Supernova Cosmology Today and the Future with *Roman*

David Jones
Einstein Fellow, UC Santa Cruz
11/18/21
• Dark energy is 70% of the energy density of the universe, and its nature is unknown
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.

\[
w(a) = w_0 + w_a (1 - a) = w_0 + \frac{w_a z}{1 + z}
\]
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 $\Lambda$CDM model parameters - $H_0$, $\sigma_8$ - 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.
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
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

*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
- *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* will probe redshifts/wavelengths/systematic uncertainty floors previously unreachable for SNe Ia

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

**Orders of mag. more SNe at z > 1**
# Session Overview

## Overview

<table>
<thead>
<tr>
<th>Time</th>
<th>Speaker/Institution</th>
<th>Title</th>
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<tbody>
<tr>
<td>9:00 AM</td>
<td>David Jones (UCSC)</td>
<td>Supernova Cosmology Today</td>
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<tr>
<td>9:10 AM</td>
<td>Ben Rose (Duke)</td>
<td>The Roman Supernova Survey Overview</td>
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<tr>
<td>9:35 AM</td>
<td>David Rubin (UoH@Manoa)</td>
<td>Using the Roman Prism</td>
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## Simulations

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<tr>
<th>Time</th>
<th>Speaker/Institution</th>
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<tbody>
<tr>
<td>9:50 AM</td>
<td>Tri Aastratmadja (STScI)</td>
<td>SNe+Galaxy Spectral Sims</td>
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<tr>
<td>10:00 AM</td>
<td>Bhavin Joshi (STScI)</td>
<td>Spectroscopic Redshifts</td>
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<tr>
<td>10:10 AM</td>
<td>Phil Macias (UCSC)</td>
<td>Light Curve Simulations</td>
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<tr>
<td>10:25 AM</td>
<td>Kevin Wang (Duke)</td>
<td>Image simulations</td>
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## Calibration

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<tr>
<th>Time</th>
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<tbody>
<tr>
<td>11:00 AM</td>
<td>Susana Deustua (STScI)</td>
<td>Calibration Requirements</td>
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<tr>
<td>11:10 AM</td>
<td>Greg Aldering (LBNL)</td>
<td>Flux Standards</td>
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## Lightning Talks (Systematics, Modeling, Classification)

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<th>Time</th>
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<tbody>
<tr>
<td>11:25 AM</td>
<td>Mi Dai (JHU)</td>
<td>Overview of Systematic Uncertainties</td>
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<tr>
<td>11:30 AM</td>
<td>Justin Pierel (STScI)</td>
<td>SALT2/3</td>
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<tr>
<td>11:40 AM</td>
<td>Stephen Thorp (Cambridge)</td>
<td>BayeSN</td>
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<tr>
<td>11:50 AM</td>
<td>Kyle Boone (UW)</td>
<td>Twinning</td>
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<tr>
<td>12:00 AM</td>
<td>Mitchell Karmen (NYU)</td>
<td>Applying Twinning to Roman</td>
</tr>
<tr>
<td>12:10 AM</td>
<td>Matt Siebert (UCSC)</td>
<td>VCR</td>
</tr>
<tr>
<td>12:20 AM</td>
<td>Helen Qu (U Penn)</td>
<td>Photometric Classification</td>
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## External Synergies

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<tr>
<td>12:00 PM</td>
<td>Michael Wood-Vasey (Pitt)</td>
<td>Synergies between Roman, Euclid, JWST, Rubin</td>
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</tbody>
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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

Spectral time series

Manifold Learning

Reduced Hubble diagram dispersion and biases

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

SN Modeling, Optical+Near-Infrared

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

Figure from J. Pierel, Mandel+11

Decreasing $\mu$ uncertainty is equivalent to increasing the SNIa sample size
Recent Progress

SN Modeling, Optical+Near-Infrared

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

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

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

Photometric Classification

• See talk from Helen Qu

Gaussian process light-curve modeling fromQu+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)
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