

# Supernovae in Image Simulations

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# Motivation

- Lot of work done on catalog-level simulations
- Need pixel-level simulations to inform catalog-level simulations and to prepare for science pipeline
- This work combines two previous works: the catalog-level simulations of Roman SN group and the image-level simulations of the Roman Weak Lensing Team (w/ updates from Rose et al. and Macias et al.)

## Simulations of the WFIRST Supernova Survey and Forecasts of Cosmological Constraints

R. Hounsell, D. Scolnic, R. J. Foley, R. Kessler, V. Miranda, A. Avelino, R. C. Bohlin, A. V. Filippenko, J. Frieman, S. W. Jha, P. L. Kelly, R. P. Kirshner, K. Mandel, A. Rest, A. G. Riess, S. A. Rodney, L. Strolger

The Wide Field InfraRed Survey Telescope (WFIRST) was the highest ranked large space-based mission of the 2010 New Worlds, New Horizons decadal survey. It is now a NASA mission in formulation with a planned launch in the mid-2020s. A primary mission objective is to precisely constrain the nature of dark energy through multiple probes, including Type Ia supernovae (SNe Ia). Here, we present the first realistic simulations of the WFIRST SN survey based on current hardware specifications and using open-source tools. We simulate SN light curves and spectra as viewed by the WFIRST wide-field channel (WFC) imager and integral-field channel (IFC) spectrometer, respectively. We examine 11 survey strategies with different time allocations between the WFC and IFC, two of which are based upon the strategy described by the WFIRST Science Definition Team, which measures SN distances exclusively from IFC data. We propagate statistical and, crucially, systematic uncertainties to predict the Dark Energy Task Force figure of merit (FoM) for each strategy. Of the strategies investigated, we find the most successful to be WFC-focused. However, further work in constraining systematics is required to fully optimize the use of the IFC. Even without improvements to other cosmological probes, the WFIRST SN survey has the potential to increase the FoM by more than an order of magnitude from the current values. Although the survey strategies presented here have not been fully optimized, these initial investigations are an important step in the development of the final hardware design and implementation of the WFIRST mission.

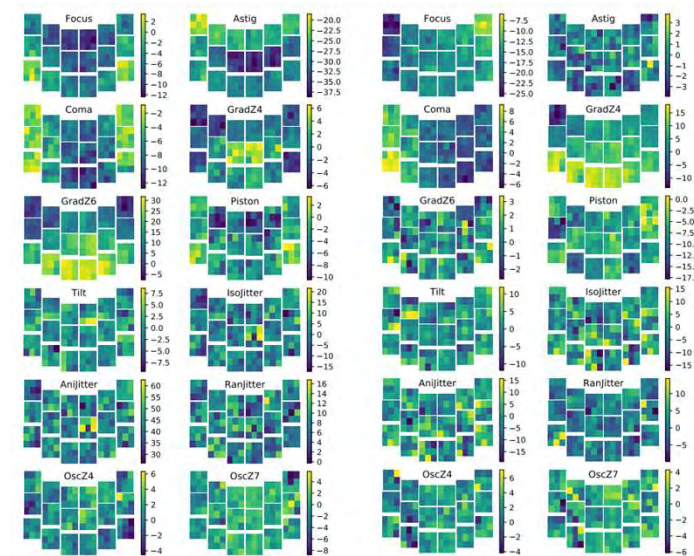
## A Synthetic Roman Space Telescope High-Latitude Imaging Survey: Simulation Suite and the Impact of Wavefront Errors on Weak Gravitational Lensing

M. A. Troxel, H. Long, C. M. Hirata, A. Choi, M. Jarvis, R. Mandelbaum, K. Wang, M. Yamamoto, S. Hemmati, P. Capak

The Nancy Grace Roman Space Telescope (Roman) mission is expected to launch in the mid-2020s. Its weak lensing program is designed to enable unprecedented systematics control in photometric measurements, including shear recovery, point-spread function (PSF) correction, and photometric calibration. This will enable exquisite weak lensing science and allow us to adjust to and reliably contribute to the cosmological landscape after the initial years of observations from other concurrent Stage IV dark energy experiments. This potential requires equally careful planning and requirements validation as the mission prepares to enter its construction phase. We present a suite of image simulations based on GalSim that are used to construct a complex, synthetic Roman weak lensing survey that incorporates realistic input galaxies and stars, relevant detector non-idealities, and the current reference five-year Roman survey strategy. We present a first study to empirically validate the existing Roman weak lensing requirements flowdown using a suite of 12 matched image simulations, each representing a different perturbation to the wavefront or image motion model. These are chosen to induce a range of potential static and low- and high-frequency time-dependent PSF model errors. We analyze the measured shapes of galaxies from each of these simulations and compare them to a reference, fiducial simulation to infer the response of the shape measurement to each of these modes in the wavefront model. We then compare this to existing analytic flowdown requirements, and find general agreement between the empirically derived response and that predicted by the analytic model.

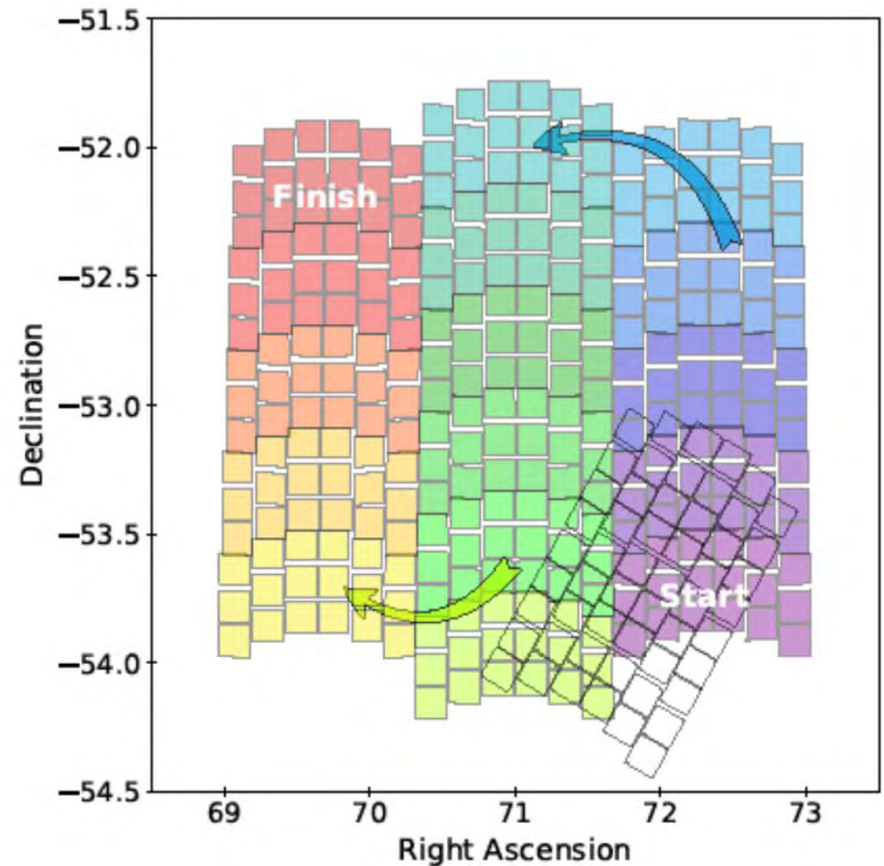
Troxel et al. 2019 simulates images over 5 square degrees using simulations of star and galaxy positions, and realistic accounting of camera artifacts

- Uses Buzzard simulations to create distribution of galaxies, then each galaxy is assigned to a CANDELS library (HST survey) galaxy for that redshift, from which we can derive galaxy properties
- Created using GalSim, open-source image simulation software with a Roman package with details of the telescope
- Model various detection effects such as reciprocity failure, dark current, and interpixel capacitance

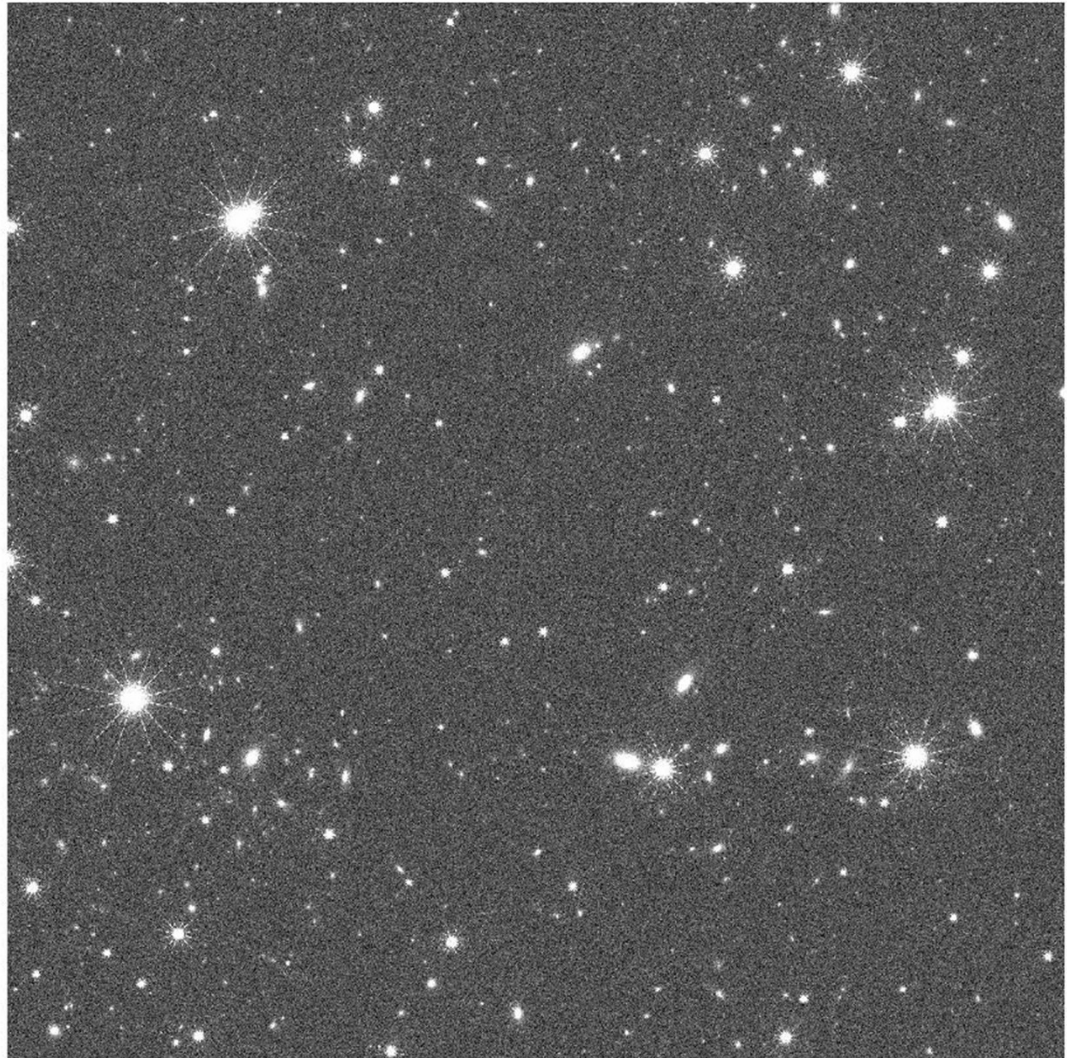


# Slewing Strategy

- For image simulations, we need to make choices that aren't done in catalog sims, like exact slewing strategy
- Deep field strategy with exposure times 300, 300, 300, 900 seconds in YJHF respectively
- Go through snake pattern then change filter and reverse through pattern for 4 filters
- Cadence of 5 days
- Rotate telescope and pattern by 30 degrees every 30 days



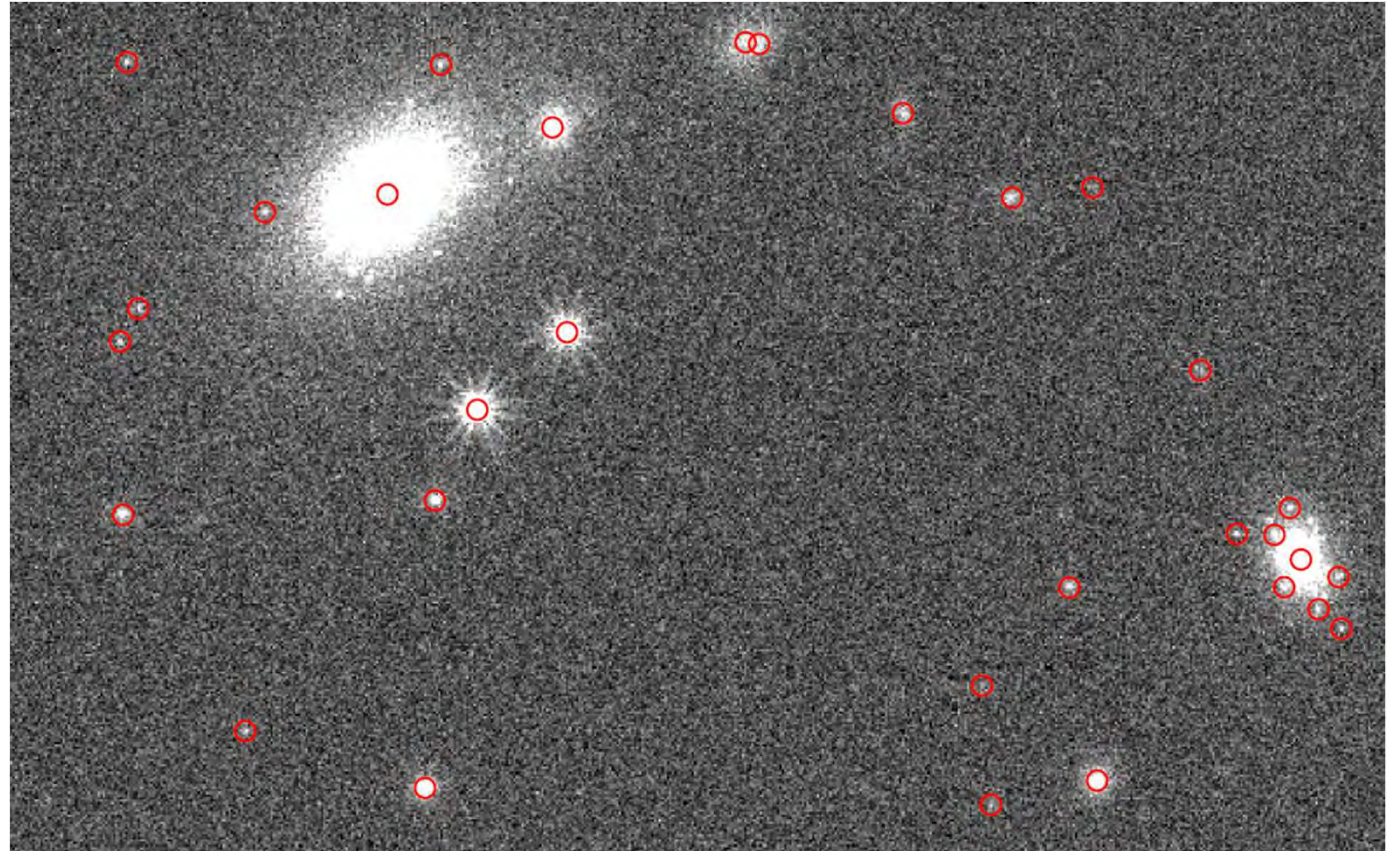
# Example Image



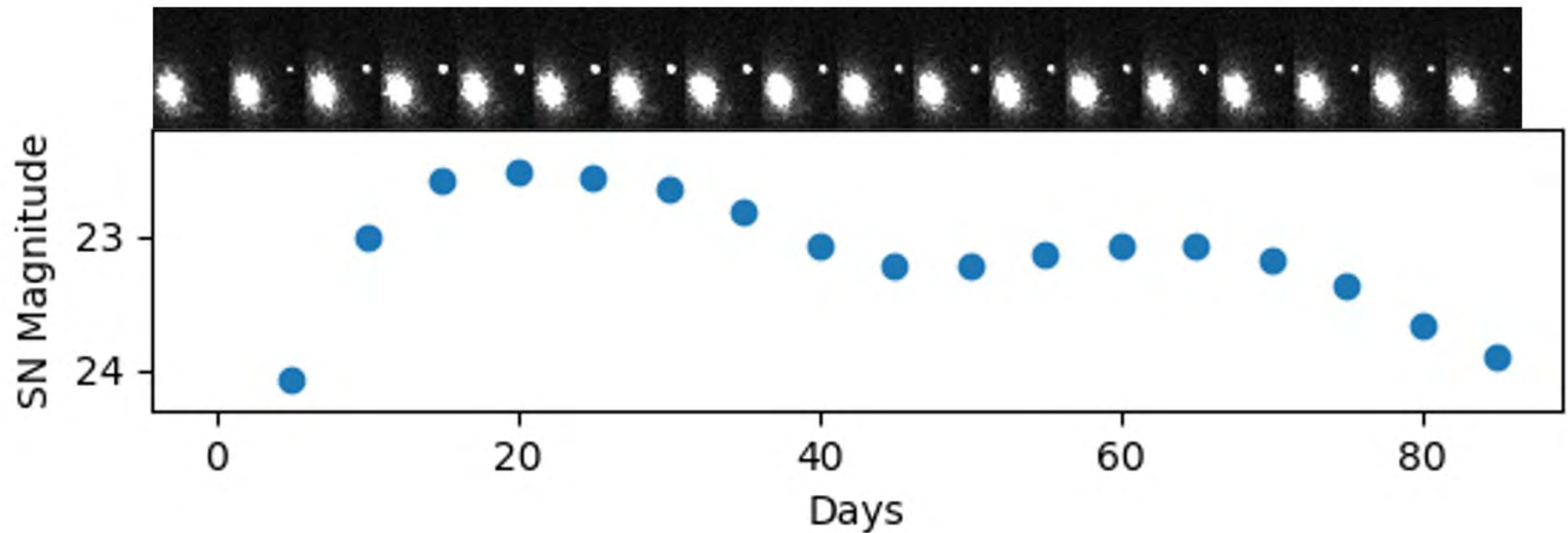


# Example Image

Using Source  
Extractor  
(AstrOmatic  
program for  
detecting objects  
in images).  
Detections  
circled in red.



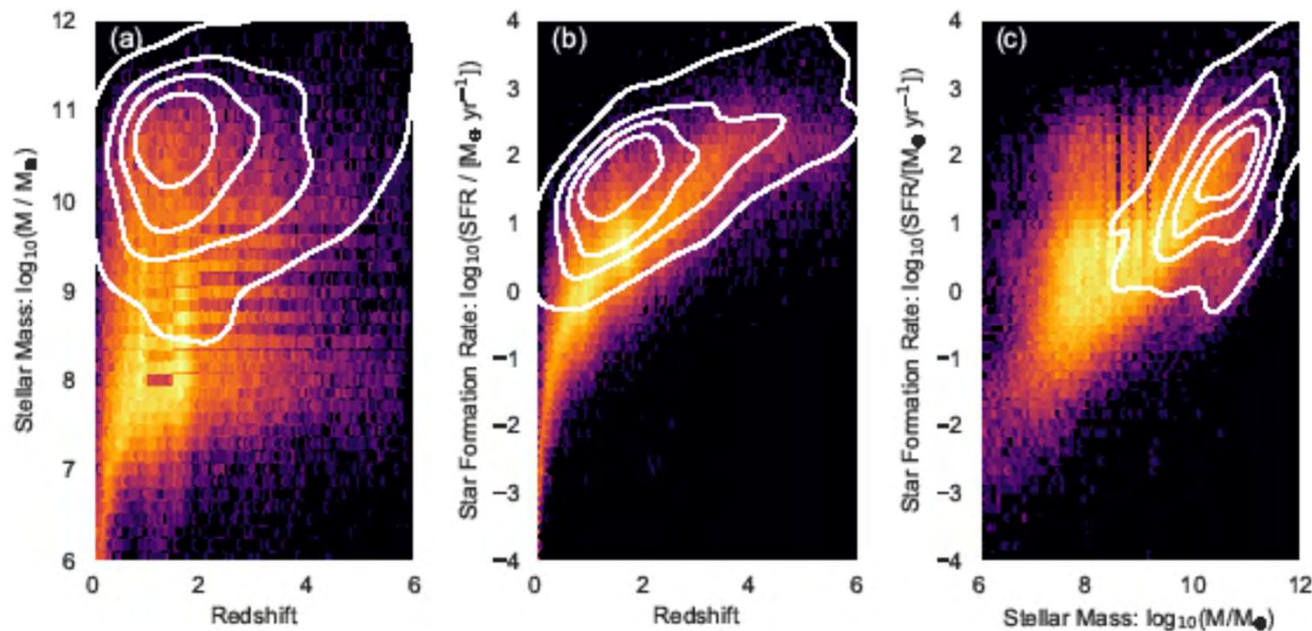
# Inject Supernovae as Stellar Point Sources



Series of cutouts of a Y-band image showing a bright supernova

# Generating Supernovae

- Give SNANA a catalogue with galaxy information
- Choose host galaxies with higher star formation rate and mass (proxies for SN rate)
- Effect is that host galaxies are brighter on average compared to galaxies overall
- On images, heatmap represents all galaxies. Contours represent host galaxies only.

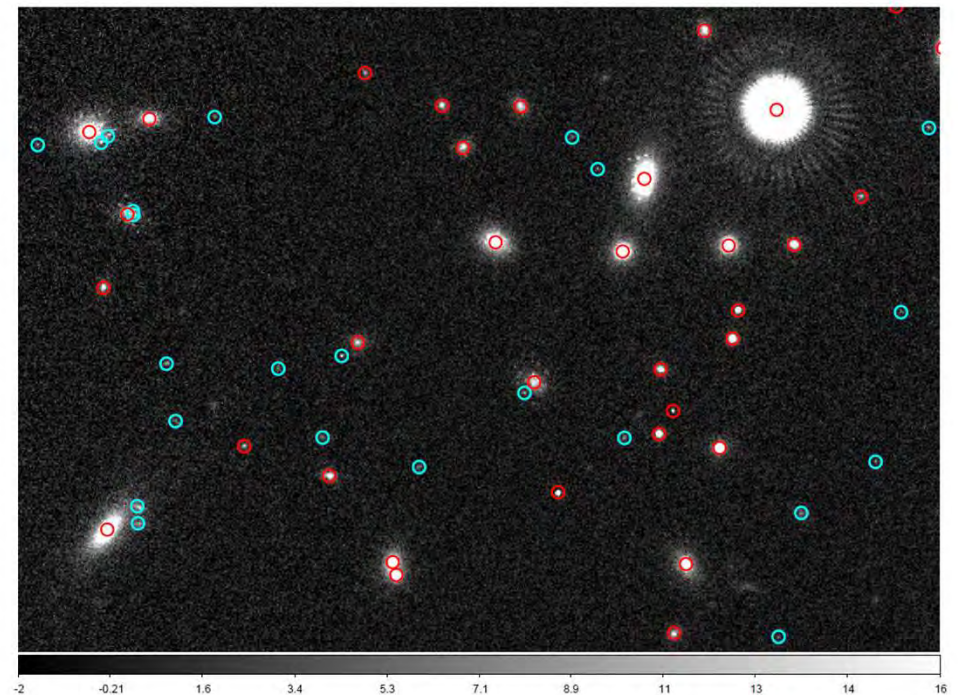
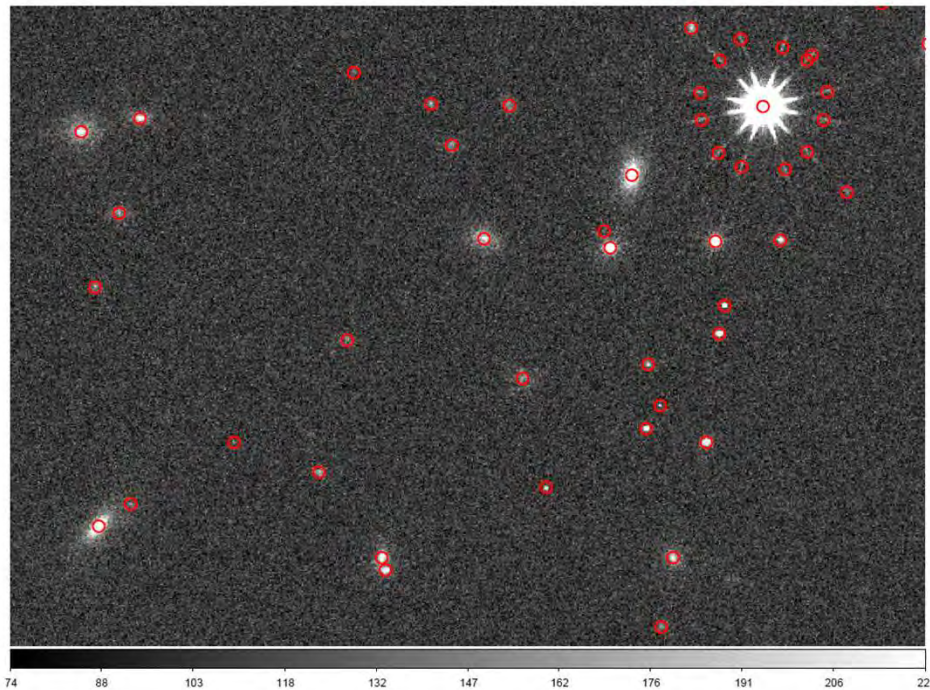




# Pipeline Preparation

# Coadds

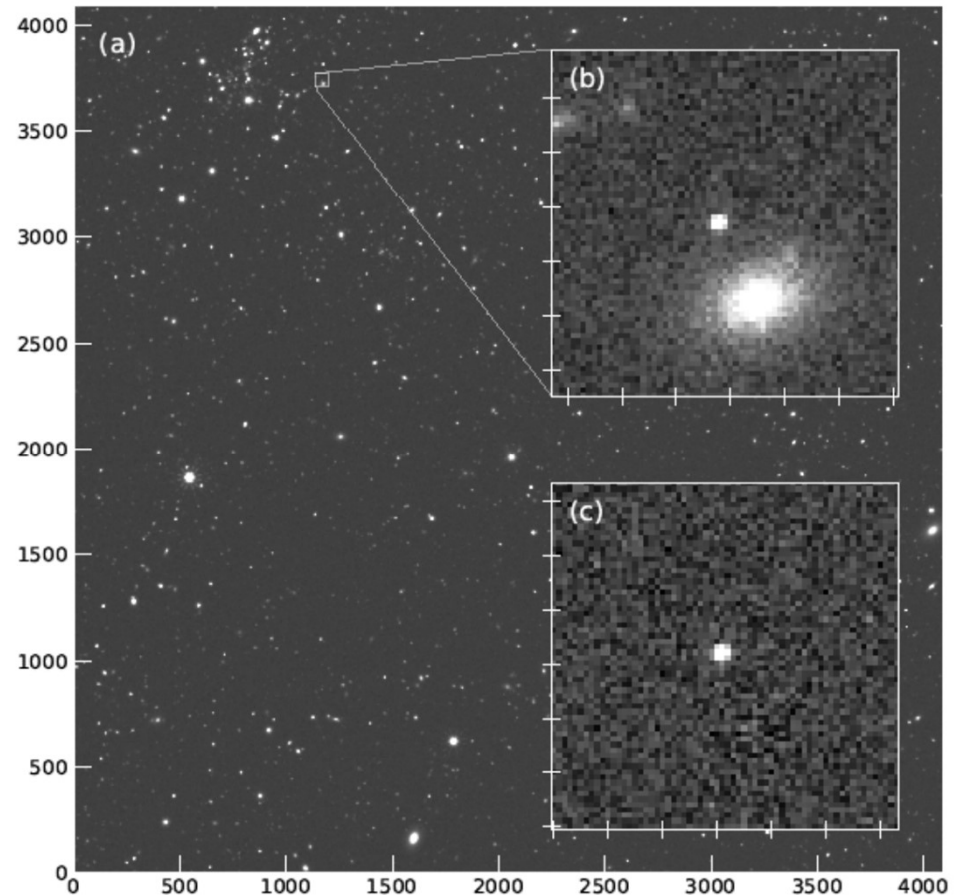
Approx. 10-15 images deep



Can run AstroDrizzle (Python implementation of MultiDrizzle for HST) to combine images. Cyan circles show additional objects detected in coadd.

# Difference Images

- Images created by subtracting a template
- Allows detection of transients
- Just an example - needs more development to be pipeline ready to run on full suite of images

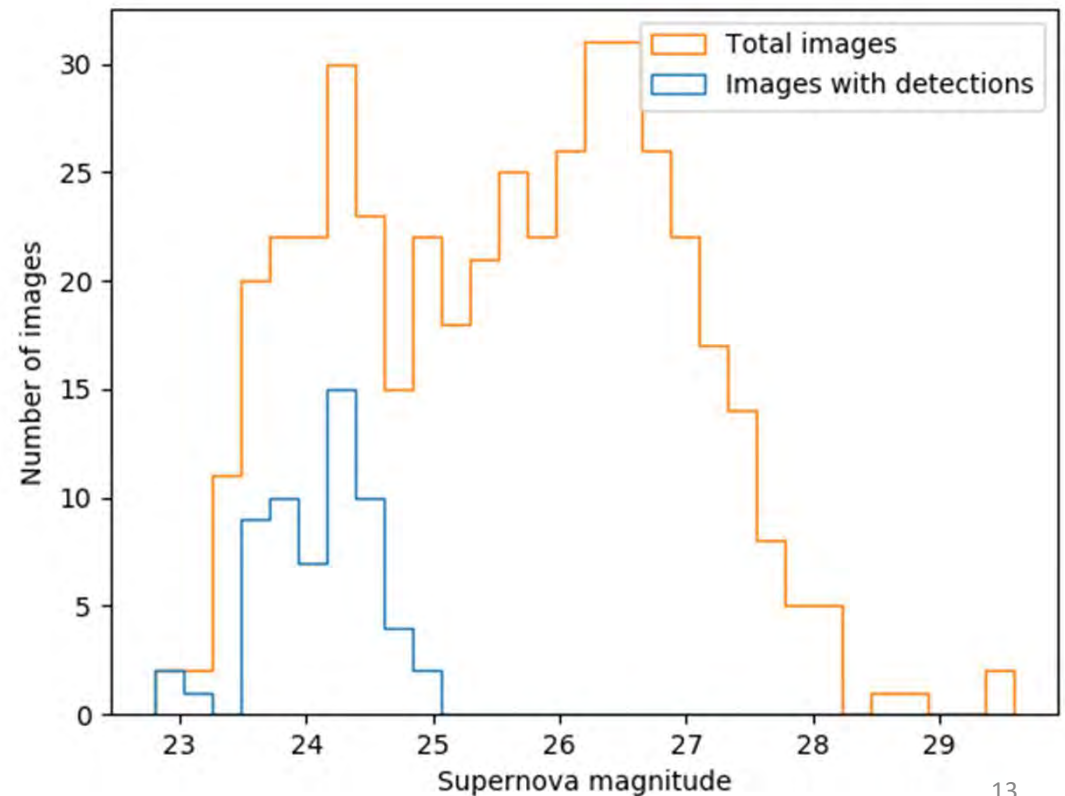


# Science Preparation

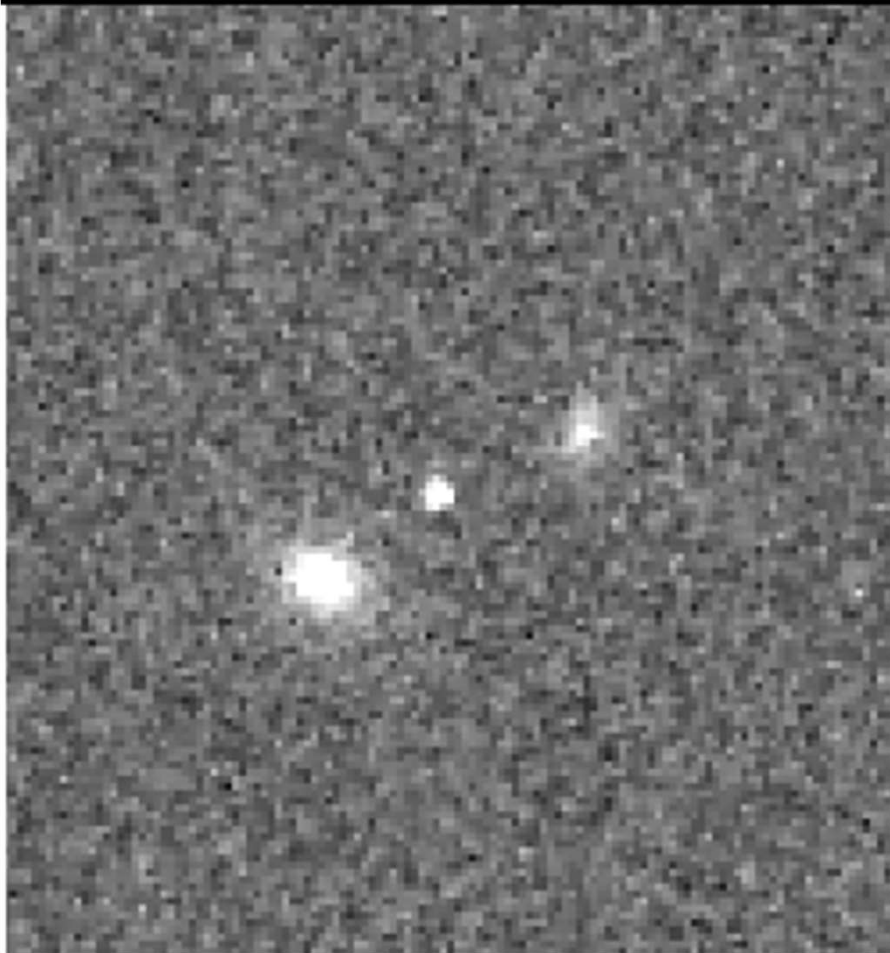


# Supernova Detection

- Detection efficiency using isolated SNe
- Not done using difference images (ideally would be)
- Only SNe not next to large or bright galaxies
- Could feed efficiency back into catalog sims

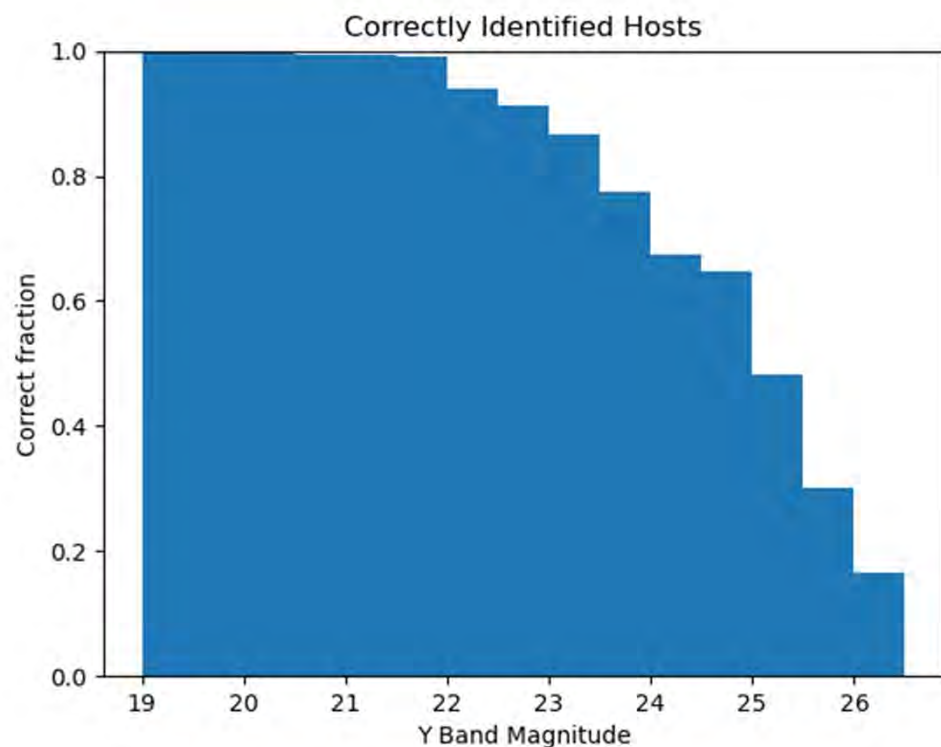


Which is the right host galaxy?



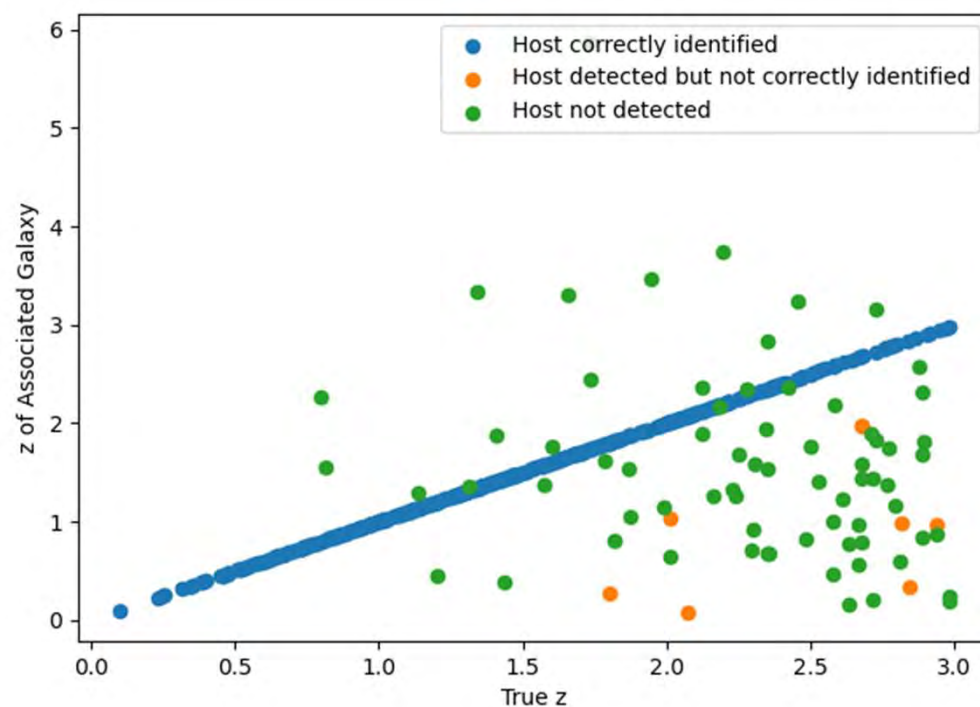
- Simplest method – Just use distance between SN and galaxy center
- More complex method
  - Also take into account size and orientation of galaxies
- Additionally, can compare redshift of SN and galaxy

# Host Galaxy Association



Using simplest method here

$z < 1$ : 96 correct, 2 not found  
 $z > 1$ : 315 correct, 8 incorrect, 68 not found



Good performance below  $z = 1$

# Output

- Set of images representing a 1 square degree subset of the deep field slewing strategy (available soon)
- Truth files for objects included
- This work will be part of Wang et al. 22 which is currently in preparation

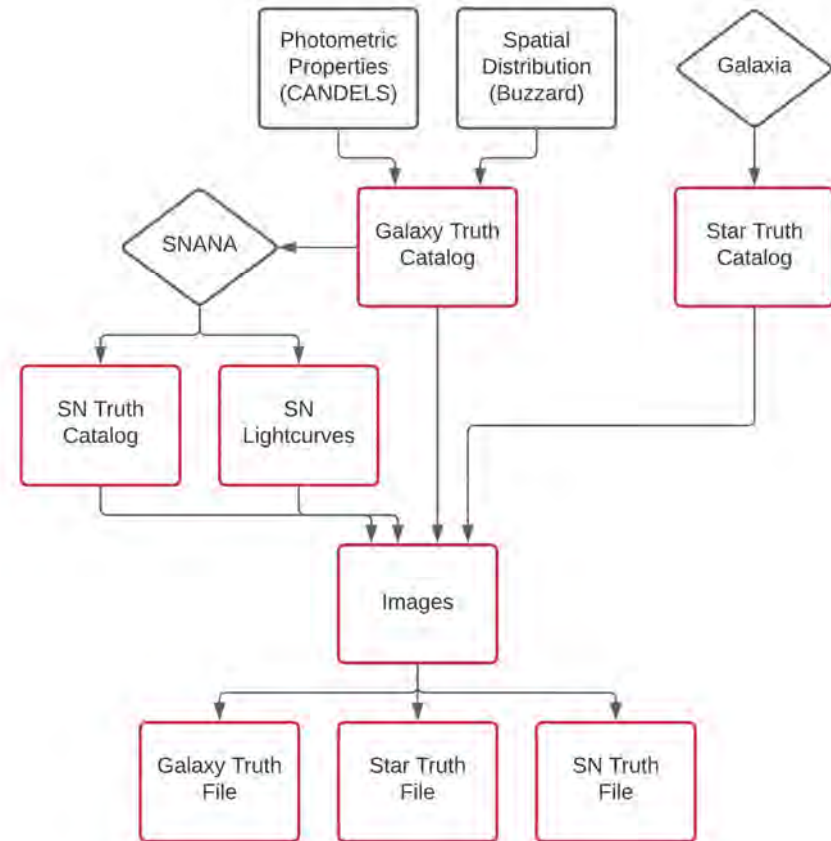


Illustration of the image simulation process. Red shapes are files that will be provided with the output



# Conclusion

- Image simulations are necessary as part of the pipeline development for Roman telescope
- We created image simulations that include injected SNe
- We show several analyses with these simulated images to demonstrate their potential utility
- We will provide a set of these images for use