ZTF Calibration for Legacy

What calibration data is needed now for Legacy later ?

N. Regnault, ZTF calibration group & SNIa working group

ZTF Legacy (from a SN perspective)

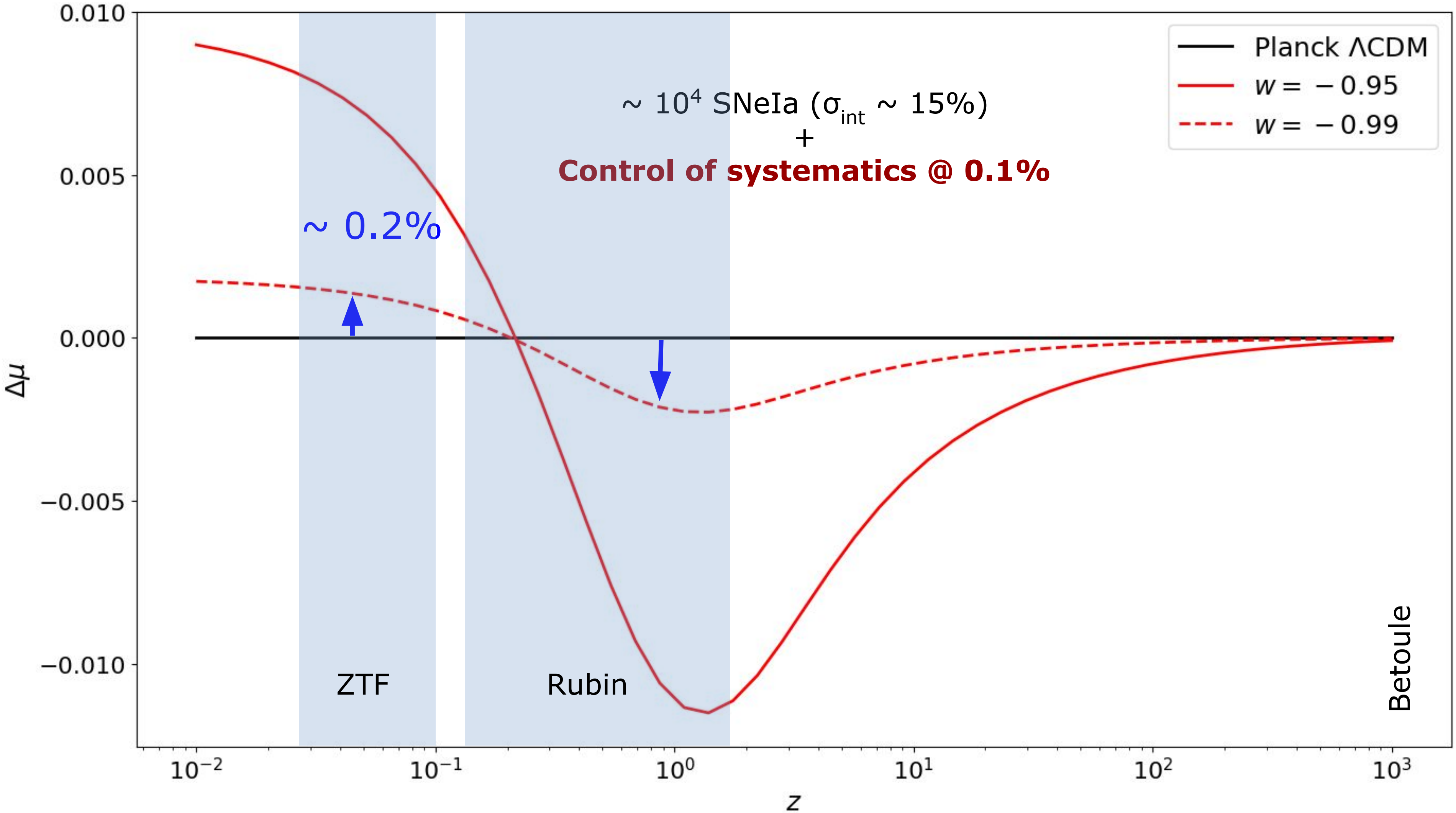
- Reference low-z SN sample for the upcoming decade
  - Spectroscopically complete
  - Exquisite light curve sampling
  - O(5000) cosmology grade SNe
- Largest low-z photometric SN sample ever
  - O(20,000) SNe
  - Homogeneous, exquisite light curve sample

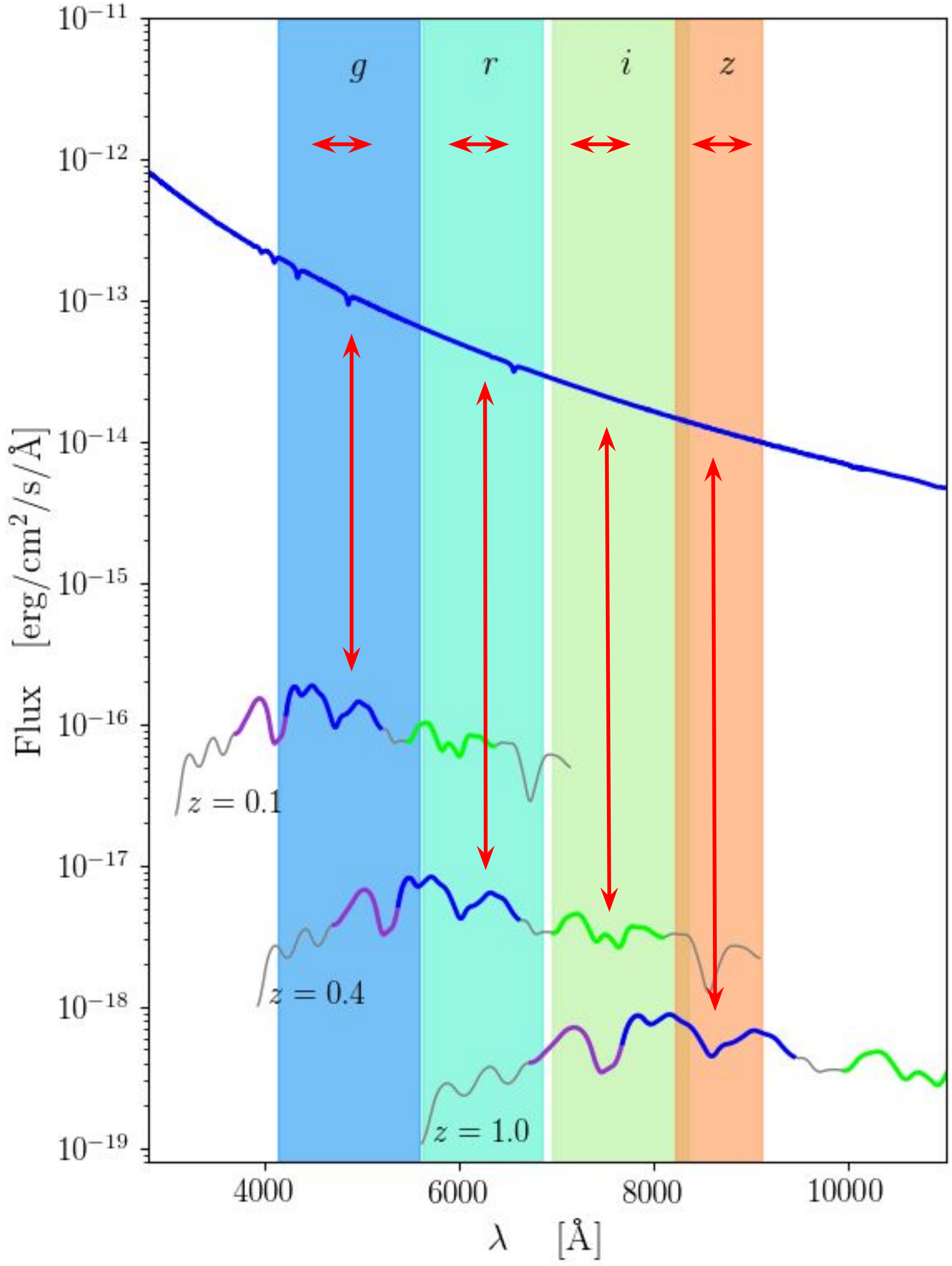
Even in the LSST era

- Full (northern) sky catalog of stars
  - Natural magnitudes
  - calibrated at the 0.1%-level
  - With clear metrology chain to the fundamental standards

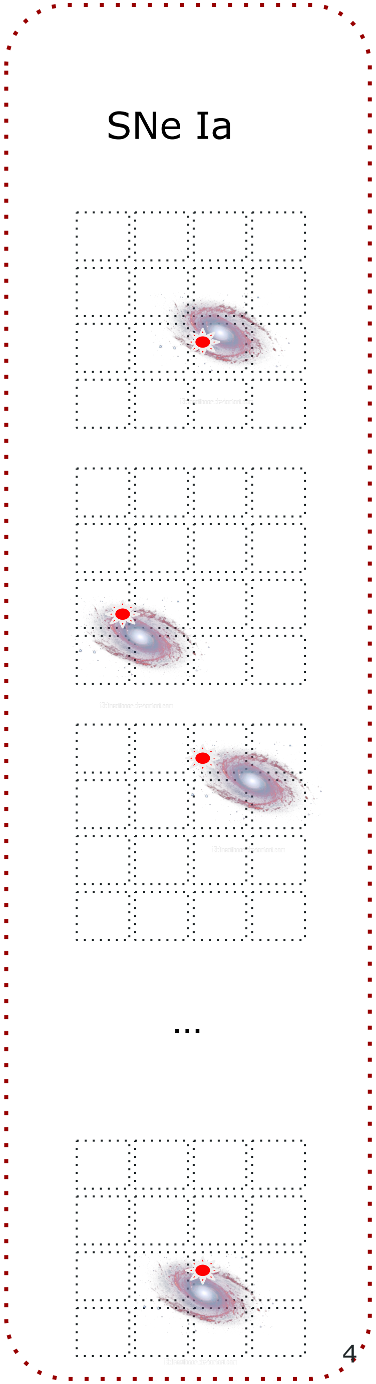
By-product of SN calibration

… if properly calibrated

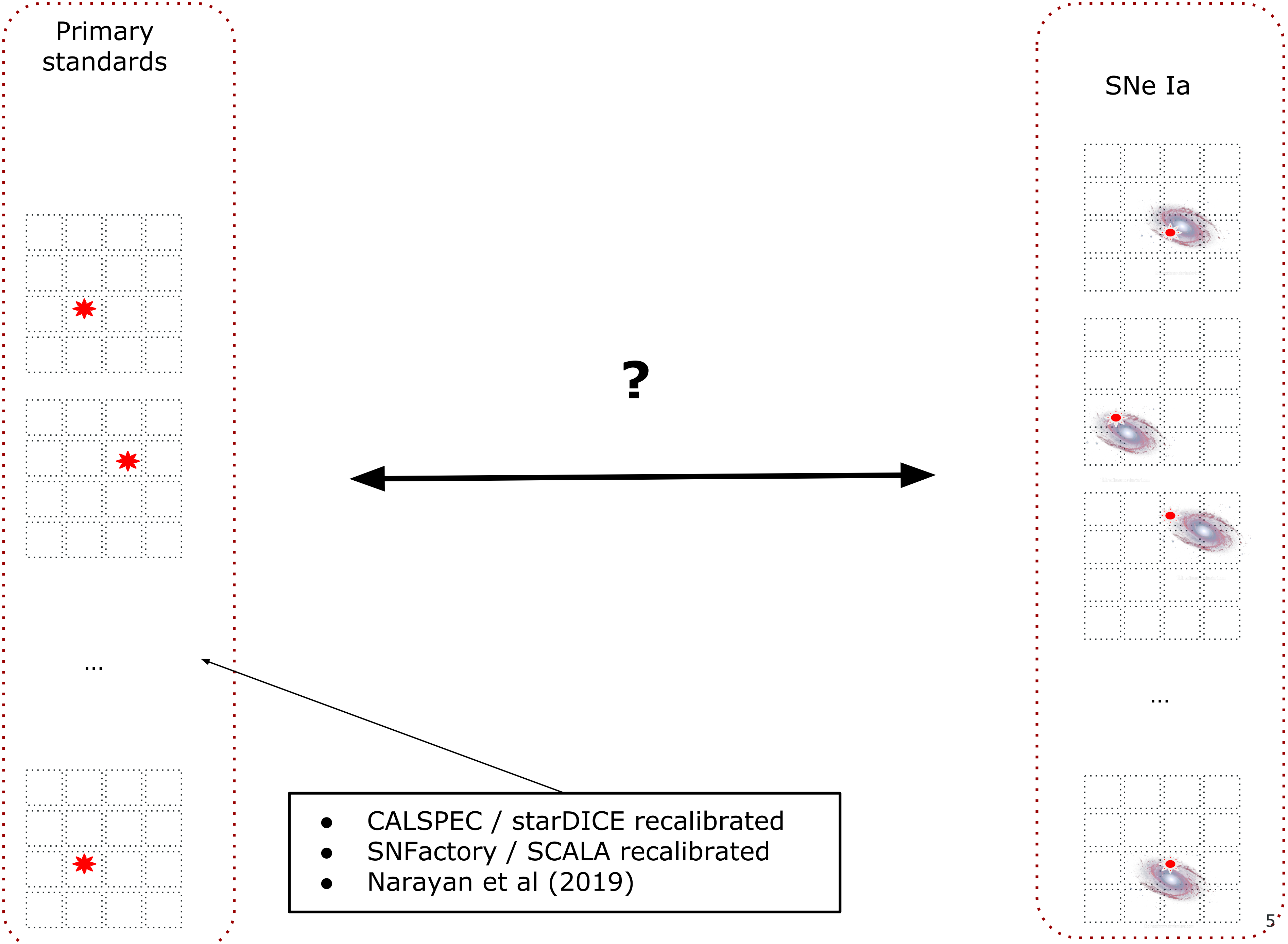




g
r
i
z
10^{-11}
10^{-12}
10^{-13}
10^{-14}
10^{-15}
10^{-16}
10^{-17}
10^{-18}
10^{-19}
Flux [erg/cm^2/s/Å]
$z = 0.1$
$z = 0.4$
$z = 1.0$
4000
6000
8000
10000
λ [Å]



SNe Ia
...



Primary standards
SNe Ia
?
...
...
CALSPEC / starDICE recalibrated
SNFactory / SCALA recalibrated
Narayan et al (2019)

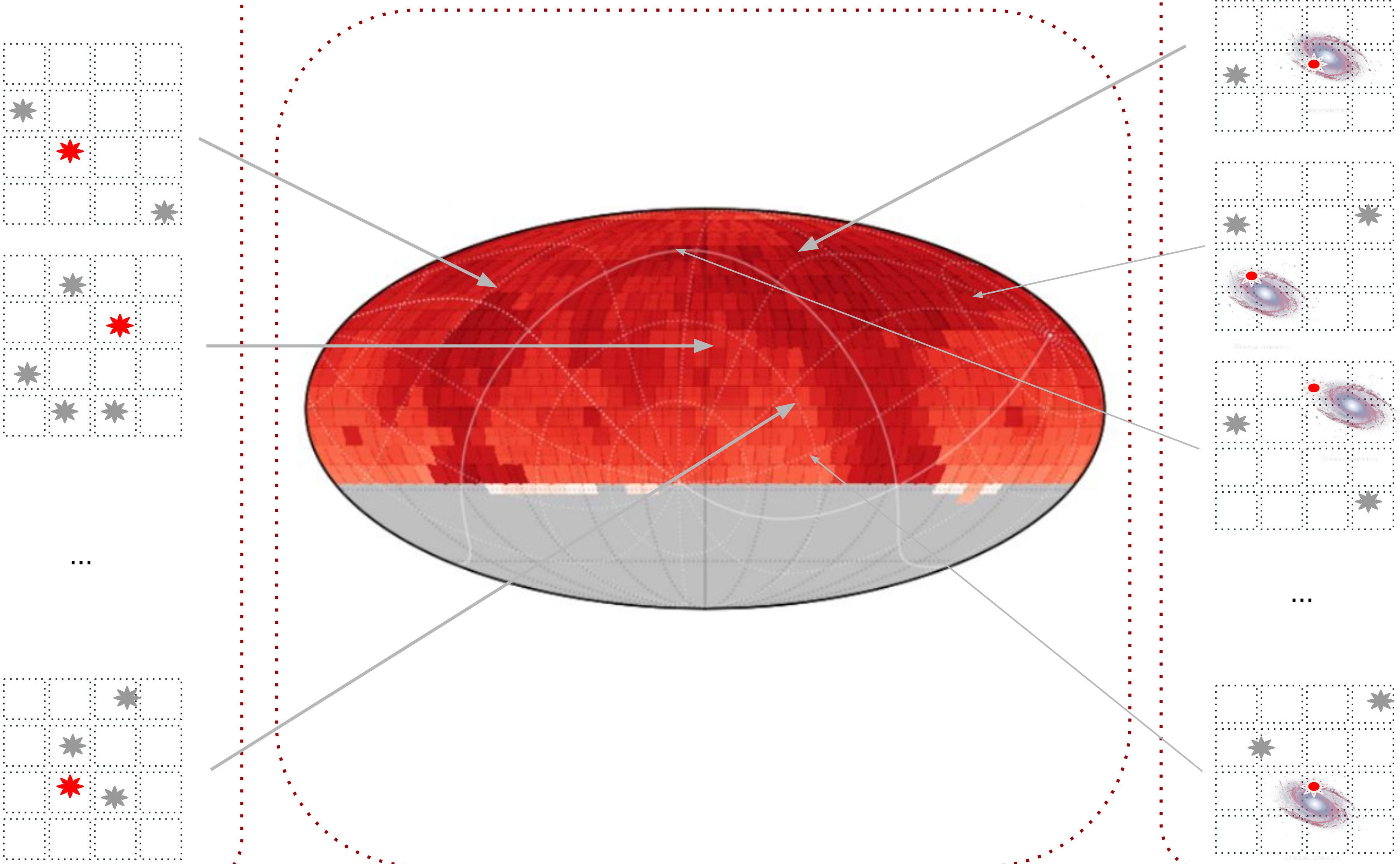
Primary standards

Ubercal

SNe Ia

$$f_{\star} = \alpha \int S_{ref}(\lambda)\lambda T(\lambda, x, t) d\lambda$$

$$f_{SN} = \alpha' \int S_{SALT}(\lambda)\lambda T(\lambda, x', t') d\lambda$$



ZTF Legacy

- Largest, homogeneous, 0.1% calibrated, sample of SNe Ia ever
    - With a clear connection to the primary flux standards
    - (easy to update when they are updated)
- Full (northern) sky catalog
    - Calibrated at the 0.1-% level
    - Common calibration anchor for ALL past and upcoming surveys
        - SNLS, Pantheon/DES, Subaru …
        - …. and LSST (very good coverage)
- Model of instrument throughput
    - Clear link between SEDs and calibrated magnitudes

Where are we as of today ?

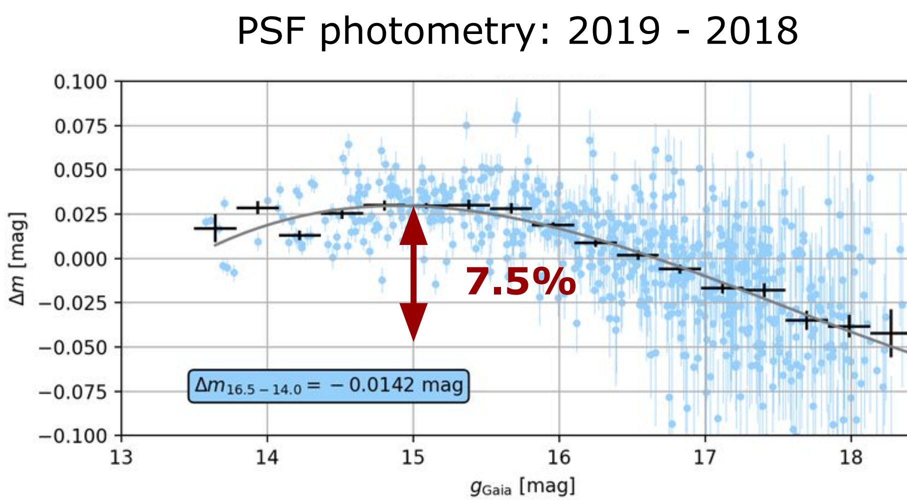
- Scene modeling pipeline works
  - Can process the full DR2 SNIa set in days
  - Getting ready for a photometric dataset (20,000 objects)
- Ubercal pipeline works
  - Exquisite control of small scale error modes (aka starflats)
  - Still need help from PS1/Gaia for large scale error modes
  - Secured ZTF photometry of the primary standards
- Work on telescope passbands just starting
  - We have a “global model” that works at the 1%-level

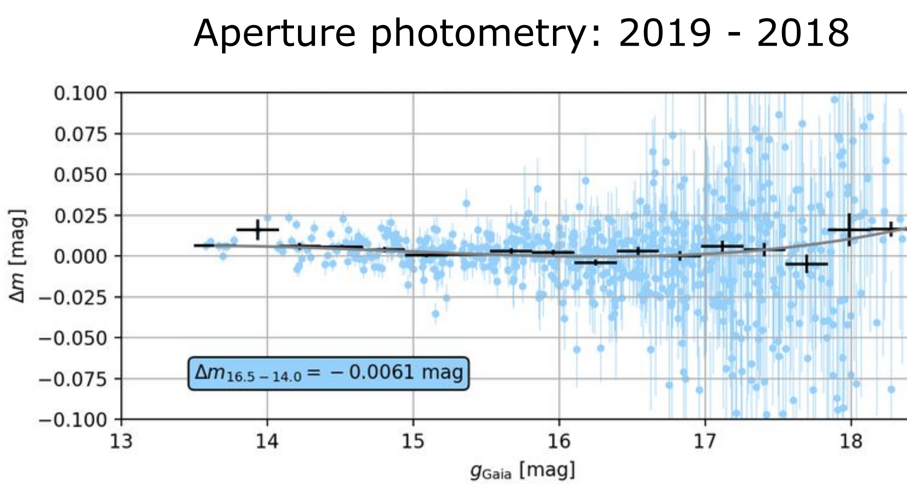
On the way to a Legacy Dataset

- Control of the linearity of PSF photometry at the 0.1% level
  - So-called “CCD-6” problem, aka “pocket effect”
  - Brighter-fatter effect
- Control of the survey uniformity at the 0.1%-level
  - Exquisite control of small scales
  - Need to rigidify the large scales
- Secure a model of the telescope throughput
  - Valid everywhere on the focal plane
  - Extensively tested w.r.t. other survey telescopes

PSF skewness

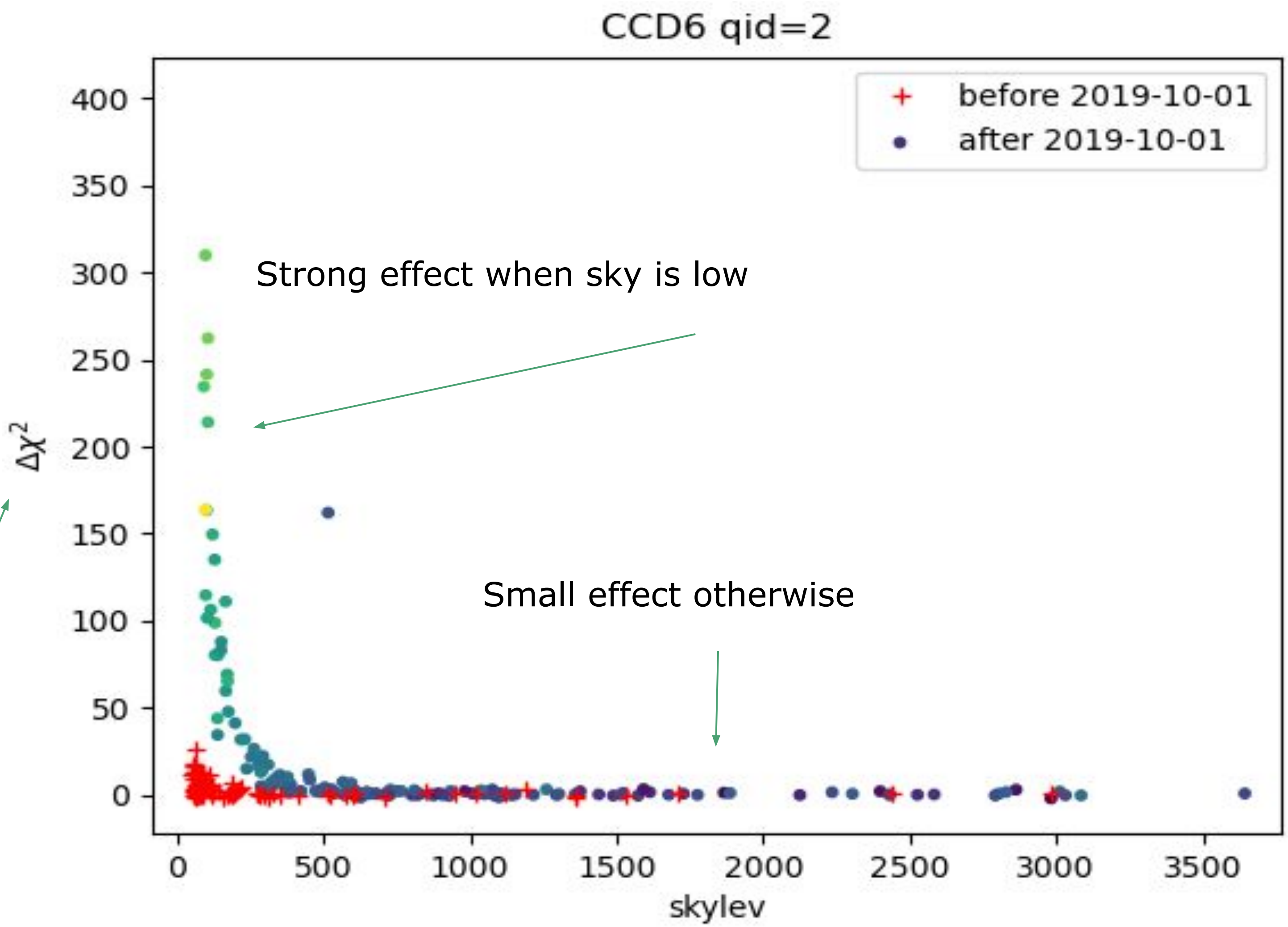
- On most CCDs,
- since ~ Oct 2019,
- *PSF shape varies with flux,*
- (faint stars are skewed)
- Impact on:
  - PSF photometry (1 - 10% non-linearities)
  - Astrometry (100 mas flux dependent errors)





Mapping the effect on real data

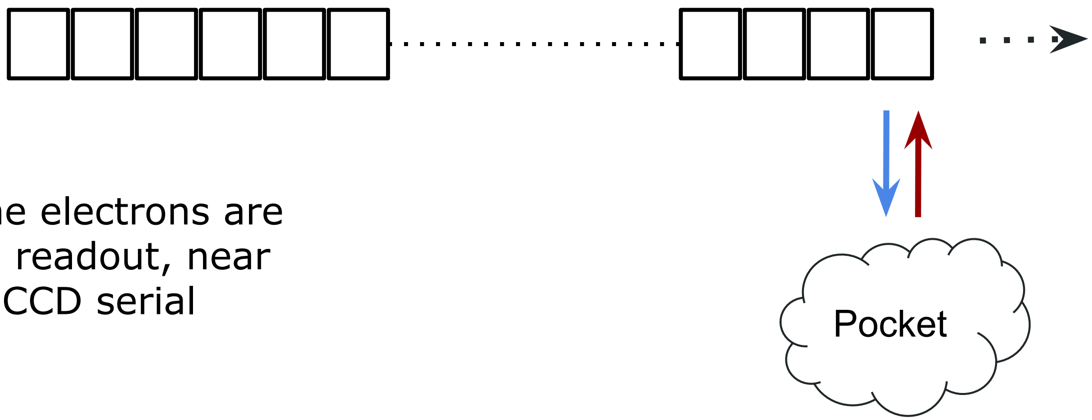
- PSF - aper versus flux



Large when effect is present

Modeling and correcting for the effect

- Hardware corrections
- Need to find a fix (at pixel level) for the 2019 - 2023 data
- Tentative model



A fraction of the electrons are trapped during readout, near the end of the CCD serial register.

All lost electrons are recovered eventually, while reading the next pixels.

Dynamics is complex (depends on the pocket level). Effect modeled with a fill and a flush function, trained on the data, for each quadrant: 2 x 64 functions to determine.

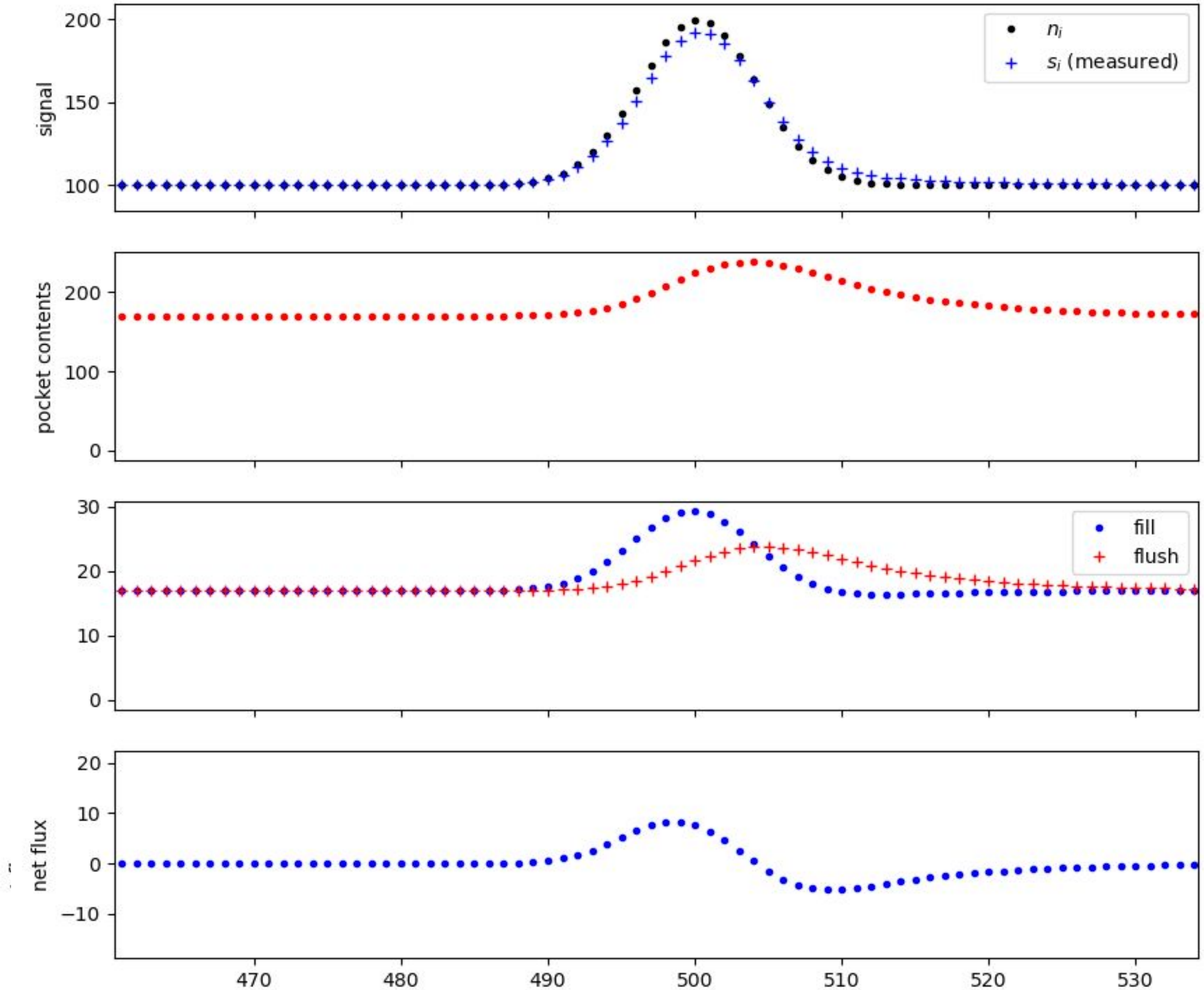
Tentative model

Star profile

Pocket level

Fill & Flush

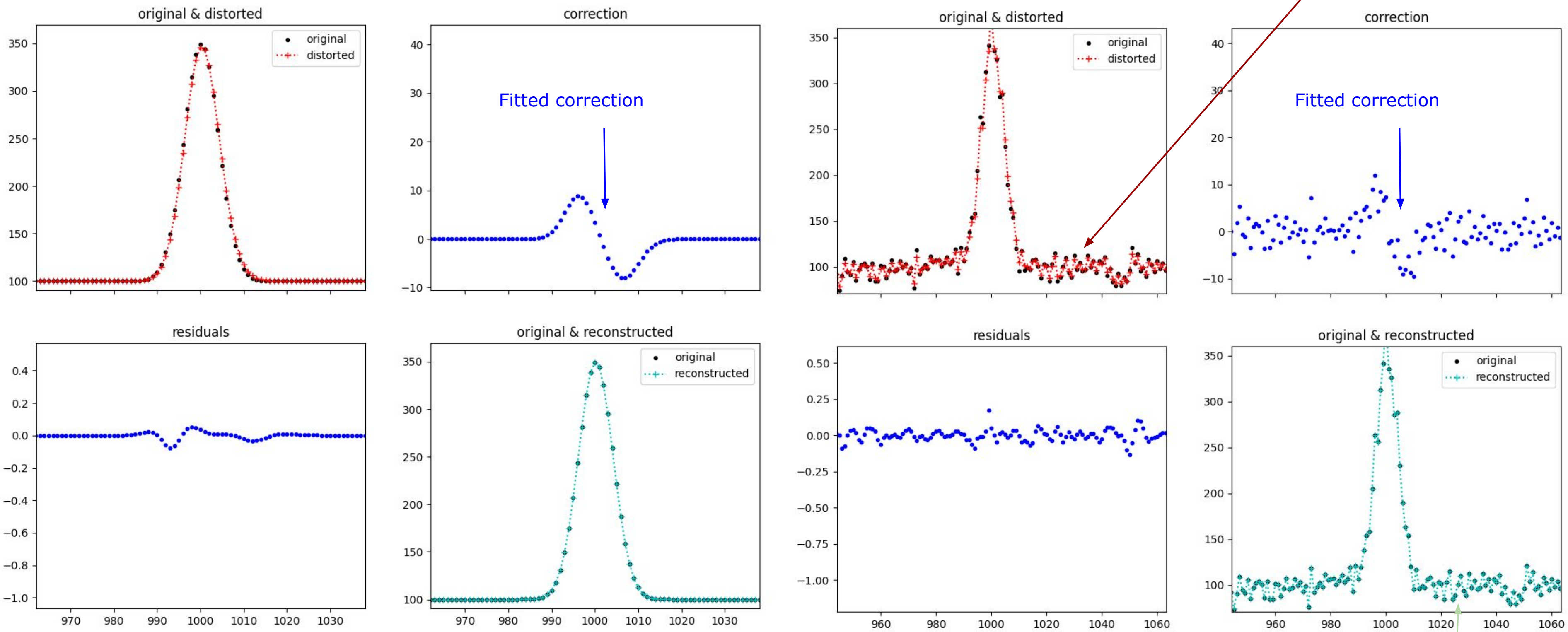
Nett effect



Inverting the effect

Note the deficit of variance in distorted image (went into pixel-to-pixel covariances)

Fit results (4 iterations, 1.4 ms / line)



No noise

With noise

Looks like correct variance / covariances could be recovered

Auxiliary Data needed

- At the moment, effect has been constrained on exposure overscans
  - Handle on how the pocket flushes
  - No firm constraints on fill function
- Fill & Flush can be constrained flat-field pixel-to-pixel correlations
- Special data needed
  - Special flat field ramps, aka PTC
  - Being taken right now
  - Also allow to constrain another subtle CCD effect: brighter-fatter, which is present on the ZTF sensors

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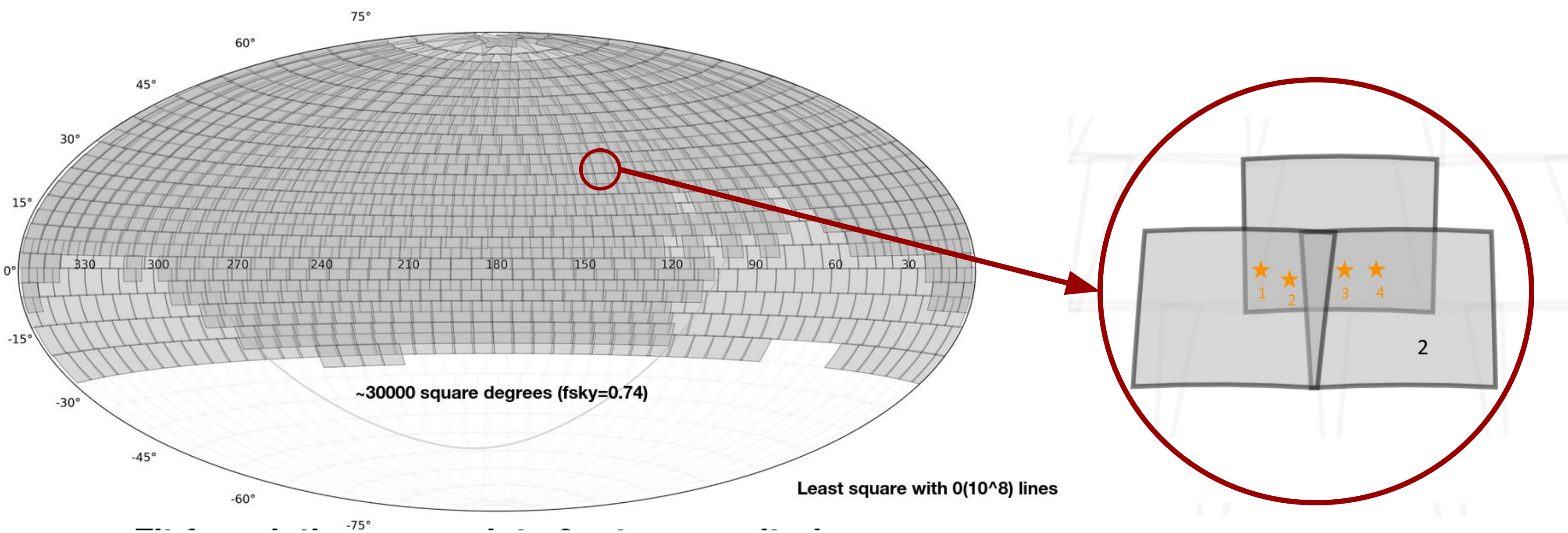
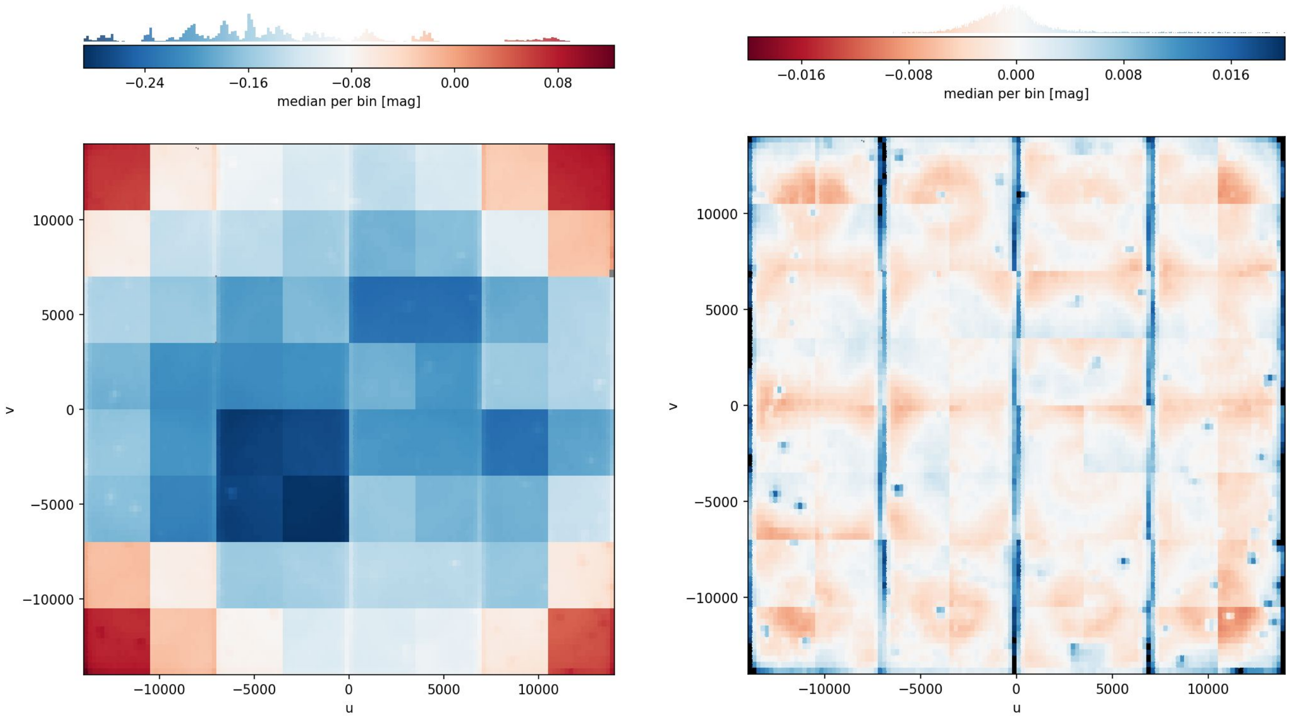
Ubercal



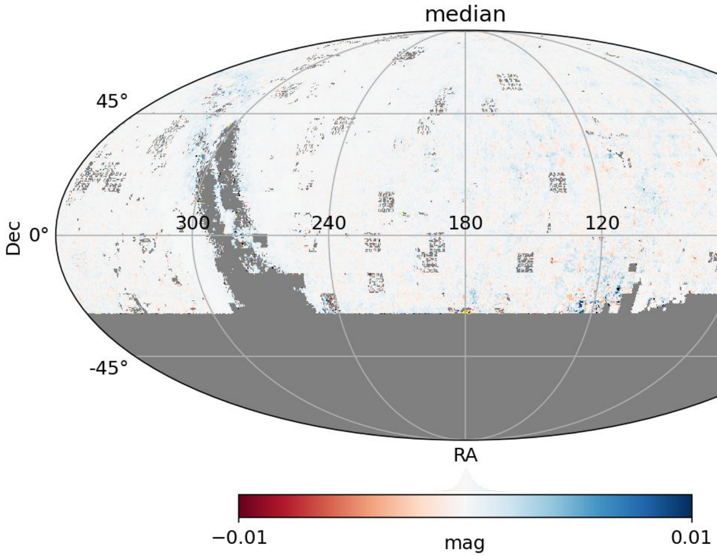
- Build on observation redundancies to constrain simultaneously
    - Quadrant zero points
    - Focal plane uniformity
    - Star uniformized magnitudes

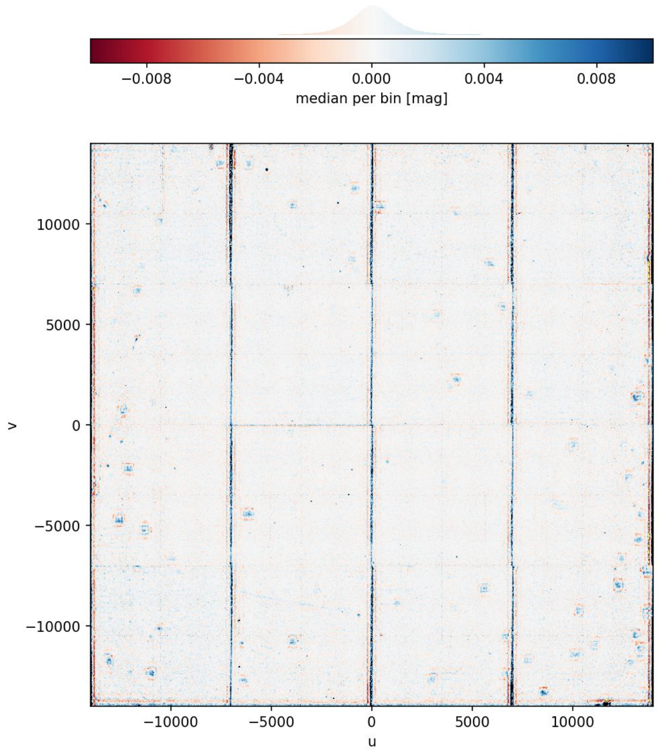
Exquisite control of small scale effects



B. Racine et al

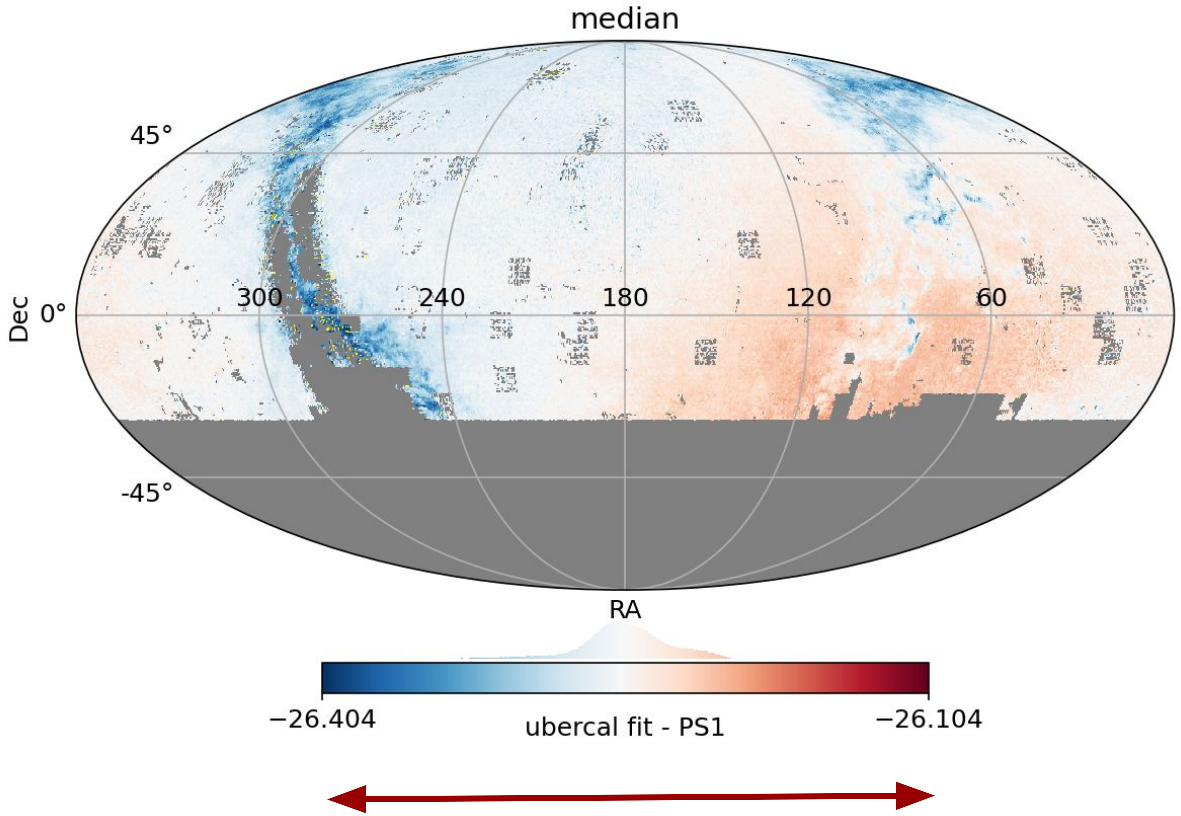
Ubercal residuals





B. Racine et al

… but large scale error modes



Comparison with PS1 : 30% peak-to-peak

B. Racine et al

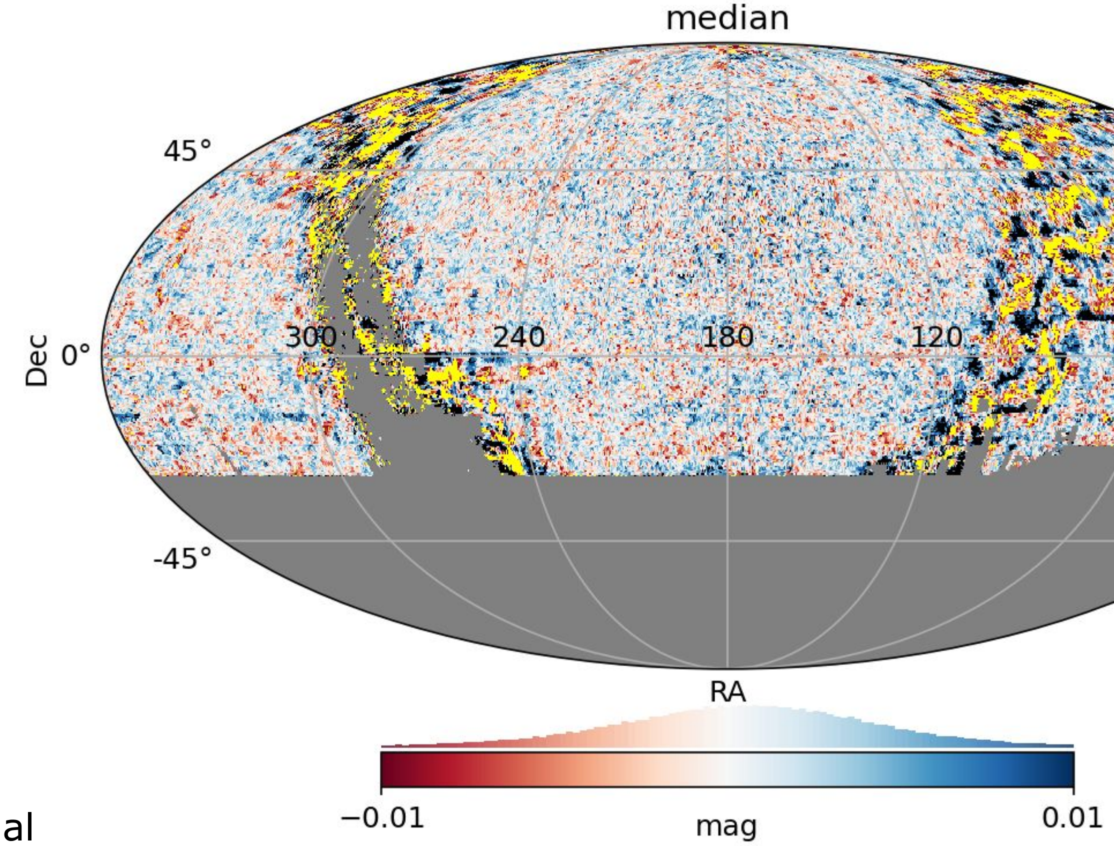
… but large s

Comparison with PS:

B. Racine et al

… temporary cure

- Use PS1 as a rigidifier
- … keeping our anchoring to CALSPEC



B. Racine et al

Long term fix

- Slight modification of ZTF observing strategy
  - To make sure that fields > 60 degrees apart in ra are observed within ~ an hour or so
  - Helps connecting distant fields
  - Better control of large scale error modes
- All surveys having rolled out successful ubercal’s have done that
  - PS1 deep pillars, SDSS special rigidifiers

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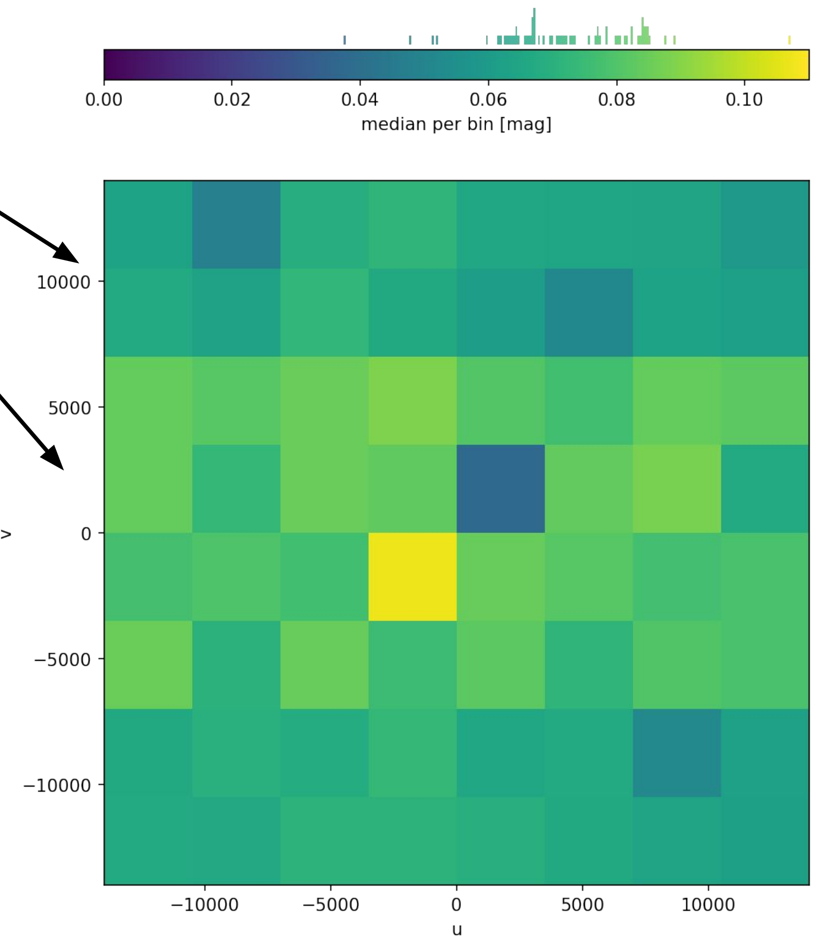
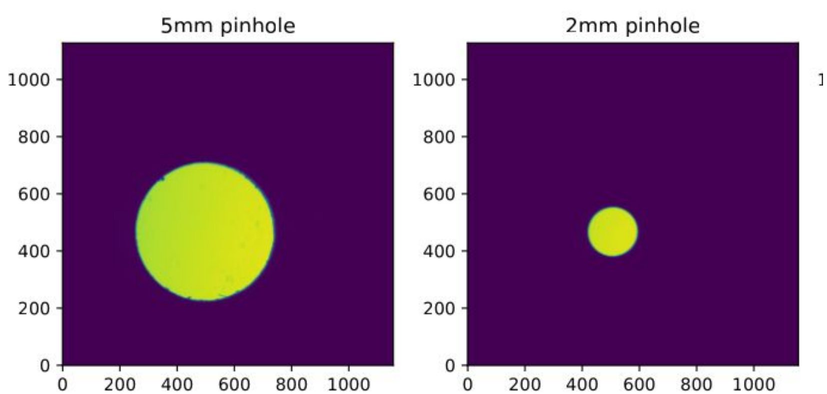
Color terms w.r.t. PS1

- Two flavors of ZTF CCDs
- Different QE's
  - -> ~ 2% chromatic effect
- We have only one (unchecked) throughput function
- Short term fix : compare with PS1, SNLS, GAIA
  - Distort what we have to match the observations
- Proposal
  - Scan the ZTF filters in situ

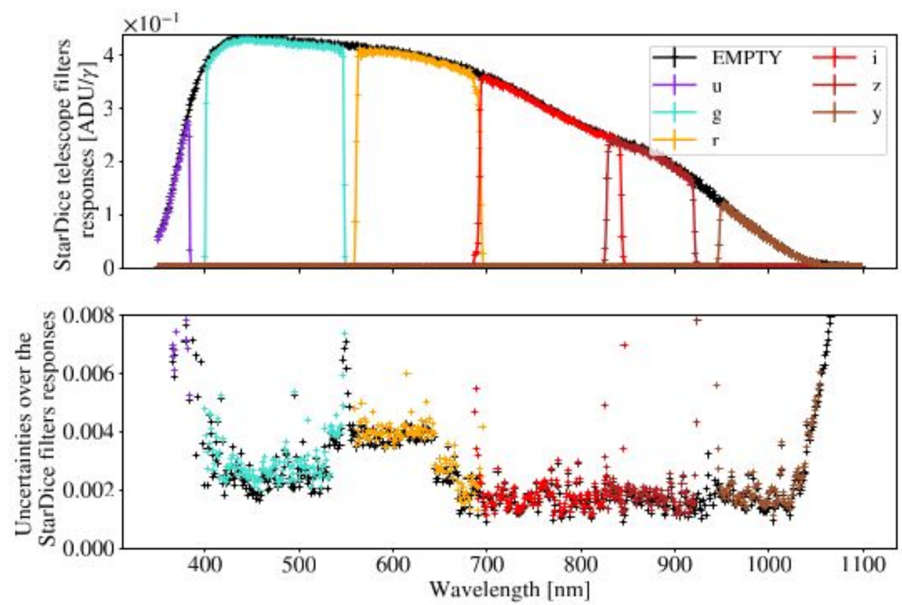


Collimated Beam Projector (CBP)

- Injects a collimated beam of calibrated light in the telescope pupil
  - Developed for Rubin
  - Lighter version available (Paris - Harvard collaboration)
  - Used to calibrate starDICE telescope
  - “Traveling CBP” under development



Neveu et al, in prep



Conclusion

- Great dataset,
  - Great Legacy value
- *... if properly calibrated*
  - will be a fundamental dataset long into the LSST era
  - Common anchor to all SNe surveys (incl. LSST)
- We need:
  - Flat field ramps (Pocket effect, brighter-fatter, linearity etc…)
  - Ubercal ridigifiers
  - Provisions for in-situ filter scans, with the traveling CBP

ongoing

Needs dicussion

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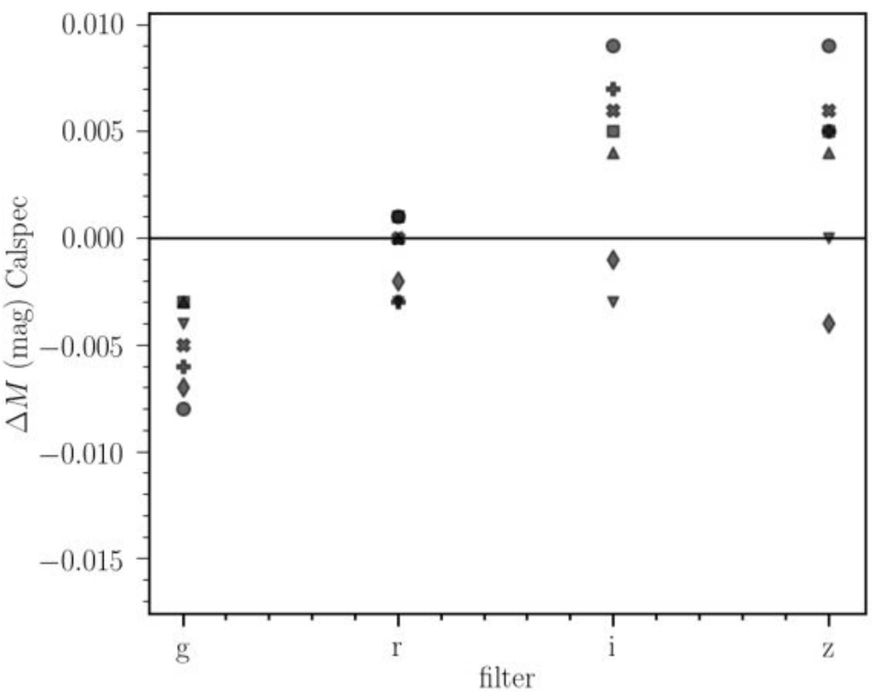
Typeset using LATEX **twocolumn** style in AASTeX63

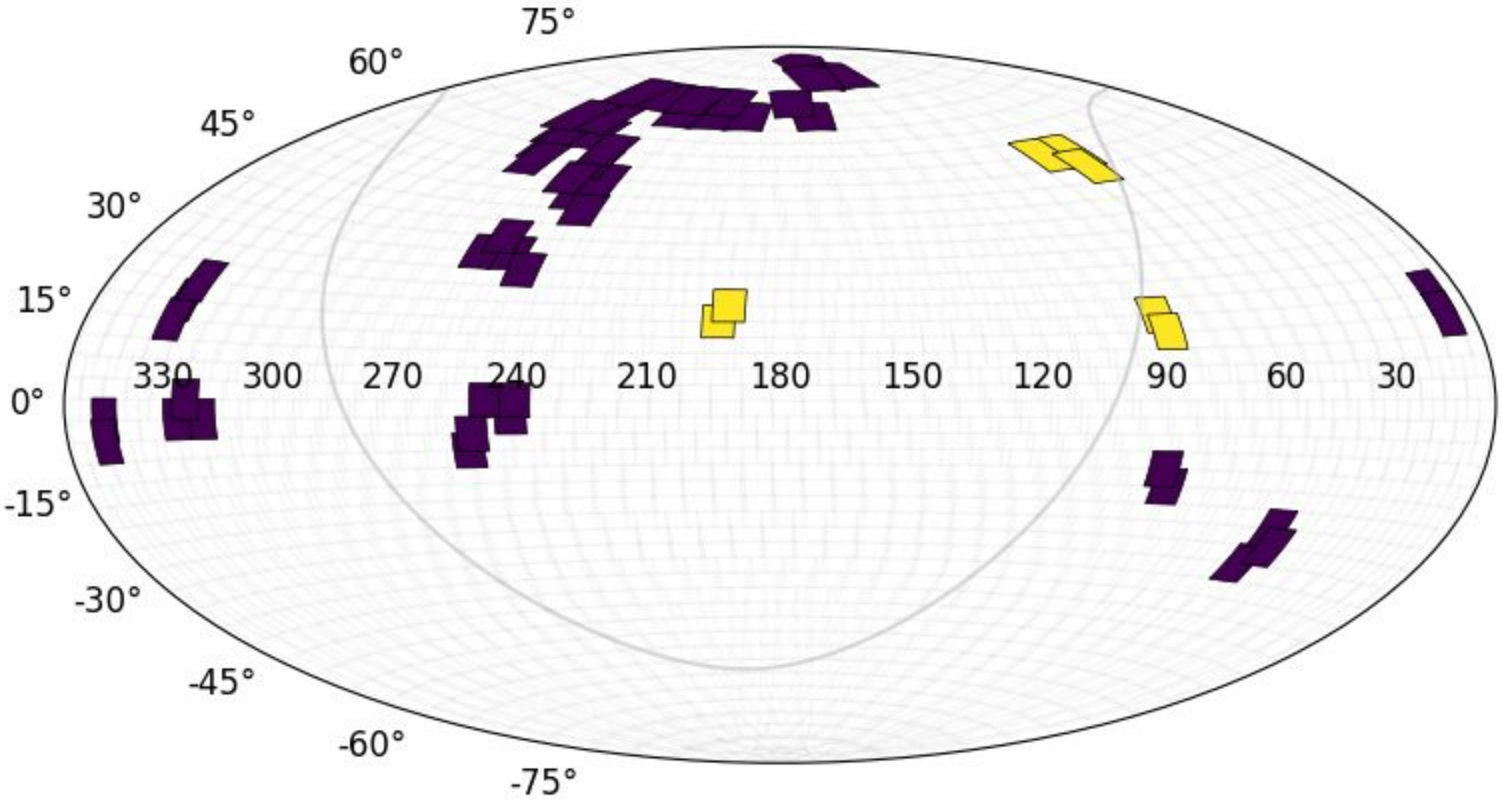
The Pantheon+ Analysis: SuperCal-Fragilistic Cross Calibration, Retrained SALT2 Light Curve Model, and Calibration Systematic Uncertainty

DILLON BROUT,[1,2] GEORGIE TAYLOR,[3] DAN SCOLNIC,[4] CHARLOTTE M. WOOD,[5] BENJAMIN M. ROSE,[4] MARIA VINCENZI,[4] ARIANNA DWOMOH,[6] CHRISTOPHER LIDMAN,[7,8] ADAM RIESS,[9] NOOR ALI,[10] HELEN QU,[11] MI DAI,[9] AND CHRISTOPHER STUBBS[12]

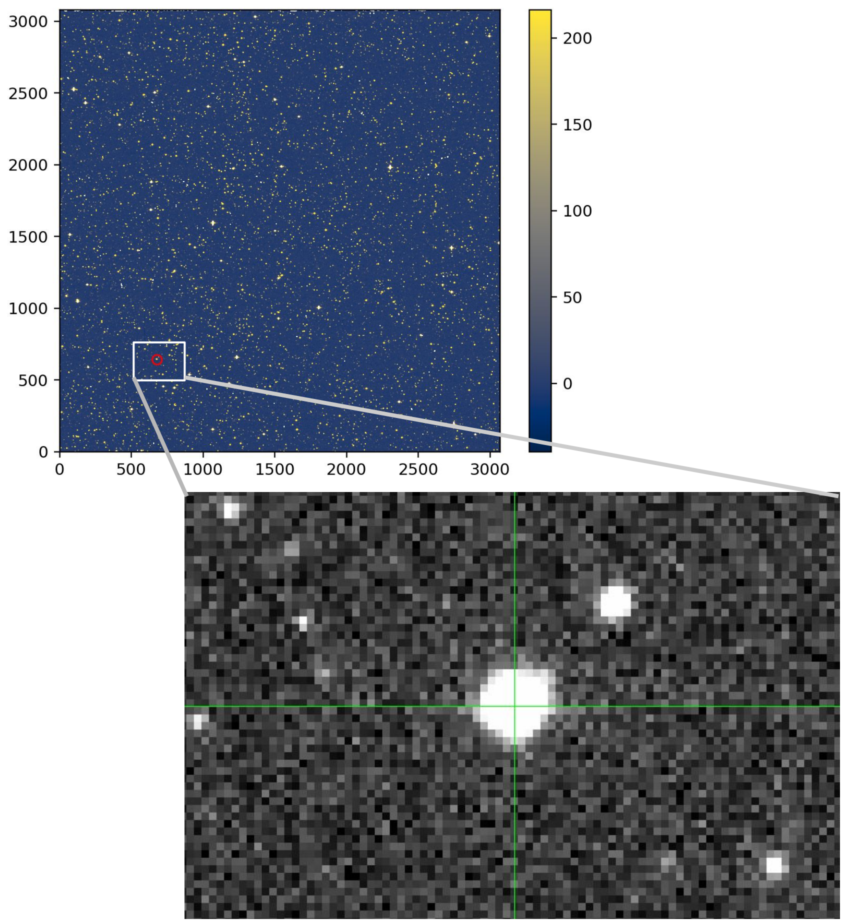


ences arising from updates to the CALSPECs. The most recent and improved stisnic 007/008 and stiswfcnic 002 versions of the CALSPECs results in a 1.5-2% change from g/B to I/z, $\sim 3\times$ larger than the expected systematic uncertainty of the CALSPEC calibration of $\sim 0.5\%$ over 7000 A. These changes in the absolute calibration due to the update of the CALSPEC standards have the largest impact in our analysis when comparing to the previous Betoule et al. (2014) and SuperCal calibrations. Since this is a change in the reference, this affects the inferred zeropoint offsets of all SN samples.

ZTF fields with CALSPEC stars



Primary flux standards in the ZTF exposures



CALSPEC primary standards (WD with models) *are just normal ZTF stars*:

- GD71 V ~ 13.032
- GD153 V ~ 13.34
- ~~G191B2B V ~ 11.78~~

Saturated in most exposures

Plus O(30) CALSPEC secondary standards (HST STIS/NICMOS spectra) with 12 < V < 16

all ra
dec > -30

6 month here: 2019-03 to 2019-08