DARK ENERGY SURVEY

Current state of relative calibration analysis:

0.5% or bust

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YaCal

- Navaho for “Sky” Cal
- Unix geek for “yet another” Cal

- YaCal and the perfect instrument approximation
  - in the perfect instrument approximation, calibration to << 0.1% possible
  - where does it break down?
- YaCal and the zero-knowledge philosophy
  - YaCal assumes nothing about the atmosphere or the stars and only geometrical facts about the camera. Pure relative photometry
  - is this sufficient?
- YaCal and 0.5% photometry
  - docdb 6618
  - docdb 6650

YaCal Solution Models

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5.3 YàCal models

We form the model using:

$$\Delta \log N_1 - \log N_2 = (a_{amp,1} - a_{amp,2}) + (b_{ccd,1} - b_{ccd,2}) + (c_{exp,1} - c_{exp,2}) + (g(r_1) - g(r_2) + (s(x_1) - s(x_2)) + (s(y_1) - s(y_2))$$

Notable is that the "color term" term is handled as a single number per ccd; good enough to get the zeropoint. The $g(r)$, $s(x)$, and $s(y)$ terms are implemented as independant 1 cm bins: 22 in $g(r)$, 44 each in $s(x)$ and $s(y)$.

In practice several YàCal models are used, depending on the situation. There are:

$$\Delta = (c_{exp,1} - c_{exp,2}) \quad \text{(exp)}$$

$$\Delta = (b_{ccd,1} - b_{ccd,2}) + (c_{exp,1} - c_{exp,2}) \quad \text{(white)}$$

$$\Delta = (a_{amp,1} - a_{amp,2}) + (b_{ccd,1} - b_{ccd,2}) + (c_{exp,1} - c_{exp,2}) \quad \text{(gray)}$$

$$\Delta = (c_{exp,1} - c_{exp,2}) + (g(r_1) - g(r_2)) \quad \text{(spokane)}$$

$$\Delta = (b_{ccd,1} - b_{ccd,2}) + (c_{exp,1} - c_{exp,2}) + (g(r_1) - g(r_2)) \quad \text{(black)}$$

$$\Delta = (a_{amp,1} - a_{amp,2}) + (b_{ccd,1} - b_{ccd,2}) + (c_{exp,1} - c_{exp,2}) + (g(r_1) - g(r_2)) \quad \text{(green)}$$

$$\Delta = (a_{amp,1} - a_{amp,2}) + (b_{ccd,1} - b_{ccd,2}) + (c_{exp,1} - c_{exp,2}) + (g(r_1) - g(r_2)) + d(x_1 - x_2) + e(y_1 - y_2) \quad \text{(red)}$$

$$\Delta = (a_{amp,1} - a_{amp,2}) + (b_{ccd,1} - b_{ccd,2}) + (c_{exp,1} - c_{exp,2}) + (g(r_1) - g(r_2)) + (s(x_1) - s(x_2)) + (s(y_1) - s(y_2)) \quad \text{(blue)}$$

The red ad blue models both are aimed at gradients. The blue model deals with them in the same way as it does with the ghost, using 44 independent bins in each of x and y. The red model posits that the gradient will be some factor times the x or y position, a slope without a zeropoint.

The map of the residuals of calibrated - truth, Δ_T shown in figure 15 was constructed using the green model.

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Star flats

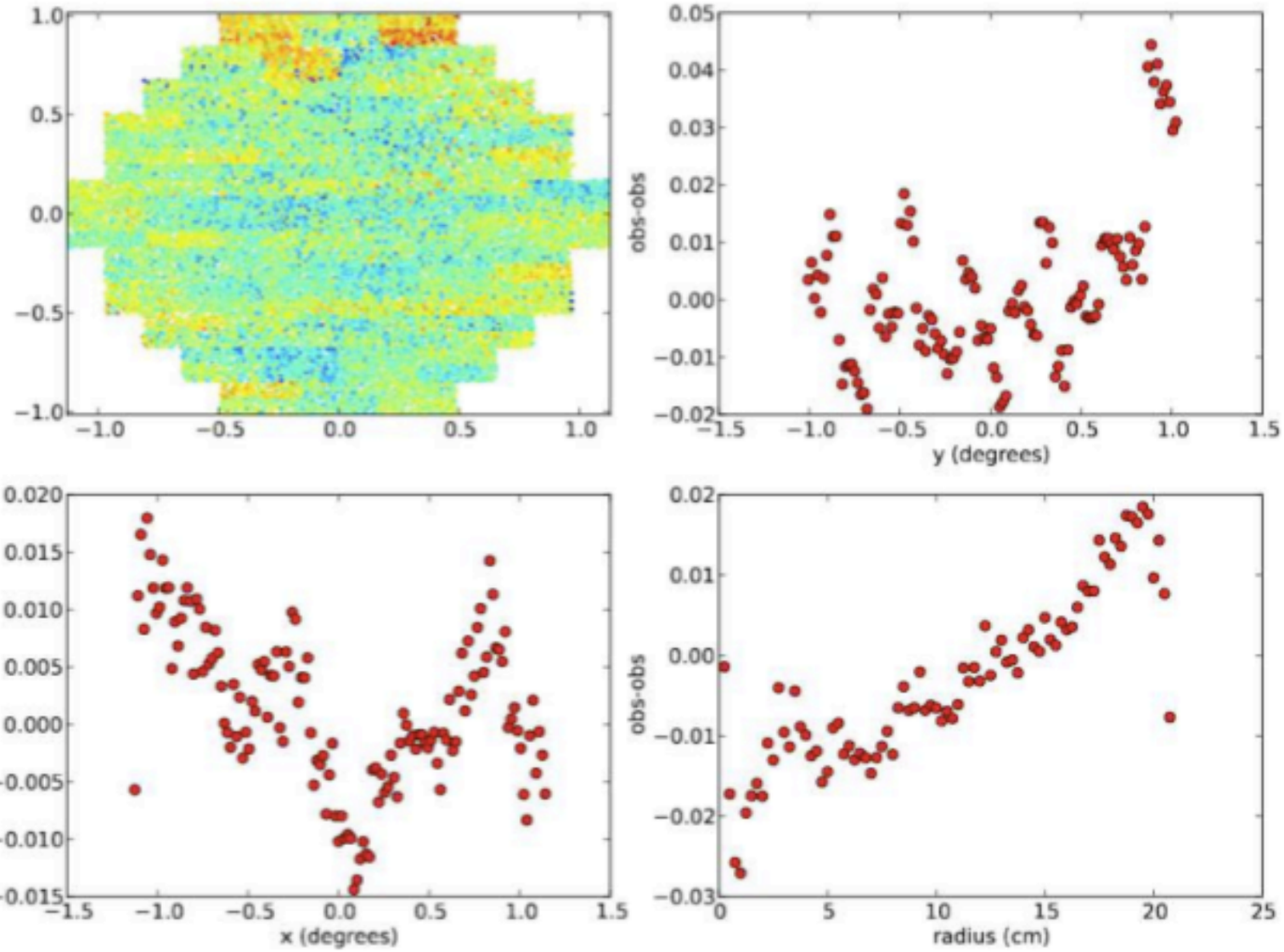

Figure 23: Upper left, focal plane map of the residuals. On the upper right, the residuals projected on the y-axis. On the lower left the residuals projected on the x-axis. On the lower right the residuals as a function of radius. This binning has 176 bins across the x-axis, about 0.25 cm/bin Both of these plots were for the case of 0.00707 %/degree in both +x and +y.

Data - Star Flat

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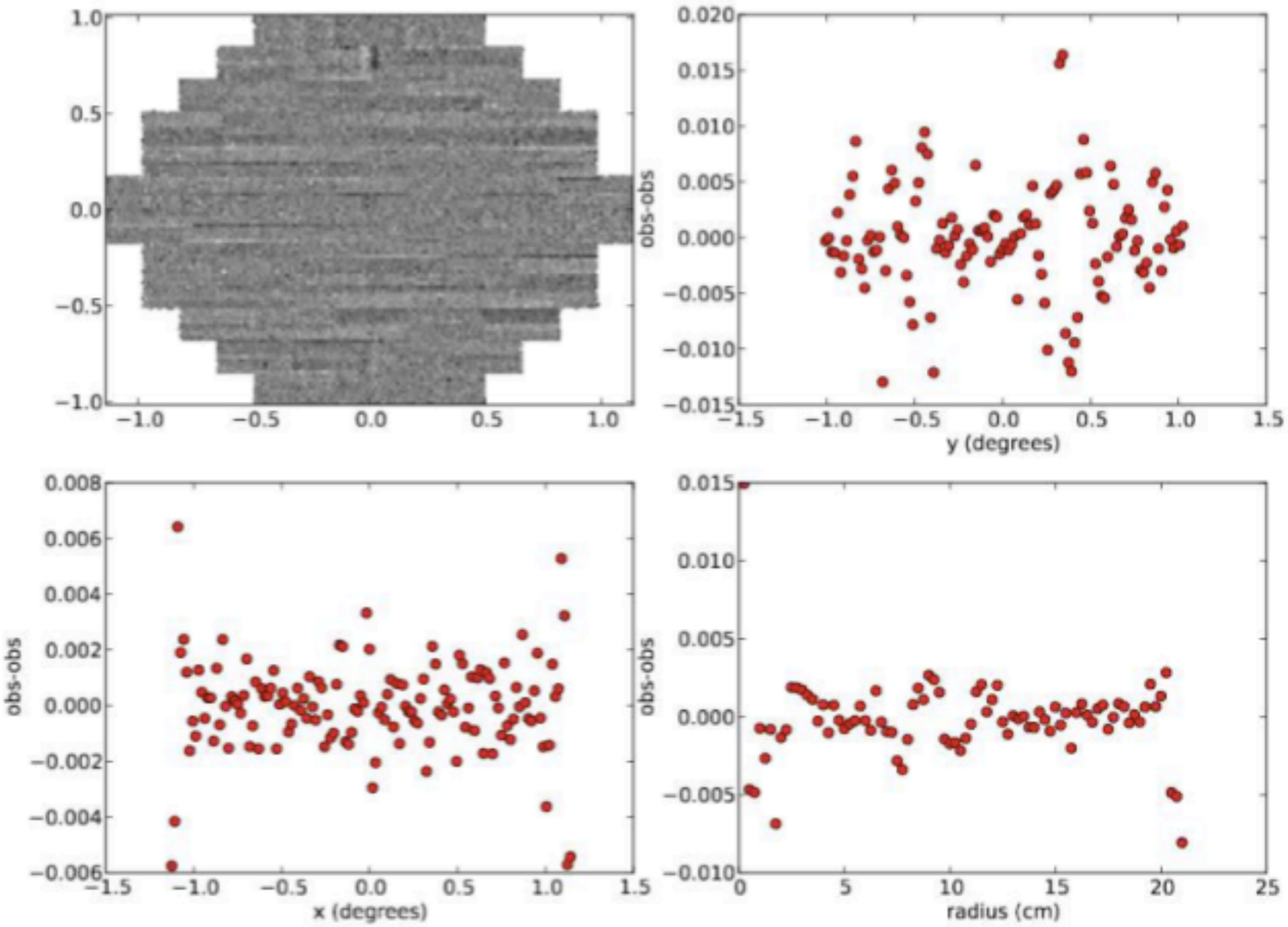

Figure 25: The focal plane residuals after removal of the pixelated version, the star map.

Resulting Solution

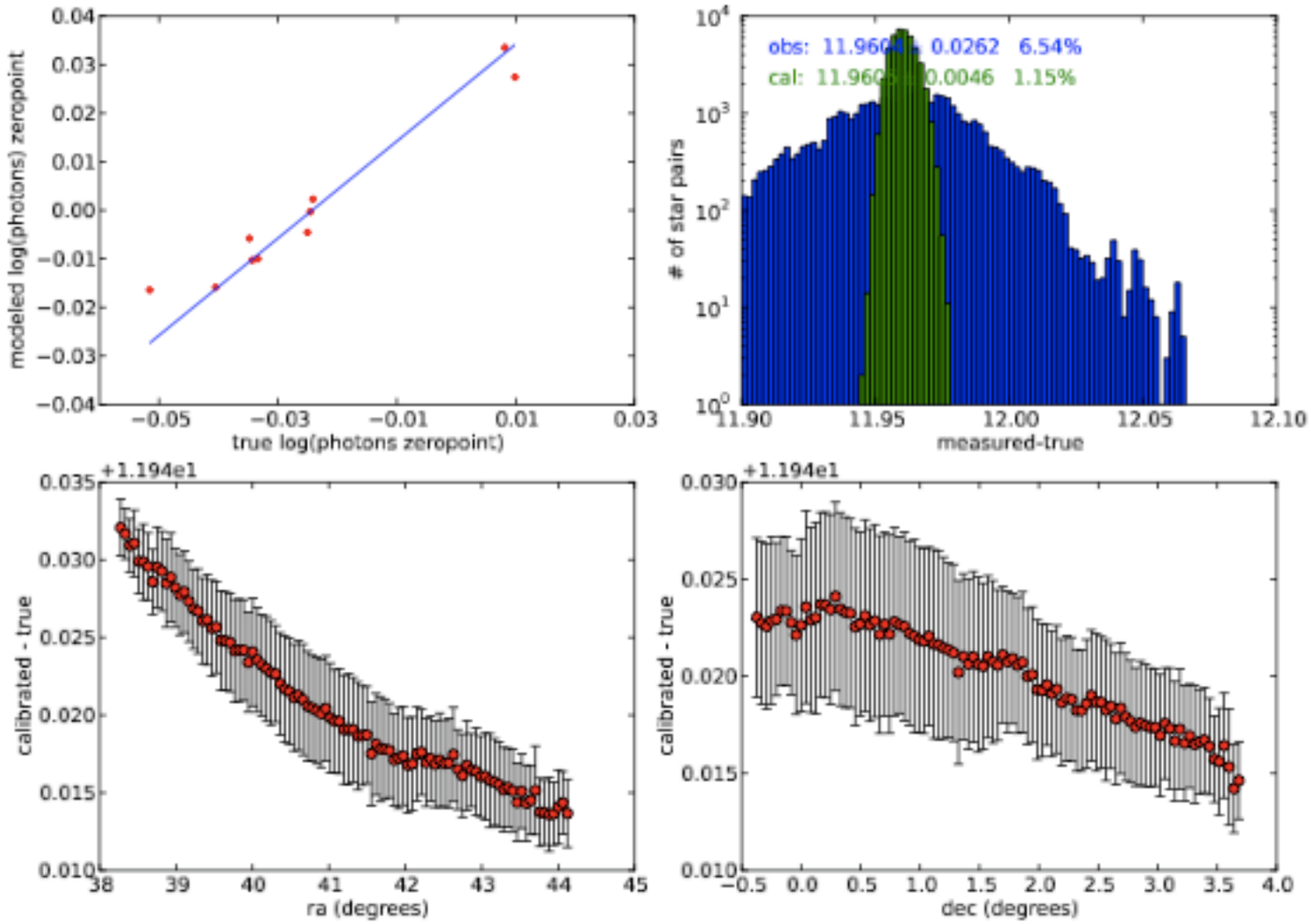

Figure 26: The spatial Δ_T of the 1-hex, 10 images after star flatting.

And the resulting solution still had gradients.

By walking though the data flow diagram, this can be explained

File flow: YaCal

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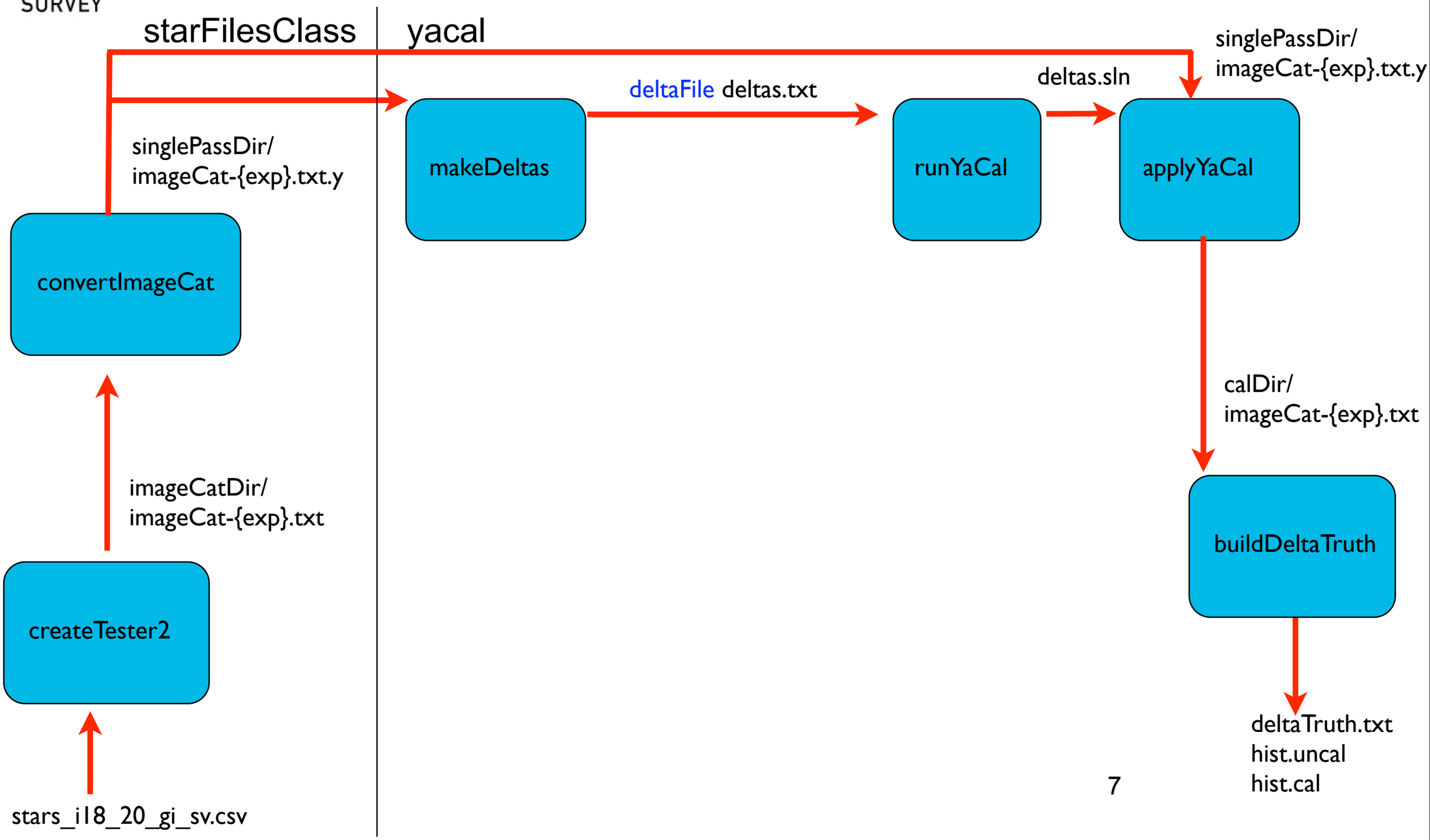

File flow: YaCal+ Starflat

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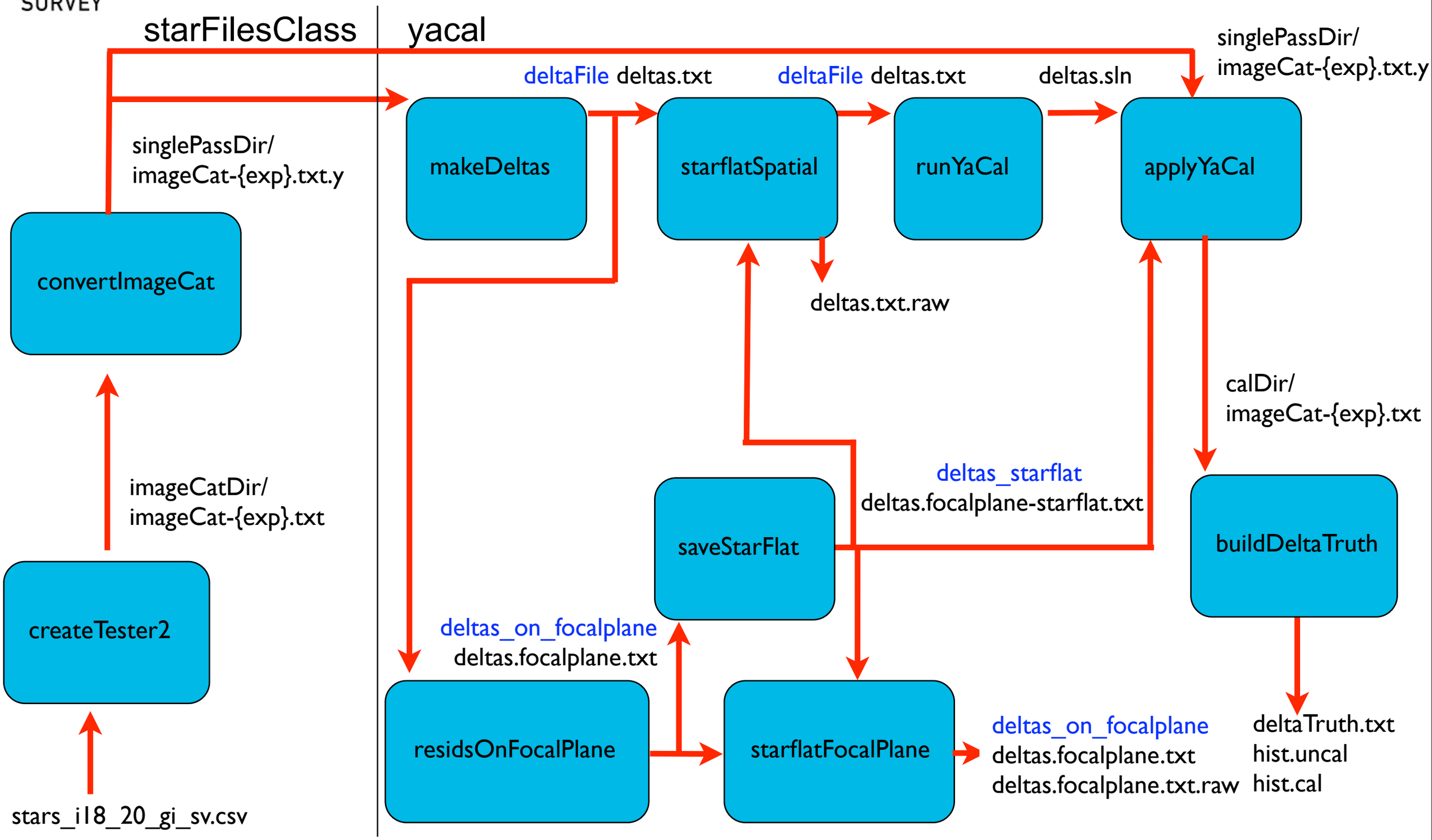
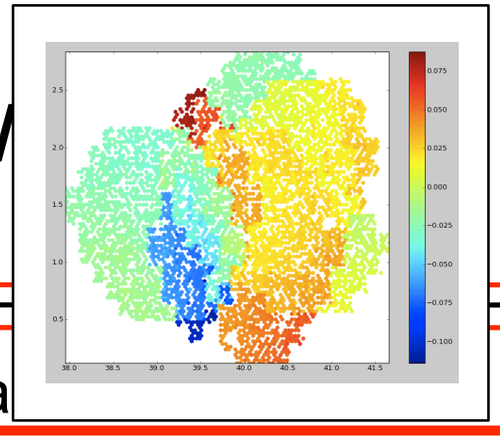
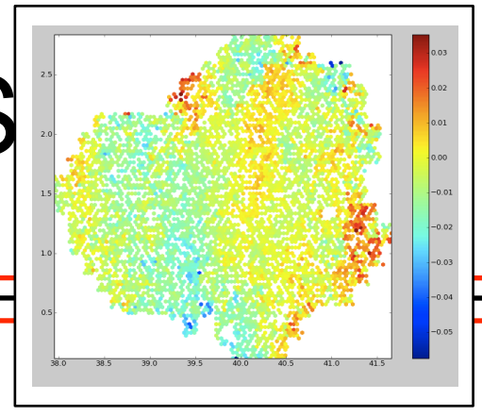


File flow S





starFilesClass | yaca

singlePassDir/
imageCat-{exp}.txt.y

deltaFile deltas.txt

deltaFile deltas.txt

deltas.sln

singlePassDir/
imageCat-{exp}.txt.y

convertImageCat

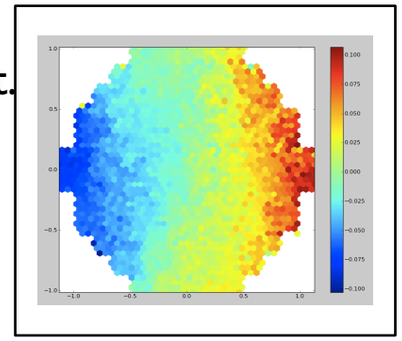
makeDeltas

starflatSpatial

runYaCal

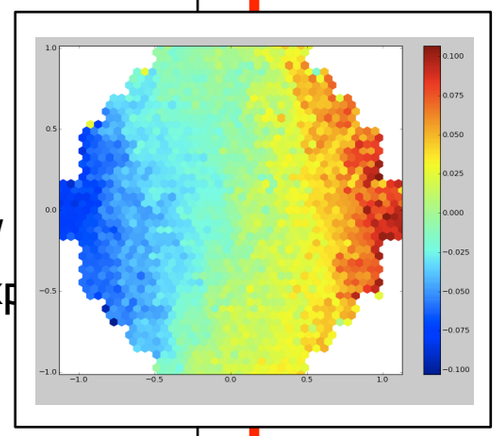
applyYaCal

deltas.txt.



calDir/
imageCat-{exp}.txt

imageCatDir/
imageCat-{exp



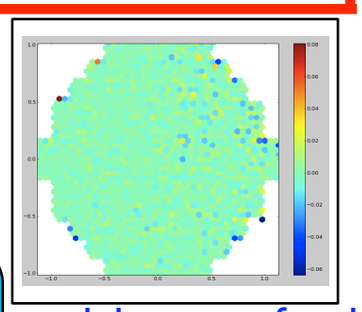
deltas_starflat
deltas.focalplane-starflat.txt

saveStarFlat

buildDeltaTruth

createTester2

deltas_on_focalplane
deltas.focalplane.txt



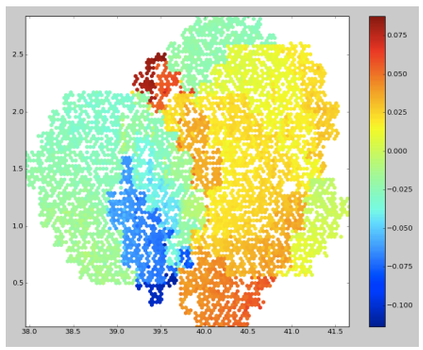
residsOnFocalPlane

starflatFocalPlane

deltas_on_focalplane
deltas.focalplane.txt
deltas.focalplane.txt.raw

deltaTruth.txt
hist.uncal
hist.cal

stars_i18_20_gi_sv.csv

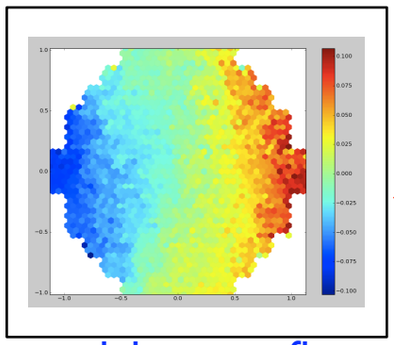


runYaCal

singlePassDir/
imageCat-{exp}.txt.y

deltas.sln

applyYaCal

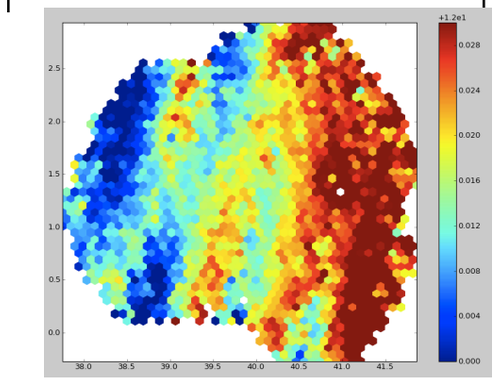


deltas_starflat
deltas.focalplane-starflat.txt

calDir/
imageCat-{exp}.txt

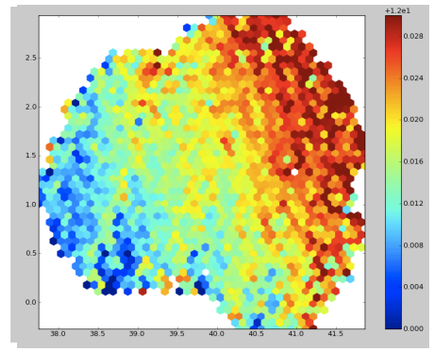
buildDeltaTruth

deltaTruth.txt
hist.uncal
hist.cal



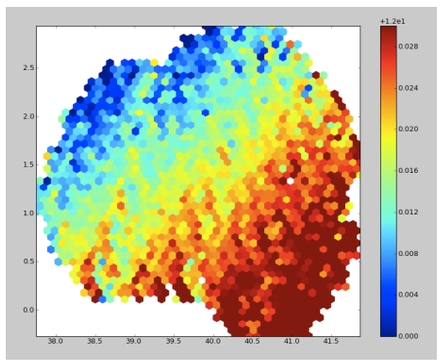
exp
exp

2.7%



white
exp
ccd

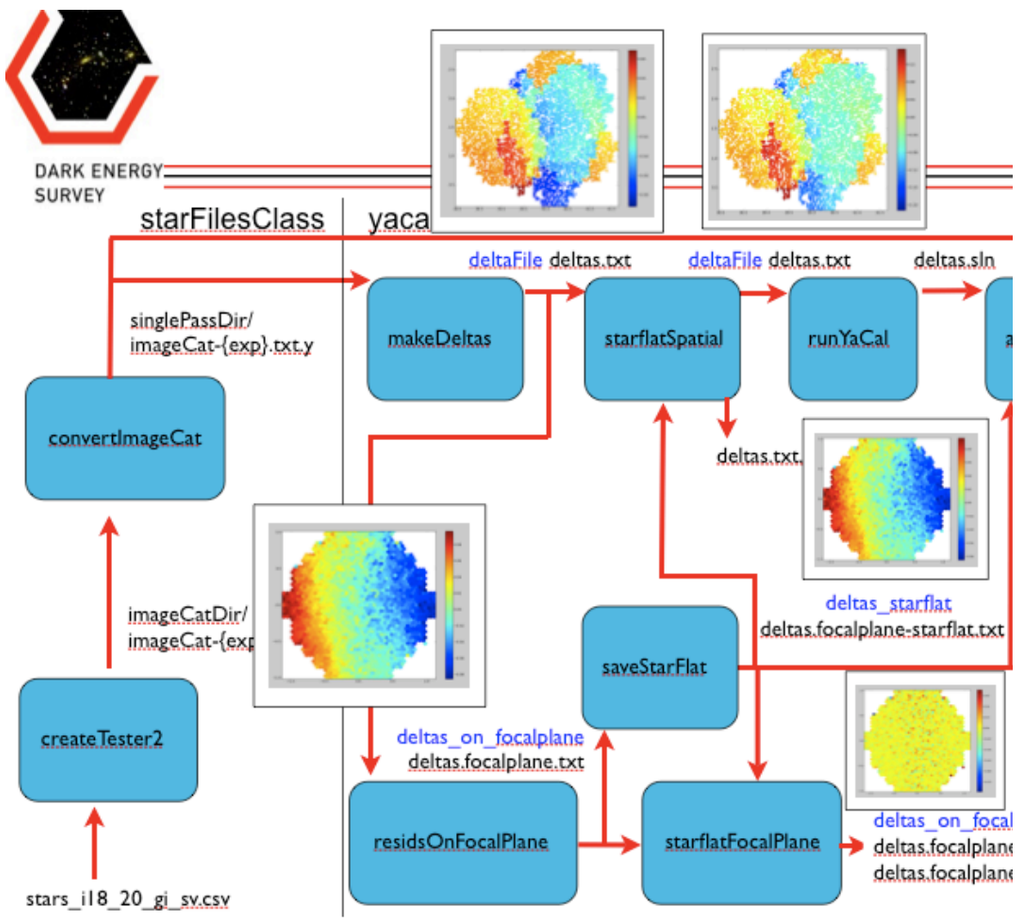
2.0%



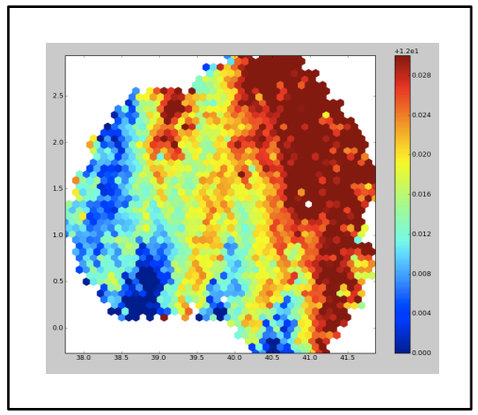
blue
exp
ccd
amp
ghost
x, y

2.5%

Minor changes.



Flip the input gradient sign



blue
exp
ccd
amp
ghost
x, y

2.7%

The Invisible Gradient

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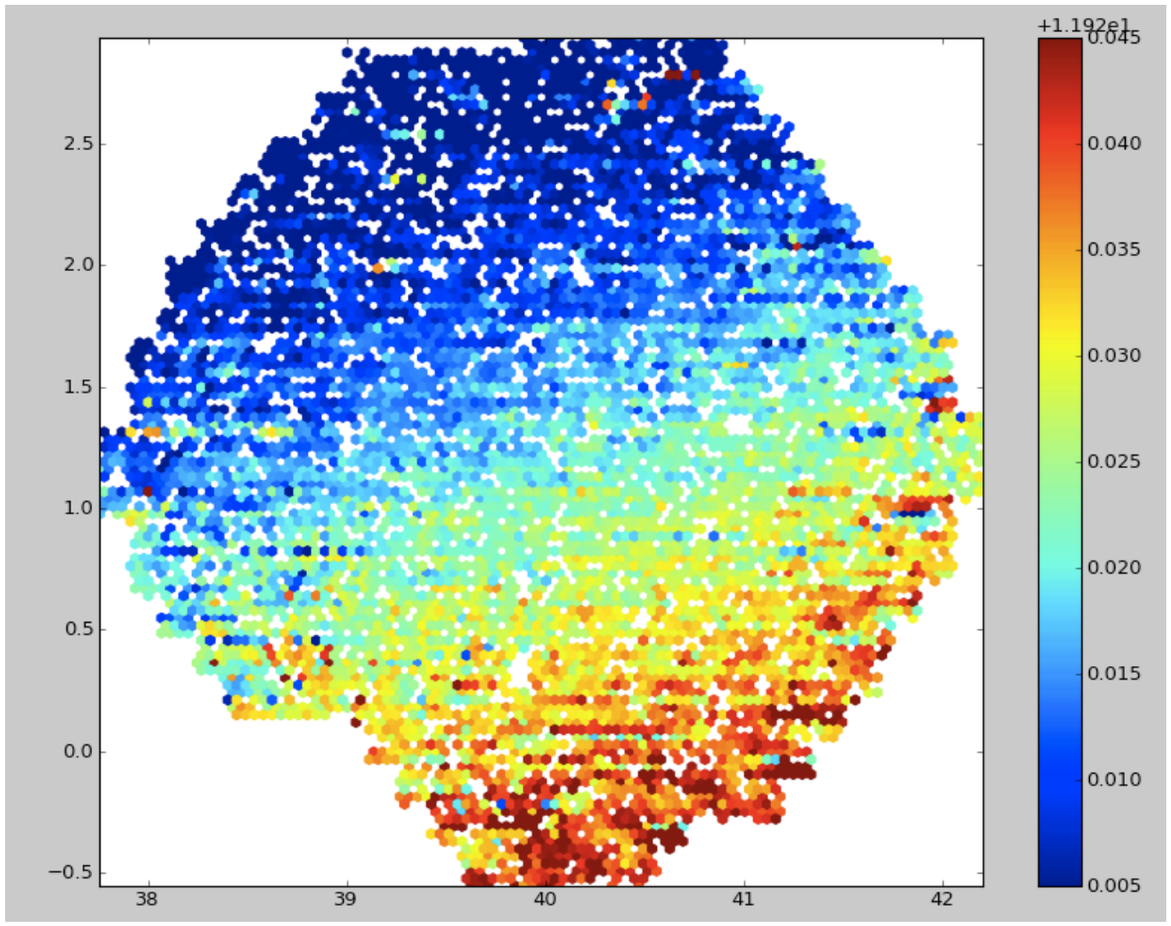
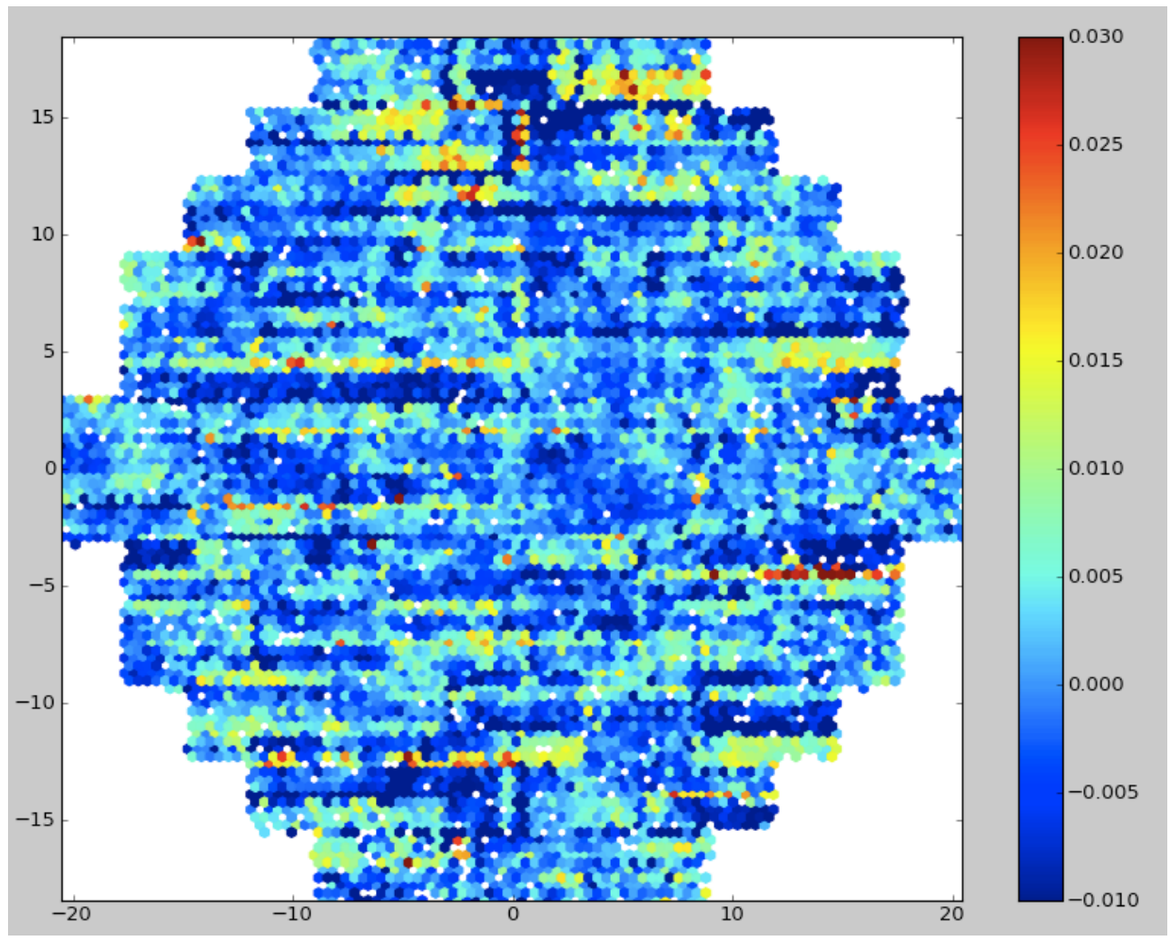
calibrated - truth,
stacked on focal plane
10 images

same stretch

calibrated - calibrated,
stacked on focal plane
10 images





The obs-obs residuals don’t show the gradient, so YaCal can’t fit for it.

Solutions with gradients

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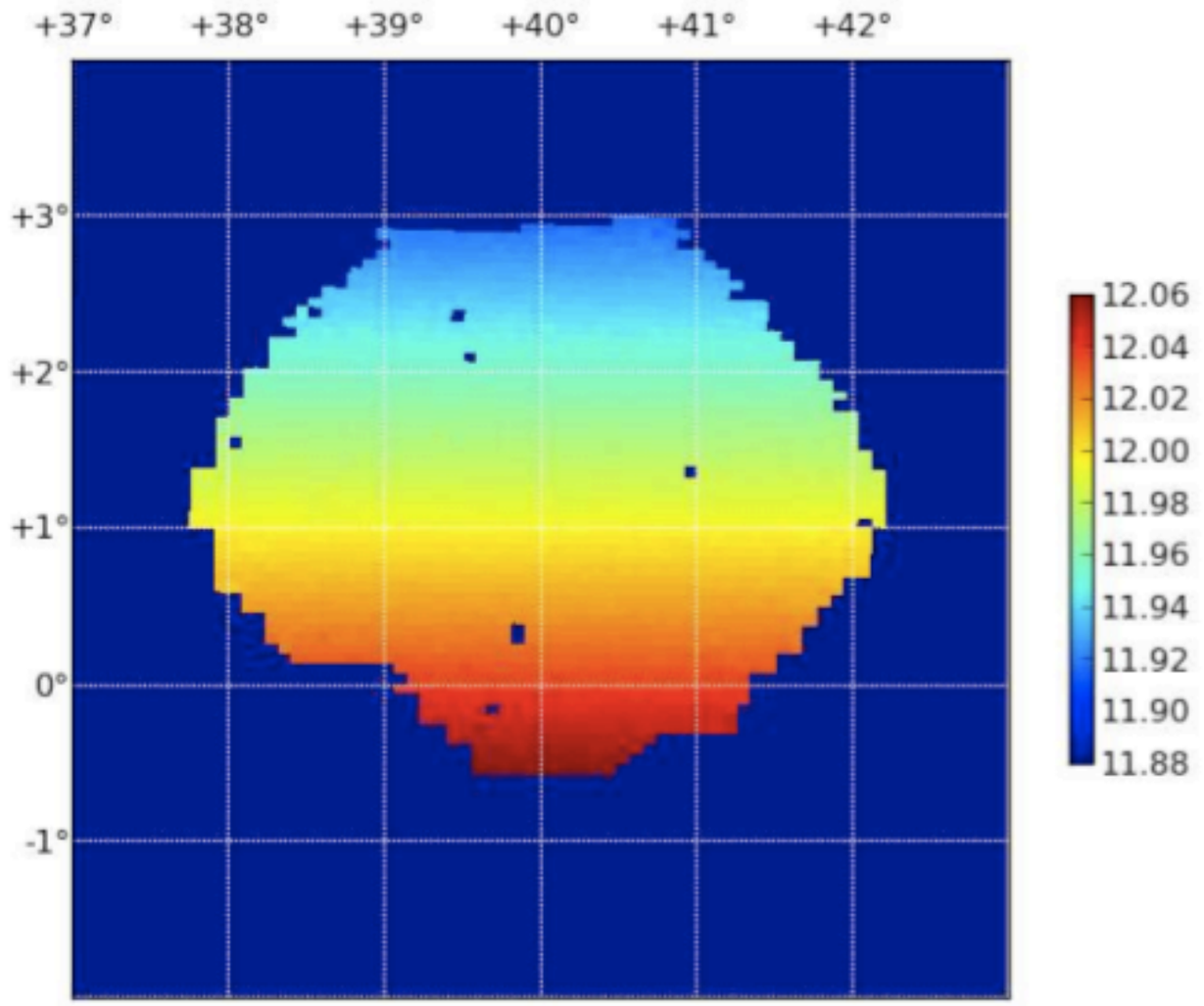

Figure 18: Map of the residuals. The gradient is obvious, just as it was in the dec projection in the previous figure.

But they -are- gradients, which are relatively easy to remove.

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Solution without gradient

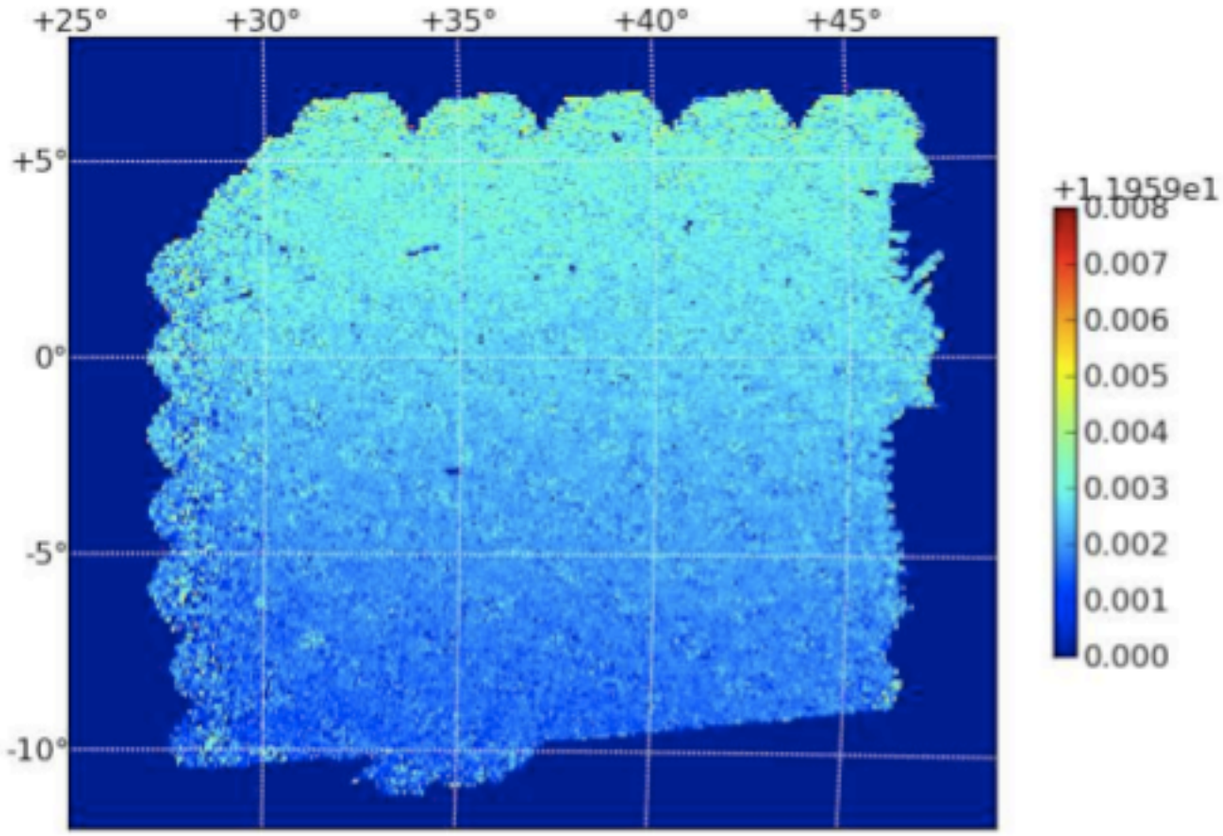

Figure 15: A residual map of the pzt area. The full scale on this image, dark blue to dark red, is 2%; the gradient must have a smaller amplitude than the 0.5% rms of the residuals.

Likely straightforward ways exist to remove the gradients
See conclusions.

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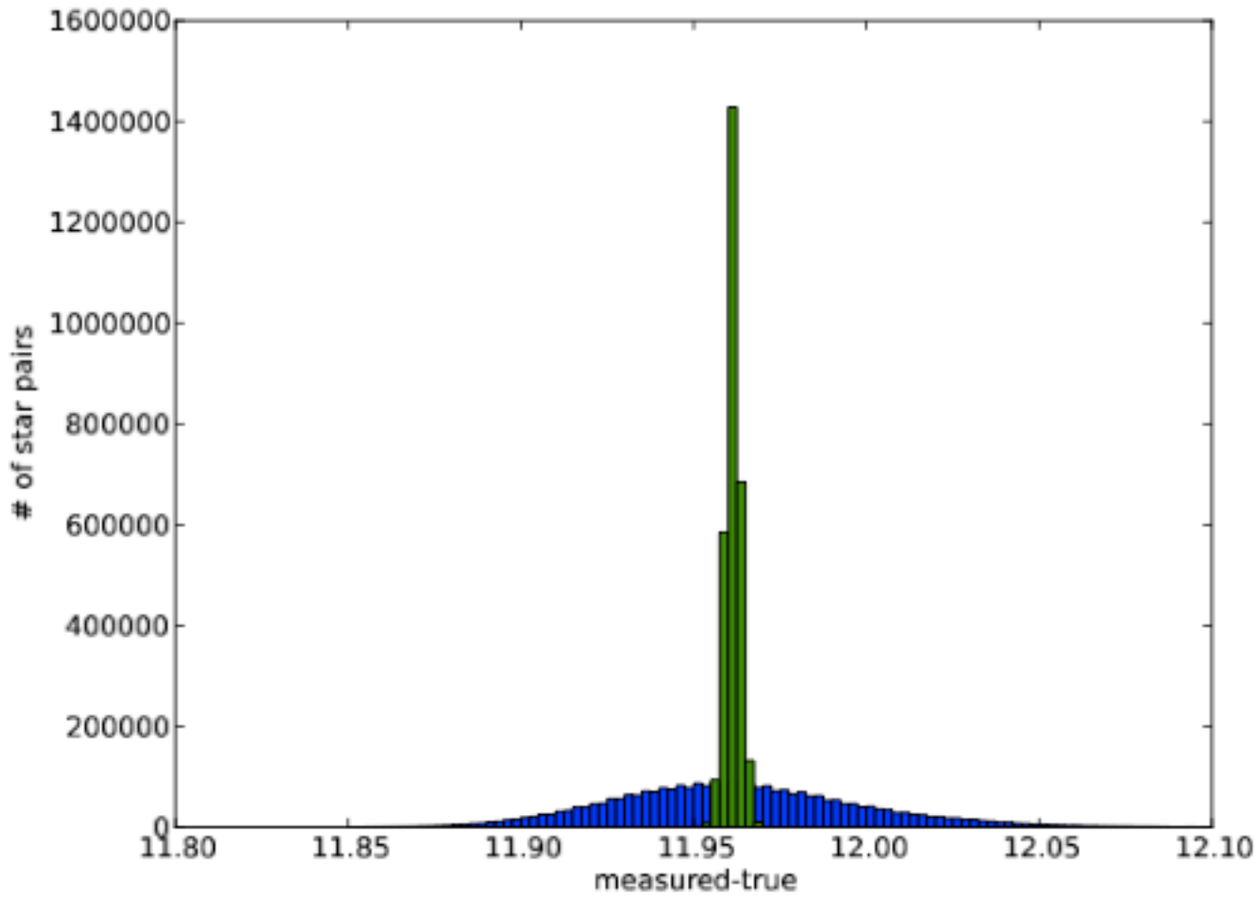
0.5% Photometry



Blue: observed 9%
Green: calibrated 0.5%

In the ensemble average, not for individual objects
(which will need bandpass corrections)

We should aim at 0.5% photometry!

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Conclusions

- Relative photometry is insensitive to gradients. Thus:
  - we need to obsess about gradients in the flat field
  - we should explore the use of standards and/or Precam data to remove gradients
  - we should consider circling the sphere at $\delta = -60°$ which would remove E/W gradients.
- Star flats will be more useful when the data is taken on stars with known photometry.
  - Stripe 82 comes to mind, but beware gradients in Zejko cat
  - also beware of its relatively high airmass
- In this work, star flats added much complexity for no gain.
  - The solutions using a star flat were in fact noiser than solutions without using them but including gradient terms (e.g., the red model).
- Using the pure YàCal approach, if the gradients in the flat field were kept to $\leq 0.5\%$/degree the solutions over the photometric redshift training area were $\sim 0.5\%$.
  - This is ensemble rms; we will need the color term/bandpass correction technology at the catalog level to read $\sim 0.5\%$ photometry on an object by object level.