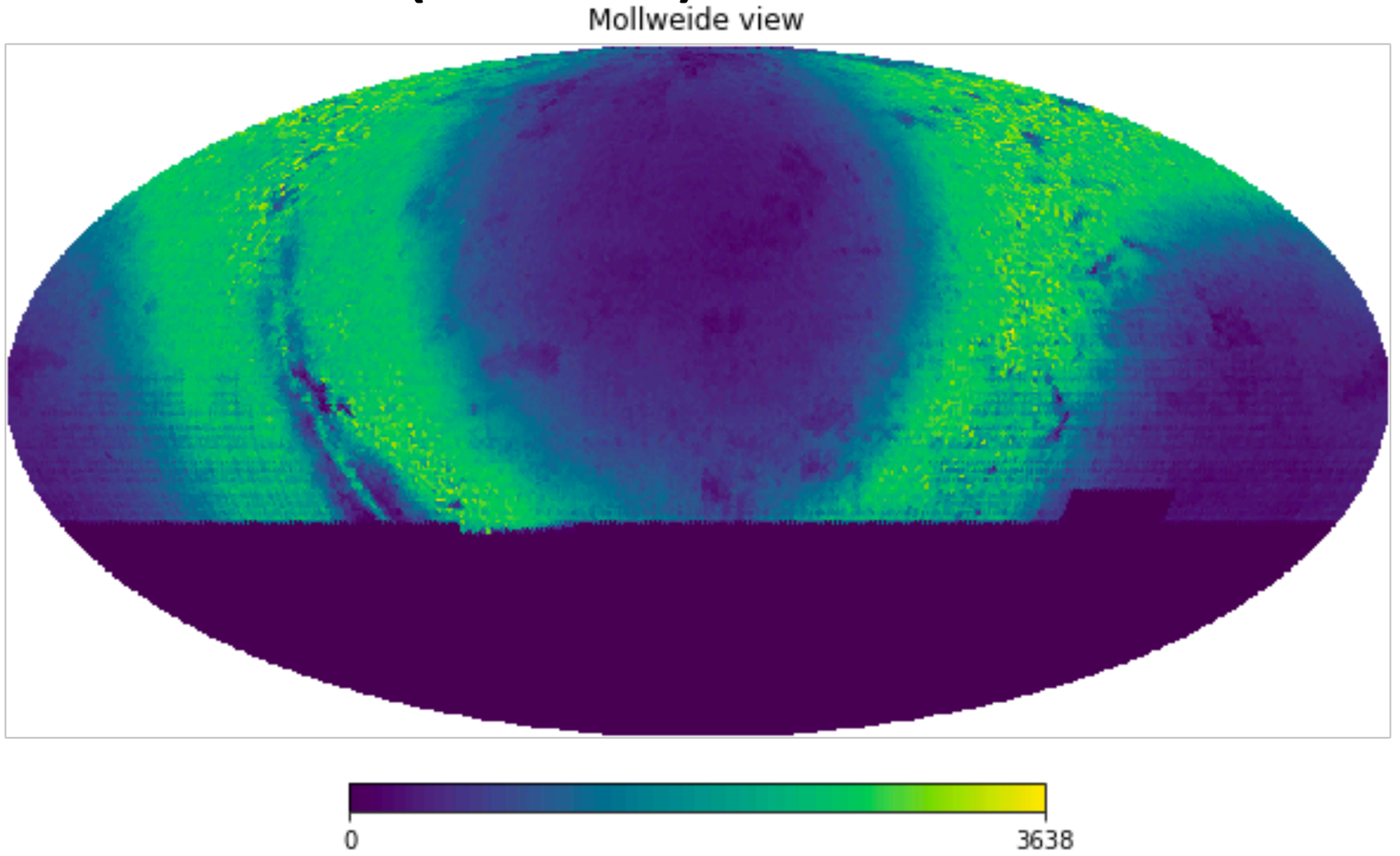
1 zero point per exposure PSF photometry

Takes ~30 minutes to solve ubercal



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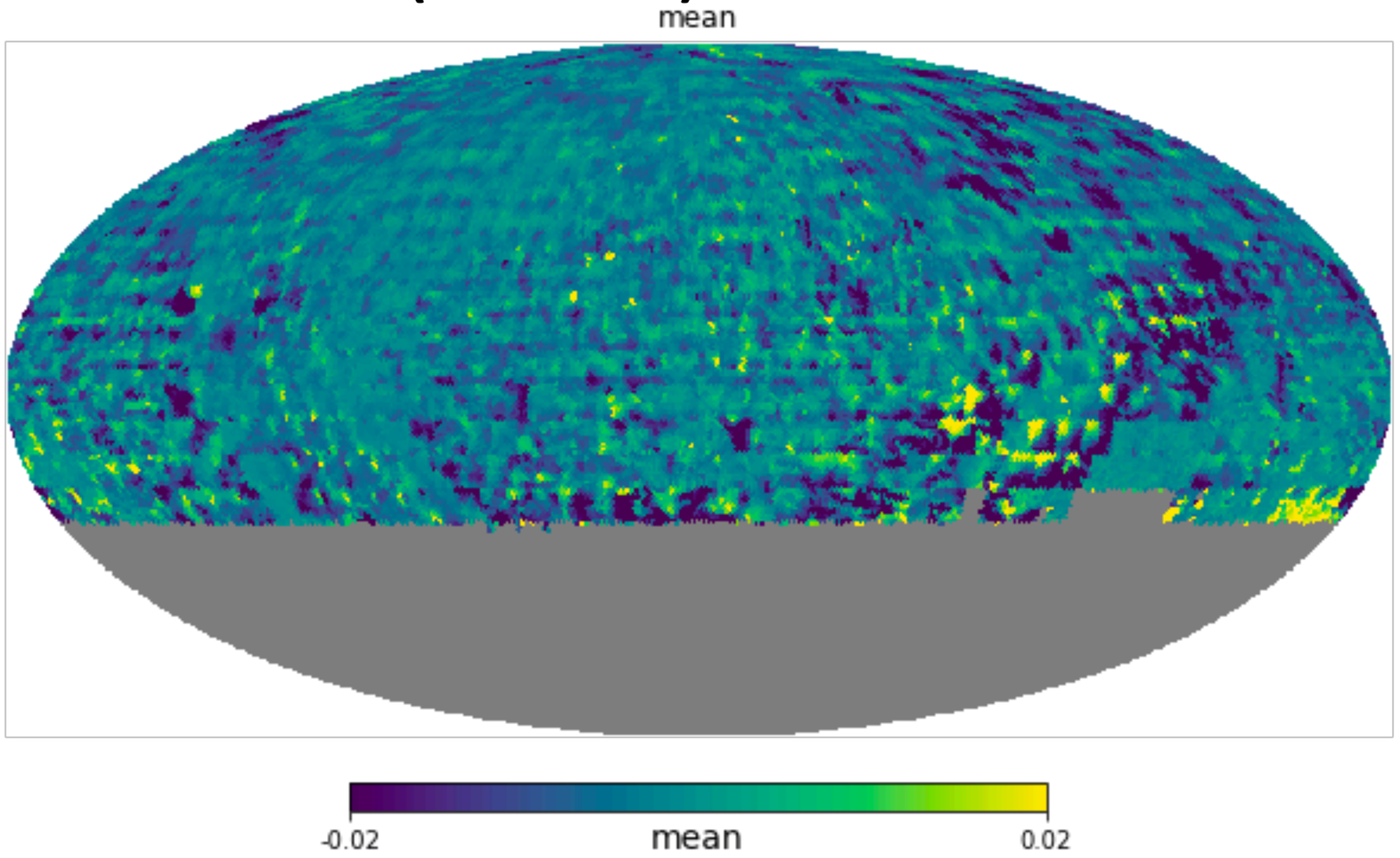

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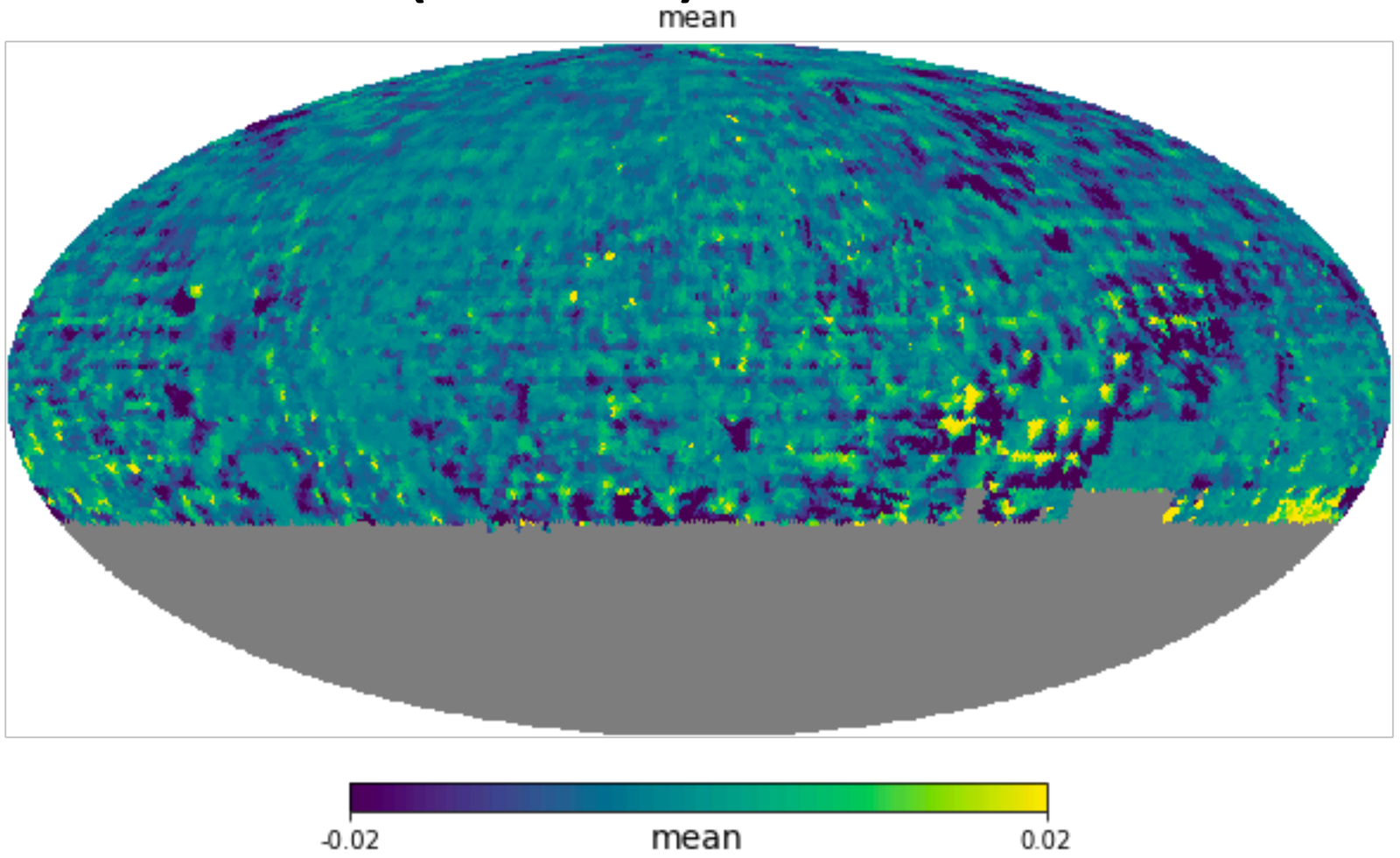
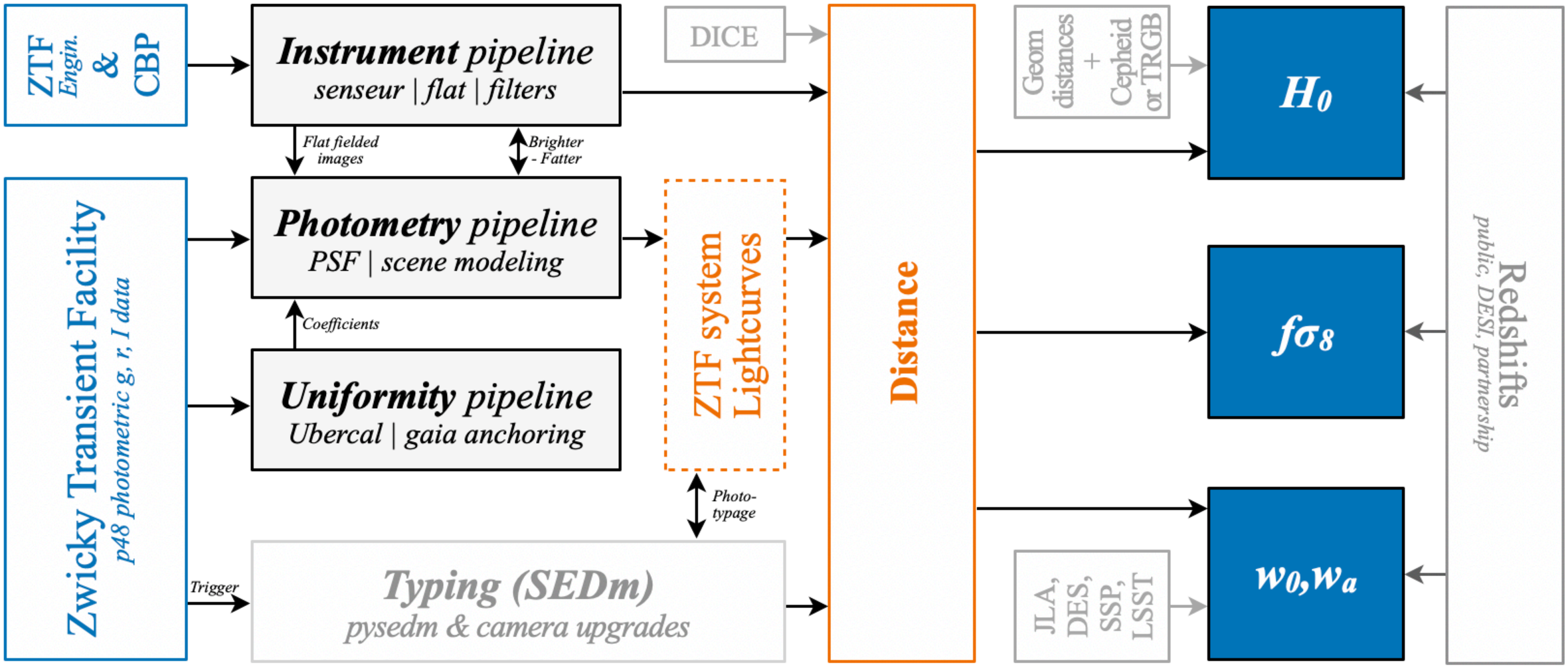
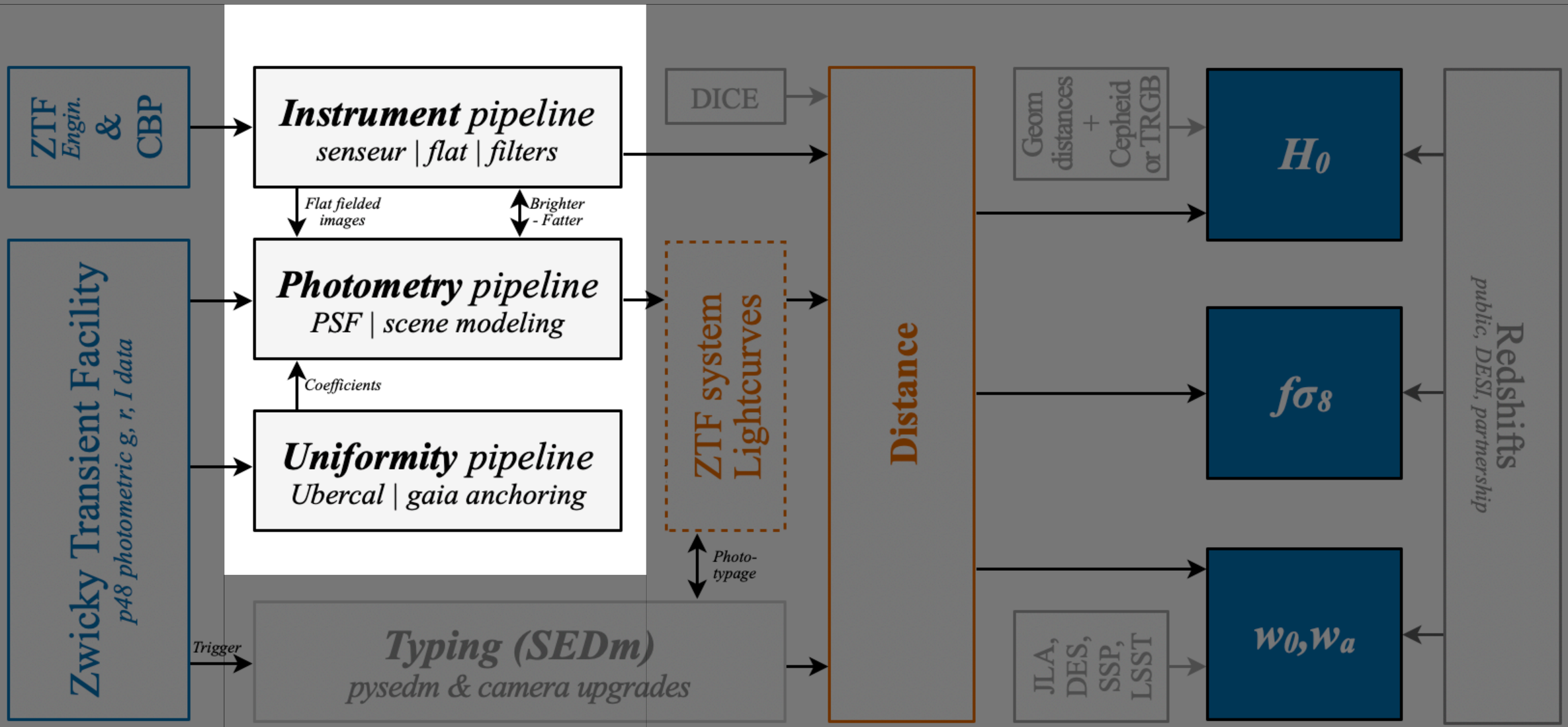


Estelle provided a fits file with starflat correction.
Now working in implementing this in our ubercal pipeline

New directions

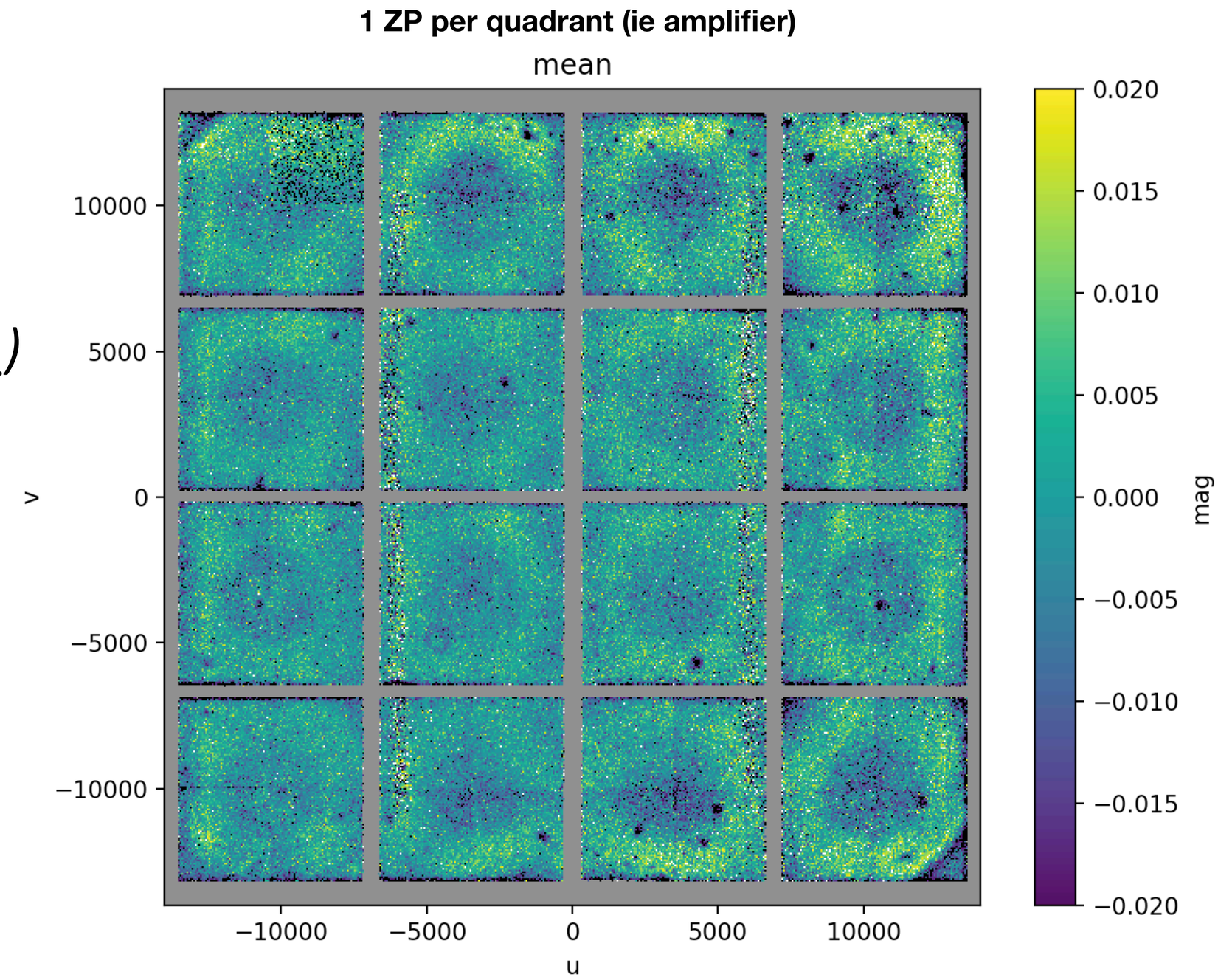


New directions



Mean residuals
as a function of focal plane position

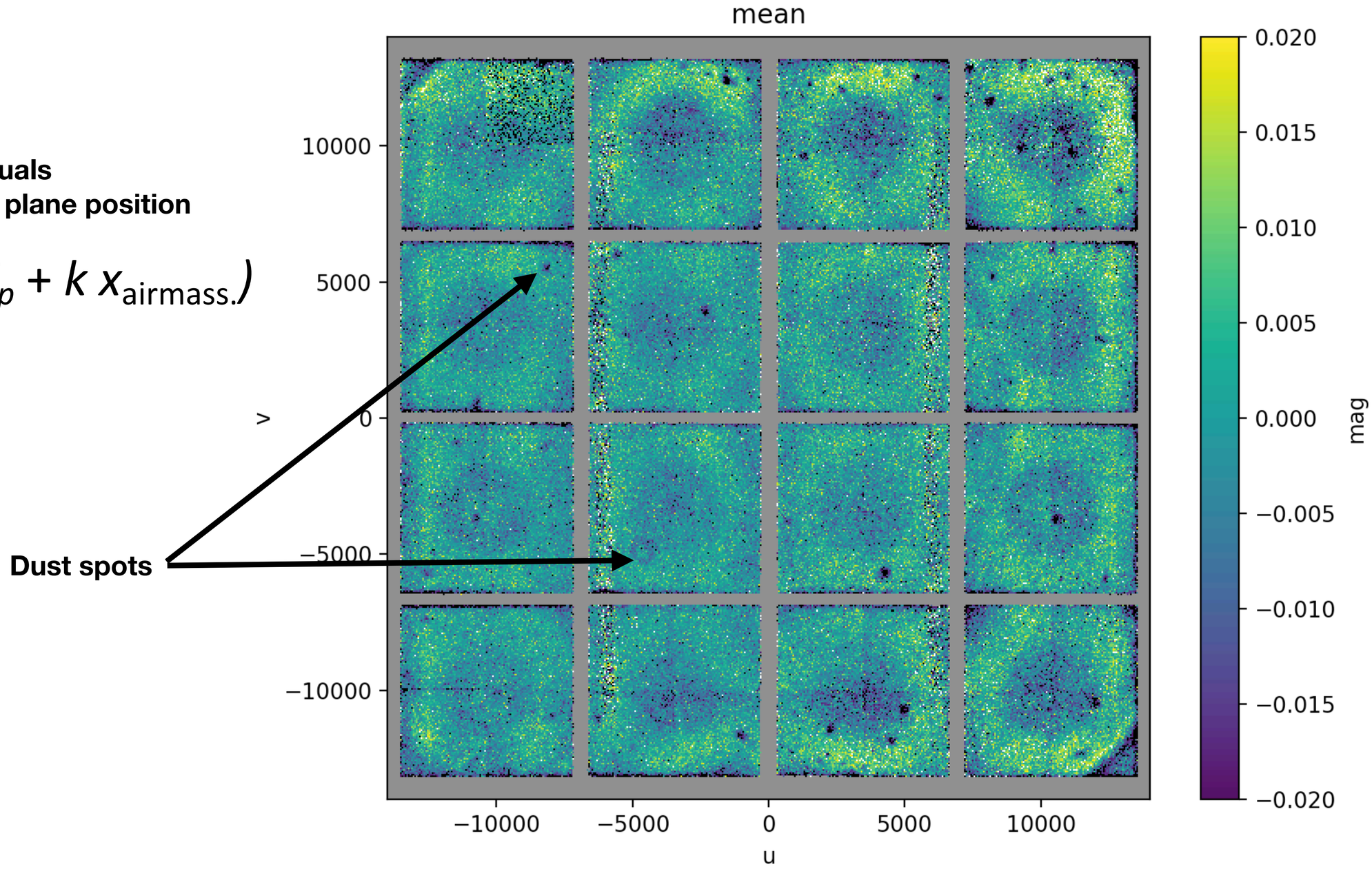
$$m^{obs}_j - (m_i + \Delta Z_p + k\, x_{airmass})$$



Mean residuals
as a function of focal plane position

$$m^{obs}_j - (m_i + \Delta Z_p + k\, x_{airmass.})$$

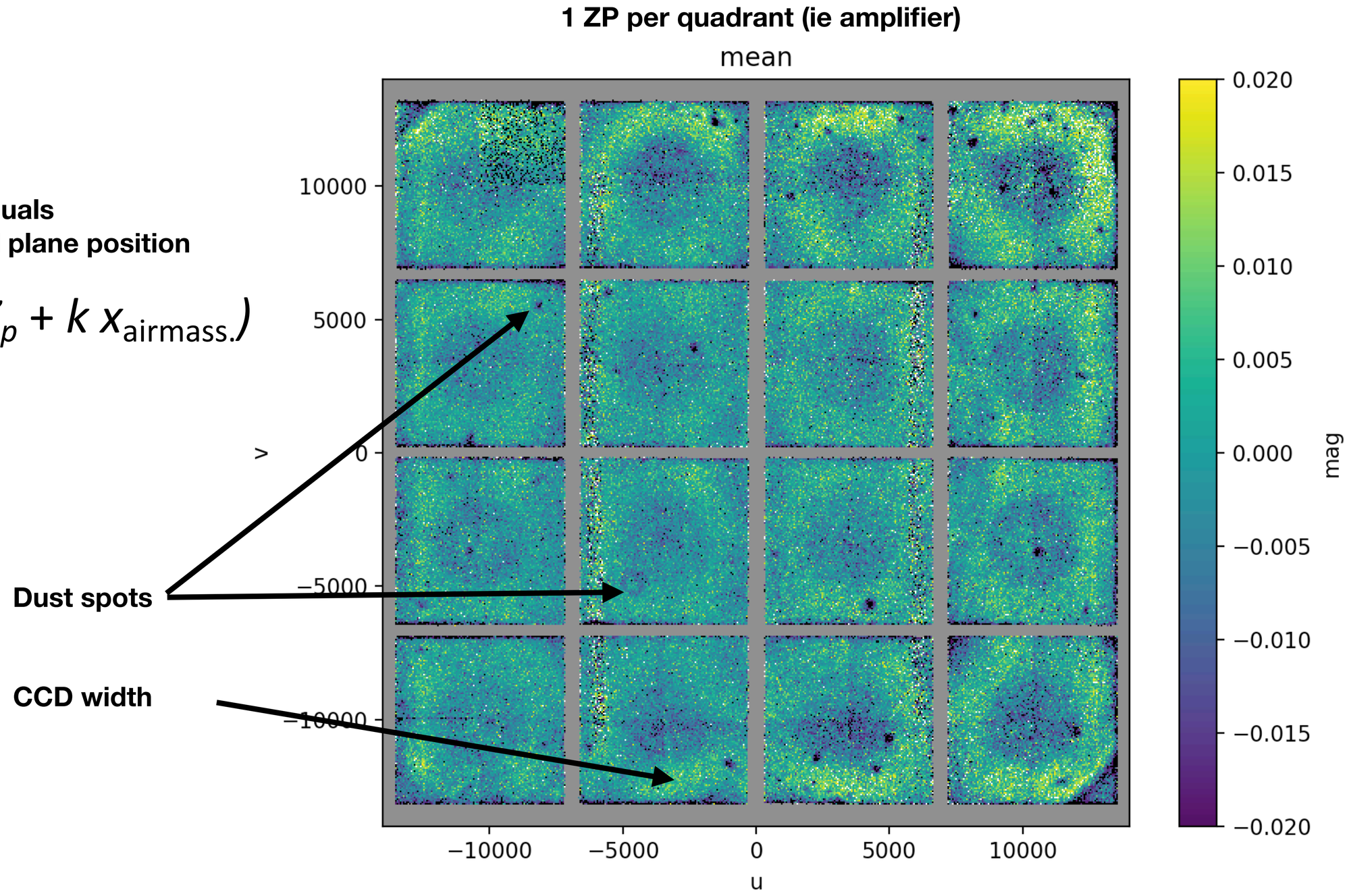
1 ZP per quadrant (ie amplifier)



Dust spots

Mean residuals
as a function of focal plane position

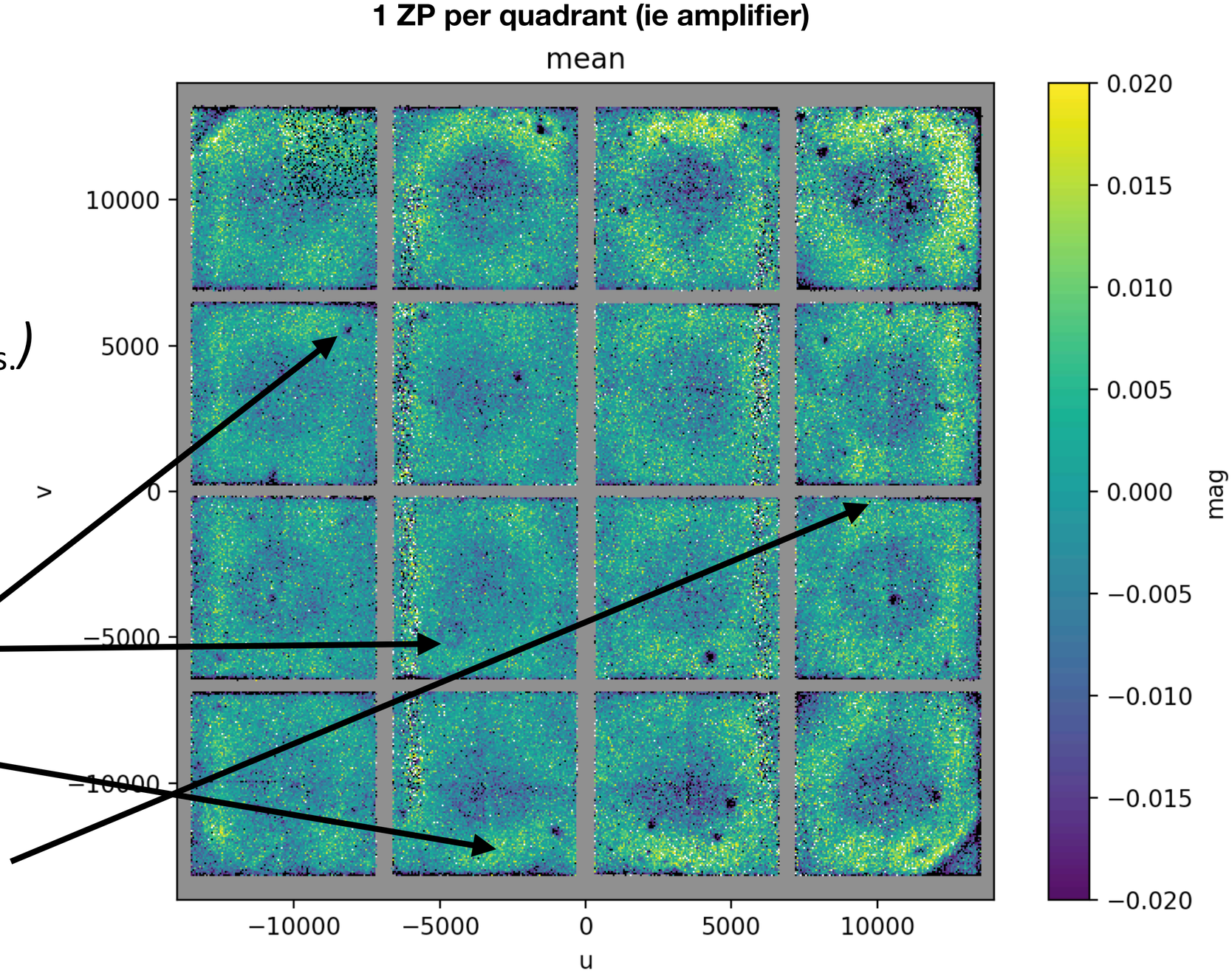
$$m^{obs}_j - (m_i + \Delta Z_p + k\, x_{airmass})$$



1 ZP per quadrant (ie amplifier)

Mean residuals
as a function of focal plane position

$$m^{obs}_j - (m_i + \Delta Z_p + k\, x_{airmass.})$$



Dust spots

CCD width

Filter optical effect?