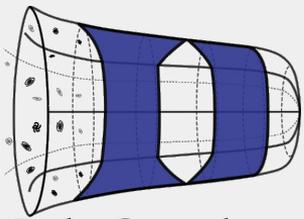
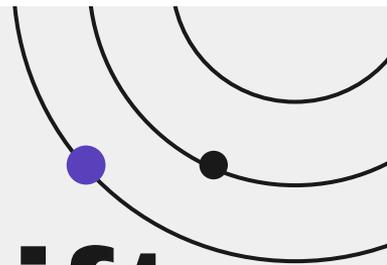




Improving Low-Redshift Supernova Cosmology with DEBASS

Maria Acevedo
April 22, 2025



Duke Cosmology



Outline

01

SNe Ia as Cosmological Tools

Why they work and
how we use them in
practice

Issues in our current Low-z Sample

Calibration
systematics from
multiple telescopes

02

DEBASS: A Uniform Low-z Survey

Single-telescope,
consistent calibration,
and our initial results

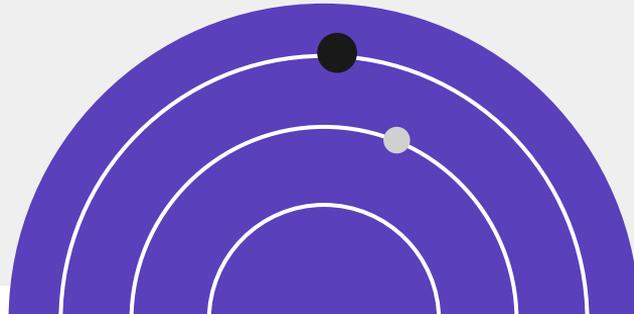
03

Future with the Full DEBASS Sample

Precision cosmology from
a single telescope

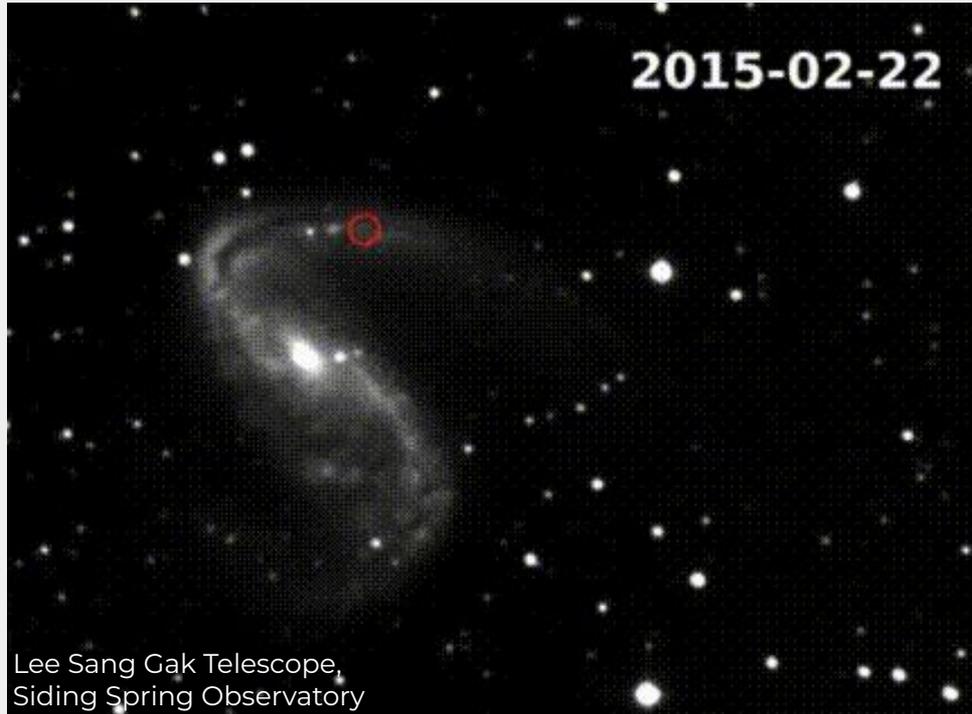
01

Motivations



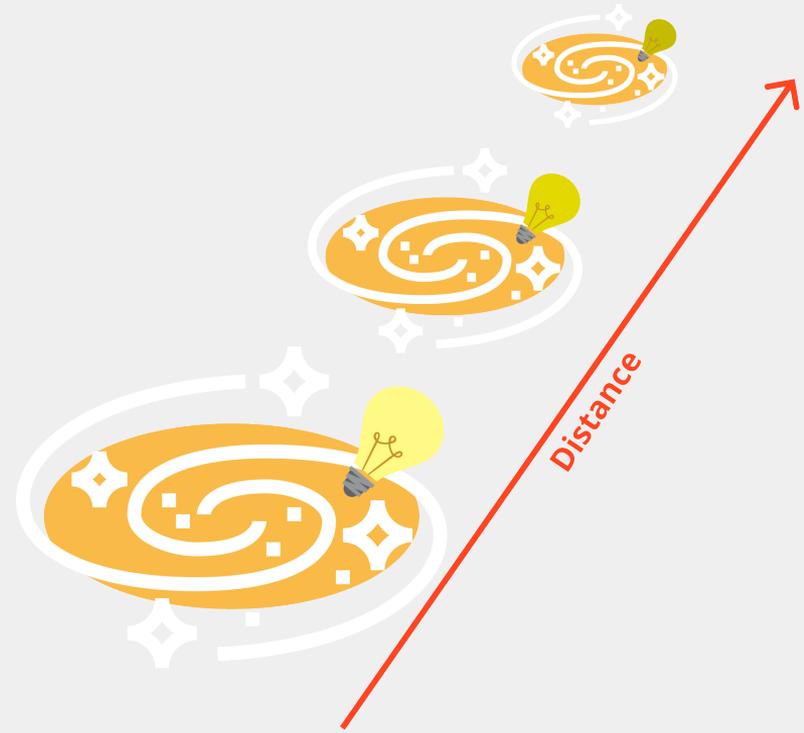
Type Ia SNe allow us to measure distance

- Type Ia Supernovae are exploding white dwarfs
- They explode at consistent mass-> have fairly consistent luminosity



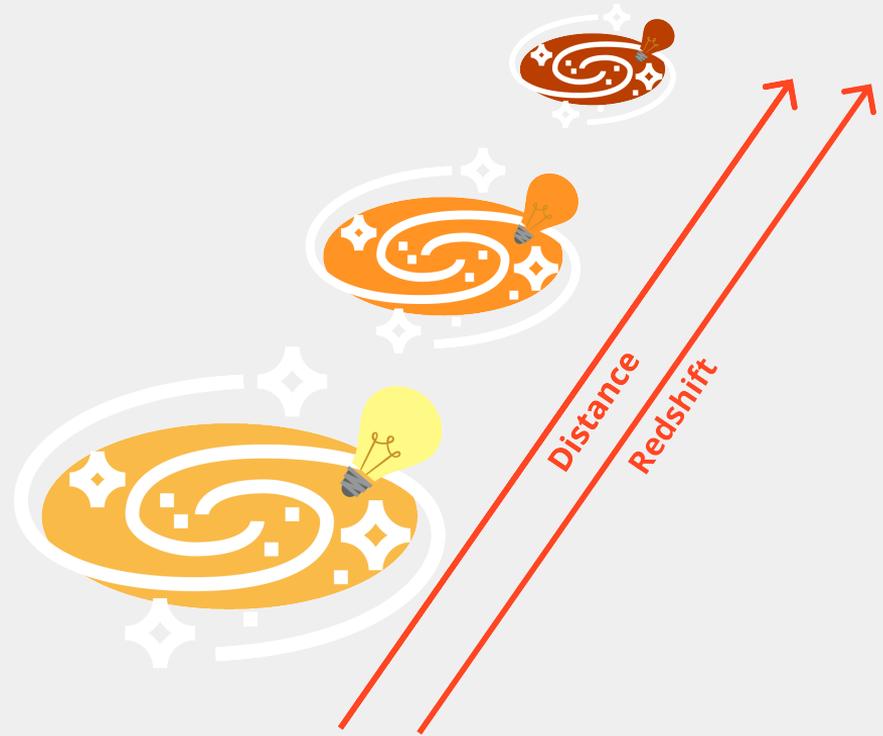
Type Ia SNe allow us to measure distance

- SNe Ia are standardizable candles
- Measure their apparent brightness
→ infer luminosity distance
- Combine with redshift to trace the expansion history of the universe

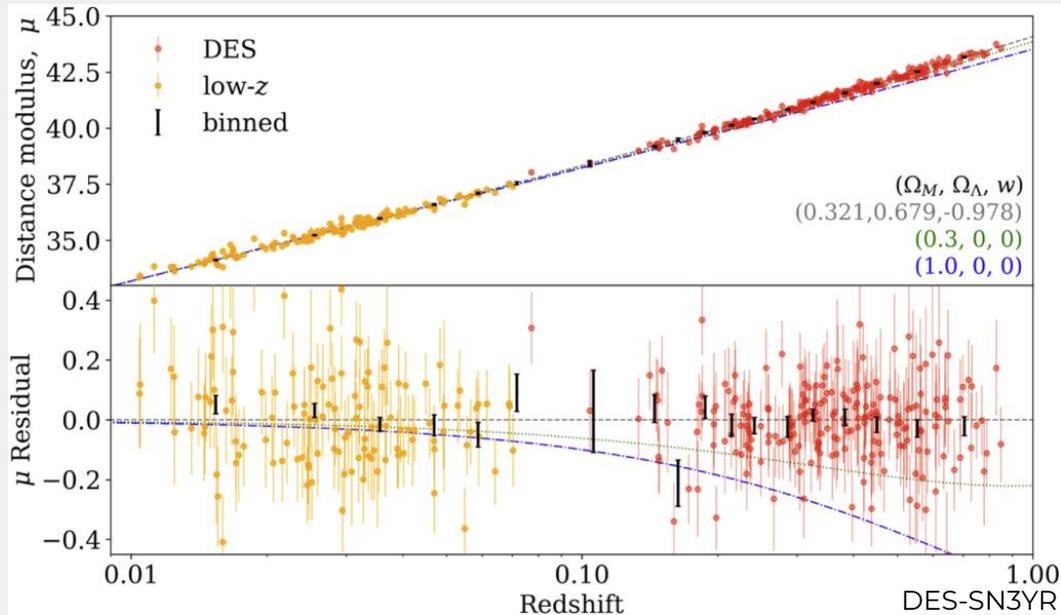


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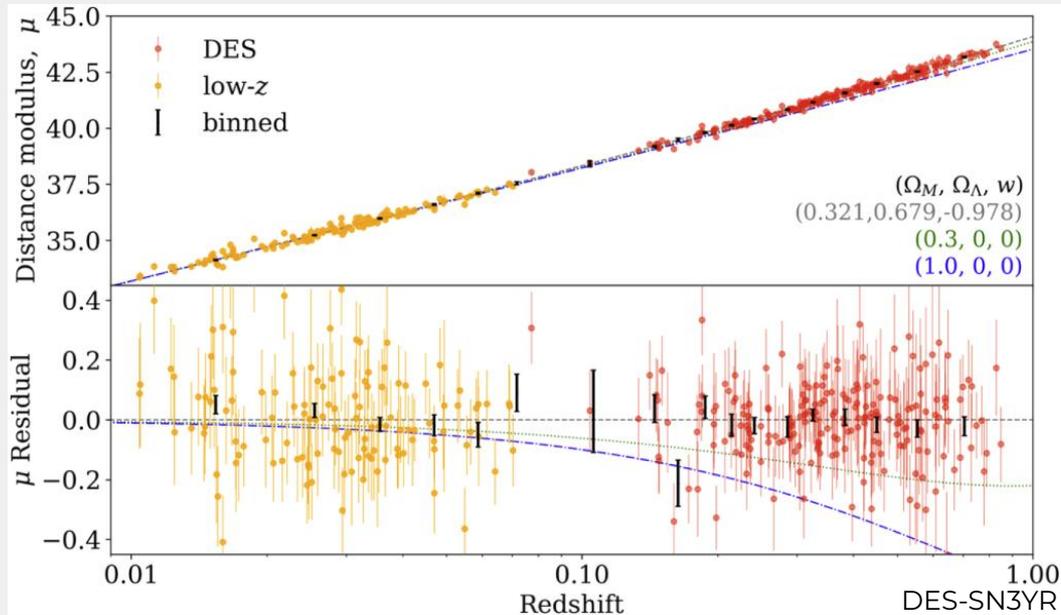
Type Ia SNe and the Hubble Diagram



- Fit light curves to extract the distance modulus

$$\mu = 5 \log(d_L / 10 \text{pc}) = m - M$$

Type Ia SNe and the Hubble Diagram



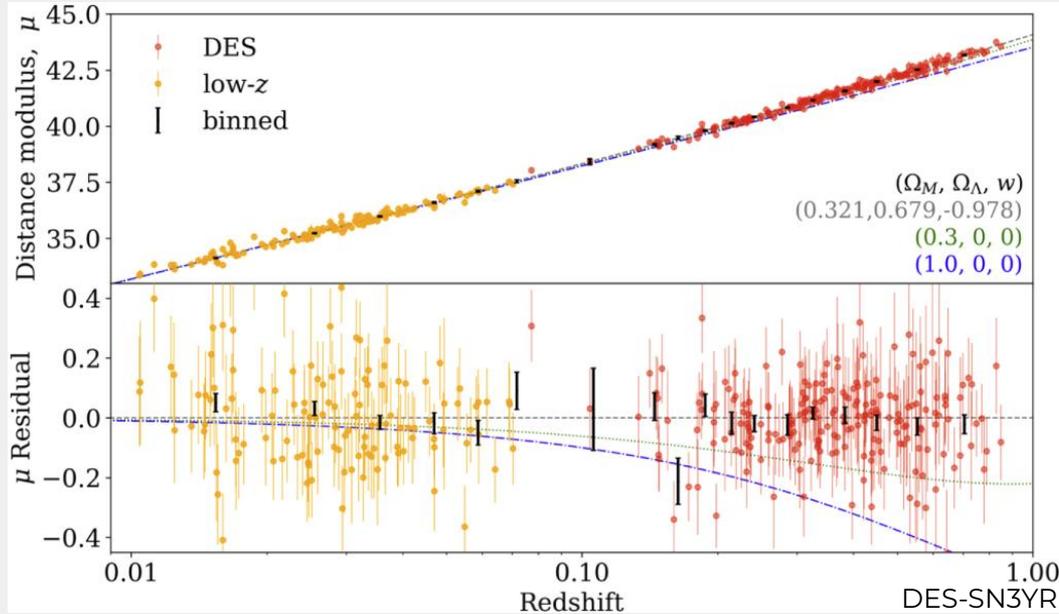
- Fit light curves to extract the distance modulus

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- SNe are standardized using the Tripp relation

$$\mu = m_B + \alpha x_1 - \beta c - M_B$$

Type Ia SNe and the Hubble Diagram



- Fit light curves to extract the distance modulus

$$\mu = 5 \log(d_L / 10 \text{pc}) = m - M$$

- SNe are standardized using the Tripp relation

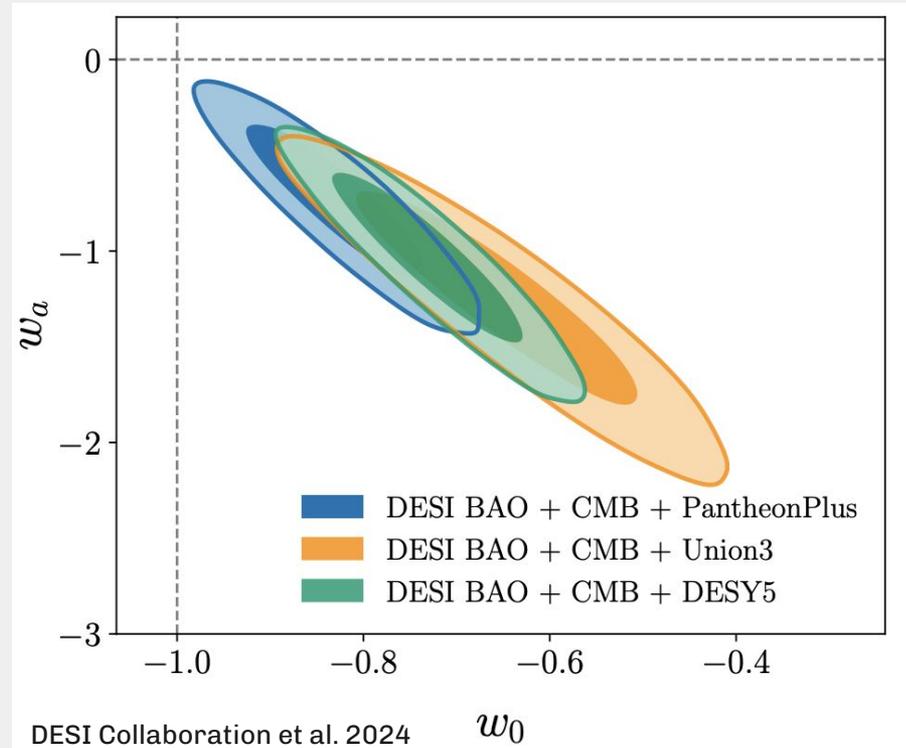
$$\mu = m_B + \alpha x_1 - \beta c - M_B$$

- Hubble diagram residuals are given by

$$\Delta\mu = \mu_{obs} - \mu_{model}(z_{obs})$$

DESI+SN Have Hinted at Evolving Dark Energy

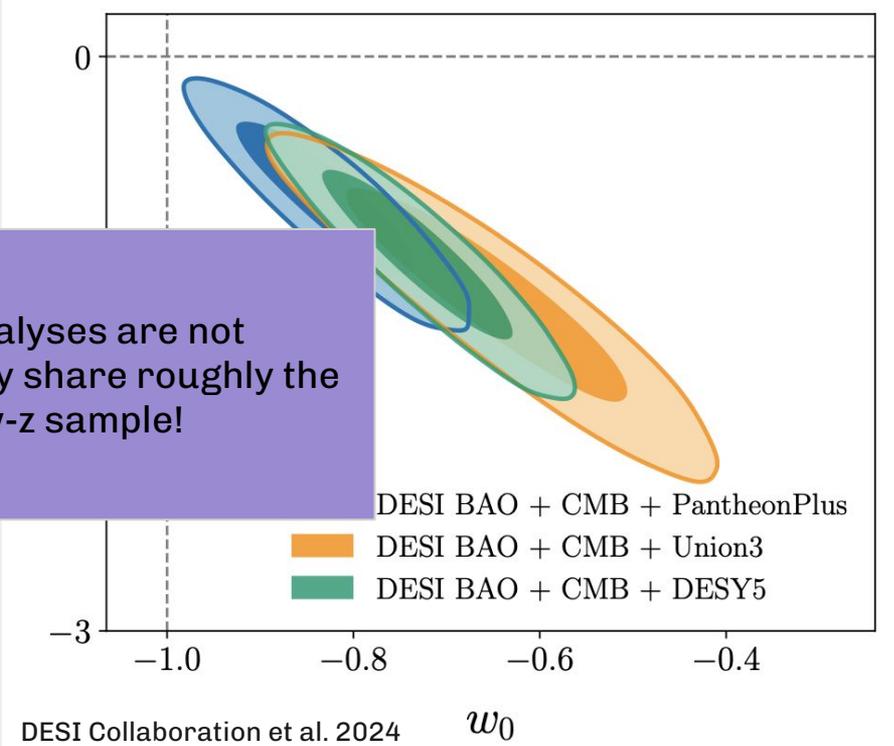
- The Dark Energy Spectroscopic Instrument (DESI) combined their Baryon Acoustic Oscillation results with SNe Surveys
- Interesting potential signal away from cosmological constant at 2-4.5sigma, depending on samples added together



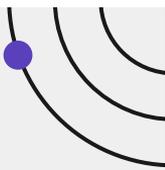
DESI+SN Have Hinted at Evolving Dark Energy

- The Dark Energy Spectroscopic Instrument (DESI) combined Baryon Acoustic Oscillation (BAO) results with SNe Ia results. Interesting potential from cosmological 2-4.5sigma, depending on samples added together

These SN analyses are not independent. They share roughly the same low-z sample!

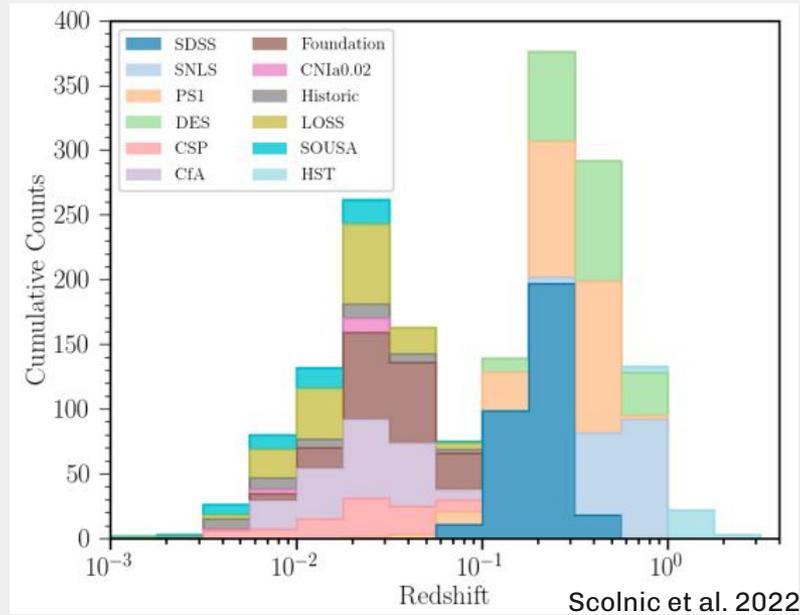


Pantheon+ Combines Multiple Surveys



- *Pantheon+ Compilation*

- One of the largest SN Ia cosmology samples to date (1700+ SNe Ia)
- Combines data from 18 different surveys across multiple telescopes

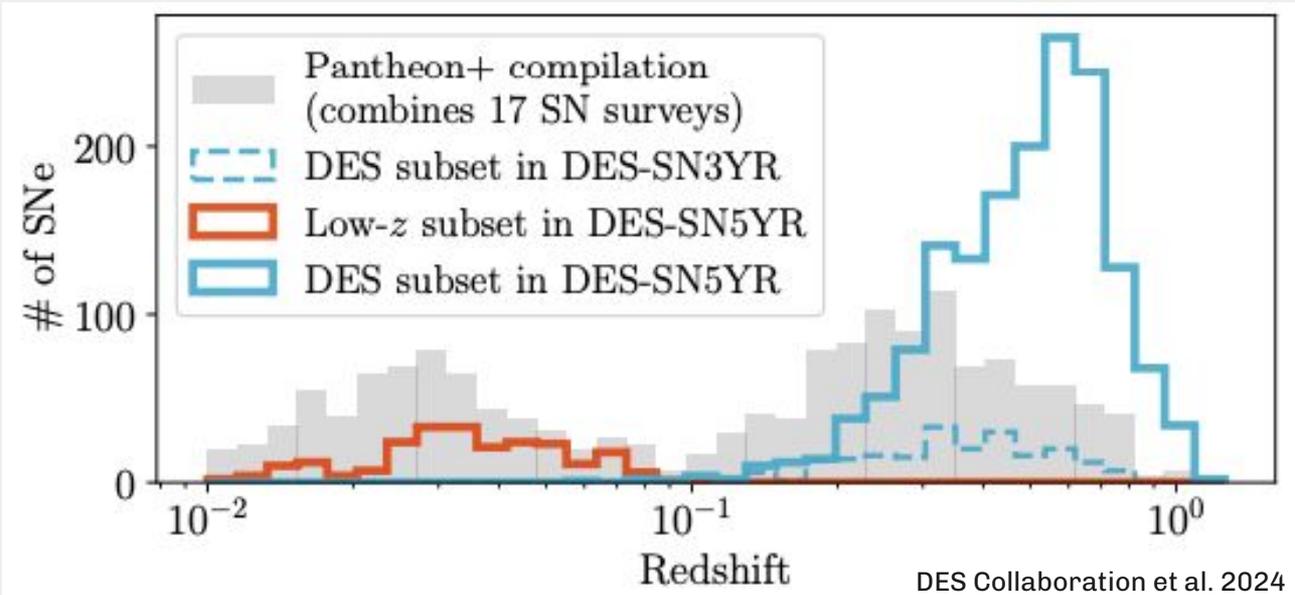


Scolnic et al. 2022



DES5YR Uses the Same Low- z Anchor

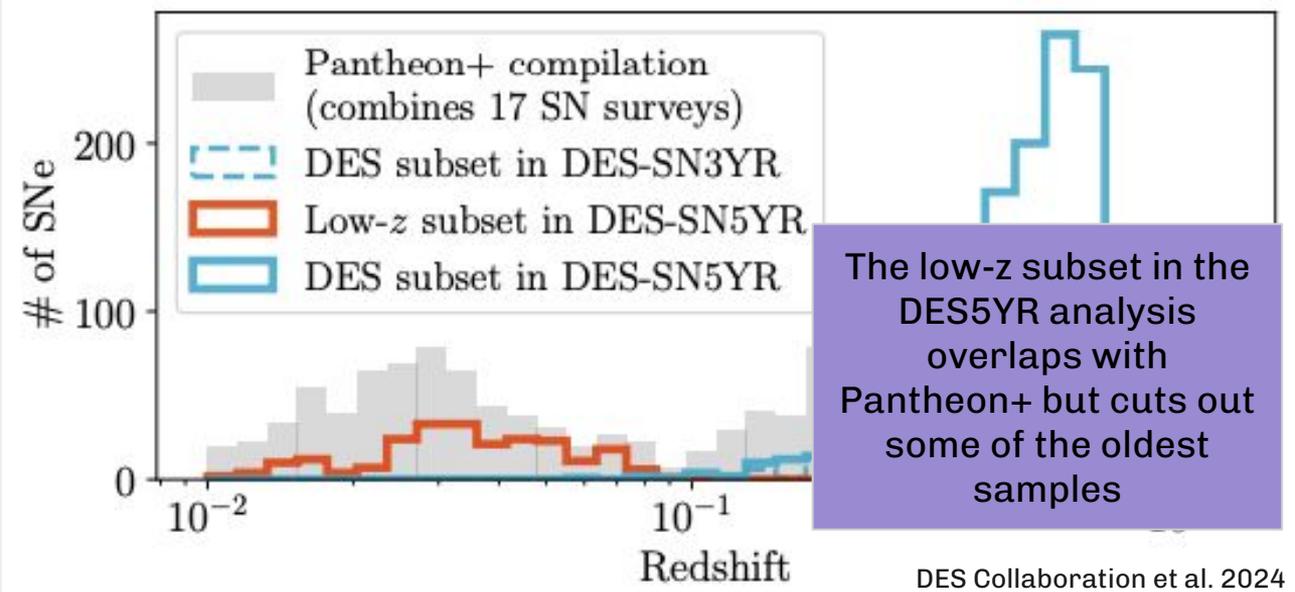
- Dark Energy Survey (DES) 5YR
 - 1500+ SNe Ia focused on $z \sim 0.1$ – 1.13





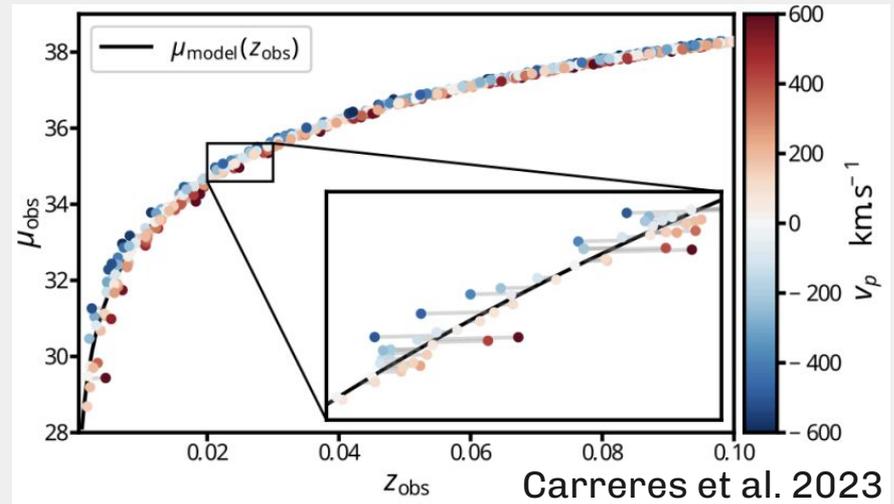
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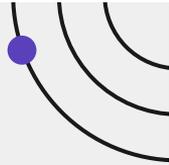
- Dark Energy Survey (DES) 5YR
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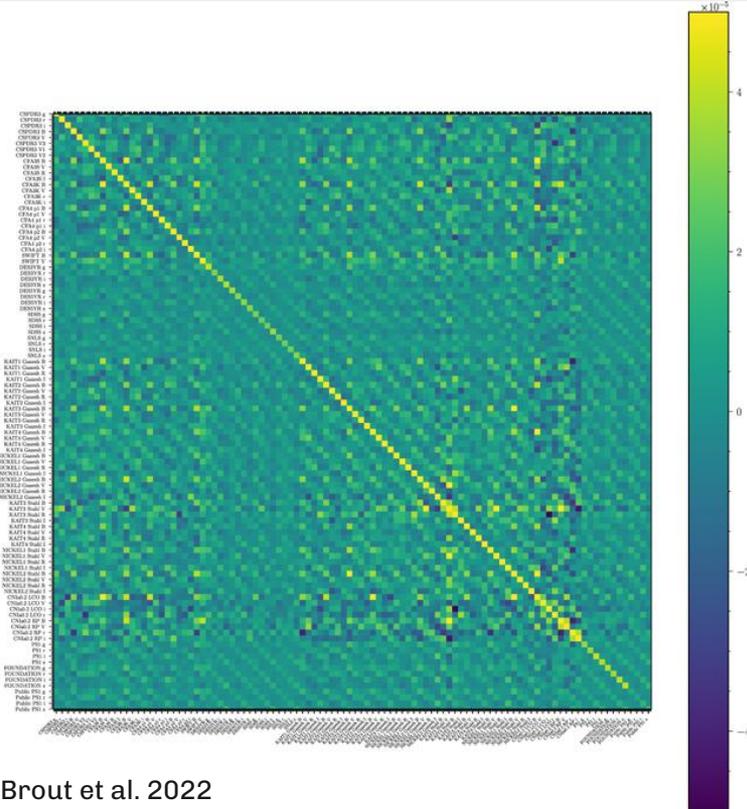
Challenge 1: Peculiar Velocities Dominate Scatter at Low Redshift

- Even after standardization, SNe Ia distances show scatter
 - Intrinsic scatter: astrophysical differences not captured by light curve models
- At low redshift ($z < 0.1$), peculiar velocities are a dominant source of scatter
 - Peculiar velocities: motions not due to the expansion of the universe





Challenge 2: Cross-Calibration is Hard

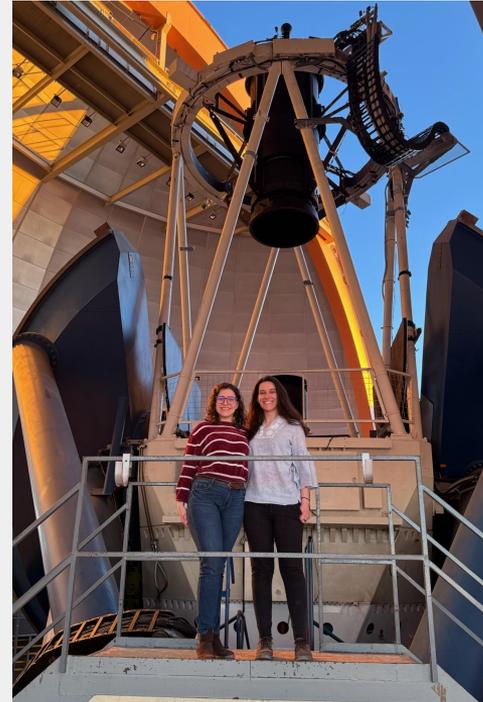


Brout et al. 2022

- Cross-survey calibration is a dominant source of uncertainty:
 - Different filter systems, zeropoints, and throughput responses
 - Complicated
 - Efforts to calibrate across surveys still report a max 0.013 uncertainty in w

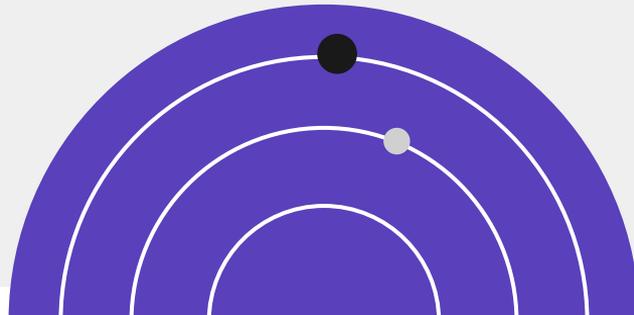
We Address These Issues With A Targeted Low-z SN Program

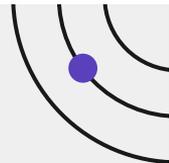
- Dark Energy Bedrock All-Sky Supernovae (DEBASS) Survey
 - All sky follow-up survey that began in 2021
 - Goal: Collect a low-z SNeIa sample to combine with the DES5YR sample to perform constraints on dark energy, the Hubble constant, and $f\sigma_8$



02

DEBASS





DEBASS: Blanco Telescope (DECam)



Location

Cerro Tololo
Inter-American
Observatory,
Chile



Field of View

3 square
degrees (2.2°
wide)



Seeing

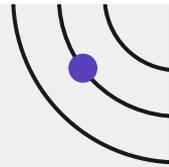
Average of 1
arcsec



Filters

u g r i z Y





DEBASS: Blanco Telescope (DECam)



Location

Cerro Tololo
Inter-American
Observatory,
Chile



Field of View

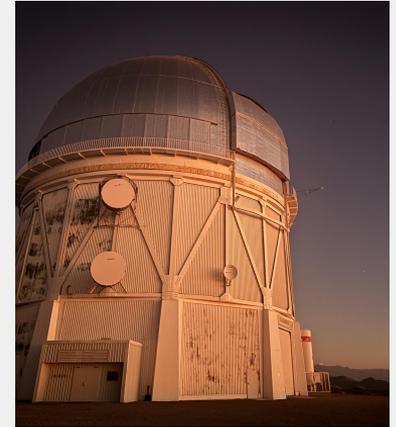
3 square
degrees (2
wide)

This is the same
telescope used for
DES which means
no internal cross
calibration
required!

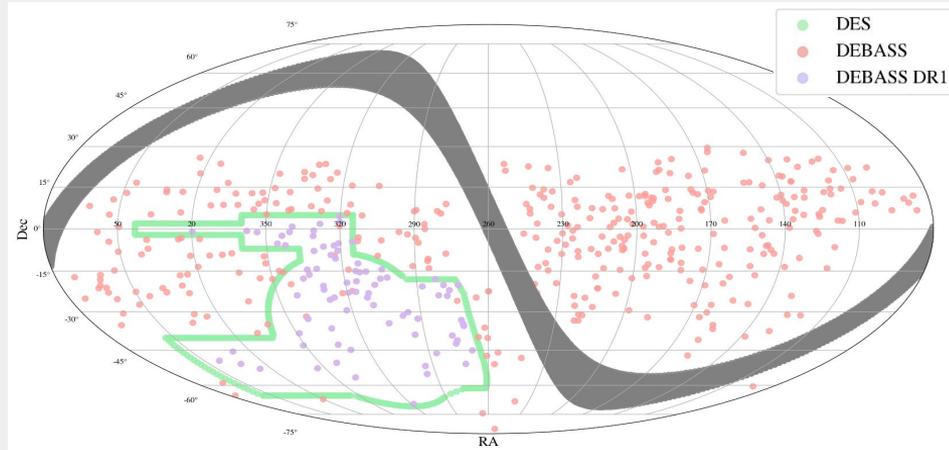


Filters

grizY



DEBASS Builds a Low-z Sample

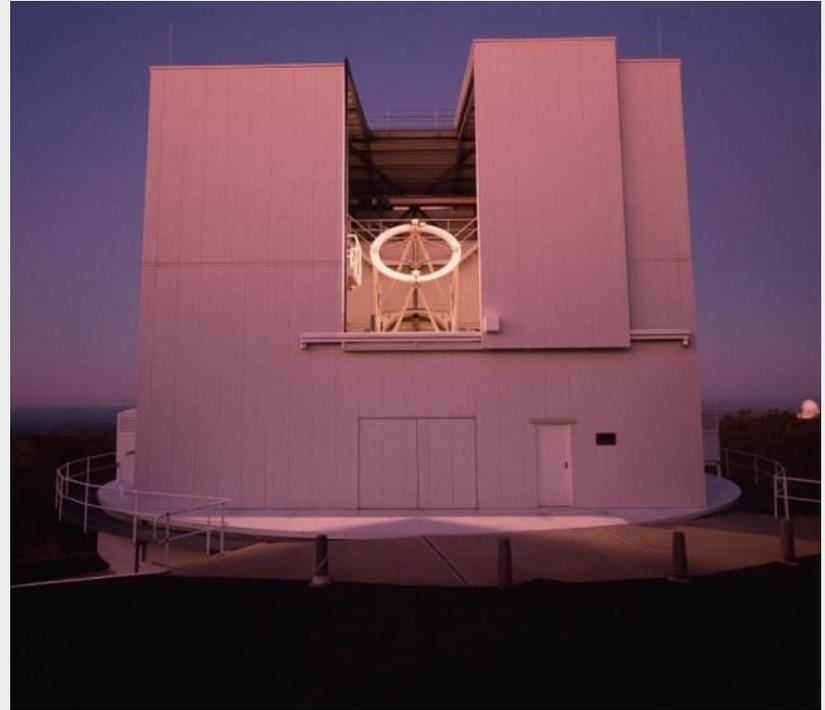


Follow-up SNe across the sky

- We select SNe within the Hubble flow ($0.015 < z < 0.1$)
- Priority is given to spectroscopically confirmed transients that will be observable by DECam for at least 45 days
- In total we have observed over 400 SNeIa

Spectroscopic Confirmation (mostly) comes from WiFeS

- Wide Field Spectrograph (WiFeS)
- Mounted on 2.3-meter ATT at Siding Spring Observatory in Australia
 - Same telescope used by OzDES
- Spectroscopic confirmation of Type Ia

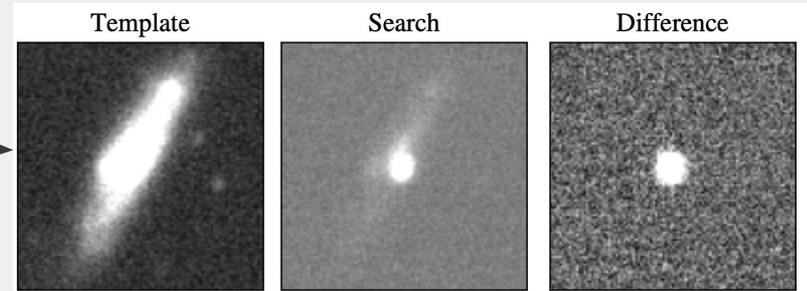


DEBASS Uses the DESSN Pipeline



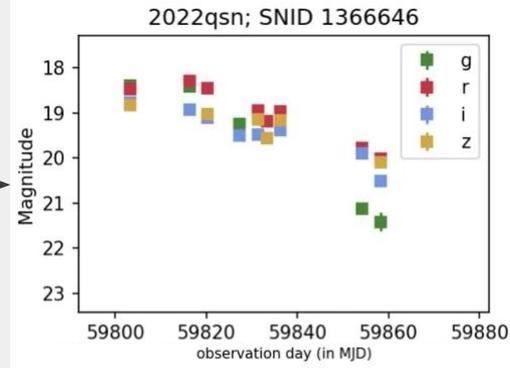
Image Processing

1. Single Epoch Processing: refines and corrects images on the pixel level
2. Difference Imaging: subtracts templates from SE processed images to highlight transients

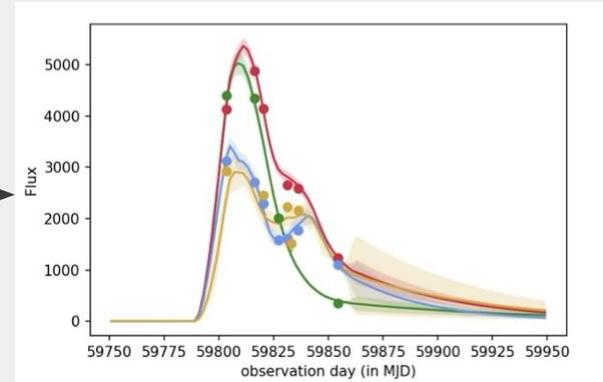


DEBASS Uses the DESSN Pipeline

Once we have our processed images, we run forced photometry on the position of our SN

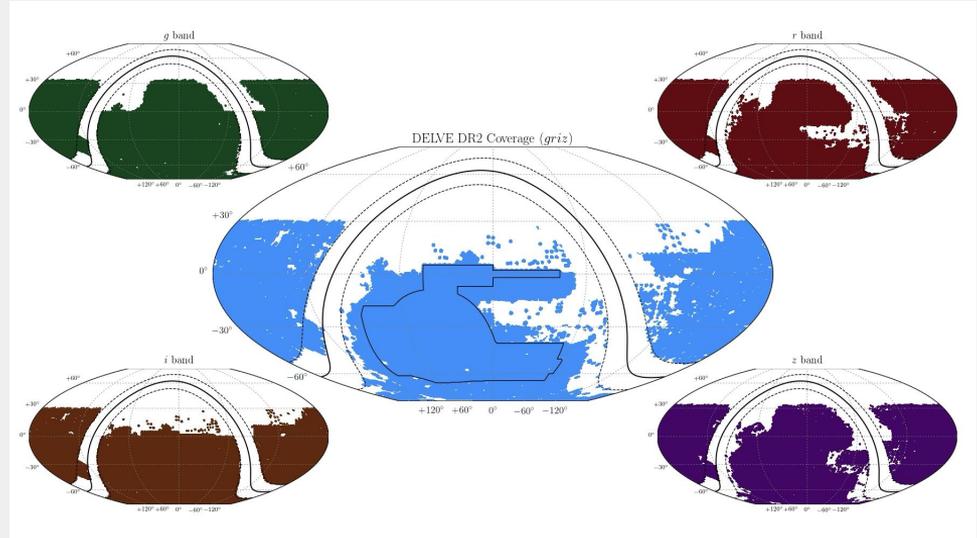


We then fit our data using SuperNova ANALysis (SNANA)



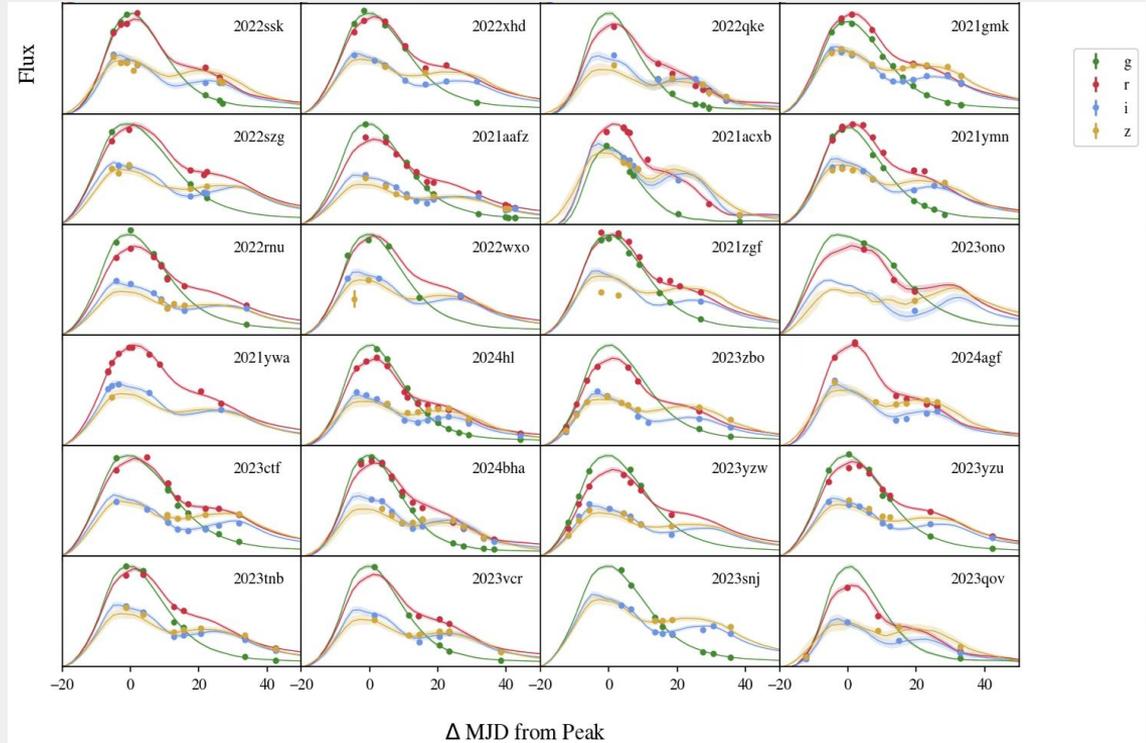
DEBASS: Internal Calibration

- When available, we use DELVE DR2 as our reference catalog
- DECam-based survey
 - Uses DES images and calibration within the DES footprint
- We found the residuals in the nightly magnitude of stars calculated in our pipeline compared to the DES5YR catalog to be ~ 0.001 mag

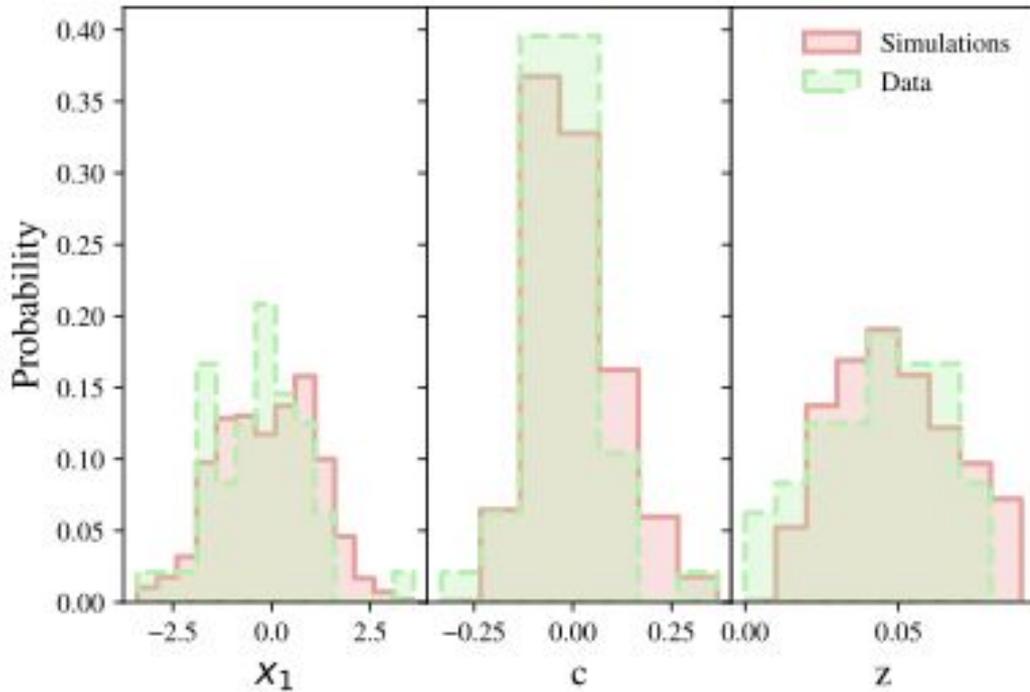


DEBASS >50 High-Quality Light Curves

- Initial release of the SNe within the DES footprint
 - Why? Greater template coverage
- >50 fitted SNe



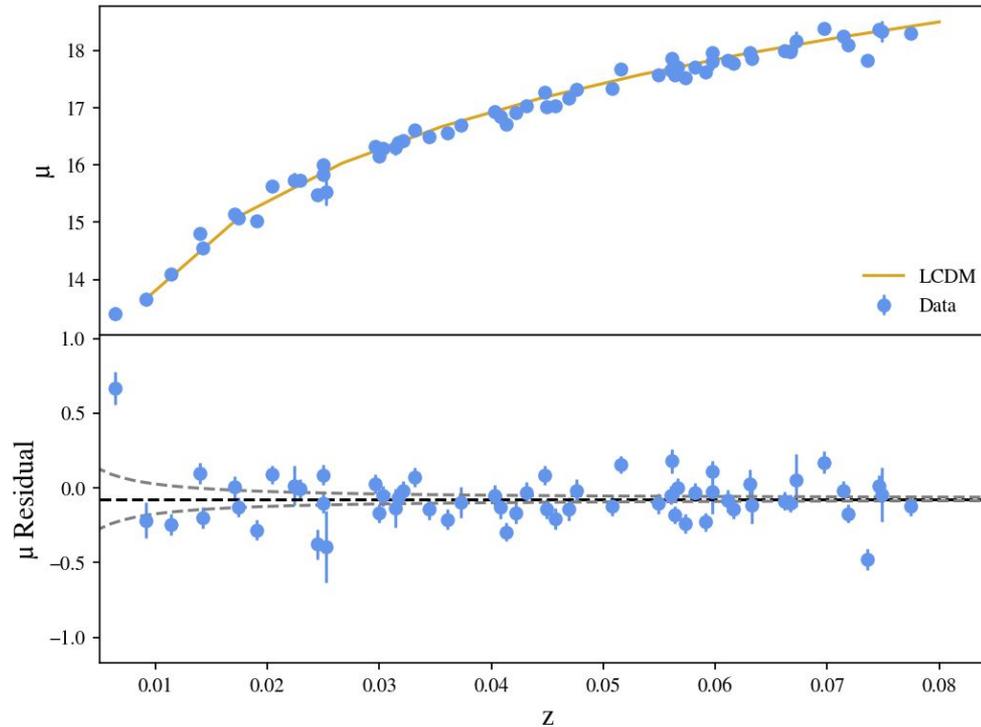
Simulations Quantify Survey Limits



- Forecast the constraining power of the final sample
- Provide a baseline to compare against real data

DEBASS: Initial Sample

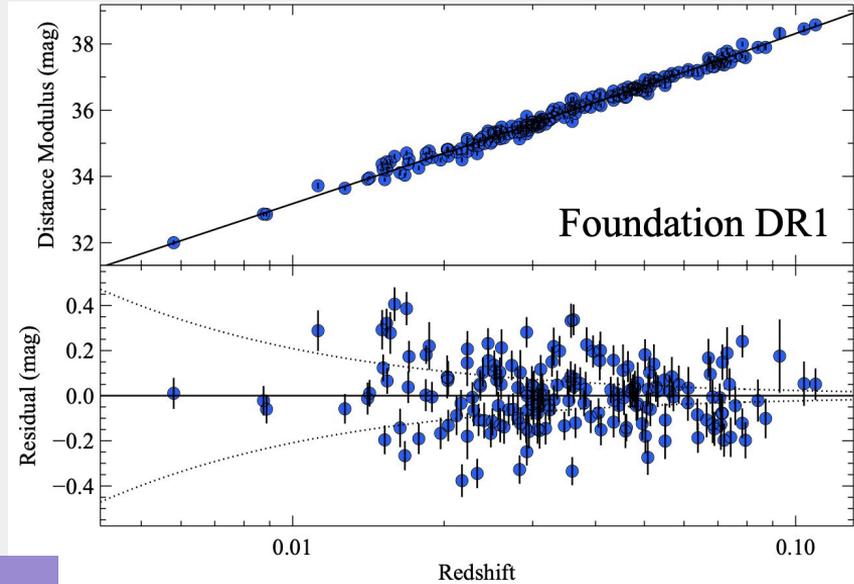
Hubble
scatter of
 ~ 0.1 mag!



An SN Survey on One Telescope is Not a Novel Idea

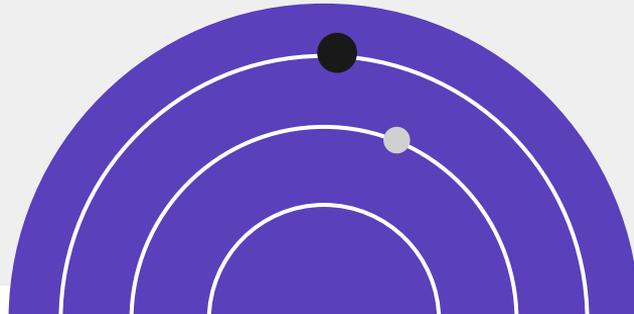
- Foundation is a low- z SNeIa Survey on the the Pan-STARRS1 telescope (Foley et al. 2018)
- Combined with the Pan-STARRS Medium Deep Survey and measured cosmological parameters with 1,338 SNe (Jones et al. 2019)

Hubble
scatter of
0.138 mag!



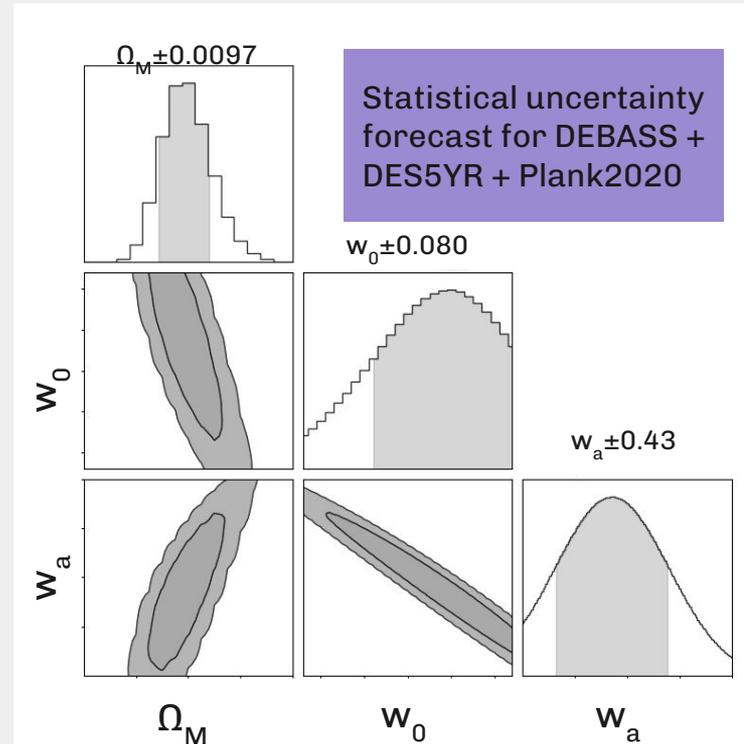
03

Looking Ahead



Over 2000 SNe Ia Combined Sample From A Single Telescope

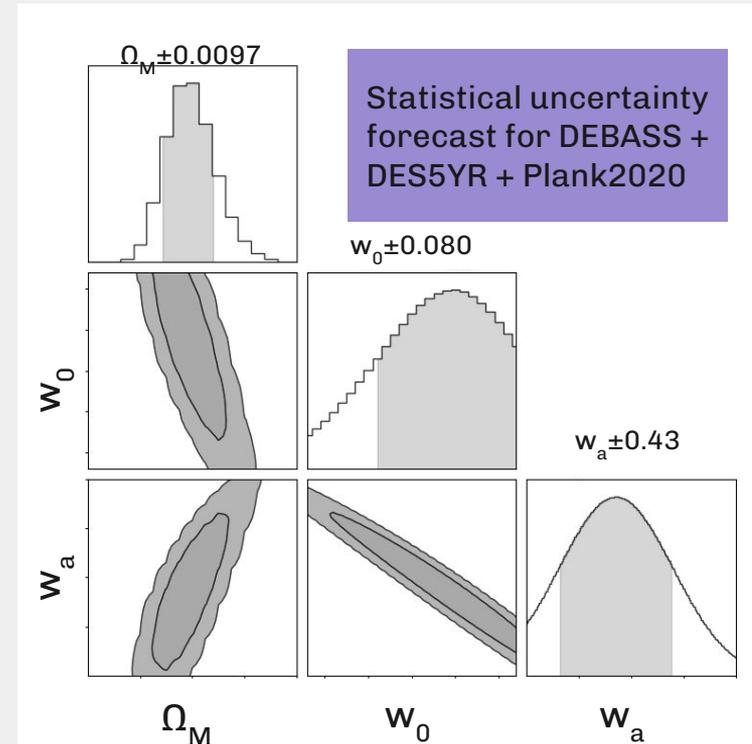
- A conservative estimate of the DEBASS Sample is at least 400 SNe
- Combined with the 1635 SNe from DS5YR



Over 2000 Combined SNe Ia Sample From A Single Telescope

- A conservative estimate of the DEBASS Sample is at least 400 SNe
- Combined with the 1635 SNe from DS5YR

	Ω_m	w_0	w_a
Foundation SN + Plank2016 (Jones et al. 2018)	0.314 ± 0.025	-0.810 ± 0.144	-0.791 ± 0.785
DES5YR + Plank2020 (DES Collaboration 2024)	$0.325^{+0.016}_{-0.012}$	-0.73 ± 0.11	$-1.17^{+0.55}_{-0.62}$



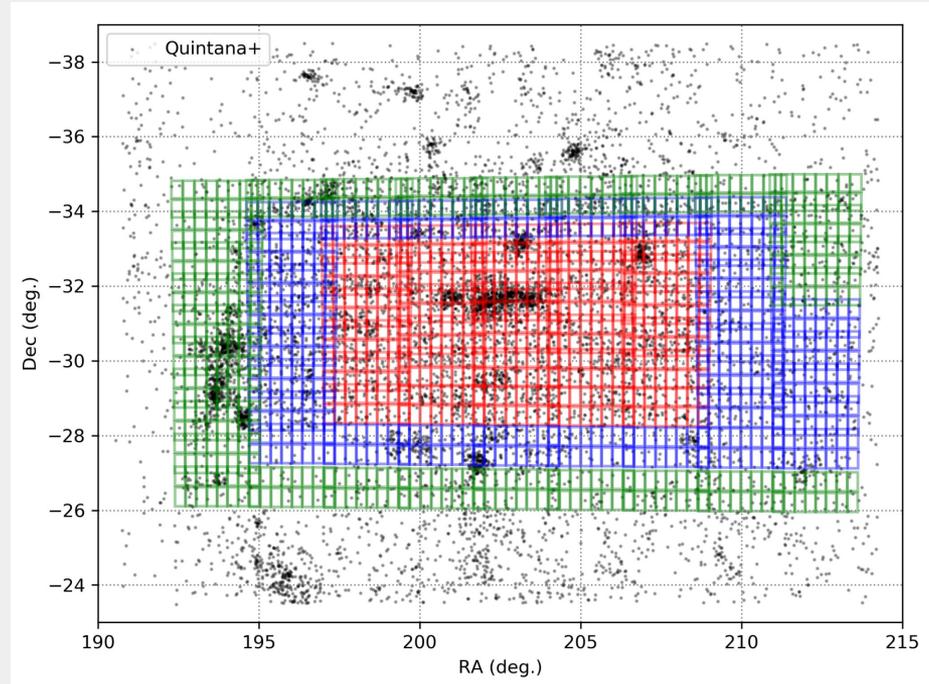
DEBASS will be among the first $f\sigma_8$ constraints with SNeIa data

$f\sigma_8 \propto$ Hubble Scatter

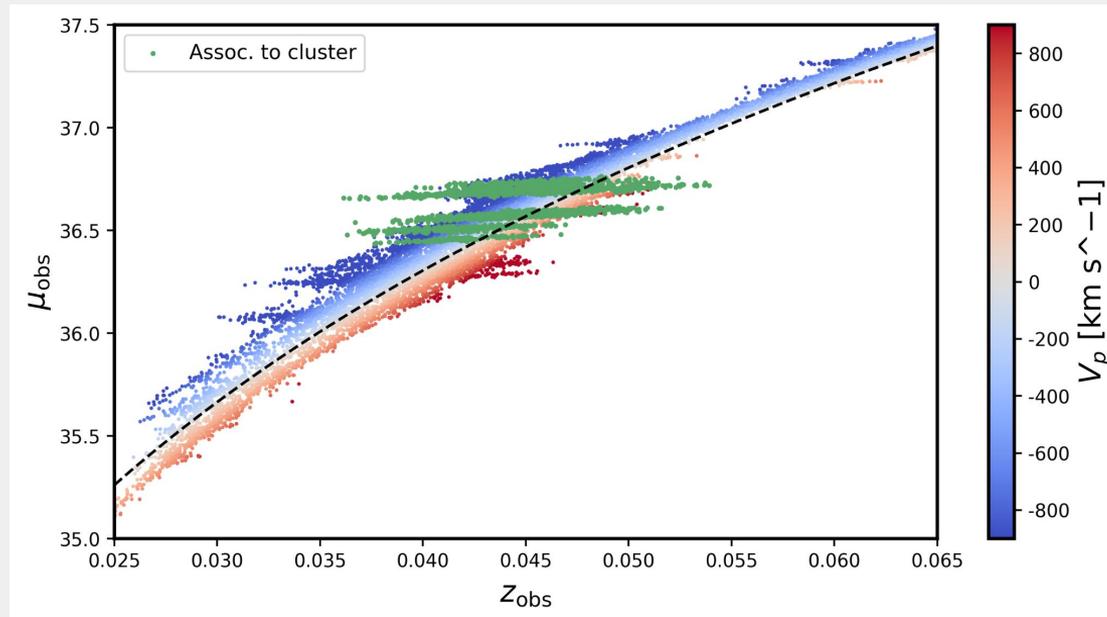
- At low redshift, galaxy motions deviate from pure Hubble flow due to gravitational attraction from large-scale structure.
- The amplitude of this scatter depends on the growth rate of structure $f\sigma_8$
- By modeling the velocity field and measuring SN residual correlations, we can infer $f\sigma_8$

We also want to refine our peculiar velocities

- Targeting SNe in clusters gives us direct tracers of peculiar velocities in massive environments
- I am leading a SNe discovery survey focused on the Shapley Supercluster
 - Weighing Haloes Accurately, Locally, and Efficiently with Supernovae (WHALES)



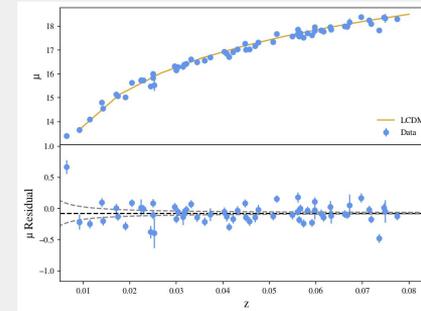
There are interesting signals on Hubble diagram near superclusters



- Simulations built from using a FoF algorithm on the Uchuu galaxy catalog

Conclusion

- SNe Ia are powerful cosmological tools for measuring the expansion history, but current constraints are limited by the low- z anchor sample
- Existing low- z samples are built from many surveys across multiple telescopes, introducing complex calibration systematics
- DEBASS is building a homogeneous low- z SN sample on the DECam system, with consistent calibration and processing, to address this
- WHALES complements DEBASS by probing peculiar velocities in the Shapley supercluster region





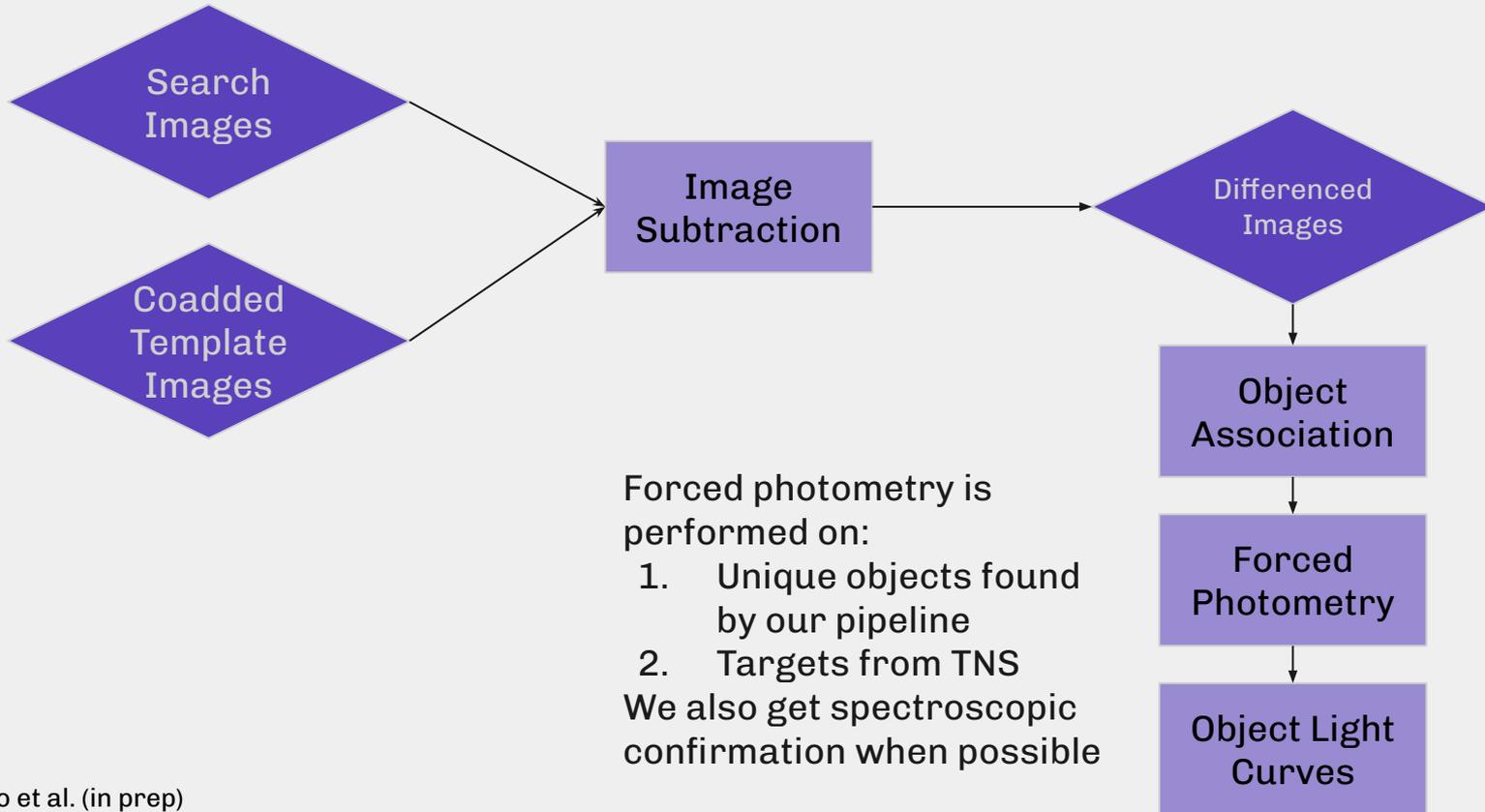
Thanks

Do you have any questions?

`maria.acevedo@duke.edu`



WHALES: Pipeline



WHALES: Initial Sample

Transients Observed (S1/S2)	29 (11/18)
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All probable transients we observed were reported on TNS by other surveys

WHALES: Initial Sample

Transients Observed (S1/S2)	29 (11/18)
Spectroscopically Classified SN	14 (4/10)

10/14 we pulled the trigger on spectroscopic confirmation!

WHALES: Initial Sample

Transients Observed (S1/S2)	29 (11/18)
Spectroscopically Classified SN	14 (4/10)
Spectroscopically Classified SNIa	9 (2/7)
Photometrically Classified SNIa	3 (2/1)

To better constrain our light curves we combine our data with publicly available ATLAS data

