VERA C. RUBIN OBSERVATORY

Updates on detection and deblending in the science pipelines

Fred Moolekamp

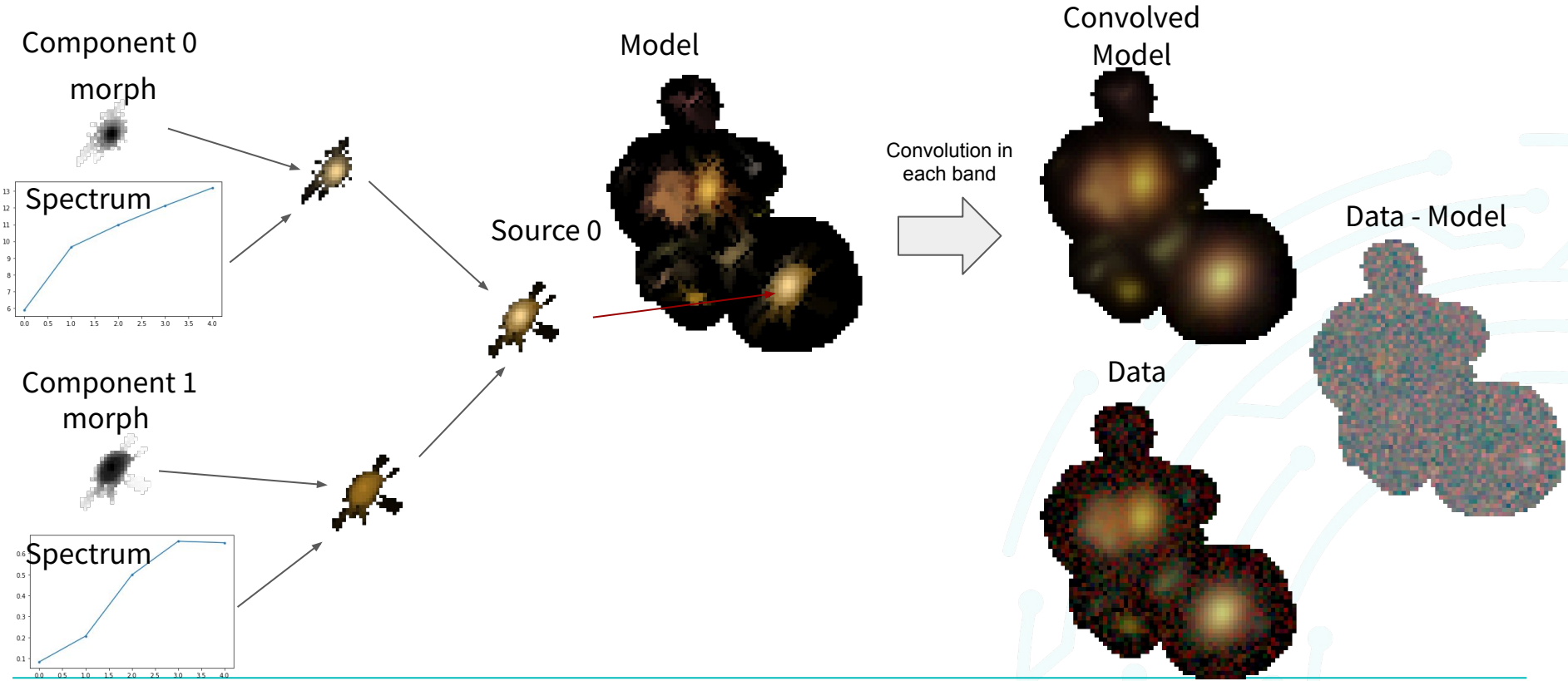
Rubin 2023 Project and Community Workshop
August 8, 2023

NSF NOIR Lab AURA SLAC U.S. DEPARTMENT OF ENERGY

VERA C. RUBIN OBSERVATORY

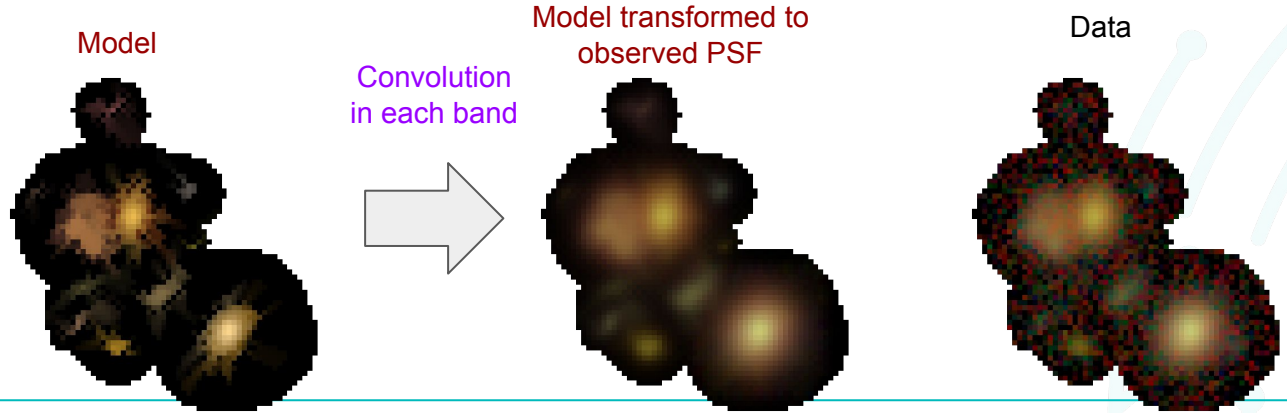
Quick recap

scarlet (and scarlet lite) models (meas_extensions_scarlet)

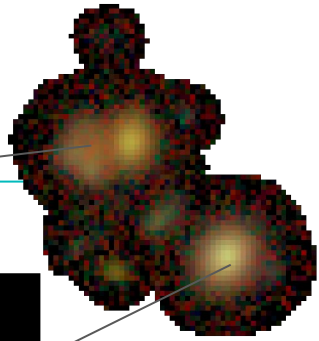


scarlet (and scarlet lite) models

- Basic algorithm
  1. The user defines an initial multiband model (basically the single-band template with monotonicity)
  2. The blend model exists in a frame with a narrow (but nyquist sampled) PSF
  3. The blend model is convolved to the observed PSF in each band
  4. A gradient-descent optimizer (ex. AdaProx, Melchior et al. 2019, is used in scarlet and default in scarlet lite) is used to apply constraints and priors to the models and calculate the gradient step
  5. The gradients are back-propagated to update the model
  6. Steps 2-5 are repeated until convergence

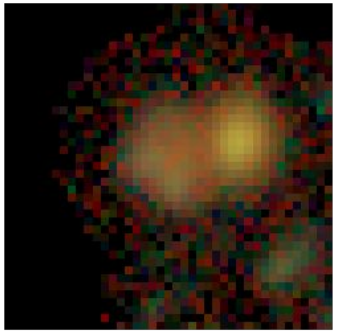


scarlet (and scarlet lite) models

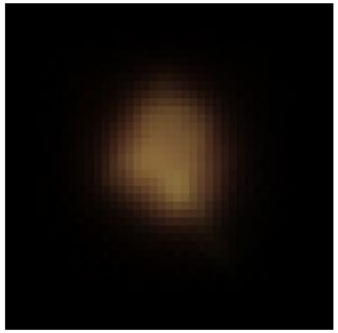


Source 2

observation

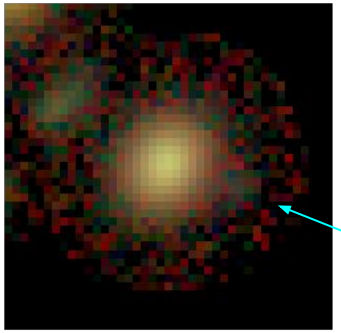


model

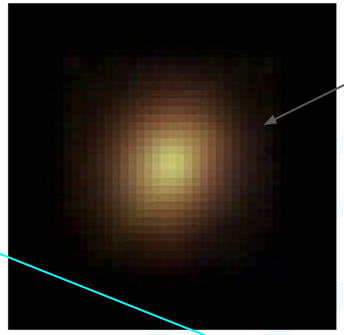


Source 0

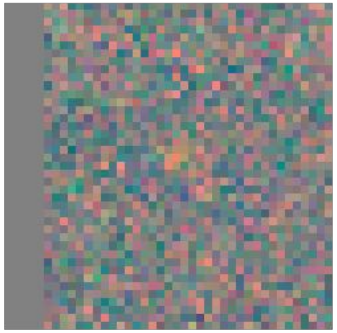
observation



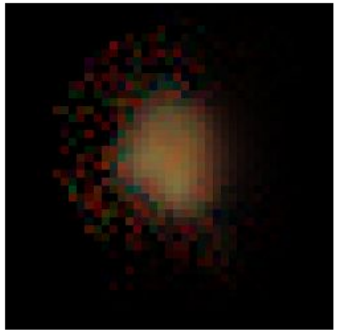
model



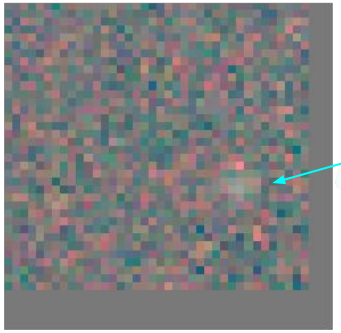
model residual



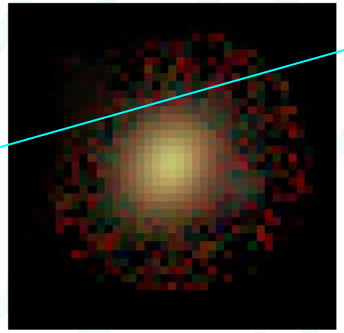
re-apportioned model



model residual



re-apportioned model



Missing detection

VERA C. RUBIN OBSERVATORY

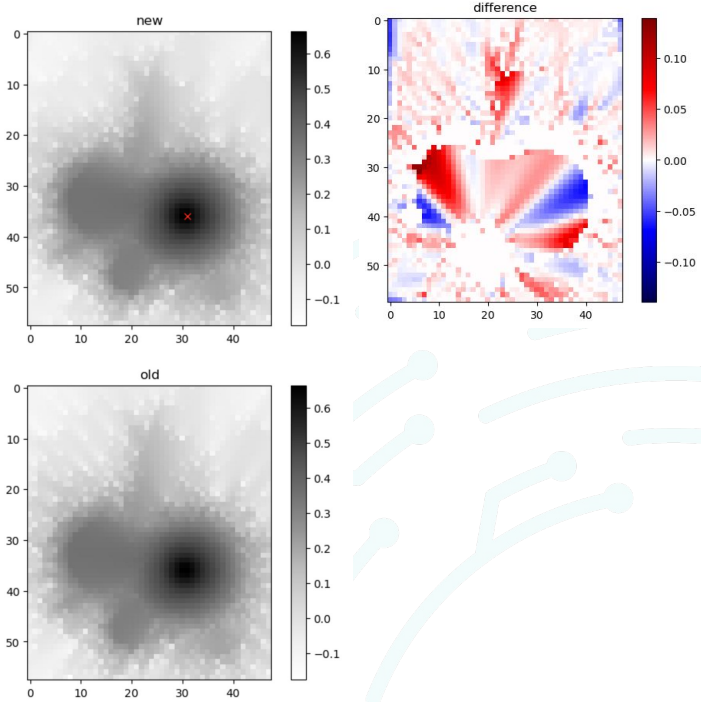
What's new?

scarlet_lite stand-alone package

- We switched from scarlet to scarlet.lite in early 2022 to save memory and processing time
  - Algorithmically equivalent to scarlet, but optimized for single camera survey data
- In late 2022 scarlet split into two new repositories: scarlet 2 and scarlet_lite
- scarlet_lite is currently in commissioning
  - Refactored scarlet.lite for easier maintenance

Monotonicity Operator

- In scarlet, each source has its own monotonicity operator used to sort indices
- In scarlet lite a single lookup table is used, making it more memory efficient
- In addition: a bug was discovered in the scarlet monotonicity operator
    - This doesn't appear to have a large impact on the overall results after convolution, except that the final models tend to be less streaky



New *Image* class

- Implements a numpy array with an origin and (optional) set of bands
- With bands, the image is 3D (bands, height, width)
- Without bands the image is 2D (height, width)
- Images can easily be resorted, sliced, or have individual bands chosen
- See scarlet_lite docs for more

VERA C. RUBIN OBSERVATORY

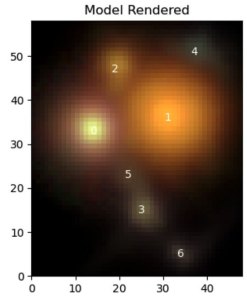
Models

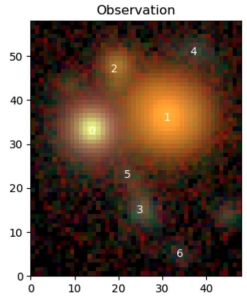
Examples, not used in production

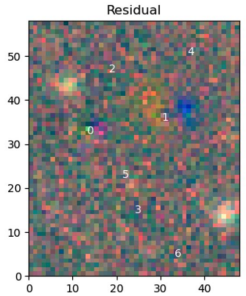
NSF AURA U.S. DEPARTMENT OF ENERGY SLAC CHARLES AND LISA SIMONYI FUND FOR ARTS AND SCIENCES LSST CORPORATION

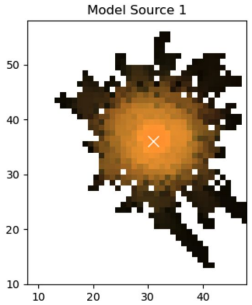
Parametric models

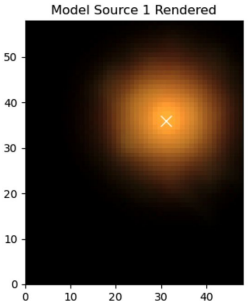
Default

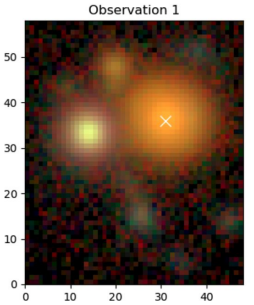




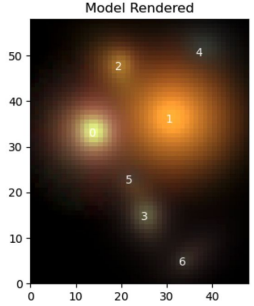


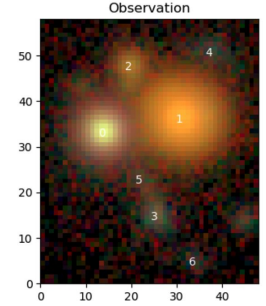


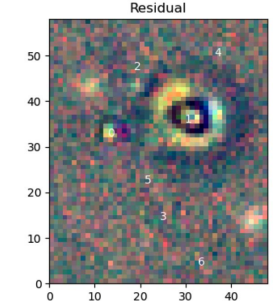


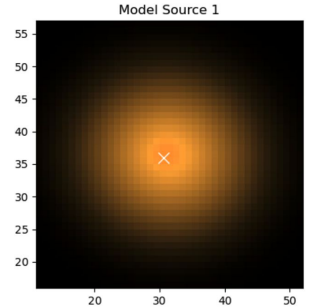


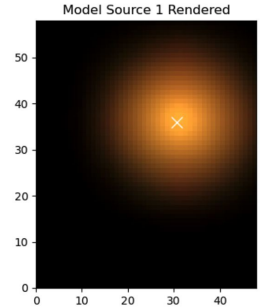
PSF + Sersic

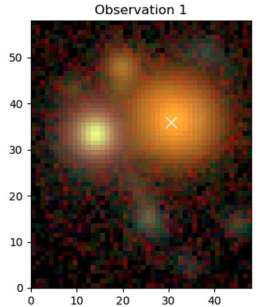






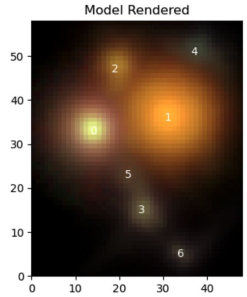


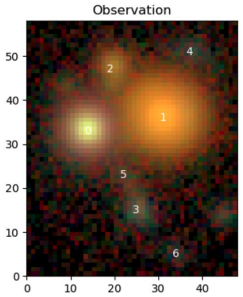


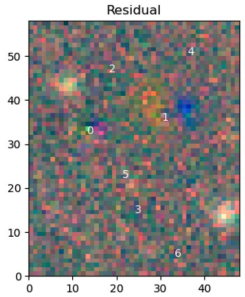


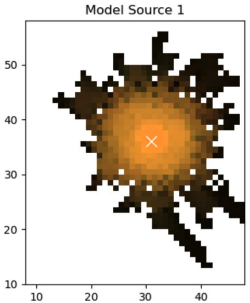
Fit PSF while deblending

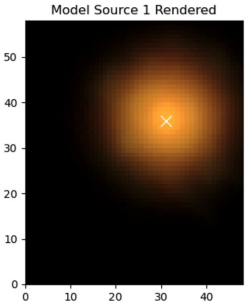
Default

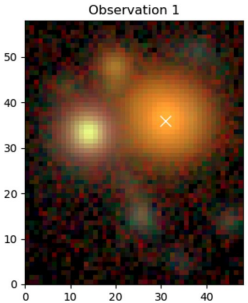




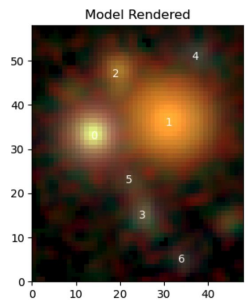


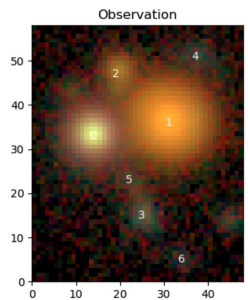


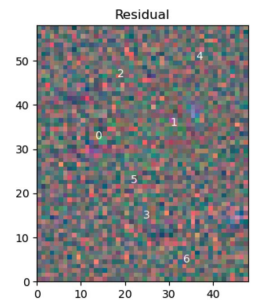


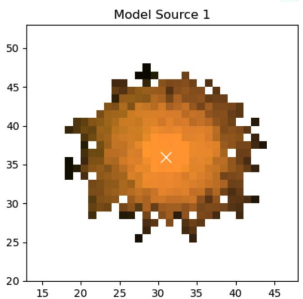


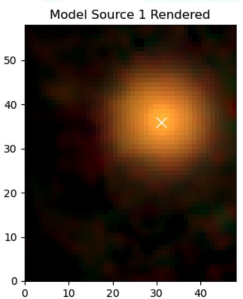
Fit PSF

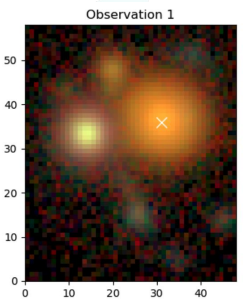






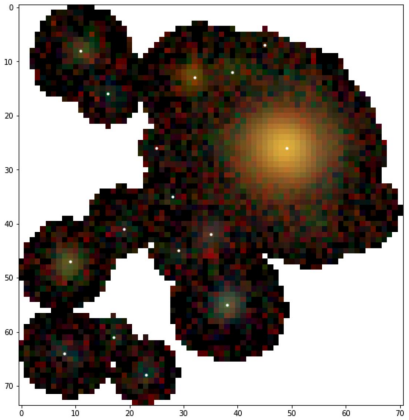




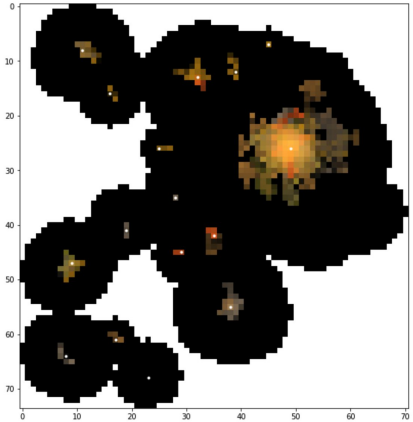


Free-form models

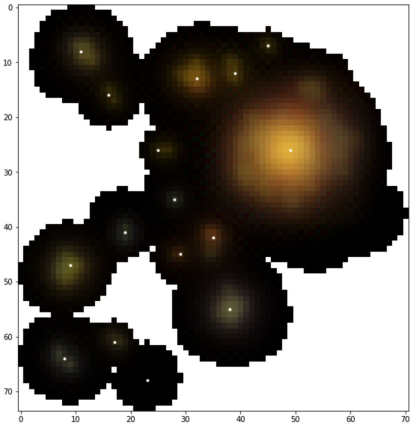
Data



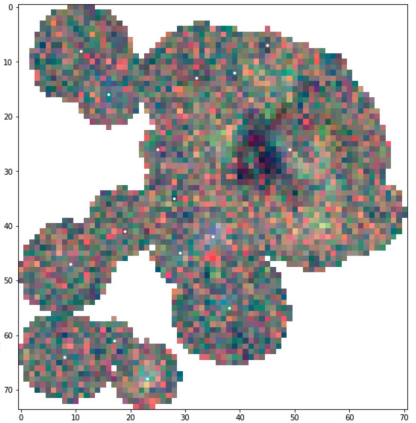
Model



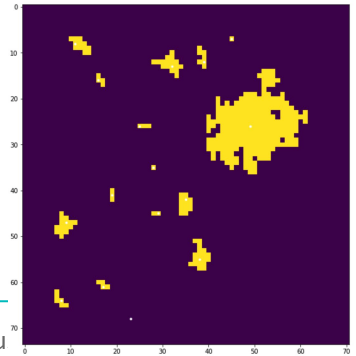
Convolved Model



Residual



Footprints



VERA C. RUBIN OBSERVATORY

Detection on χ^2 coadds

NSF AURA U.S. DEPARTMENT OF ENERGY SLAC CHARLES AND LISA SIMONYI FUND FOR ARTS AND SCIENCES LSST CORPORATION

Current coadd detection in the science pipelines

- Detection is performed in each band using lsst.pipe.tasks.multiBand.DetectCoaddSourcesTask
- Detections in each band are merged using lsst.pipe.tasks.mergeDetections.MergeDetectionsTask
  - Peaks are matched across bands if they are within (by default) 0.3 arcsec
  - Peaks are culled in an attempt to remove spurious detections and removed if
    - Detected in a single band (default)
    - Are not sufficiently bright compared to the other neighboring sources in their footprint

χ^2 coadds

- References:
  - Szalay et al. 1999
  - Kaiser 2001
  - Lupton whitepaper (ask Robert for PDF)
  - DMTN-015
  - Jim's slides on coadds
- $$\chi = \sum_b \frac{I_b \bigotimes \phi^\dagger}{\sigma_b}$$
  - I_b = image in band b
  - $\phi^\dagger$ = reflection of the PSF
  - σ_b = median variance in band b

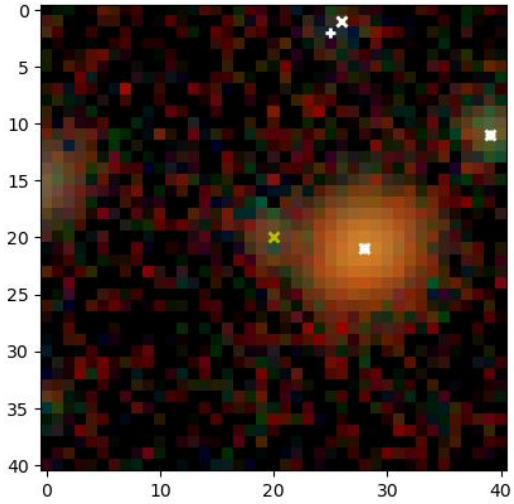
χ^2 coadd catalog notes

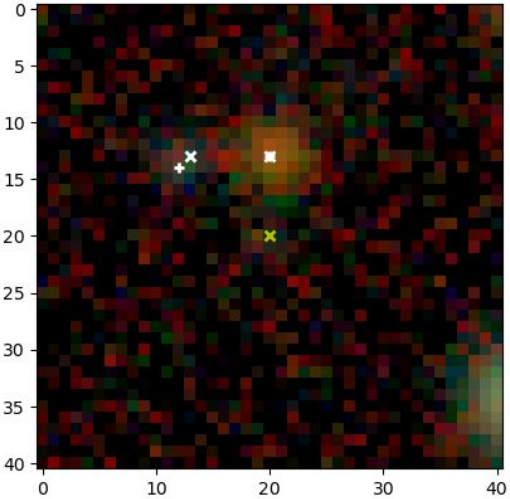
- χ^2 Detection catalog will be improved
  - Currently using SourceDeblendTask with no PSF smoothing or background subtraction
  - Needs background subtraction
  - Detection has not been tuned (eg. the threshold can be modified)
- I am using the DC2 “truth_summary” catalog to compare catalogs

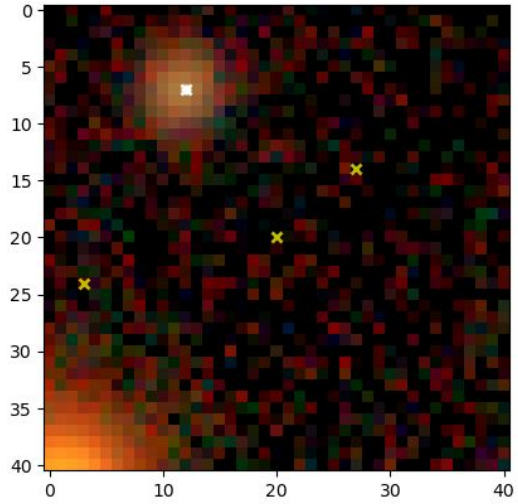
Comparison on HSC RC2 images

- Comparing the mergeDet and χ^2 catalogs in HSC RC2 tract 9813, patch 40
- Real data, no truth catalog
- Looking for qualitative differences between matches in one catalog and not the other

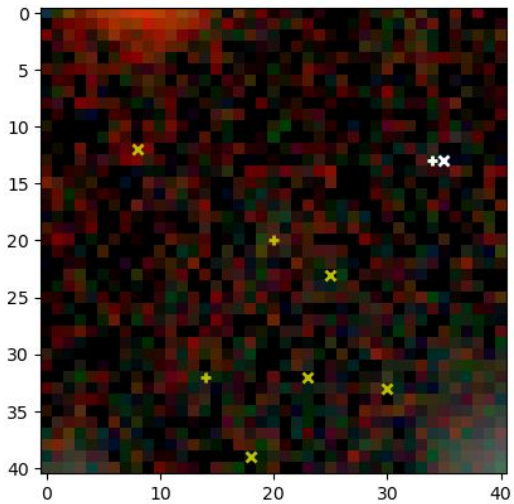
Comparison on HSC RC2 images

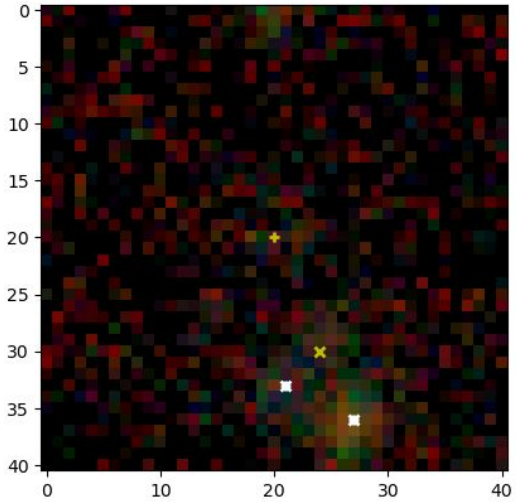


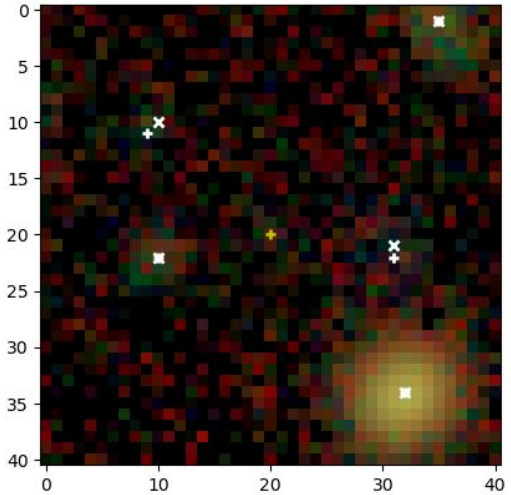




Comparison on HSC RC2 images





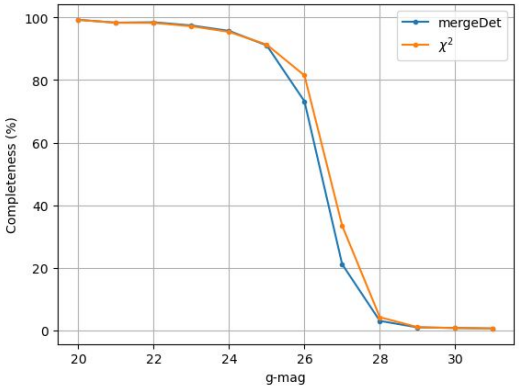


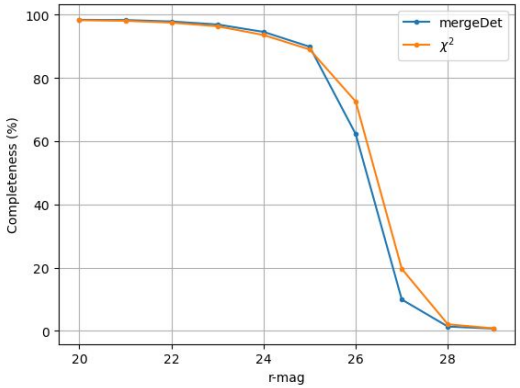
DC2 3828 Comparison with mergeDet (similar stats for 3829)

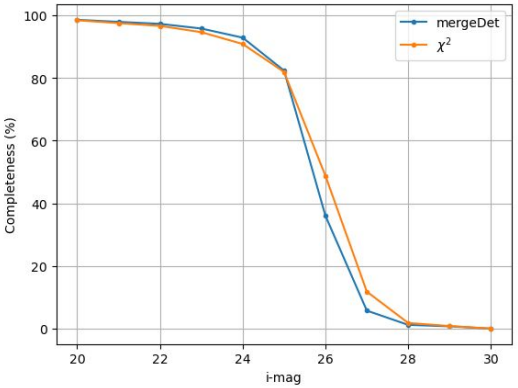
	mergeDet	χ^2
Total sources	895,355	1,039,368
False positives	207,828 (23%)	213,407 (21%)
Unique sources	687,018	825,219
Split sources	254	371

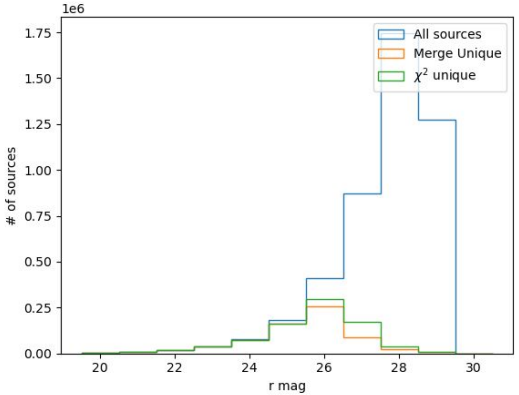
- 601,482 sources in both catalogs
- 85,536 sources in mergeDet (but not χ^2)
- 223,737 sources in χ^2 (but not mergeDet)

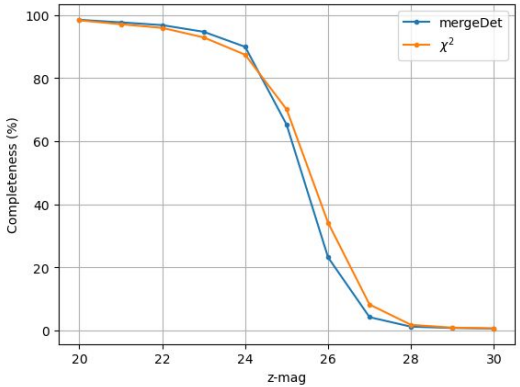
Completeness

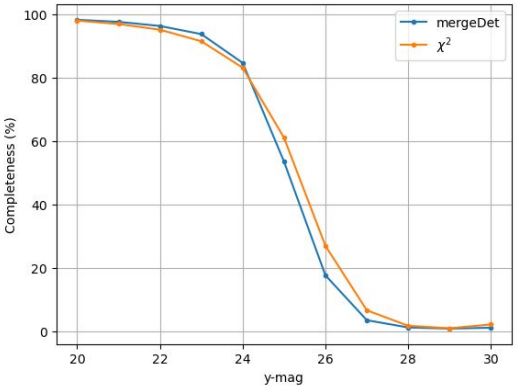




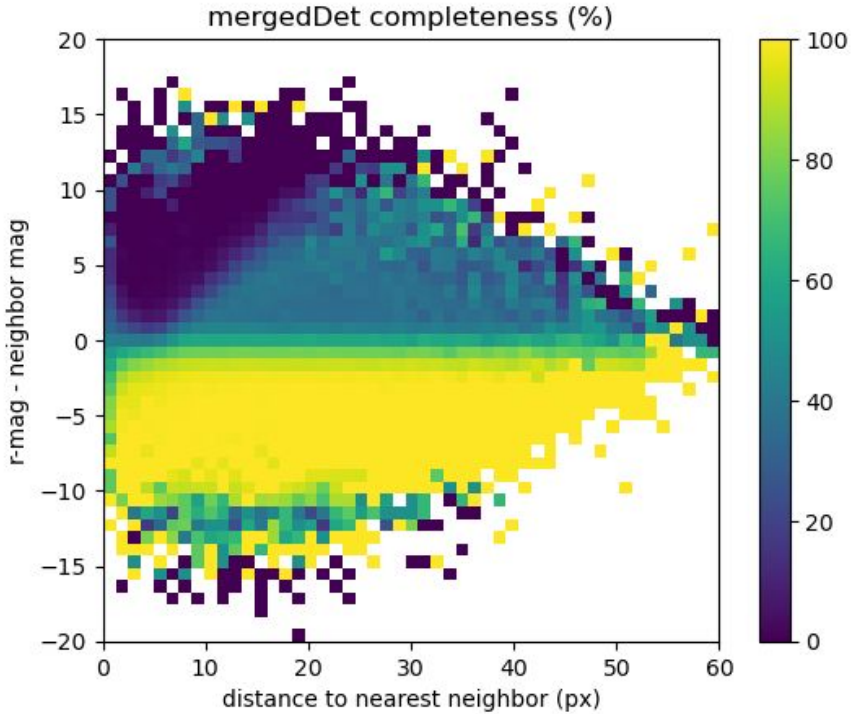


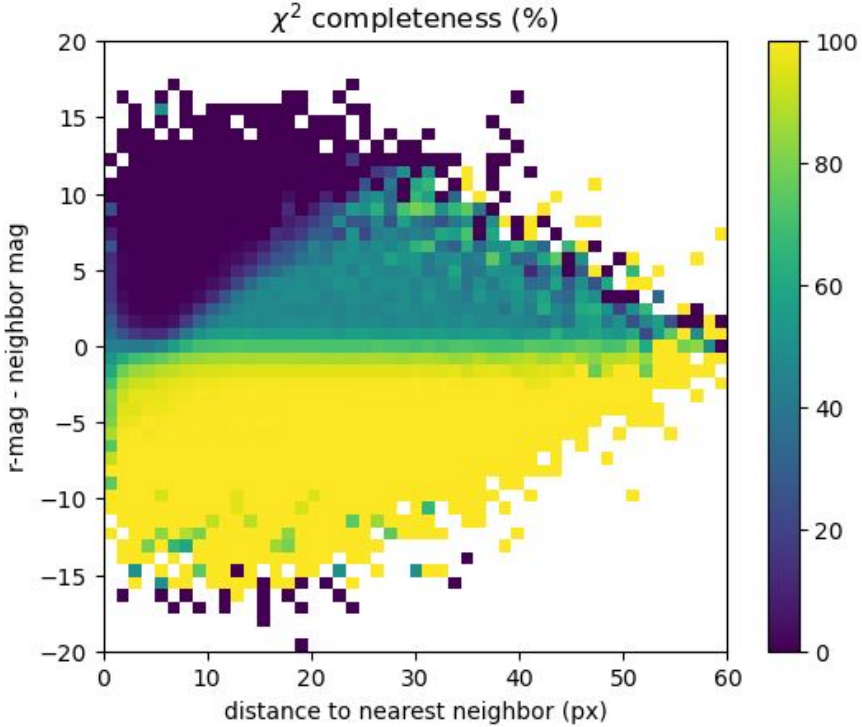




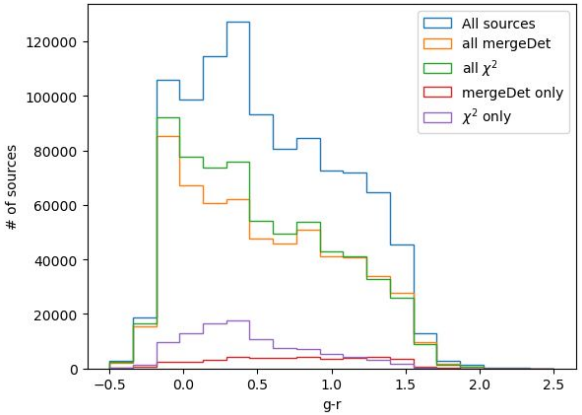


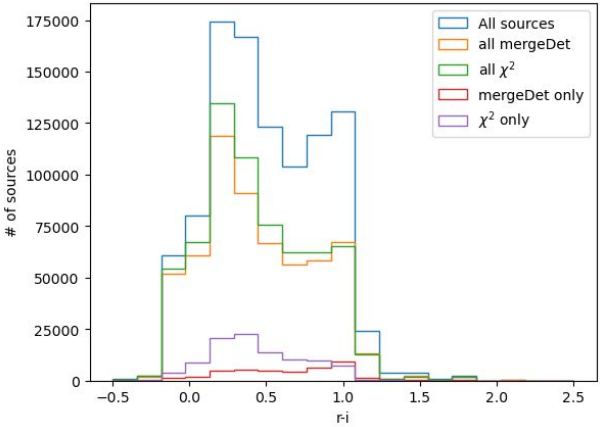
Nearest neighbor distance

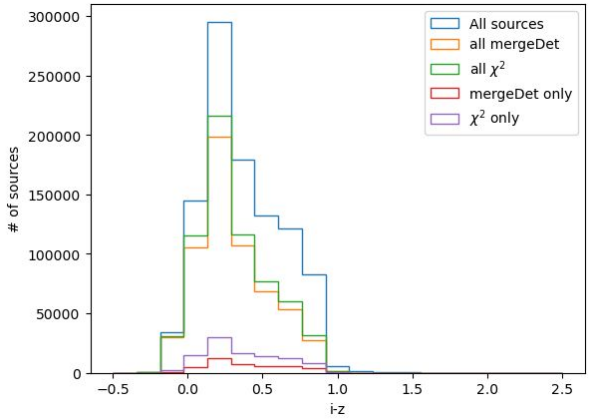




Color distribution







Conclusion and Future work

- lsst.scarlet.lite has been peer reviewed
  - Currently testing on DC2 and HSC RC2 datasets to confirm robustness
- Monotonicity with improved memory usage and bug fix
- Examples for creating custom models (parametric, free-form, fitting the PSF)
  - Not fully tested and working, but should be enough to get people started
- Detection needs to be improved in new task
  - Implement background subtraction
  - Tune threshold
- χ^2 catalogs have more true detections with a smaller (but still high) false positive rate
- χ^2 catalogs are biased to miss nearby sources with fainter magnitudes
  - Detection on difference images may be able to locate missing sources (credit Jim Bosch)
  - Any other ideas?