The University Of Sheffield.

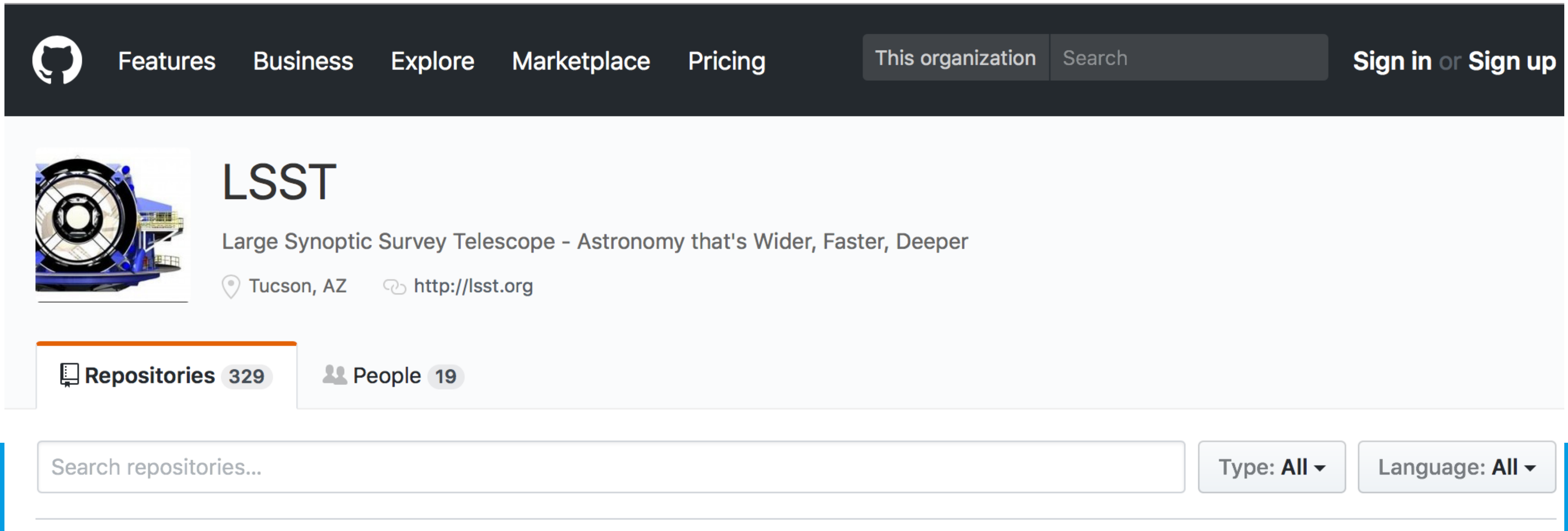
Processing other wide-area surveys with the Rubin Science Pipeline

James Mullaney & Lydia Makrygianni
+ The GOTO Collaboration

arXiv: 2010.15142 and 2105.05128

What is the Rubin Science Pipeline (the “LSST stack”)?

- It will deliver Rubin’s data products:
  - **Prompt:** Nightly processing; sources that have changed in brightness/position; catalogues from difference imaging.
  - **Data Release:** Annual release of coherent processing of entire dataset to date; fluxes, shapes, variability, light curve description.
- Written in:
  - Python (high level “calling” scripts)
  - C++ (lower level calculations)
- Designed to be a standard processing pipeline for other wide-field surveys.



LSST

Large Synoptic Survey Telescope - Astronomy that's Wider, Faster, Deeper

Tucson, AZ   http://lsst.org

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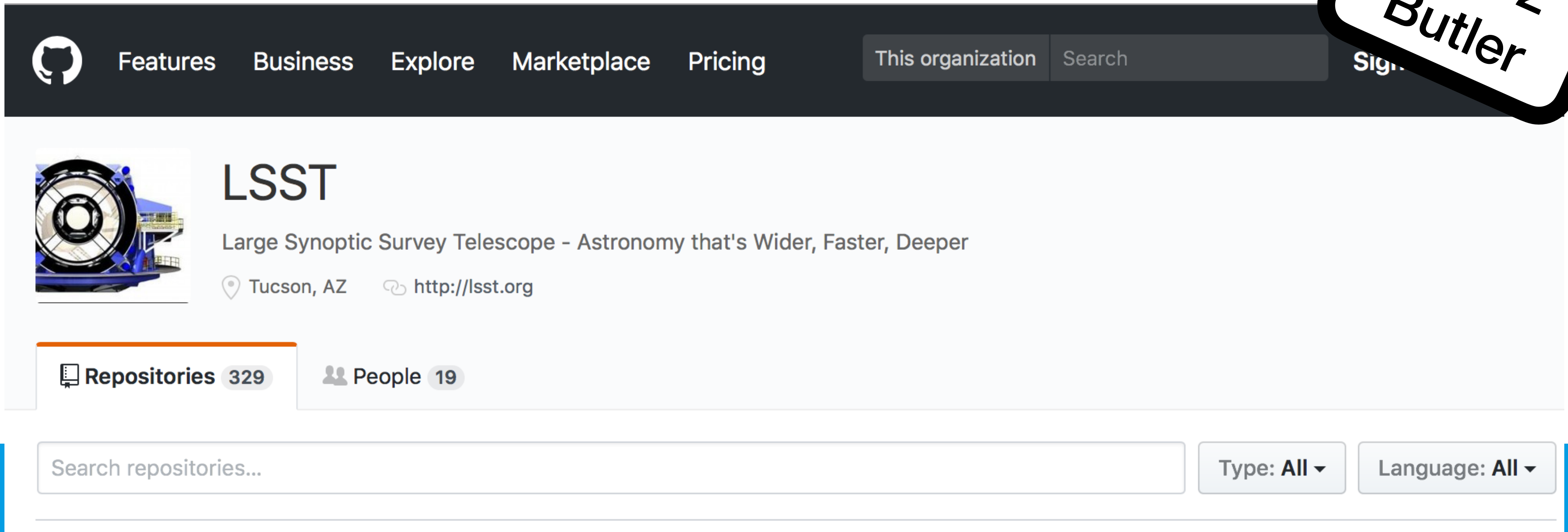
! Gen 2 Butler



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Our experience with the LSST stack

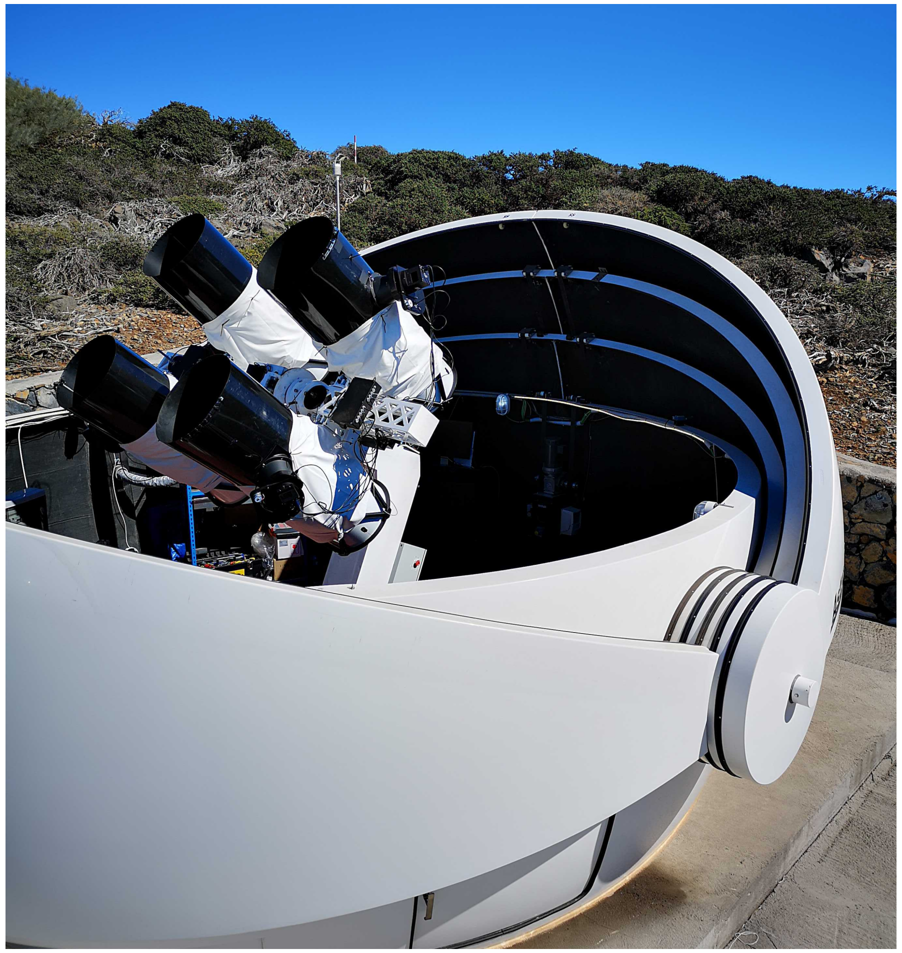
- GOTO:
  Gravitational-wave Optical Transient Observatory*

- Currently 8 x 40cm, 5 sq. deg FOV `scopes on common mount on La Palma.

- Expanding to 32 `scopes (16 north, 16 south).

- Conduct high-cadence survey to 20th mag & follow-up LIGO triggers.

- Total FOV, cadence and desired outputs similar to LSST.



- In addition to in-house pipeline, we also used the LSST stack to process GOTO data:

  - created static coadded images;

  - coadds used as reference for nightly forced photometry.

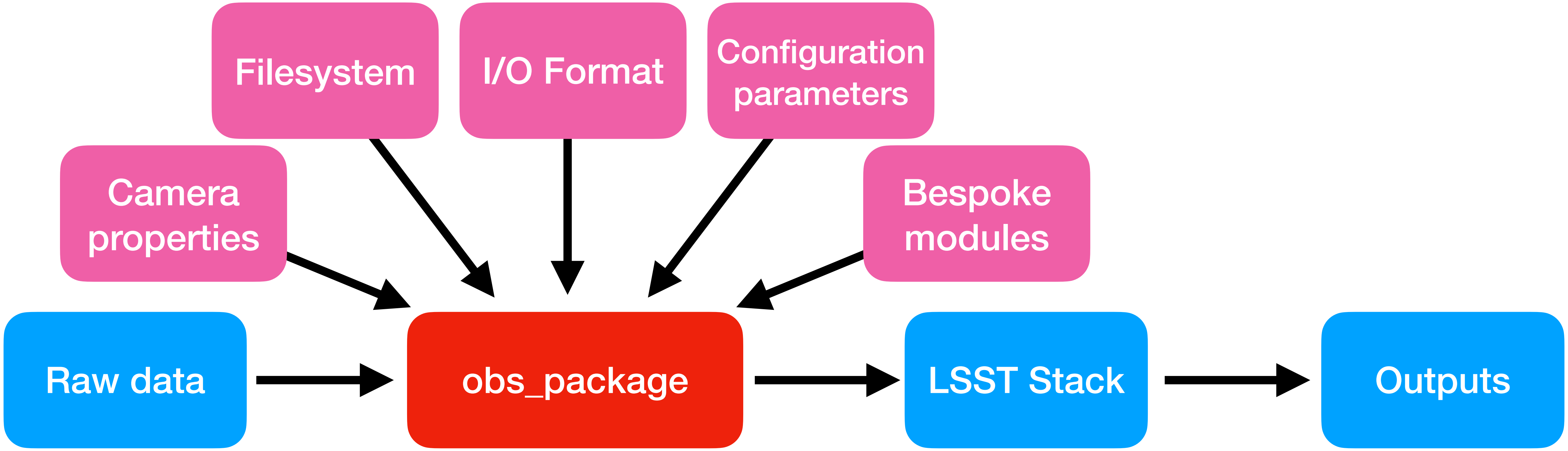
*Warwick, Monash, Sheffield, Leicester, Armagh, NARIT, IAC, Turku, Manchester, Portsmouth

Adapting the LSST stack to other surveys

The obs package

The LSST stack needs to know a lot of information about your telescope/images/system.

This is communicated via an “obs package”…



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- Organises raw input frames (database of image type, date etc);
- Instrument signature removal (i.e., bias, dark, flat correct);
- Background subtraction;
- PSF modelling;
- Astrometric and photometric calibration.

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Calibrated Exposures (calexps)

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- Source detection and deblending;
- Photometry (aperture, PSF, Guassian, Kron, CModel, deVauc., etc.);
- Shape measurement;

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- Deep detection, photometry and catalogue merging;

Outputs → **Coadded exposures and merged catalogues**

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- Forced photometry, difference imaging.

Outputs → **Nightly forced photometry and diffims.**

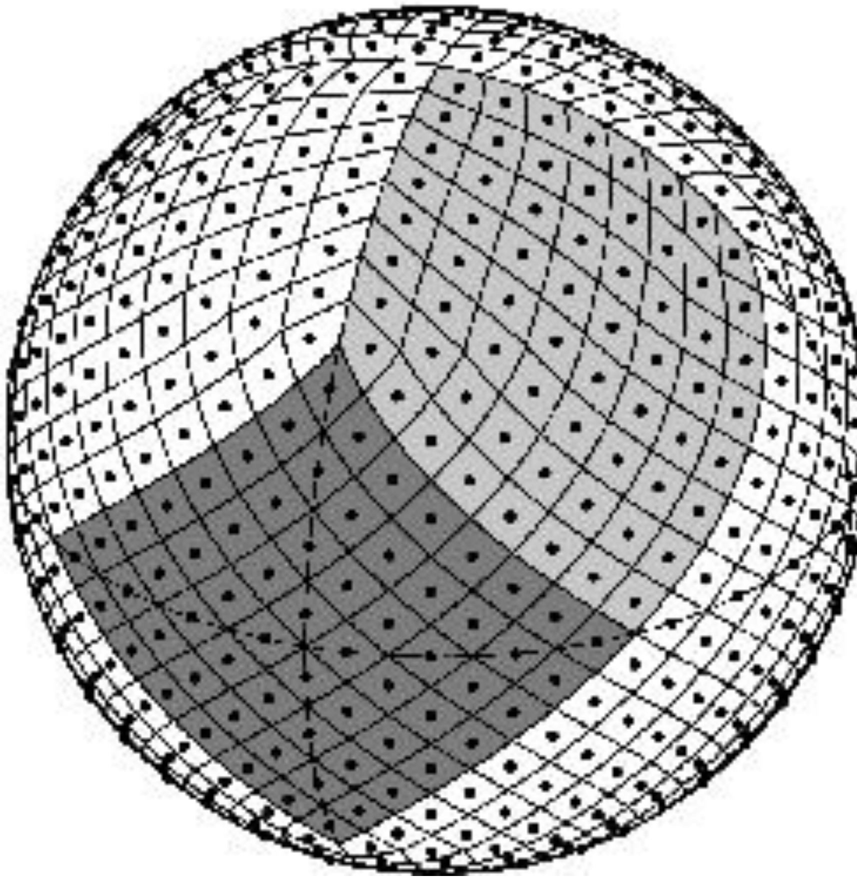
Coaddition

The depth of the LSST survey is achieved via the coaddition of multiple epochs of data.

Prior to coaddition, the Stack re-projects calexp images onto a single sky map (e.g., HEALPix).

Involves warping each calexp onto the sky map (CPU-intensive & slow).

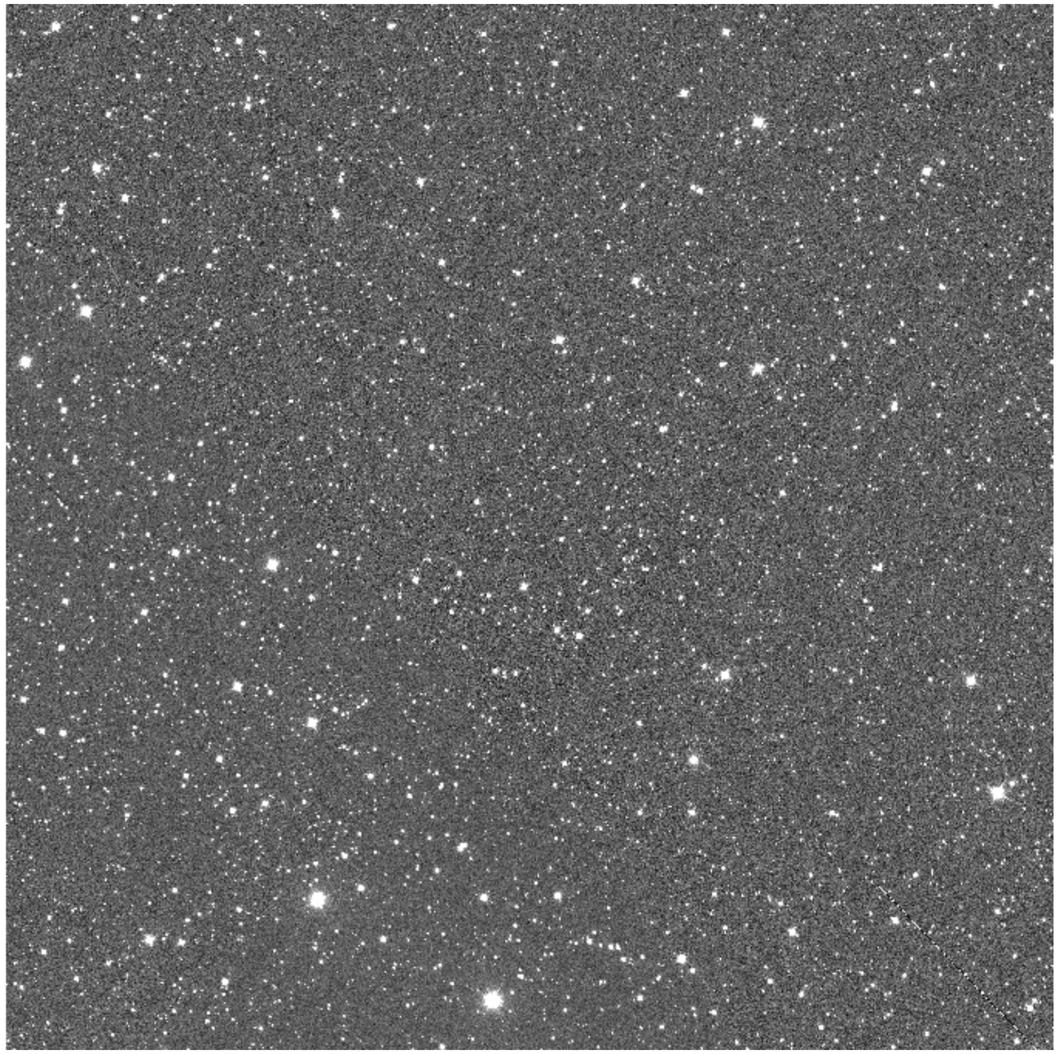
However, once warped, any combination of exposures can be combined to produce a coadd (fast).



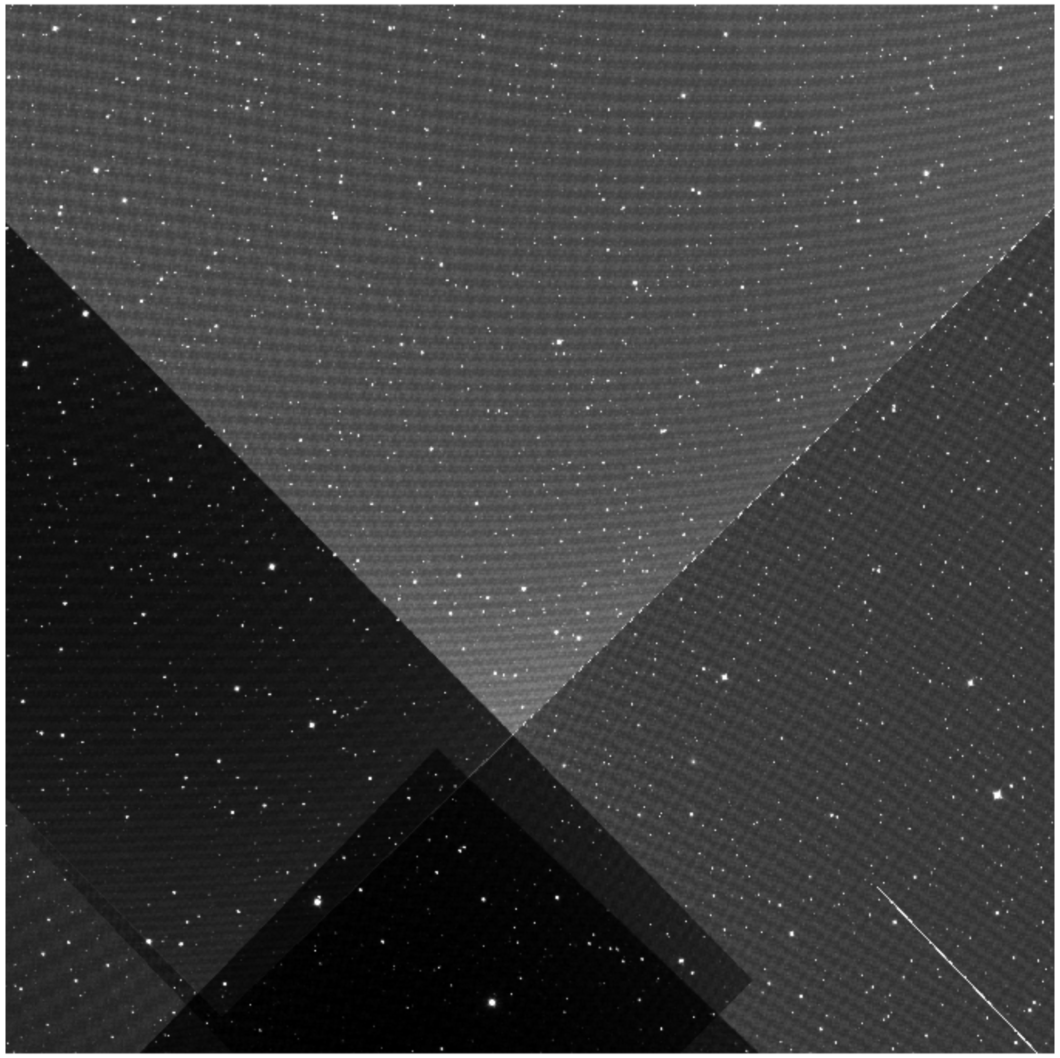
HEALPix projection

Coadd bookkeeping

…and each warped science image and coadd comes with its own variance image to ensure errors are propagated correctly…



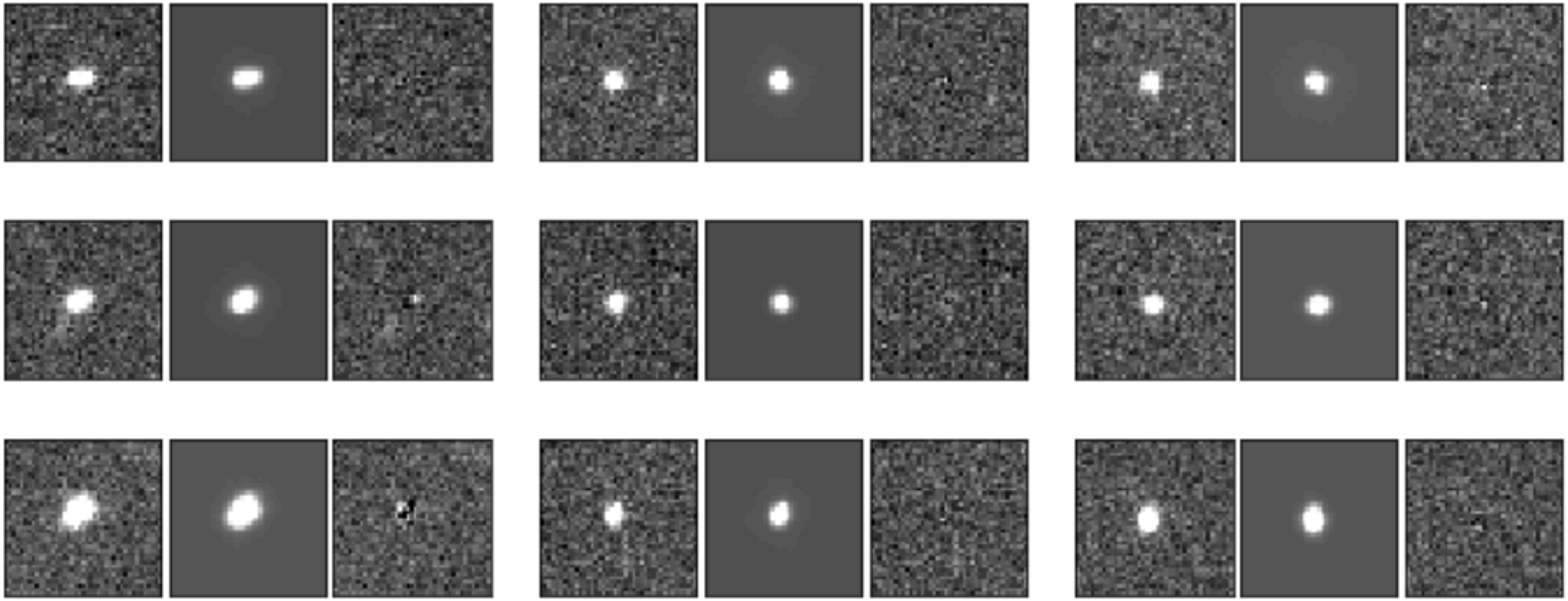
Warped and coadded GOTO science image



Accompanying variance image

PSF Modelling

Results from PSF-fitting using Principal Component Analysis:

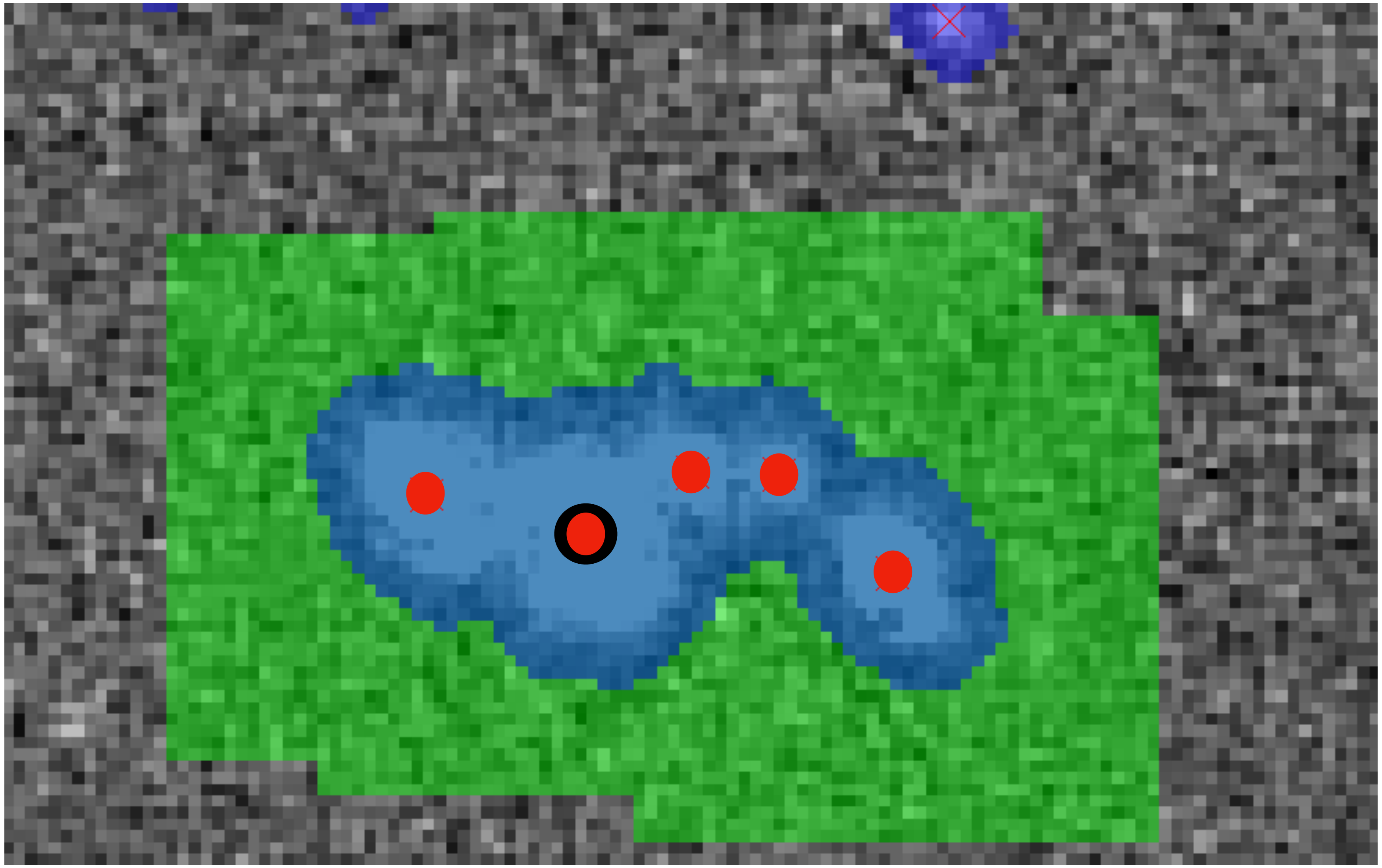


Images show the variation of PSF across one of our GOTO exposures, with top left group corresponding to top left of image, and so on. Each group of three sub-images show the original PSF, the modelled PSF, and the residuals.

***our implementation!**

Deblending

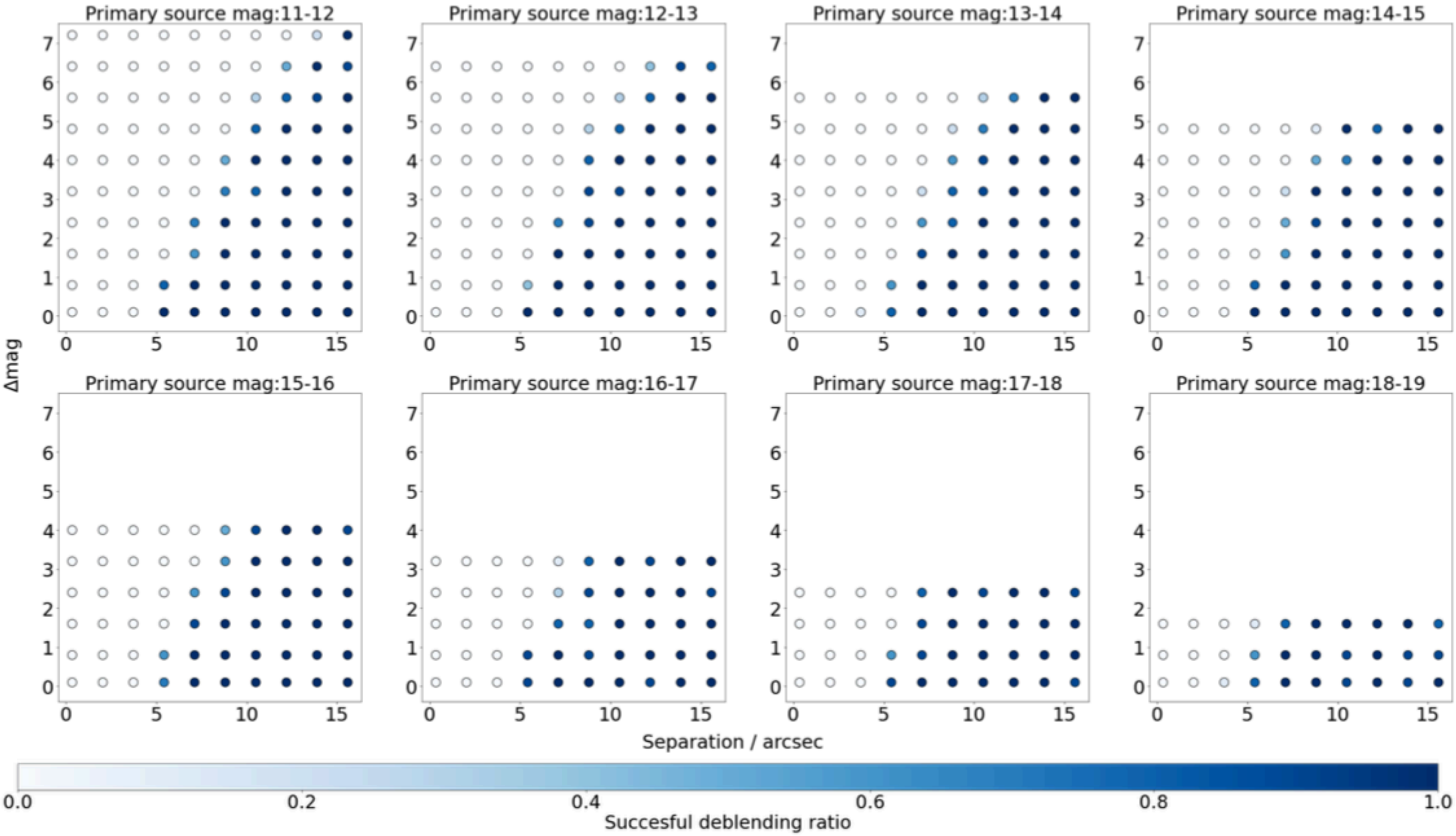
Results from meas_deblender (as opposed to SCARLET)



With GOTO’s pixel scale and PSF differing significantly from that of Rubin’s, a lot of effort went into adjusting deblending parameters.

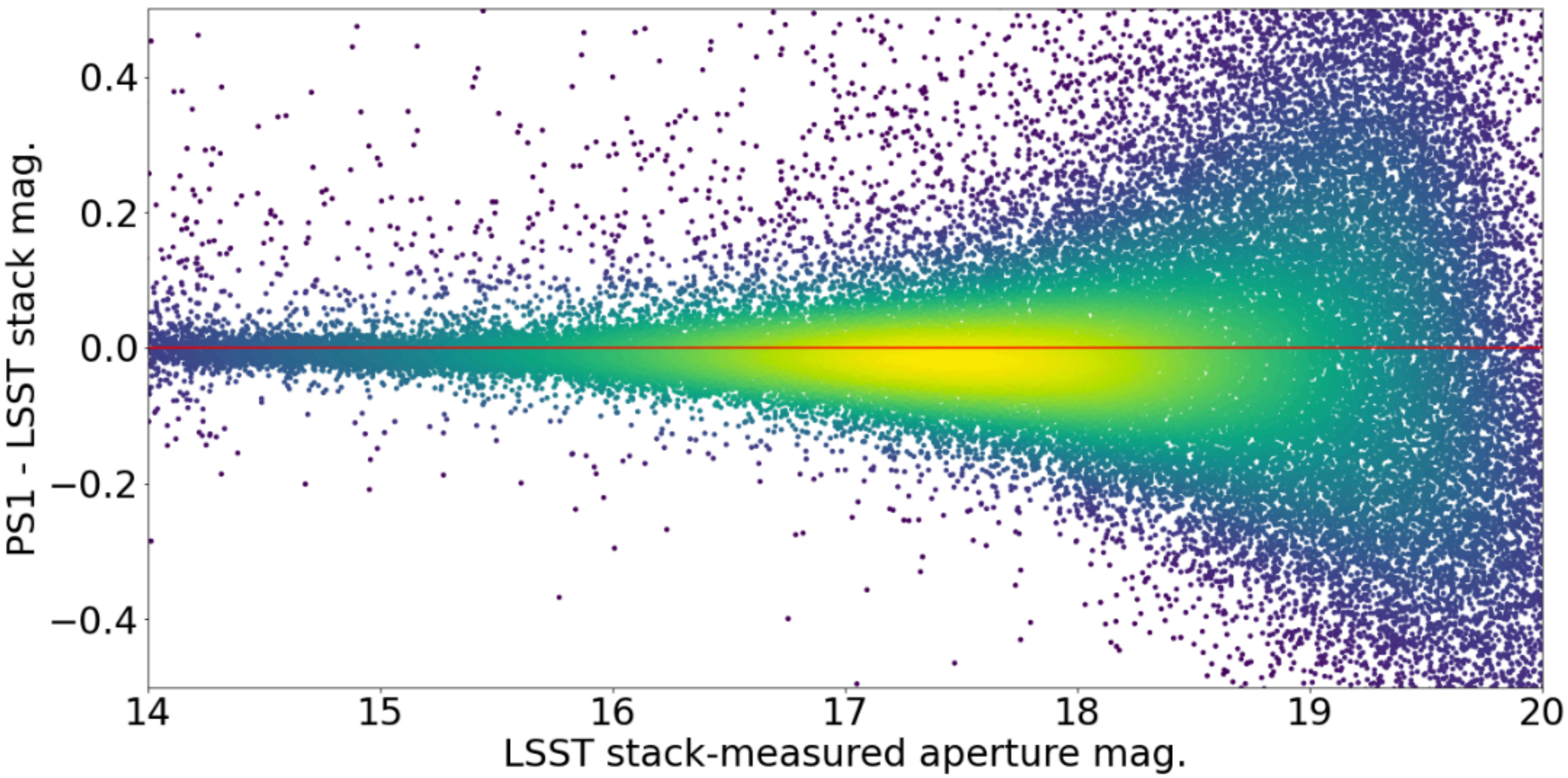
***our implementation!**

Deblending



*our implementation!

Coadd photometry



Photometric accuracy:
~ 20 mmag @ <16 mag
~ 200 mmag @ 18 mag

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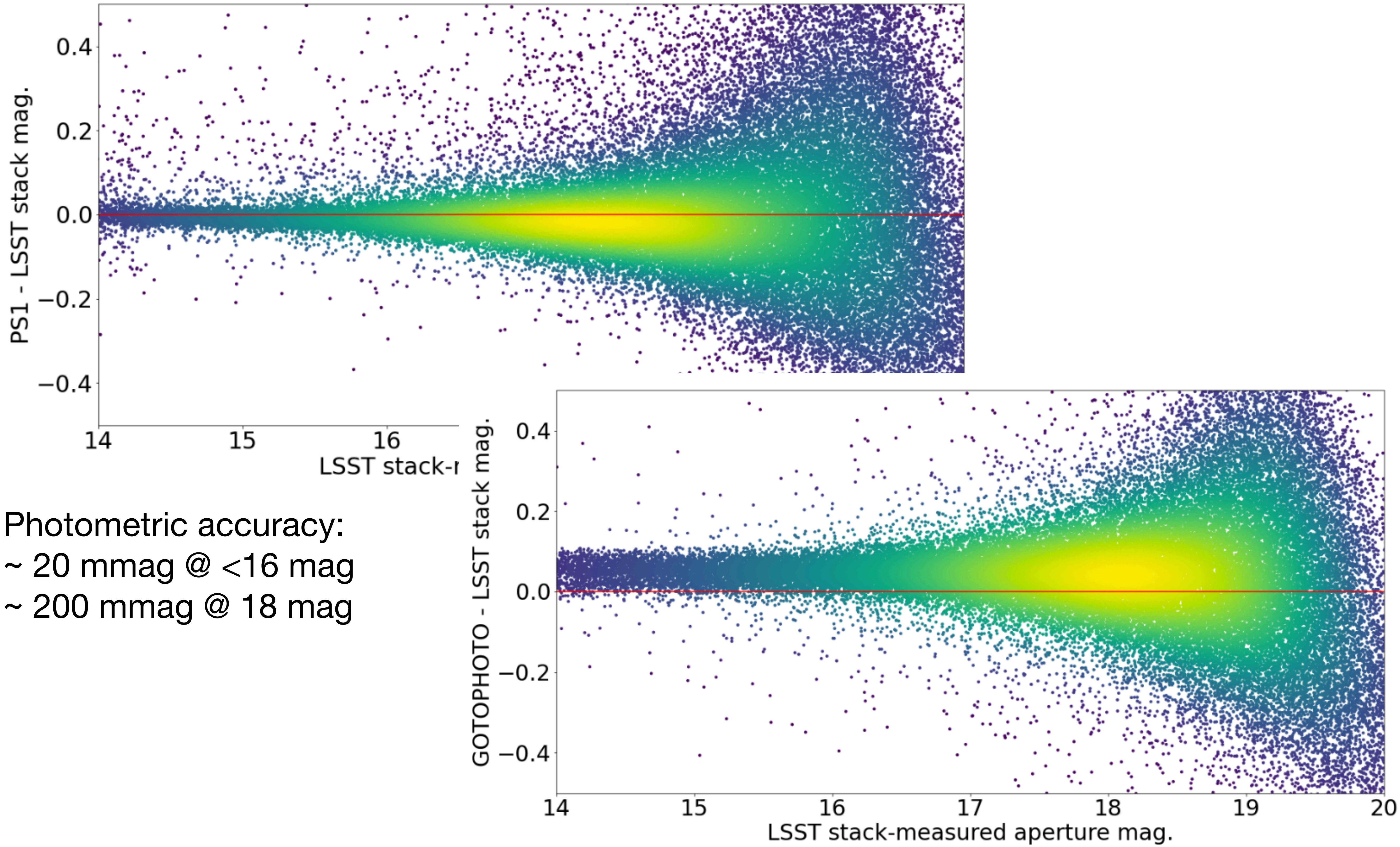

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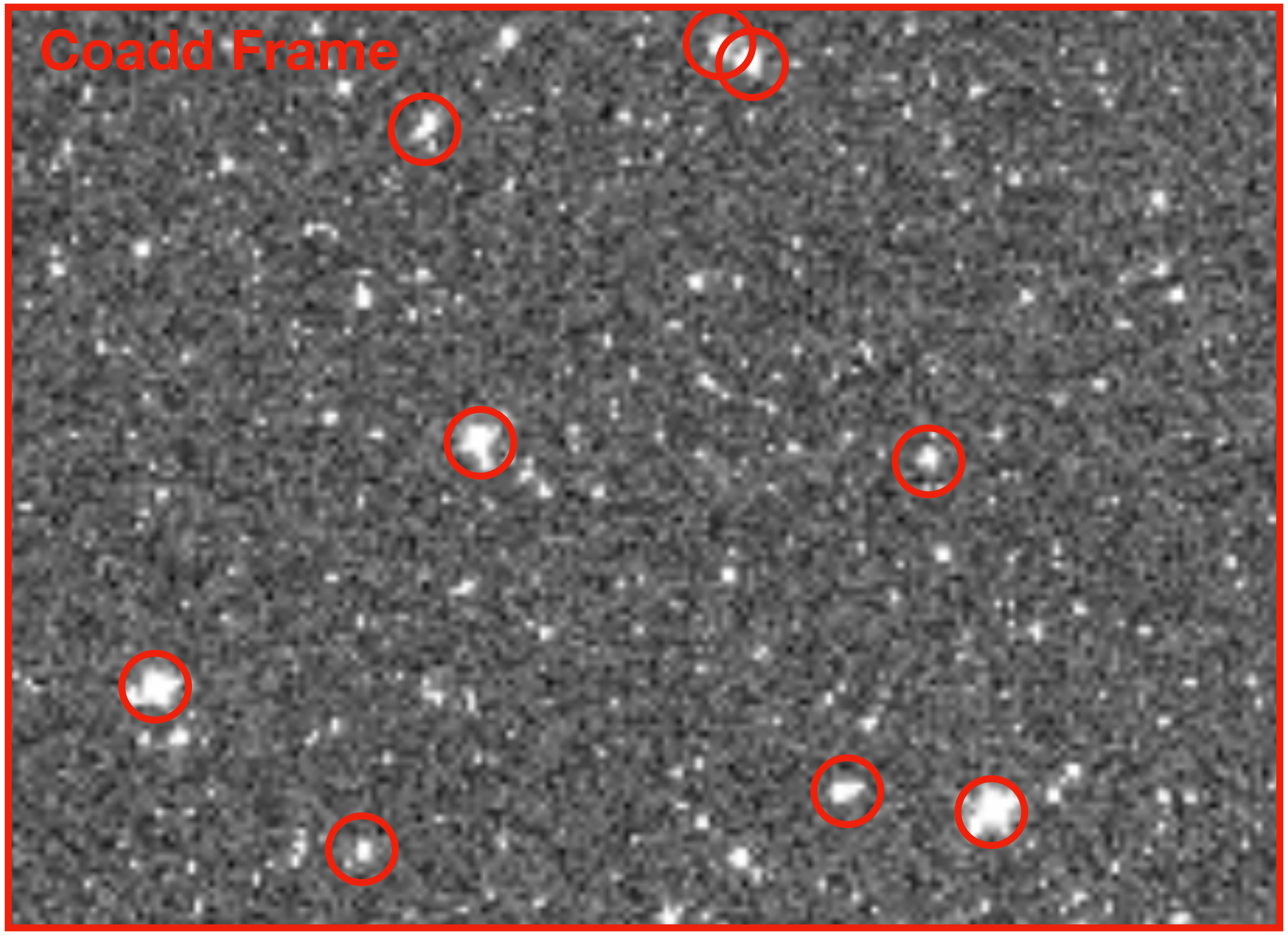
Forced photometry

Measure photometry at coadd-defined fixed positions on every new incoming frame:



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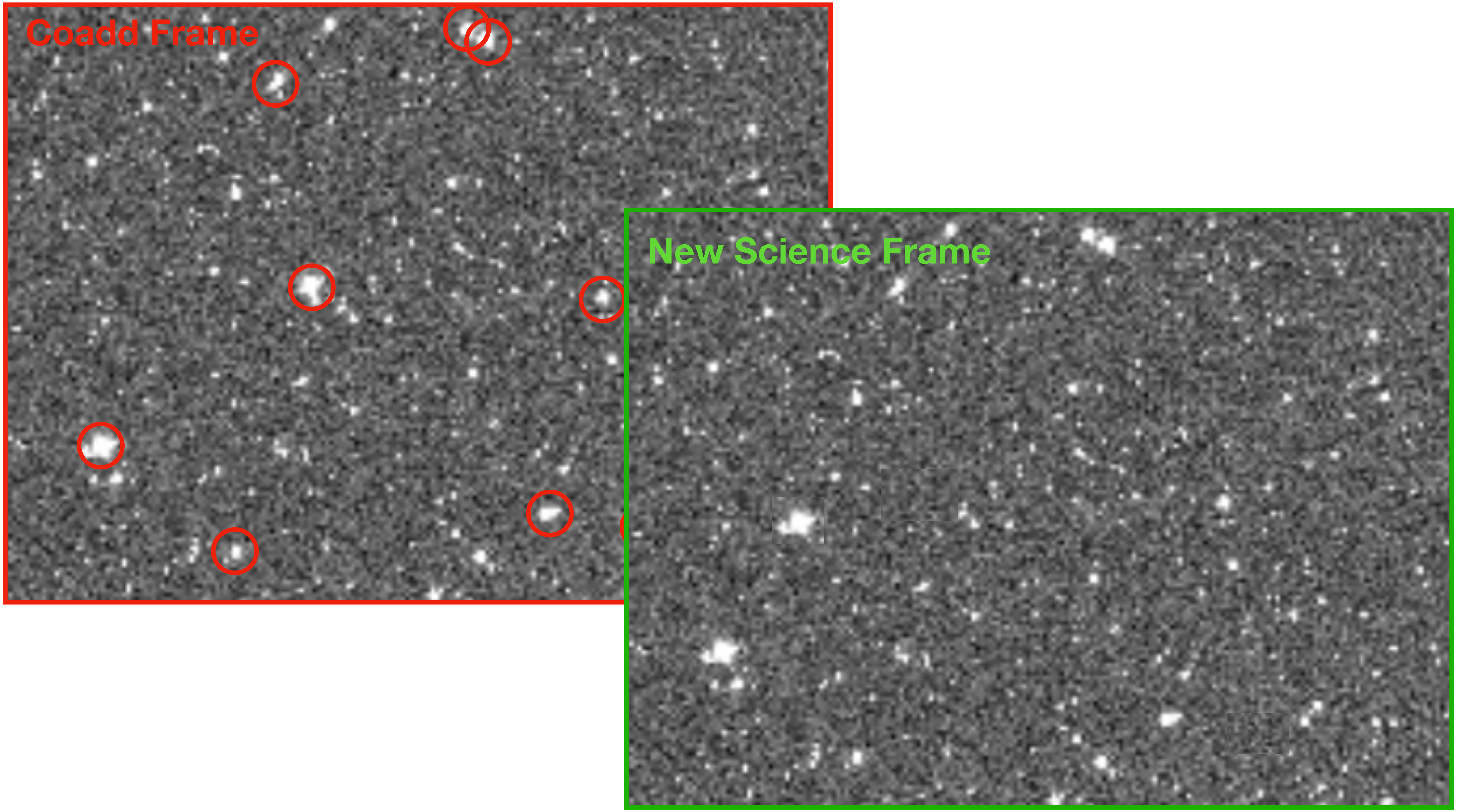

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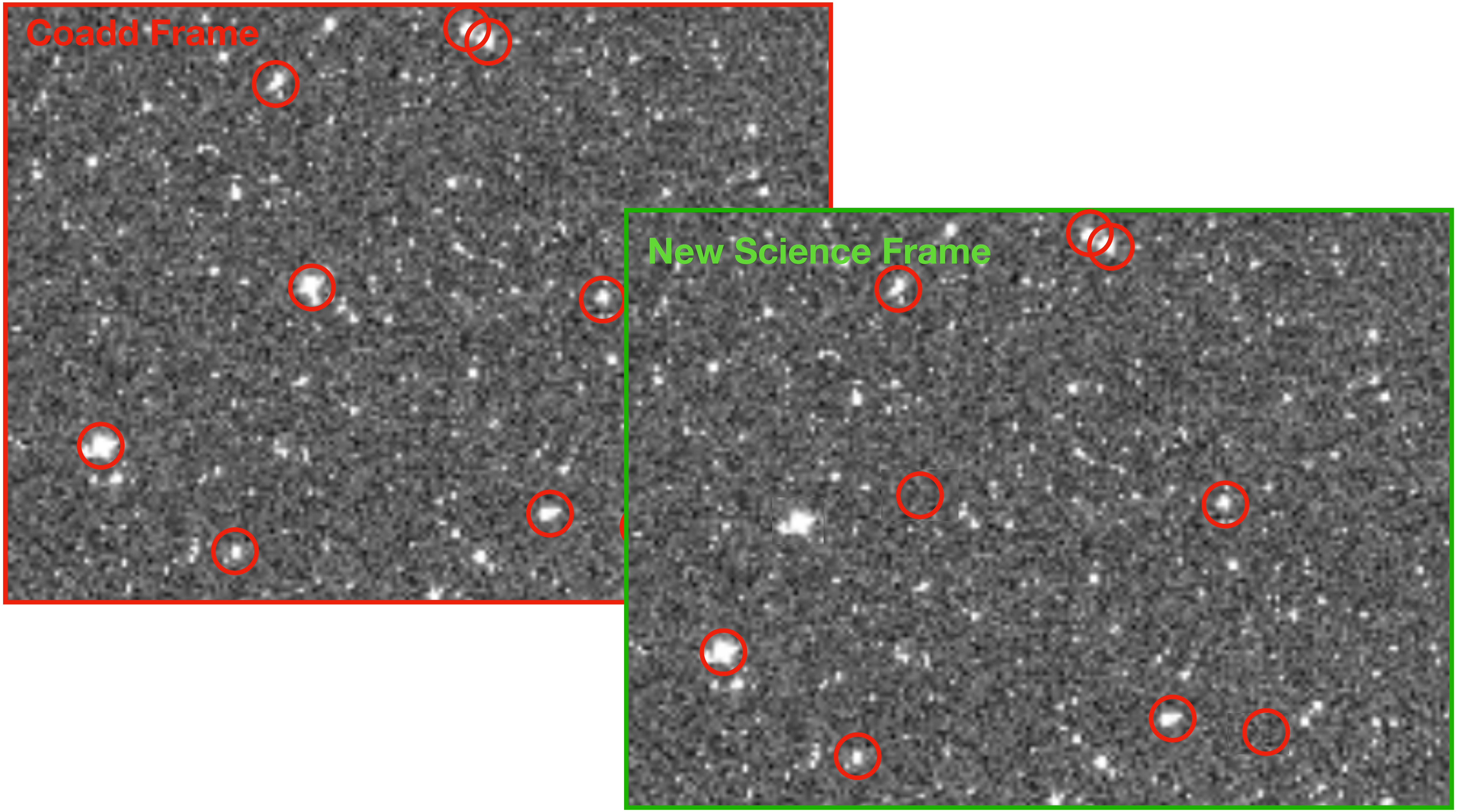

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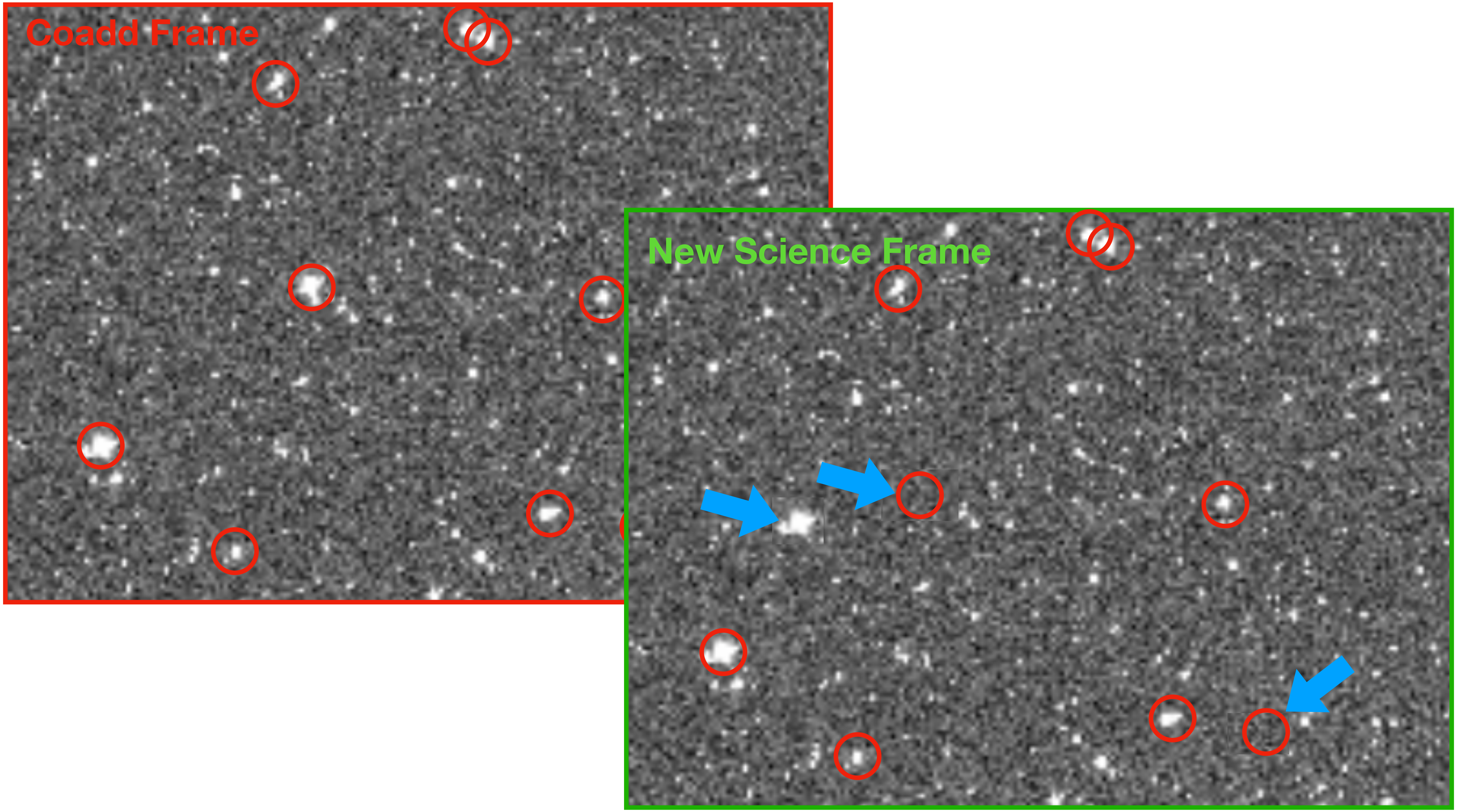
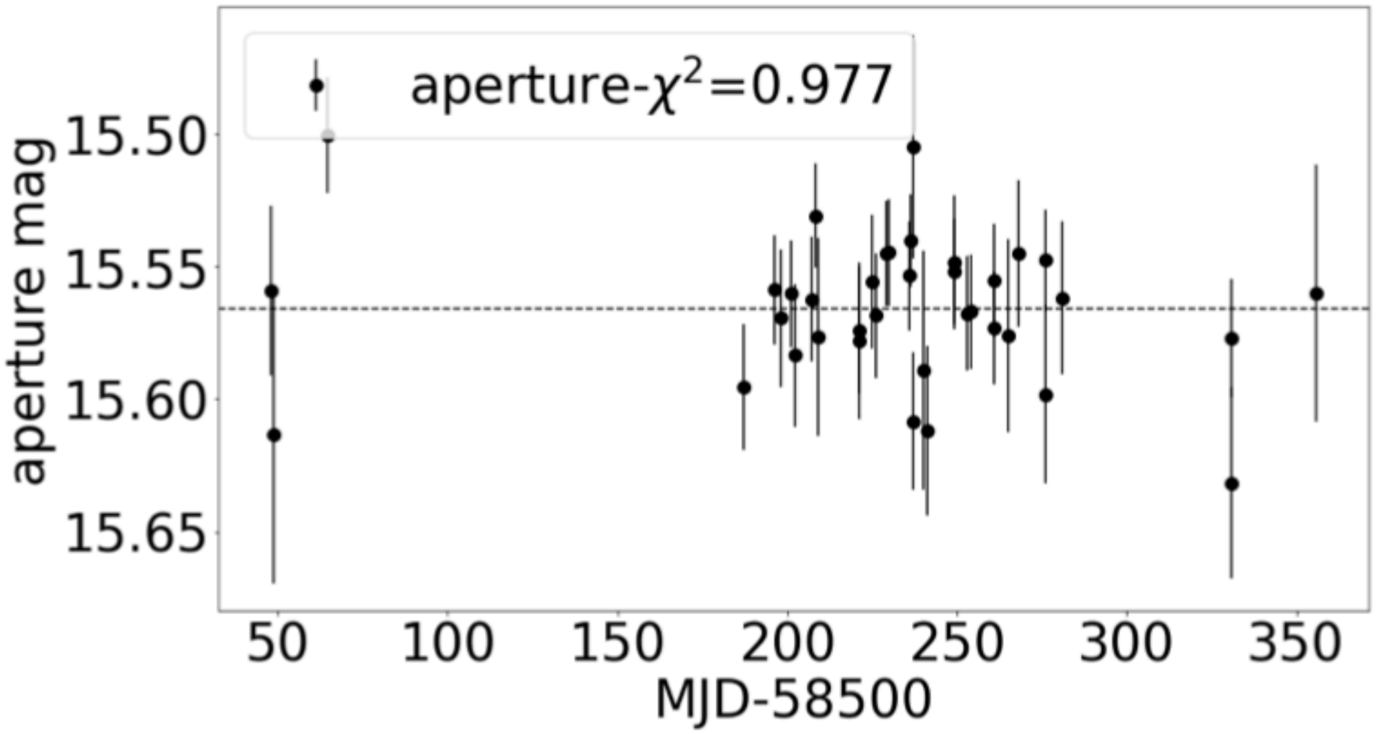


Forced Photometry Precision



Repeat measurement of non-varying sources allows us to test the precision of our photometry measurements…

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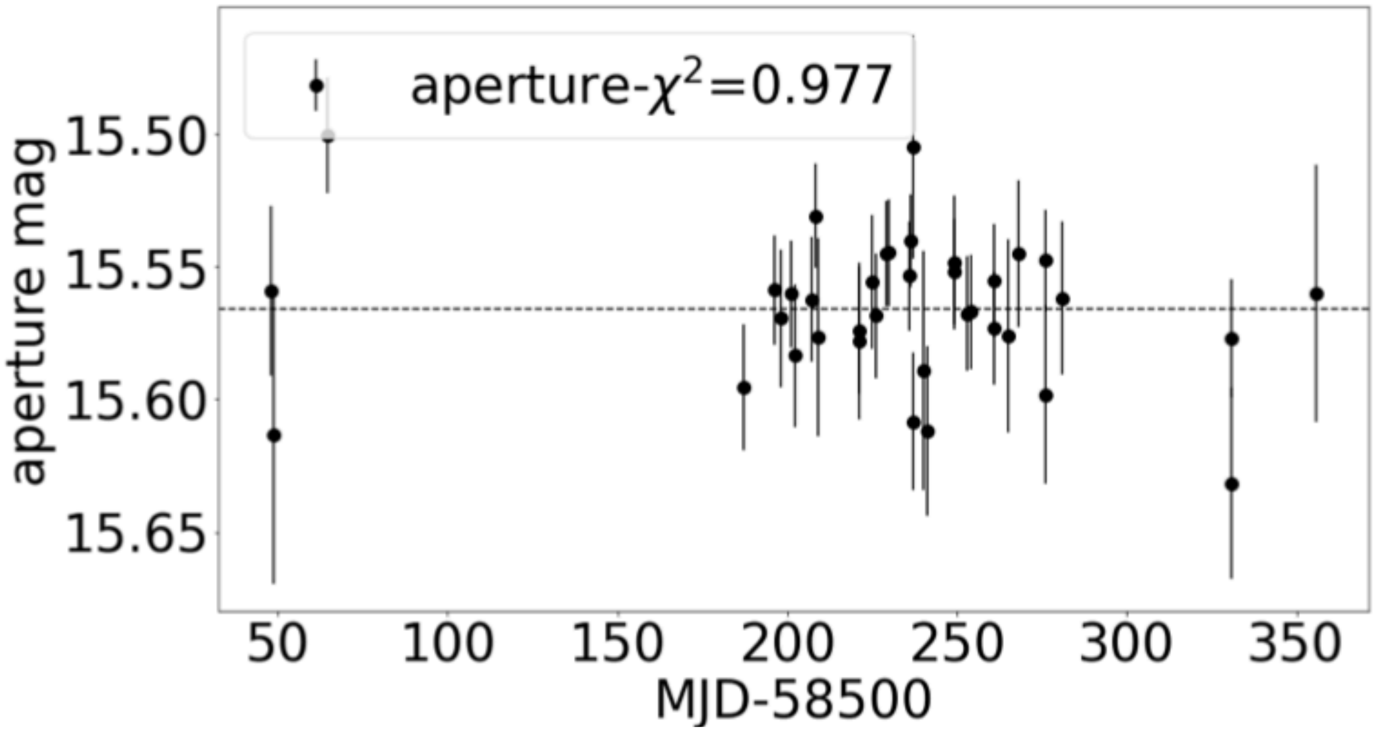

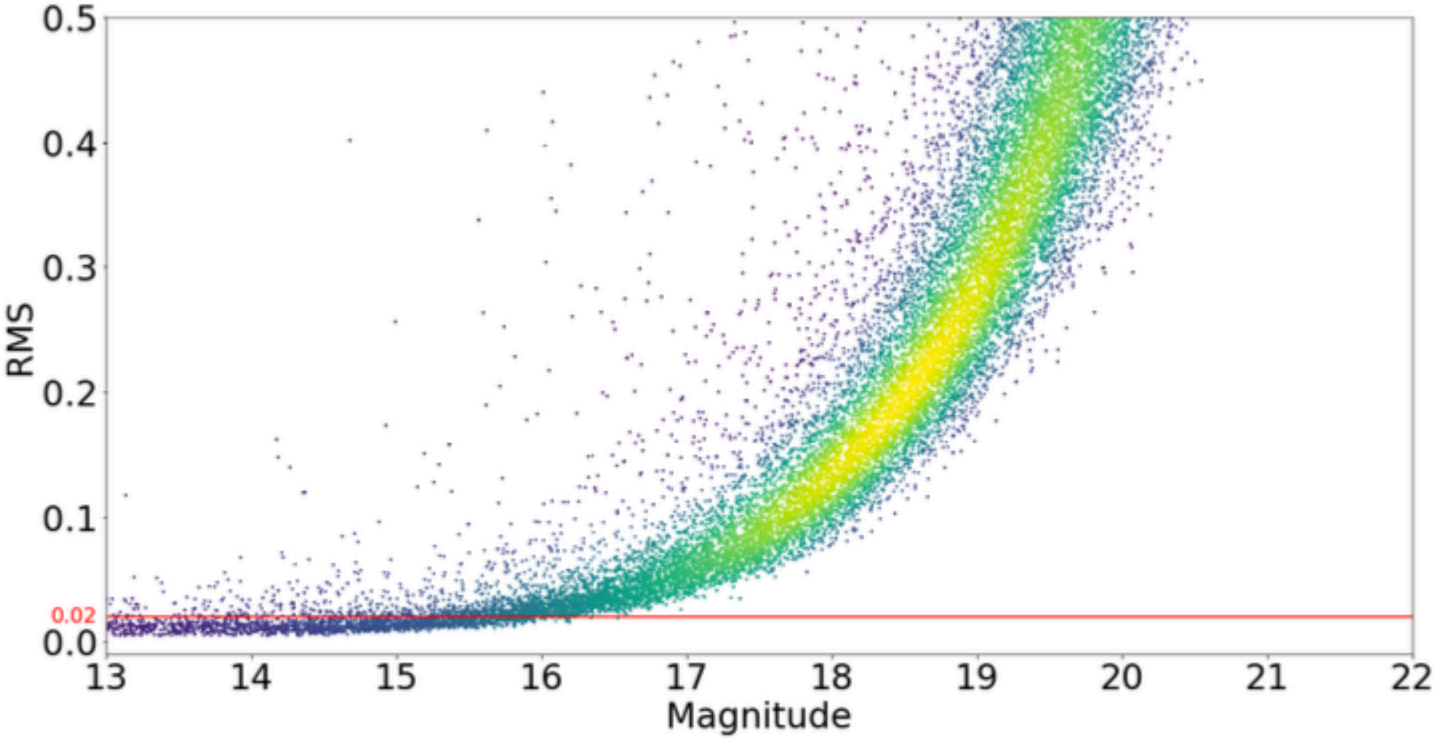

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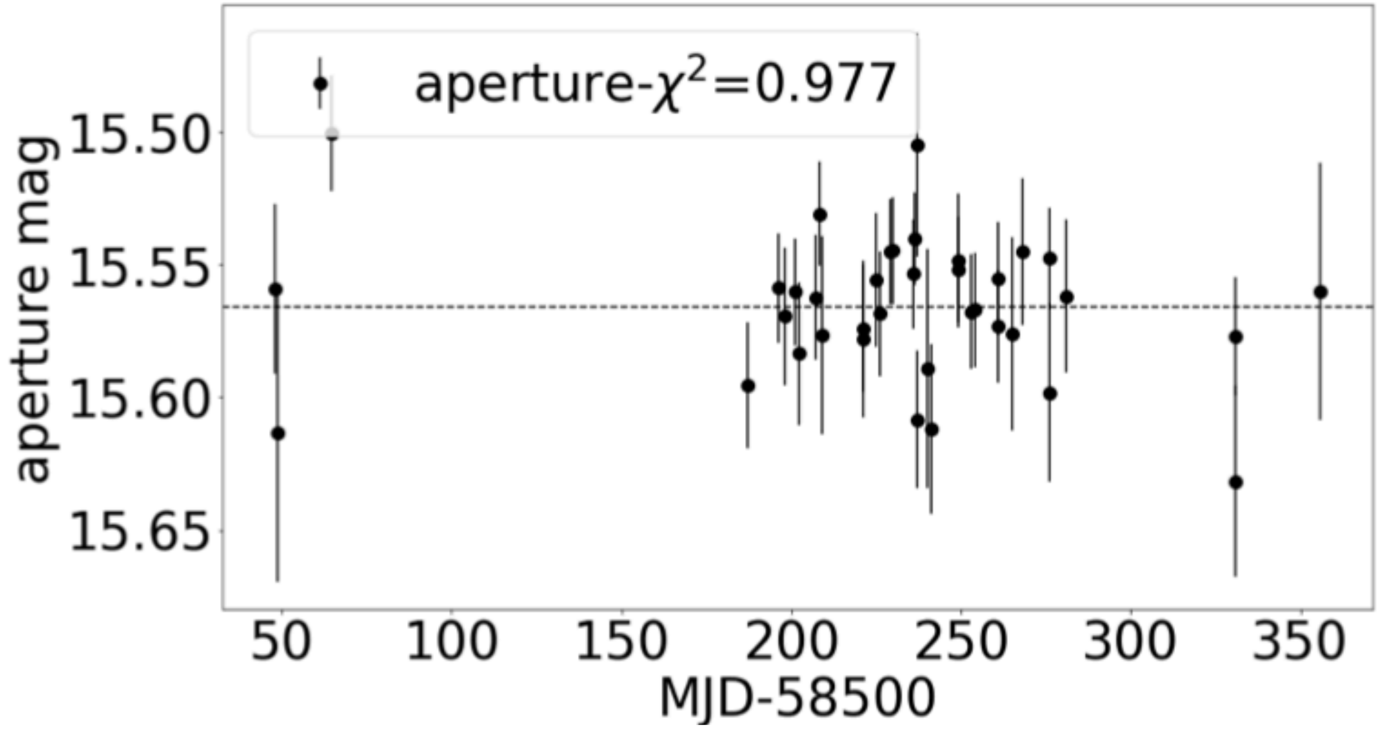

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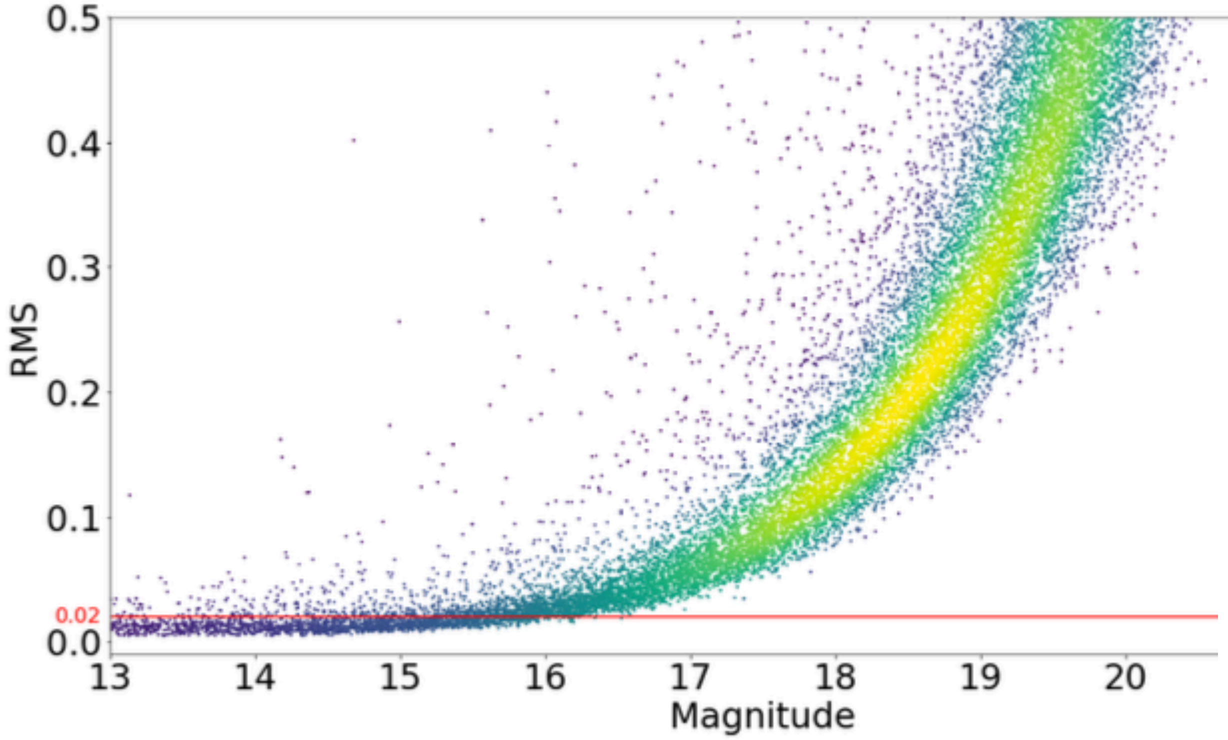

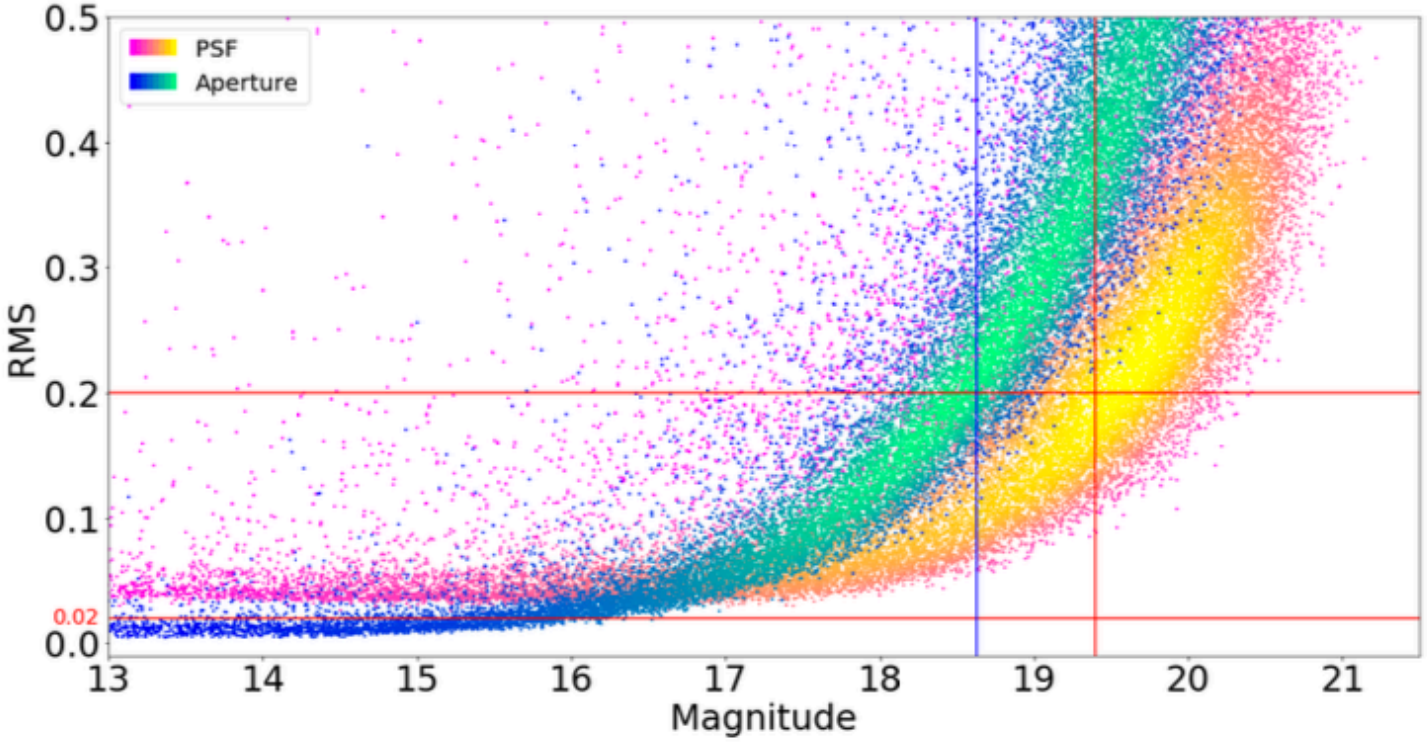

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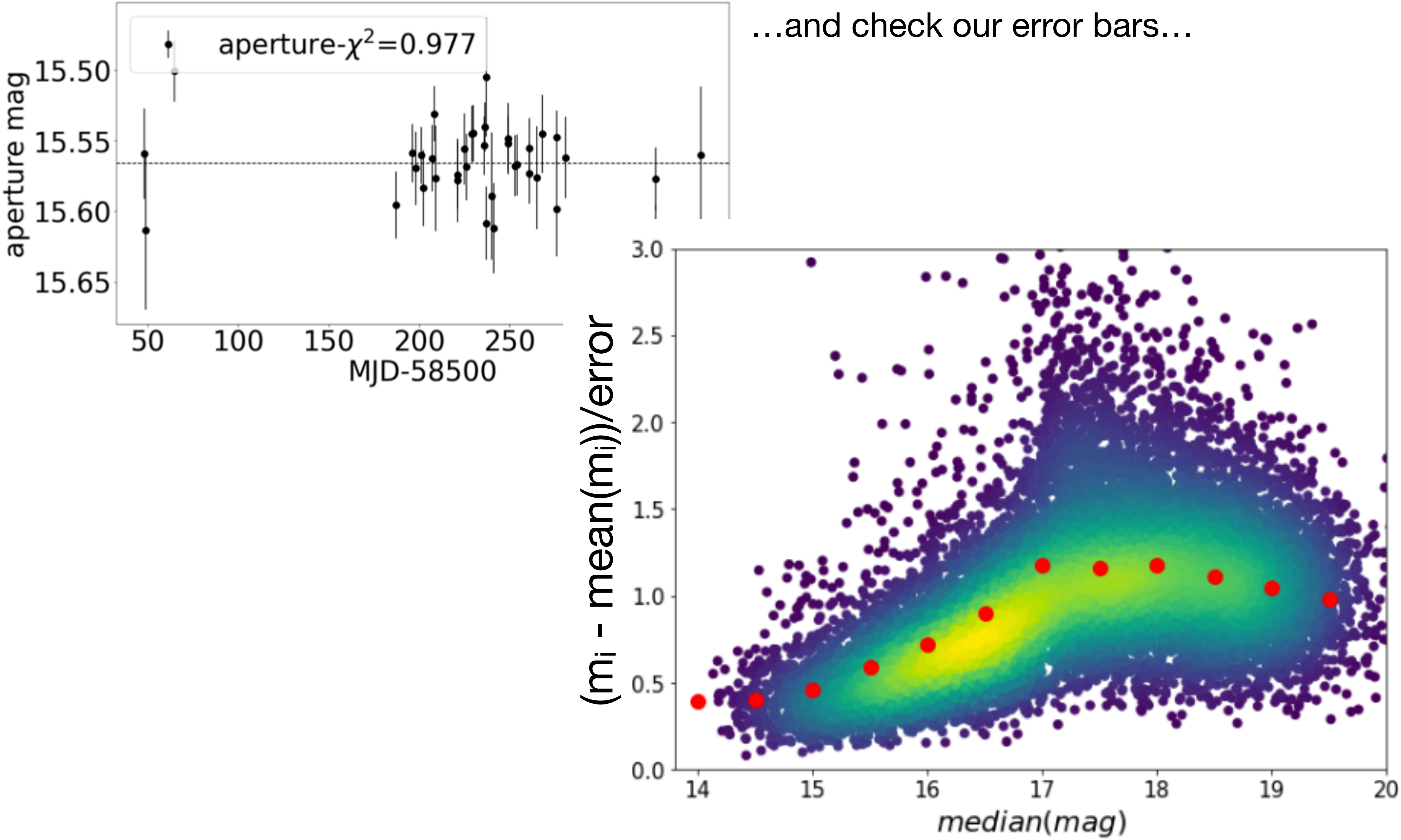

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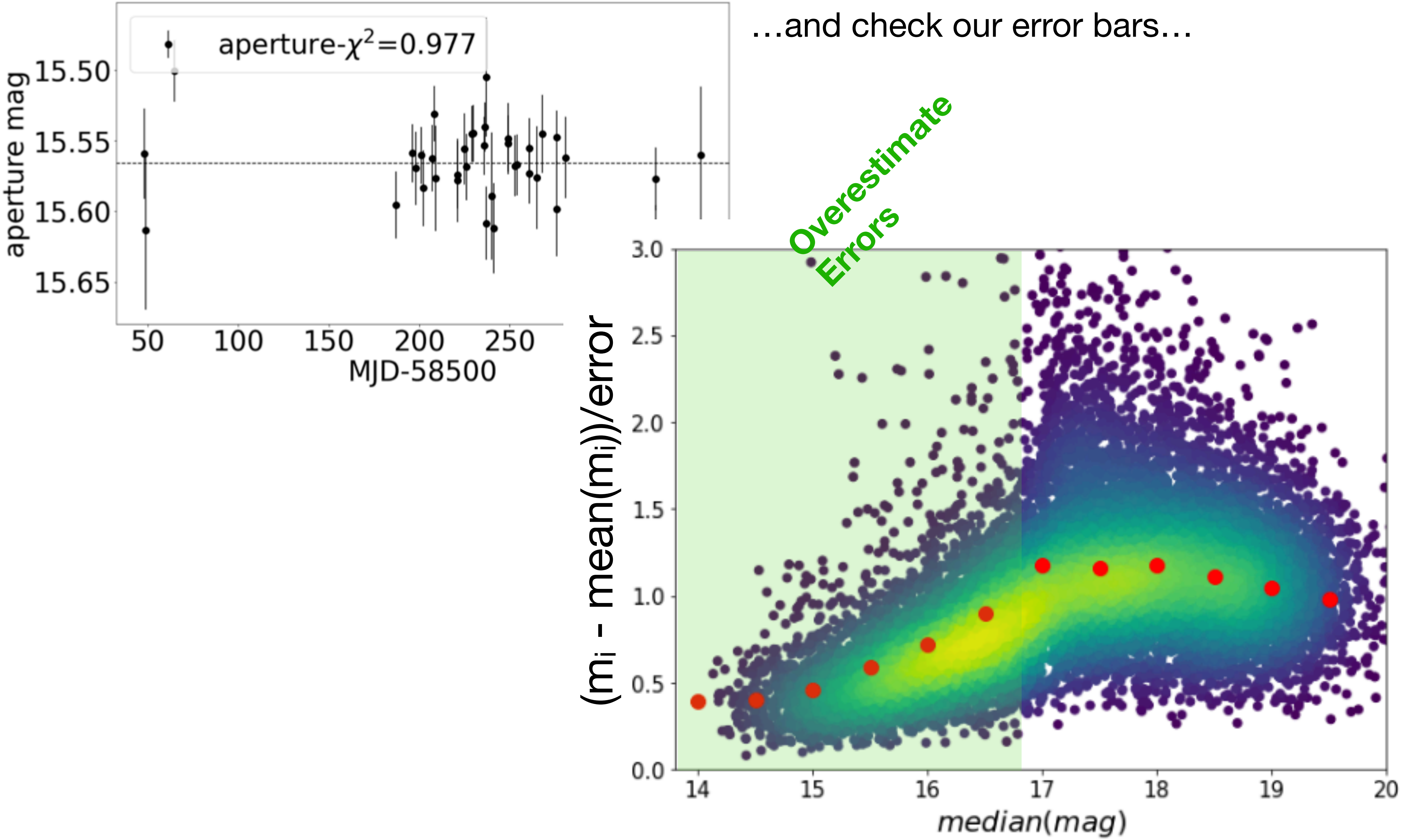

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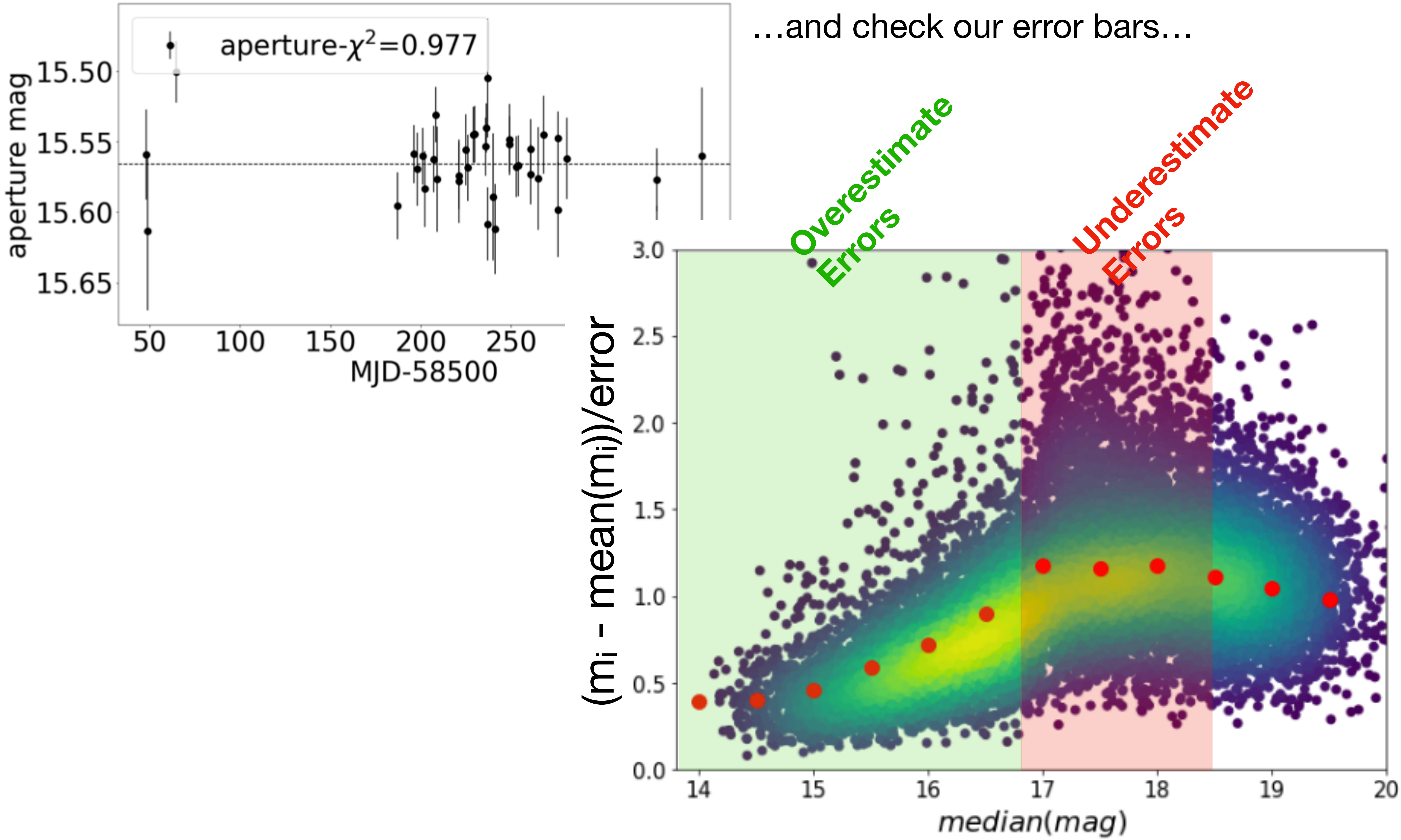
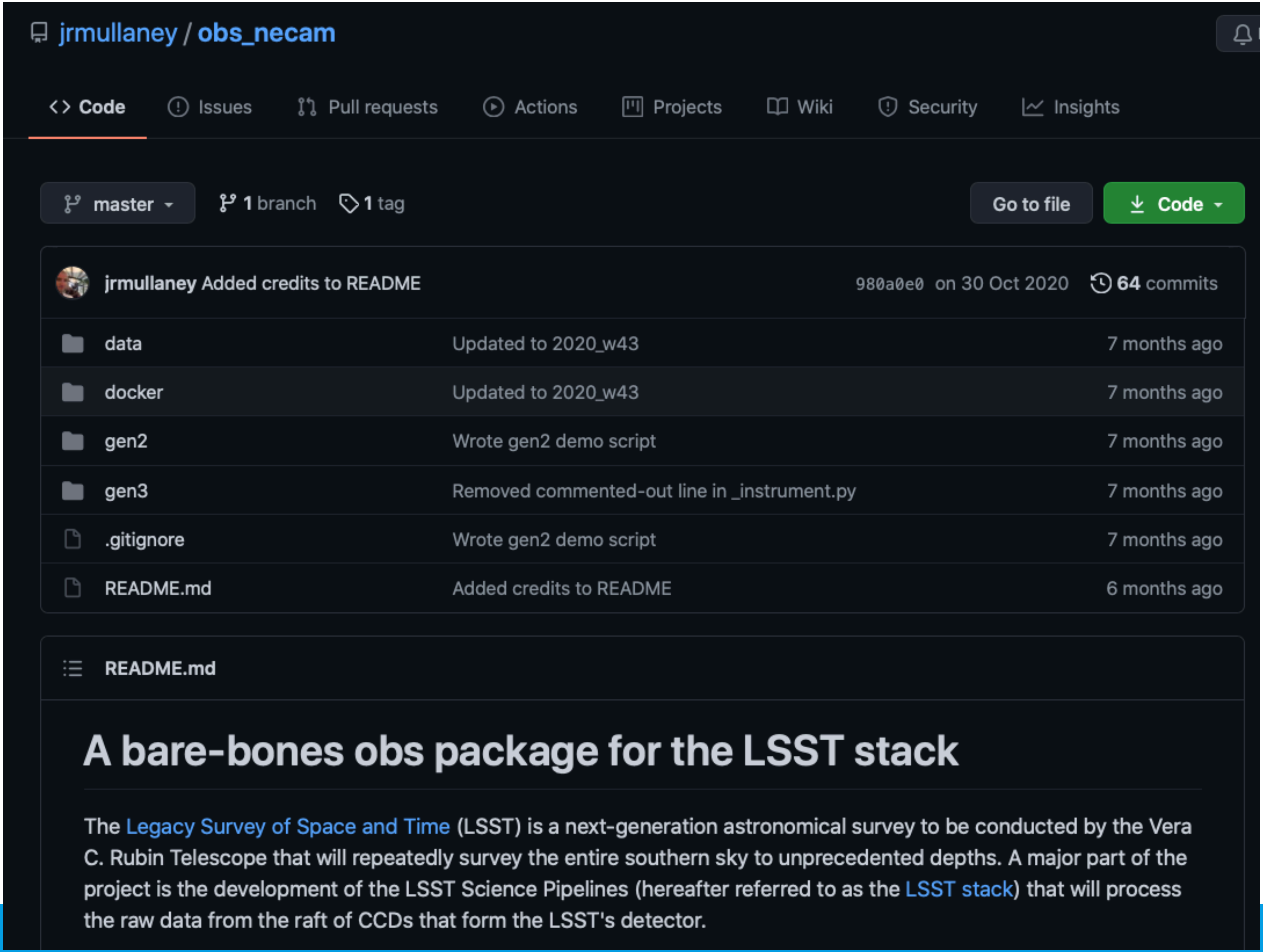


*our implementation!

obs_necam: a “bare-bones” obs package



jrmullaney / obs_necam

jrmullaney Added credits to README 980a0e0 on 30 Oct 2020 64 commits

data	Updated to 2020_w43	7 months ago
docker	Updated to 2020_w43	7 months ago
gen2	Wrote gen2 demo script	7 months ago
gen3	Removed commented-out line in _instrument.py	7 months ago
.gitignore	Wrote gen2 demo script	7 months ago
README.md	Added credits to README	6 months ago

README.md

A bare-bones obs package for the LSST stack

The Legacy Survey of Space and Time (LSST) is a next-generation astronomical survey to be conducted by the Vera C. Rubin Telescope that will repeatedly survey the entire southern sky to unprecedented depths. A major part of the project is the development of the LSST Science Pipelines (hereafter referred to as the LSST stack) that will process the raw data from the raft of CCDs that form the LSST's detector.

Summary

- Adapting the Rubin Pipeline involves writing your own obs package.

- We have successfully adapted the Rubin Processing Pipelines to process GOTO data.

- Getting robust results out; comparable to GOTO’s in-house pipeline that uses more familiar routines (e.g., SExtractor).

- obs_necam is available for those thinking of doing something similar, or those who’d just like to see how the pipeline “works”.