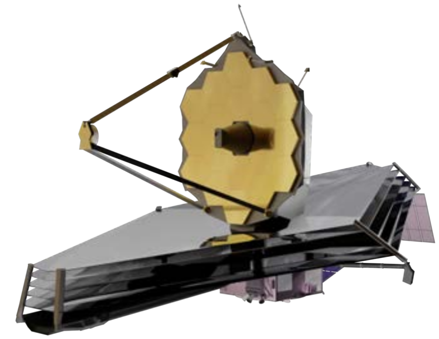
Adam Riess
Johns Hopkins University
Space Telescope Science Institute



JWST and the Hubble Tension

SH_0ES Team and Collaborators

Riess, A.G.+ , ApJ, 2024: All JWST Samples, all methods

Riess, A.+, ApJL, 2023,
ApJL, 2024, 962, L17: JWST Cepheids
Anand, G+ ApJ, 2024, 966, 89: JWST TRGB
Li, S + ApJ, 2024, 966, 20: JWST JAGB
Li, S+ ApJ, 2024,976,177: JWST TRGB
Li, S+ arxiv 250205259: JWST JAGB 2.0

Data Products, code: https://pantheonplussh0es.github.io, paper zenodo links

1. SH$_0$ES Overview

2. Systematics and Scrutiny, ~20 years

3. JWST cross-checks

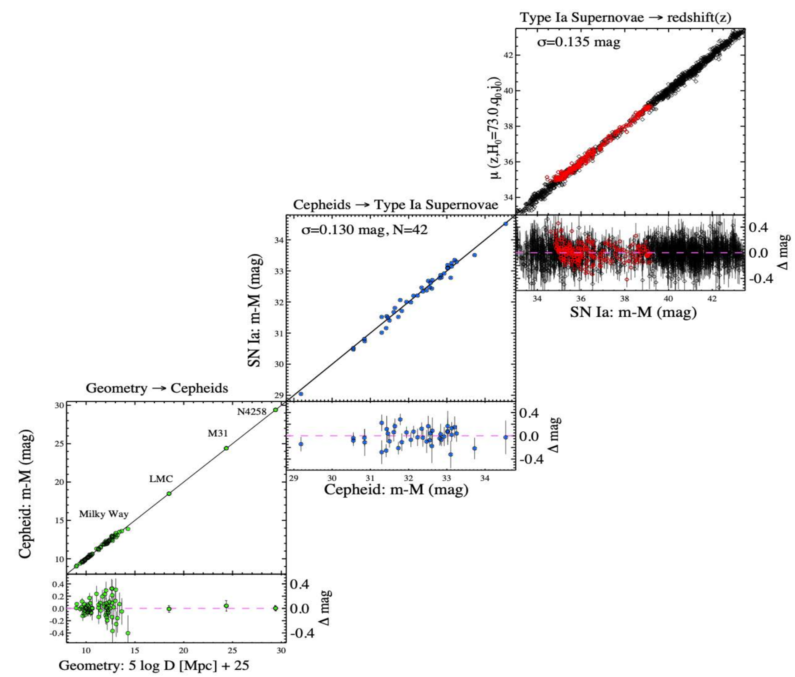
4. H$_0$ differences from SN Sub-sample selection

Brief Review: The SH$_0$ES Project (since 2005)  "most ambitious" ~1%

HST Cycle 11-32, 23 competed proposals,~1200 orbits, 2 JWST

Keys to SH$_0$ES: empirical rigor+gold standards: geometry, Cepheids, SN Ia

SH0ES "DR5"
(Riess et al. 2022)



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- 4 geometric anchors (N4258,MW,LMC,SMC),

-cancel flux calibration rung 1-2 using HST for all Cepheids

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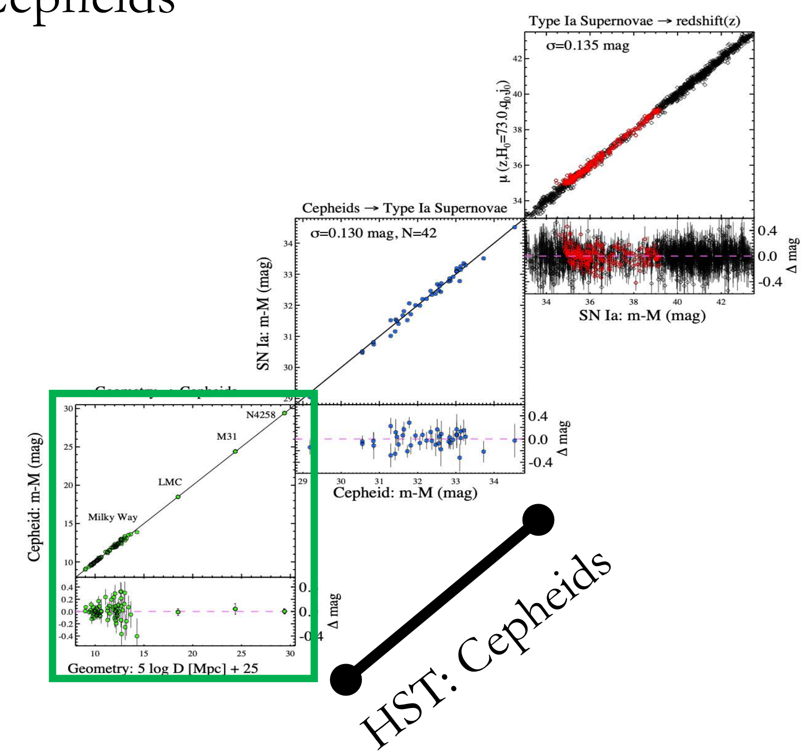

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- Near-Infrared (NIR) + colors minimize dust

- 42 SN Ia in 37 hosts, distance-limited to D~40 Mpc

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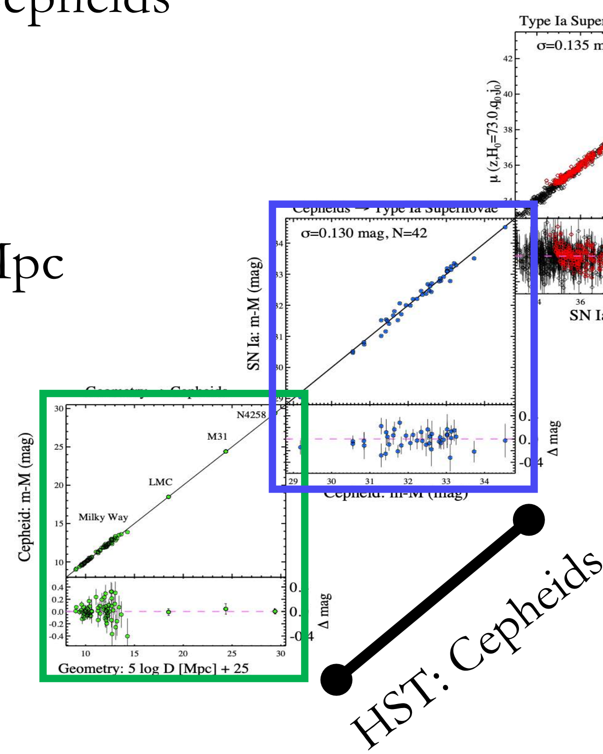

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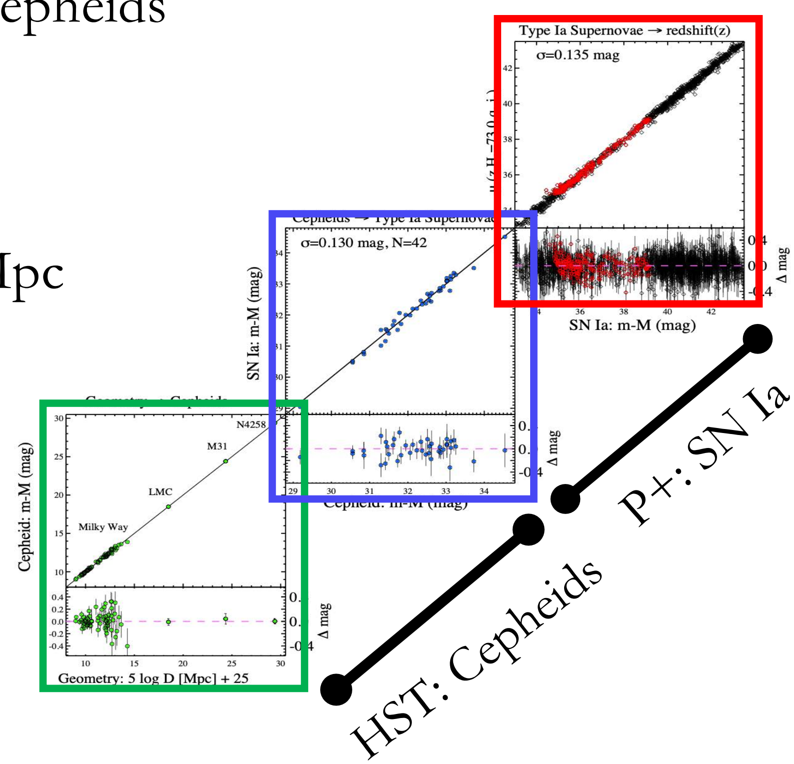


Rung 2: Cepheid variables

- Near-Infrared (NIR) + colors minimize dust

  \- 42 SN Ia in 37 hosts, distance-limited to D~40 Mpc

Rung 3: SN Ia

- Largest hi-quality low-z SN data, calibration

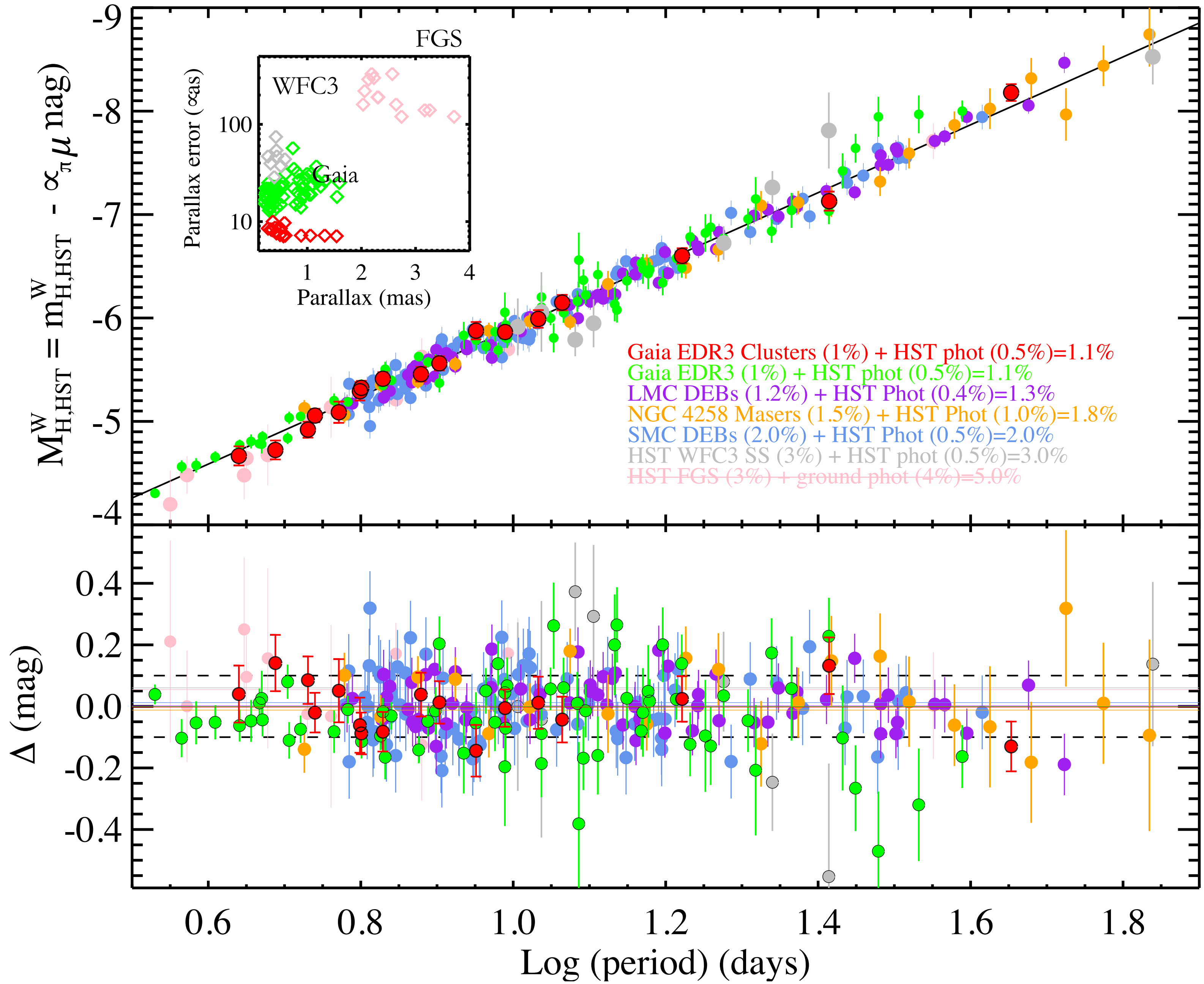
  Pantheon+, survey and host type matched

Overall

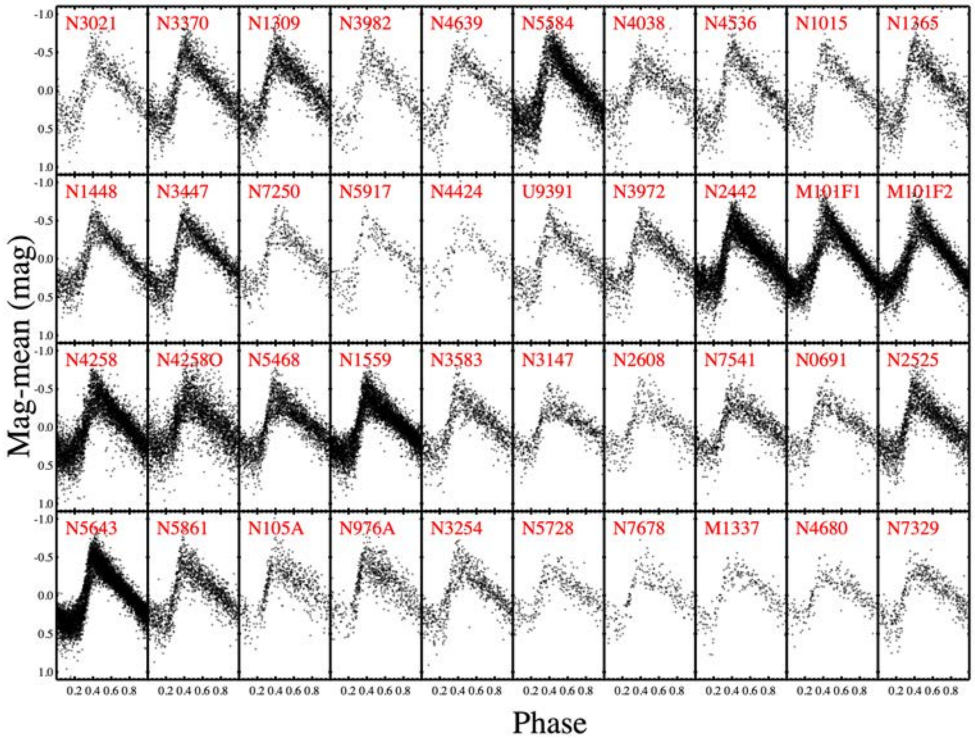
- Comprehensive error analysis propagation, covariance, systematics: 67 analysis variants
- Only team w/ Public release of data, 10^7 data #s, code
- 40+ journal papers, >10,000+ citations since 2005
- Brief tour…

HST/WFC3 Geometric Absolute Cepheid Calibration

- 3 Independent types of Geometric measures, consistent, all w/ HST



SN Ia Host Cepheid Measurements—HST/WFC3



Composite Cepheid
Light Curves,
<u>all periods→ identify</u>

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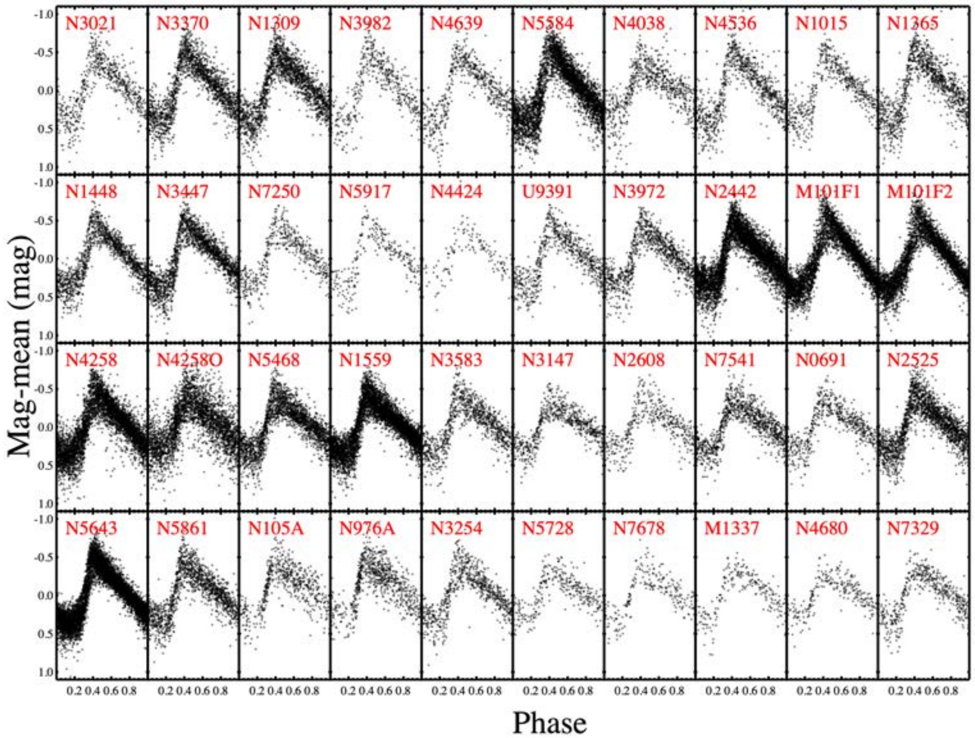
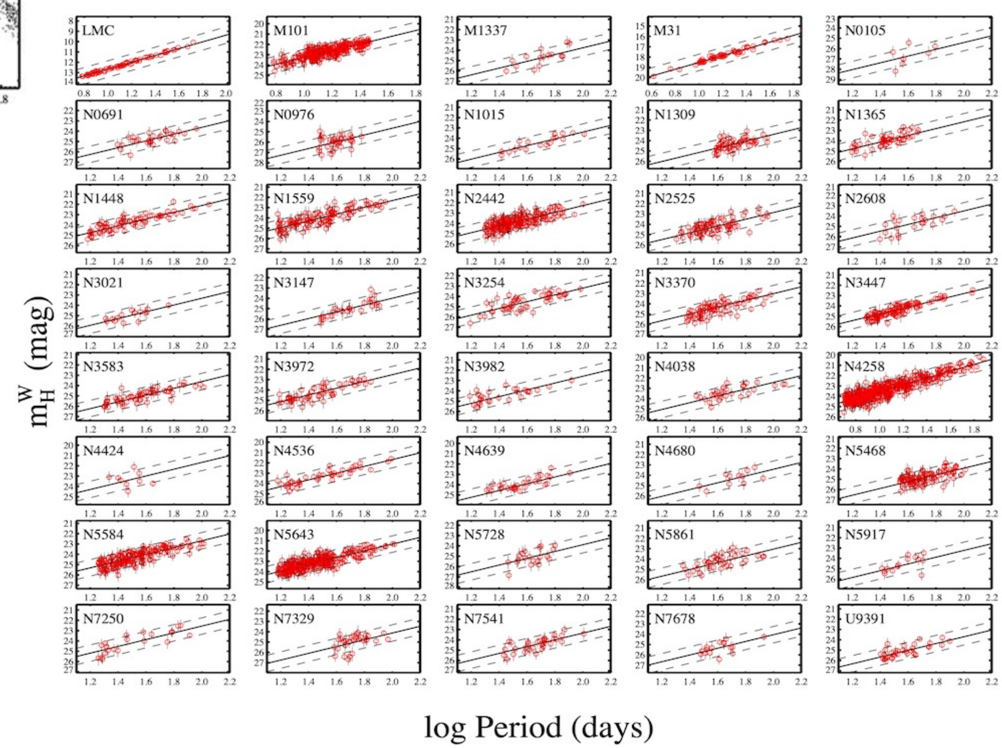


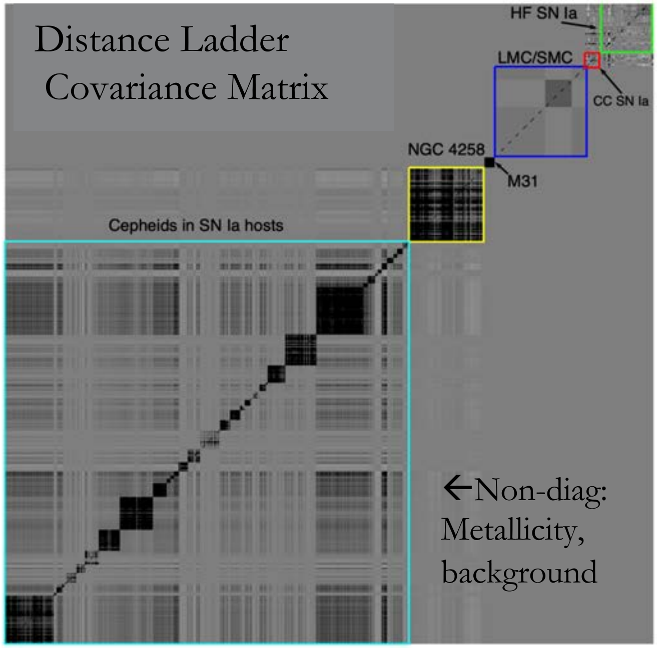
Composite Cepheid
Light Curves,
<u>all periods→ identify</u>

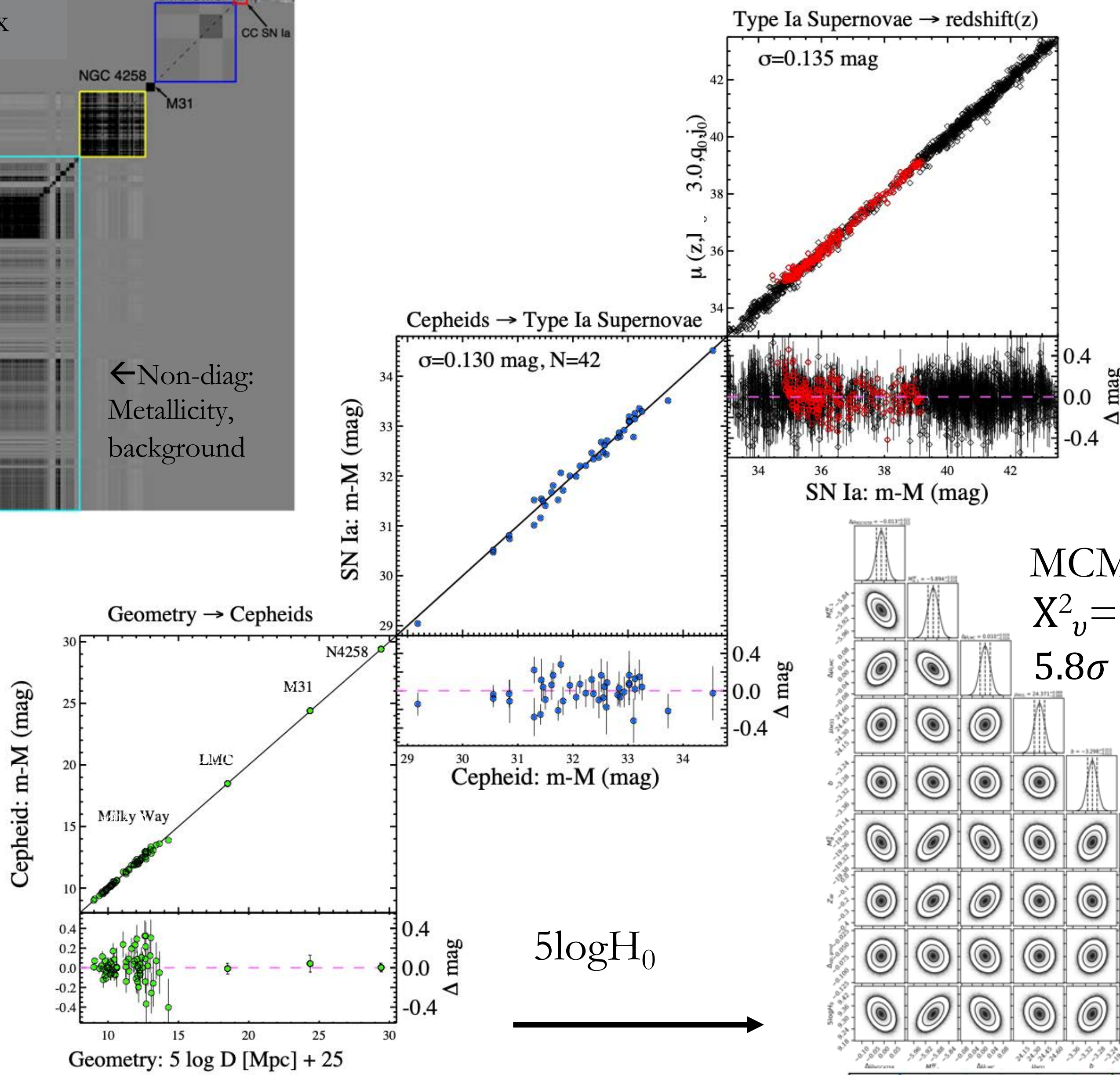
Host Period-
Luminosity
relations,
reddening-free
3 bands→distance



SH$_0$ES Baseline Fit: **H$_0$=73.04 +/- 1.04**, km s^{-1} Mpc^{-1}, w/ systematics

5 free params: [SN Ia, Lum., Cepheid slope, Z, 5logH$_0$]

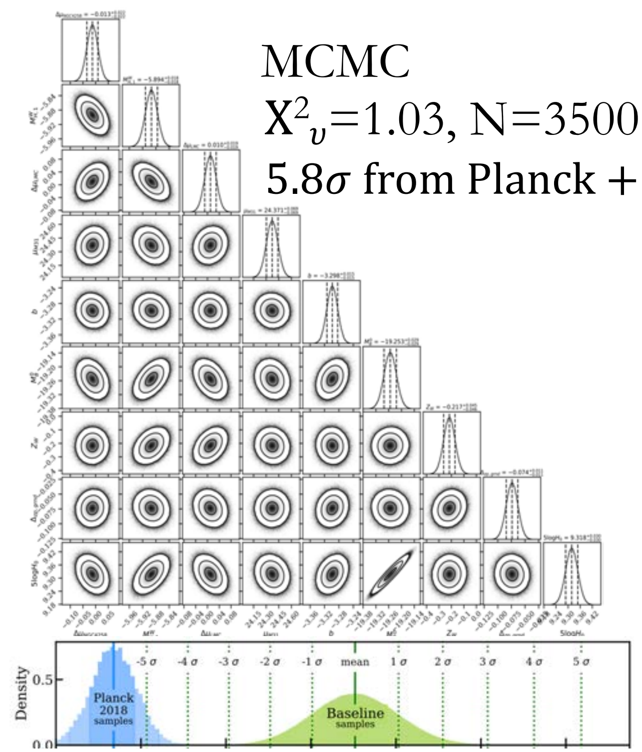




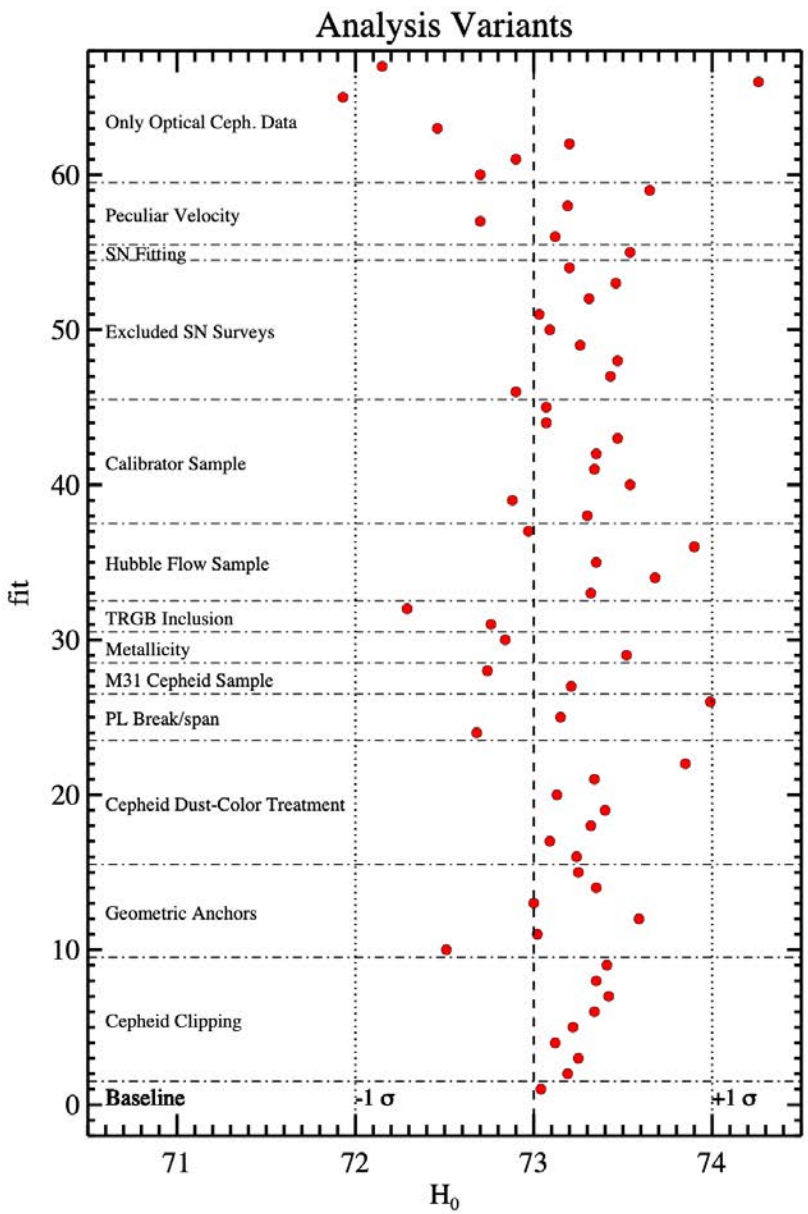
Riess+2022
SH$_0$ES DR5

MCMC
X^2_{υ}=1.03, N=3500
5.8σ from Planck + ΛCDM

5logH$_0$



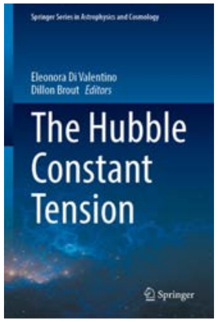
Thorough, Careful, Comprehensive Analysis: 67 variants, bifurcations, etc

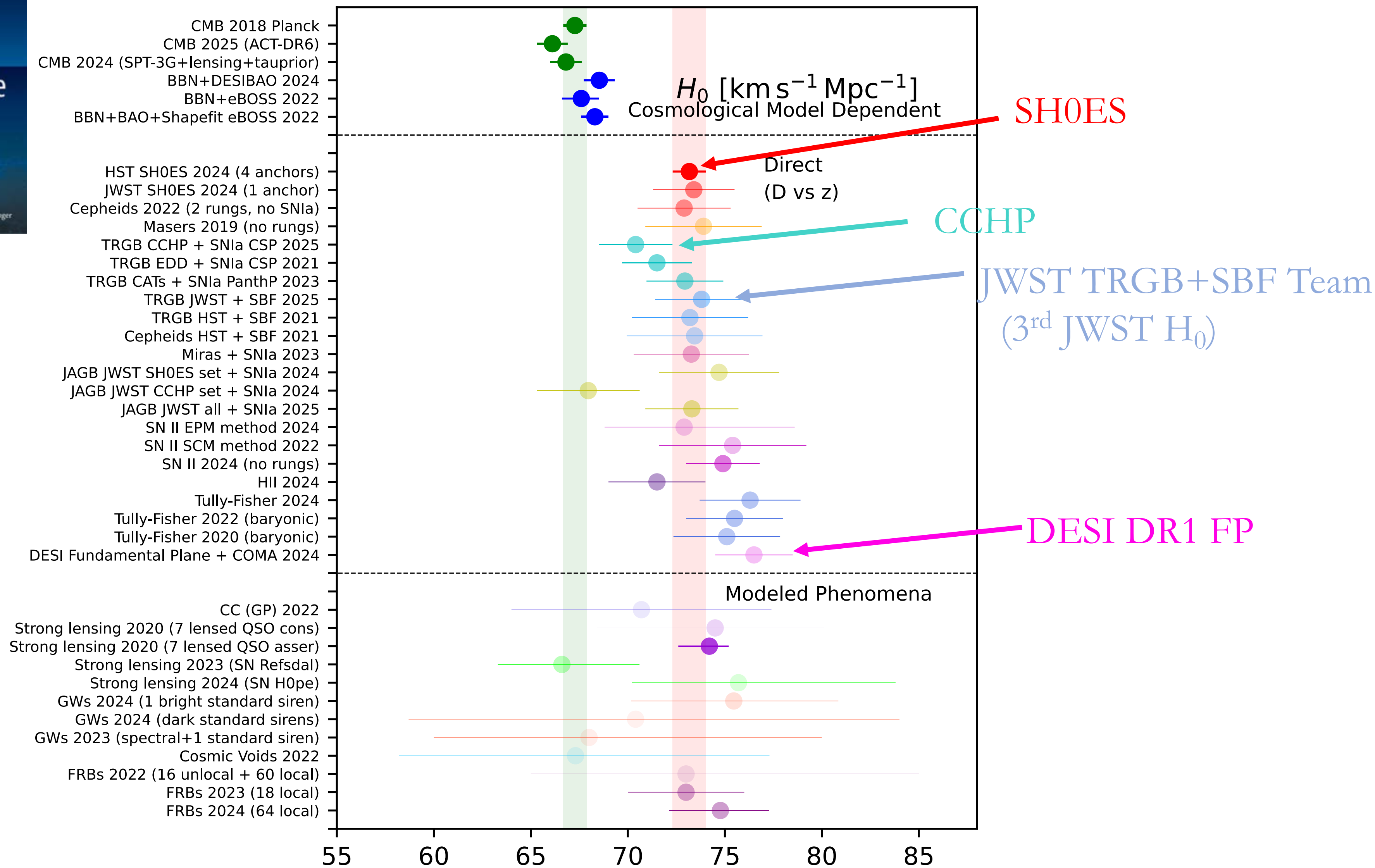


- Optical Cepheid data only (72.7)
- **Different pec. vel map or none (73.1,72.7)**
- SN scatter ind. wave+mass step (73.5)
- No pre-2000 SNe (73.2)
- **closest half hosts D<28 Mpc (73.1)**
- most crowded half (73.4)
- least crowded half (73.3)
- Skip "local hole" z>0.06 (73.4)
- All host types (73.3)
- include TRGB (consistent) jointly (72.5)
- No metallicity term (73.5)
- Break in PL at P=10 days (72.7)
- Period Cut >10 days (73.2)
- No dust correction (74.8)
- Individual host dust law (73.9)
- Free param dust law (73.3)
- Low R_V=2.5 dust law (73.2)
- Two of three anchors (73.0,73.4,73.2)
- No outlier rejection (73.4)

Exhaustive tests: hard to get below 72, above 74. No single source suspect!

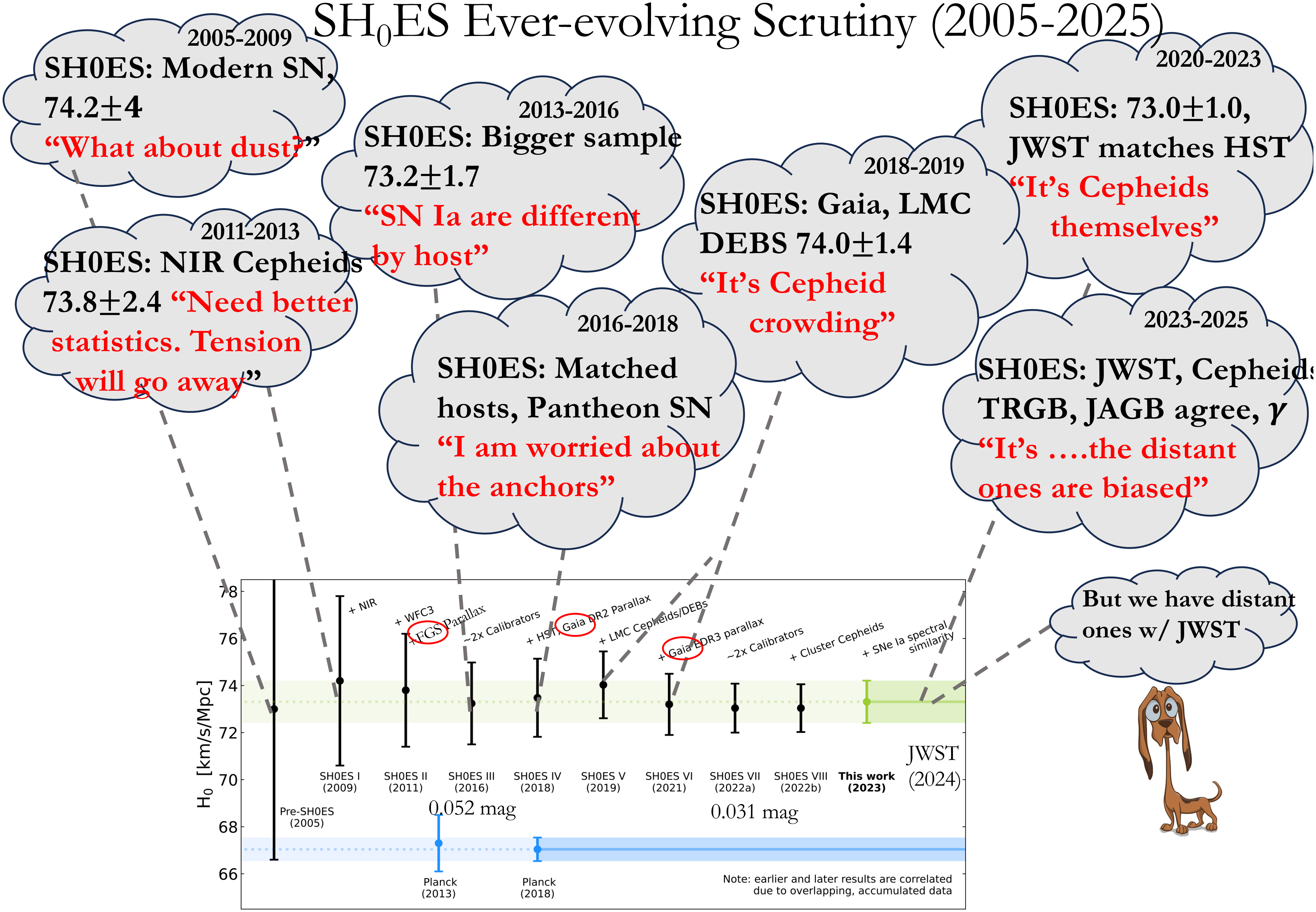
Hubble Tension: Direct vs Cosmological (modeled phenomena ~muddy)





From CosmoVerse paper (500+ authors), arXiv:2504.01669 (EDV+25)
in preparation: Consensus "Distance Network"

SH_0ES Ever-evolving Scrutiny (2005-2025)



Iteration, public releases essential for progress. Updates: good, not for "gotchas",use latest!

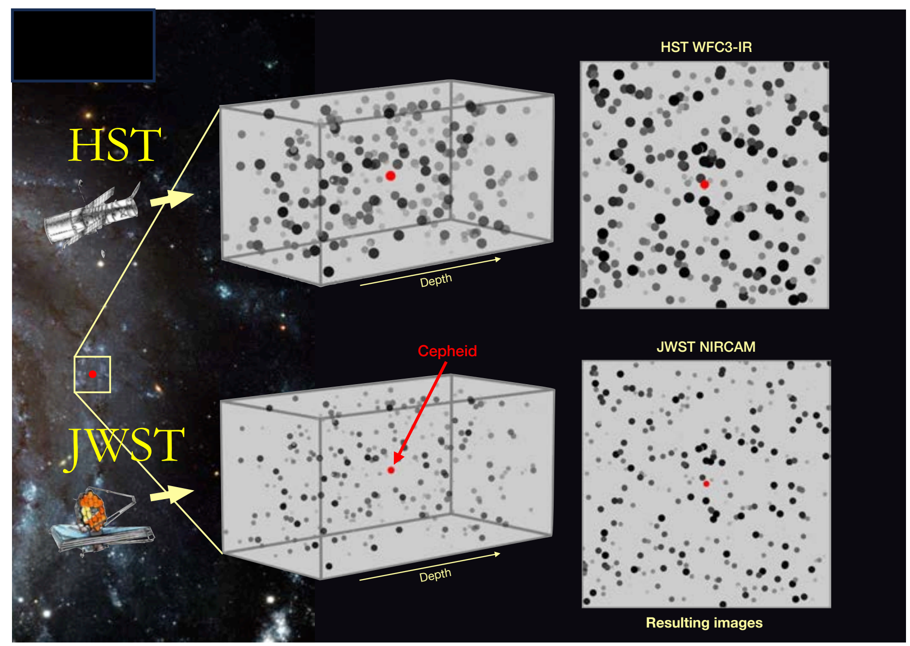
Errors or New Physics? Hubble Tension Proposals (2013-2023)

Most Frequently Asked-and-Answered Questions

1. ~~HST zeropoint/linearity error?~~
2. ~~Dust (weird dust)?~~
3. ~~Cepheid metallicity dependence?~~
4. ~~Not significant?~~
5. ~~Error in the CMB measurements?~~
6. ~~LMC/N4258 distance, Gaia parallaxes wrong?~~
7. ~~Extragalactic Cepheids are different?~~
8. ~~We live in a giant void (z~0.05)?~~
9. ~~Problem/difference in SN Ia?~~
10. Near-infrared Cepheid crowding?

QR Code link to literature checks

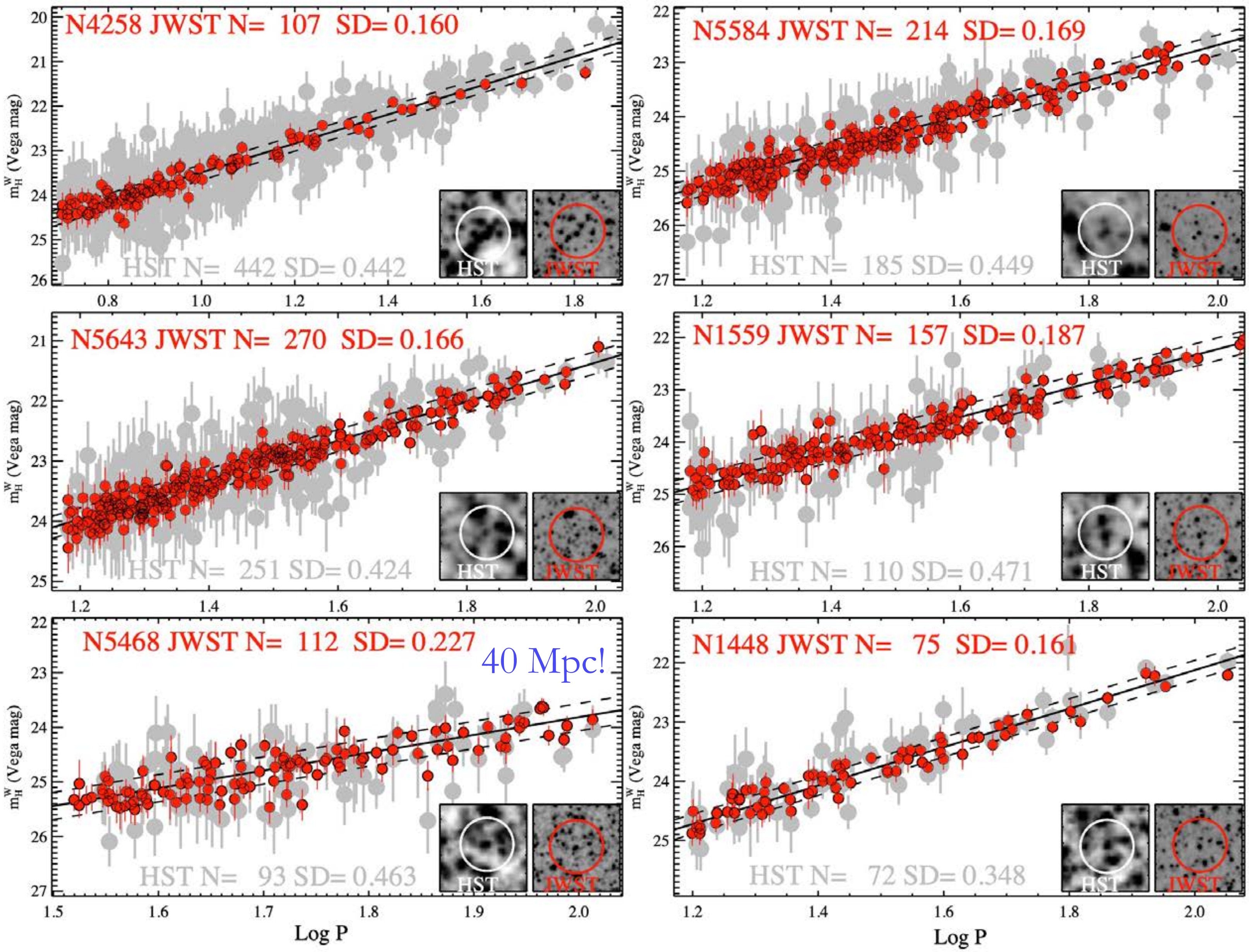
https://djbrout.github.io/SH0ESrefs.html



Crowding corrected w/ artificial stars not systematic, but biggest noise

High Precision JWST PLRs vs HST: ~**1000** Cepheids in 5 hosts of 8 SN Ia & N4258

With 2 epochs and multi-color we can recover Cepheid phase, 2.5x less NIR scatter than HST!
Crowding (stellar background) reduced by a mean factor of ~6. Remaining << Hubble tension

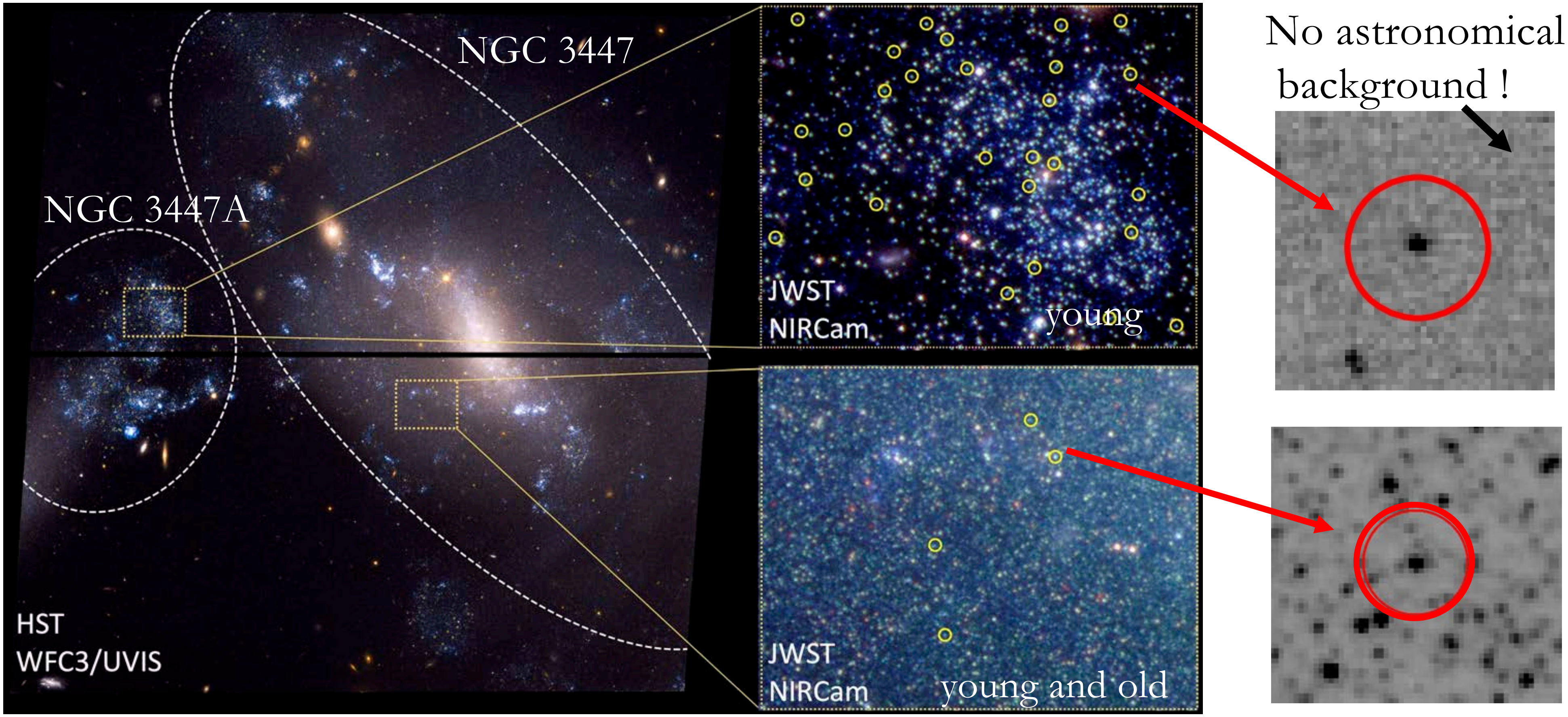


Riess+ 23,24

NEW Cycle 2: Better than low crowding? The **perfect host**, NGC 3447A

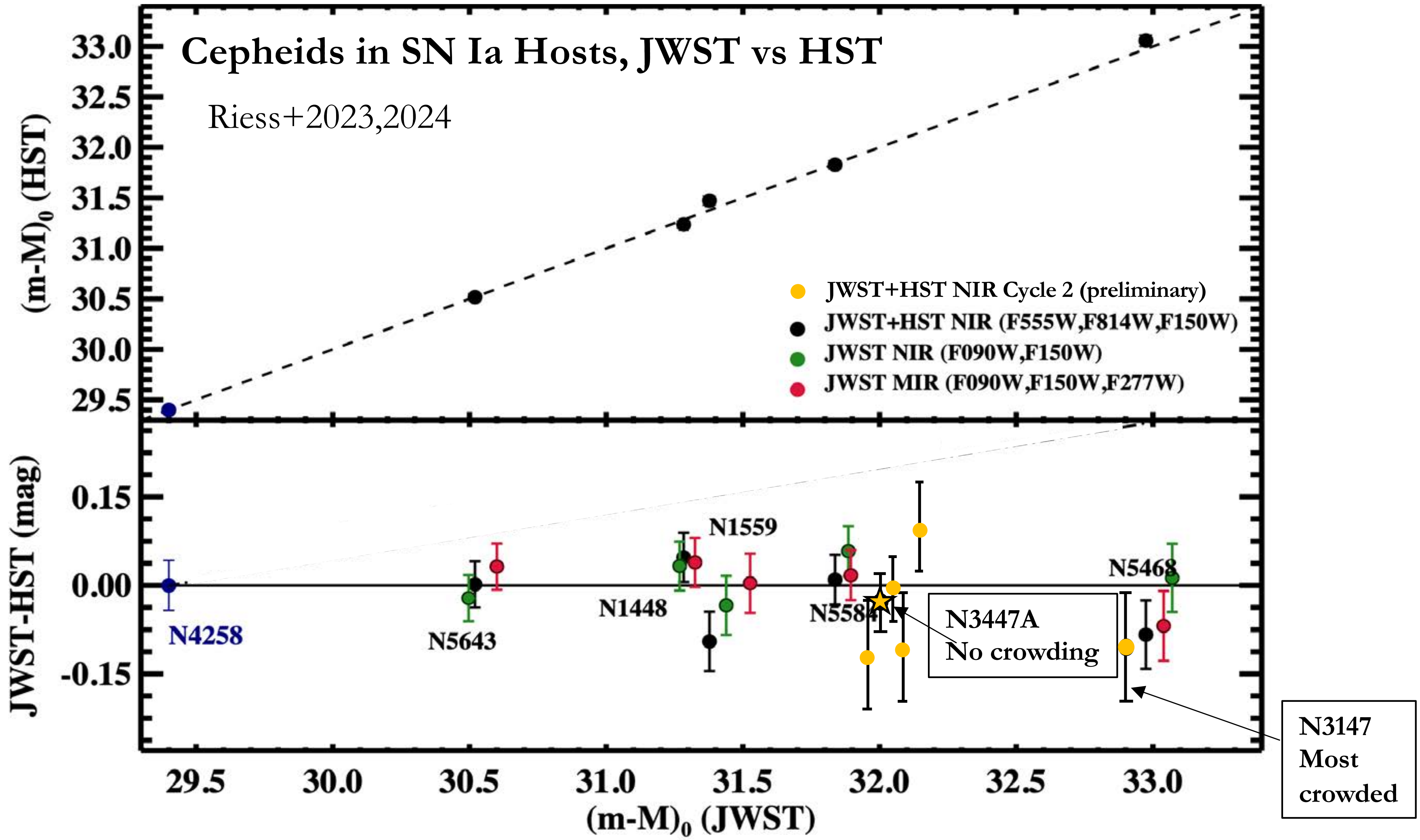
SH_0ES host D~25 Mpc is a merging system: Spiral (NGC 3447) + Tidal dwarf (NGC 3447A)

Spiral: Cepheids form on top of old pop (RG), Tidal: burst, no old pop → no background!



Uncrowded JWST Measurements vs. HST, rules out crowding solution >8σ

Now **19 hosts of 24 SN Ia (>half)** JWST-HST=-0.02 ±0.02 mag, **8 at D>23 Mpc** 0.00 ± 0.03 mag



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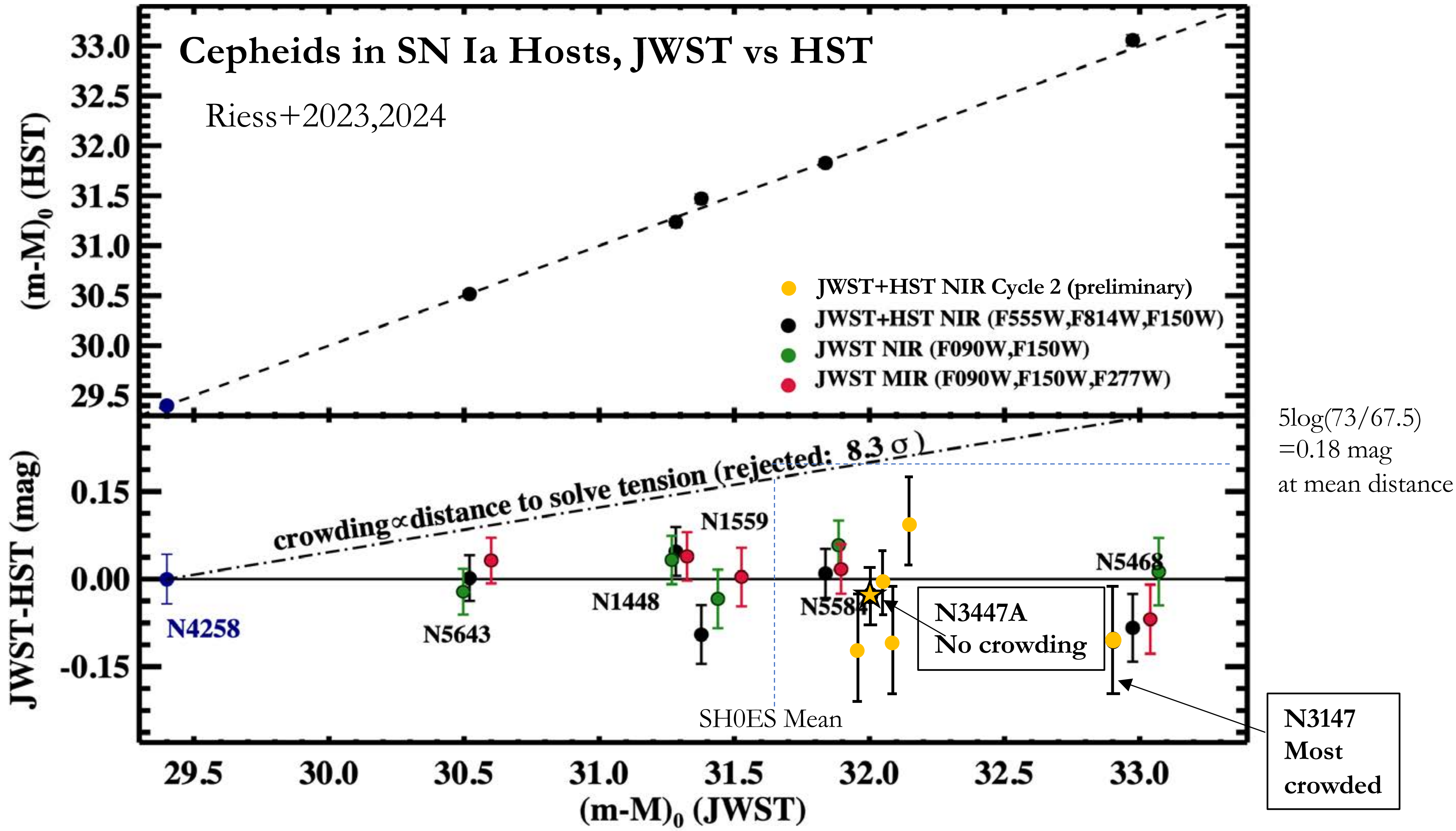

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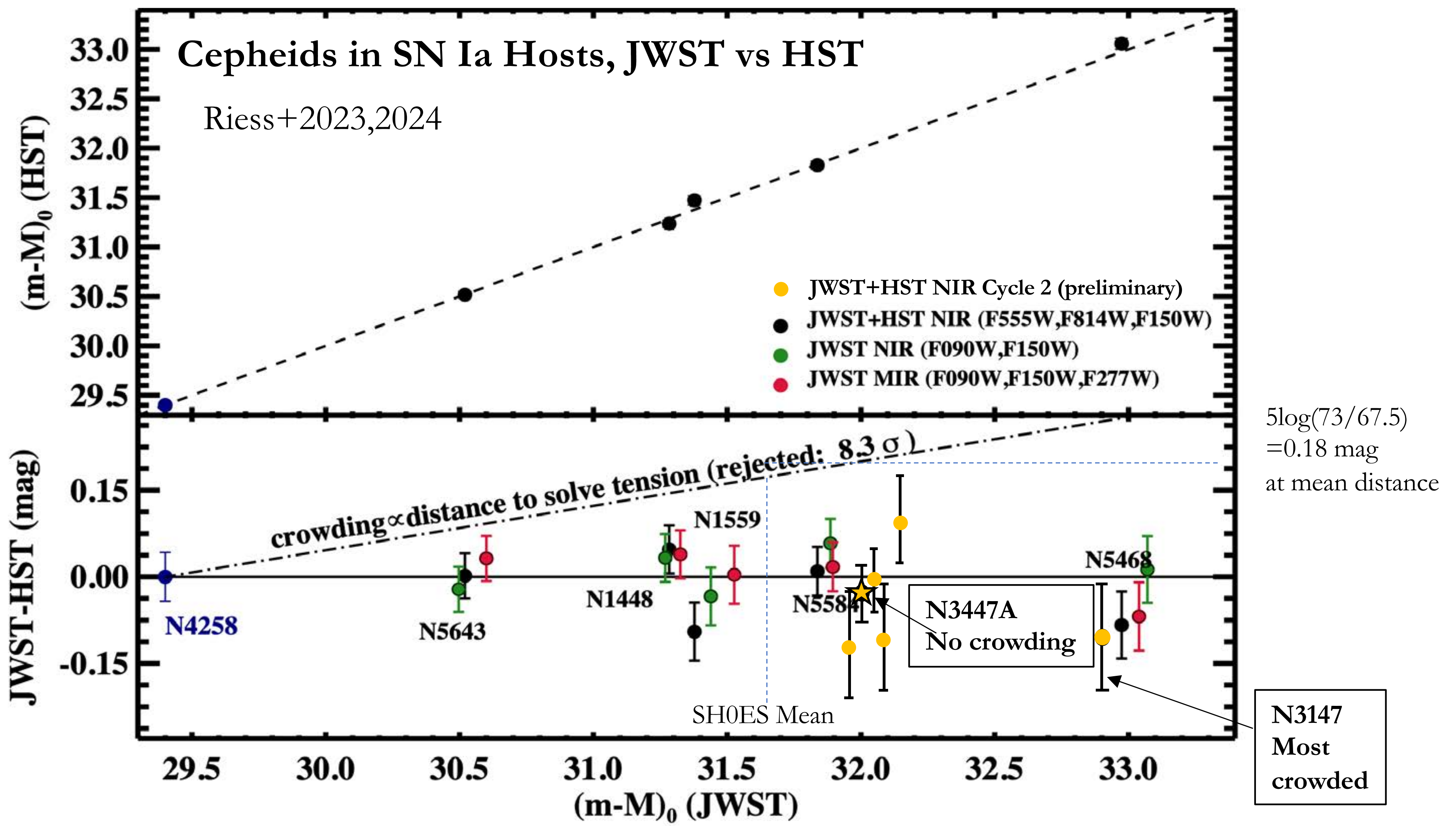
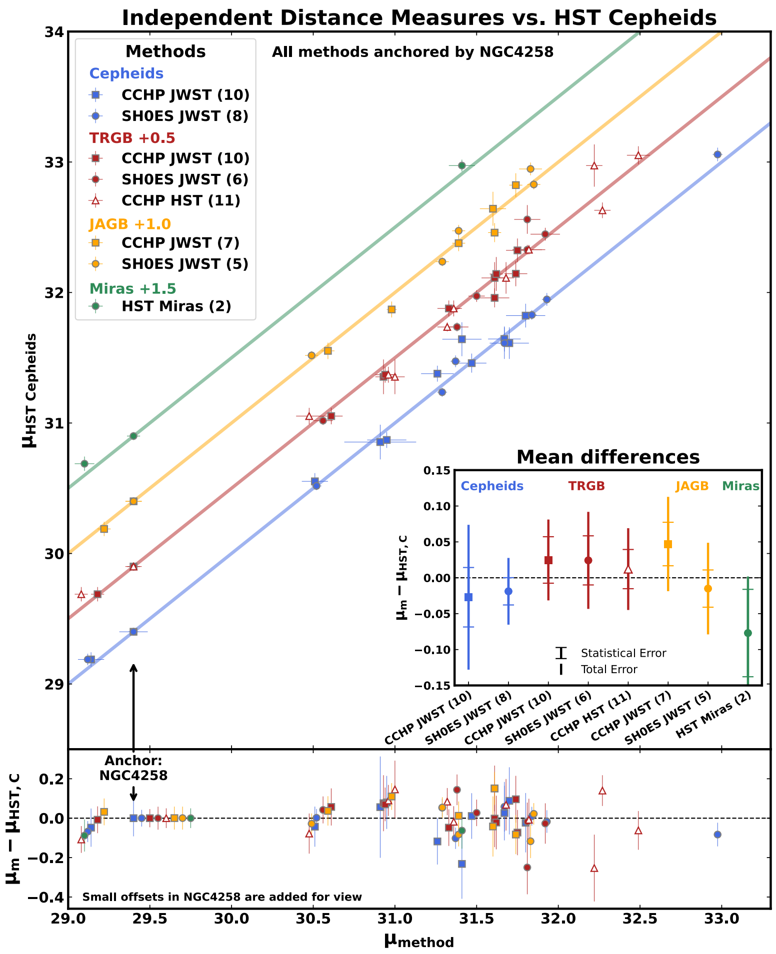


Freedman+2019: "[p]ossibly the **most significant challenge for Cepheid measurements beyond 20 Mpc** is crowding"
Efstathiou 2023 (Munich) "This is really convincing! I have changed my perspective on the Hubble tension…"
JWST TAC 2025: "the previous JWST work on Cepheids show that there is no large systematic bias due to crowding or reddening: not clear further improving the precision with JWST at this point would lead to new insight as to origin of tension"

Other types of stars--consistent distances: 2^{nd} rung not source of tension

Same anchor (N4258) to same SN Ia hosts

- both HST and JWST
- 4 indicators
- Two teams's data (as given, 8 Combos N=59)



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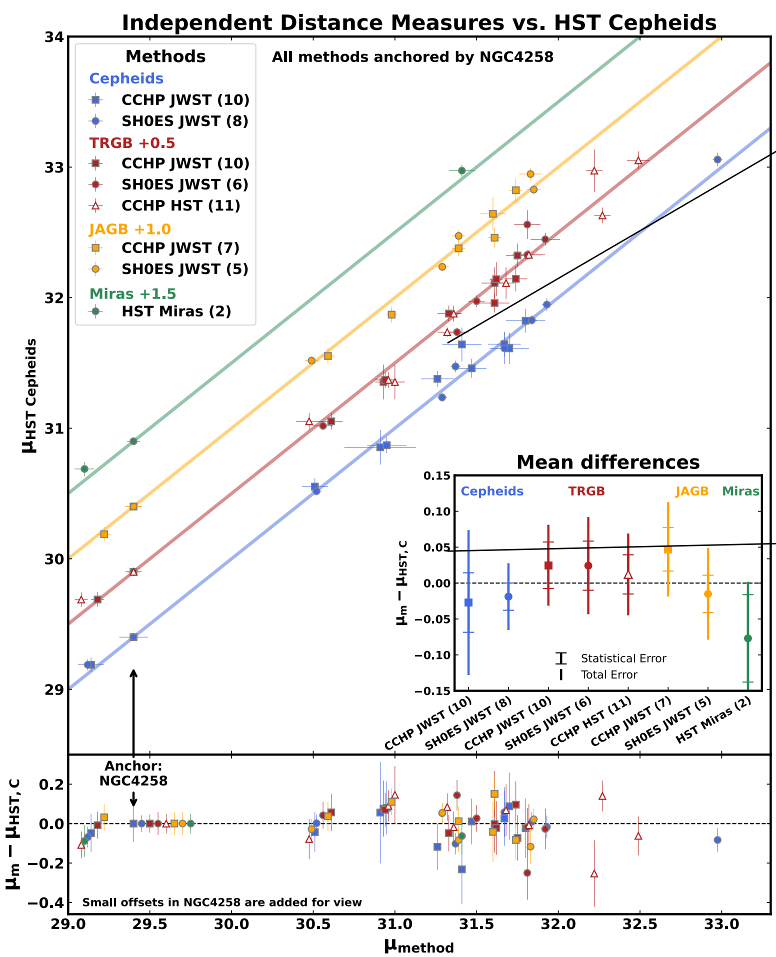
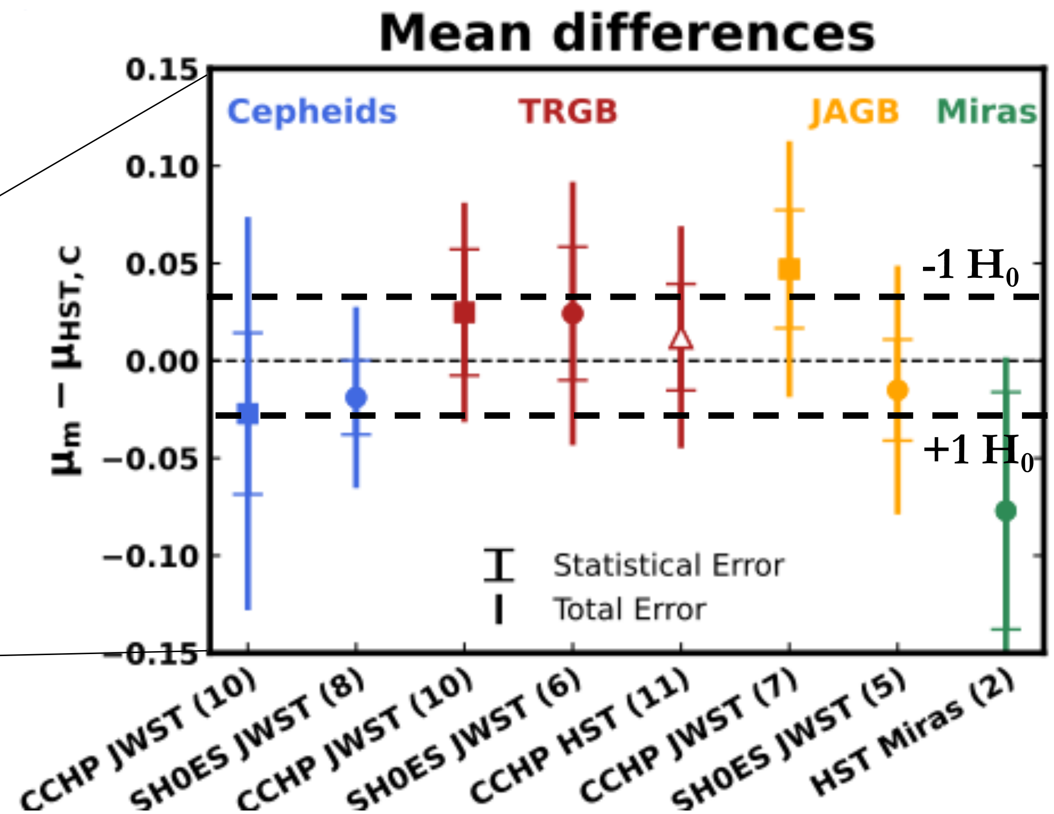
Test is independent of distance to NGC 4258

- All 8 tests ~0 at ~1σ, no evidence not 0
- Most +/- 0.03 mag, vs 0.18 mag Tension





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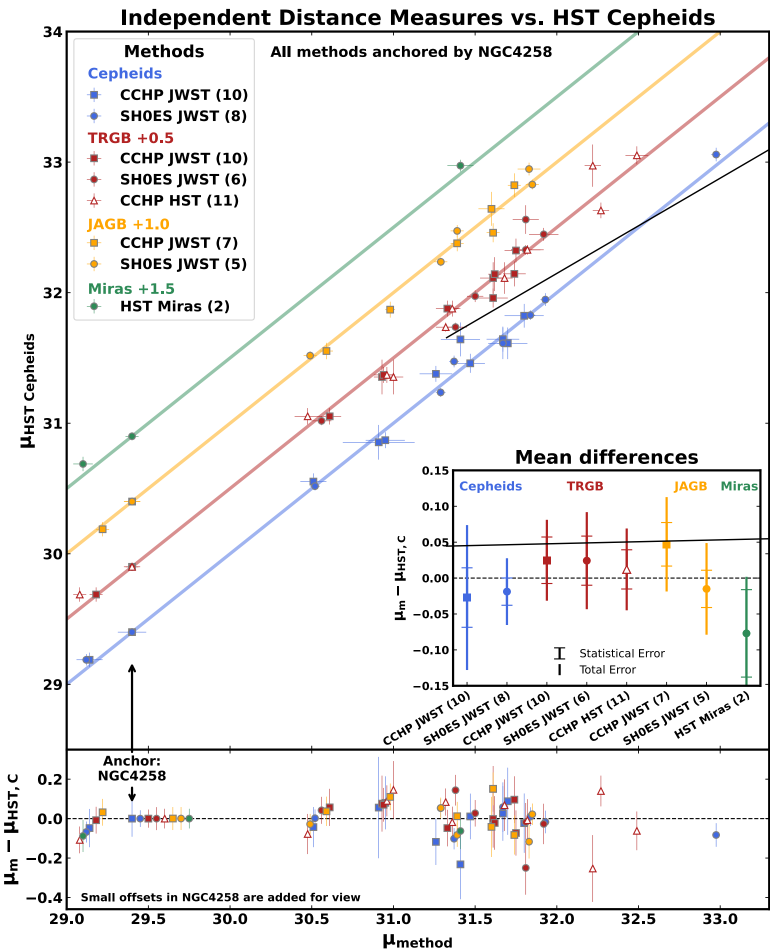
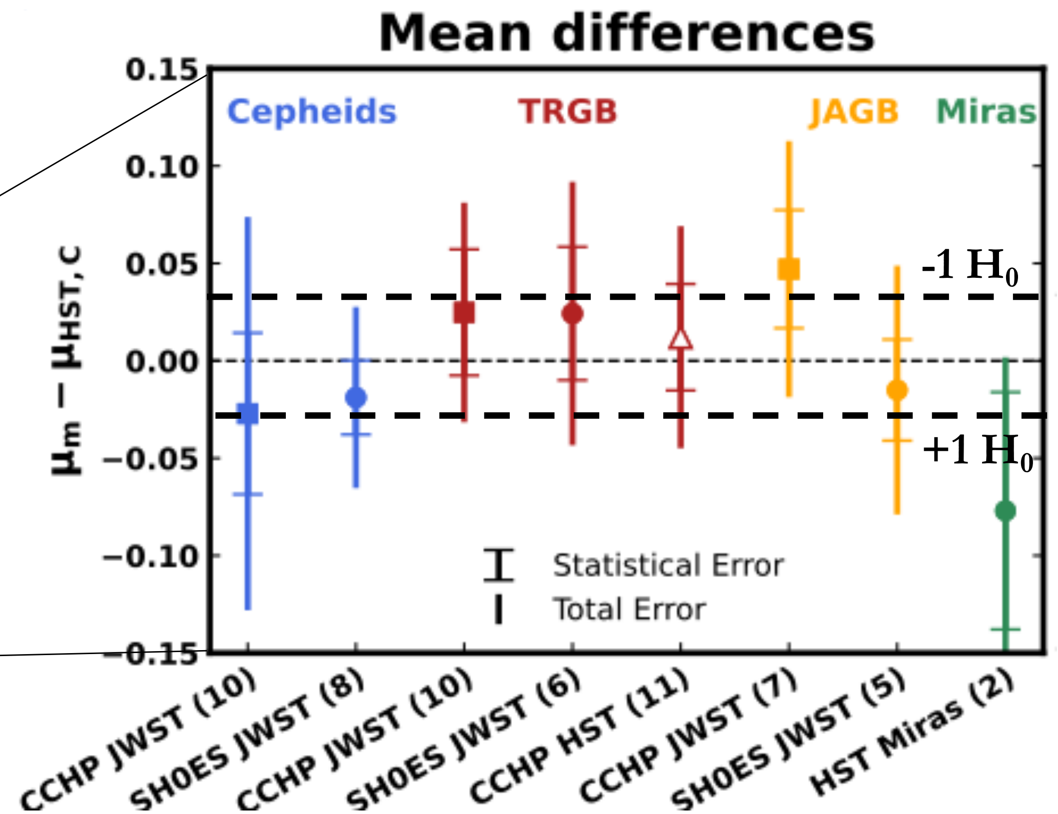
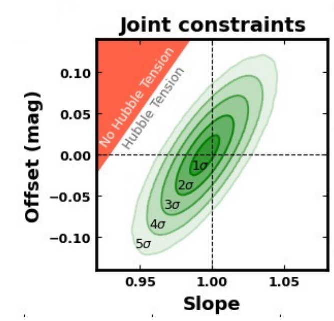




- Cepheid (<1σ) and SN Ia (<1.5σ) distances are linear (vs other indicators)

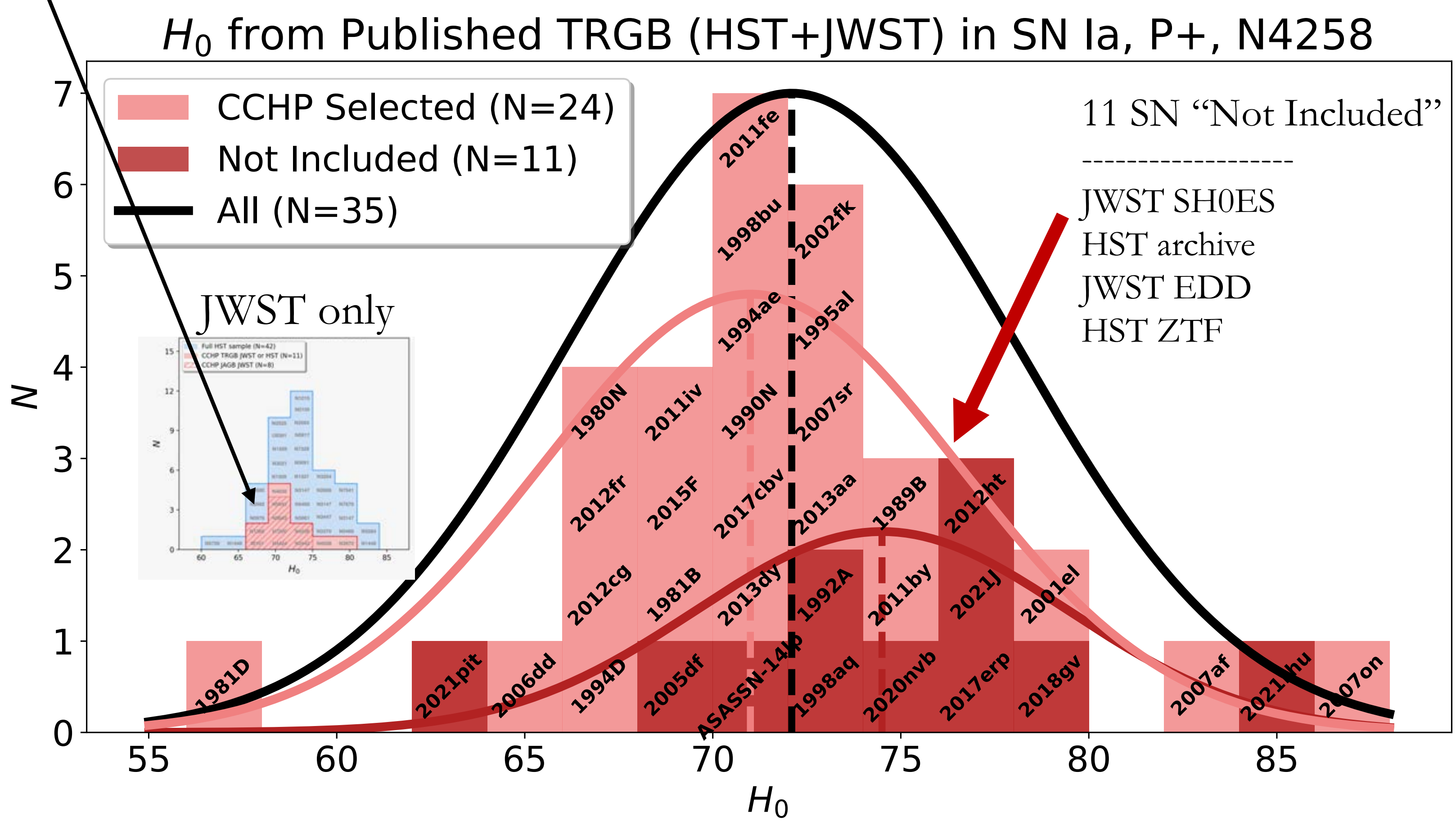


Selection of SN Subsamples Explains Remaining Differences in H_0 *

ALL TRGB Sample HST+JWST **N=35** H_0→72+, CCHP subsample less by~1.5 (Li+2025)

just JWST: CCHP targets lower H_0 by ~2 as seen within Cepheid sample (Riess+22,24)

No reason not to use full available sample 🤷

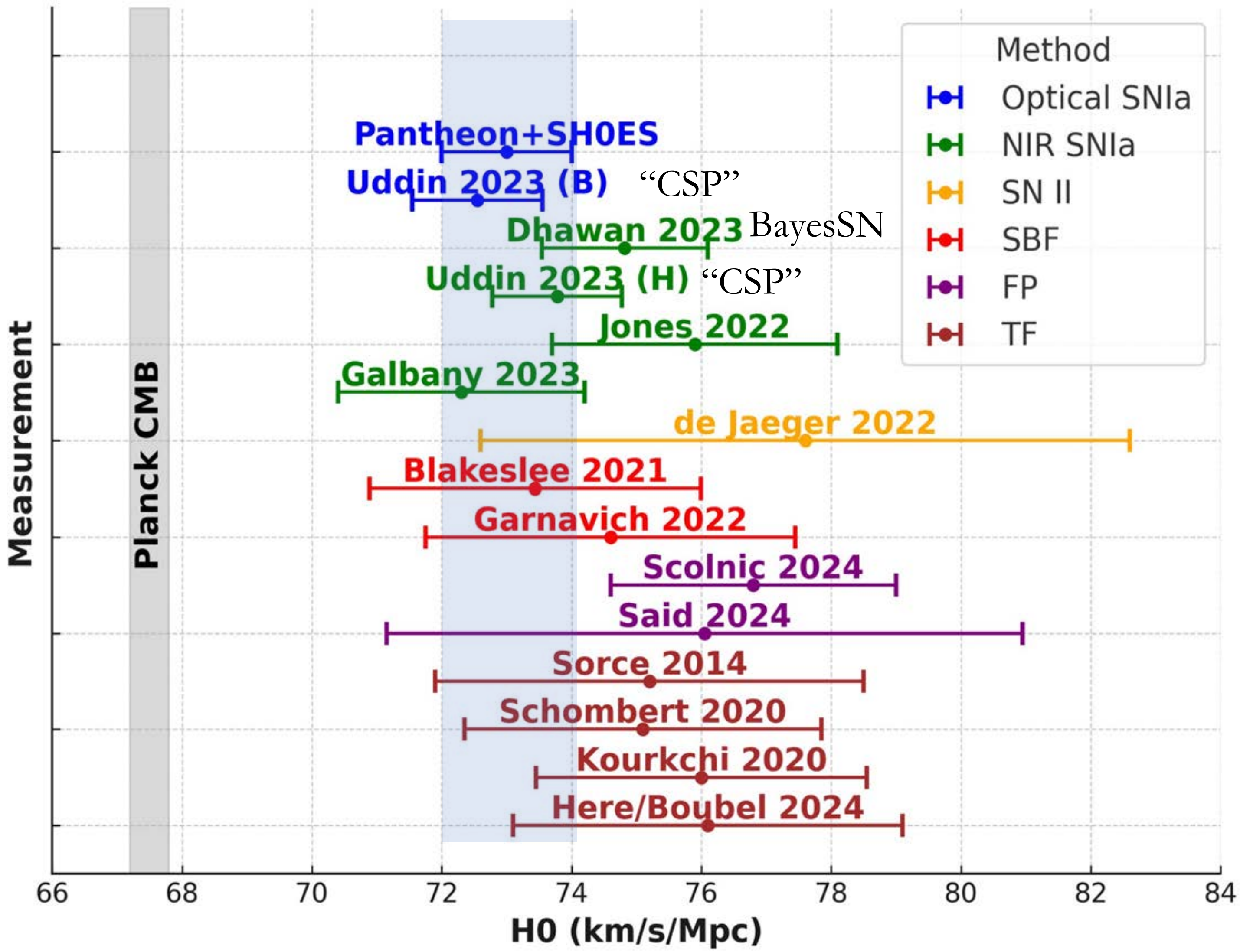


*Smaller: Differences in H_0 between CSP I+II vs Pantheon+ & pec vel corr. at ~0.5 level

Not from Pantheon+ SN: replace it with something else, H_0 goes up

Why prefer Pantheon+ vs CSP SN Ia?

- CSP has only observed ~25% of calibrators
- most of CSP (CSP II) remains **unpublished**



Scolnic+2024

Conclusions

- The local value of H_0 remains inconsistent with CMB+ΛCDM at $>5\sigma$
- 8 Sets of distance Measurements to SN Ia hosts agree (~1%)
  - Cepheids, TRGB, JAGB, Miras, two telescopes, multiple groups
  - Cepheid crowding not an issue, JWST is incredible !
- Supernova subsample selection Explains Differences in Estimates of H_0

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- Supernova subsample selection Explains Differences in Estimates of H_0

- Hubble tension remains compelling because:

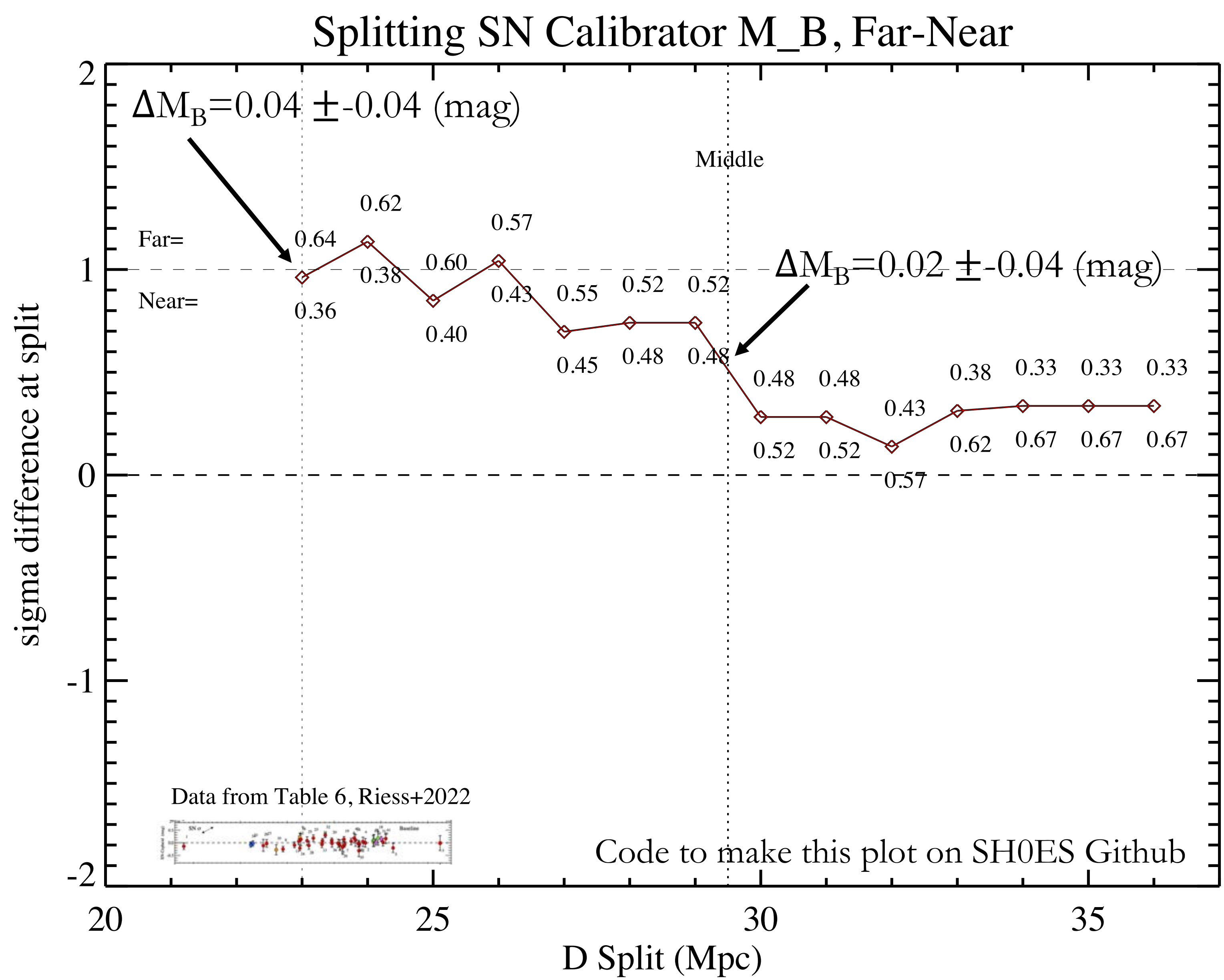
    - Comes from best tools (HST, JWST, Gaia, Planck), data public
    - Lasted 10 years, steadily growing in significance
    - The model it challenges, Λ CDM, is phenomenological, dark sector

Don't get distracted by critiques, can't **data select** our way out,
Hubble Tension demands a satisfying explanation, what are we missing?

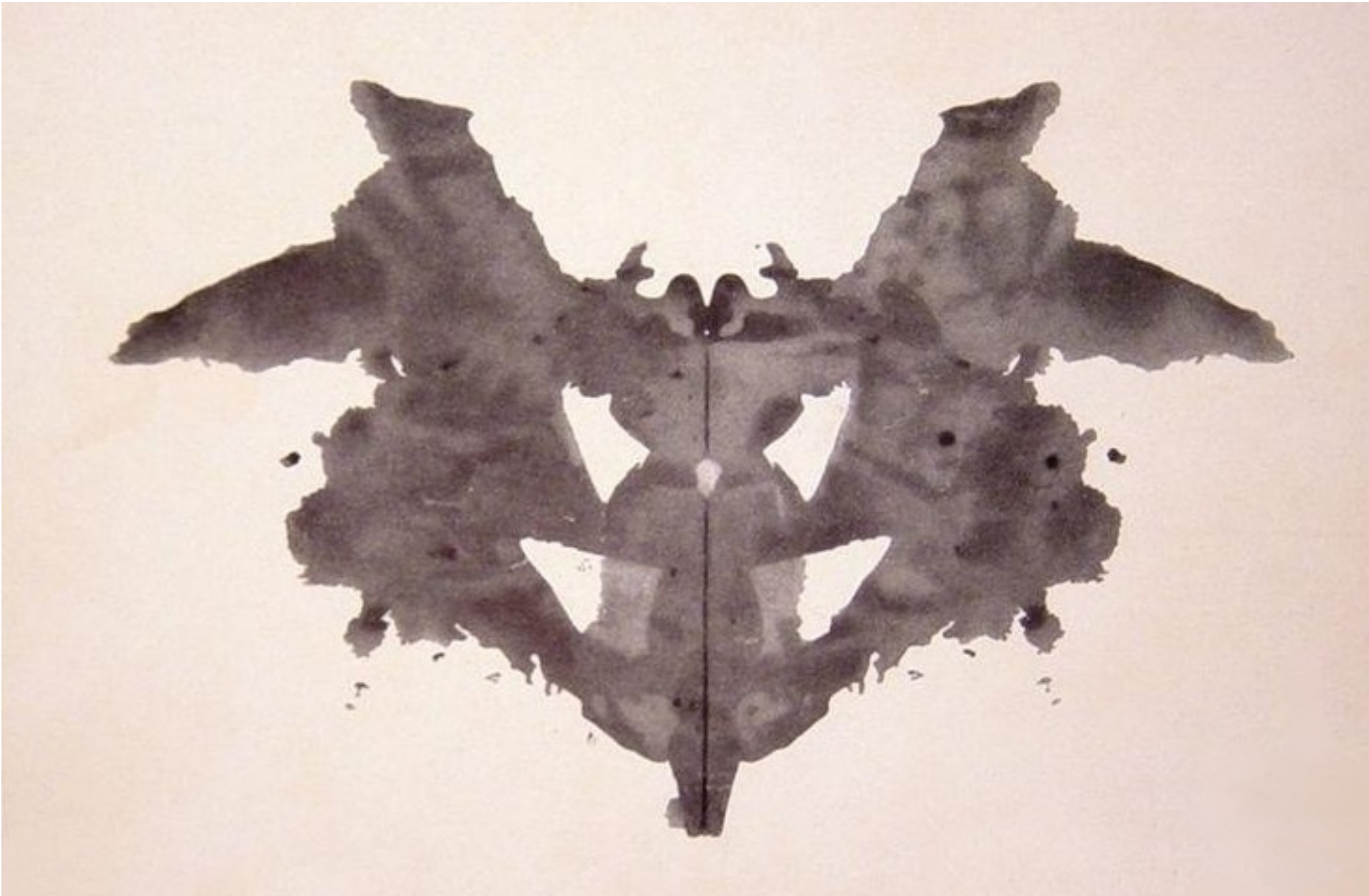
Back Up

Do nearer hosts have brighter SN magnitudes?. Not significant

- 1 σ at D=23 Mpc split, 0.5 σ at sample middle, either place no evidence



Do you see ΛCDM or Tension?



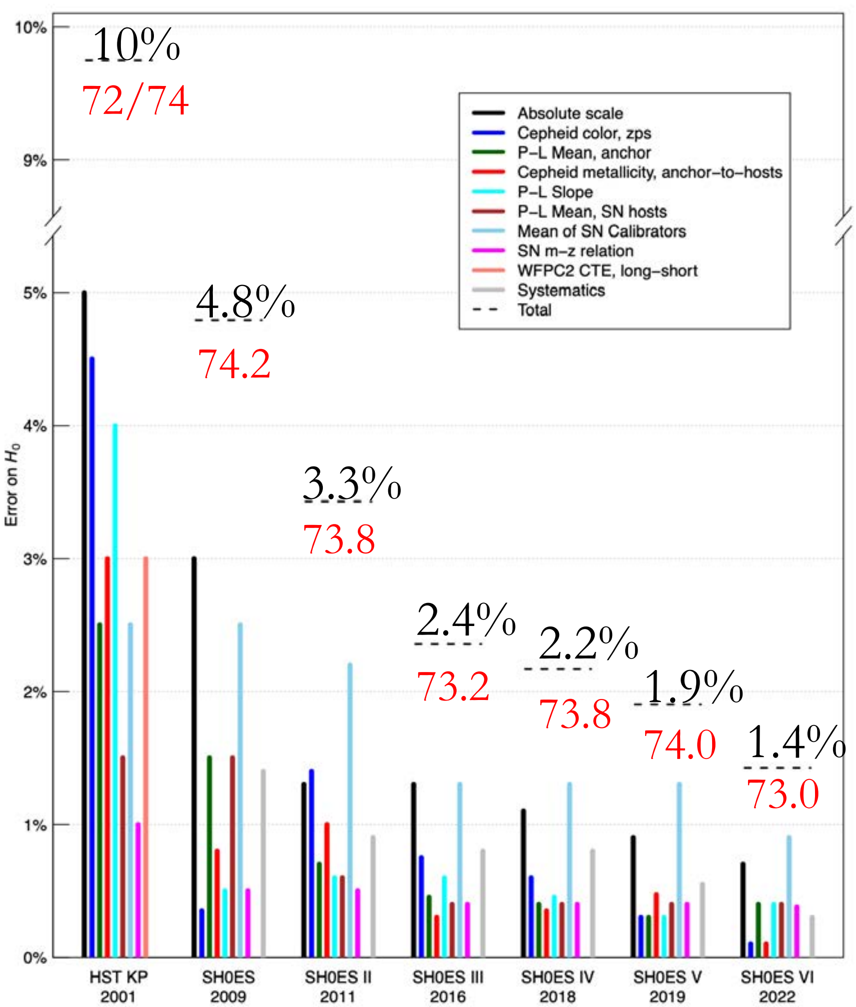
SH0ES Publicly Released data (photometry, mean mags, code, etc)

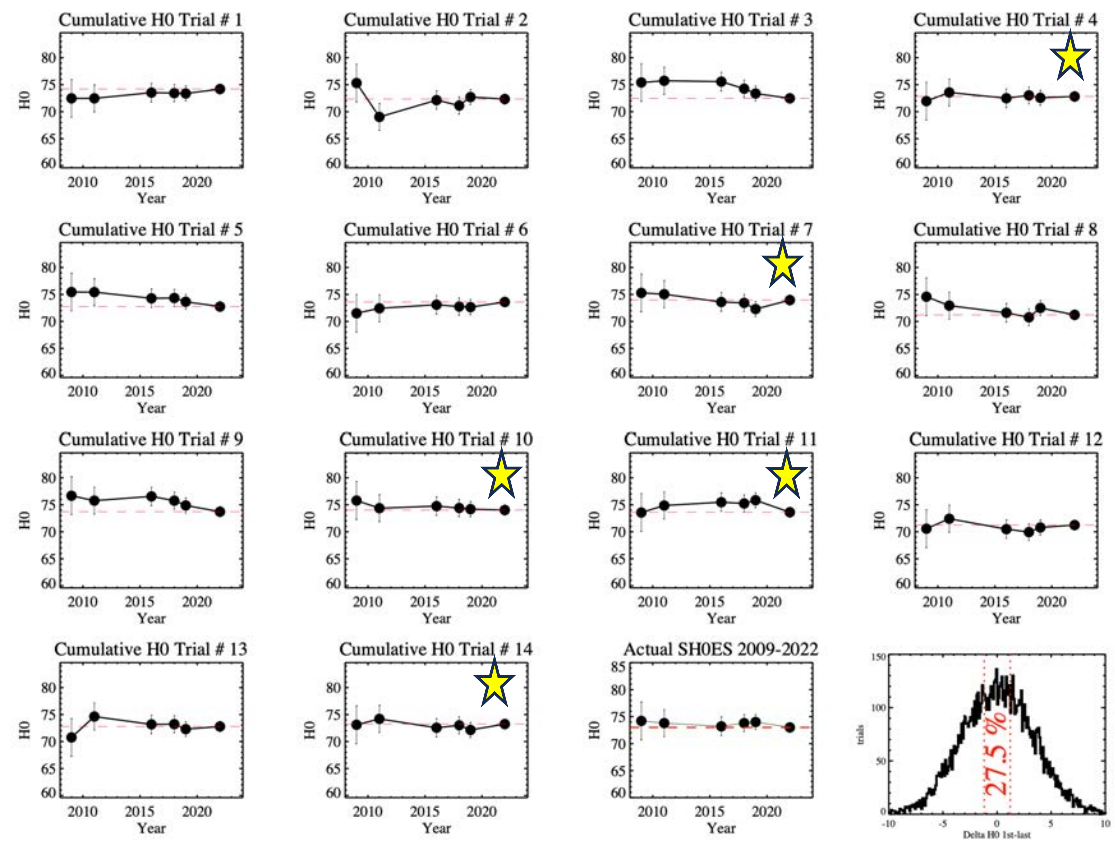
Gagandeep S. Anand *et al* 2024 *ApJ* 966 89 (JWST TRGB I): https://github.com/gsanand/anand24_jwst_trgb
Louise Breuval *et al* 2024 *ApJ* 973 30 (SMC): https://content.cld.iop.org/journals/0004-637X/973/1/30/revision2/apjad630et1_mrt.txt
Yukei S. Murakami *et al* arXiv :2503.09702 (Dust) :https://github.com/SterlingYM/sphot
Daniel Scolnic *et al* 2025 *ApJL* 979 L9 (Coma): https://github.com/dscolnic/Coma ; Zenodo DOI: 10.5281/zenodo.14213131
Adam G. Riess *et al* 2024 *ApJ* 977 120 (JWST Validates): https://content.cld.iop.org/journals/0004-637X/977/1/120/revision3/apjad8c21t5_mrt.txt (compiled from other papers)
Adam G. Riess *et al* 2024 *ApJL* 962 L17 (JWST Crowding): https://content.cld.iop.org/journals/2041-8205/962/1/L17/revision3/apjlad1dddt2_mrt.txt
Caroline D. Huang *et al* 2024 *ApJ* 963 83 (M101): https://content.cld.iop.org/journals/0004-637X/963/2/83/revision1/apjad1ff8t4_mrt.txt
Adam G. Riess *et al* 2023 *ApJL* 956 L18 (Crowded no more): https://iopscience.iop.org/2041-8205/956/1/L18/suppdata/apjlacf769t2_ascii.txt?doi=10.3847/2041-8213/acf769
Yukei S. Murakami *et al* JCAP11(2023)046 (twins SN): Data drawn from other studies, listed in Table 1
D. Scolnic *et al* 2023 *ApJL* 954 L31 (CATs H0): https://github.com/JiaxiWu1018/CATS-H0
Louise Breuval *et al* 2023 *ApJ* 951 118 (M33): https://content.cld.iop.org/journals/0004-637X/951/2/118/revision1/apjacd3f4t9_mrt.txt
J. Wu *et al* 2023 *ApJ* 954 87 (CATs): https://github.com/JiaxiWu1018/CATS-H0
Wenlong Yuan *et al* 2022 *ApJL* 940 L17 (First look JWST): https://iopscience.iop.org/2041-8205/940/1/L17/suppdata/apjlac9b27t1_ascii.txt?doi=10.3847/2041-8213/ac9b27
Adam G. Riess *et al* 2022 *ApJ* 938 36 (Cluster Cepheids): https://iopscience.iop.org/0004-637X/938/1/36/suppdata/apjac8f24t2_ascii.txt?doi=10.3847/1538-4357/ac8f24
Louise Breuval *et al* 2022 *ApJ* 939 89 (Cepheid metallicity): Data drawn from other studies, listed in Table 2
Adam G. Riess *et al* 2022 *ApJ* 934 7 (Big SH0ES): **https://pantheonplussh0es.github.io**

Does SH0ES H_0 Vary So Little, 74.2 to 73.0 in ~15 years?

Answer: Our measurements are **cumulative**, beating down errors in 10 categories. Simulate accumulation w/ random errs

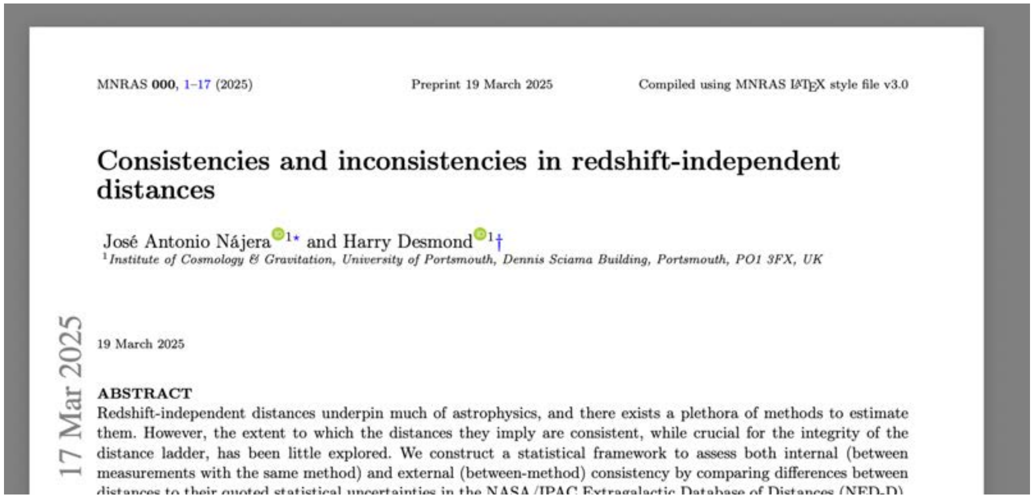
Error Budget in 10 categories





10,000 trials (show 14 of them vs real), 28% of the time ΔH_0 would be what we find (or less) so not unexpected. ☆Trials "luckier" than SH0ES

External Testing


MNRAS 000, 1–17 (2025) Preprint 19 March 2025 Compiled using MNRAS LaTeX style file v3.0

Consistencies and inconsistencies in redshift-independent distances

José Antonio Nájera[1*] and Harry Desmond[1†]
[1]*Institute of Cosmology & Gravitation, University of Portsmouth, Dennis Sciama Building, Portsmouth, PO1 3FX, UK*

17 Mar 2025

19 March 2025

ABSTRACT
Redshift-independent distances underpin much of astrophysics, and there exists a plethora of methods to estimate them. However, the extent to which the distances they imply are consistent, while crucial for the integrity of the distance ladder, has been little explored. We construct a statistical framework to assess both internal (between measurements with the same method) and external (between-method) consistency by comparing differences between distances to their quoted statistical uncertainties in the NASA/IPAC Extragalactic Database of Distances (NED-D)

Abstract: **We also investigate consistency of Cepheid distances in the SH0ES 2022 catalogue, finding no evidence for unaccounted-for systematics.**
Test: Fig. 5 and the top row of Table 3 indicate that the SH0ES 2022 catalogue agrees well with the null hypothesis of statistical consistency. The two galaxies used for the first rung that calibrates the PL relation are also consistent with the null hypothesis. **Indeed, we find the Cepheids in the SH0ES 2022 catalogue not to exhibit significant problems. This supports the findings of Riess et al. (2022) that the dispersion in the Cepheid measurements agrees with the fiducial uncertainties without any unexplained variance.**

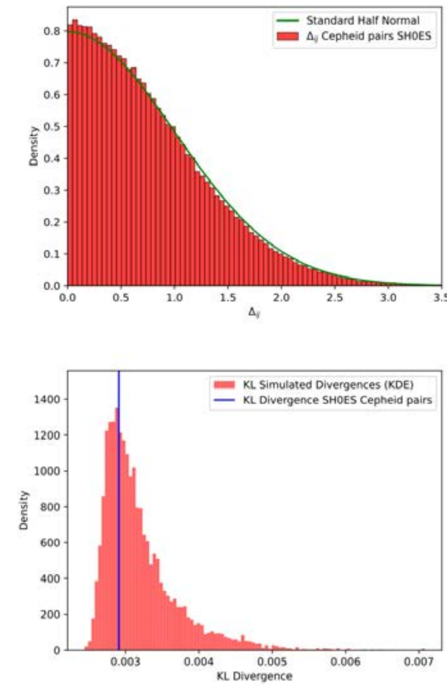


Figure 5. *Top:* Normalized probability distribution function (pdf) of the difference in units of Δ_{ij} for the SH0ES 2022 catalogue. We show the theoretical pdf of the standard half-normal for comparison. *Bottom:* Histogram for the mock KLD values generated under the null hypothesis of consistency compared to the KLD value of the real data.

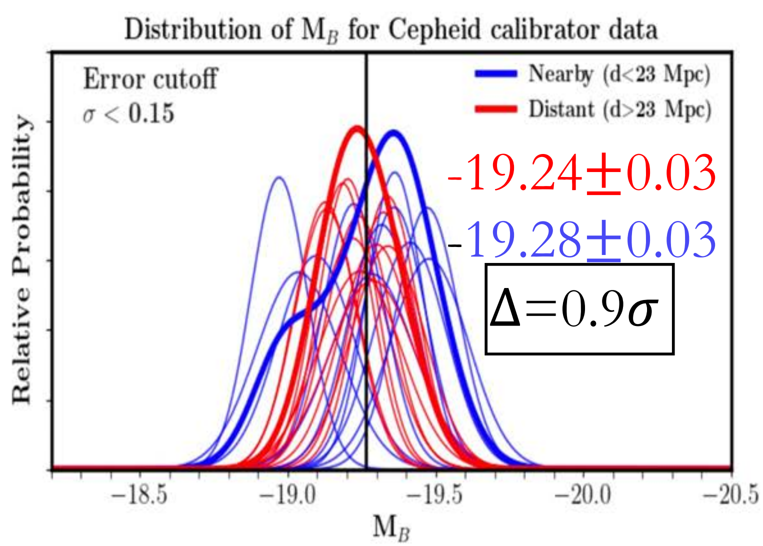
Do nearer or lower-error-hosts have brighter SN magnitudes?

WLF et al. (2024)

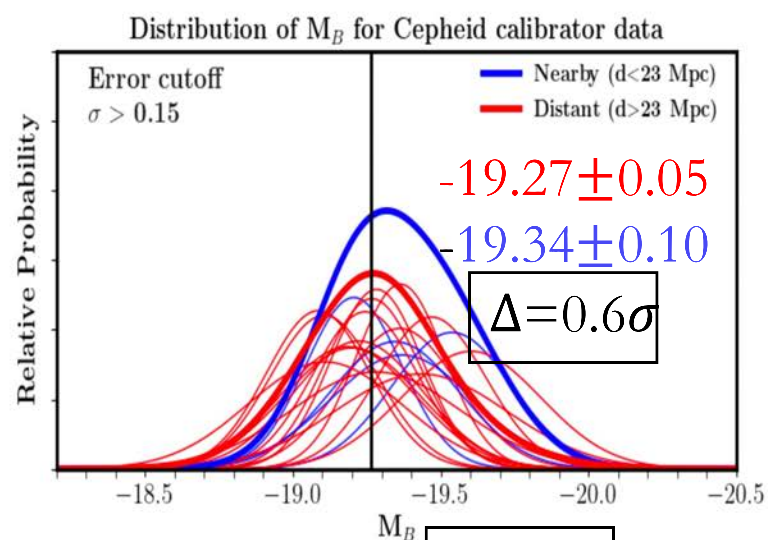
- **The current sample of SNIa host galaxies is small (42 SNe in 37 galaxies).**
- **The galaxies with the smallest uncertainties have systematically brighter M_B magnitudes**

…I just calculate means from SH0ES R22, Table 6

Higher SNR



Lower SNR

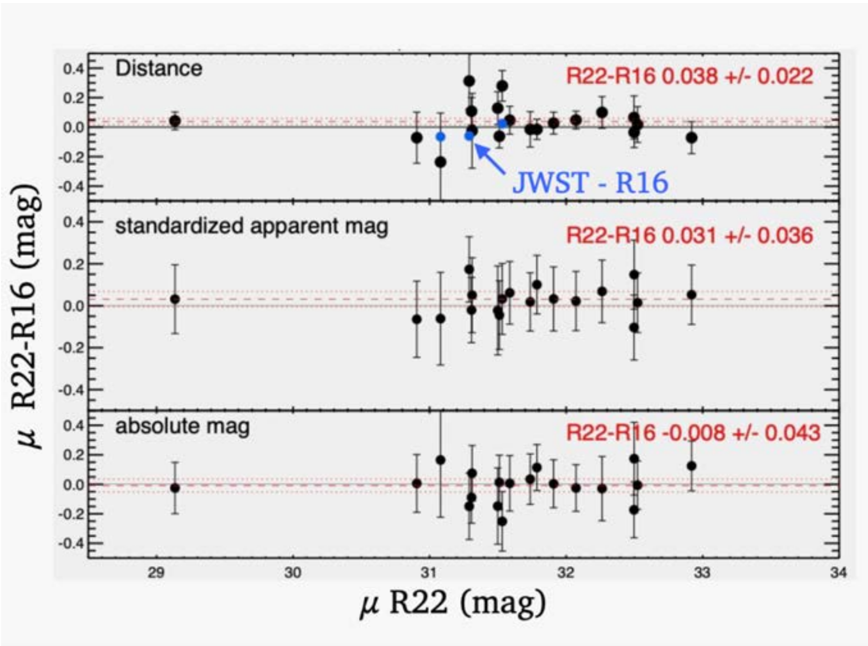


High: -19.26±0.02 vs Low: -19.28±0.04 $\boxed{\Delta=0.5\sigma}$

Near: -19.29±0.03 vs Far: -19.25±0.03 $\boxed{\Delta=1.0\sigma}$

The empirical differences are ~1 σ so not significant

SH0ES 2016 to 2022 differences



Distance: up 0.038+/-0.022 mag
(Gaia EDR3 rel. HST FGS)
SN m_B: up 0.031 +/- 0.036 mag
(P+, more LCs)

SN M_B: down 0.008+/-0.043 mag
Pantheon+ HF up 0.007 mag

Net down 0.002 mag for H0
Changes well understood and Explained in 2022

The Astrophysical Journal Letters, 934:L7 (52pp), 2022 July 20 Riess et al.

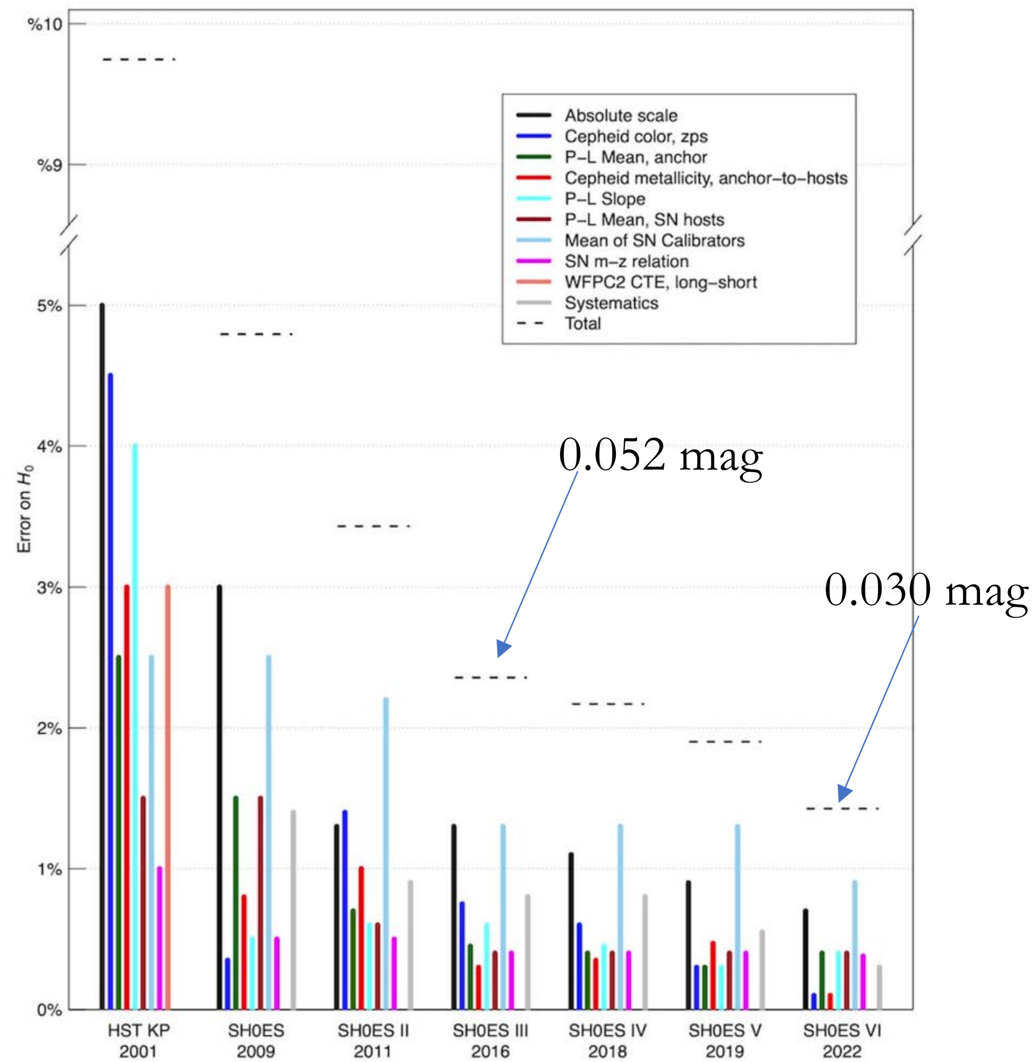
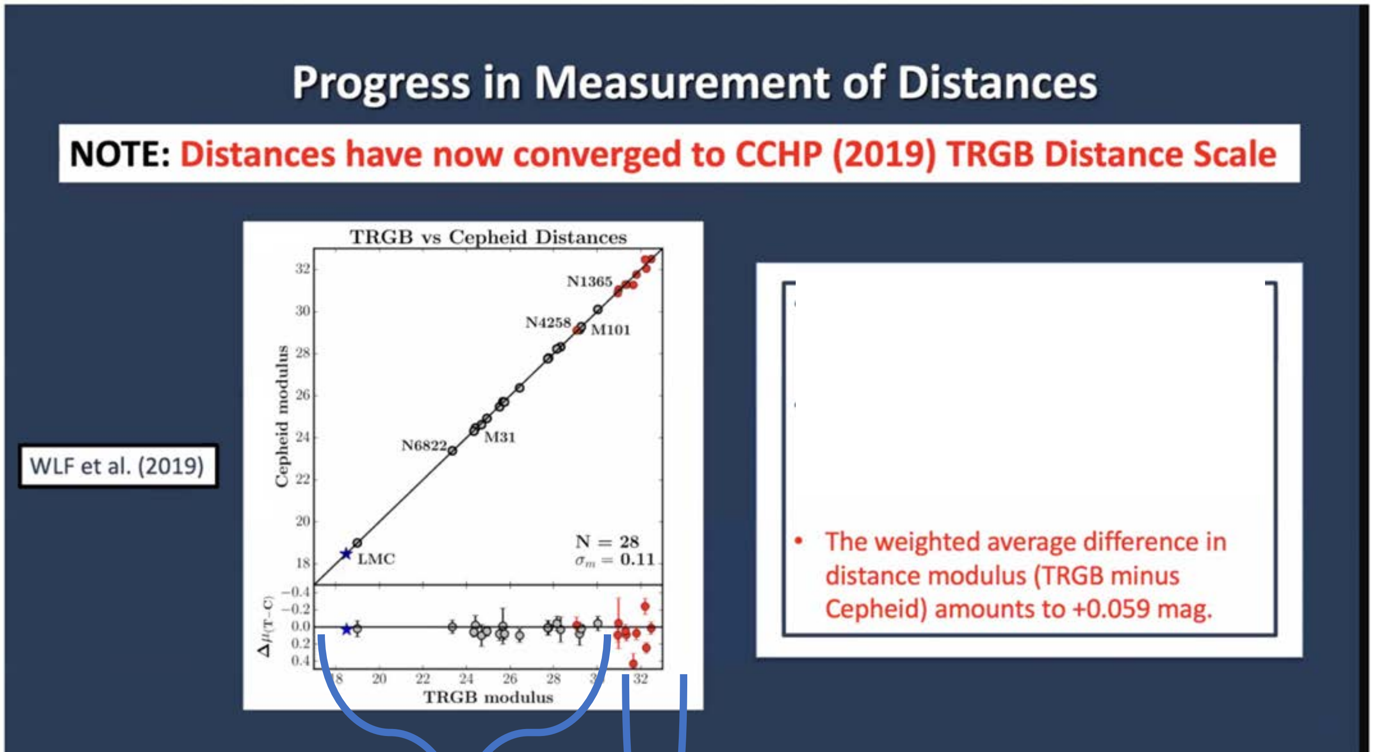


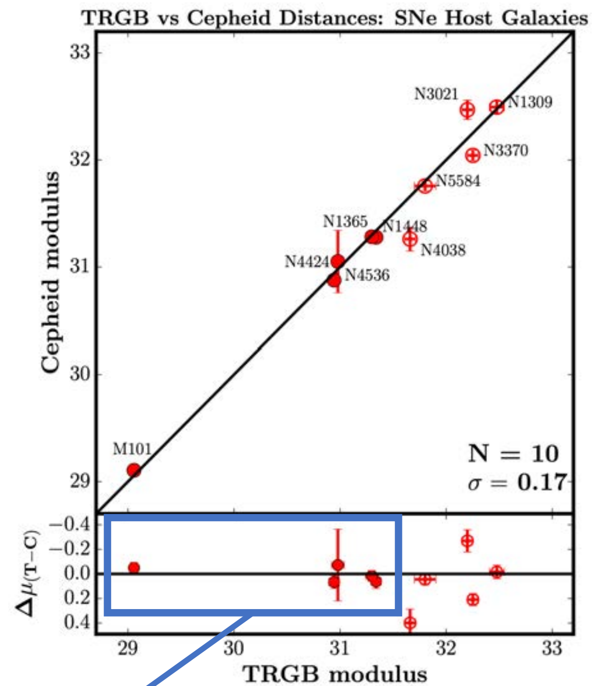
Figure 24. Comprehensive error budgets for six iterations of the SH0ES measurement of H_0 including this one (2022) and the Key Project from 2001 (Freedman et al. 2001). The greatest improvement here is realized by the increase in the number of SN calibrators, to decrease all terms to <1%. The combined error is indicated by horizontal dashed lines.

No evidence of past scale difference-SH0ES Cepheids vs CCHP TRGB

CCHP Claim: $<\Delta\mu> = 0.06$ **mag [2.8%] (Change in distance moduli between 2016 and 2022)**

F19 comparison, <u>only 5 of 28 a direct comparison </u>(w/ SH0ES circa 2016), **Δ**=-0.01 +/- 0.03 mag





Not SH0ES data: (unspecified: NED, "compilations", etc)

Not CCHP data: (from Jang, Lee 17)

Only 5/28 points, red, compared SH0ES measured Cepheids vs CCHP measured TRGB, Δ =-0.01 +/- 0.03

- Glad distances agree but we were never far apart

Updates between R16 (DR4) and R22 (DR5)

Each iteration improves on last, with better statistics lower threshold for systematics
2016: H_0 **error 0.052 mag**, 3σ tension, **2022** : H_0 **error 0.030 mag**, 5σ tension

Changes: **Bolded are externally imposed**

- **Pixel-based CTE, new flat fields, time-dependent sensitivity (STScI)**
- **2021 STScI pipeline geometric distortion**
- More iterations (CPU time) for host background
- Use of Covariance (Cepheid metallicity, background)
- New optical pipeline (Hoffmann→ Yuan)
- **Gaia EDR3 replace FGS parallax, HST MW phot (-0.08 mag) (1 anchor of 3)**
- **LMC DEBs (+0.02),** HST LMC photometry (+0.03)
- **Revised NGC 4258 distance (Reid+2019),** 3x Cephs (-0.02)
- **SN Supercal→Pantheon+, multiple LCs per cal. (+0.025)**
- All discussed in Appendix B of 2022 paper
- Mean differences between DRs have been $\leq 1\ \sigma$

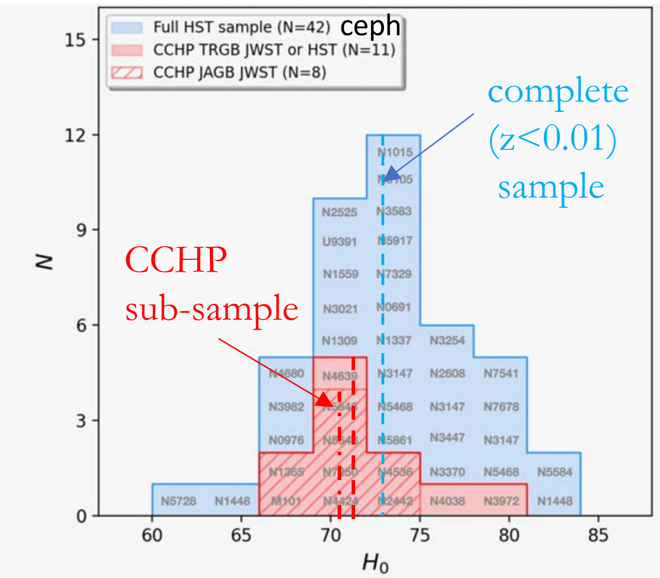
Progress thrives on iteration, open data, and refining methods—not on over attachment to first/past results. Confidence builds from following iterative process. Updates good!

Welcome to scrutinize and nitpick but for progress most attention to latest, greatest DR.

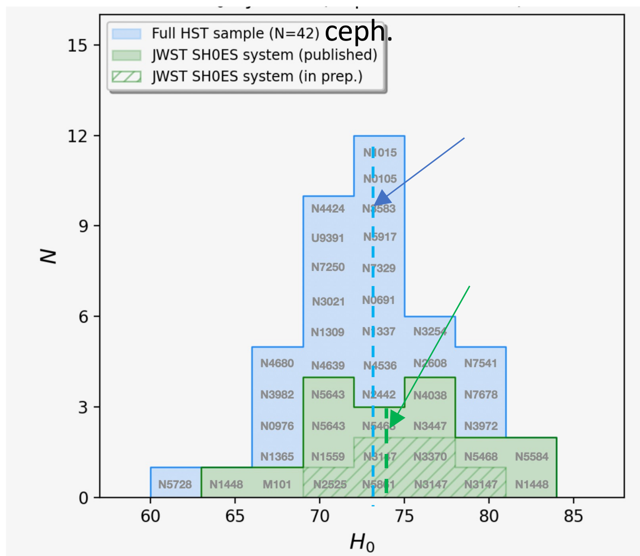
“Sub-sample Roulette”: Selection + Small Samples can cause large differences in H_0!

with Pantheon+ SN Ia, NGC 4258 as sole anchor…

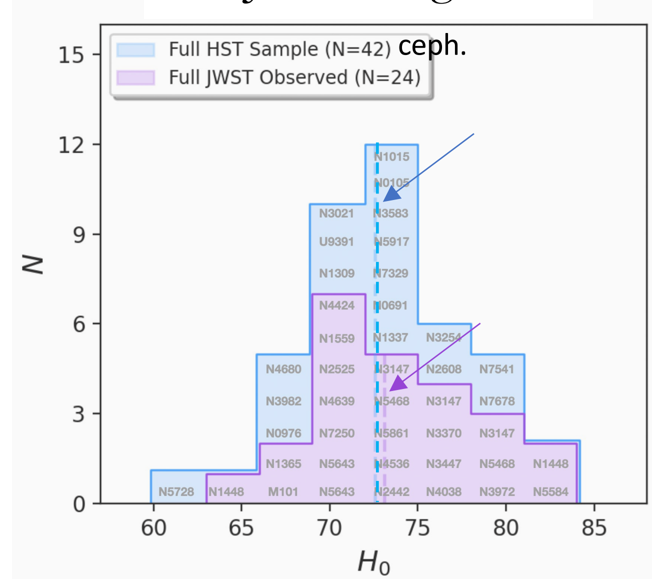
CCHP selected JWST targets



SH0ES system JWST targets



all JWST targets



HST Expect H0~71 (TRGB/Cepheids),
70* (JAGB) (~72 w/ NIR)
Freedman et al 25 (JWST TRGB): ~70

HST Expect H0~74
JWST (R24, 3 methods): 74.5

HST Expect (Cycle 1 sample) 72.8,
JWST all methods (Cycle 1): 72.6
(at D<25 Mpc, D’s from teams, R24)

Distance methods converged, H_0 (?) because CCHP only uses their SN selections and do not use other SN samples

* CCHP use of CSP SN (not larger Pantheon+) lowers by ~0.6, mode lowers by 1.2, expect H_0 ~68 (JAGB)

From: George Efstathiou <ge12@cam.ac.uk>
Subject: astrophysicist
Date: August 1, 2023 at 8:55:47 AM EDT
To: Adam Riess ariess@stsci.edu

Hi Adam

This is really convincing!

Thanks for showing me these results in Munich. They have changed my perspective on the Hubble tension, though I am no closer to finding a plausible theoretical explanation.

Regards
George

George Efstathiou FRS

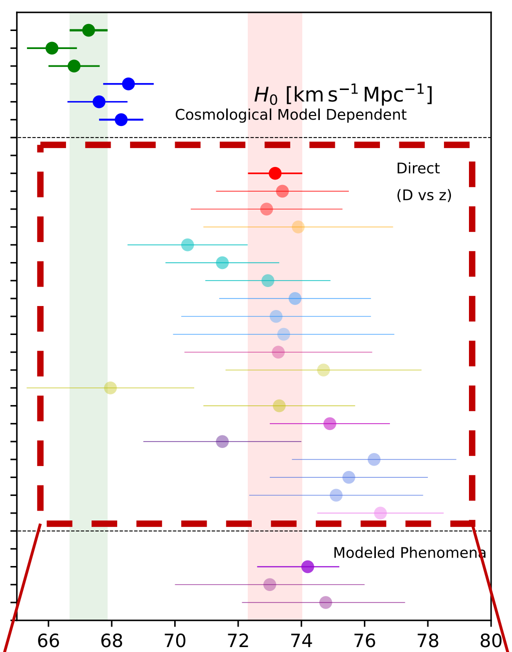
The H_0 Distance ~~Ladder~~ *Network*: a de-correlated, consensus framework

- **ISSI Workshop 03/2025: 36 Experts from all data areas participation widely invited**

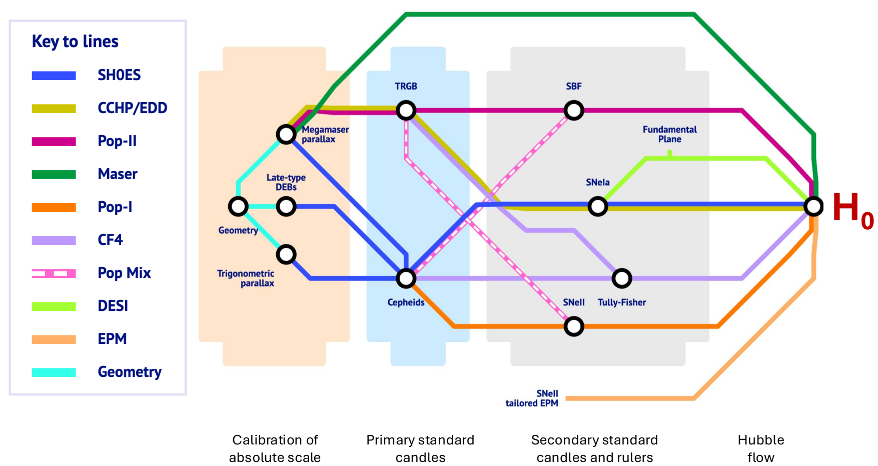
Casertano,Anand,Anderson,Beaton,Bhardwaj,Blakeslee,Boubel,Breuval,Brout,Cantiello,Csörnyei,De Jaeger, Dhawan,Di Valentino,Emre,Galbany,Gil-Marin, Graczyk,Huang,Jensen ,Kervella,Khaled,Leibundgut, Lengen,Li,Nota,Ozulker,Pesce,Cruz,Reyes,Riess,Romaniello,Schöneberg,Scolnic,Sicignano,Skowron,Uddin,Verde

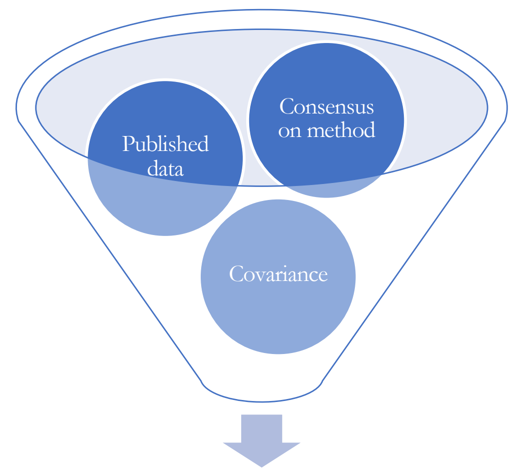
CosmoVerse White Paper 2025

workshops.issibern.ch/hubble-



Goal: best, correlation-free, combined, local constraint





$$\begin{bmatrix} y_1\\ \vdots \\ y_n\end{bmatrix} = \begin{bmatrix}1 & x_{12} & \cdots & x_{1k}\\ \vdots & \vdots & \ddots & \vdots\\ 1 & x_{n2} & \cdots & x_{nk}\end{bmatrix}\begin{bmatrix}\beta_1\\ \vdots\\ \beta_k\end{bmatrix} + \begin{bmatrix}\epsilon_1\\ \vdots\\ \epsilon_n\end{bmatrix}$$

INTERNATIONAL SPACE SCIENCE INSTITUTE

- Open-source code & data
- Fully democratic data selection
- Analysis defined before deriving result

The H_0 Consensus Report (H_0CR)

Expected: July 2025

Data releases, iterations, progress
(or Are we doomed to hold to the the past?)

Table 1. Parameters of the base ΛCDM cosmology (as defined in PCP13) determined from the publicly released nominal-mission `CamSpec` DetSet likelihood [2013N(DS)] and the 2013 full-mission `CamSpec` DetSet and cross-yearly (Y1×Y2) likelihoods with the extended sky coverage [2013F(DS) and 2013F(CY)]. These three likelihoods are combined with the WMAP polarization likelihood to constrain τ. The column labelled 2015F(CHM) lists parameters for a `CamSpec` cross-half-mission likelihood constructed from the 2015 maps using similar sky coverage to the 2013F(CY) likelihood (but greater sky coverage at 217 GHz and different point source masks, as discussed in the text). The column labelled 2015F(CHM) (`Plik`) lists parameters for the `Plik` cross-half-mission likelihood that uses identical sky coverage to the `CamSpec` likelihood. The 2015 temperature likelihoods are combined with the *Planck* lowP likelihood to constrain τ. The last two columns list the deviations of the `Plik` parameters from those of the nominal-mission and the `CamSpec` 2015(CHM) likelihoods. To help refer to specific columns, we have numbered the first six explicitly. The high-ℓ likelihoods used here include only TT spectra. H_0 is given in the usual units of km s^{-1} Mpc^{-1}.

[1] Parameter	[2] 2013N(DS)	[3] 2013F(DS)	[4] 2013F(CY)	[5] 2015F(CHM)	[6] 2015F(CHM) (`Plik`)	$([2]-[6])/\sigma_{[6]}$	$([5]-[6])/\sigma_{[5]}$
$100\theta_{MC}$	1.04131 ± 0.00063	1.04126 ± 0.00047	1.04121 ± 0.00048	1.04094 ± 0.00048	1.04086 ± 0.00048	0.71	0.17
$\Omega_b h^2$	0.02205 ± 0.00028	0.02234 ± 0.00023	0.02230 ± 0.00023	0.02225 ± 0.00023	0.02222 ± 0.00023	−0.61	0.13
$\Omega_c h^2$	0.1199 ± 0.0027	0.1189 ± 0.0022	0.1188 ± 0.0022	0.1194 ± 0.0022	0.1199 ± 0.0022	0.00	−0.23
H_0	67.3 ± 1.2	67.8 ± 1.0	67.8 ± 1.0	67.48 ± 0.98	67.26 ± 0.98	0.03	0.22
n_s	0.9603 ± 0.0073	0.9665 ± 0.0062	0.9655 ± 0.0062	0.9682 ± 0.0062	0.9652 ± 0.0062	−0.67	0.48
Ω_m	0.315 ± 0.017	0.308 ± 0.013	0.308 ± 0.013	0.313 ± 0.013	0.316 ± 0.014	−0.06	−0.23
σ_8	0.829 ± 0.012	0.831 ± 0.011	0.828 ± 0.012	0.829 ± 0.015	0.830 ± 0.015	−0.08	−0.07
τ	0.089 ± 0.013	0.096 ± 0.013	0.094 ± 0.013	0.079 ± 0.019	0.078 ± 0.019	0.85	0.05
$10^9 A_s e^{-2\tau}$	1.836 ± 0.013	1.833 ± 0.011	1.831 ± 0.011	1.875 ± 0.014	1.881 ± 0.014	−3.46	−0.42

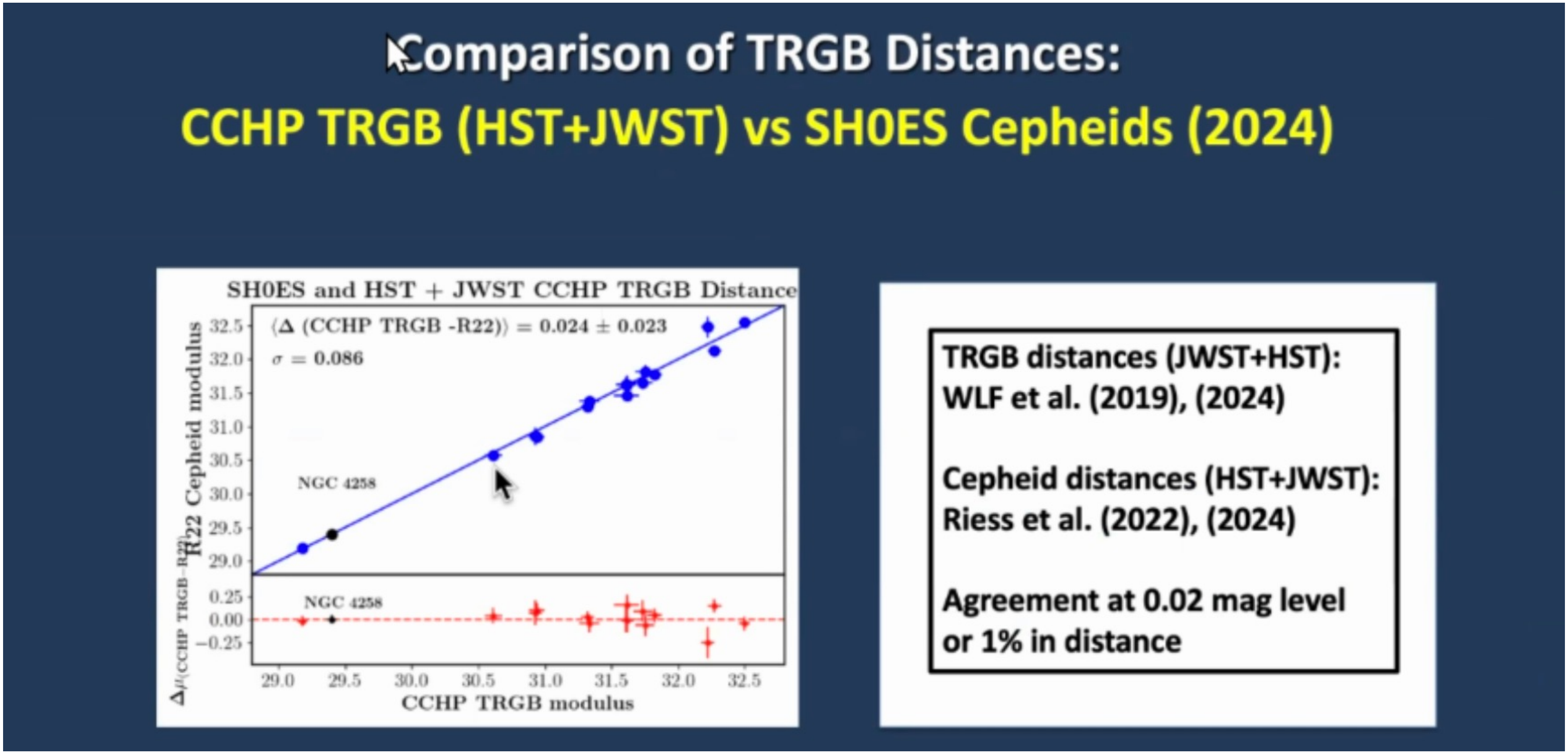
Planck 2018

TT,TE,EE+lowE+lensing+BAO 68% limits
0.02242 ± 0.00014
0.11933 ± 0.00091
1.04101 ± 0.00029
0.0561 ± 0.0071
3.047 ± 0.014
0.9665 ± 0.0038
67.66 ± 0.42
0.6889 ± 0.0056
0.3111 ± 0.0056
0.14240 ± 0.00087
0.09635 ± 0.00030
0.8102 ± 0.0060
0.825 ± 0.011
0.6051 ± 0.0058
7.82 ± 0.71
2.105 ± 0.030
1.881 ± 0.010

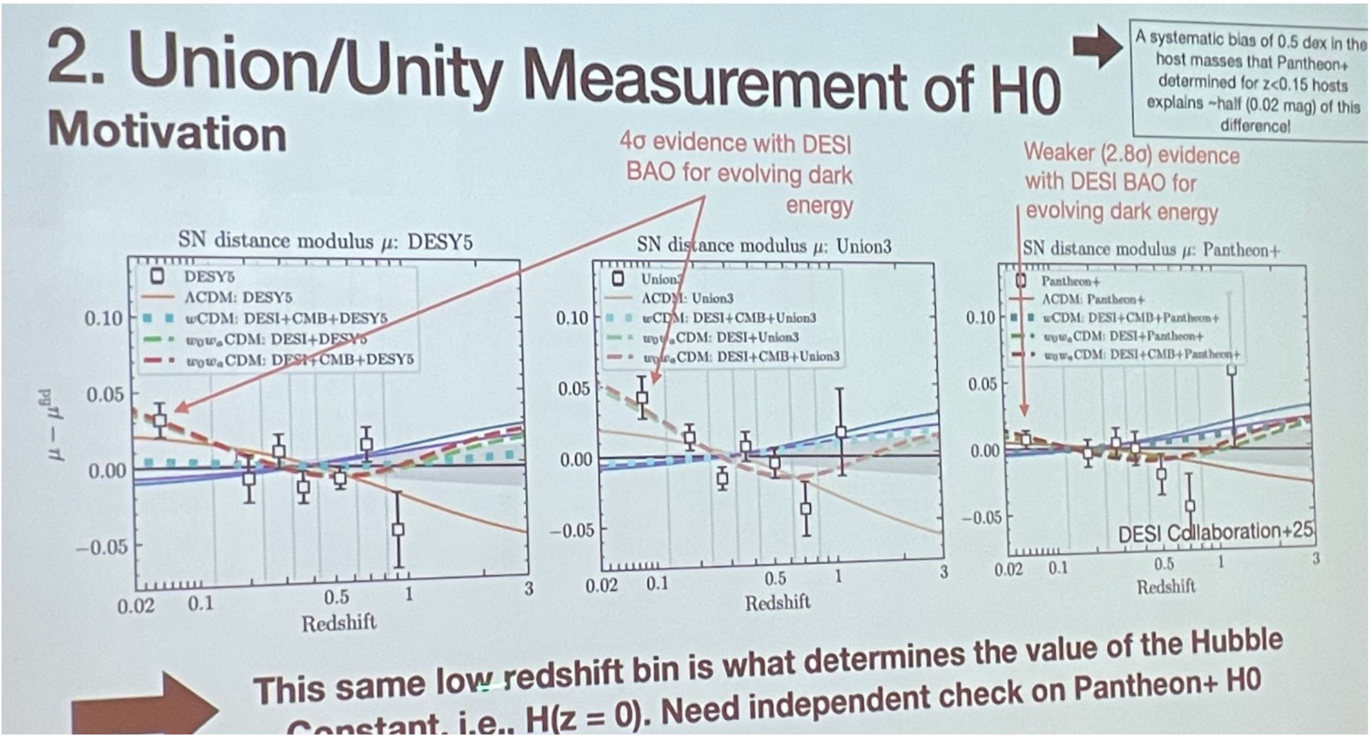
Planck 2013-2018

-4.5σ

From Freedman CCHP Talk last month



Can Pantheon + Reduce H0 and DESI Tension?



Let's say P+ point is too bright/close—so we move it 0.02 mag to match Union. SH0ES H0 goes down from 73→72.2. But Early Universe H0 also goes to 65.91. We do not gain!

$w_0 w_a$CDM

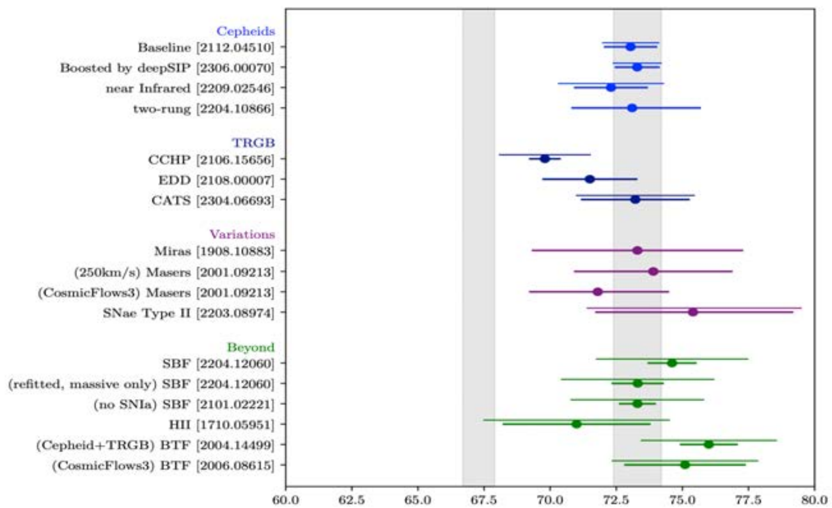
DESI+CMB+Pantheon+	0.3114 ± 0.0057	67.51 ± 0.59
DESI+CMB+Union3	0.3275 ± 0.0086	65.91 ± 0.84
DESI+CMB+DESY5	0.3191 ± 0.0056	66.74 ± 0.56

What do many recent measurements of H_0 show?

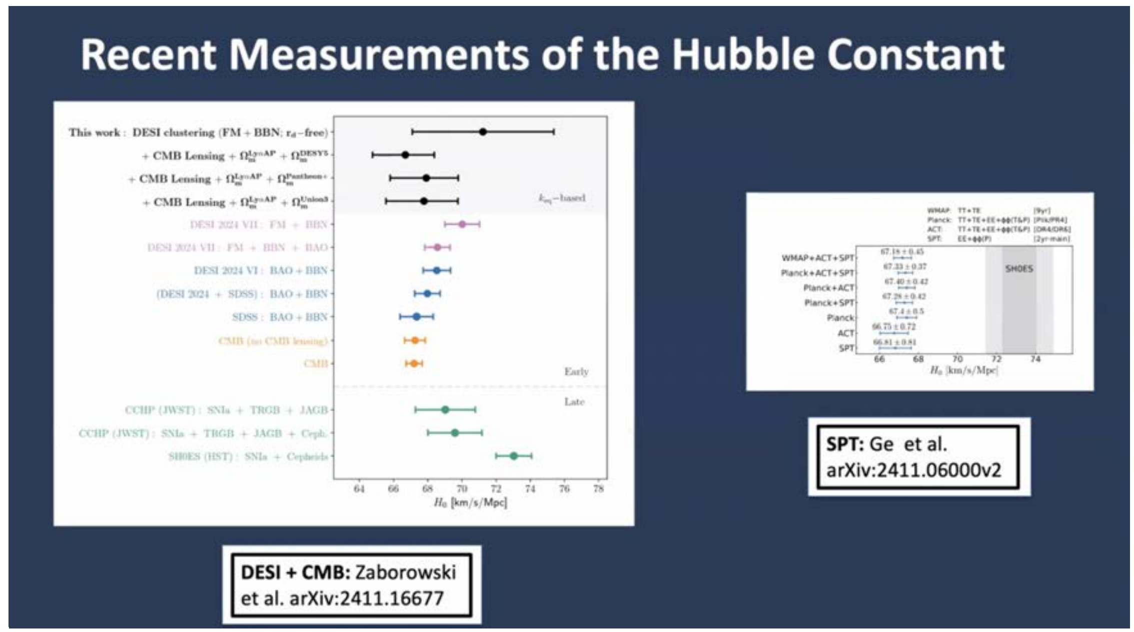
What you take from these depends on how/why they were compiled.

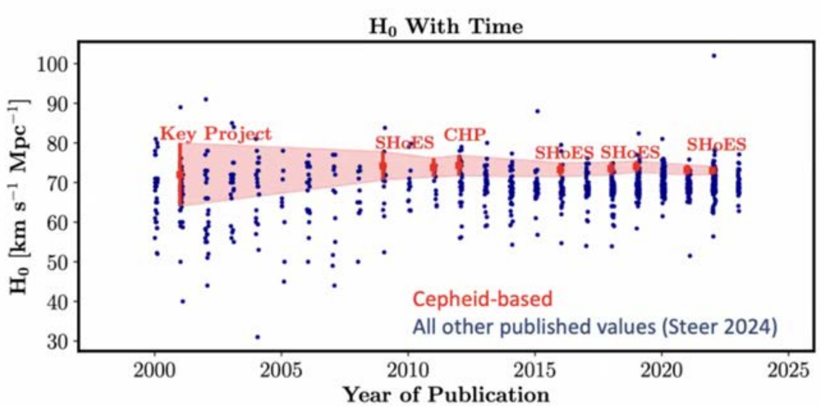
Reviews of H_0 show ~15-20 Local measures, good consistency!

CMB papers highlight consistency of CMB, excludes most local measures, hides local consensus



ARAA Verde+ 2024



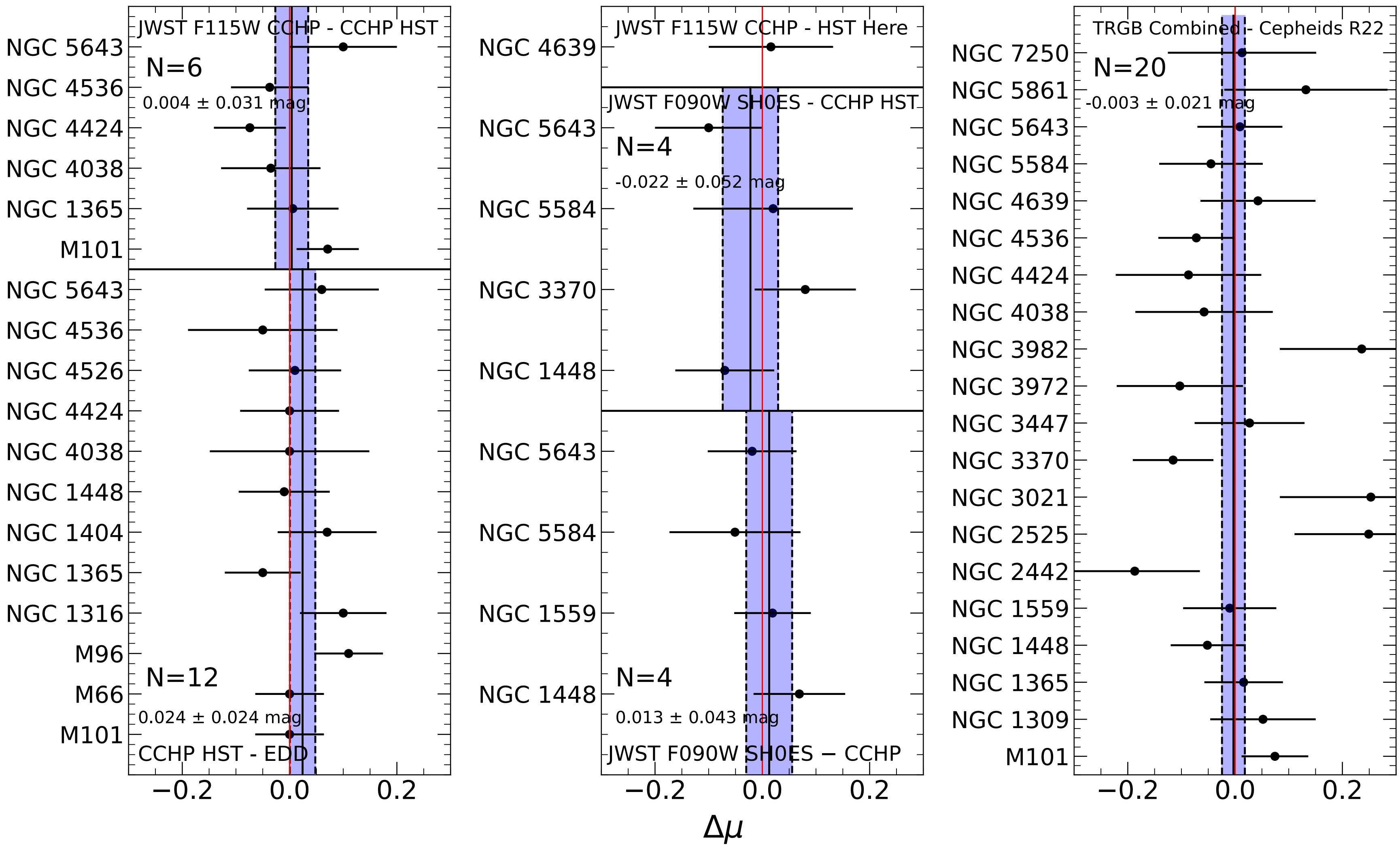


Steer (2024, unpublished) does not separate early/late, higher "Cepheid" values are consistent with Hubble tension, not high relative to other local

Good agreement between different measures of TRGB and TRGB vs Cepheids

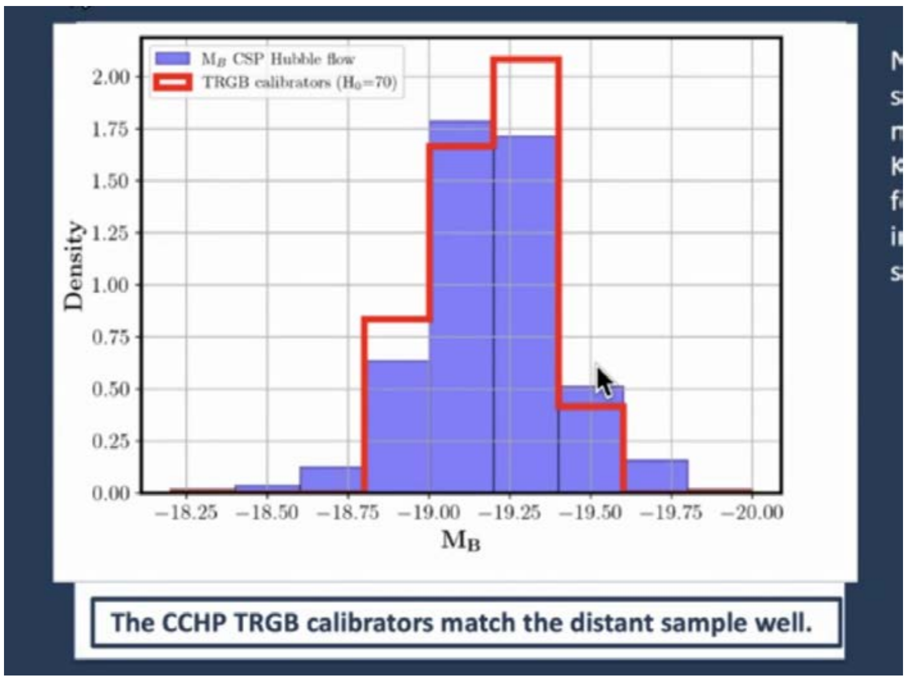
TRGB vs TRGB

TRGB vs Cepheids

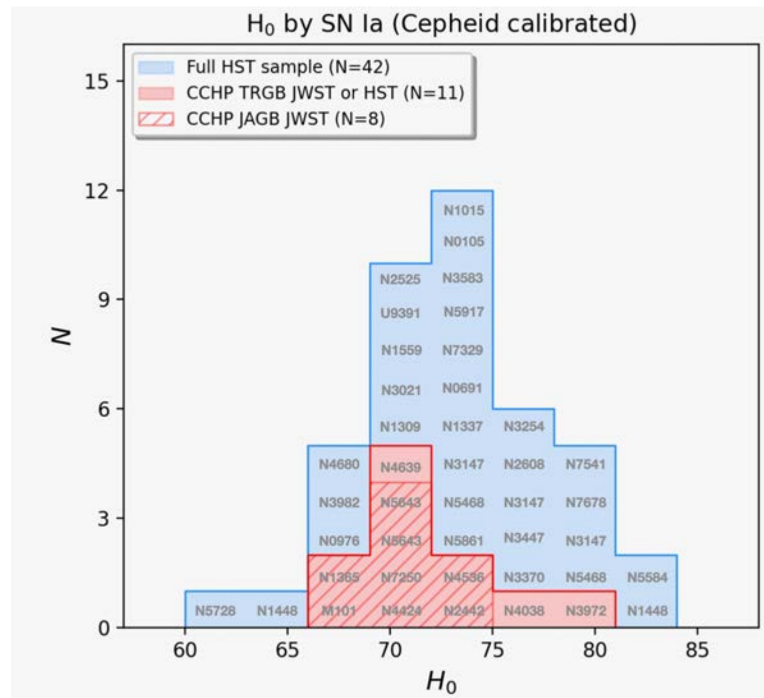


What do we mean by SN sub-sample differences?

Comparing SN on <u>different rungs</u> cannot test a sample difference, because they align *by construction*, we make them match to measure H_0



A *sub-sample difference* is between sub and full sample on <u>same rung</u>, measured same way see red



HST SN Ia Calibrators: Sub-sample Differences

The Astrophysical Journal Letters, 934:L7 (52pp), 2022 July 20

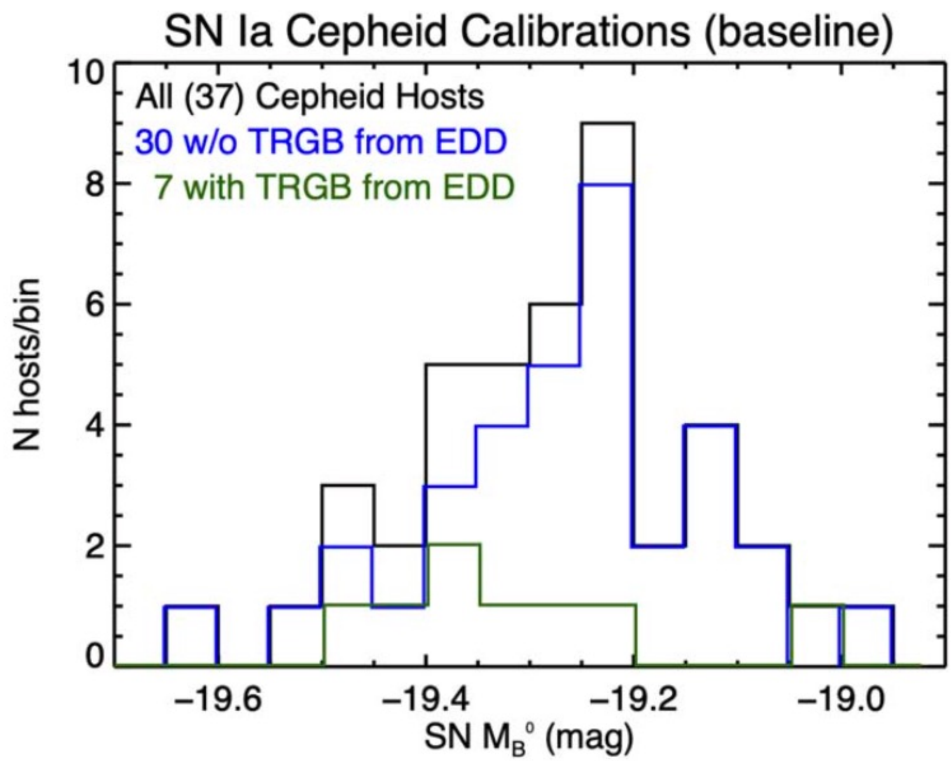


Figure 25. Histogram of the 42 SN Ia absolute magnitudes of SNe Ia calibrated from Cepheids in 37 hosts. The 9 SNe Ia in 7 hosts for which a TRGB distance is available from both EDD and CCHP are shown in green (calibrated here with Cepheids), and the 33 SNe Ia in 30 hosts without a TRGB measure from both in blue (calibrated here with Cepheids). The difference in their means of 0.08 ± 0.05 mag is consistent with the shot noise of the SN samples as discussed in Section 7.2, and combined with other differences between the TRGB calibrator set (lines 6–8) produce a net difference in H_0 of 1 km s^{-1} Mpc^{-1} (0.03 ± 0.05 mag) as shown in Table 8, which is less than 1σ from the shot noise of the two samples.