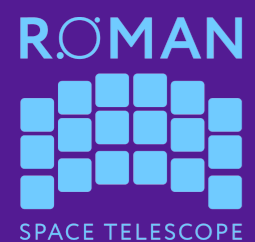


# The Roman Supernova Survey

Rebekah Hounsell - on behalf of the Supernova Science Investigation Teams

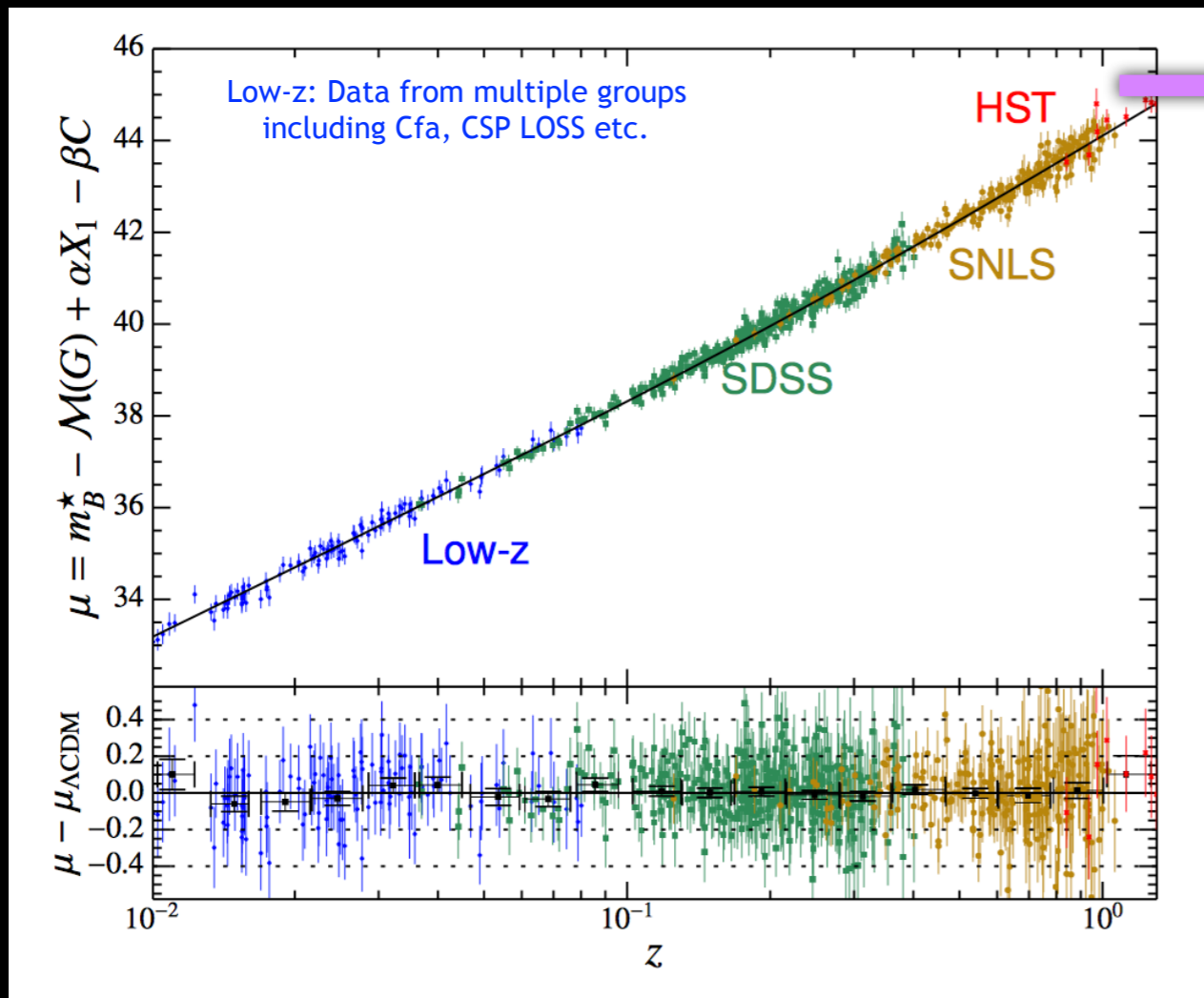
January 8th 2020



# The Dark Energy Objective

The Roman mission is tasked with increasing the FoM by a factor of 10!

SN Ia will act as a key cosmological probe for this.



Roman  $z \sim 3$

Roman will probe an area of SN Ia space previously unreachable.

To achieve the dark energy objectives we need,

- A good understanding of Optical to NIR SN Ia systematic uncertainties
- To collect a SN sample that is broad in redshift and magnitude space
- For the SNe to be well sampled over a broad wavelength range.

Hubble diagram of combined SN surveys.

Black line = best fit  $\Lambda$ CDM model. Bottom panel = residuals from best fit.

Image taken from [Betoule et al. \(2014\)](#)

# Supernova Survey Studies

Baseline Survey Characteristics				
SN Survey				0.5 years (in a 2-yr interval)
Wide	Y, J	27.44	Y = 27.1, J = 27.5	5 days
Medium	J, H	8.96	J = 27.6, H = 28.1	
Deep	J, H	5.04	J = 29.3, H = 29.4	
IFU Spec	7 exposures with S/N=3/pix, 1 near peak with S/N=10/pix, 1 post-SN reference with S/N=6/pix Parallel imaging during deep tier IFU spectroscopy: Z, Y, J, H ~29.5, F184 ~29.0			

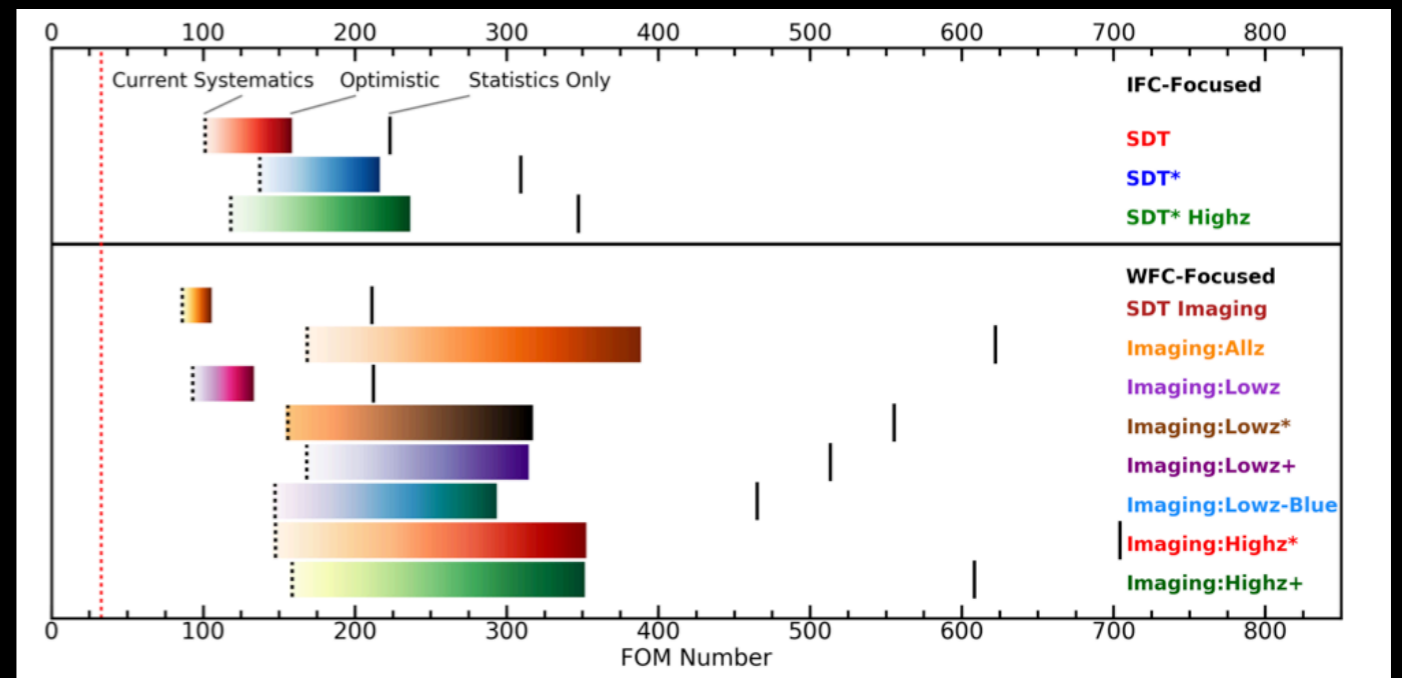
Credit: WFIRST-2.4: What Every Astronomer Should Know

## Original Design

- 6 months over 2 yrs
- 5 day cadence
- 3 tiers
- 2 filters per tier
- IFU Spectra focused

## Initial Simulations

- 6 months over 2 yrs
- 5 day cadence
- 3 & 2 tier surveys
- 2 - 6 filter options
- IFU Spectra focused
- Imaging focused

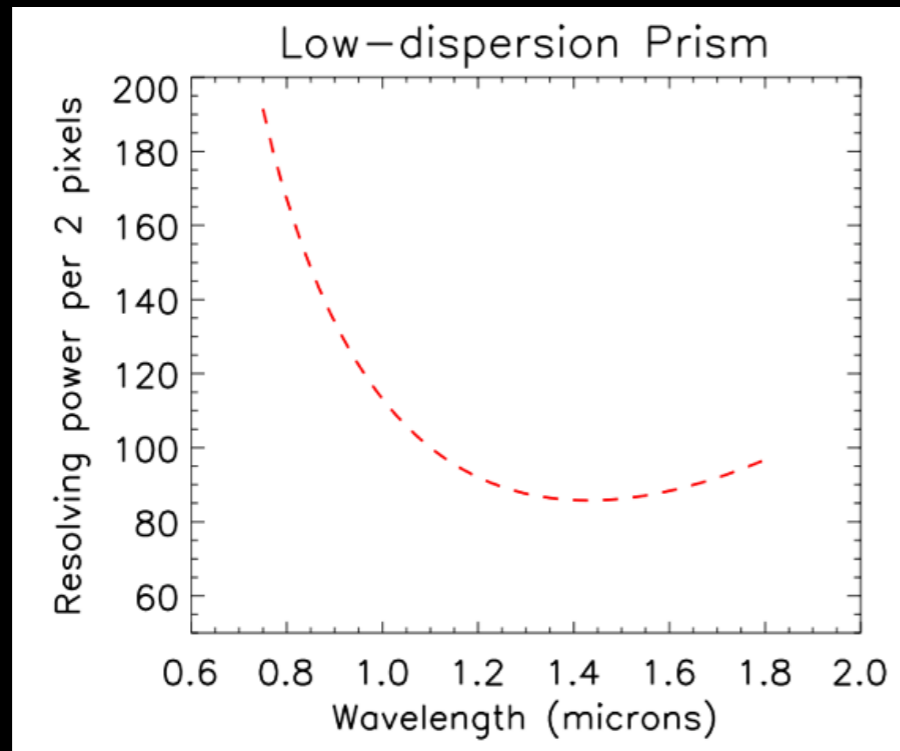


Predicted dark energy FoMs for the simulated Roman SN survey strategies outlined in Hounsell et. al., 2018. IFC-focused and WFC-focused strategies are presented in the top and bottom panels, respectively

**We have simulated dozens of Supernova survey strategies using multiple tools!**

# Basic SN Design

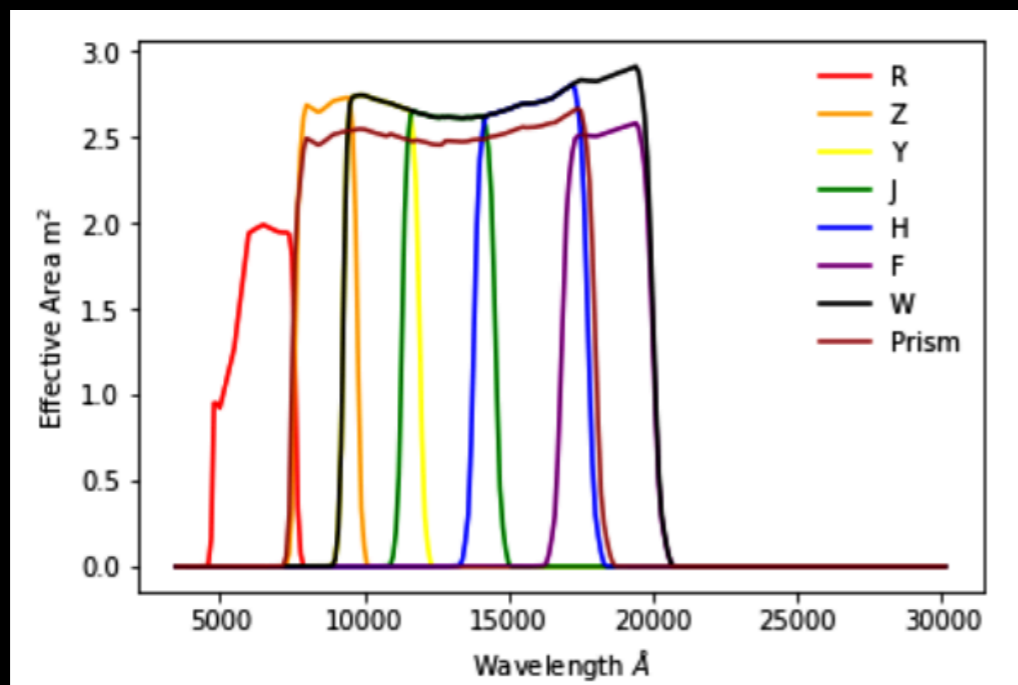
PRISM



## Outline

- 6 months over 2 yrs
- 5 day cadence
- 2 tier survey:
  - Shallow:  $z < 1$
  - Deep:  $z < 1.5$
- 4 filters per tier:
  - Shallow: RZYJ
  - Deep: YJHF
- ~30 hr visits
- Some fraction of imaging and prism spectroscopy
  - ★ Imaging exposures based on achieving a S/N  $\sim 10$  for each filter at peak.
  - ★ Prism exposures based on achieving a S/N  $\sim 25$  in rest frame V, even just using spectra  $\pm 5$  days around peak.

IMAGER



# Four Designs

Tier	Imaging Area (deg <sup>2</sup> )	Imaging Filters	Imaging Exp. (sec)	Imaging Time (hrs)	SN Light curves	Prism Area (deg <sup>2</sup> )	Prism Exp. (sec)	Prism Time (hrs)	SNe with spectra
<b>10% Prism Time</b>									
Shallow	21.84	RZYJ	460+(4x70)	16.0	5427	1.12	900+70	1.0	277
Deep	5.32	JYHF	1800+(4x70)	11.0	3661	0.56	3600+70	2.0	326
<b>Total</b>				<b>27.0</b>	<b>9088</b>			<b>3.0</b>	<b>603</b>
<b>25% Prism Time</b>									
Shallow	15.96	RZYJ	460+(4x70)	11.7	3960	3.36	900+70	3.2	831
Deep	5.32	YJHF	1800+(4x70)	11.0	3661	1.12	3600+70	4.1	652
<b>Total</b>				<b>22.7</b>	<b>7621</b>			<b>7.3</b>	<b>1483</b>
<b>50% Prism Time</b>									
Shallow	10.92	RZYJ	460+(4x70)	8.0	2701	7.0	900+70	6.7	1731
Deep	3.36	YJHF	1800+(4x70)	6.9	1953	2.24	3600+70	8.2	1302
<b>Total</b>				<b>14.9</b>	<b>4654</b>			<b>14.9</b>	<b>3032</b>
<b>75% Prism Time</b>									
Shallow	5.32	RZYJ	460+(4x70)	3.9	1320	5.32	900+70	5.1	1320
Deep	1.68	YJHF	1800+(4x70)	3.5	1156	1.68	10400+70	17.5	1156
<b>Total</b>				<b>7.4</b>	<b>2476</b>			<b>22.6</b>	<b>2476</b>

# Survey Considerations

## 10% Prism Time

- Lots of light curves for statistical gain.
- Use SN on Hubble Diagram without spectra
- Potentially tricker classification
- Limited spectroscopic redshift coverage ~7%
  - ★ Photo-z's?
  - ★ HLS data?
  - ★ Ground-based support  $z < 0.8$
  - ★ Can make templates - new parameters derived

## 50% Prism Time

- Many less light curves - reduced statistical gain
- Good spectroscopic coverage ~65%
  - ★ Could focus on high-z SNe
  - ★ Ground-based support  $z < 0.8$
  - ★ Templates + SNe evolution studies
- Results depend on analysis method.

## 25% Prism Time

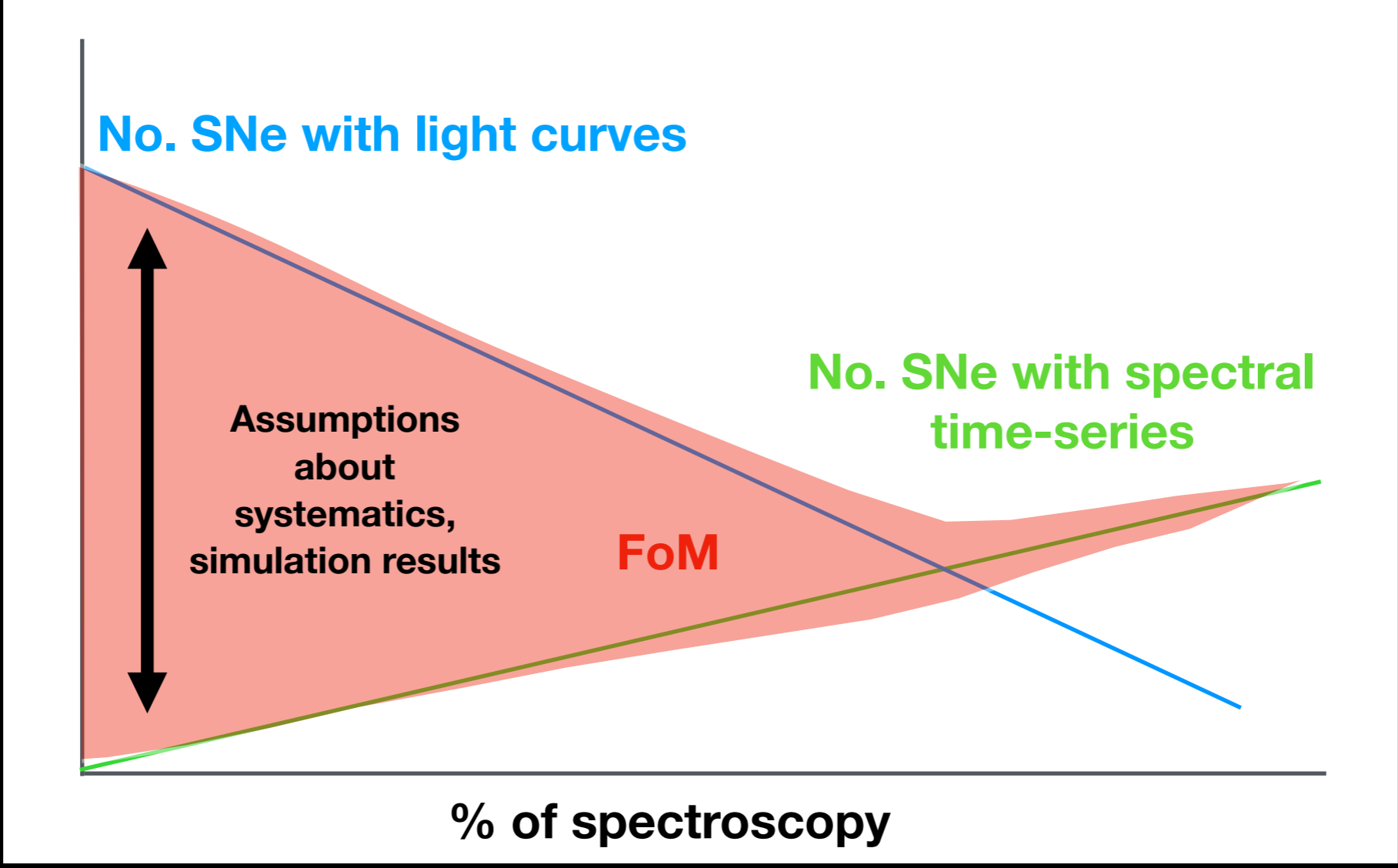
- Fewer light curves
- Slightly better spectroscopic redshift coverage ~19%
  - ★ Photo-z's?
  - ★ HLS data?
  - ★ Ground-based support  $z < 0.8$
  - ★ Templates
  - ★ Check for systematic effects

## 75% Prism Time

- Significantly fewer SN light curves
  - ★ Less overlap with other missions like Rubin
- Complete spectroscopic coverage
  - ★ Potentially out to  $z < 1.7$
  - ★ Classification
  - ★ Systematic/evolution studies
  - ★ Templates
- Results depend on analysis method.



# Survey Considerations

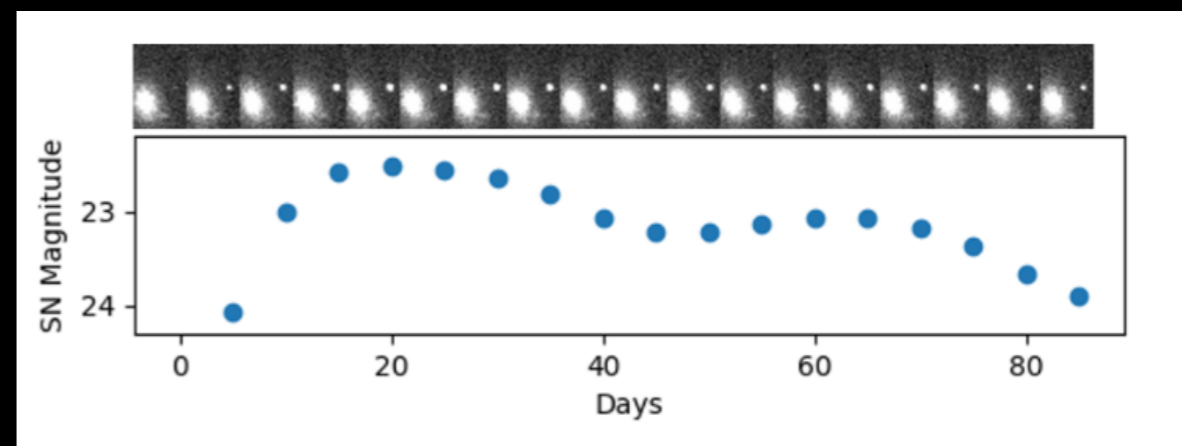


# Current Studies

- All our analyses include major systematics - but these are based on optical data not NIR.
- The use of SALT2 like models is not optimal for constraining unknown parameters that might alter our understanding of SN Ia.
- Many classification tools rely on high S/N individual spectra.
  - Photometric classifiers have improved
  - Combined low S/N spectra may be used, but this needs more study
- Redshifts can be obtained from combined low S/N spectra
- Our understanding of Photo-z's estimates have improved

## Simulations

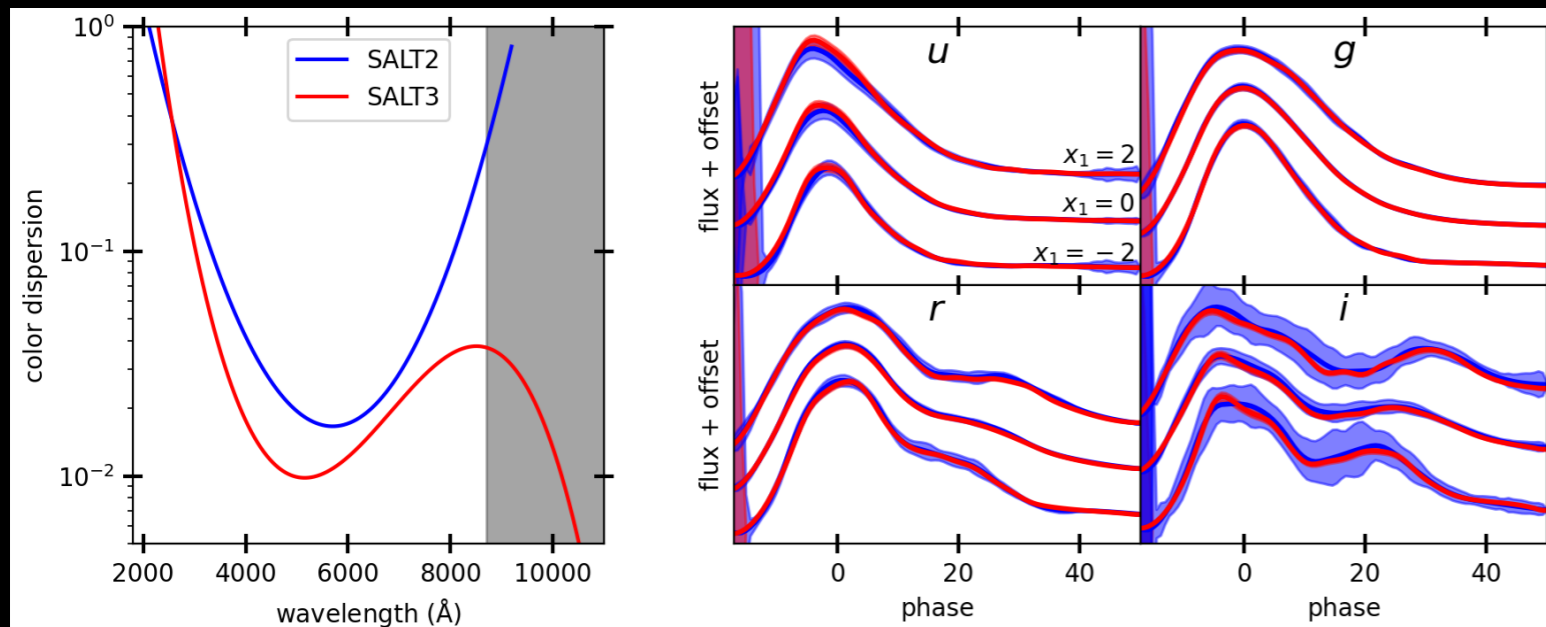
- **Survey optimization:** Simulating the four strategies to obtain a FoM. We include all major systematics (SNANA+WFIRST\_SIM)
- **Image simulations:** The first Roman difference images have been created. SNe were injected and the light curves recovered (Wang et. al, in prep).
- **Forward modeling:** We are conducting two separate forward modeling studies, one for image subtractions and one for prism spectrum subtractions. Both intend to isolate the light from the SN



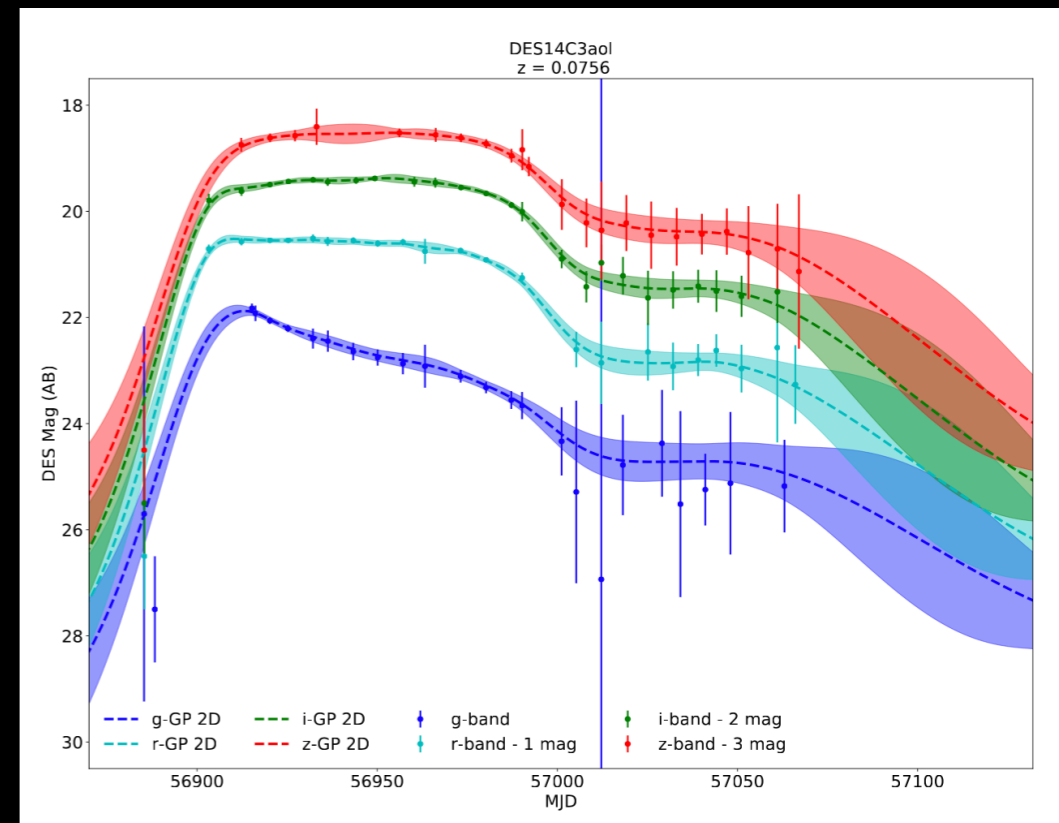
Supernova light curve recovered from Roman image simulations in the Y-band.  
Taken from Wang et. al., in prep.



# Current Studies



Color dispersion (left) and example light curves with model uncertainties from SALT2 (blue) and SALT3 (red). On the left, the grey shaded region illustrates the wavelengths red-ward of the rest-frame z band where the color scatter is extrapolated and unconstrained by data from the K20 sample.



The 2D GP Core Collapse SN data for DES14C3aol. Taken from Hounsell et. al., in prep.

## SN Templates

- **BYOSED:** Python-based module used within the SNANA framework to simulate light curves by applying spectral variations directly to model SEDs. Allows flexible testing of possible systematic shifts in SN Ia distance measurements caused by known relationships (Pierel et. al, submitted to ApJ).
- **SALT3:** Re-built the SALT2 model. Revised the calibration of the model, plus it is over a broader wavelength range (Kenworthy et. al., in prep).
- **SNEMO:** In an attempt to understand SN diversity beyond SALT2 (intrinsic scatter) we are adding additional SN models into the simulation capabilities of SNANA. The addition of the SNEMO models will allow for unique properties of SN to carry as a function of redshift, a bias we might see in Roman data.
- **Core Collapse:** Created new CC SN templates using DES SN data.

# Current Studies

## TWINNING

We are conducting a study of the feasibility (and redshift range) when using the prism spectrum to position each supernova in a 3+color-parameter Twins-Embedding space, so that we can account for evolutionary population drift.

## Host Galaxies

In understanding SN Ia we must understand their hosts. In [Rose et. al., 2020](#) the authors use the Bayesian hierarchical model UNITY, to simultaneously fit for the SN Ia light curve and host galaxy standardization parameters on a set of 103 Sloan Digital Sky Survey II SNe Ia. The paper investigates the influences of host stellar mass, along with both localized ( $r < 3$  kpc) and host-integrated average stellar ages, derived from stellar population synthesis modeling. We find that the standardization for the light-curve shape ( $\alpha$ ) is correlated with host galaxy standardization terms ( $\gamma_i$ ) requiring simultaneous fitting.

## Understanding SNe in the NIR

- **RAISIN:** Dark energy properties have never been measured using NIR SN data. The RAISIN survey (Jones et. al., in prep) is using rest-frame NIR observations at  $z \sim 0.4$  to measure the dark energy equation of state in the NIR for the first time and prepare for data from Roman.
- **SIRAH:** A HST program in which WFC3/IR photometry and spectrophotometry of a sample of 24 Hubble-flow ( $0.02 < z < 0.07$ ) SN Ia, are obtained. The goals of this work are to (1) establish a legacy sample of well-calibrated SN Ia spectrophotometry covering a continuous rest-frame wavelength range from 0.8 to 1.7 microns as a foundation for Roman (2) yield a 2.7% measurement of  $H_0$  with near-infrared only observations of SN Ia, and (3) constrain dark energy in concert with data from the RAISINs surveys, producing a WFC3/IR- only Hubble diagram from  $z = 0.02$  to  $z = 0.6$ .

**Plus many other studies including -  
Ground-based z, Photo-z studies  
etc...**