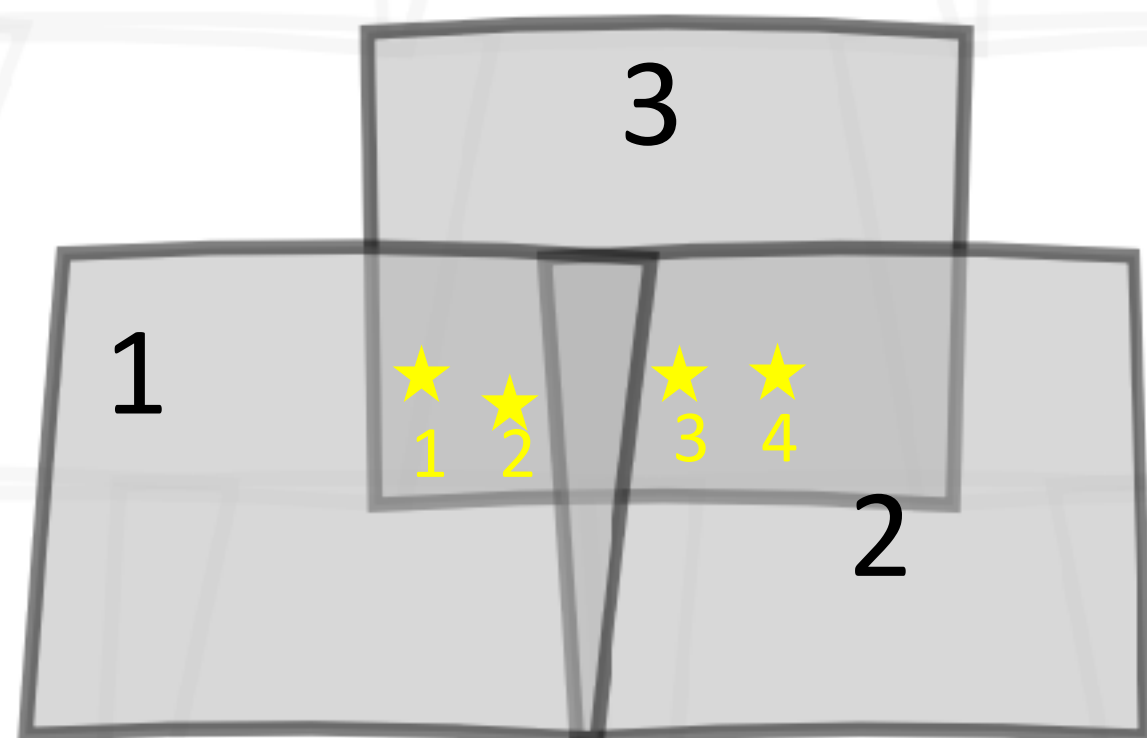


# Update on Ubercal

Benjamin Racine & Fabrice Feinstein



# Ubercal method

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

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

$A_{8 \times 6}$

$\cdot X_{6 \times 1}$

$=$

$B_{8 \times 1}$

system of 8 equations :

$$A X = B$$

least square fit :

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

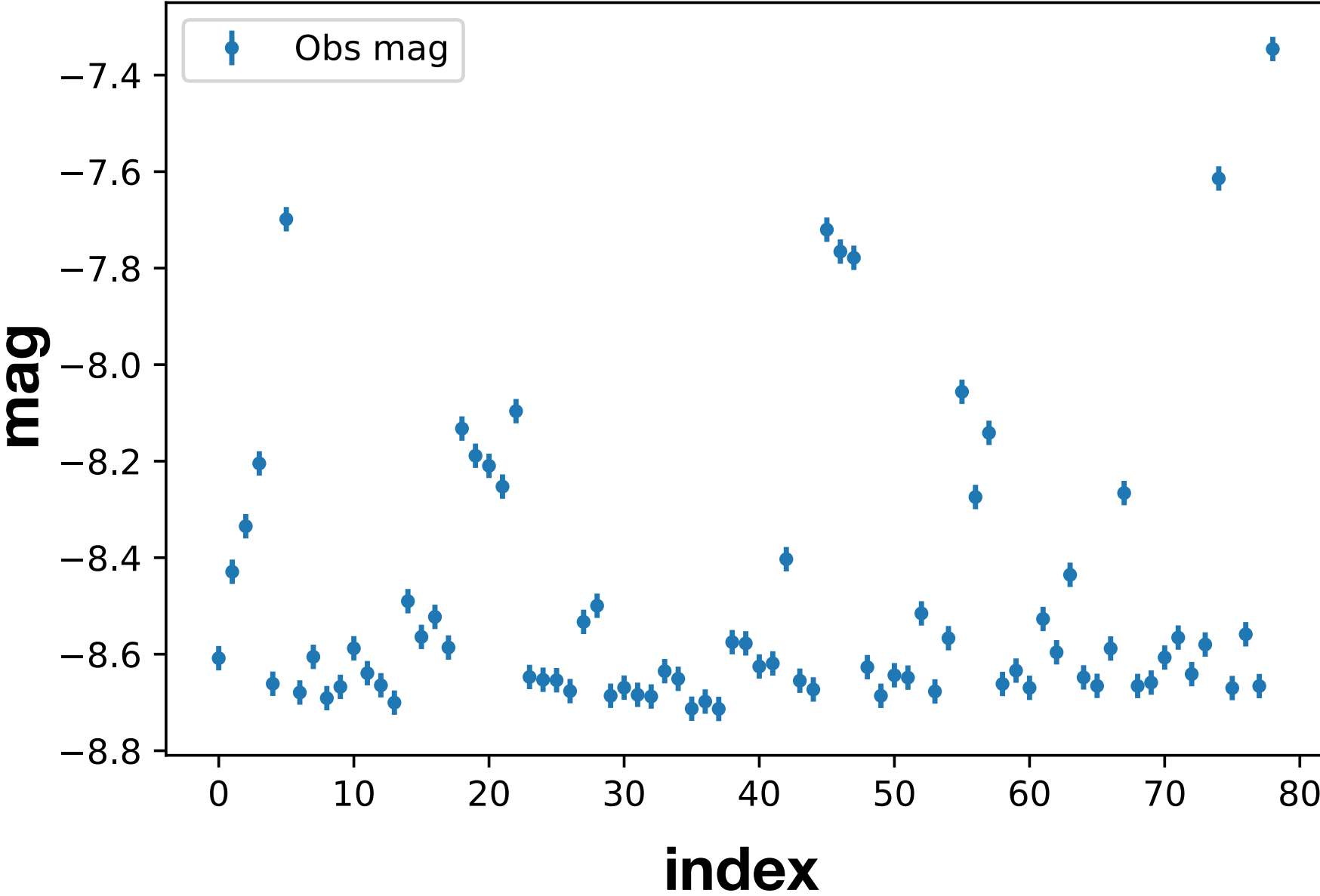
$C$  : diagonal matrix with weights of  $m_{i,j}$  measurements

**Covariance of parameters**

**given by:  $[A^t C A]^{-1}$**

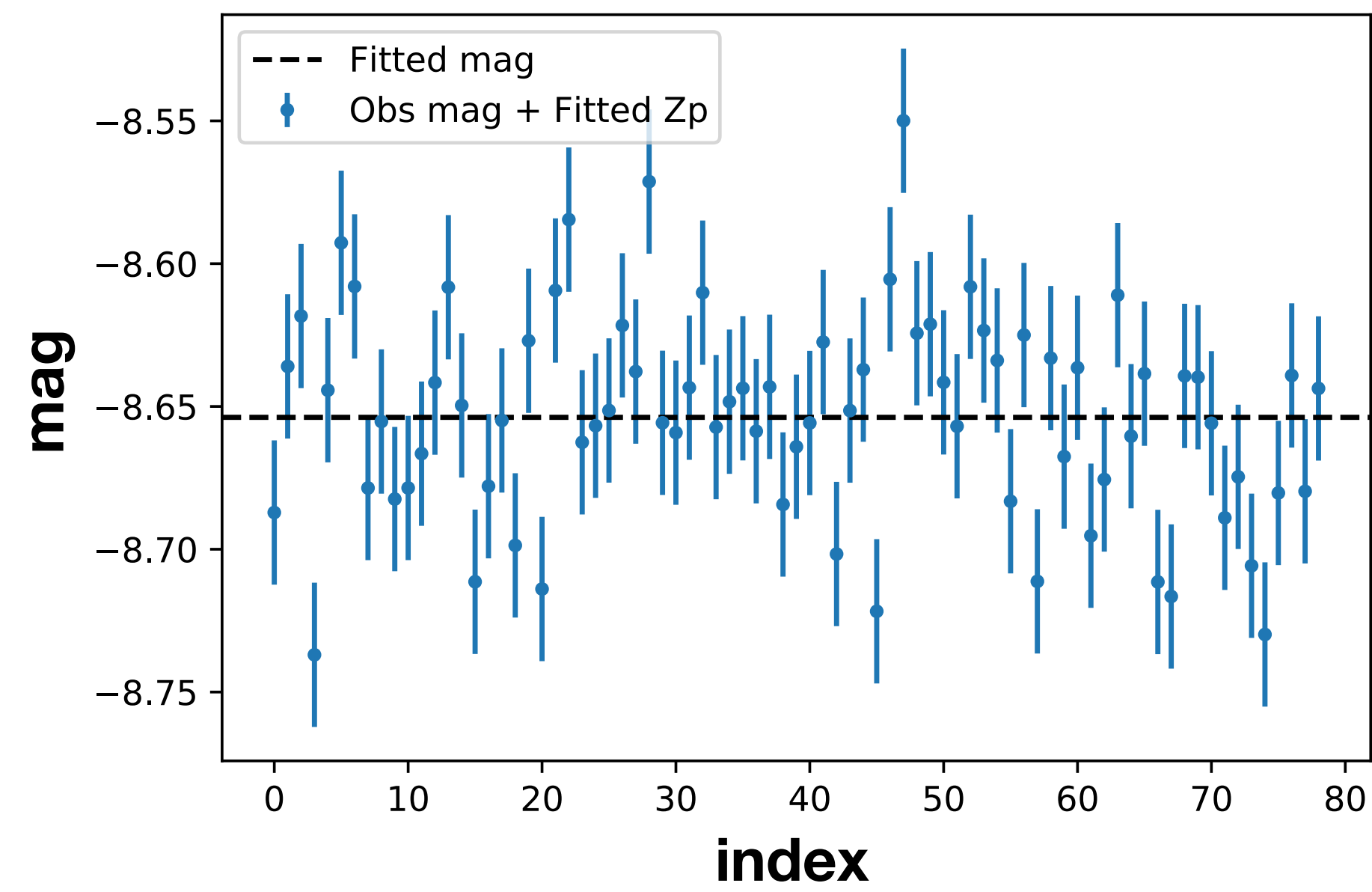
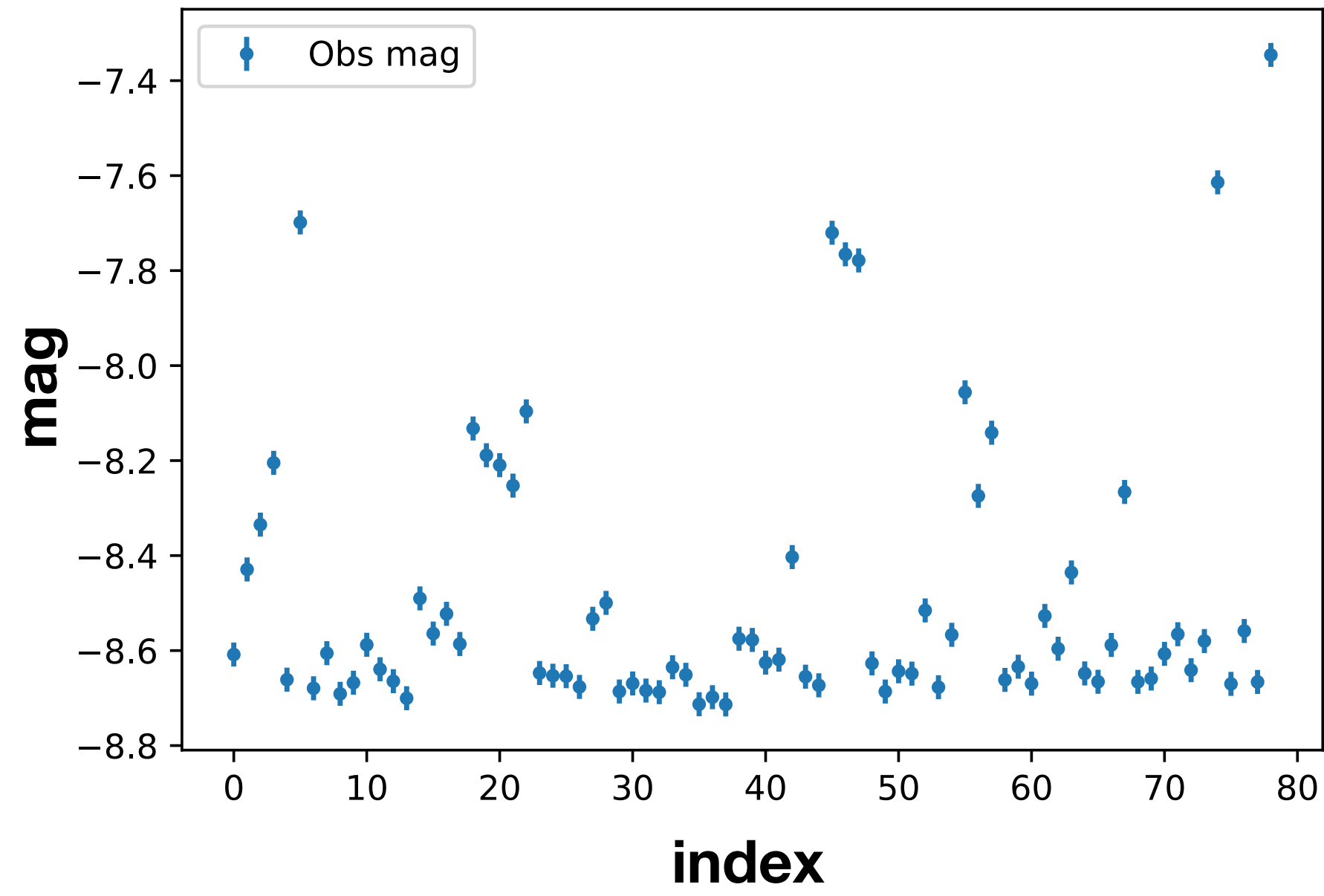
# Result on one star (79 obs here)

⚠ ubercal mags are relative

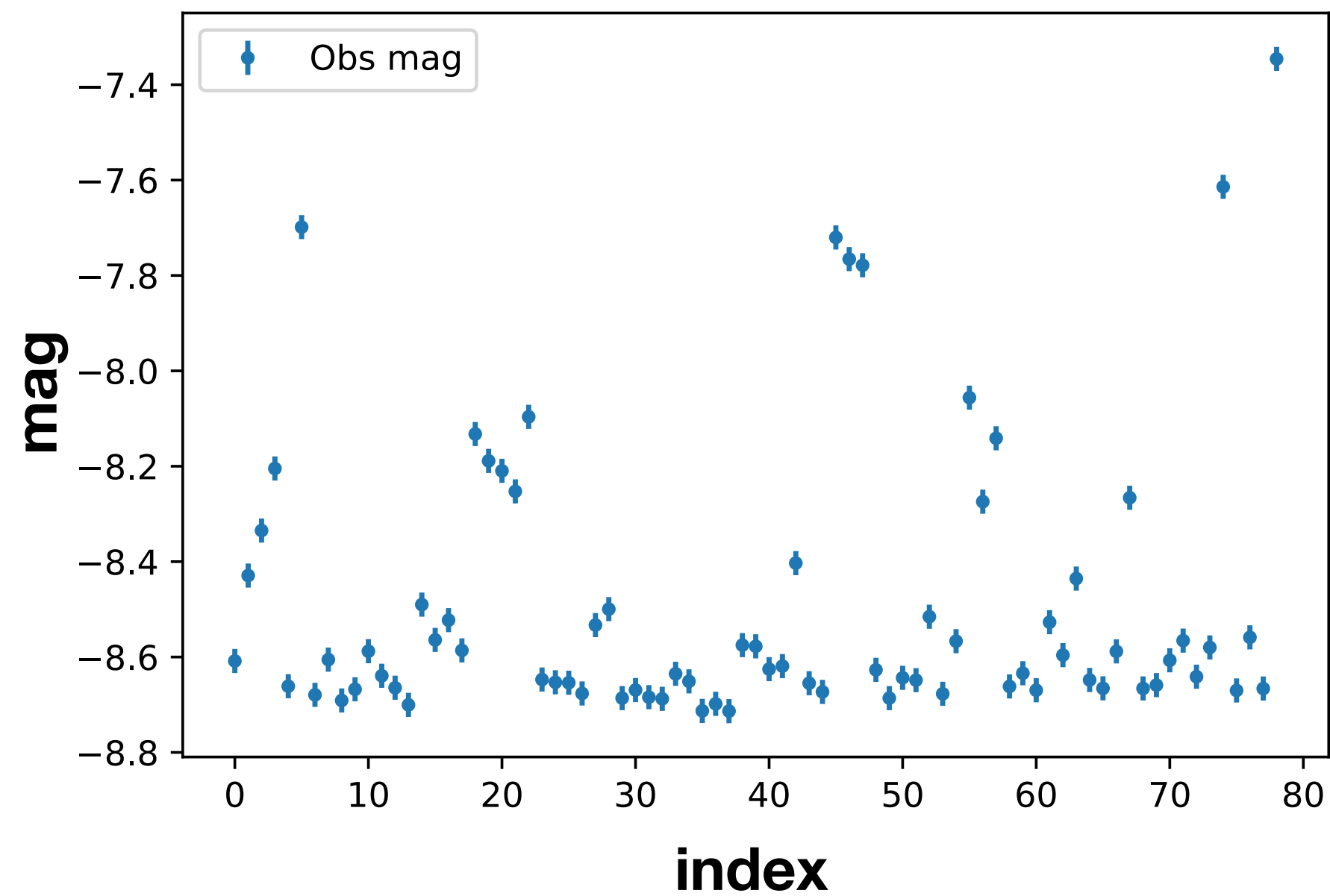


# Result on one star (79 obs here)

⚠ ubercal mags are relative

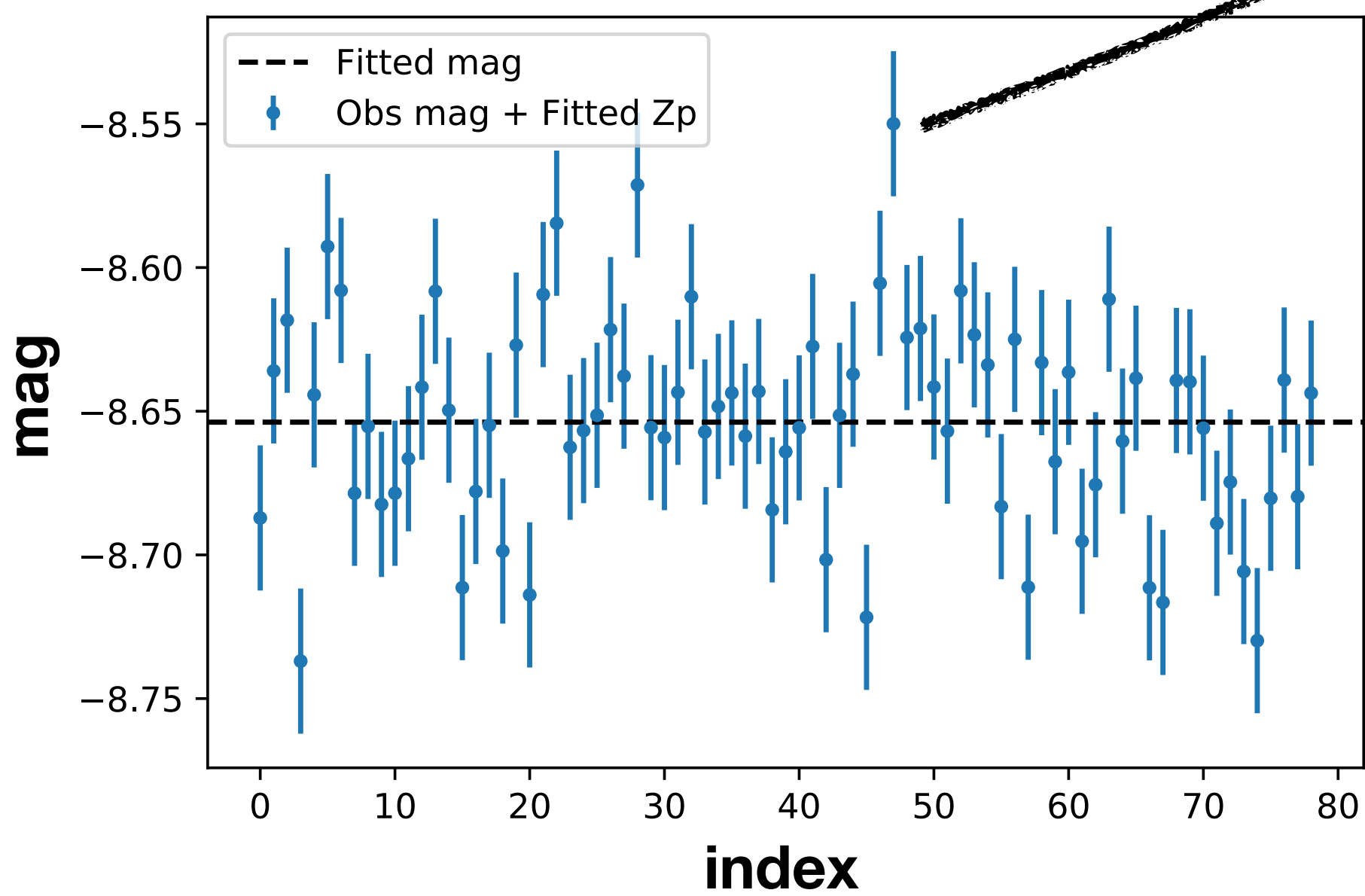
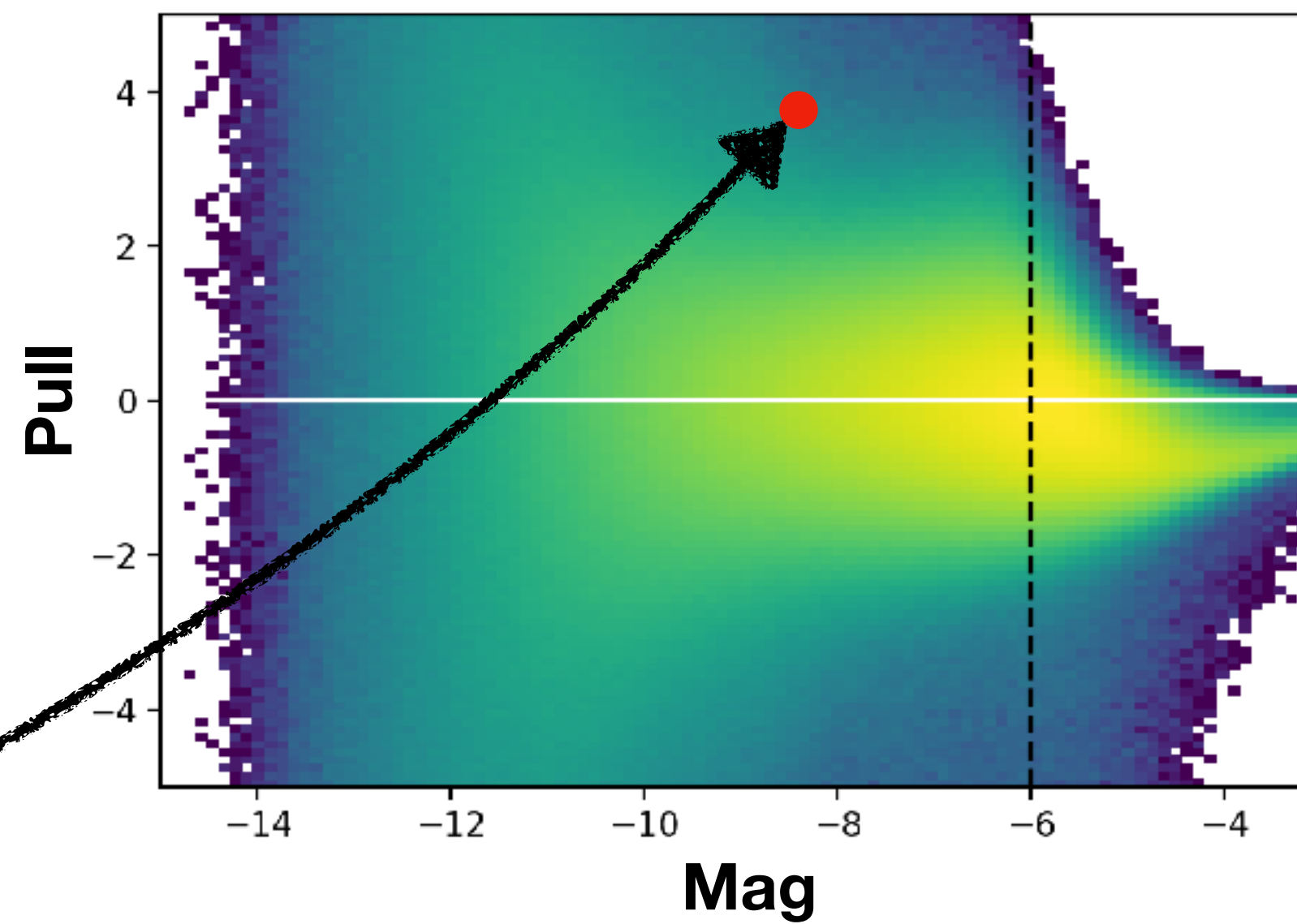


# Result on one star (79 obs here)

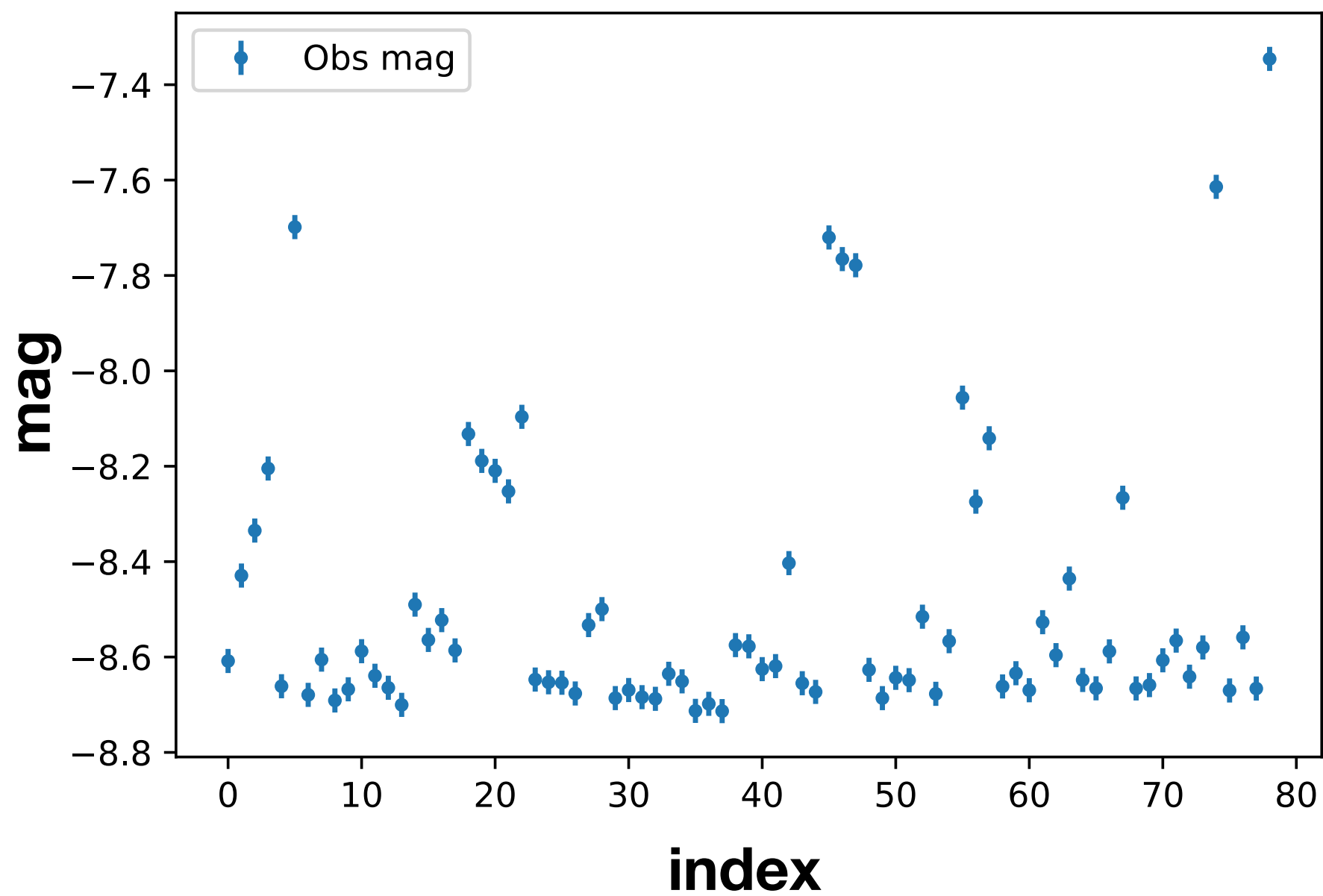


# Result on all stars

! ubercal mags are relative

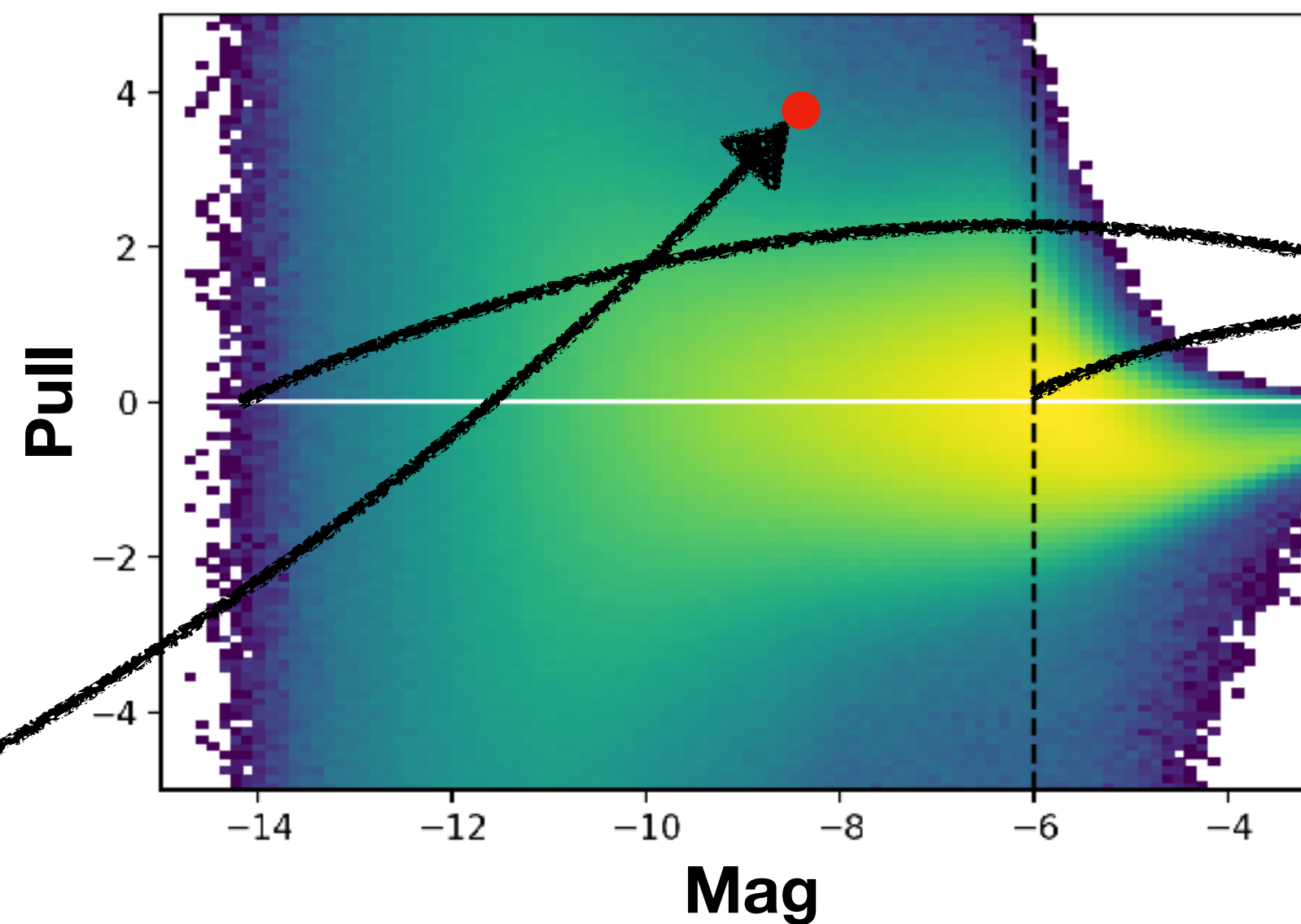


# Result on one star (79 obs here)

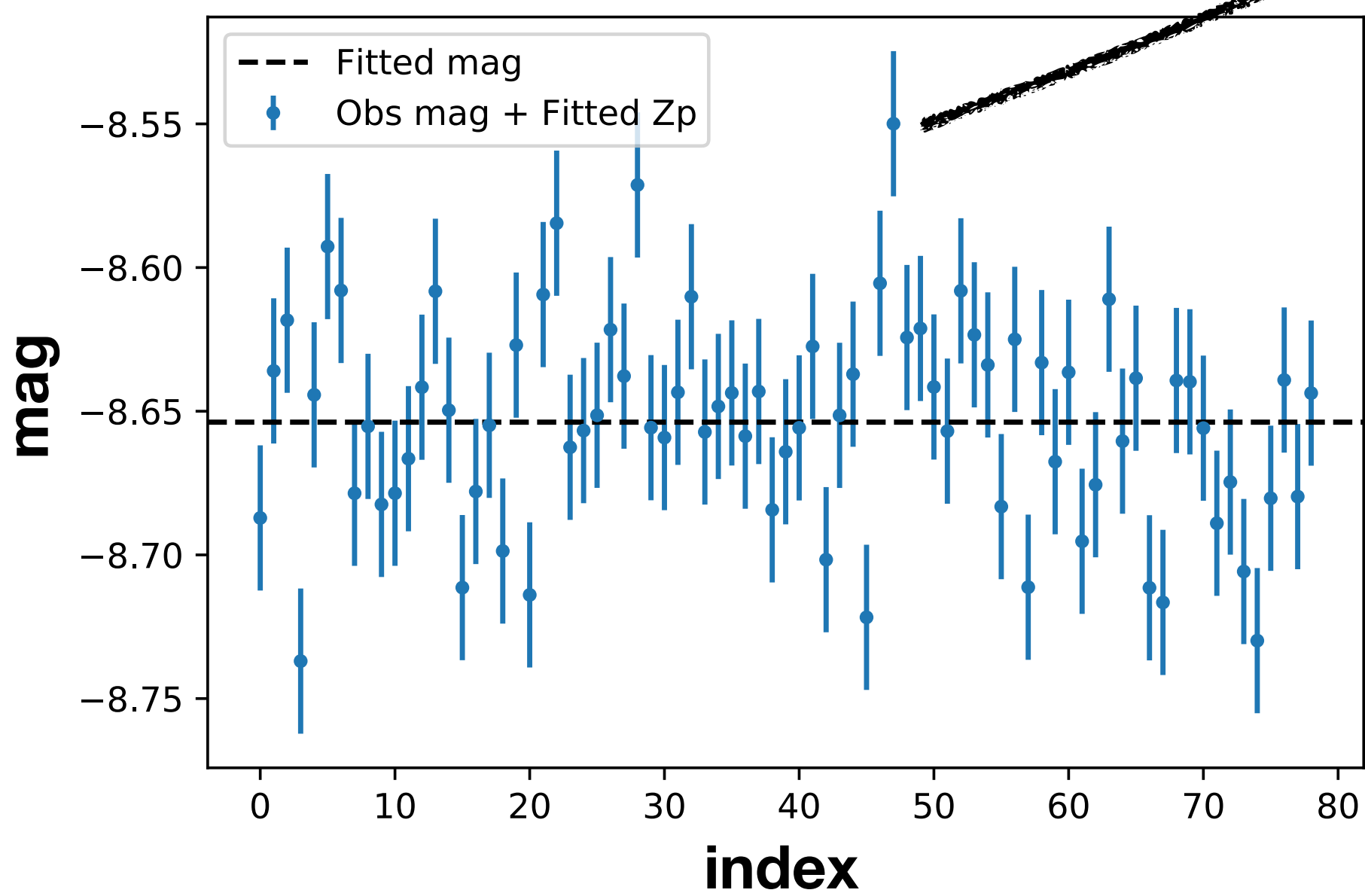
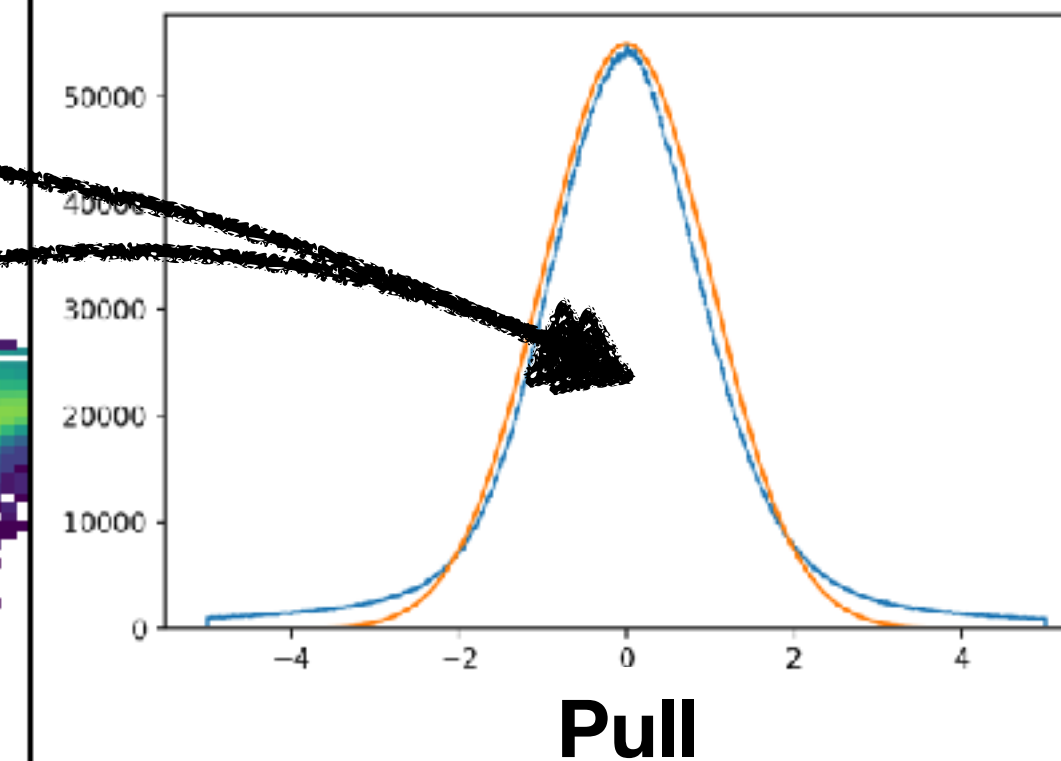


# Result on all stars

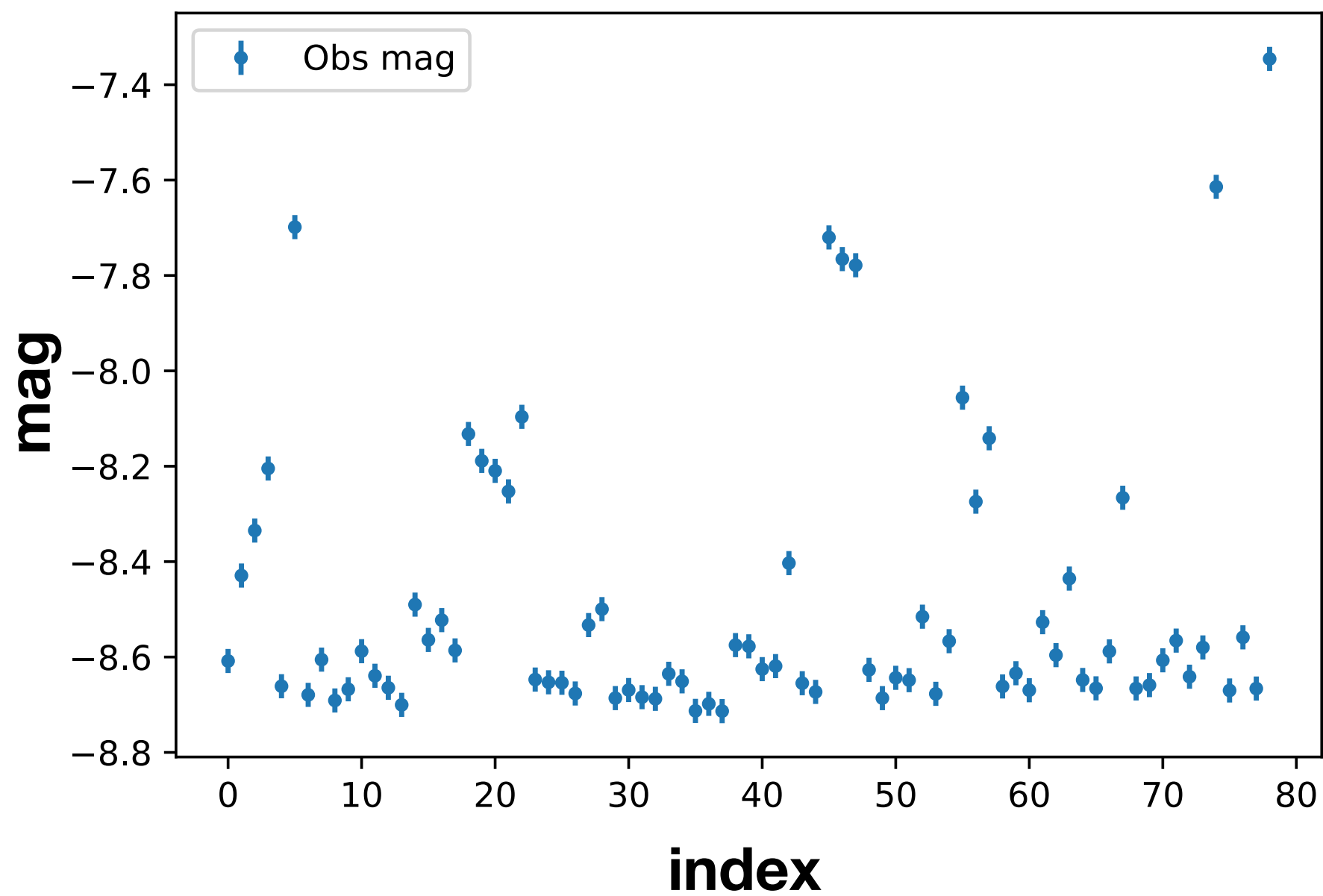
⚠ ubercal mags are relative



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

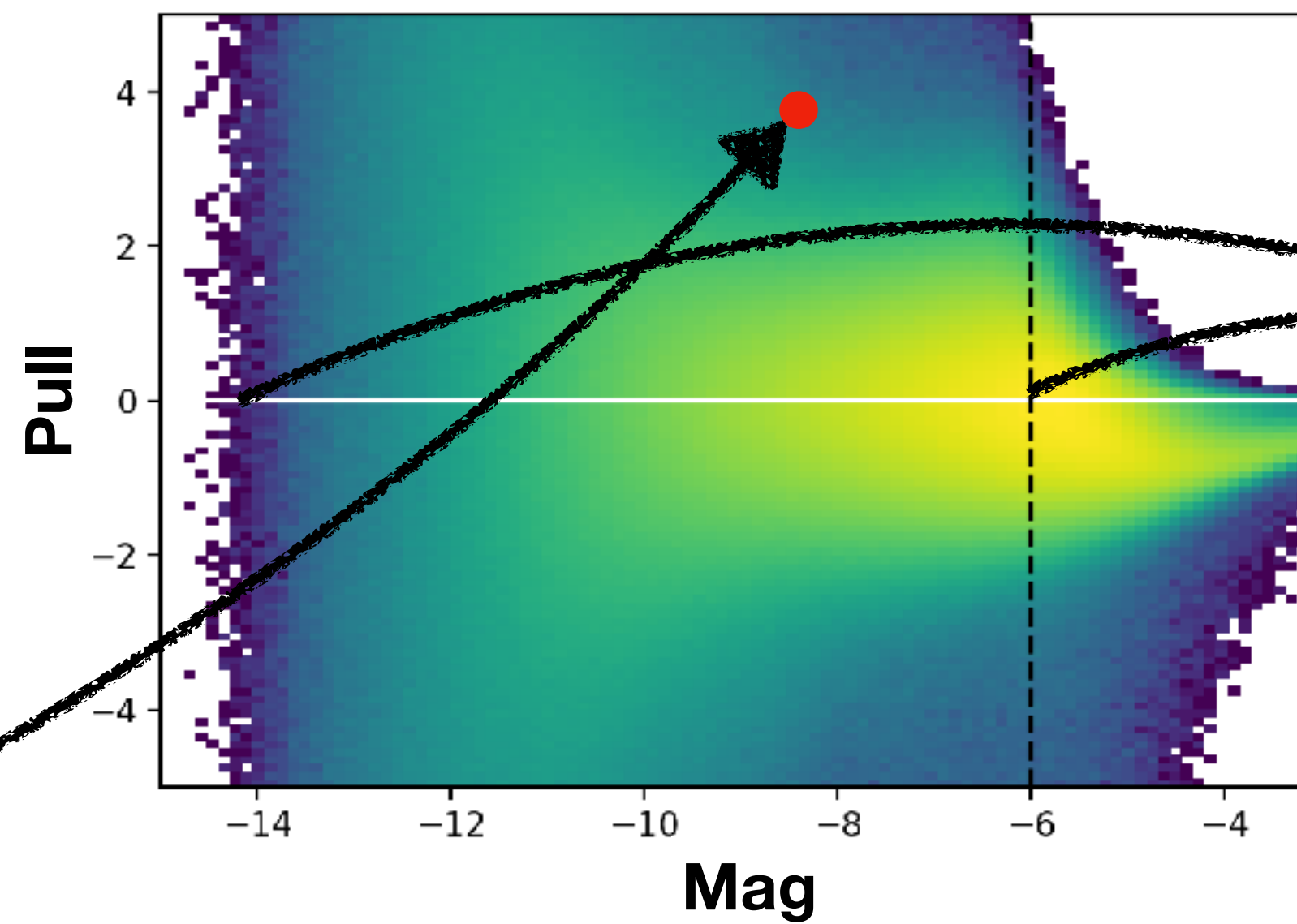


# Result on one star (79 obs here)

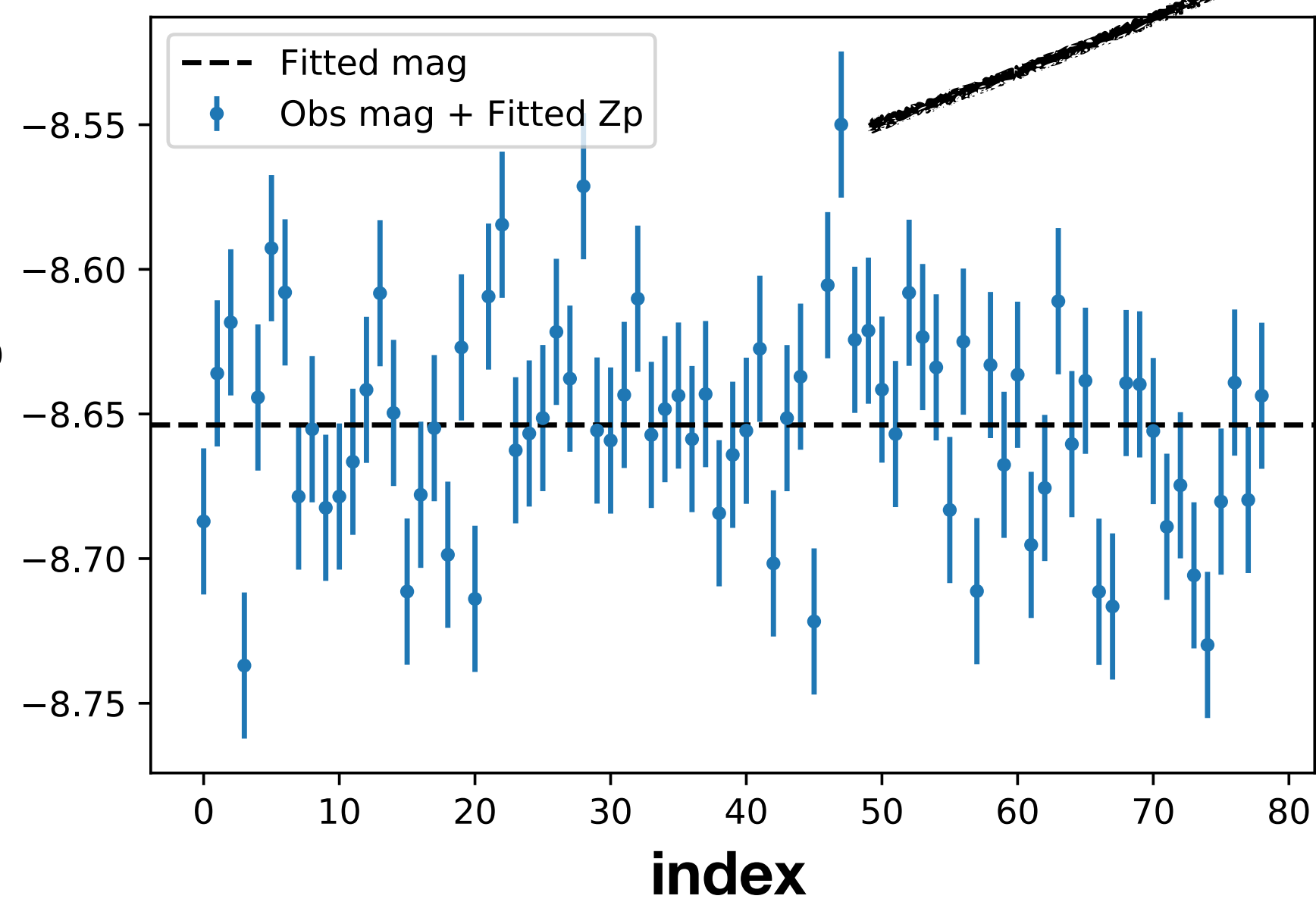
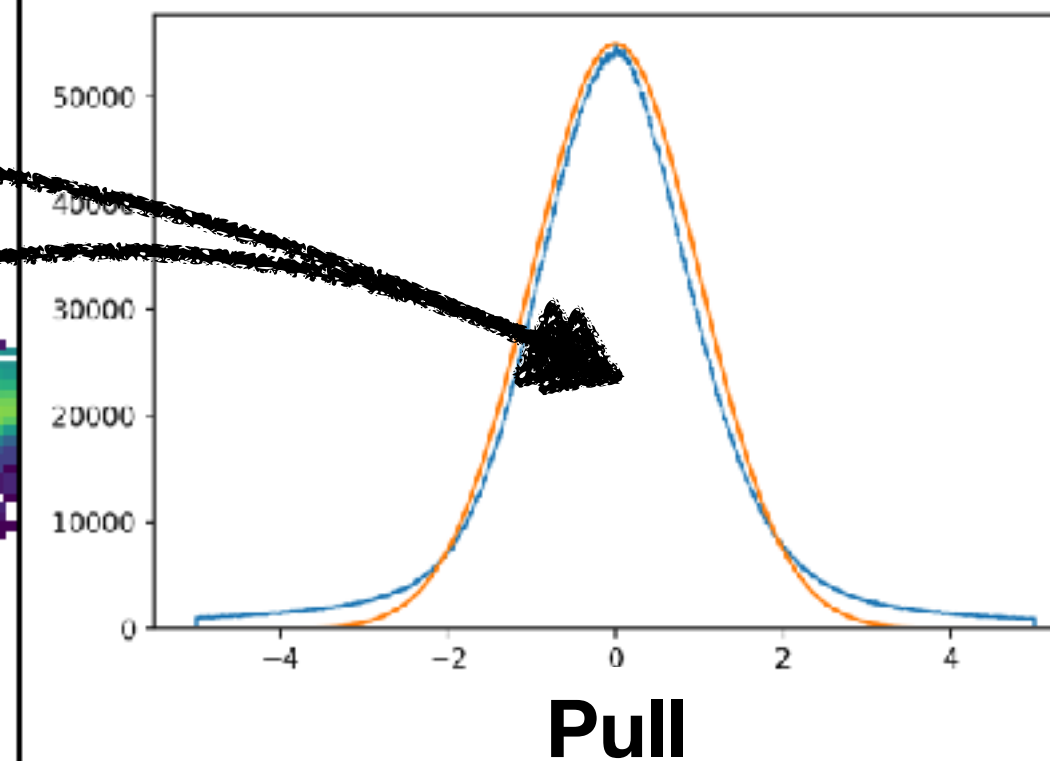


# Result on all stars

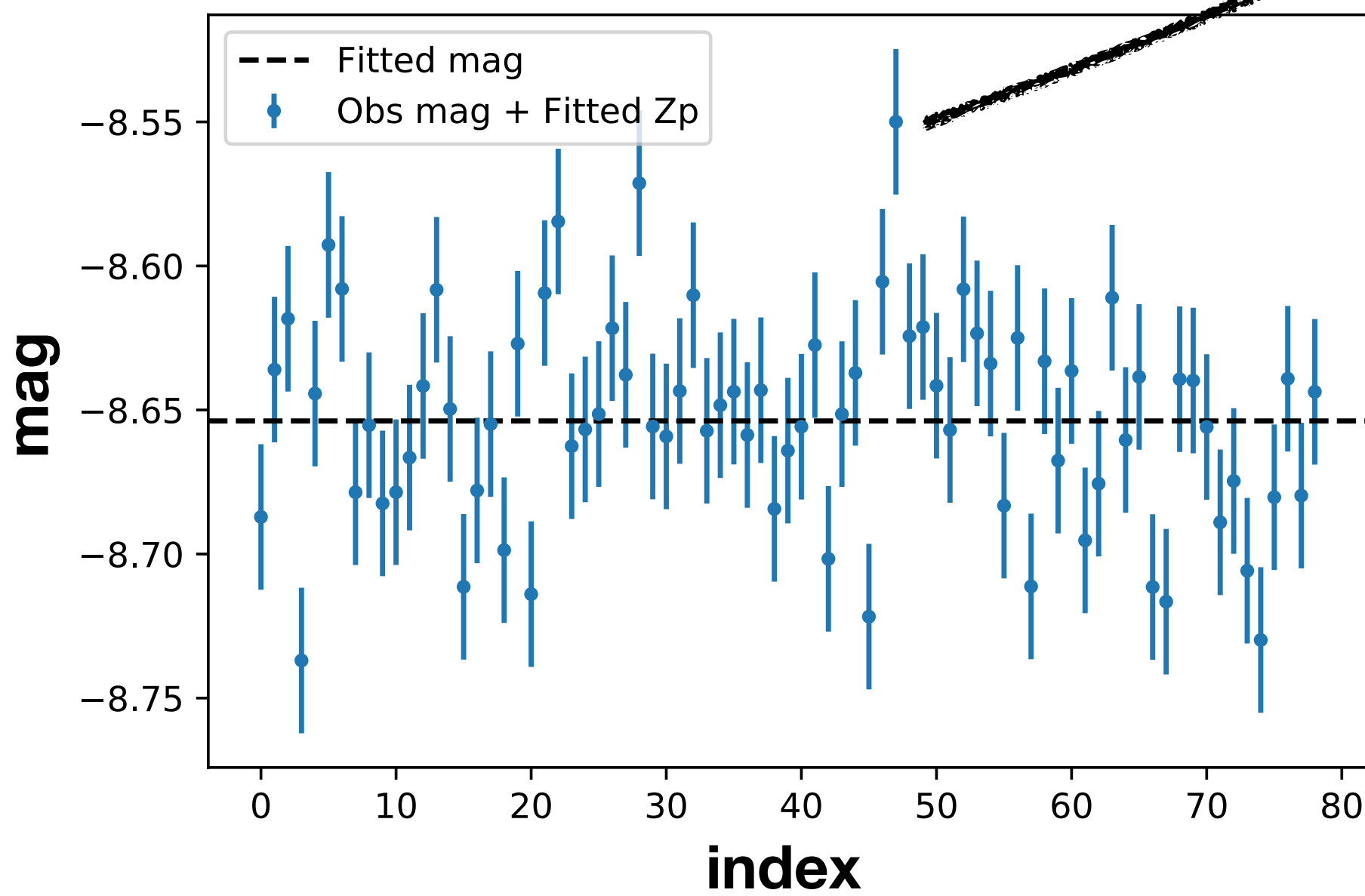
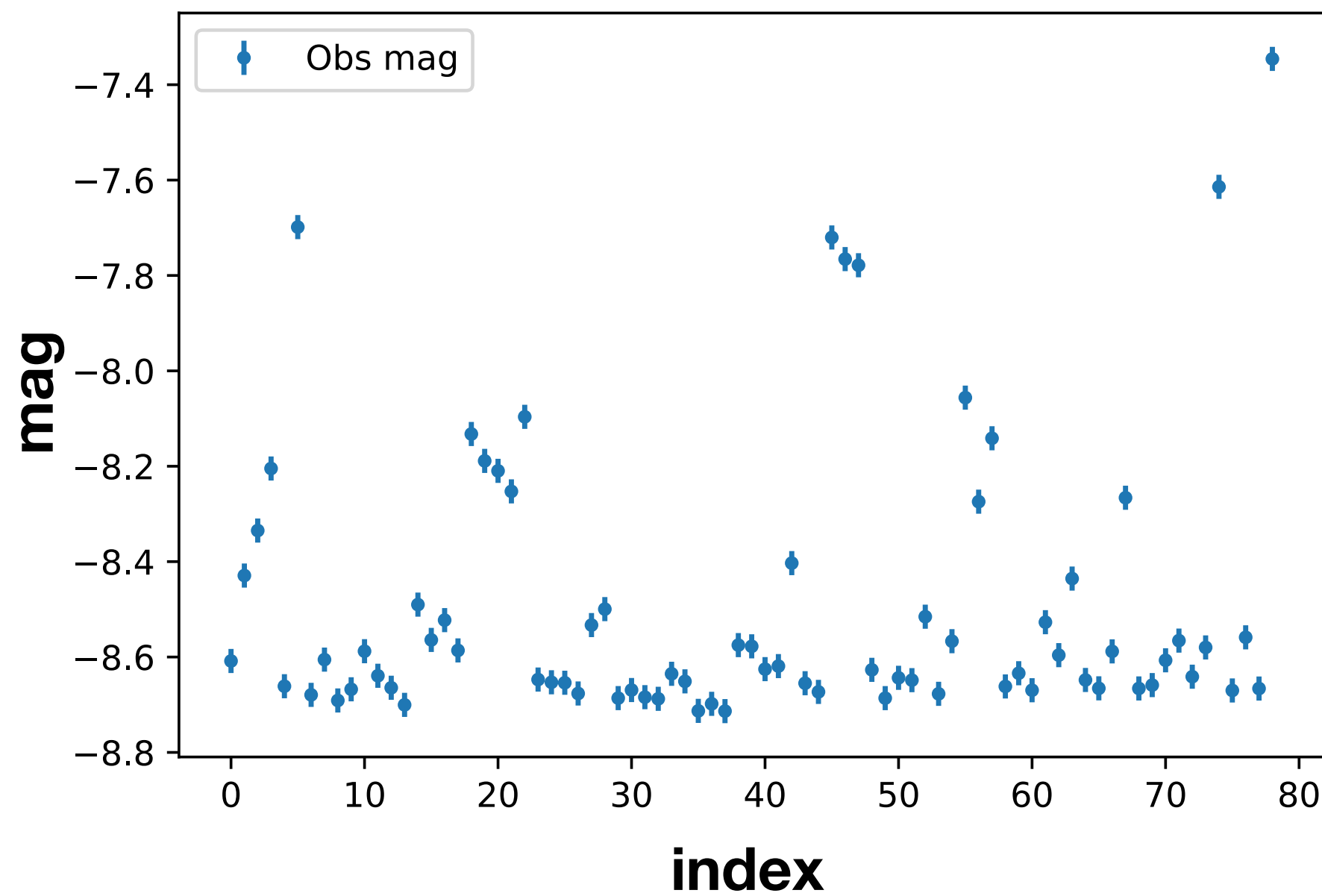
⚠ ubercal mags are relative



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

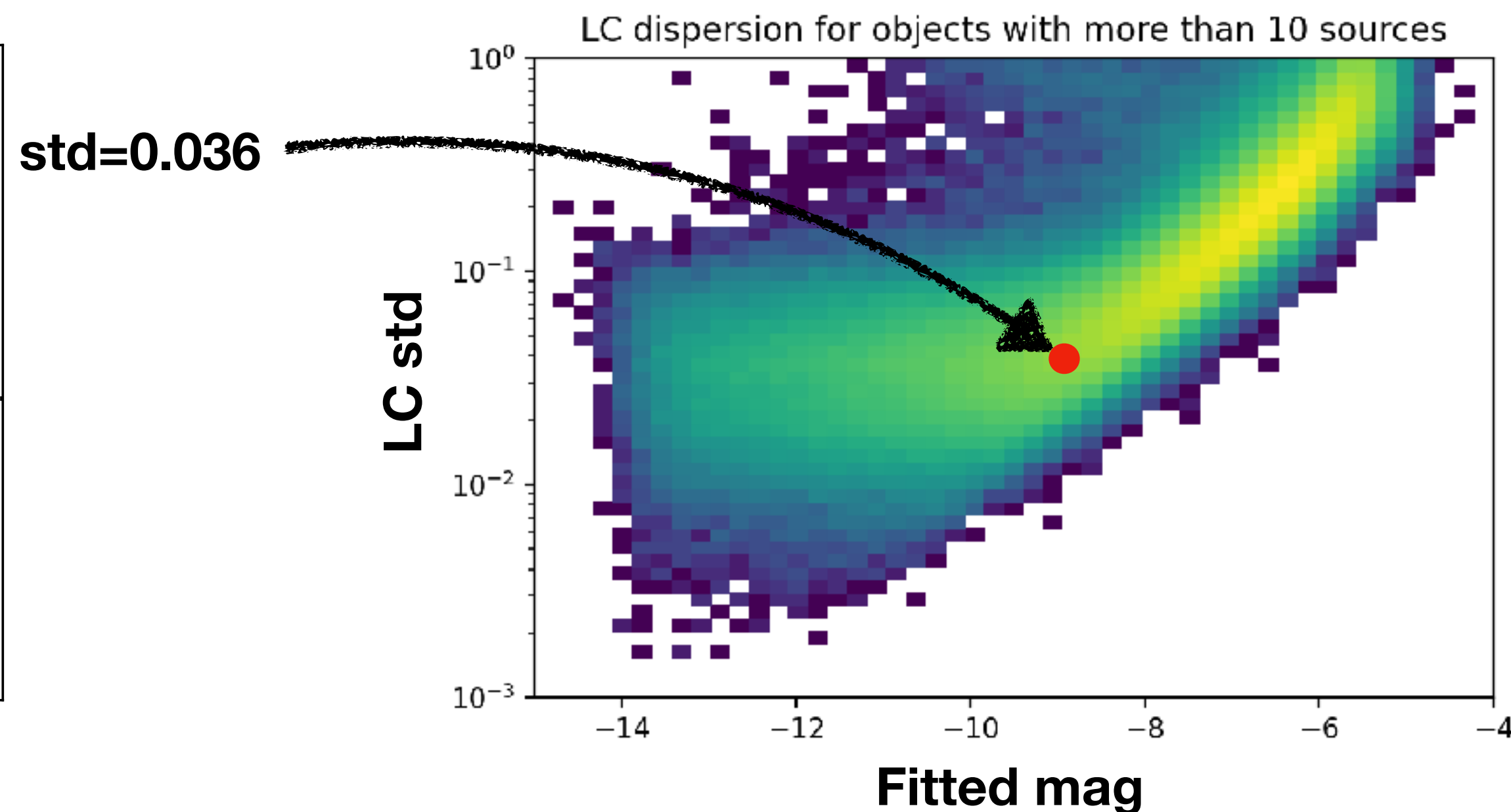
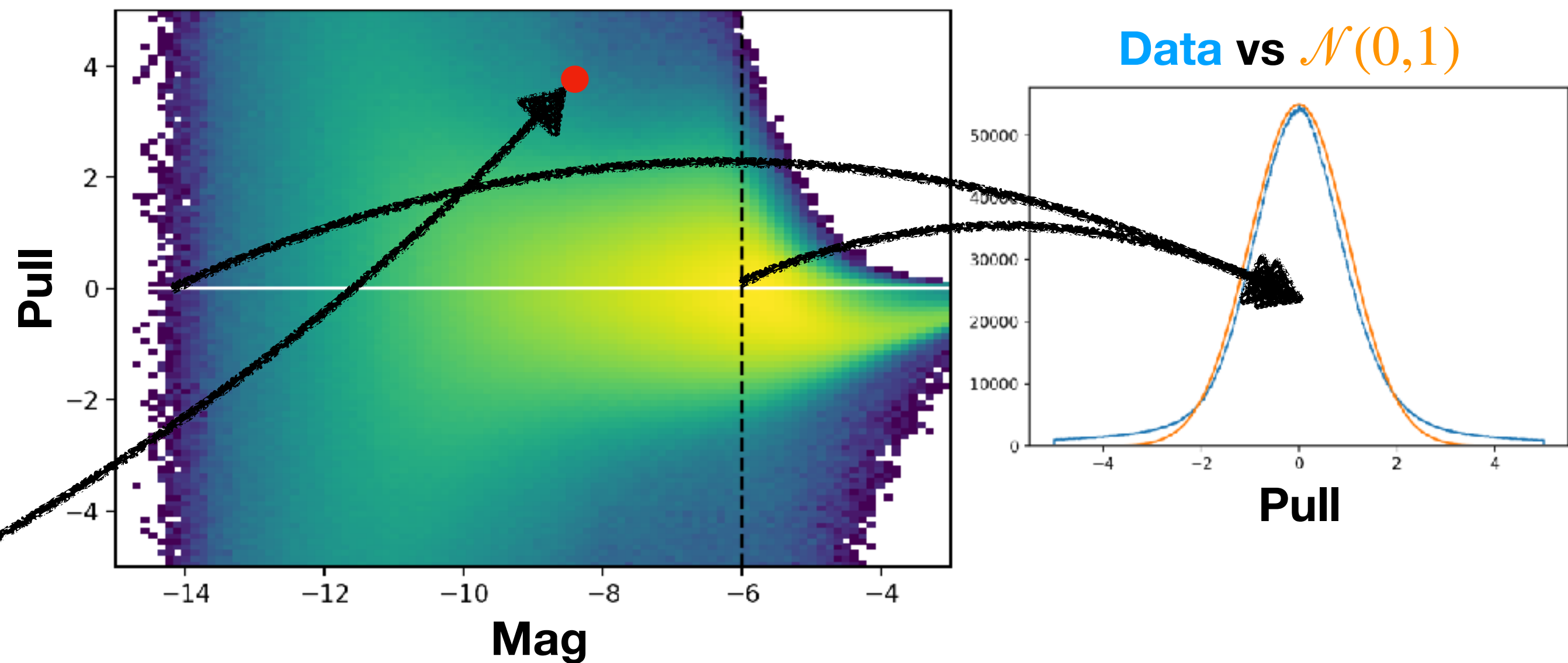


# Result on one star (79 obs here)



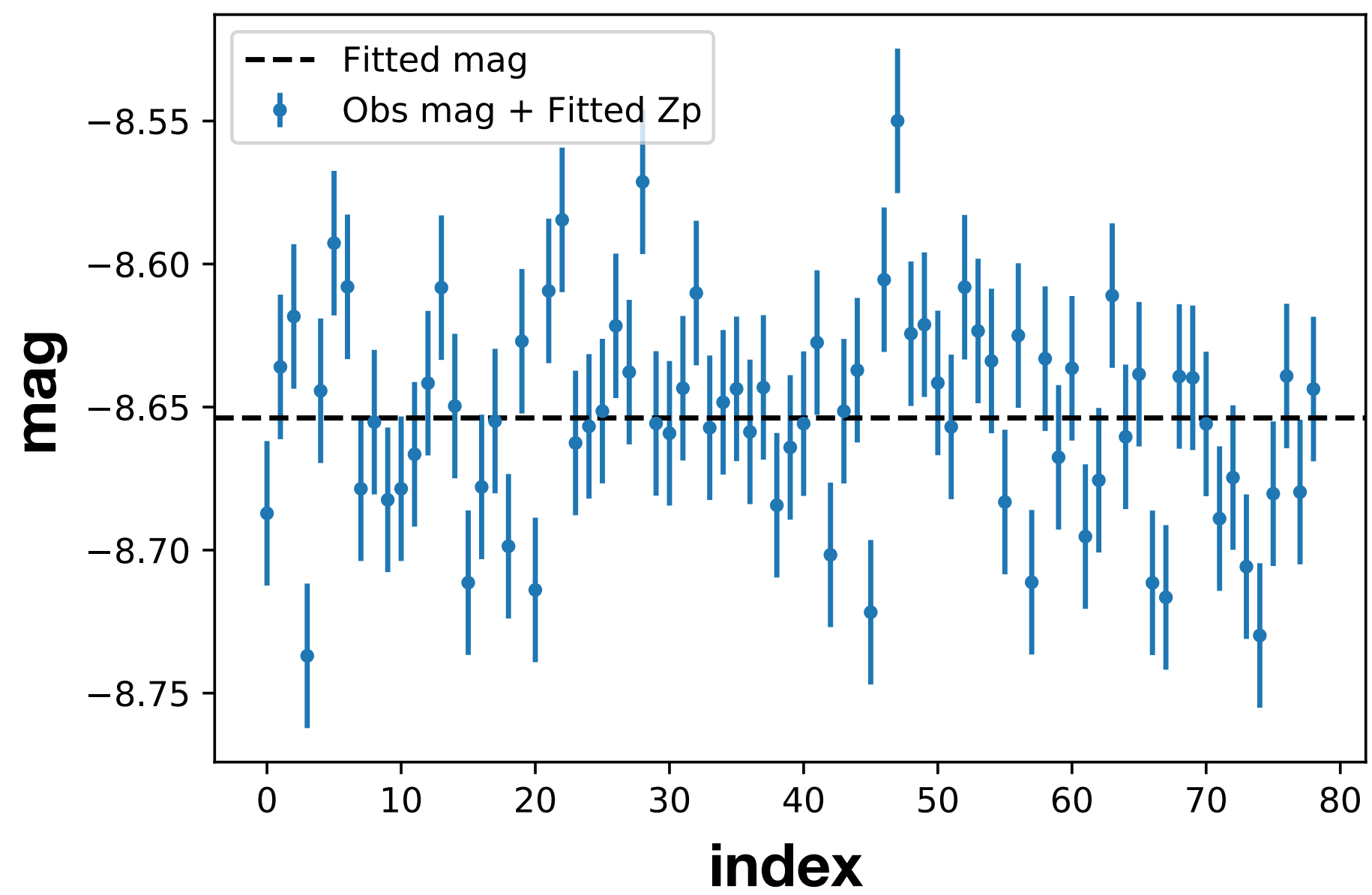
# Result on all stars

⚠ ubercal mags are relative

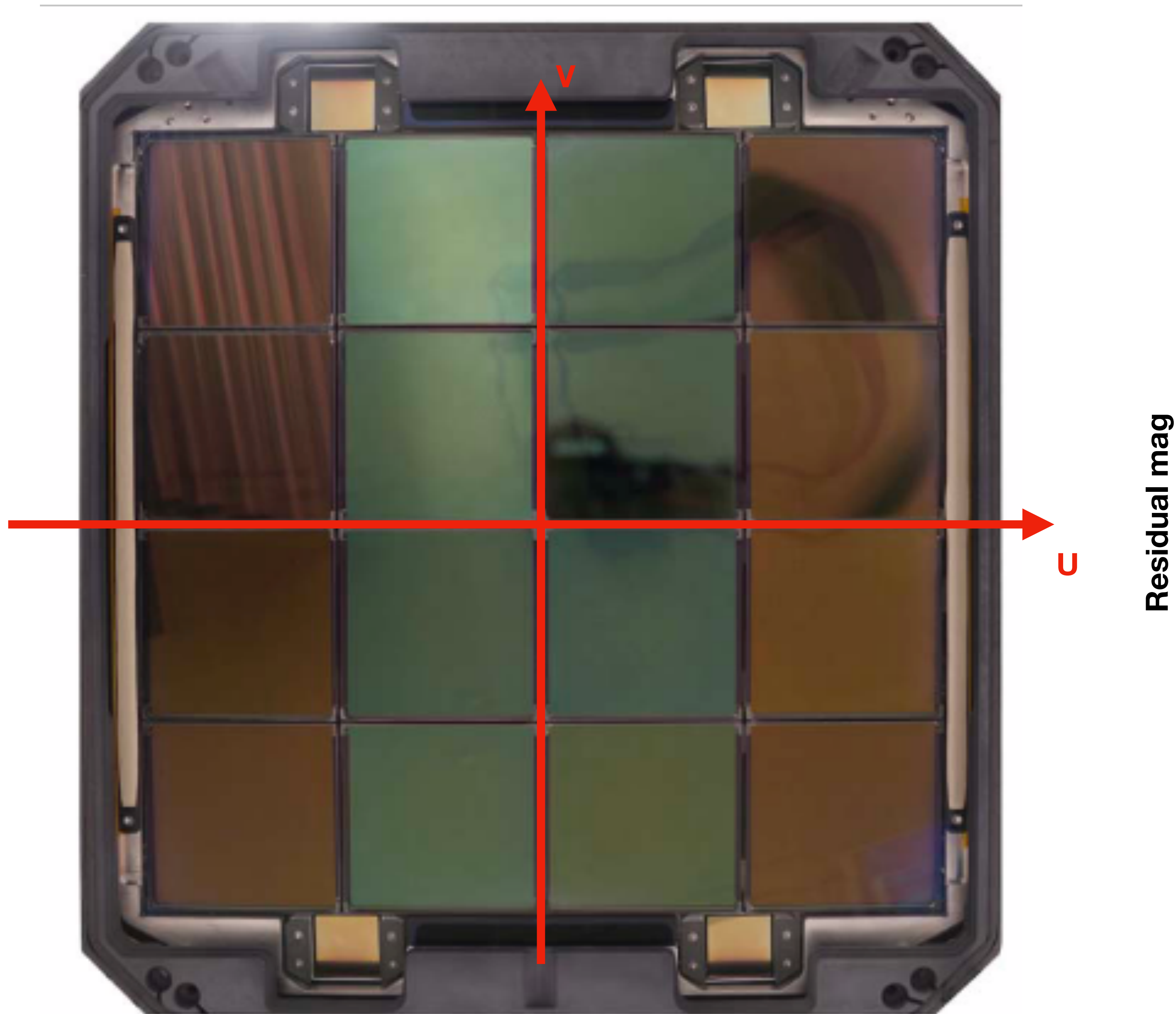




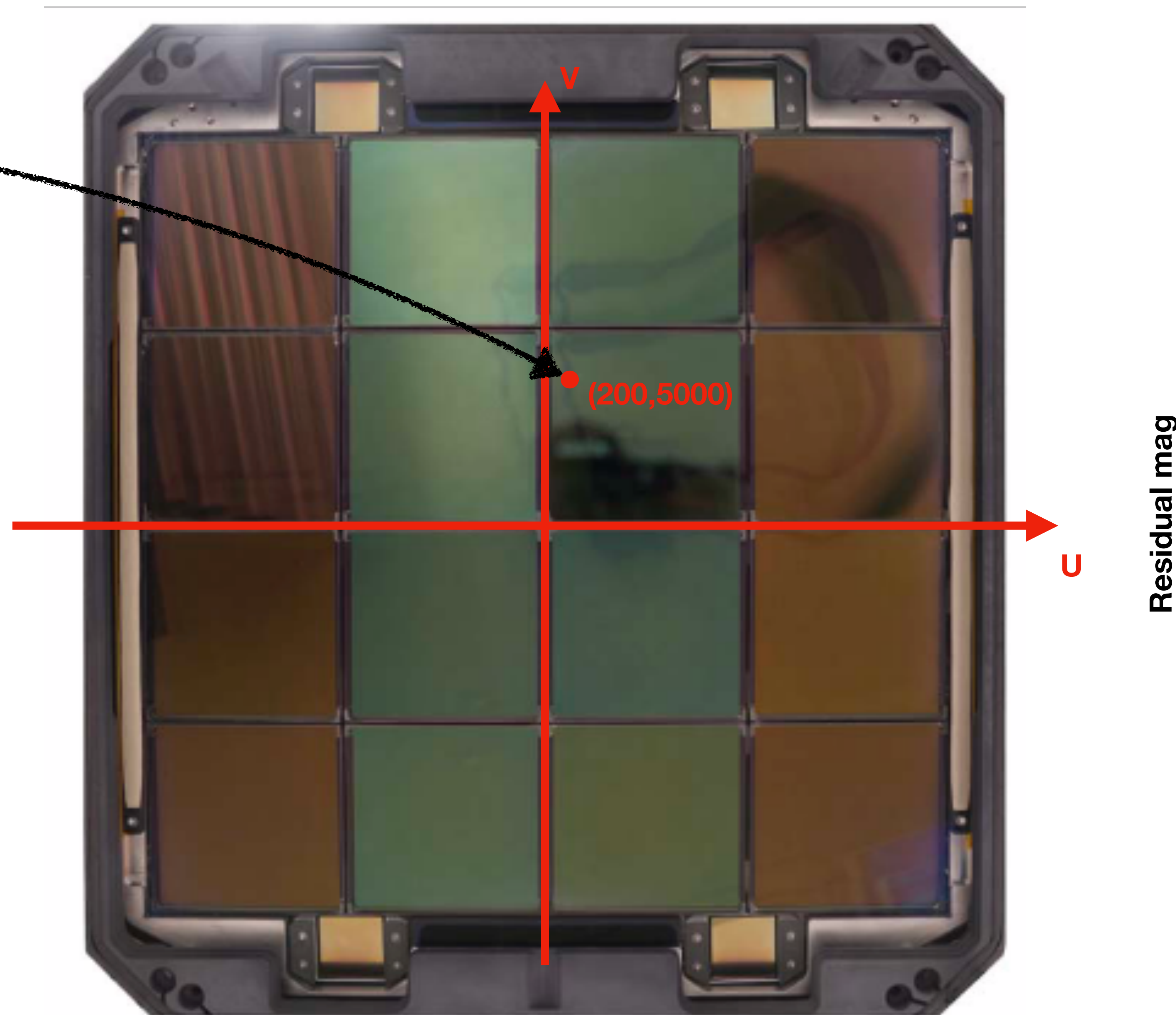
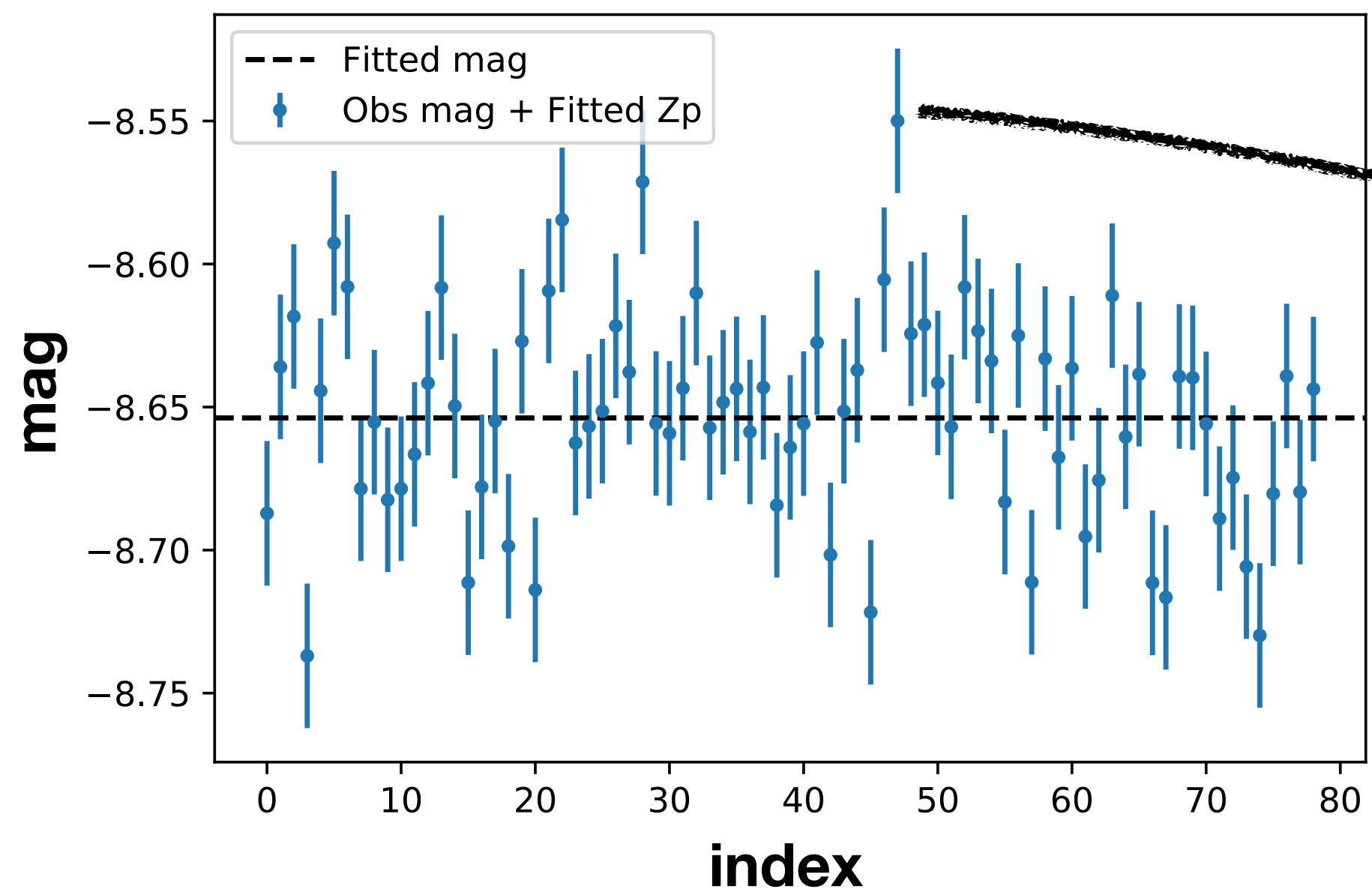
# Result on one star (79 obs here)



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

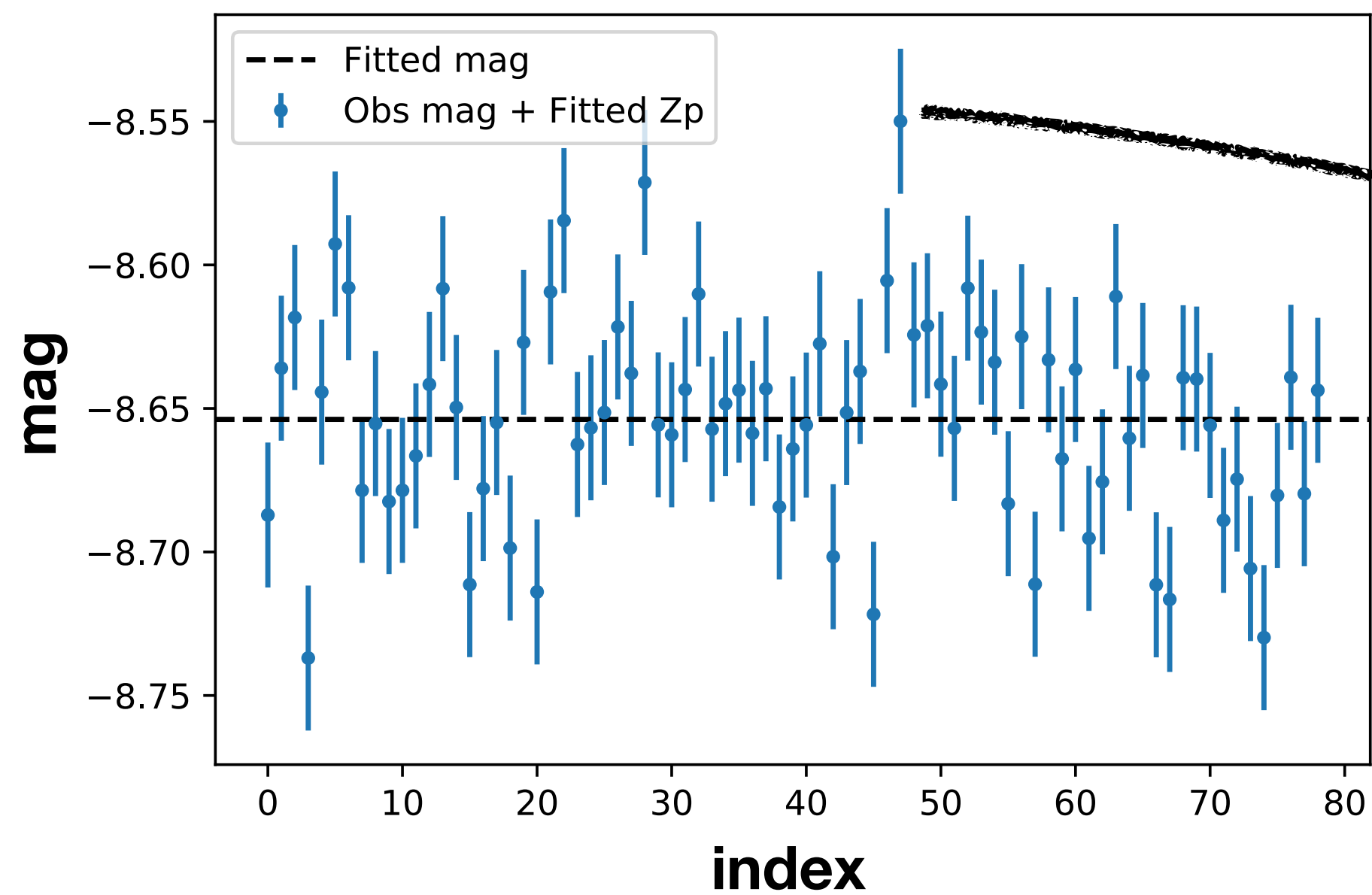


# Result on one star (79 obs here)



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

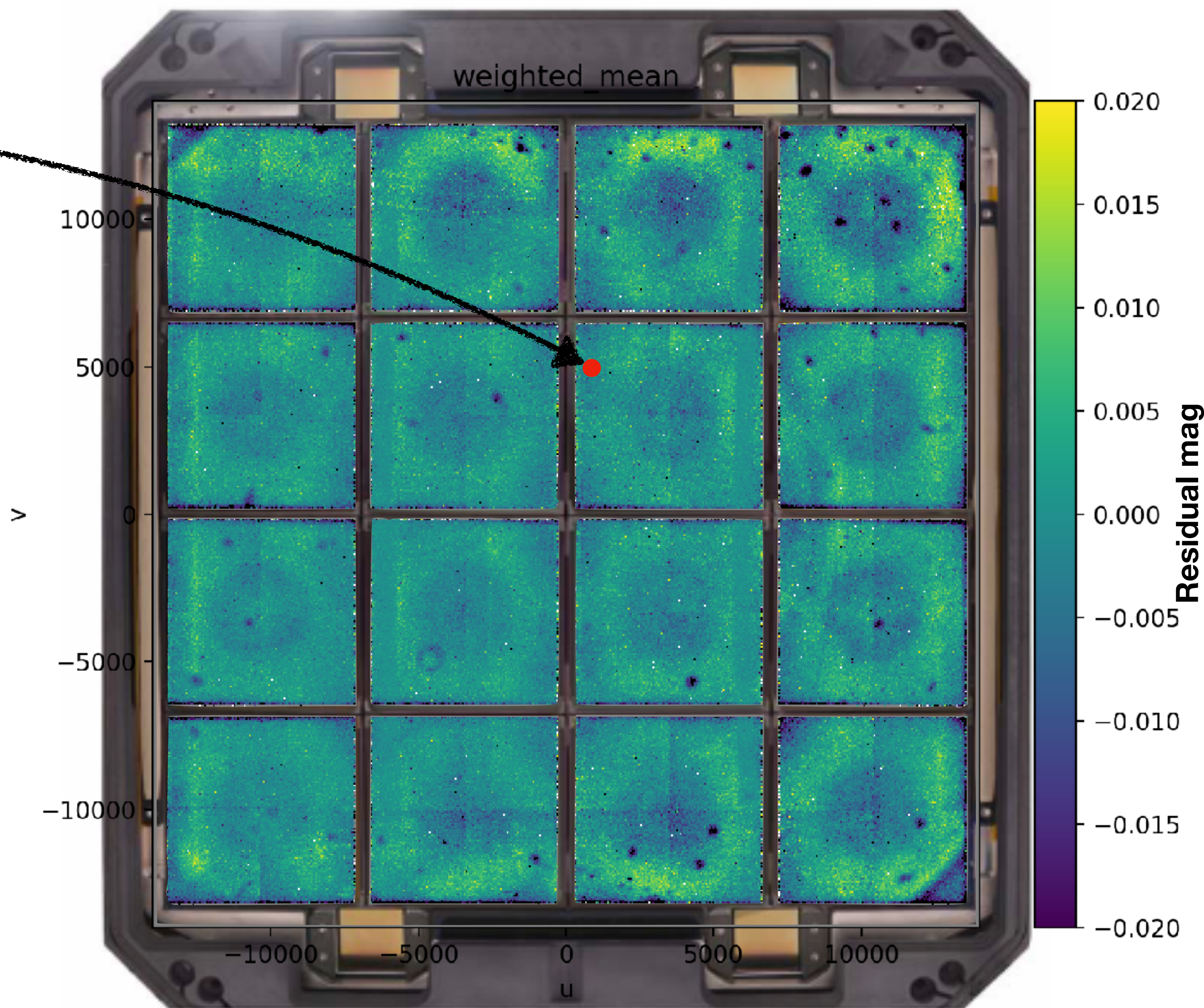
# Result on one star (79 obs here)



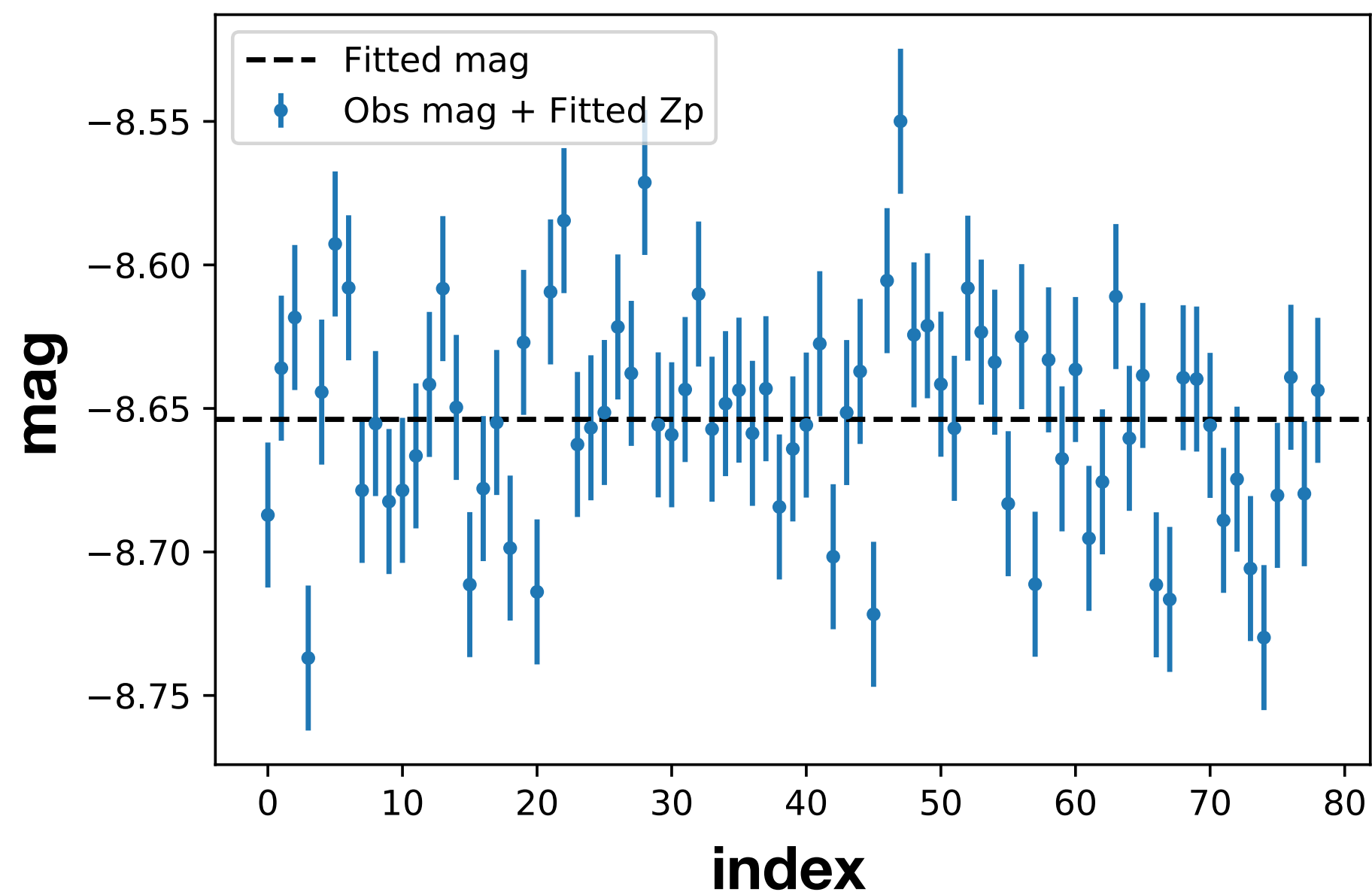
**For each exposure, sources are observed  
at a specific position on the focal plane  
(uv coordinates)**

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

# Result on all stars



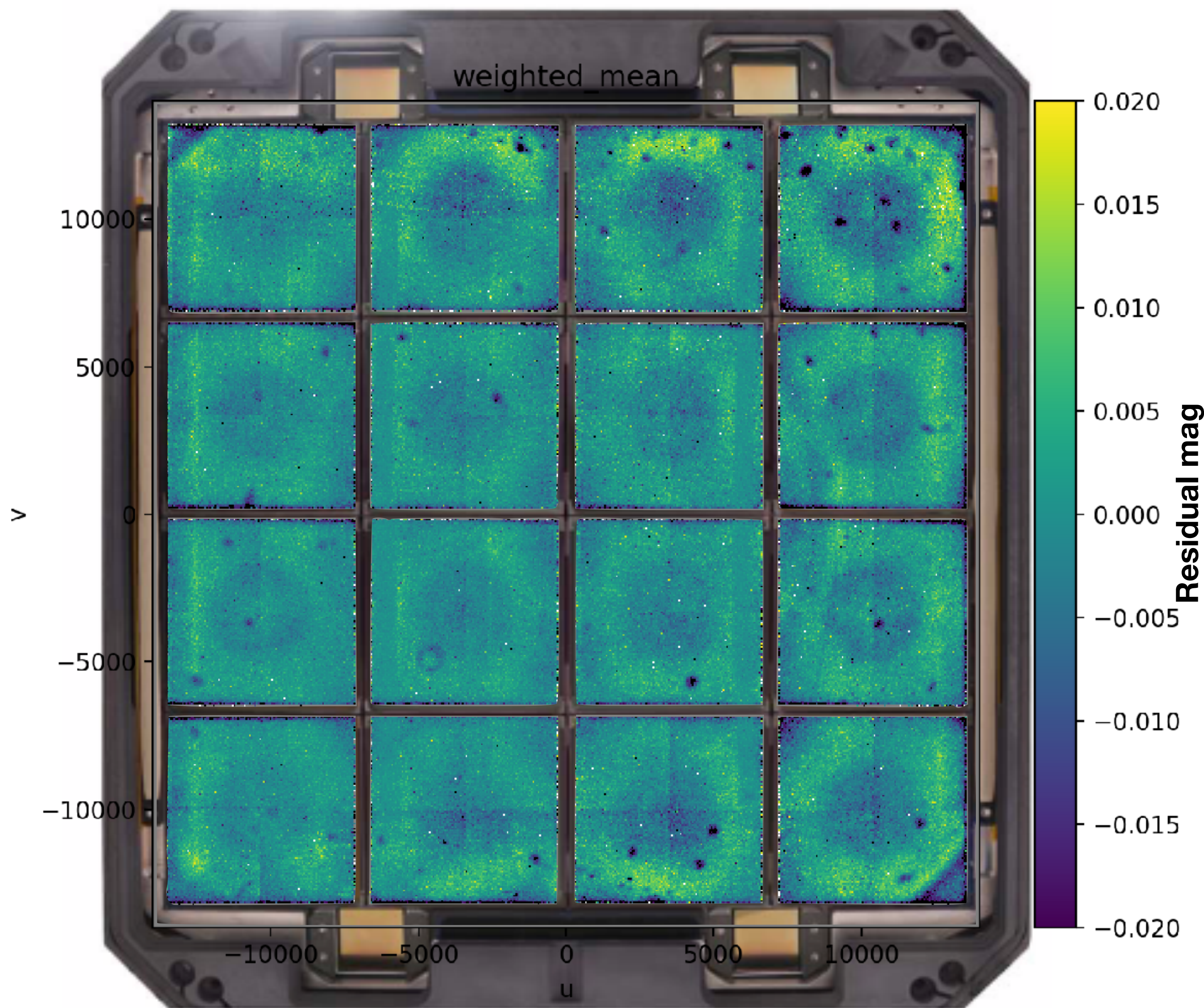
# Result on one star (79 obs here)



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

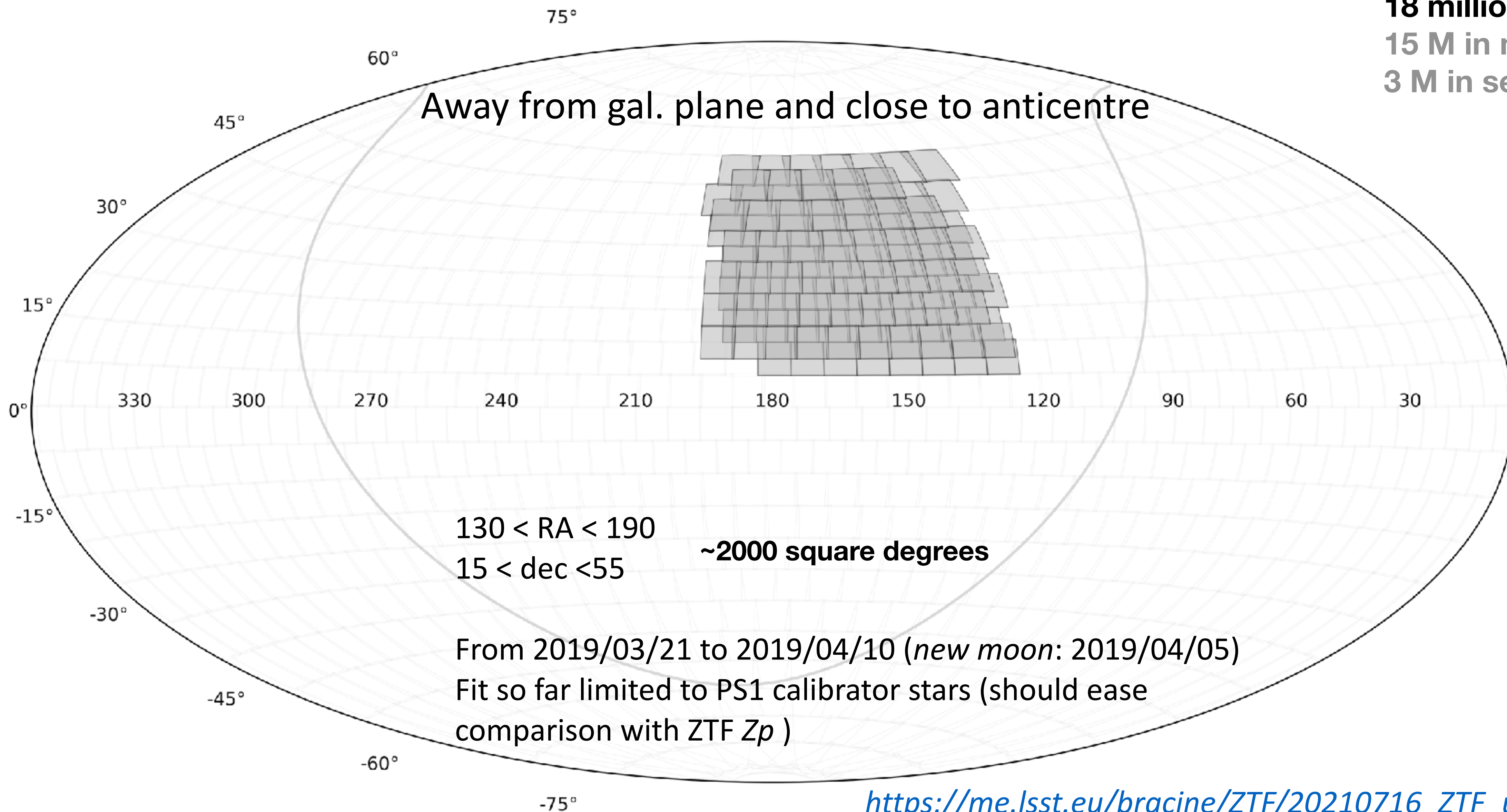
**We can then bin in uv  
each observation's residual  
and plot the weighted mean**

# Result on all stars



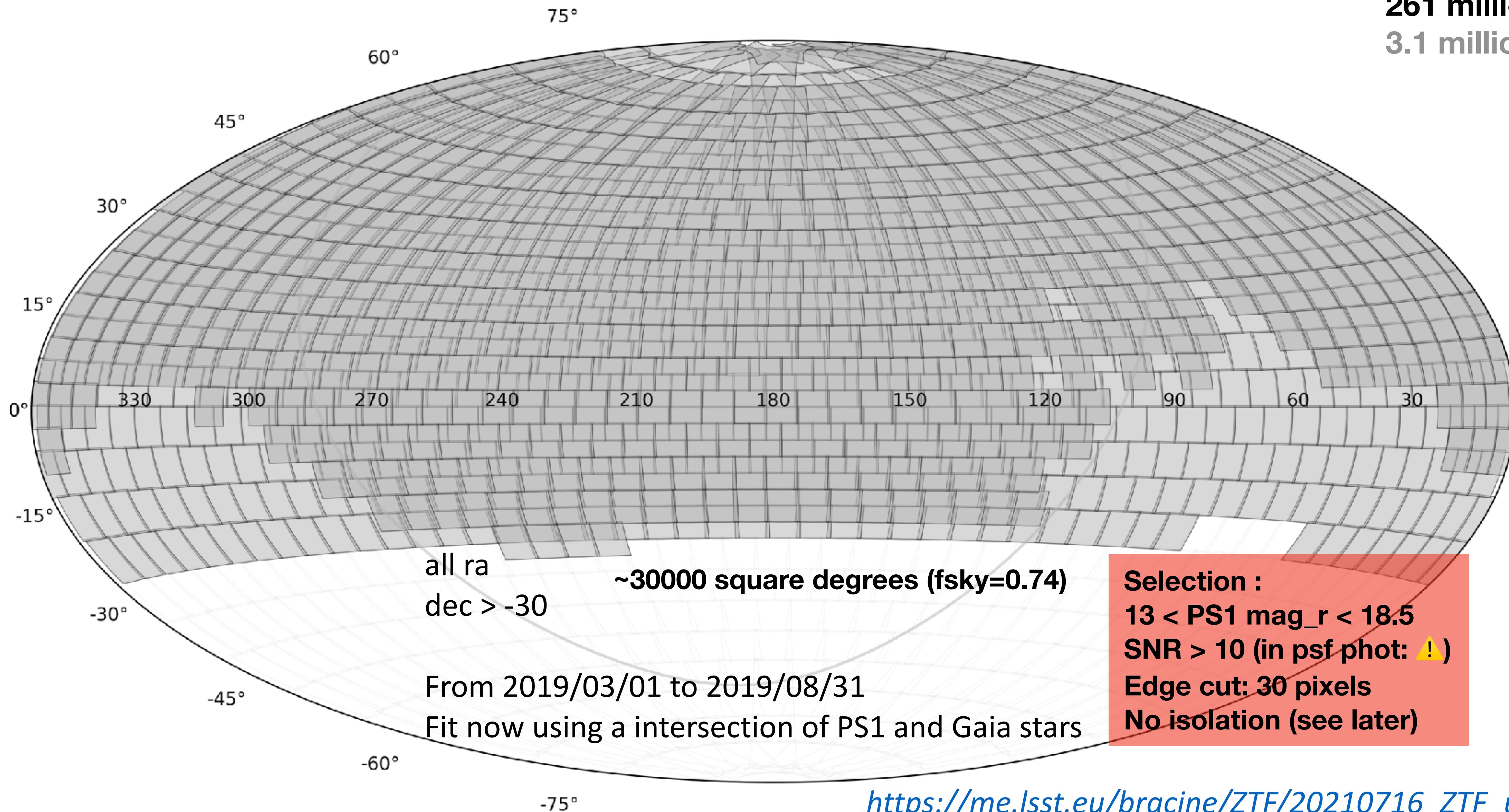
## Toy test case

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



## 6 month case

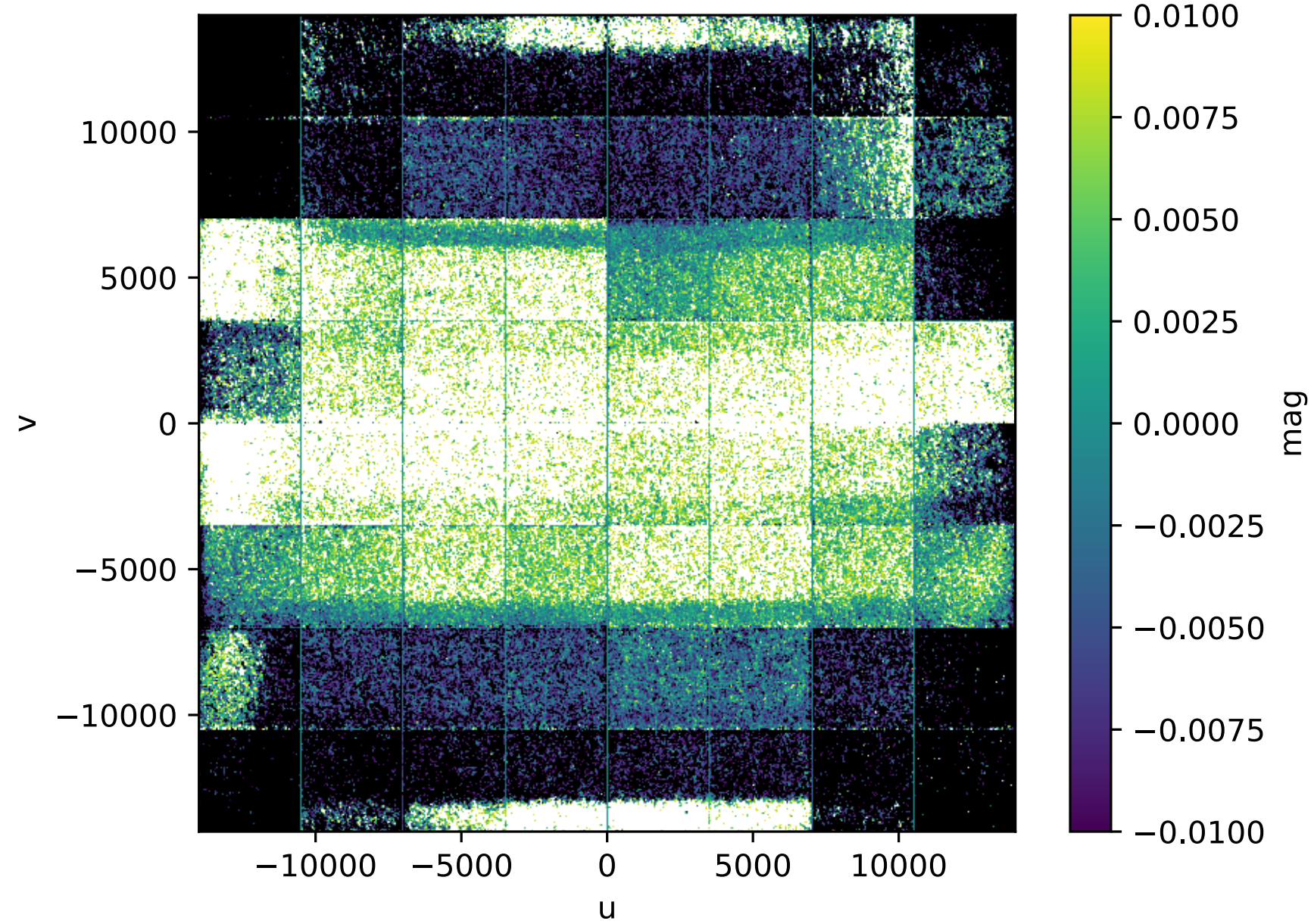
**Reduced stats:**  
~8.8 million stars  
**261 million sources**  
3.1 million images



**Selection :**  
13 < PS1 mag\_r < 18.5  
SNR > 10 (in psf phot: ⚠)  
Edge cut: 30 pixels  
No isolation (see later)

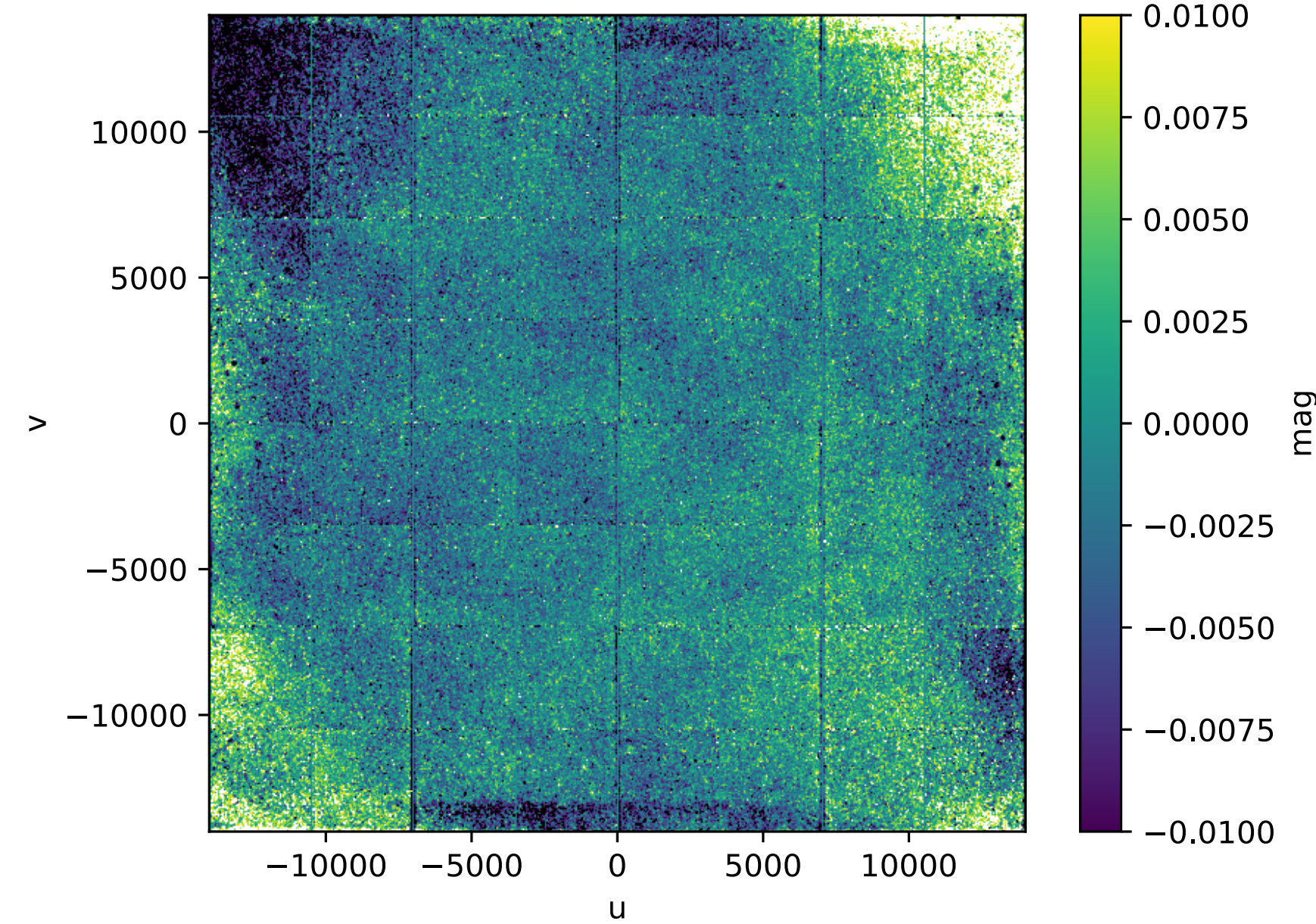
**PSF no starflats (1/50 stat)**

residuals median



**PSF with starflats (1/50 stat)**

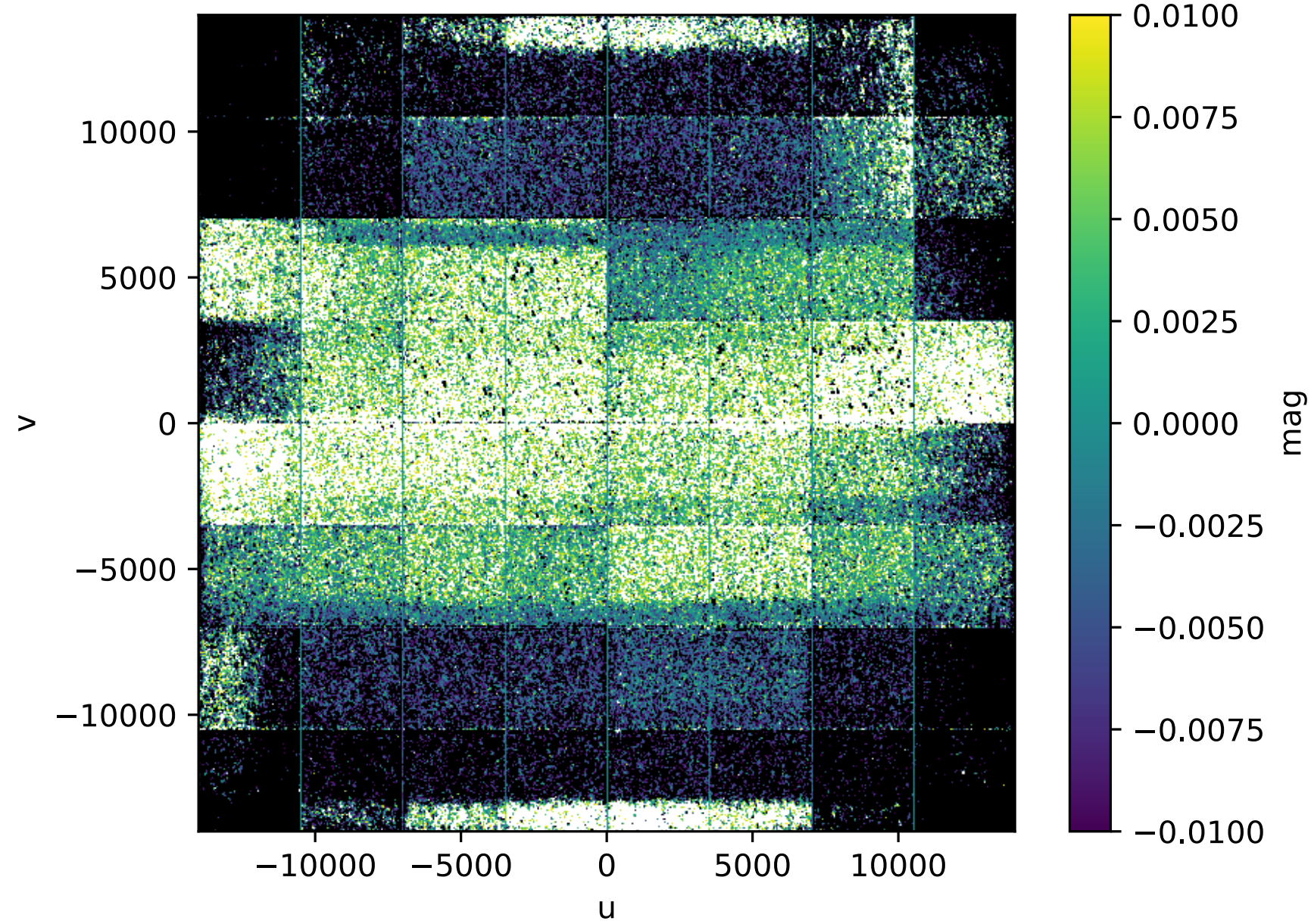
residuals median



**ZTF-r**

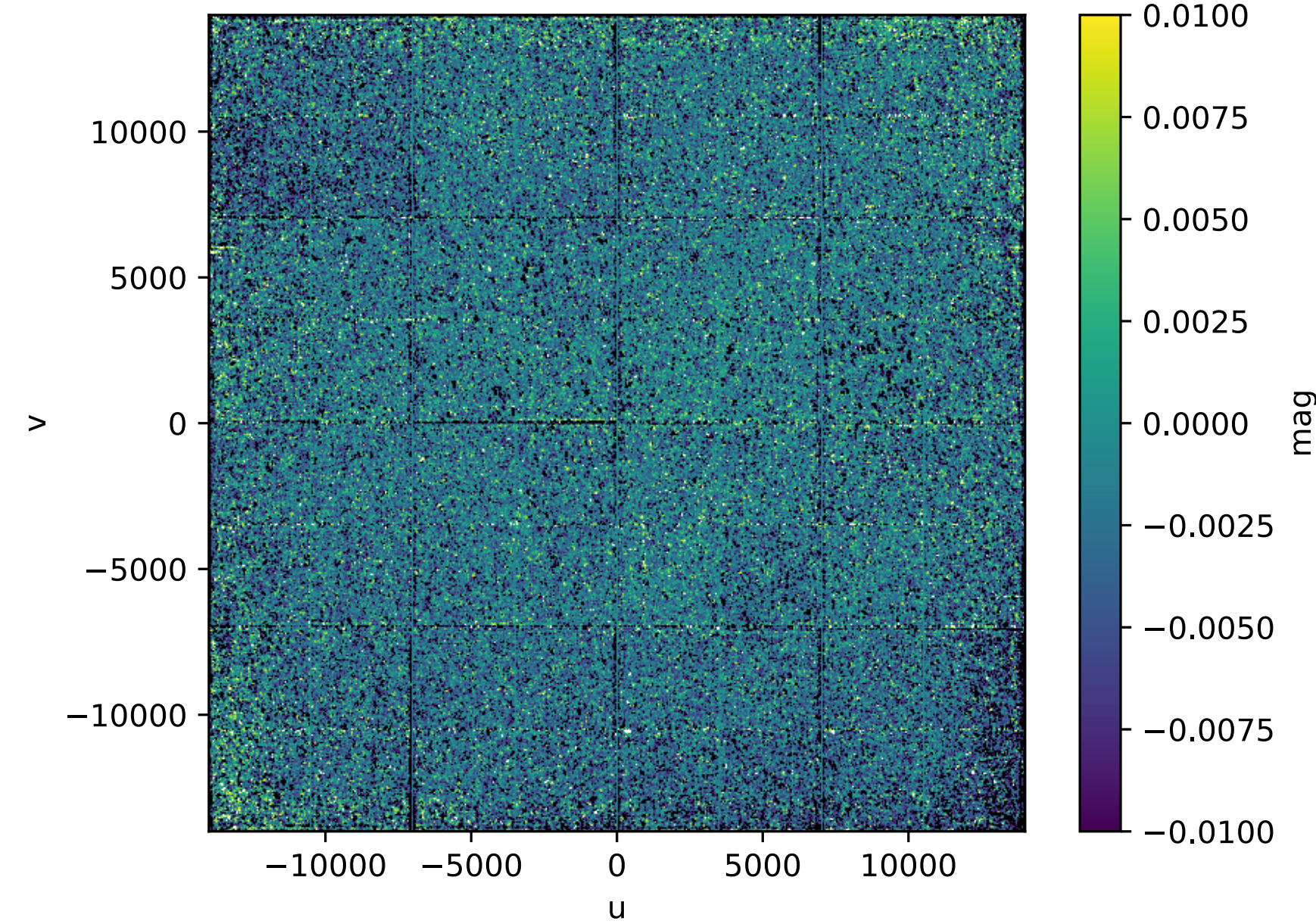
**AP no starflats (1/50 stat)**

residuals median



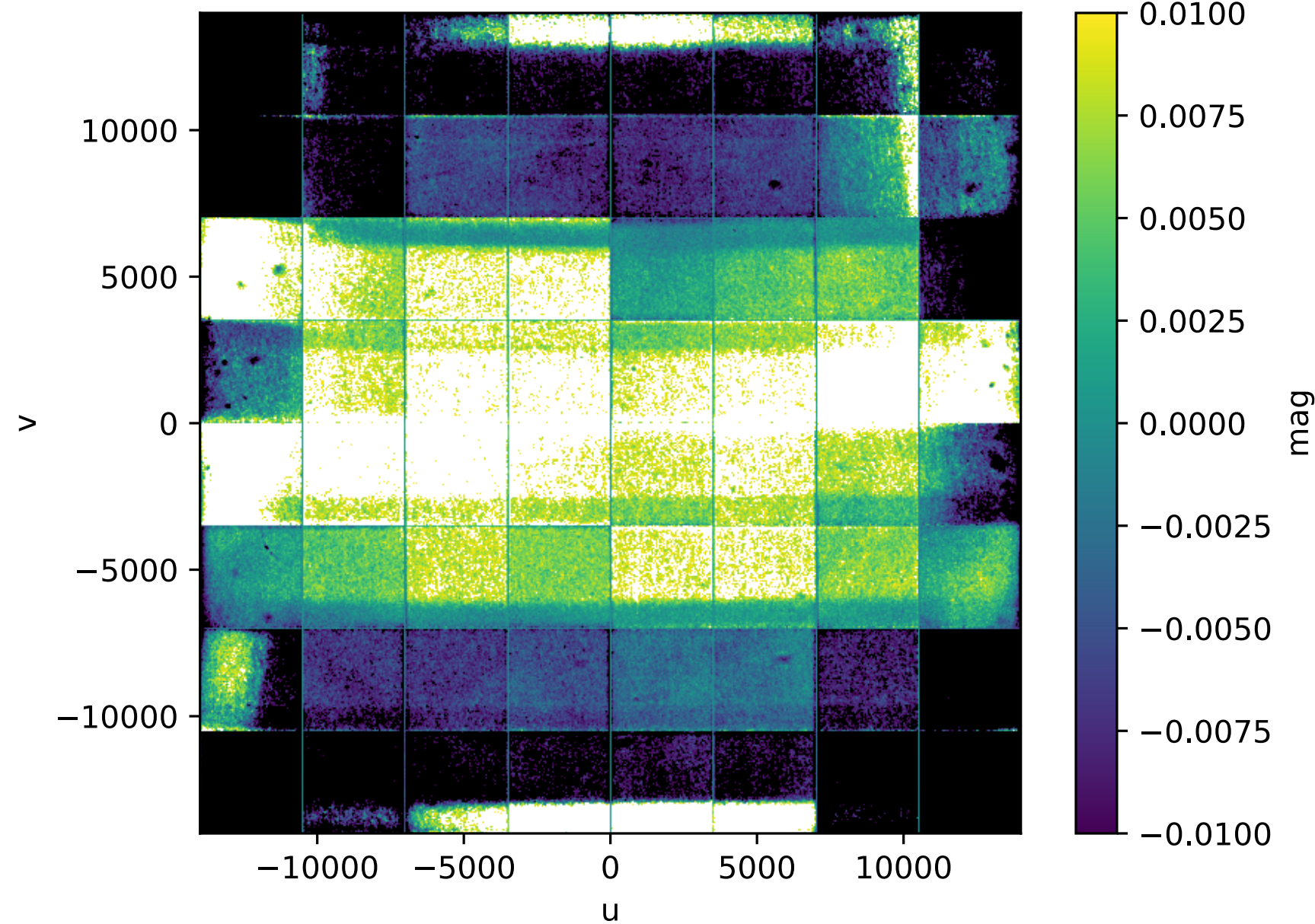
**AP with starflats (1/50 stat)**

residuals median



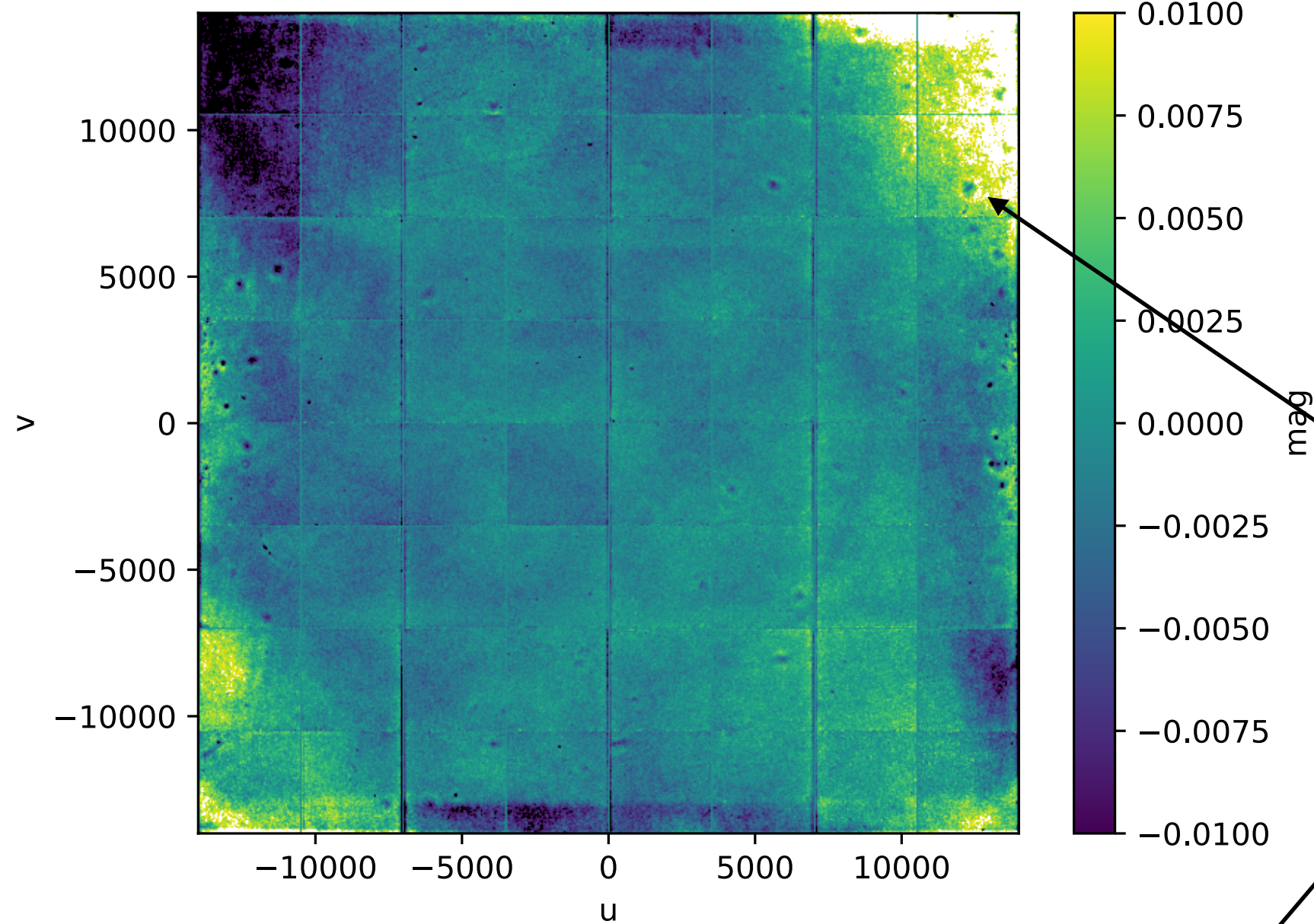
**PSF no starflats (1/5 stat)**

residuals median



**PSF with starflats (1/5 stat)**

residuals median

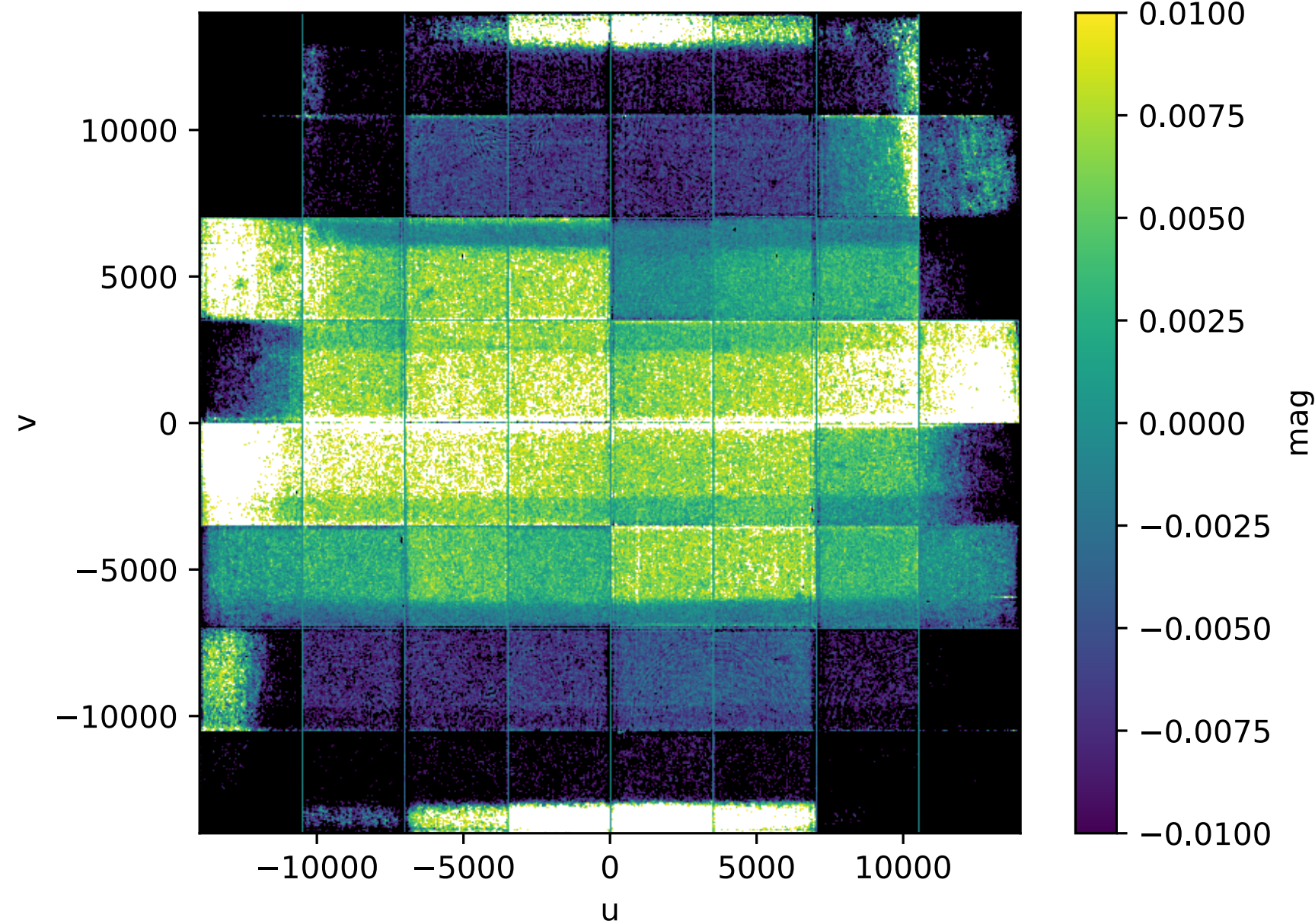


**ZTF-r**

**Dust spots still visible**

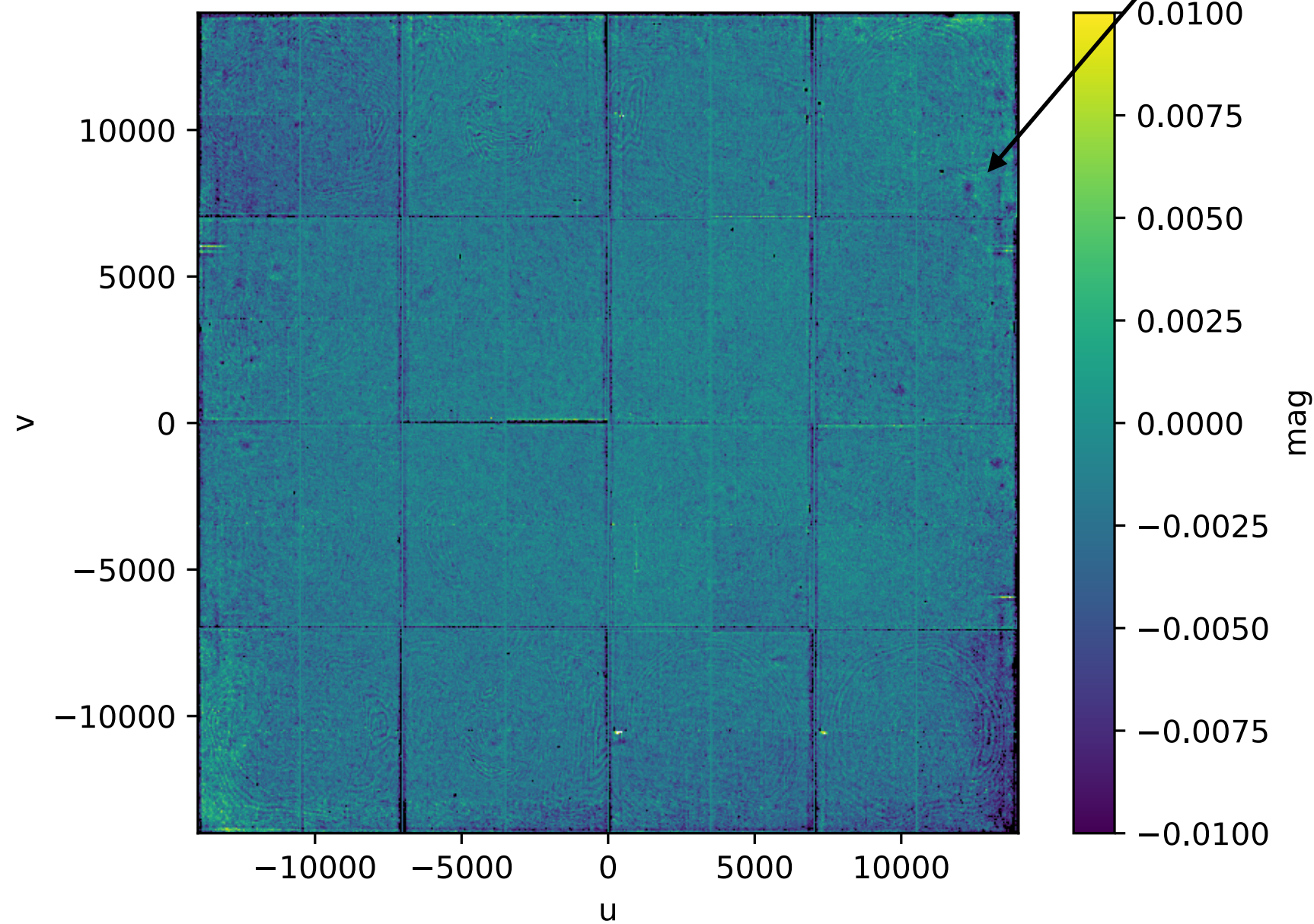
**AP no starflats (1/5 stat)**

residuals median

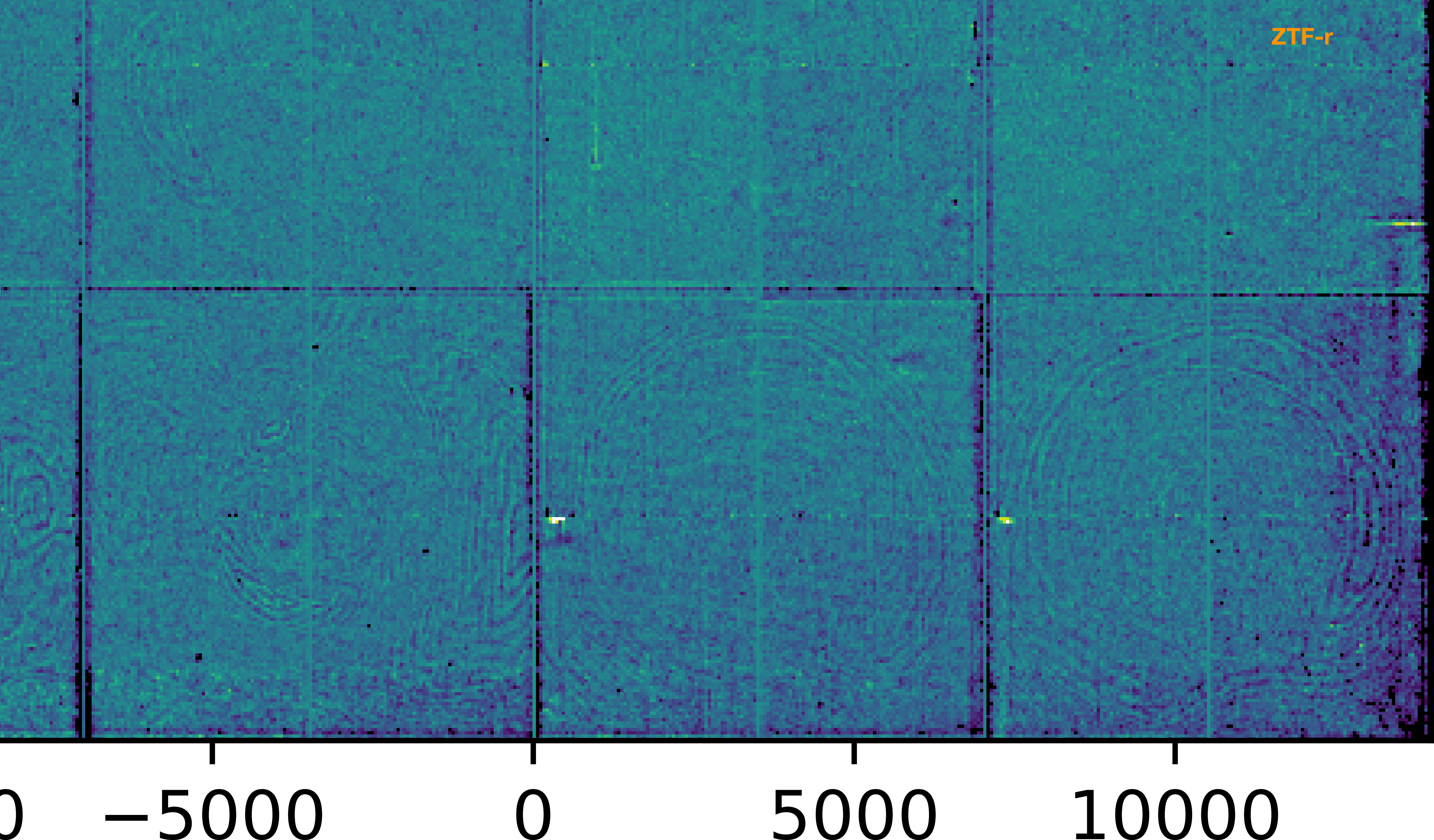


**AP with starflats (1/5 stat)**

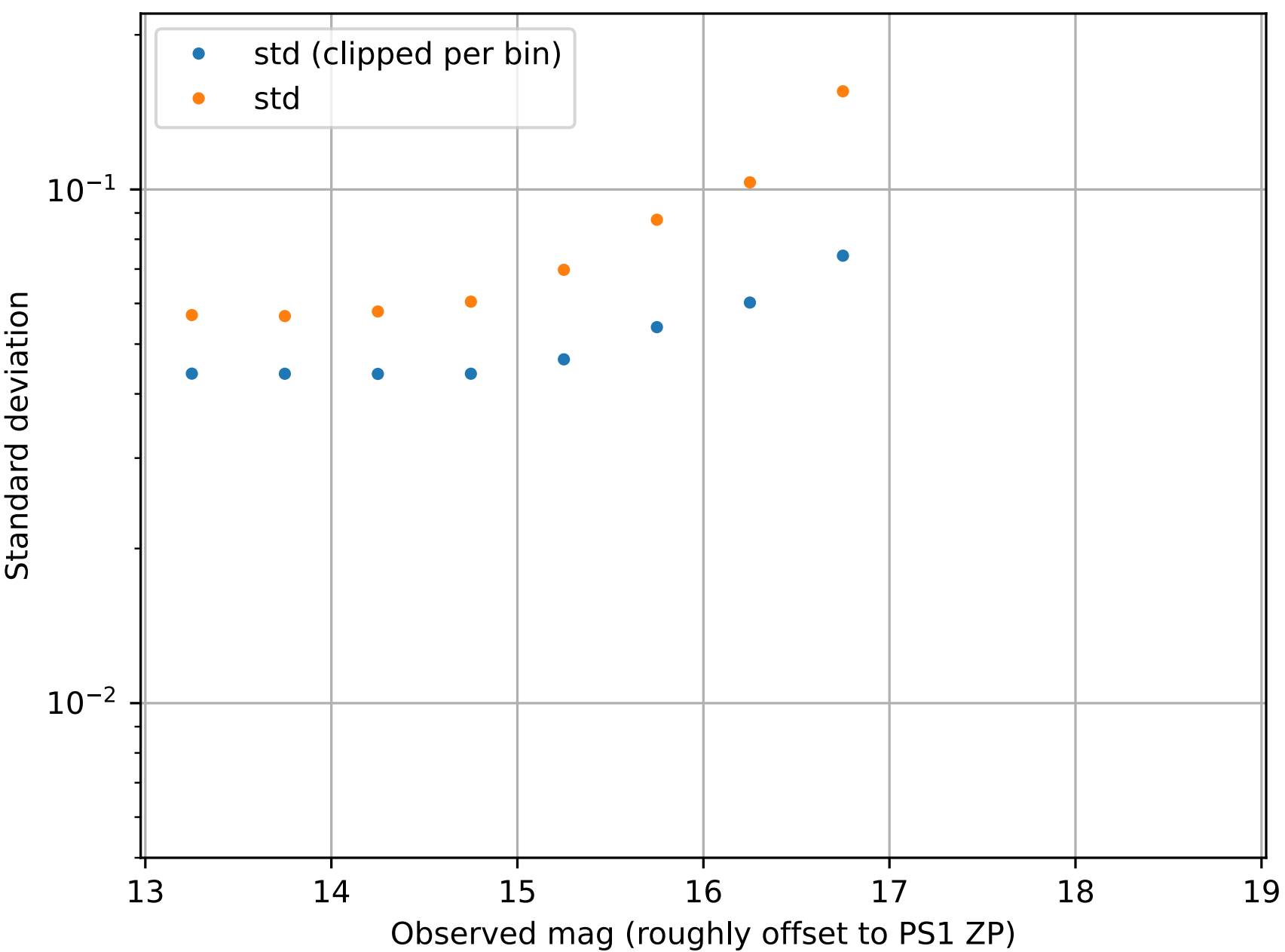
residuals median



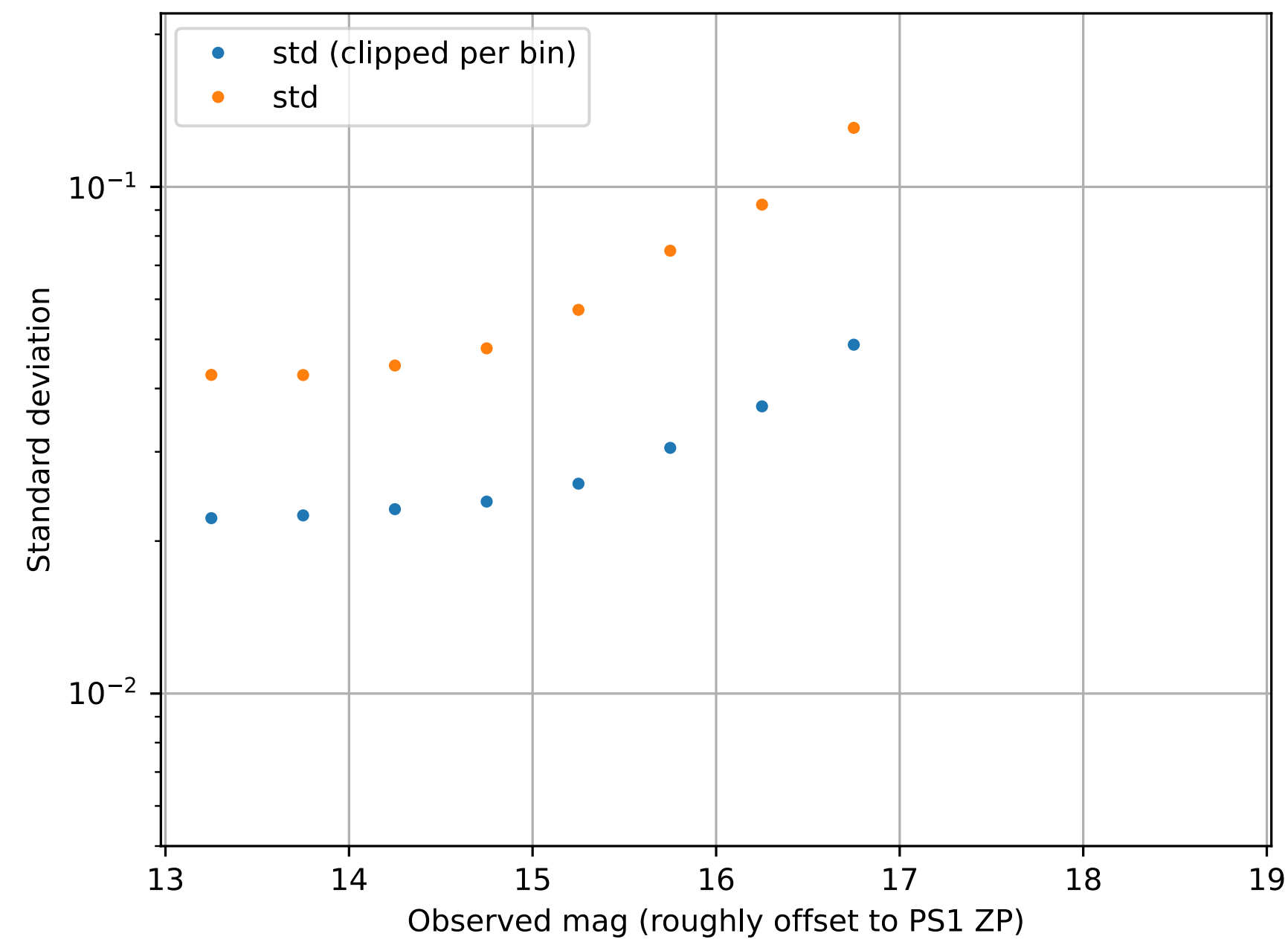




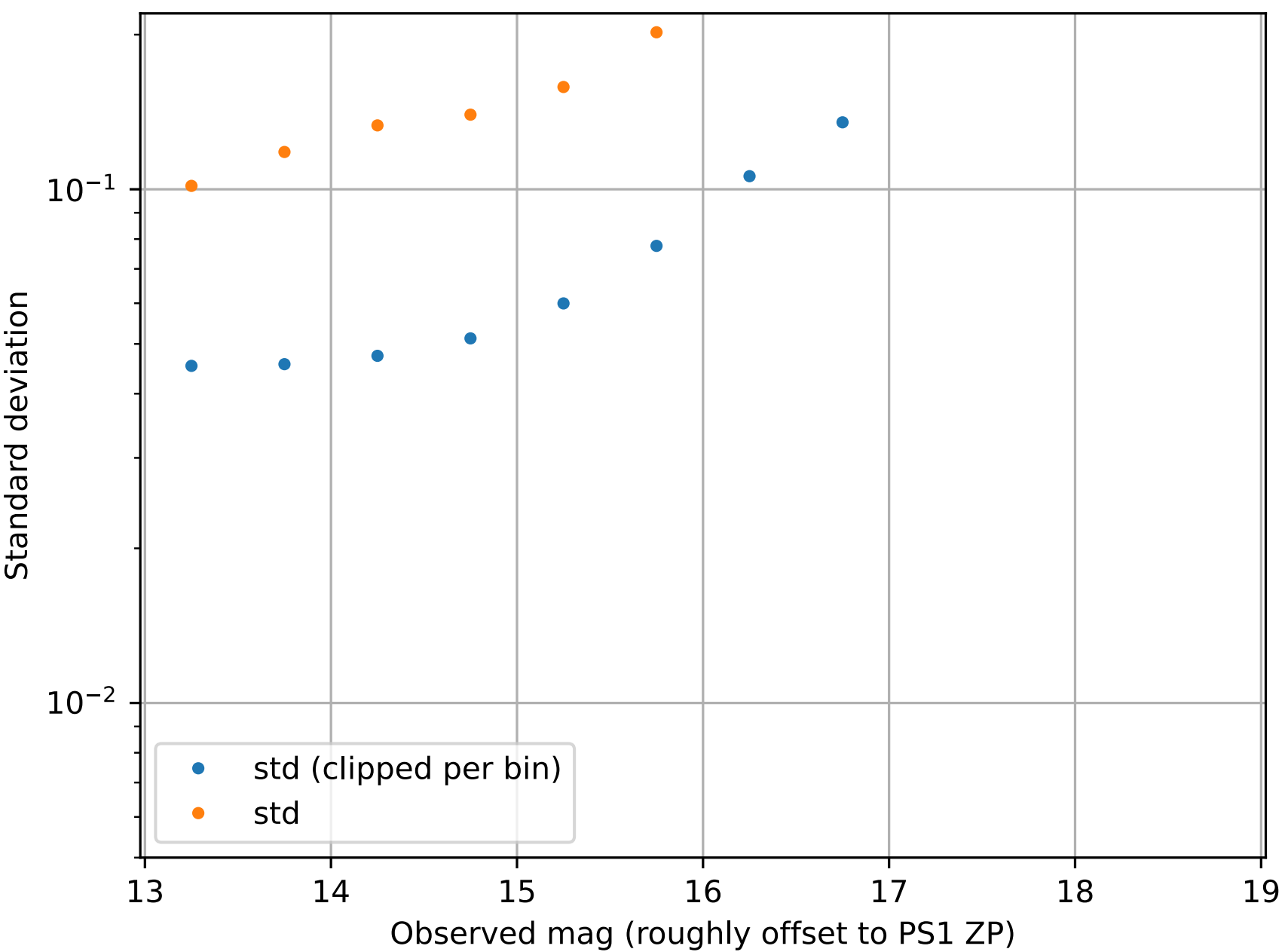
**PSF no starflats (1/5 stat)**



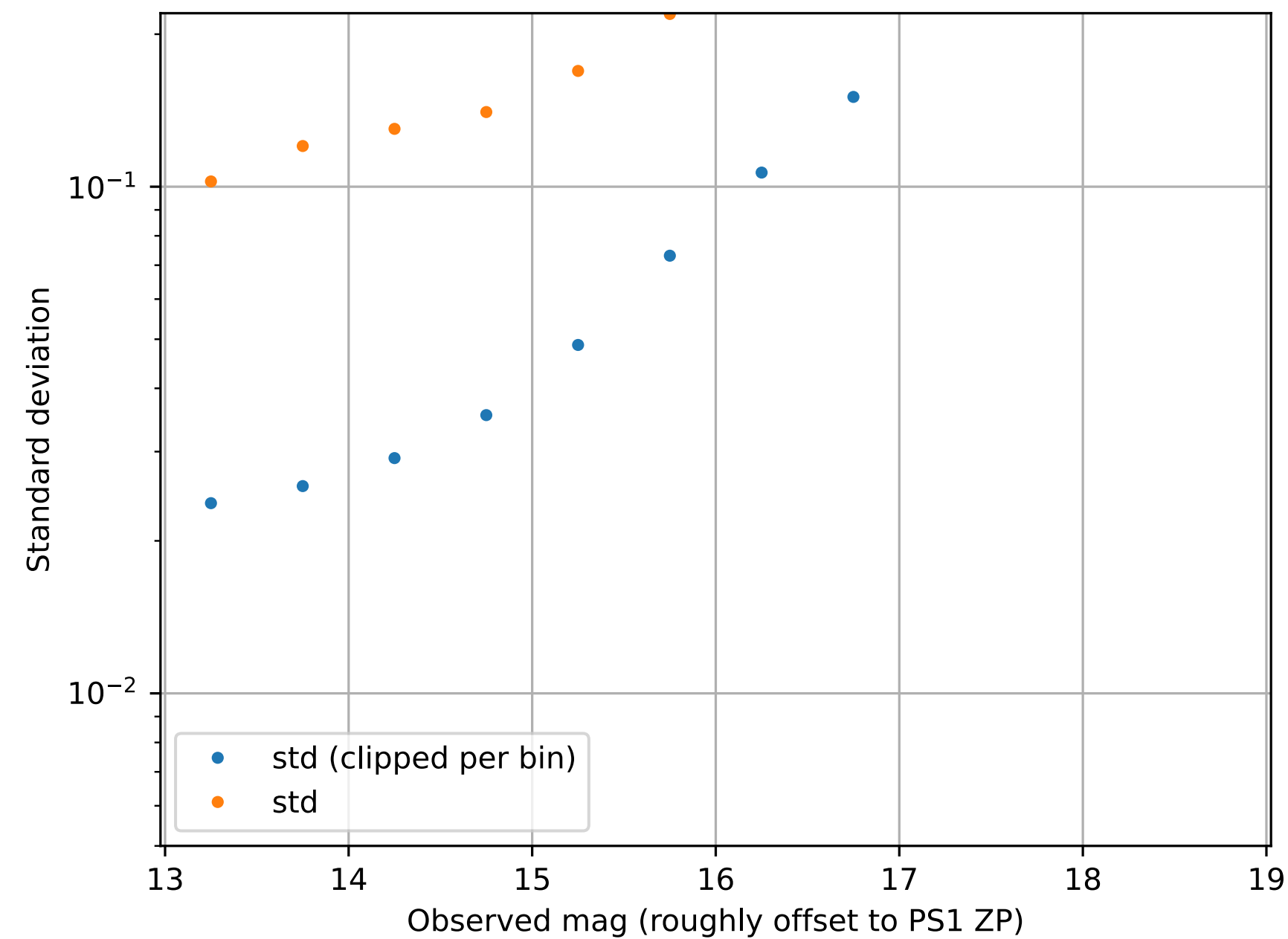
**PSF with starflats (1/5 stat)**



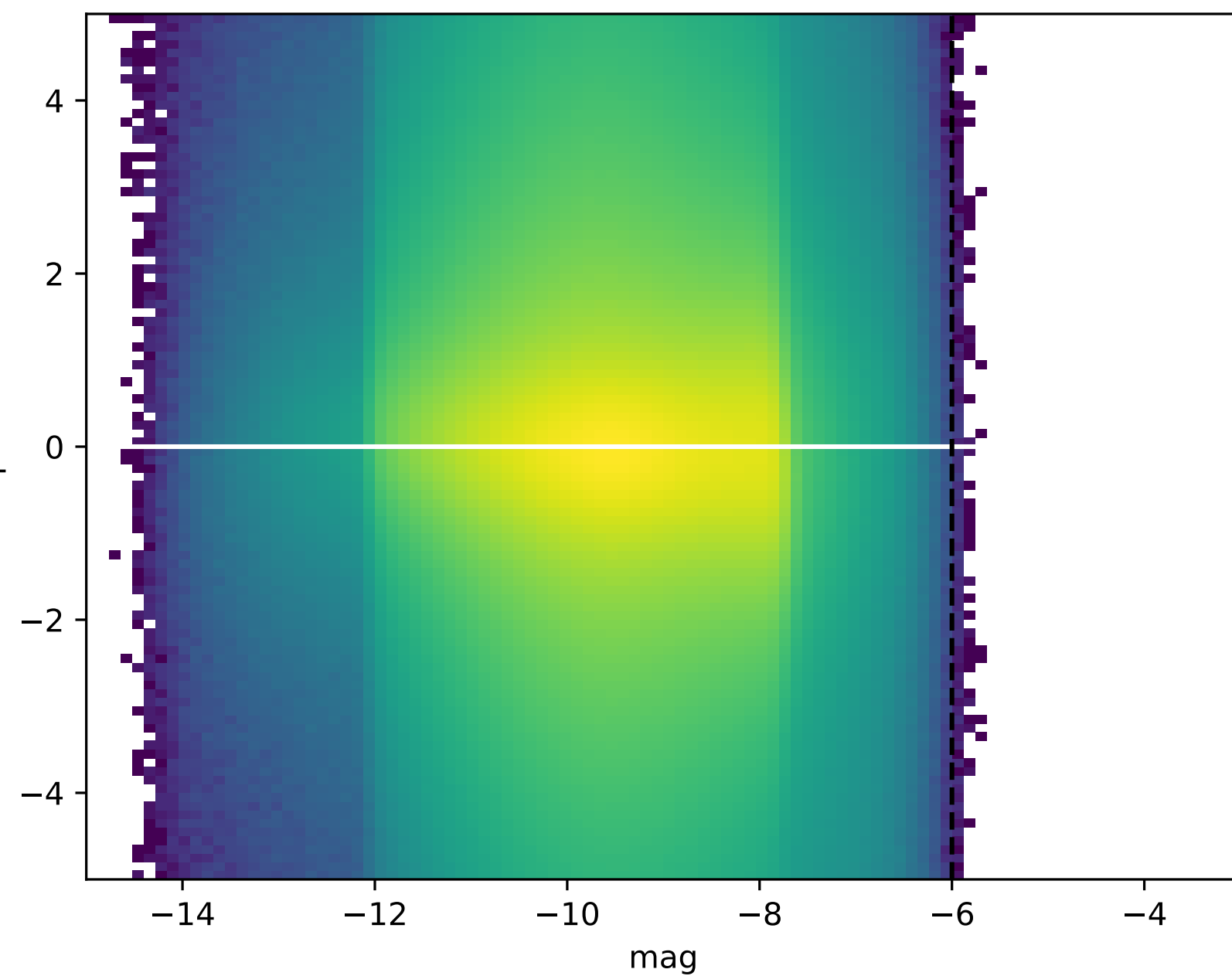
**AP no starflats (1/5 stat)**



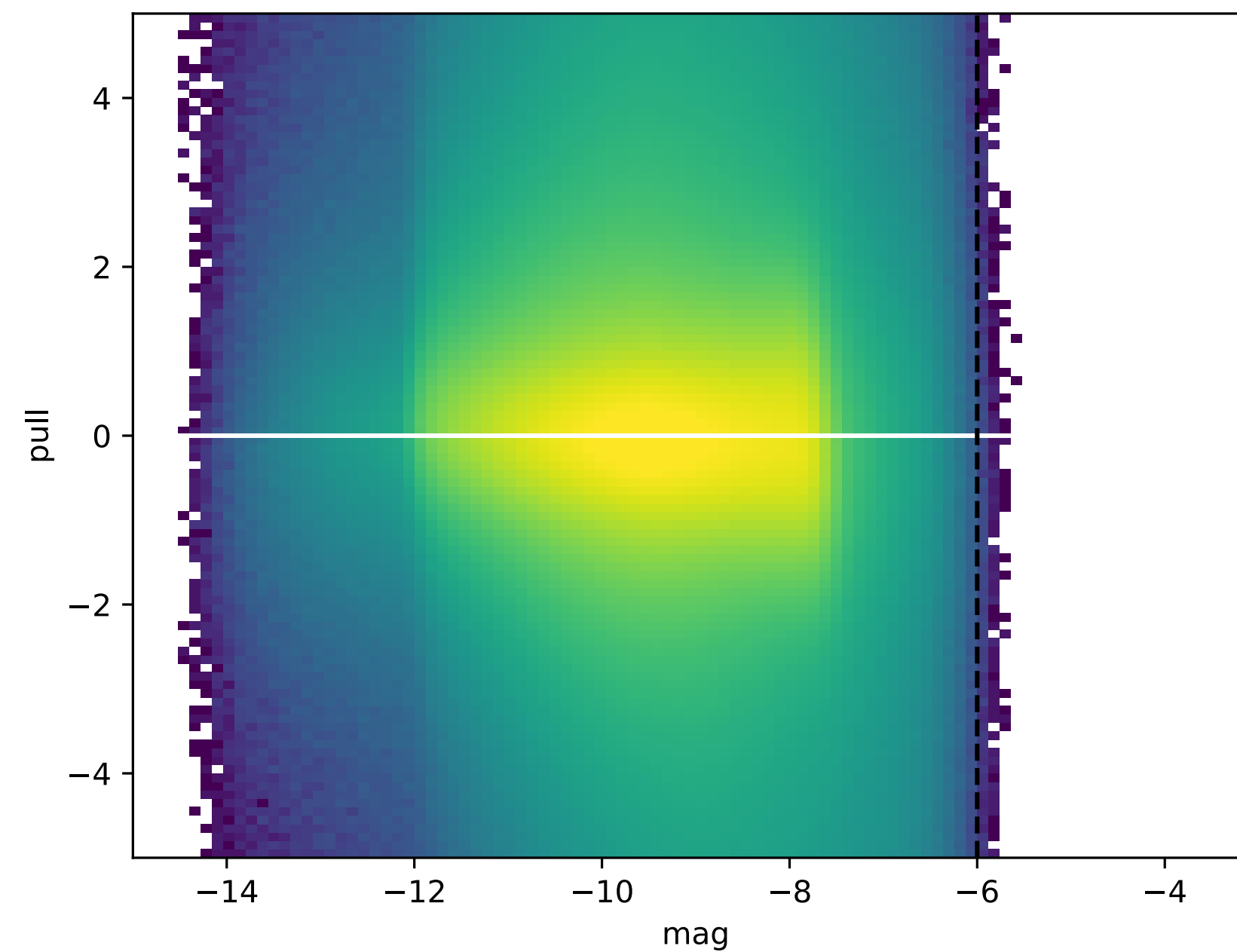
**AP with starflats (1/5 stat)**



**PSF no starflats (1/5 stat)**

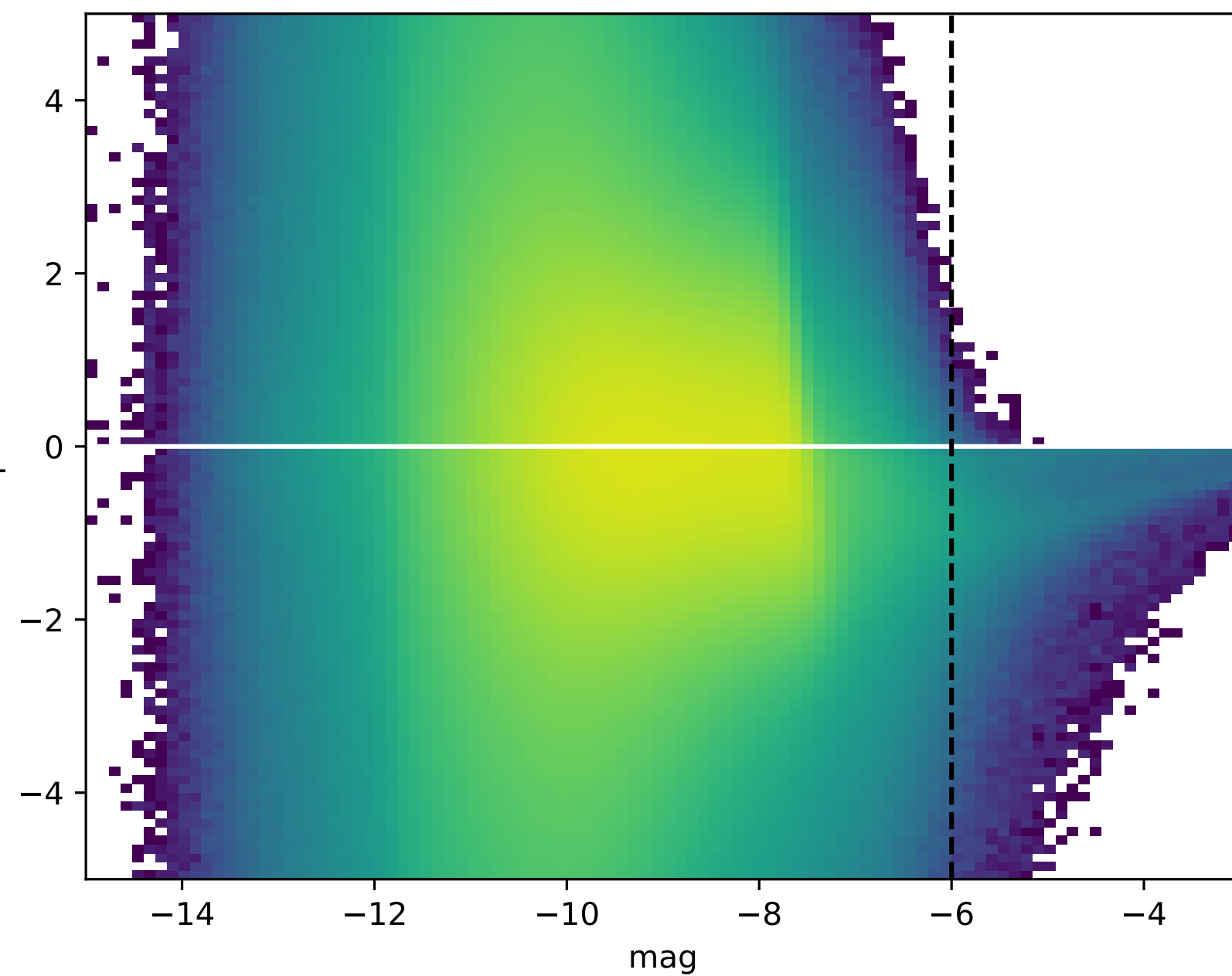


**PSF with starflats (1/5 stat)**

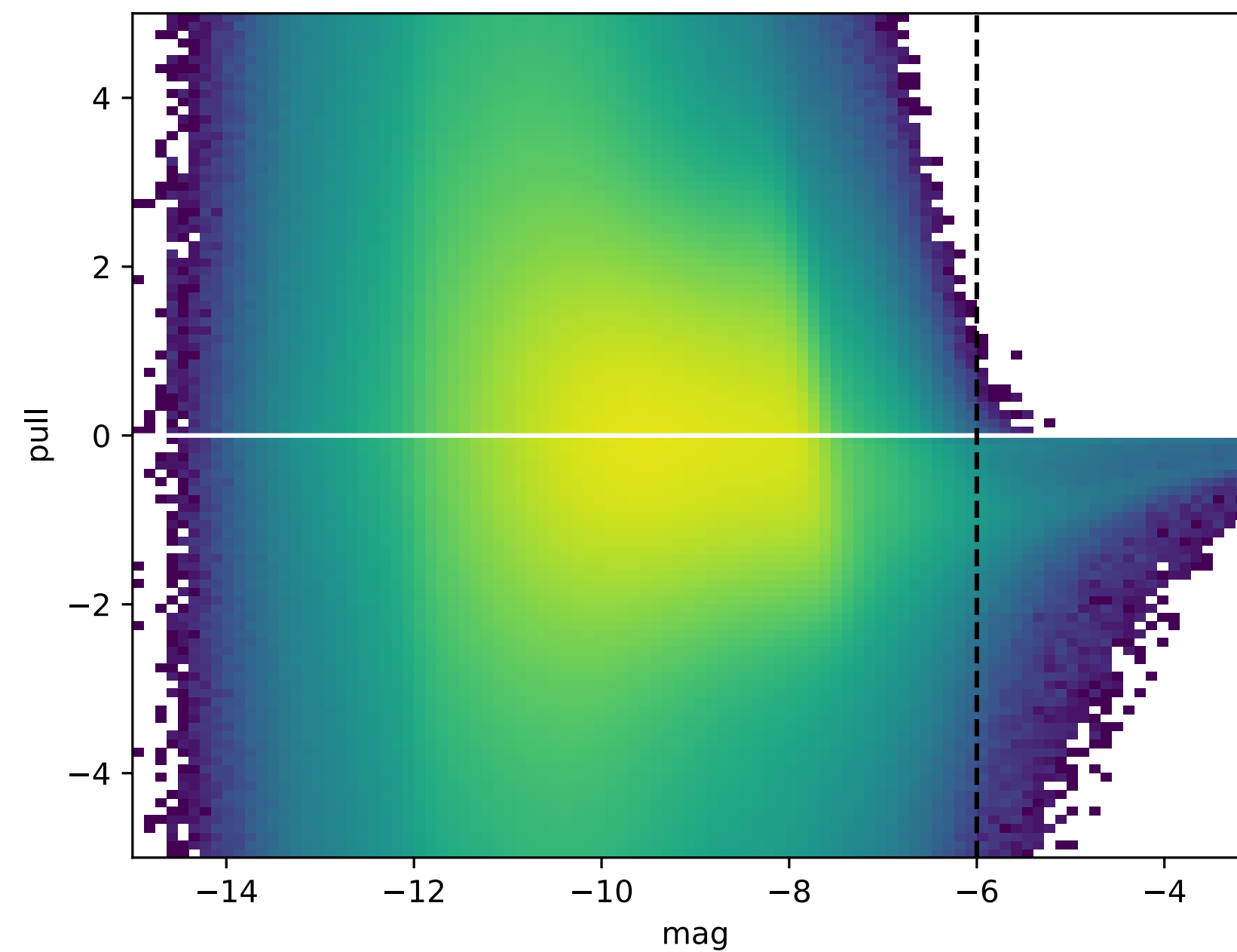


**ZTF-r**

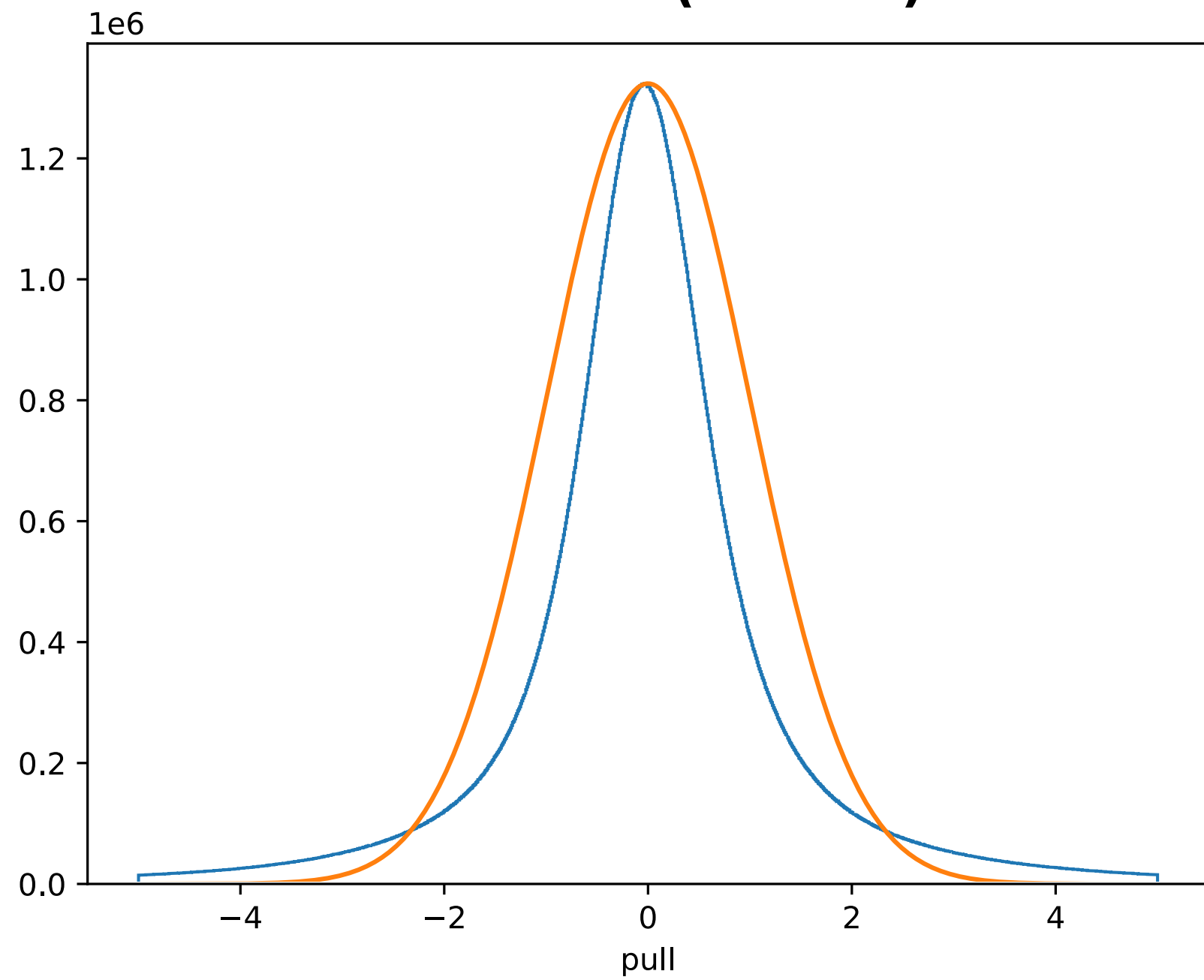
**AP no starflats (1/5 stat)**



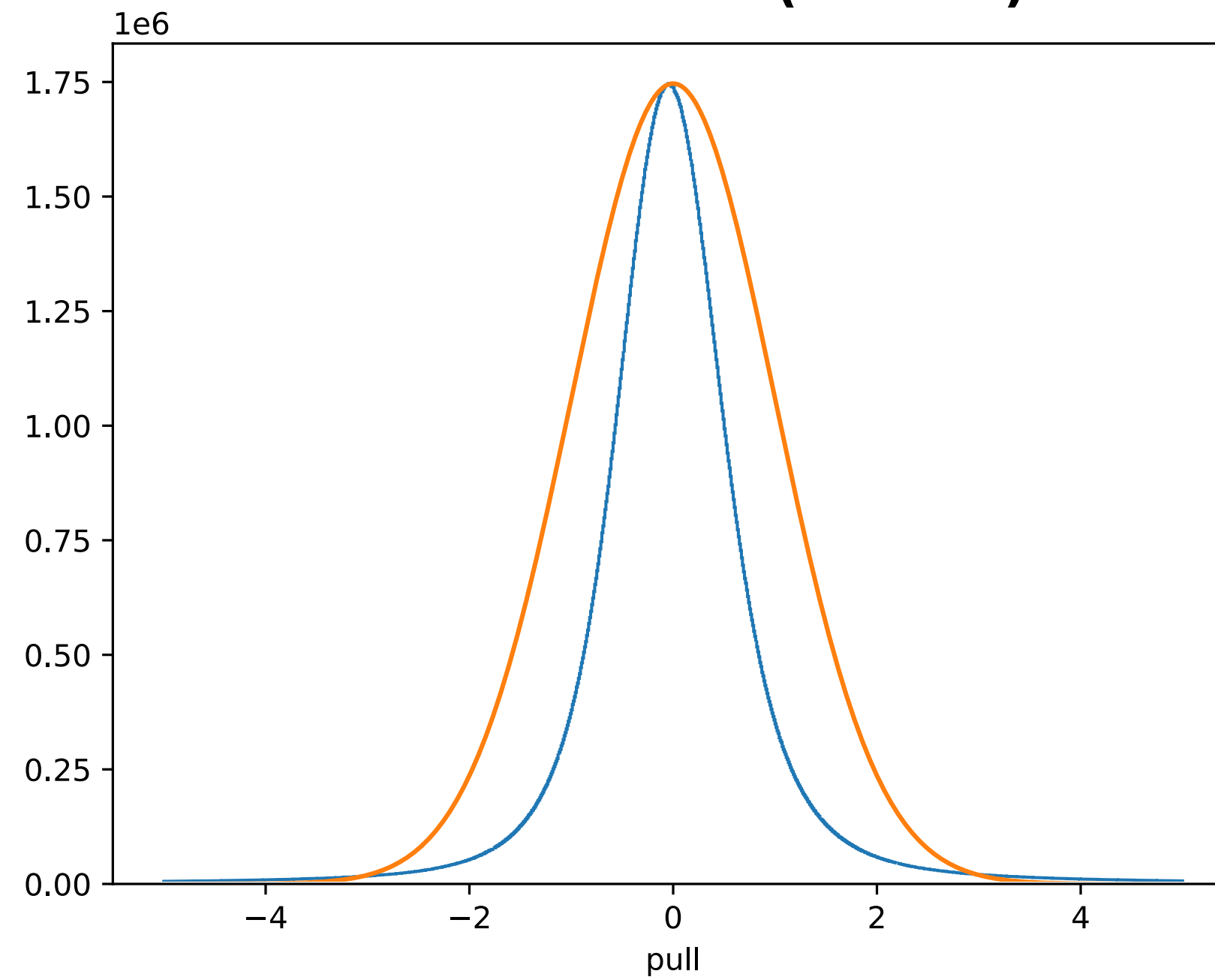
**AP with starflats (1/5 stat)**



**PSF no starflats (1/5 stat)**

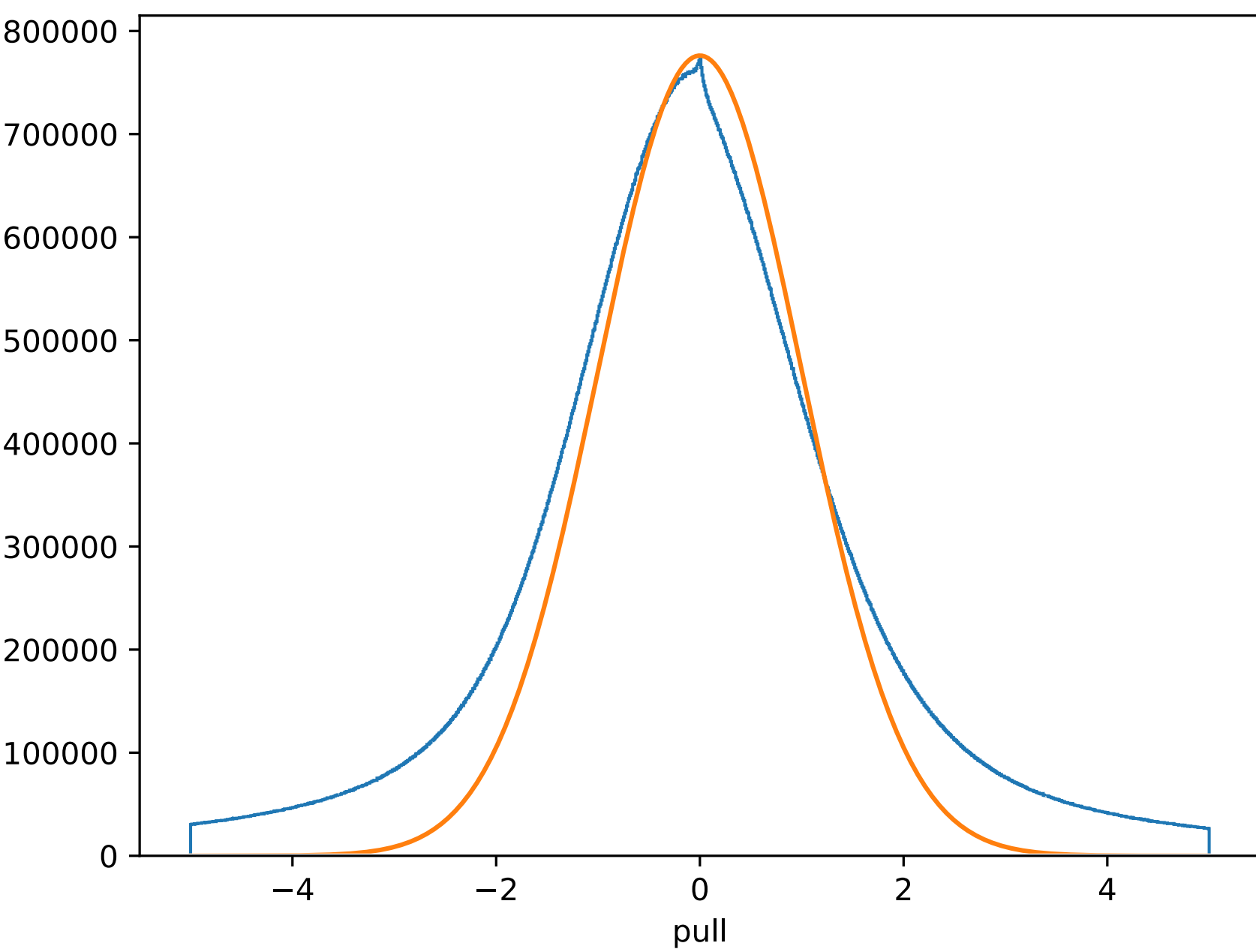


**PSF with starflats (1/5 stat)**

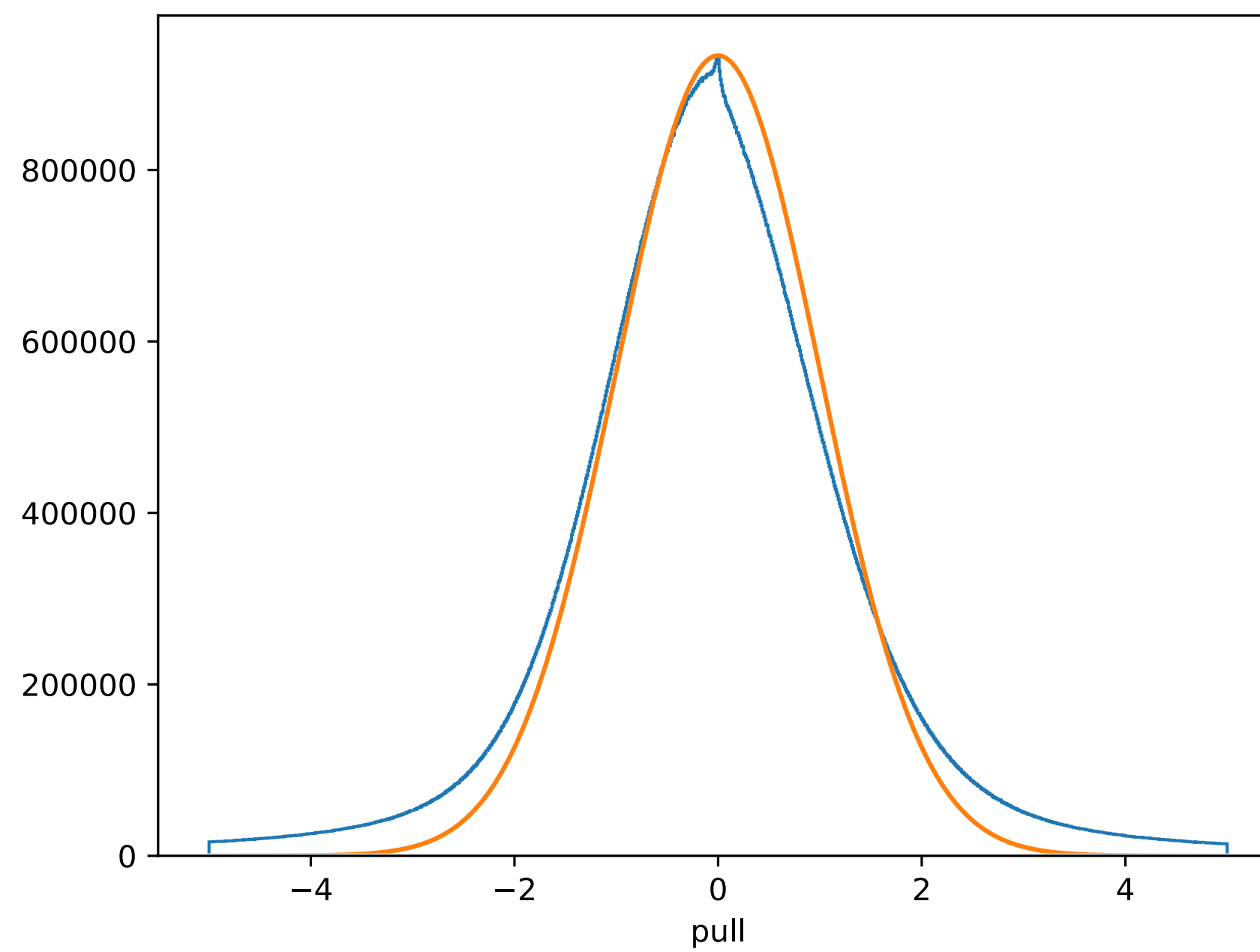


**ZTF-r**

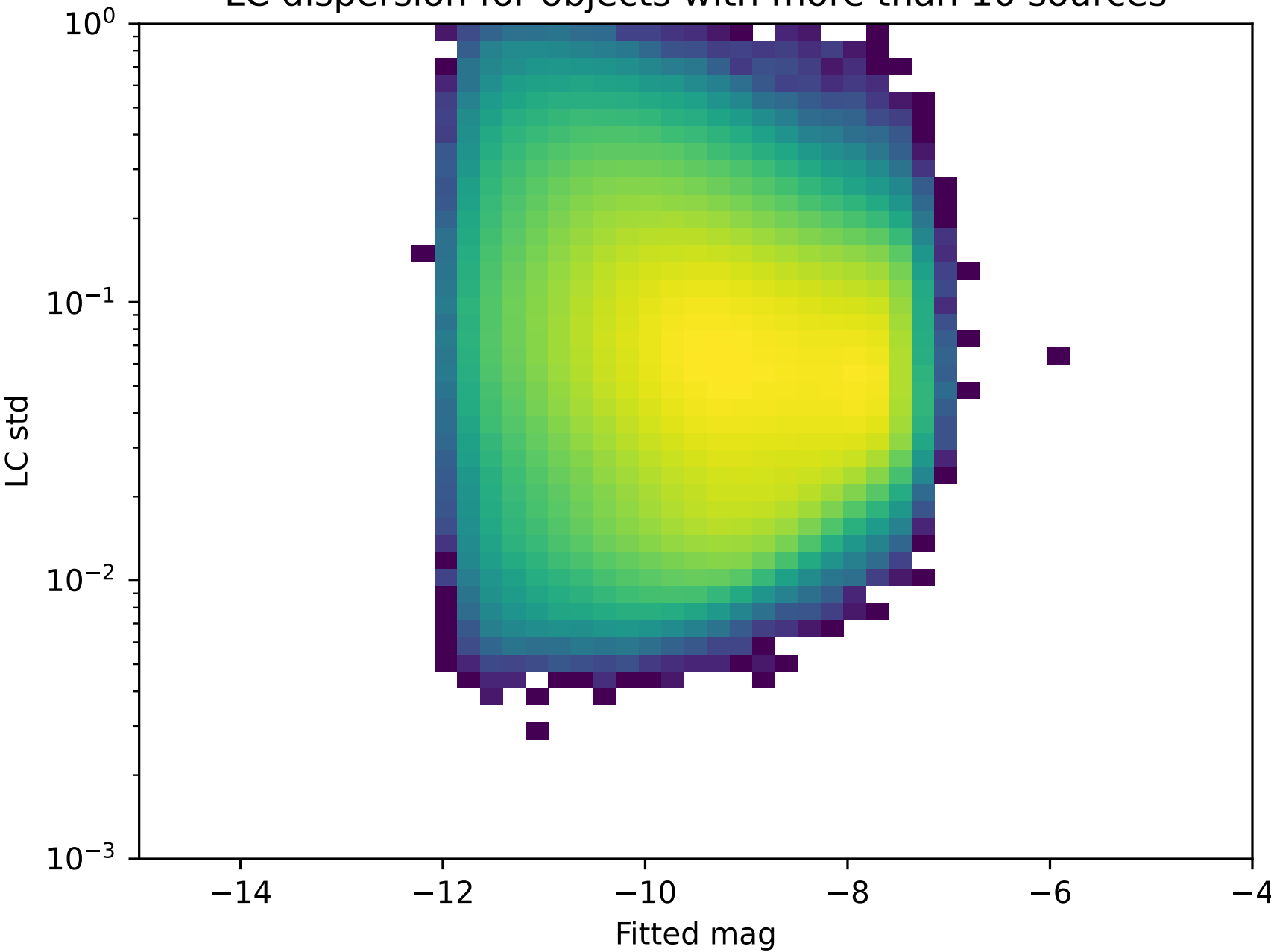
**AP no starflats (1/5 stat)**



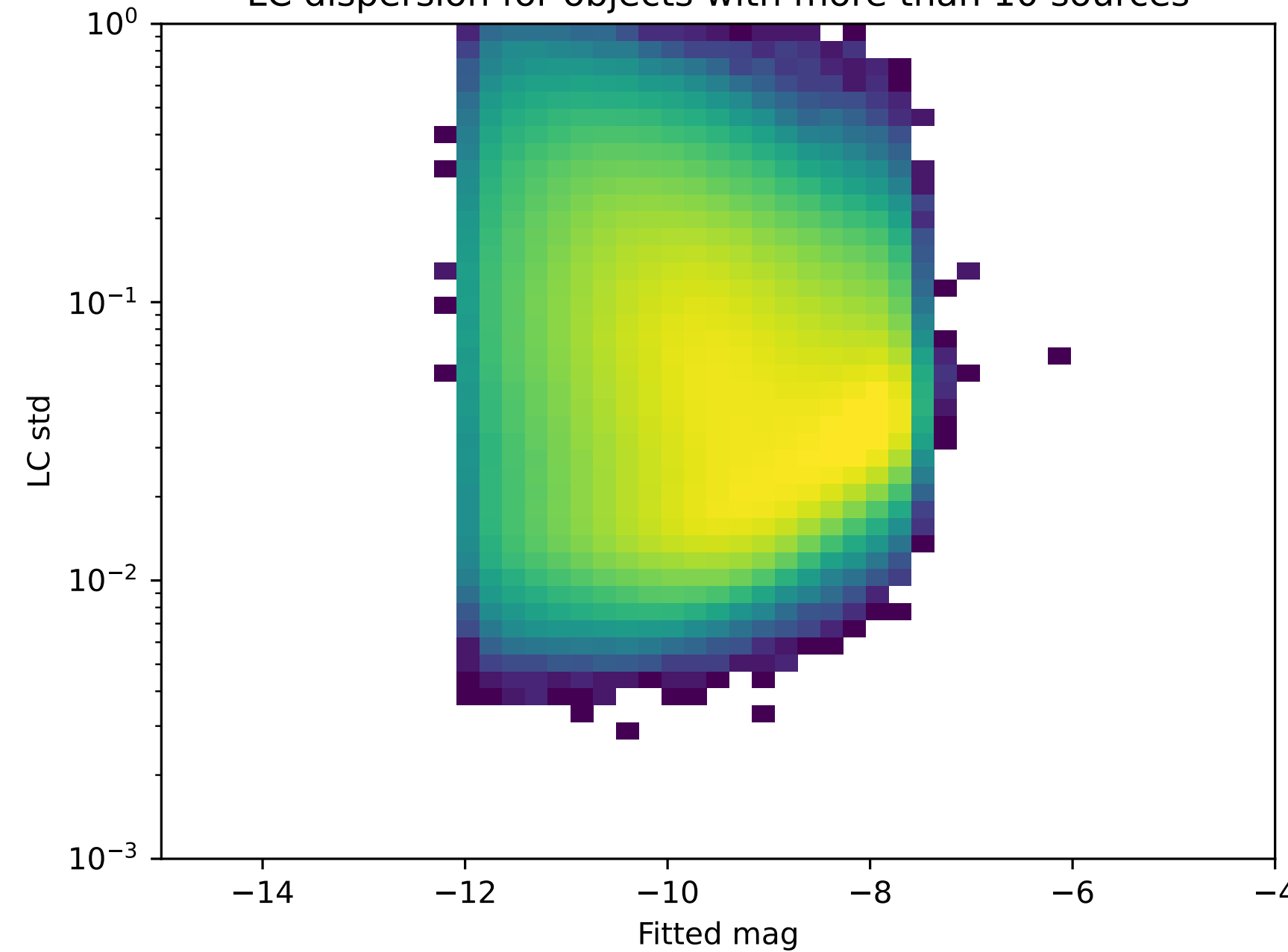
**AP with starflats (1/5 stat)**



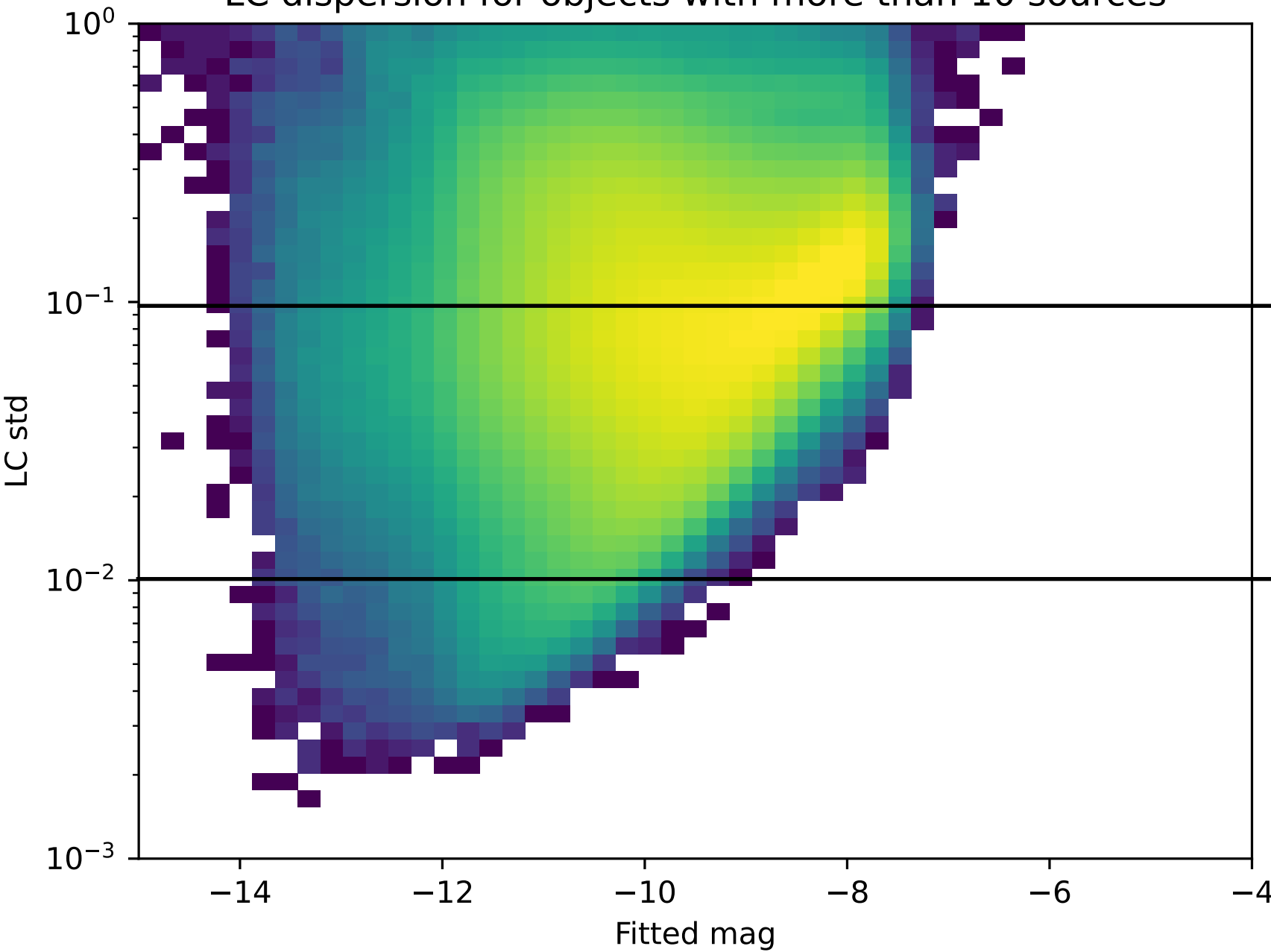
**PSF no starflats (1/5 stat)**  
LC dispersion for objects with more than 10 sources



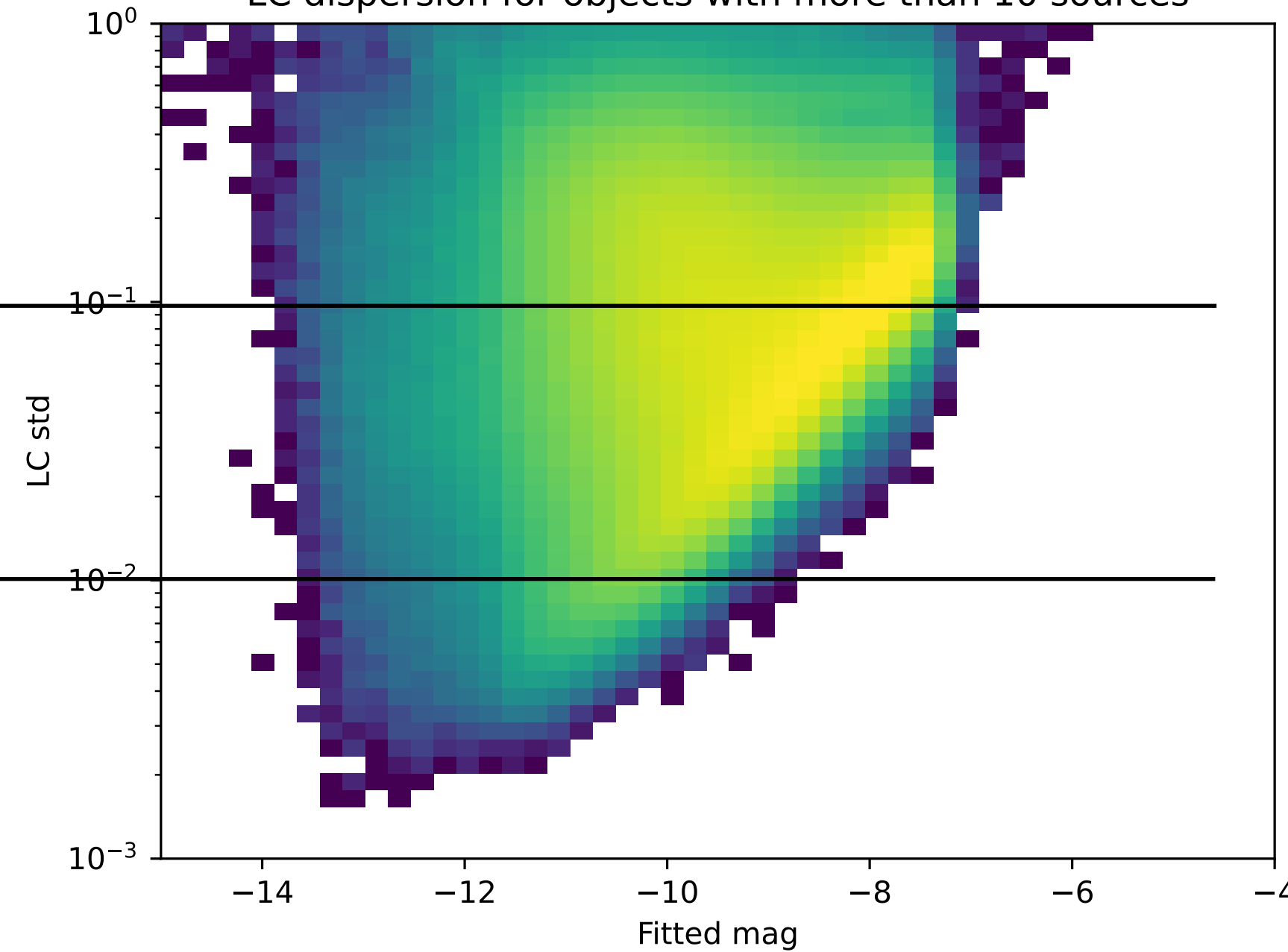
**PSF with starflats (1/5 stat)**  
LC dispersion for objects with more than 10 sources



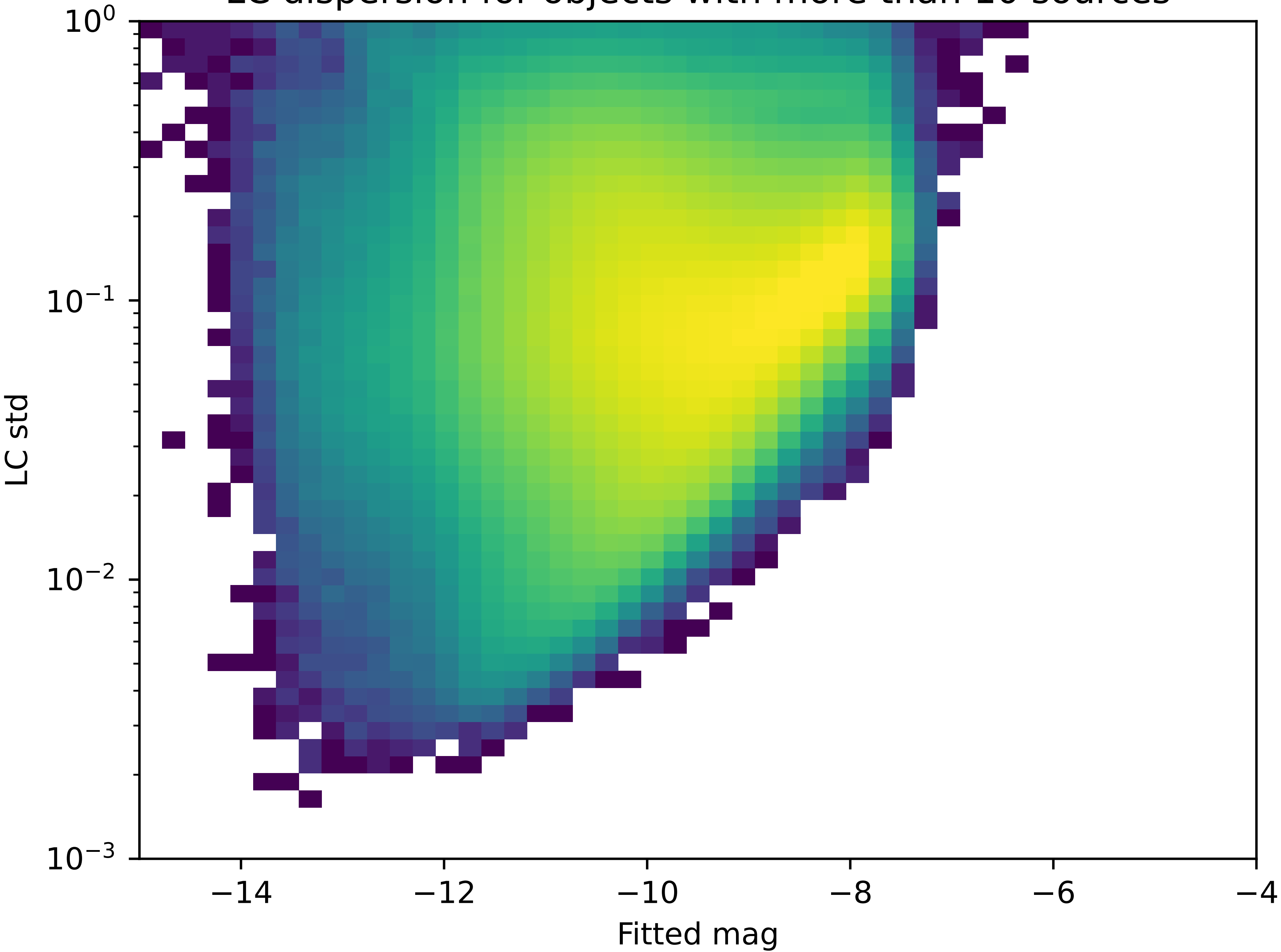
**AP no starflats (1/5 stat)**  
LC dispersion for objects with more than 10 sources



**AP with starflats (1/5 stat)**  
LC dispersion for objects with more than 10 sources

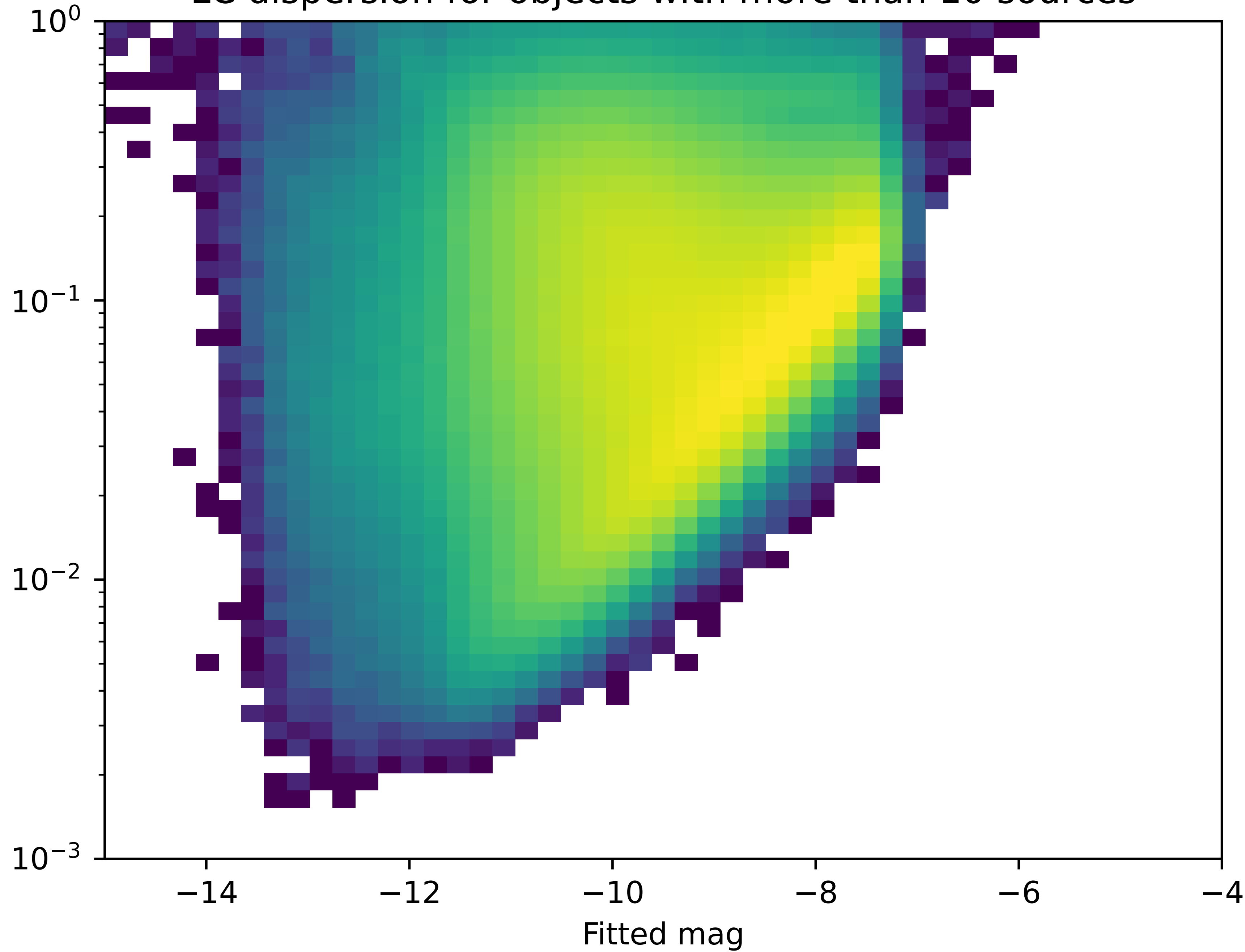


LC dispersion for objects with more than 10 sources



**Fitted mag shift due to reference  
Having a shift due to starflats?  
Is is with 0 mean?**

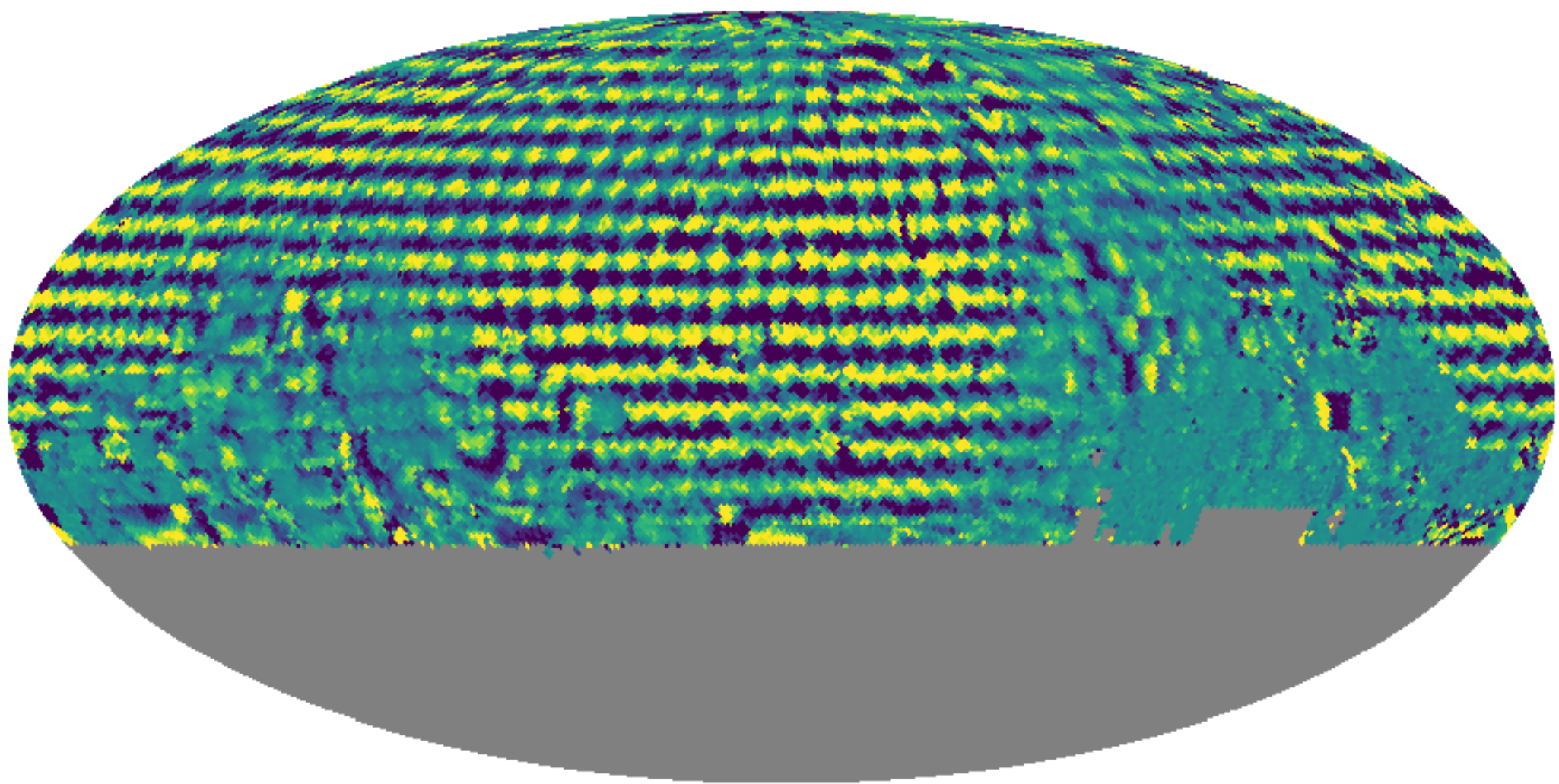
LC dispersion for objects with more than 10 sources



**Fitted mag shift due to reference  
Having a shift due to starflats?  
Is is with 0 mean?**

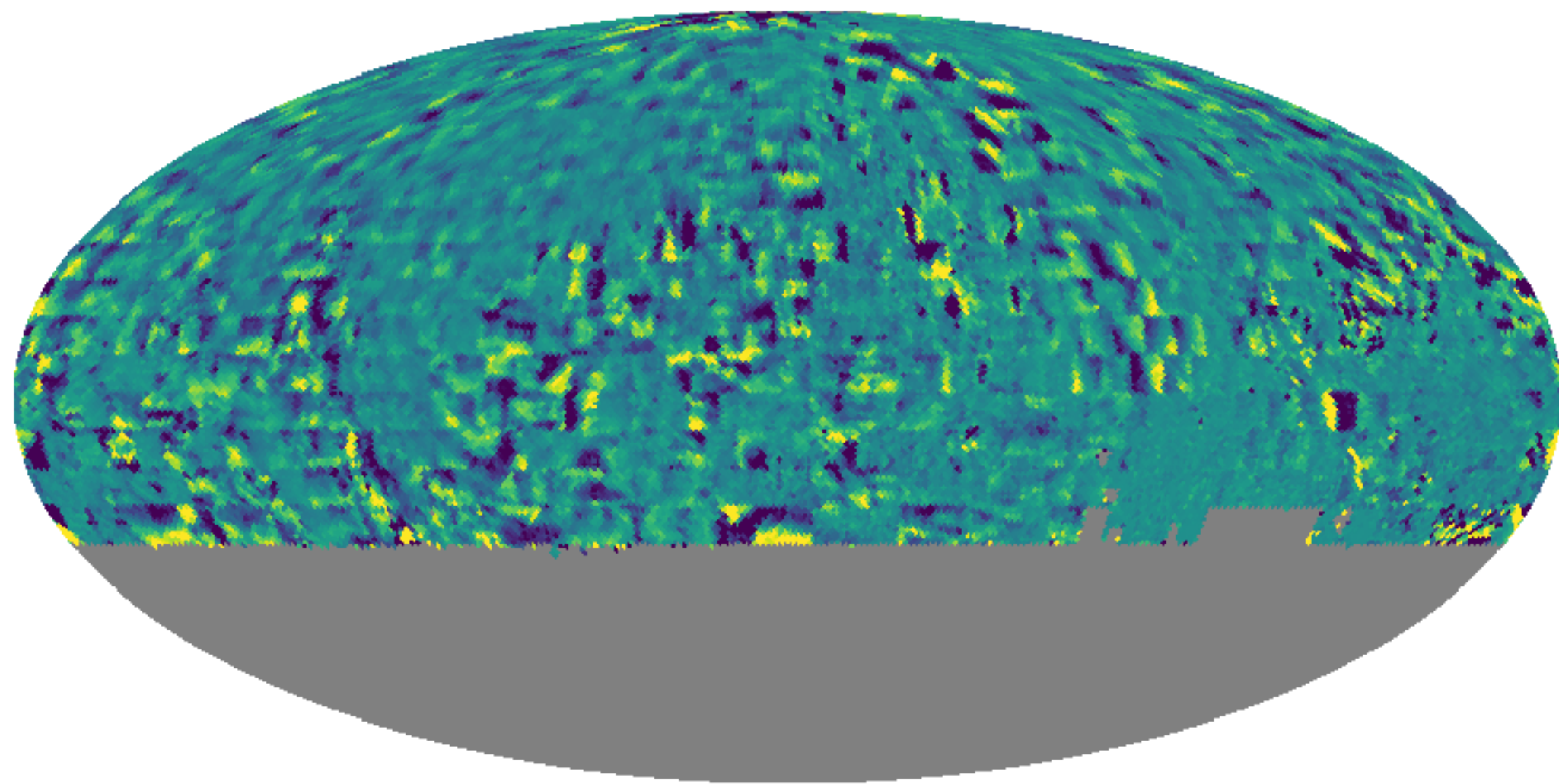
**PSF no starflats (1/5 stat)**

median



**PSF with starflats (1/5 stat)**

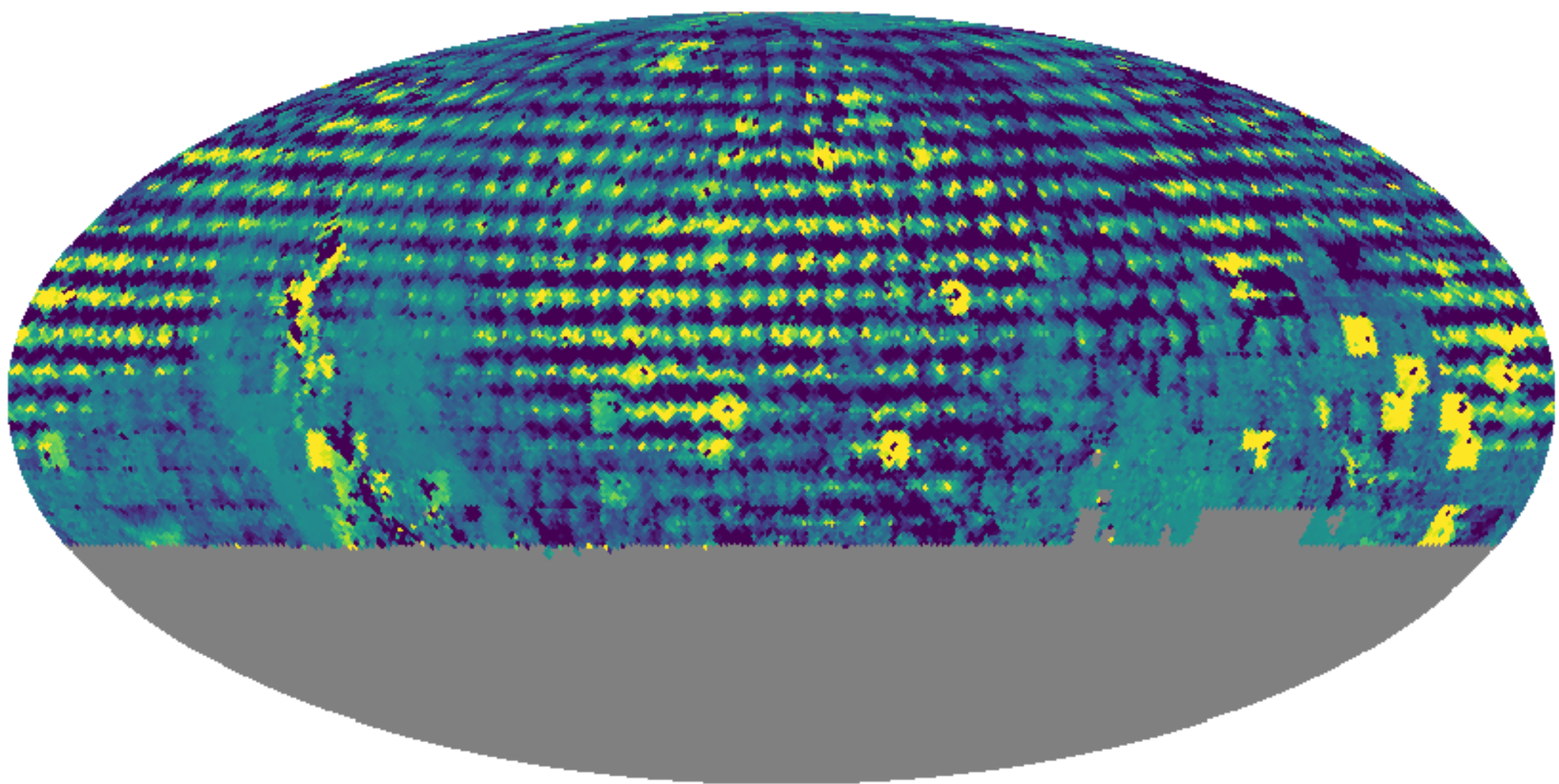
median



**ZTF-r**

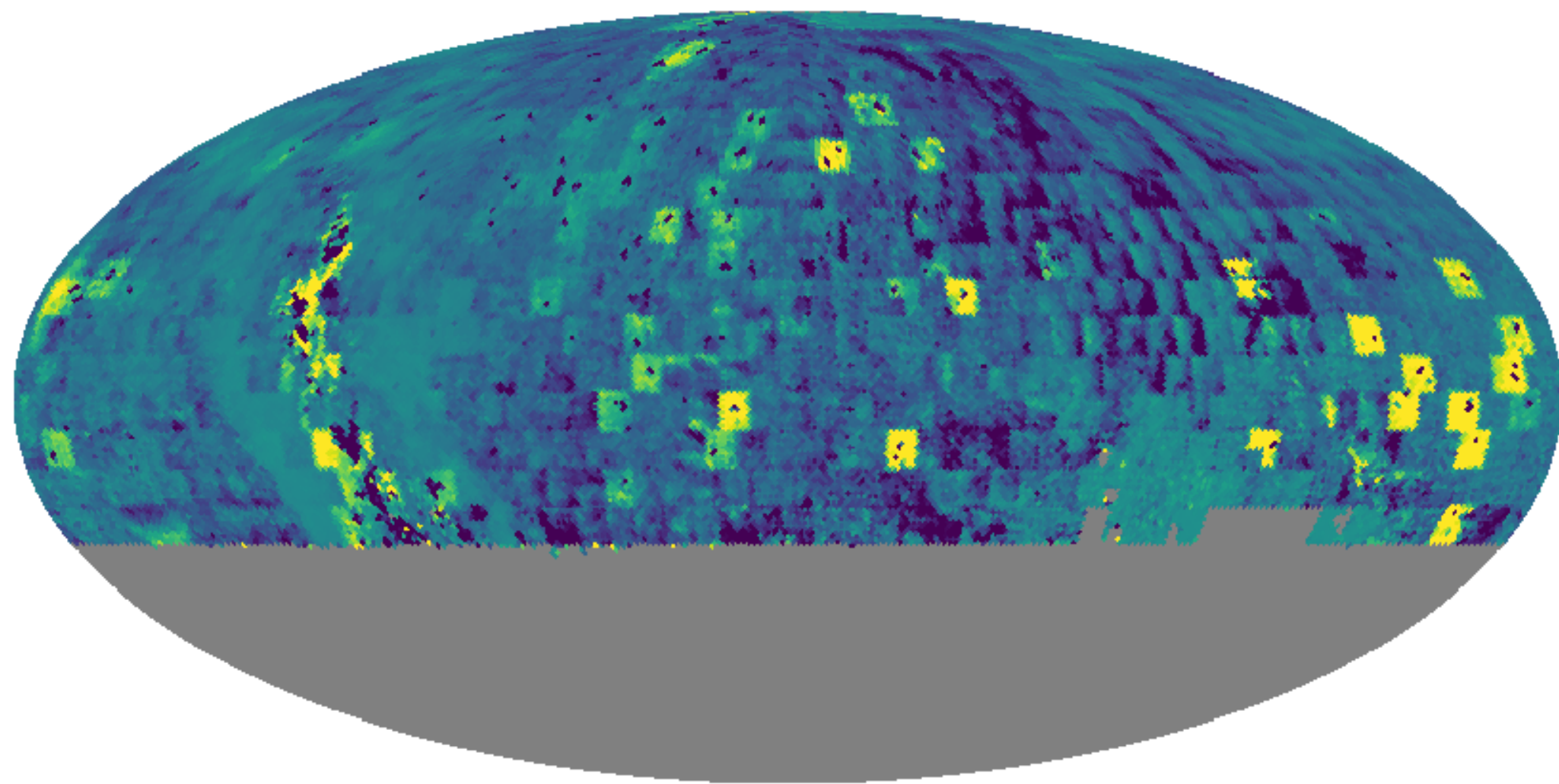
**AP no starflats (1/5 stat)**

median



**AP with starflats (1/5 stat)**

median



**Residual Look worst  
when alternative grid?**



**PSF no starflats (1/5 stat)**

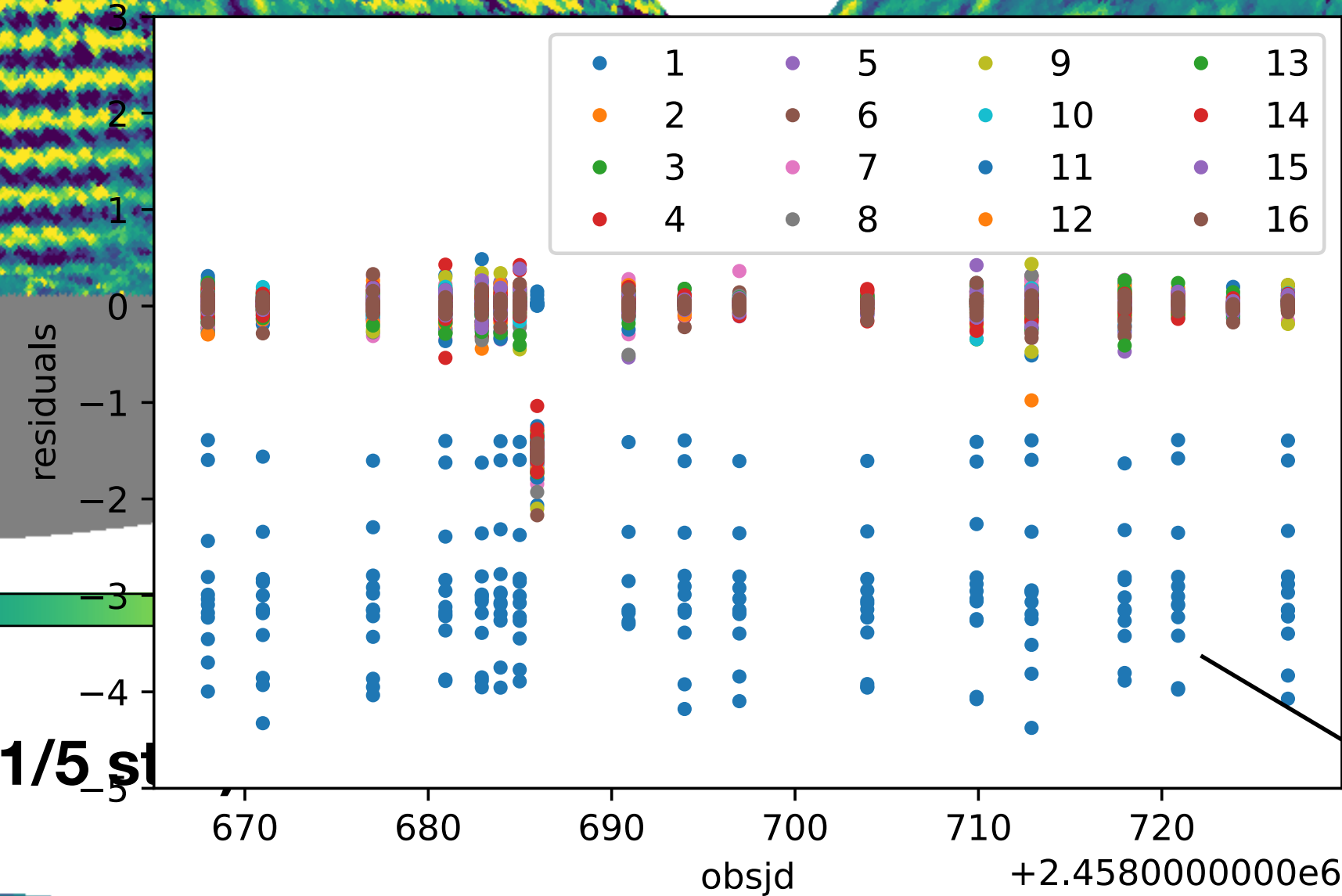
**PSF with starflats (1/5 stat)**

**ZTF-r**

median

median

field 399



**AP no starflats (1/5 stat)**

**with starflats (1/5 stat)**

median

median



**Residual Look worst when alternative grid?**

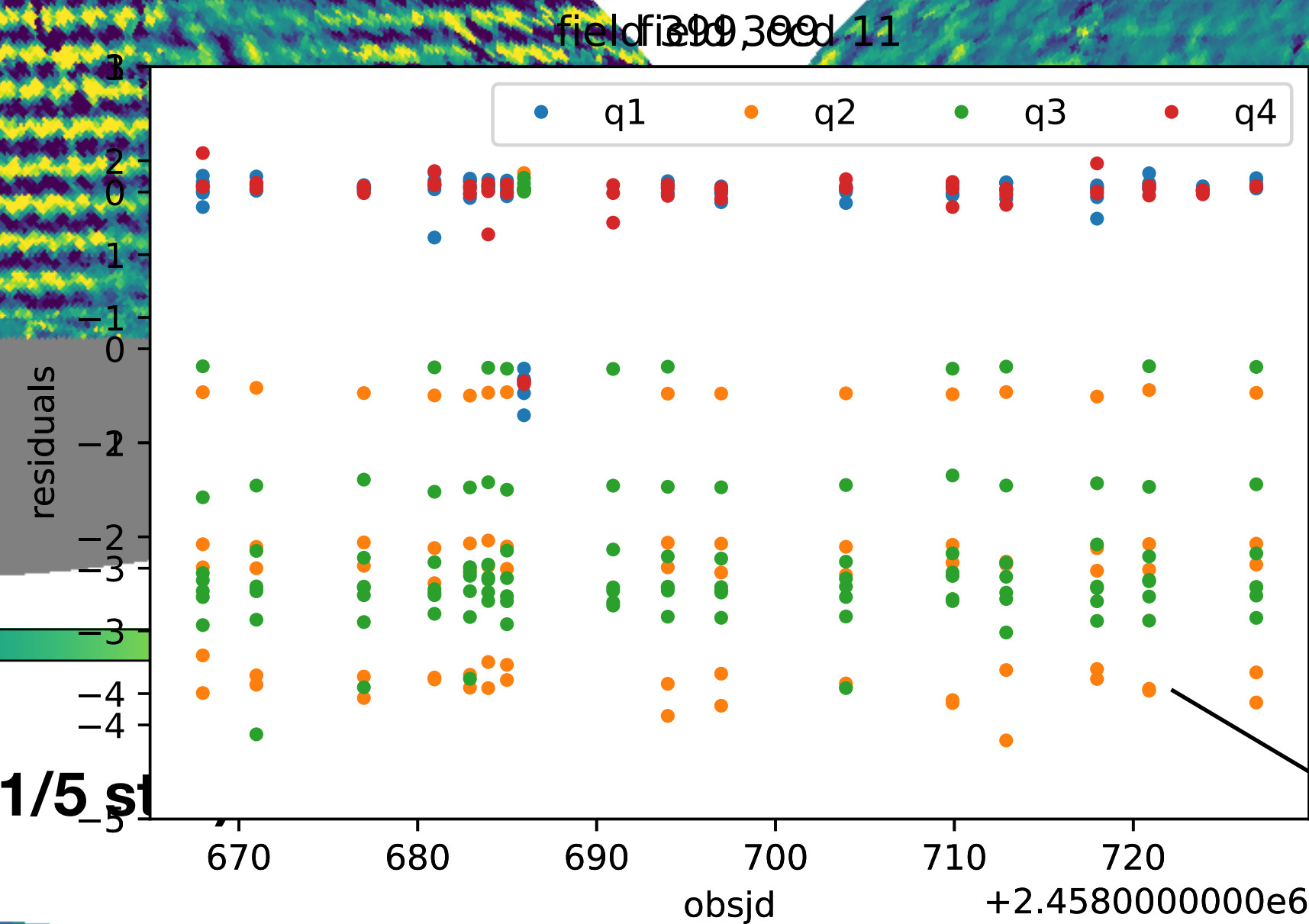
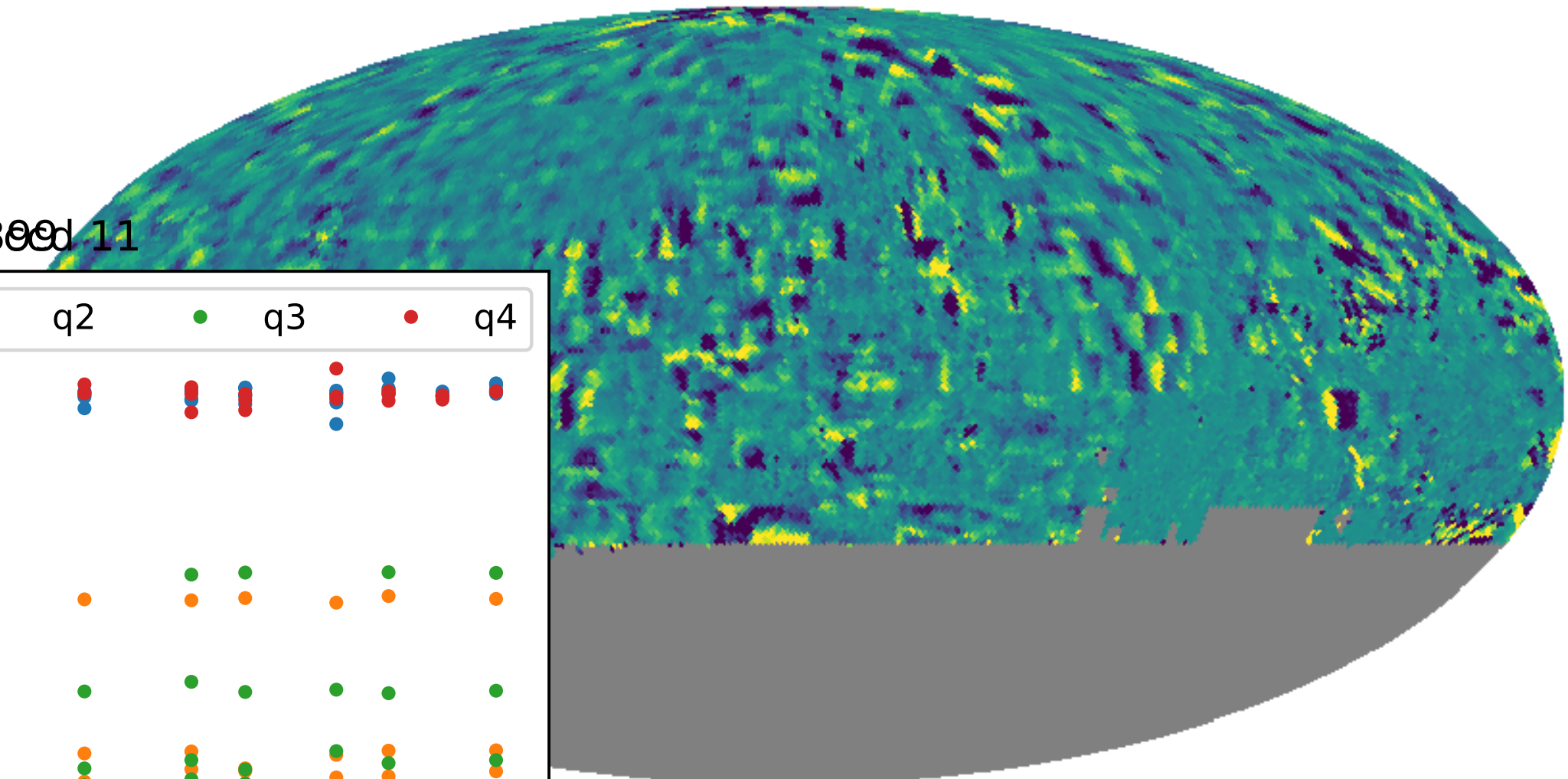
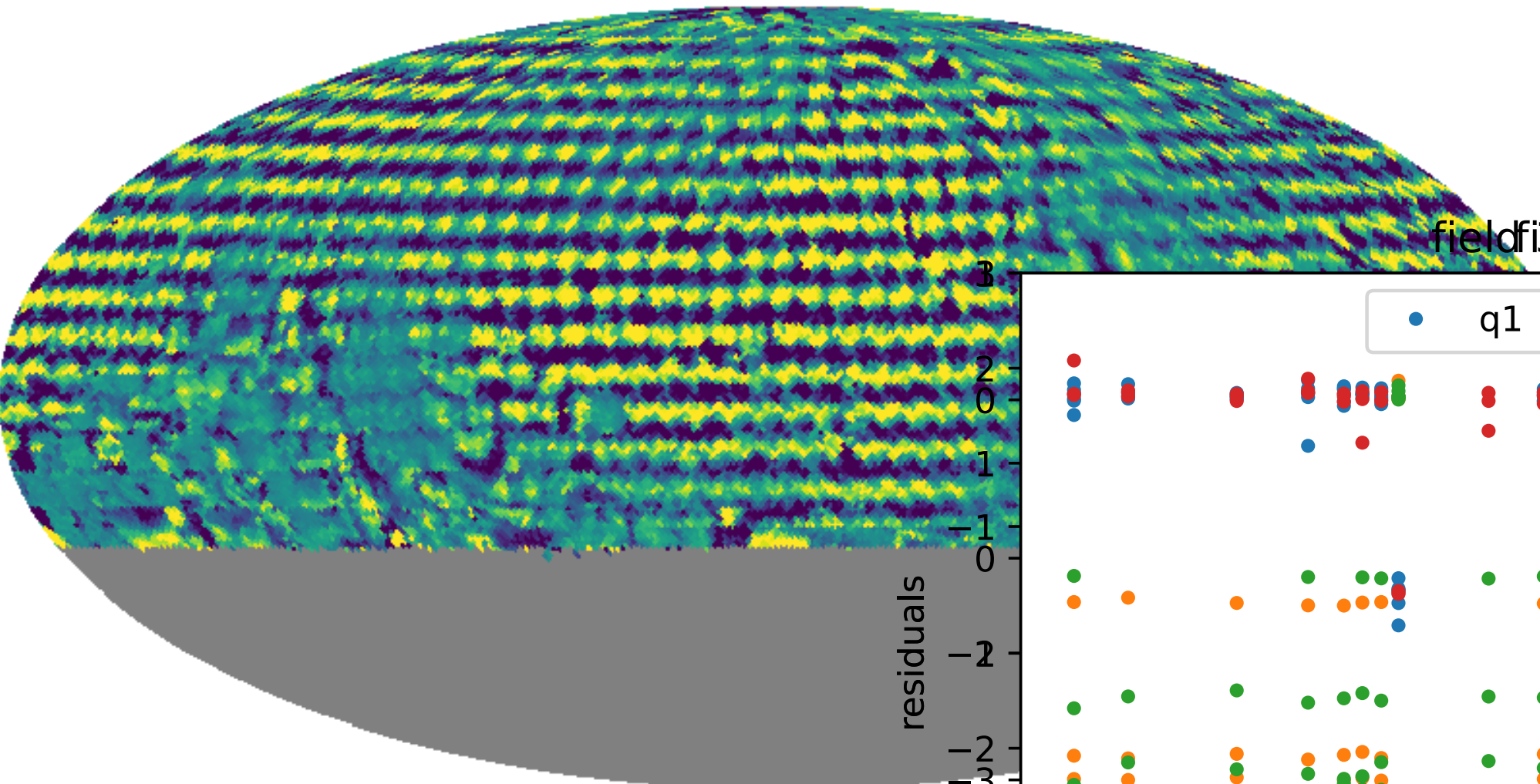
**PSF no starflats (1/5 stat)**

**PSF with starflats (1/5 stat)**

**ZTF-r**

median

median

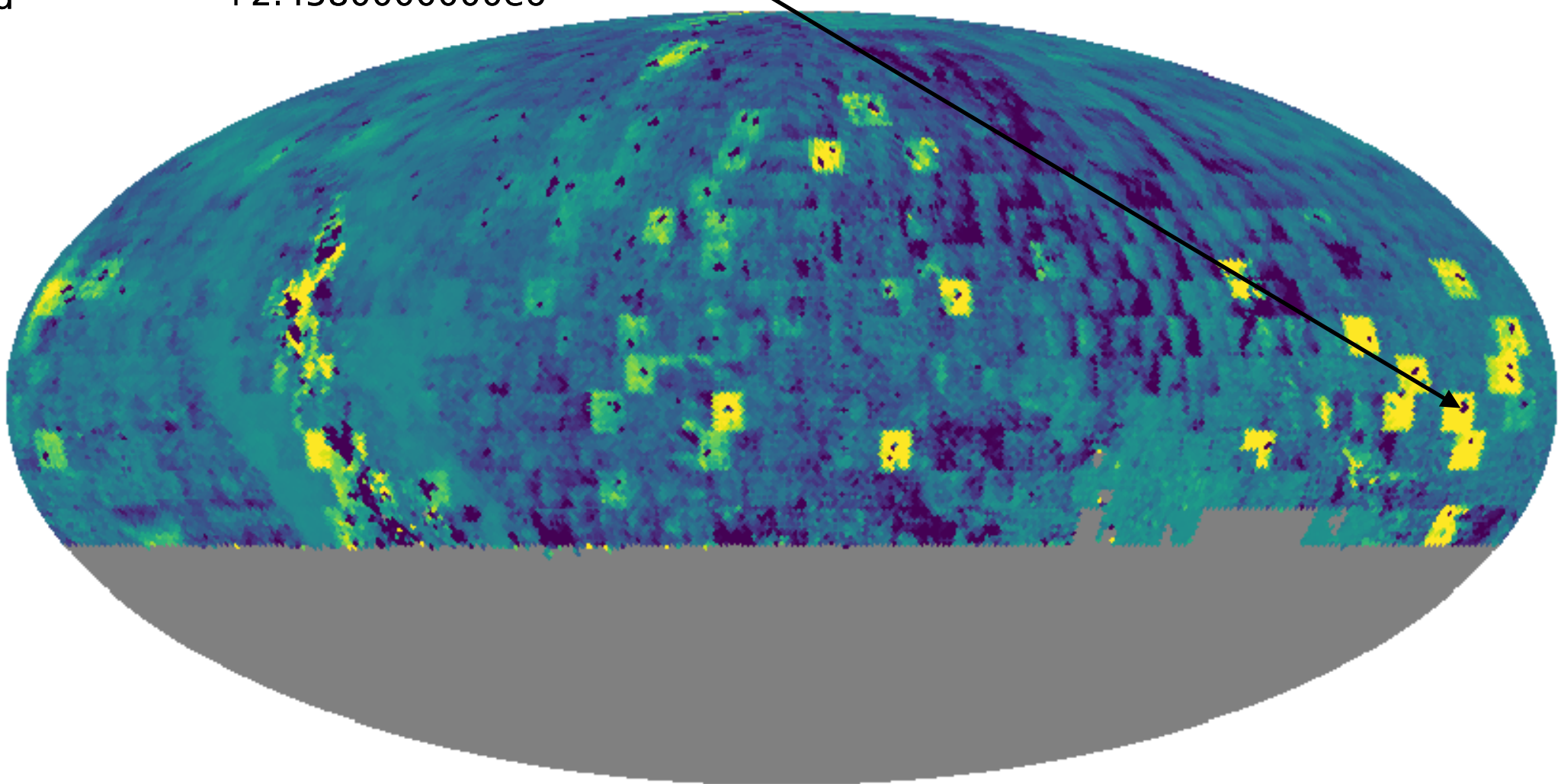
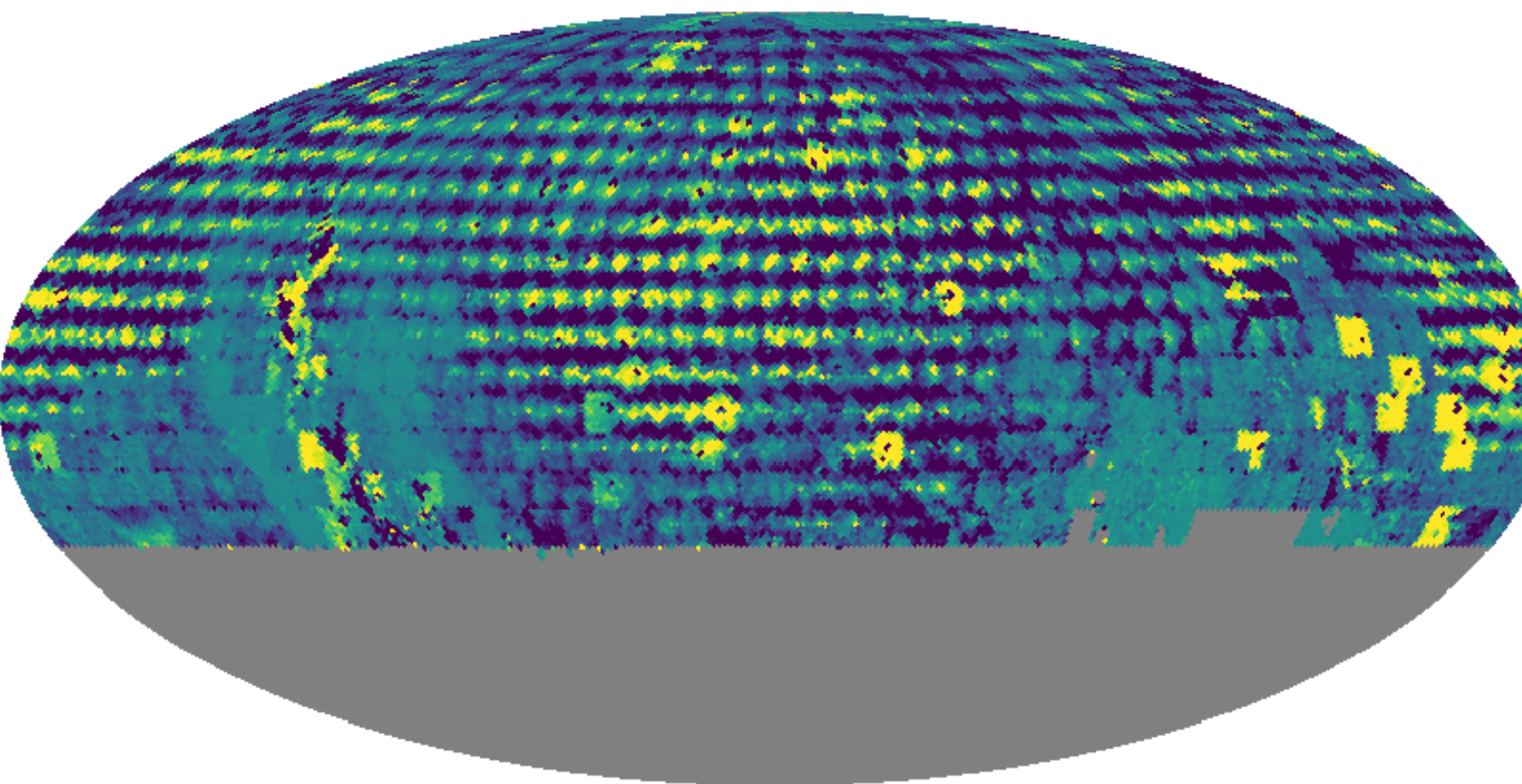


**AP no starflats (1/5 stat)**

**with starflats (1/5 stat)**

median

median

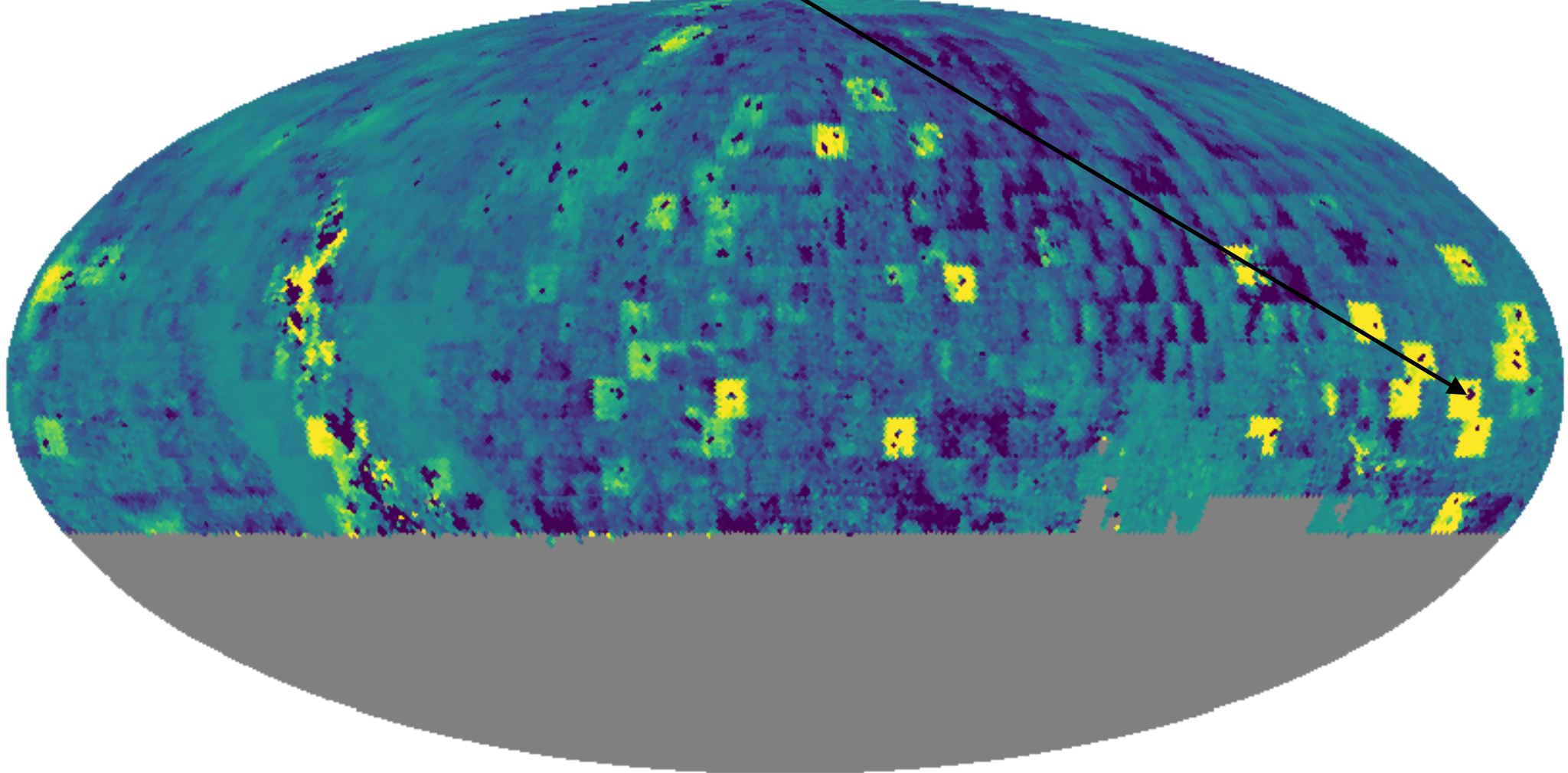
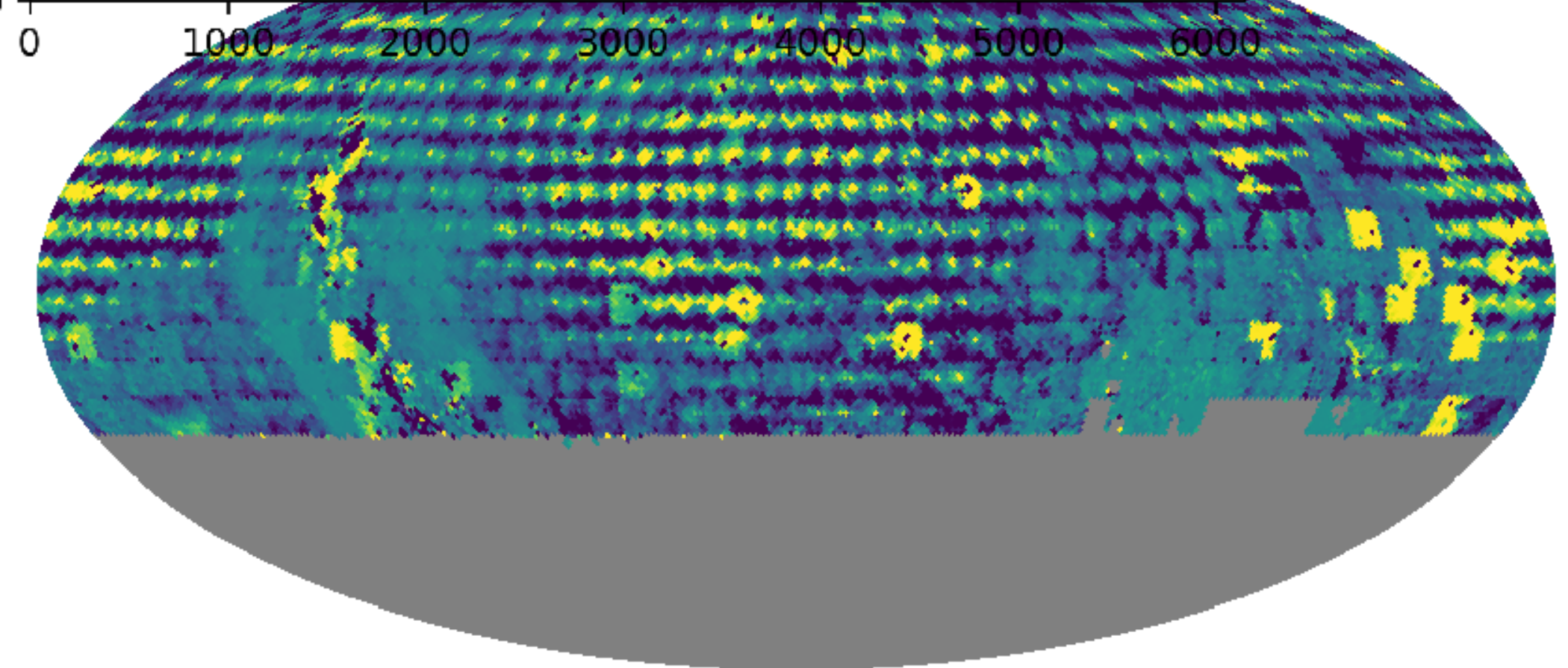
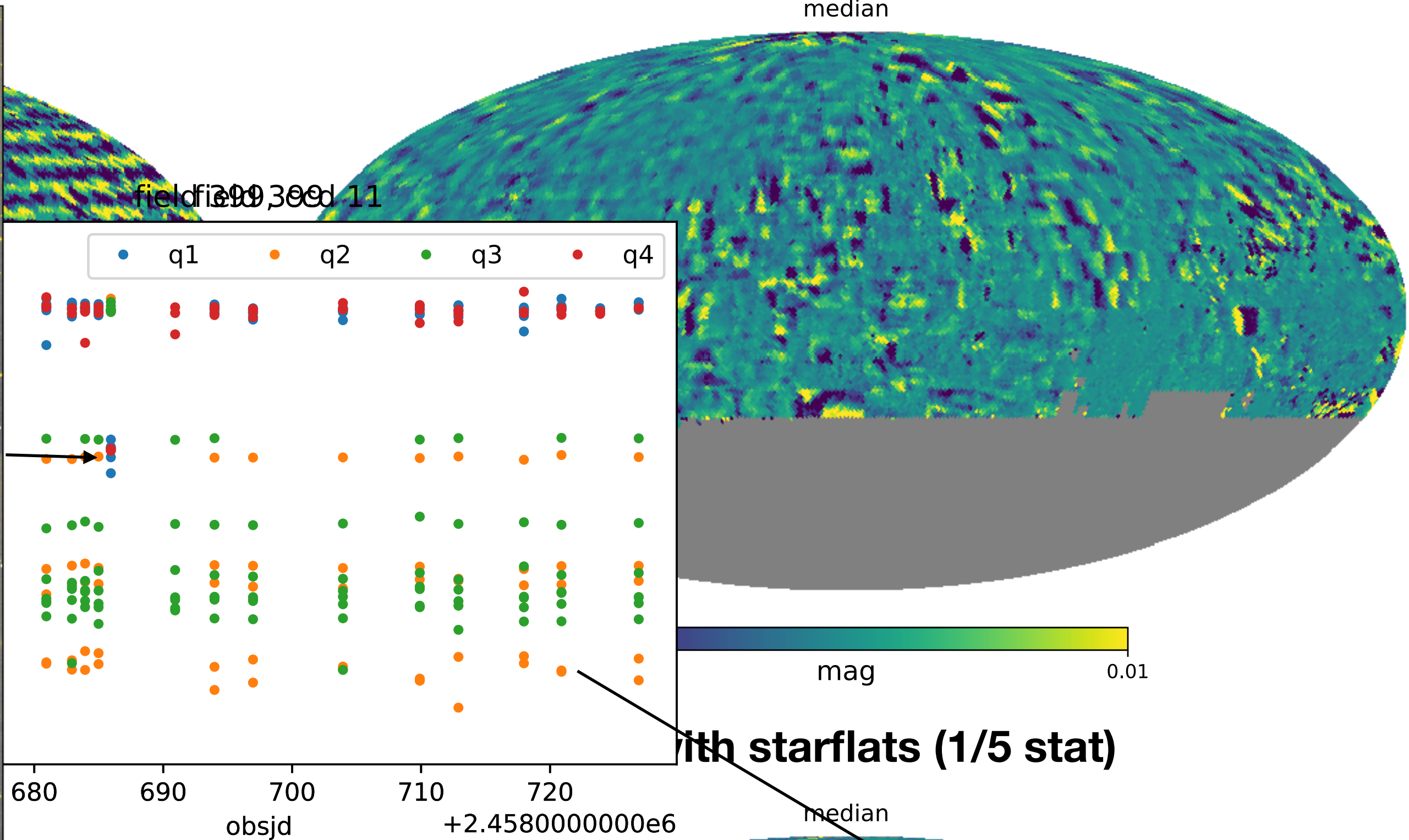
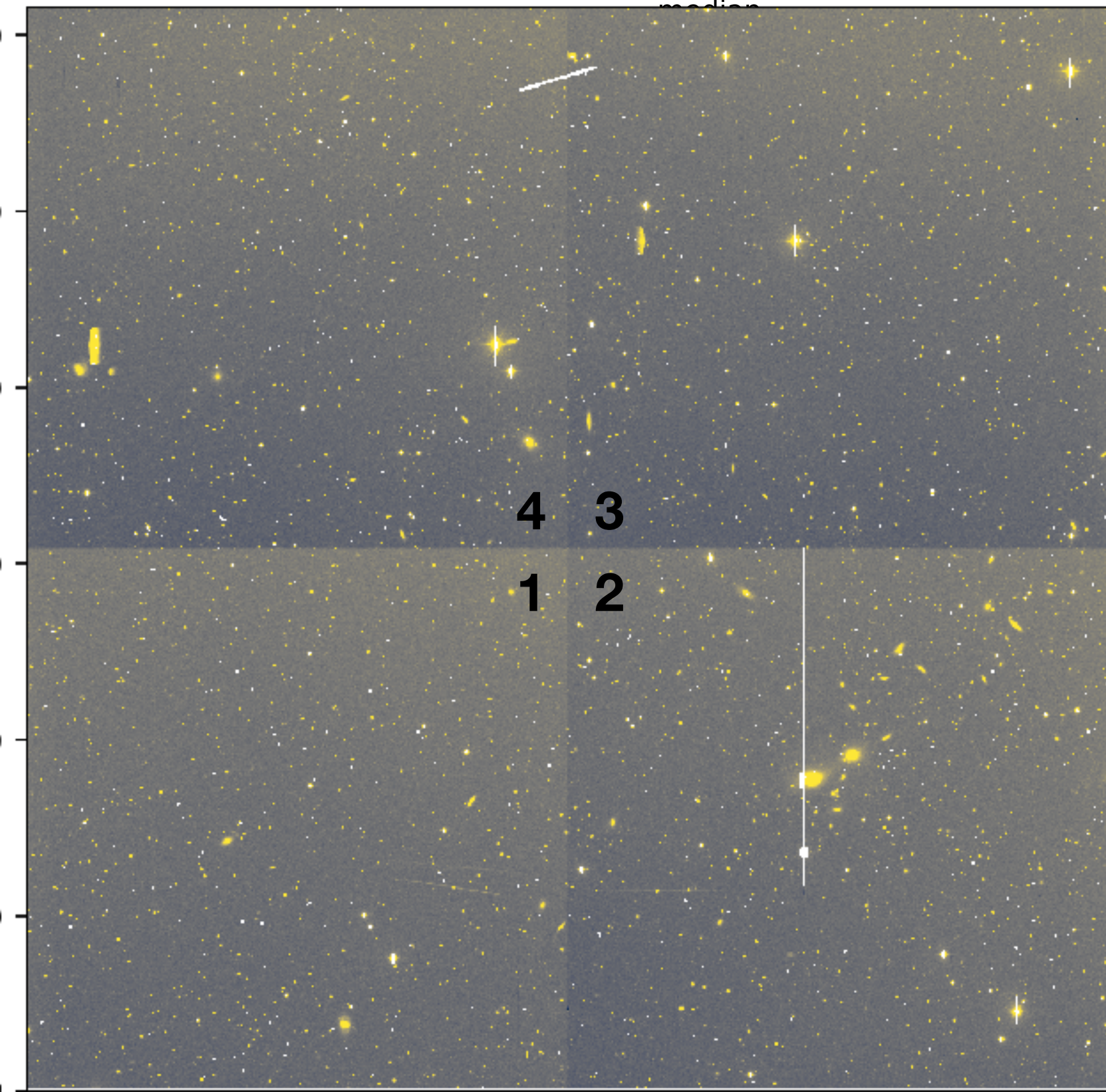


**Residual Look worst when alternative grid?**

PSF no starflats (1/5 stat)

PSF with starflats (1/5 stat)

ZTF-r

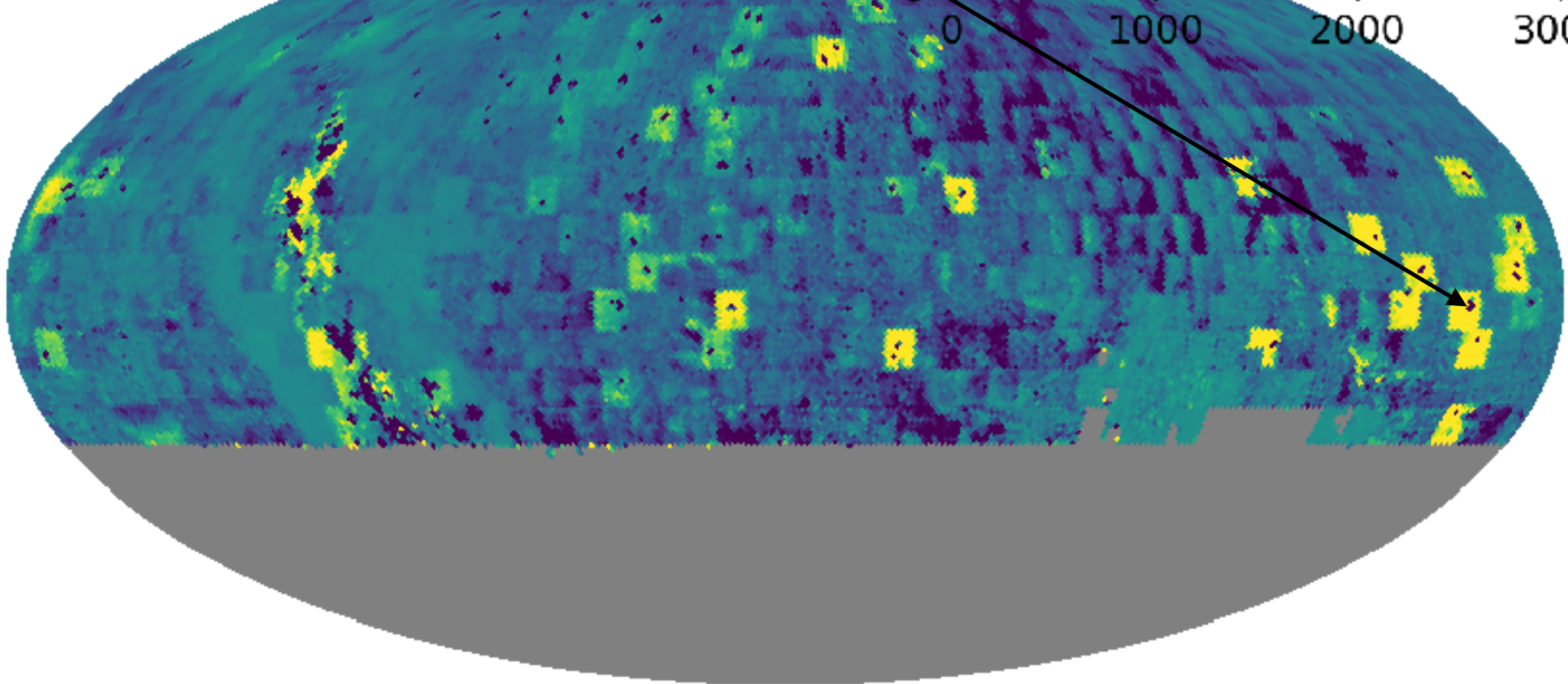
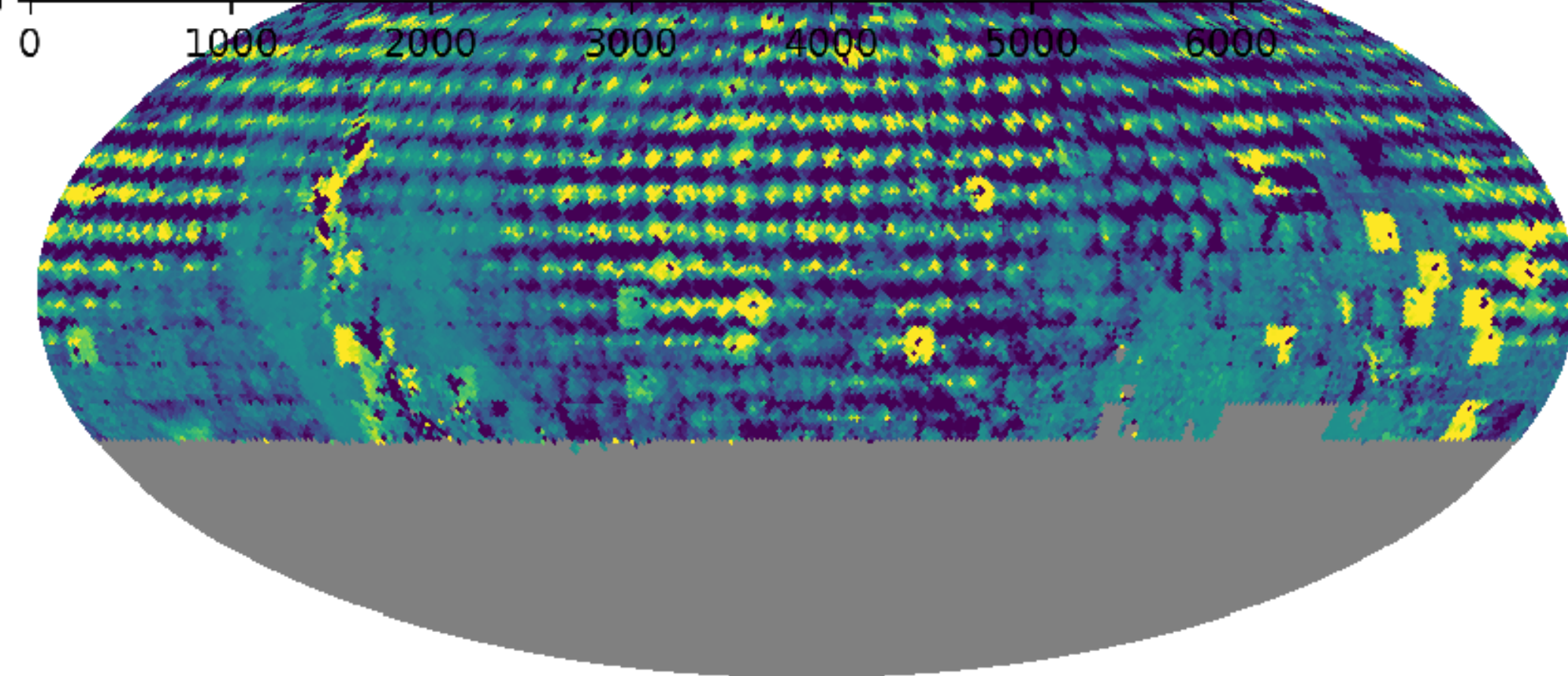
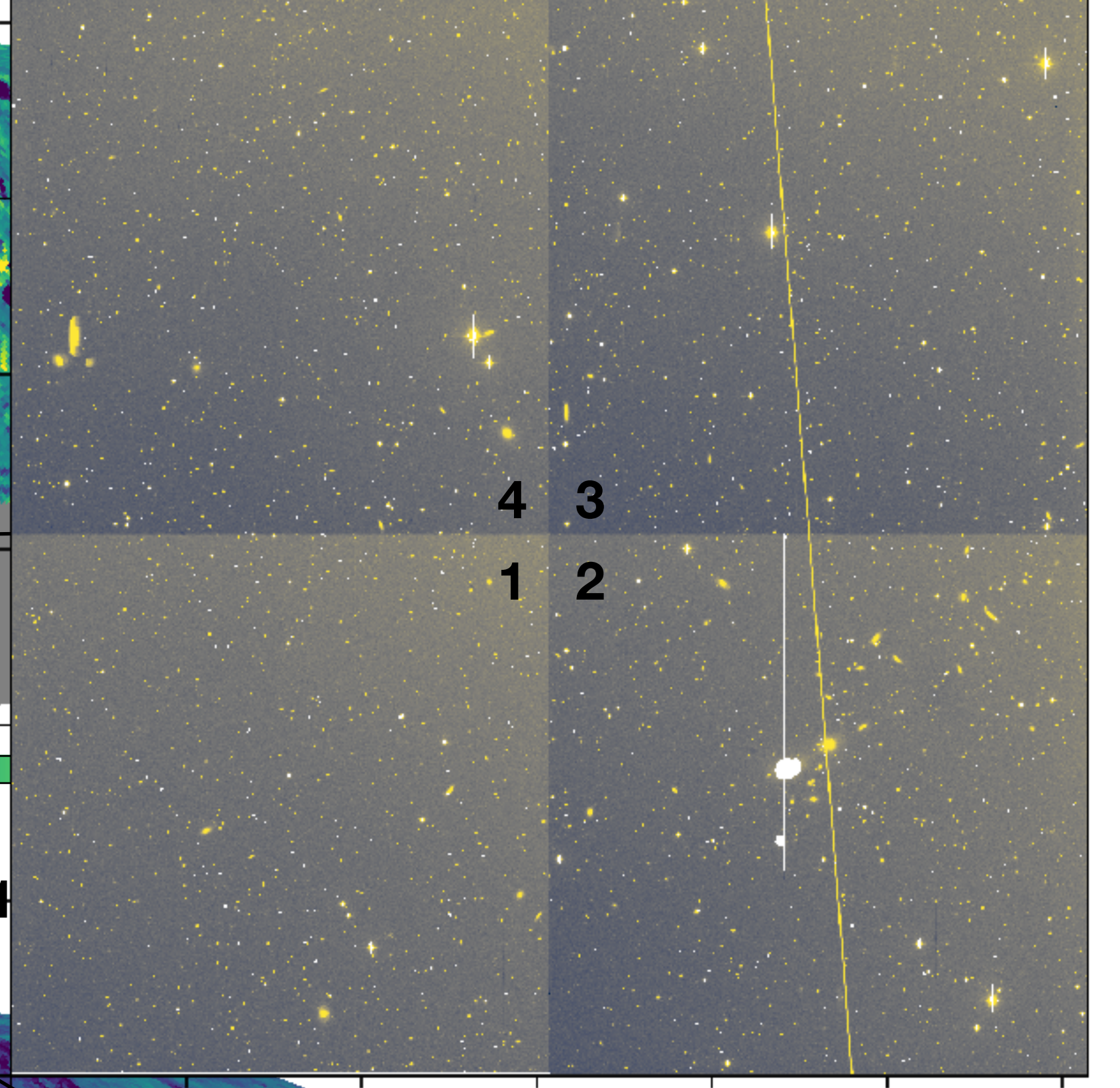
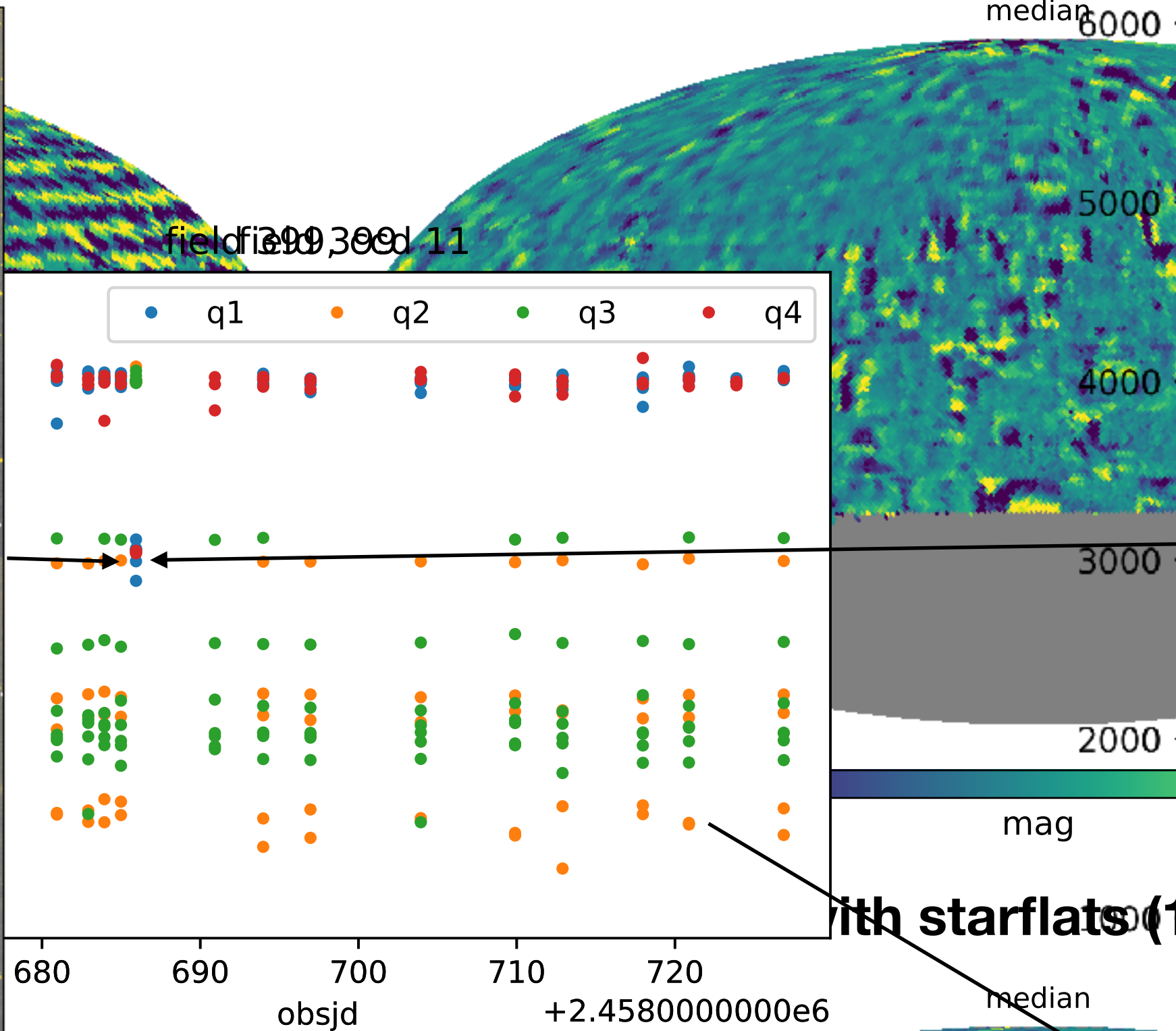
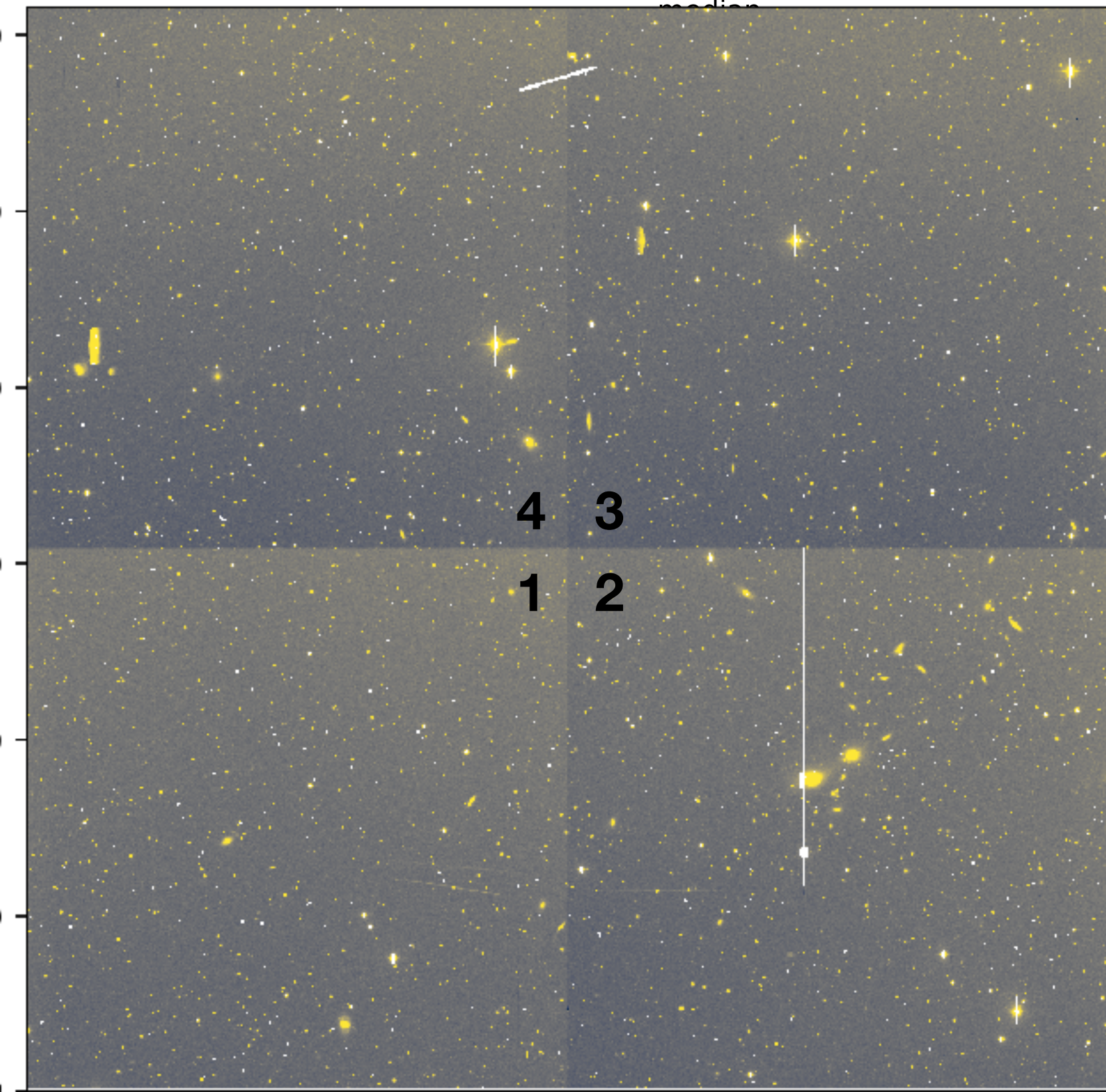


Residual Look worst when alternative grid?

PSF no starflats (1/5 stat)

PSF with starflats (1/5 stat)

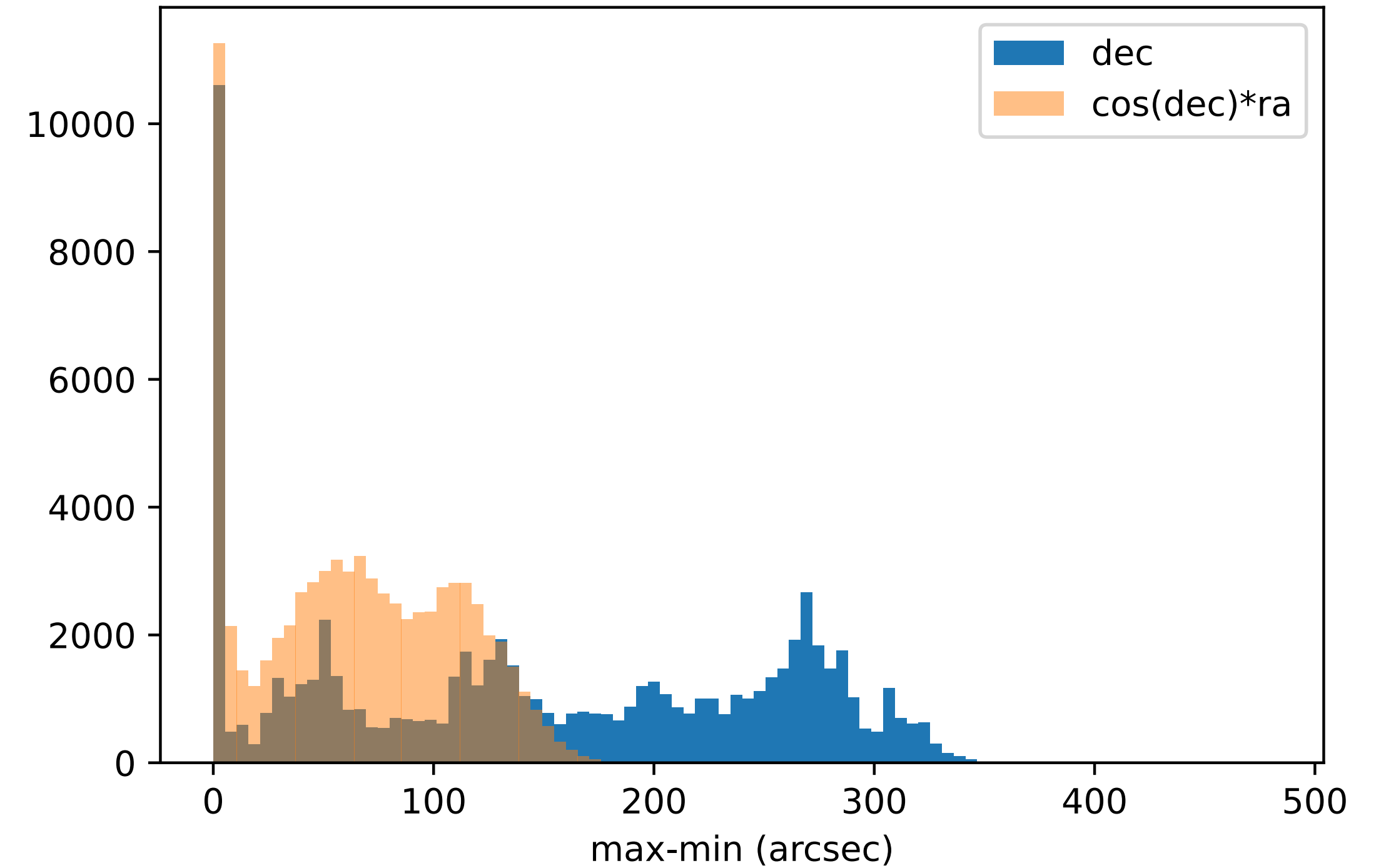
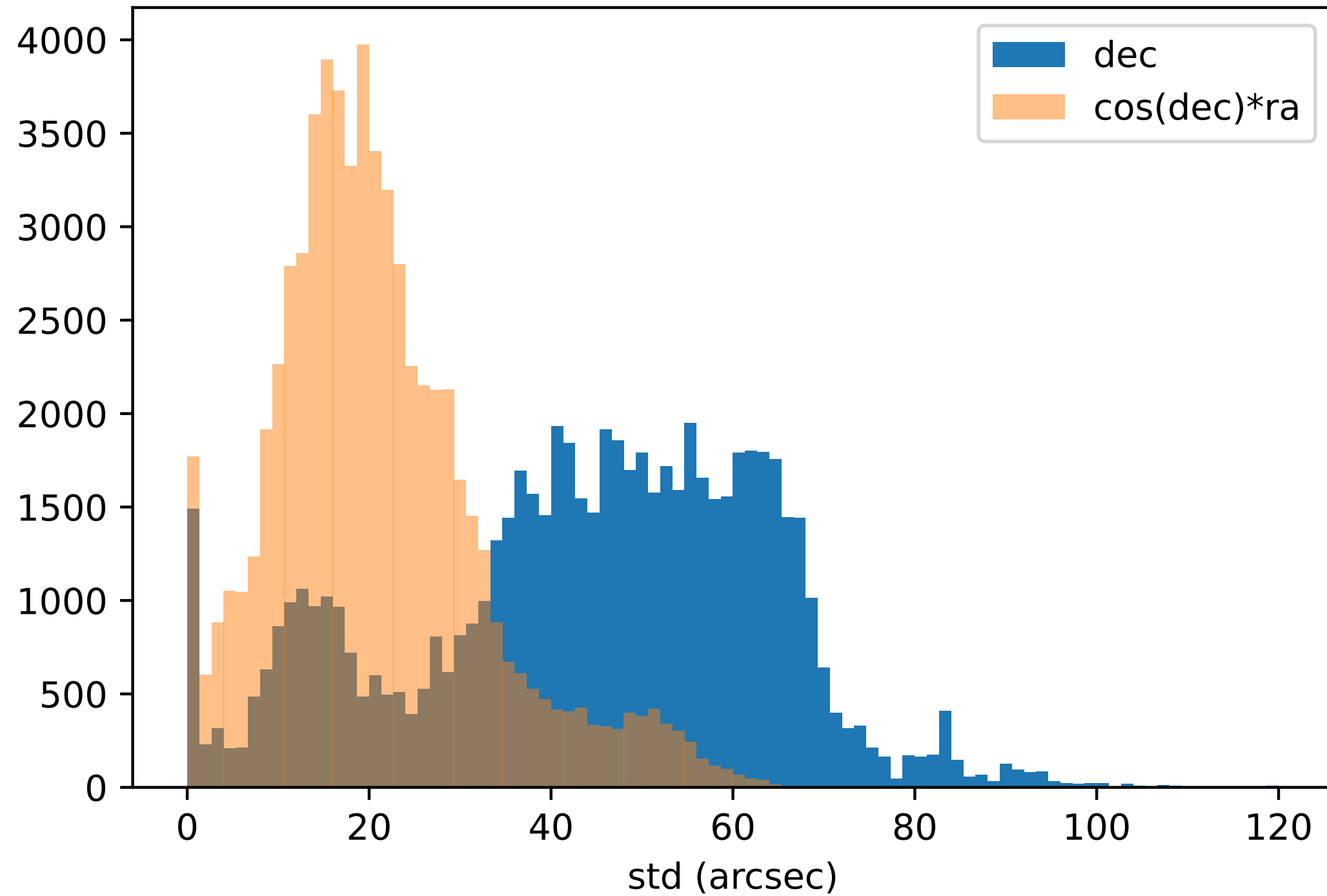
ZTF-r



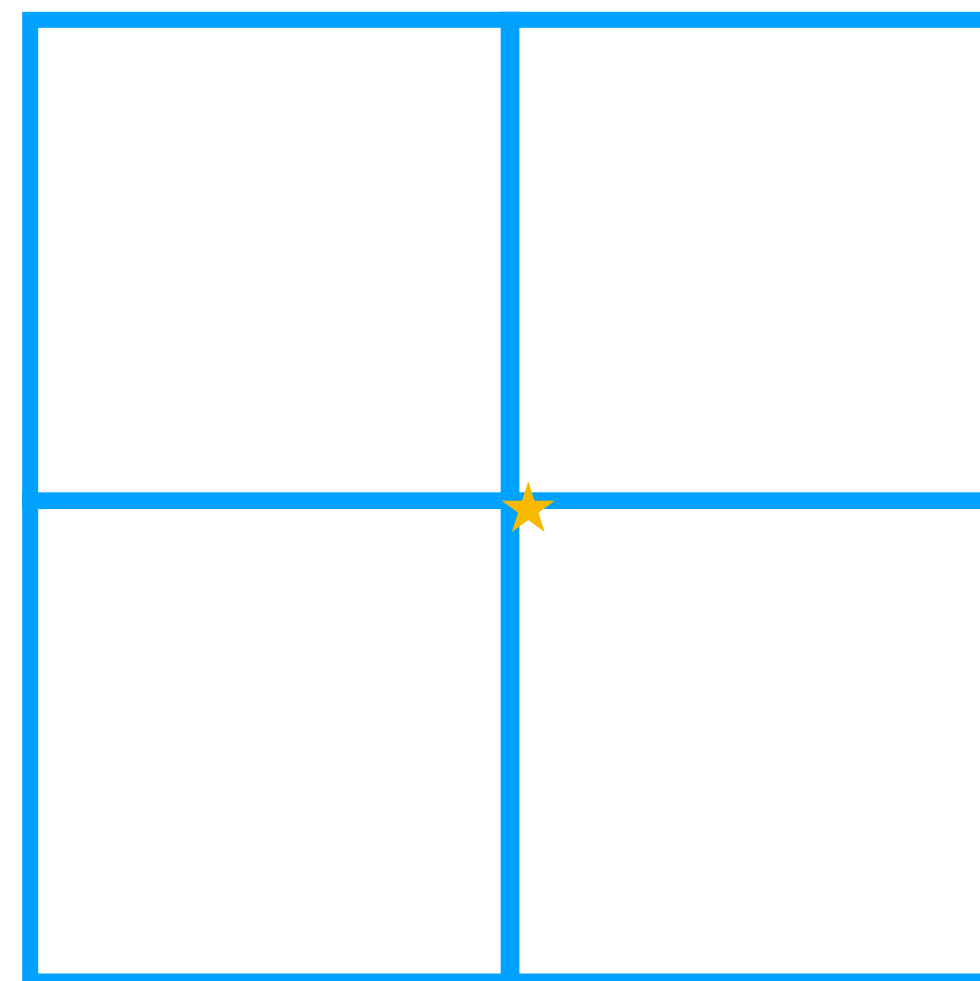
Residual Look worst when alternative grid?



# Lucky dithering !

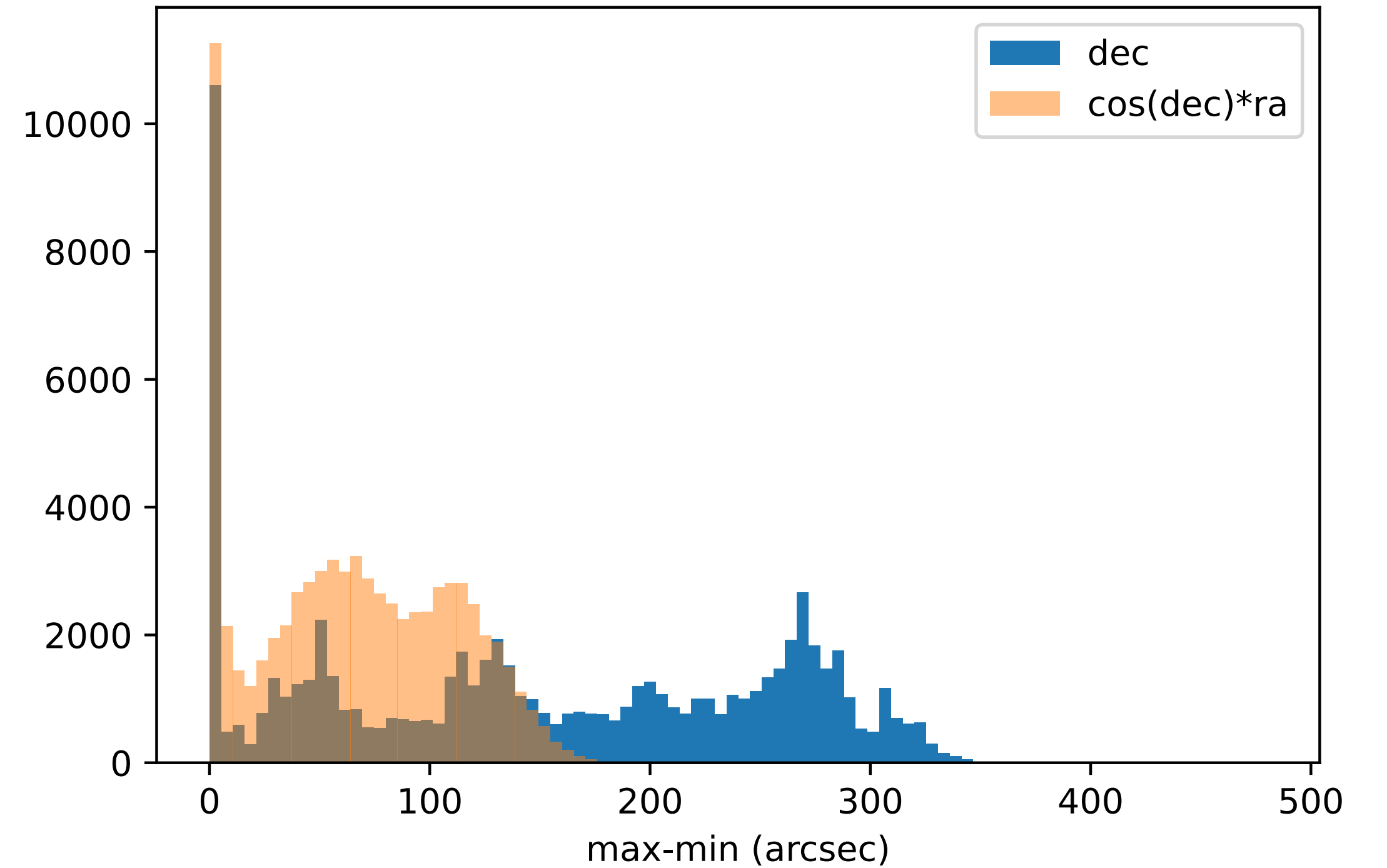
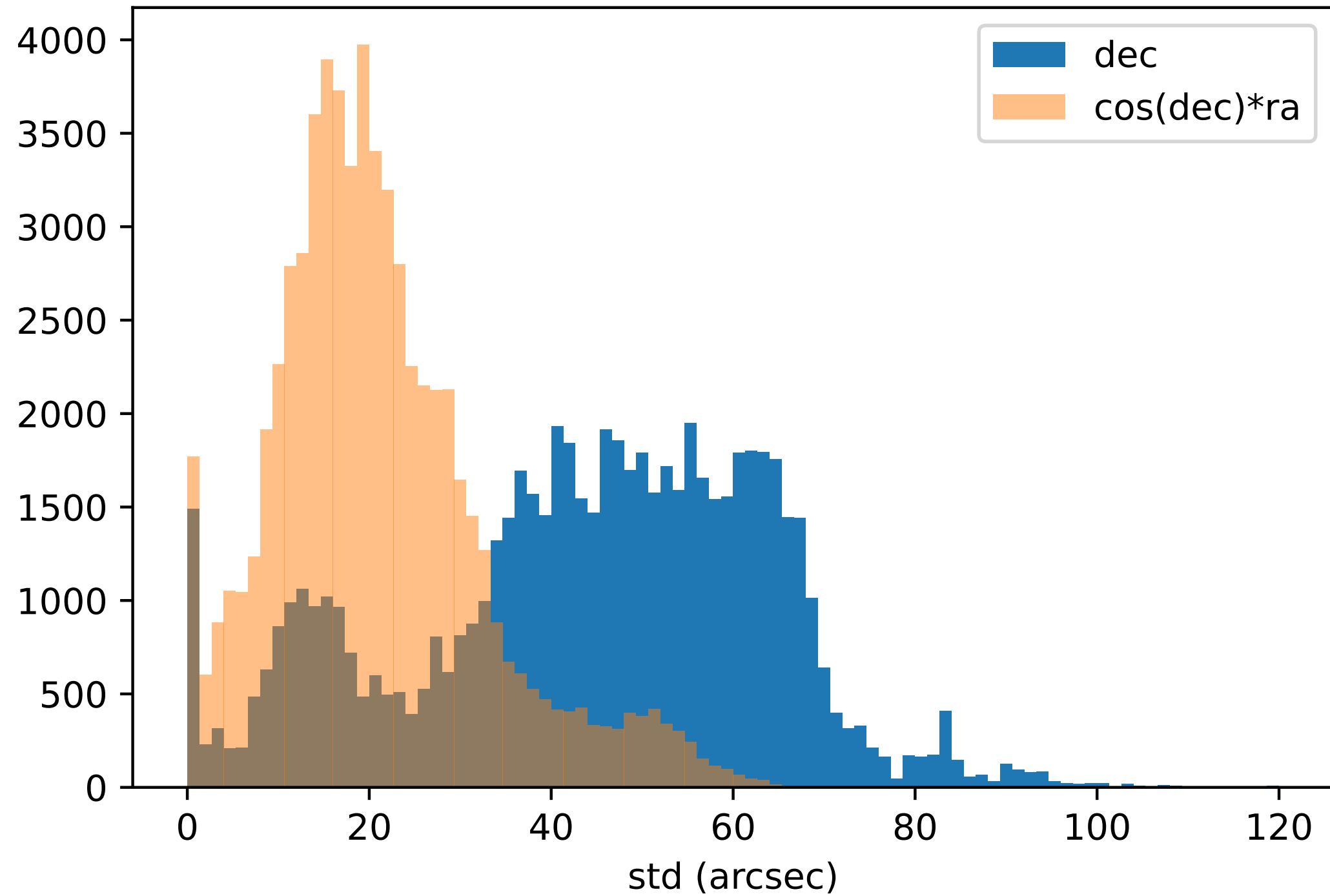


**For now, quadrant resolution**  
**« not positive definite »**  
**Can use regularization,**  
**but not sure of meaning for**  
**« disconnected islands »**

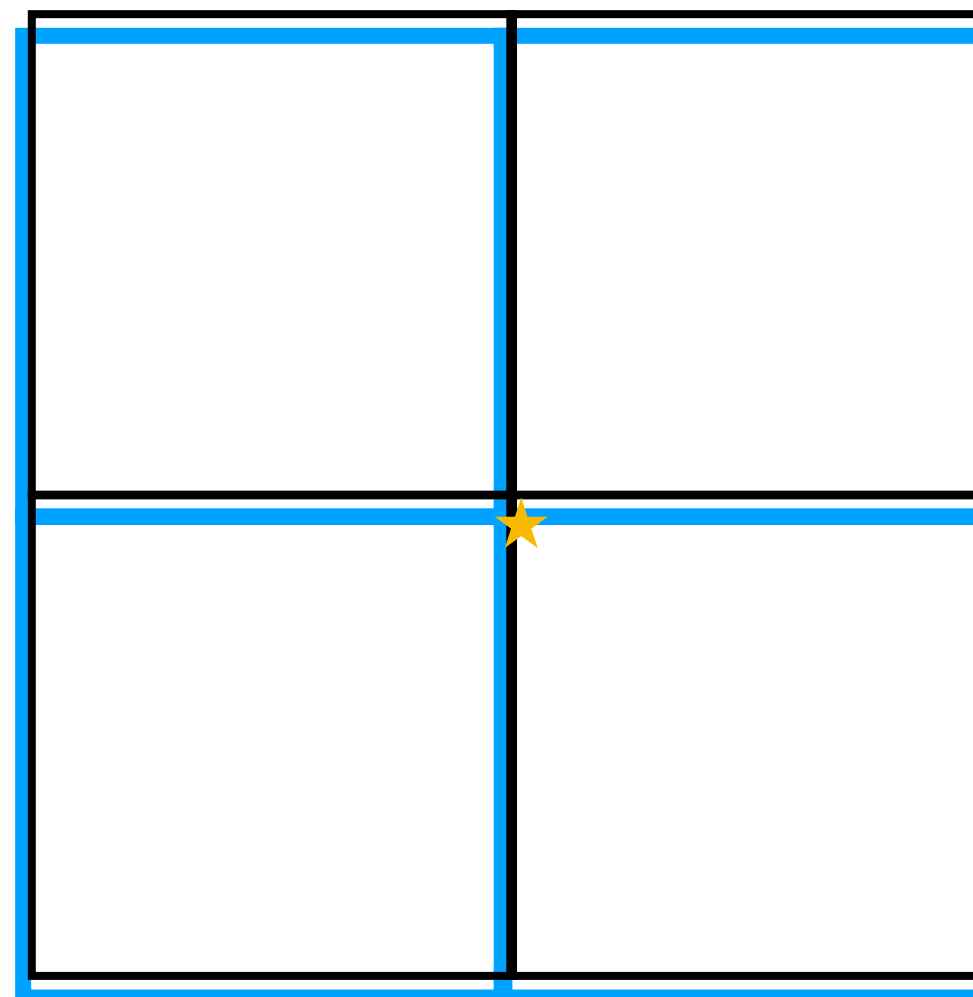


**O(arcmin) pointing dithering**  
Stars at the boundary are observed by adjacent quadrant (CCD?)  
Reconsider edge cuts (30 pix for now)  
Even reinforce stats there?  
What about starflats on these edges.  
Could go to higher res than quadrant?

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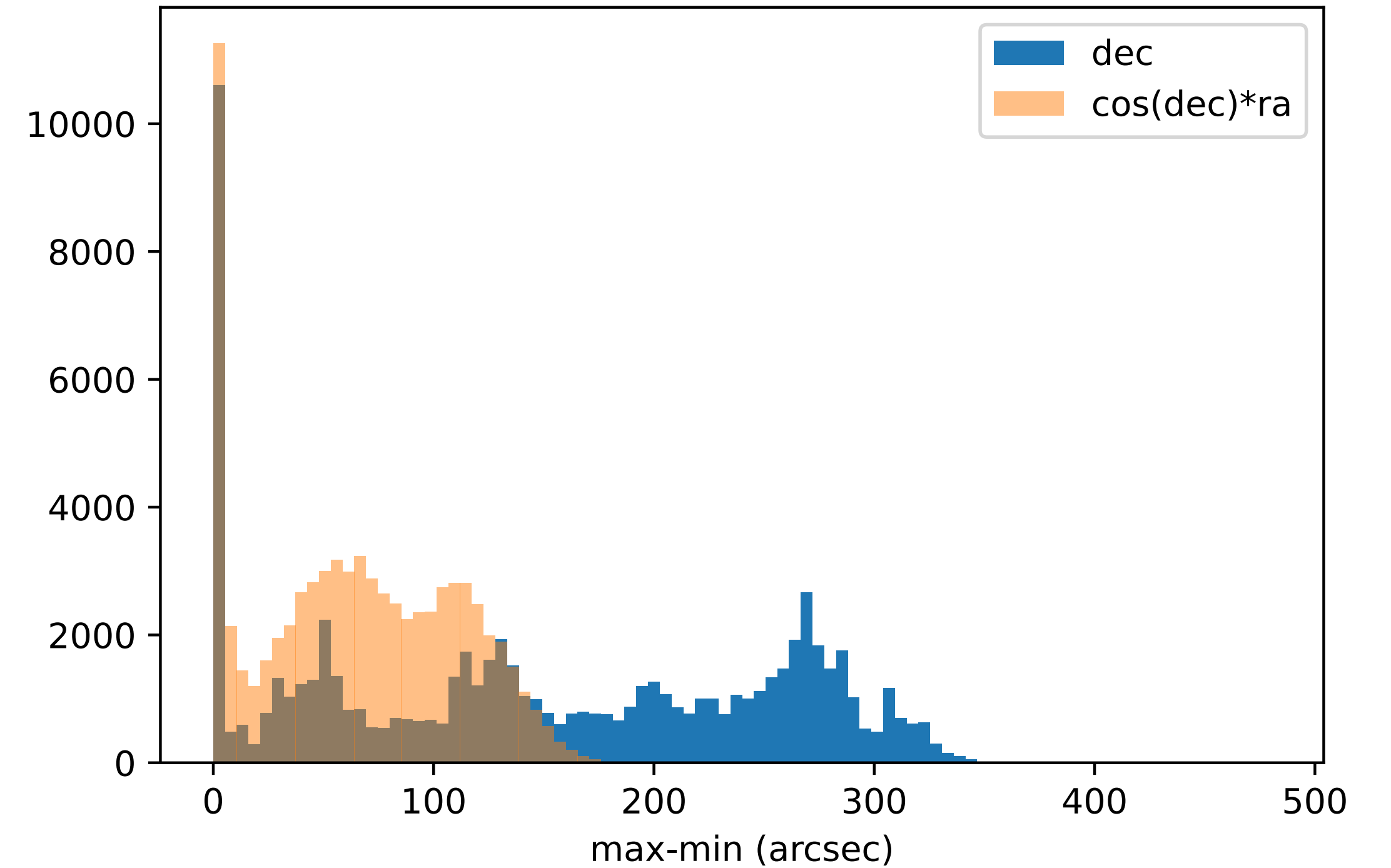
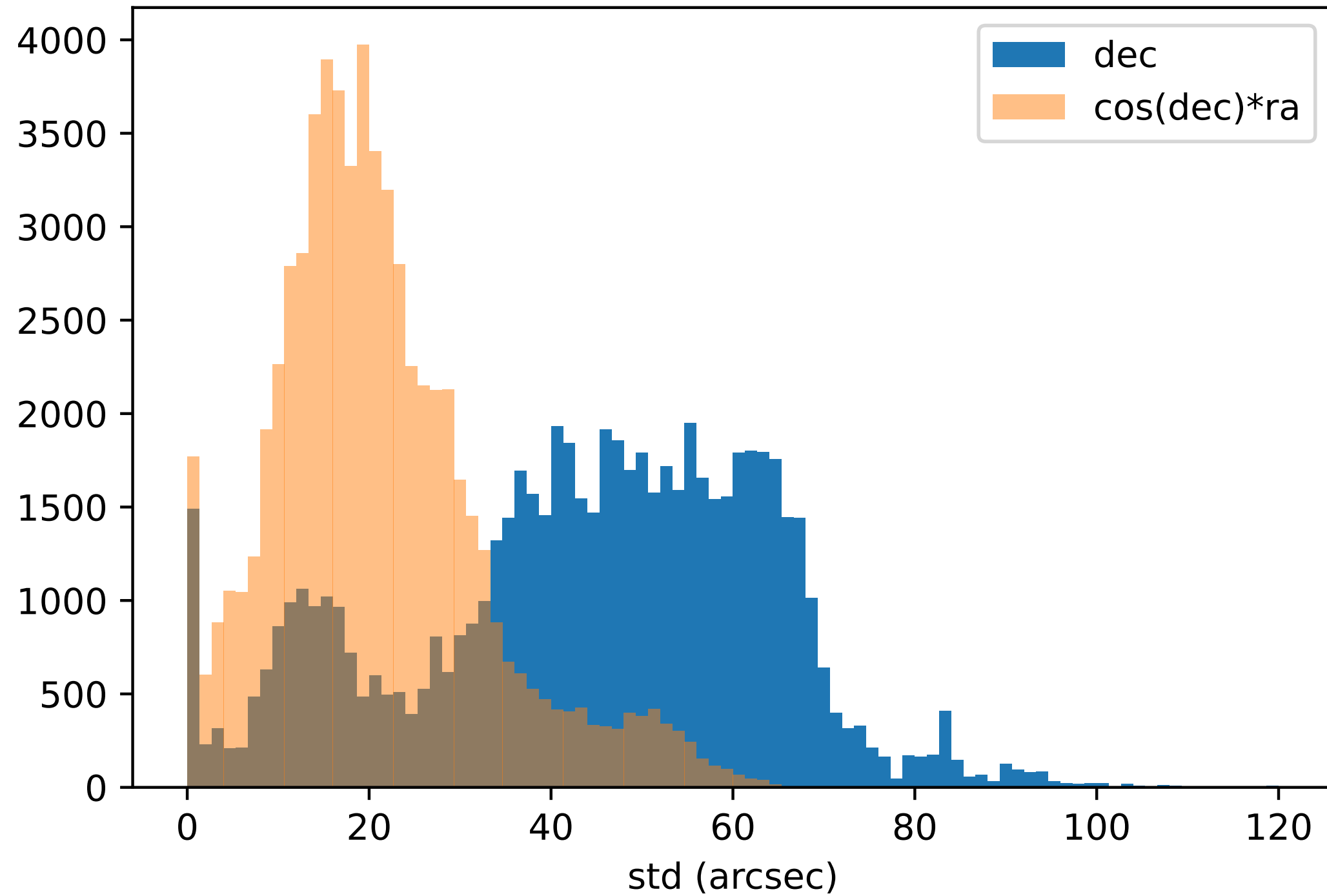


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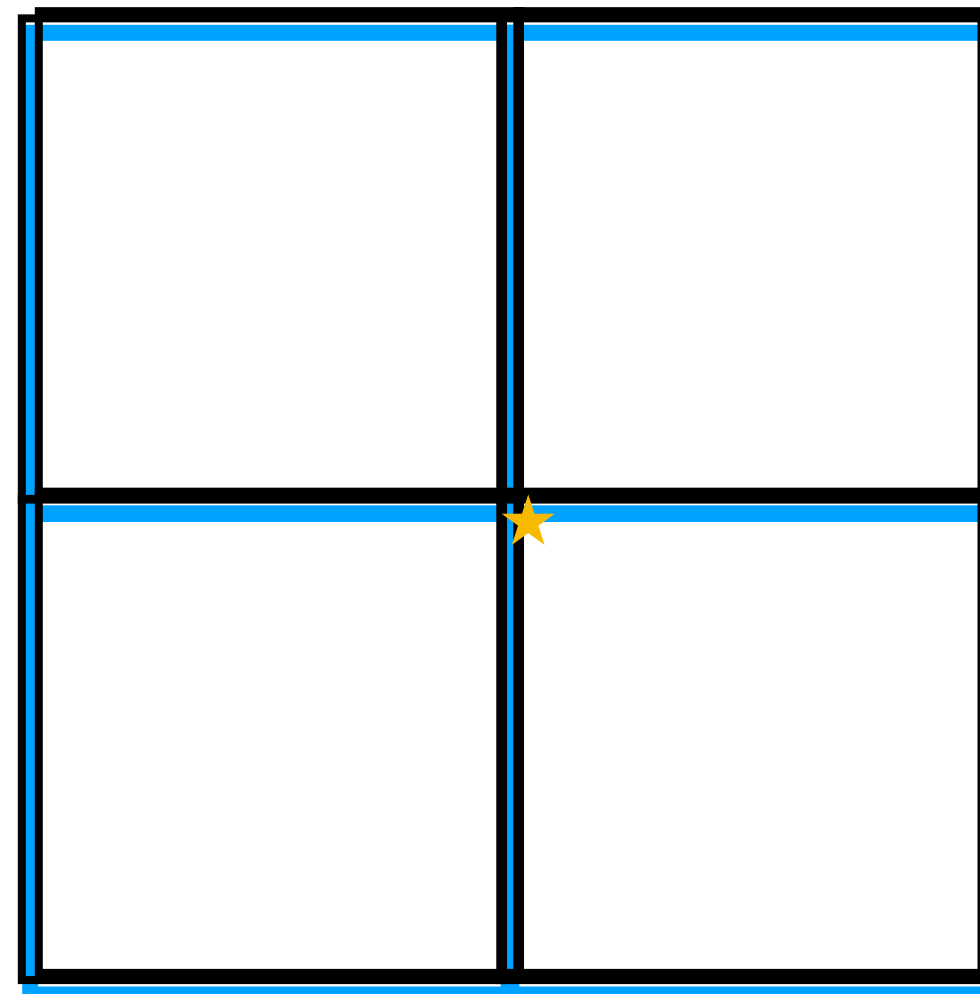


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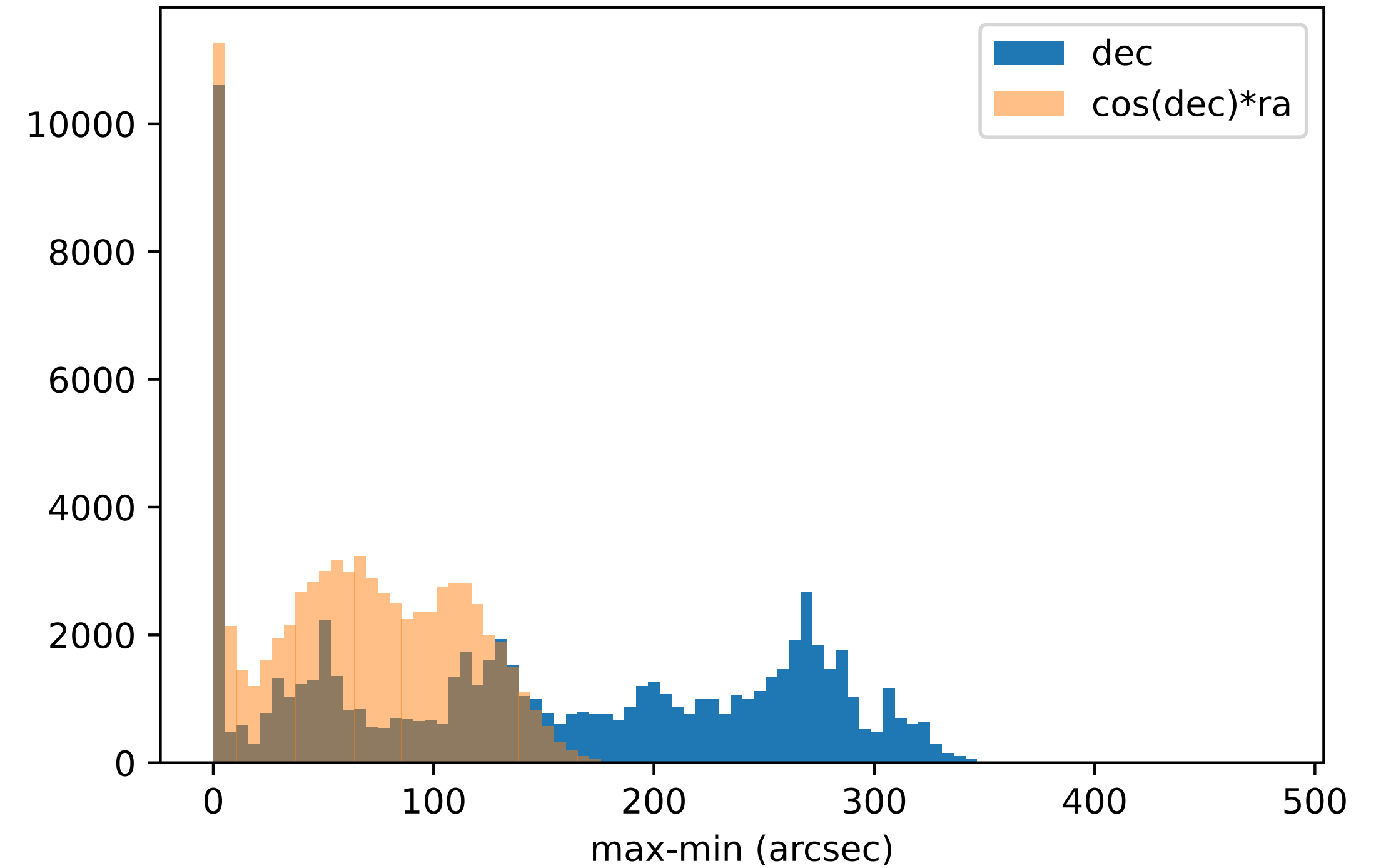
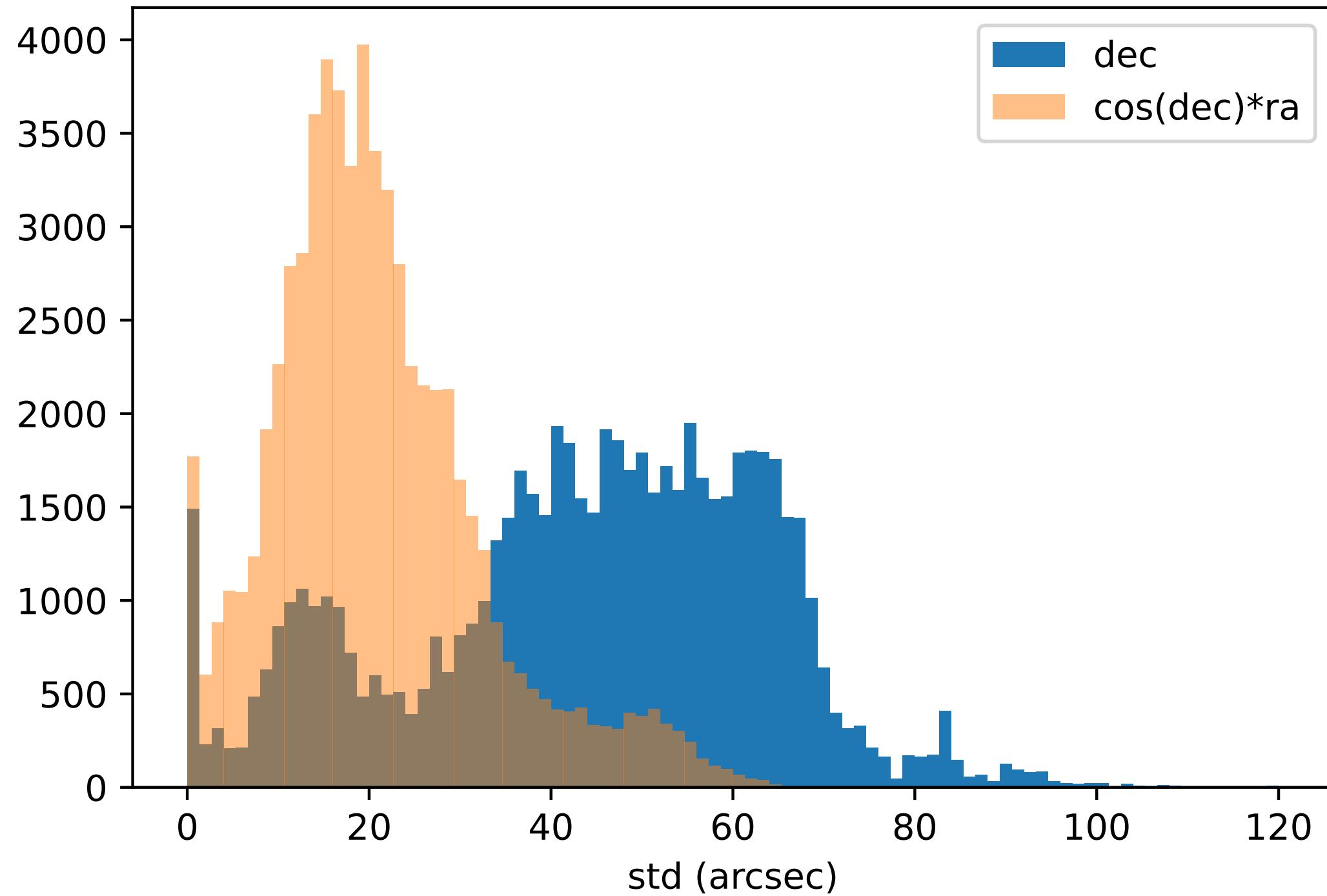


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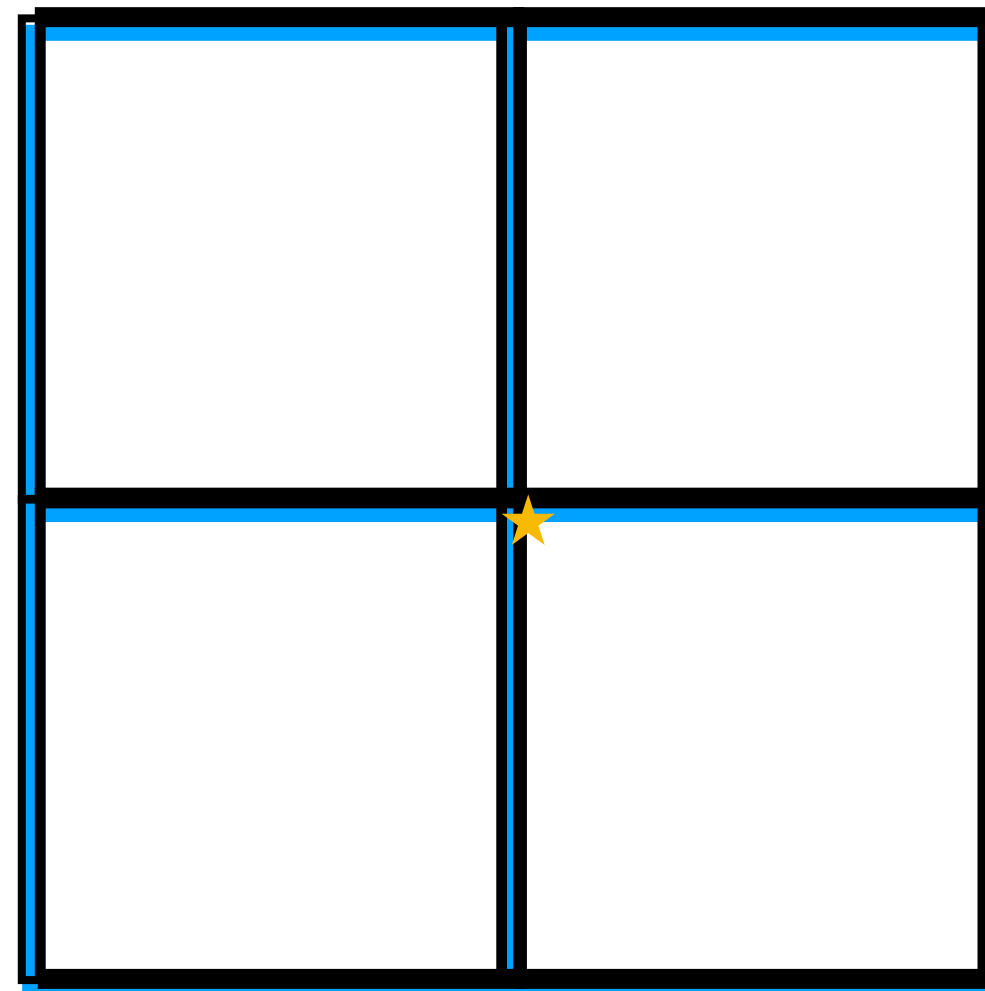


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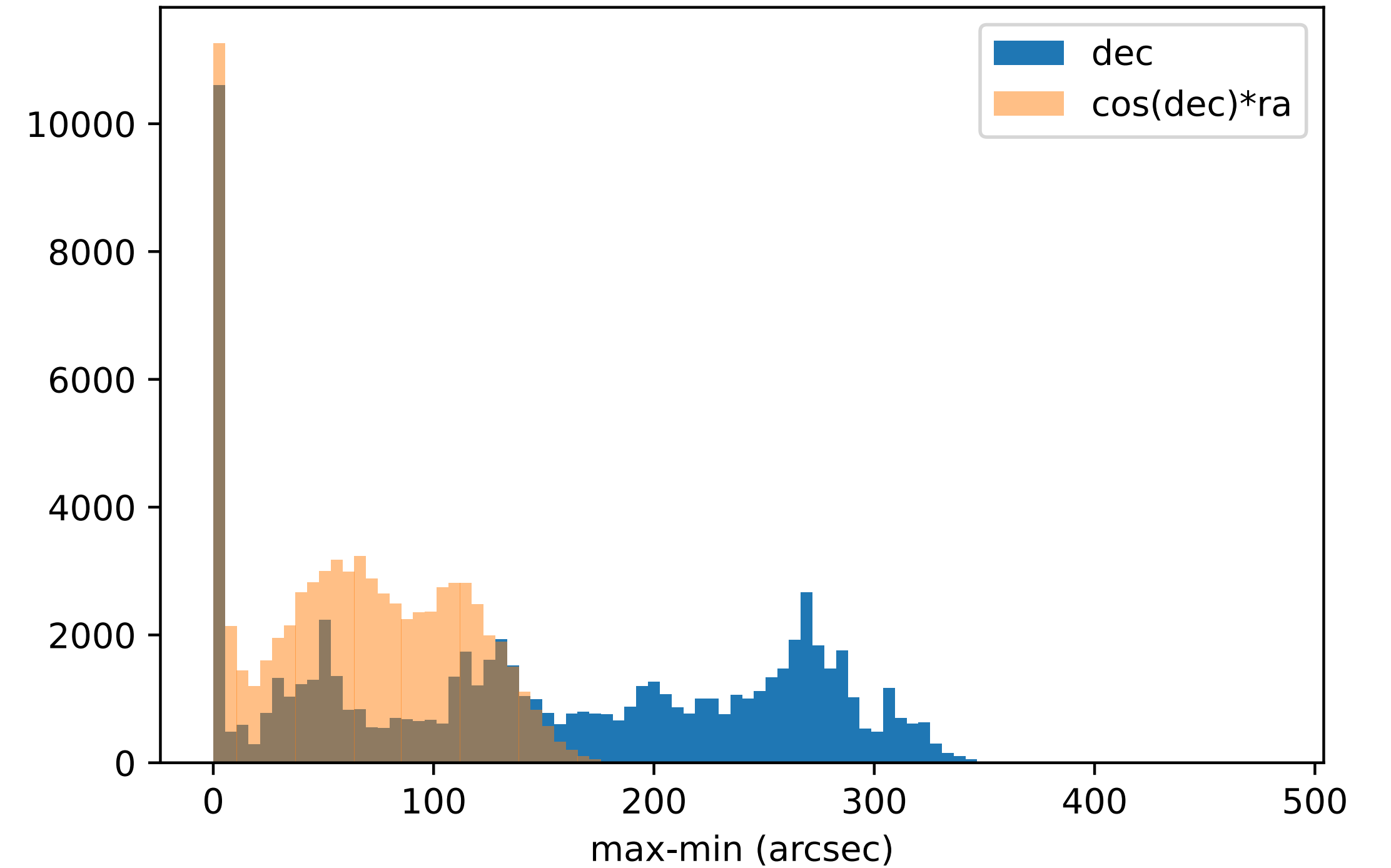
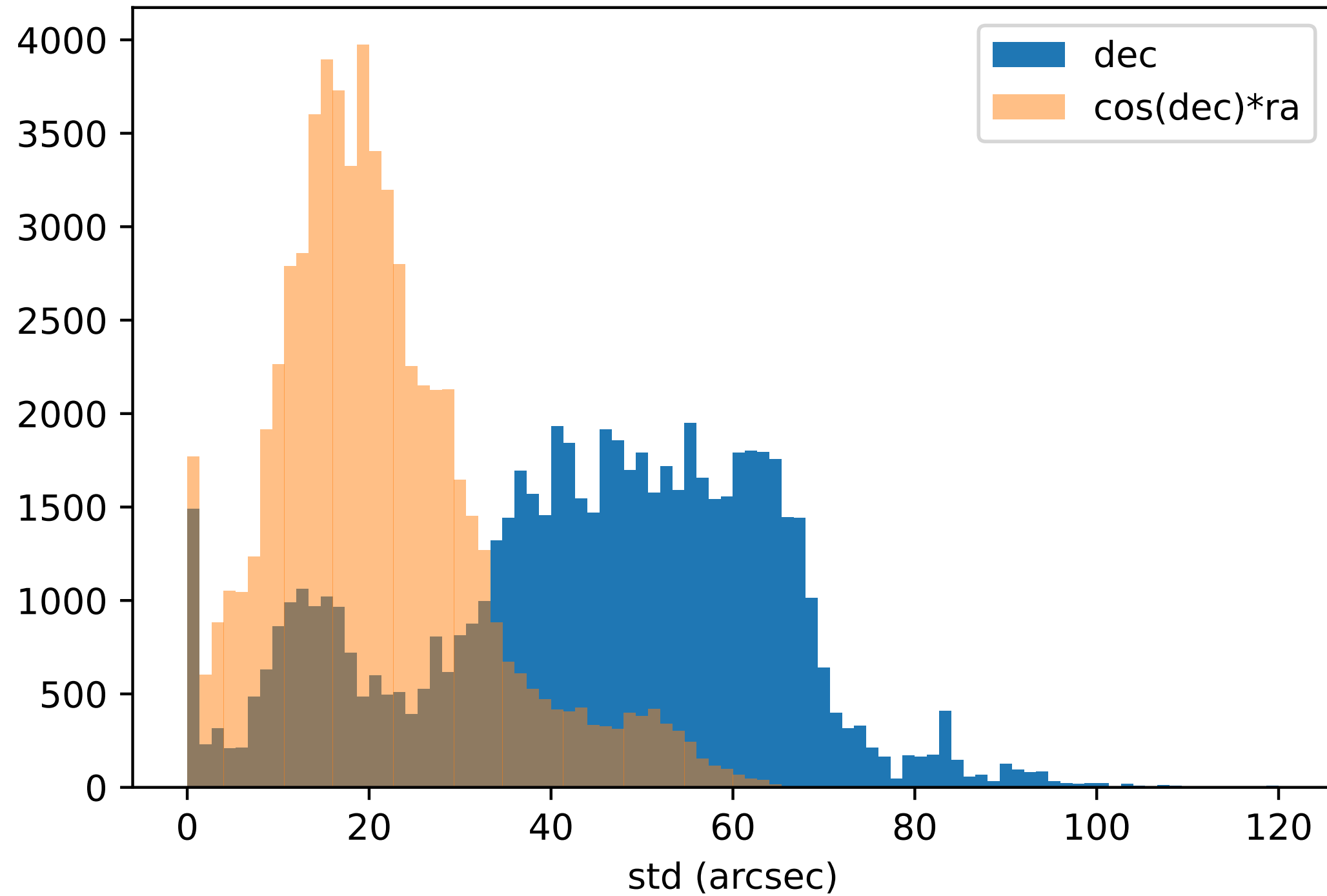
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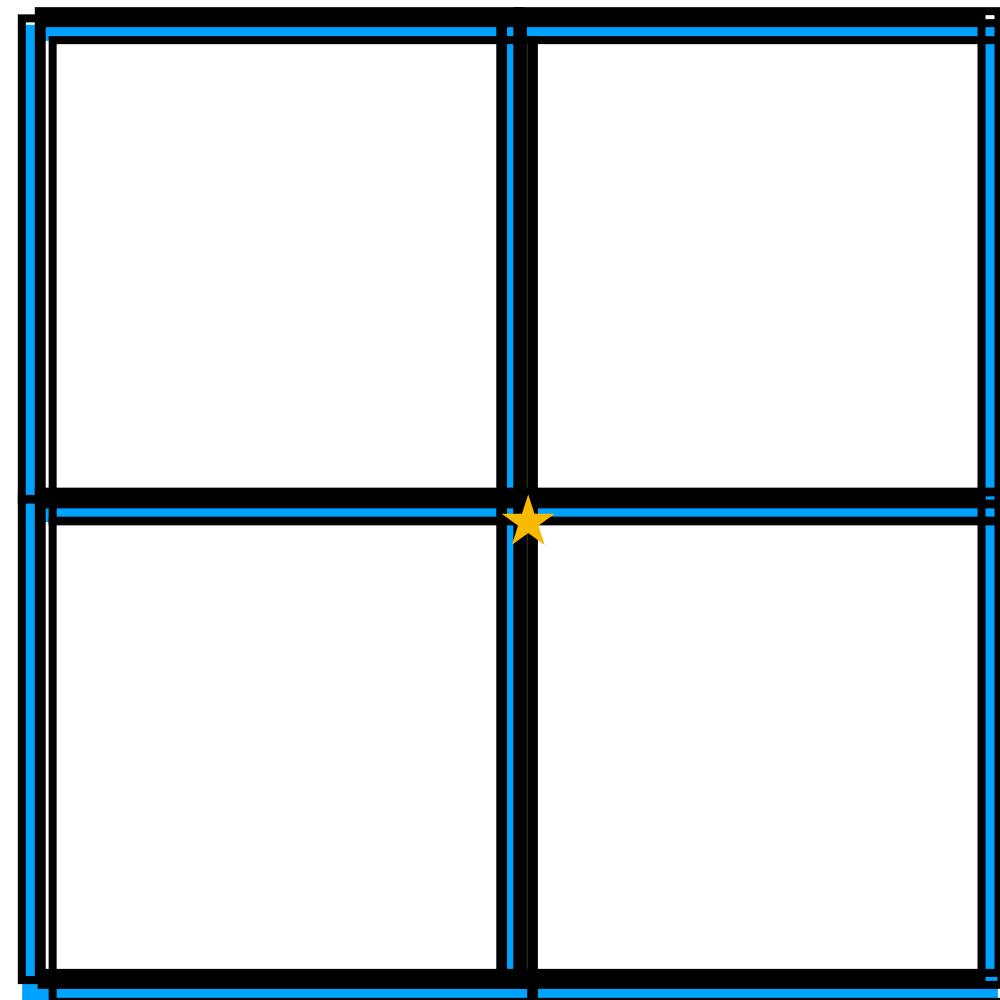
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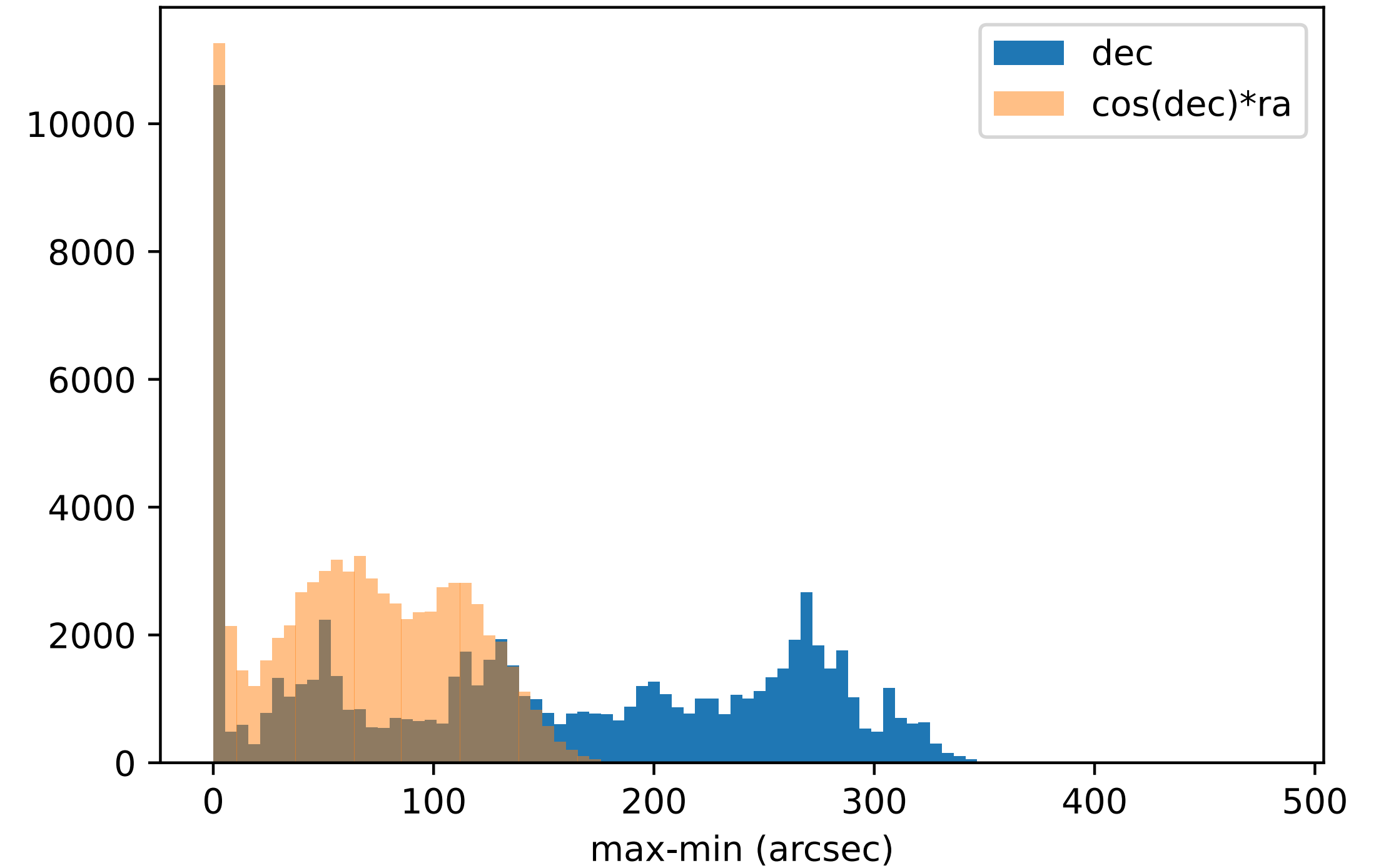
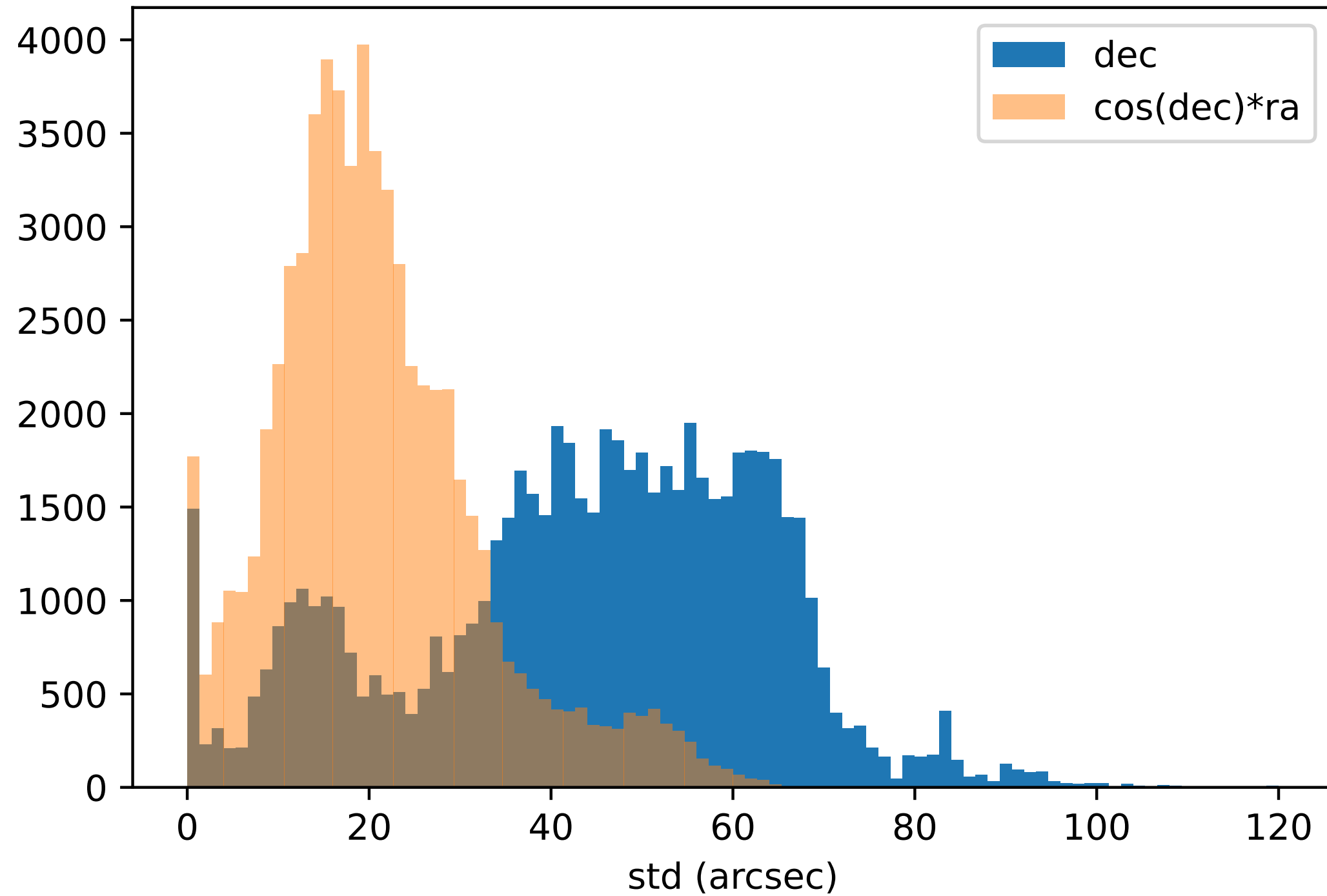
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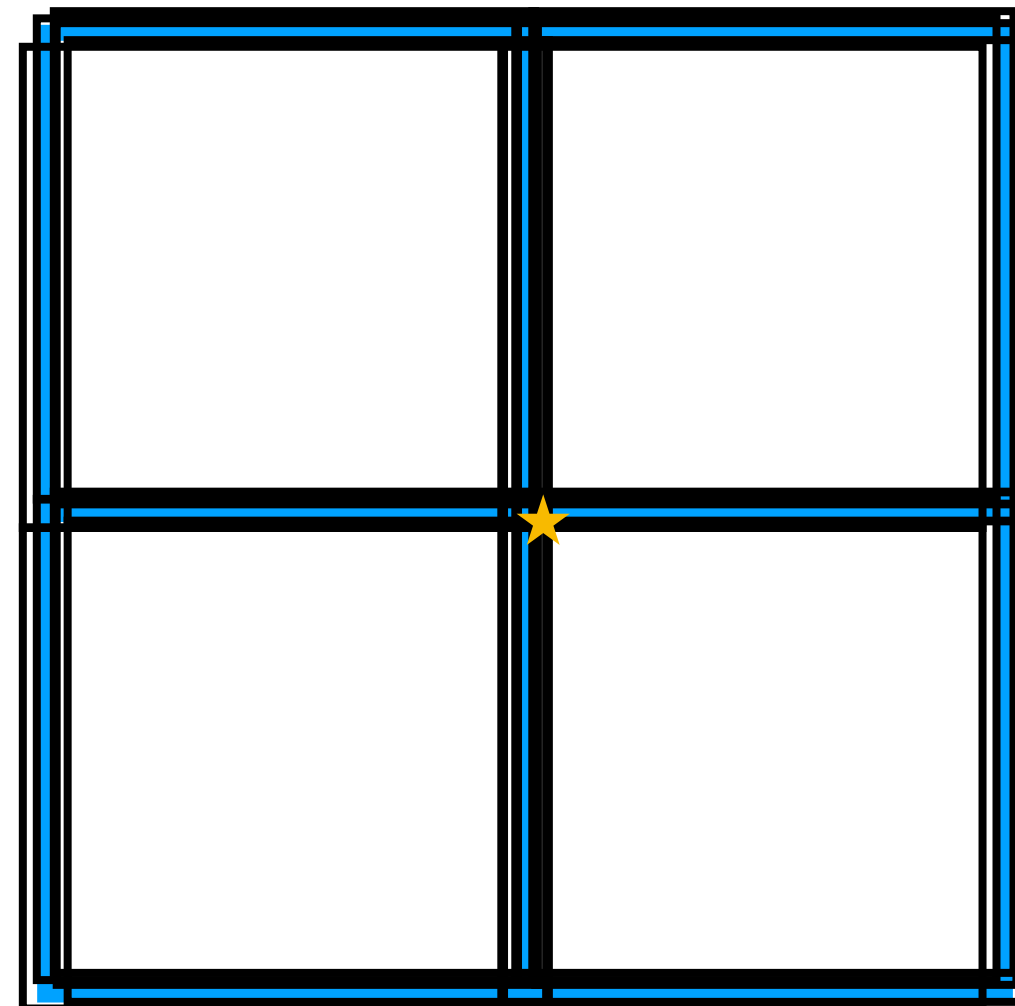
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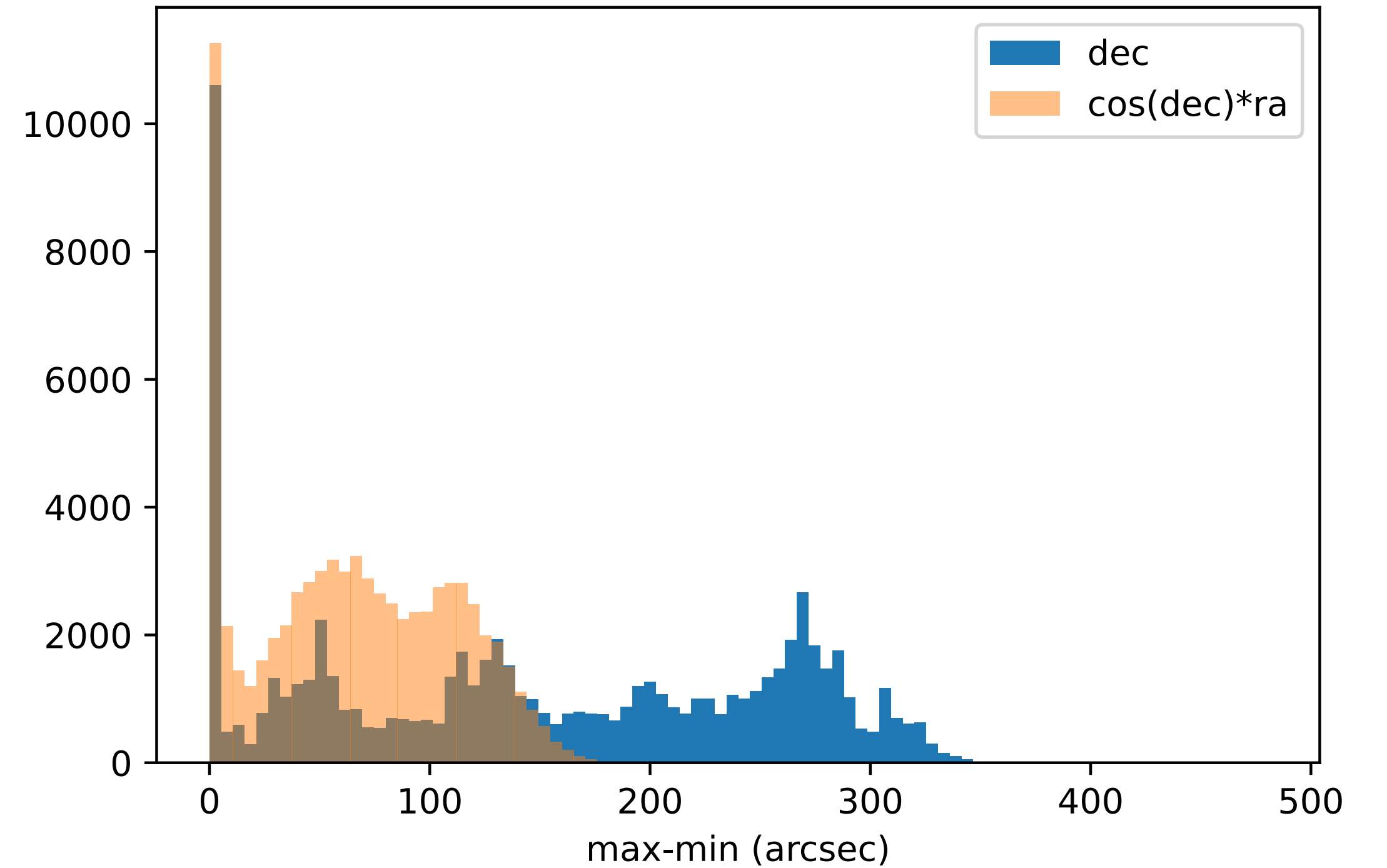
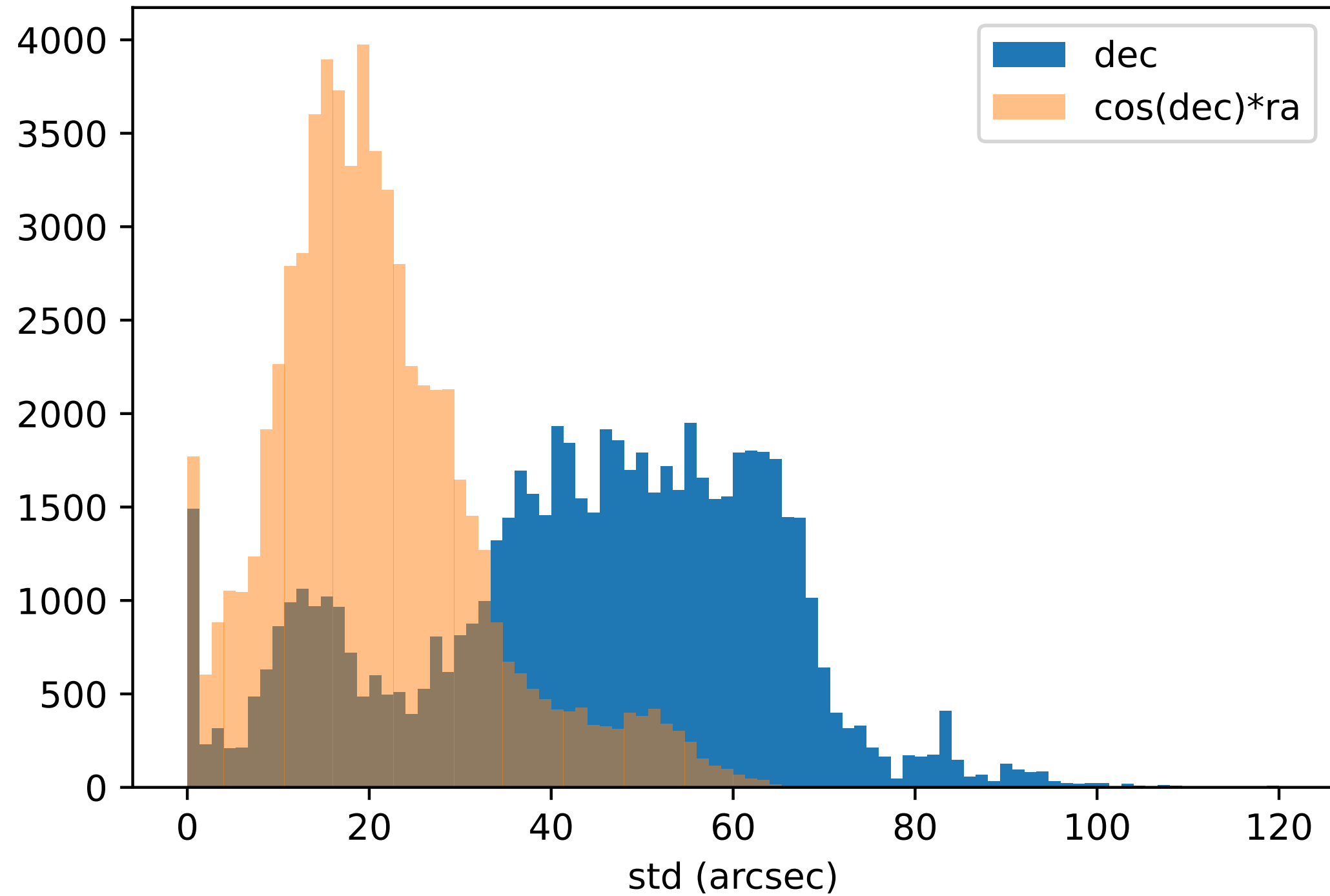
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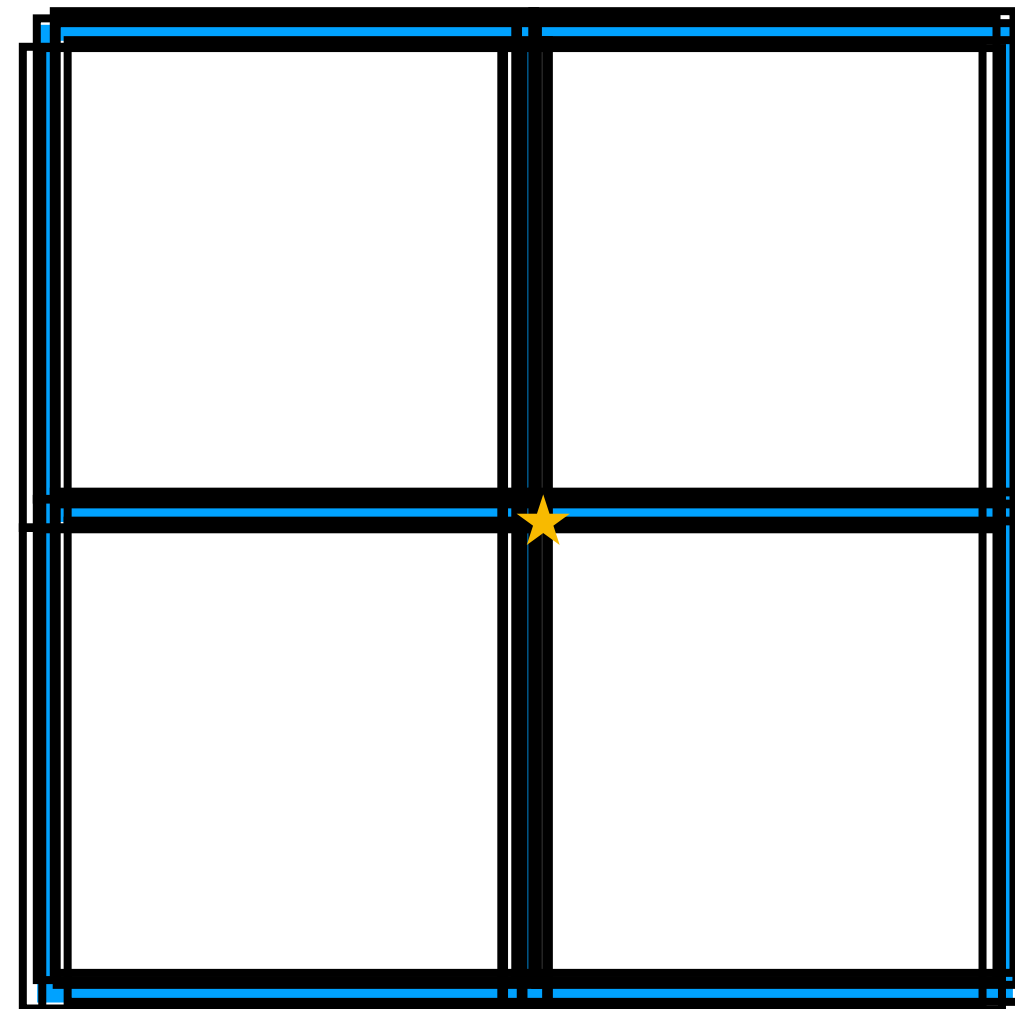
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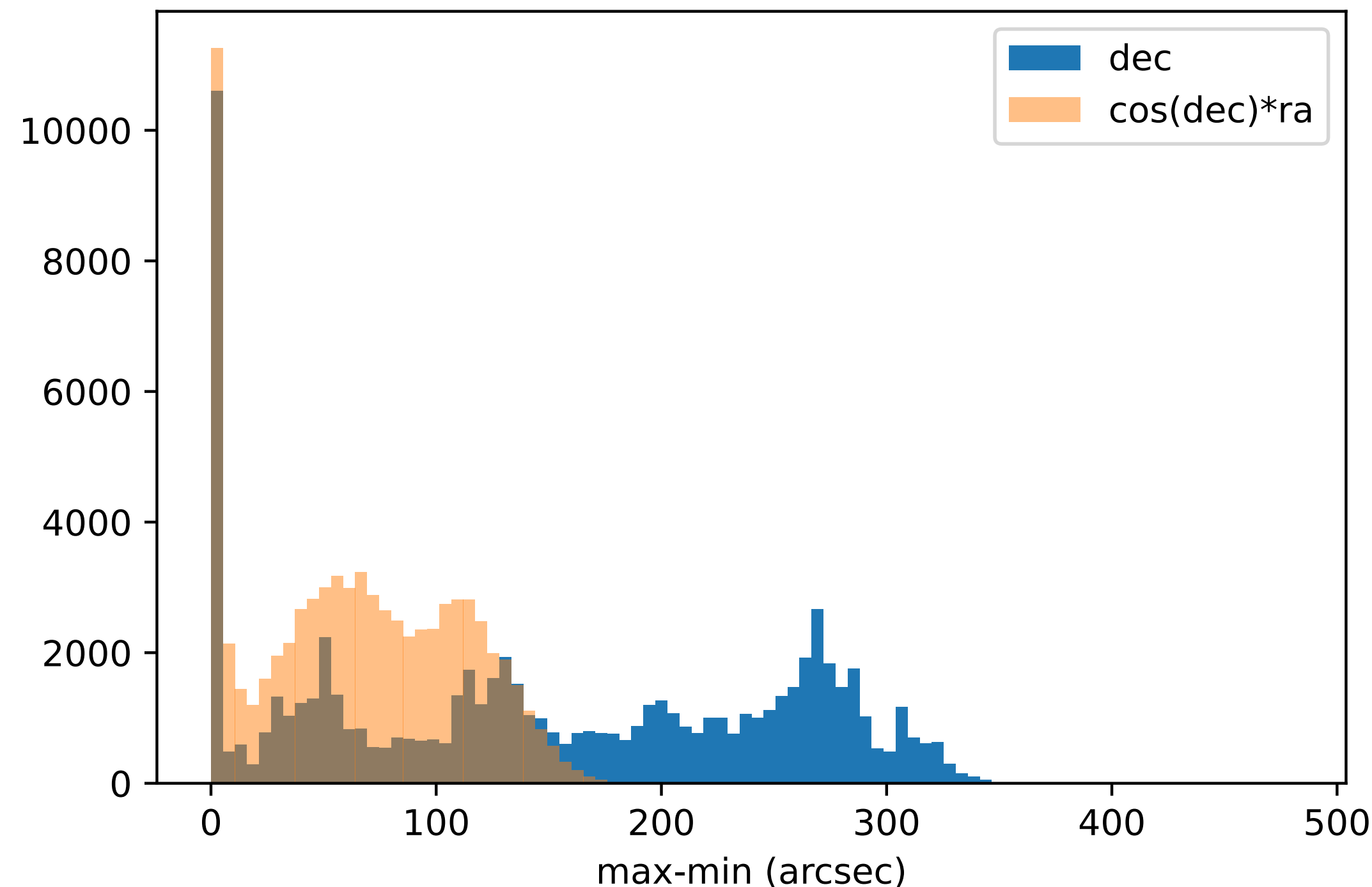
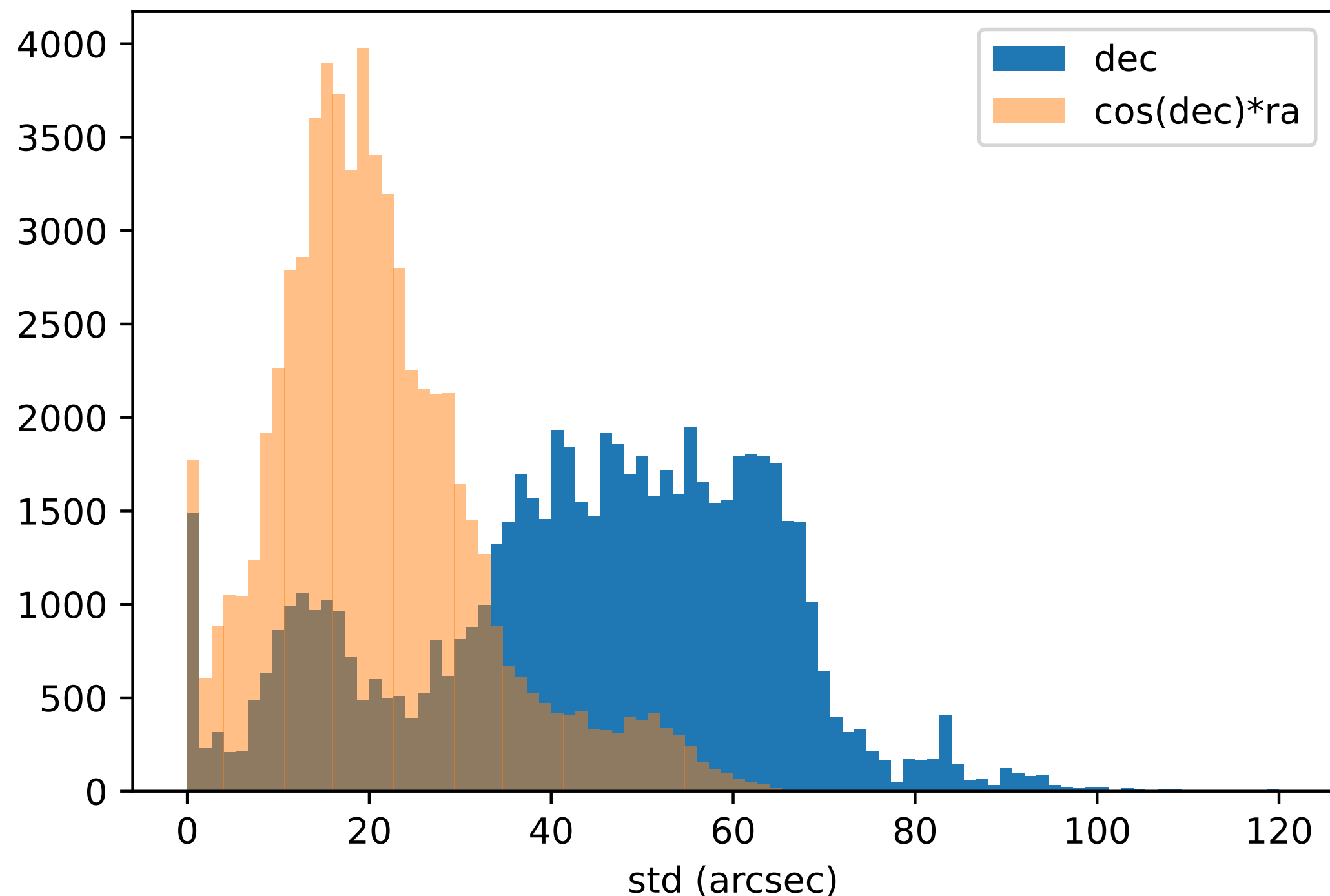
Reconsider edge cuts (30 pix for now)

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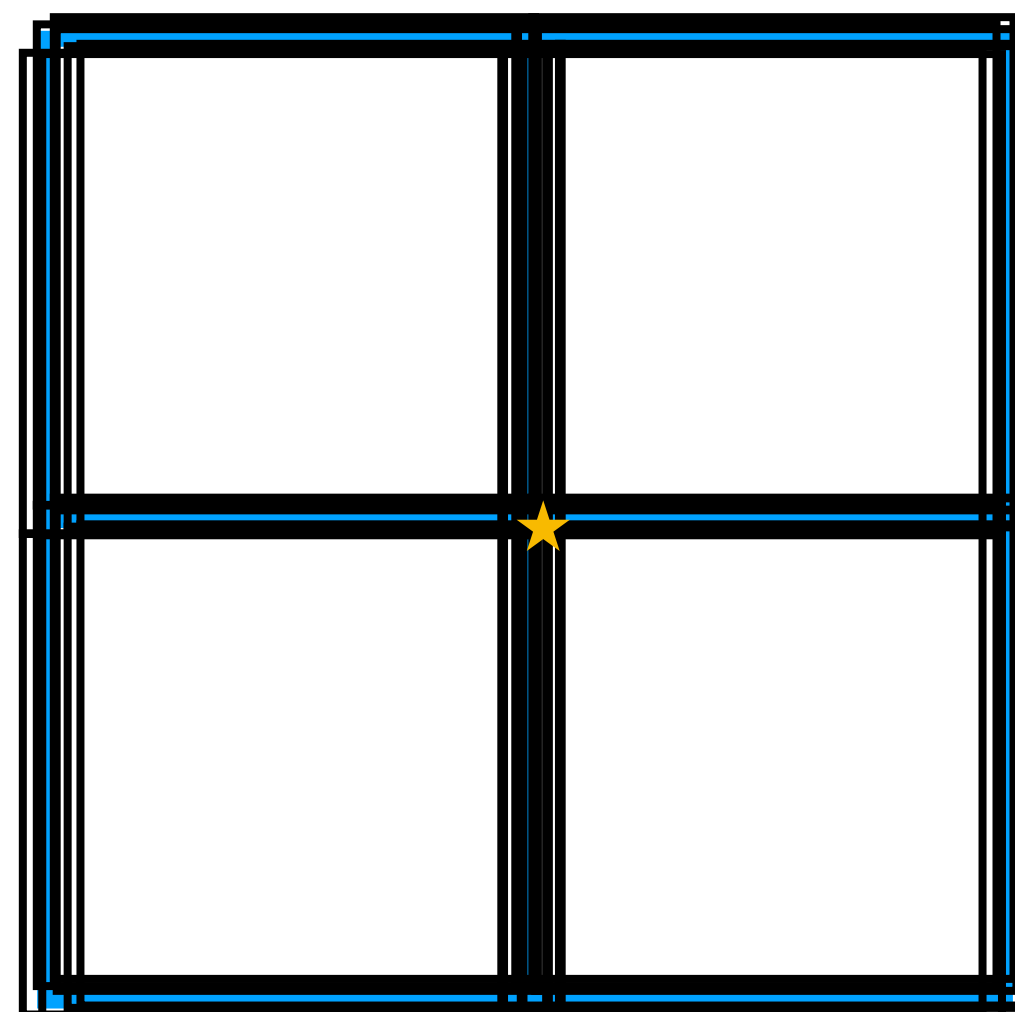
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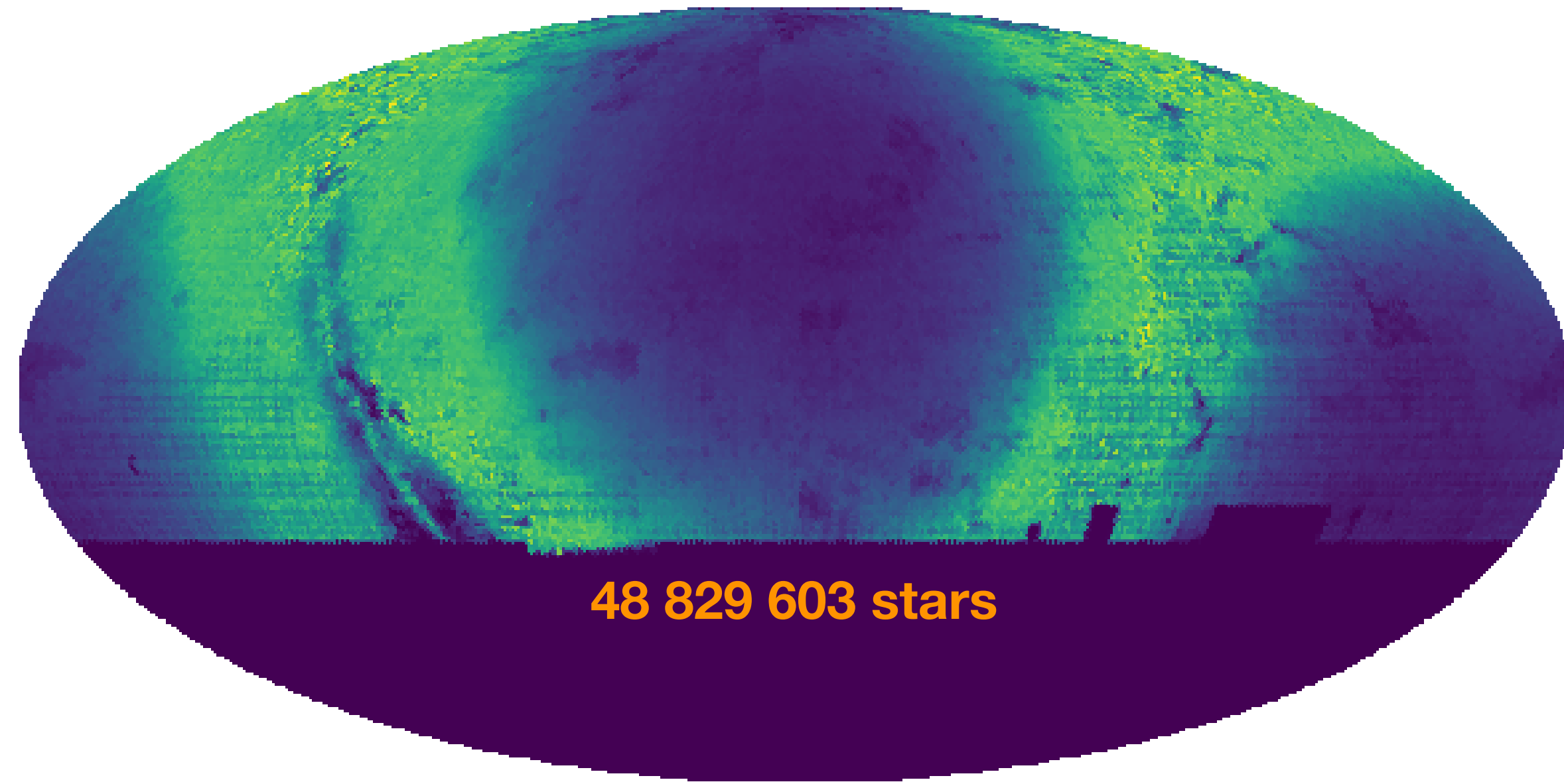
Even reinforce stats there?

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**Crowding**

number of star per nside=64 pixels

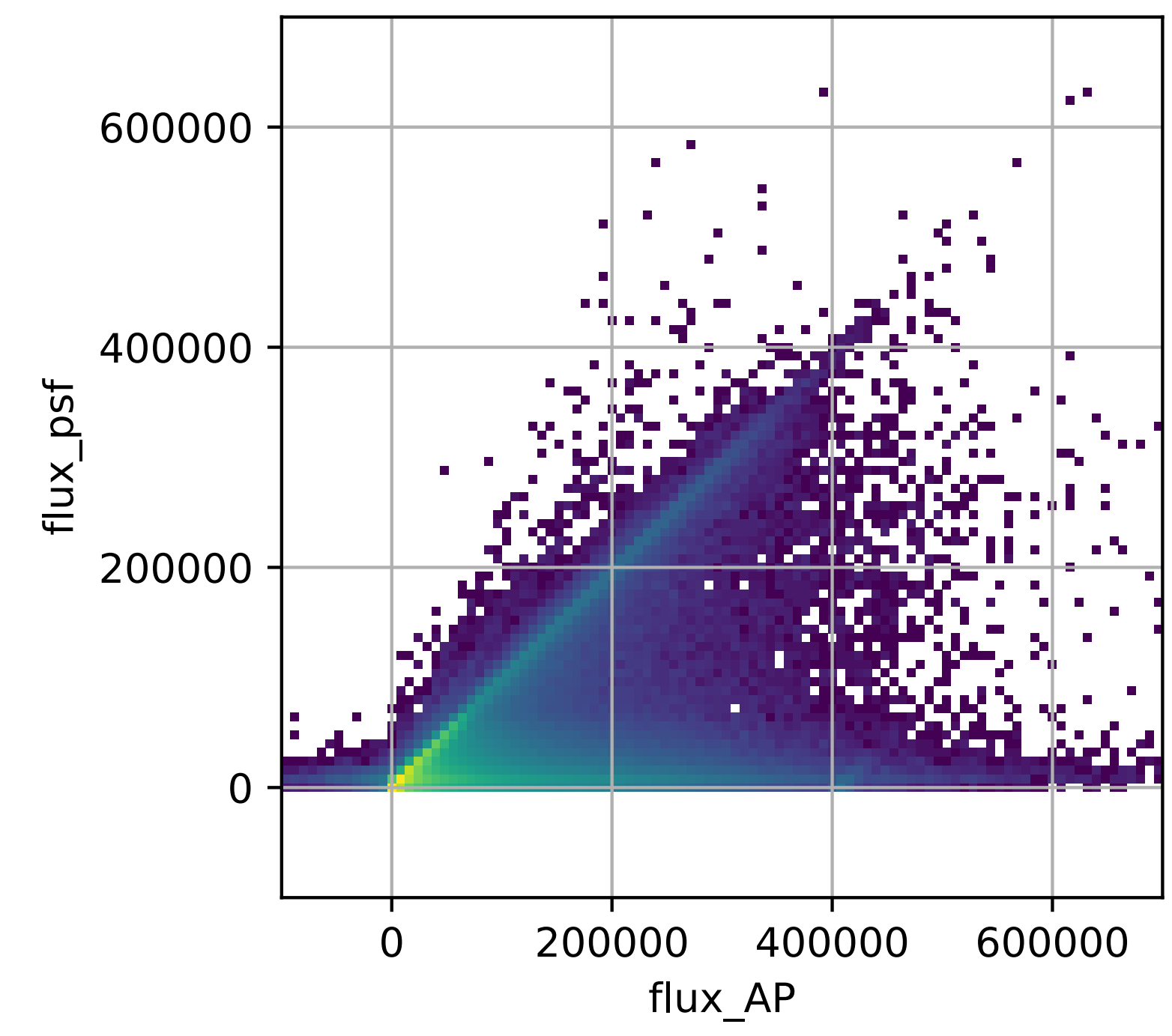
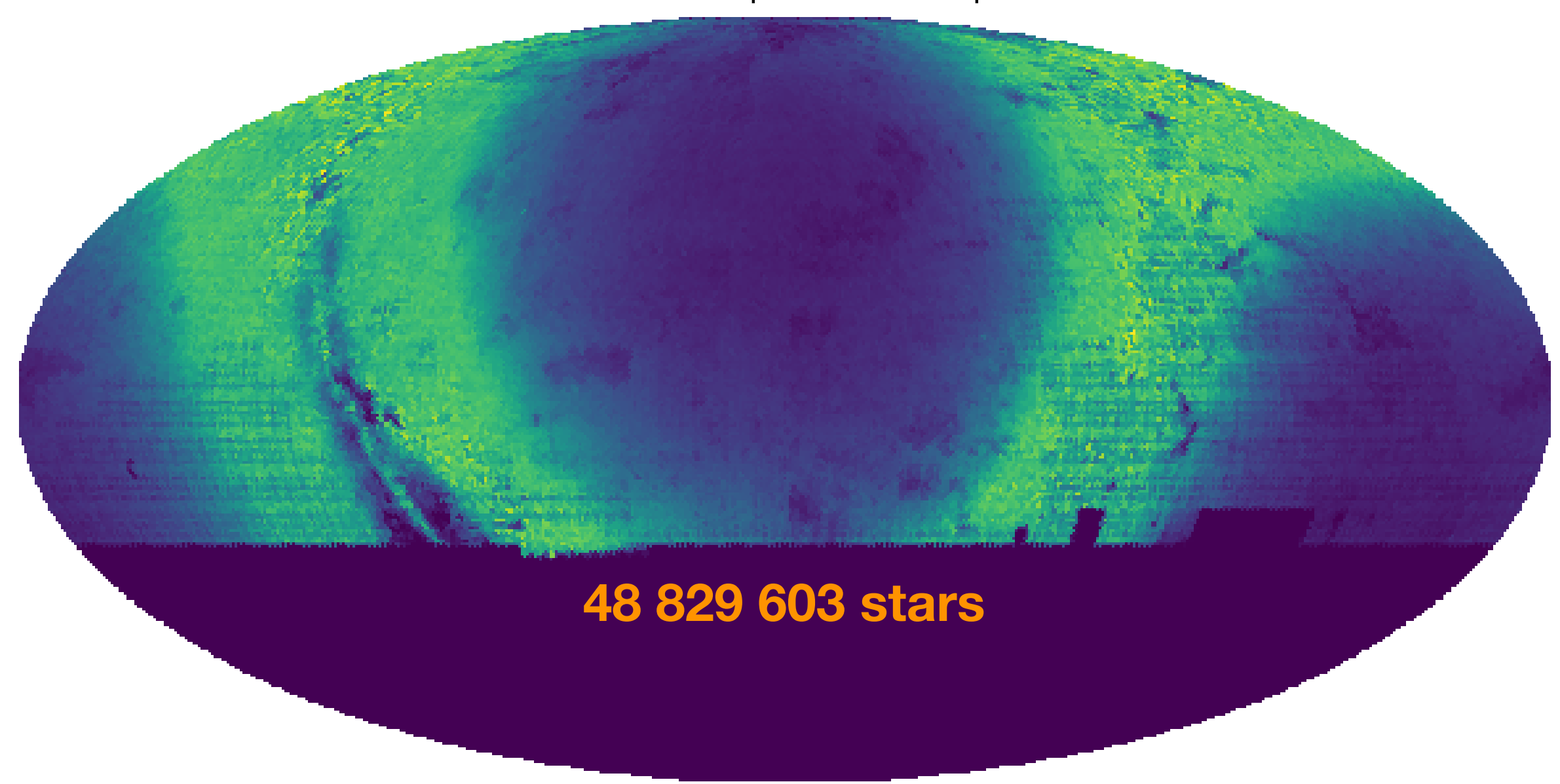


48 829 603 stars



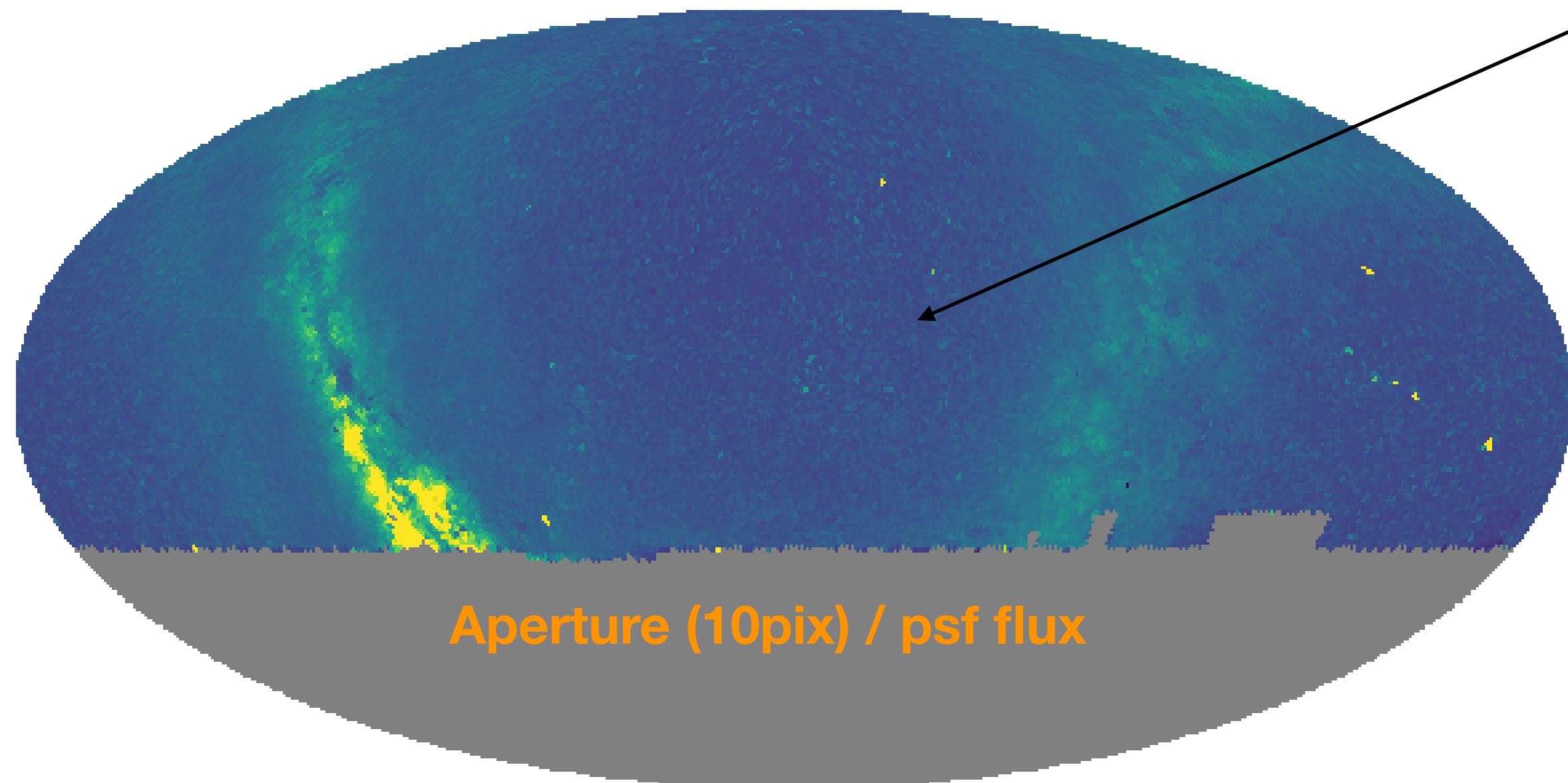
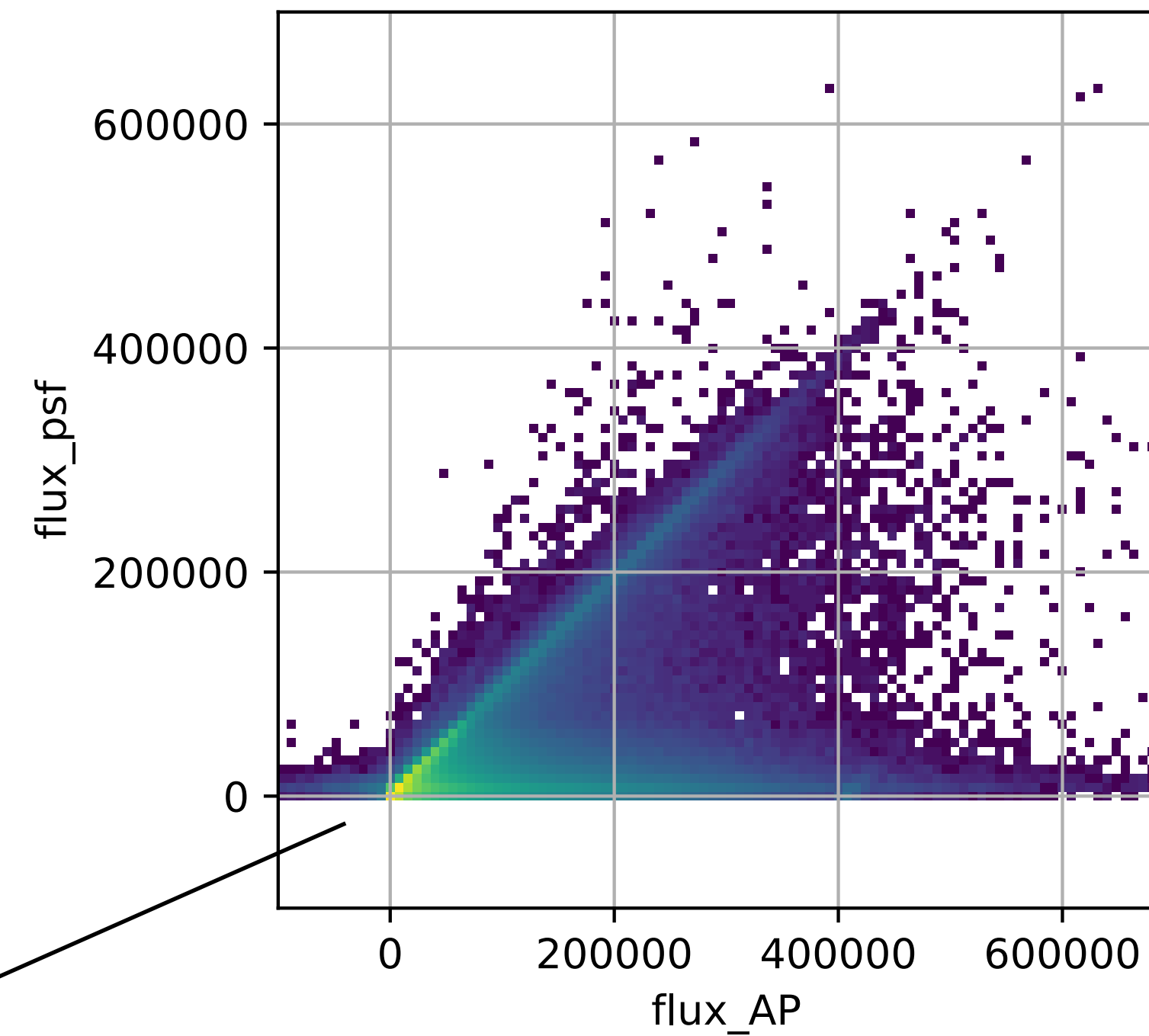
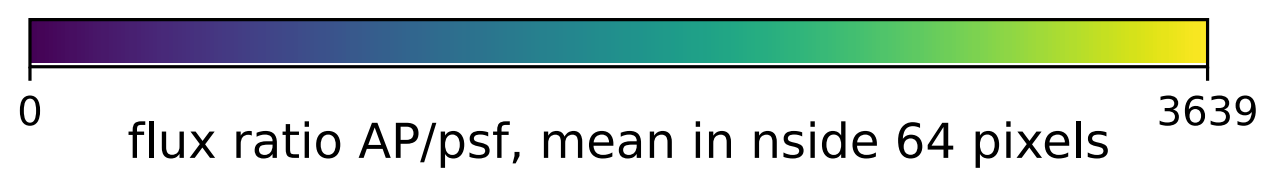
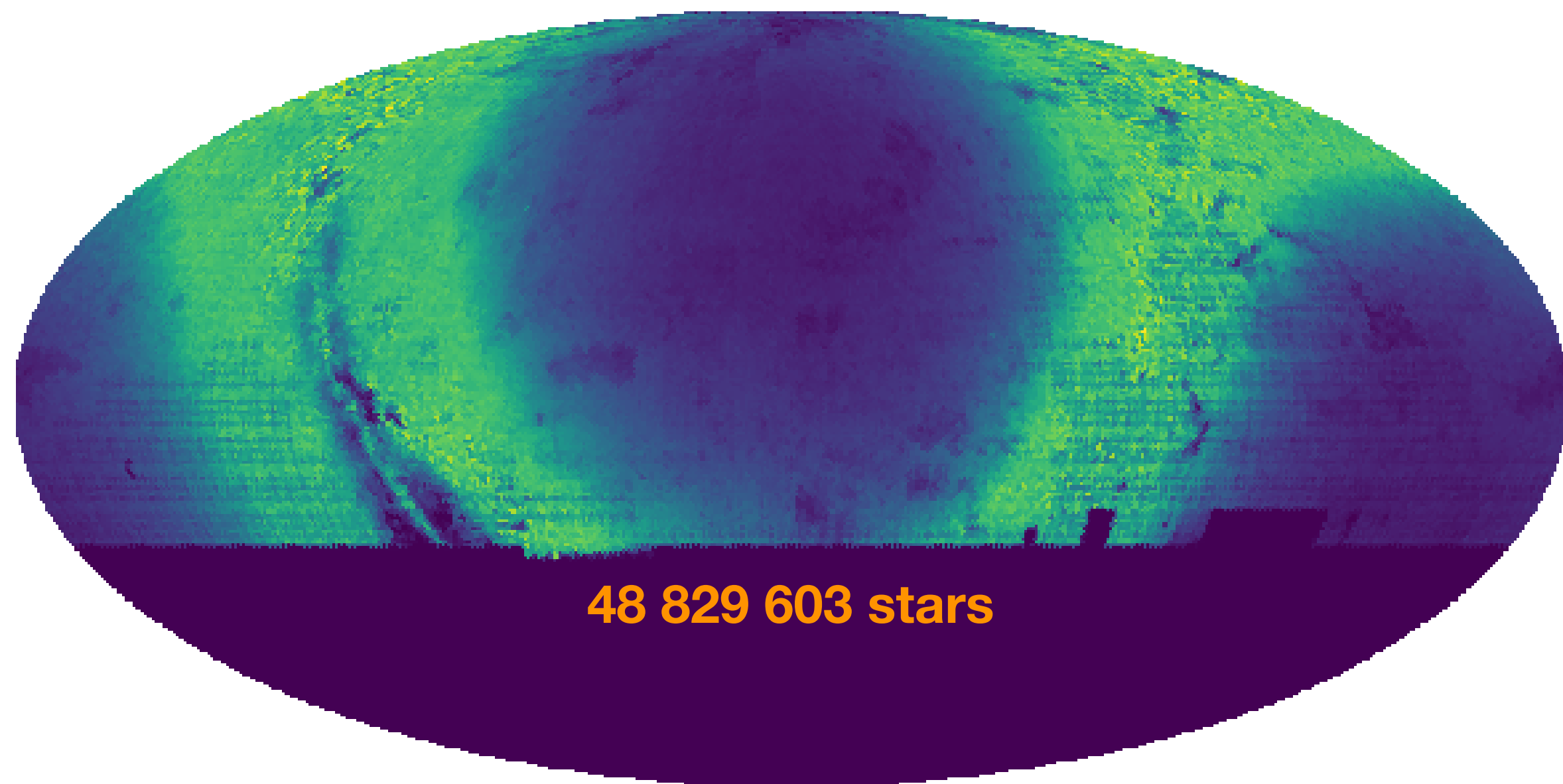
Aperture (10pix) / psf flux

number of star per nside=64 pixels



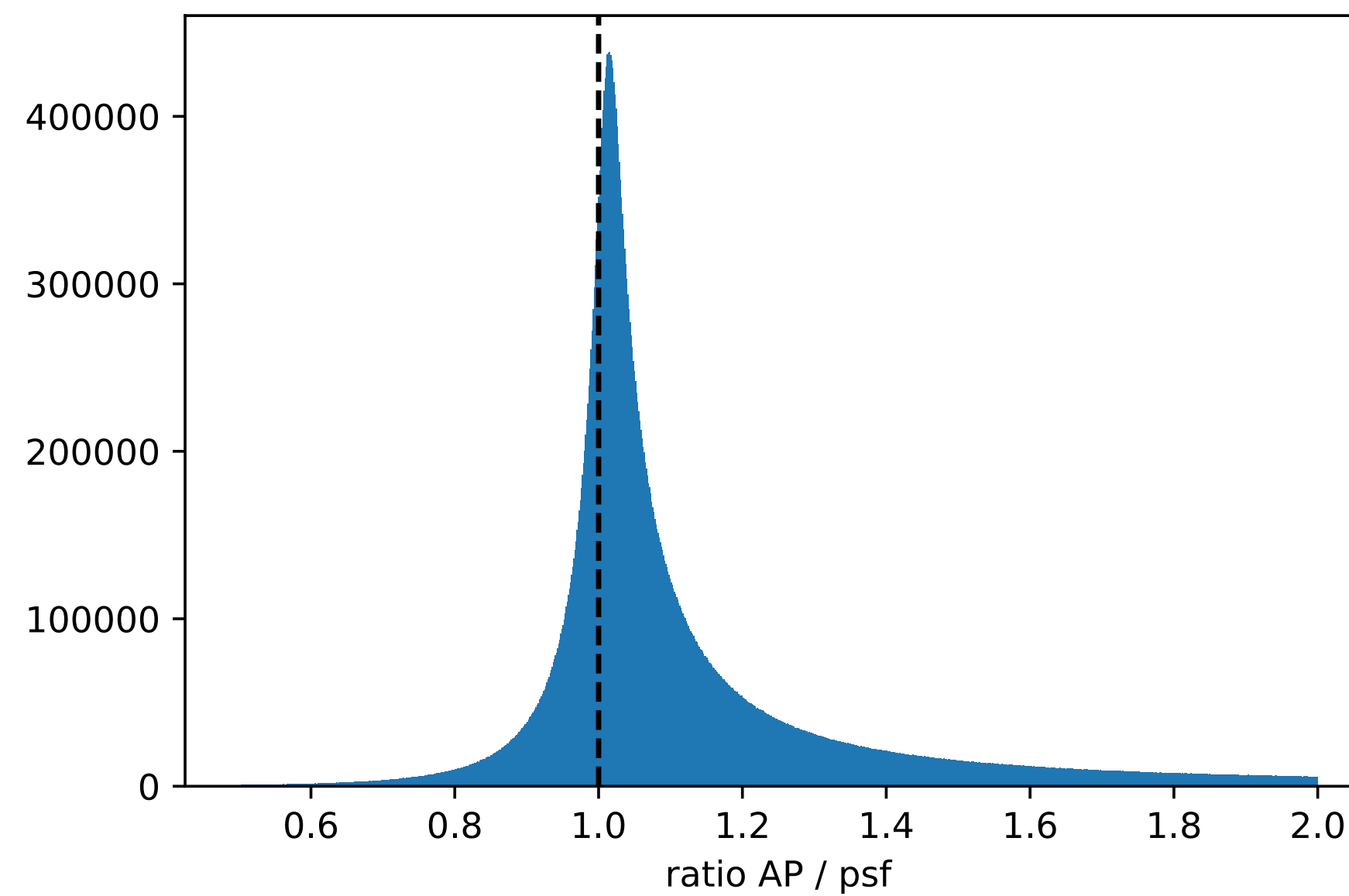
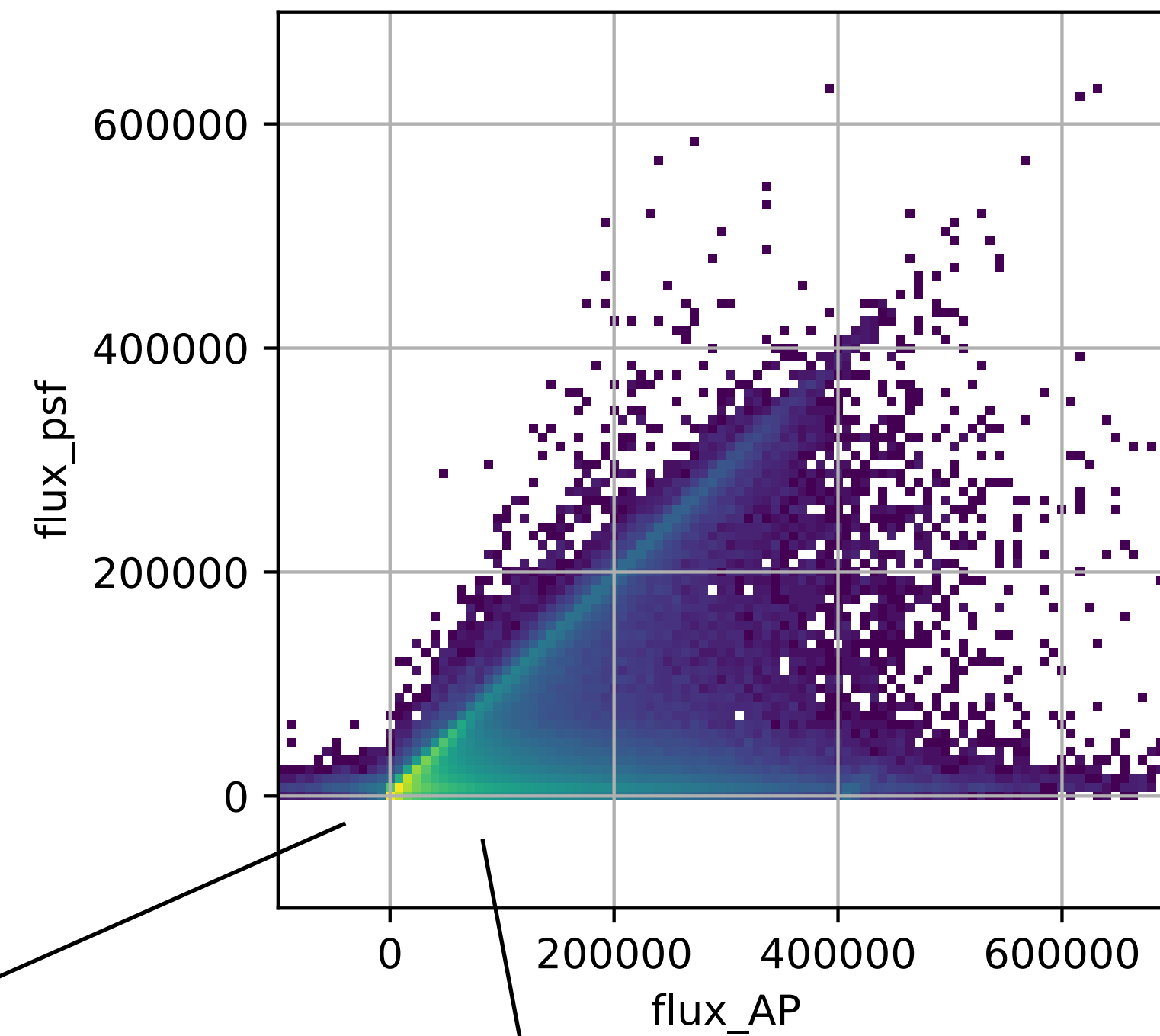
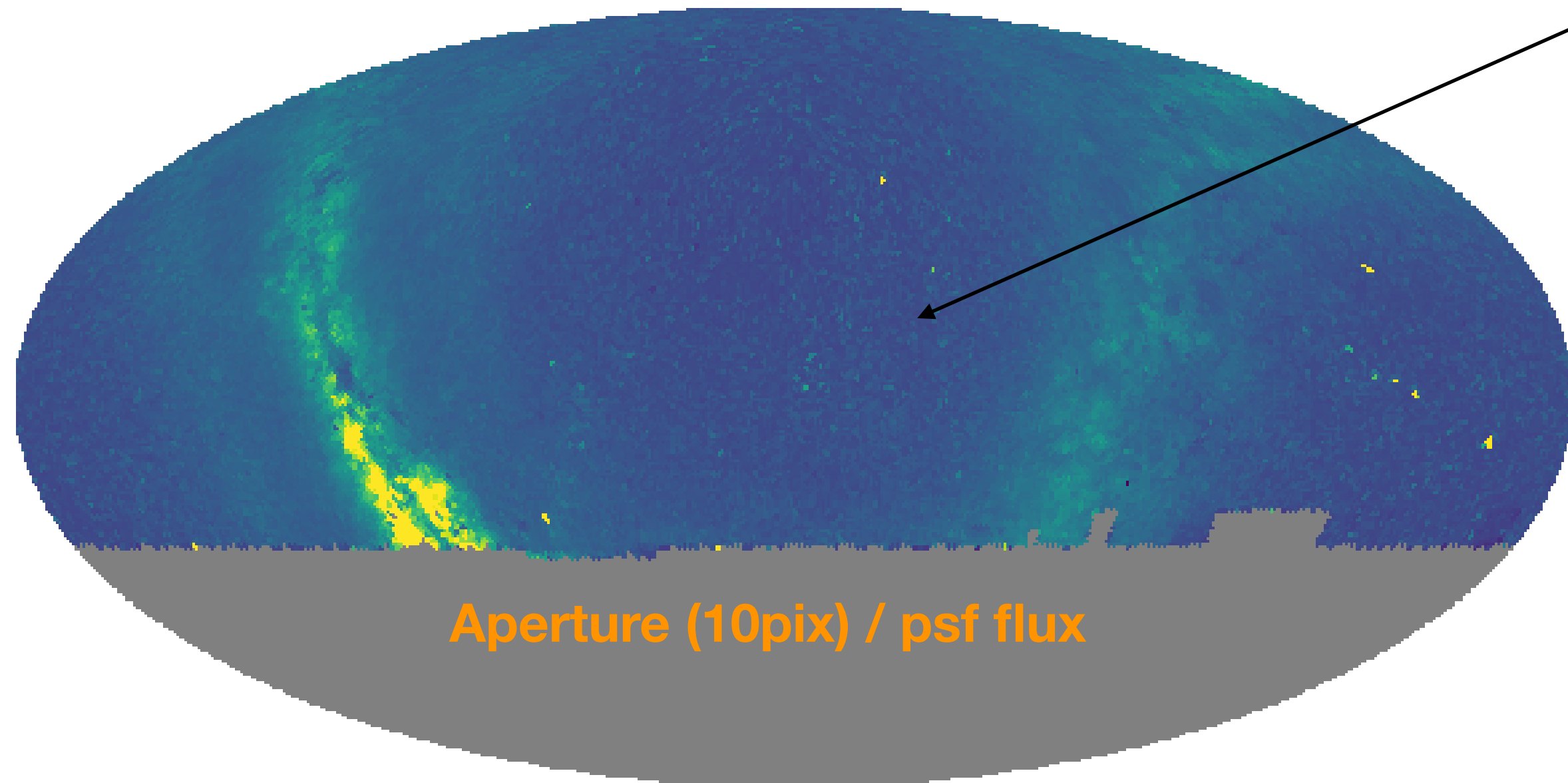
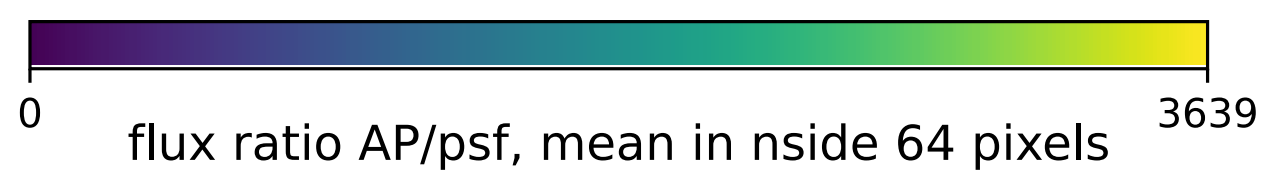
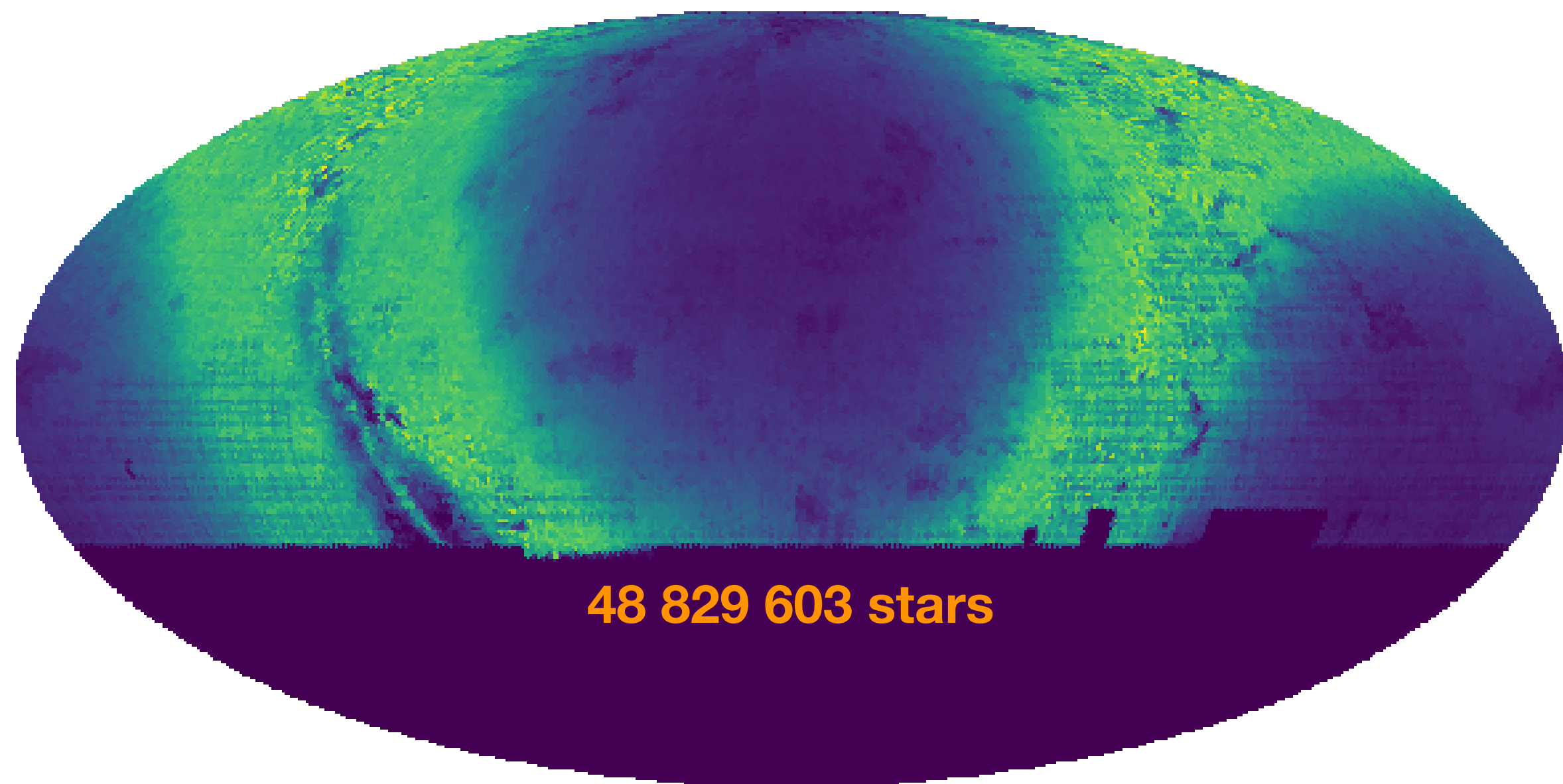
Aperture (10pix) / psf flux

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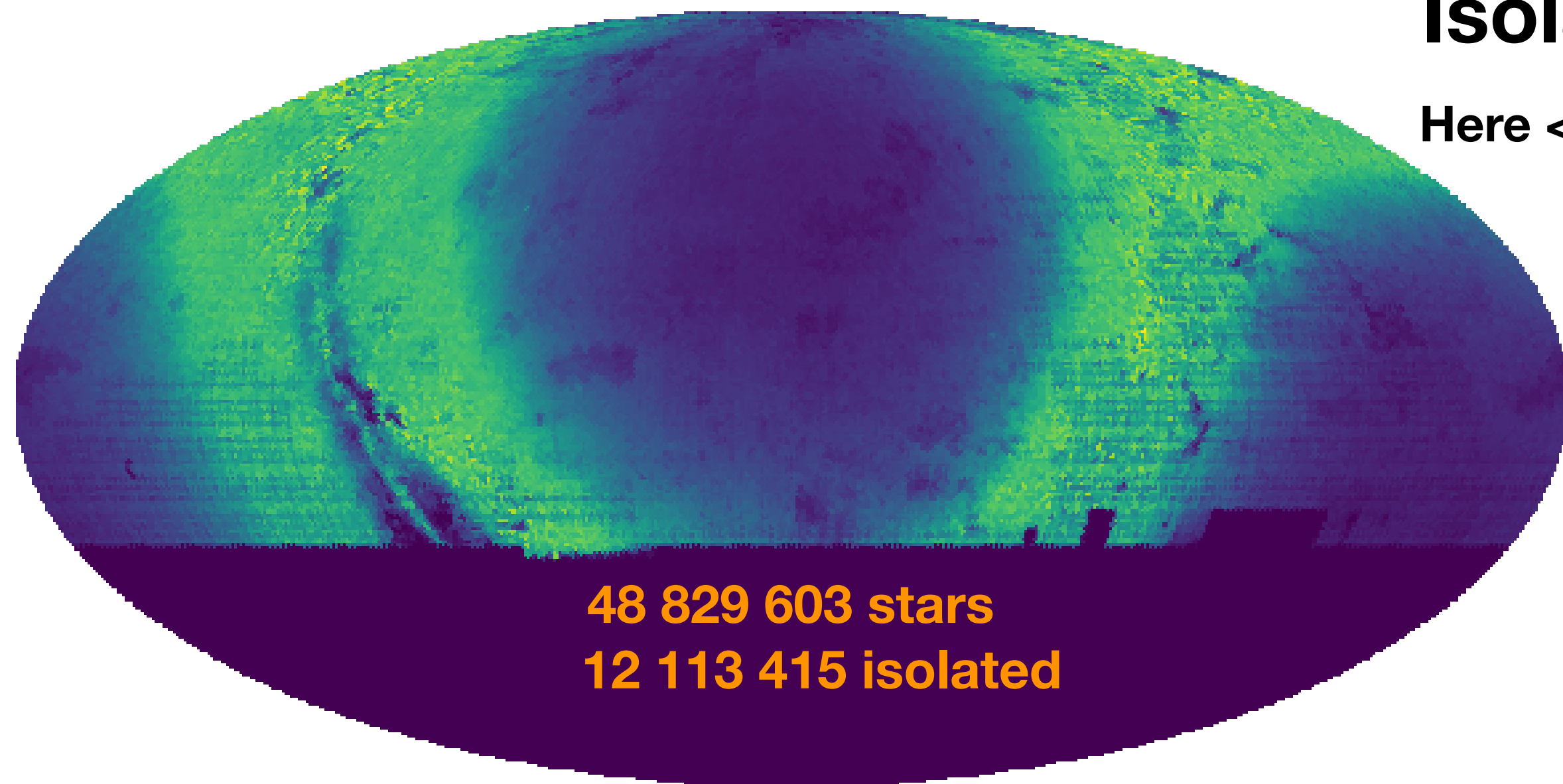
number of star per nside=64 pixels



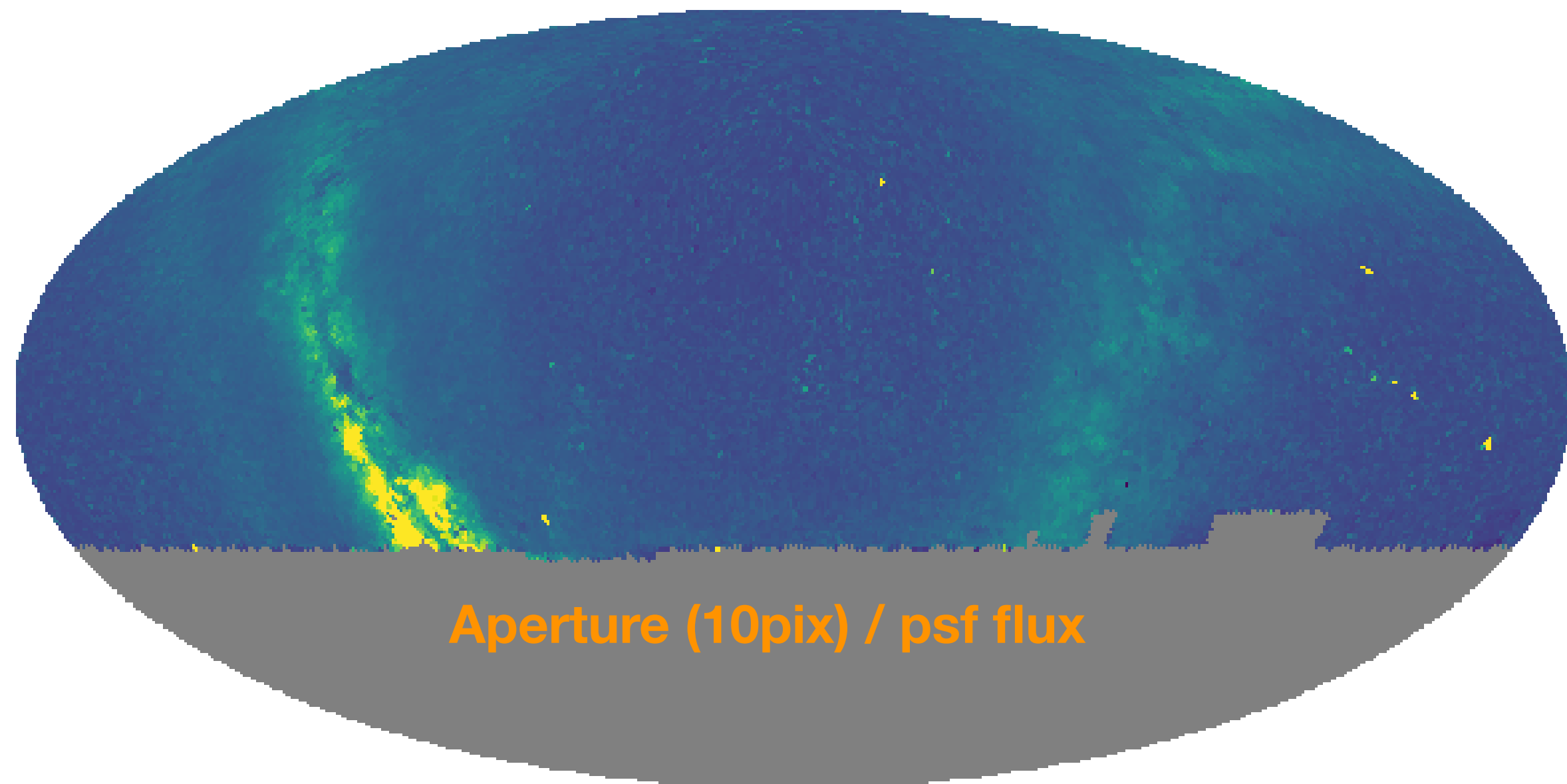
number of star per nside=64 pixels

# Isolation !

Here <20 arcsec



48 829 603 stars  
12 113 415 isolated



Aperture (10pix) / psf flux

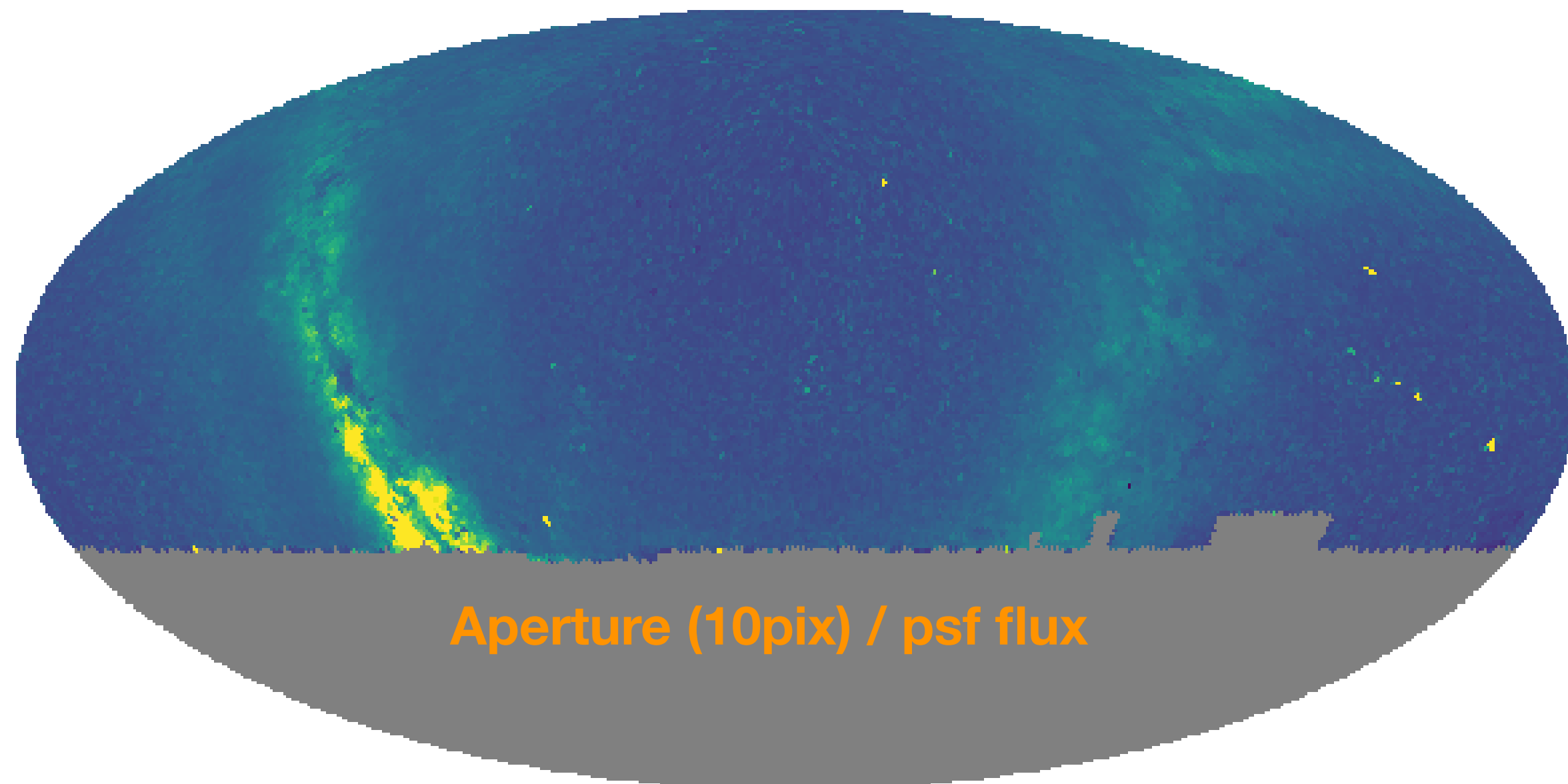
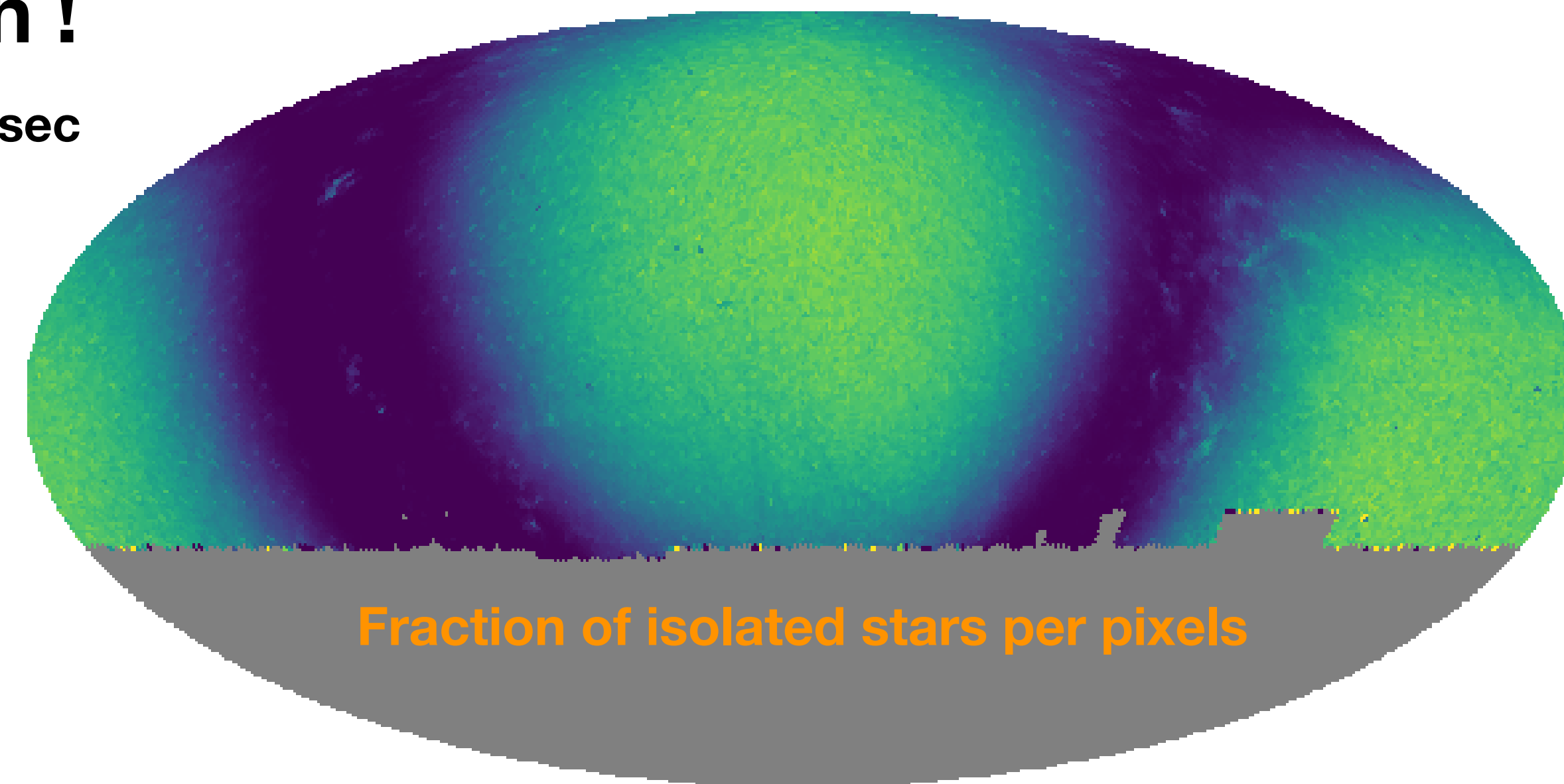
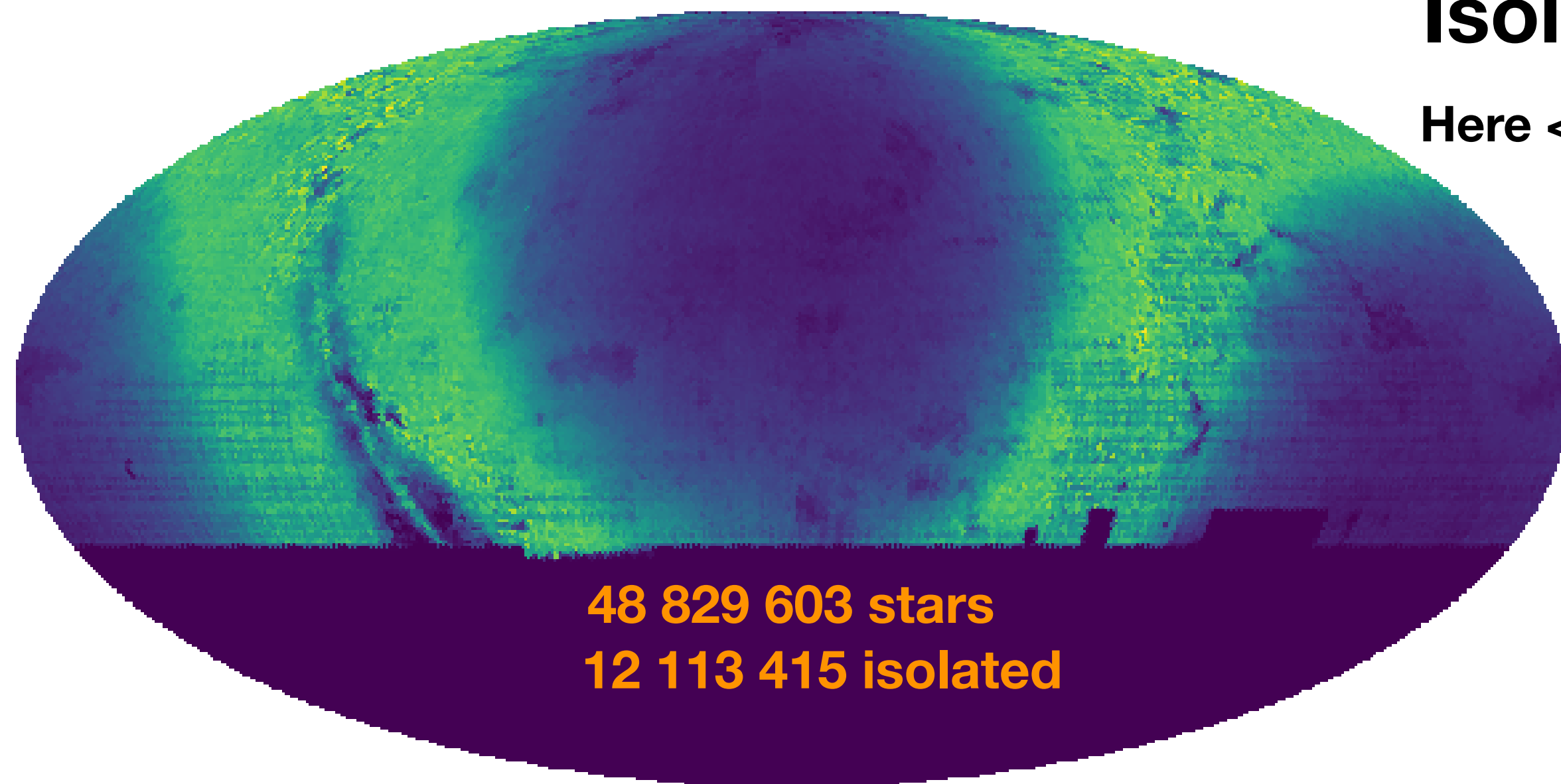


number of star per nside=64 pixels

# Isolation !

Here <20 arcsec

ratio isolated/all stars

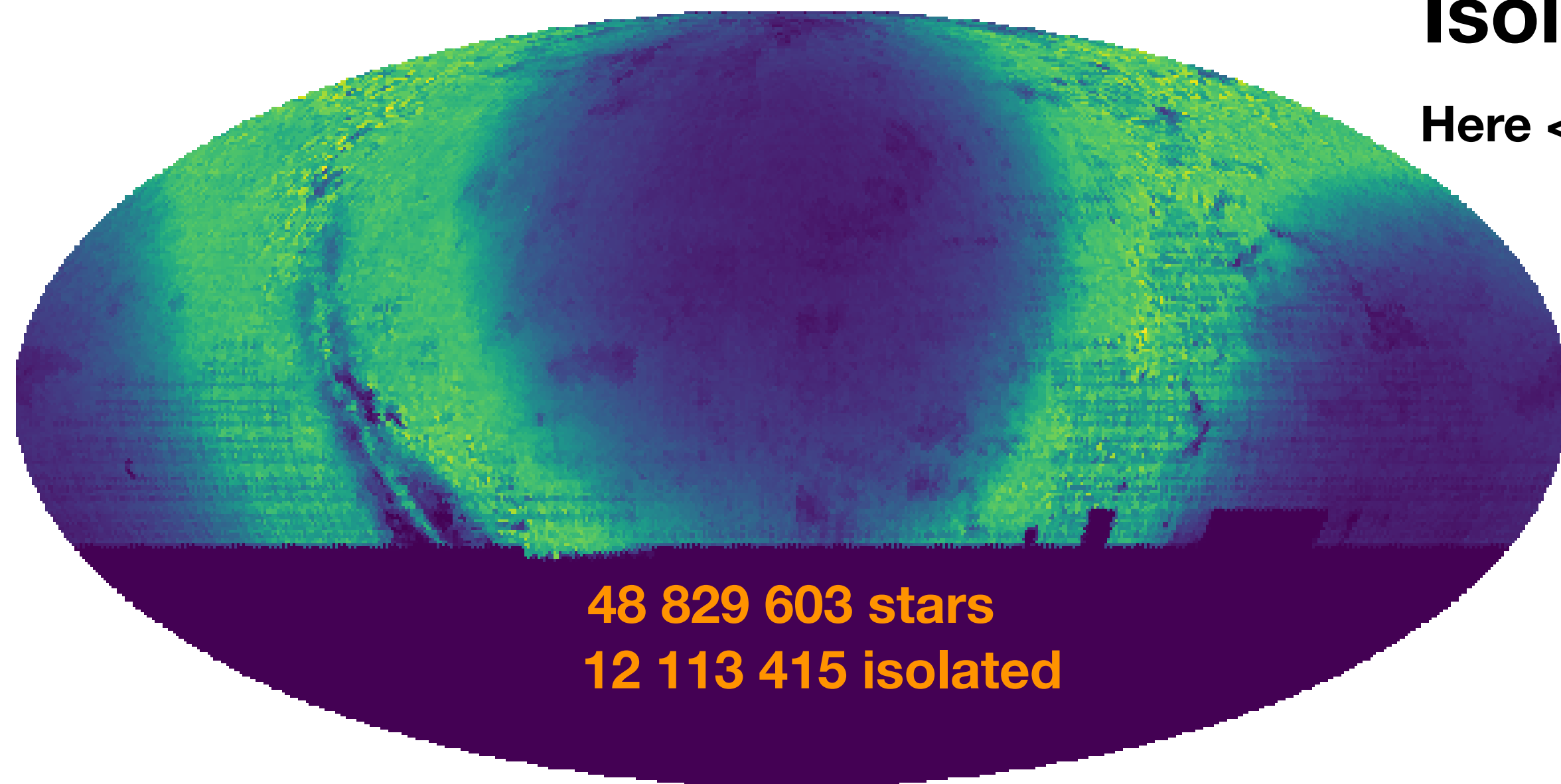


number of star per nside=64 pixels

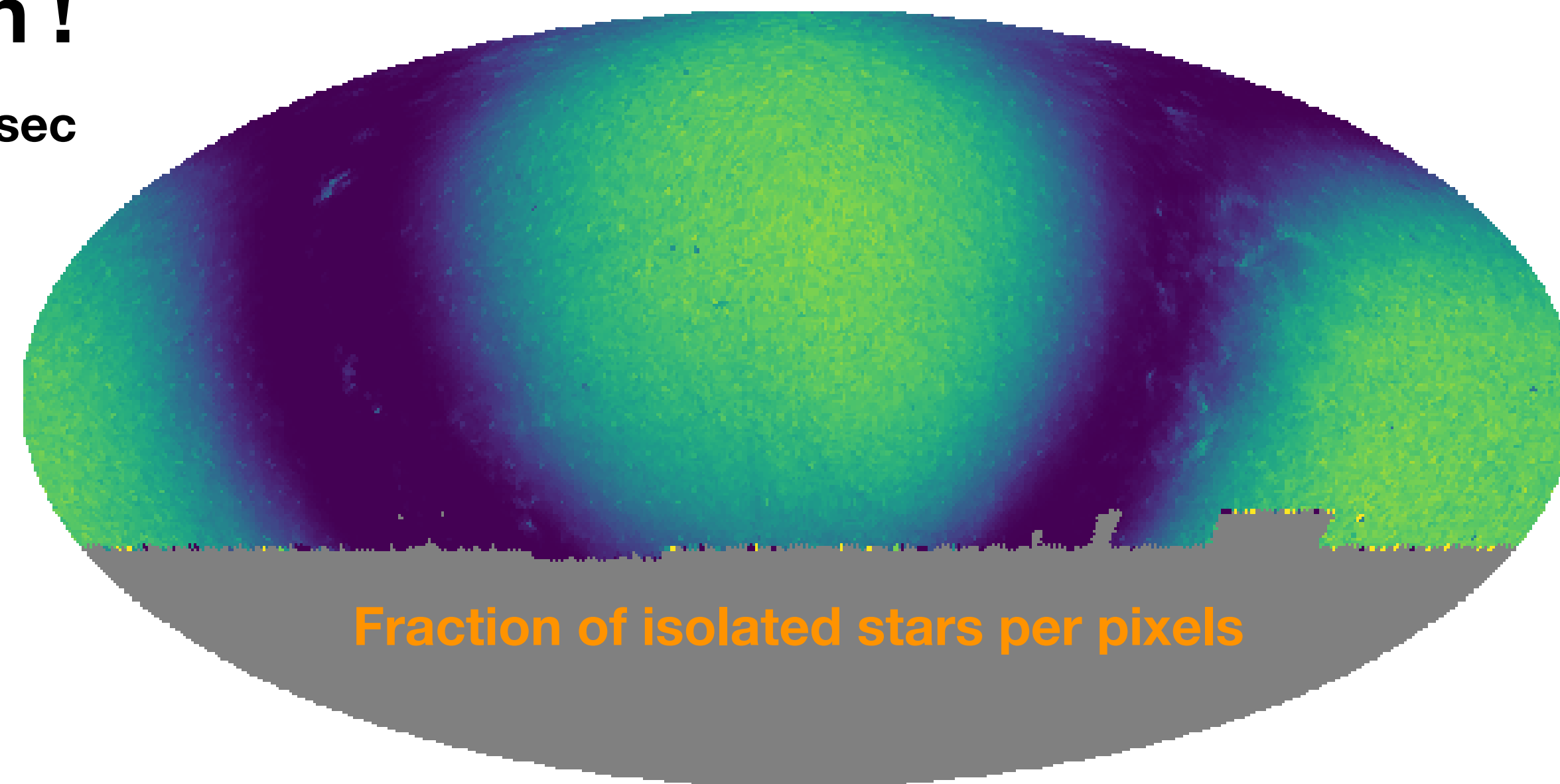
# Isolation !

Here <20 arcsec

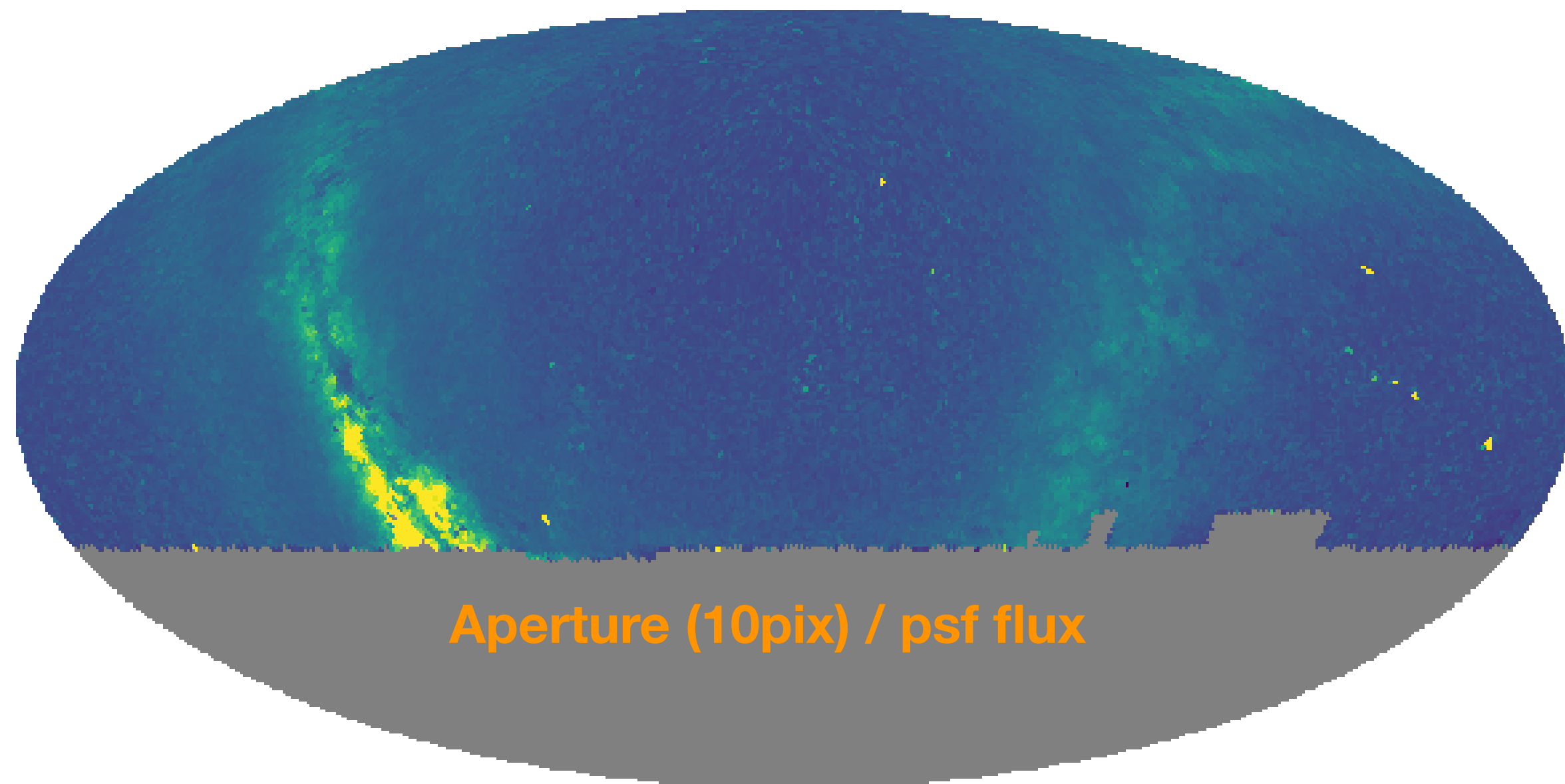
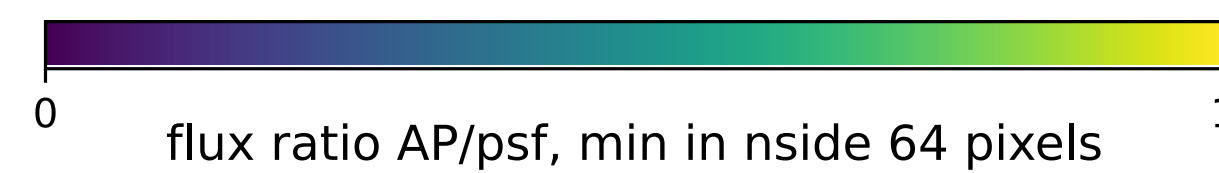
ratio isolated/all stars



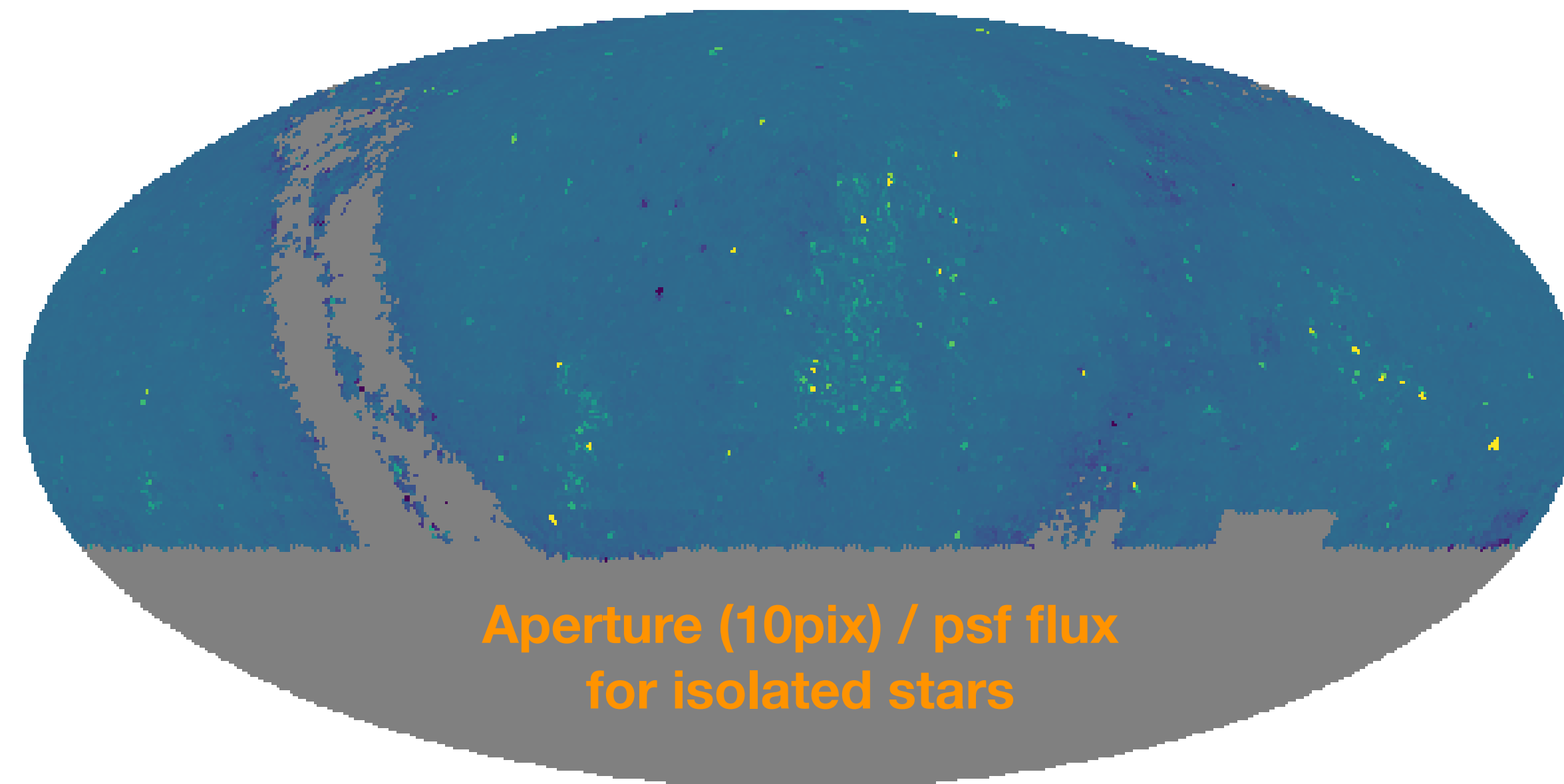
48 829 603 stars  
12 113 415 isolated



Fraction of isolated stars per pixels



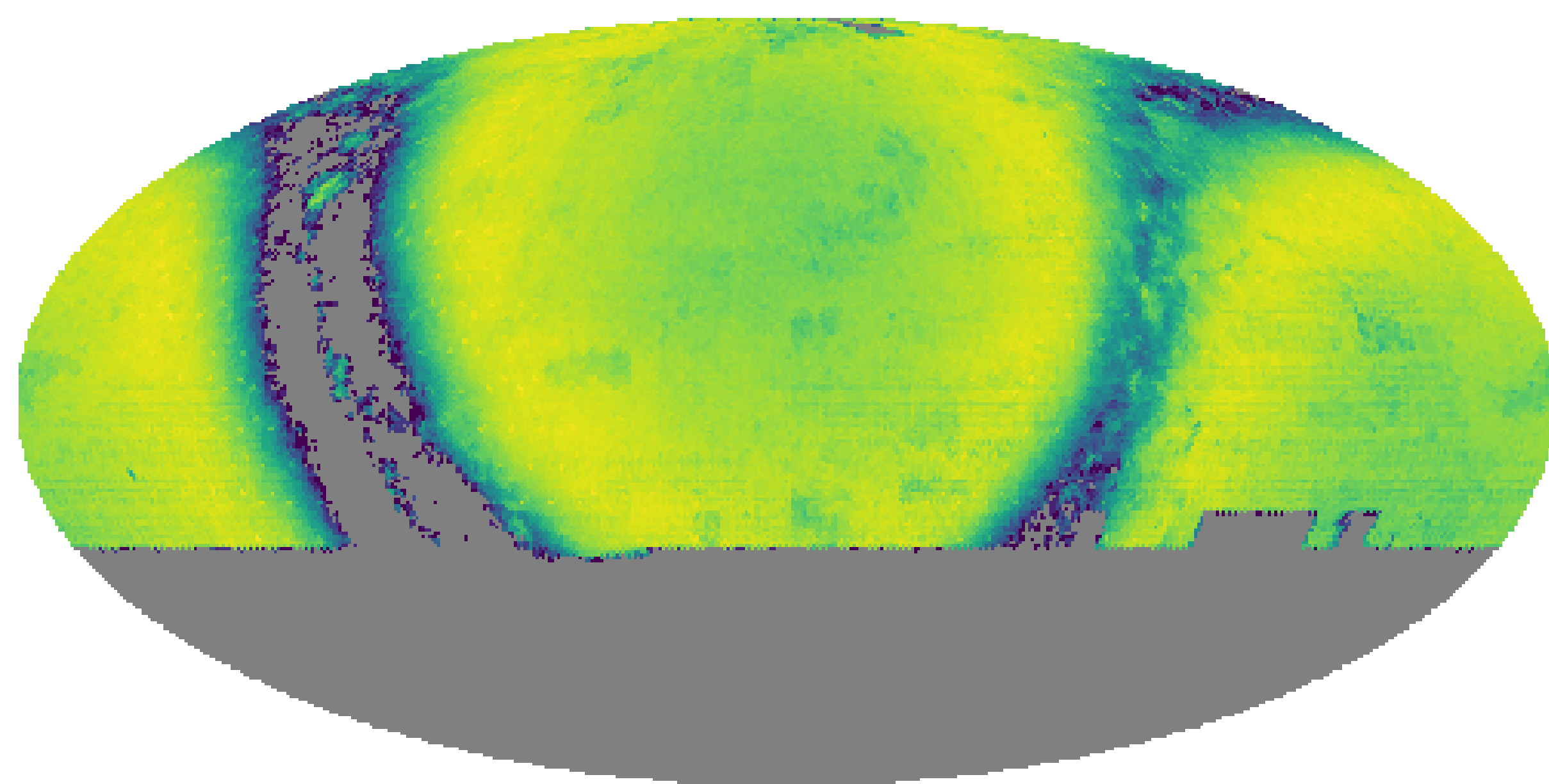
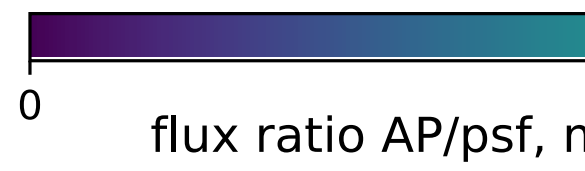
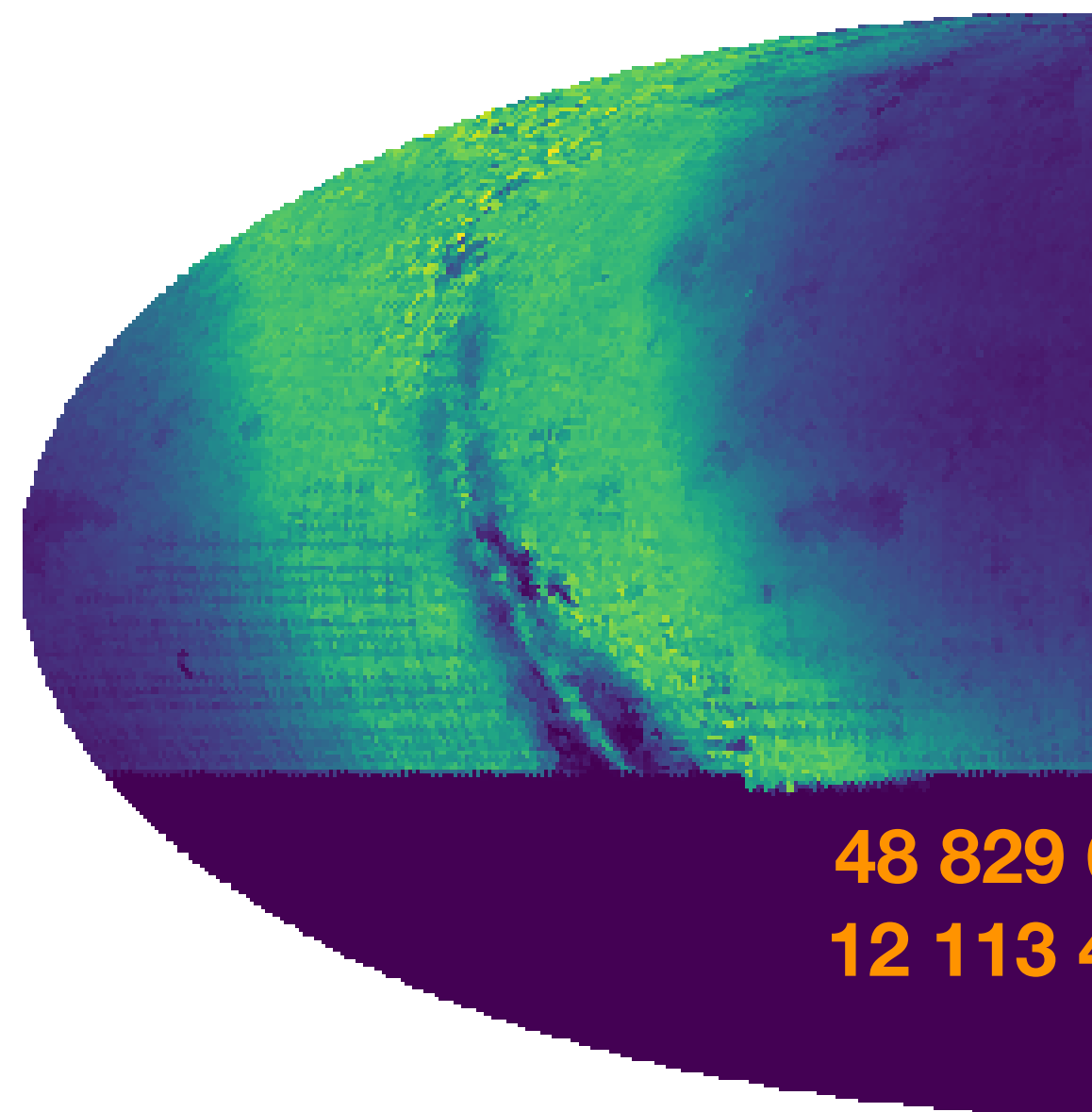
Aperture (10pix) / psf flux



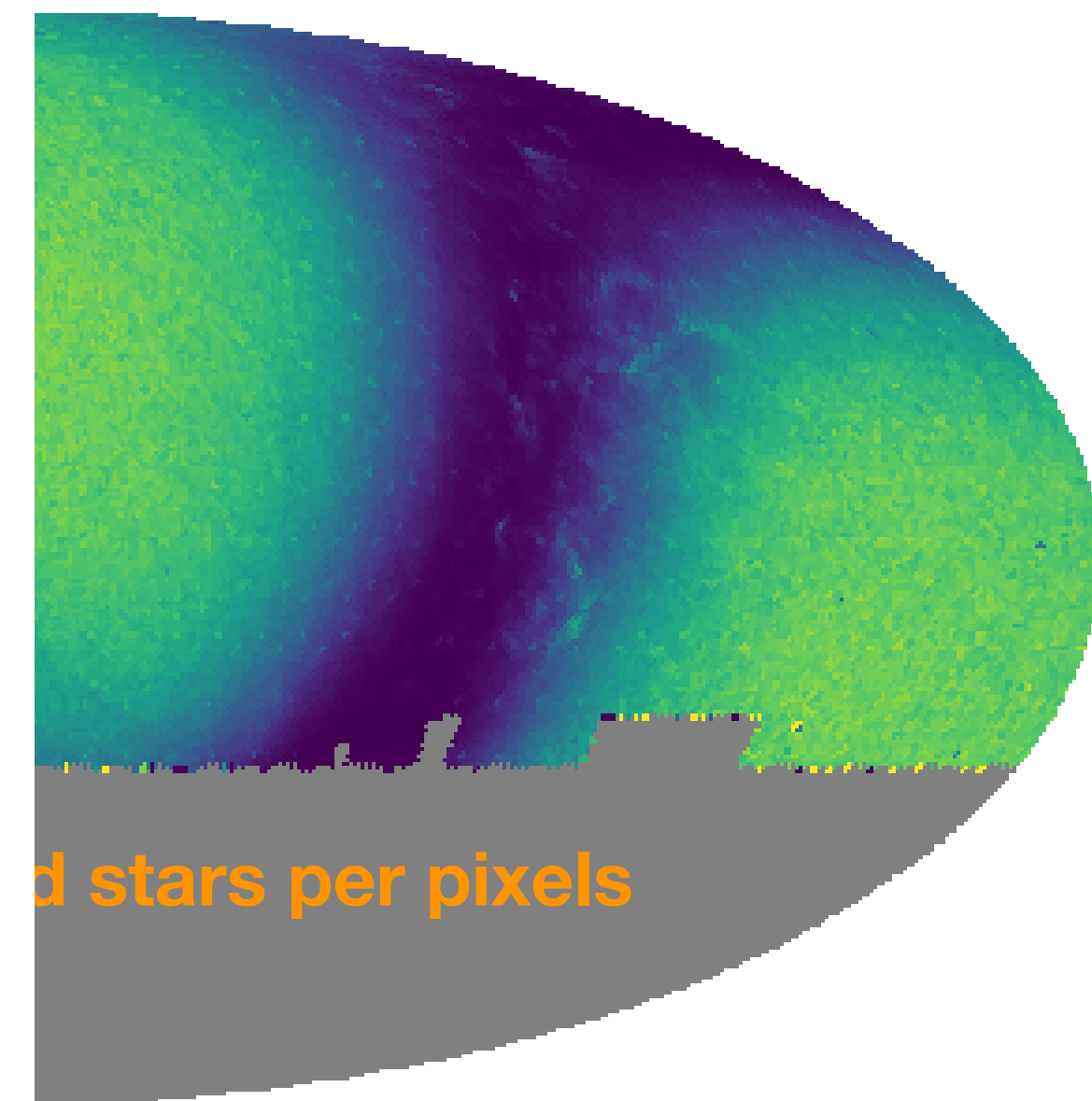
Aperture (10pix) / psf flux  
for isolated stars



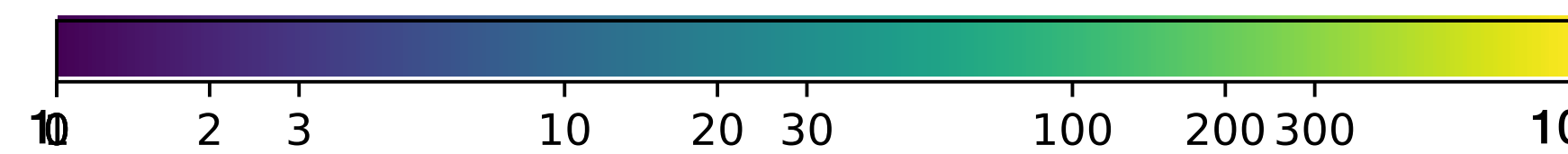
number of star p



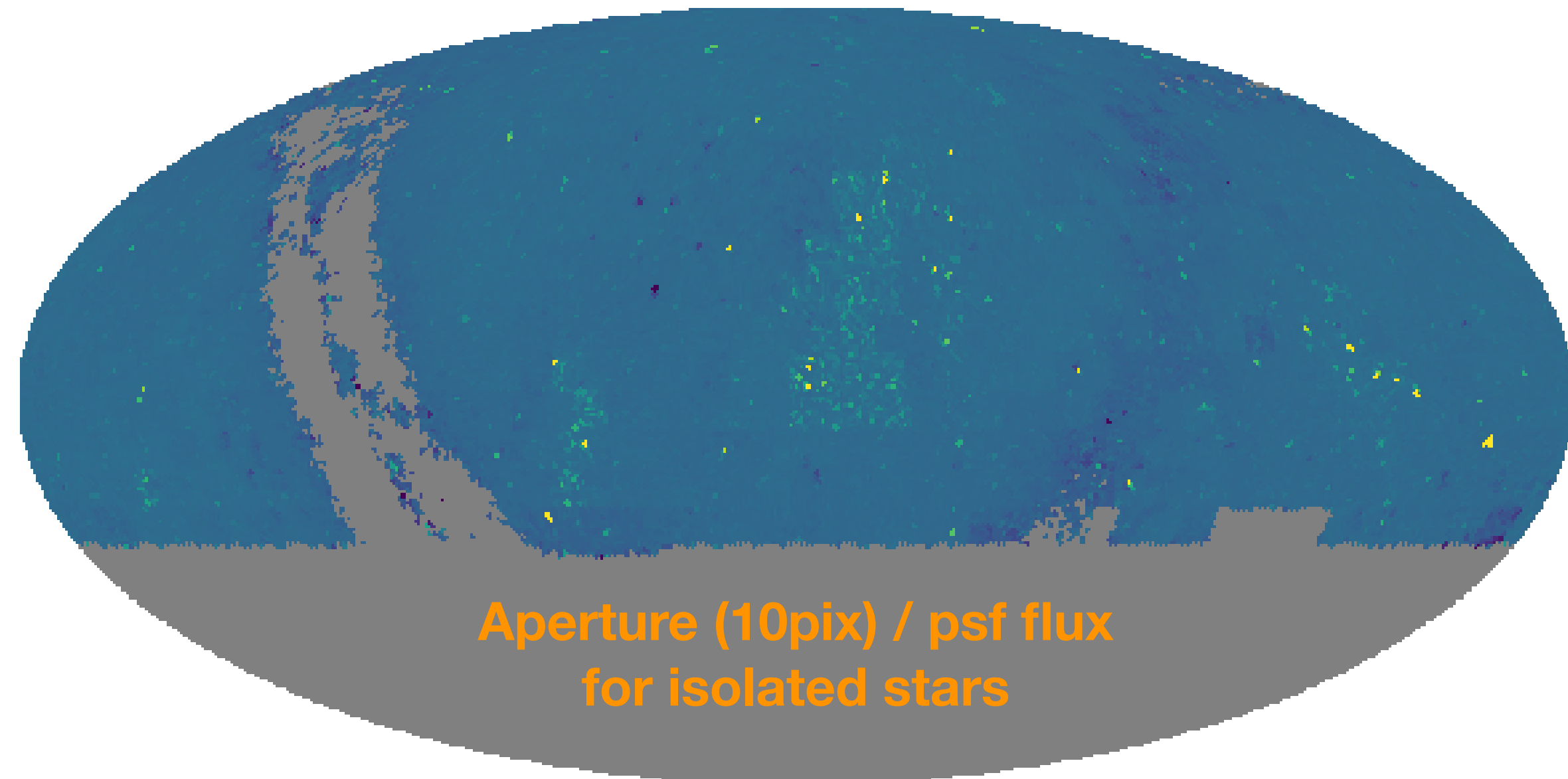
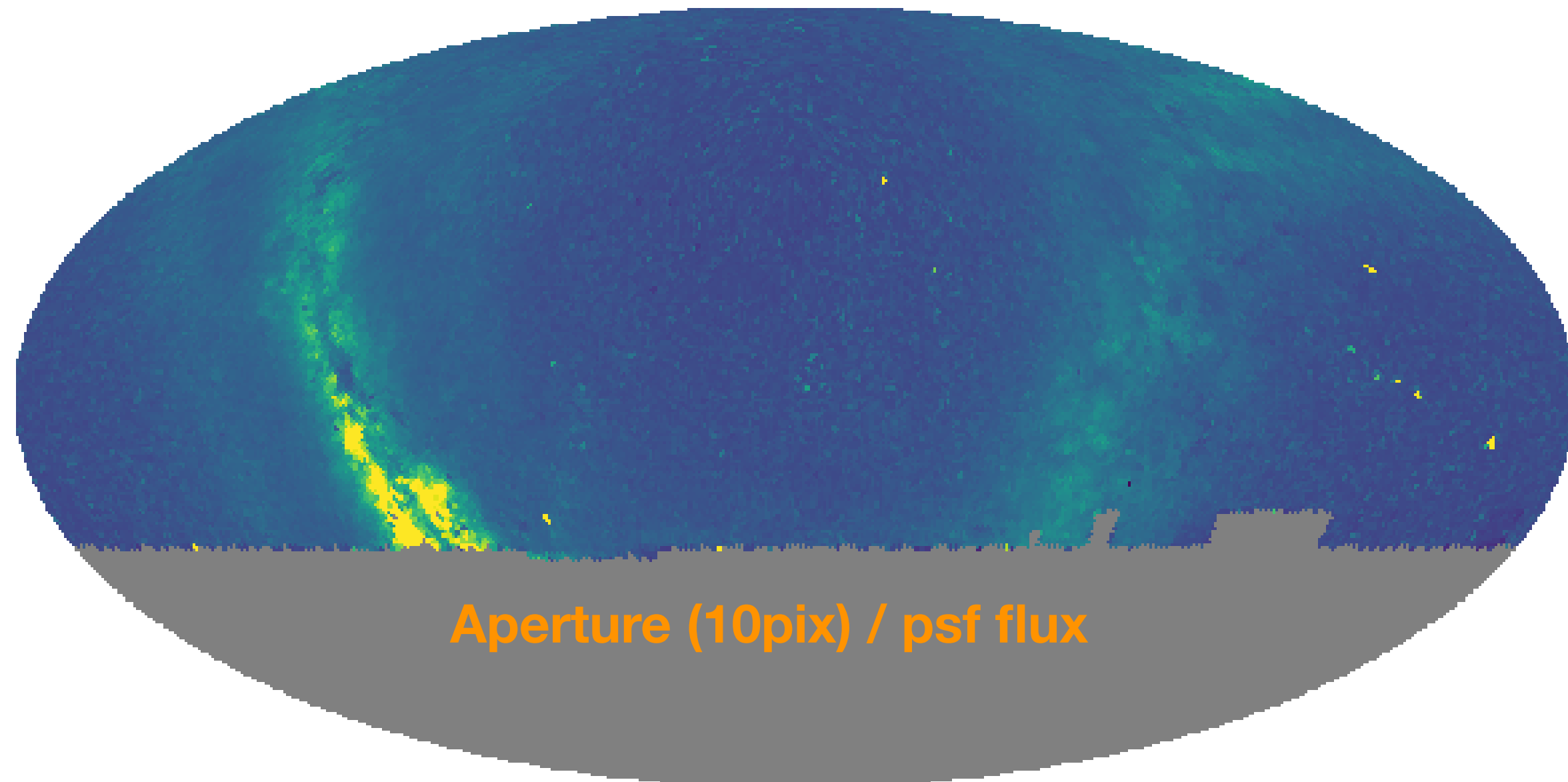
d/all stars



flux ratio AP/psf, min inside 64 pixels



max ratio AP/psf, min inside 64 pixels

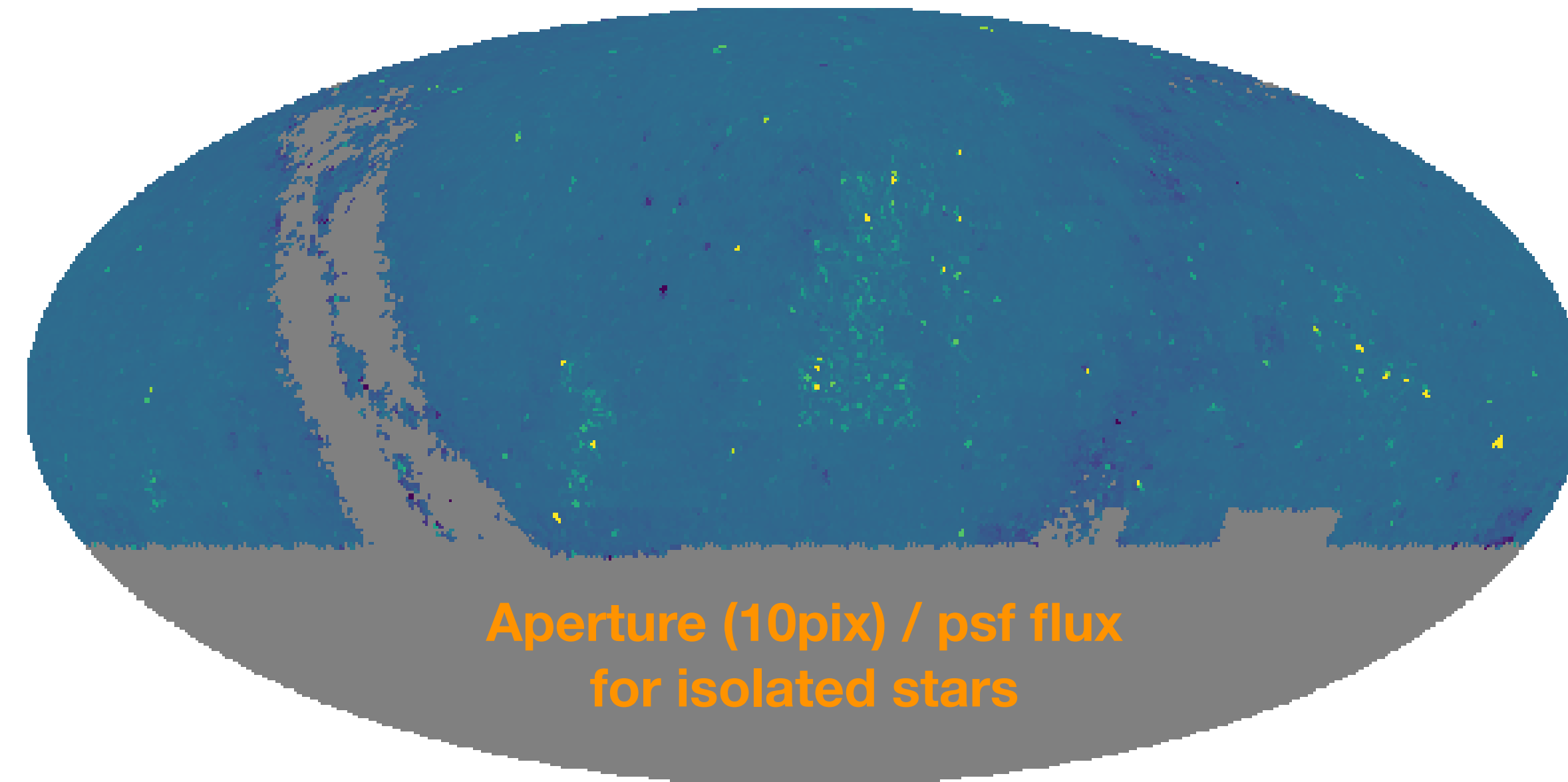
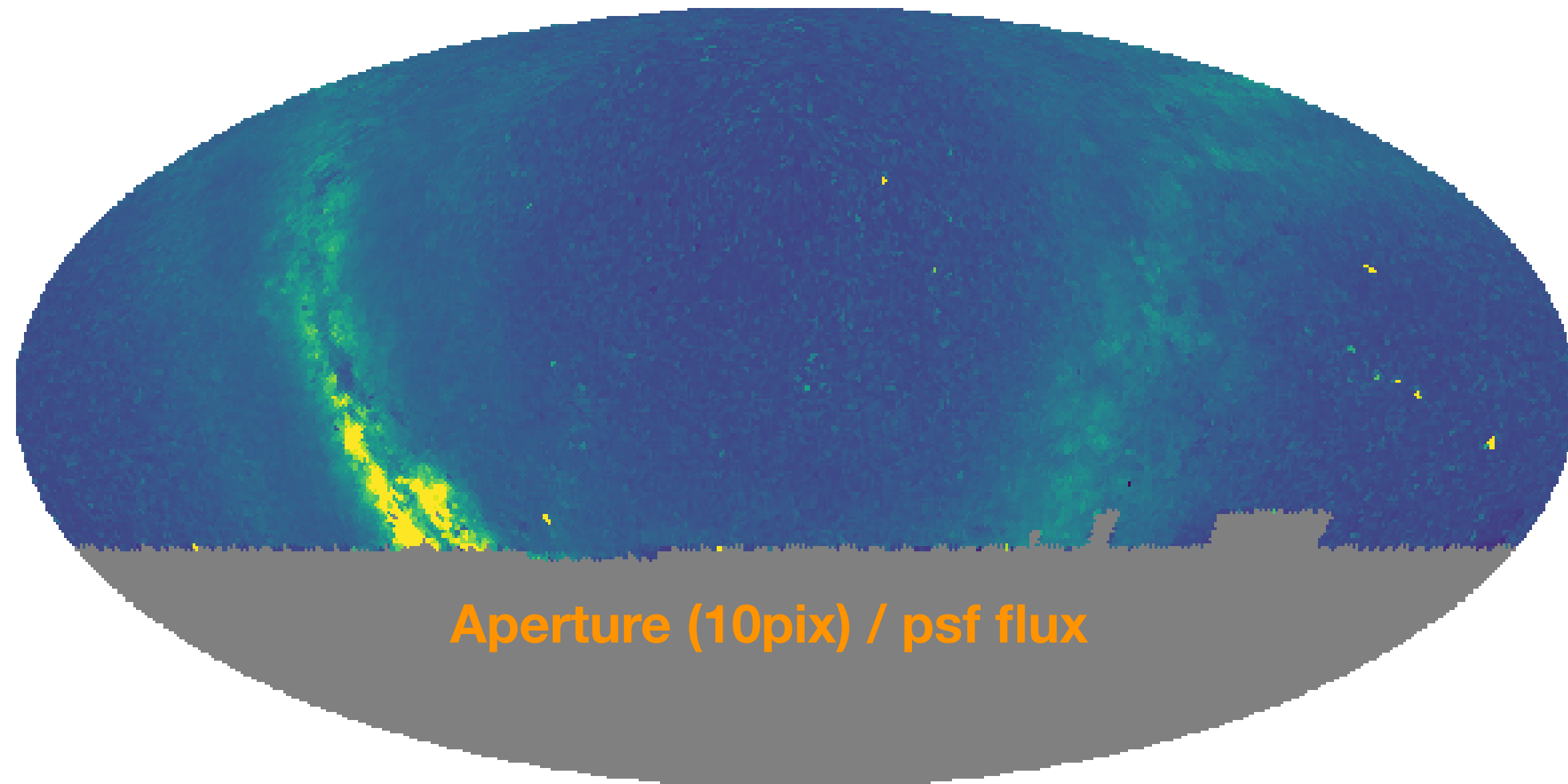
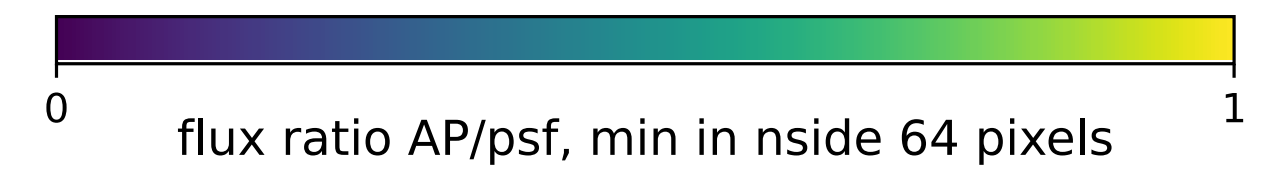
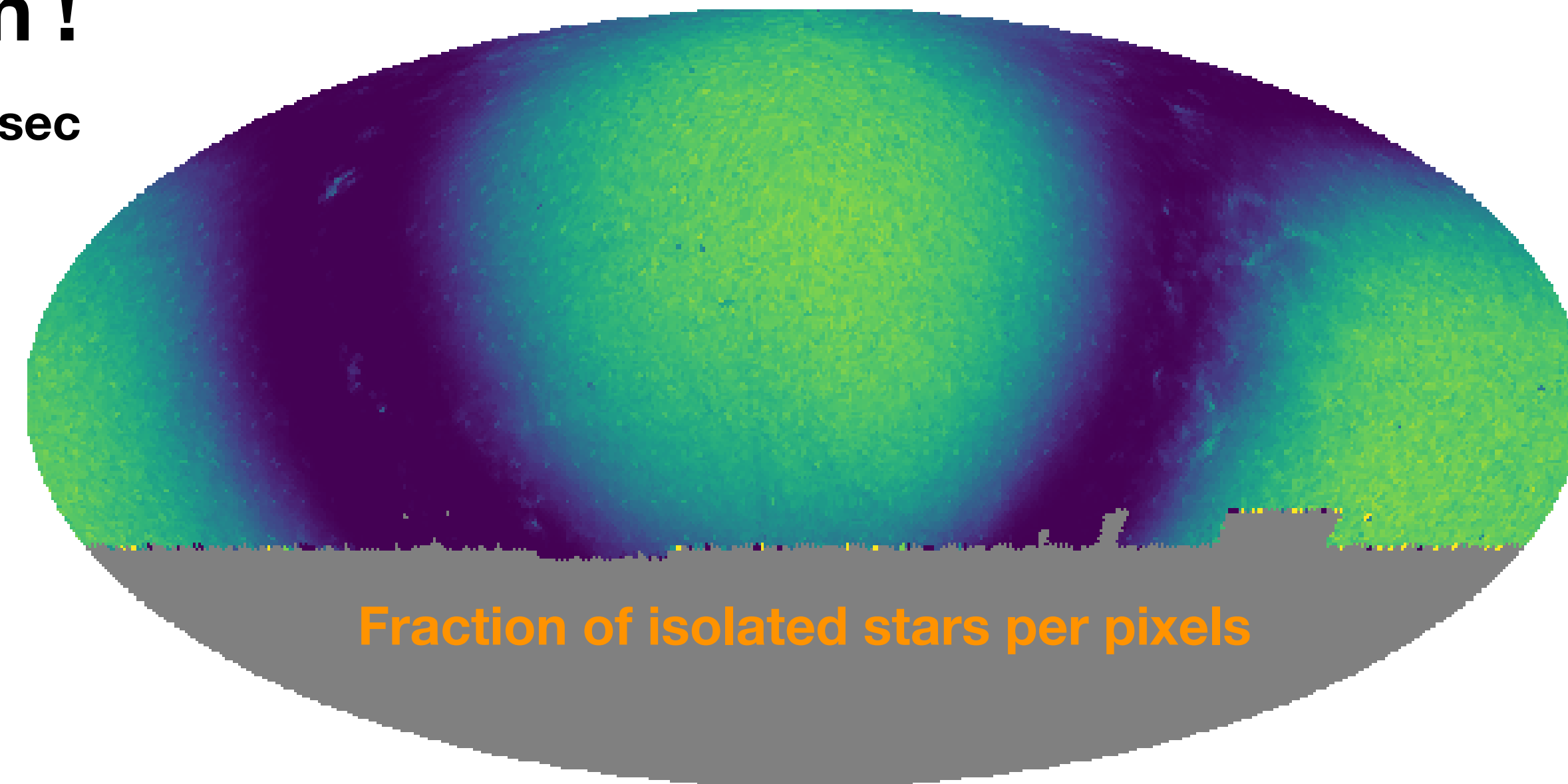
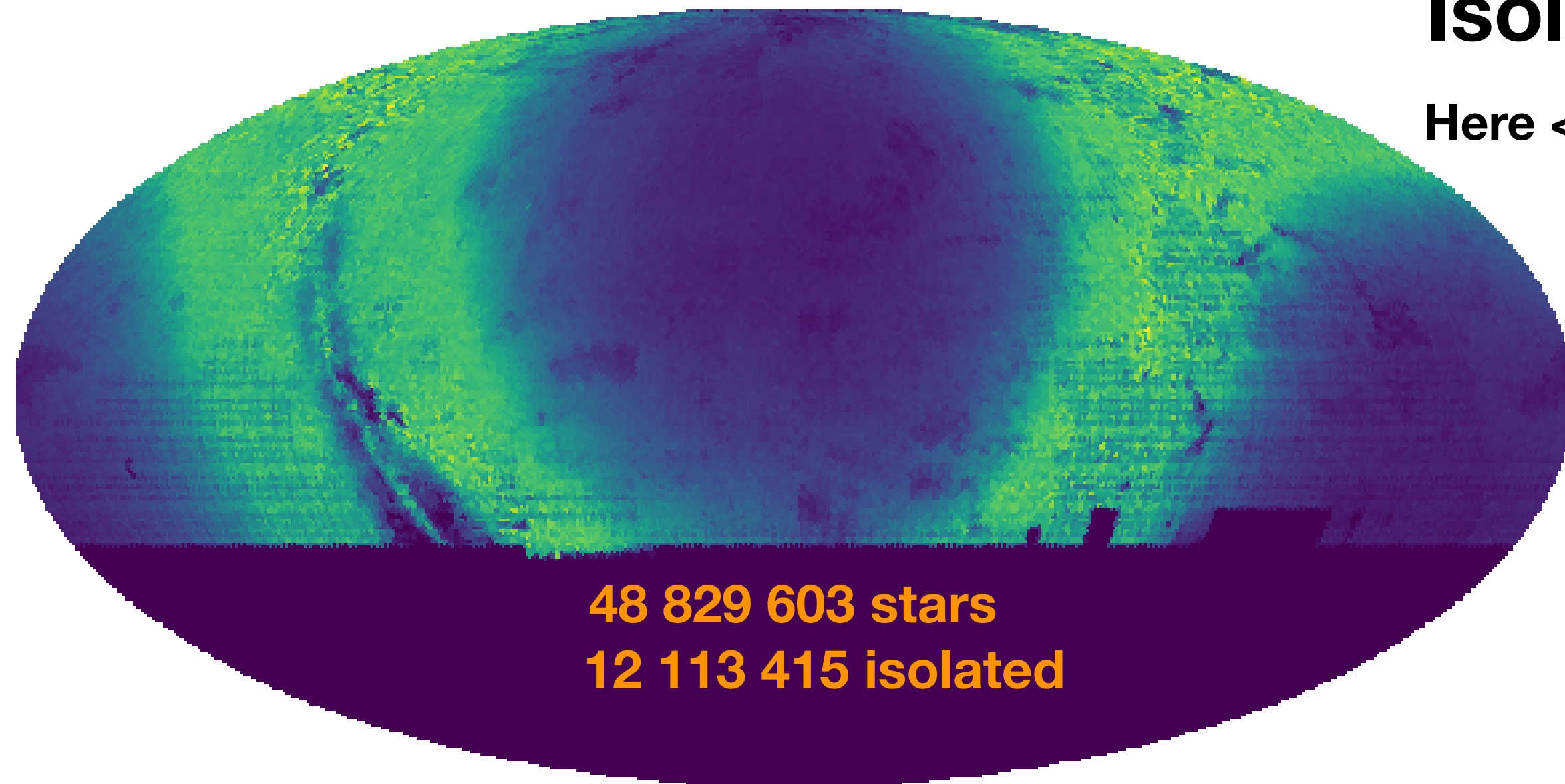


number of star per nside=64 pixels

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ratio isolated/all stars

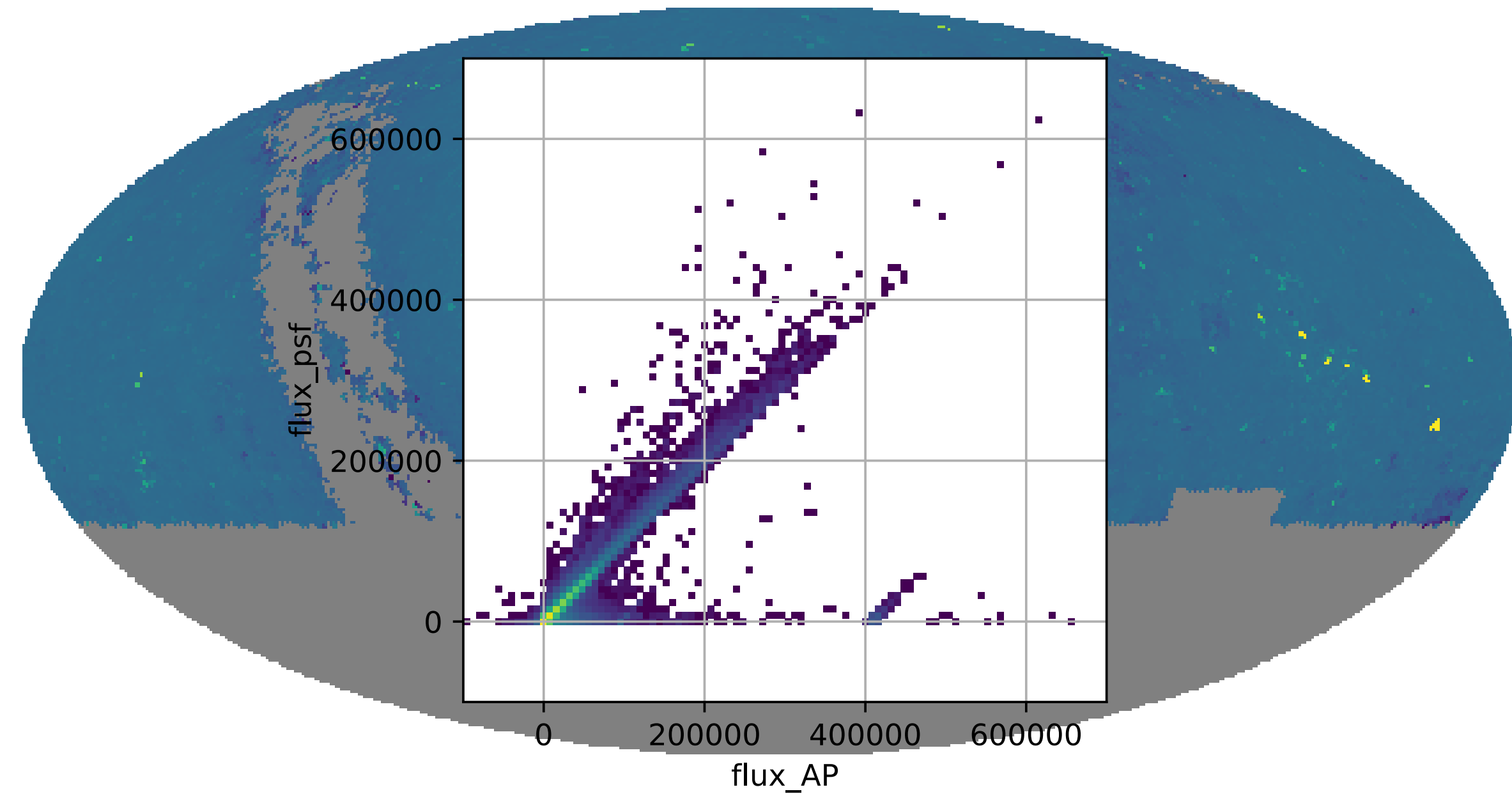
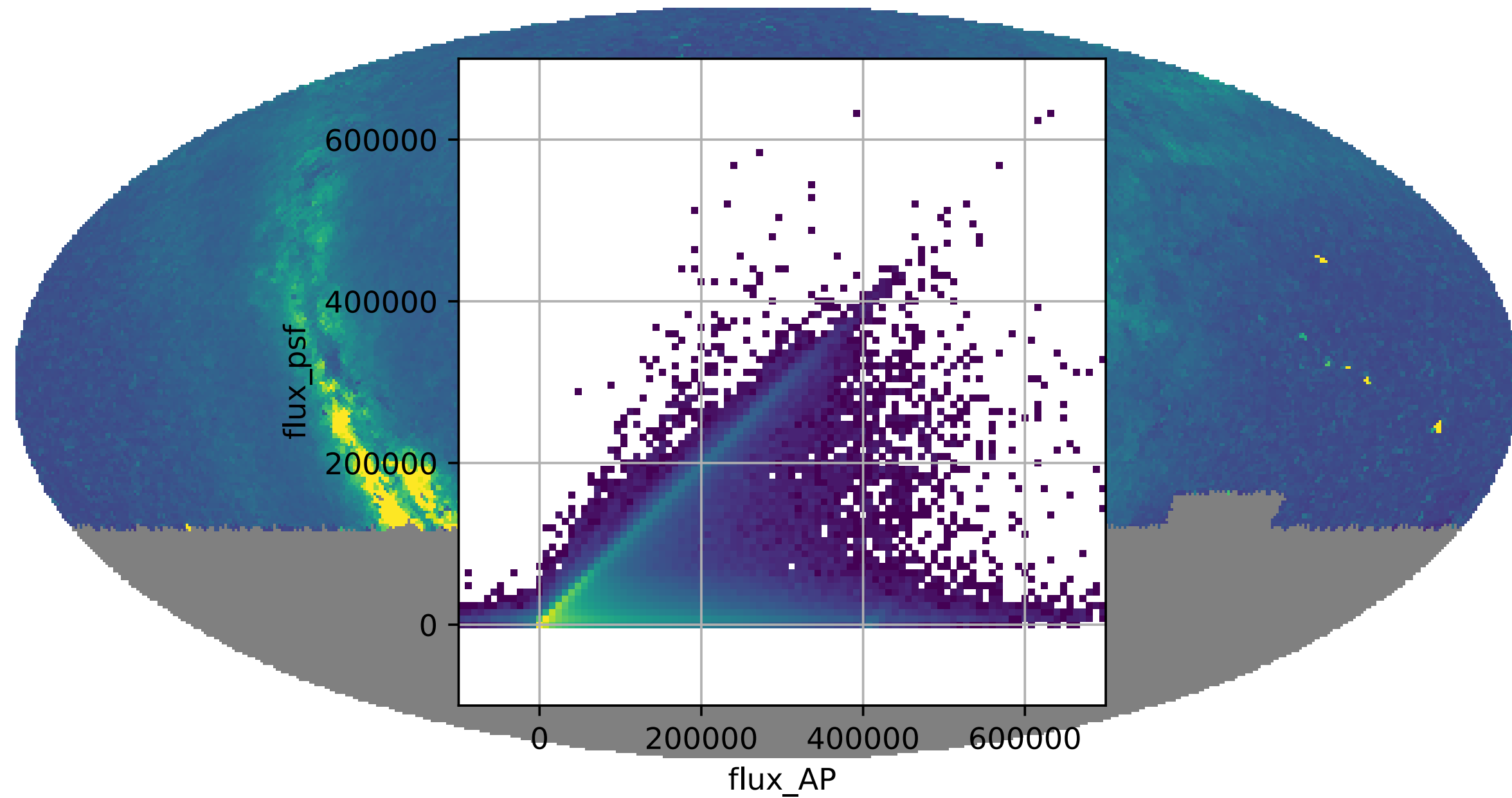
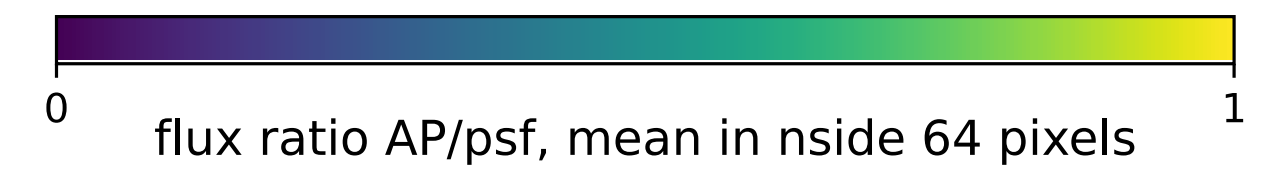
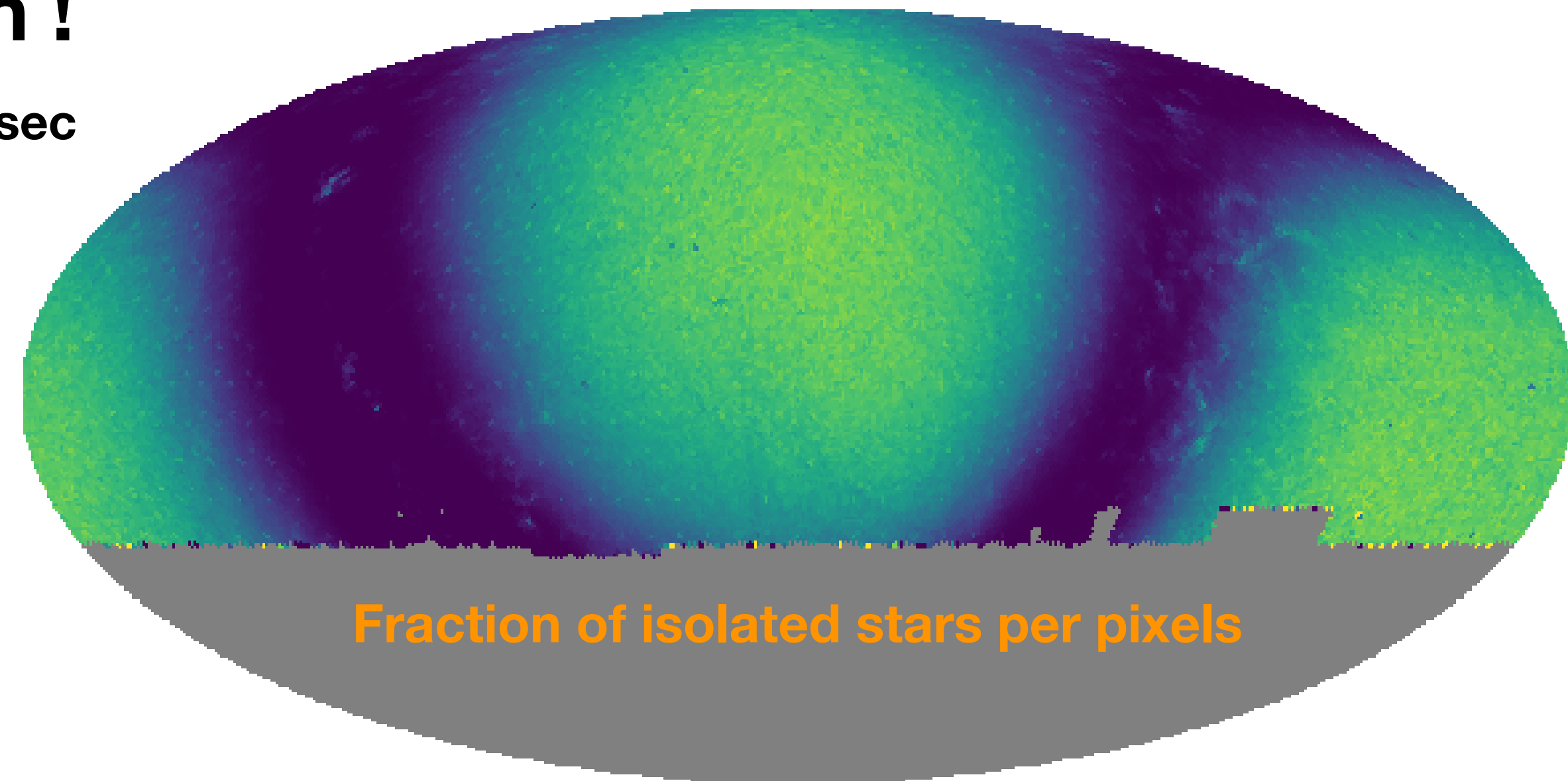
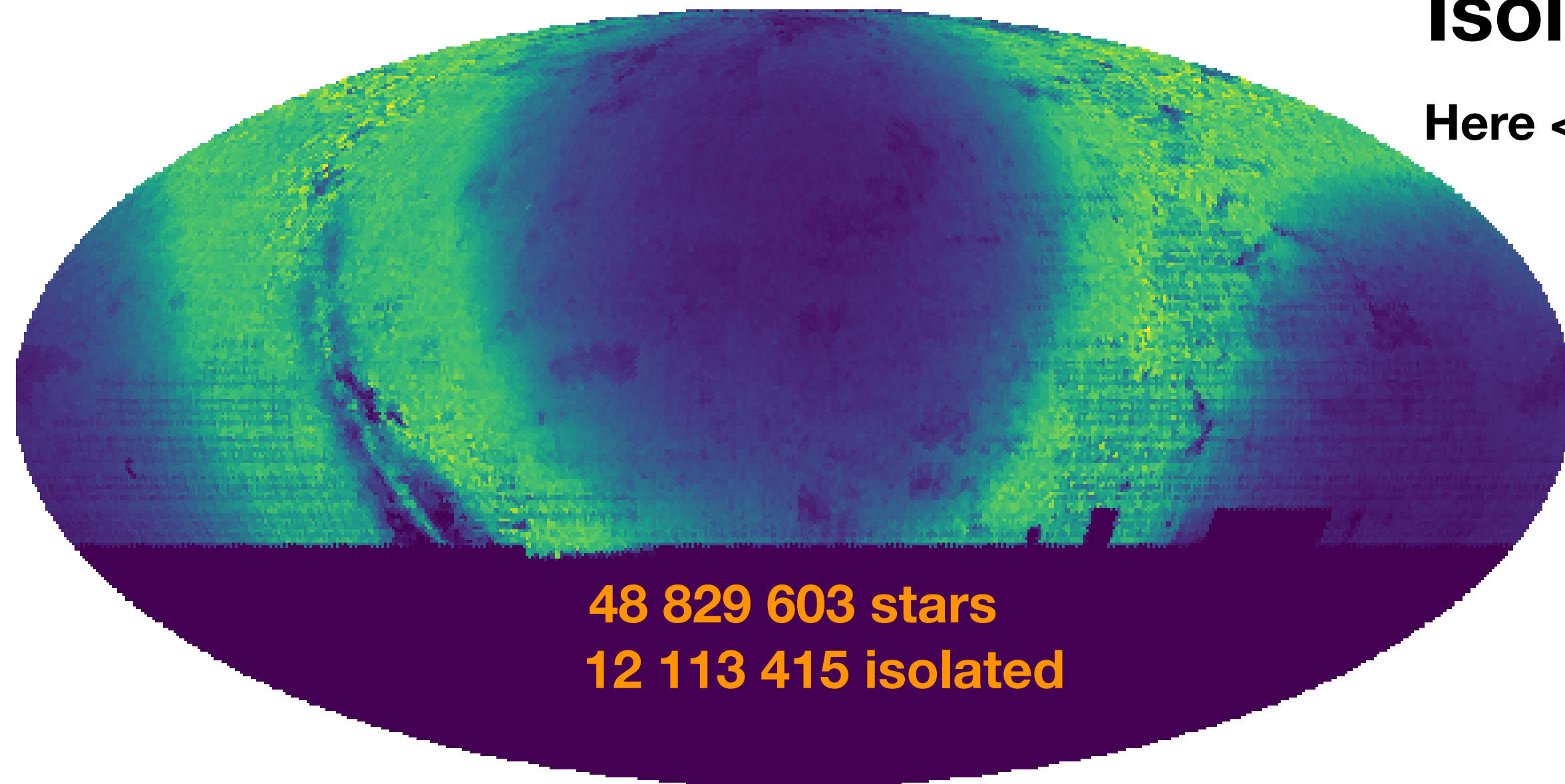


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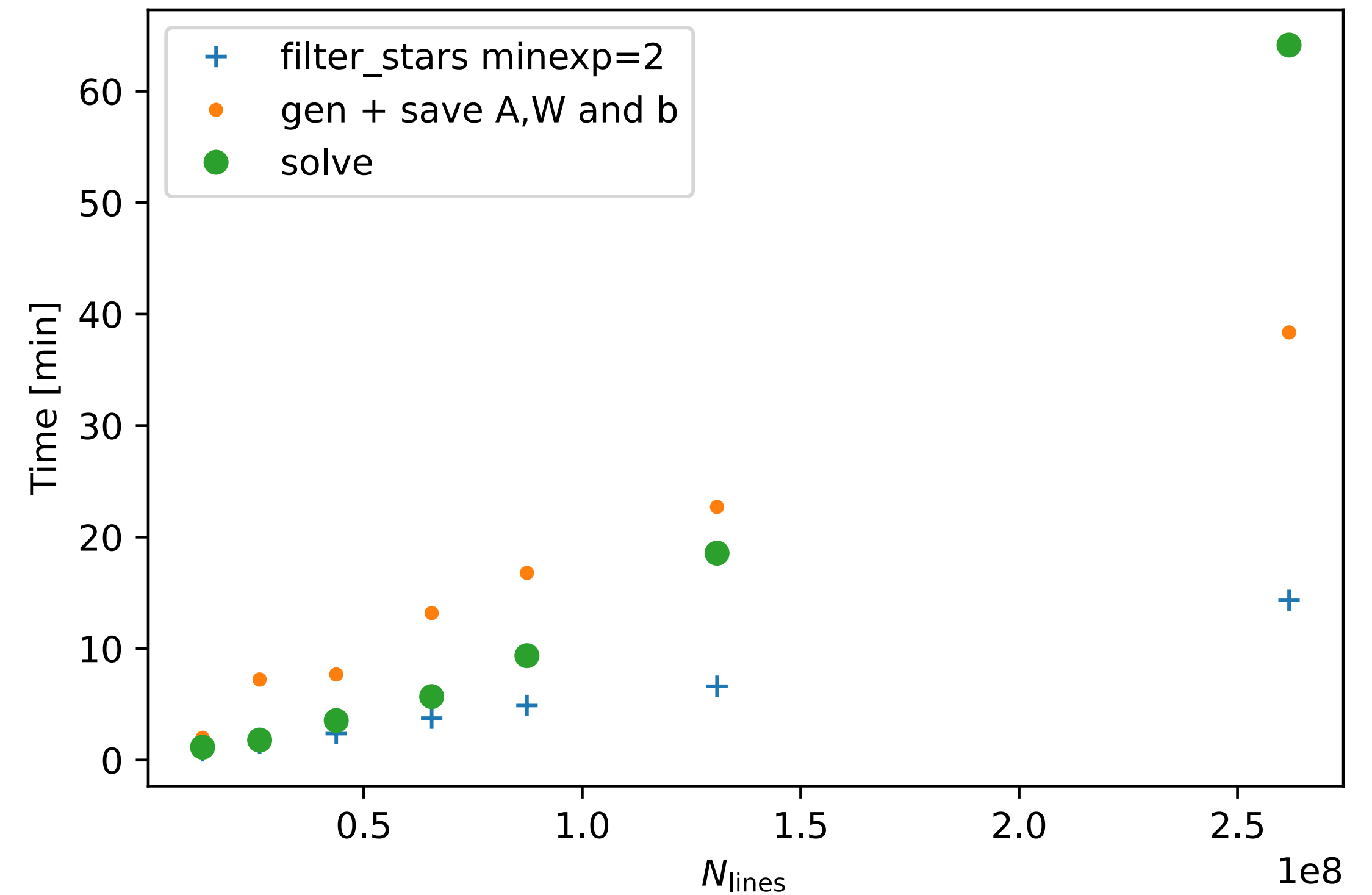
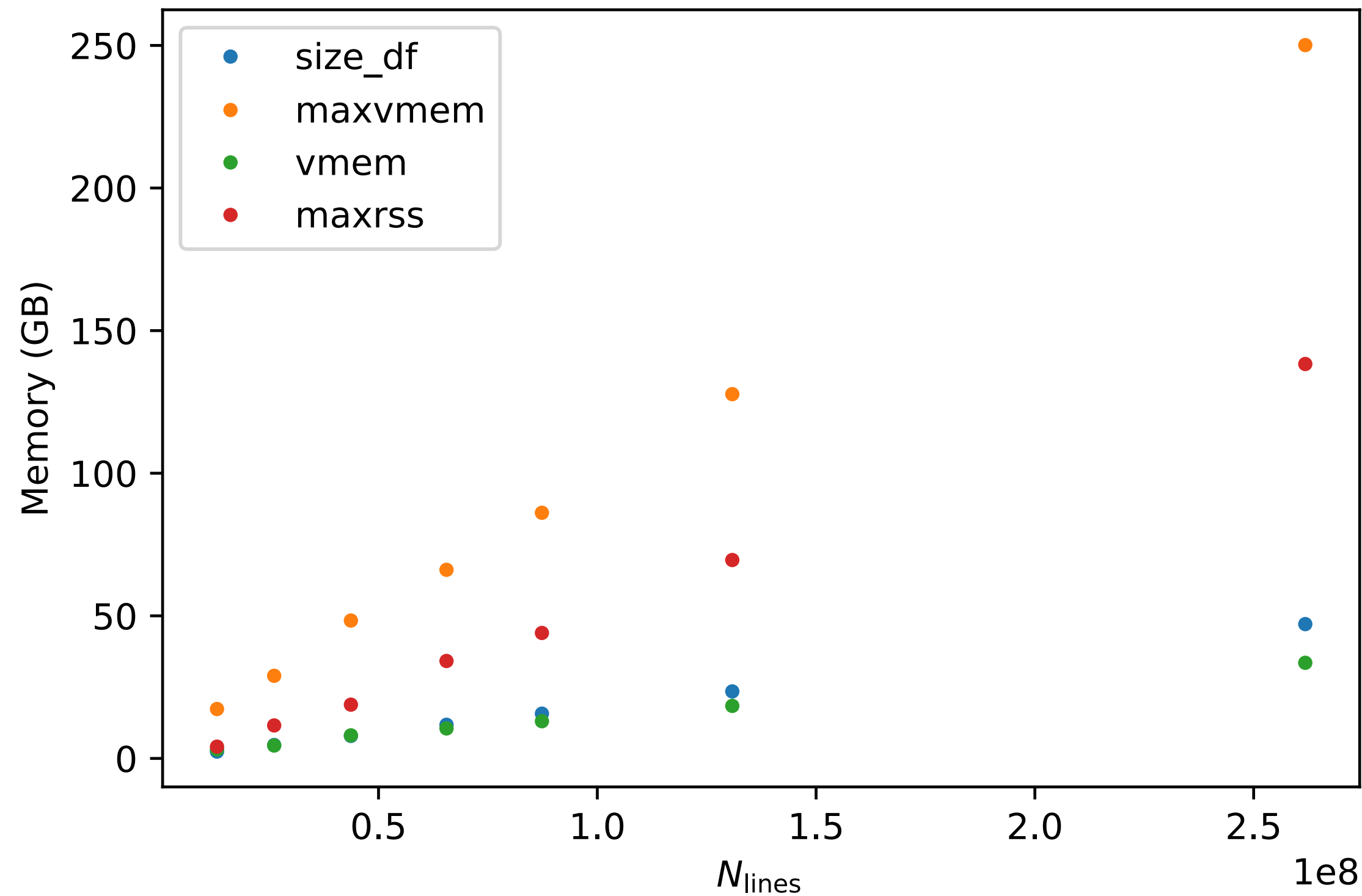
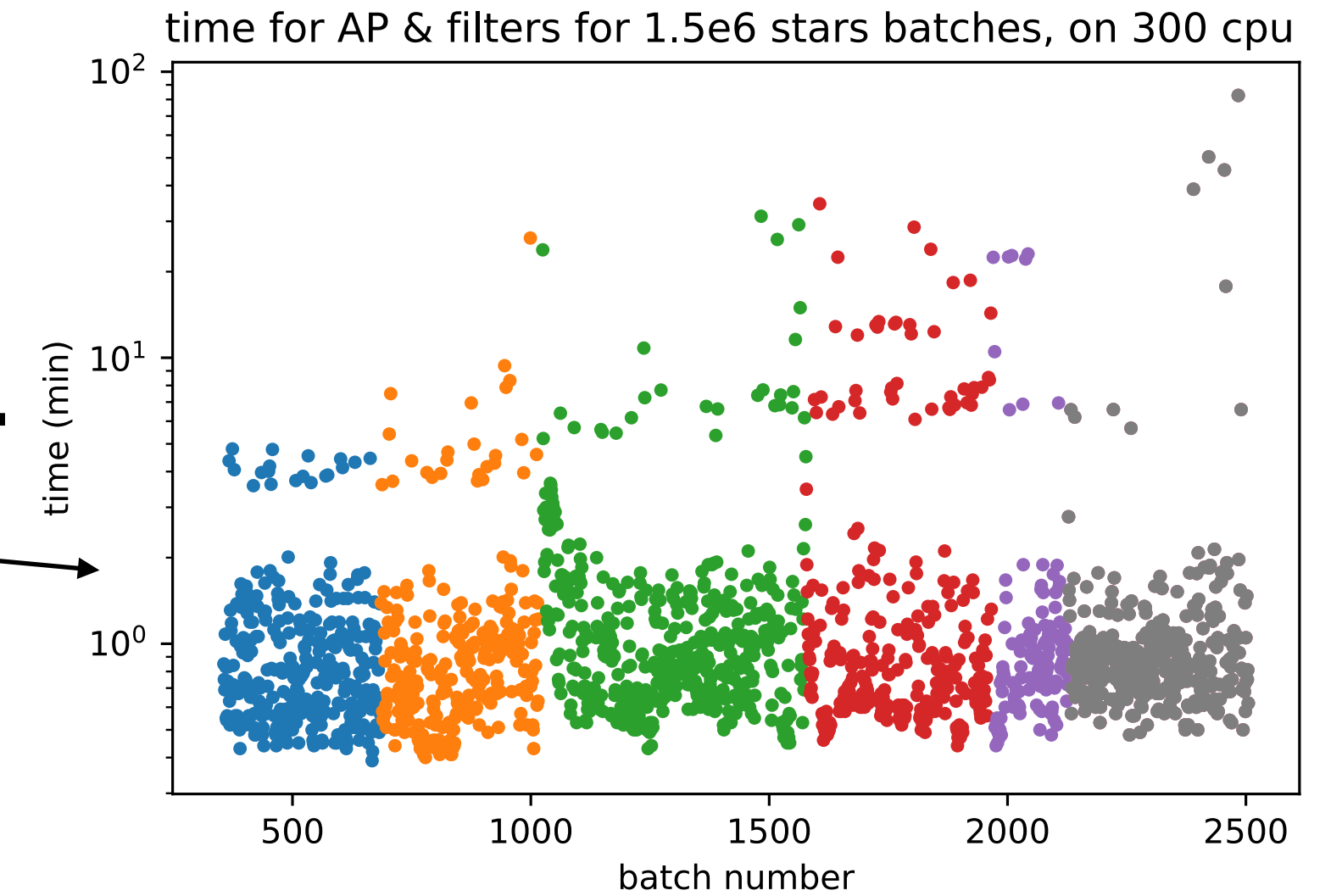
ratio isolated/all stars



# Time and memory

For 6 month case (in R):

- Download Gaia cat (1 time thing)
- Download masks and sciimg: 16h for August on 300 cpu, 3 crashes...
- Perform AP (and filter) : 69h with many crashes
- Merge for giant catalog (in 2 steps, using jobs): ~1h
- Filter usable stars and prepare ubercal: ~1h
- Solve : O(1h) for now, but not linear...

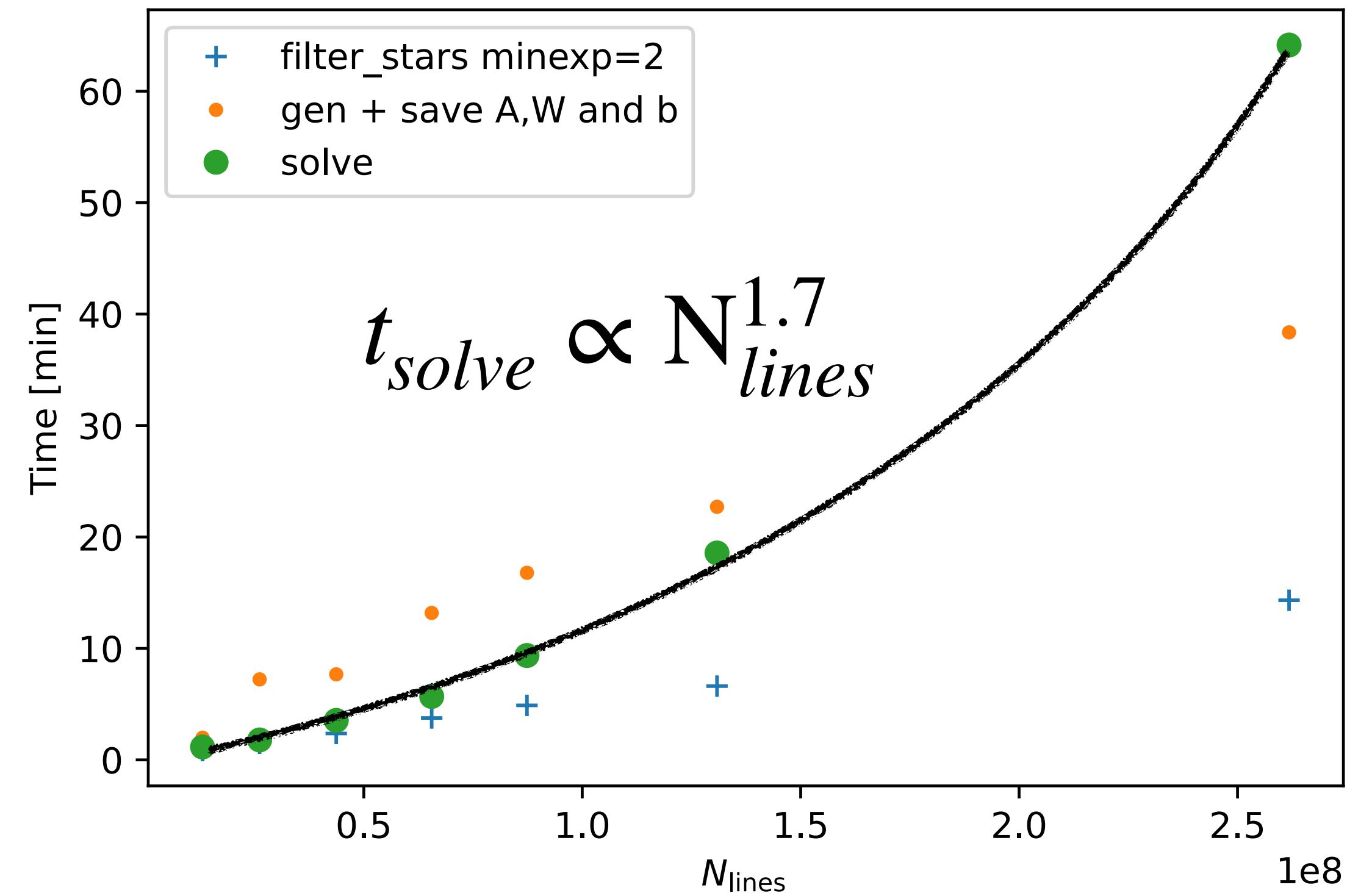
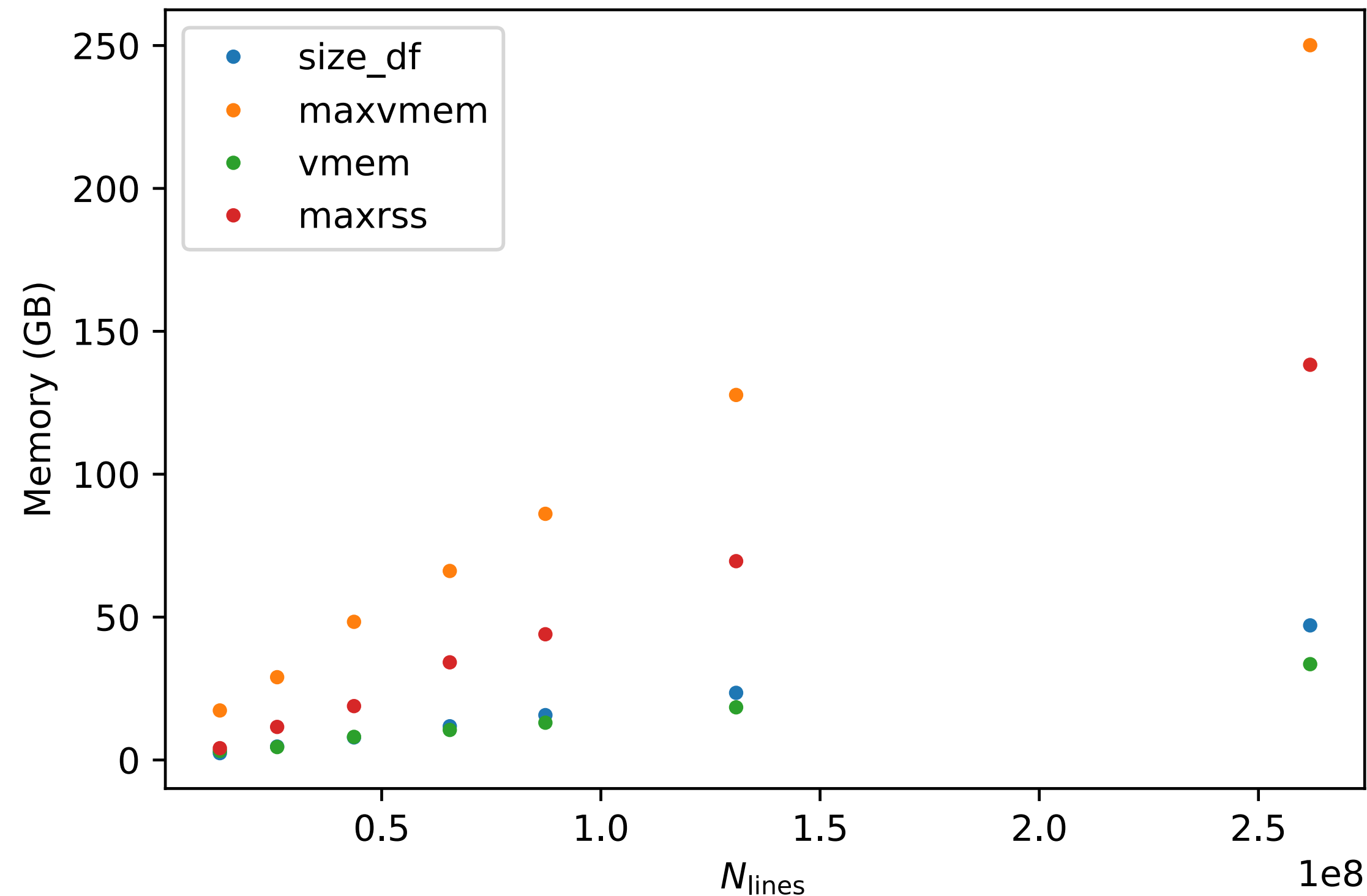
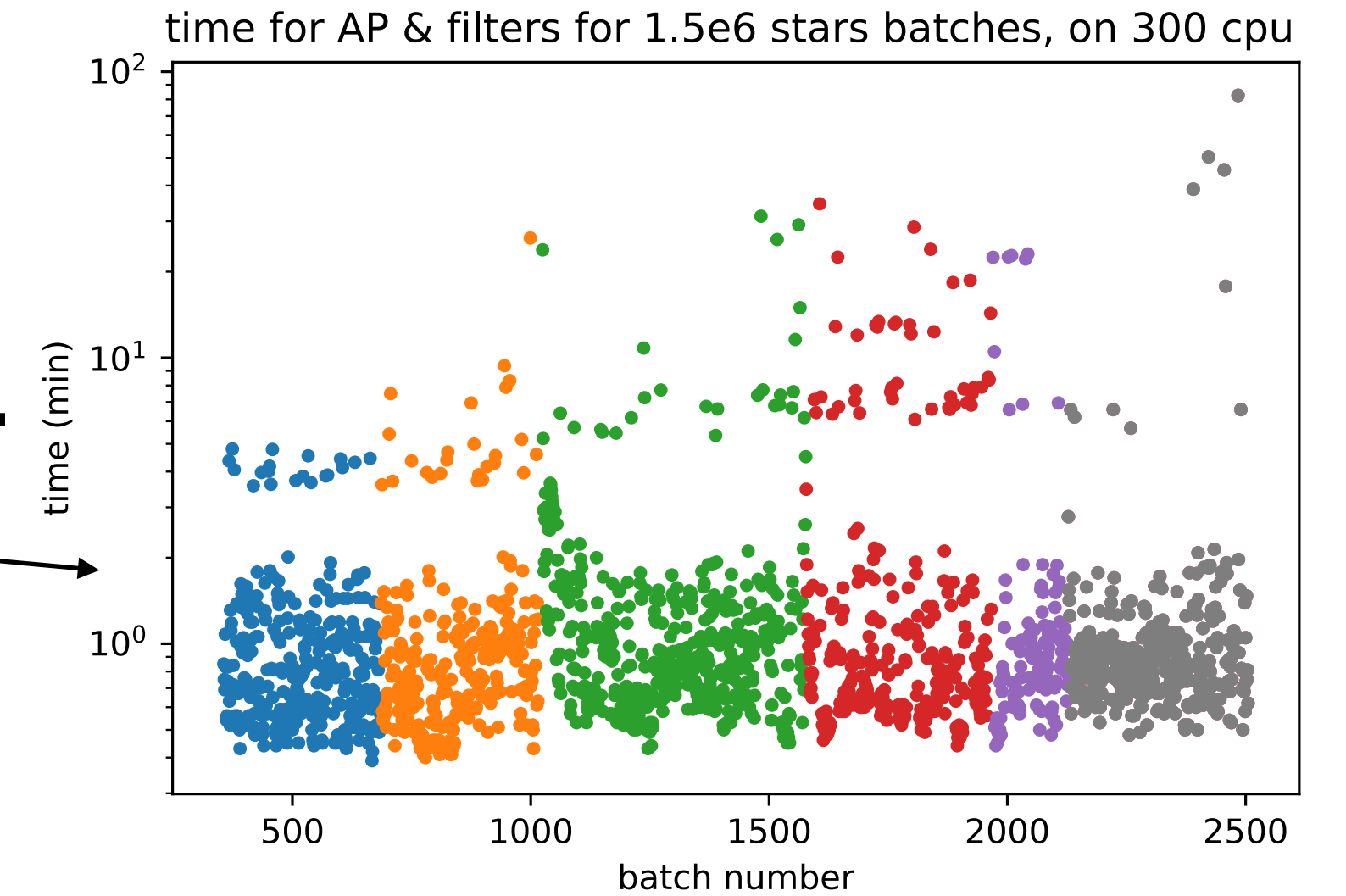




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## To-do

- **do more control plots**
- **review selection:** SNR, edge cuts, isolation, infobits
- **iterate:** cut bad data post-ubercal, outliers, bad chi2
- **rerun for ztf-g and ztf-i**
- **unlock selinv (broken for now on CC)**
- **compare with MC**
- **push for quadrant resolution:** regularization, dense edges
- **more seasons**
- **complexify model :** airmass, color
- **many more stuff !**