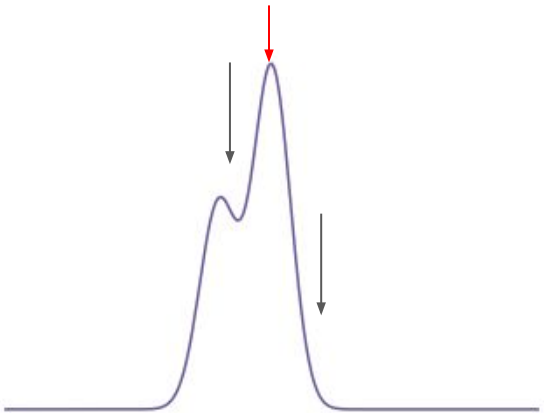
Deblending in the Rubin Observatory LSST Stack

Fred Moolekamp

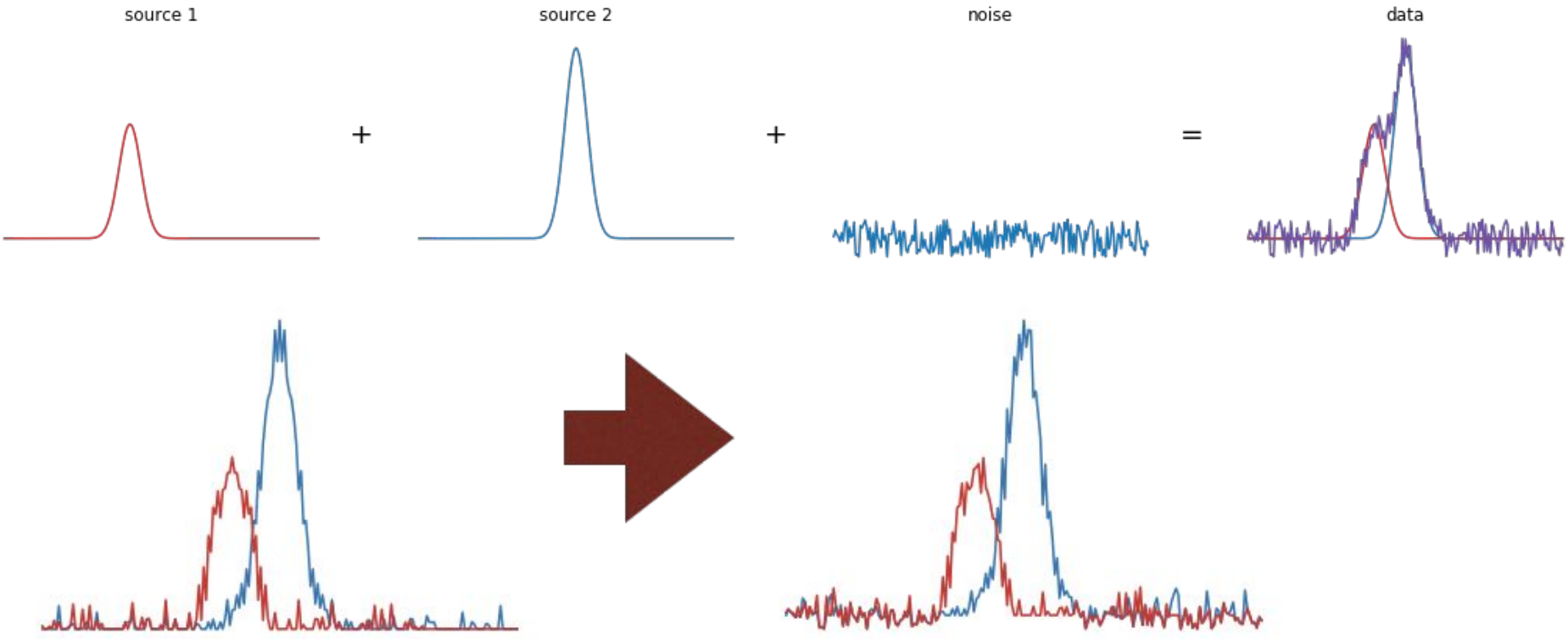
Current Stack Deblender

- Based on Robert Lupton's SDSS deblender
- Attempts to use the least restrictive model:
  - Attempt to fit each source to the PSF (stars and very faint galaxies)
  - Make a symmetric template for each remaining source
  - Make that template monotonically decreasing from the peak
  - Use the template to redistribute the flux in the original image

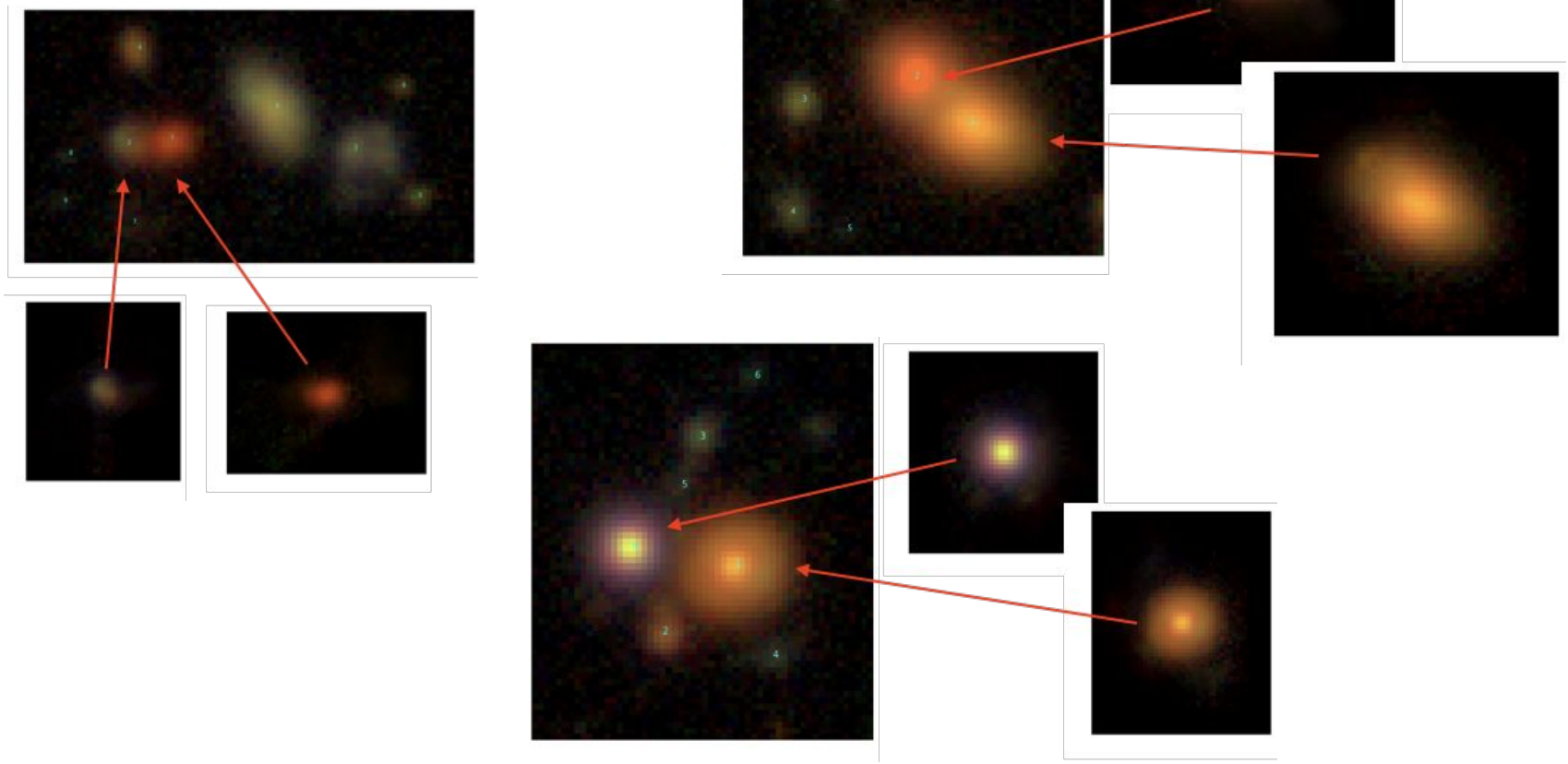


Current Stack Deblender

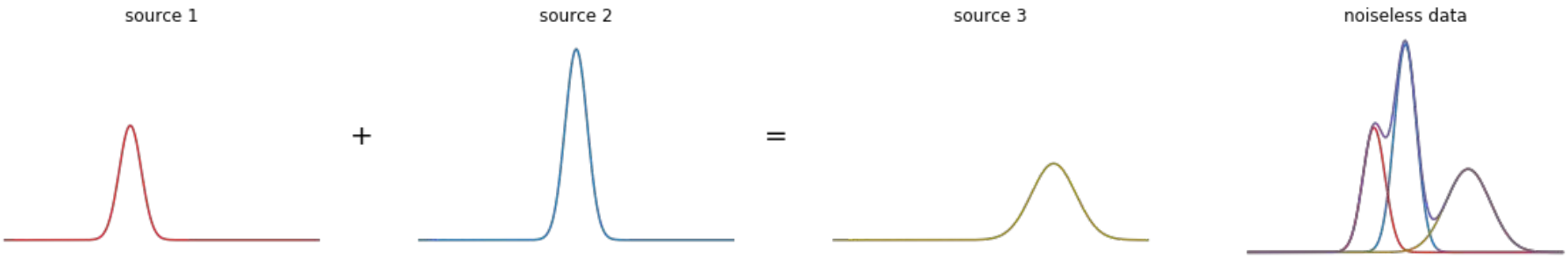
1D Example



This works shockingly well!



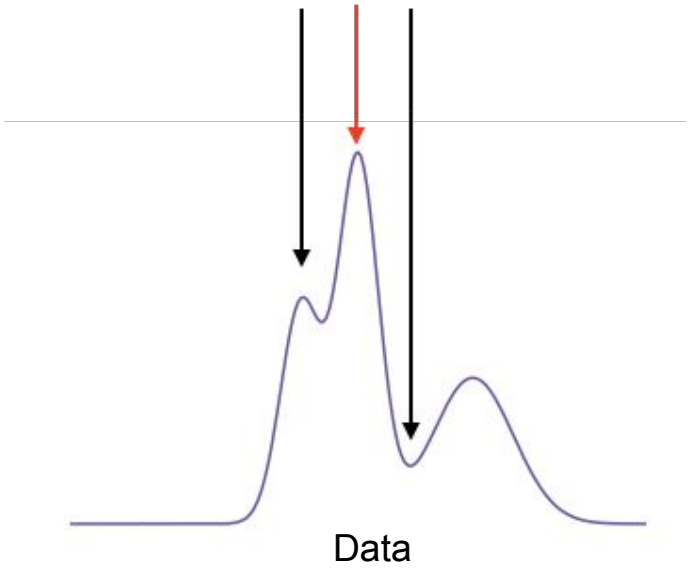
A more pathological example

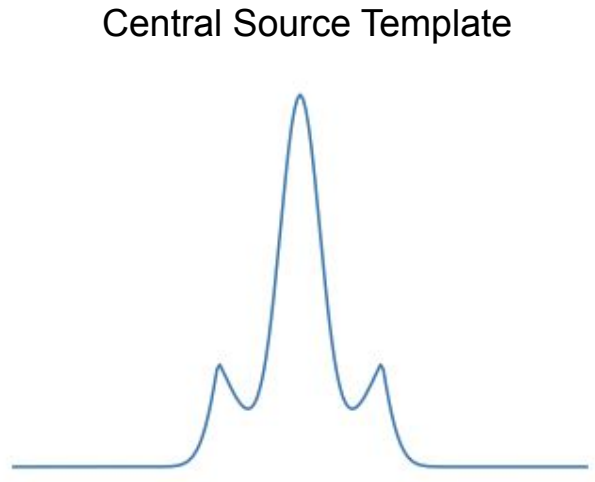


Current Stack Deblender

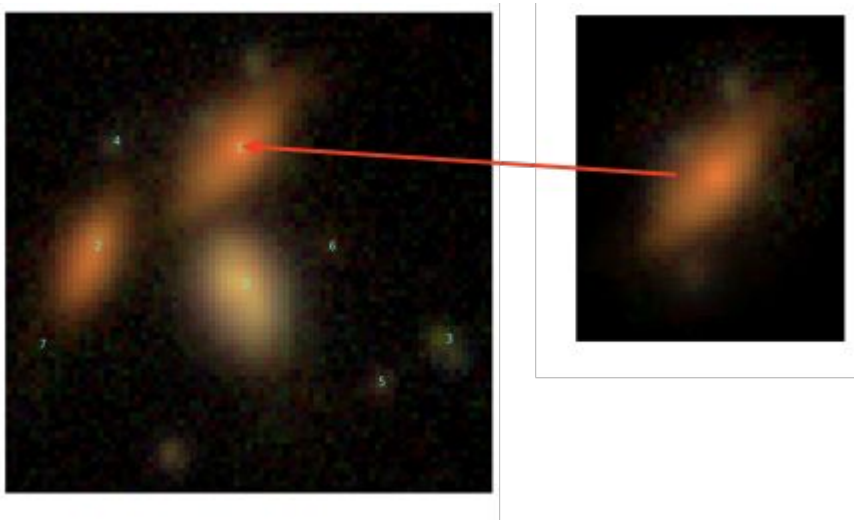
Problem:

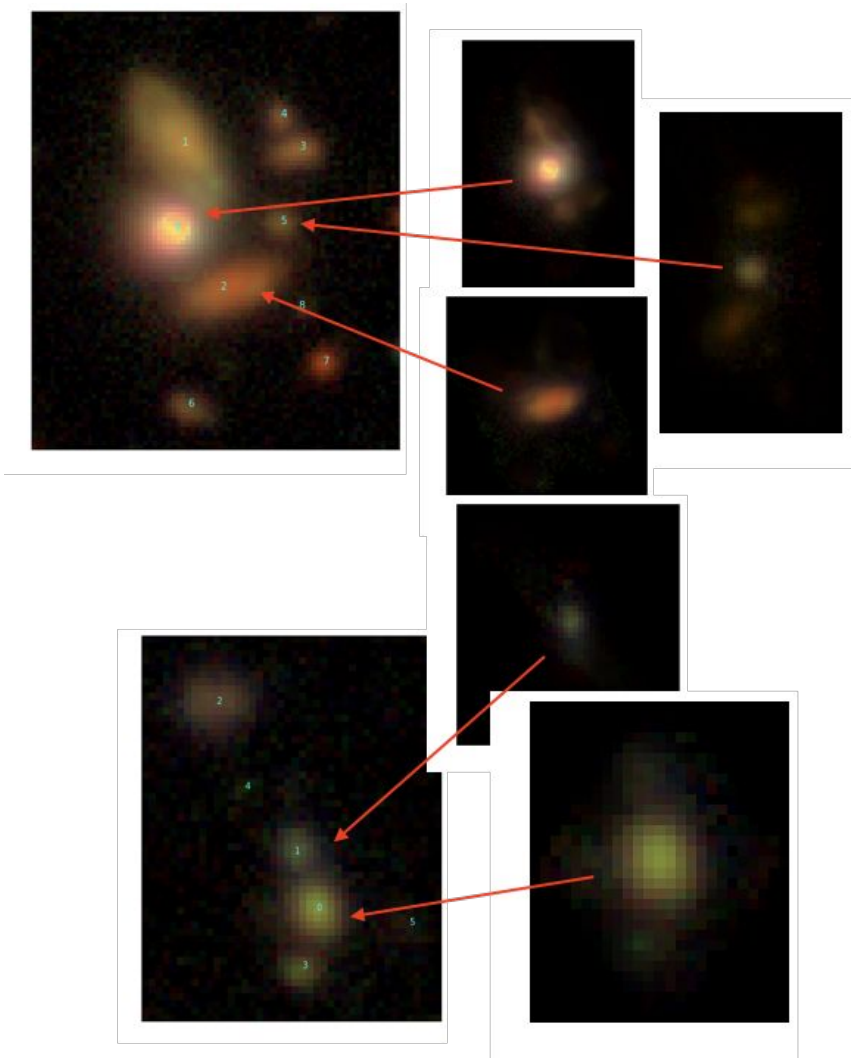
- The source in the center has objects on both sides
- When redistributing flux with the templates all three sources will have incorrect photometry





Here be dragons!





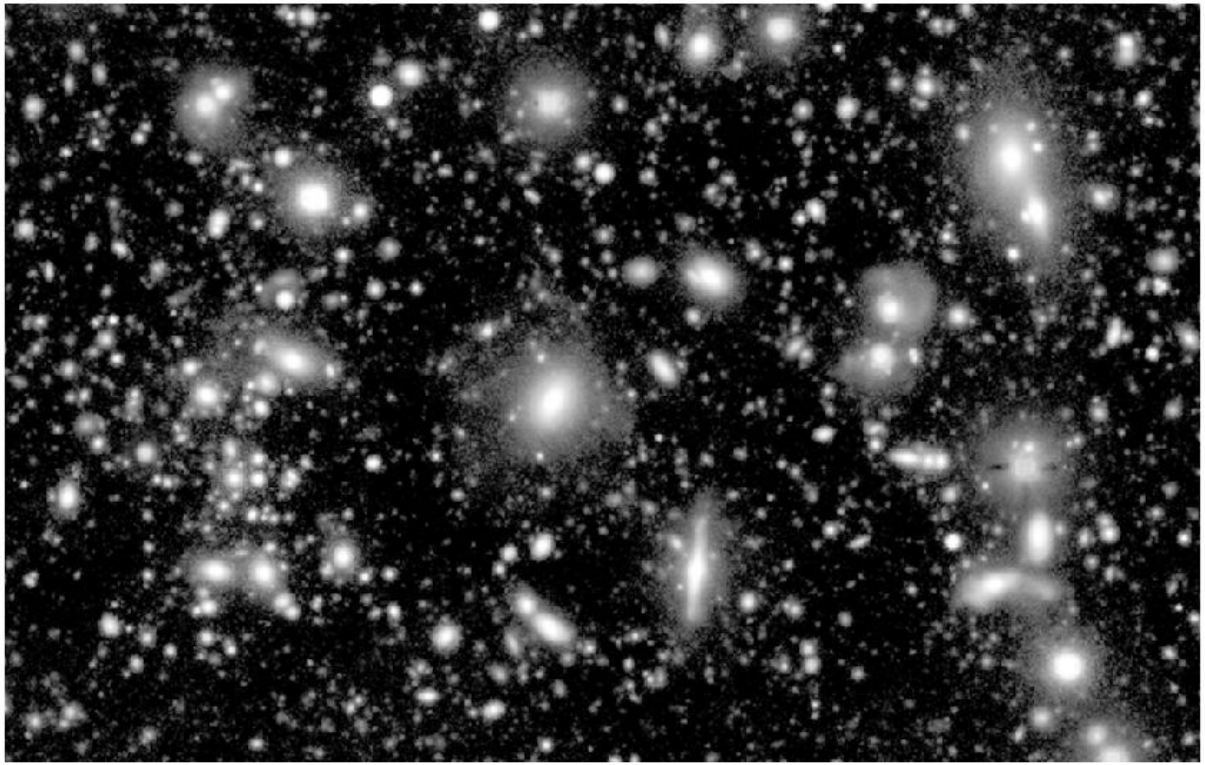
scarlet

Co-created with Peter Melchior (Princeton)

Other contributing developers:

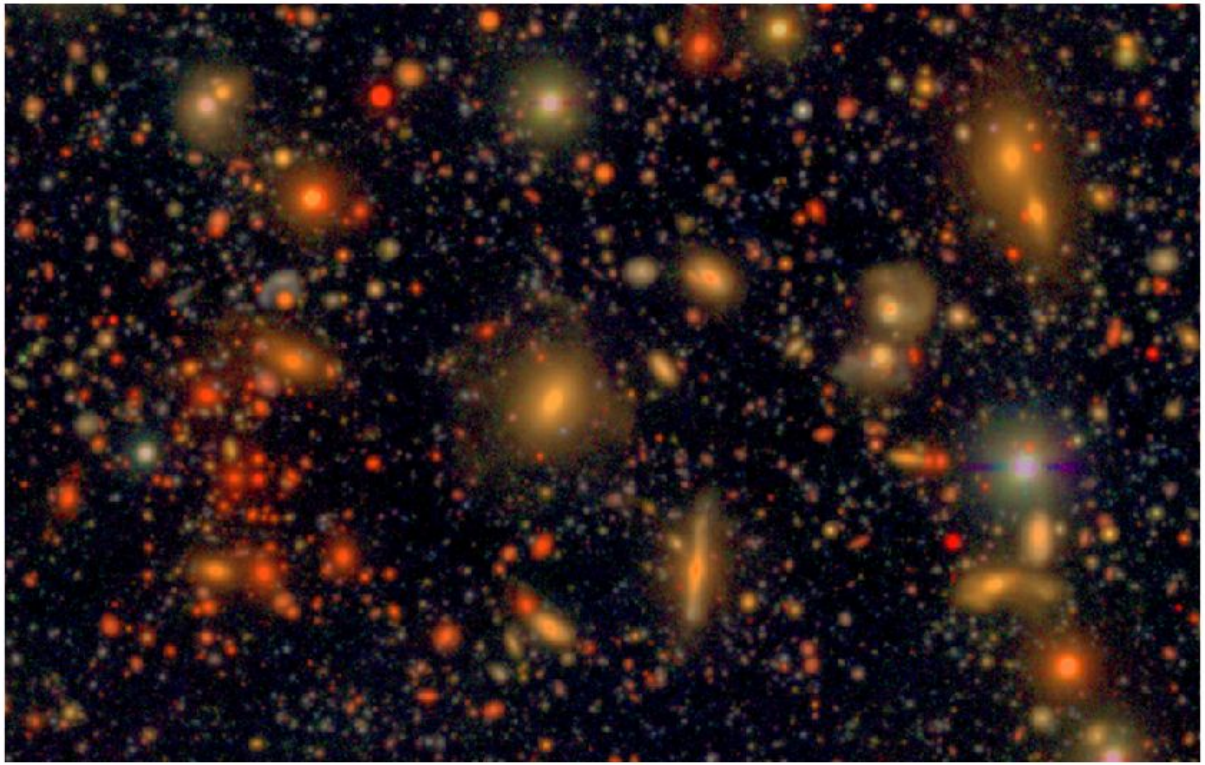
- Remy Joseph (Princeton)
- Francois Lanusse (UC Berkeley)

All of the previous deblenders (other than MOF) use single band images:



HSC i-band image credit: Nate Lust

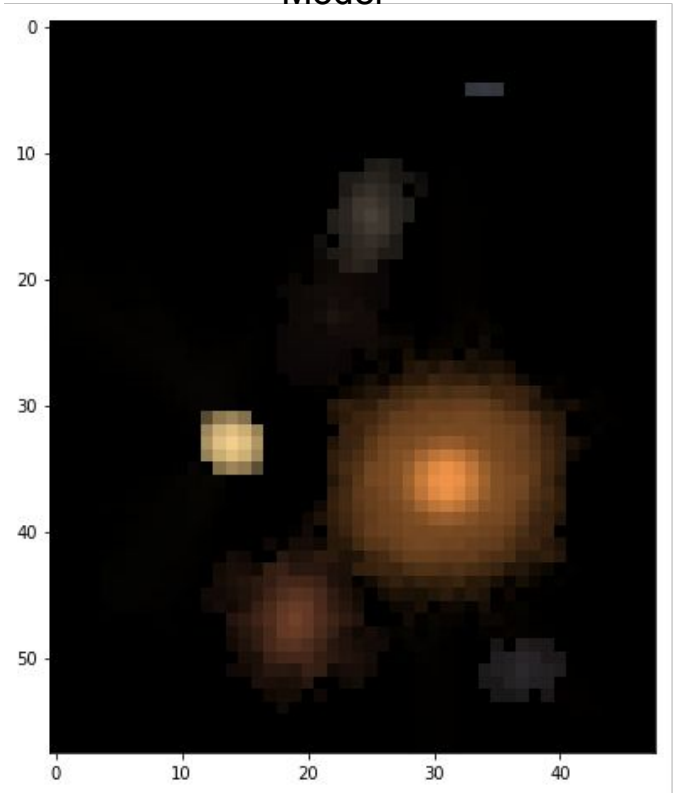
All of the previous deblenders (other than MOF) use single band images:



HSC gri-bands image credit: Nate Lust

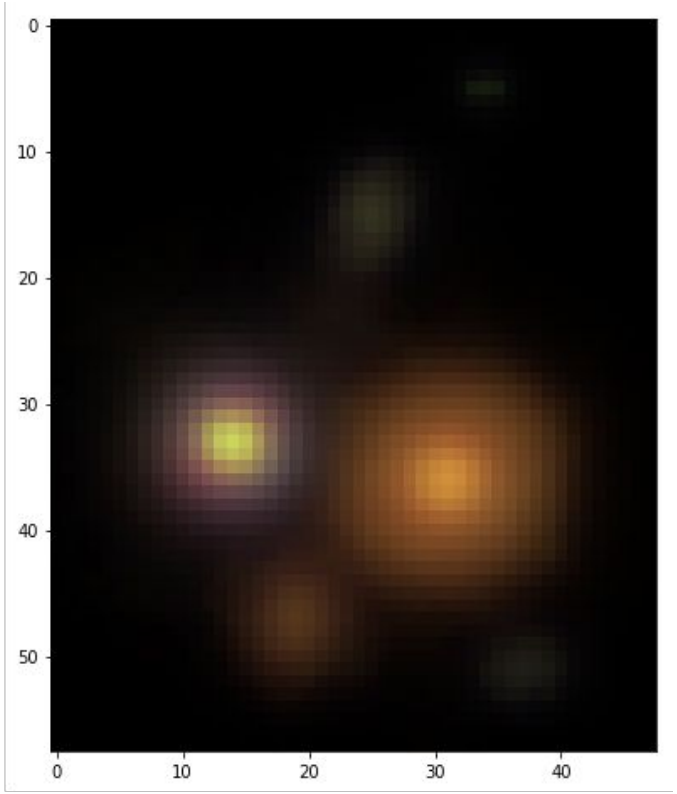
Basic “Single Component” Model

Model



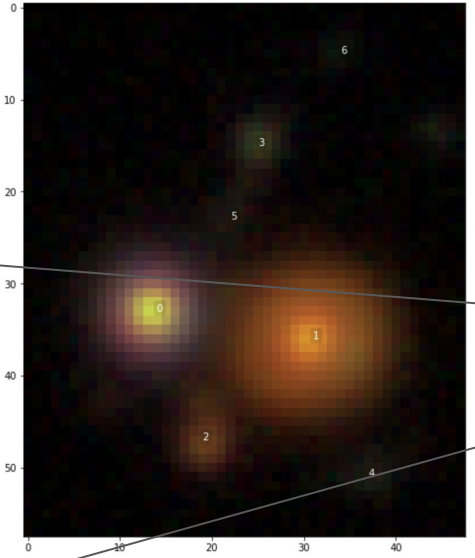
Convolution in each band

Model transformed to observed PSF



Basic Model

Data



Model

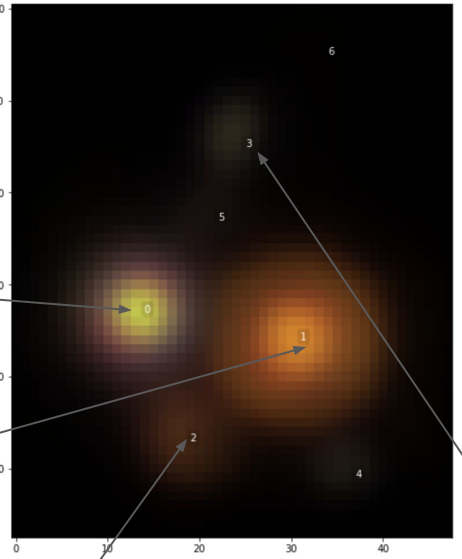
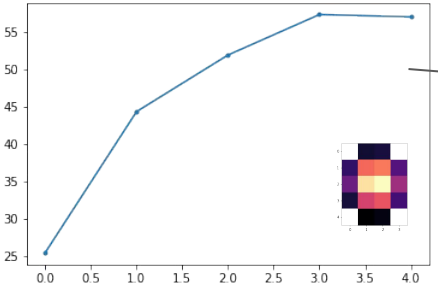
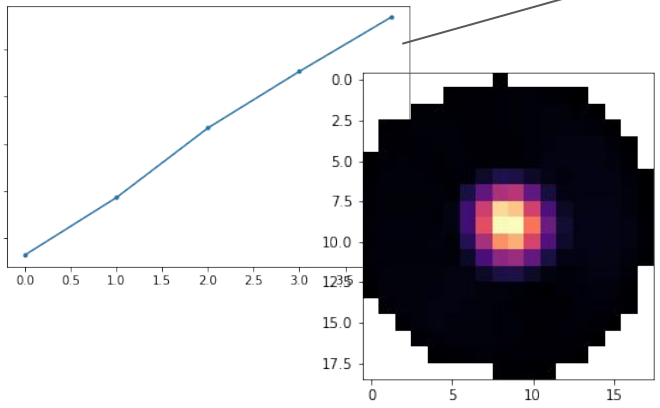


Image from HSC Deep Field

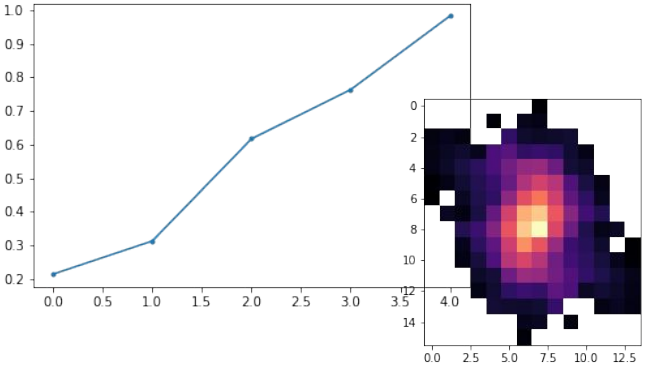
Source 0



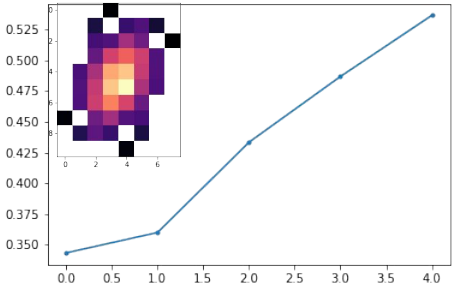
Source 1



Source 2



Source 3



Constraints

SED

- Non-negative

Morphology

- Non-negative
- Normalize peak to unity
- Monotonicity
- Symmetry
- Sparsity
- Color
- Smoothness
- Galaxy template priors (Francois Lanuse)

New scarlet 1.0

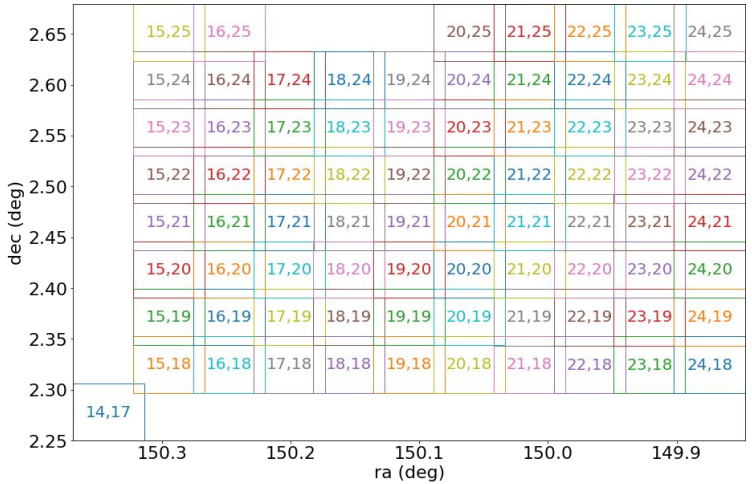
Significant updates made by Peter Melchior in the fall:

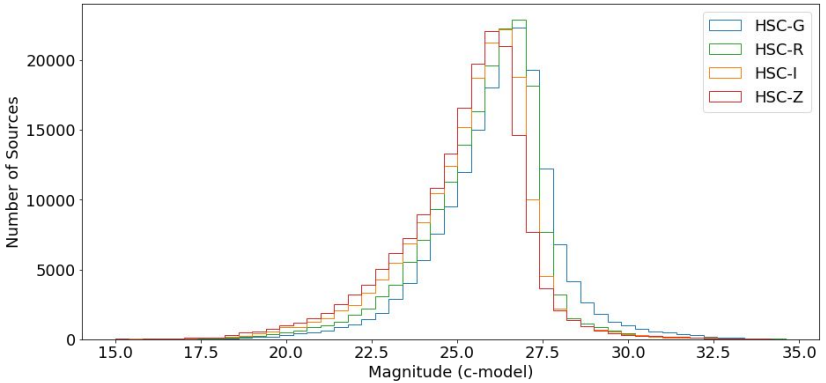
- Updated optimization algorithm to ADAM (adaptive gradients)
- Allows a much wider range of models that can all be fit jointly:
  - Single Component Extended Sources (morph and sed, from original scarlet)
  - Multiple Component Sources (e.g. bulge, disk, star forming regions)
  - Point Source models (amplitude and position)’
  - Parametric Models (e.g. Sersic Bulge with Exponential disk)
  - Pixel CNN network with real galaxy templates (Francois Lanusse, in development)
  - Custom models defined by the user
- Allows the addition/deletion of sources (or change in models) from iteration to iteration
- See Peter’s presentation from earlier today in the DESC-Blending Working Group for more details on this update (link)

Testing the deblenders

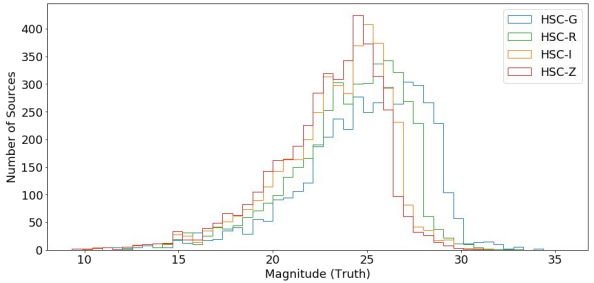
HSC Data Info

- **78** 1k ×1k patches from HSC COSMOS dataset, tract **9813**, with fake sources injected by Sophie Reed
- Using LSST Science Pipeline detection:
  - Total sources: 179,064
  - Total blends: 23,765
  - Total isolated sources: 42,112 (23.5%)
  - Total fakes injected (and detected): 4,760 (2.7%)
  - Unique fakes: 3,580 (2%)

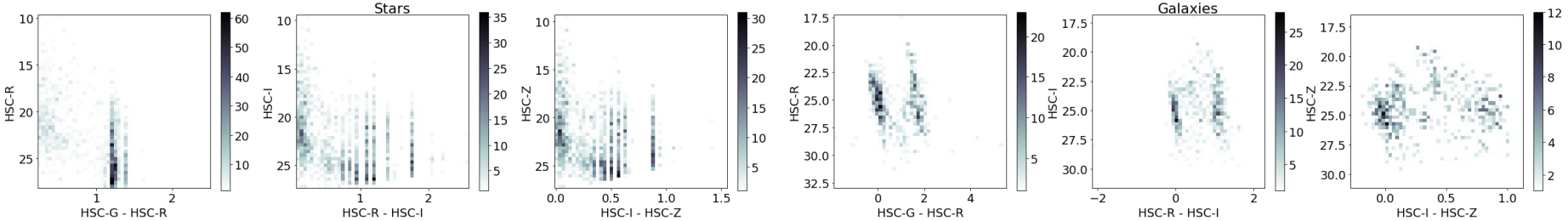




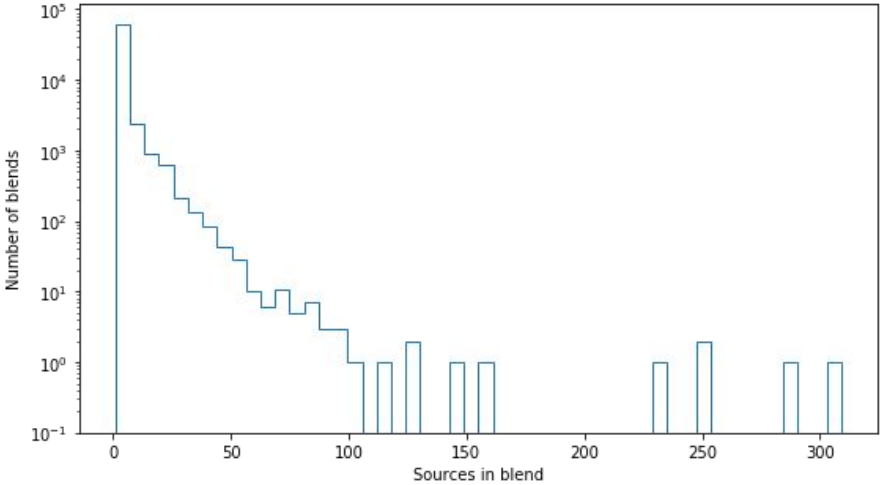
Simulated Sources Info

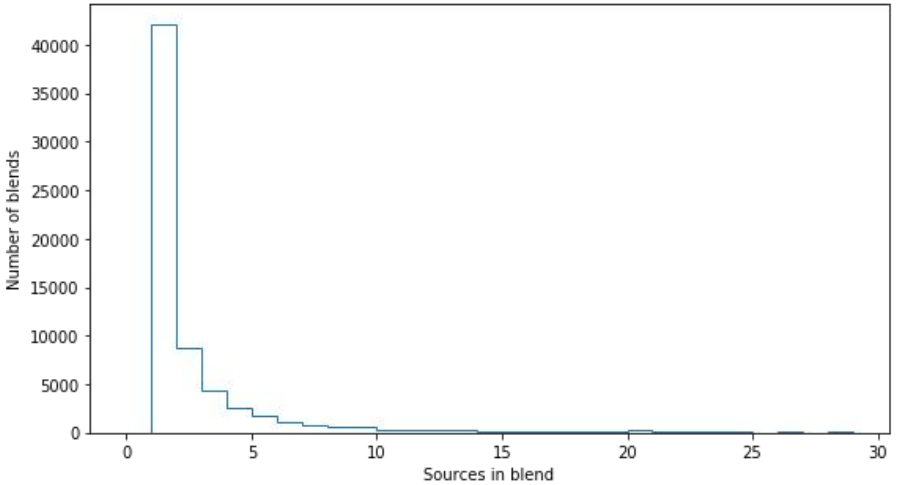


- **~4760** total fake sources ~(3265 stars, 1495 galaxies)
- Injected sources come from the Fatboy catalog at UW, which gives RA/DEC positions and magnitudes for stars and galaxies, and parametric model parameters (Sersic bulge, exponential disk) for galaxies
- All sources within the sky coordinates of the HSC patches were injected using the insertFakes task.



HSC Data Info: Blending





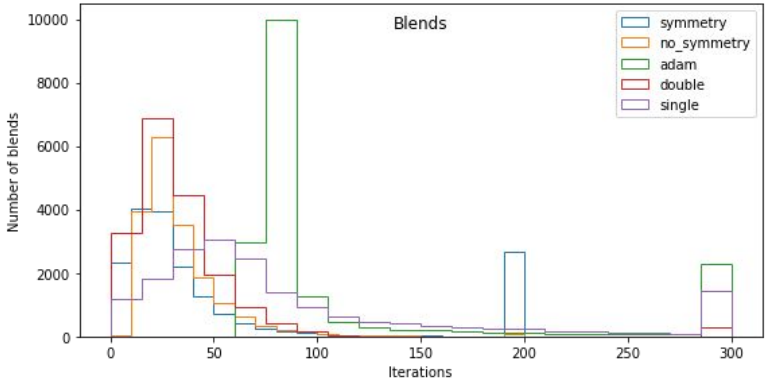
Blending Statistics

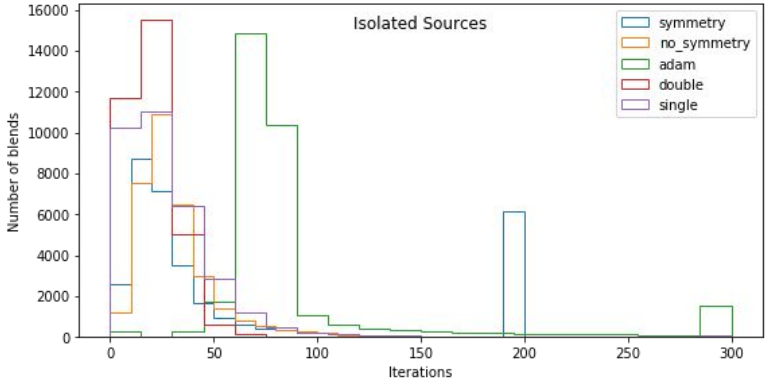
- Statistics and plots have the following configurations:
  - Default
    - The current stack deblender (meas_deblender)
  - Old scarlet (v 0.5)
    - Symmetry
      - Uses symmetry and monotonicity to constrain the morphology
    - No Symmetry
      - Only uses monotonicity to constrain the morphology
  - New scarlet (v 1.0) (none of these use symmetry)
    - Adam
      - Uses the new version of scarlet with a high pixel detection threshold=small boxes
    - Single
      - Same as ADAM but uses a lower threshold, giving larger boxes
    - Double
      - Same as single except it attempts to model each source with 2 components

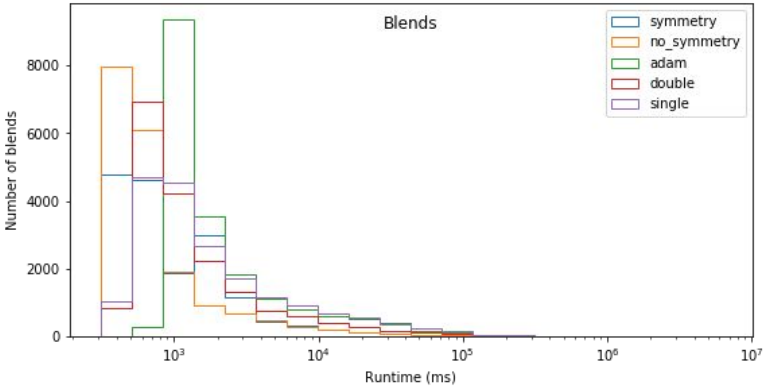
Blending Statistics

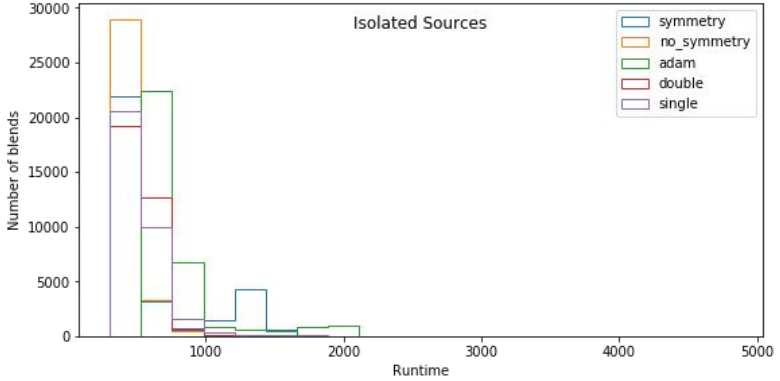
	Default	Symmetry	No Symmetry	ADAM	Single	Double
Total Sources	140,794	149,820	172,205	172,962	172,948	158,443
Runtime per isolated source (ms)	-	605.7	450.1	807.2	539.3	514.2
Runtime per blended source (ms)	-	494.1	319.6	858.9	847.4	579.2

Blending Statistics

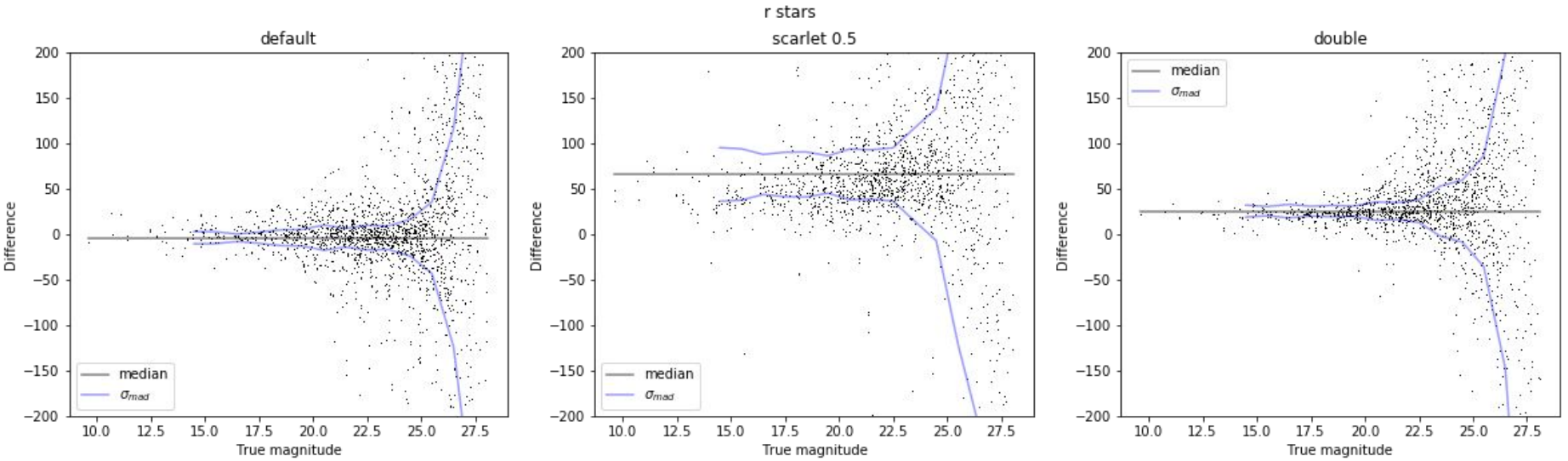




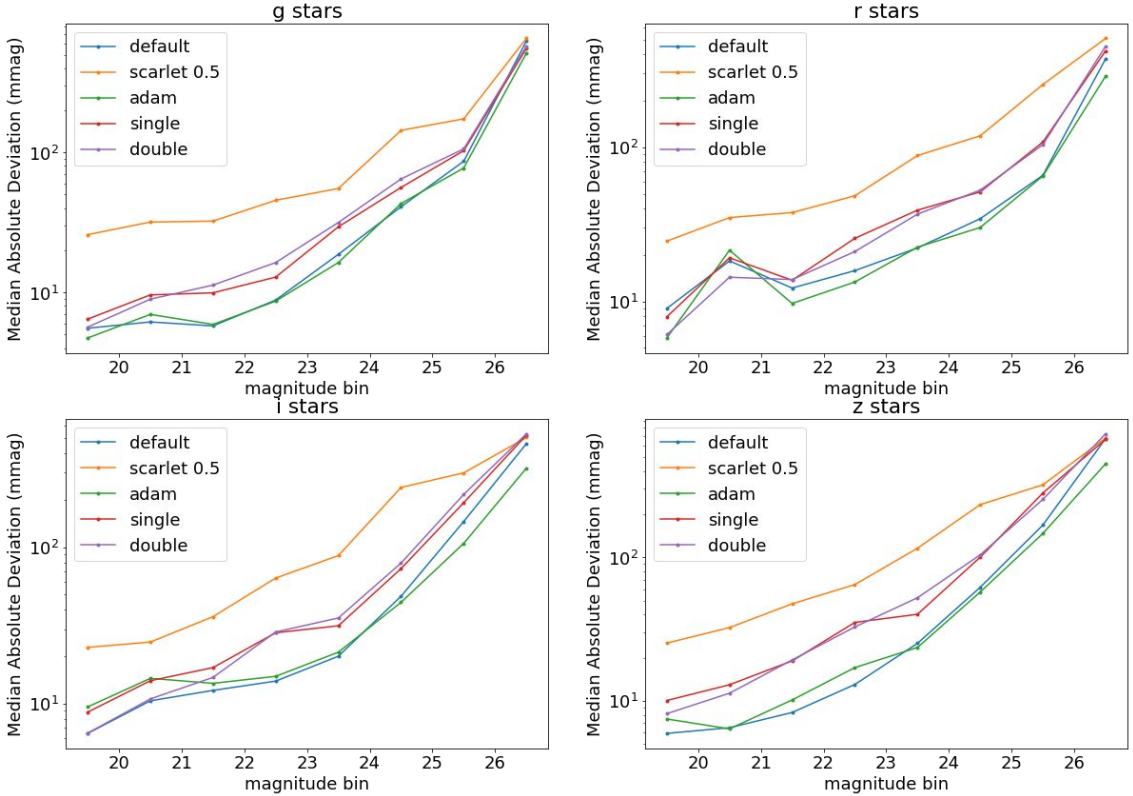




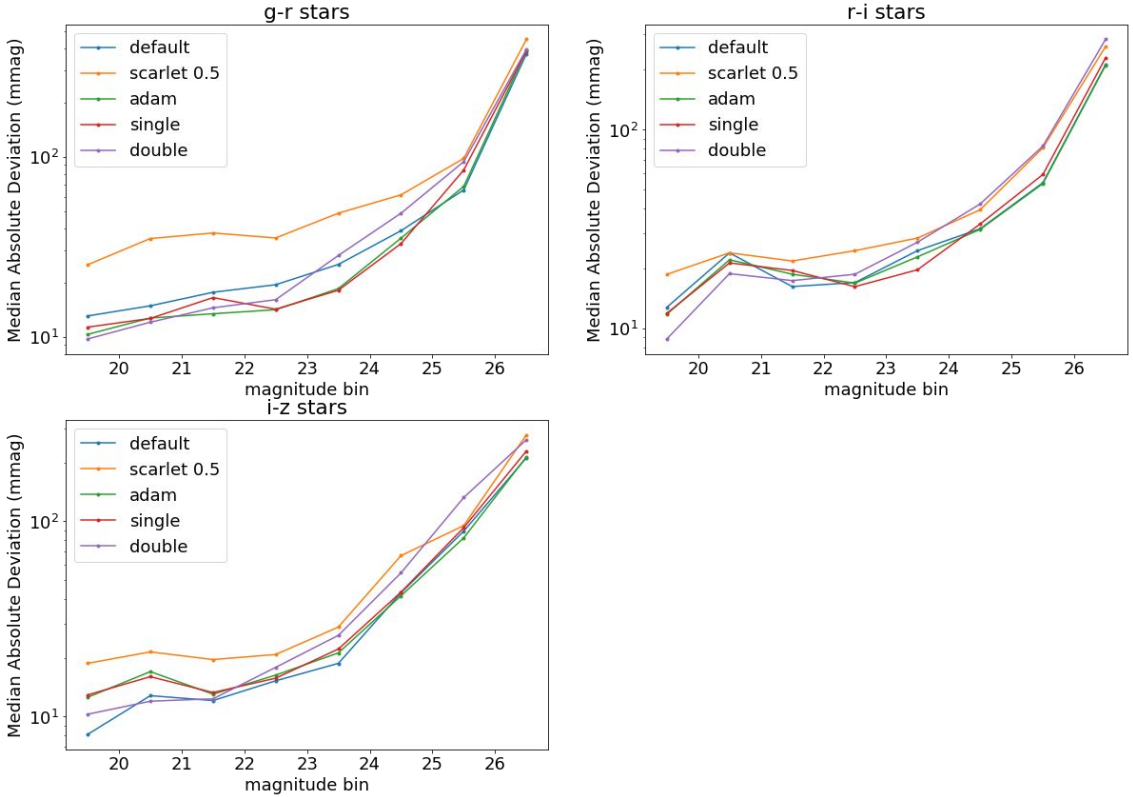
Analysis


r stars
default
scarlet 0.5
double
median
σ_{mad}
Difference
True magnitude
200
150
100
50
0
−50
−100
−150
−200
10.0
12.5
15.0
17.5
20.0
22.5
25.0
27.5

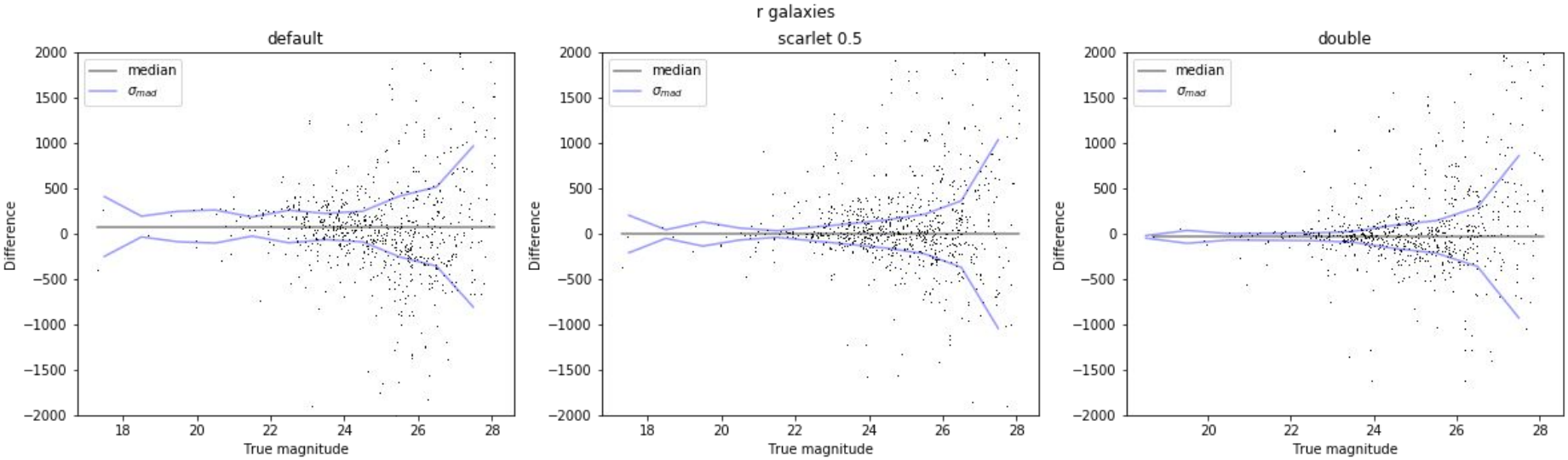
Analysis


g stars
r stars
i stars
z stars
default
scarlet 0.5
adam
single
double
Median Absolute Deviation (mmag)
magnitude bin
10^1
10^2
20
21
22
23
24
25
26

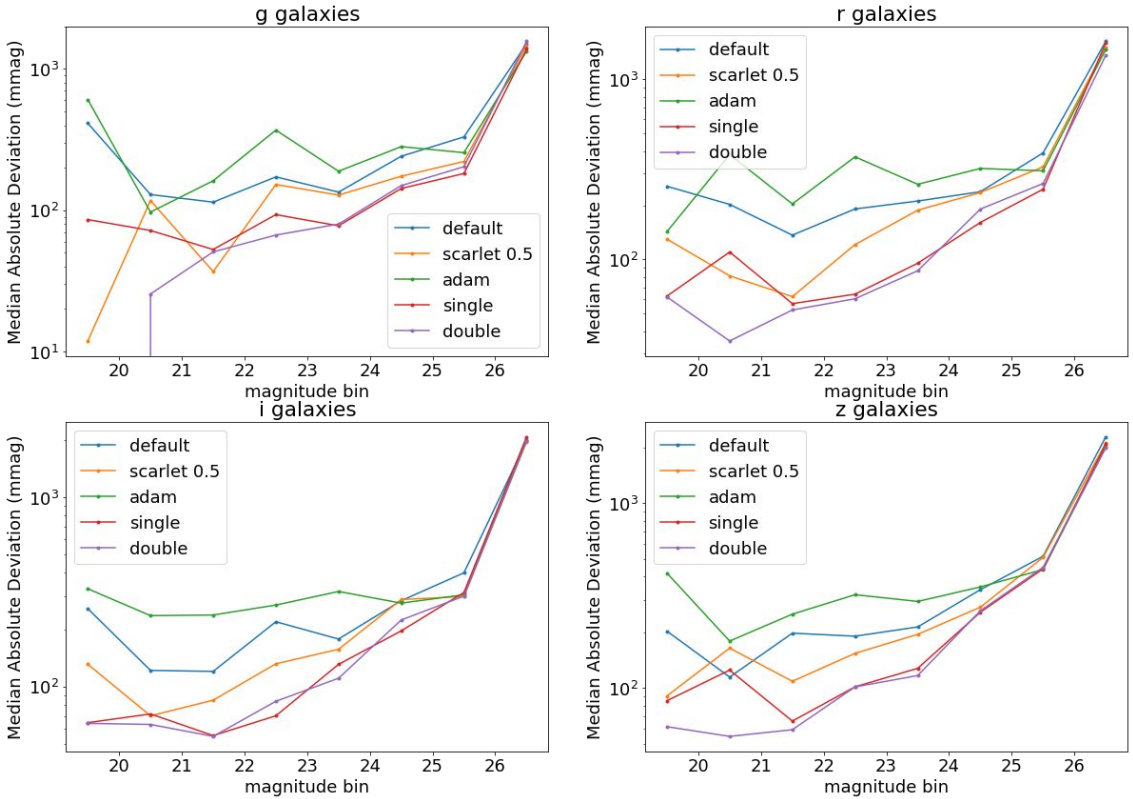
Analysis


g-r stars
r-i stars
i-z stars
default
scarlet 0.5
adam
single
double
Median Absolute Deviation (mmag)
magnitude bin
10^1
10^2
20
21
22
23
24
25
26

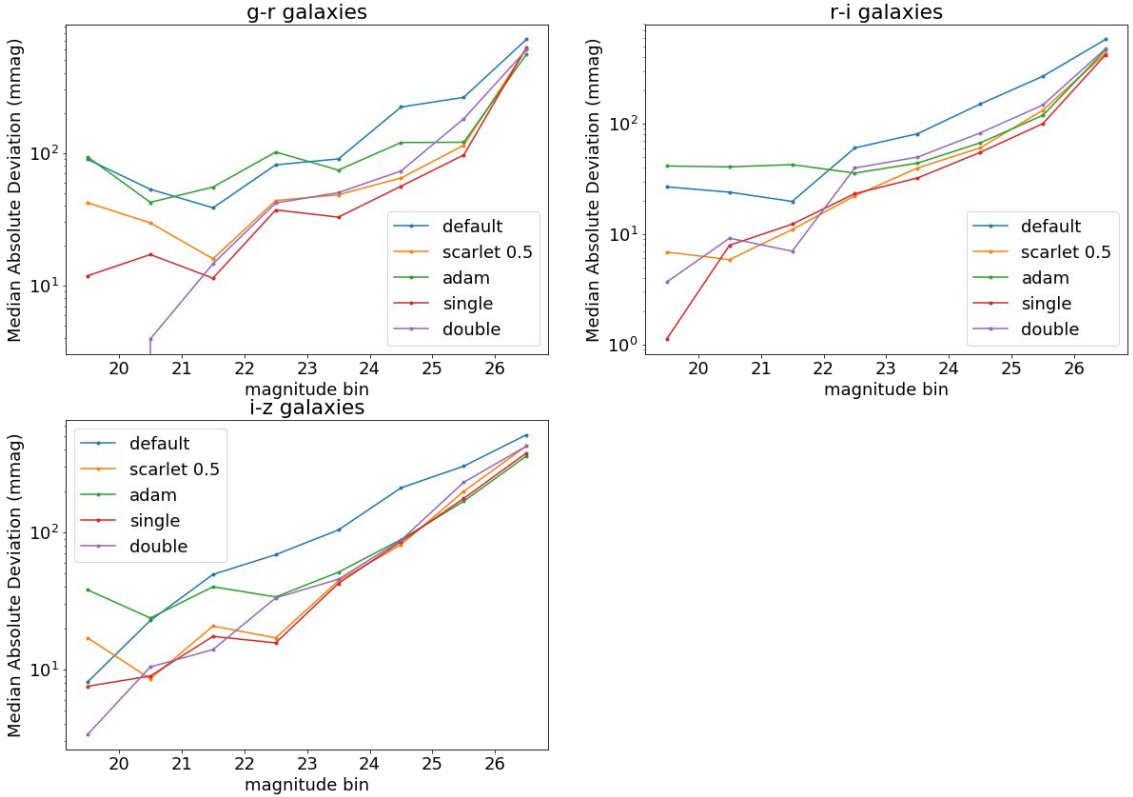
Analysis


r galaxies
default
scarlet 0.5
double
median
σ_{mad}
Difference
True magnitude
2000
1500
1000
500
0
−500
−1000
−1500
−2000
18
20
22
24
26
28

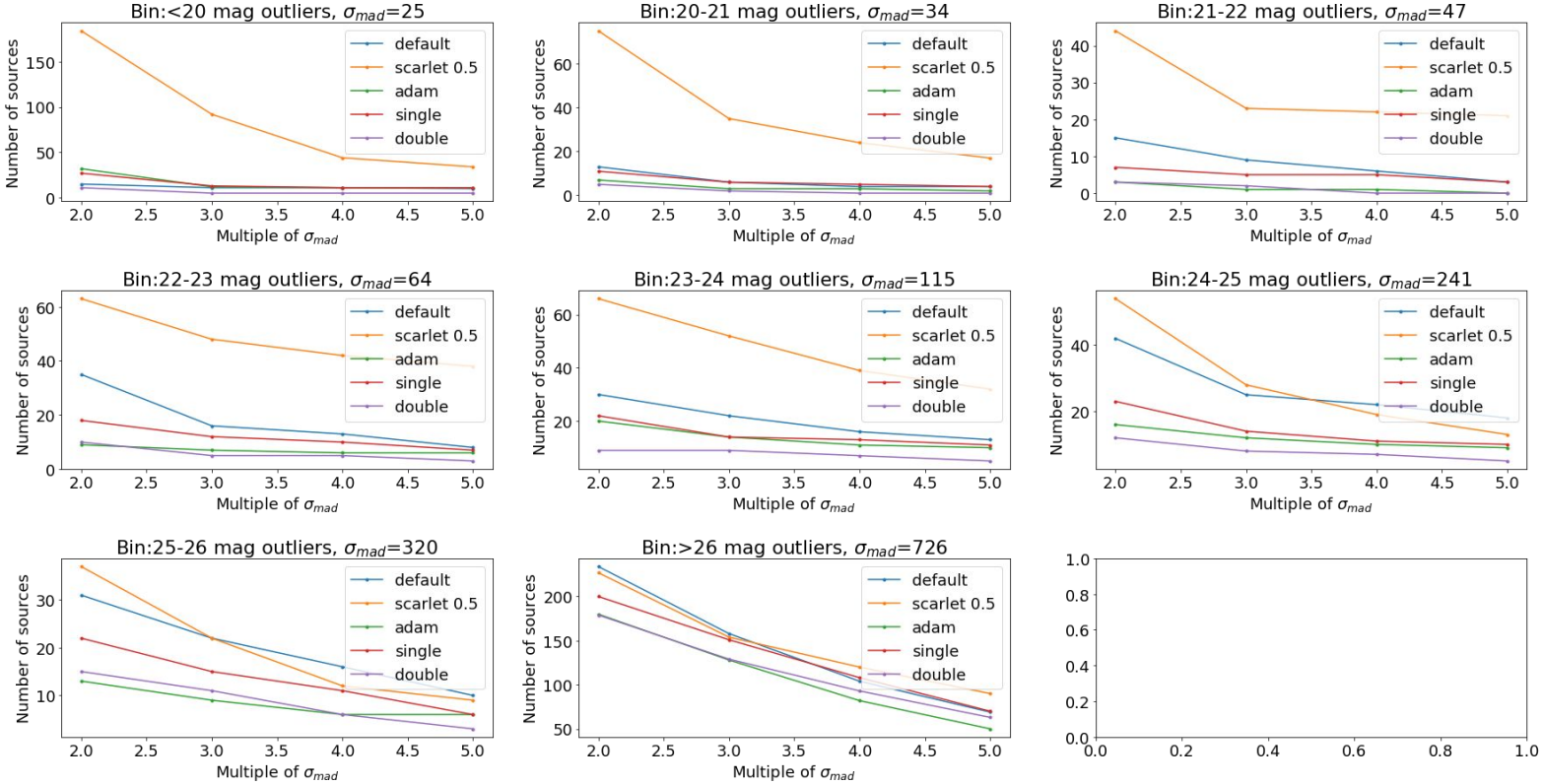
Analysis


g galaxies
r galaxies
i galaxies
z galaxies
Median Absolute Deviation (mmag)
magnitude bin
default
scarlet 0.5
adam
single
double

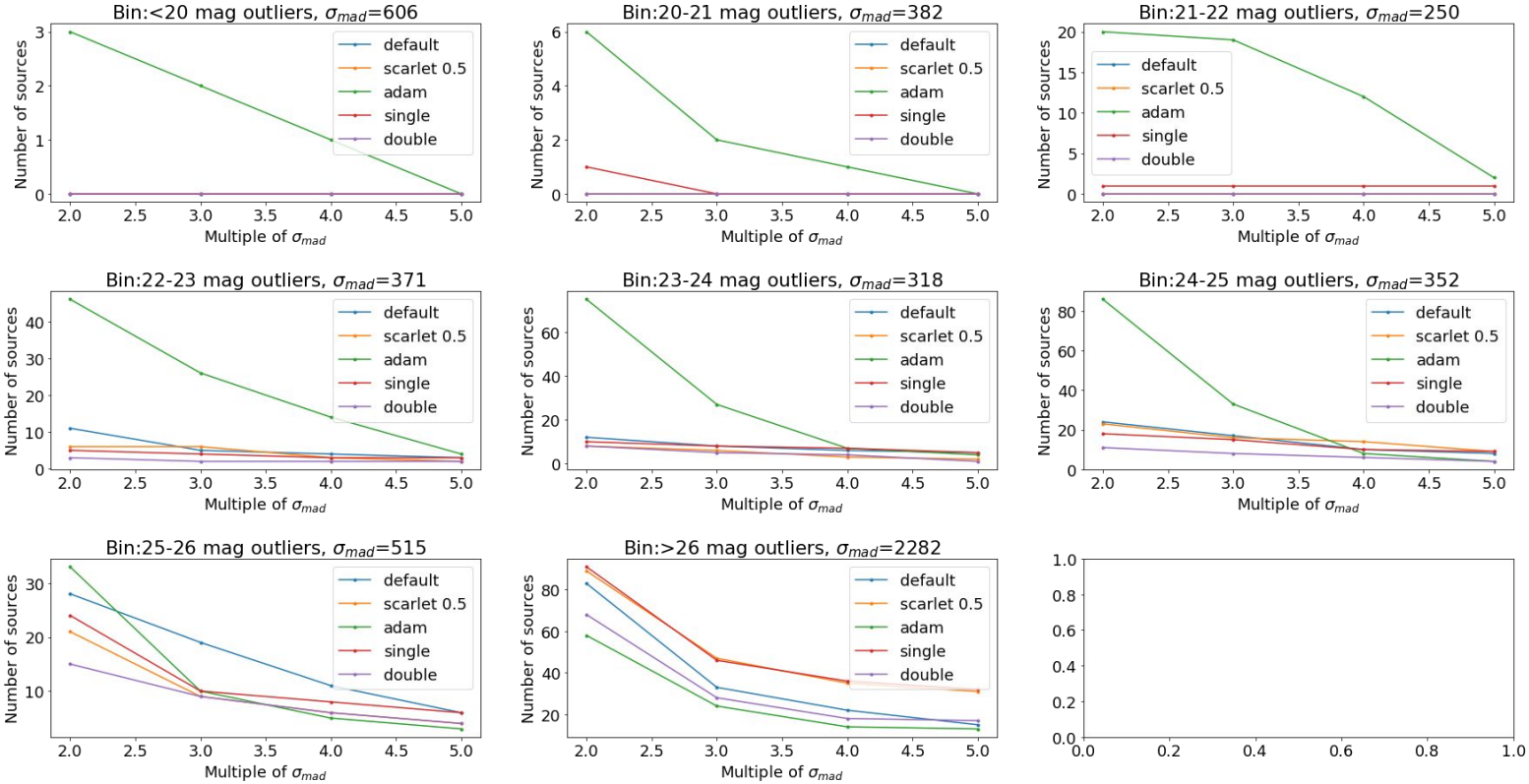
Analysis


g-r galaxies
r-i galaxies
i-z galaxies
Median Absolute Deviation (mmag)
magnitude bin
default
scarlet 0.5
adam
single
double

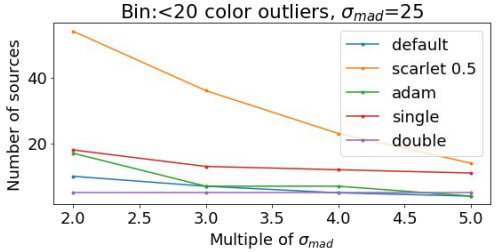
Outliers (stellar mag)

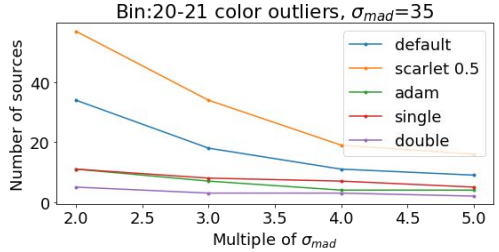


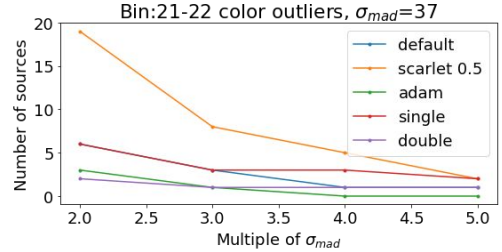
Outliers (galaxy mag)

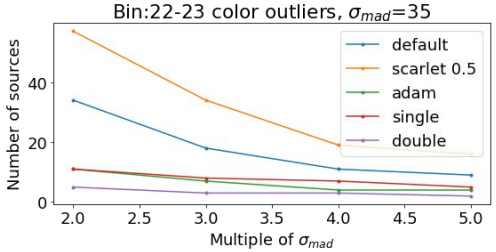


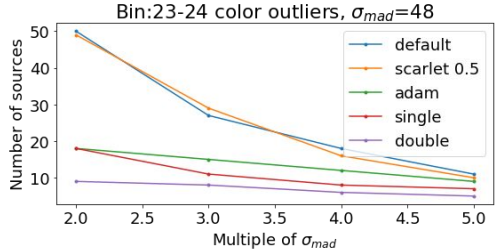
Outliers (stellar colors)

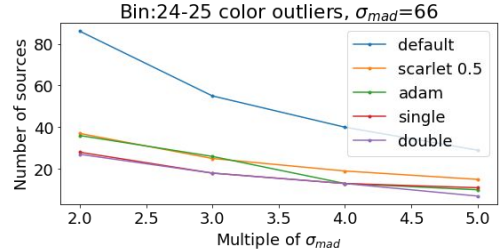


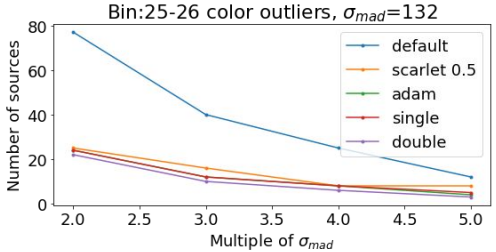


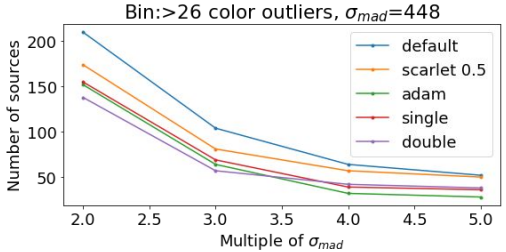




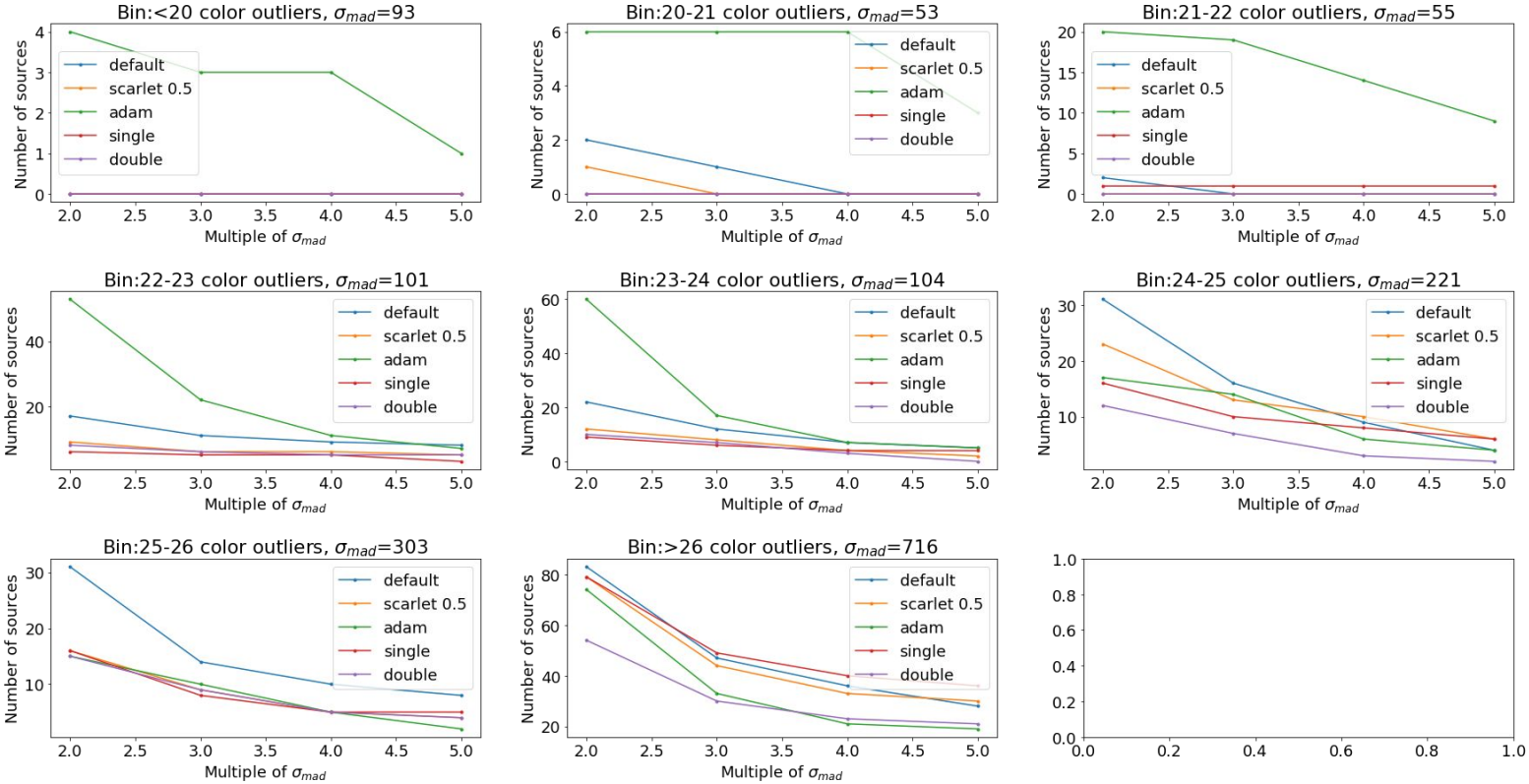








Outliers (galaxy colors)



Most important short-term issues to address

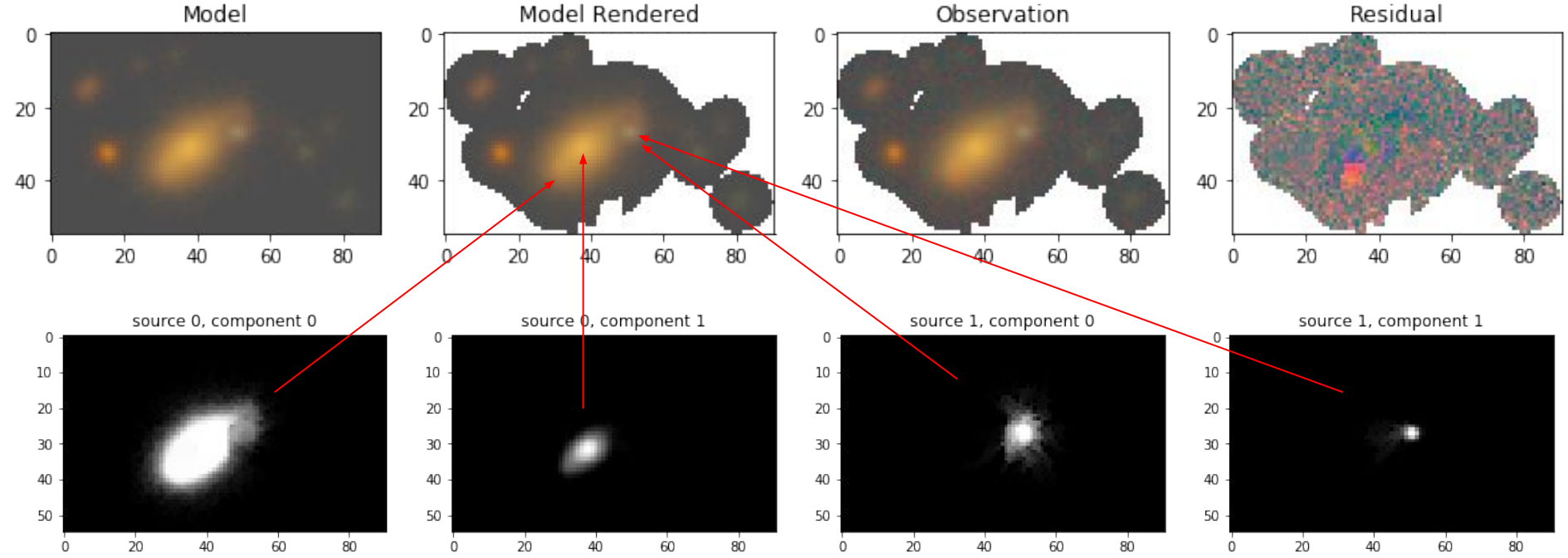
- Identification of source type
- Iterative detection and deblending to find new sources in the residuals and remove spurious detections
- Optimization of runtime
  - CSML scientist testing pytorch and JAX implementations for performance
  - Analytic convolutions instead of FFTs?
- Test memory usage
  - Old scarlet used the entire blend and could not deblend a full HSC patch
  - New scarlet uses boxes and may finally be able to deblend a full patch

Summary and Future Work

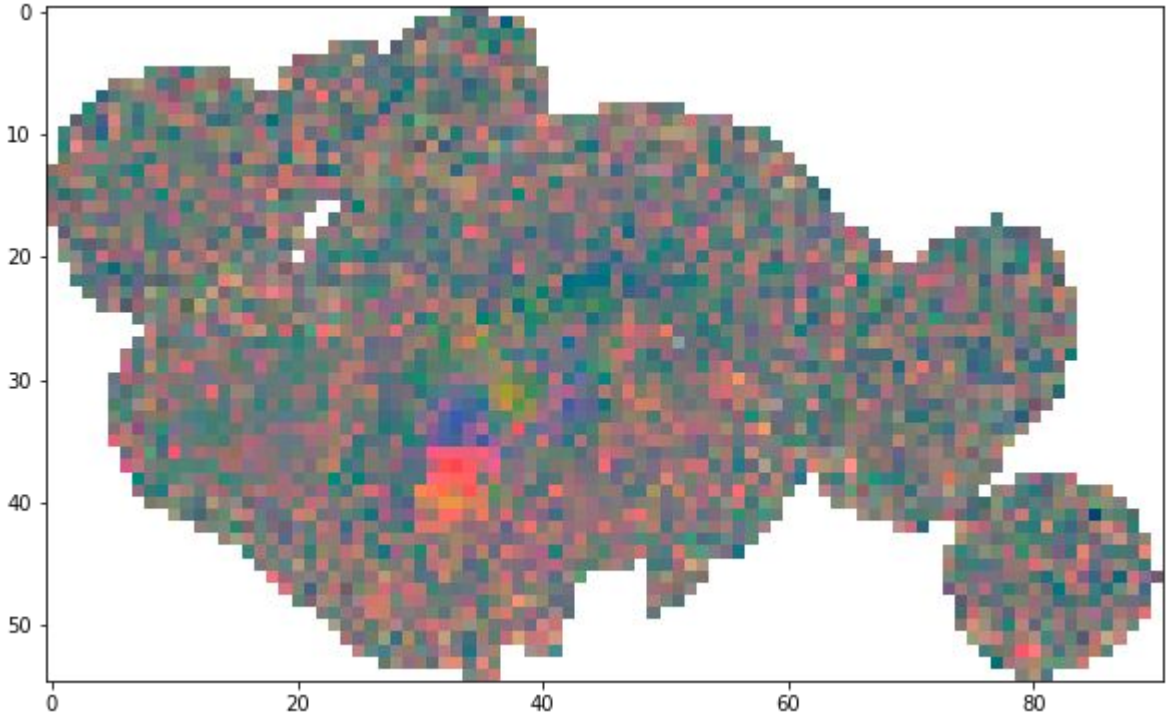
- There exists at least one deblending configuration in scarlet that produces more accurate stellar and galactic photometry and colors (but not jointly)
- Future work on initializations, iterative deblending and detection, and identification of source type should lead to a deblender that is more robust in all categories
- Test shape parameters and bias that will affect weak lensing
- Run time will always be more expensive than the current deblender, but may be partially offset by savings in measurement time

Extras

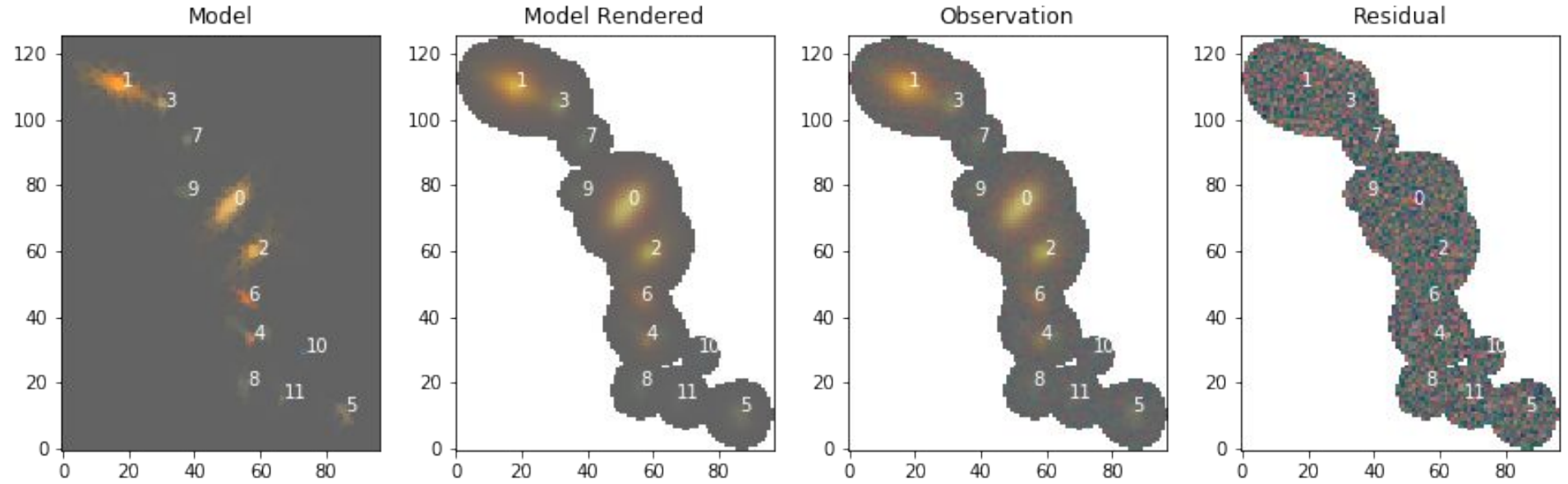
Examples


Model
Model Rendered
Observation
Residual
source 0, component 0
source 0, component 1
source 1, component 0
source 1, component 1

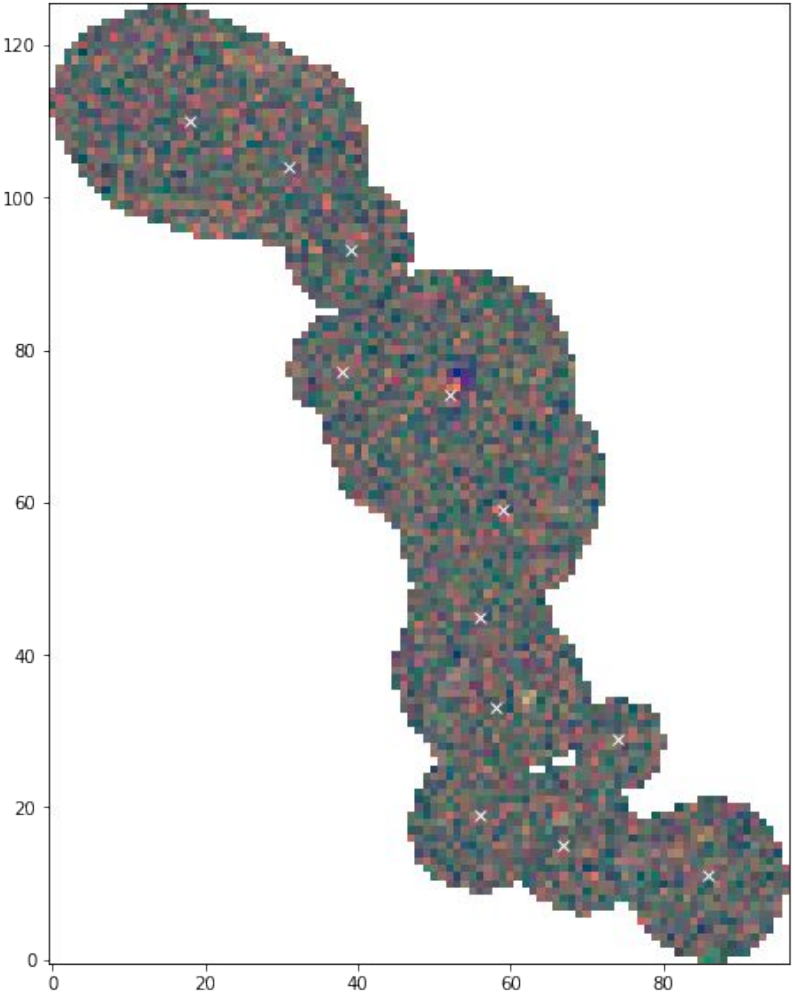
Examples



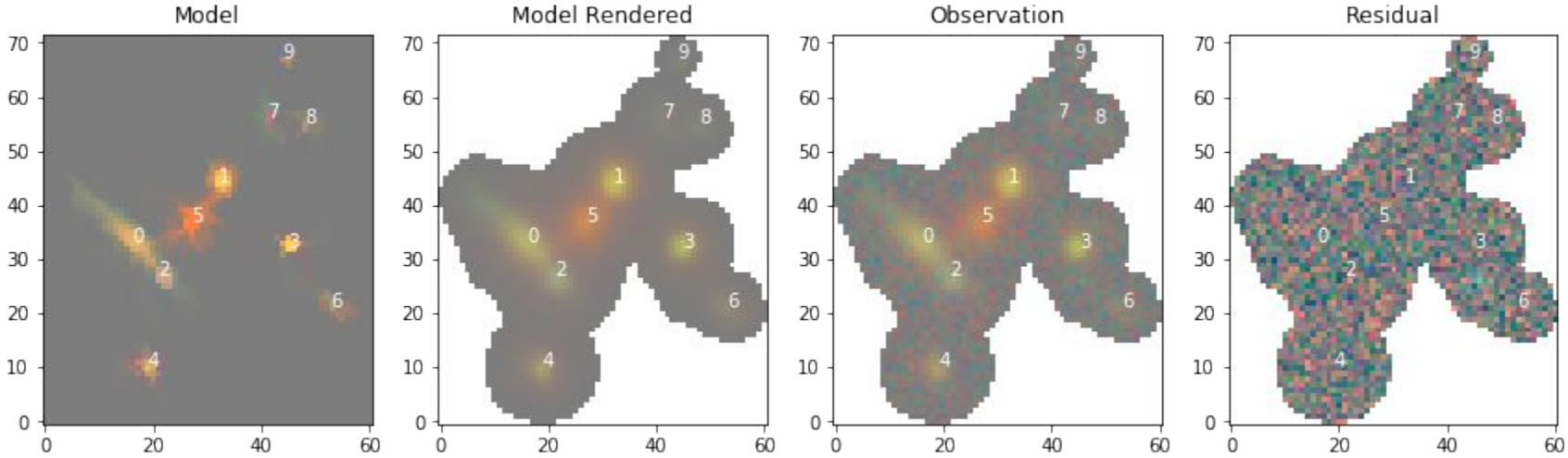
Examples


Model
Model Rendered
Observation
Residual
0
20
40
60
80
100
120
1
3
7
9
0
2
6
4
10
8
11
5

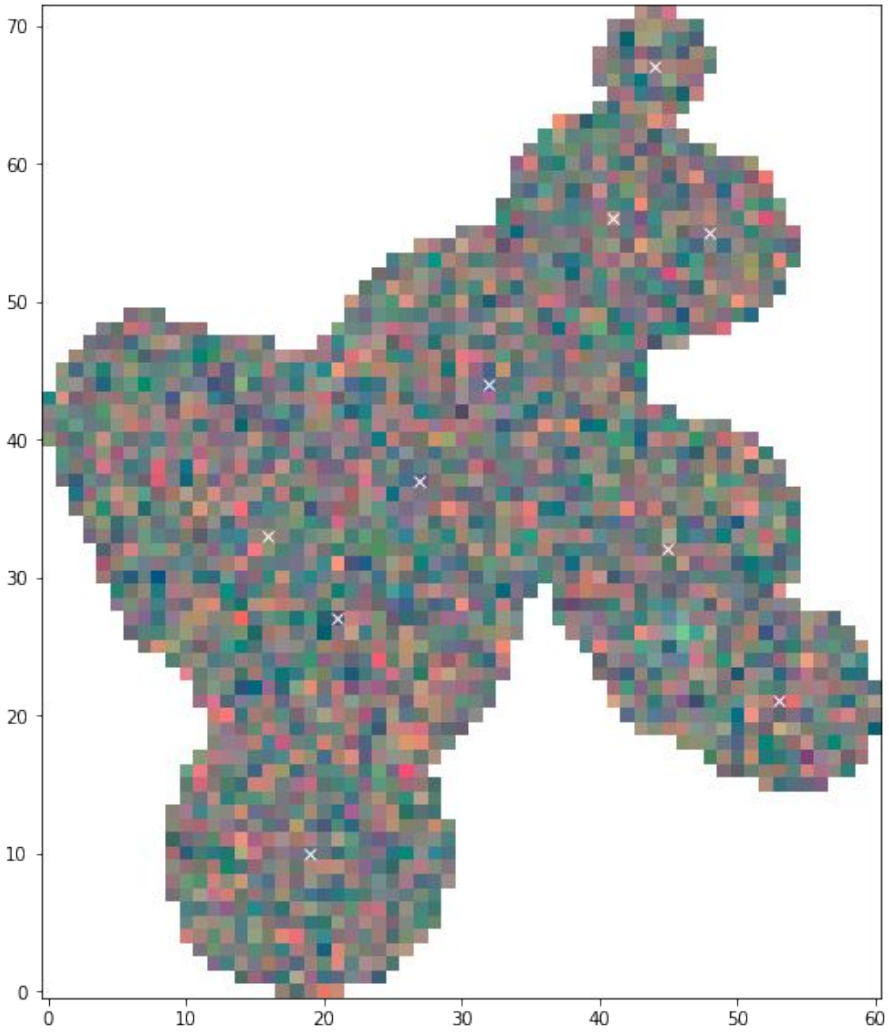
Examples



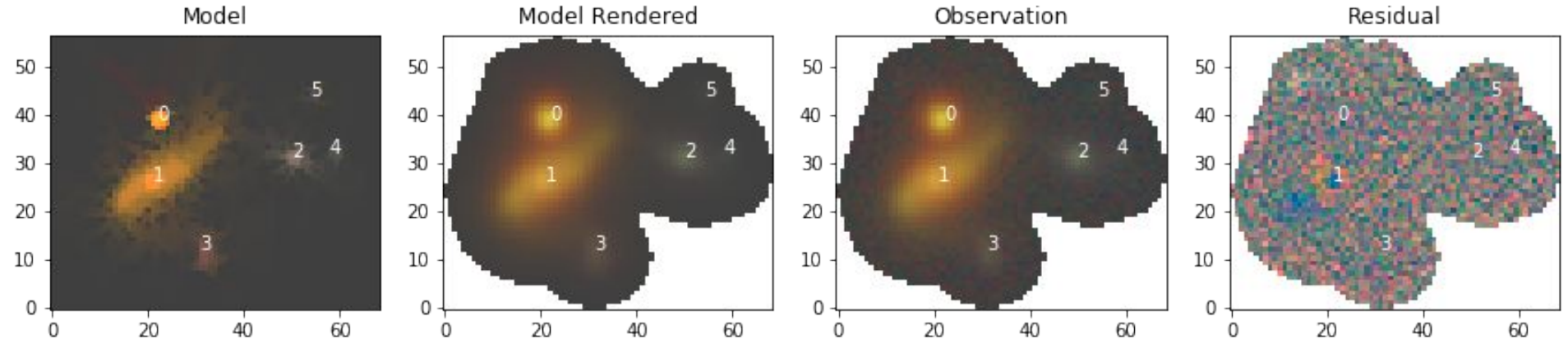
Examples



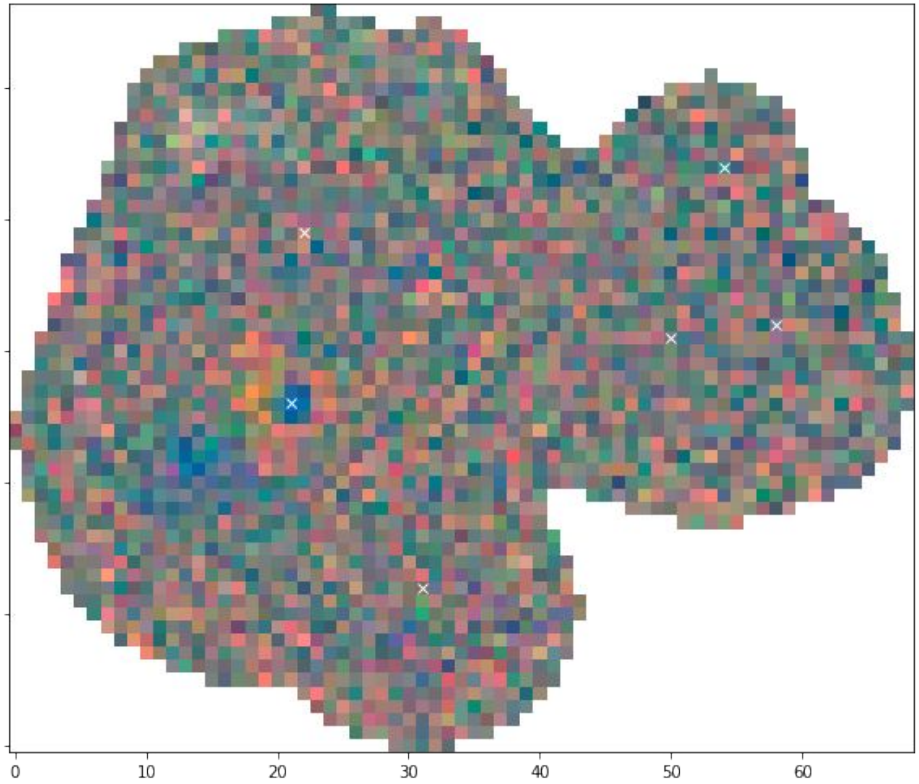
Examples



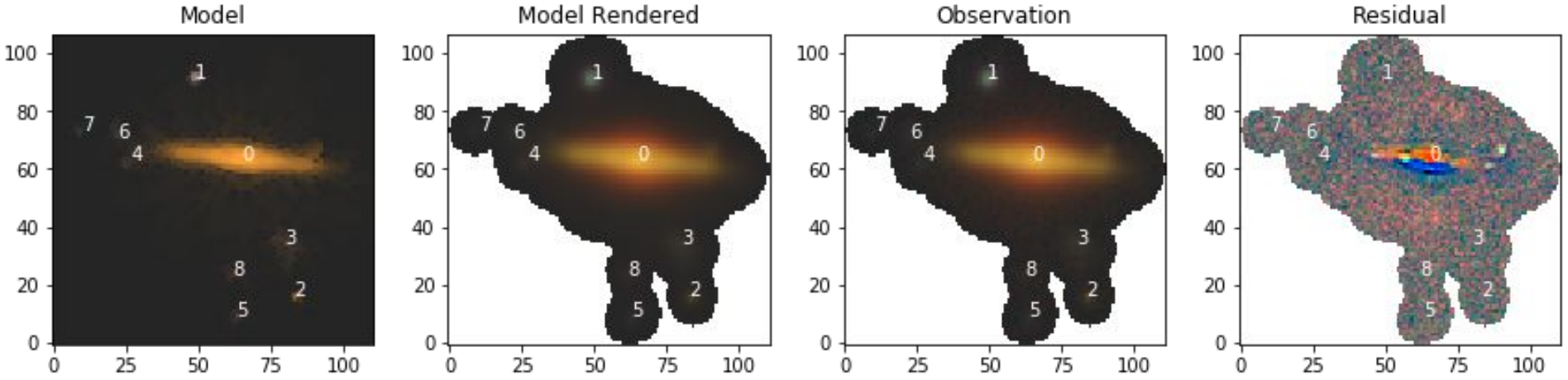
Examples


Model
Model Rendered
Observation
Residual
0
1
2
3
4
5
0
10
20
30
40
50
0
20
40
60

Examples



Examples


Model
Model Rendered
Observation
Residual
0
1
2
3
4
5
6
7
8
0
25
50
75
100
0
20
40
60
80
100

Examples