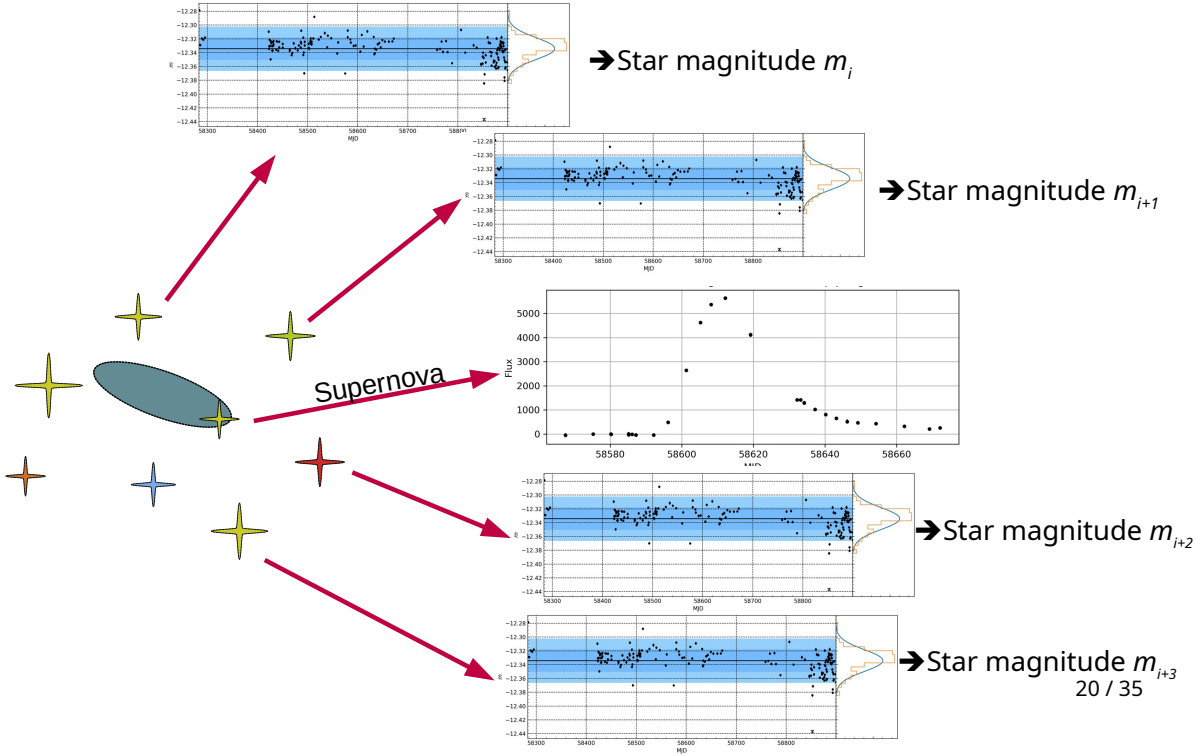
# Ubercal update

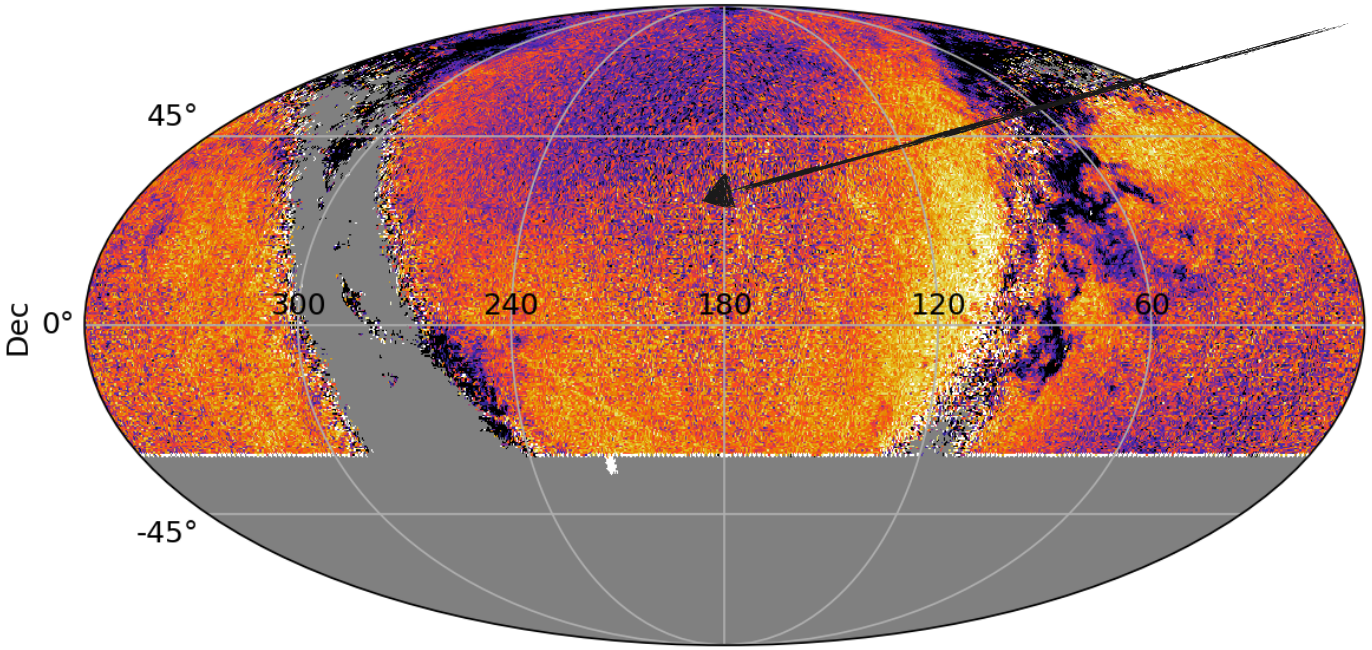
Barcelona, 10/12/24

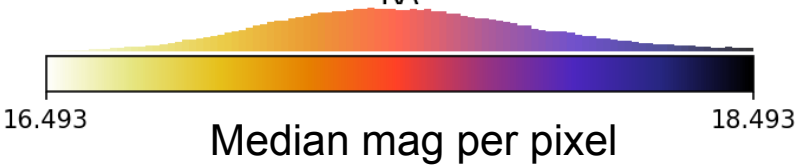
# Why?

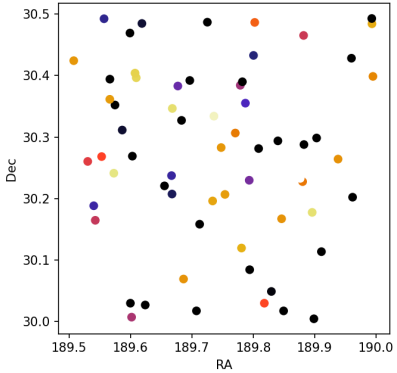
Scene modelling plot from Leander Lacroix



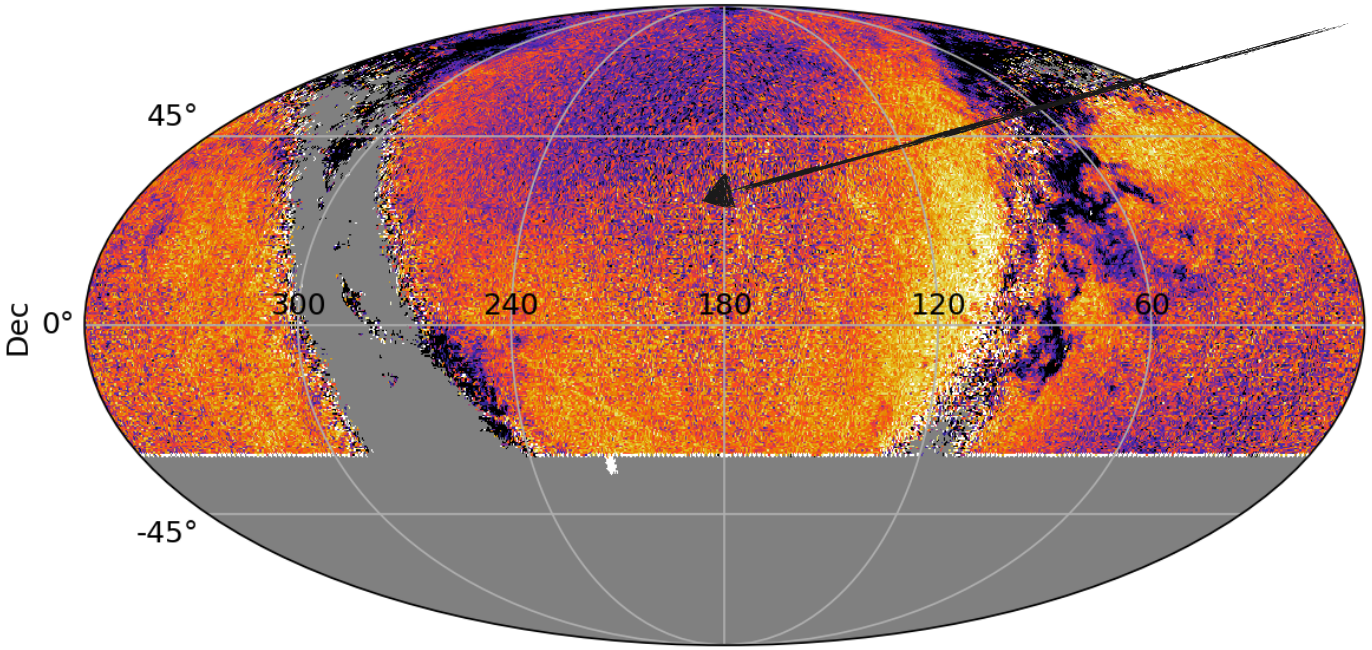
# Something like this…

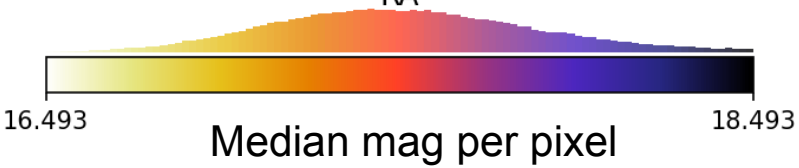


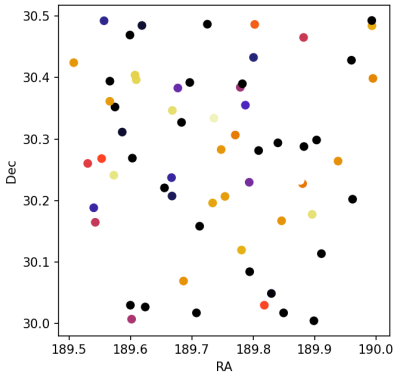



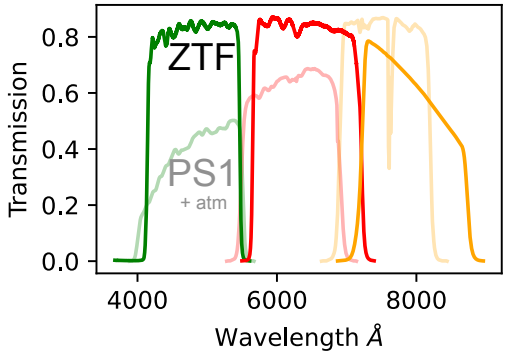



# Something like this…

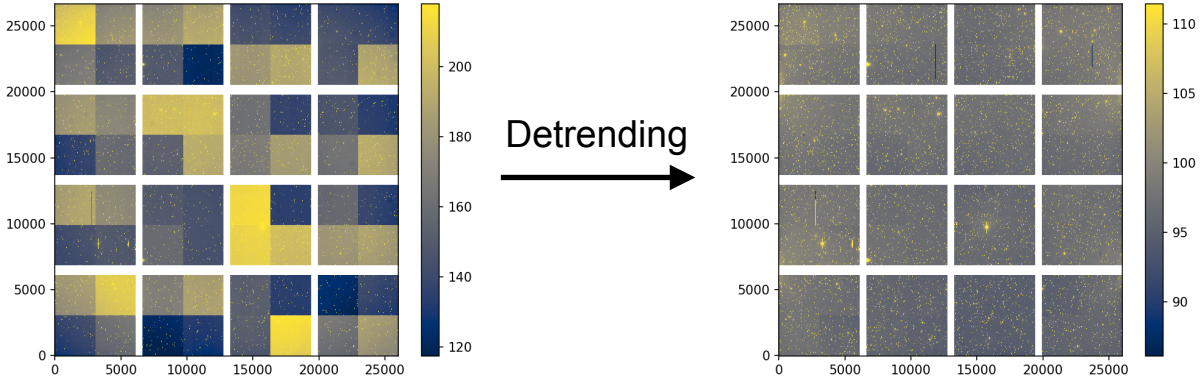


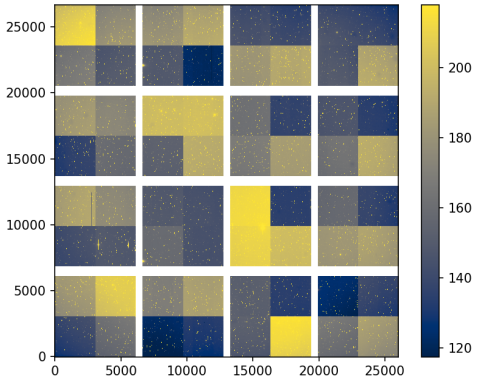



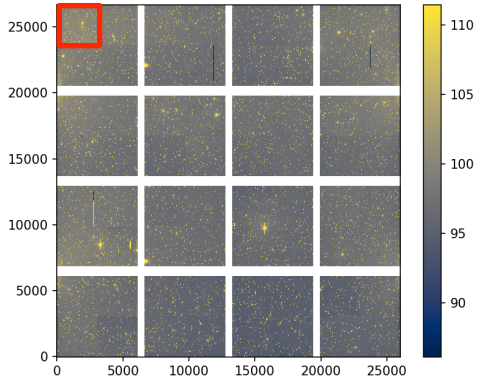




… but here it is PS1 g

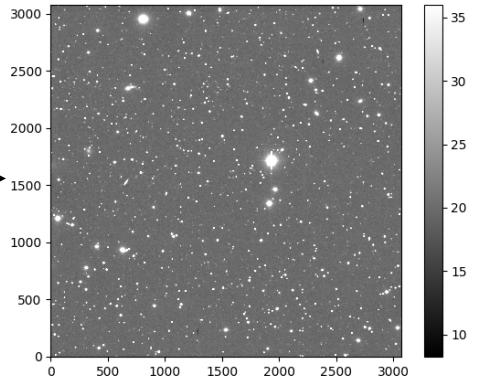

25000
20000
15000
10000
5000
0
0
5000
10000
15000
20000
25000
200
180
160
140
120
Detrending
25000
20000
15000
10000
5000
0
0
5000
10000
15000
20000
25000
110
105
100
95
90

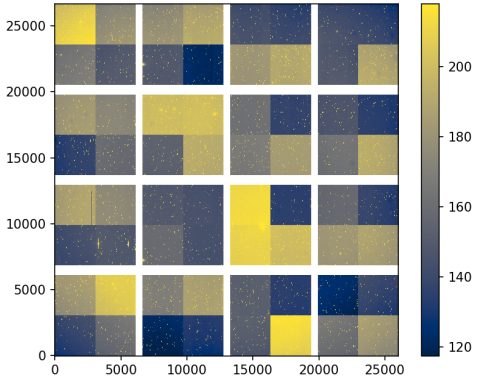



Detrending

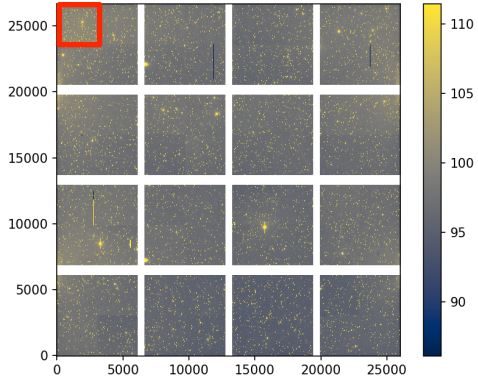



Background removal

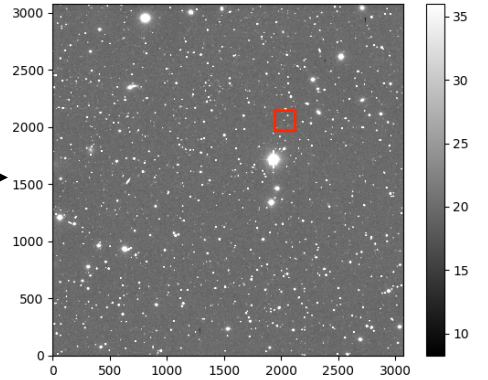




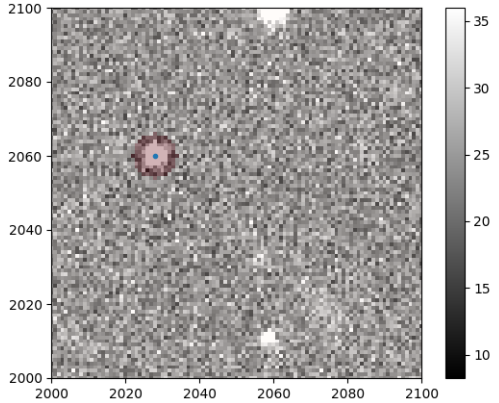
Detrending

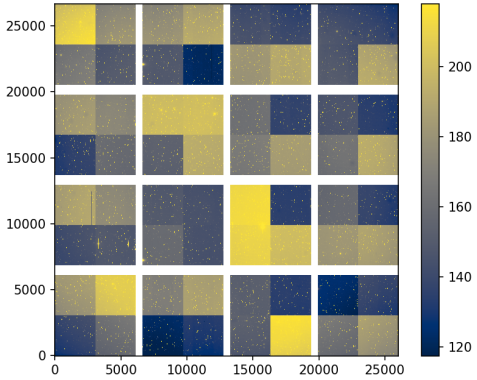


Background removal

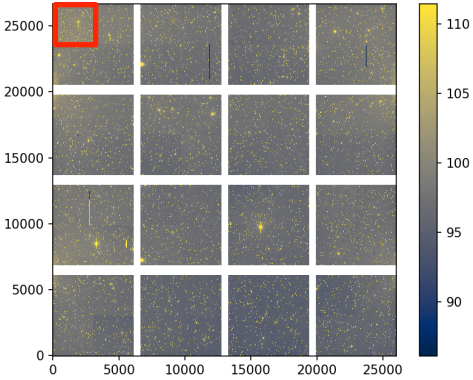


Gaia DR3
Forced AP
6pix

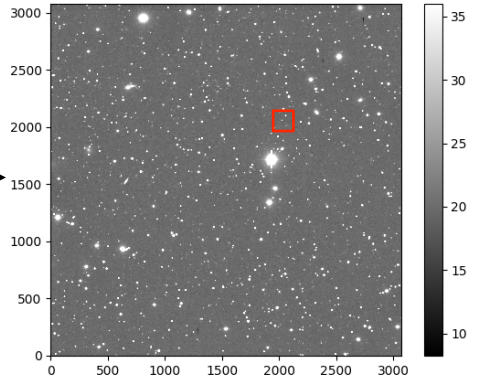




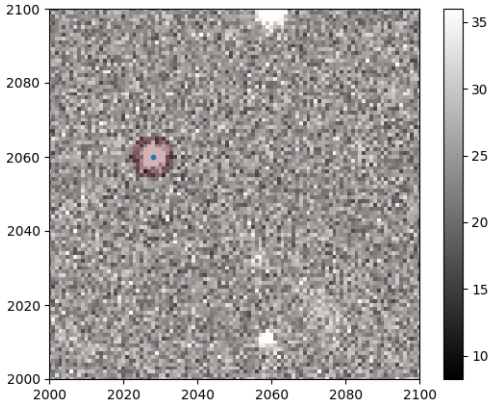
Detrending



Background removal



Gaia DR3 Forced AP 6pix



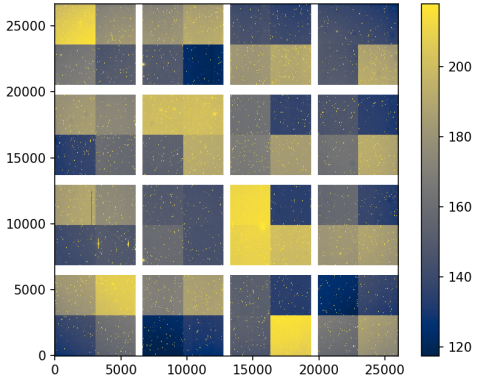
Circle of radius r around a given pixel.

$$\text{Flux} = \sum_{\text{pix}\in\text{disk}} \text{image}$$

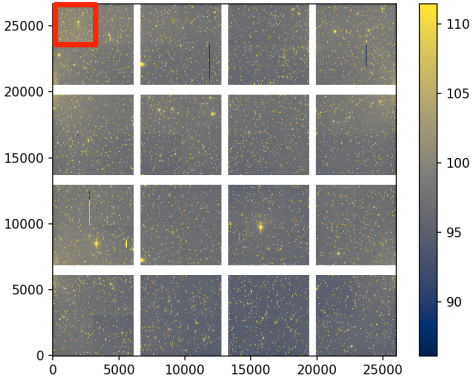
$$\text{Flux error} = \sqrt{\sum_{\text{pix}\in\text{disk}} \text{background rms}^2}$$

## Aperture Photometry catalogs

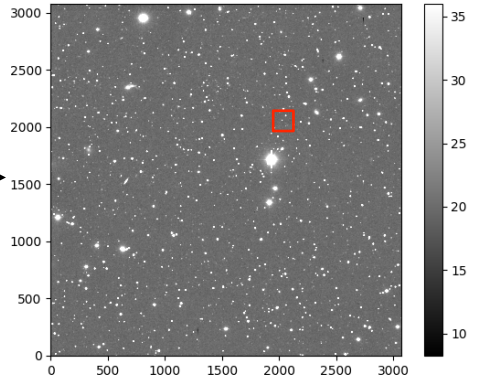
| | source_id | ra | dec | phot_g_mean_mag | phot_bp_mean_mag | phot_rp_mean_mag | x | y | isolated | f_0 | f_1 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 6334168771145457011 | 224.23587 | -5.512197 | 21.257378 | 21.096867 | 19.003939 | 2961.637 | 4.35642 | False | 112.94968 | 92.16835 |
| 1 | 6334168771145457062 4 | 224.23291 | -5.510719 3 | 16.730742 | 17.685032 | 15.774773 | 2951.2046 | 9.626395 | False | 1374.4391 | 1473.864 7 |
| 2 | 6334168775449247616 | 224.24603 | -5.505976 7 | 20.856293 | 21.28884 | 19.565767 | 2997.6877 | 26.42609 2 | True | -17.088558 | -9.475877 |
| 3 | 6334169325205066496 | 224.15619 | -5.510555 | 20.710463 | 20.941505 | 20.208666 | 2679.4966 | 10.56559 2 | True | 73.665596 | 70.67294 |
| 4 | 6334169325205882240 | 224.14804 | -5.510255 3 | 16.249336 | 16.610512 | 15.714474 | 2650.6633 | 11.66501 5 | True | 5236.026 | 5609.919 |
| 5 | 6334169359564769536 | 224.1648 | -5.50691 | 20.005707 | 21.009947 | 18.858234 | 2709.9949 | 23.48913 4 | True | 122.03508 | 135.1740 3 |
| 6 | 6334169428284278656 | 224.21414 | -5.511864 7 | 20.564213 | 21.422235 | 19.651264 | 2884.686 | 5.643868 | True | 23.016891 | 20.88452 3 |
| 7 | 6334169462644834816 | 224.1918 | -5.507846 4 | 16.289682 | 16.838337 | 15.596187 | 2805.617 | 20.03786 5 | False | 3811.3215 | 4037.859 1 |
| 8 | 6334169497003755136 | 224.21526 | -5.504074 | 20.940569 | 21.22556 | 20.098907 | 2888.6772 | 33.34148 8 | True | 28.000797 | 27.40733 1 |
| 9 | 6334169531363492352 | 224.22807 | -5.496324 | 20.751453 | 21.083628 | 19.972359 | 2934.1282 | 60.83726 5 | True | 23.973114 | 24.91605 6 |



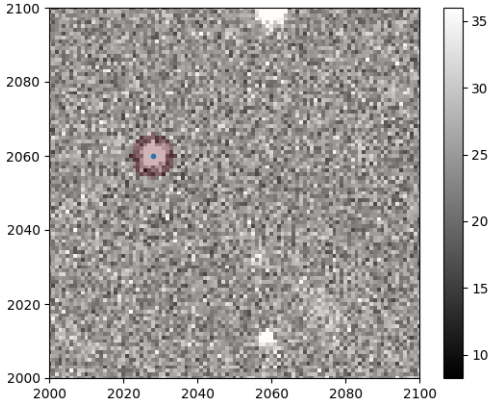
Detrending



Background removal



Gaia DR3 Forced AP 6pix



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$$\text{Flux} = \sum_{\text{pix}\in\text{disk}} \text{image}$$

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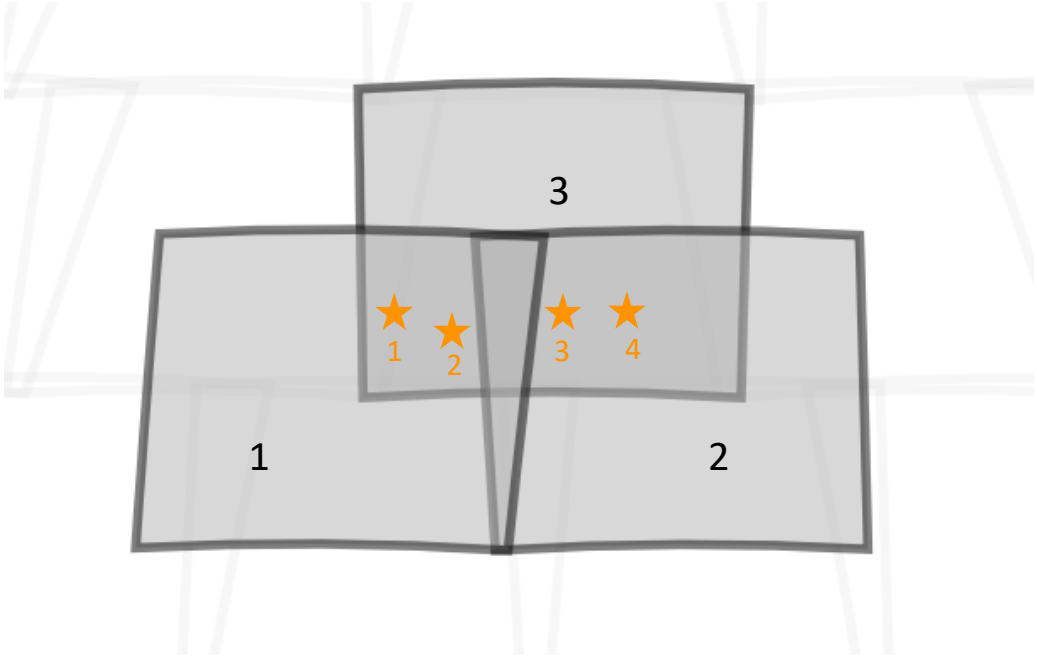
| 0 | 6334168771154570114 | 224.23587 | -5.512197 | 21.257378 | 21.096867 | 19.003939 | 2961.637 | 4.35642 | False | 112.94968 | 92.16835 |
| 1 | 6334168771154570624 | 224.23291 | -5.510719 | 16.730742 | 17.685032 | 15.774773 | 2951.2046 | 9.626395 | False | 1374.4391 | 1473.8647 |
| 2 | 6334168775449247616 | 224.24603 | -5.505976 | 20.856293 | 21.28884 | 19.565767 | 2997.6877 | 26.42609 | True | -17.088558 | -9.475877 |
| 3 | 6334169325205066496 | 224.15619 | -5.510555 | 20.710463 | 20.941505 | 20.208666 | 2679.4966 | 10.56559 | True | 73.665596 | 70.67294 |
| 4 | 6334169325205882240 | 224.14804 | -5.510255 | 16.249336 | 16.610512 | 15.714474 | 2650.6633 | 11.66501 | True | 5236.026 | 5609.919 |
| 5 | 6334169359564769536 | 224.1648 | -5.50691 | 20.005707 | 21.009947 | 18.858234 | 2709.9949 | 23.48913 | True | 122.03508 | 135.17403 |
| 6 | 6334169428284278656 | 224.21414 | -5.511864 | 20.564213 | 21.422235 | 19.651264 | 2884.686 | 5.643868 | True | 23.016891 | 20.884523 |
| 7 | 6334169462644834816 | 224.1918 | -5.507846 | 16.289682 | 16.838337 | 15.596187 | 2805.617 | 20.03786 | False | 3811.3215 | 4037.8591 |
| 8 | 6334169497003755136 | 224.21526 | -5.504074 | 20.940569 | 21.22556 | 20.098907 | 2888.6772 | 33.34148 | True | 28.000797 | 27.407331 |
| 9 | 6334169531363492352 | 224.22807 | -5.496324 | 20.751453 | 21.083628 | 19.972359 | 2934.1282 | 60.83726 | True | 23.973114 | 24.916056 |

$$m_{obs} = -2.5\log(\text{Flux})$$

# Ubercal method

**Use redundant observations of *stable* stars…**

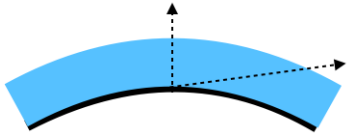



$$m_1 + 0 = m_{11}^{obs}$$
$$m_2 + 0 = m_{21}^{obs}$$
$$m_3 + \Delta ZP_2 = m_{32}^{obs}$$
$$m_4 + \Delta ZP_2 = m_{42}^{obs}$$
$$m_1 + \Delta ZP_3 = m_{13}^{obs}$$
$$m_2 + \Delta ZP_3 = m_{23}^{obs}$$
$$m_3 + \Delta ZP_3 = m_{33}^{obs}$$
$$m_4 + \Delta ZP_3 = m_{43}^{obs}$$

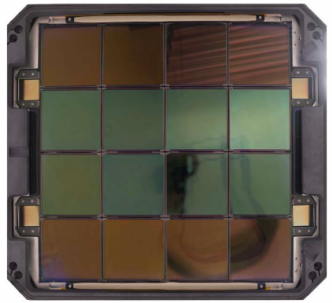
**… to fit for relative zero points & star magnitudes**

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

Fast change from clouds
Slow change from mirror aging?



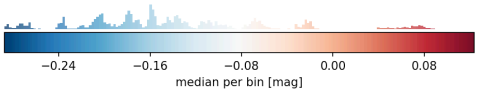
Low elevation
=
Observing through high airmass

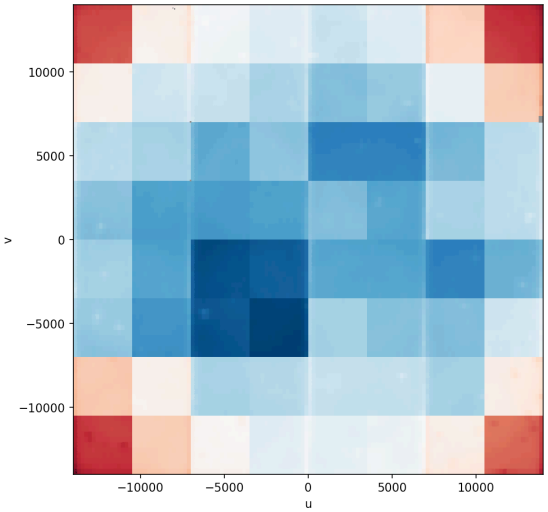


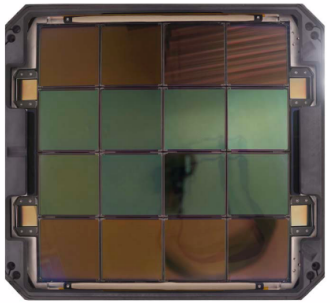
Flat offset
Gain variability
CCD width variation
Dust spots
Fringing
Laser annealing
...

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

# Uberflat



Flat offset
Gain variability
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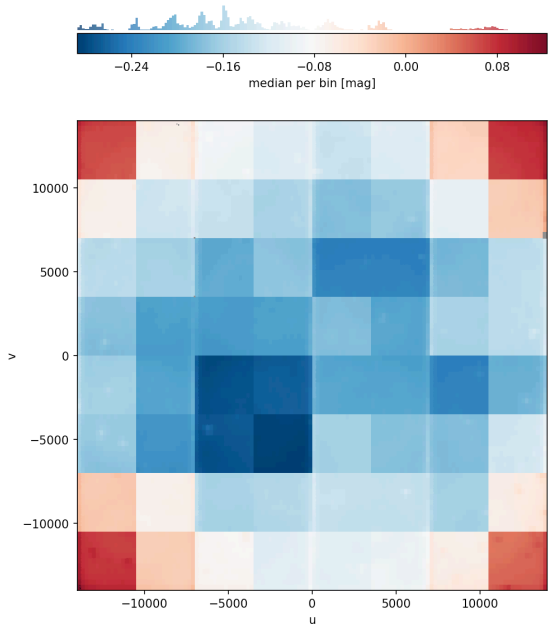
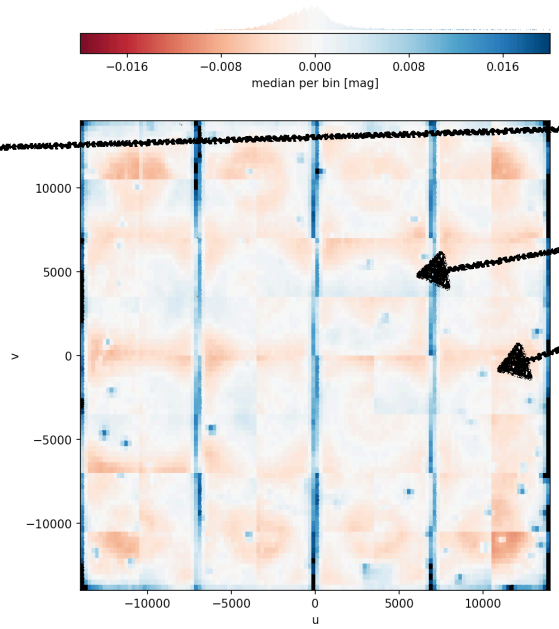
Fringing
Laser annealing
...

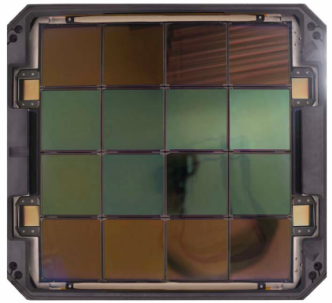
$$m_{obs} = m_{star} + ZP(t_{exposure}) + k(t_{night}) * \text{airmass} + \delta ZP(u, v)$$

## Uberflat



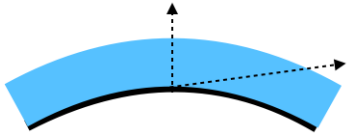

## Mean removed

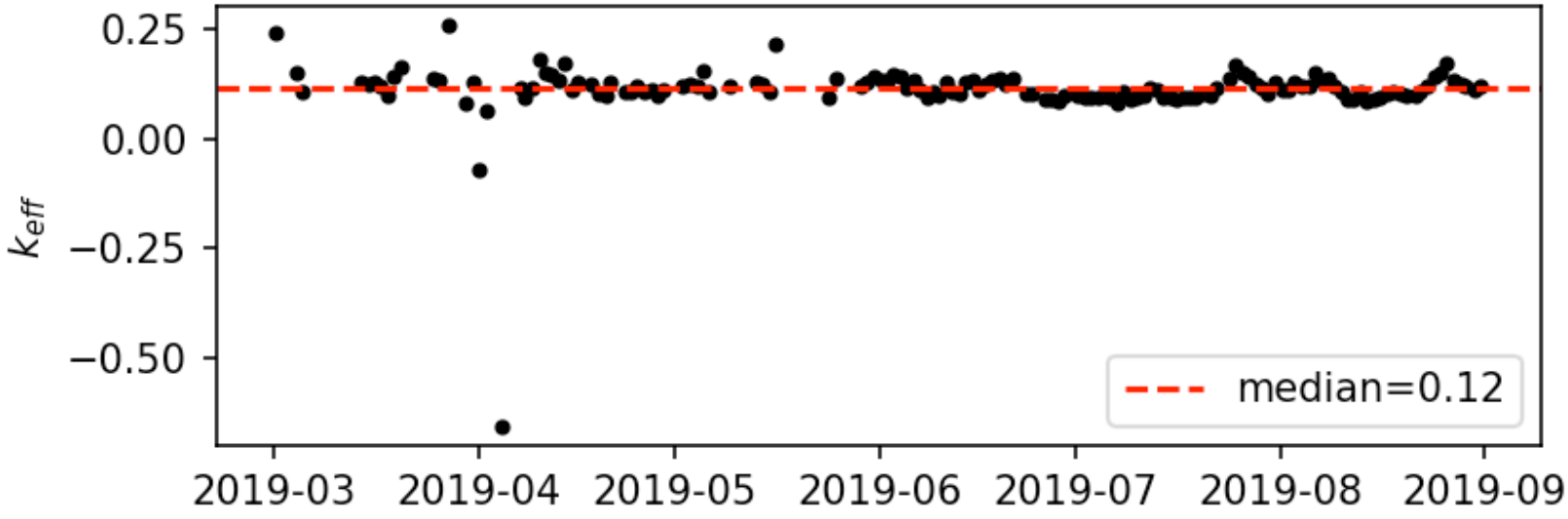


- Flat offset
- Gain variability
- CCD width variation
- Dust spots
- Fringing
- Laser annealing
- ...

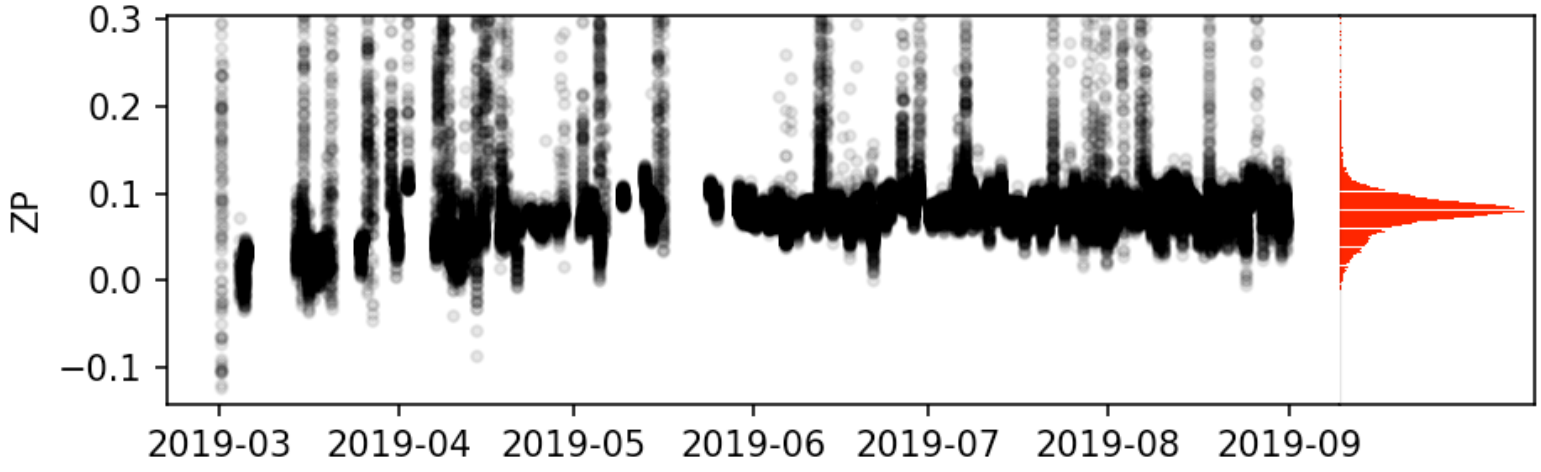
$$m_{obs} = m_{star} + ZP(t_{exposure}) + k(t_{night}) * \text{airmass} + \delta ZP(u, v)$$





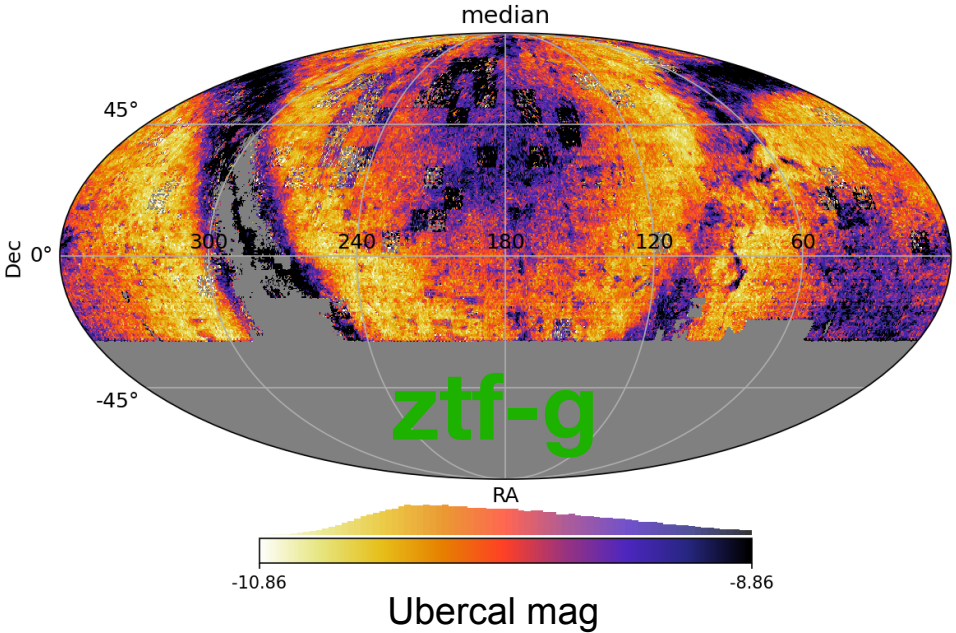
$$m_{obs} = m_{star} + ZP(t_{exposure}) + k(t_{night}) * \text{airmass} + \delta ZP(u, v)$$

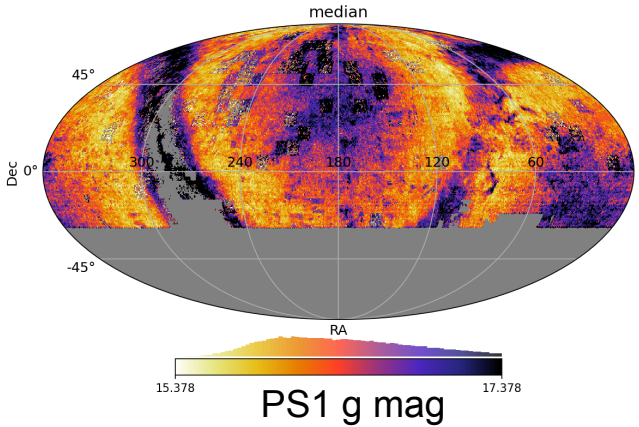
**Fast change from clouds**
**Slow change from mirror aging?**

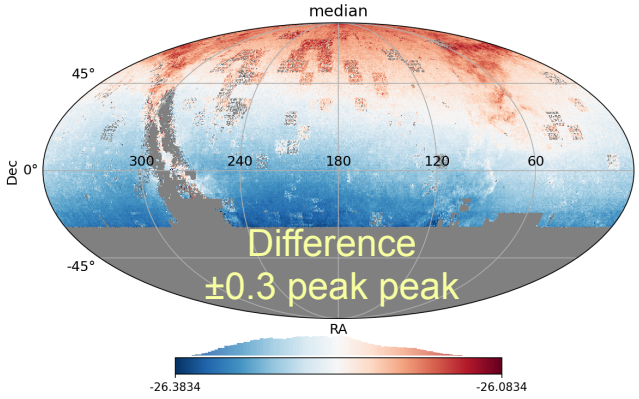


$$m_{obs} = m_{star} + ZP(t_{exposure}) + k(t_{night}) * \text{airmass} + \delta ZP(u, v)$$

Results a year ago 😬



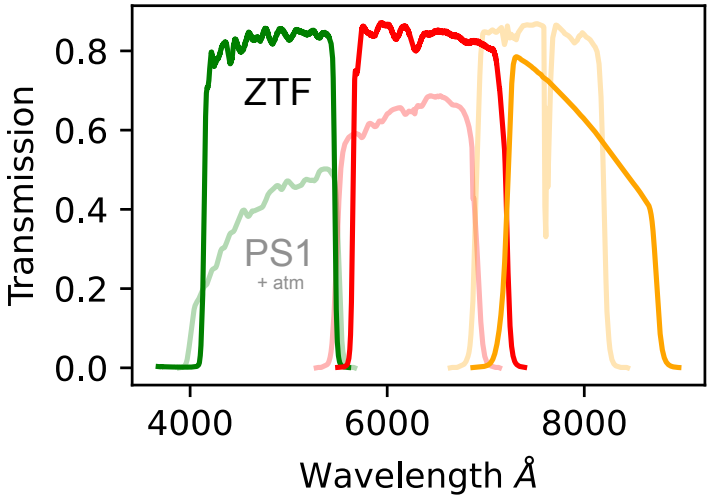
# Temporary solution

Use PS1 to anchor ubercal

# Temporary solution DR2.5: Anchor on PS1

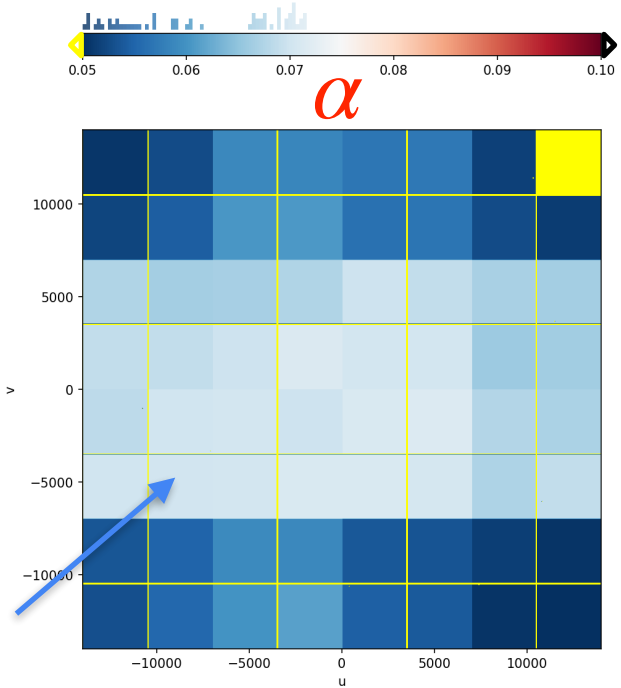
$$m_{obs} - m_{ps_g} = \alpha(m_{ps_g} - m_{ps_r}) + ZP(t_{exposure}) + k(t_{night}) * \text{airmass} + \delta ZP(u, v)$$

Needs color correction $\alpha$

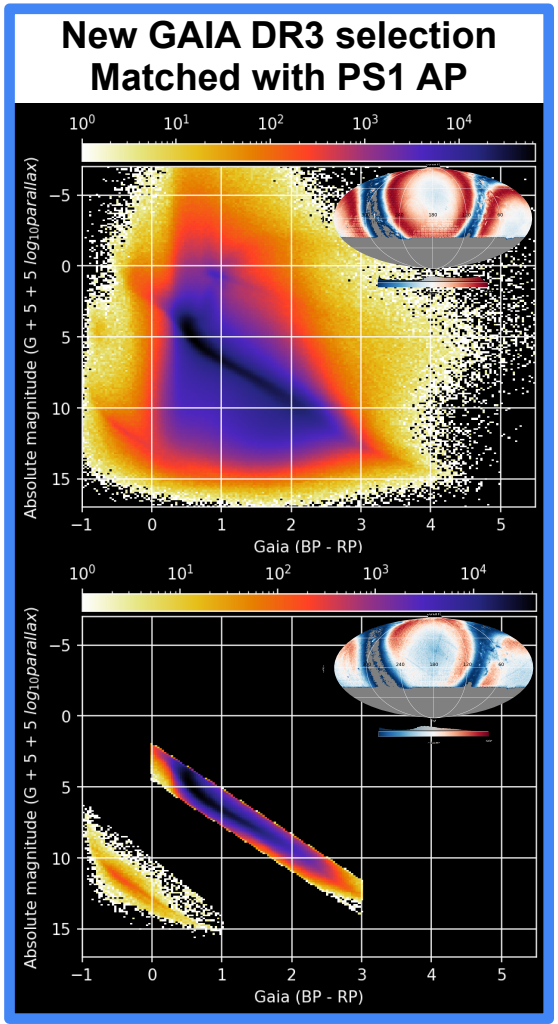



Color correction different for Single vs Double IR coating

Slope larger for Double Coating

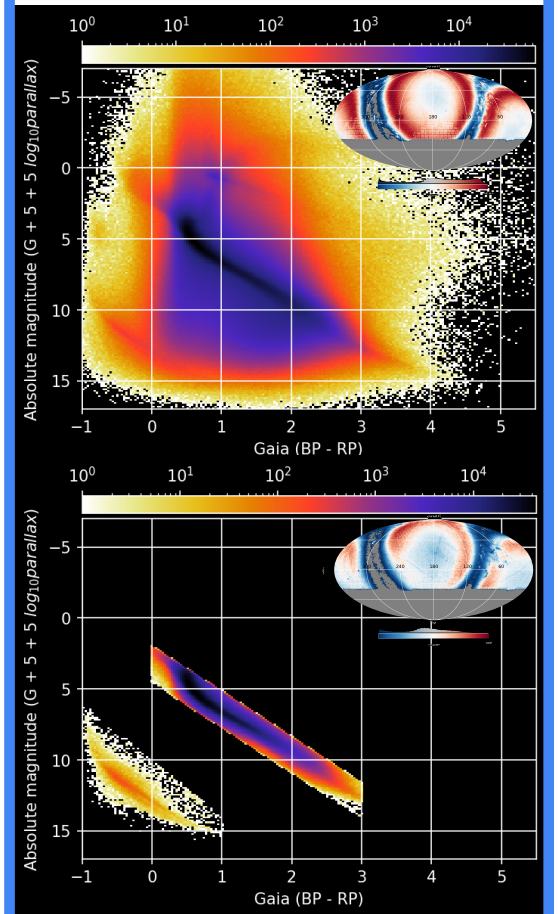


# 2024 Ubercal



# 2024 Ubercal

**New GAIA DR3 selection**
**Matched with PS1 AP**



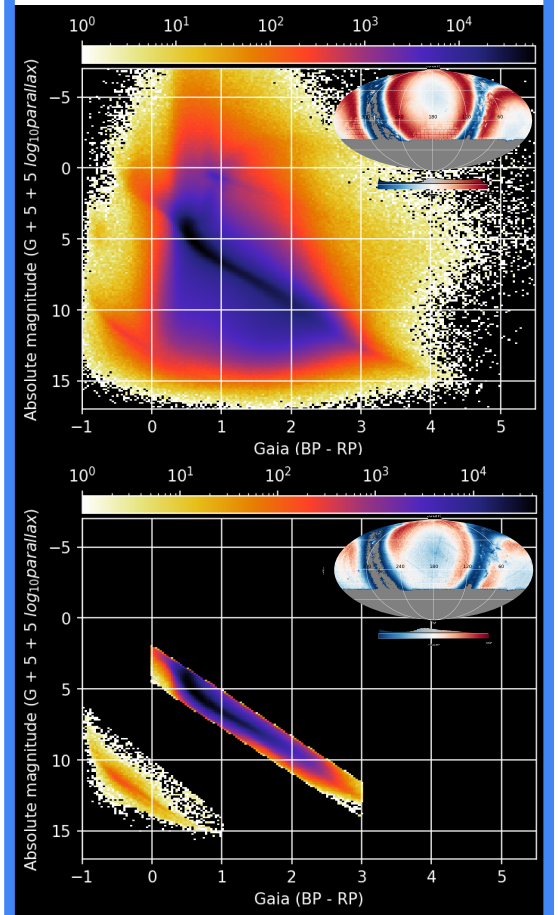

**Better outlier removal**
Includes noise modelling
Sigma clipping
And chi2-based cuts
More modular

**Different time range**
Removed march 2019
Extended to October 22nd
Where pocket effect gets stronger

**Same images**
Sciimg from IPAC

# 2024 Ubercal

**New GAIA DR3 selection**
**Matched with PS1 AP**

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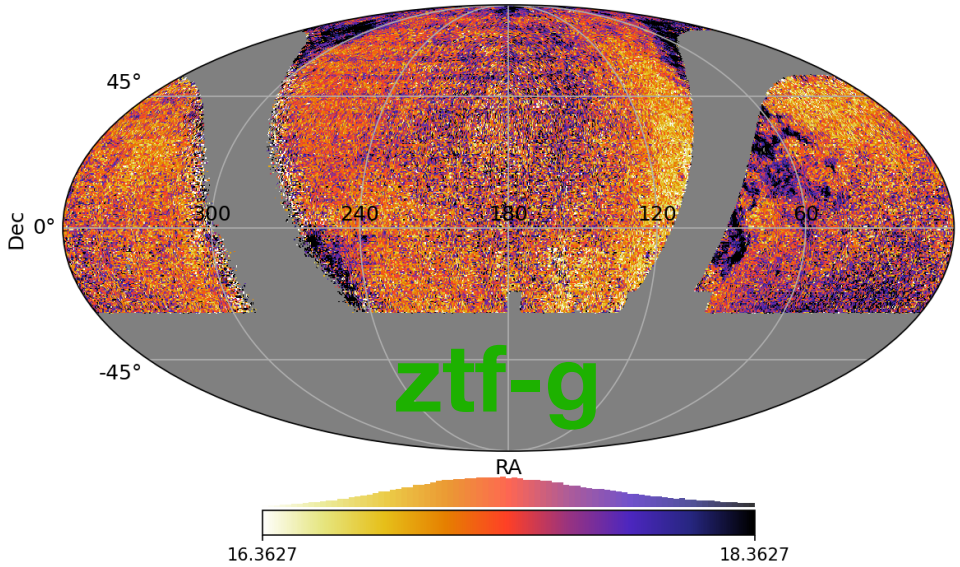
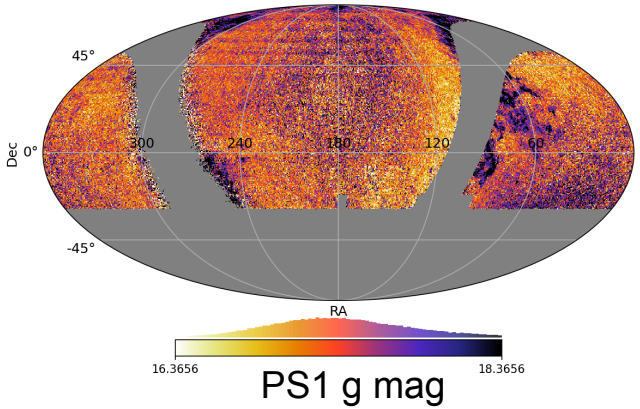
**New model**
Anchored on PS1
PS1 DR2 Aperture Photometry
See previous slides

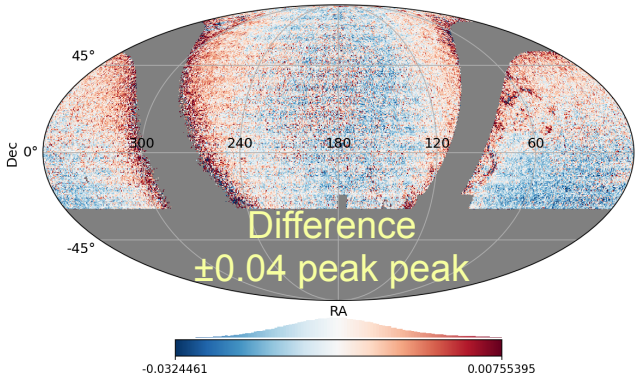
**Caltech images**
Apr to Nov 2019
**ztf-g**

# Temporary solution DR2.5: Anchor on PS1

## Results last summer

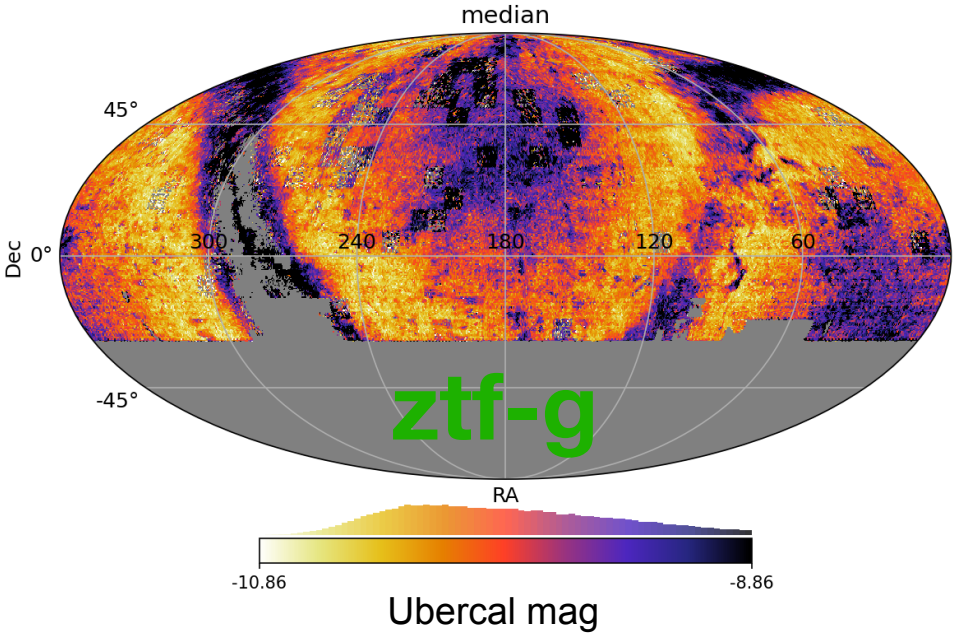


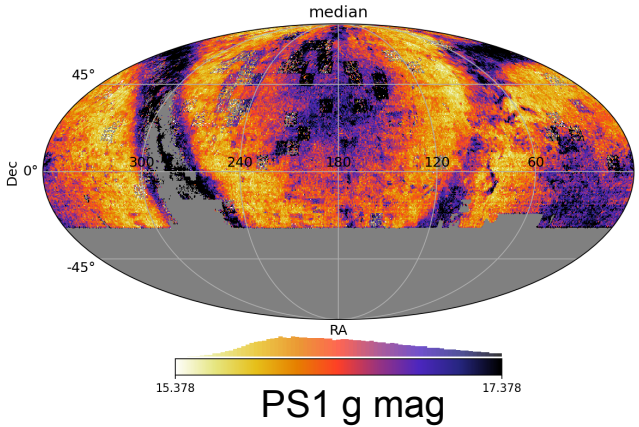



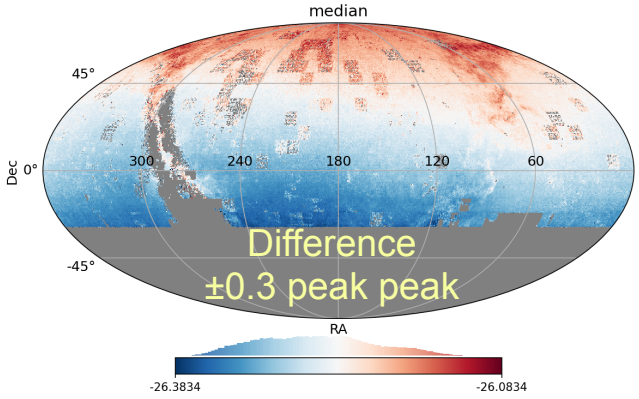



$$m_{obs} = m_{star} + ZP(t_{exposure}) + k(t_{night}) * \text{airmass} + \delta ZP(u, v)$$

Results a year ago 😬



**Caltech images**
Apr to Nov 2019
**ztf-g**

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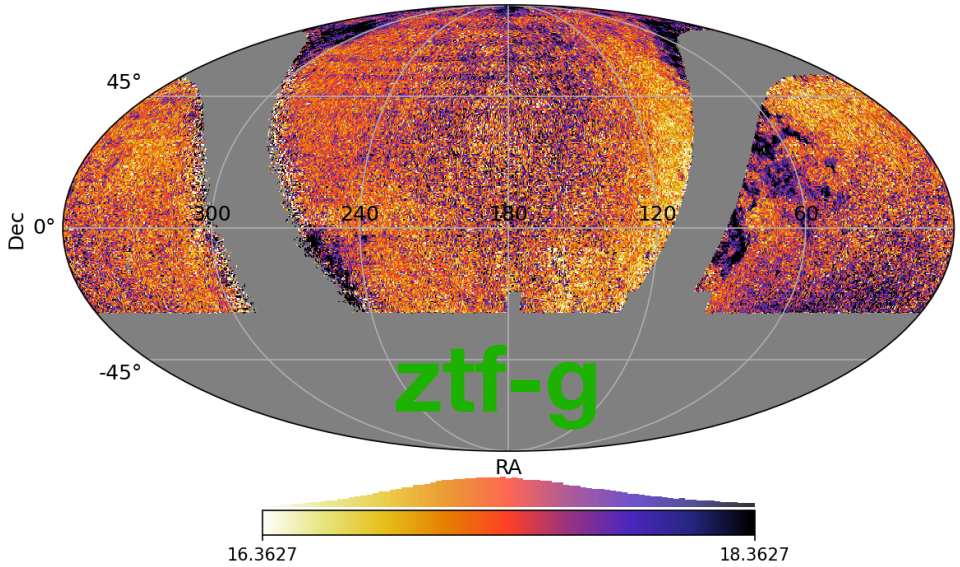
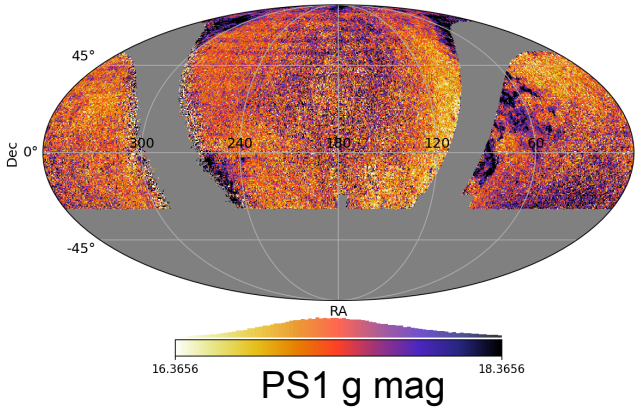
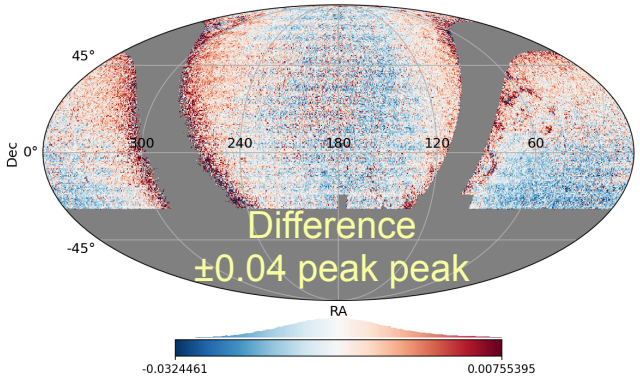


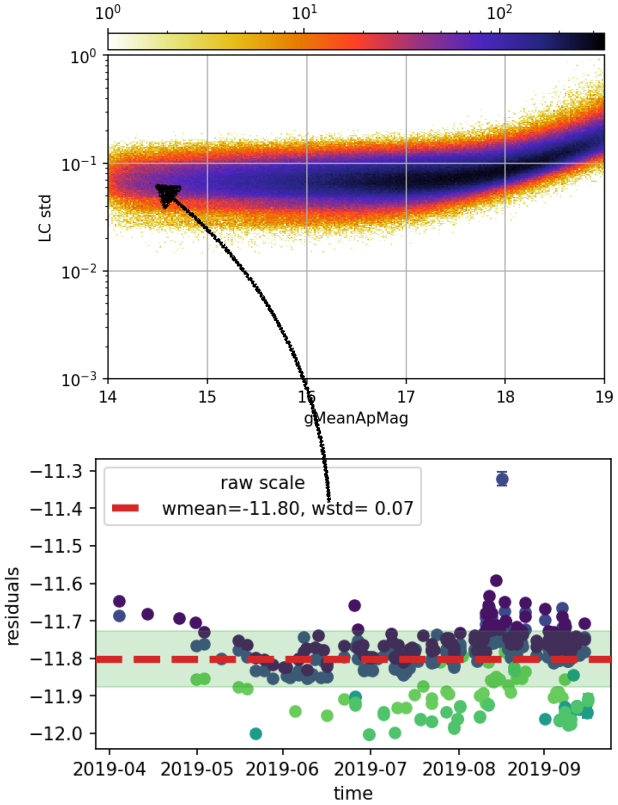



**Caltech images**
Apr to Nov 2019
**ztf-g**

# Anchored on PS1

## Repeatability

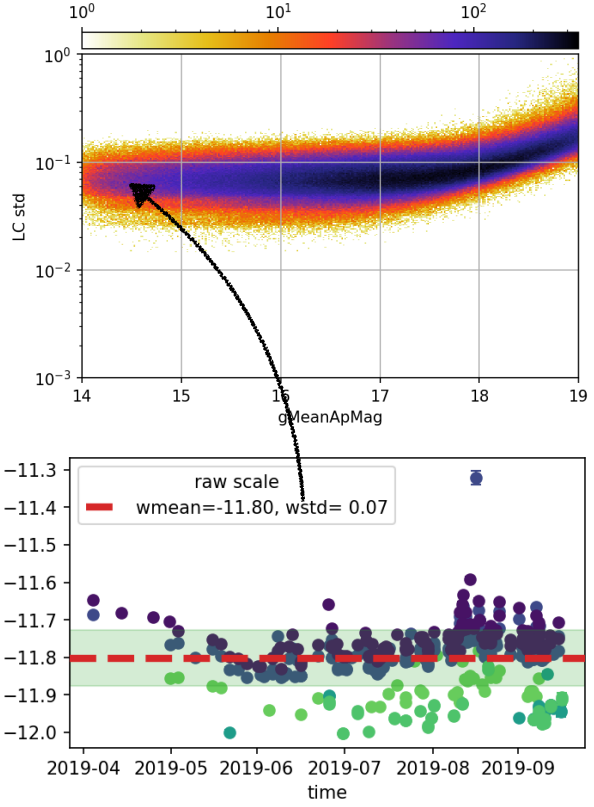



Before calibration

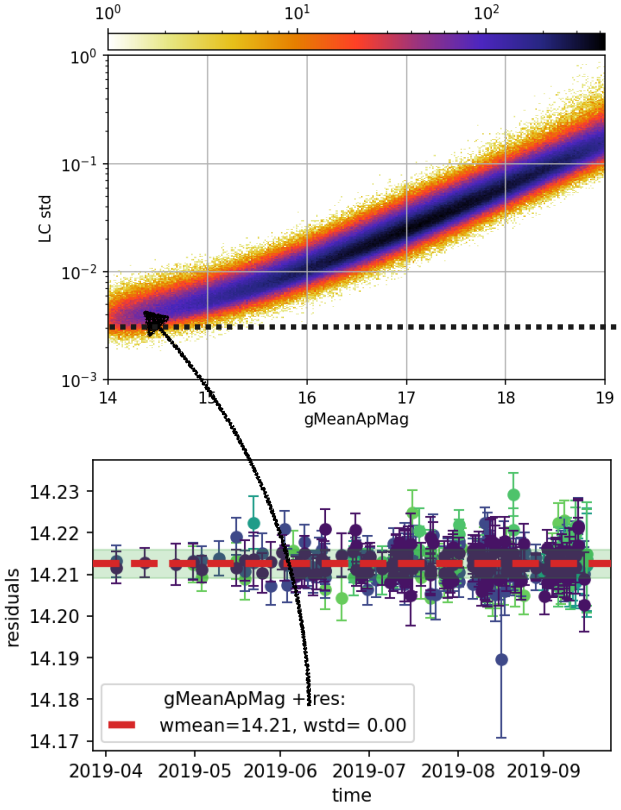
**Caltech images**
Apr to Nov 2019
**ztf-g**

# Anchored on PS1

## Repeatability




Before calibration




After calibration

Somewhat limited by AP radius of 6pix

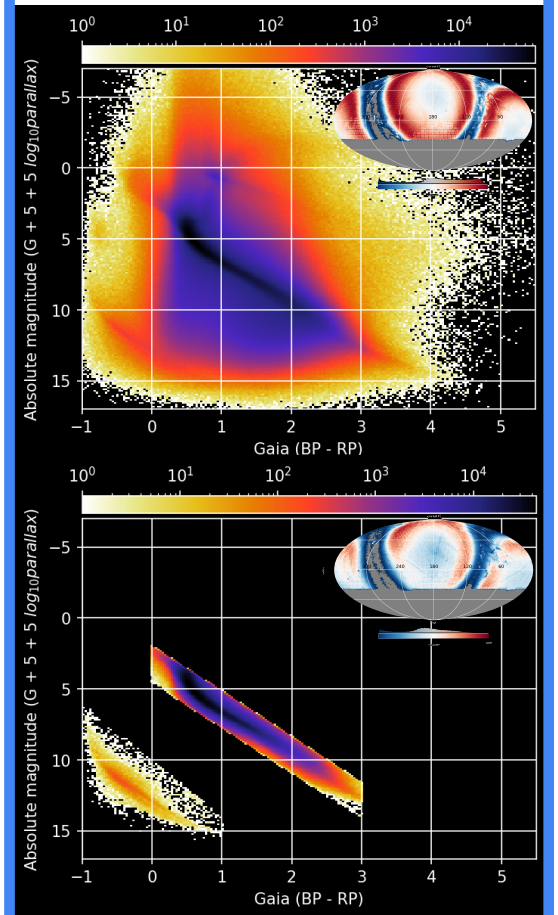
Repeatability ~ 3 permil for bright stars

# Ubercal on the new pipeline data

Started this fall

# New Ubercal

**New GAIA DR3 selection**
**Matched with PS1 AP**

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Where pocket effect gets stronger

**New images**
Detrending from **new pipeline**

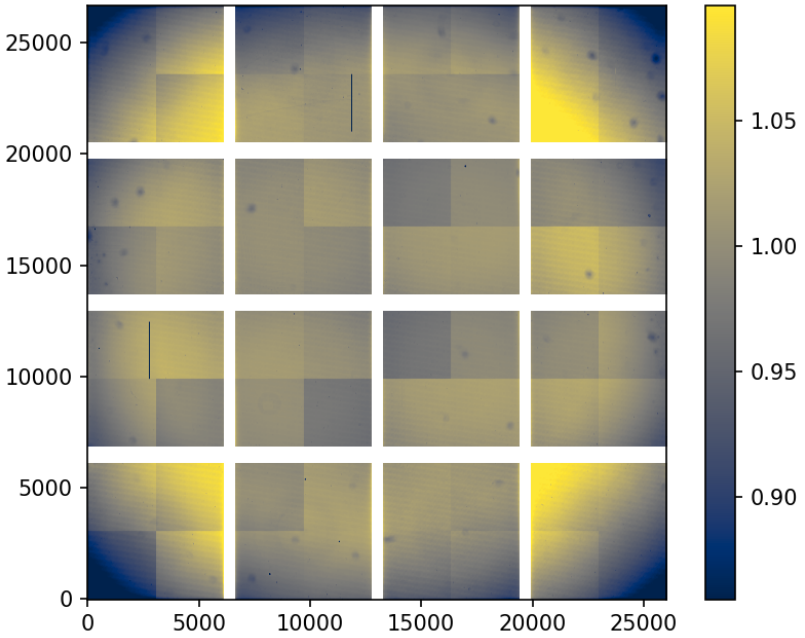
**New model**
Anchored on PS1
PS1 DR2 Aperture Photometry
See next slides

# New detrending pipeline

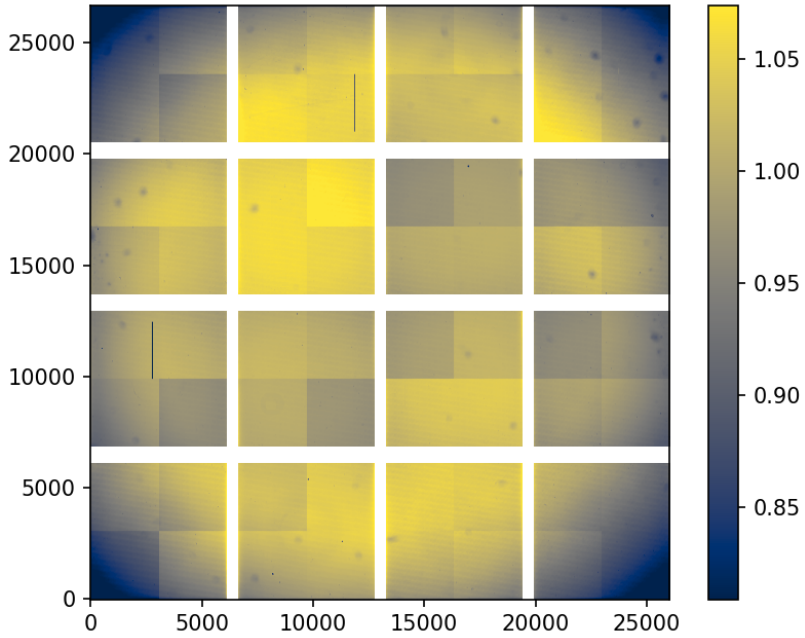
Main change is the new flat fielding
No pocket effect correction here
Should be small before Nov 2019 and AP is less sensitive

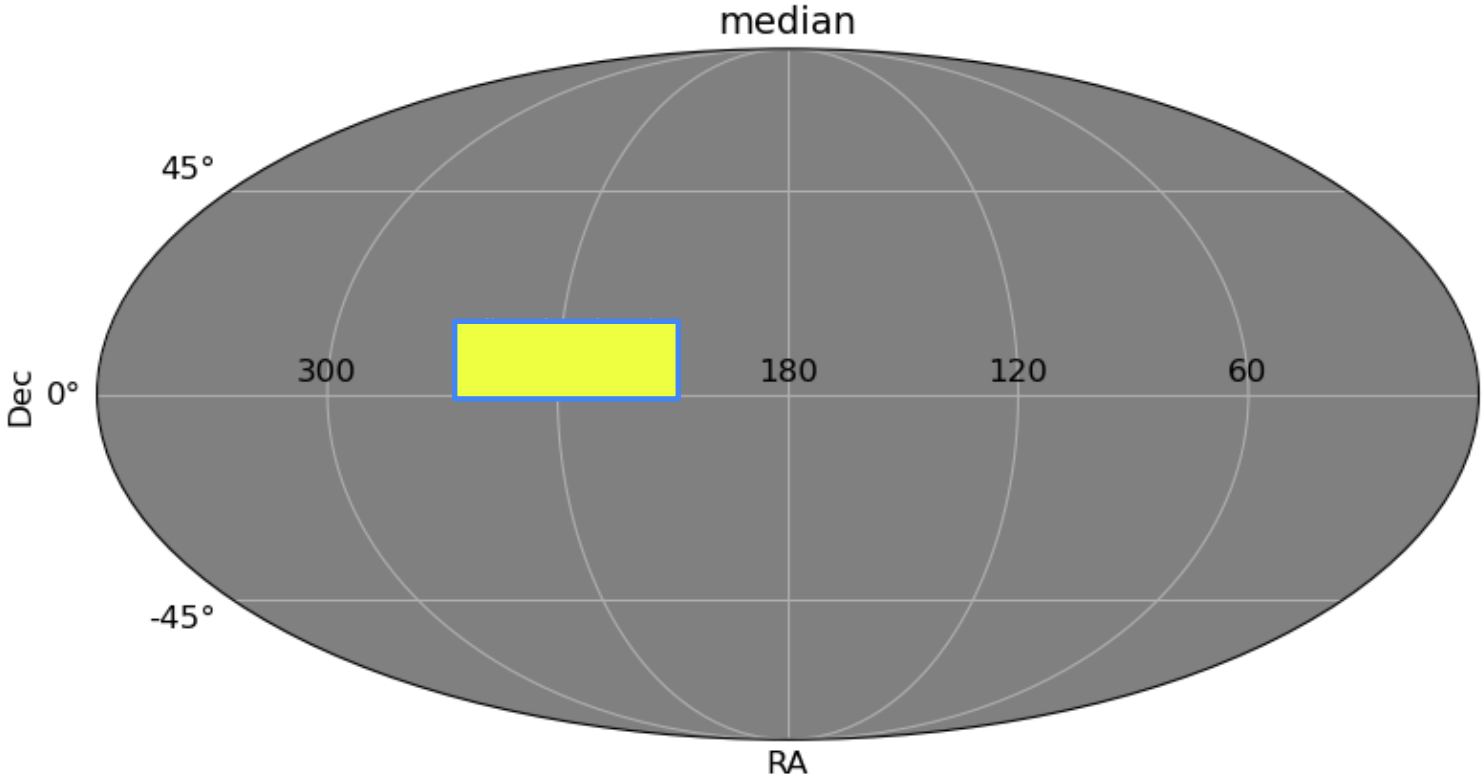
+ new selection

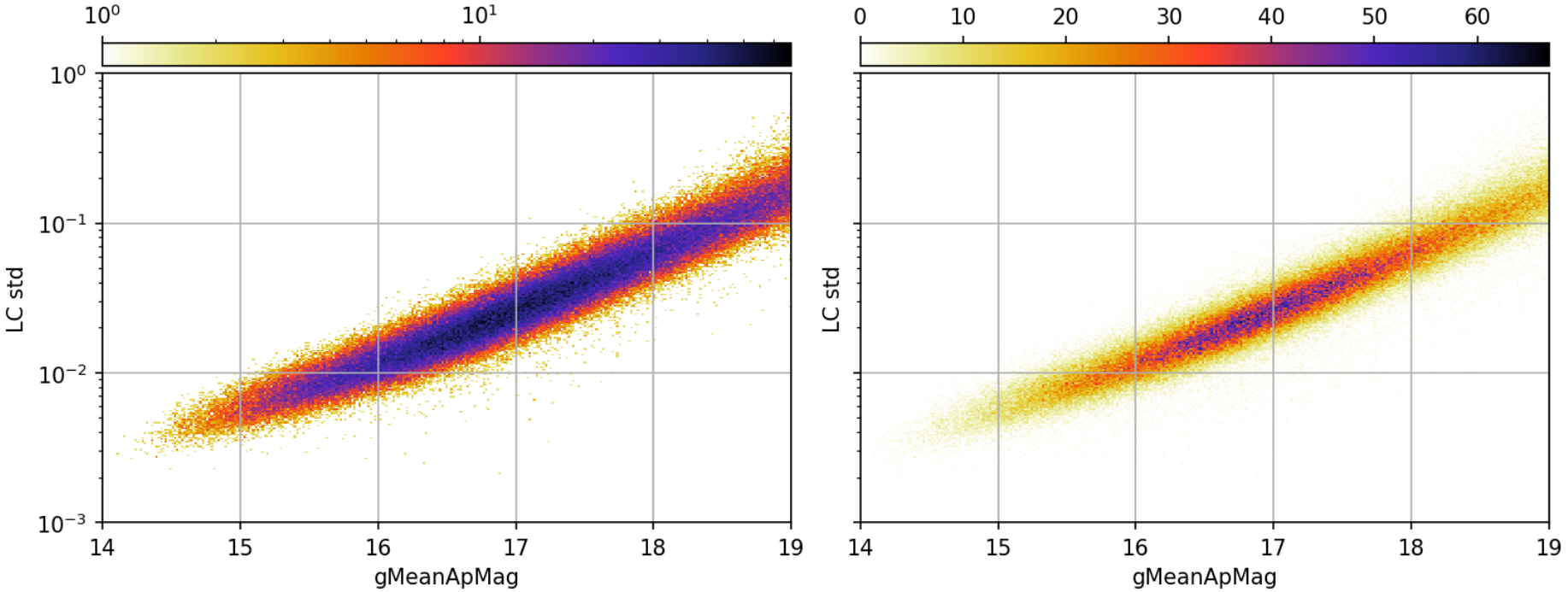
Old: flats normalised per quadrants



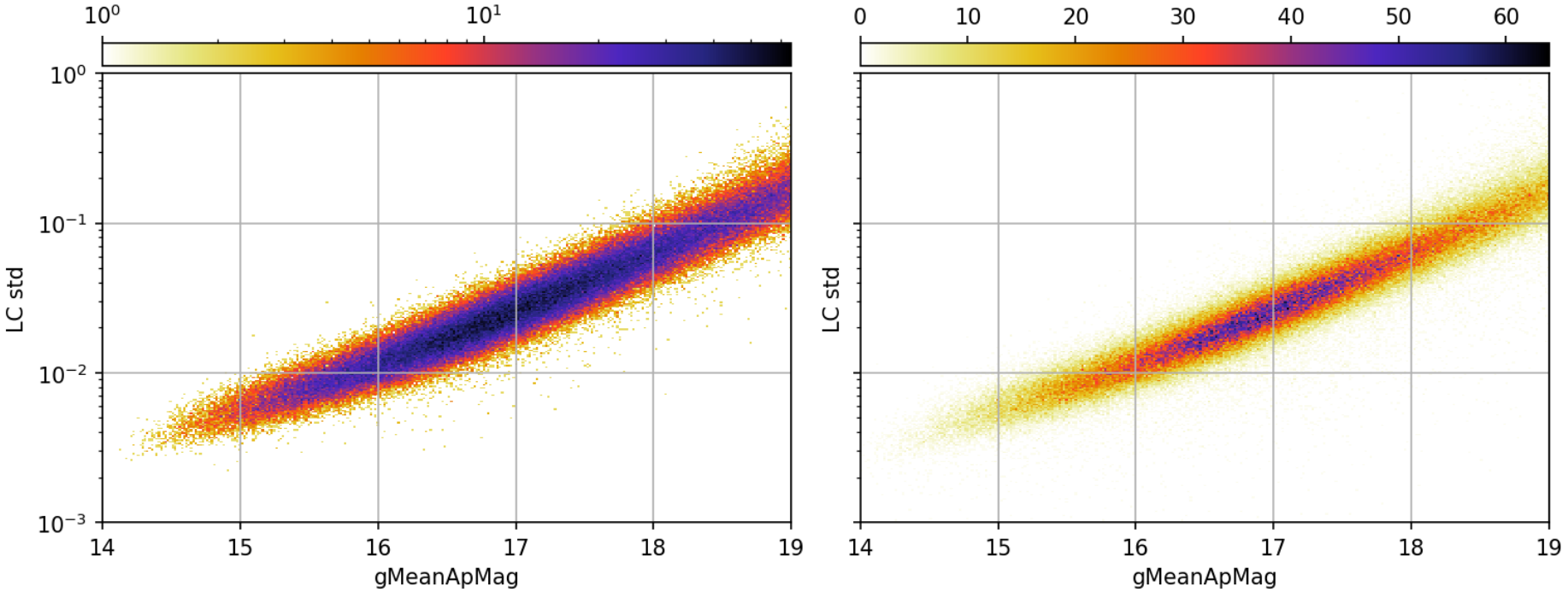

New: flats normalised per focal plane



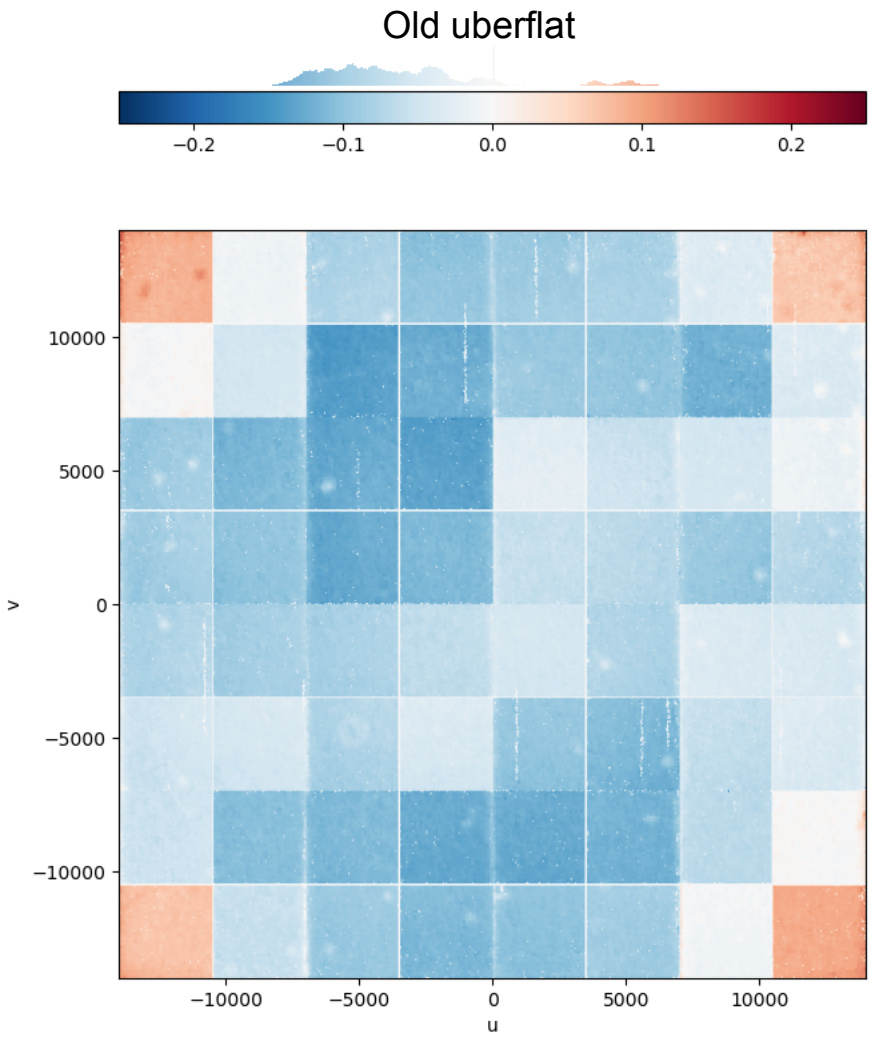

median
45°
0°
-45°
Dec
300
180
120
60
RA

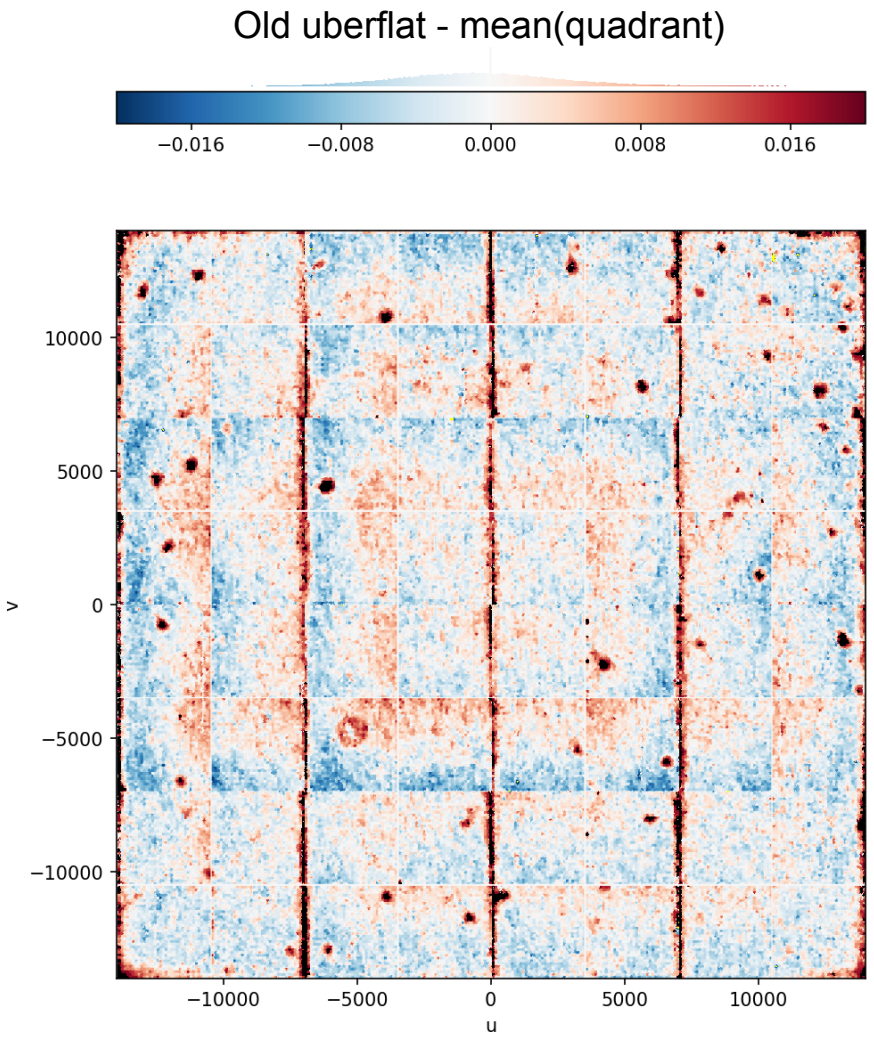


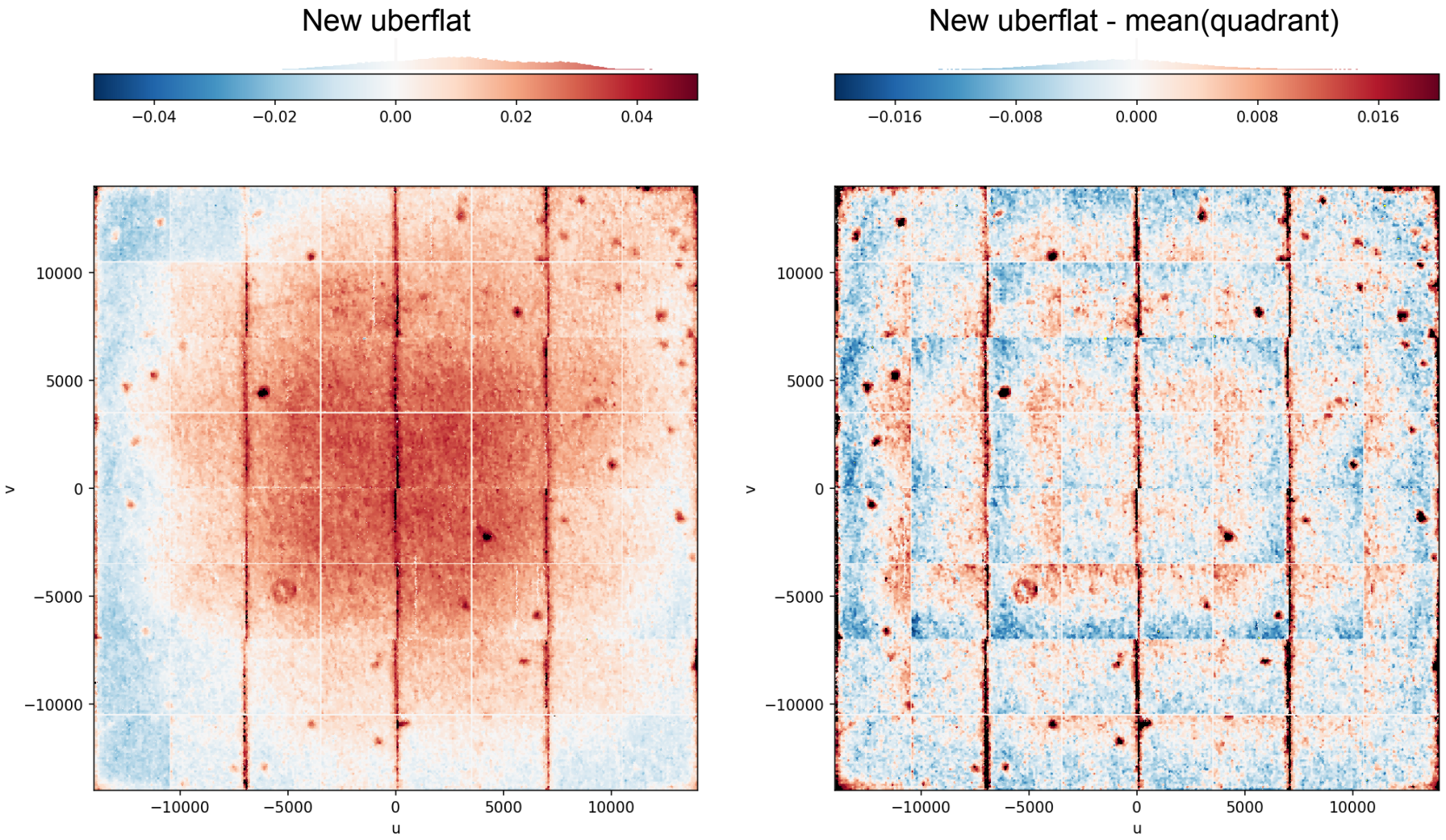

# Residual dispersion (caltech sciimg+ AP)




# Residual dispersion (in2p3 pipeline+ AP)


Old uberflat
−0.2
−0.1
0.0
0.1
0.2
10000
5000
0
−5000
−10000
v
−10000
−5000
0
5000
10000
u

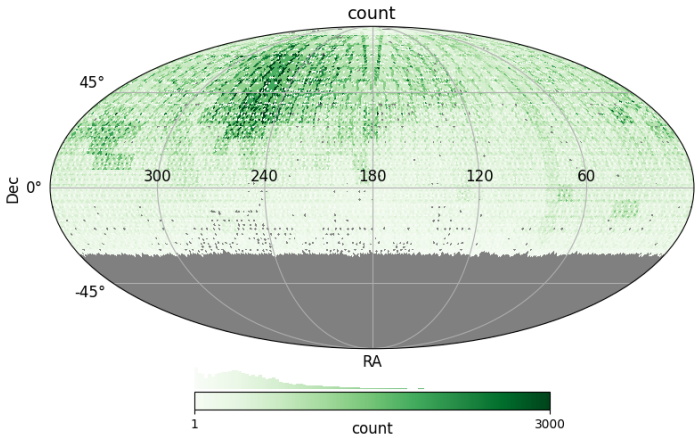

Old uberflat - mean(quadrant)
−0.016
−0.008
0.000
0.008
0.016
10000
5000
0
−5000
−10000
v
−10000
−5000
0
5000
10000
u

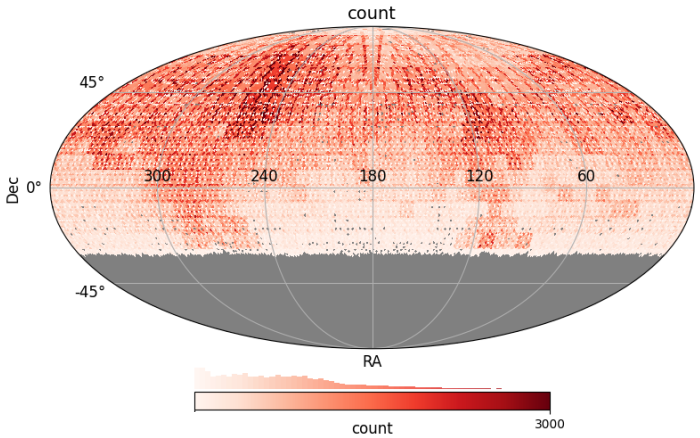

New uberflat
−0.04
−0.02
0.00
0.02
0.04
10000
5000
0
−5000
−10000
v
−10000
−5000
0
5000
10000
u
New uberflat - mean(quadrant)
−0.016
−0.008
0.000
0.008
0.016
10000
5000
0
−5000
−10000
v
−10000
−5000
0
5000
10000
u

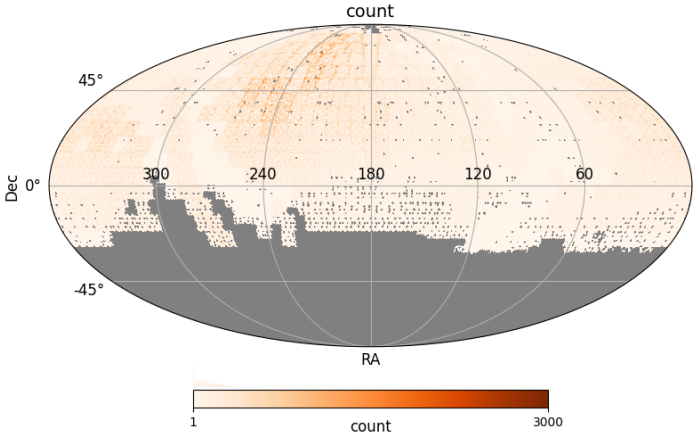
# December 2024
# Toy Sample

A possible selection to test the new in2p3 pipeline all the way to SN calibration using a “small” ubercal

# Count per pix 64 from 2018 to 2023



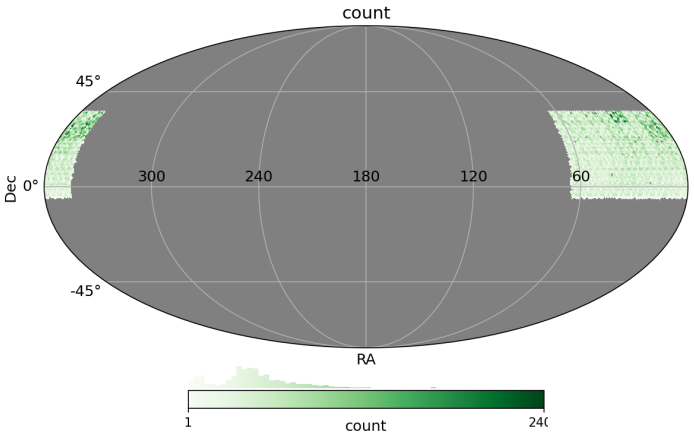




**<u>Why on the whole time-span?</u>**
Needed for decent i coverage

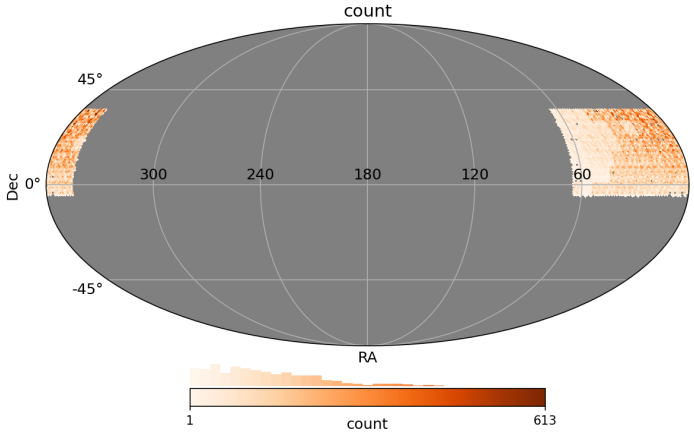
Bonus:
We will provide extinction per night and uberflat per stable instrument period to scene modelling pipeline

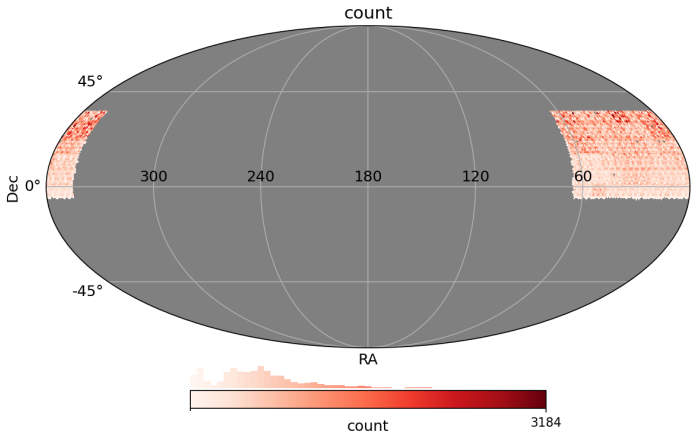
# After selection (infobits = 0, radec cut)




1_736_896 pids

474_171 pids

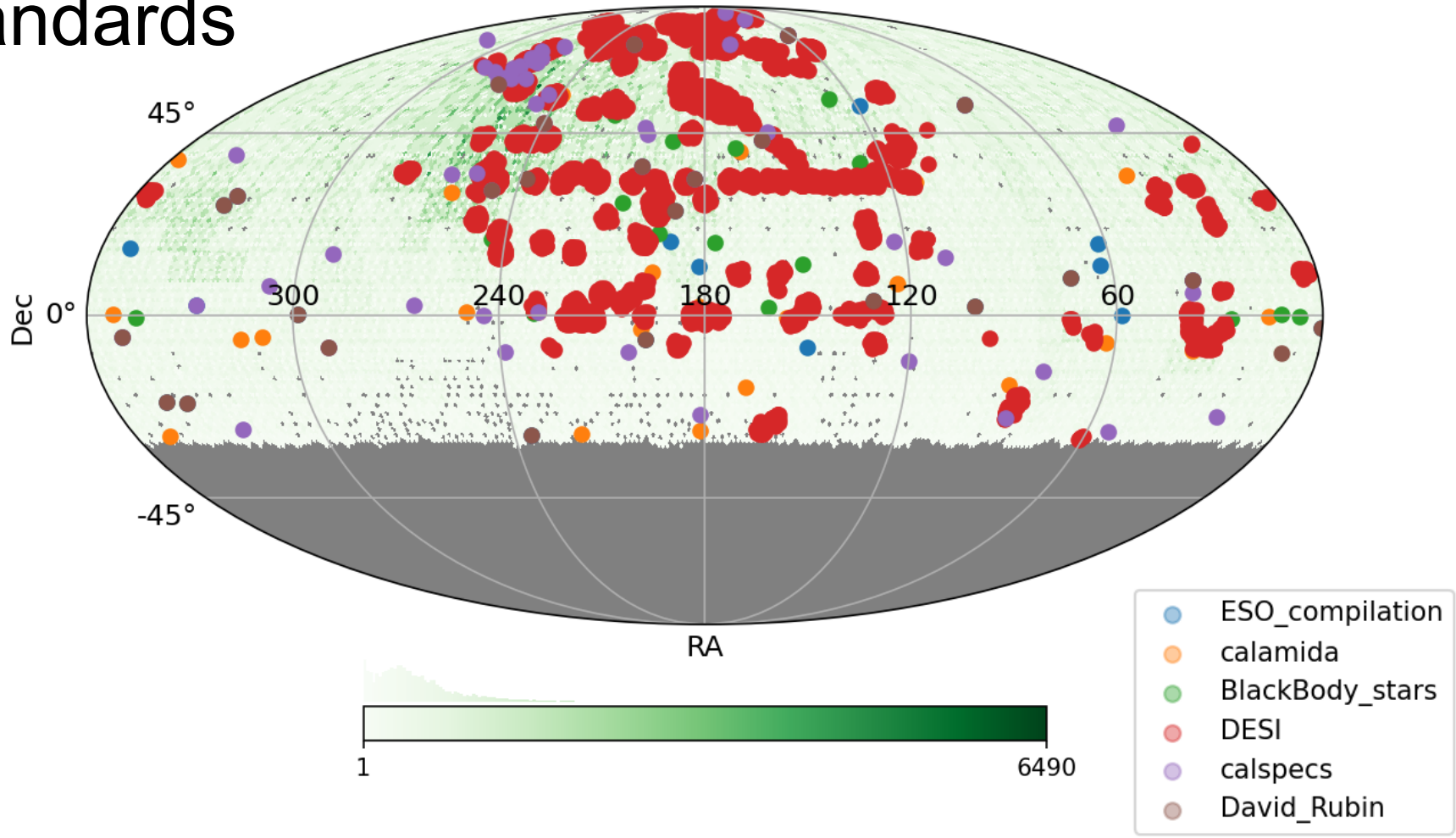



2_351_020 pids

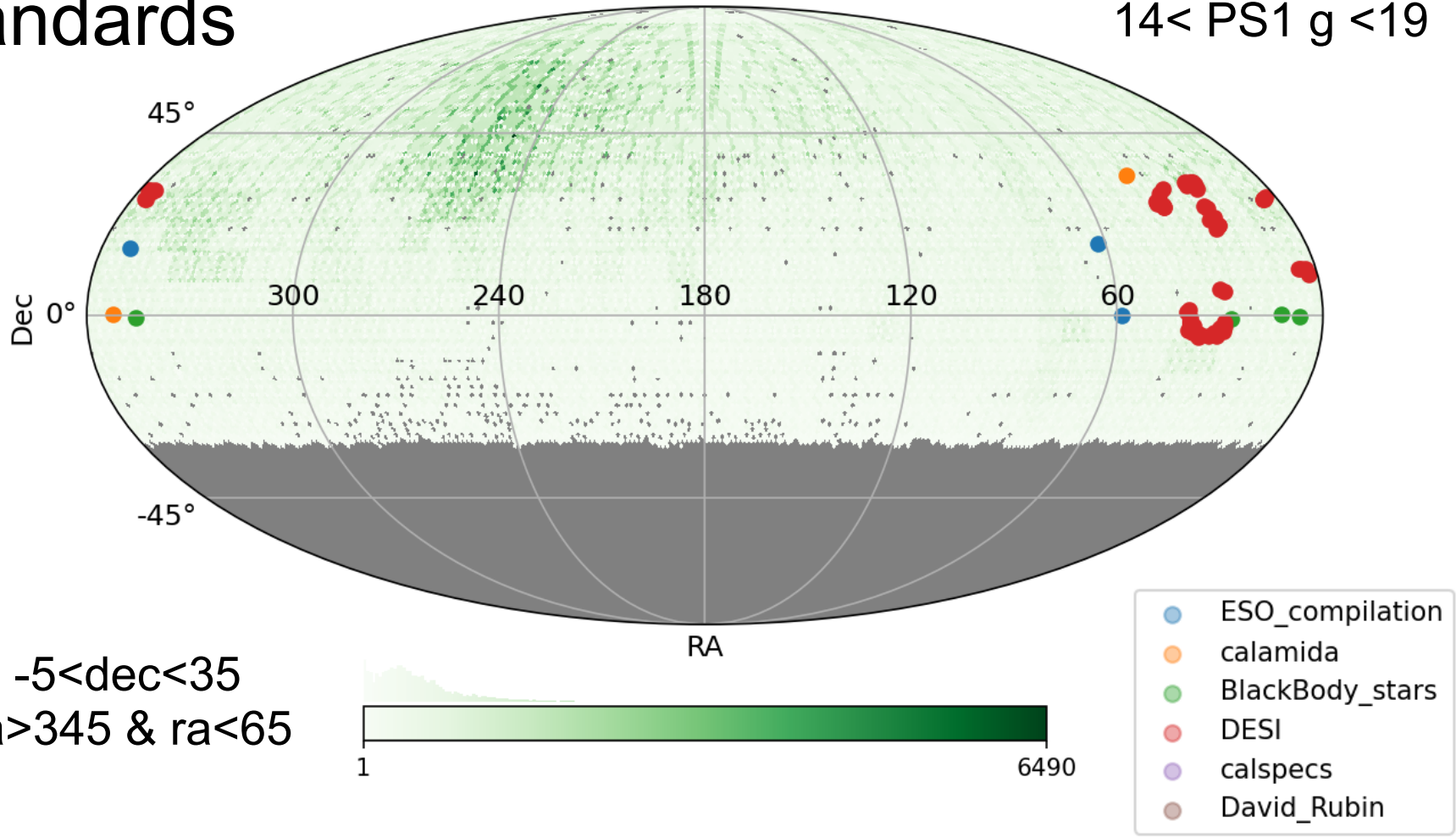
-5<dec<35
ra>345 & ra<65

# Standards


45°
0°
-45°
Dec
300
240
180
120
60
RA
1
6490
ESO_compilation
calamida
BlackBody_stars
DESI
calspecs
David_Rubin

# Standards

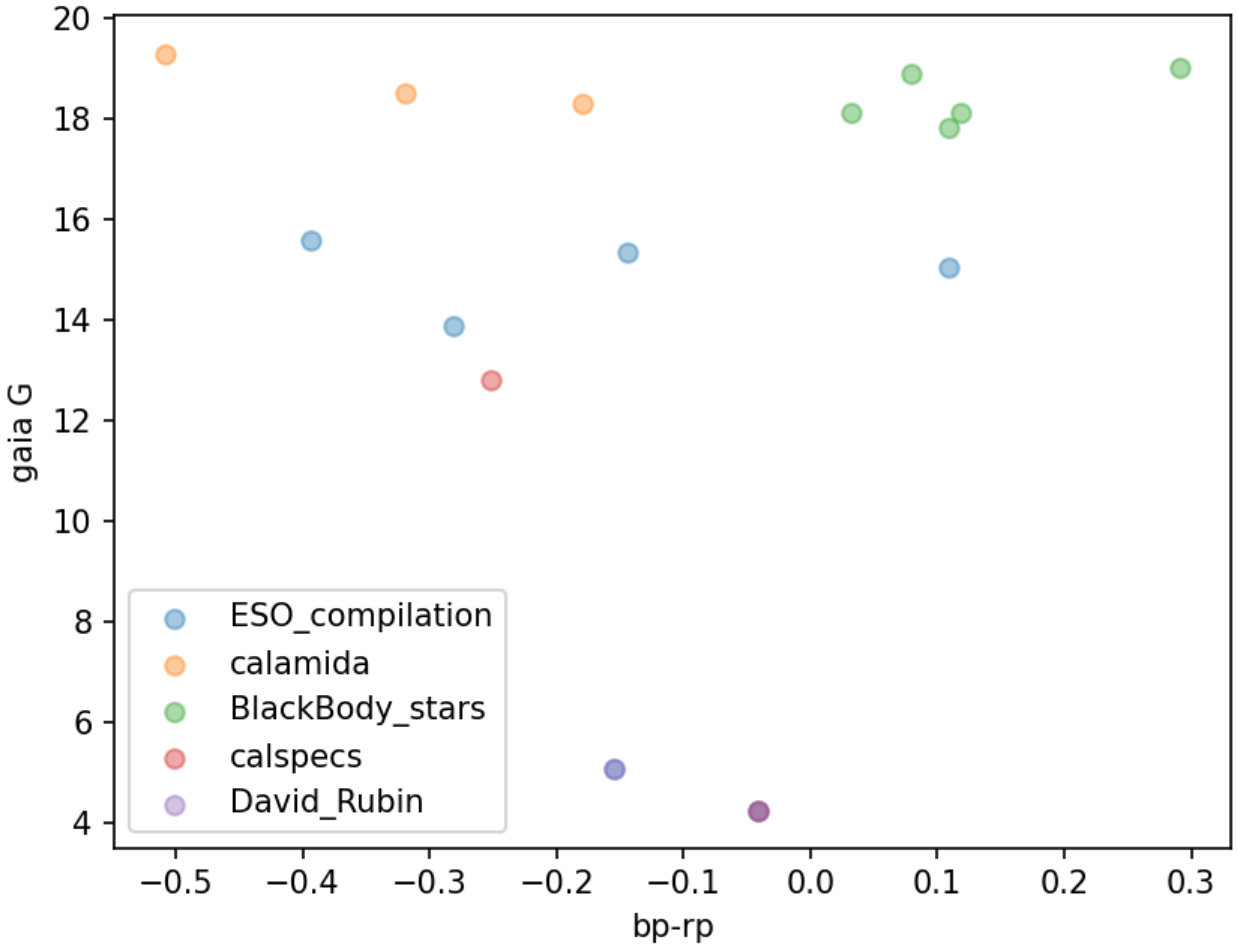
14< PS1 g <19




-5<dec<35
ra>345 & ra<65

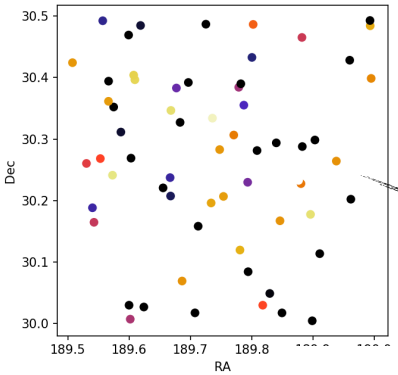
# Standards

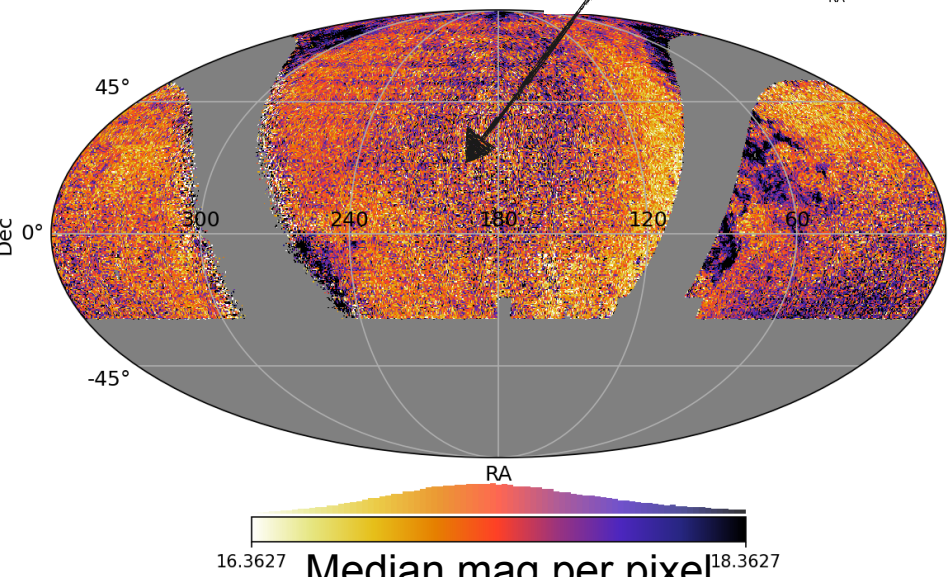
Here in gaia mags (PS1 doesn't have AP mags for all these)

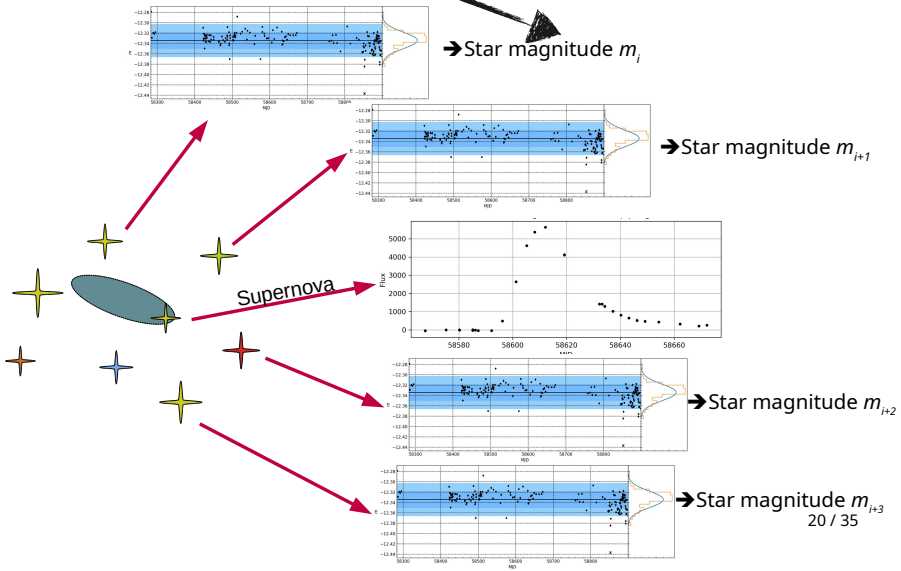



-5<dec<35
ra>345 & ra<65

# Will then provide the ubercal catalog to calibrate the SMP



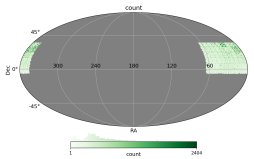



# Status

- New pipeline data look ok and we have a similar ubercal solution.

- We reach a few per-mil repeatability using PS1 as an anchor.

# To-do




- Run on the new sample from 2019 to 2023
  - Need to check if the flats changed a lot (multiple uberflats?)
  - Need to check impact of pocket effect correction
  - Note that we never looked at data beyond 2019

- Steps (It will take a few weeks):
  - go from APcat per quadrant to large per-field catalogs of isolated stars
  - merge into even larger files after selecting white dwarf + main sequence stars
  - compute stats to select data (to remove saturated and too low fluxes)
  - run ubercal and iterate after removing outliers
  - analyse the results and probably iterate

We will also run :
  - on PSF catalogs which can be used as starflats for SMP
  - on PSF/seeing-corrected AP, to improve SNR and avoid seeing-related biases

This will be a thorough test for the DR2.5 run on the full sky.