Roman, Euclid, JWST, Rubin: Synergistic Opportunities for Type Ia Supernova Cosmology

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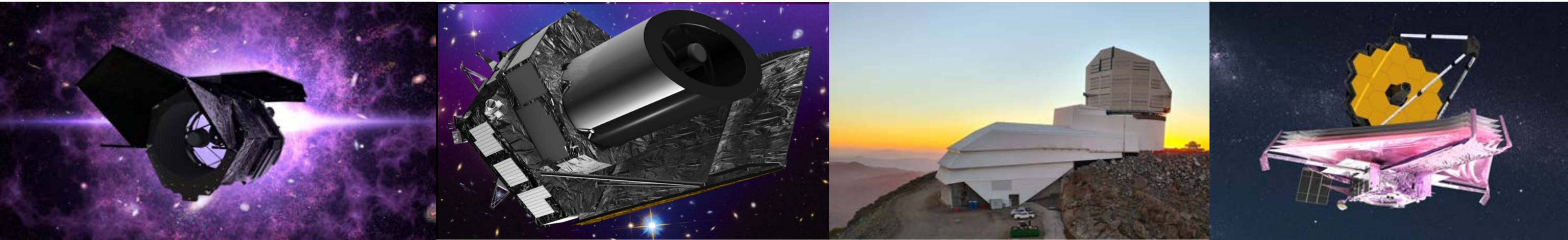
Roman Supernova Ia Cosmology, 2021 Nov 18

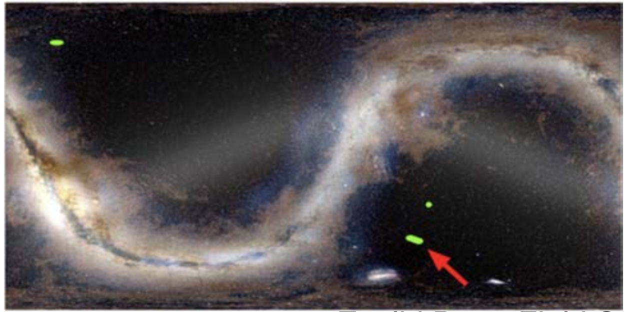


(ESA)

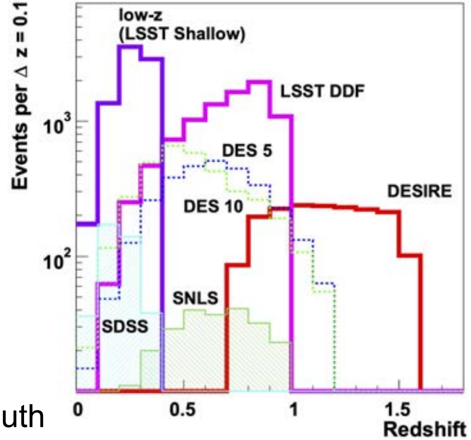
Euclid: 2023-2030

SNeIa to z~1.5

1.2-m mirror
VIS (0.55-0.90 μm)
NIR (Y, J, H: ~0.9-2 μm)
0.5 sq. deg FoV



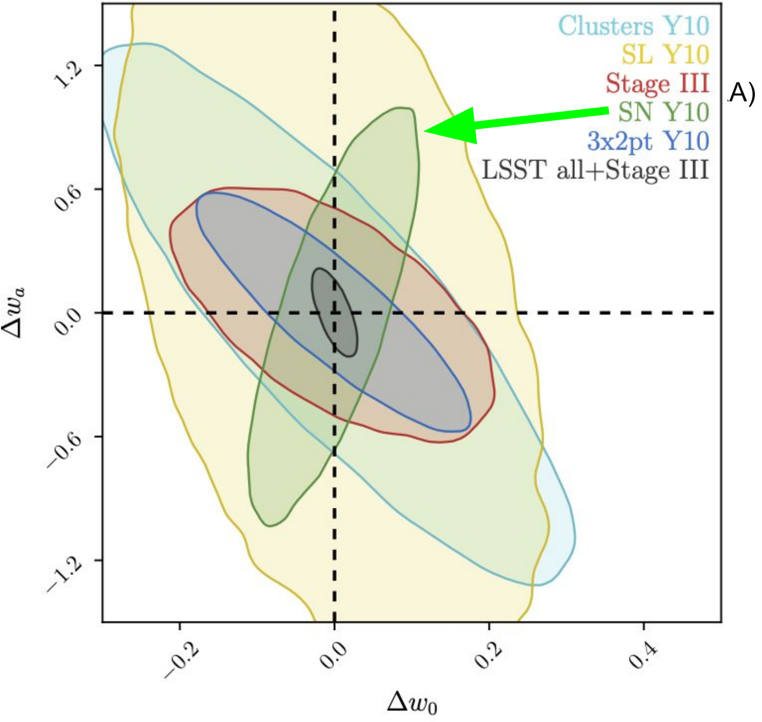
Euclid Deep Field South



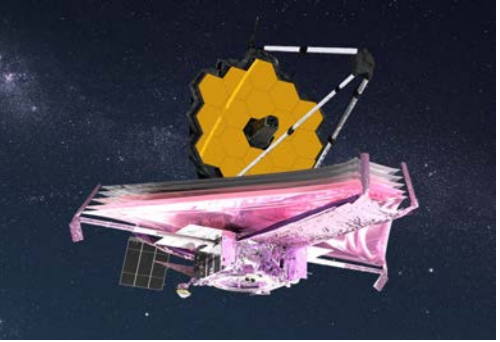
- Launch in 2023 Q3 for a 6.25-year primary mission for Dark Energy, Dark Matter
  - Weak Lensing (0<z<2), Galaxy Clustering (BAO, RSD; 0.7<z<1.8), Clusters, Sachs-Wolf
- SN Ia survey could be last 6 months of mission ~2030.
- “Dark Energy Supernova InfraRed Experiment” (Astier+2014, A&A, 572, 80)
- Euclid Deep Fields: 40 sq. ~around Ecliptic “poles”. 26 mag 5 sigma depth.
- SN Survey: 20 sq. degree in one of the poles. 4-day cadence.
- 1.5-hour integrations => Y, J, H (25.5, 26, 26) mag.
- Needs ground-based observer i- and z-band photometry: Possibilities:
  Rubin (6.5m, S) LSSTCam, Blanco (4m, S) DECam, Subaru (8m, N) HSC
- Visible to the Vera Rubin Observatory means Euclid Deep Field South
- LSST Deep Field: 5-sigma~ (g, r, i, z, y) = (26.5, 26.5, 26, 25.5, 24.5) mag

Vera Rubin Observatory
LSST: 2024-2034
SNeIa: $0.1 < z < 1$

- 100,000 SNeIa from $0.1 < z < 1.0$
  - ~10,000 from dedicated deep fields
- By $z\sim1$, most SNIa light will shift out of optical.
  - But see the great work from HSC SSC (Yasuda+) with SNeIa out to $z\sim1.2$.
- Coordinated observations improve photometry for Roman and LSST from $0.6<z<1.5$.
  - Get complete restframe g, r, i, z, y, J, H to $z\sim0.7$
- Discover ~1000 of $z < 0.1$ / year for follow-up on other facilities.
  - Low-z anchor remains key.
- 1% calibration goal across the sky.
- Will also have cluster mass maps for potential of a few strongly lensed SNeIa in field.

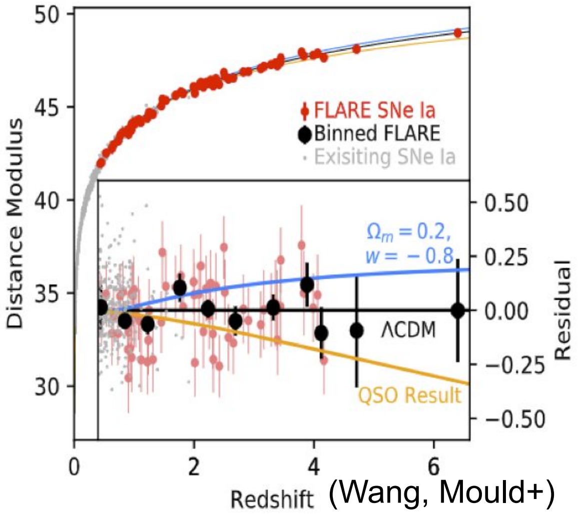


LSST DESC Predicted 10-yr Constraints
https://arxiv.org/pdf/1809.01669.pdf



(NASA GSFC/CIL/Adriana Manrique Gutierrez)

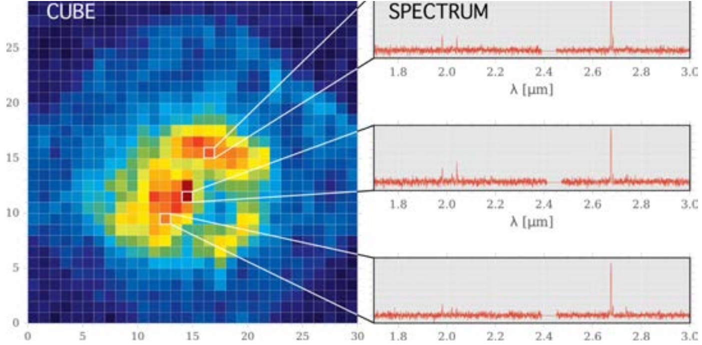
JWST: 2021-2026 (2031)
SNeIa to z~5, NIR to z~3
Host studies,
SN Ia evolution



(Wang, Mould+)

- Deep JWST dedicated NIRCam time-domain survey
  - 50-100 SNeIa out to z~5 (AB ~27 mag, 2-3 μm, 0.05 sq. deg).
  - Compare to Lyman alpha forest probes from quasars z>2.
  - L. Wang, J. Mould, et al.: https://arxiv.org/abs/1710.07005
    "A First Transients Survey with JWST: the FLARE project"
  - Could do restframe NIR SN Ia Hubble diagram to z~3.
- NIRSpec: Spatially resolved spectra of SNIa hosts out to z=2.
  - Complement with ground-based IFU. CALIFA, MaNGA, AMUSING
  - Are we getting resolved spectroscopy at z~0.5--1? VLT?
- 100 SN Ia spectra at z>1.5 will measure if SNeIa radically evolve, particularly at z~3-5 which may be the first SNeIa.
- Strongly Lensed SNeIa in Roman fields need JWST.

https://jwst-docs.stsci.edu

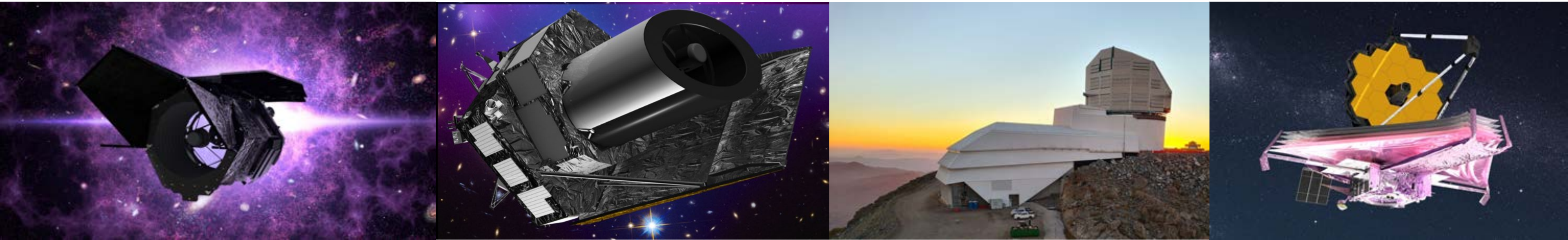


Roman SNIa Cosmology Needs Some Complement Can Benefit from Lots More

- The low-redshift reference requires much larger area to capture the volume to get enough SNeIa. Things like Foundation and Young Supernova Experiment, to more NIR-targeted efforts such HST RAISINS, CSP-I/II, SweetSpot, SNFactory.
- Low-z SNe found by LSST, followed by other resources.
- Opportunity to do a rest-frame NIR out to z=0.7. Powerful independent check, particularly of dust systematics and residual lightcurve systematics such as host galaxy mass|SFR correlations with Hubble residuals.
- Contemporaneous observations of SNeIa observed with Rubin/LSST.
- Targeted follow-up with JWST of sample to investigate and validate high-redshift SNIa spectroscopic properties. Can’t be comprehensive, but 100 SN Ia spectra would be very informative. Particularly as Roman pushes to z~1.7 where different progenitor channels may dominate.

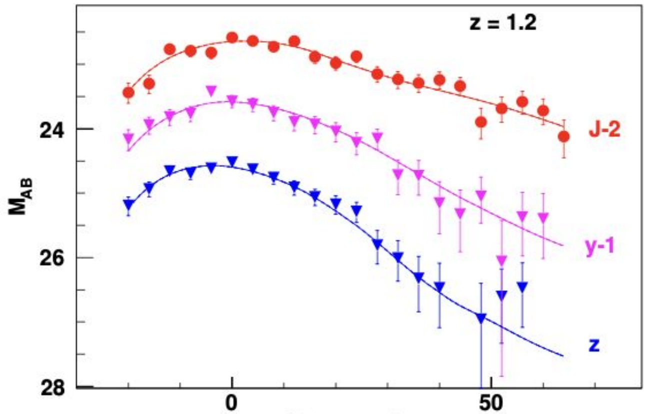
Roman and Friends Make a Strong Team

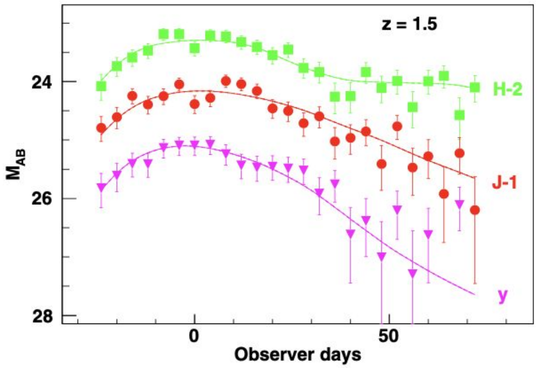
- Roman will make substantial SN Ia Cosmology measurements with ~5,000-10,000 SNeIa to z~1.7.
- Vera Rubin Observatory LSST will discover 100,000 well-observed SNeIa with 1% calibration. 10,000 in deep field. Strong complement with Roman.
- Euclid can provide a complementary high-redshift z~1.5 survey
- JWST can uniquely study astrophysics of SNeIa and their hosts at 1<z<3.
- For some more on future of SNIa cosmology see, Scolnic, Perlmuter, et al. Astro 2020 White paper: “The Next Generation of Cosmological Measurements with Type Ia Supernovae” https://arxiv.org/pdf/1903.05128.pdf

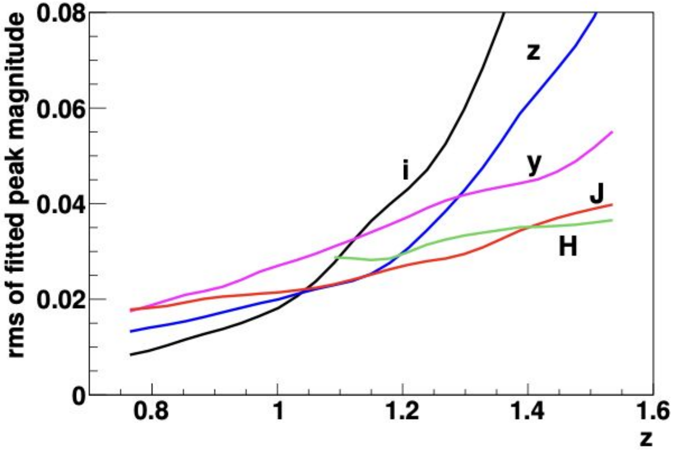


Extra Slides

Euclid Astier+14 Figures. Lightcurve Example and fits.



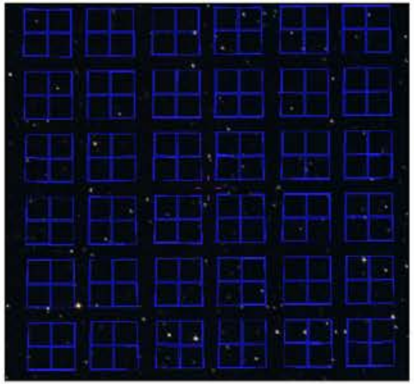


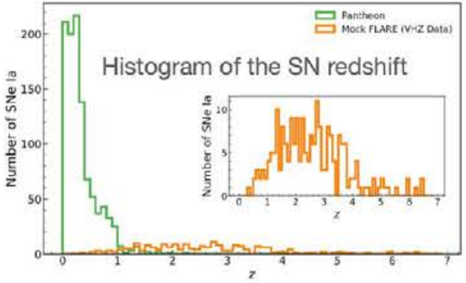


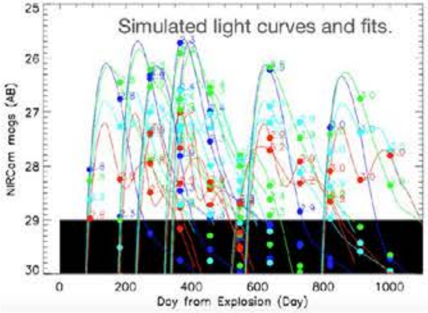
Synergies with JWST

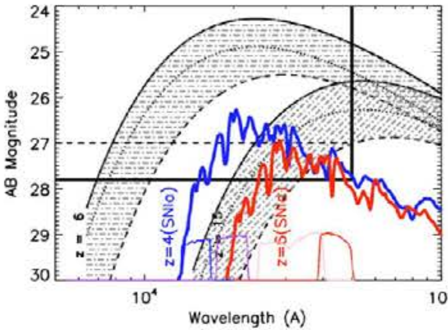
The JWST SNIa Survey

1. Survey area of 0.05 sq deg
2. Cadence ~ 91 days
3. In the area of North Ecliptic Pole
4. A total of around 70 SNela above z = 2 in three years

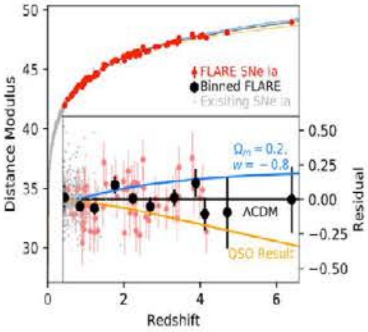


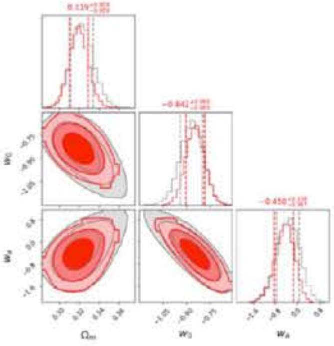




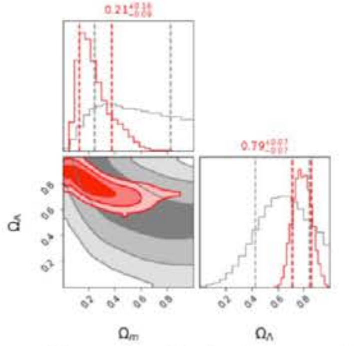


Survey filters and Depth. The blue and red lines are for SNela at z ~ 4 and 6, respectively. The shaded area show the SED of super-luminous SNe. The 10 sigma Limiting mag is show by the horizontal solid line, and the vertical solid line shows the reddest wavelength the survey will probe.

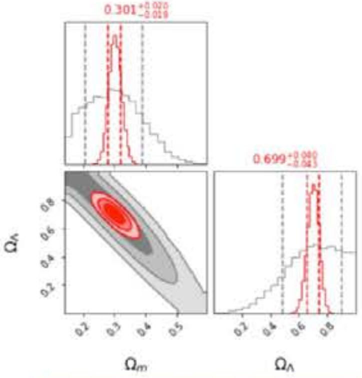




Constraints of the flat LCDM using the supernova data combined with Planck18 prior. The gray contours are from the Pantheon data enhanced by decreasing the statistical errors by a factor of 8. The red contours show the addition of the Very High Redshift data from the JWST. The difference is small, indicating that the JWST SNe and the Planck Prior are **mutually replaceable**.



When a logarithmic distance evolution of the SN luminosity distance is assumed. The cosmological constraints **weakens** considerably without the JWST SNe, even with the Planck18 prior included.



The JWST SNela set constraints on the magnitude evolution of SNela and restores the statistical power of cosmological constraints of SNela at z below 2.