A better use of SNe Ia to address the Hubble tension

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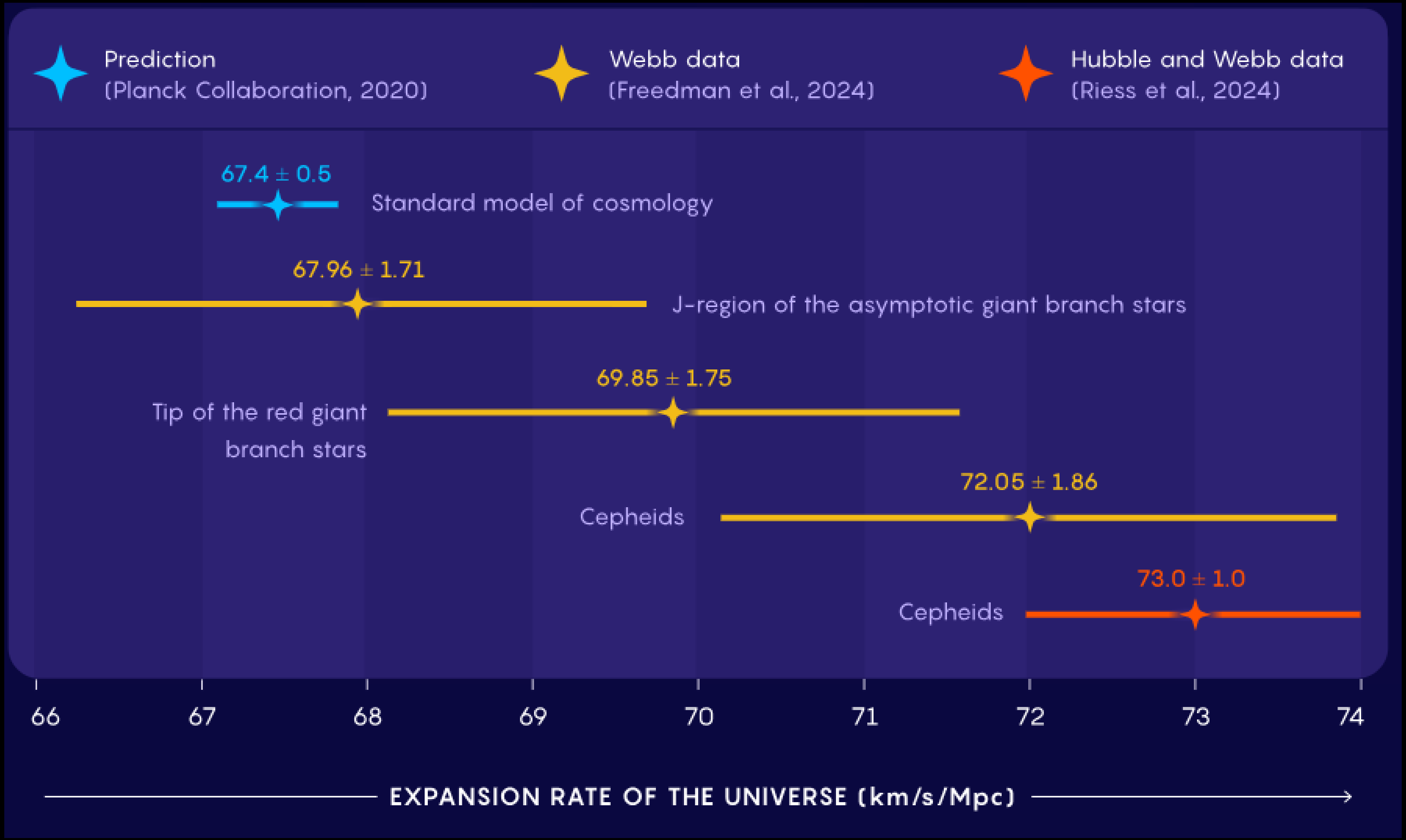
DSU 2024, Corfu

The H_0 tension



(credit *Quanta Magazine*)

The H_0 tension: recent *JWST* data

Freedman et al. (2024)

Calibrator	
TRGB	H_0 = 69.85 ± 1.75 (stat) ± 1.54 (sys) Km s^{-1} Mpc^{-1}
Cepheids	H_0 = 72.05 ± 1.86 (stat) ± 3.10 (sys) Km s^{-1} Mpc^{-1}
JAGB	H_0 = 67.96 ± 1.85 (stat) ± 1.90 (sys) Km s^{-1} Mpc^{-1}

Riess et al. (2024)

TRGB	H_0 = 72.1 ± 2.2 Km s^{-1} Mpc^{-1}
Cepheids	H_0 = 73.4 ± 2.1 Km s^{-1} Mpc^{-1}
JAGB	H_0 = 72.2 ± 2.2 Km s^{-1} Mpc^{-1}

?

The H_0 tension

- Value derived from the CMB (*Planck* 2020, assuming the ΛCDM cosmological model):

$$H_0 = 67.4 \pm 0.5 \text{ km s}^{-1} \text{ Mpc}^{-1}$$

- Locally determined value (*SH0ES* 2024, Cepheids + SNeIa):

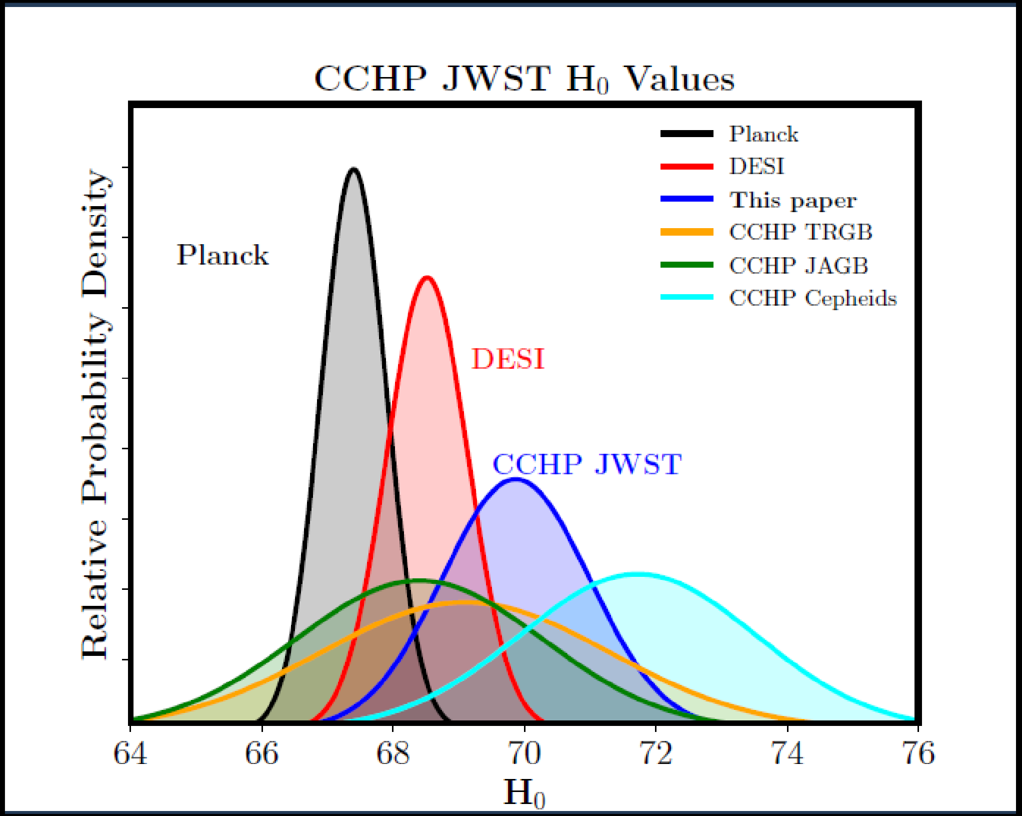
$$H_0 = 73.0 \pm 1 \text{ km s}^{-1} \text{ Mpc}^{-1}$$

which is a discrepancy at the 5.6σ level

OLD !

The H_0 tension

- There are, however, other methods to determine distances to galaxies in the Hubble flow that give H_0 values intermediate between the *Planck* and the *SH0ES* values:



(from Freedman et al. 2024)

The H_0 tension

CMB temperature and polarization anisotropy maps (Planck collaboration 2020): $H_0 = 67.4 \pm 0.5$ km s^{-1} Mpc^{-1}

Cepheids (Riess et al.; *SH0ES* 2022, 2024): $H_0 = 73.0 \pm 1$ km s^{-1} Mpc^{-1}

Tip of the Red Giant Branch (*TRGB*) stars (Freedman et al. 2019): $H_0 = 69.8 \pm 0.8$ (stat) ± 1.7 (sys) km s^{-1} Mpc^{-1}

Carbon/J band Asymptotic Giant Branch (*JAGB*) stars (Lee et al. 2024): $H_0 = 67.96 \pm 1.85$ (stat) ± 1.90 (sys) km s^{-1} Mpc^{-1}

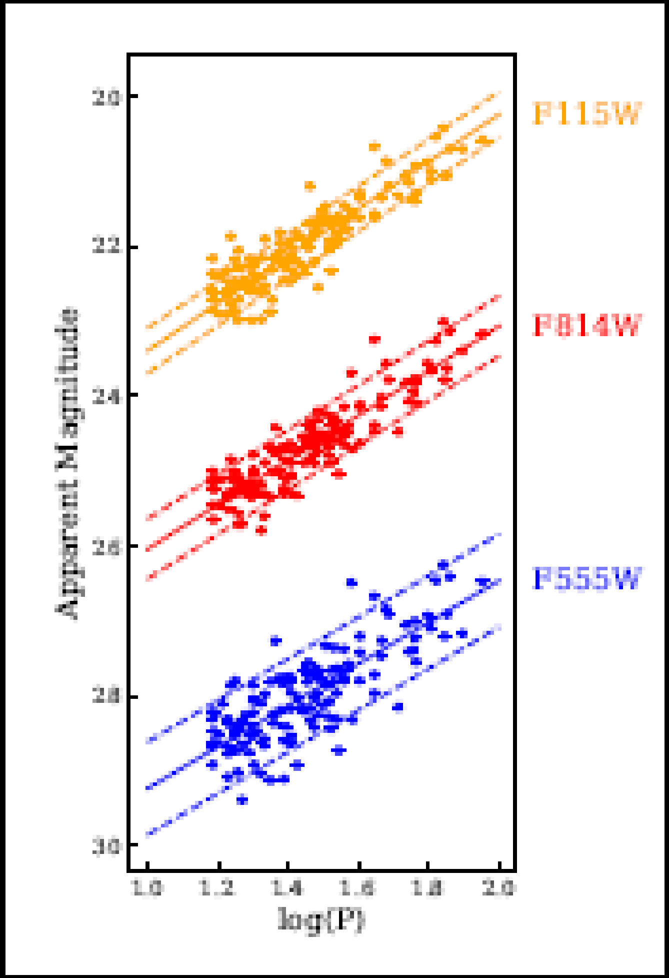
The H_0 tension: *Cepheids*

Basically, Leavitt's laws

Issues:

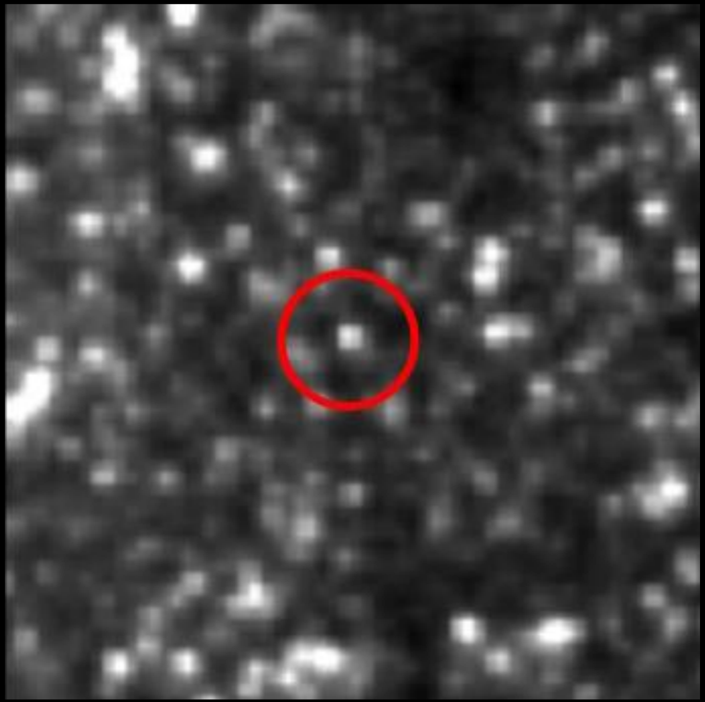
Dependence on metallicity

Crowding in the images (advantage of *JWST* over *HST*)



Leavitt's laws in various filters at the *HST WFC3*

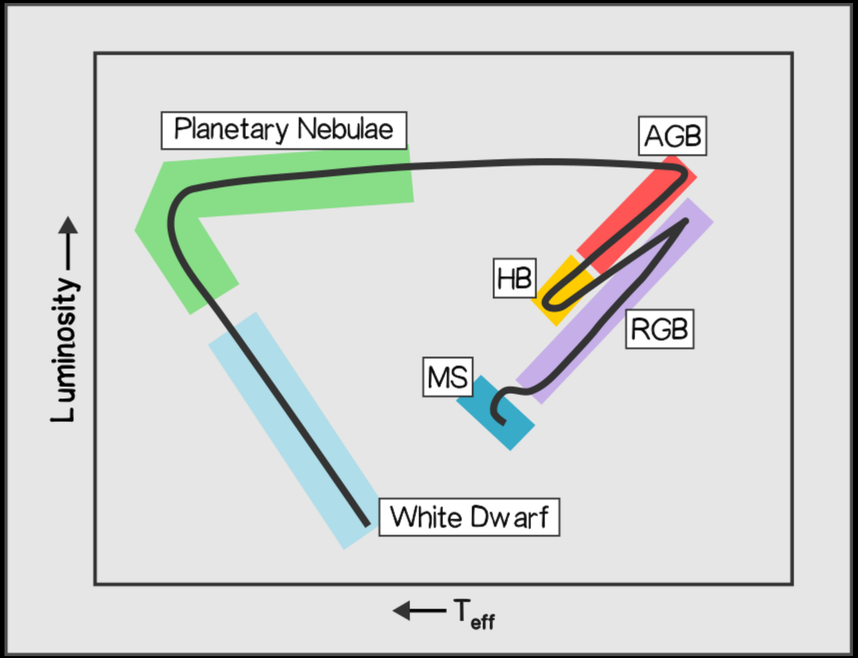
The H_0 tension: *Cepheids*

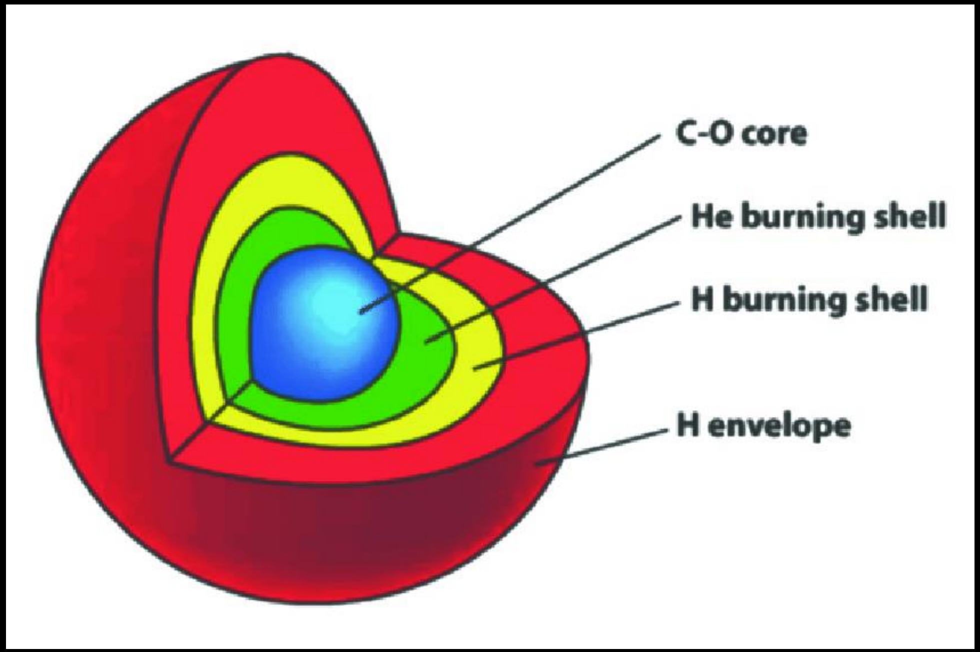


Cepheid in NGC 7250
Left: *HST* image

Right: *JWST* image

The H_0 tension: TRGB and *JAGB* stars





Very schematic H-R diagram showing the evolution of a 1 M_O star. The AGB stage is marked in red. Marked in purple is the RGB. In yellow is the Horizontal Branch stage, of central He burning

Internal structure of and AGB star

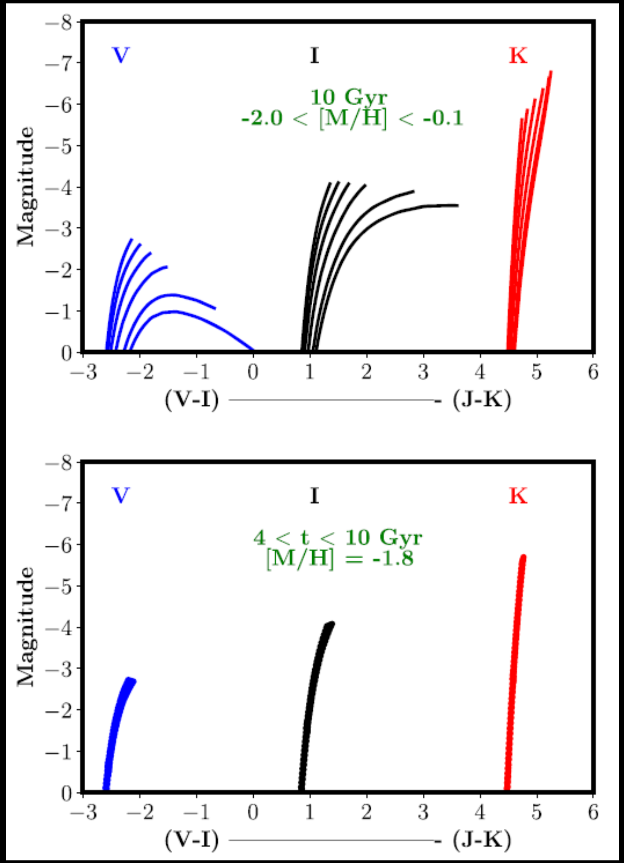
The H_0 tension: *TRGB* stars

Low-mass stars, after H burning, grow an electron-degenerate He core. During this stage, luminosity and radius increase as well as the central temperature.

When the central temperature reaches ~ 100 million K, He is ignited and then luminosity and radius start decreasing. This maximum in luminosity is the *Tip of the Red Giant Branch.*

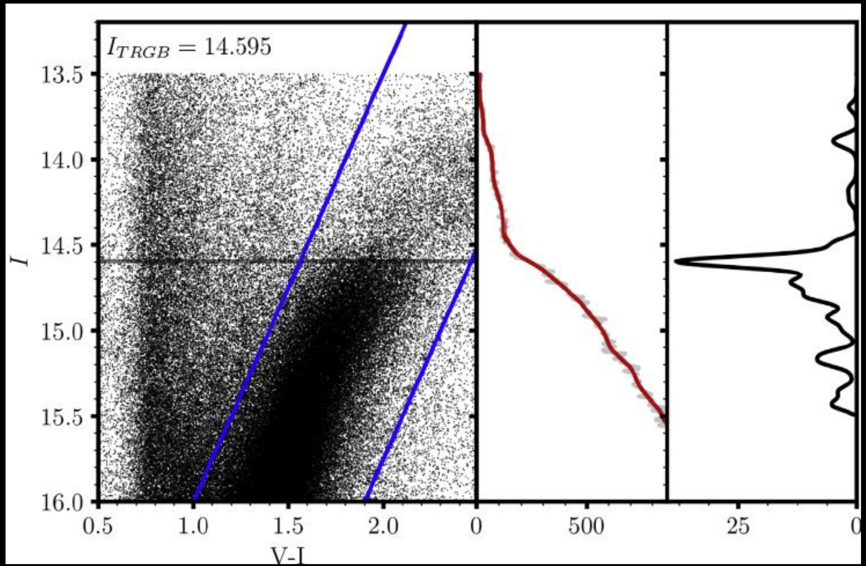
At that point, the He core has a fixed mass = 0.47 $M_{\odot}$
So, ignition happens at a well-determined luminosity, which makes the *TRGB* a standard candle

The H_0 tension: *TRGB* stars



Isochrones for red giant stars with a constant age of 10 Gyr and a metallicity spread (upper panel) and with a constant metallicity and age spread 4-10 Gyr (lower panel)

(from Freedman et al, 2020)

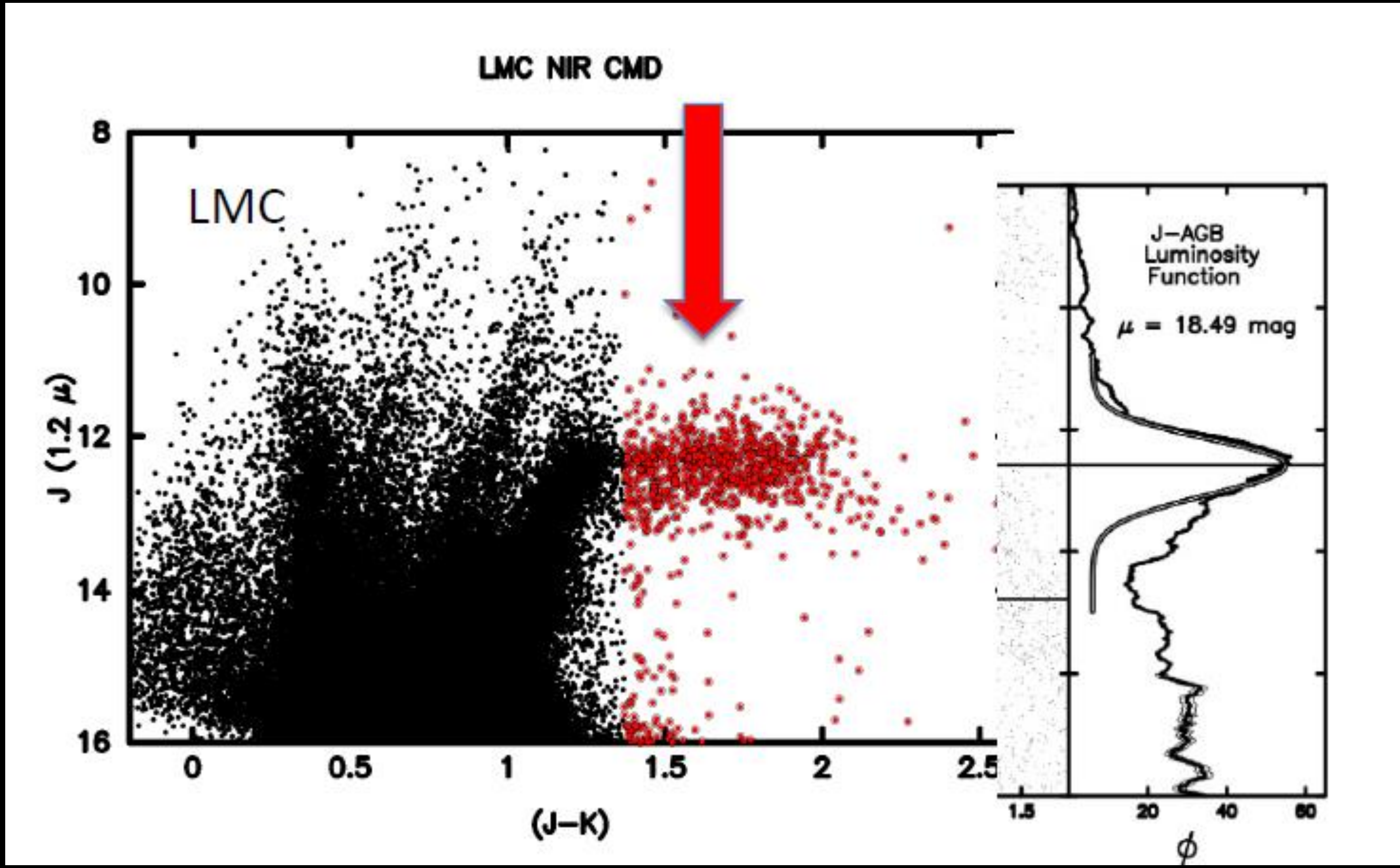


Colour-magnitude diagram (left panel), luminosity function (middle panel) and edge-detection response (right panel) for the outer región of the LMC

(from Freedman et al. 2019)

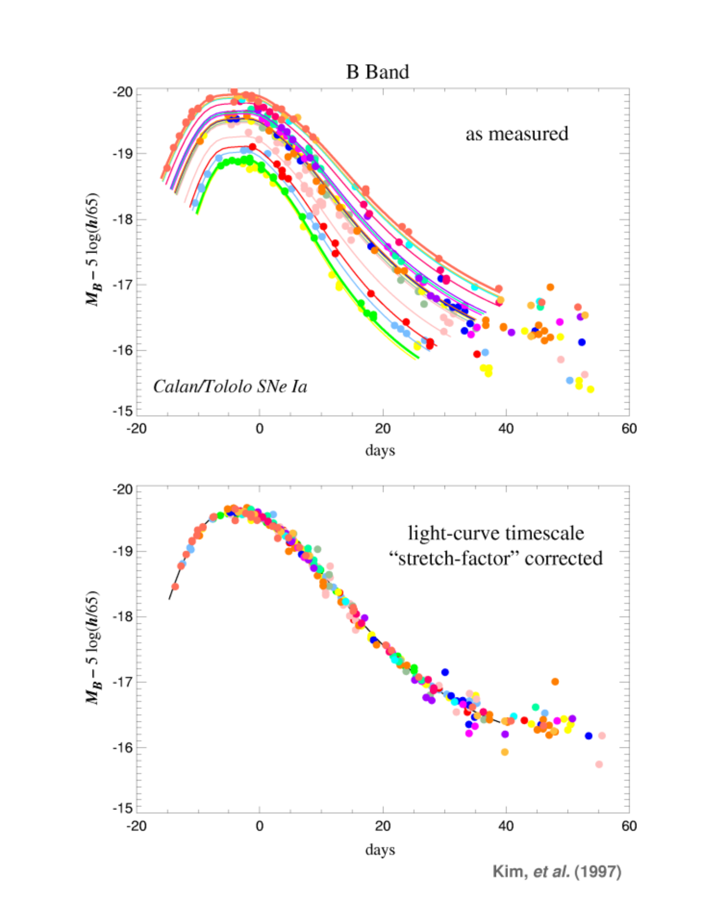
The H_0 tension: *J-band AGB* stars

A class of luminous, C-rich AGB stars which show a small intrinsic luminosity dispersión in the near IR (*J*-band)



(from Madore and Freedman 2020)

SNeIa light curves



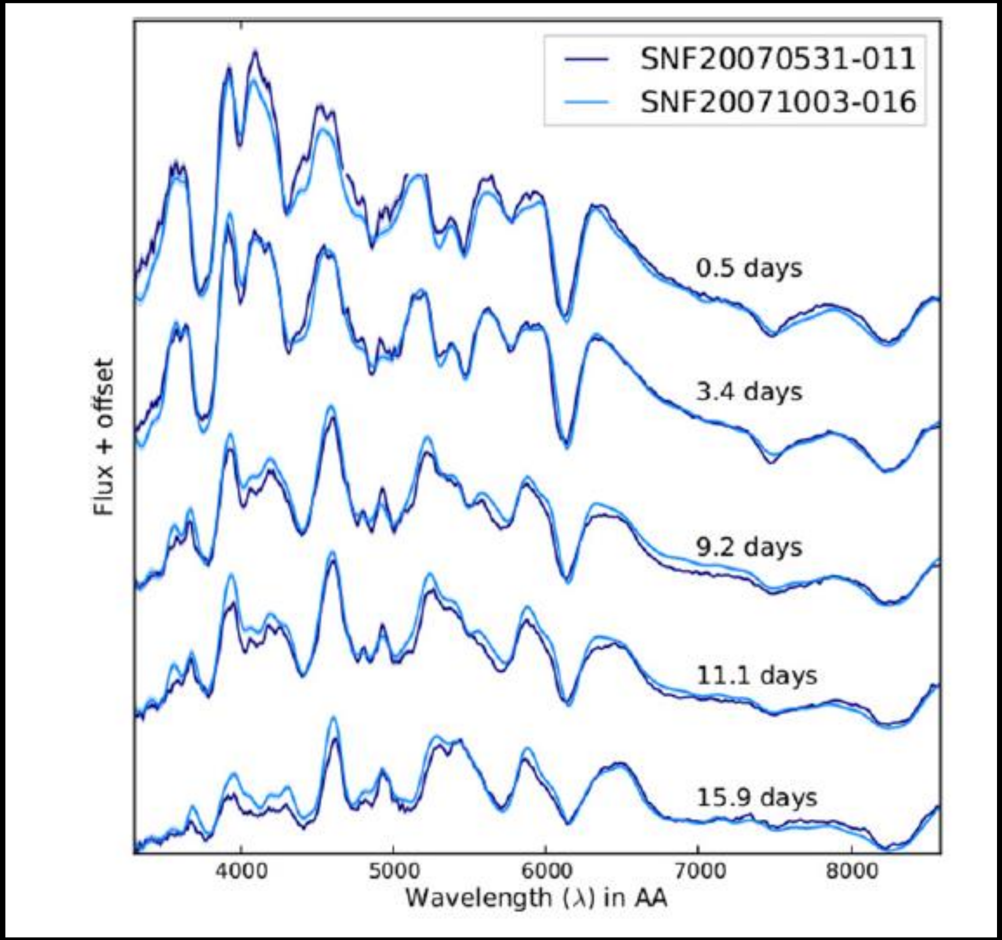
With **light-curve fitting, distance moduli are obtained with an error of σ_μ** = 0.11 mag

By **fitting spectra of twin SNeIa, distance moduli are obtained with an error of σ_μ** = 0.04 mag only

Ruiz-Lapuente & González Hernández 2024, ApJ in press
arXiv 2312.10334

Twin SNeIa

Using twin SNeIa, Fakhouri et al. (2015) were able to standardize SNeIa in the redshift range 0.03 ≤ z ≤ 0.08 within 0.06-0.07 mag



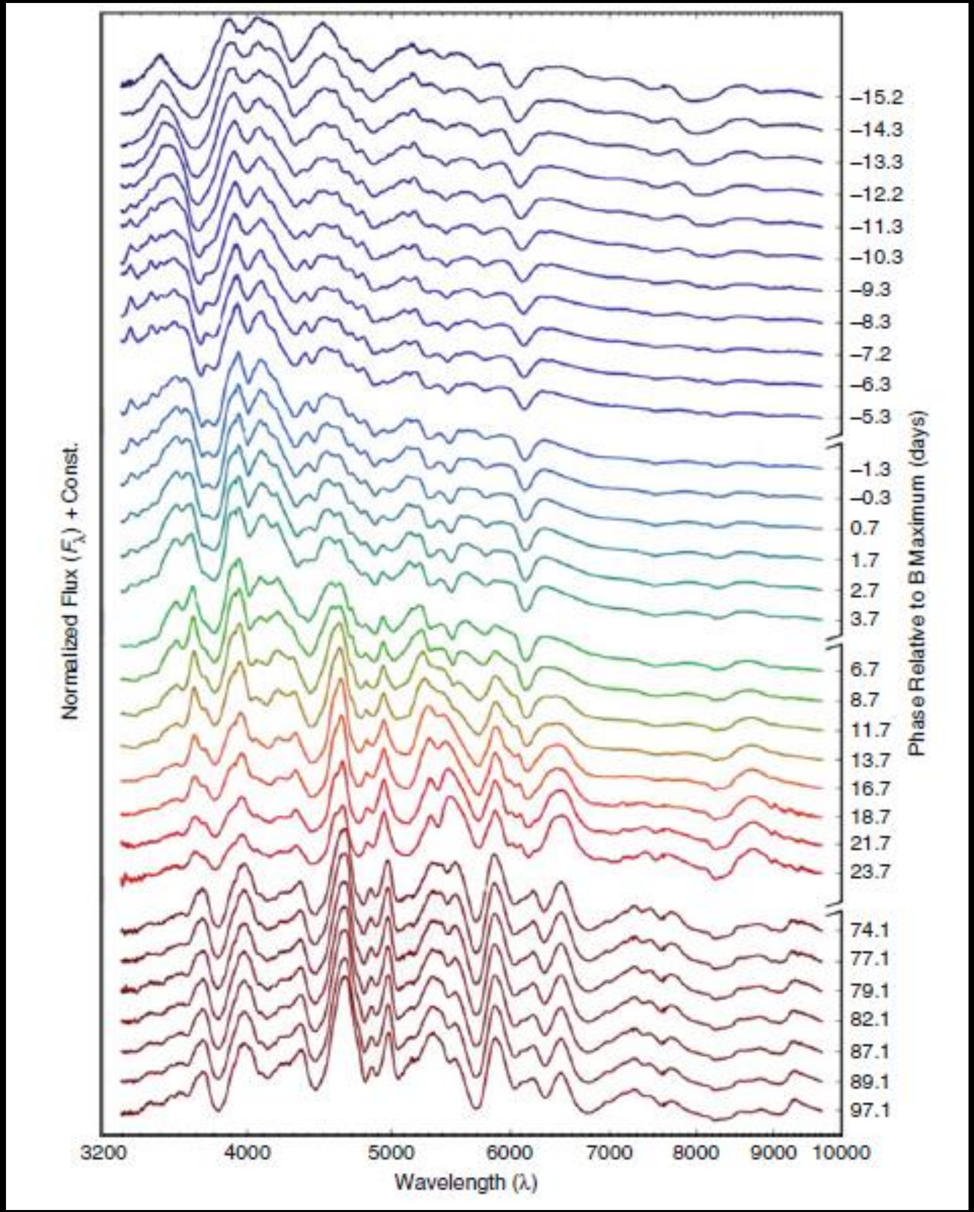
(from Fakhouri et al. 2015)

Twins estimate distances with parameters corresponding to the spectral diversity of the SNeIa

Here, instead, we use twin SNeIa in all phases, from the early to the late, nebular phases, what we call “twins for life”

Ruiz-Lapuente & González Hernández (2024)

Spectral sequence of a Type Ia supernova (Branch & Wheeler 2017)



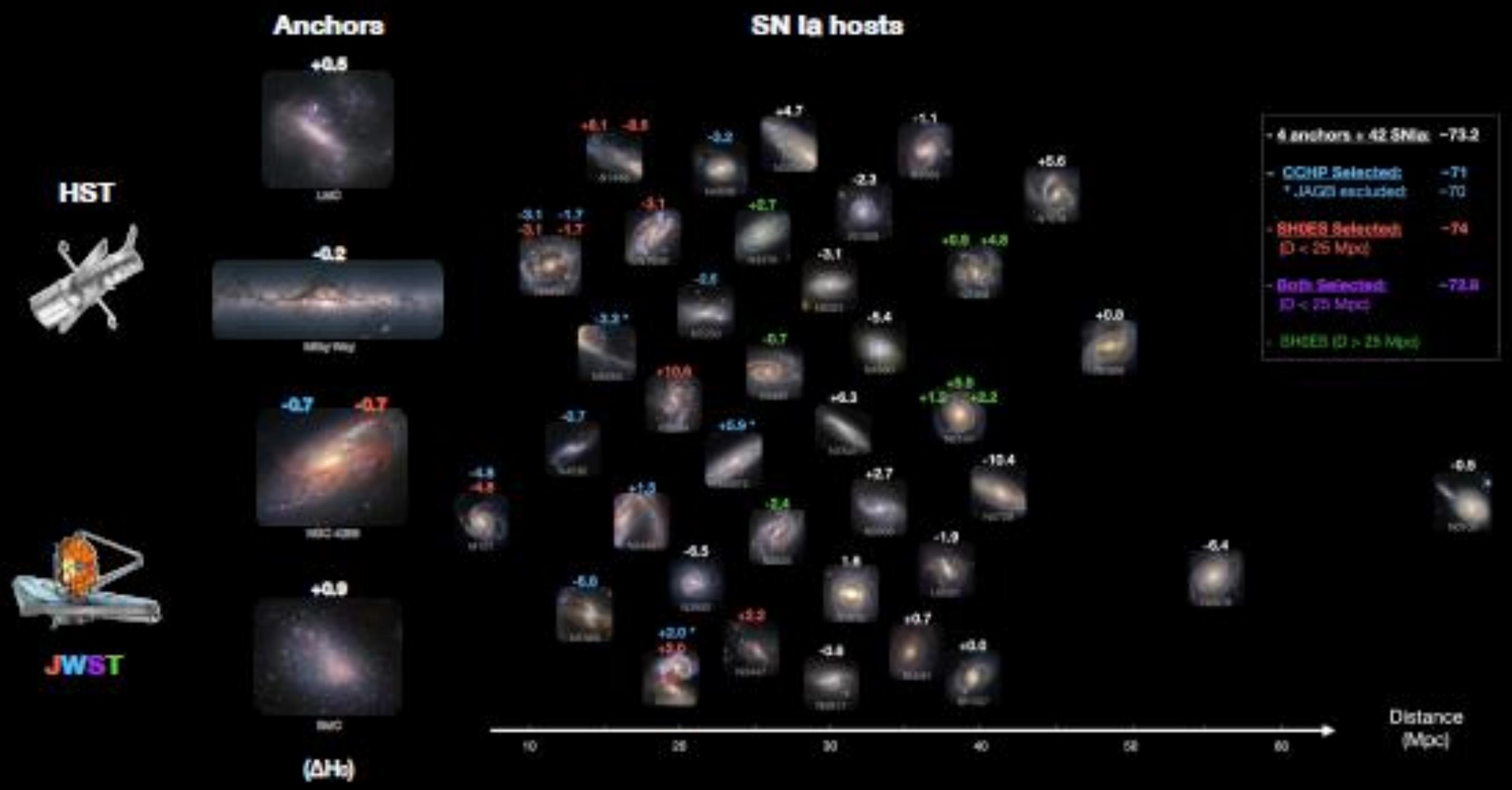
Standard method

In all the preceding methods:

Three steps of the cosmological distance ladder

1. Calibration of the primary distance indicators (*Cepheids, TRGB, JAGB …*) in nearby galaxies
2. Standardization of SNeIa sample by determining an average M_B^{max} (z still too low to measure H_0)
3. SNeIa sample in the Hubble flow ($z \approx 0.01$-0.03)

$M_B^{max} – H_0$



(from Riess et al. 2024)

Standard method

$$B_{corr} = P^0 - P^1(s_{BV} - 1) - P^2(s_{BV} - 1)^2 - \beta(B - V) - \alpha_M(\log_{10} M_*/M_\odot - M_0)$$

$$\mu(z, H_0, q_0) = 5\ \log_{10}\{\frac{(1 - z_{hel})cz}{(1 + z)H_0}(1 + \frac{(1 - q_0)}{2}z)\} + 25$$

$$\mu_{\rm obs} = m_x - P^0 + P^1(s_{BV} - 1) + P^2(s_{BV} - 1)^2 + \beta(B - V) + \alpha_M(\log_{10} M_*/M_\odot - M_0)$$

where μ_{obs} is the observed distance modulus, m_x the peak magnitude in the x band and P^0 the absolute magnitude M_x of a SNIa with zero (B-V) color, color stretch $s_{BV} = 1$ and in a host galaxy with stellar mass $M = M_0$

Standard method: M_B^{max} and H_0

$$\mu_{obs} = m_x - P^0 + P^1(s_{BV} - 1) + P^2(s_{BV} - 1)^2 + \beta(B - V) + \alpha_M(\log_{10} M_*/M_\odot - M_0)$$

where μ_{obs} is the observed distance modulus, m_x is the peak magnitude in the x band and P^0 the absolute magnitude M_x of a SNIa with zero $(B-V)$ color, color stretch $s_{BV} = 1$ and in a host Galaxy with stellar mass $M = M_0$

P^1 is the linear coefficient and P^2 a quadratic coefficient in $(s_{BV} - 1)$; β is the slope of the color correction, V is the apparent peak magnitude at V, K-corrected, and α_M is the slope of the correlation between peak luminosity and host stellar mass M_*

The apparent magnitudes at maximum are computed by fitting the light curves with *SNooPy*, providing the time of maximum, the light-curve shape s_{BV}, and the magnitude at maximum for each filter.

These quantities are then provided as inputs to a *Markov Chain Monte Carlo* sampler that simultaneously provides the corrected magnitudes for all the correction factors P^1, P^2, α_M and β.

The *MCMC* sampler then provides the corrected magnitudes, as well as the full covariance matrix, which is used when determining H_0 and its errors

The H_0 tension

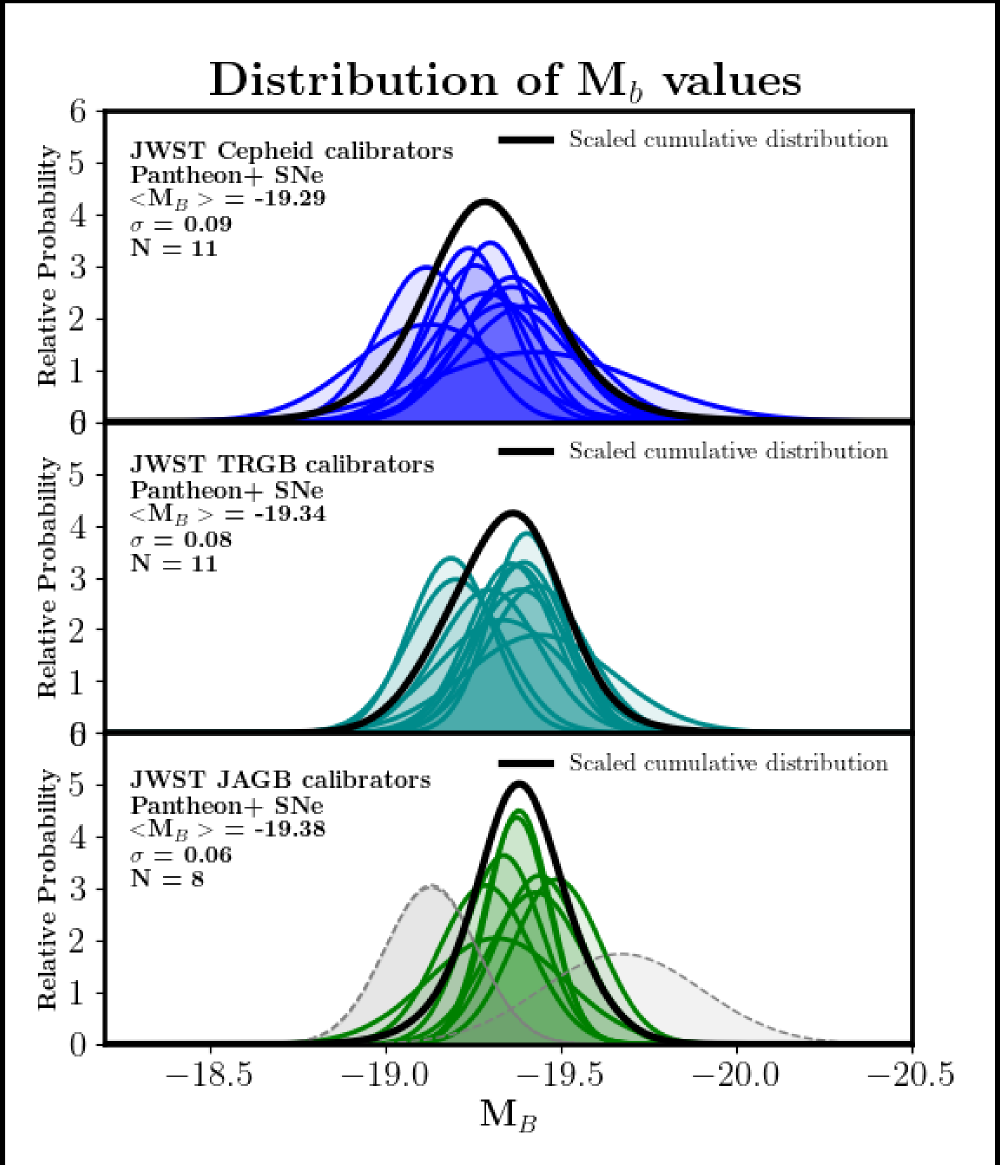
Results recently obtained with the JWST

We see the distribution of M_B values from different distance calibrators

$\langle M_B \rangle$ = -19.29 mag (JWST Cepheids)

$\langle M_B \rangle$ = -19.34 mag (JWST TRGB)

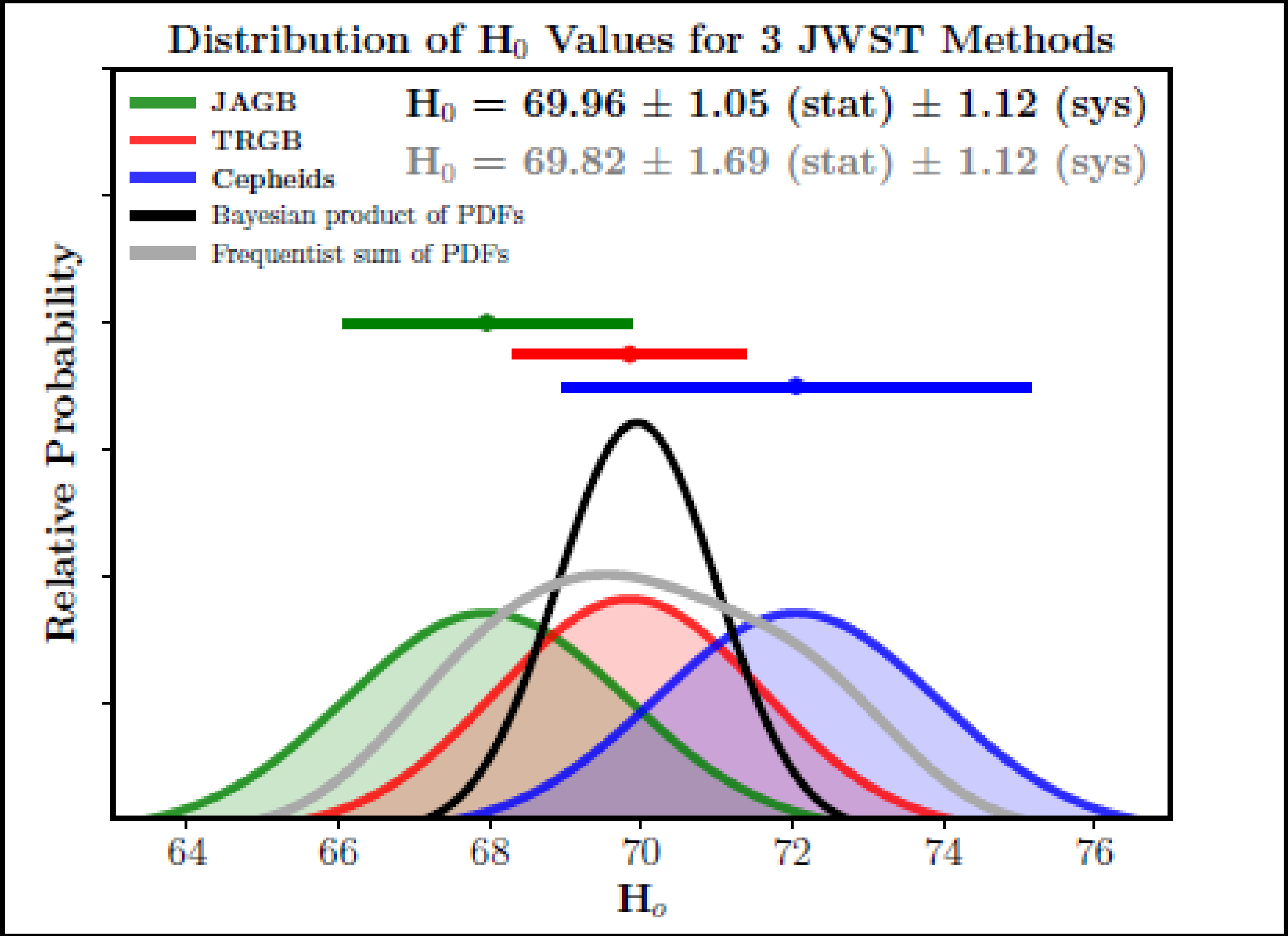
$\langle M_B \rangle$ = -19.38 mag (JWST JAGB)



(from Freedman et al. 2024)

The distribution of H_0 values resulting from the new *JWST* data, depending on the three different methods used to derive them.

The first value comes from the Bayesian product of the 3 PDFs, and the second one from the Frequentist sum of distributions



(from Freedman et al. 2024)

The H_0 tension

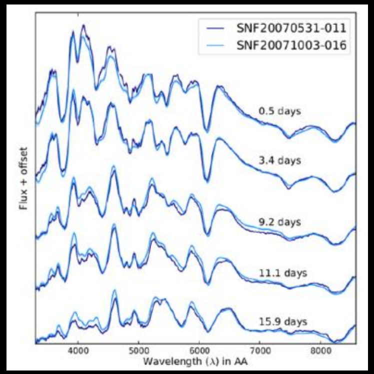
The weighted (unweighted) mean difference between the *JAGB* minus *Cepheid* distance moduli is 0.086 ± 0.028 (0.083 ± 0.031) mag or 4% (Freedman et al. 2024)

5 x log(73,2/67.5) ~0.18 mag is the Hubble tension

The twin SNeIa method

In this approach:

Two steps of the cosmological distance ladder



SNeIa twins of the "anchors" in the Hubble flow ($z \approx$ 0.01-0.03)

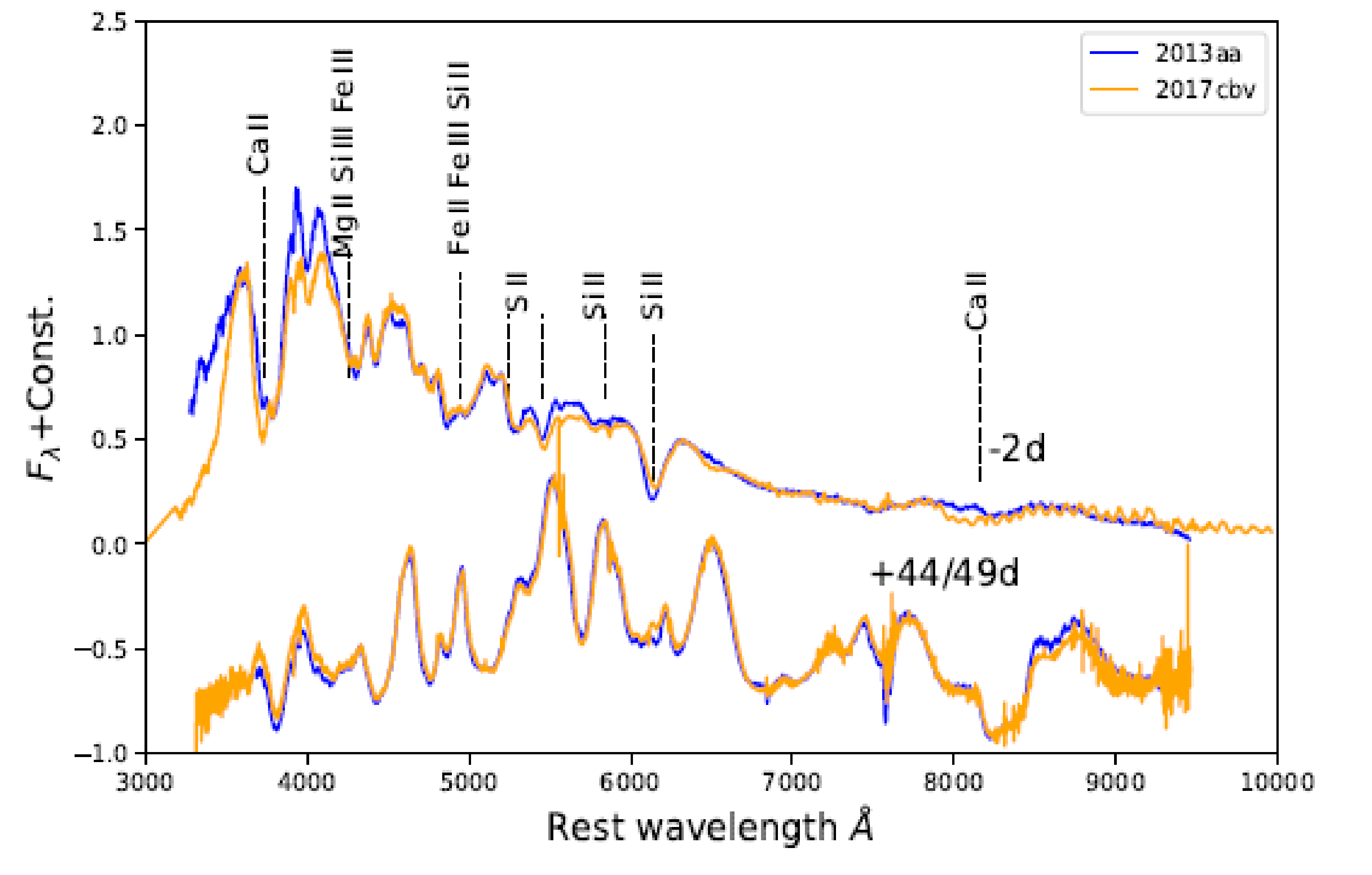
Ruiz-Lapuente & González Hernández (2024)

Distances to nearby SNeIa ("anchors")

The twin SNeIa method

Extending the method to reach SNeIa that are on the Hubble flow should allow to avoid using a fiducial absolute magnitude M_B-H_0 relation and to get a direct comparison of distances, that leading straightforwardly to the value of H_0

Spectral characterization of twins



Spectral characterization of twins

pWs at Maximum Light (Angstrom)

SN	pW1 Ca II H&K	pW2 Si II 4130	pW3 Mg II	pW4 Fe II	pW5 S II W	pW6 Si II 5972	pW7 Si II 6355	pW8 Ca II IR	Project
CN									
2007ol	106(1)	22(1)	80(1)	82(1)	56(1)	16(1)	78(1)	···	CSP-I
2008bz	86(2)	22(2)	70(1)	106(2)	88(1)	17(1)	99(1)	105(3)	CSP-I
2008fr	107(2)	11(1)	71(2)	109(1)	80(1)	17(1)	82(2)	72(5)	CSP-I
2009I	140(3)	9(1)	82(3)	111(2)	72(1)	10(1)	70(1)	89(3)	CSP-I
2009cz	120(1)	9(1)	92(1)	131(1)	67(1)	12(1)	81(1)	104(4)	CSP-I
2009le	60(2)	11(1)	104(2)	124(1)	62(1)	9(1)	86(1)	114(2)	CSP-I
ASASSN-14hr	135(2)	32(1)	101(2)	138(1)	67(2)	30(1)	104(2)	107(4)	CSP-II
ASASSN-14hu	150(2)	11(1)	97(2)	115(1)	76(1)	7(1)	83(1)	···	CSP-II
ASASSN-14kq	139(1)	11(1)	100(1)	115(1)	73(1)	11(1)	77(1)	127(3)	CSP-II
ASASSN-14lp	116(3)	10(1)	93(4)	140(3)	69(1)	13(1)	70(1)	117(4)	CSP-II

We have measured lines relevant for describing the similarity of the spectra. Those of the twins have very similar pseudo-equivalent widths (*pWs*) in the list of lines (Morrell et al. 2024), *pW1* (Ca H & K), *pW2* (Si II λ 4130 Å), *pW3* (Mg II λ 4481 Å blended with Fe II), *pW4* (Fe II at ≈ λ 4600 Å blended with S II), *pW5* (S II "W" ≈ λ 5400 Å), *pW6* (Si II λ 5972 Å), *pW7* (Si II λ 6355 Å) and *pW8* (Ca II IR).

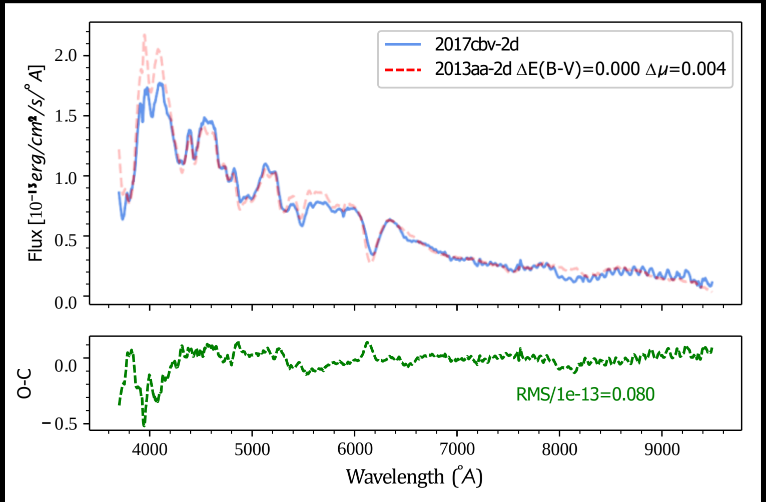
In particular, the *pW6* should be very similar between twin SNeIa, the dicrepancy being by less than 5%. This line correlates with stretch (Δm_{B15}, s_{BV}), being similar in SNeIa with similar stretches and nearly identical in twins. In the *pW6 vs pW7* diagram, twins should fall into almost the same place

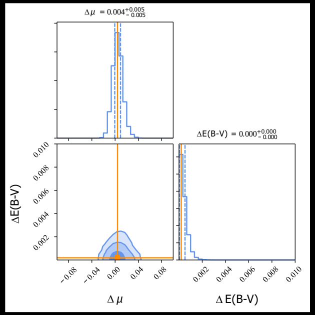
The twin SNeIa method

The gain in using the “twins for life” approach is that it provides a direct measurement of distance, intrinsic color and reddening by Galactic and extragalactic dust by the use of the whole spectra of the SNeIa.

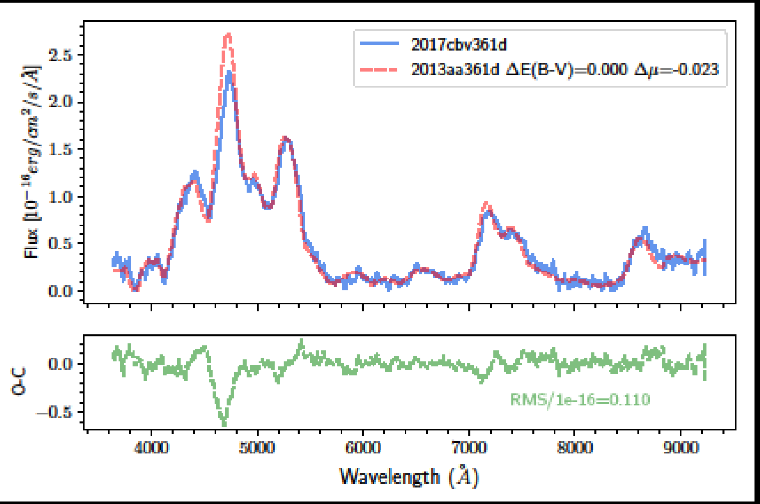
It allows the consistent pairing of SNeIa through all phases. The selection of twins is made of SNeIa with a similar stretch, being then of similar luminosities, but n addition the “twinness factor” can make more precise the distance estimate, with a modulus error of 0.04 mag in all filters, as we will show. So, all this makes it a very useful tool to establish the right distance ladder

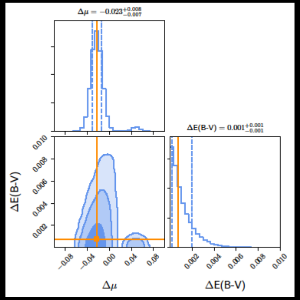
SN 2013aa/SN 2017cbv in NGC 5643

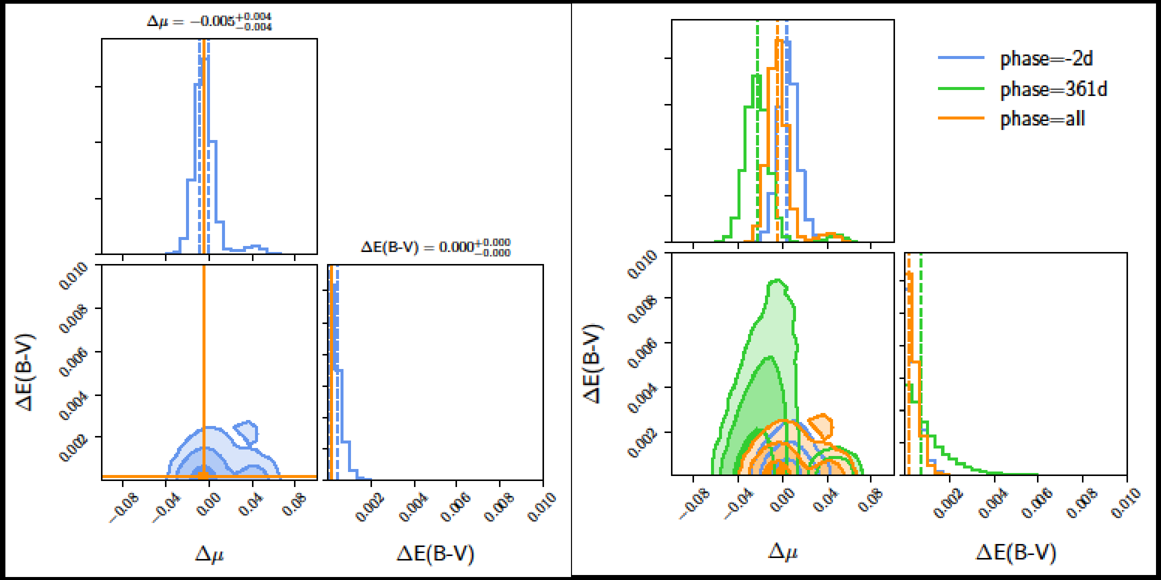




Comparison of early (-2d) and late time (+361d) spectra of the twin SNe Ia SN 2013aa and SN 2017cbv, both in the galaxy NGC 5643, with the 1σ, 2σ and 3σ contours of the probability distribution for Δμ (difference in distance moduli) and ΔE(B-V) (difference in reddening), in each case. We use Markov Chain Monte Carlo techniques and the EMCEE Python package to obtain the best values and their uncertainties for the two variables. We obtain the final joint result for the two phases







Ruiz-Lapuente & González Hernández (2024)

SN 2013aa/SN 2017cbv in NGC 5643

Since the twin pair SN 2013aa/SN 2017cbv appeared in the same galaxy, NGC 5643, we use it as a test of the method.

We obtain $\Delta\mu = 0.004 \pm 0.005$ mag from the early spectra and $\Delta\mu = -0.023^{+0.008}_{-0.007}$ mag from the late ones, which corresponds to a precisión of 23 kpc for the first spectrum and of around 100 kpc for the second one.

The joint result from the two spectra is $\Delta\mu = -0.005 \pm 0.004$ mag, with a precision of 20 kpc. We also obtain $\Delta E(B-V) = 0.00 \pm 0.00$ mag, which would correspond to negligible reddening in the host galaxy and the same reddening in our own.

The distance to NGC 5643

Galaxy	Distance modulus (mag)	Method	Reference
NGC 5643	30.480±0.1	TRGB	Hoyt et al. (2021)
NGC 5643	30.42±0.07	TRGB	Anand et al. (2024)
NGC 5643			Anand et al. (2022)
NGC 5643	30.570±0.050	Cepheids	Riess et al. (2022)
NGC 5643	30.52±0.02	Cepheids (JWST+HST)	Riess et al. (2024)
NGC 5643	30.518±0.033	Cepheids (HST)	Riess et al. (2024)
NGC 5643	30.48± 0.065	SN 2013aa/SN 2011fe	
NGC 5643	30.48±0.065		Obtained NGC 5643 ladder step

SN 2013aa/SN 2017cbv in NGC 5643

For the absolute distance, we obtain μ = 30.48 ± 0.065 mag (D = 12.47 ± 0.37 Mpc)

(Ruiz-Lapuente & González Hernández 2024)

Other distance determinations are:

From Cepheids:

μ = 30.570 ± 0.050 mag (D = 13.00 ± 0.30 Mpc) (Riess et al. 2022)

μ = 30.518 ± 0.033 mag (D = 12.69 ± 0.20 Mpc) (Riess et al. 2024a)

μ = 30.52 ± 0.02 mag (D = 12.70 ± 0.12 Mpc) (*JWST +HST* Riess et al. 2024b)

μ = 30.51 ± 0.02 mag (D = 12.64 ± 0.12 Mpc) (Freedman et al. 2024)

Consistent distance scale!!

From TRGB:

μ = 30.48 ± 0.1 mag (D = 12.47 ± 0.59 Mpc) (Hoyt et al. 2021)

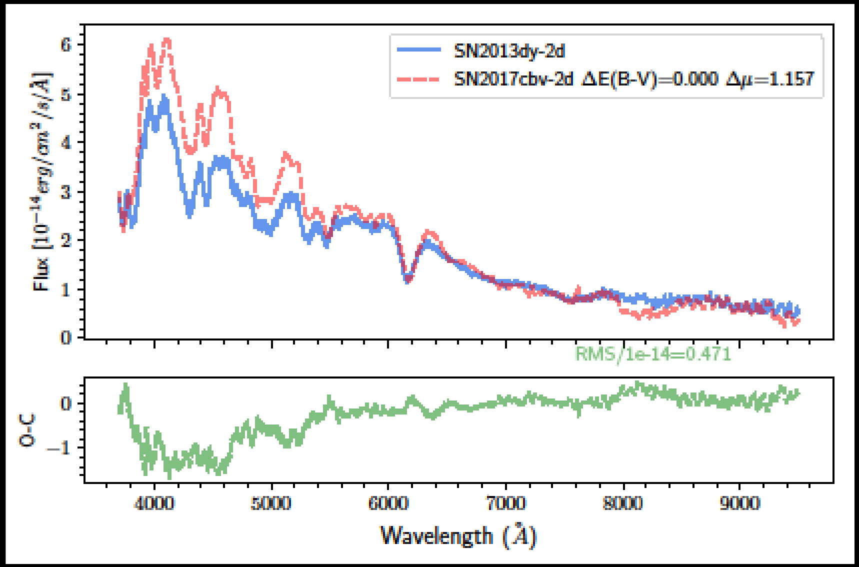
μ = 30.42 ± 0.07 mag (D = 12.13 ± 0.40 Mpc (Anand et al. 2024)

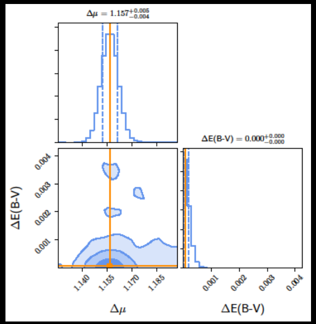
μ = 30.61 ± 0.07 mag (D = 13.24 ± 0.42 Mpc) (Freedman et al. 2024) ?

μ = 30.59 ± 0.04 mag (D = 13.12 ± 0.24 Mpc) (Freedman et al. 2024)

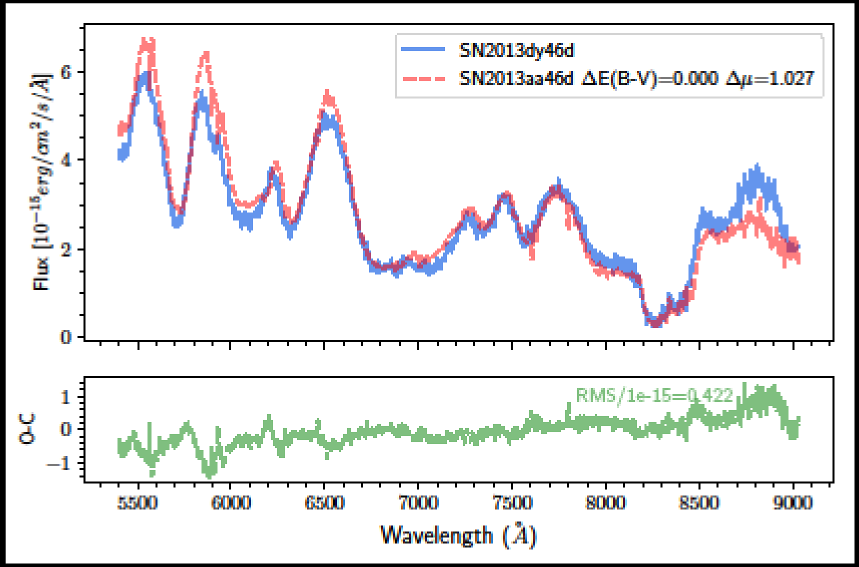
A broken or misplaced step in the distance ladder ?

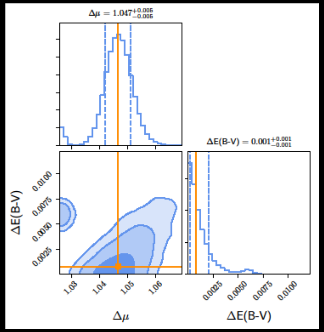
2013dy in NGC 7250

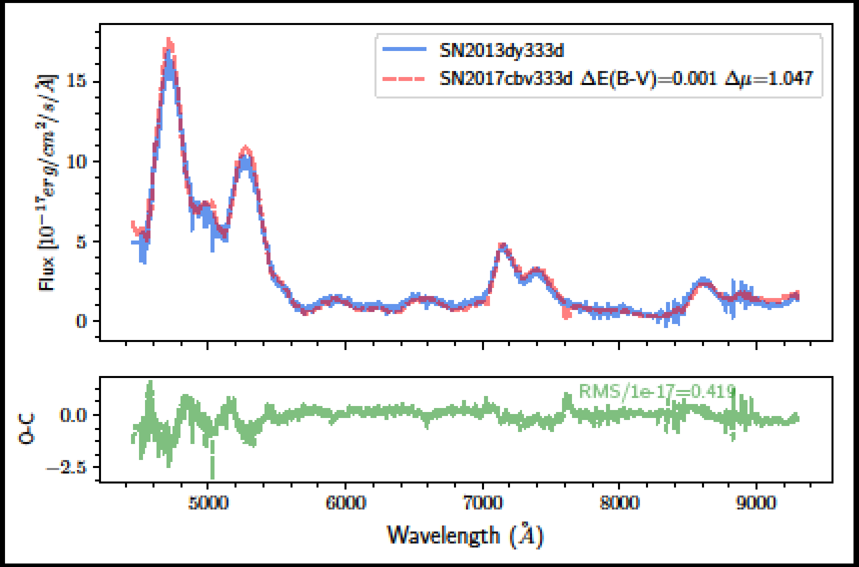


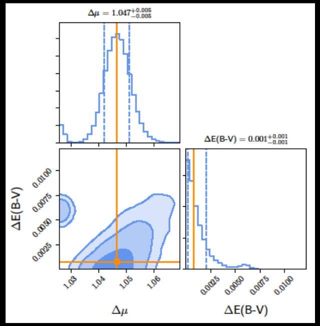


Comparison of the spectra of SN 2013dy, in NGC 7250, at three different phases (-2d, +46d and +333d) with those of its twins SN 2013aa and SN 2017 cbv

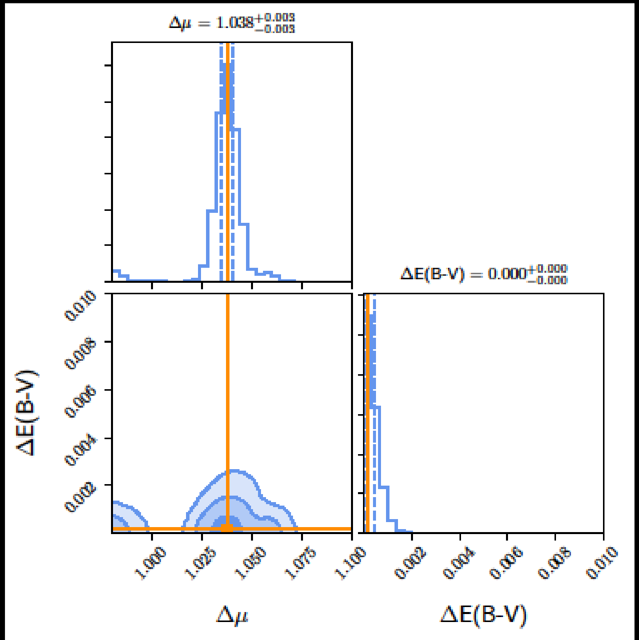


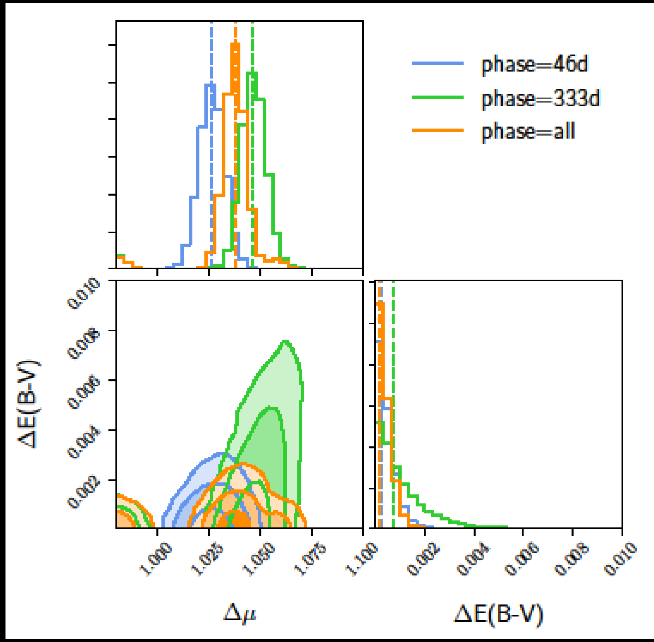






SN 2013dy in NGC 7250





Final values favored by the joint phases at +46d and +333d of SN 2013dy and its twins (left). They are: Δμ = 1.038 ± 0.003 mag and ΔE(B-V) = 0.0 ± 0.000 mag. Results for each phase and the joint phases (right)

SN 2013dy in NGC 7250

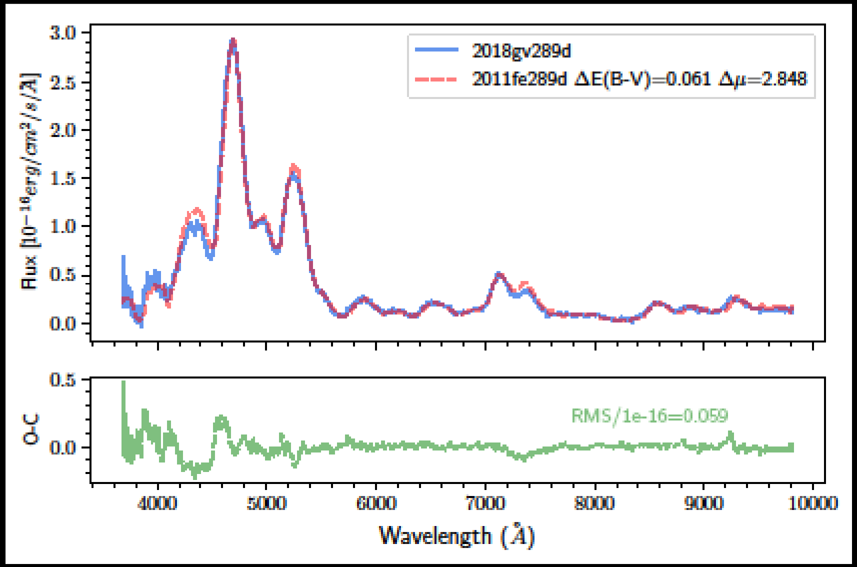
Our value for the distance modulus is μ = 31.518 ± 0.065 mag (D = 20.12 ± 0.70 Mpc)

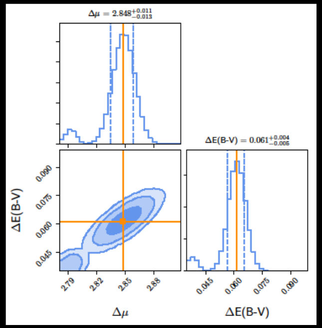
An earlier value (from Cepheids), with a large error, was: μ = 31.628 ± 0.126 mag (D = 21.16 ± 1.27 Mpc) (Riess et al. 2022)

New values, from *JWST* data:

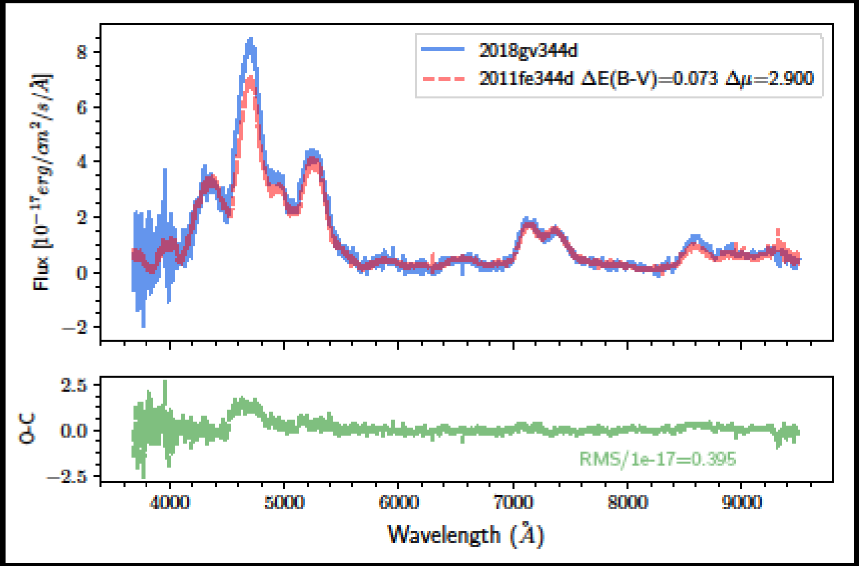
μ = 31.62 ± 0.04 mag (D = 21.08 ± 0.40 Mpc) (*TRGB*, Freedman et al. 2024)
μ = 31.41 ± 0.12 mag (D = 19.14 ± 1.09 Mpc) (*Cepheids*, Freedman et al.2024)
μ = 31.6 ± 0.08 mag (D = 20.89 ± 0.79 Mpc) (*JAGB*, Freedman et al. 2024)

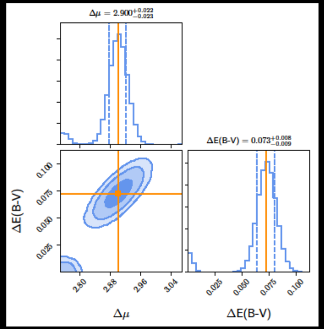
SN 2011fe in M101/SN 2018gv in NGC 2525

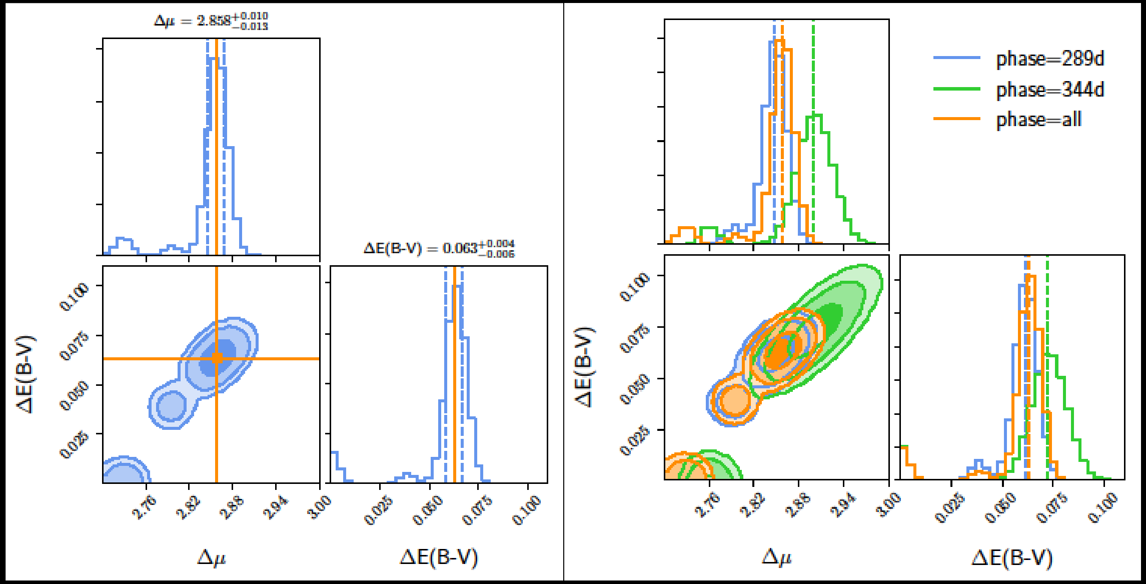




Comparison of the spectra at +289d and at +344d of the twin SNeIa SN 2011fe, in M101, and SN 2018gv, in NGC 2525, and final joint result for the two phases







SN 2011fe in M101/SN 2018gv in NGC 2525

SN 2011fe, being a well studied, standard, nearby SNIa, appears as a very promising "anchor" of a family of twin SNeIa, of which SN 2018gv is a first member.

We obtain $\Delta\mu = 2.858 \pm 0.013$ mag.
As for the difference in reddening, $\Delta E(B-V) = 0.063^{+0.004}_{-0.005}$ mag (SN 2018gv being more reddened than SN 2011fe).

The absolute distance to NGC 2525 depends on that to M101.

Our value is $\mu = 31.933 \pm 0.069$ mag D = 24.35 ± 0.77 Mpc.

There was an earlier value, from Cepheids, with large error: $\mu = 32.067 \pm 0.100$ mag
D = 25.90 ± 1.23 Mpc (Riess et al. 2022)
The present value from the *JWST* TRGB is μ=31.81 ± 0.08, D=23.014 +- 0.86 Mpc (Riess et al. 2024)

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Now, with *JWST* data: $\mu = 31.81 \pm 0.08$ mag (D = 23.01 ± 0.87 Mpc) (*Cepheids*, Li et al. 2024)

The distances to SN 2018gv and SN 2011fe

2018gv	$\mu = 32.067 \pm 0.10$	Cepheids[1]
2018gv	$\mu = 31.933 \pm 0.069$	This work
2011fe	$\mu = 29.135 \pm 0.045$	Cepheids[2]
2011fe	$\mu = 29.194 \pm 0.039$	Cepheids[1]
2011fe	$\mu = 29.07 \pm 0.09$	Tip of the Red Giant Branch[3]
2011fe	$\mu = 29.10 \pm 0.06$	Mira variables[4]
2011fe	$\mu = 29.06 \pm 0.05$	Appendix A
2011fe	$\mu = 29.075 \pm 0.068$	Obtained M101 ladder step

[1] Riess et al. (2022). [2] Riess et al. (2016).
[3] Freedman et al. (2019). [4] Huang et al. (2024).

Ruiz-Lapuente & González Hernández (2024)

Moduli and distances from the present work *vs* Cepheid and TGB moduli

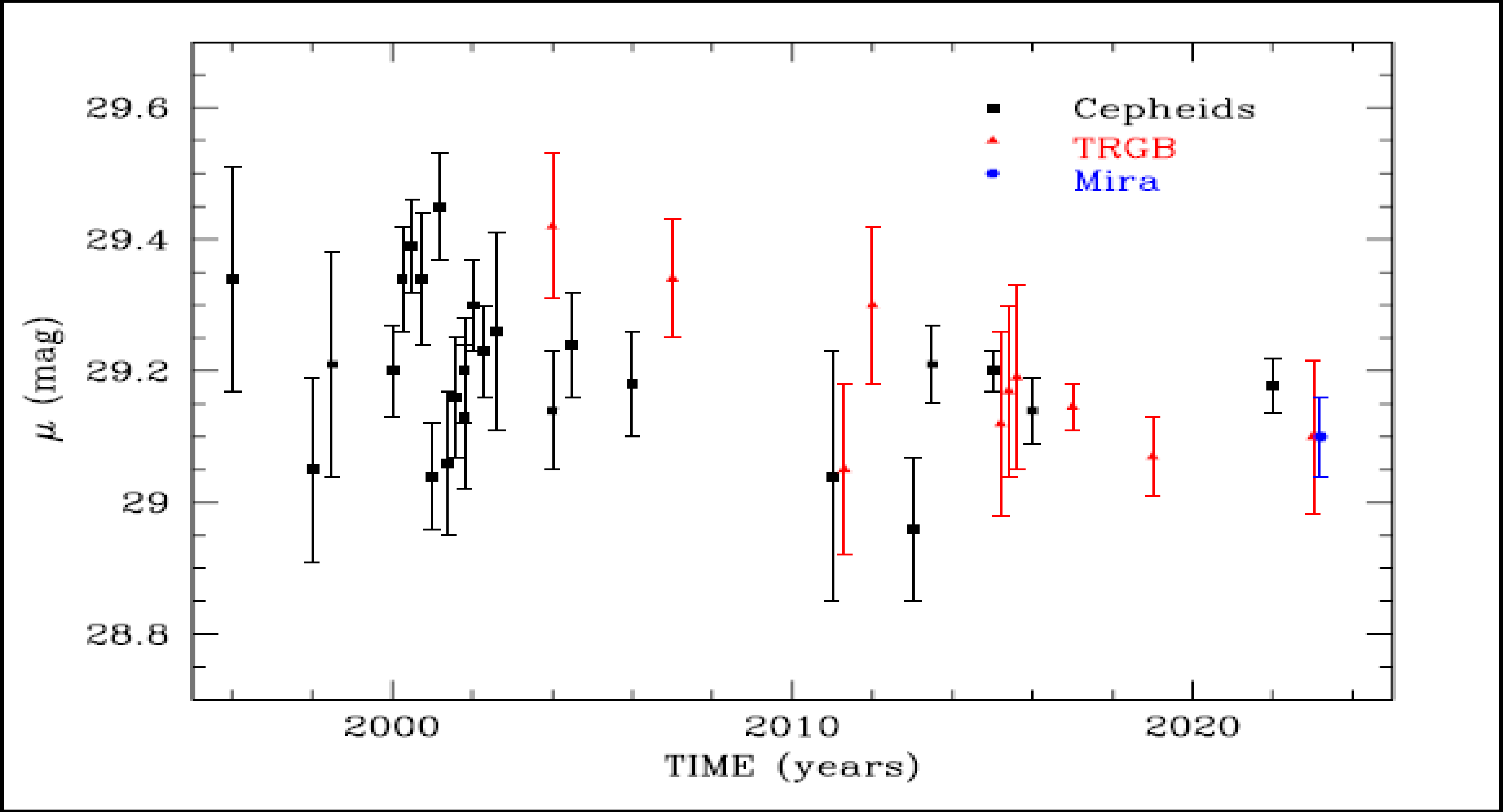
Galaxy	μ (mag)	D (Mpc)	μ Cepheids (mag)[1]	μ TRGB (mag)
M 101	29.075±0.068	6.53±0.20	29.194±0.039[2]	29.08±0.04[3]
NGC 5643	30.48± 0.065	12.47± 0.37	30.570±0.050[4]	30.48± 0.1[5]
			30.51±0.08[6]	30.61±0.07[6]
NGC 7250	31.518±0.065	20.12±0.70	31.628±0.126	...
			31.41±0.12[6]	31.62±0.04[6]
NGC 2525	31.933±0.069	24.35±0.77	32.067±0.100	...
			31.81±0.08[7]	

[1]Riess et al. (2022). [2]29.10±0.06 from Mira variables (Huang et al. 2024). [3]Freedman et al. (2019). [4]Changed to 30.52±0.02 in Riess et al. (2024). [5]Hoyt et al. (2021). [6]Freedman et al. (2024). [7]Li, Anand, Riess et al. (2024)

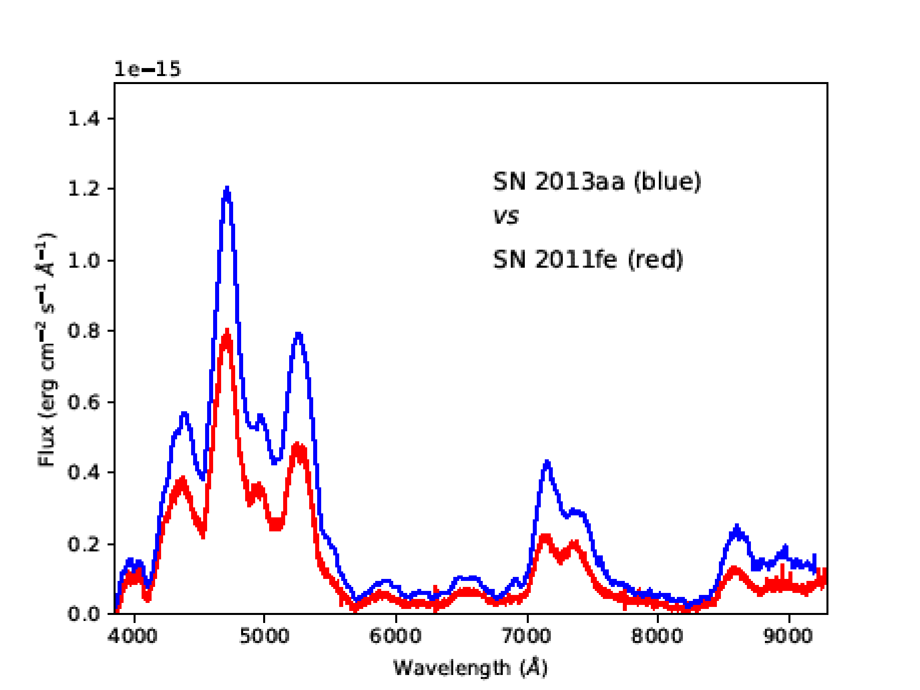
The distance to M101

Reference	Distance Modulus (mag)	Notes
Cepheid Distances		
Kelson et al. (1996)	29.34 ± 0.17	
Stetson et al. (1998)	29.05 ± 0.14	
	29.21 ± 0.17	
Kennicut et al. (1998)	29.20 ± 0.07	
	29.34 ± 0.08	
	29.39 ± 0.07	
Ferrarese et al. (2000)	29.34 ± 0.10	
Macri et al. (2001)	29.04 ± 0.08	Inner field, $F160W$
	29.45 ± 0.08	Outer field, $F160W$
Newman et al, (2001) 29.06 ± 0.11		
	29.16 ± 0.09	
Willick & Batra (2001)	29.20 ± 0.08	
Freedman et al. (2001)	29.13 ± 0.11	final result of the HST Key Project
Paturel et al.(2002)	29.30 ± 0.07	
	29.23 ± 0.07	
	29.26 ± 0.15	
Sakai et al. (2004)	29.14 ± 0.09	
	29.24 ± 0.08	
& Saha et al. (2006)	29.18 ± 0.08	
Shappee & Stanek (2011)	29.04 ± 0.05 (stat) ±0.18 (sys)	
Mager et al. (2013)	28.96 ± 0.11	
Tully et al. (2013)	29.21 ± 0.06	
Nataf (2015)	29.20 ± 0.03	Using Cepheid sample from Shappee & Stanek (2011)
Riess et al. (2016)	29.14 ± 0.05	SH0ES 2016 result
Riess et al. (2022)	29.178 ± 0.041	Distance without inclusion of SN, SH0ES 2022 result
Freedman et al. (2024)	29.14 ± 0.08	
TRGB Distances		
Sakai et al. (2004)	29.42 ± 0.11	
Rizzi et al. (2007)	29.34 ± 0.09	
Shappee & Stanek (2011)	29.05 ± 0.06 (stat) ± 0.12 (sys)	
Lee & Jang (2012)	29.30 ± 0.01 (stat) ±0.12 (sys)	
Tikhonov et al. (2015)	29.12 ± 0.14	
	29.17 ± 0.13	
	29.19 ± 0.14	
Jang & Lee 2017	29.145 ± 0.035	
Beaton et al. (2019)	29.07 ± 0.04 (stat) ±0.05 (sys)	Carnegie-Chicago Hubble Program result
Scolnic et al. (2023)	29.10 ± 0.116	Assuming tip luminosity $M_{I,\mathrm{TRGB}}^{R=4} = -4.030 \pm 0.035$ mag
Freedman et al. (2024)	29.18 ± 0.04	
Mira Distances		
Huang et al. 2023	29.10 ± 0.06	

The distance to M101

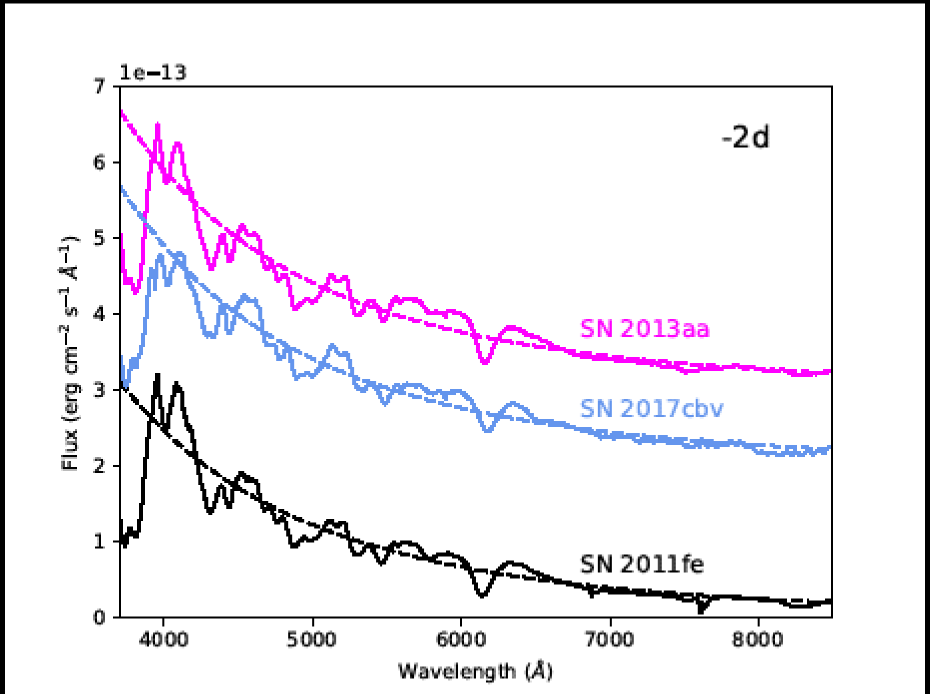


Twin and not twin SNeIa



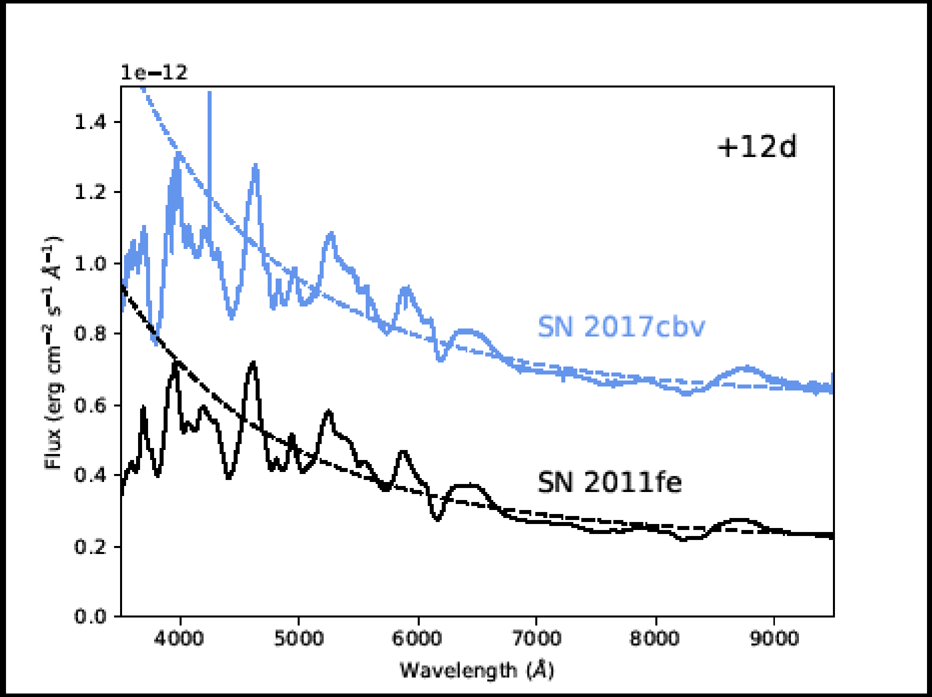
Comparison of the spectra of SN 2013aa and SN 2011fe at he same phase. A reddening of E(B-V) = 0.15 mag has been applied to SN 2011fe for that

Twin and not twin SNeIa



Comparison of SN 2017cbv/SN 2013aa with SN 2011fe at -2d. The T_{eff} of the photosphere of SN 2017cbv/SN 2013aa is 2000 K higher tan that of SN 2011fe

Twin and not twin SNeIa



Comparison of SN 2017cbv with SN 2011fe at +12d. The T_{eff} of the photosphere of SN 2017cbv is 2000 K higher tan that of SN 2011fe

Supernova	Δm_{15} (B) [mag]	s_{BV}^{D}	$pW1$ (Ca II H&K) [Å]	$pW5$ (S II W) [Å]	$pW6$ (Si II 5972) [Å]	$pW7$ (Si II 6355) [Å]
SN 2011fe	1.07±0.06	0.919±0.004	111±1	74±1	16.0±0.5	98±1
SN 2013aa	0.96±0.01	1.11±0.02	74±1	67±1	10.0±0.5	84±1
SN 2017cbv	0.96±0.02	1.11±0.03	64±1	69±1	10.0±0.5	76±1

Supernova	$\Re_{Si}$
SN 2011fe	0.23±0.05
SN 2013aa	0.10±0.05
SN 2017cbv	0.13±0.05

(from Ruiz-Lapuente & González Hernández 2024: ApJ (in press), arXiv:2312.10334)

Discussion

Comparison of the spectra of twin SNeIa along different phases can determine distance moduli within an error down to $\Delta\mu \approx 0.04$ mag

The discrepancies on the value of H_0 obtained from *Cepheids* with those from the *TRGB* and *JAGB* methods arise from the distance ladder by different methods, and the link between the nearby SNeIa sample and that in the Hubble flow

The weighted (unweighted) mean difference between the *JAGB* minus *Cepheid* distance moduli is 0.086 ± 0.028 (0.083 ± 0.031) mag or 4%

Conclusions

To account for the gap between the CMB and Cepheid values for H_0 a change in distance modulus of 5 x log(73,2/67.5) ~0.18 mag for the Cepheid-calibrated SNeIa hosts would be necessary

Since discrepancies increase with distances, very accurate distance indicators are needed. Our method does meet such requirement, given that SNeIa are much more luminous than the usual distance indicators

To deal with the Hubble tension, we plan to apply the twin SNeIa method to pairs reaching up to $z \approx 0.01$-0.03, with spectra covering from the early to the nebular phase. That is achievable with the *JWST* or the *ELT*