Ubercal

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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


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ZP


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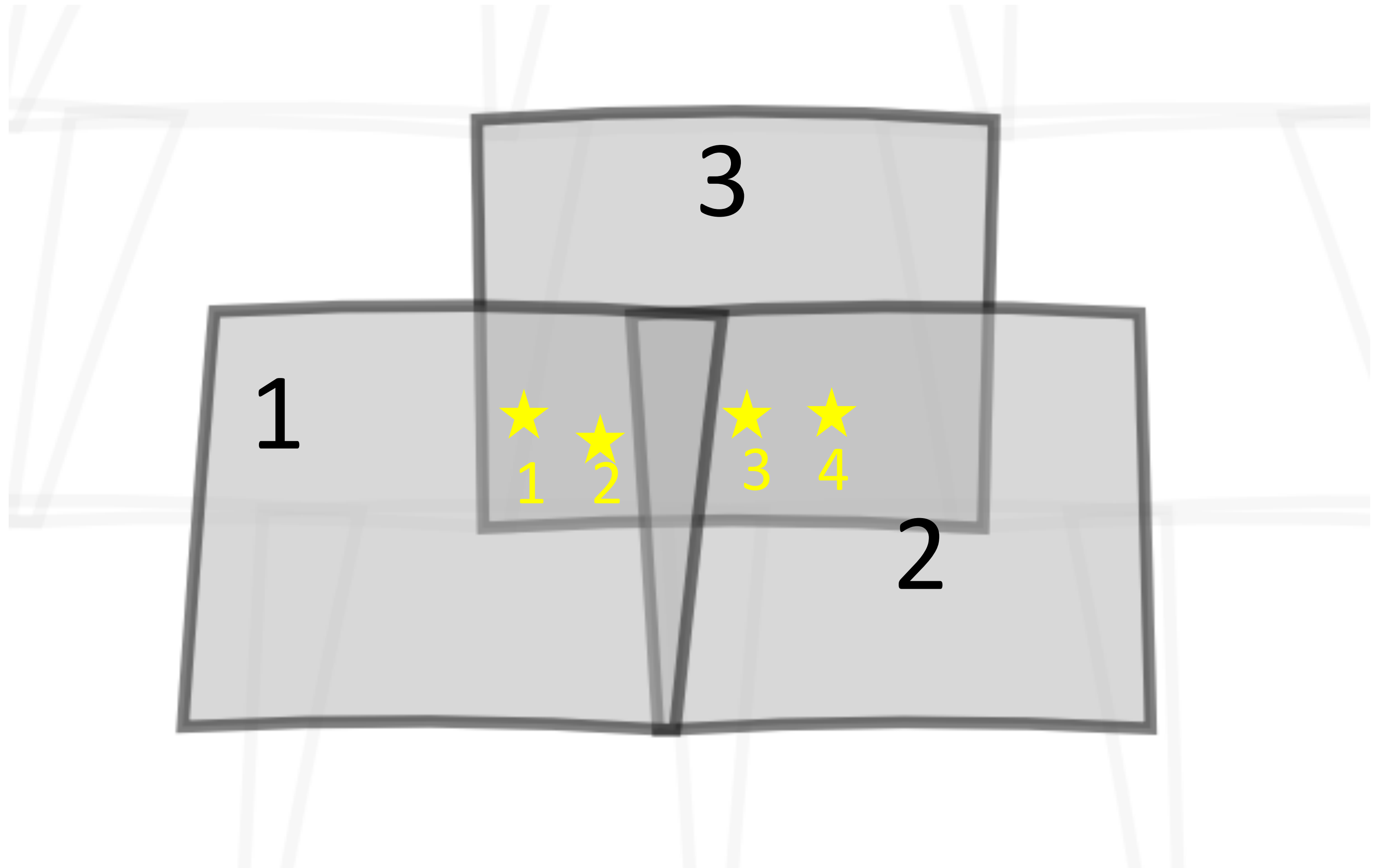
Instrument
Dust spots? Aging?
Mirrors etc. : Flux αβF
Dust? Frequency dependence of course
Filters : Flux αβγF
Edges, dust, coating etc.
Detectors : Flux αβγδF
Gain variations etc?
Amplifiers : Flux αβγδεF
+V
-V
Signal measured in ADU
$m_{meas} = -2.5 \log (F_{meas})$
$= -2.5 \log (F) - 2.5 \log (\alpha\beta\gamma\delta\epsilon)$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

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

in ADU/s

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



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> :

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

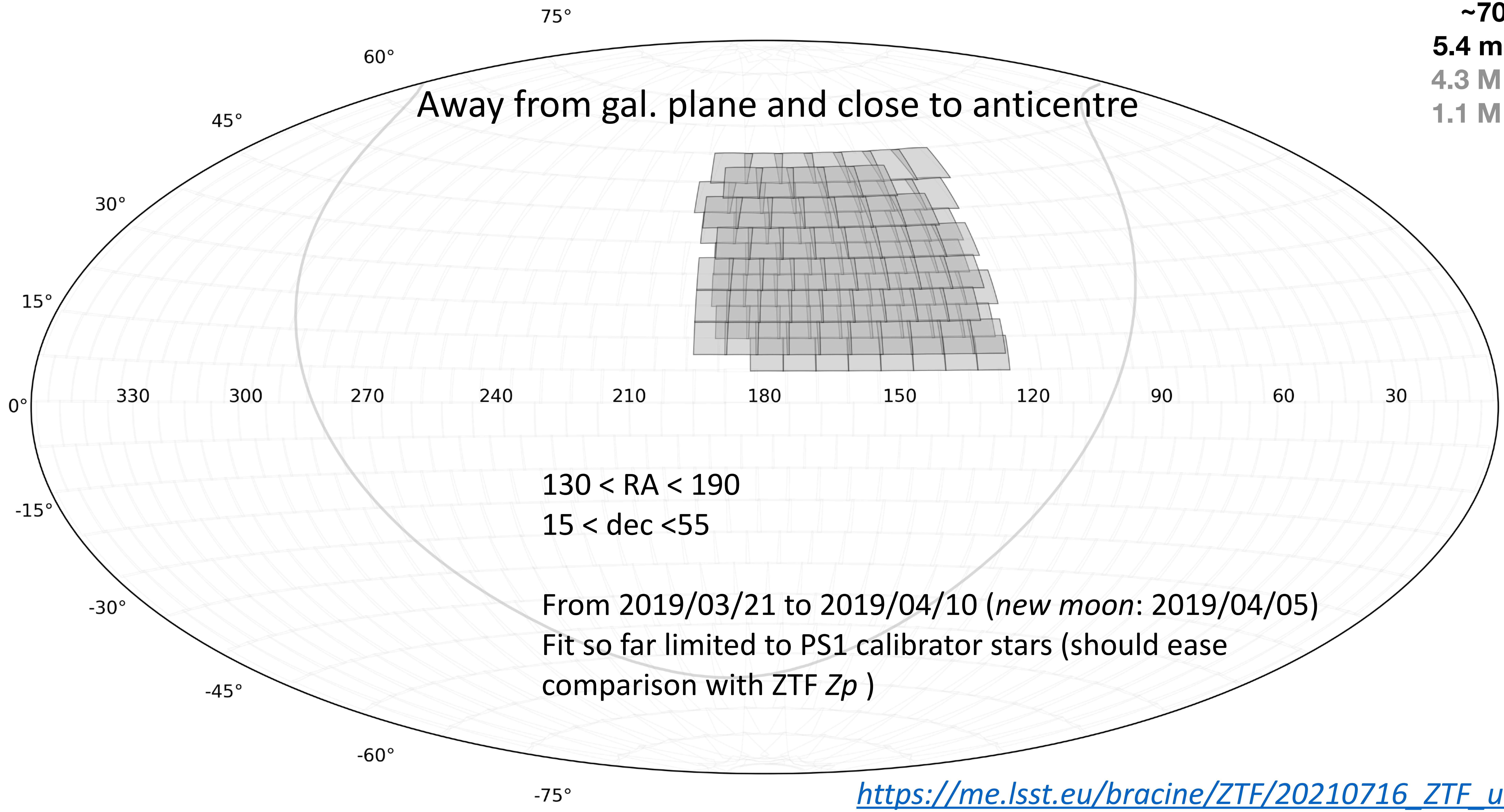
C : diagonal matrix with weights of $m_{i,j}$ measurements

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

Test case

~700 000 stars
5.4 million sources
4.3 M in main grid
1.1 M in secondary

Away from gal. plane and close to anticentre



130 < RA < 190
15 < dec <55

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/

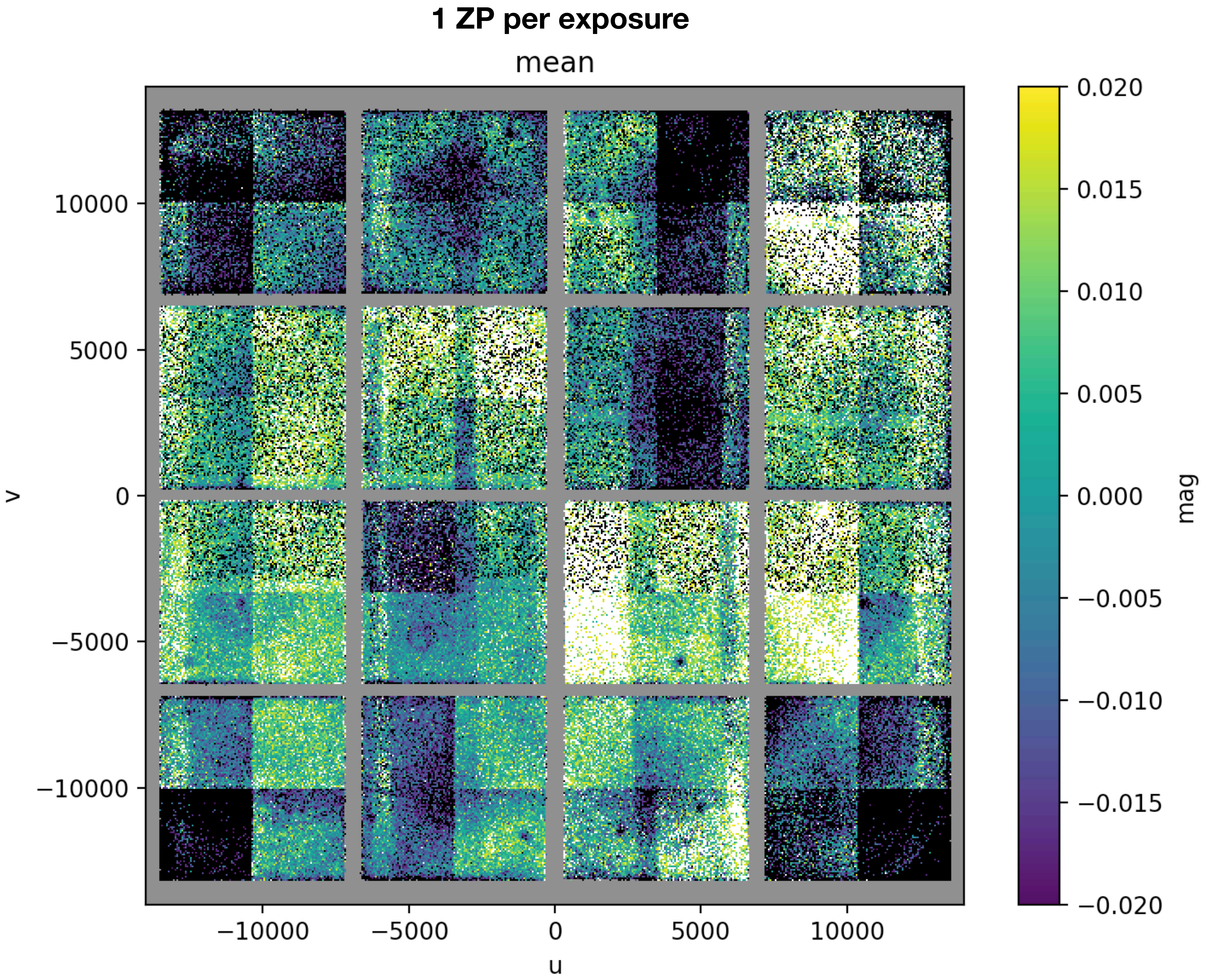
Mean residuals
as a function of focal plane position

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

We see a clear per-quadrant structure.

Easier per exposure than per quadrant
with the small dithering
from ZTF.

We can use starflat
ZP correction for the instrumental part,
assuming they do not vary much with time



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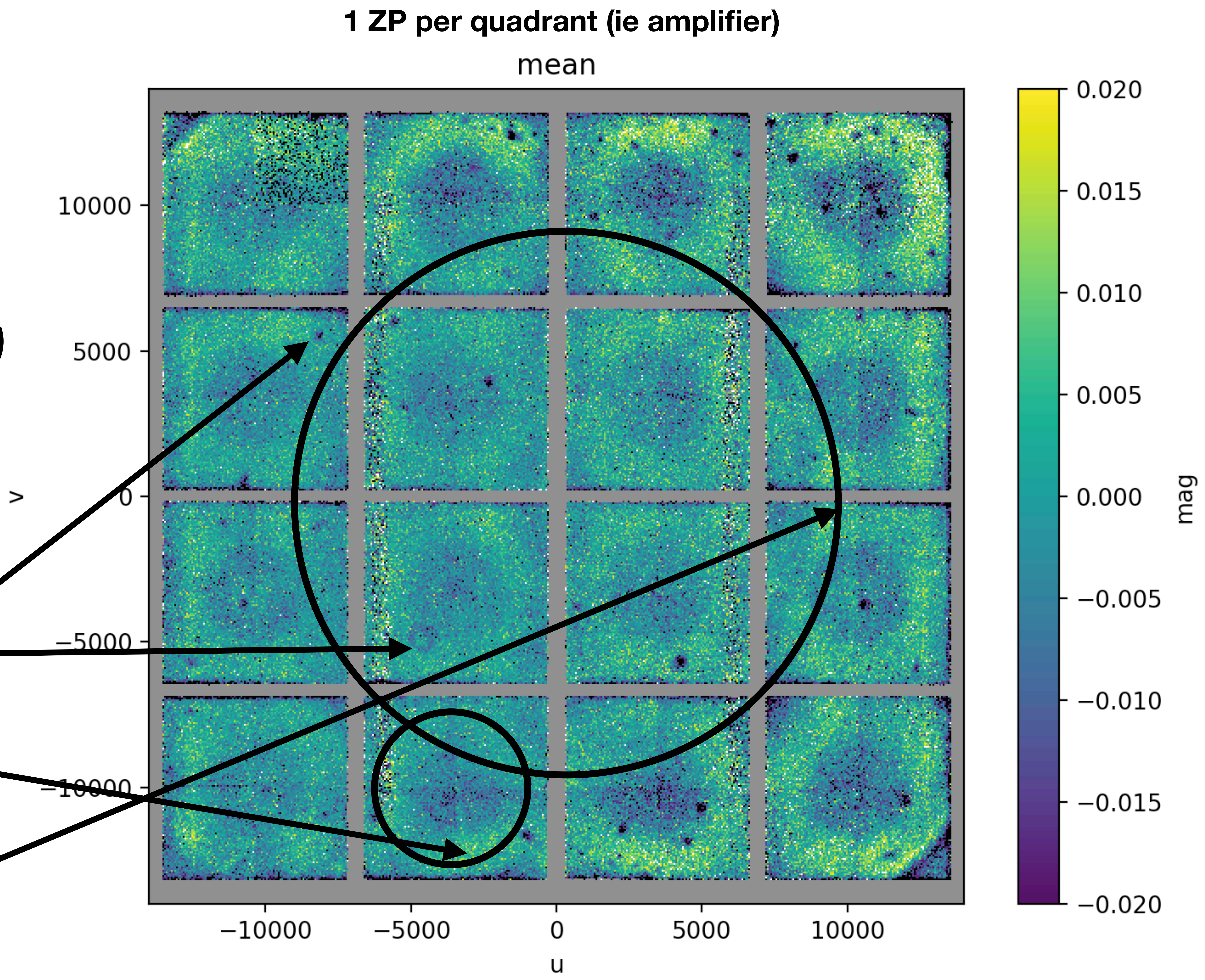

Dust spots

CCD width

Filter optical effect?

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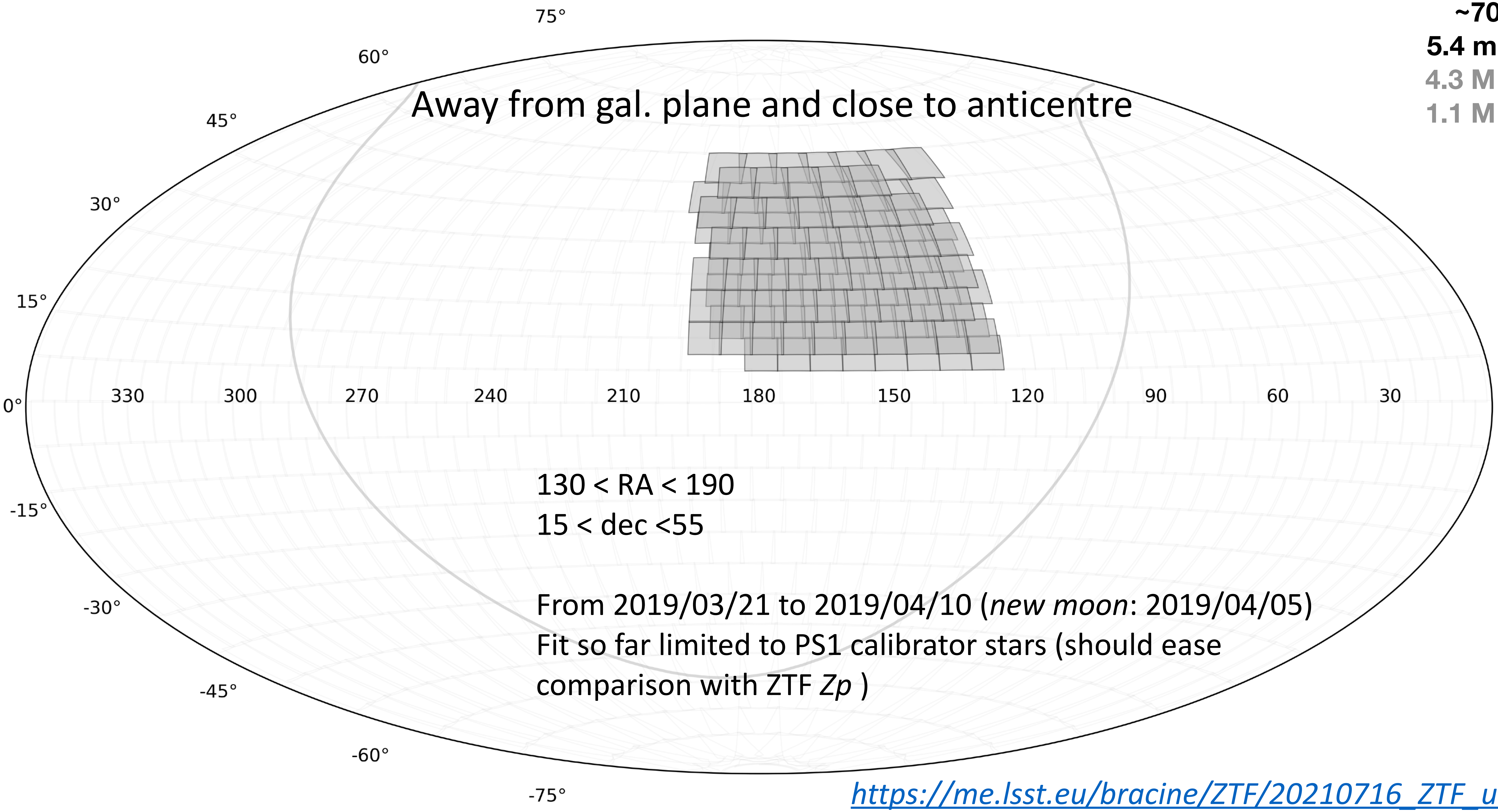

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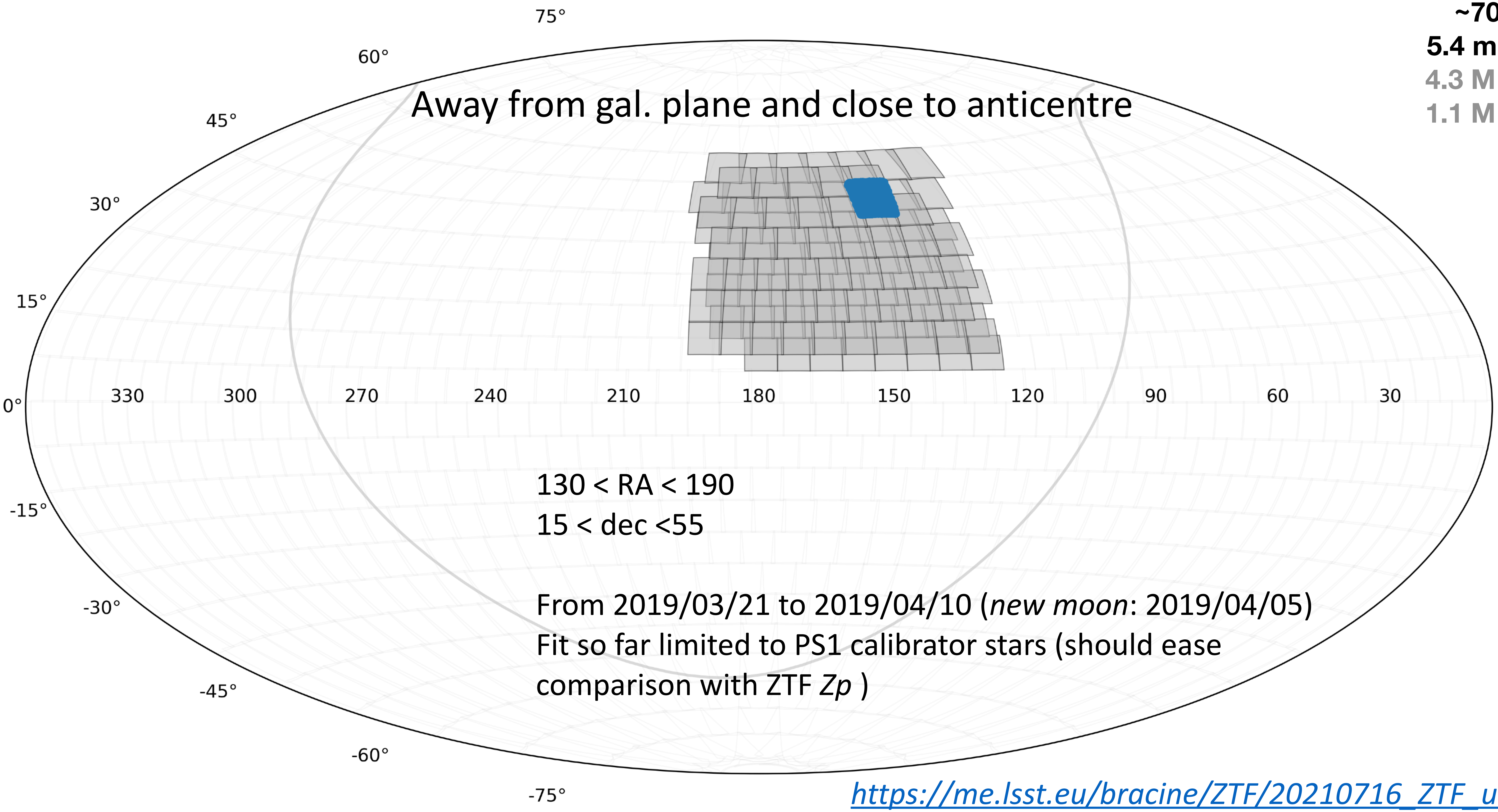

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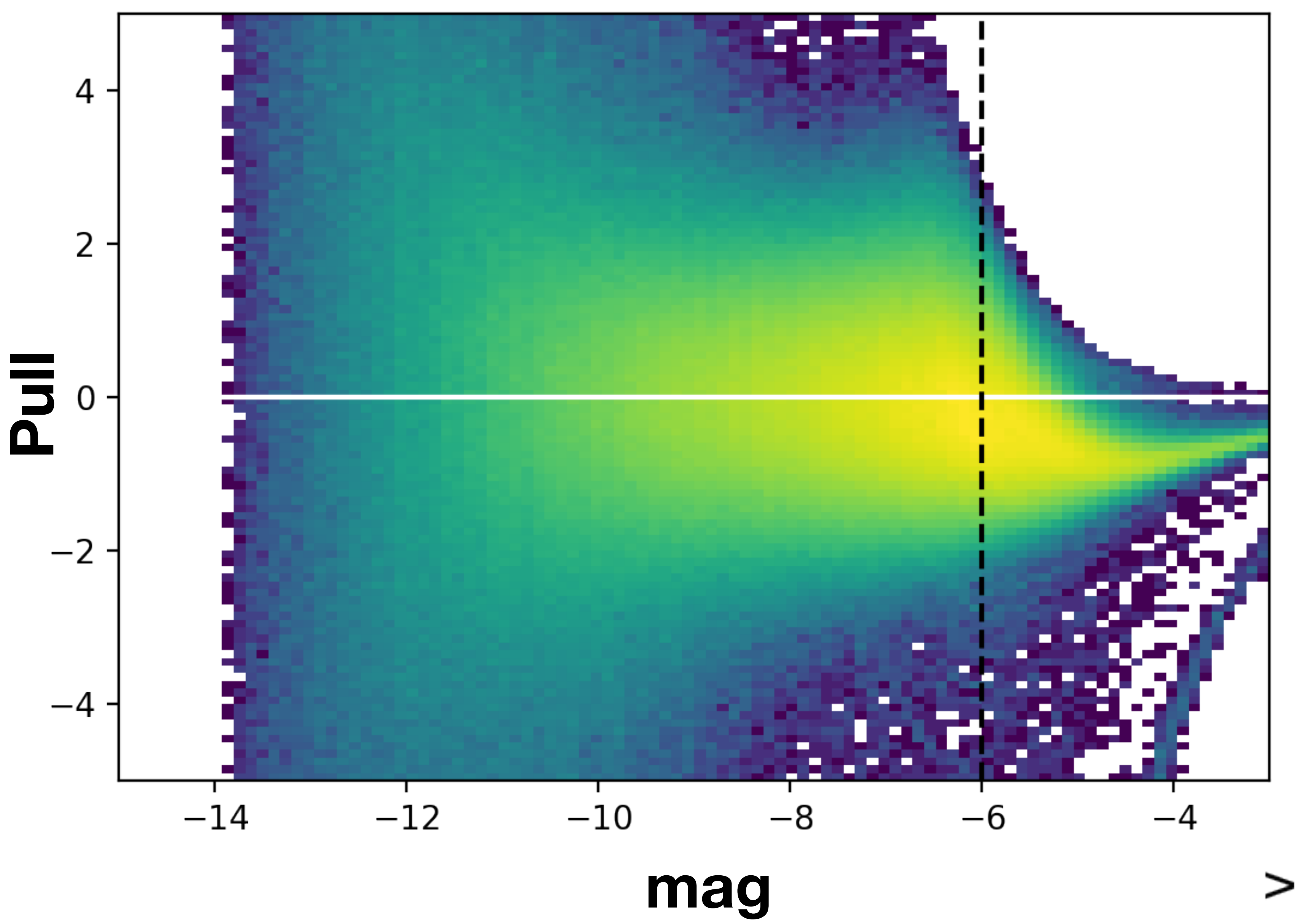
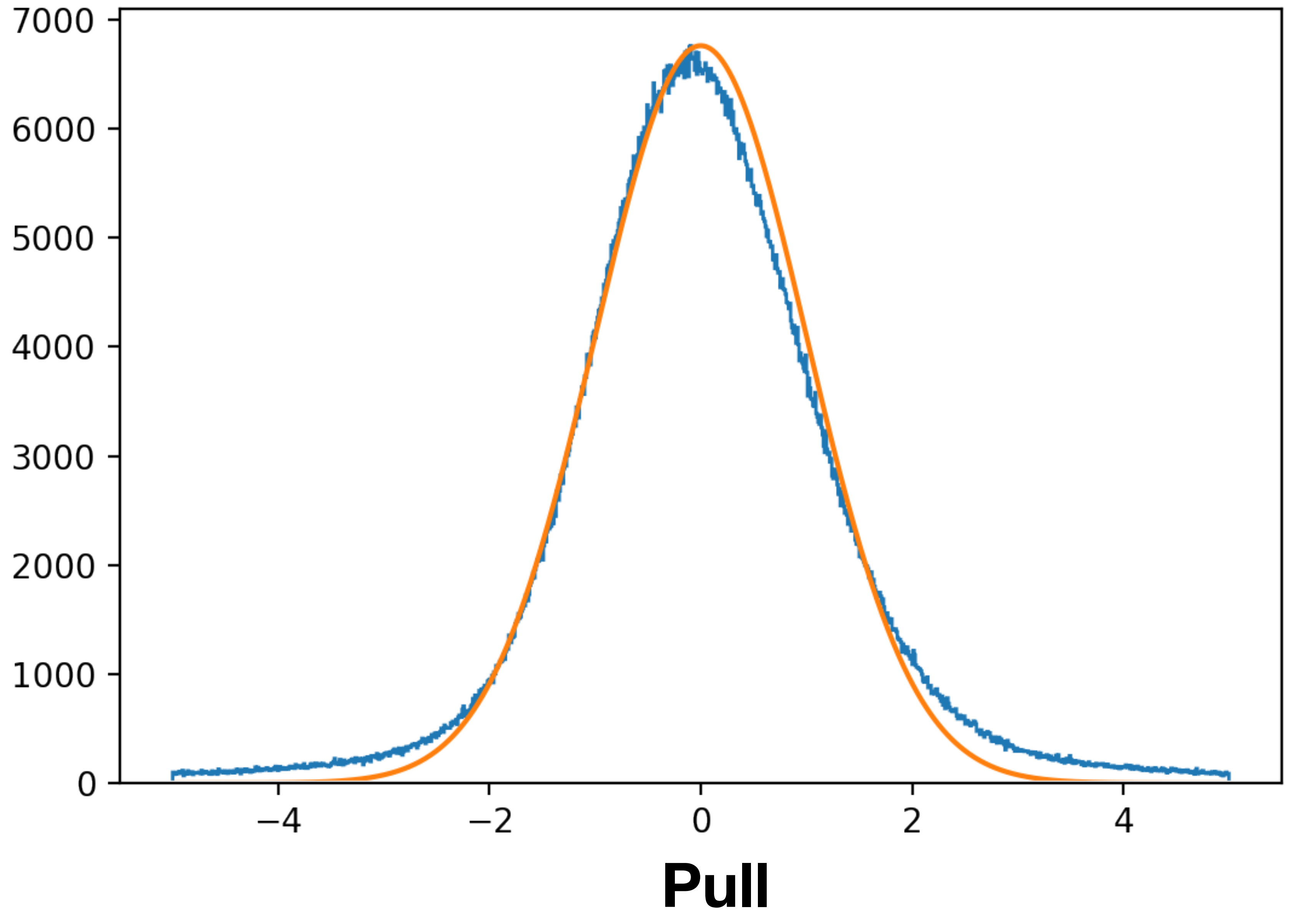
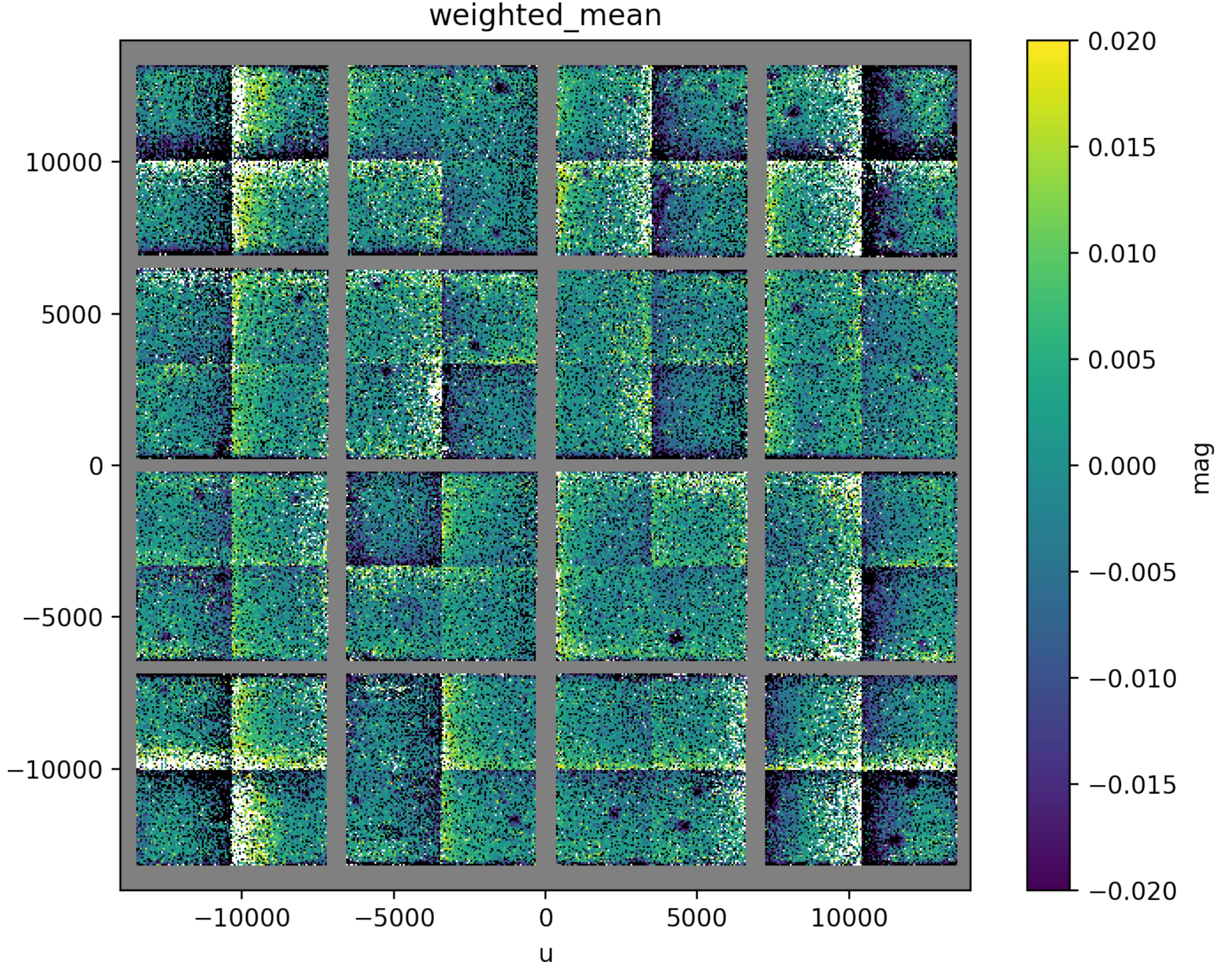
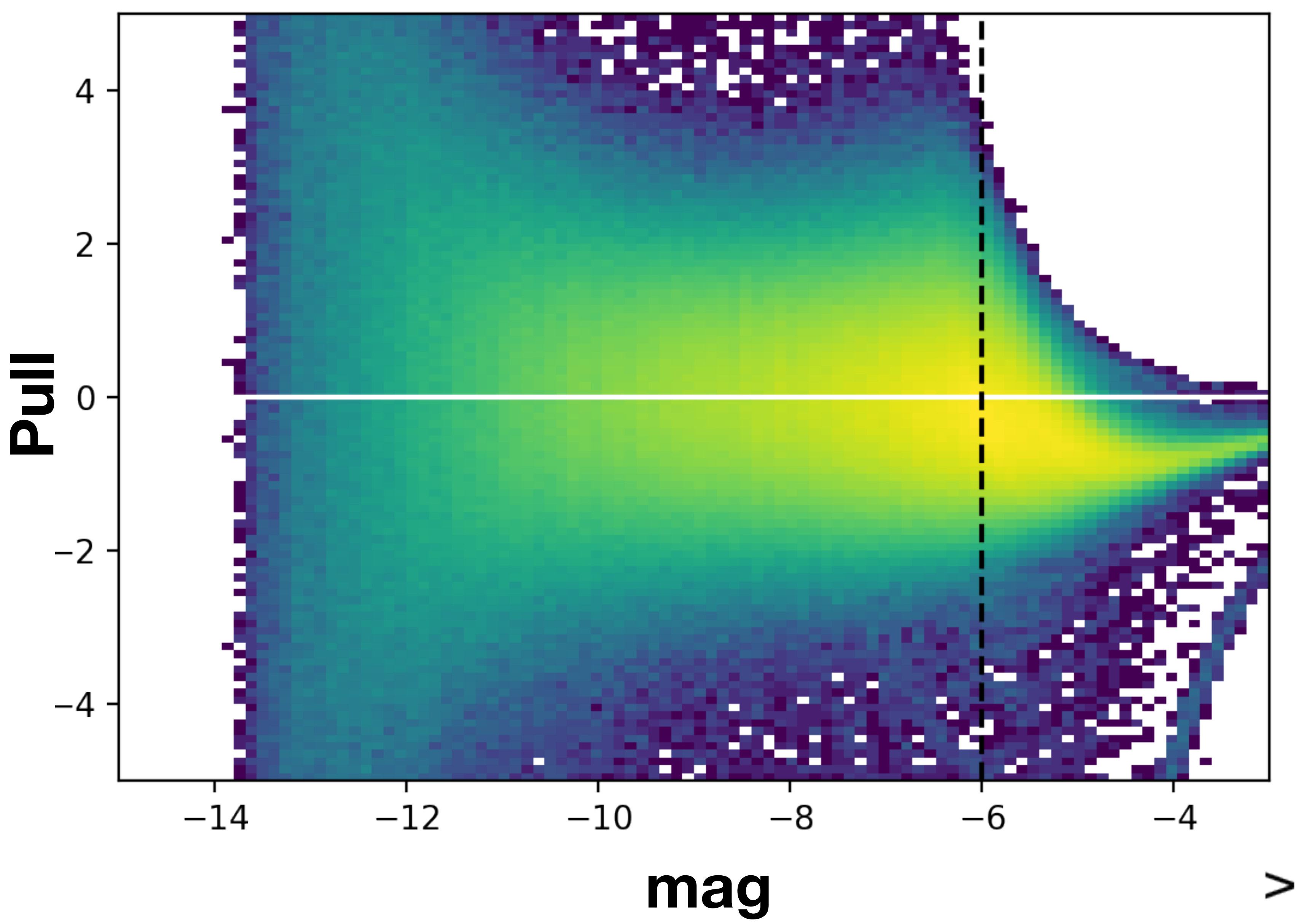
Aperture photometry

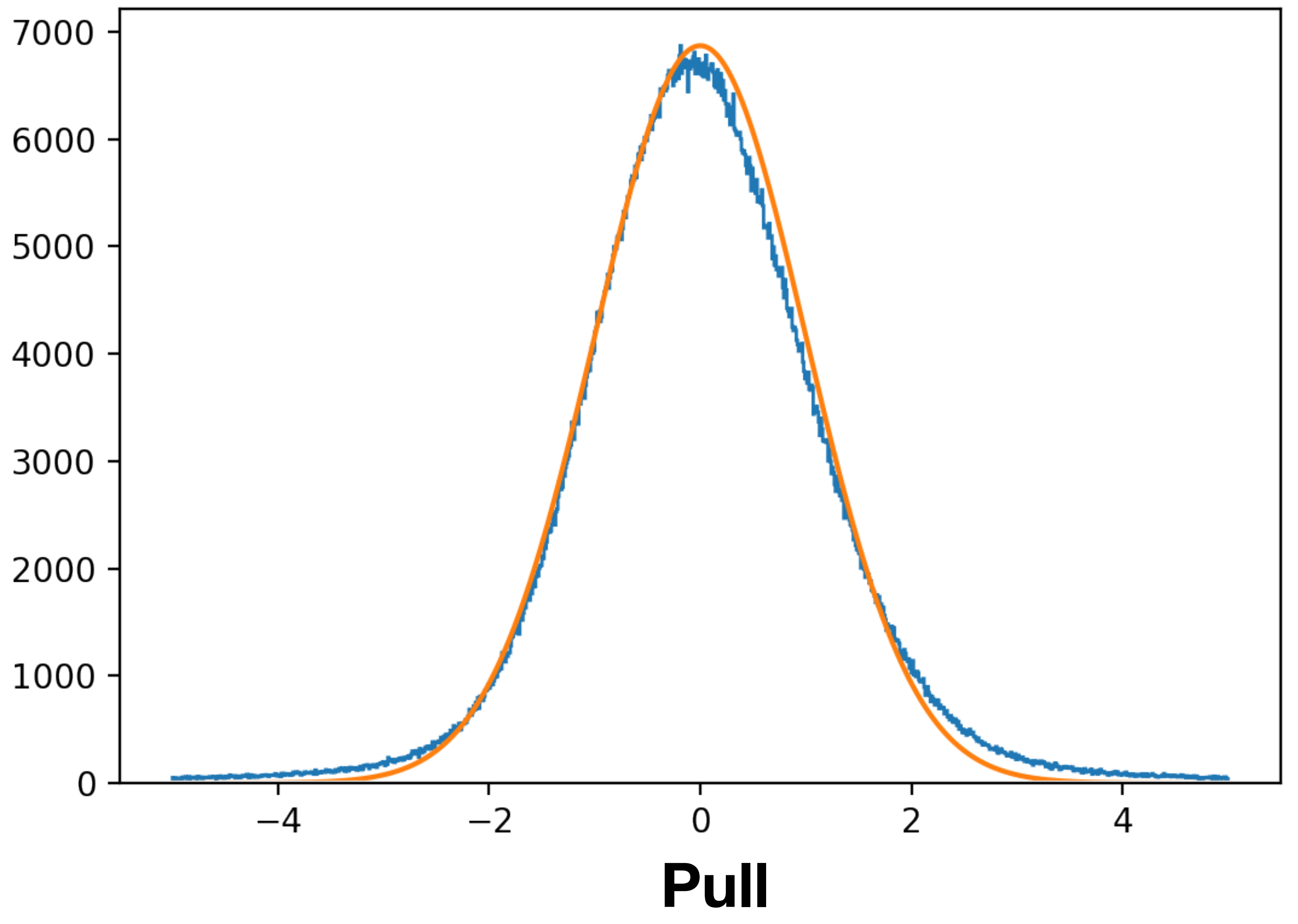


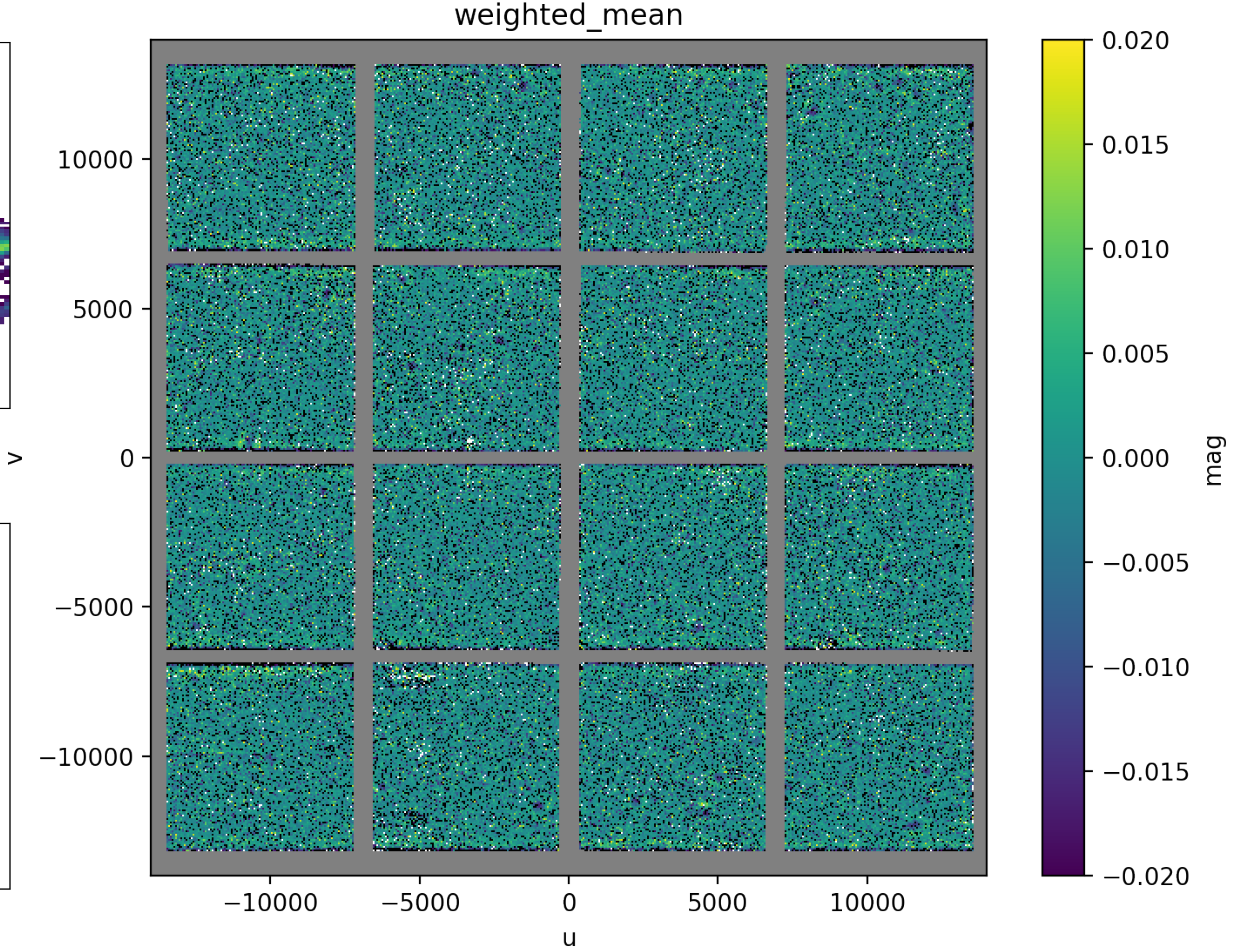




Starflat corrected aperture photometry

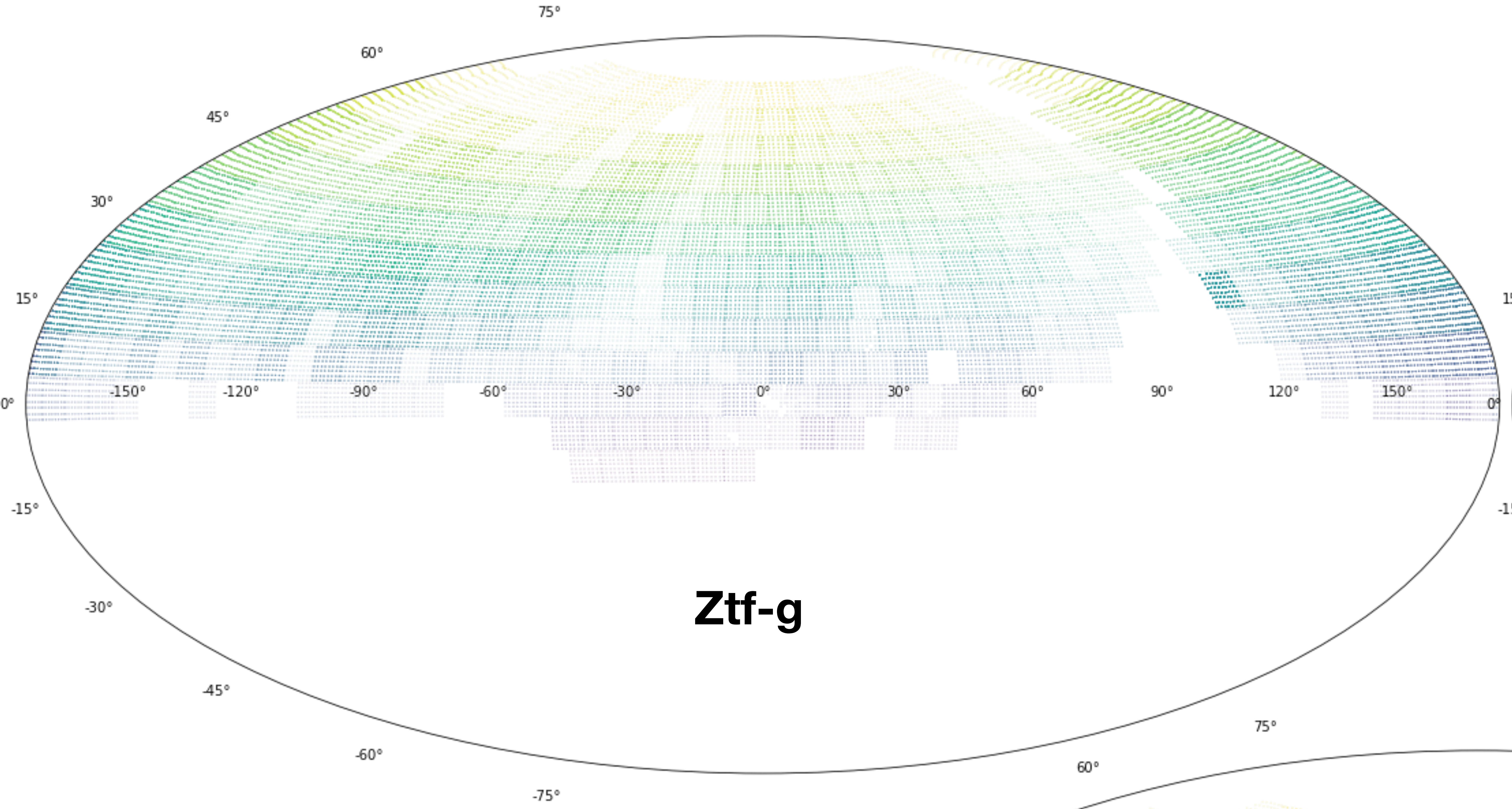


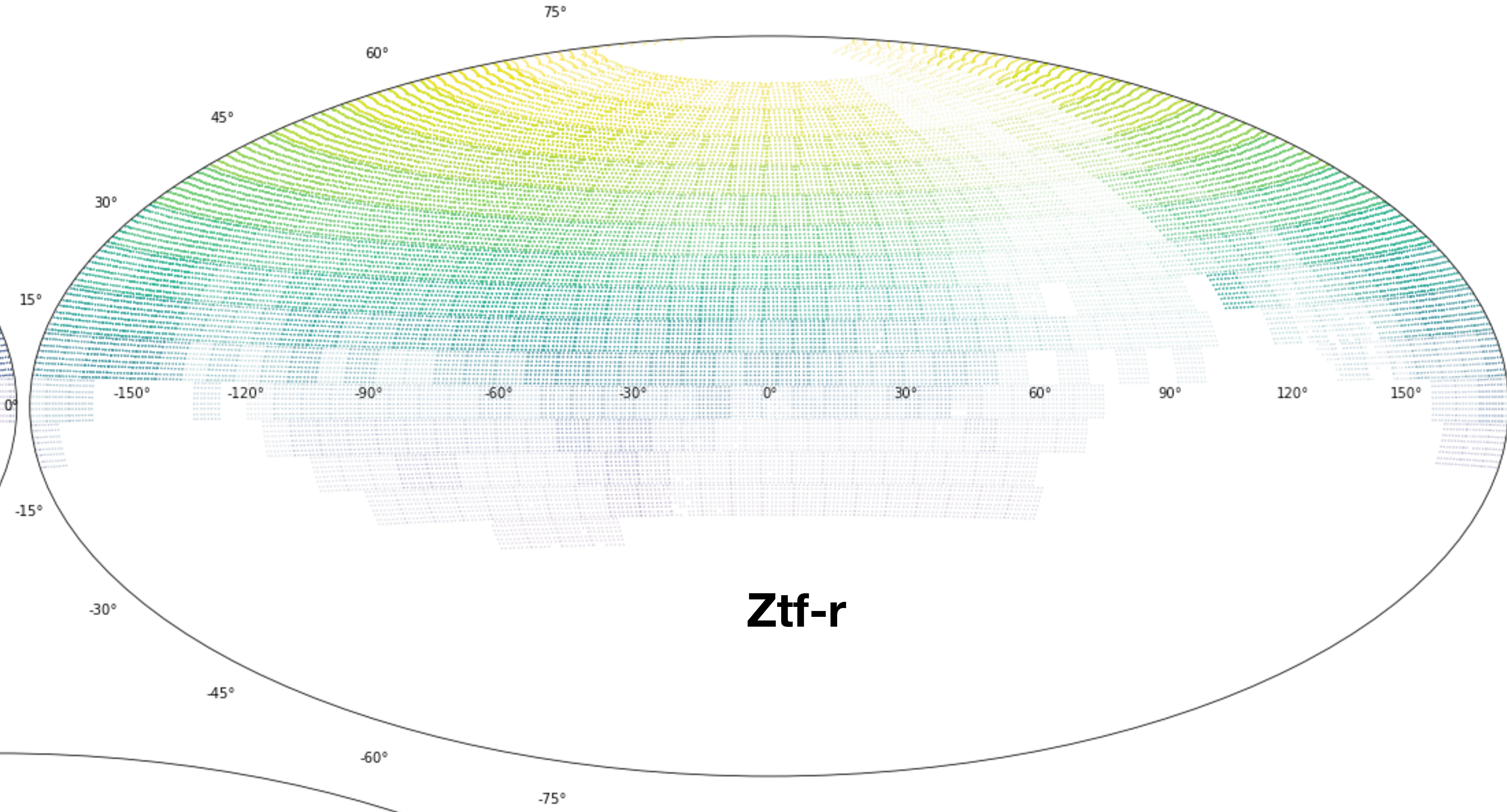


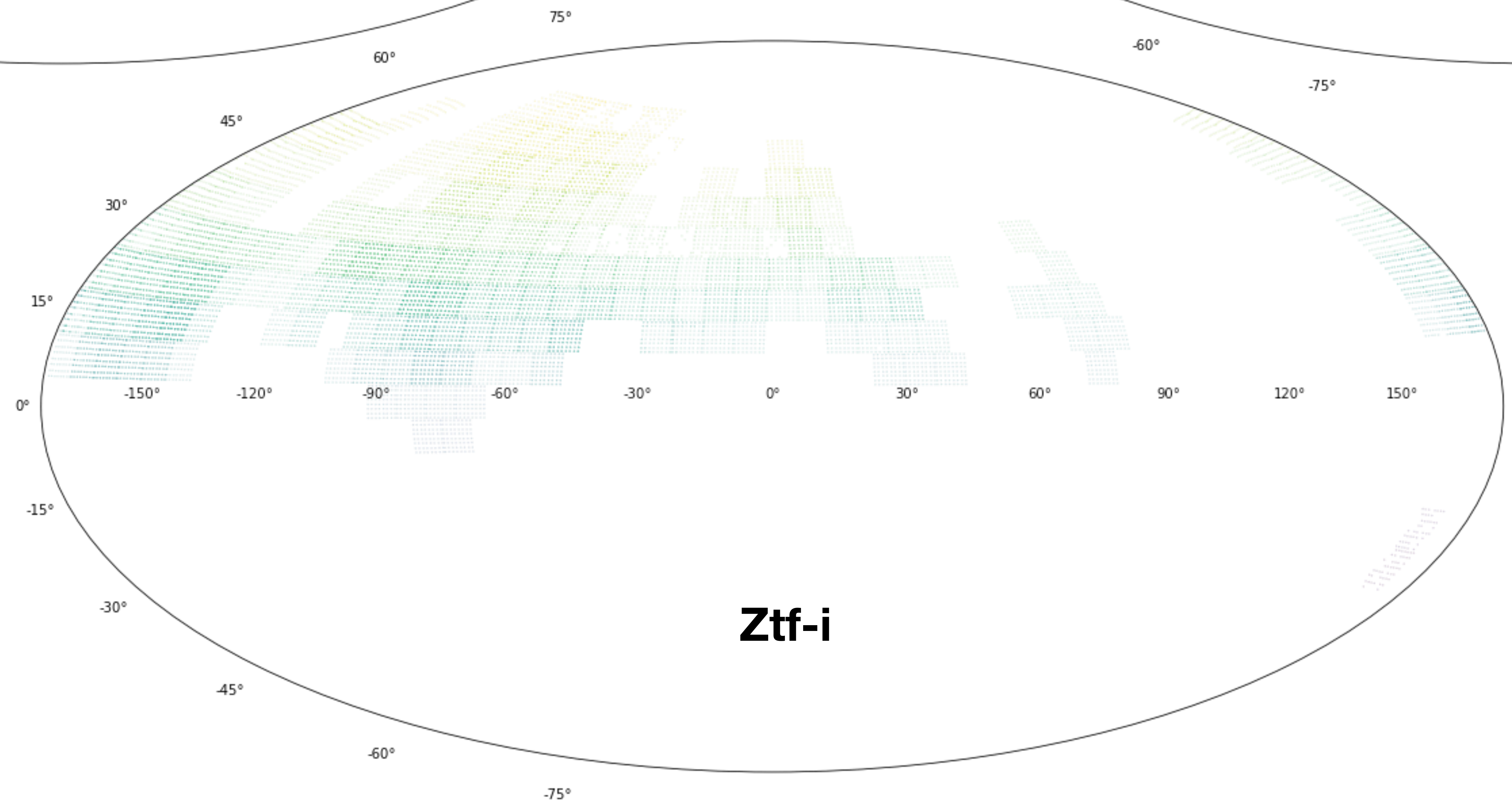


PSF photometry

All data from March to August 2019 (6 month)







~4 billion sources
~200 Gb