Constructing a 3D Galactic Data Cube Using *Sloan Digital Sky Survey* Imaging Data

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Introduction

Measuring the Universe

- Type Ia supernovae are standard candles, objects with an intrinsic luminosity
- A fainter apparent magnitude generally means the object is farther away, indicating an older age
- SNe Ia brightness and distance help to determine dark energy parameters

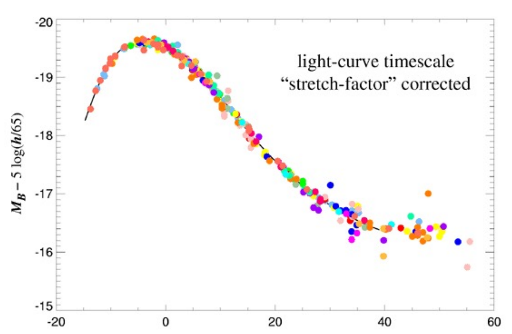


Figure 1. The standardized light curve of Type Ia supernovae, peaking around -19.5. Adapted from "Environmental Dependence of Type Ia Supernova Luminosities from the YONSEI Supernova Catalog," by Kim ***et al.,*** 2019.

Host Galaxy Contamination

- The *Roman* Space Telescope will observe an enormous amount of SNe Ia spectra, but observed spectra are contaminated by host galaxies
- The host galaxy spectrum must be subtracted from the telescope-obtained spectra to obtain clean SNe Ia spectra
- Using SDSS imaging data as templates, simulated host galaxy spectra are generated and stored in data cubes
- The SDSS telescope images the night sky in five filters, ***ugriz***, spanning wavelengths of ~3500-10000 Å – just into UV and infrared light

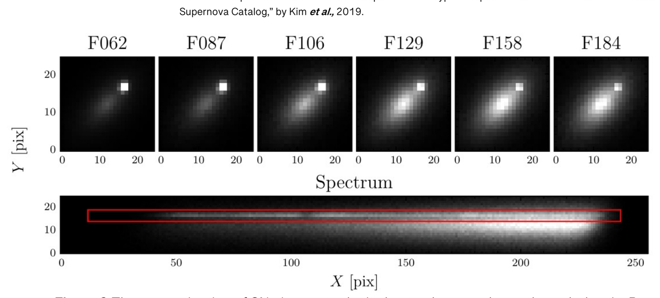


Figure 2. The contamination of SNe Ia spectra by its host galaxy, as shown through the six *Roman* filters. Adapted from "3D datacube reconstruction using Roman slitless prism spectra," Astraatmadja ***et al.,*** 2022.

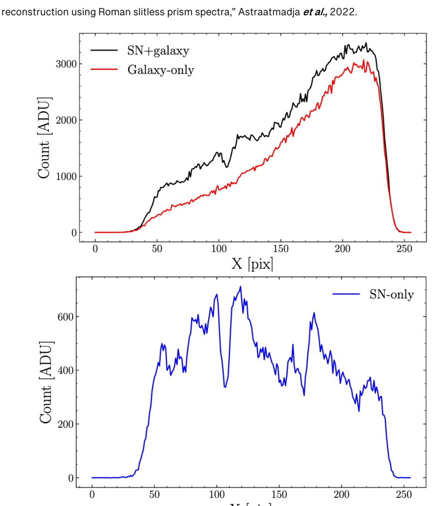


Figure 3. a) The SN+galaxy and galaxy spectra. b) Clean SN spectra after subtraction of the host galaxy. Adapted from Astraatmadja ***et al.***

Methods

1. Download SDSS images

- Randomly select a galaxy satisfying input conditions (redshift or ID) from a filtered catalog
- Download FITS imaging files from web using indicators: ***run, rerun, camcol, filter, field***

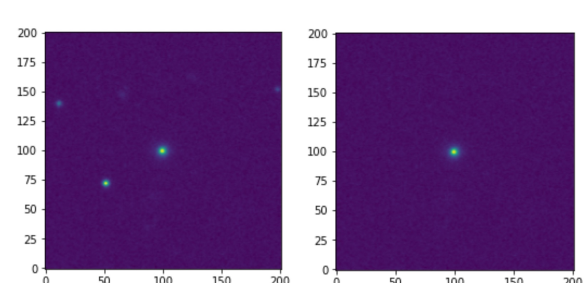


Figure 4. a) Pre-cleaning of light sources in the g-band of a galaxy at redshift 0.1. b) Post-cleaning and isolation of the central galaxy.

2. Resample, cutout, and clean

- Each filter ***(ugriz)*** of the same galaxy is slightly offset
- Realign images according to r-band
- Generate a 201x201 pixel cutout centered on the central galaxy, and clean other non-central light sources
- Generate noise, or error, maps based on ***gain*** and ***darkVariance*** values for each filter
- Save fluxes and flux errors for galaxy pixels to an ASCII file

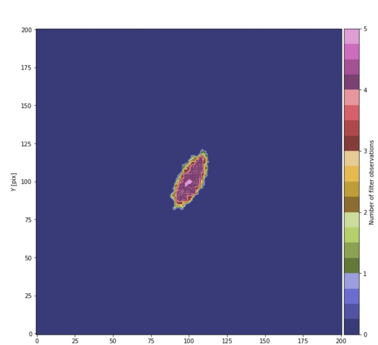


Figure 5. A filter observation map detailing the number of observations of the central galaxy across ***ugriz*** bands. Galaxy pixels are defined as having ≥ 1 source observation.

3. Fit to CIGALE

- ASCII file as CIGALE's input
- Uses interpolating galaxy-fitting model to generate continuous spectra across a wavelength range
- Different spectra for each galaxy pixel; output data saved to FITS files

4. Assemble data cube!

- Reassemble each pixel's model spectrum into its correct (x,y) position
- Non-galaxy pixels are filled with spectra of 0
- Data cube represents a continuous spectra, instead of five discrete fluxes for the image

Results

Figure 6. Spectra of various pixels within the central galaxy of a data cube generated for redshift 0.1. Results are reasonable within the SDSS wavelength range, 350-1000 nm.

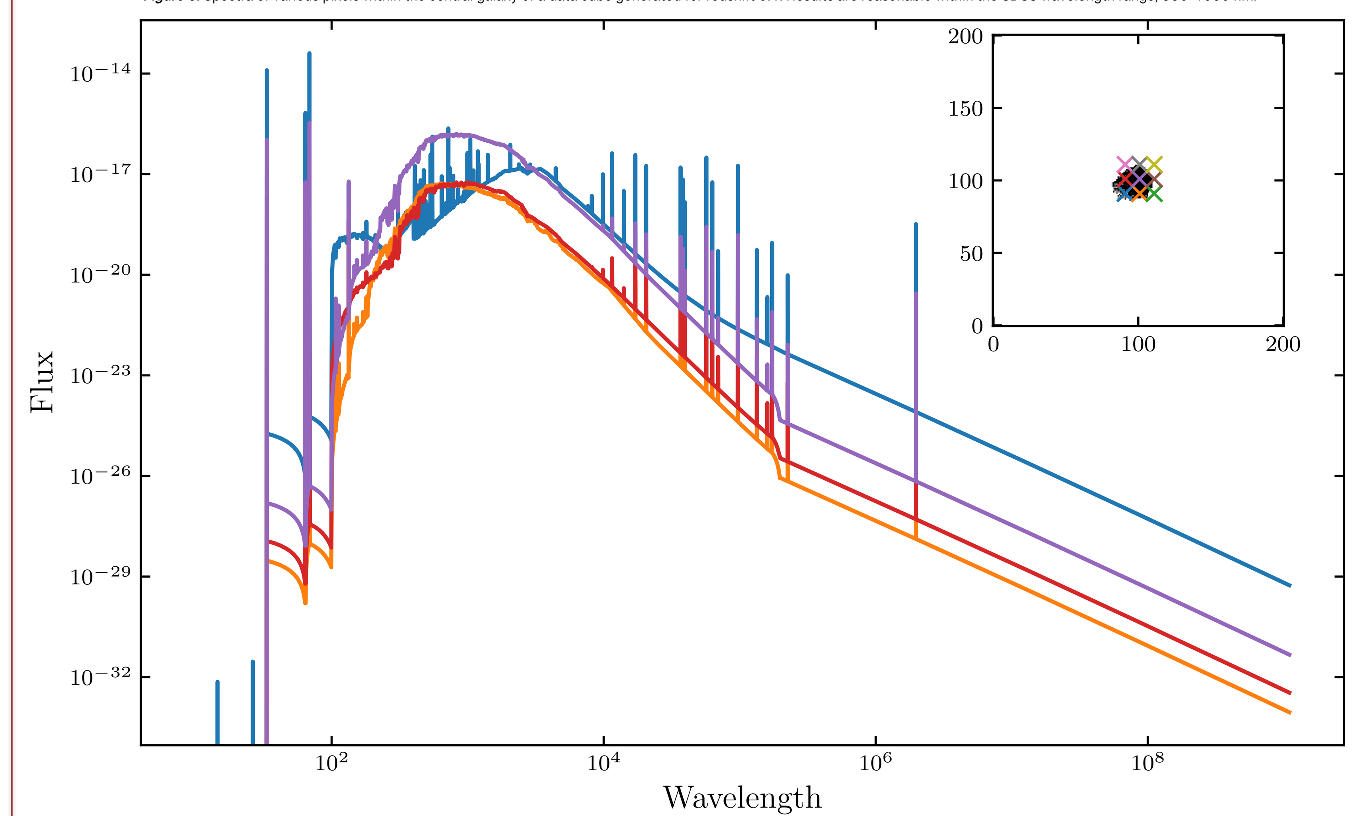
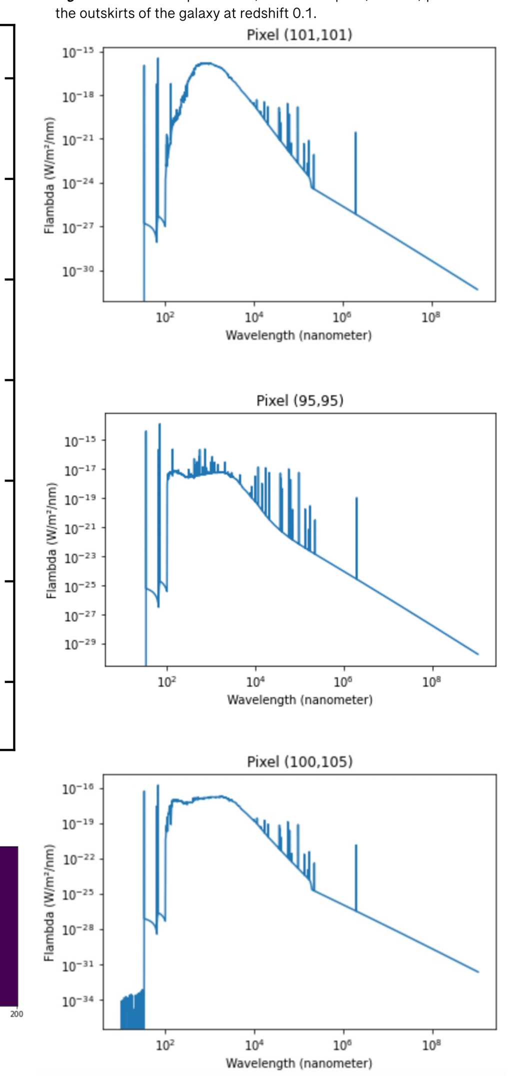


Figure 7. Individual spectra of a) the central pixel, b and c) pixels on the outskirts of the galaxy at redshift 0.1.



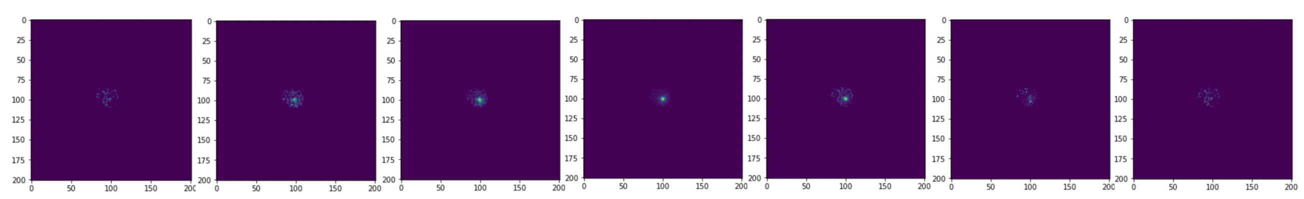
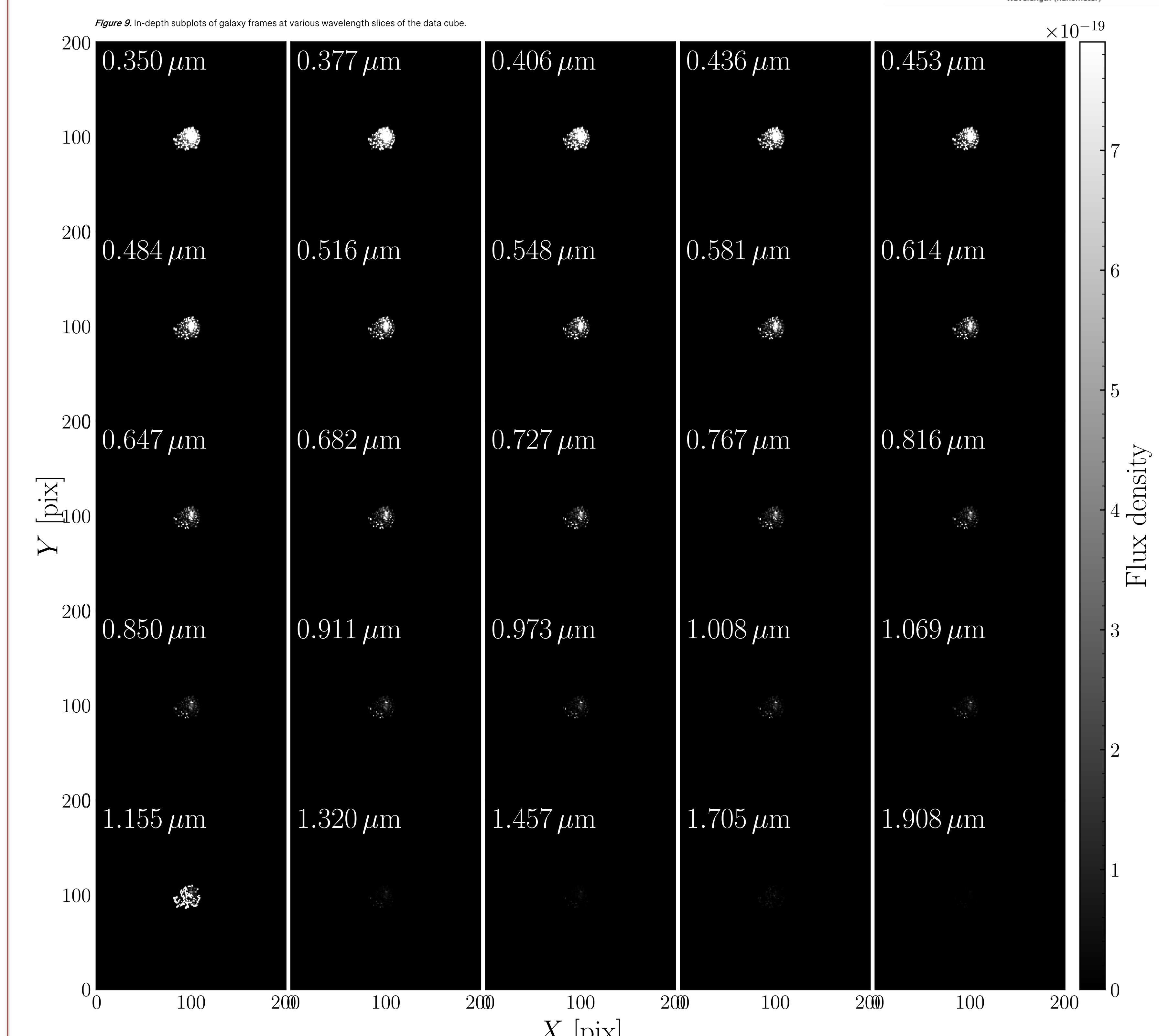


Figure 8. Slices of the data cube for a galaxy at redshift 0.1, across a range of wavelengths. Towards the ends of the SDSS range, the galaxy appears to fade out.

Figure 9. In-depth subplots of galaxy frames at various wavelength slices of the data cube.



Conclusions

Future Steps

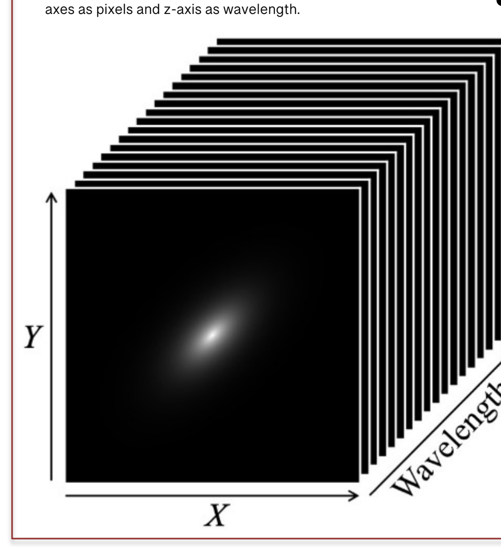
- Using SDSS data as a template, this project automates the construction of galactic data cubes at any user-defined redshift or galaxy of interest
- For a supernova in this galaxy, the host galaxy spectrum (data cube) can be subtracted from ***Roman***'s SN+galaxy observations, set to launch in 2027

Modifications

- Other variations which may lead to slightly different model spectra of galaxies include:
  - Assuming Gaussian noise or standard deviation for error maps
  - Varying parameters that make source detection looser or stricter
  - Considering redshift-dependent star formation models

Broader Significance

Figure 10. An illustration of a simulated data cube, with x and y axes as pixels and z-axis as wavelength.



- Analyzing numerous clean SNe Ia spectra leads to improved standardization of SN light-curves, which ultimately helps to:
  - Measure redshift directly from SN spectra
  - Distinguish between SNe Ia subtypes
  - More accurately determine the dark energy equation of state parameters to measure the acceleration of the universe's expansion

References

Astraatmadja, T., Fruchter, A., Deustua, S., Qu, H., & Sako, M. (2022). 3D datacube reconstruction using Roman slitless prism spectra. ***Bulletin of the AAS, 54***(6). https://baas.aas.org/pub/2022n6i318p02

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