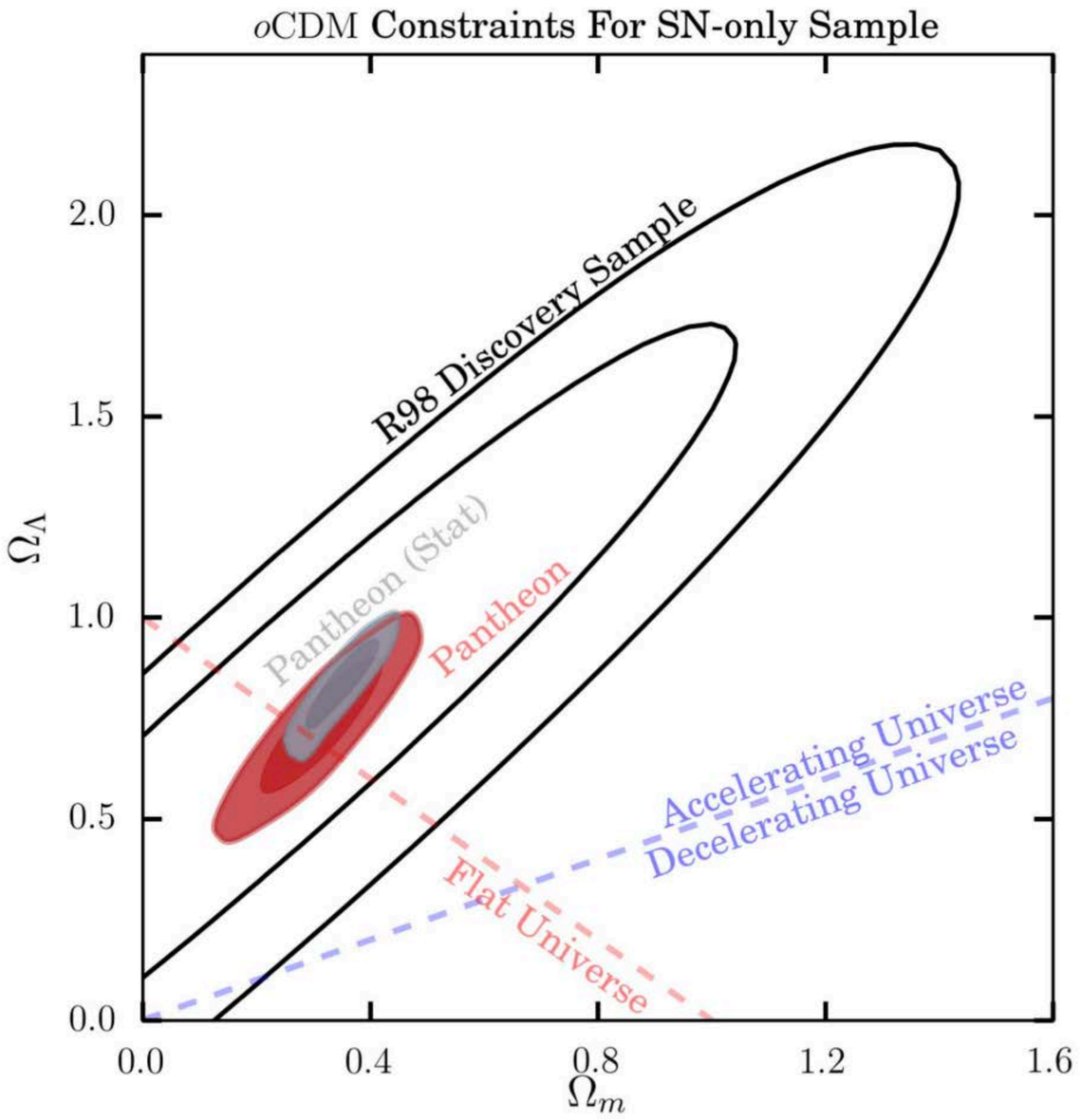
Supernova Cosmology Today and the Future with *Roman*

David Jones
Einstein Fellow, UC Santa Cruz
11/18/21

Understanding Dark Energy

- Dark energy is 70% of the energy density of the universe, and its nature is unknown



Scolnic+2018

Understanding Dark Energy

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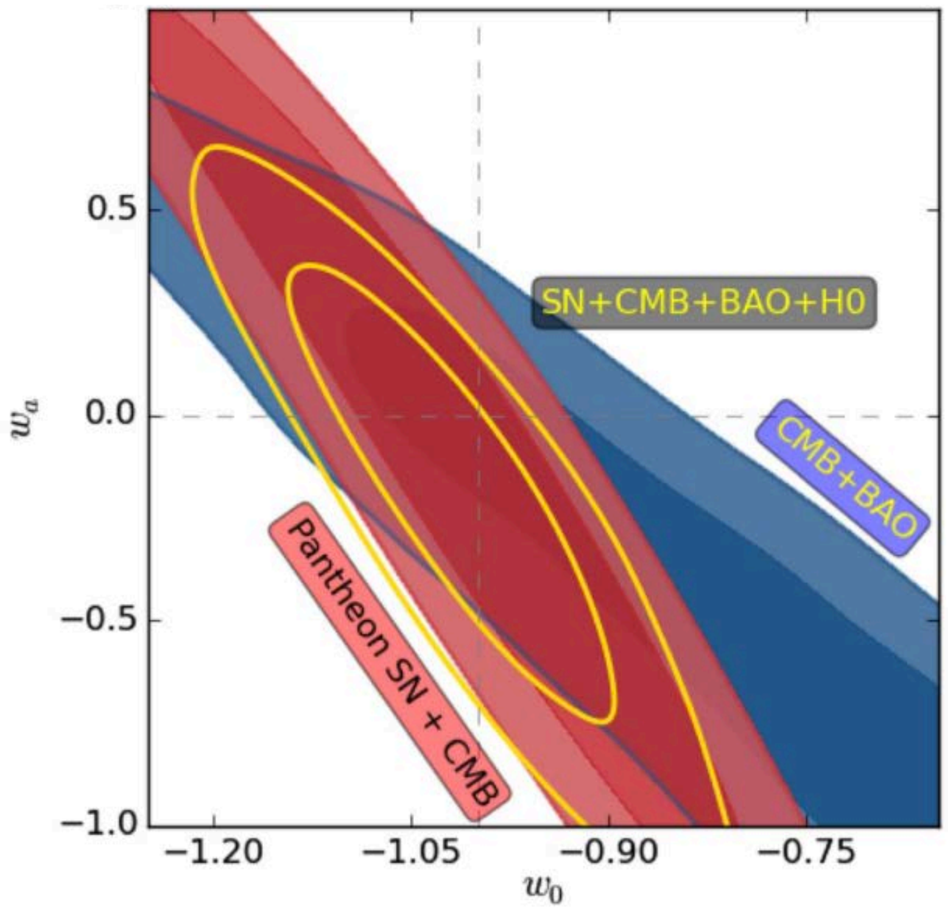
- Current constraints on the dark energy equation of state, w, are consistent with a cosmological constant but the redshift-dependence of w is poorly constrained

Constraints on a parametric z-dependent dark energy

$$w(a) = w_0 + w_a(1-a) = w_0 + \frac{w_a z}{1+z}$$



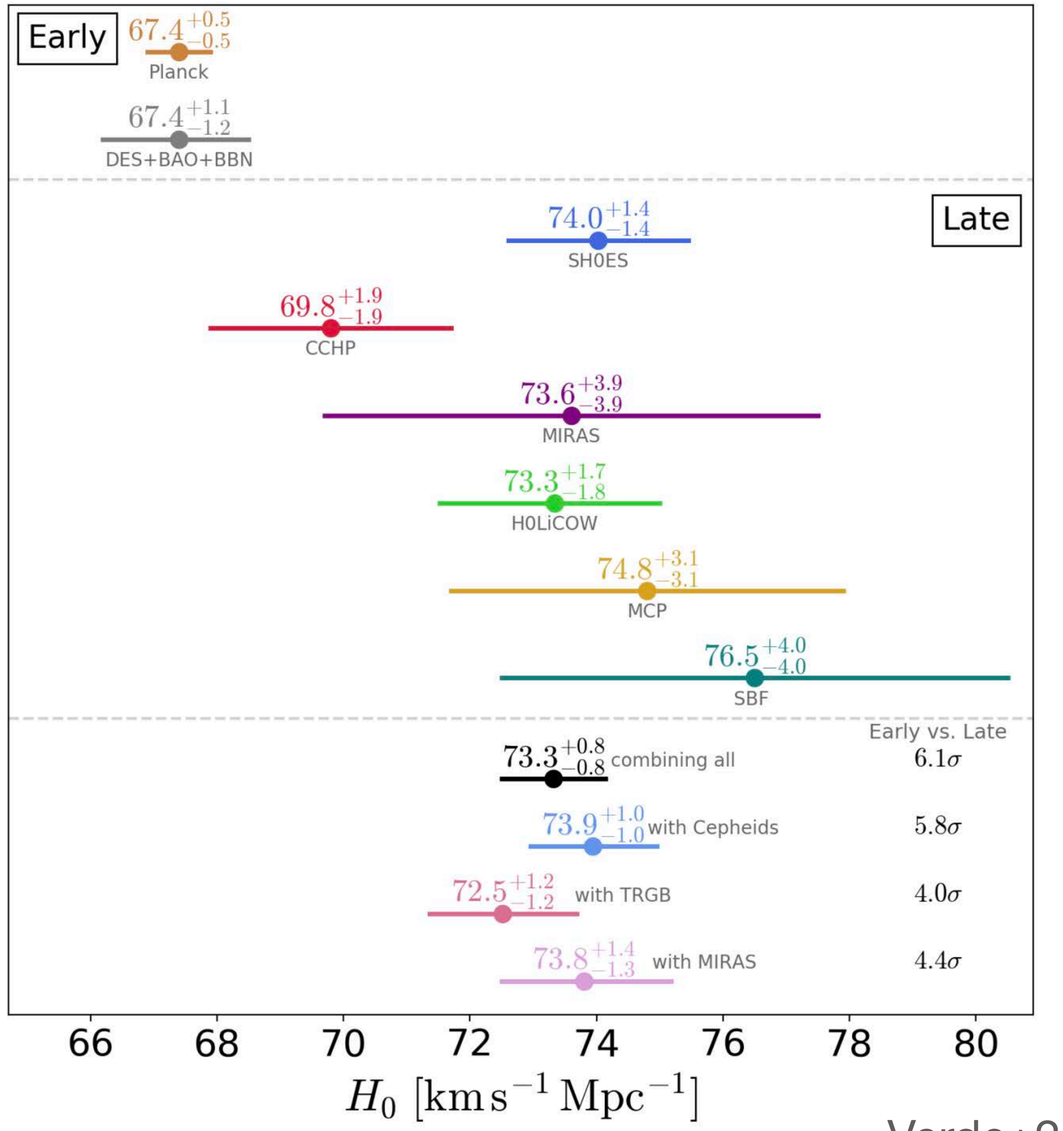
Scolnic+2018

Understanding Dark Energy

- Dark energy is 70% of the energy density of the universe, and its nature is unknown
- Current constraints on the dark energy equation of state, w, are consistent with a cosmological constant but the redshift-dependence of w is poorly constrained
- Evidence for tension in ΛCDM model parameters - H_0, σ_8 - emphasize that understanding our cosmological model is nowhere close to a solved problem
- Type Ia supernovae (SNe Ia) were critical for first discovering dark energy and measuring the H_0 tension

Tension in H_0

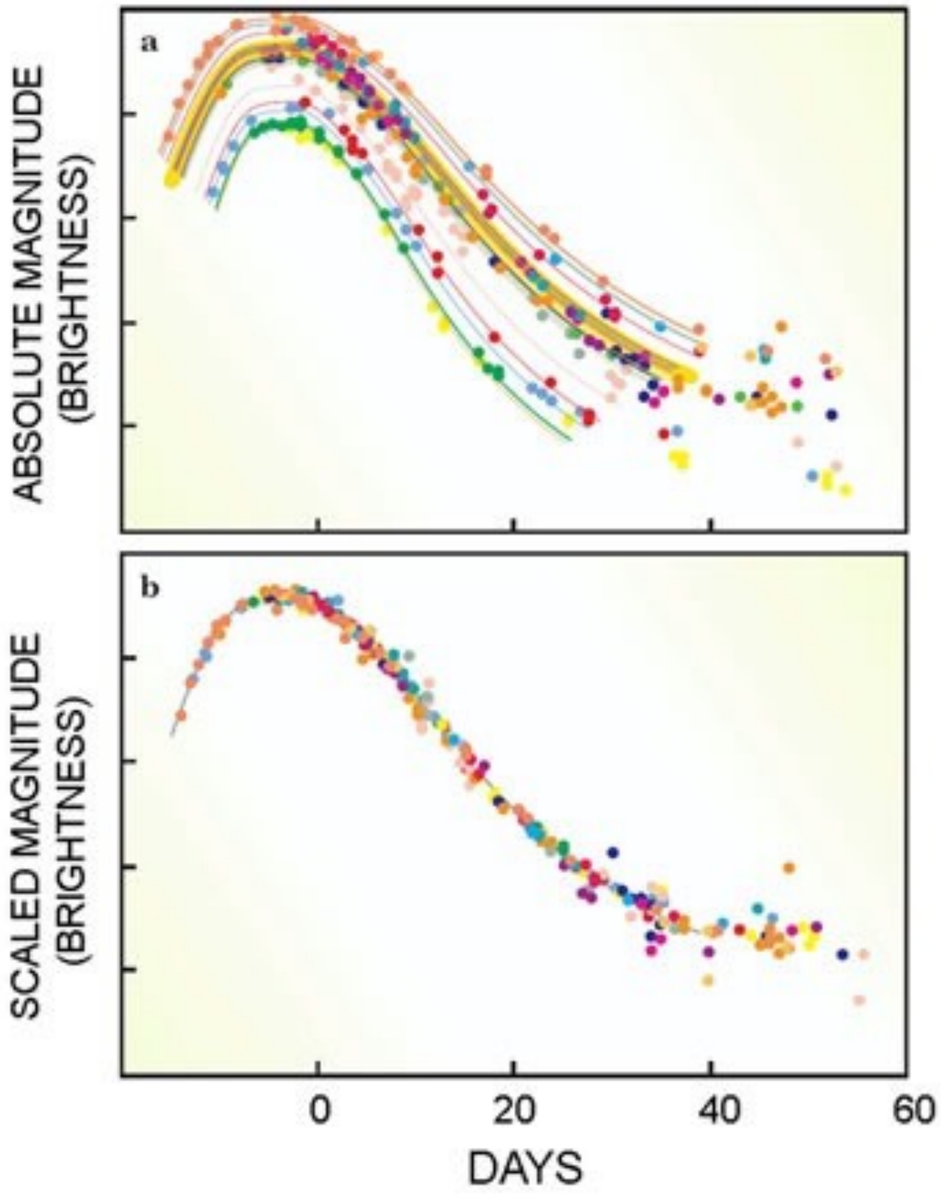
Early Universe *Late Universe*



Verde+2019

Measuring Distances with Type Ia Supernovae

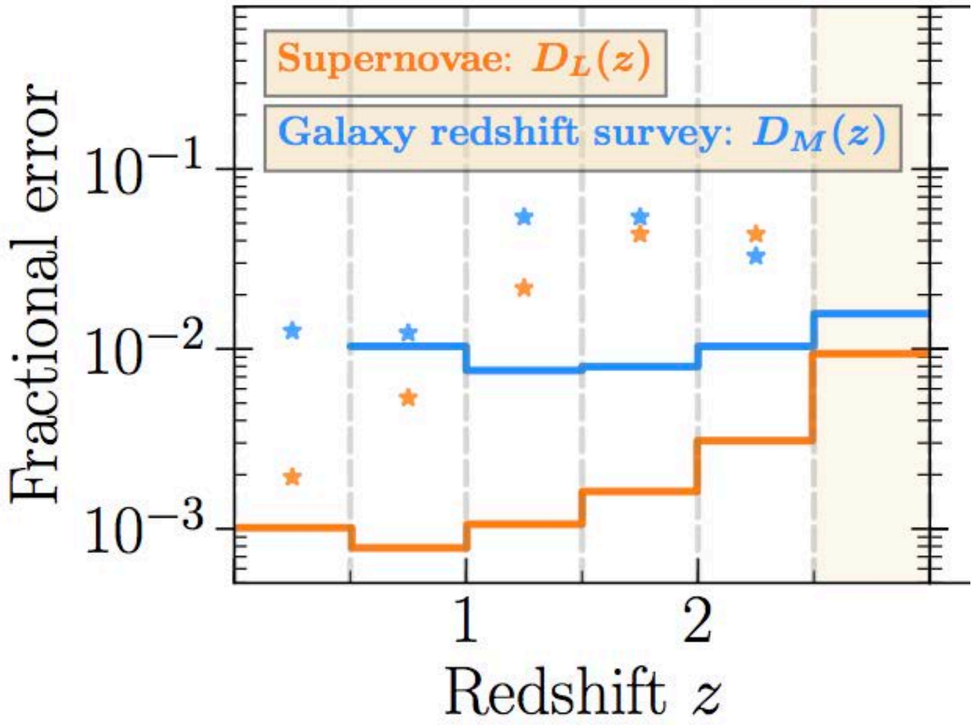
- Type Ia Supernovae (SNe Ia) are a standardizable candle that can measure distances with up to ~5% accuracy
- Current surveys are constraining dark energy properties with ~2,000+ SNe Ia



Supernova Cosmology Project

SN Cosmology with the *Roman Space Telescope*

- *Roman* will make a generation-defining measurement of dark energy with >10,000 SNe Ia
- *Roman* is tasked with improving our "knowledge" of dark energy (the Figure of Merit) **by a factor of 10**
- SNe Ia will be a key cosmological probe for this goal



Roman distance constraints (lines) versus current constraints (*) from Doré+19 Astro2020 white paper

Caveat: SN Ia measurement systematics are more correlated between bins than galaxy redshift survey points

SN Cosmology with the *Roman Space Telescope*

- *Roman* will make a generation-defining measurement of dark energy with >10,000 SNe Ia
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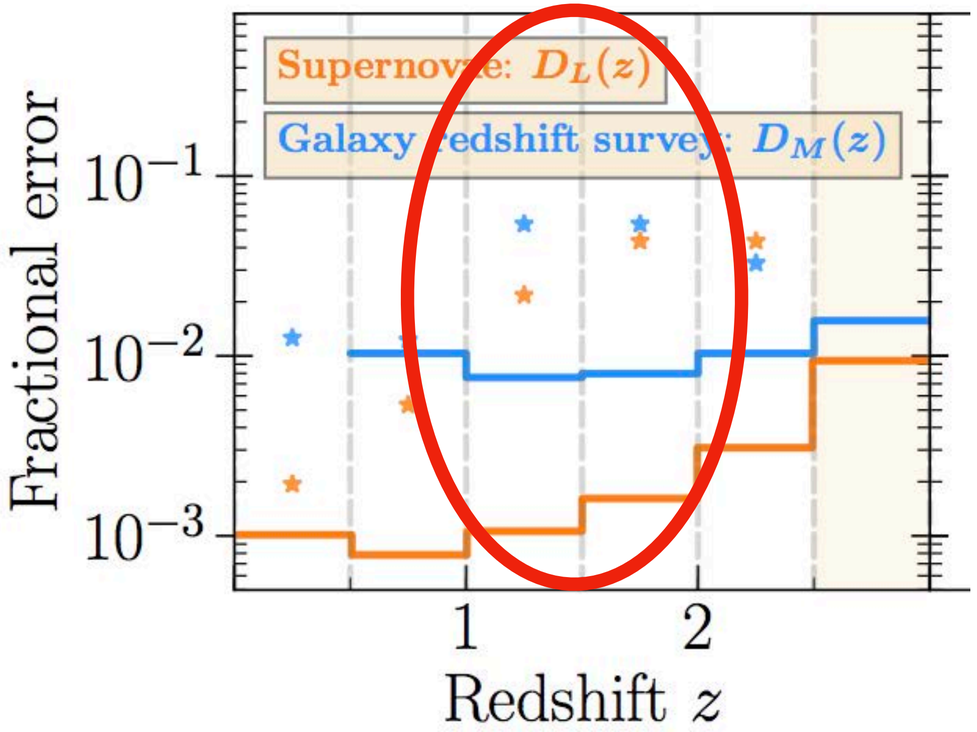
- SNe Ia will be a key cosmological probe for this goal
- Roman will probe redshifts/ wavelengths/systematic uncertainty floors previously unreachable for SNe Ia

Orders of mag. more SNe at z > 1



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Session Overview

Overview

9:00 AM	David Jones (UCSC)	Supernova Cosmology Today
9:10 AM	Ben Rose (Duke)	The Roman Supernova Survey Overview
9:35 AM	David Rubin (UofH@Manoa)	Using the Roman Prism

Simulations

9:50 AM	Tri Aastratmadja (STScI)	SNe+Galaxy Spectral Sims
10:00 AM	Bhavin Joshi (STScI)	Spectroscopic Redshifts
10:10 AM	Phil Macias (UCSC)	Light Curve Simulations
10:25 AM	Kevin Wang (Duke)	Image simulations

Calibration

11:00 AM	Susana Deustua (STScI)	Calibration Requirements
11:10 AM	Greg Aldering (LBNL)	Flux Standards

Lightning Talks (Systematics, Modeling, Classification)

11:25 AM	Mi Dai (JHU)	Overview of Systematic Uncertainties
	Justin Pierel (STScI)	SALT2/3
	Stephen Thorp (Cambridge)	BayeSN
	Kyle Boone (UW)	Twinning
	Mitchell Karmen (NYU)	Applying Twinning to *Roman*
	Matt Siebert (UCSC)	VCR
	Helen Qu (U Penn)	Photometric Classification

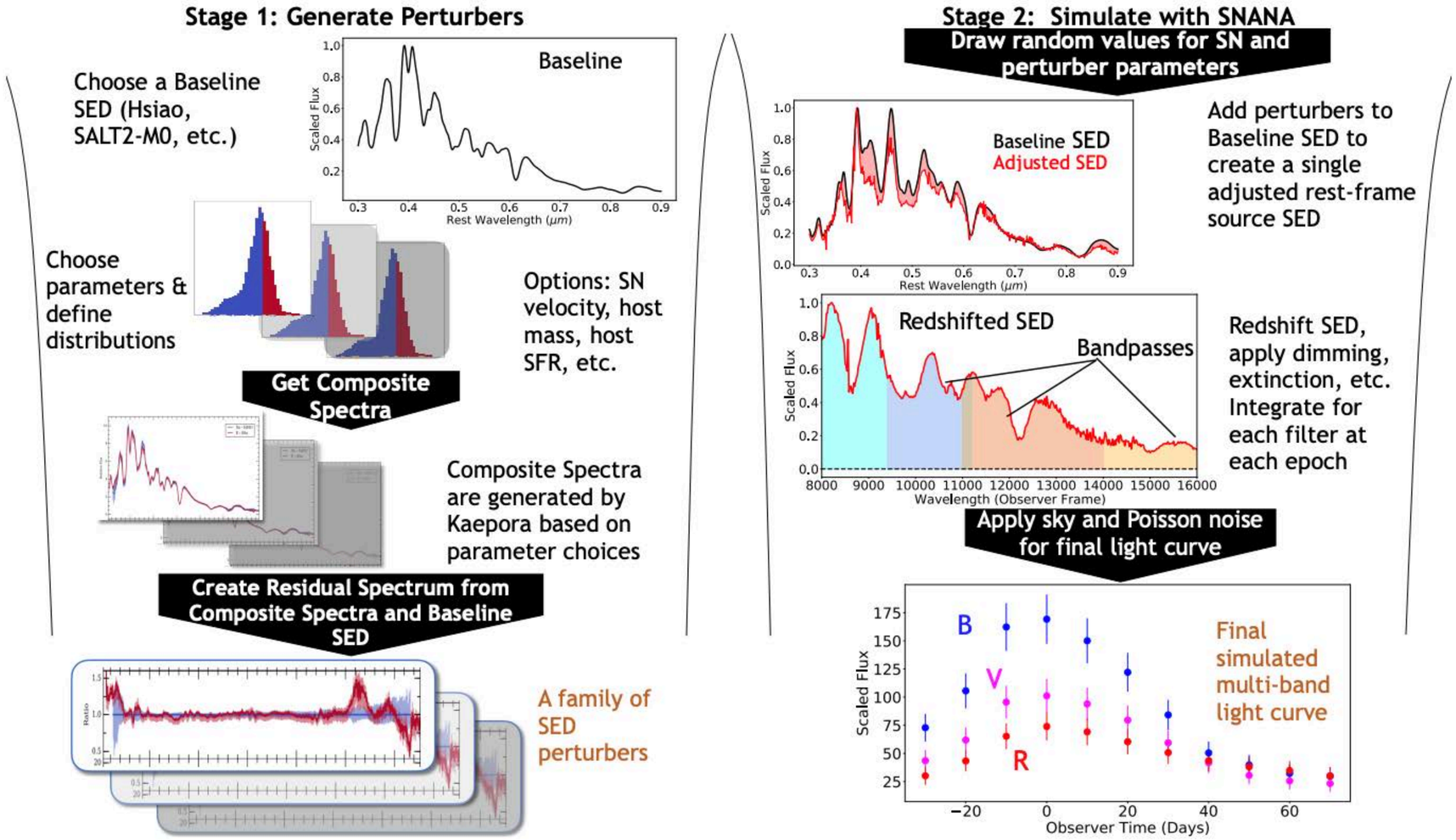
External Synergies

12:00 PM	Michael Wood-Vasey (Pitt)	Synergies between Roman, Euclid, JWST, Rubin

Recent Progress

Simulations

- Sophisticated simulation tools:
  - pixel-level (Kevin Wang talk)
  - catalog-level (Phil Macias, Justin Pierel talks)
  - spectroscopic (Tri Aastratmadja, Bhavin Joshi talks)



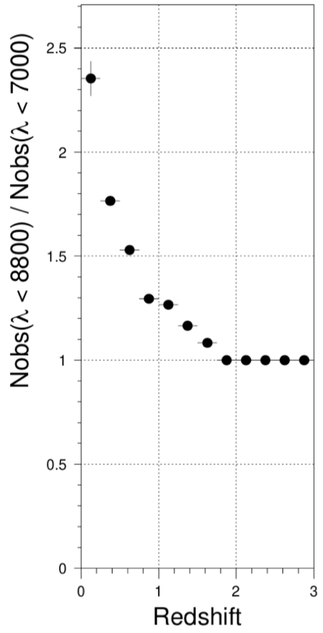
A model-independent simulation of *Roman* SNe (Pierel+21)

Recent Progress

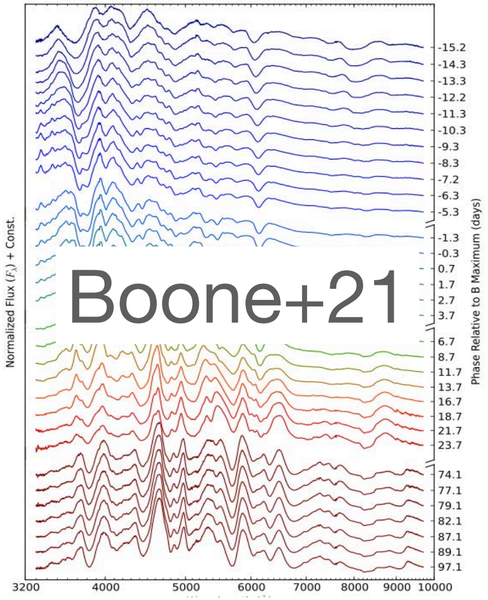
SN Modeling for Distance Measurements

- Talks from Kyle Boone, Justin Pierel, Stephen Thorp, Mitchell Karmen

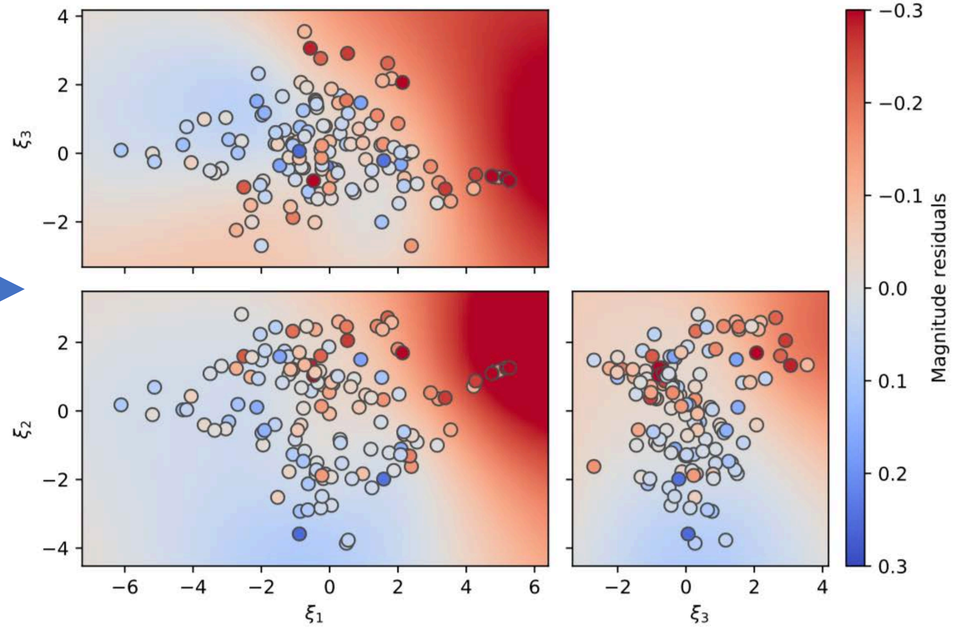
Ratio of useful *Roman* observations vs. redshift between SALT3 and SALT2 (Kenworthy+21)



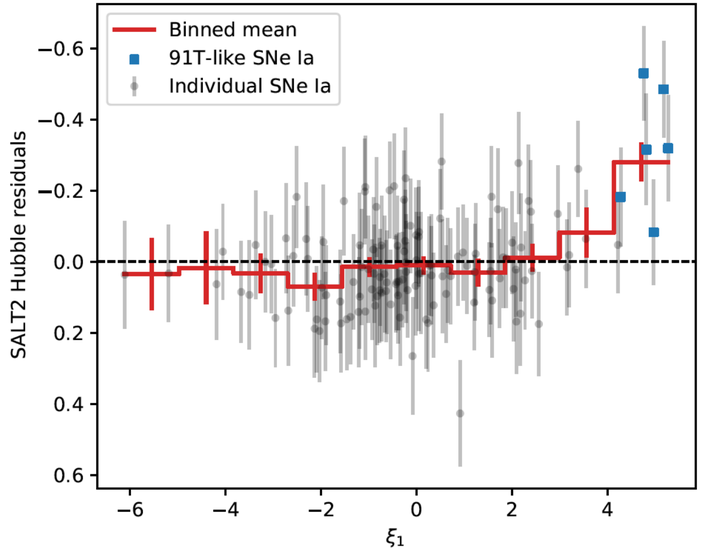
Spectral time series



Manifold Learning



Reduced Hubble diagram dispersion and biases

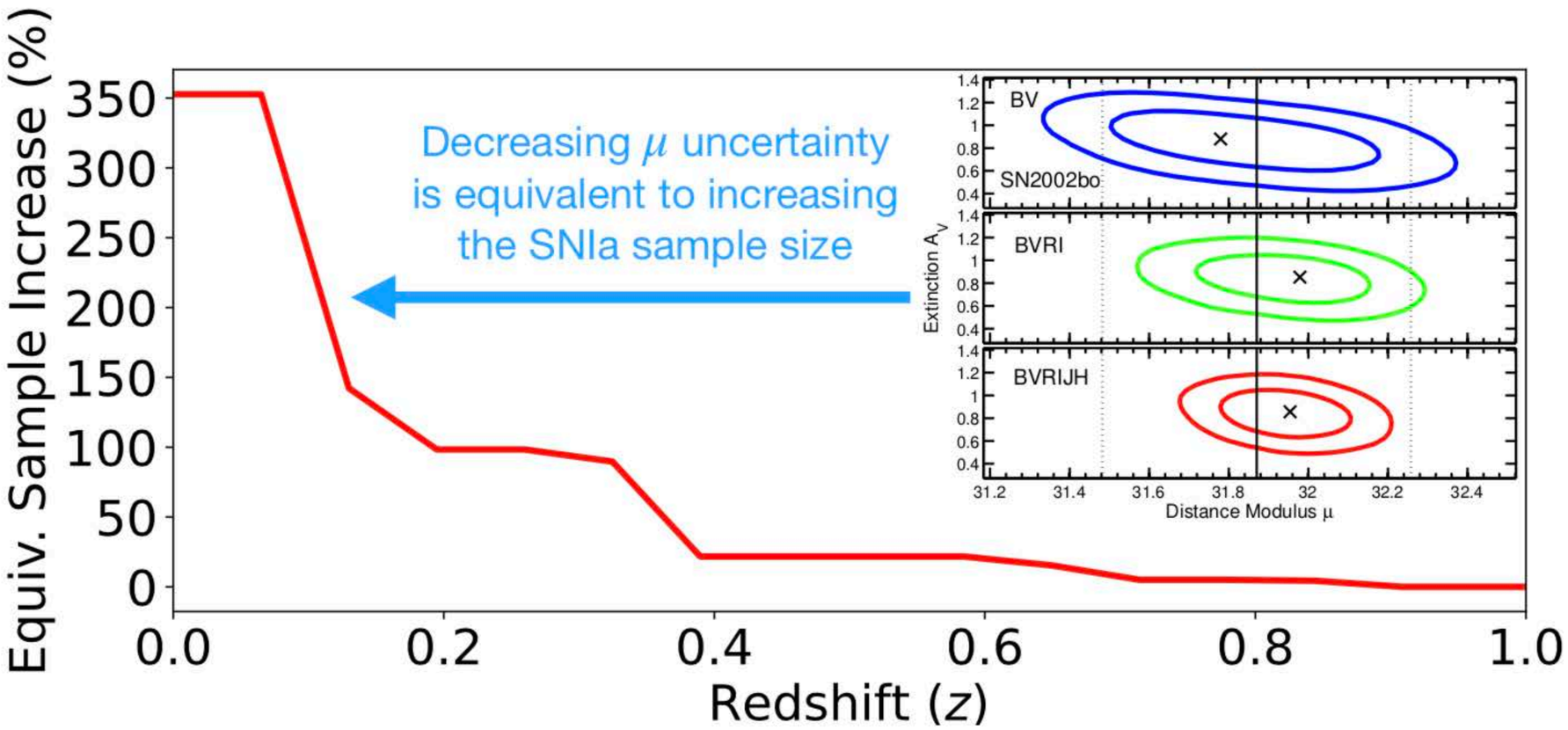


Recent Progress

Figure from J. Pierel, Mandel+11

SN Modeling, Optical+Near-Infrared

- NIR is going to be a valuable subset of the *Roman* data (Dai, Pierel talks)

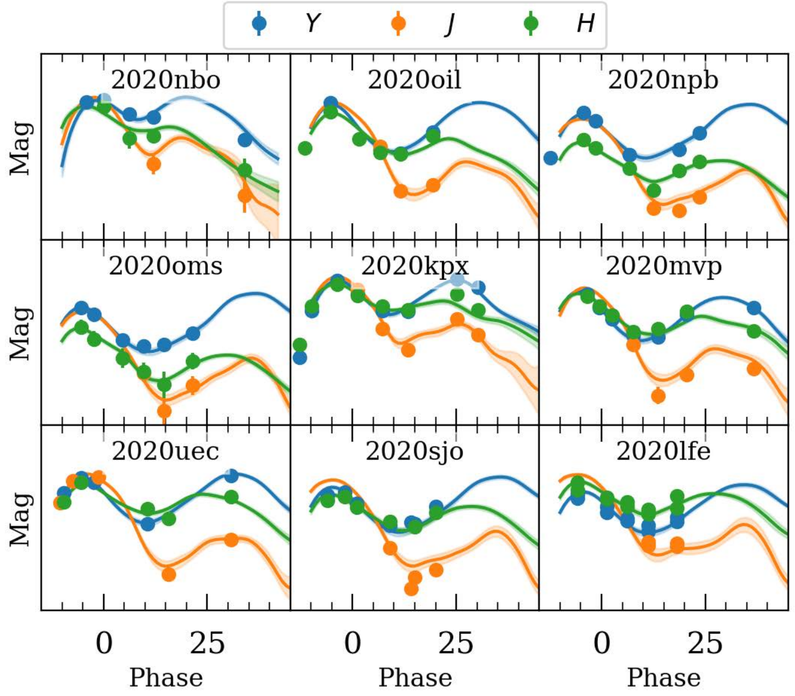


Recent Progress

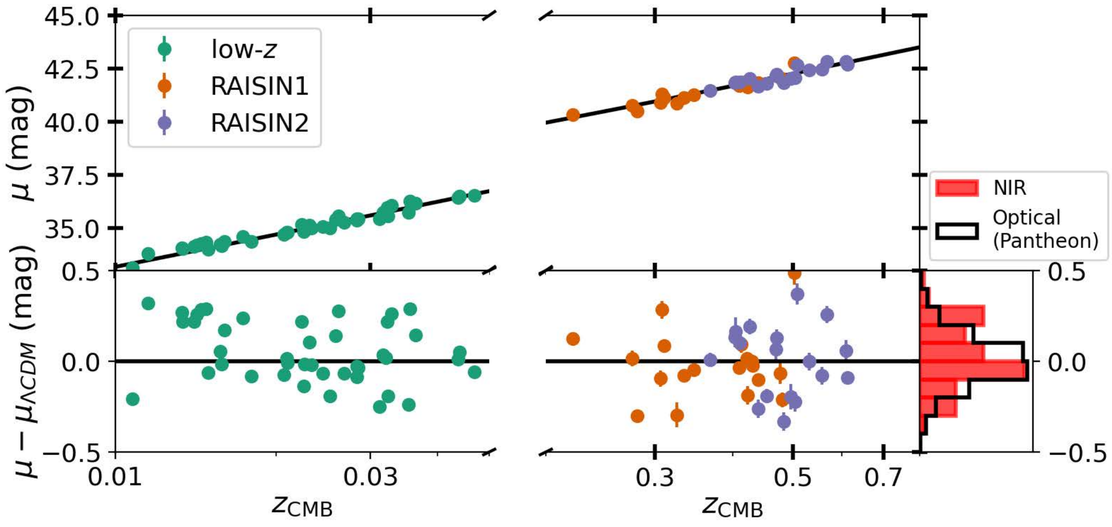
SN Modeling, Optical+Near-Infrared

- NIR is going to be a valuable subset of the *Roman* data (Dai, Pierel talks)

Sample lightcurves from DEHVILS (UKIRT), Peterson+in prep



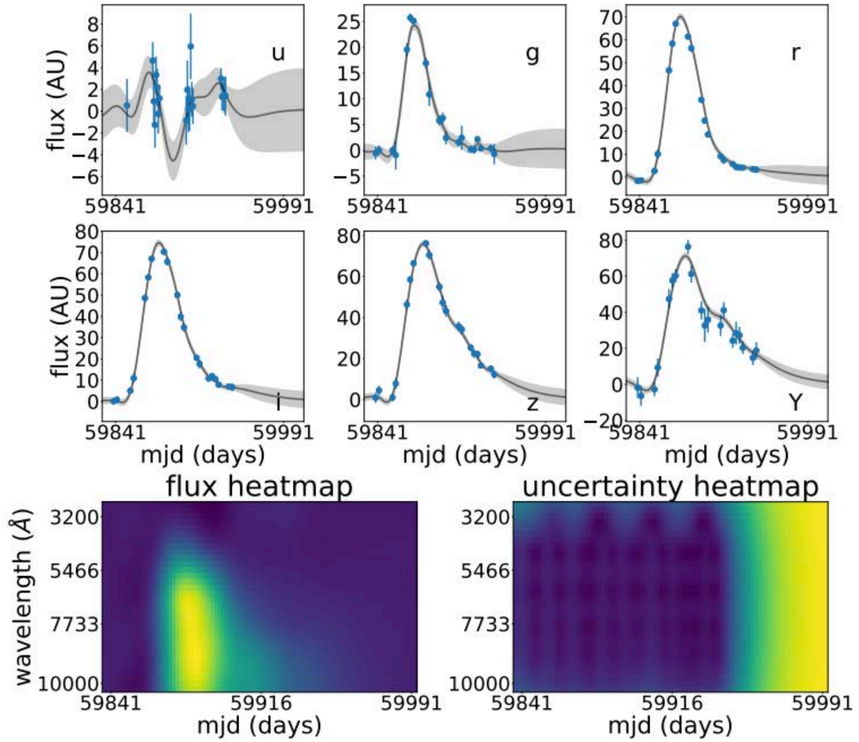
NIR-only Hubble diagram from RAISIN (Jones+in prep)



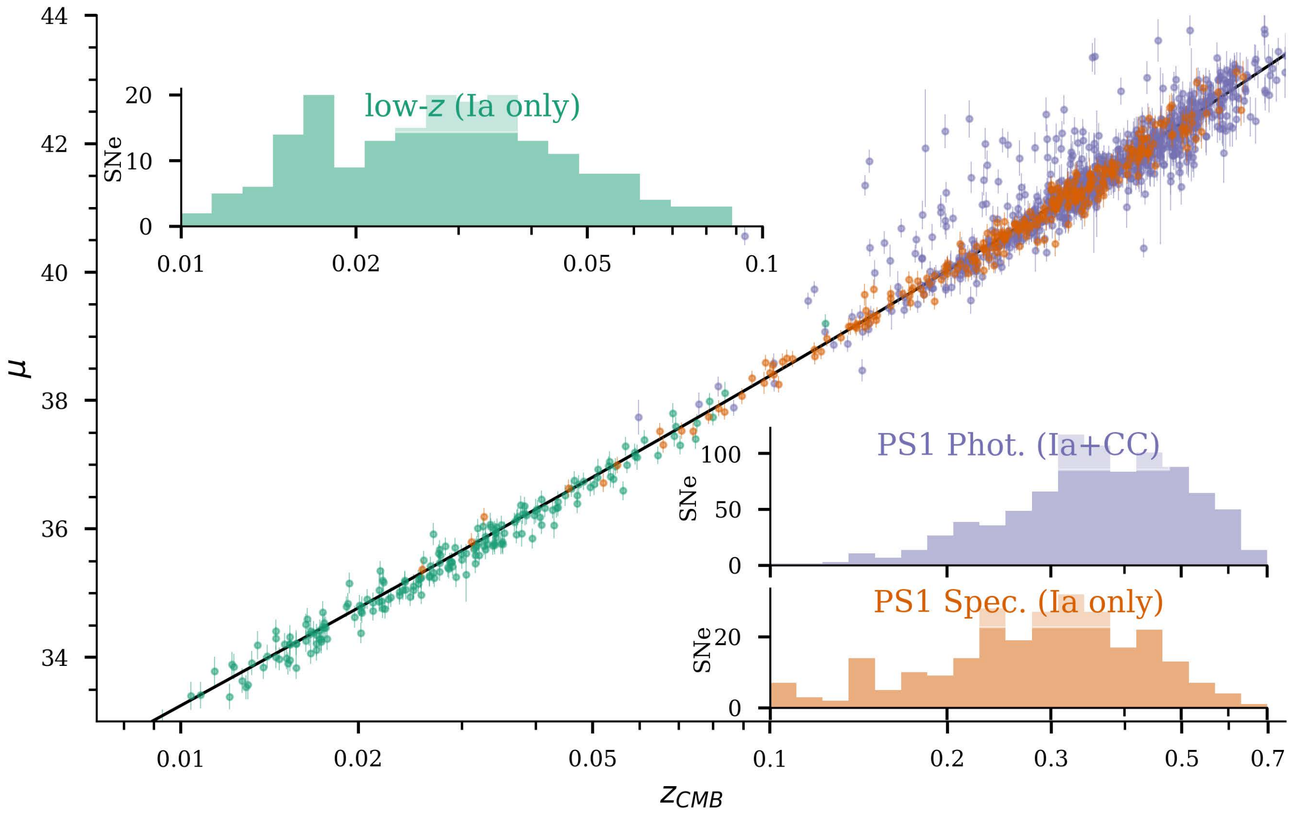
Recent Progress

Photometric Classification

- See talk from Helen Qu



Gaussian process light-curve modeling from Qu+2021

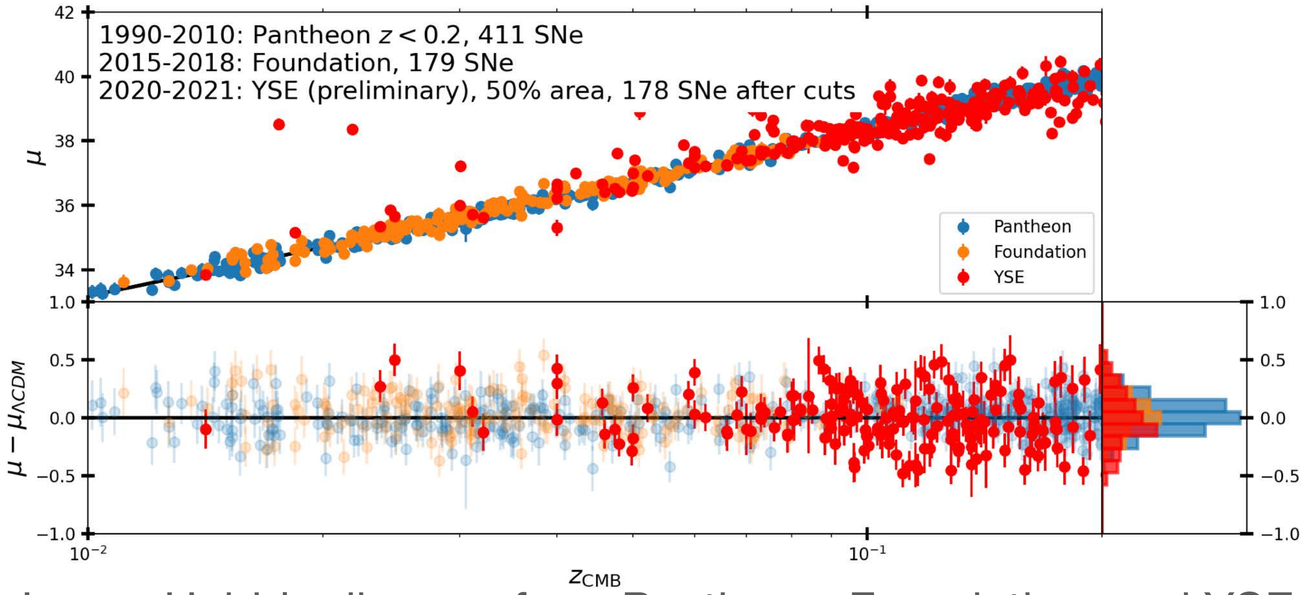


Jones+18 photometrically classified Hubble diagram

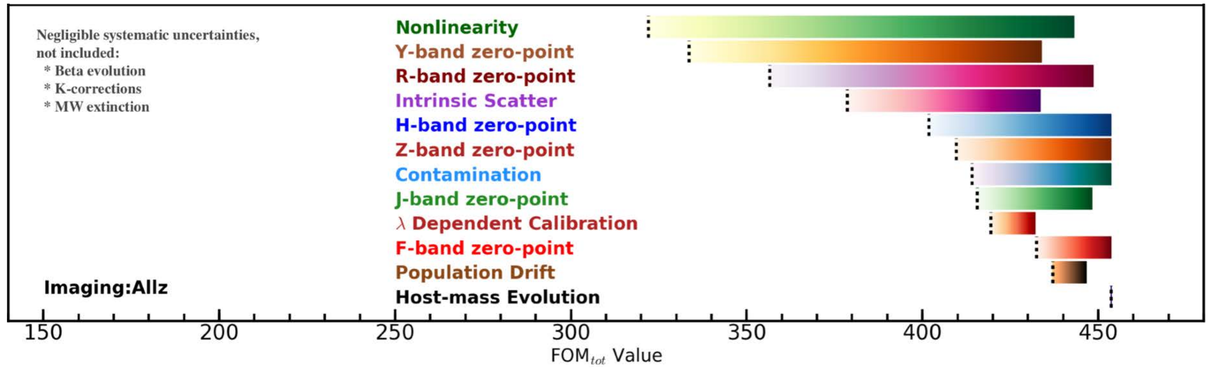
Recent Progress

Calibration

- New “Anchor” Samples: Foundation, Young Supernova Experiment, SNFactory at low-*z* with mmag-level calibrations
- Exquisite *Roman* calibration at high-*z* (Deustua, Aldering talks)



Low-z Hubble diagram from Pantheon, Foundation, and YSE
Foley+18, Jones+19,21

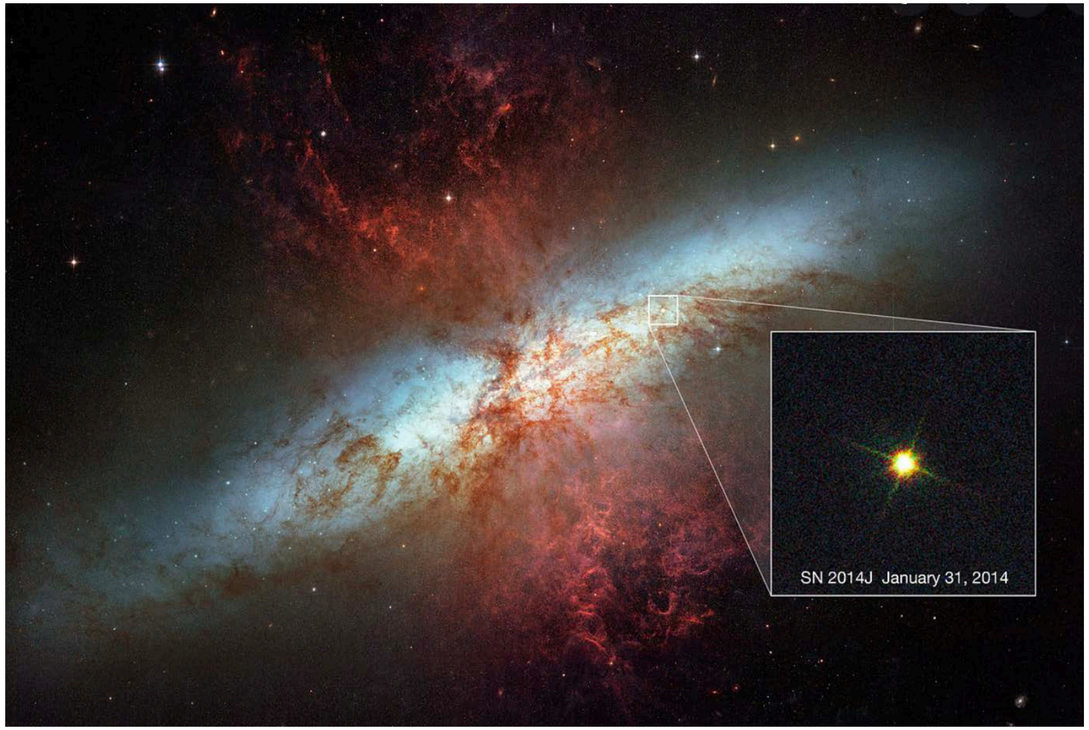


Understanding *Roman* calibration, from Hounsell+18

Solving Long-standing Mysteries

With *Roman*, we are poised to decades-old questions in the SN Ia community

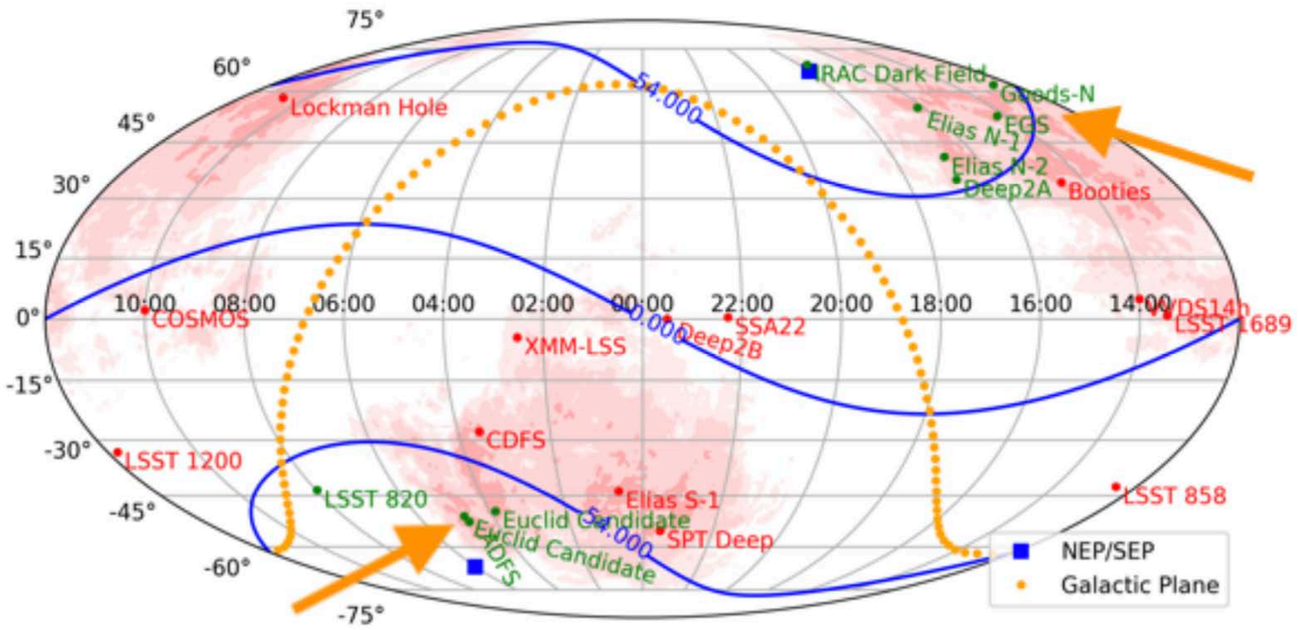
- What is the role of dust in SN Ia distance measurements (both host galaxy and circumstellar)?
- What is the underlying physics behind the dependence of SNe Ia Hubble residuals on their host galaxies?
- How do dust and progenitor properties evolve with redshift and how can we best control for them in cosmological studies?



Conclusions

- Roman is our **best chance** to understand the nature of dark energy in the next decade
- Along the way, we will unravel persistent mysteries in SN Ia physics and progenitors
- The SN SITs and the Ia community are putting ourselves in position to take advantage of these data

Potential Roman SN Survey Fields



Rose+21