A Photometric Approach to Type Ia SN Science

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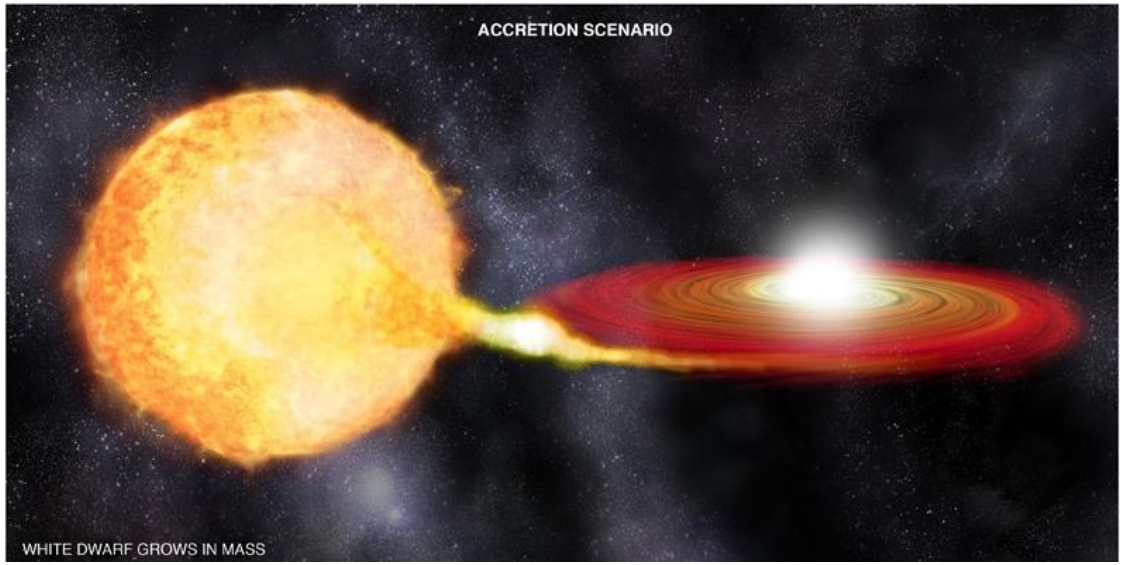
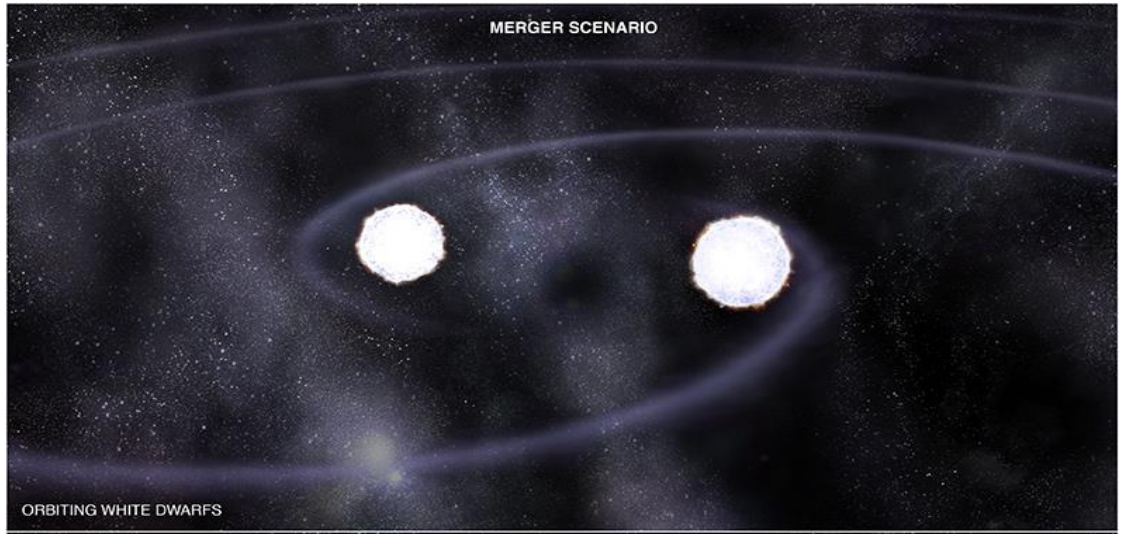
Type Ia Supernova (SN Ia)

- Thermonuclear explosions of a carbon-oxygen white dwarf and a companion star
- Progenitors poorly understood
- Light curve powered by the radioactive decay of ^{56}Ni





NASA/CXC/M.Weiss

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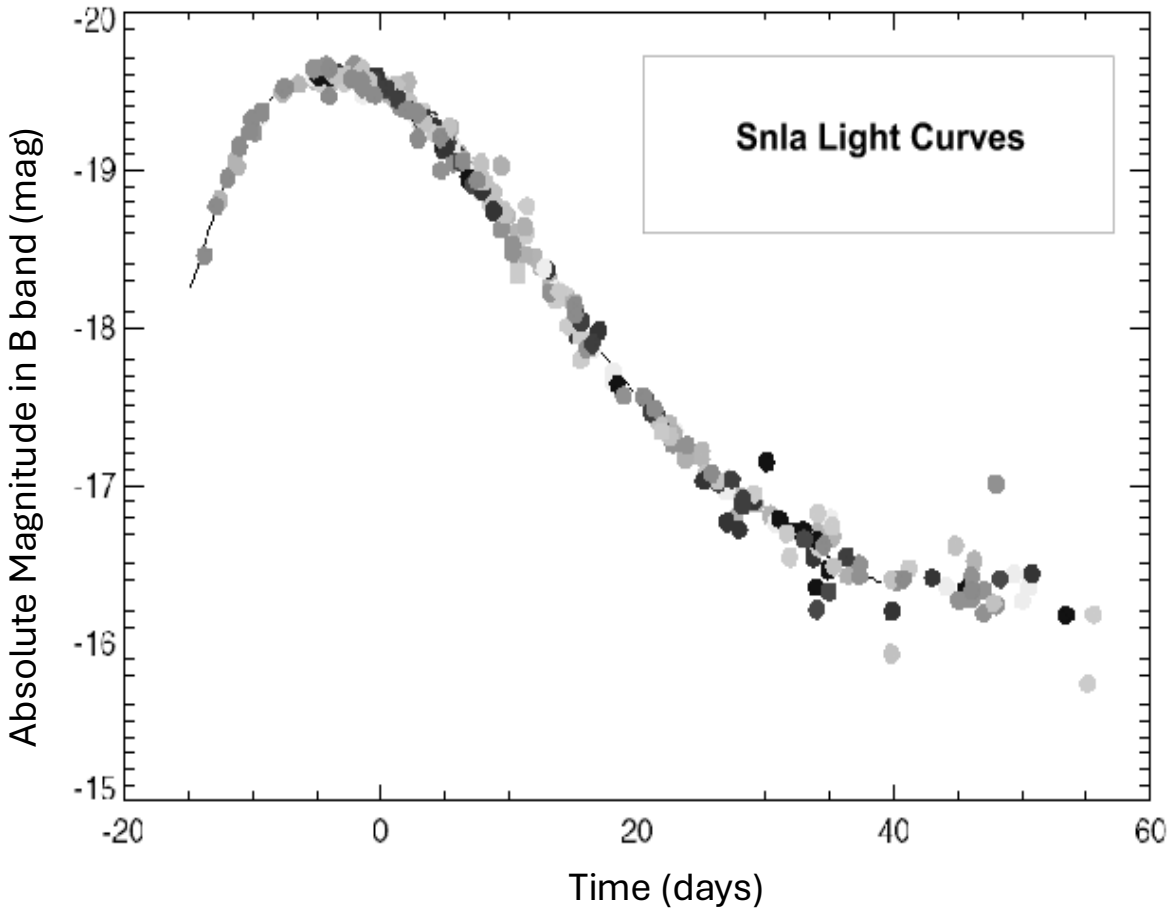
Adapted from Leibundgut (2000)



C/O fusion → nucleosynthesis → ^{56}Ni → ^{56}Co → ^{56}Fe

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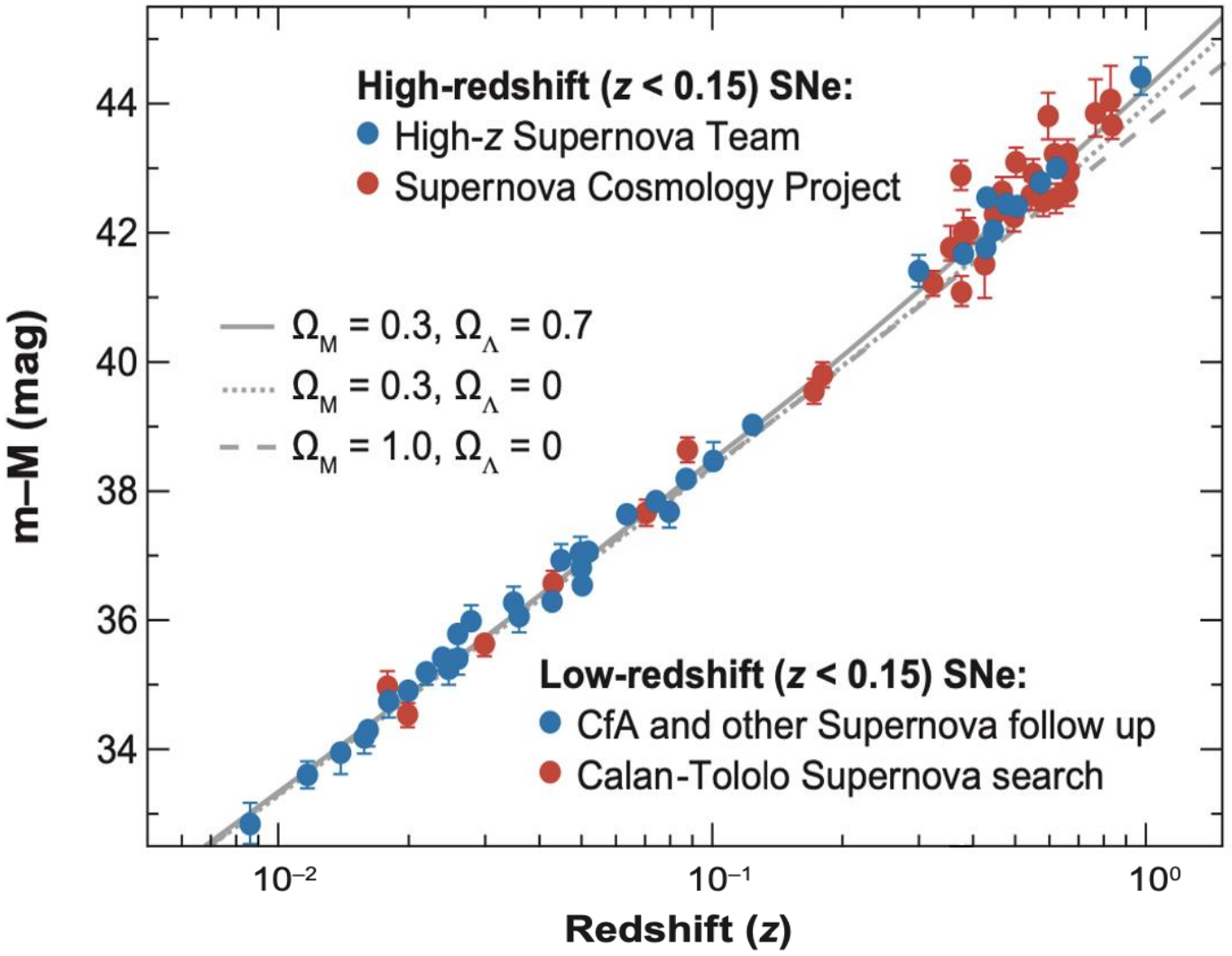
Importance of SNe Ia

- **Astrophysics**:
  1. galaxy chemical evolution
  2. galaxy feedback
  3. stellar evolution
- **Cosmology**:
  1. standardizable candles
  2. measure cosmic distances
  3. constrain dark energy



Adapted from Frieman (2008); based on Riess (1998), Perlmutter (1999)

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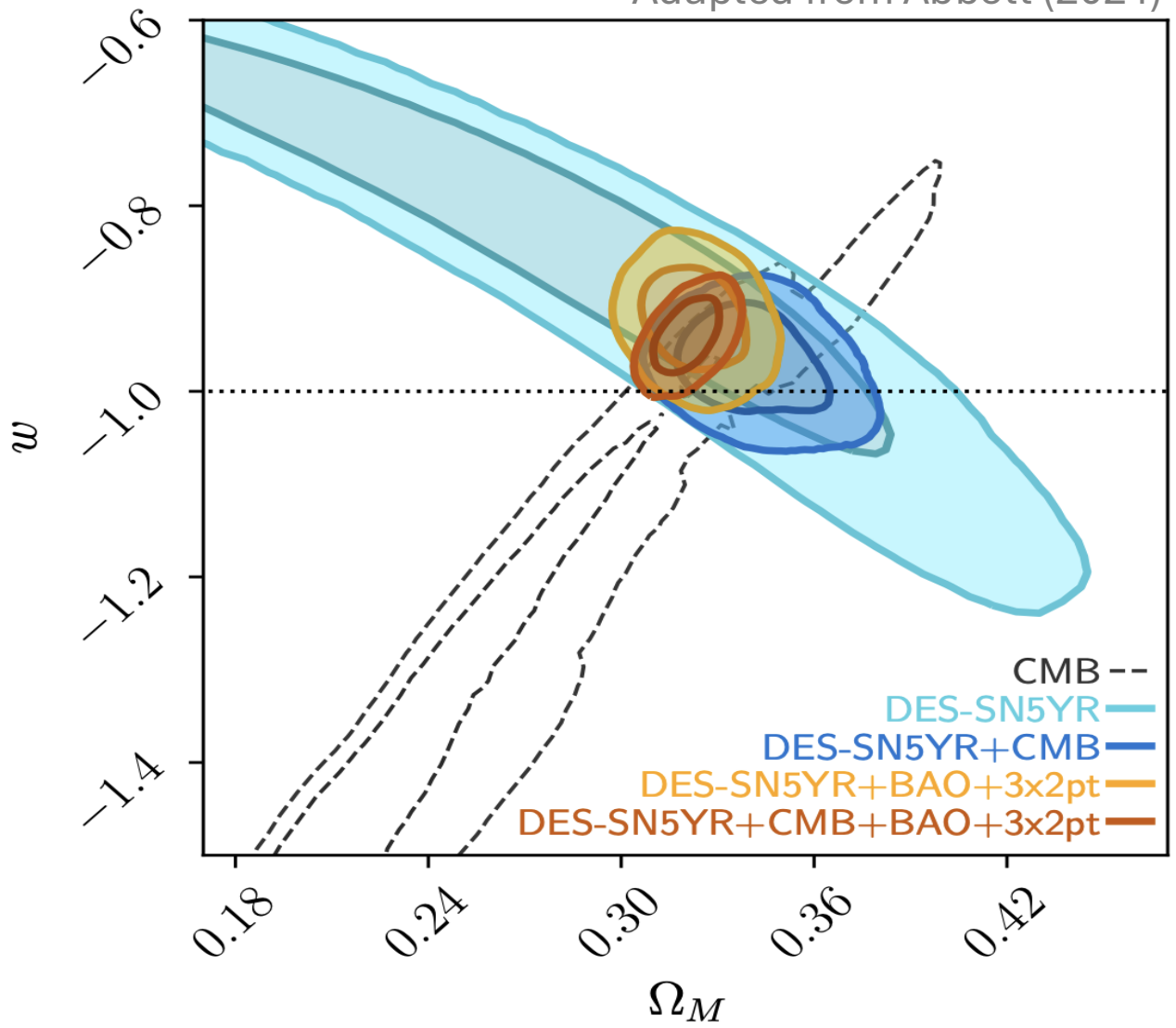
Dark Energy Survey Results (DES)

- DES observed ~3,500 SN Ia
- Largest sample of high-z SNe to date
- Results based only on ~1,500 SNe Ia with a host galaxy spectroscopic redshift

Adapted from Abbott (2024)



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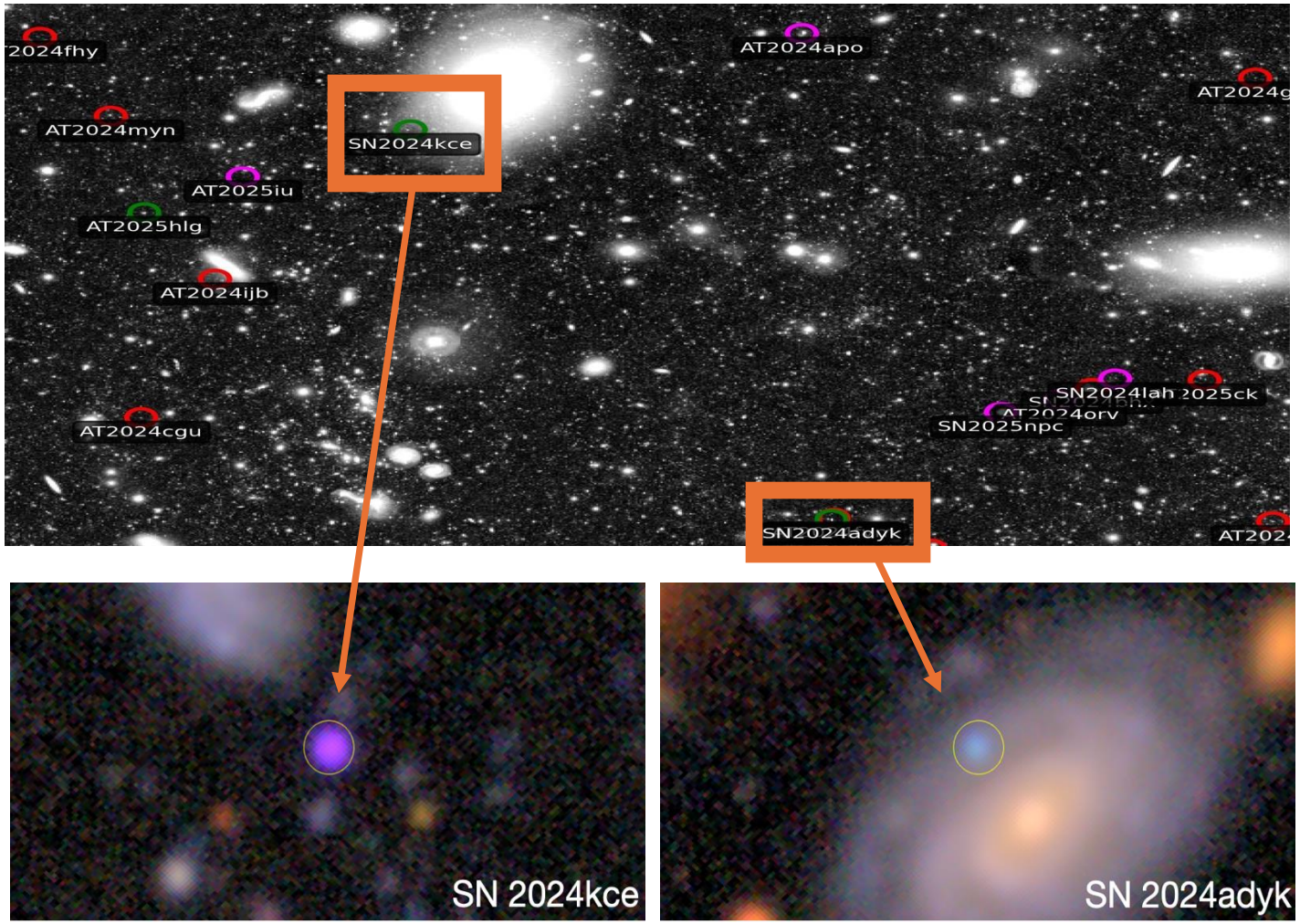
The Legacy Survey of Space and Time (Rubin - LSST)

- Set to observe millions of SNe Ia
- Spectroscopic follow up for only a small fraction of them
- To construct larger, more complete and less biased catalogues we need photometry



Lee (2025), RubinObs/NOIRLab/SLAC/NSF/DOE/AURA

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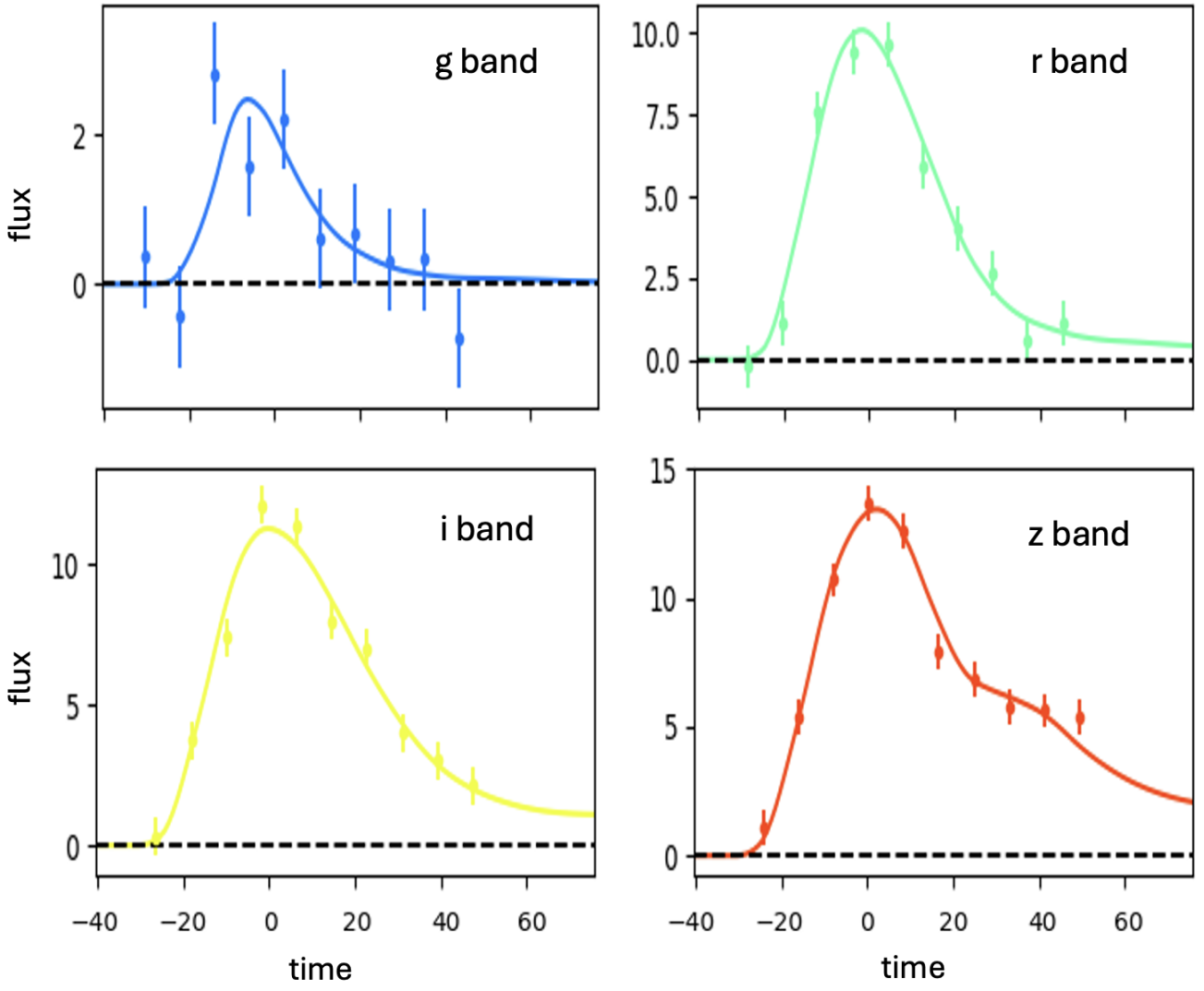
Photometric Redshift Estimation

- DES5YR-SN sample, classified without host galaxy spectroscopic redshifts (Möller 2024)
- We fit templates on the light curves and vary the redshift z
- Retain the photo-z estimate based on flexible selection criteria and the reduced χ^2

Parameters: redshift (z), amplitude (x_0), stretch (x_1), colour (c), time of peak (t_0)



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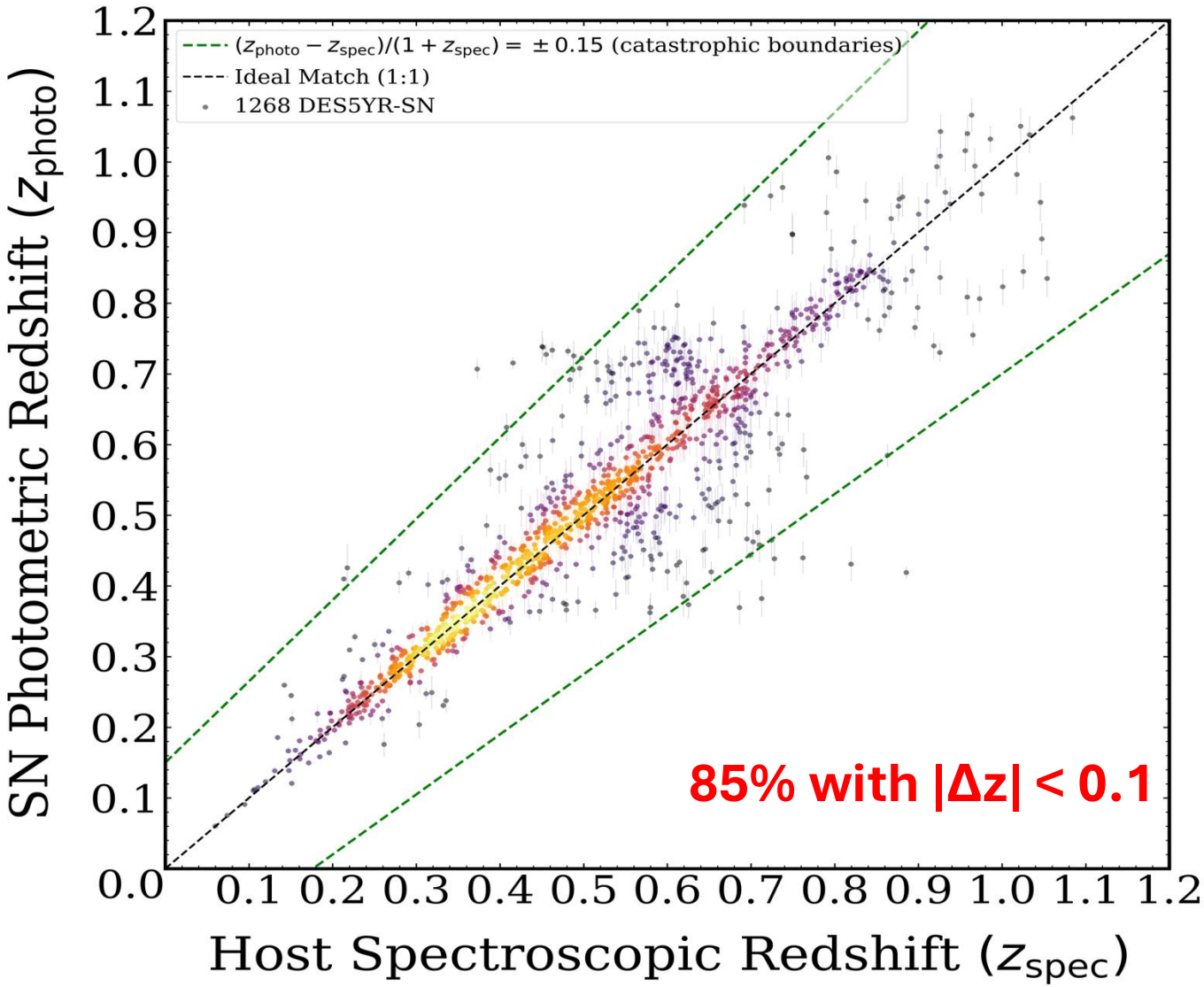
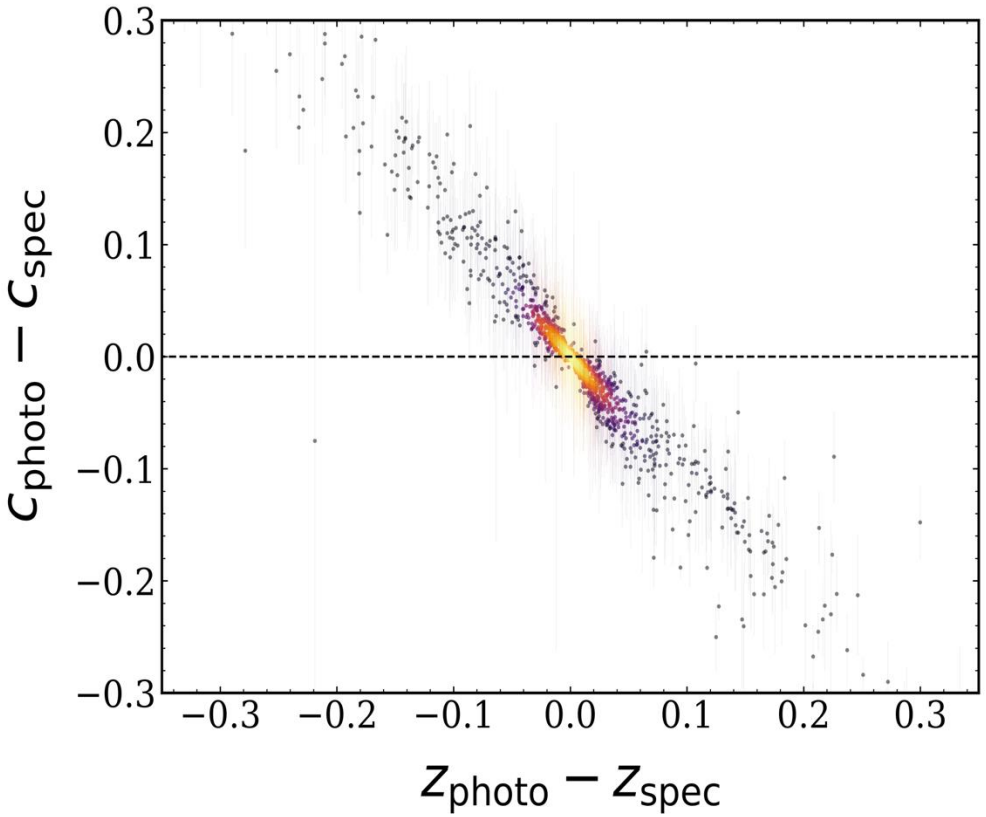
Photometric Redshift Estimation

20 catastrophic outliers (1.6%), bias=-0.003, σ_{NMAD} = 0.022





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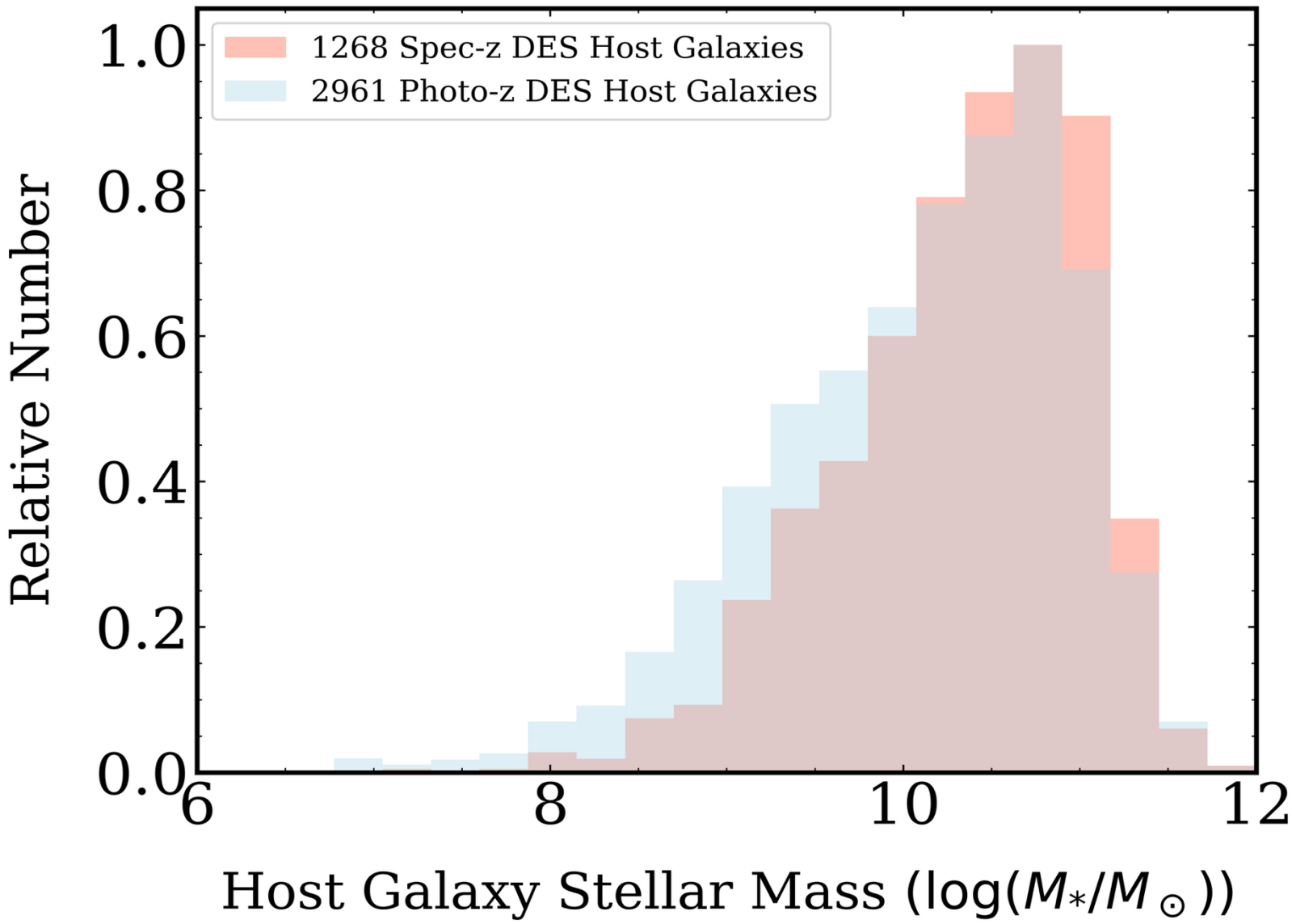
Host Galaxy Demographics

- Doubled the size of the DES spec-z sample
- Photo-z sample more complete in the low mass end
- Caveat: hostless SNe Ia not included



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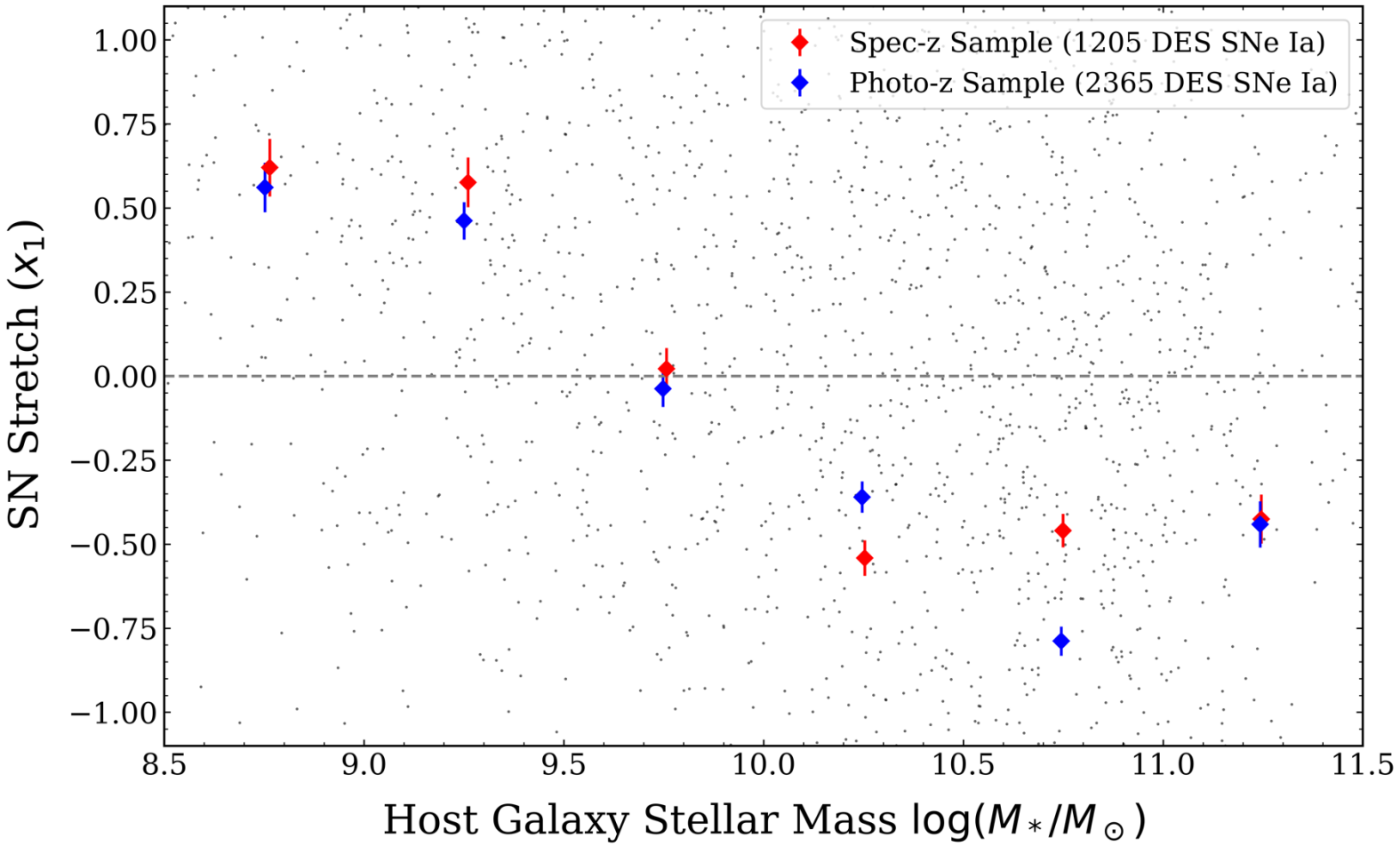
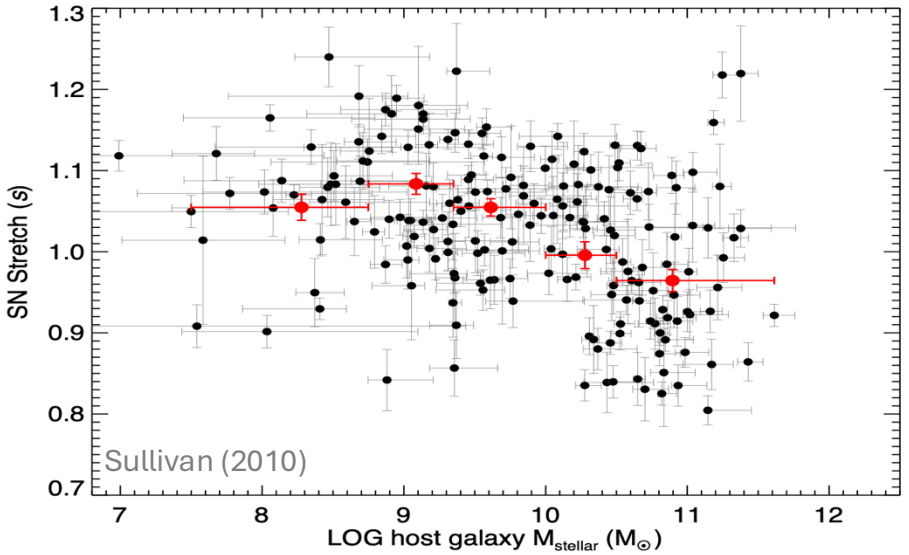
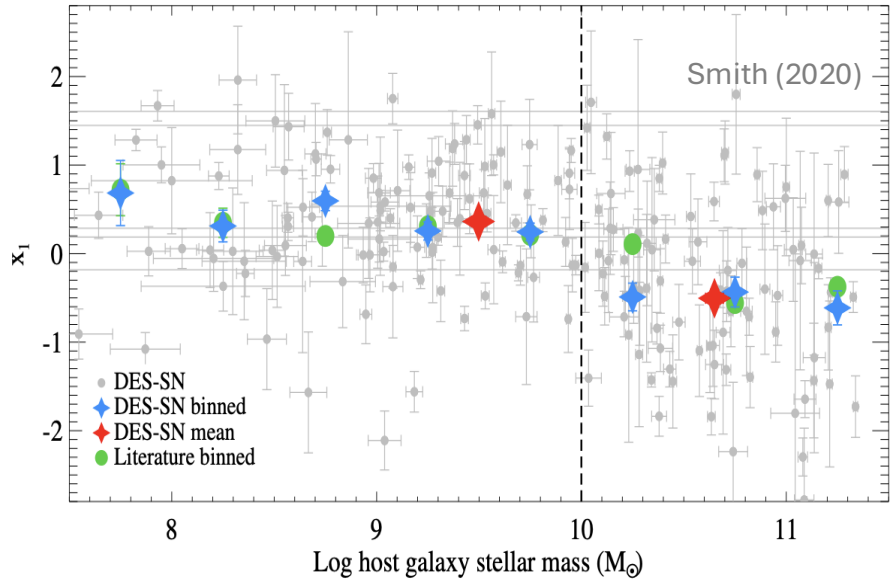
SN Parameters – Stretch x_1







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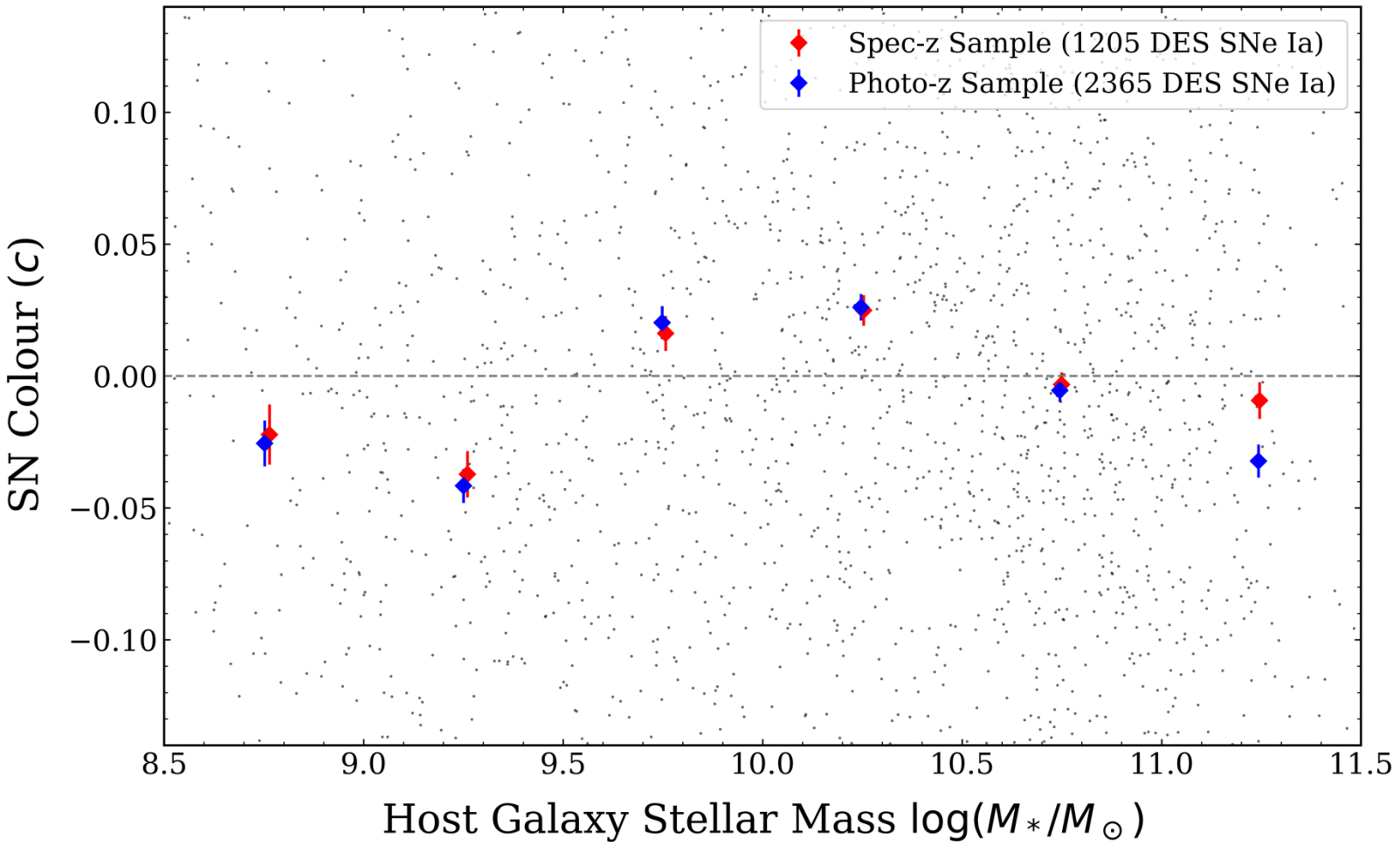
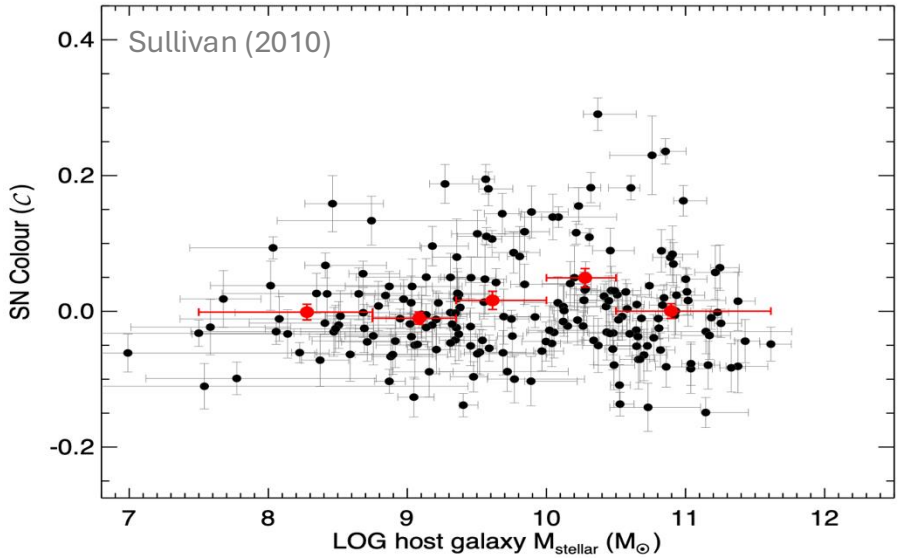
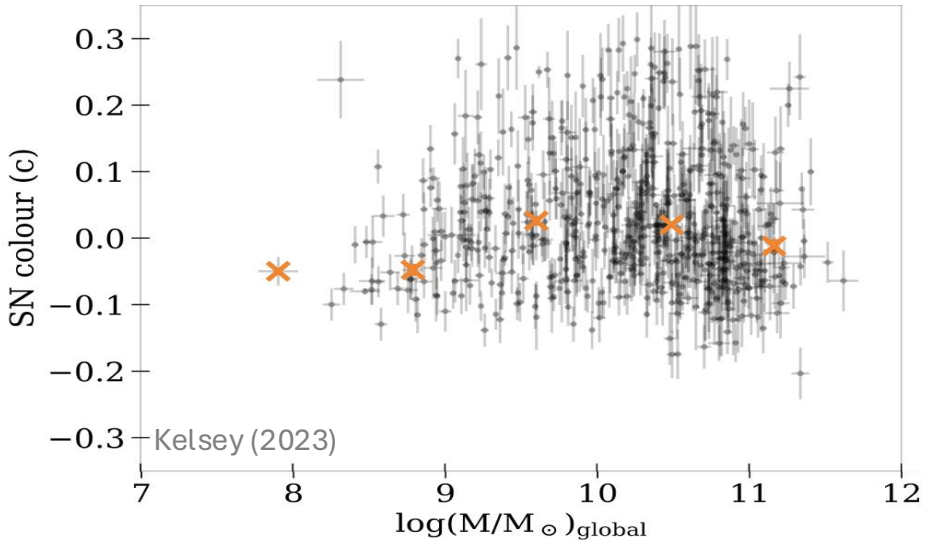
SN Parameters – Colour c







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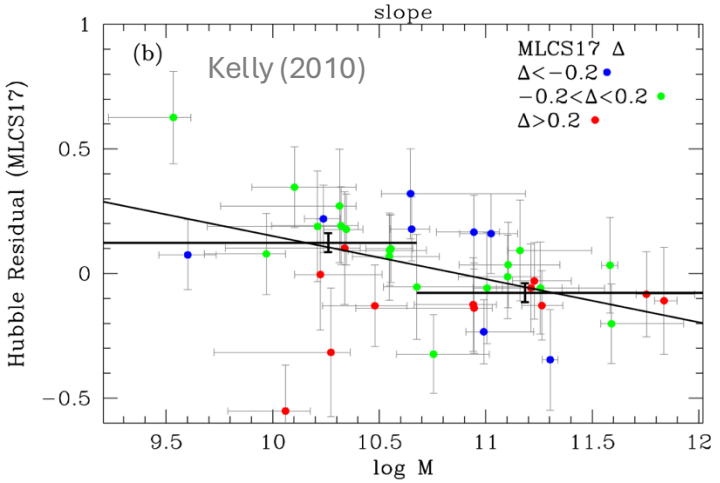
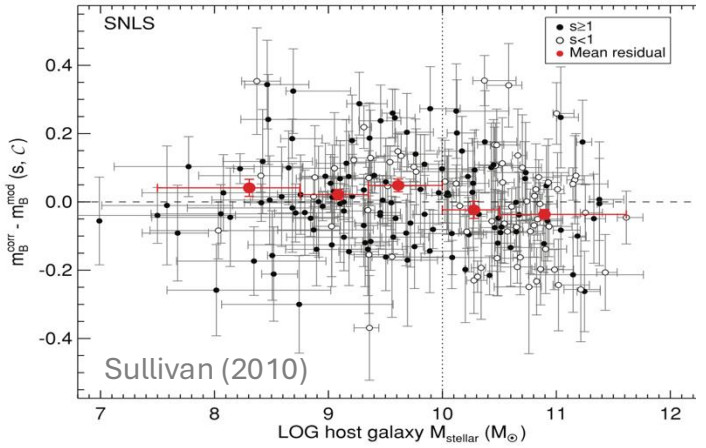
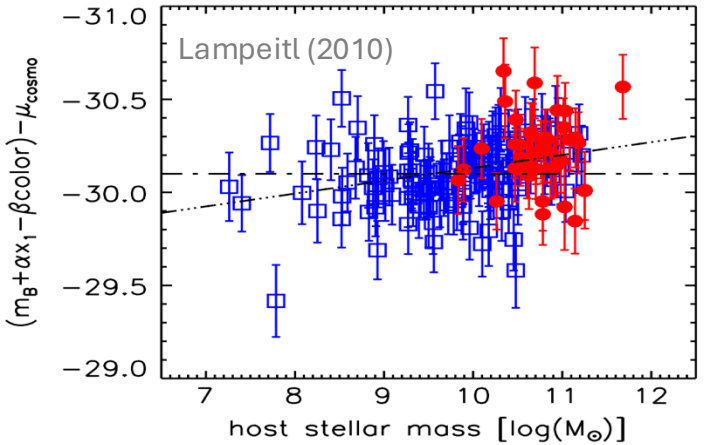
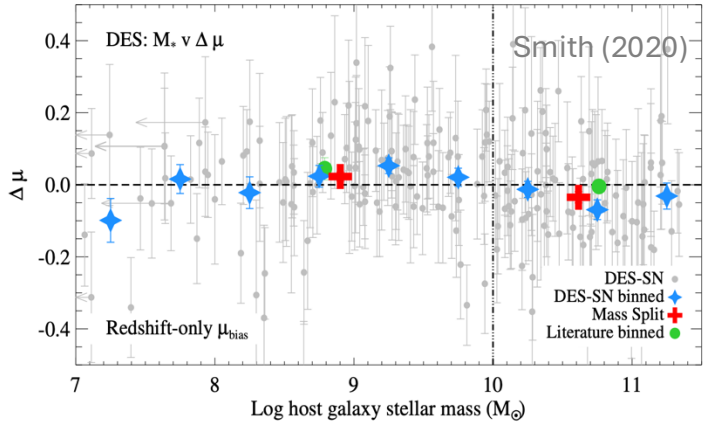
The Mass-Step

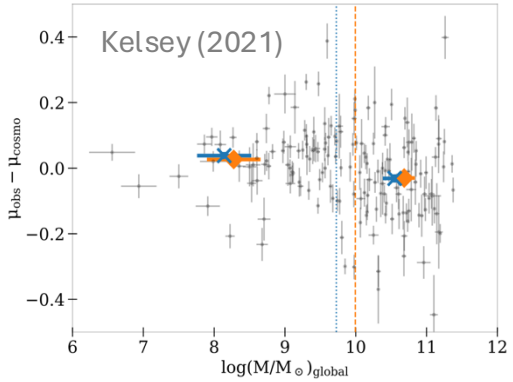
- SNe Ia detected in lower mass galaxies appear fainter, and vice versa
- Affects the cosmological distances
- Results in a residual step-like dependency of order of 0.05-0.15mag

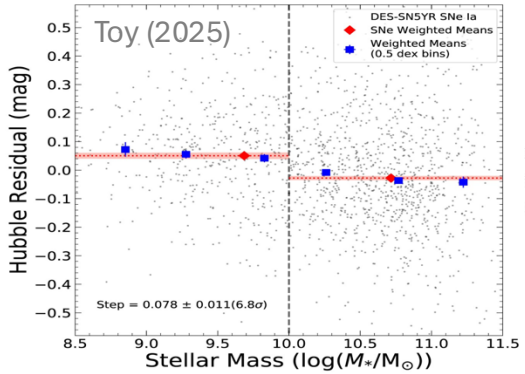


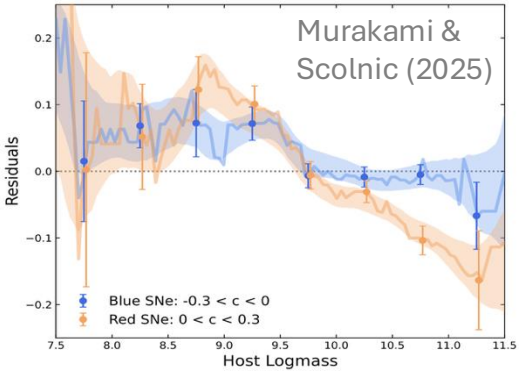












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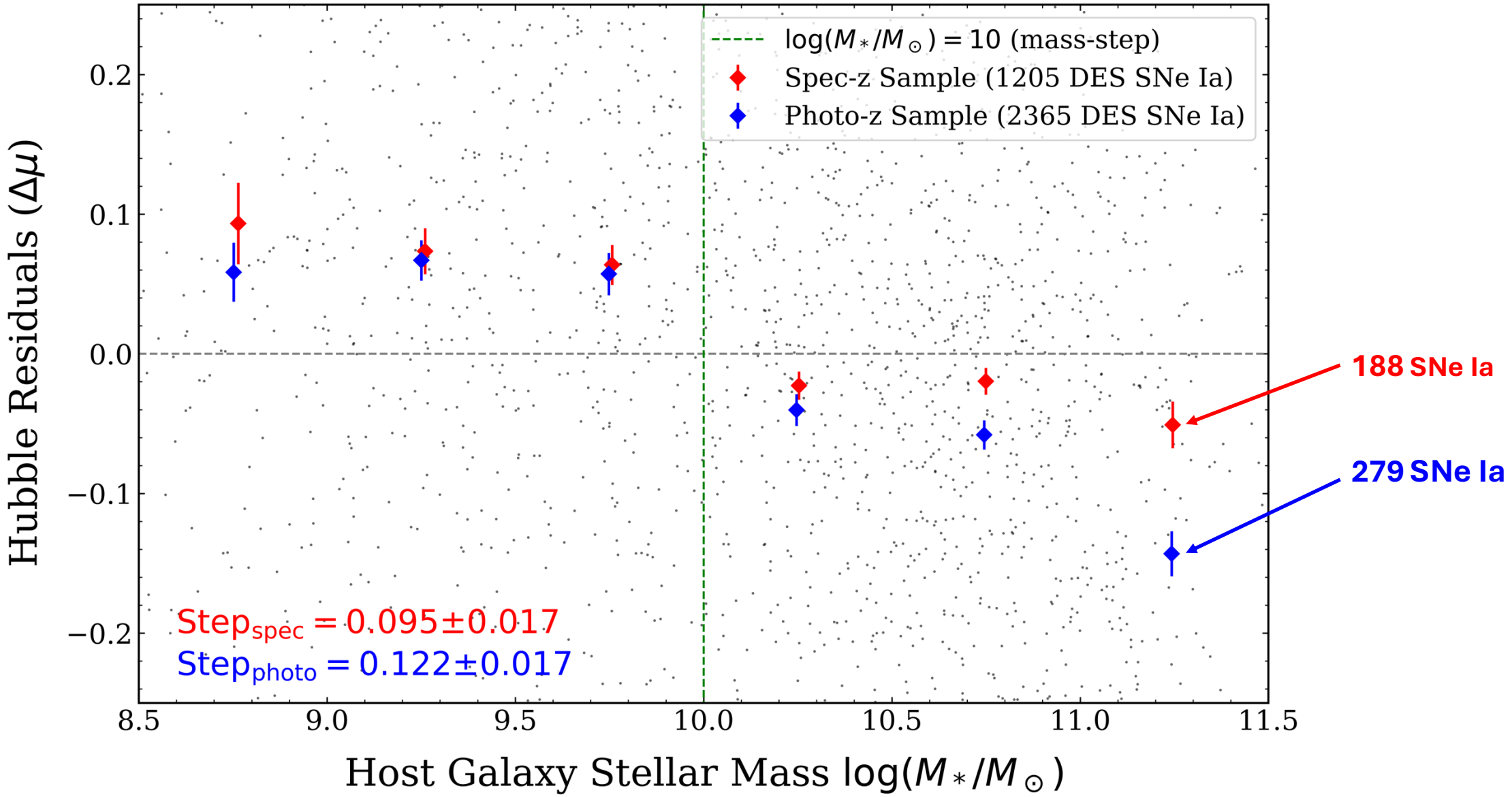
The Mass-Step



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Summary and Future Work

Summary:

- Known trends are not a result of biases from spectroscopic surveys
- Photometric samples can reproduce the results of spectroscopic samples
- Solely photometric catalogues are larger, more complete and less biased

Future Work:

- Incorporate the hostless SN Ia to our analysis
- Account for efficiencies and the incompleteness of sample
- Investigate the implications for progenitors
- Investigate the cosmological implications

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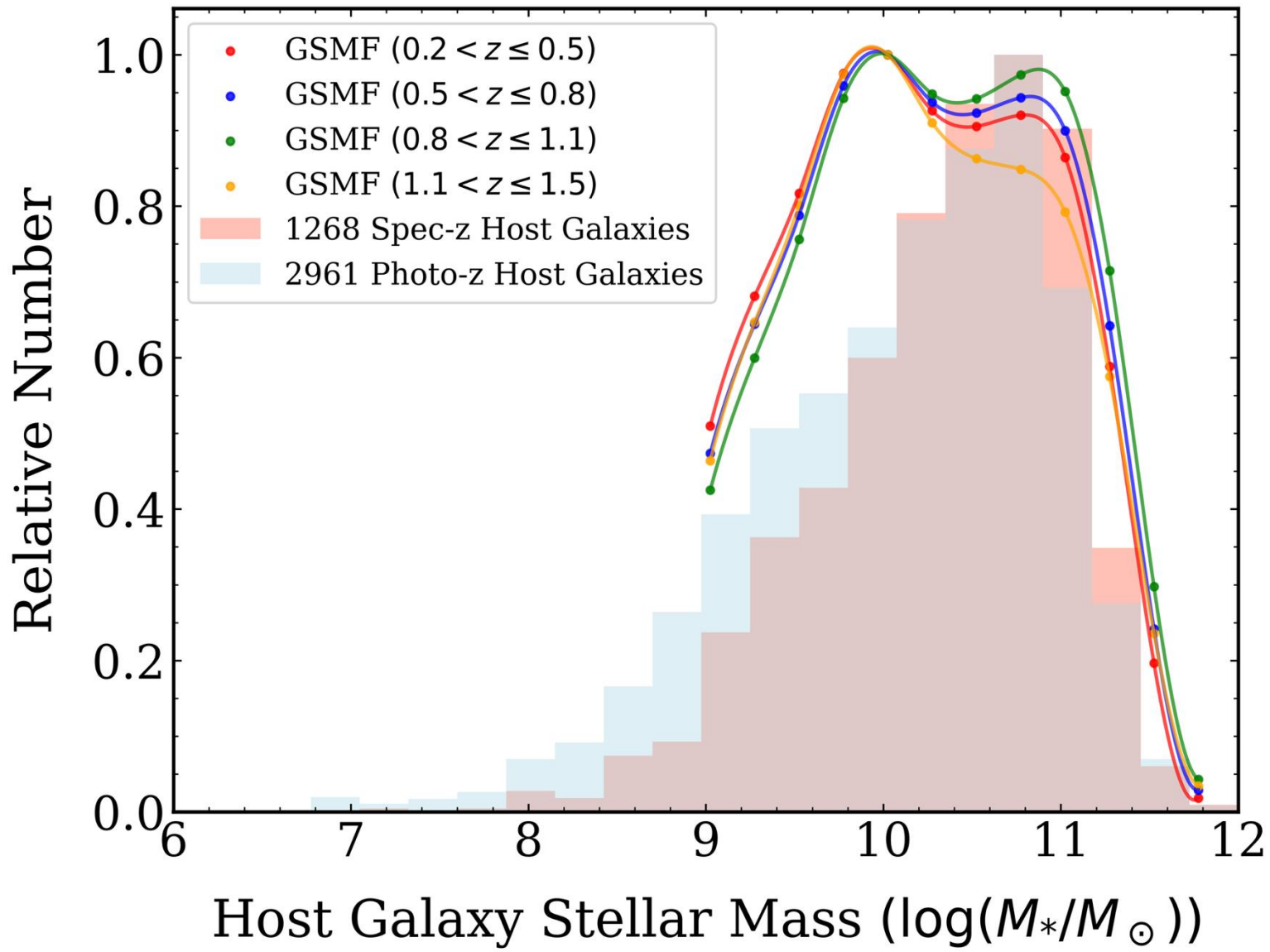
Extra



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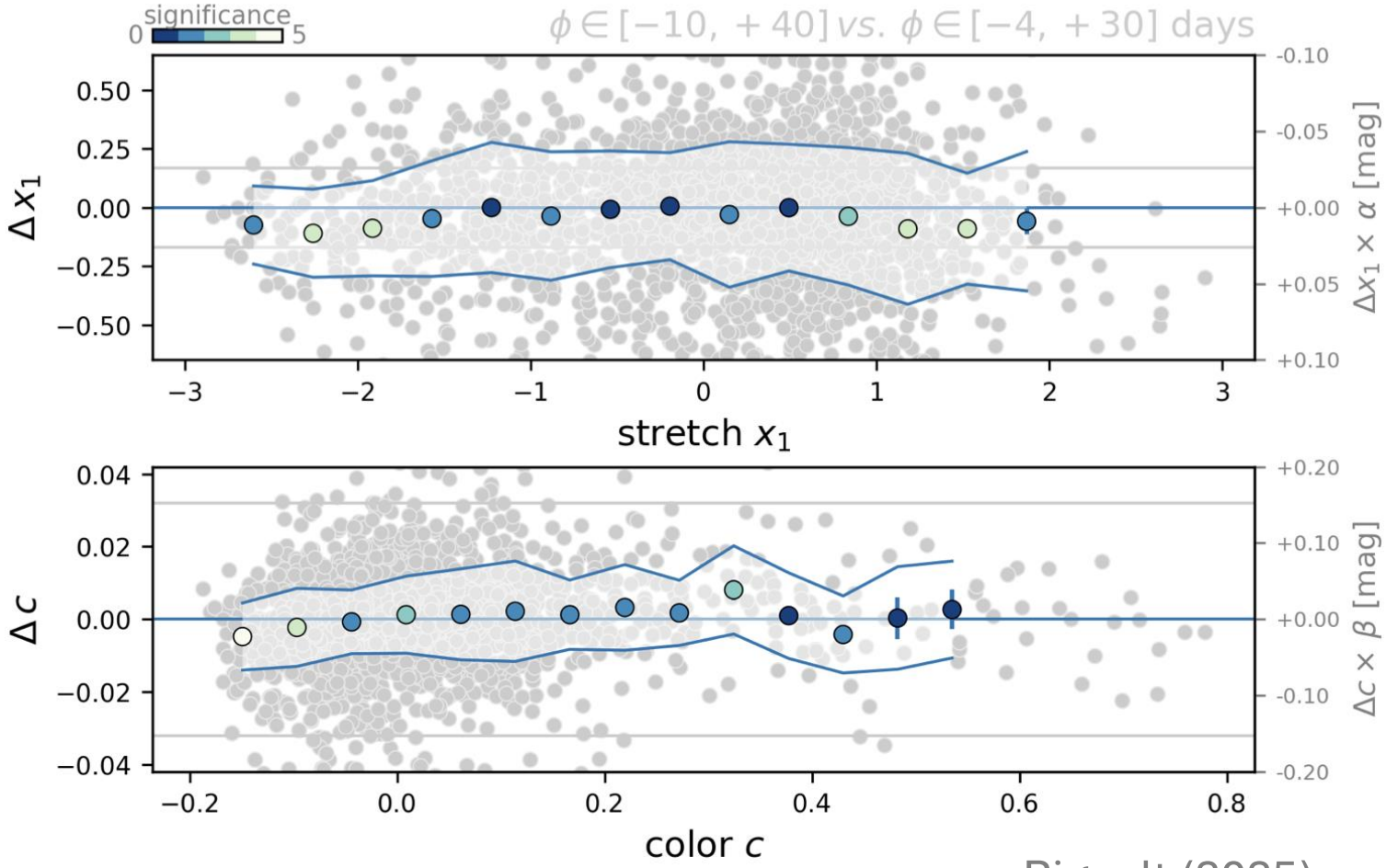
Extra

Selection Criteria:

- $|x_1| \leq 3.5$
- $-0.2 \leq c \leq 0.5$
- $\left|m_B^{fit} - m_B^{cosmo}\right| \leq 1\, mag$



Rigault (2025)

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