Amalgame: Cosmological Constraints from the First Combined Photometric Supernova Sample

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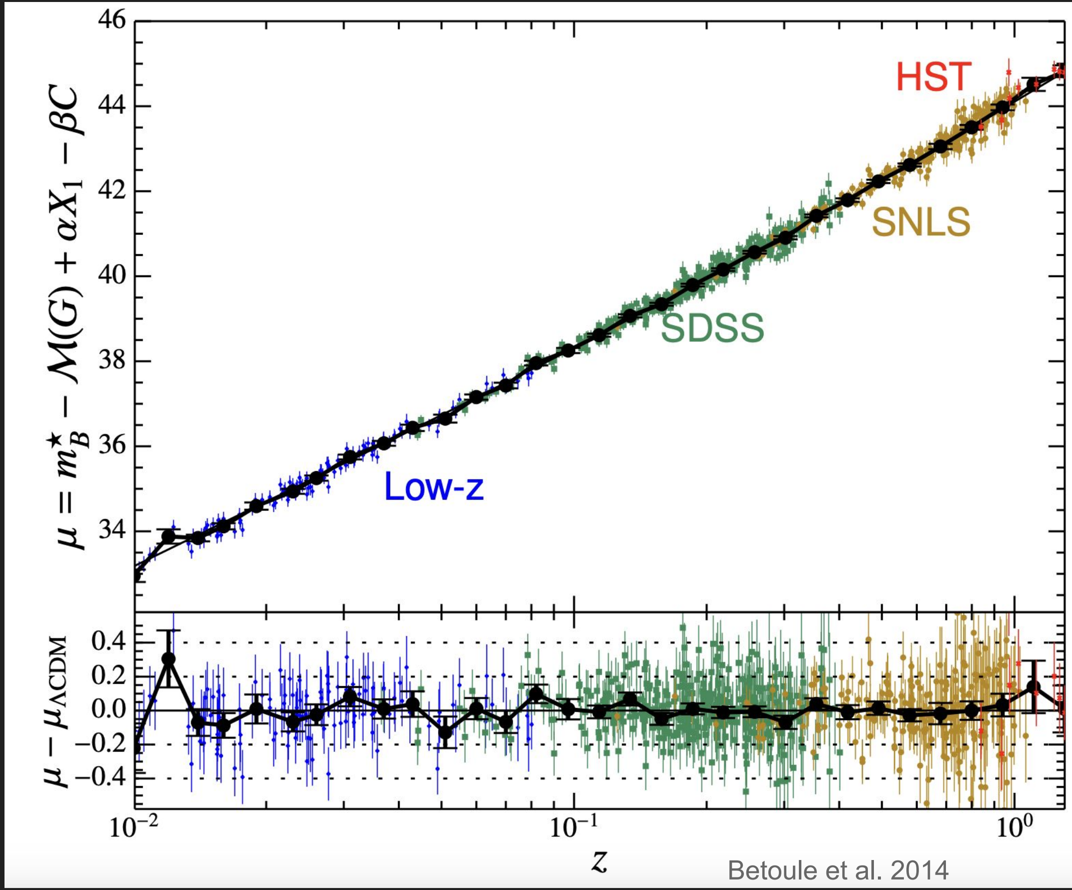
IP2I/IN2P3

A (Brief) History of SNeIa

In 2014, Betoule et al. released the Joint Light-Curve Analysis (JLA), a combination of 740 supernovae from Low-z, the Sloan Digital Sky Survey (SDSS), the SuperNova Legacy Survey (SNLS), and Hubble Space Telescope (HST).



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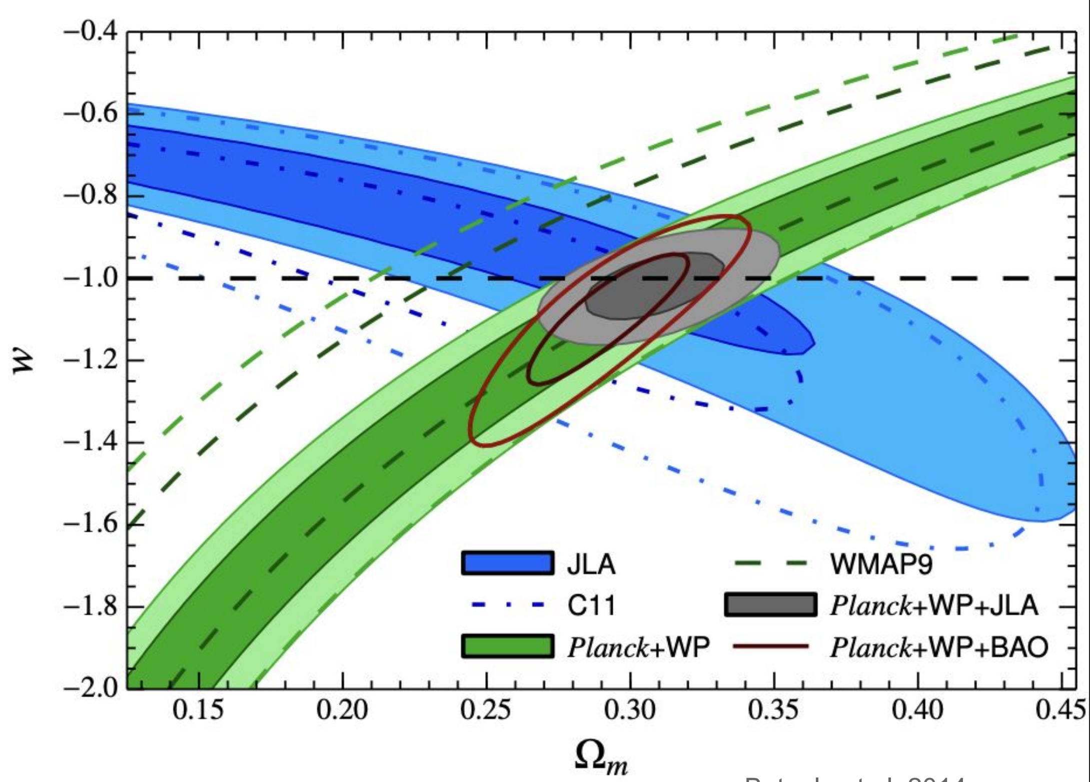
JLA finds:

$\Omega m = 0.303 \pm 0.012$

$w = -1.027 \pm 0.055$

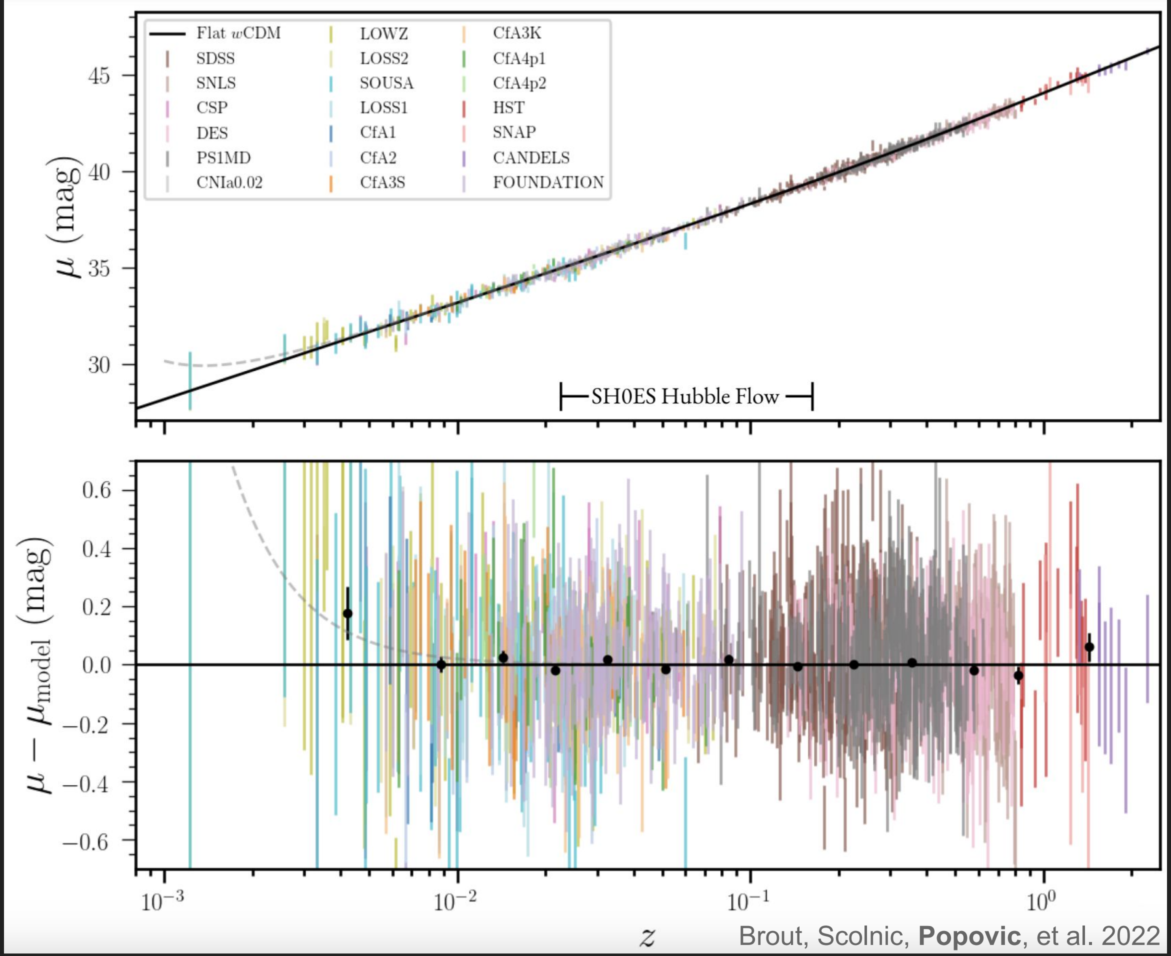


Betoule et al. 2014

Pantheon+ (2022)

Years hence, Pantheon+ is released, containing 1550 unique light curves from a... large number of SN surveys.

This represents the largest to-date collection of SNIa ever assembled.



Brout, Scolnic, **Popovic**, et al. 2022

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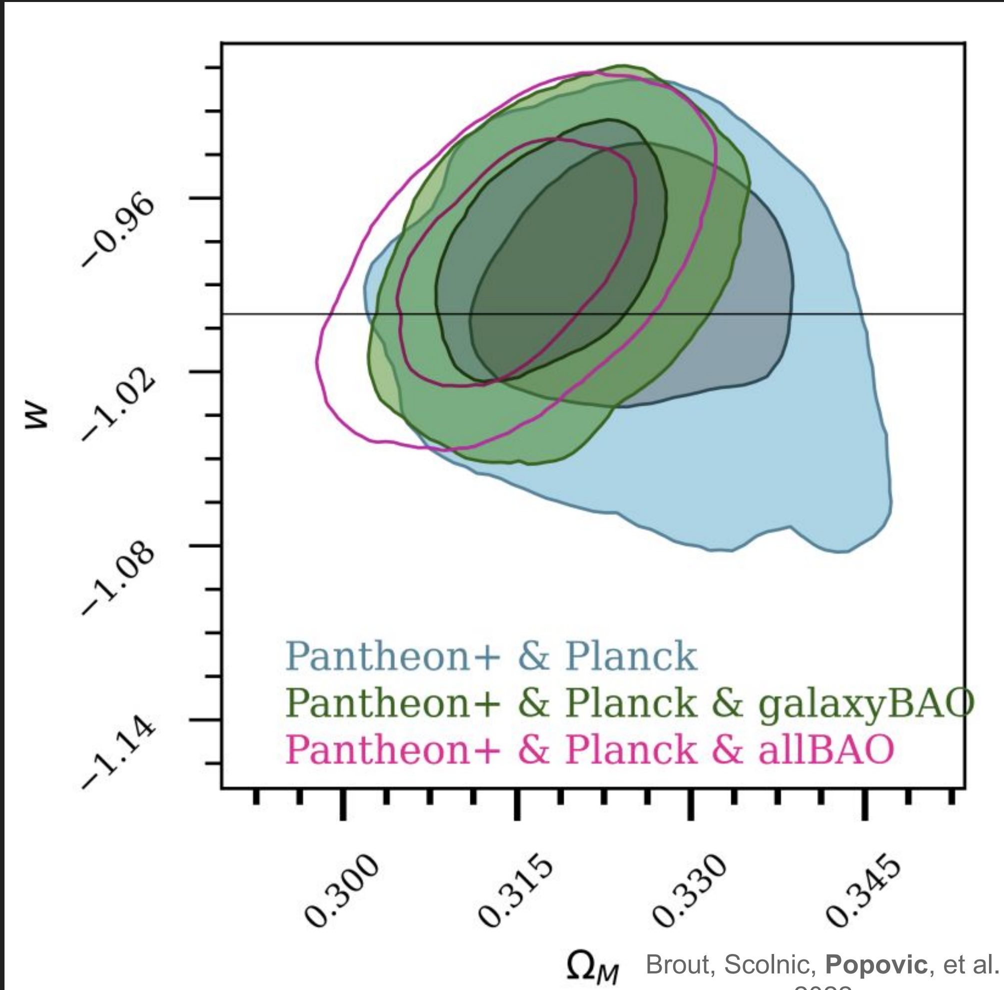
We find

w = −0.978 +/- 0.028



Brout, Scolnic, **Popovic**, et al. 2022

What's changed in the past ~10 years?

- **New Surveys**
  - Dark Energy Survey
  - Foundation
  - Pan-STARRS
  - Myriad other low-redshift
- **New Methodologies**
  - Simultaneous fits of cosmology alongside SH0ES
  - New Covariance Matrix Calculations
  - More in-depth bias corrections
- **Better Understanding of SNe Ia**
  - More complex models of selection and SNIa scatter

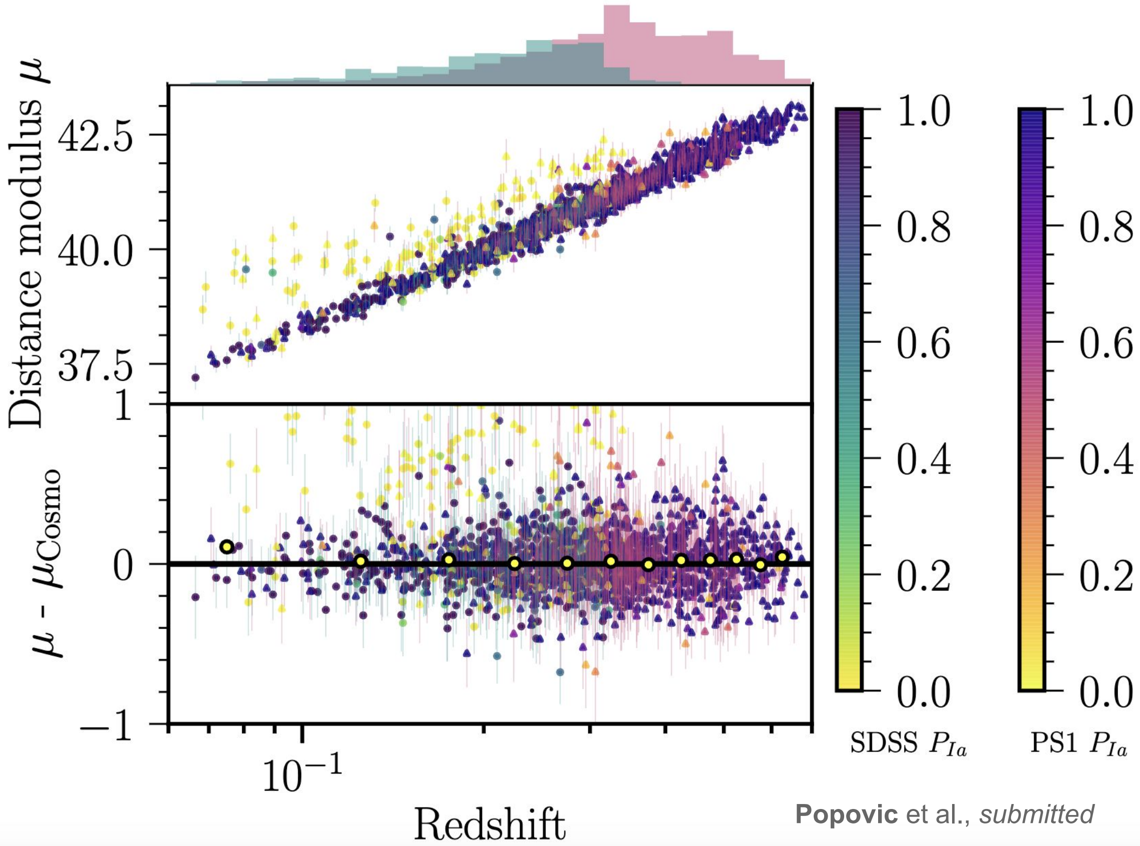
What **hasn't** changed in the past ~10 years?

- **Low-redshift anchor**
  - The addition of Foundation increased the sample, but we are still relying on Low-z
  - Low-z is… complicated! Essential, but complicated!
- **Spectroscopy**
  - **Every SNe Ia we have seen has been spectroscopically confirmed** - that is to say, we have spectra of the supernova and can confirm that it is type Ia.
  - **Pro:** Type Ia are the only standardisable supernova! No contamination from other SNe!
  - **Con:** Severely restricts our sample size, as only ~10% of observed SNe Ia have spectroscopy measurements

Introducing Amalgame

1792 photometrically-classified SNe Ia from SDSS and Pan-STARRS (PS1). The largest SNe Ia compilation ever, with no low-z sample!

But how did we get here?

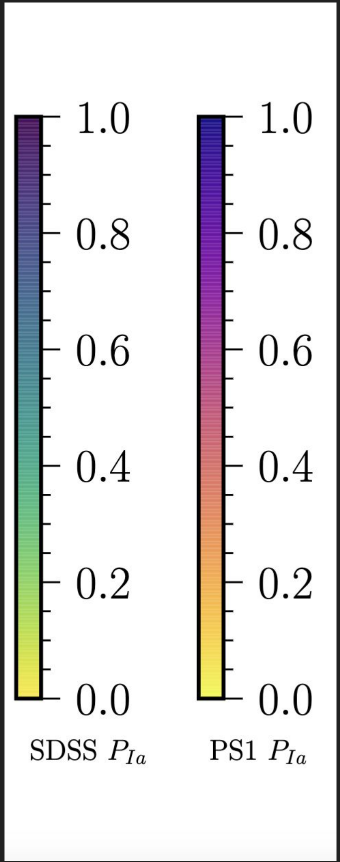


Popovic et al., *submitted*

Accounting for Non-Ia SNe

We are no longer using only those SNe that have spectroscopy. This drastically increases our sample size, but we need a way to account for potential non-Ia supernovae.

If we have a probability of being an SNIa, we can weigh the SNe by its probability when doing the cosmology fit using the **B**ayesian **E**stimation **A**pplied to **M**ultiple **S**pecies (BEAMS) method - but where do we get our probabilities?

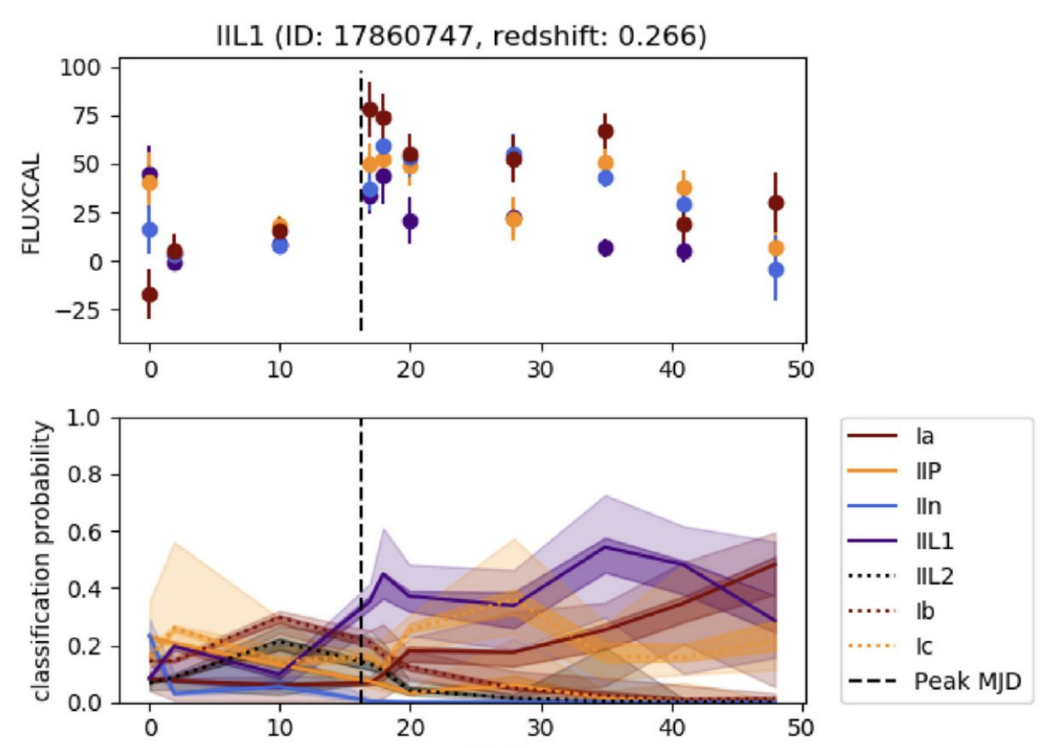


SuperNNova

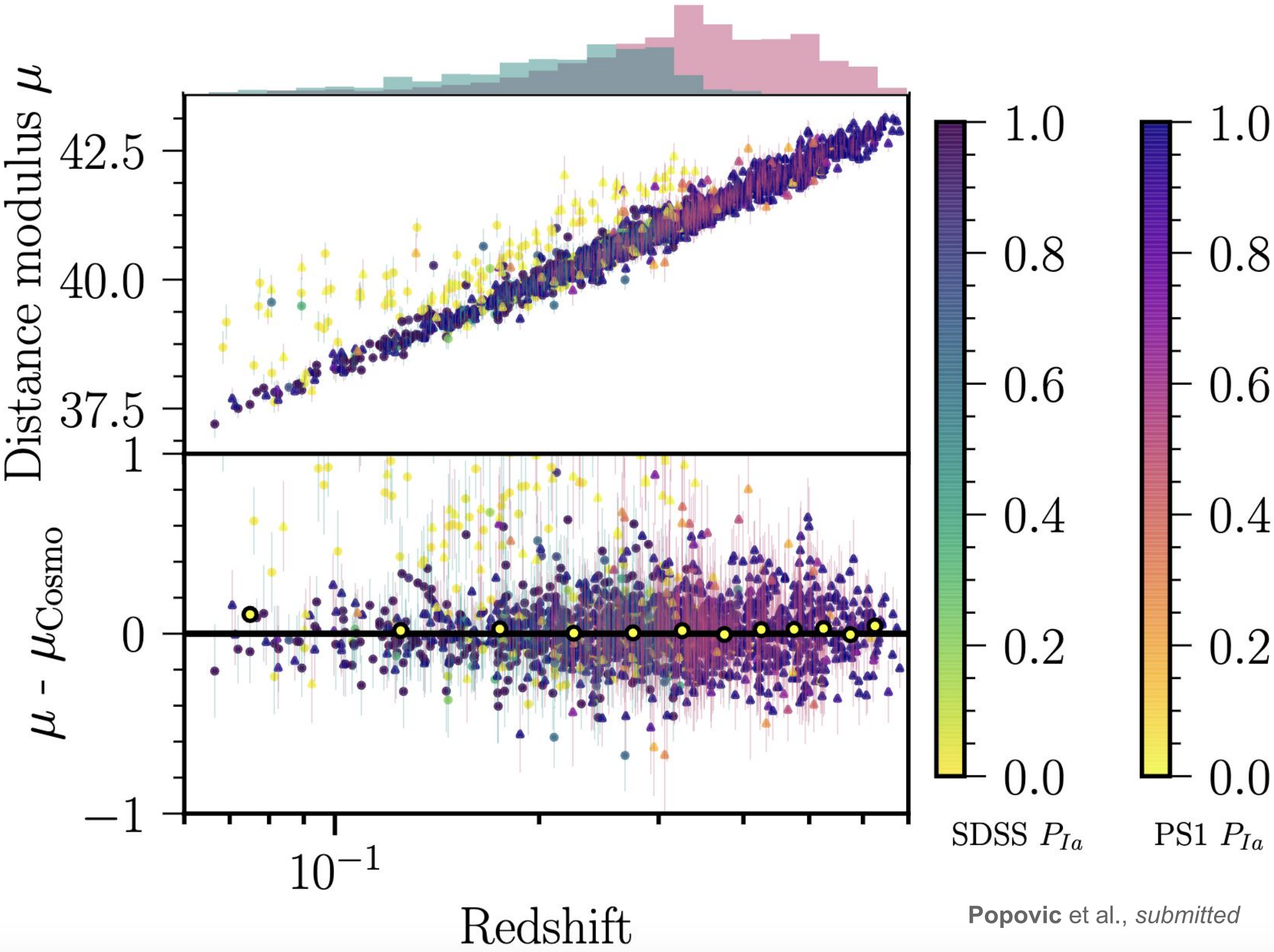
We utilise SuperNNova, a recurrent Neural Network to train and classify light curves. We train on a combination of non-Ia simulations from Vincenzi et al. 2019 and Ia simulations from Amalgame.

For high redshift (e.g. z >0.1), this works quite well! Accuracy of >99%.

This, in combination with BEAMS, handles non-Ia pretty well!



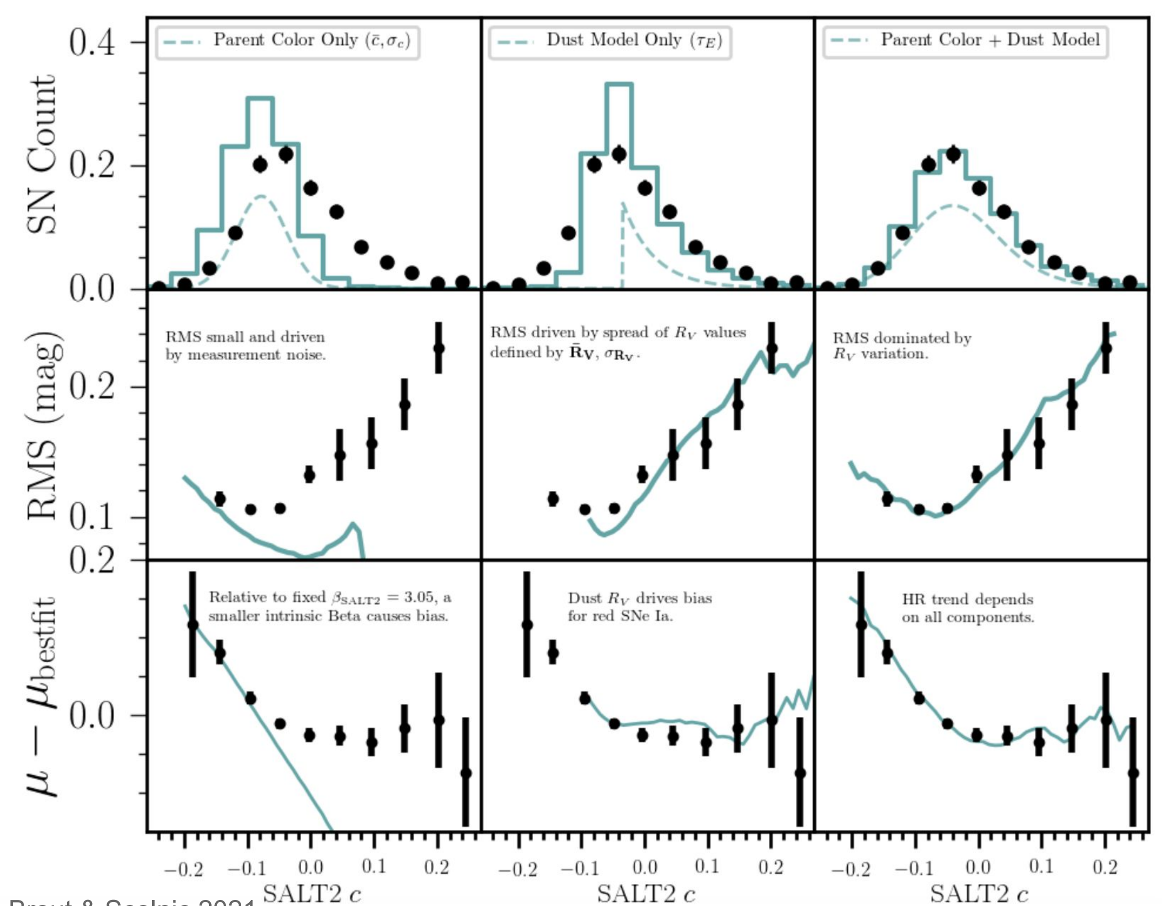
Möller & de Boissière 2019



Popovic et al., *submitted*

New Method of Modeling SNIa Scatter

We are incorporating the effects of dust into how we model SNIa scatter. Introduced by Brout & Scolnic 2021 and improved in Popovic et al. 2023, we incorporate E(B-V) reddening into SNIa fitted colour *c* and Rv into explaining our best-fit residuals.

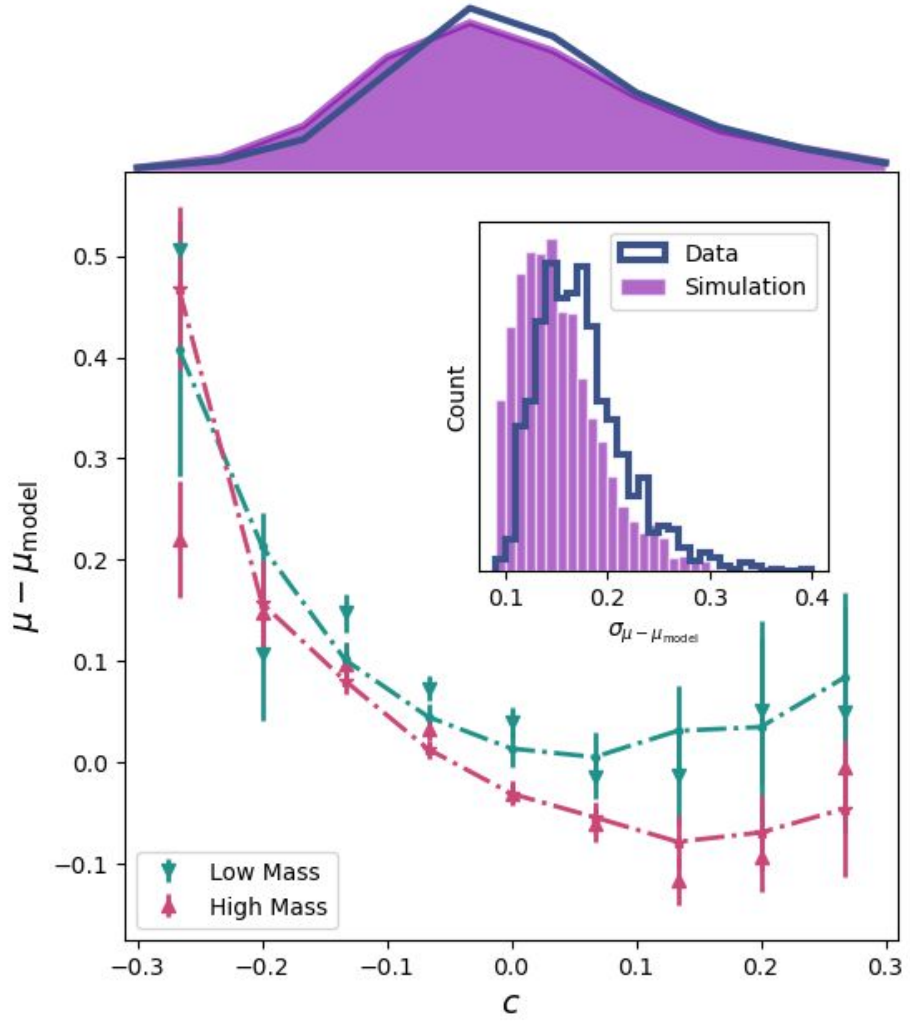


Brout & Scolnic 2021

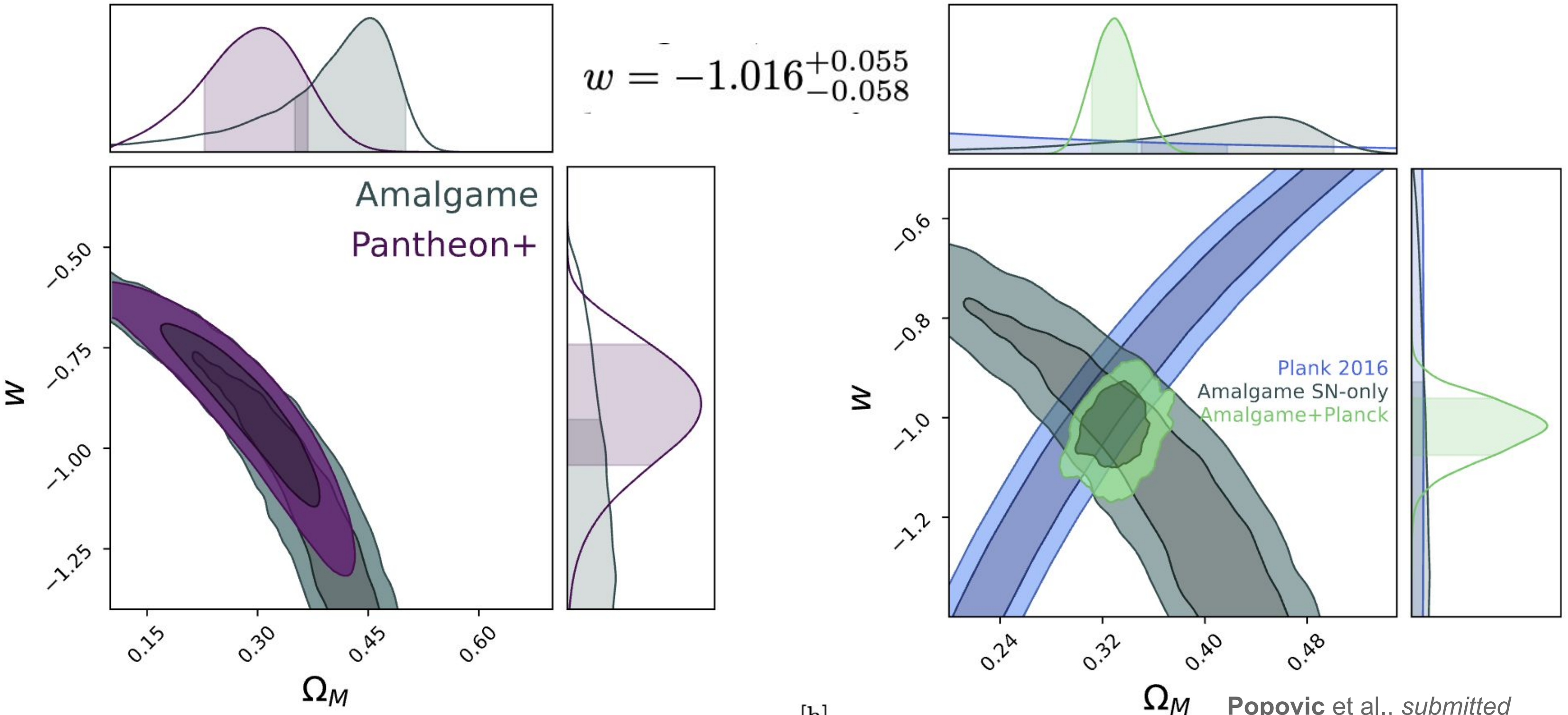
Dust Modeling (Popovic et al. 2023)

We use three criteria to determine the parameters of our dust model:

1. Colour distribution
2. Residuals of to best-fit cosmology as a function of SNIa fitted colour *c*
3. The scatter in those residuals



Cosmology with Amalgame



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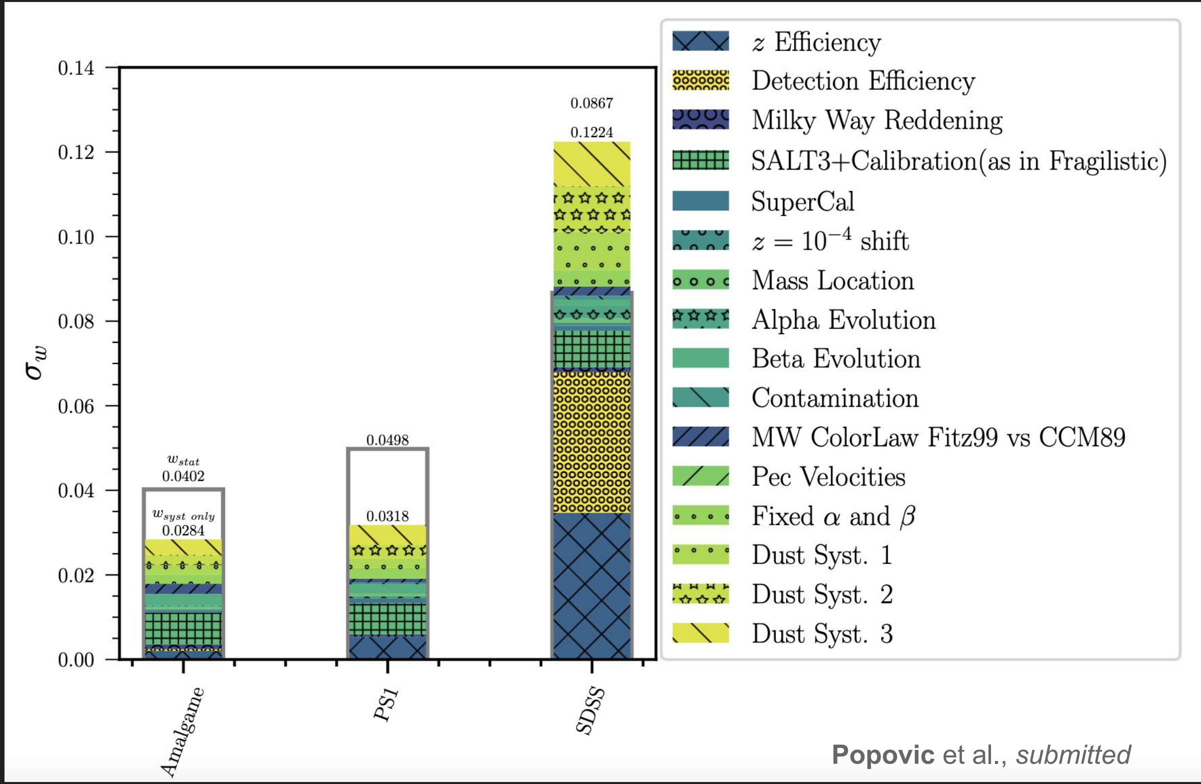
Popovic et al., *submitted*

What's the largest source of our errors?

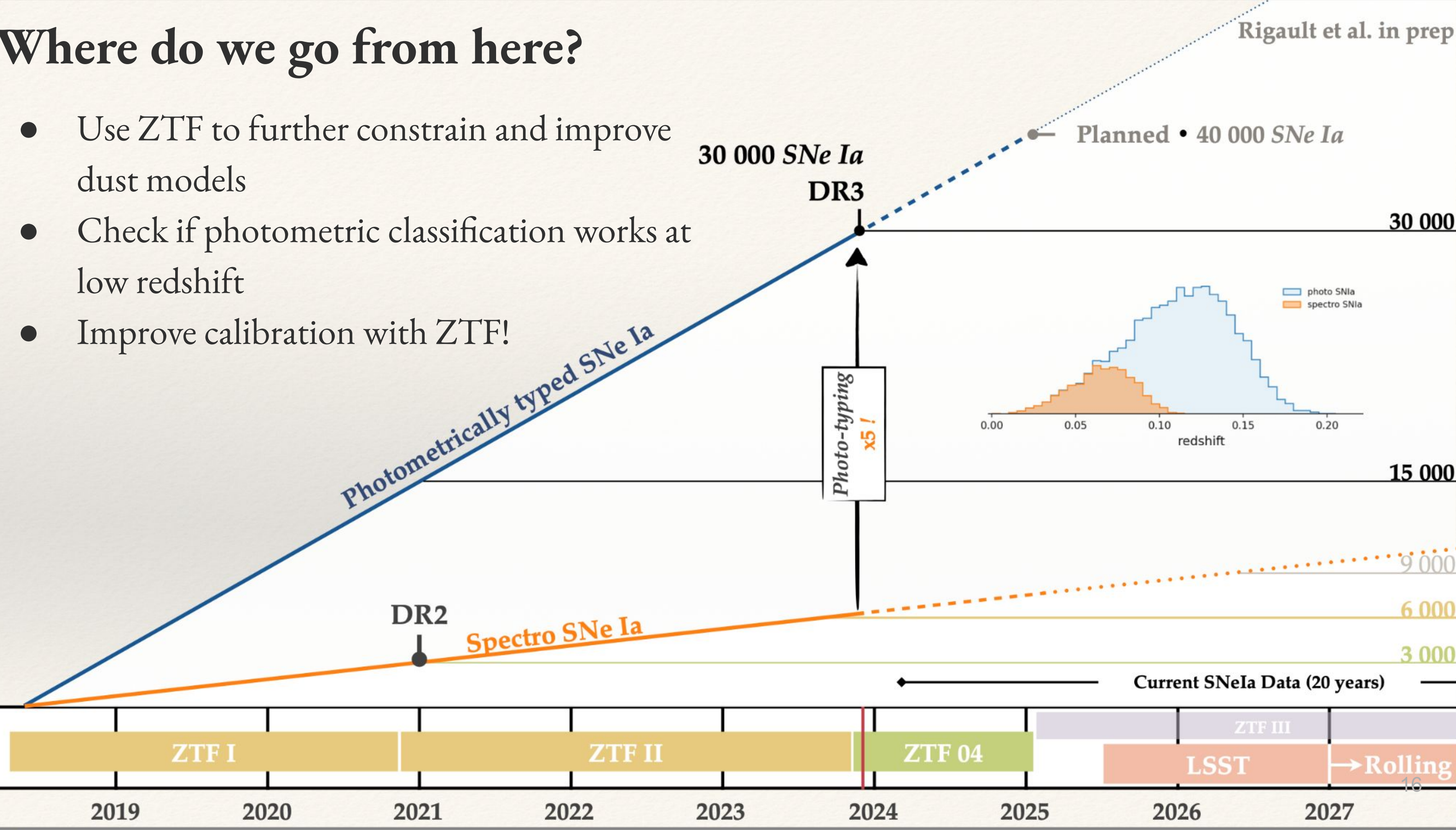
Largest issue is still calibration.

Second largest systematic relates to how we determine our new scatter model - as you can see, the model specifics are not terribly well constrained!



Where do we go from here?

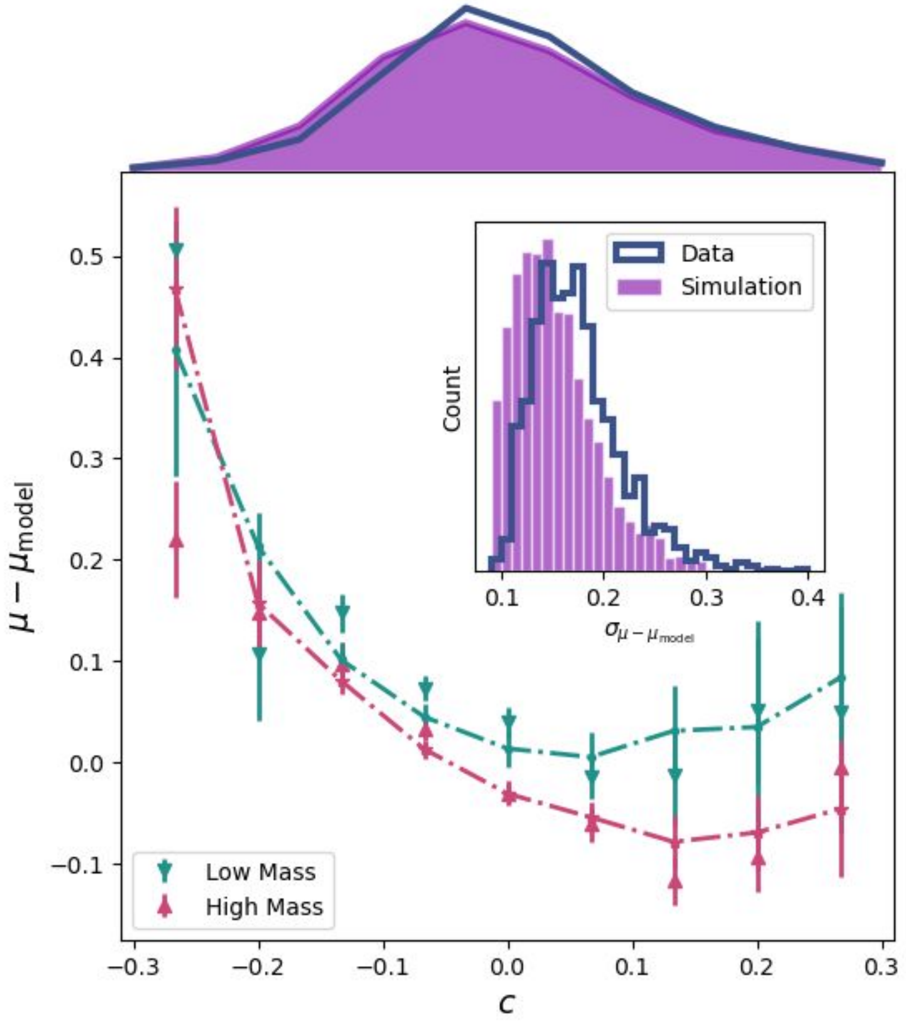
- Use ZTF to further constrain and improve dust models
- Check if photometric classification works at low redshift
- Improve calibration with ZTF!



ZTF In Dust Modeling

ZTF will enable us to:

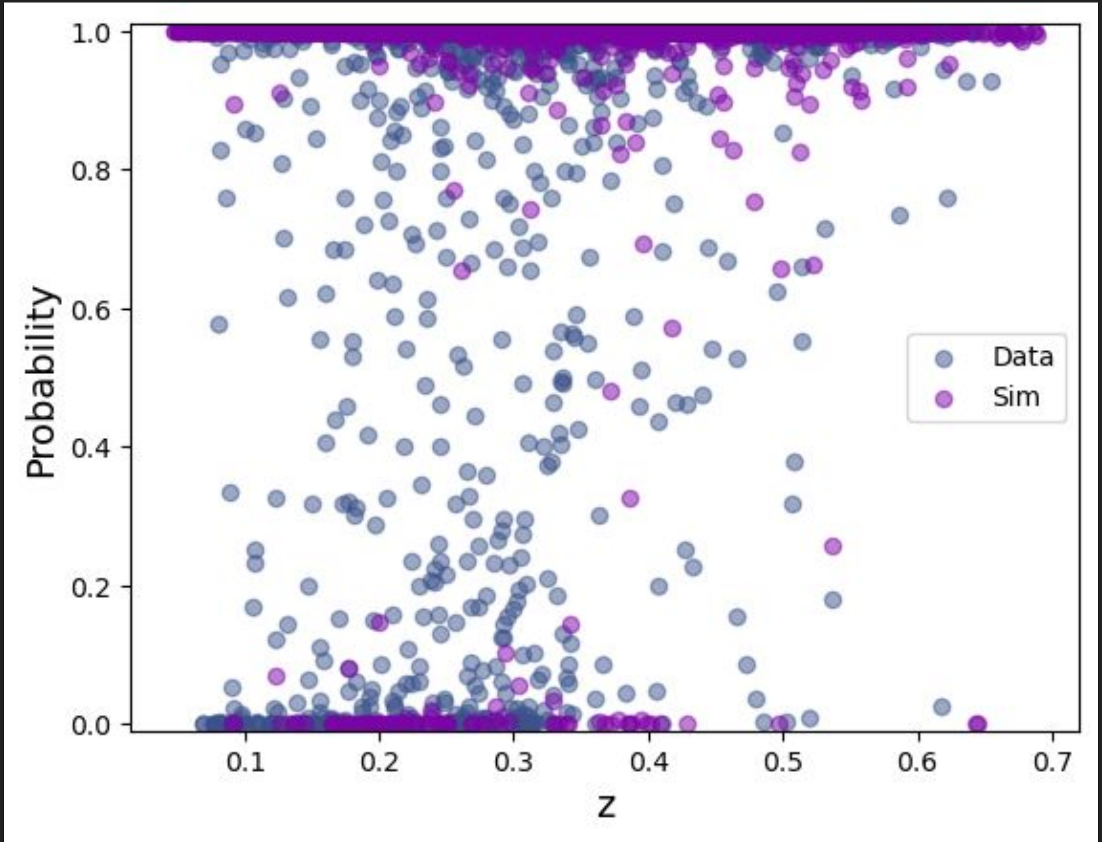
1. Add redshift dependence (super important, degenerate with cosmology!)
2. Implement more realistic dust distributions than the existing "step"
3. Investigate other tracers of host galaxy properties
4. Tie in progenitor effects (not just colour!)



Photometric Classification at Low Redshift is Still a Mystery

Initial results from Berlin indicate that our classification accuracy is redshift dependent.

At the very least, there is a variability in the data that we are not able to replicate presently!



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