Tip of the Red Giant Branch in SN Ia Host Galaxies

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Section 1

Lecture 1 Review

Review

From Lecture 1:

› Theoretical basis of TRGB:

→ Helium flash, constrained core mass & luminosity

› Observational applications:

→ Where to observe (halos), color corrections

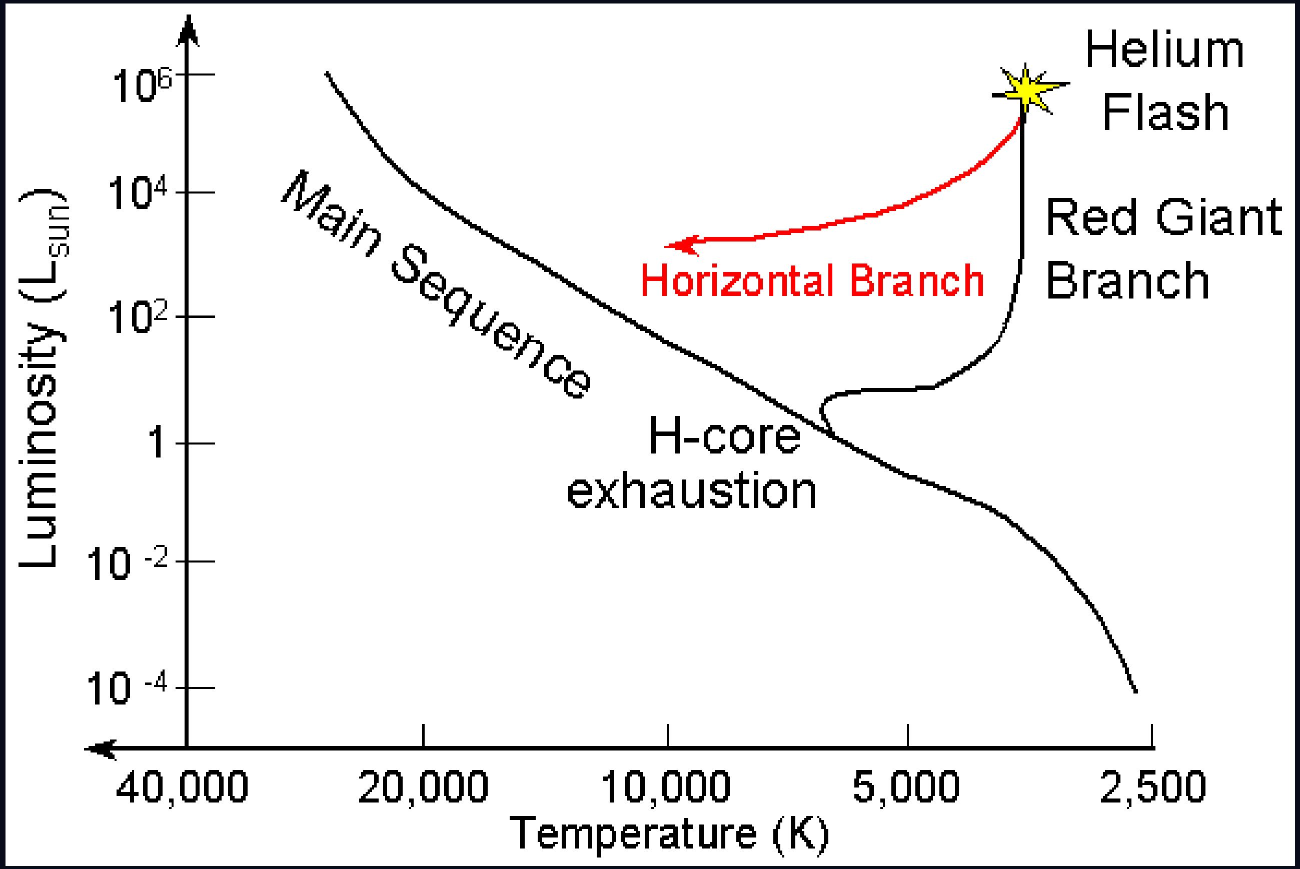
→TRGB apparent magnitude (m_{TRGB}) w/ Sobel filter

The Key Number: $M_{c,flash} \approx 0.50\ M_\odot$

- This number constrains the TRGB standard candle
- Set by quantum mechanics (degeneracy) + nuclear physics (triple-alpha)
- Valid for low-mass stars (0.6–2 $M_\odot$)
- Small scatter in M_I dominated by metallicity
- Theory (Salaris & Cassisi 1997, 2005) well understood

After the Flash — The Horizontal Branch

- He flash lifts core degeneracy → star contracts
- Surface luminosity DROPS by ~1.5–2 magnitudes
- He core begins burning stably (non-degenerate)
- Star settles on Horizontal Branch (HB)
- Sudden drop in luminosity forms the ‘tip’ of the red giant branch



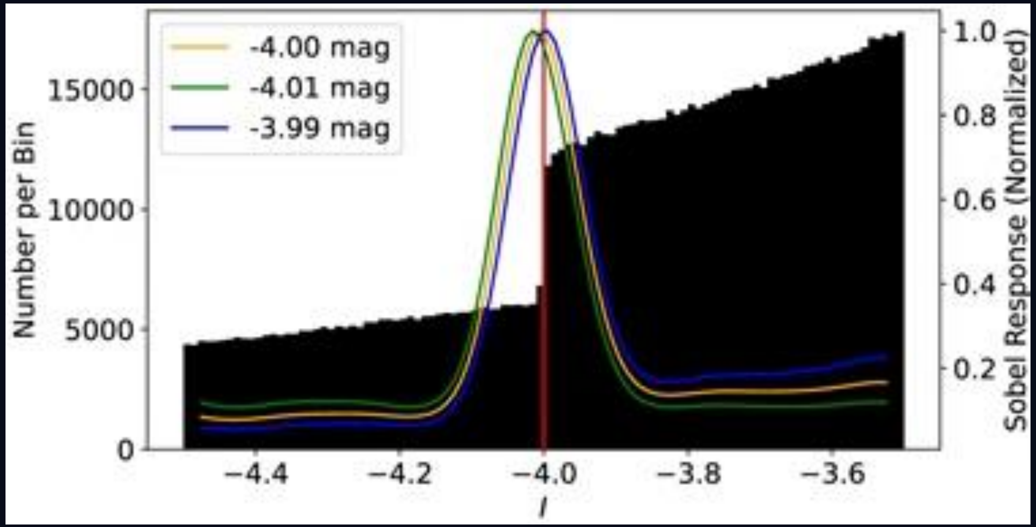
Credit: Ohio State

The Problem — Finding the Edge

Poisson statistics make the sharp edge noisy

The ideal TRGB LF:

› Sharp step function in the luminosity function at m = m_tip

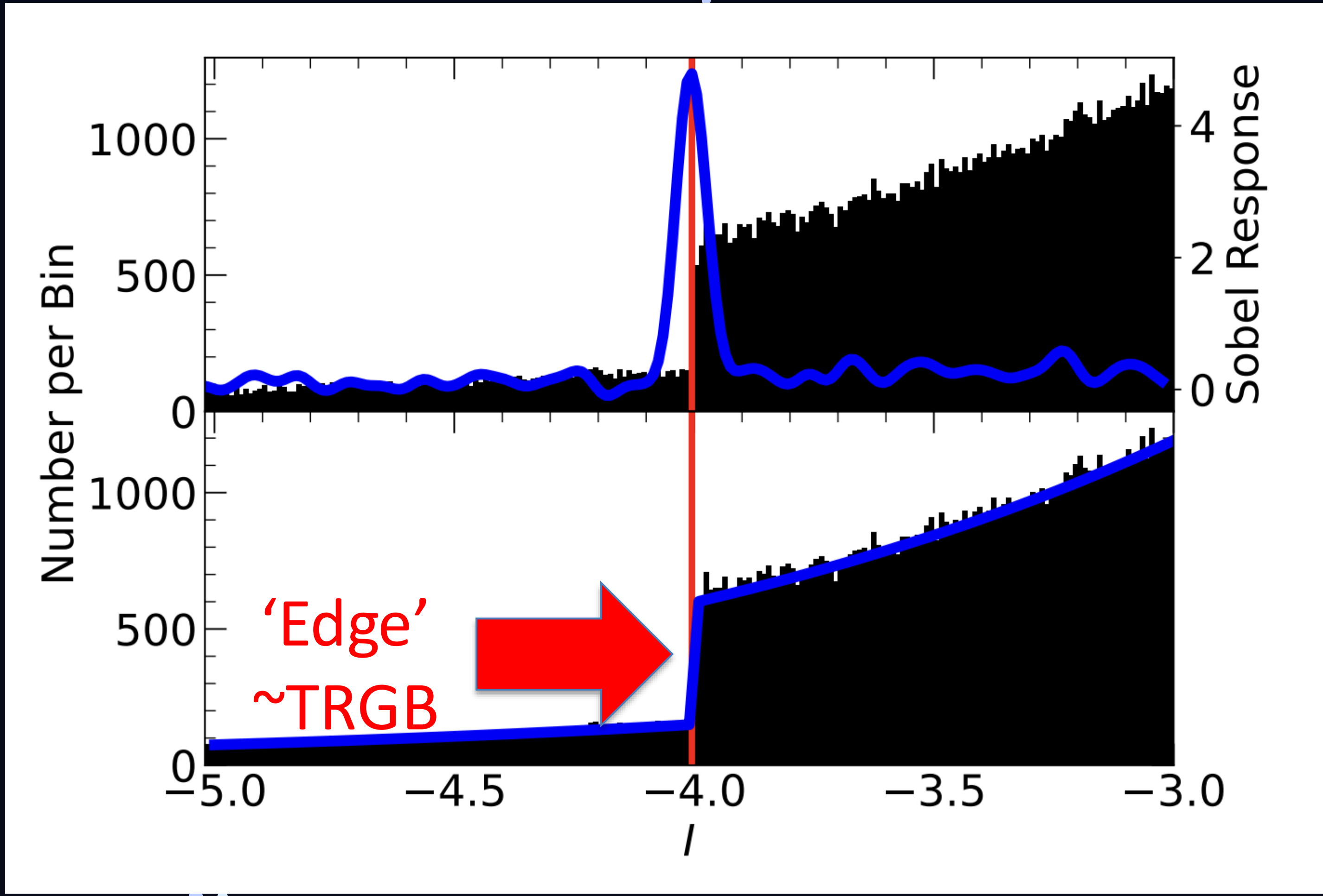


Li +23

$$g(m) = \begin{cases} 10^{a(m-m_{\mathrm{TRGB}})} , & \text{if } m - m_{\mathrm{TRGB}} > 0 , \\ 10^{b(m-m_{\mathrm{TRGB}})-c} , & \text{if } m - m_{\mathrm{TRGB}} < 0 . \end{cases}$$

The RGB Luminosity Function (cont'd)

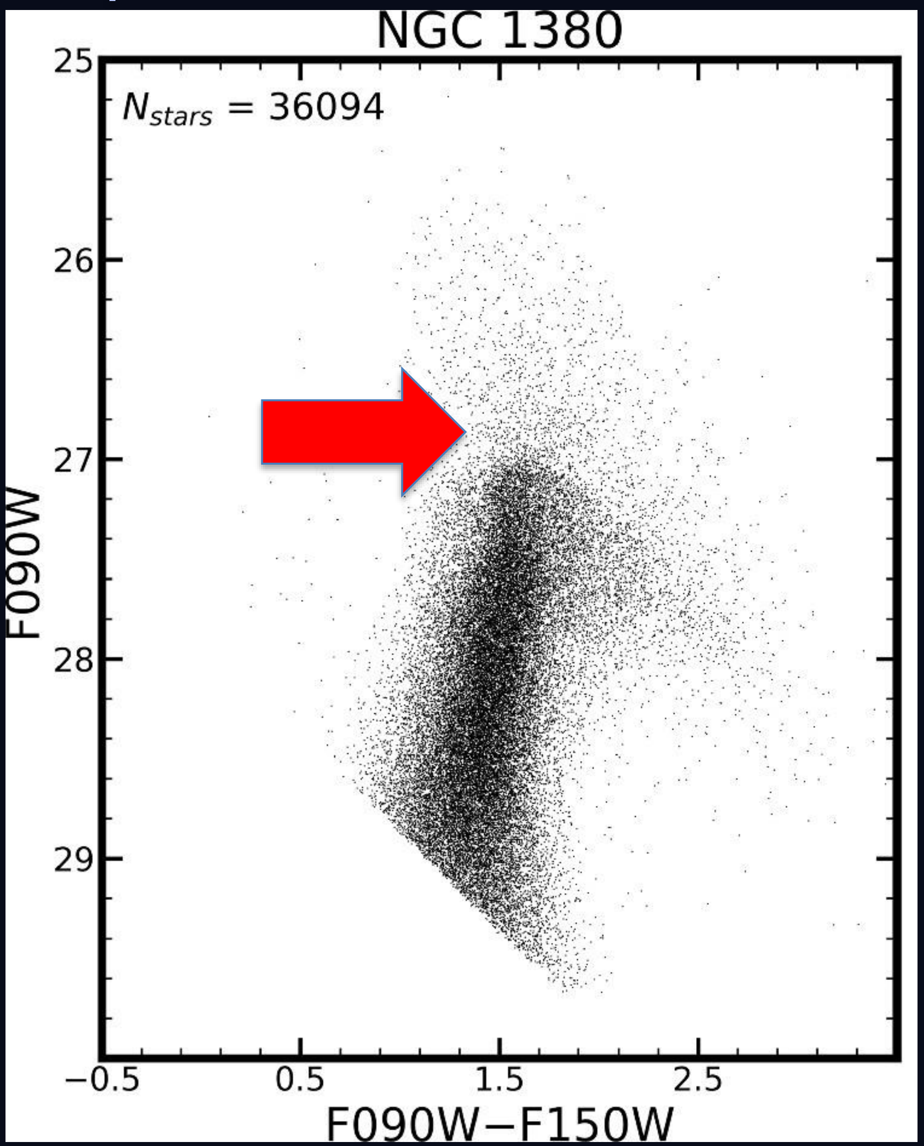
Goal: find the magnitude of the discontinuity (the edge)



Li & Beaton 24

Why the I-Band?

- TRGB changes w/ color
- Least observed variation in I-band
- For simplicity, many TRGB measurements restricted to this area; color rectifications possible (e.g. see Rizzi+07, Jang+17, Newman+24)



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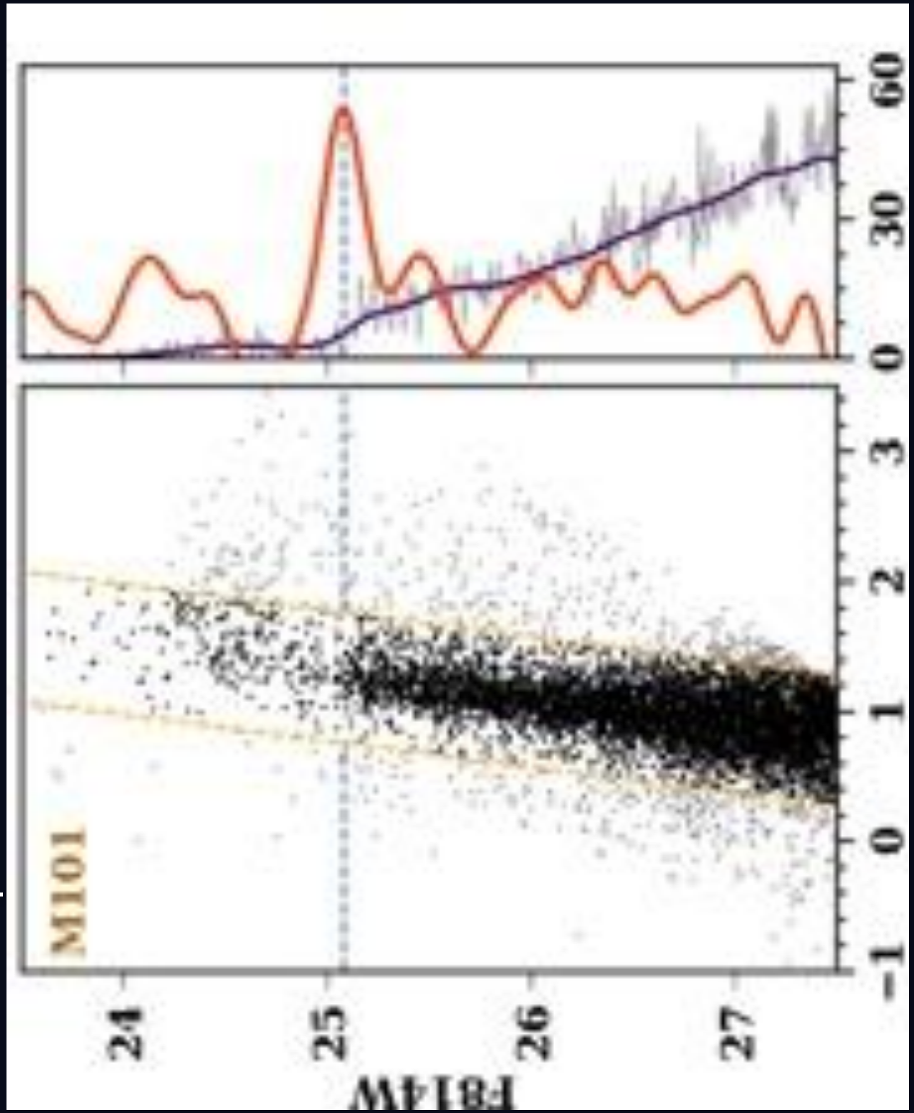
The Problem — Finding the Edge

Poisson statistics make the sharp edge noisy

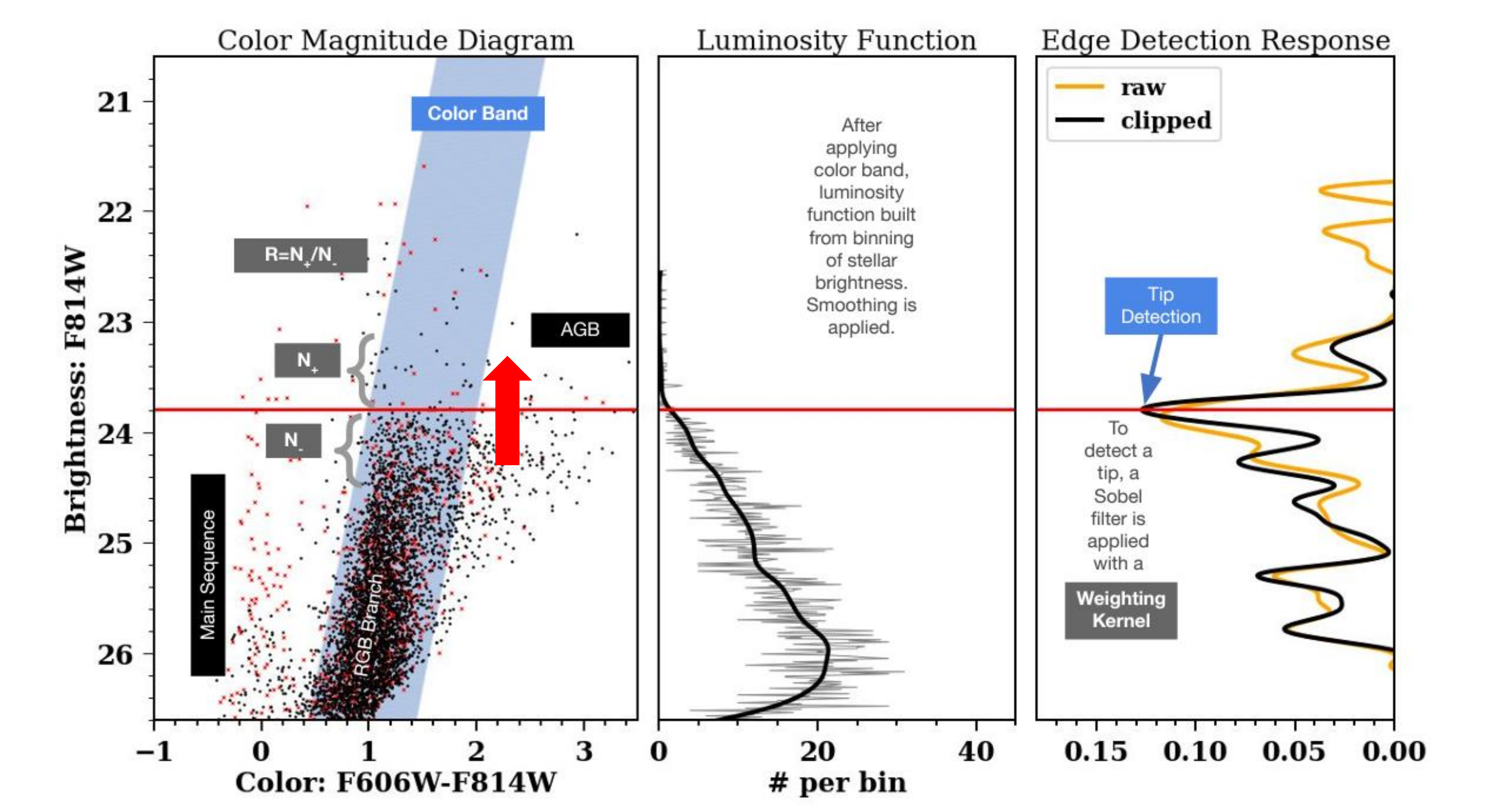
Real data complications:

- › Finite star counts: Poisson noise ∝ √N in each magnitude bin
- › Photometric uncertainties: stars scatter across the true edge
- › Incompleteness: stars near the limiting magnitude are missed
- › AGB contamination: rare AGB stars can appear above the TRGB



Scolnic+23

Measuring the TRGB w/ the Sobel Filter



Wu+23

Section 2

From TRGB Measurements to Distances

How do we Measure Distances to Galaxies?

NGC 4258

$m - M_{N4258} = \mu_{N4258}$

Calibration → Find M

m: apparent brightness

M: intrinsic brightness

μ: distance

*Knowing m & μ_{N4258}

→ solve for M

How do we Measure Distances to Galaxies?

NGC 4258

$$M_{N4258} = M_{N5584}$$

NGC 5584

$$m - M_{N4258} = \mu_{N4258}$$

Solve for M

$$m - M_{N5584} = \mu_{N5584}$$

Solve for μ_{N5584} (distance)

Measuring H_0 with a Distance Ladder

Geometry calibrates candle → distance → calibrate SNe Ia → even further distance

4 Anchor-Cepheid-SNe Ia ladder currently most mature, highest precision: **Test**


NASA

Anchor
e.g., Milky Way, NGC 4258; LMC, SMC

Cepheids

TRGB

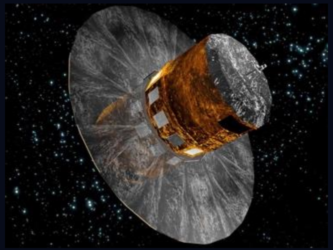
Miras

JAGB

Host galaxy w/ Type Ia supernova

→

Even further Type Ia supernovae


ESA

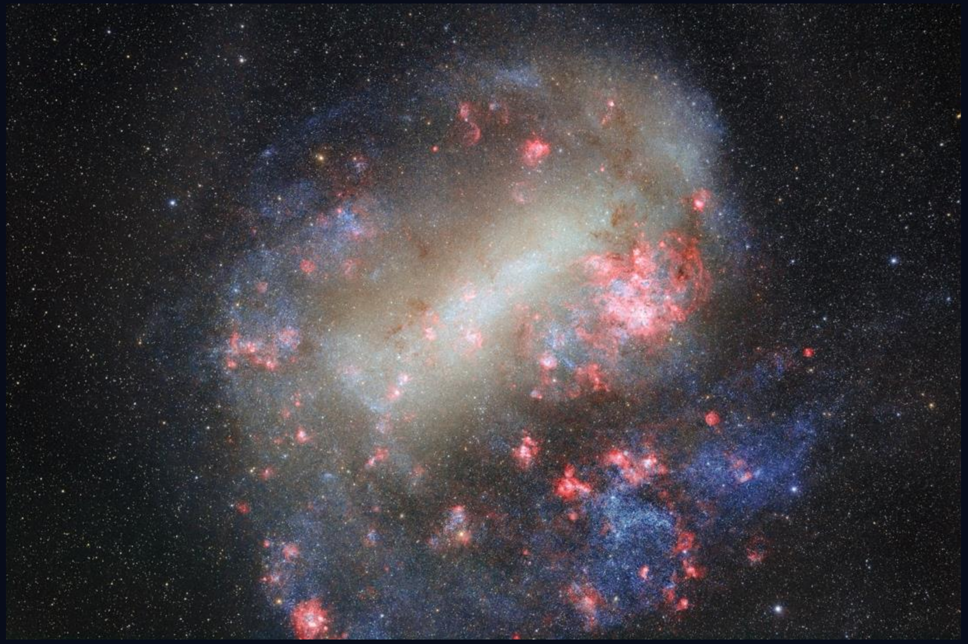

NASA

Anchors — Calibrating M_I(TRGB)

Geometric distance to the Large Magellanic Cloud

The Large Magellanic Cloud (LMC):

- Irregular satellite galaxy of the Milky Way
- Distance: 49.59 ± 0.09 (stat) ± 0.54 (sys) kpc (Pietrzyński et al. 2019)
- Geometric distance measured w/ Detached Eclipsing Binaries (DEBs)
- See Louise’s lecture



Petr Horálek

Anchors — Calibrating M_I(TRGB)

The calibrator sample: a constrained but growing list

NGC 4258 (geometric anchor):

› Contains a water megamaser: geometric distance d = 7.60 Mpc (Reid+2019)

› NOT a SN Ia host, but used as the zero-point anchor for TRGB calibration

Question to think about: For JWST, why don't we use LMC, SMC, MW?

NGC 4258 — The Geometric Anchor

A water megamaser provides a model-independent distance

What is a water megamaser?

› Maser = Microwave Amplification by Stimulated Emission of Radiation (Microwave analogue of a laser)

› Water (H_2O) molecules in an accretion disk around a supermassive black hole

› Stimulated emission → extremely bright, narrow microwave spectral lines

NGC 4258 — The Geometric Anchor (cont'd)

A water megamaser provides a model-independent distance

Why masers give geometric distances:

› Radio interferometry w/ VLBI (Very Long Baseline Interferometry — radio telescope array) maps the maser disk in milli-arcsec

› Observe proper motion (angular velocity) + Doppler velocities (km/s)

› Geometric model: disk radius from angular size + Keplerian orbit

› d = v_Keplerian / (angular velocity) → purely geometric distance!

› No stellar physics, no standard candles, no calibration chain needed

NGC 4258 — The Geometric Anchor (cont'd)

A water megamaser provides a model-independent distance

NGC 4258 distance (Reid et al. 2019):

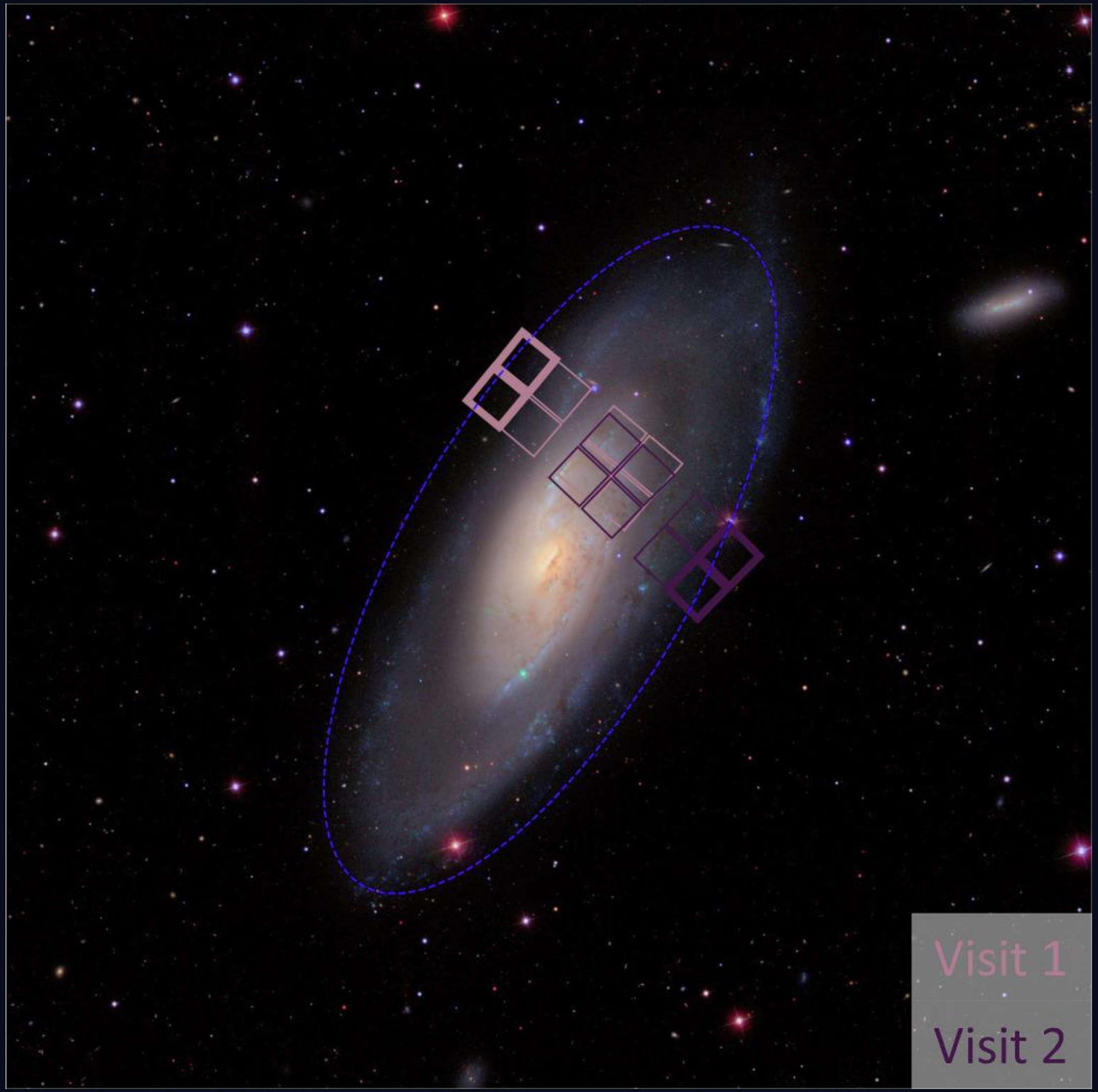
› d = 7.60 ± 0.17 (stat) ± 0.15 (sys) Mpc

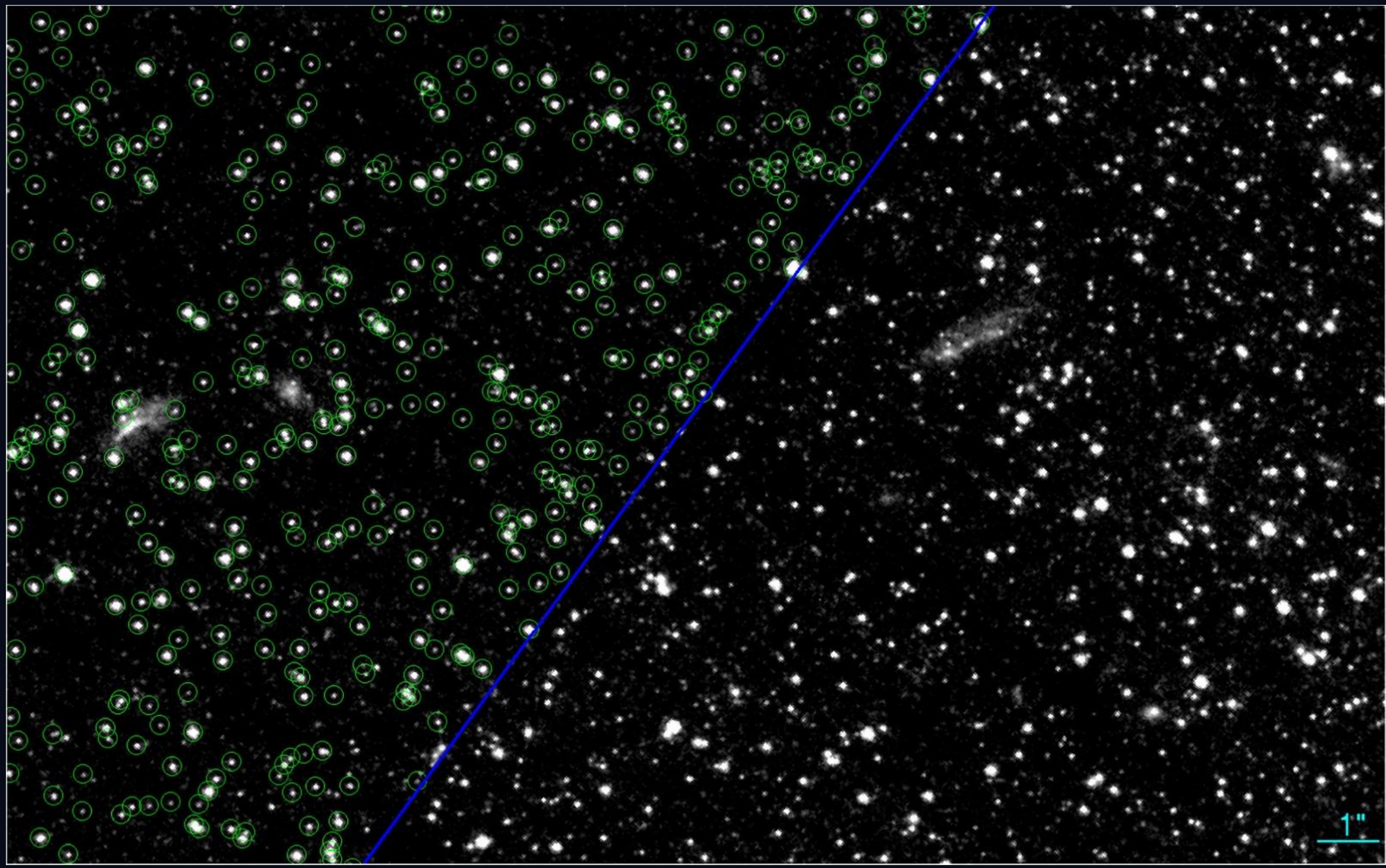
→ μ = 29.397 ± 0.032 mag

› This anchors the TRGB calibration for HST, JWST TRGB distance measurements

Anchor Galaxies

Example TRGB JWST observation (Anand+24); JWST GO-1685 (PI: A. Riess)





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Anchor Galaxies

$\textcolor{green}{m} - \textcolor{red}{M_{N4258}} = \textcolor{green}{\mu_{N4258}}$

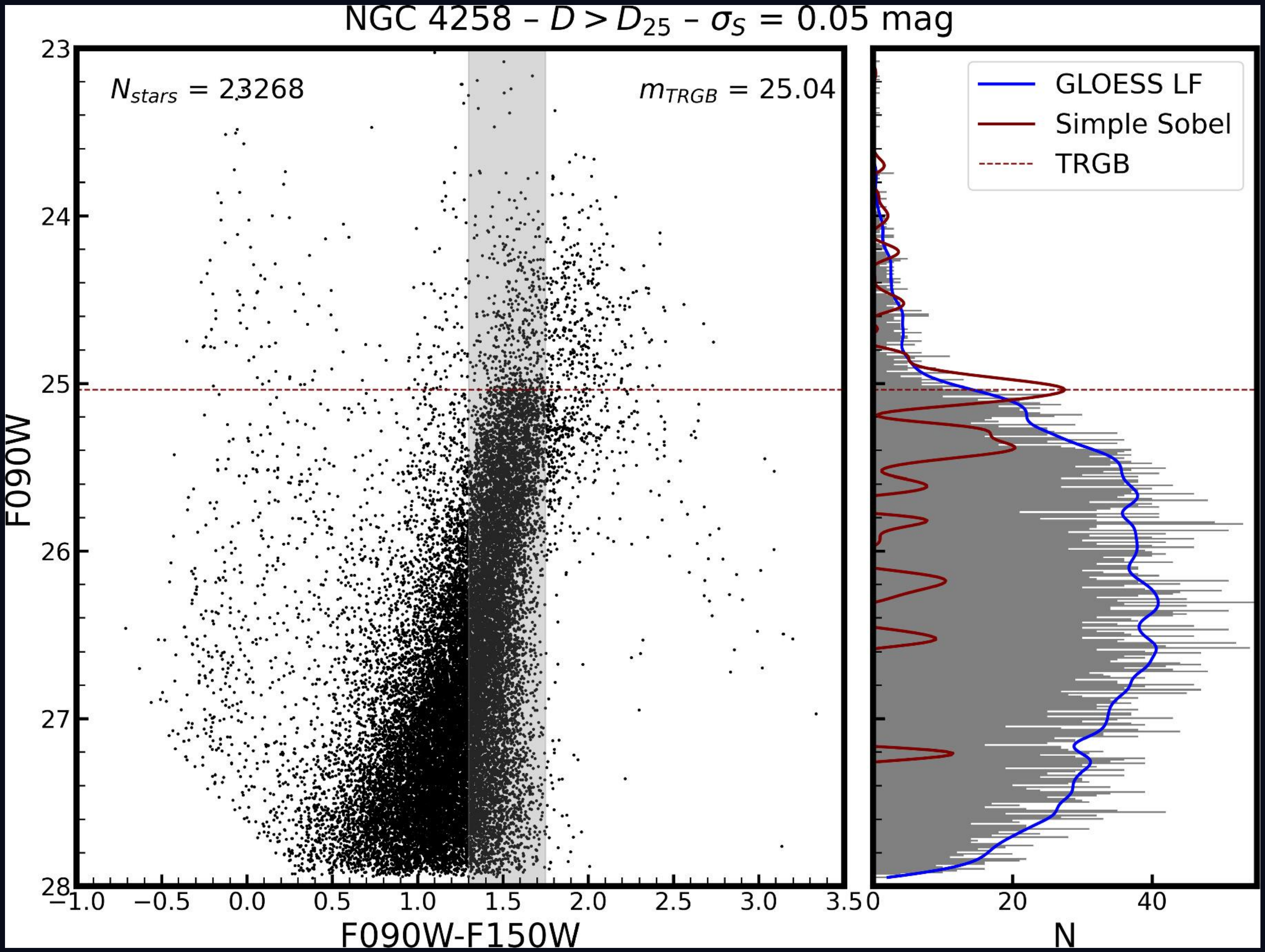
Calibration → Find M

$\textcolor{green}{m} - \textcolor{green}{\mu_{N4258}} = \textcolor{red}{M_{N4258}}$

$m_{\text{TRGB, 0}}$ = 25.035 ± 0.02 mag

M(N4258) = 29.397 ± 0.032 (Reid+19)

$M_{\text{TRGB, 0}}$ = −4.362 mag



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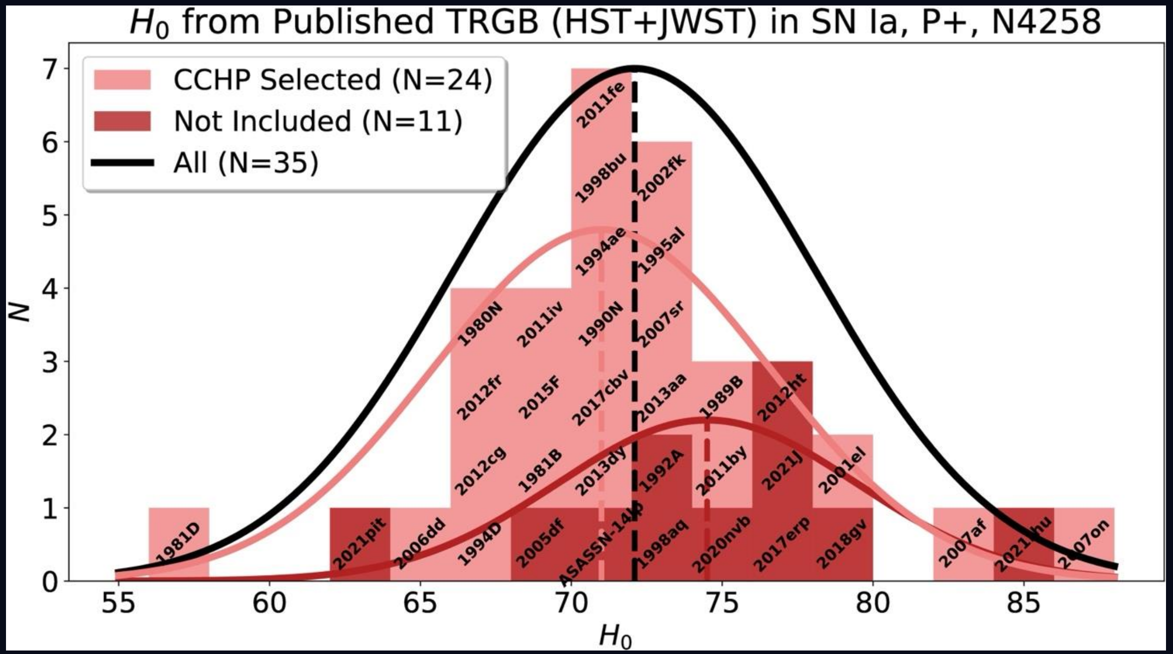
Which Galaxies Have Both TRGB and SN Ia?

Current sample (HST & JWST):

- **35 SN Ia** observed in 30 host galaxies

- One galaxy can have multiple observed SN Ia



LI+26

Which Galaxies Have Both TRGB and SN Ia? (cont'd)

One useful reference + compilation in Li+26:

Table 2
Host Galaxy Distances, SN Ia Magnitudes, and H_0 Values

SN #	Galaxy	$\mu_{\rm HST}^{\rm TRGB}$	σ^*	Src	$\mu_{\rm HST}^{\rm TRGB}$(A22)	σ^*	$\mu_{\rm JWST}^{\rm TRGB}$	σ^*	Src	$\mu_{\rm JWST}^{\rm TRGB}$(F25)	σ^*	$\bar{\mu}$	σ^*	SNe Ia	P+SN (mag)	σ	M_B	σ	H_0	$\mu_{\rm HST}^{\rm Ceph}$	σ
1	M101	29.08	0.04	F19	29.08	0.05	29.151	0.042	F25	…	…	29.11	0.03	2011fe	9.78	0.12	−19.33	0.13	71.1	29.188	0.055
2	M66	30.22	0.04	F19	30.22	0.05	…	…	…	…	…	30.22	0.04	1989B	10.98	0.15	−19.24	0.16	74.2	…	…
3	M96	30.31	0.04	F19	30.20	0.05	…	…	…	…	…	30.31	0.04	1998bu	11.00	0.15	−19.31	0.16	71.8	…	…
4	N1309	32.50	0.07	J17	…	…	…	…	…	…	…	32.50	0.07	2002fk	13.20	0.12	−19.30	0.14	72.2	32.552	0.069
5	N1316	31.46	0.04	F19	31.36	0.07	…	…	…	…	…	31.46	0.04	1980N	12.002	0.097	−19.46	0.11	67.1	…	…
6	N1316	31.46	0.04	F19	31.36	0.07	…	…	…	…	…	31.46	0.04	2006dd	11.94	0.108	−19.52	0.12	65.2	…	…
7	N1316	31.46	0.04	F19	31.36	0.07	…	…	…	…	…	31.46	0.04	1981D	11.61	0.23	−19.85	0.24	56.0	…	…
8	N1365	31.36	0.05	F19	31.41	0.05	31.366	0.069	F25	…	…	31.36	0.04	2012fr	11.90	0.09	−19.46	0.10	67.0	31.378	0.061
9	N1380	…	…	…	…	…	31.397	0.072	A24	…	…	31.397	0.07	1992A	12.095	0.135	−19.30	0.15	72.1	…	…
10	N1404	31.36	0.06	H21	31.29	0.07	31.364	0.074	A24	…	…	31.36	0.06	2011iv	11.974	0.099	−19.39	0.11	69.3	…	…
11	N1404	31.36	0.06	H21	31.29	0.07	31.364	0.074	A24	…	…	31.36	0.06	2007on	12.46	0.19	−18.9	0.20	86.7	…	…
12	N1448	31.32	0.06	F19	31.33	0.06	31.39	0.07	L24	31.321	0.049	31.35	0.05	2001el	12.254	0.136	−19.10	0.14	79.1	31.298	0.051
13	N1448	31.32	0.06	F19	31.33	0.06	31.39	0.07	L24	31.321	0.049	31.35	0.05	2021pit	11.752	0.20	−19.60	0.21	62.8	…	…
14	N1559	…	…	…	…	…	31.51	0.05	L24	31.491	0.051	31.51	0.05	2005df	12.141	0.086	−19.37	0.10	69.9	31.5	0.071
15	N2442	…	…	…	…	…	31.646	0.097	F25	…	…	31.65	0.10	2015F	12.23	0.09	−19.42	0.14	68.4	31.459	0.073
16	N2525	…	…	…	…	…	31.81	0.09	L24	…	…	31.81	0.09	2018gv	12.728	0.074	−19.08	0.12	79.8	32.059	0.105
17	N3021	32.22	0.05	J17	…	…	…	…	…	…	…	32.22	0.05	1995al	12.97	0.12	−19.25	0.14	73.8	32.473	0.162
18	N3370	32.27	0.05	J17	…	…	32.19	0.08	L24	…	…	32.25	0.04	1994ae	12.937	0.082	−19.30	0.10	72.1	32.132	0.062
19	N3447	…	…	…	…	…	31.92	0.09	L24	…	…	31.92	0.09	2012ht	12.736	0.089	−19.18	0.13	76.1	31.947	0.049
20	N3972	…	…	…	…	…	31.747	0.068	F25	…	…	31.75	0.07	2011by	12.55	0.09	−19.20	0.12	75.7	31.644	0.096
21	N3982	31.50	0.13	Here	…	…	…	…	…	…	…	31.50	0.13	1998aq	12.252	0.078	−19.25	0.15	73.9	31.736	0.08
22	N4038	31.68	0.05	J17	31.68	0.14	31.645	0.078	F25	…	…	31.67	0.04	2007sr	12.41	0.11	−19.26	0.12	73.6	31.612	0.121
23	N4414	31.24	0.09	Here	…	…	…	…	…	…	…	31.24	0.09	2021J	12.1046	0.14	−19.14	0.17	77.8	…	…
24	N4424	31.00	0.06	F19	31.00	0.07	30.926	0.03	F25	…	…	30.94	0.03	2012cg	11.487	0.19	−19.46	0.19	66.9	30.854	0.133
25	N4457	31.05	0.10	Here	…	…	…	…	…	…	…	31.05	0.1	2020nvb	11.85	0.14	−19.20	0.17	75.6	…	…
26	N4526	31.00	0.07	F19	30.99	0.05	…	…	…	…	…	31.00	0.07	1994D	11.532	0.093	−19.47	0.12	66.8	…	…
27	N4536	30.96	0.05	F19	31.01	0.13	30.923	0.052	F25	…	…	30.94	0.04	1981B	11.55	0.13	−19.39	0.14	69.2	30.87	0.061
28	N4639	31.79	0.09	Here	…	…	31.774	0.073	F25	…	…	31.78	0.06	1990N	12.45	0.12	−19.33	0.13	71.1	31.823	0.091
29	N4666	30.90	0.05	Here	…	…	…	…	…	…	…	30.90	0.05	ASASSN-14lp	11.585	0.13	−19.31	0.14	71.7	…	…
30	N5584	31.82	0.10	J17	…	…	31.8	0.11	L24	31.851	0.053	31.81	0.07	2007af	12.804	0.079	−19.01	0.11	82.6	31.766	0.062
31	N5643	30.48	0.08	H21	30.42	0.07	30.58	0.06	L24	30.599	0.057	30.54	0.05	2013aa	11.25	0.08	−19.30	0.09	72.2	30.553	0.063
32	N5643	30.48	0.08	H21	30.42	0.07	30.58	0.06	L24	30.599	0.057	30.54	0.05	2017cbv	11.21	0.08	−19.34	0.09	70.9	…	…
33	N5861	…	…	…	…	…	32.10	0.11	L24	…	…	32.1	0.11	2017erp	12.945	0.107	−19.16	0.15	77.2	32.232	0.105
34	N7250	…	…	…	…	…	31.629	0.047	F25	…	…	31.63	0.05	2013dy	12.28	0.18	−19.35	0.19	70.6	31.642	0.13
35	N7814	30.86	0.07	D22	…	…	…	…	…	…	…	30.86	0.07	2021rhu	11.92	0.15	−18.94	0.17	85.2	…	…

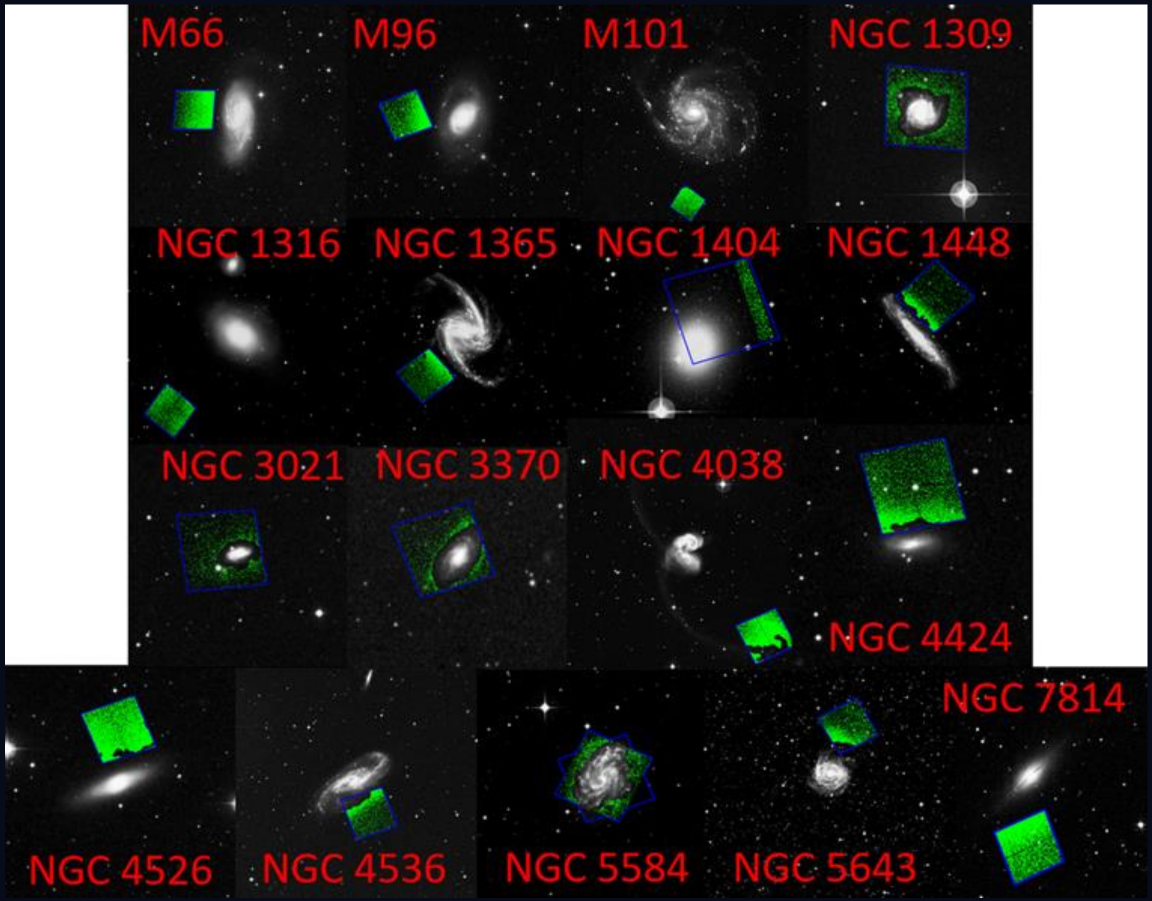
LI+26

SN Ia Host Galaxies

› HST/JWST observations SN Ia host galaxies

› Typically designed to observe halos of galaxies, but sometimes also contains disk if also optimized for other purposes

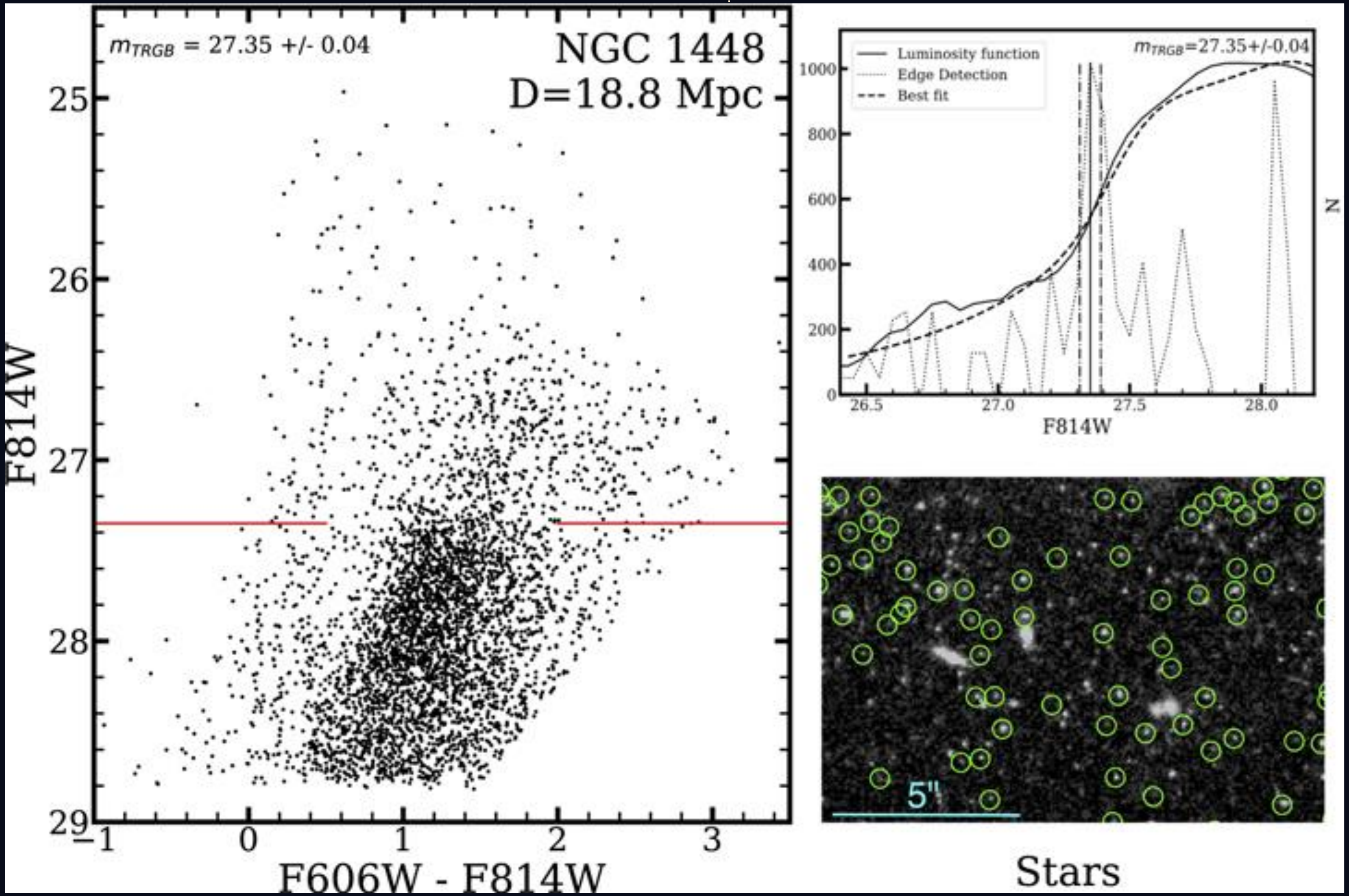
› Spatial selection/clipping to remove younger stars, contamination, high crowding regions, etc.



Scolnic+23

SN Ia Host Galaxies

$m - M_{Host} = \mu_{Host}$



Anand+22

Section 3

Examples of Systematics

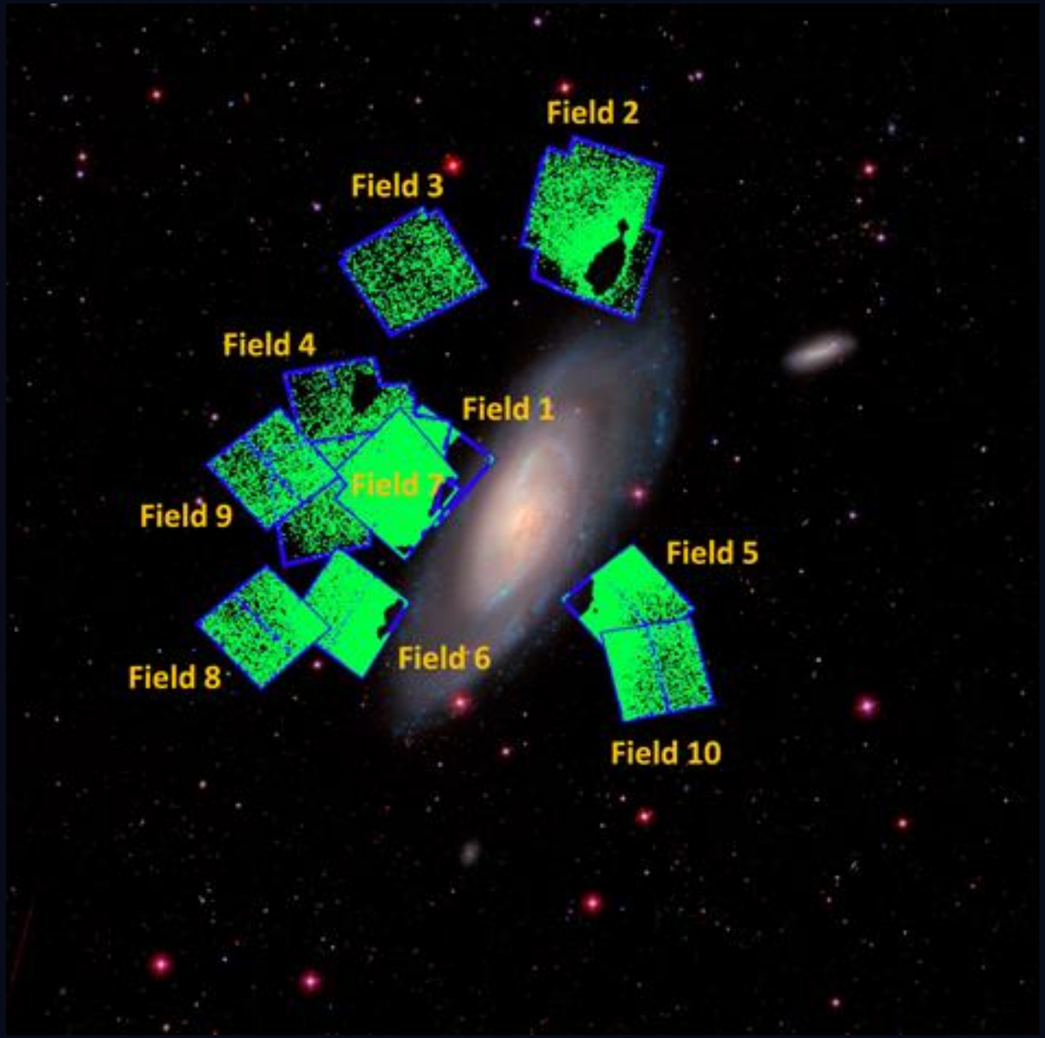
Systematic 1: Population Effects

Does the TRGB vary w/ populations?

› Theory predicts little variation w/ age; larger variation w/ metallicity (calibrated)

› But…observational evidence suggests variations depending n field

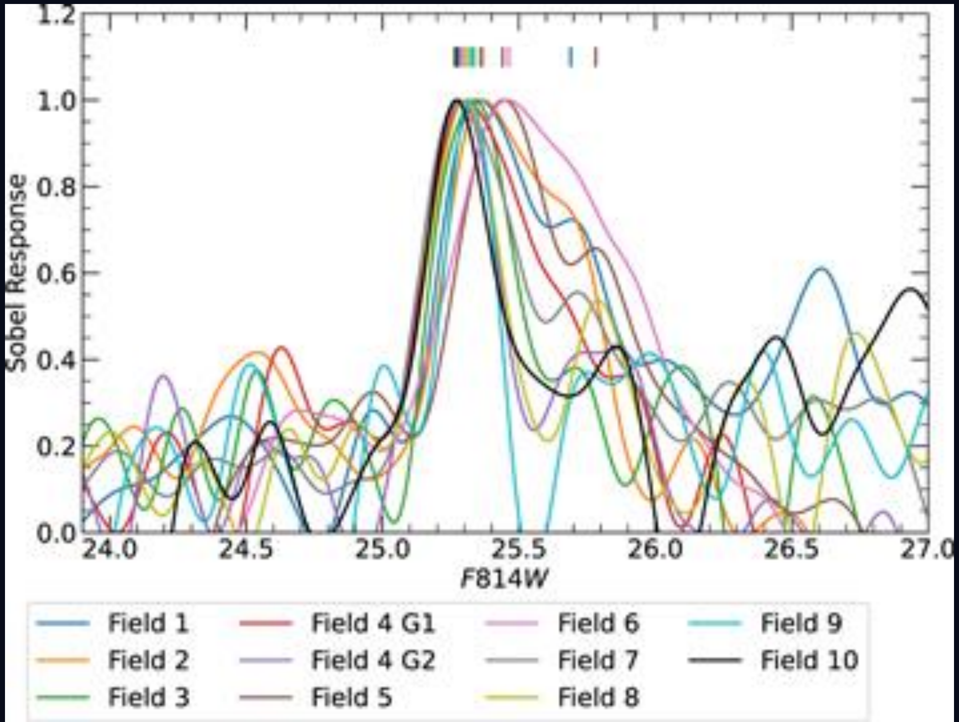
› See CATs e.g. Wu+23, Li+23, Scolnic+23



Systematic 1: Population Effects

› Applying the same measurement parameters to different fields → inconsistent TRGBs

› TRGBs in the same galaxy should be the same in the halo… what's going on?



Question to you: How do you think this should be handled?

Standardizing the TRGB: CATs

Wu+23, Li+23, Scolnic+23

https://www.thehappycatsite.com/why-do-cats-wag-their-tails/

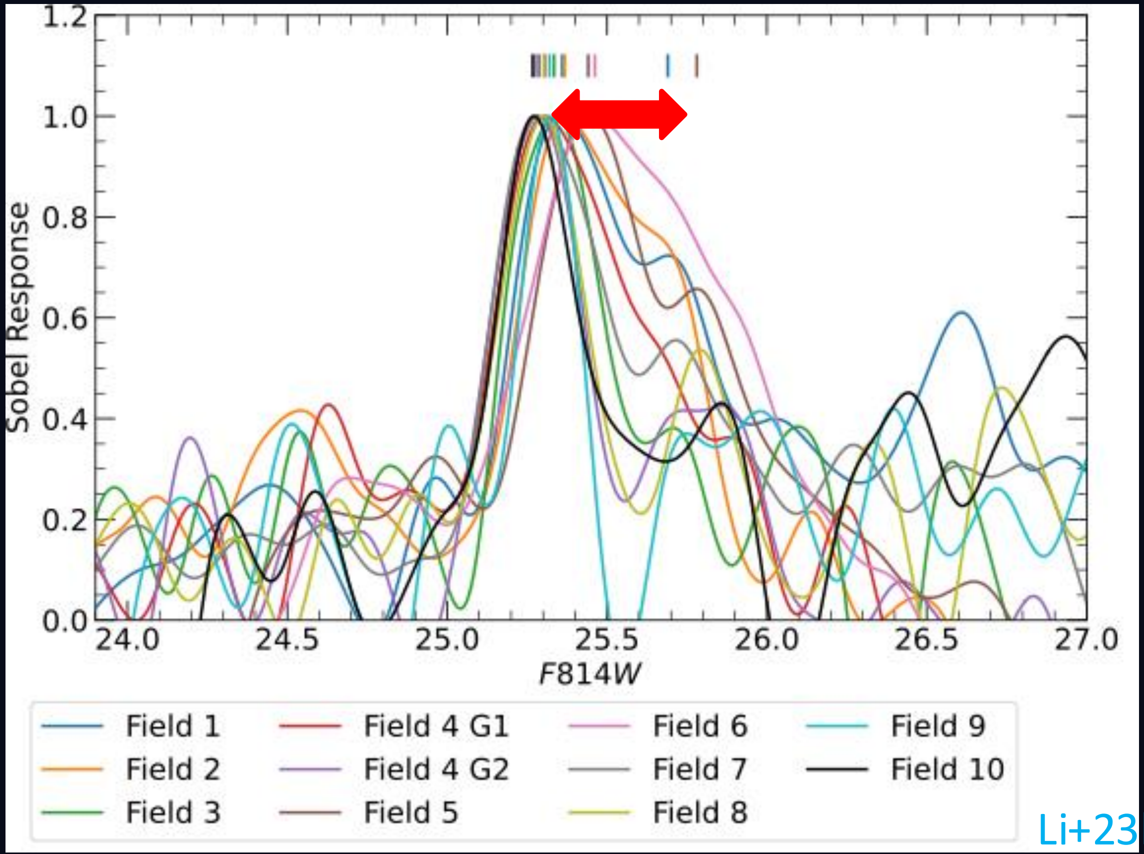
CATs: Comparative Analysis of TRGBs

- **Problem:** Variations in TRGB measurements directly impact distance & H_0 measurements

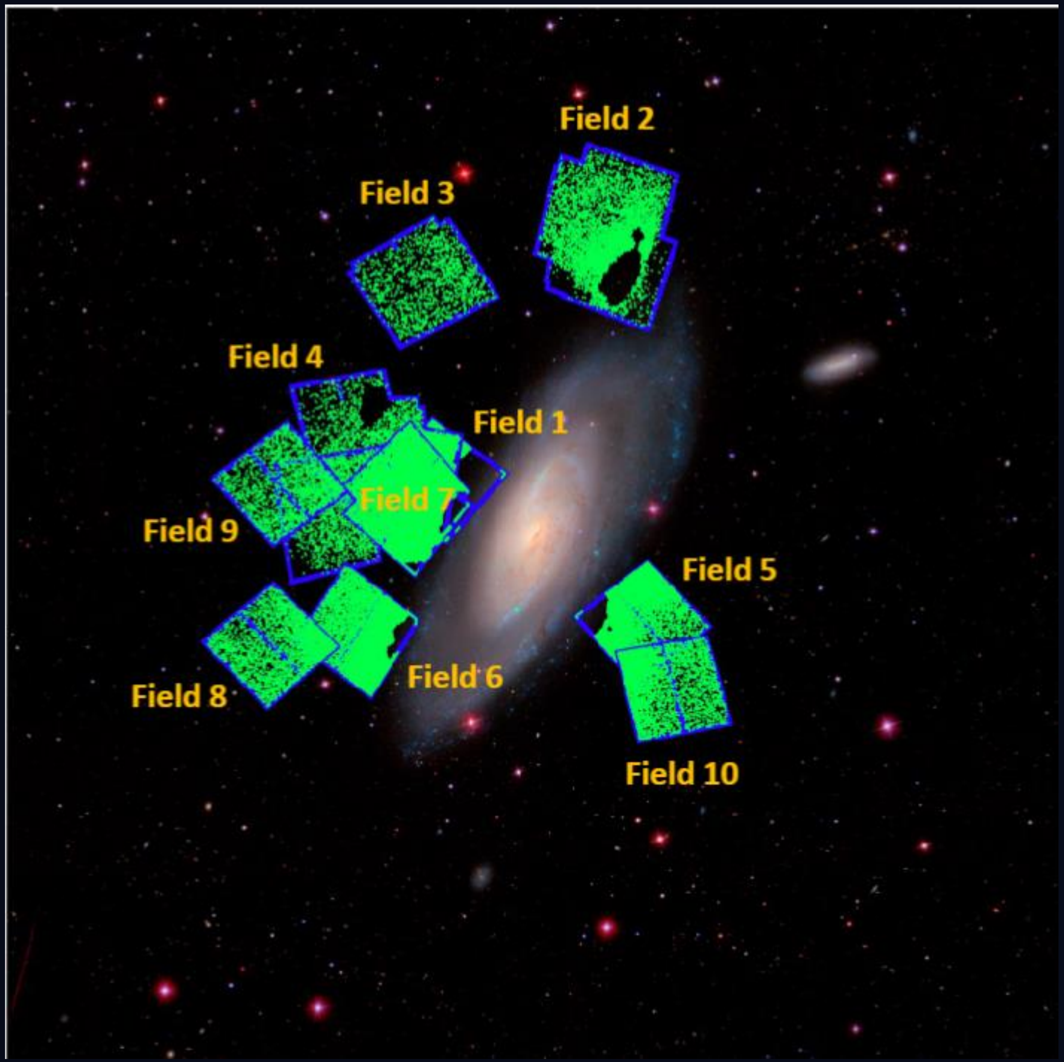
- **Two-fold approach:**
  - Develop an unsupervised TRGB measurement algorithm to avoid subjective biases (Wu+22)
  - Additional ***standardization*** to improve consistency along the distance ladder (Wu+22, Li+23, Scolnic+23)

Why do these TRGBs all differ?

- ~0.3 mag field-to-field tip **dispersion** in NGC 4258
- Which is *typical* (for SN host)?

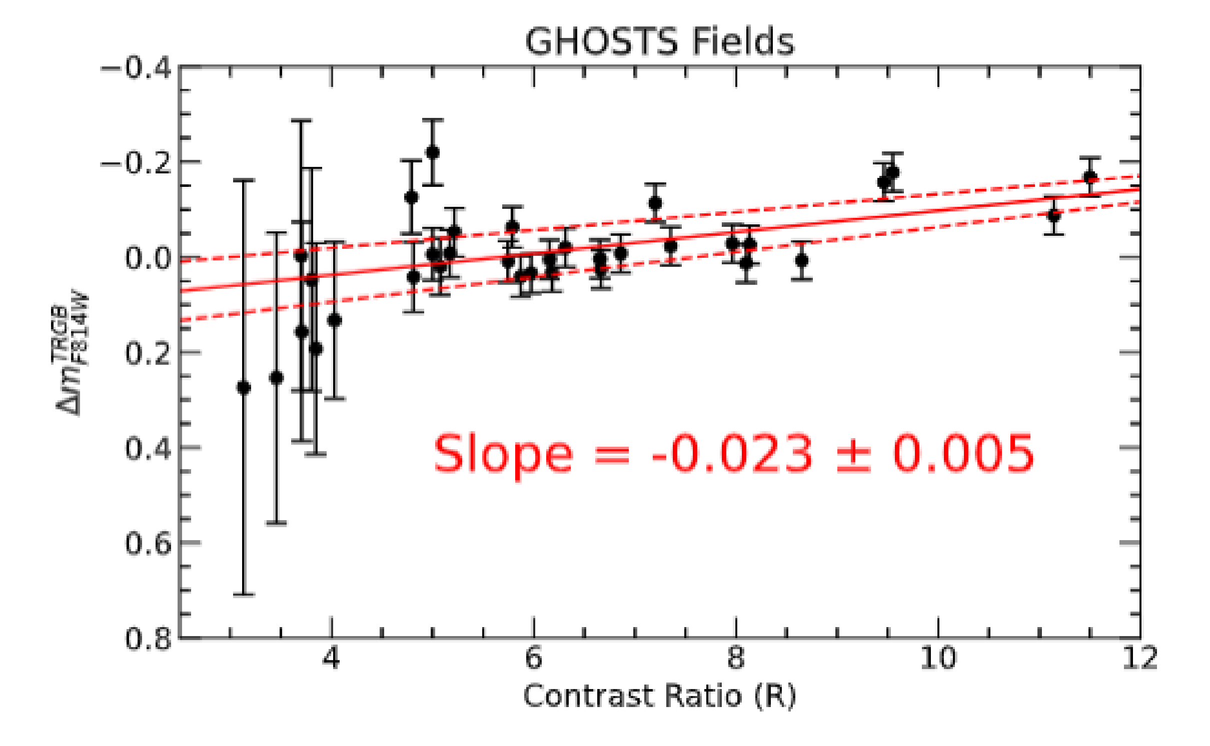


Li+23b

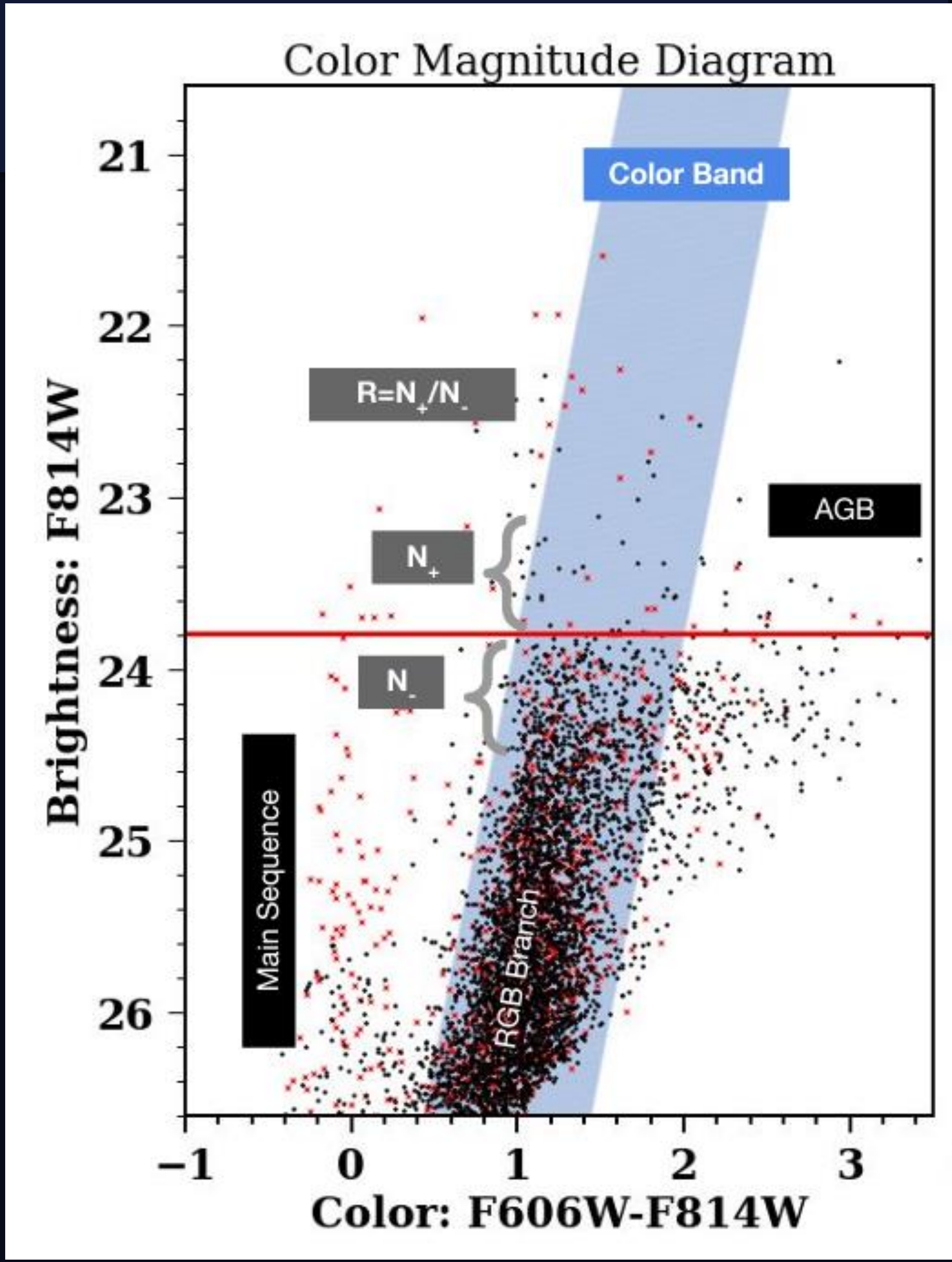


Introducing the Contrast Ratio

- **Contrast Ratio (R):** ratio between # stars 0.5 mag fainter and brighter than TRGB
- Applied to NGC 4258 & SN Ia host galaxies



Wu+22; Li+23b



Wu+22

Tip-Contrast Ratio Calibration

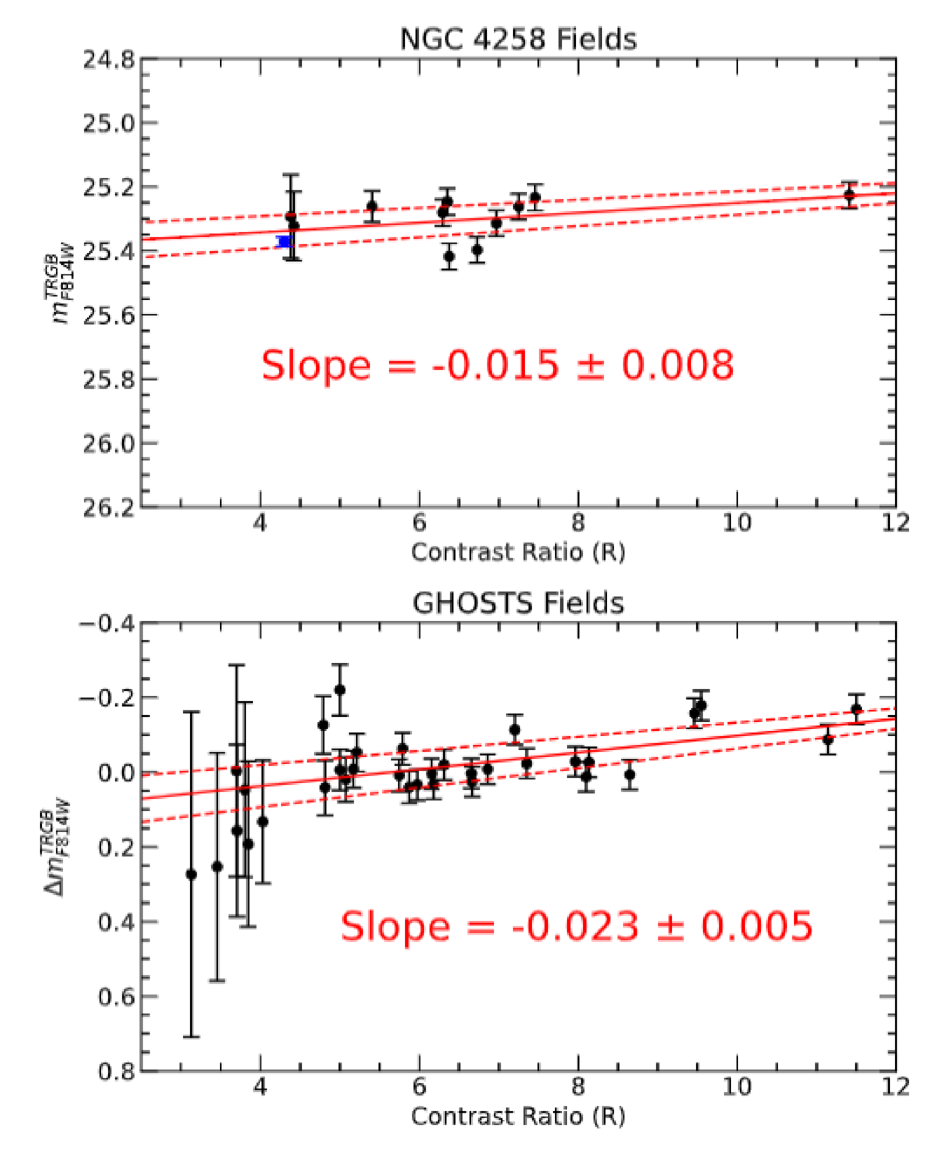
- Tip-Contrast Ratio (TCR) in NGC 4258: 1σ agreement w/ TCR from Wu+23

- **Result:** combining calibrations yields

$$M(\text{TRGB}; \mathit{F814W}) = -4.025 \pm 0.035 - (R - 4) \times 0.021$$

Corrected Tip Luminosity | Tip at fiducial | Fiducial R | TCR Slope

- Applied to measure H_0 in Scolnic+23



Li+23

Systematic 1: Population Effects

- Field-to-field variations: not only red giants

→ relative RGB/AGB #, etc. can also produce this effect

- CATs methodology is one approach
- Other approaches: build into error budget, etc.
- You can explore field-to-field effects in the data challenge too

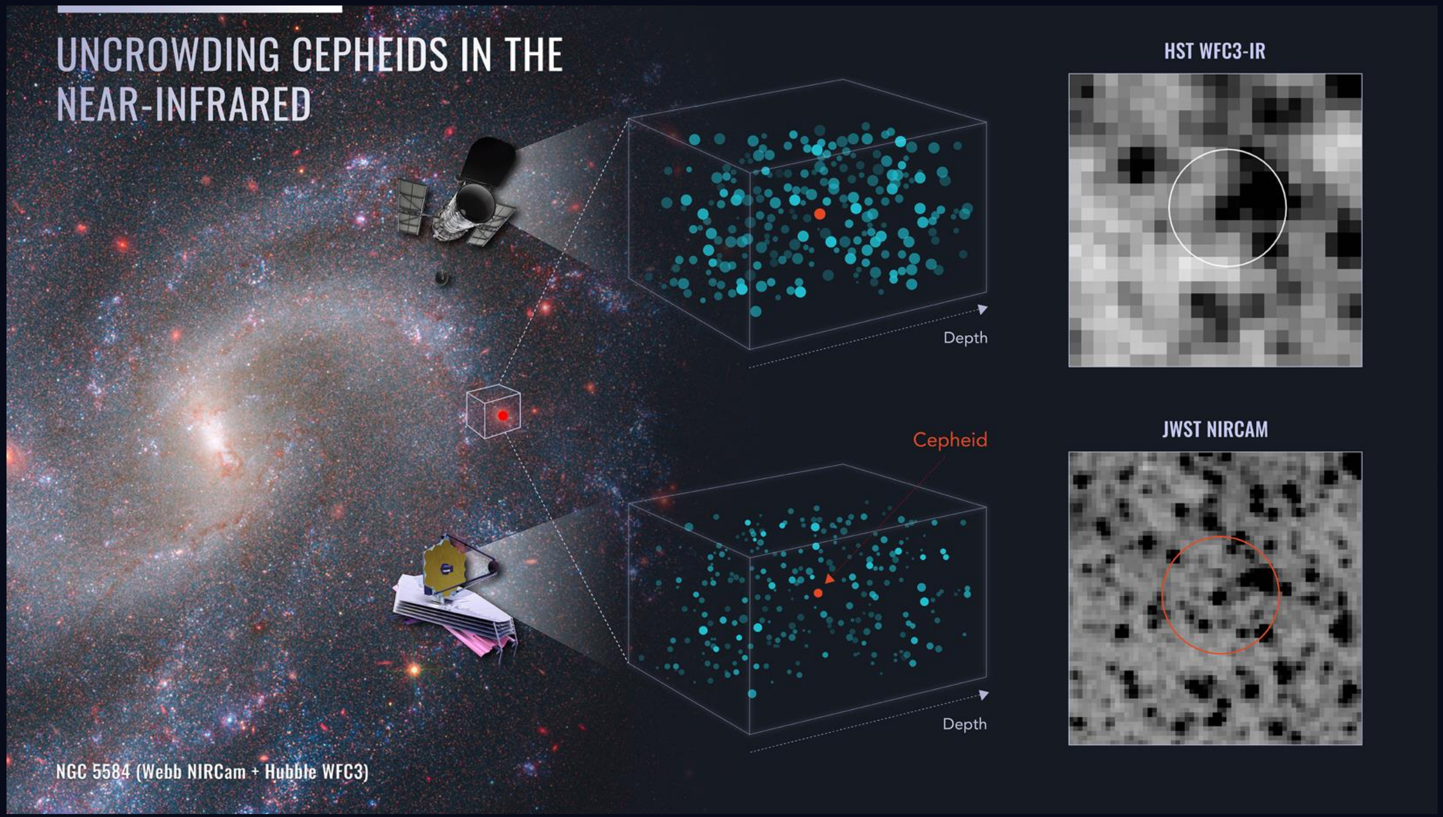
Systematic 2: Blending & Crowding

What it is:

› Blending: PSF overlap; two objects appear as one

› Crowding: nearby stars contaminate brightness measurement of a given star

› Both effects shift measured magnitudes brightward



STScI

Systematic 2: Blending & Crowding (cont'd)

Effect on TRGB measurement:

› Magnitudes biased bright → TRGB edge detected at the wrong (too bright) magnitude

Question to you: How does blending & crowding bias the distance measurement?

› Distance modulus $\mu = m - M$ → m too bright → μ underestimated → distance too small

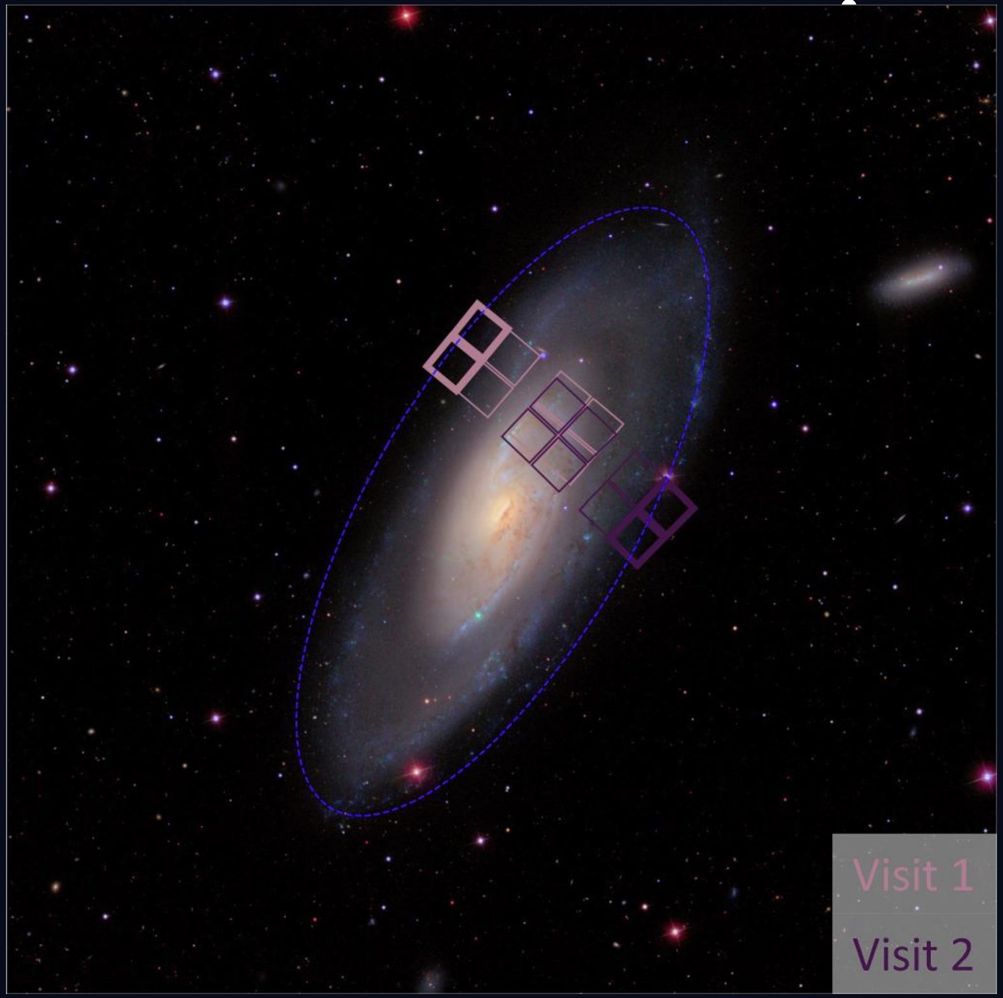
Systematic 2: Blending & Crowding (cont'd) (cont'd)

Mitigation strategies:

› Use uncrowded outer halo fields (spatial clipping removes inner disk)

› Artificial star tests: inject fake stars into images and recover them to quantify the bias

› JWST: smaller PSF → less crowding at the same physical distance



Anand+24

Systematic 3: Dust Extinction

Correction formula:

$A_I = R_I \times E(B-V)$ $m_{I,0} = m_I - A_I$

A_I : extinction in I-band | $R_I \approx 1.49$ | E(B−V): reddening from dust maps

Dust maps used:

› Schlegel, Finkbeiner & Davis 1998 (SFD) — all-sky 100 μm thermal emission map

› Schlafly & Finkbeiner 2011 — recalibrated (used in data challenge)

Systematic 3: Dust Extinction (cont'd)

Field selection matters:

› Halo fields: typically $A_I < 0.05$ mag

› Inner disk fields: A_I can exceed order 0.1 mag (avoid if possible)

Map limitations:

› High-extinction sightlines ($E(B-V) > 0.1$): 20% map uncertainty → significant A_F814W error

› Examples in this dataset: NGC 2442, NGC 5643, NGC 7250

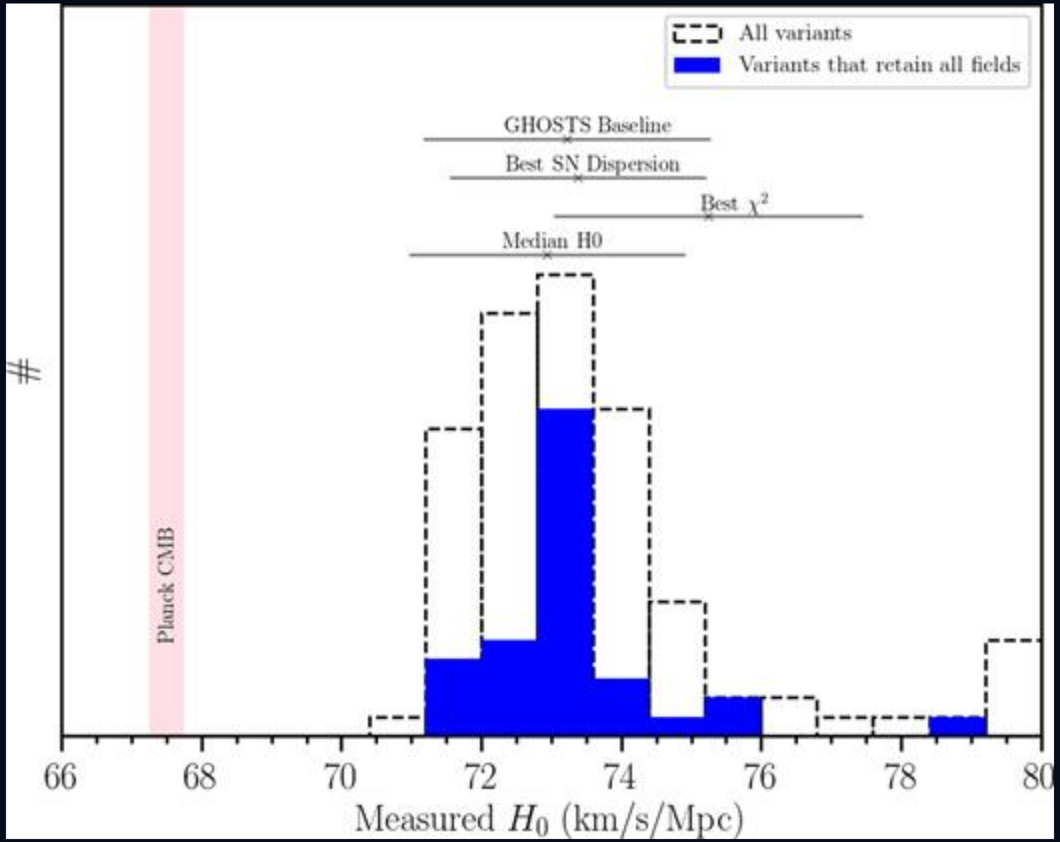
Systematic 4: Methodological Variations

The problem:

› TRGB measurement requires many choices: smoothing (τ), color limits, spatial clipping, Sobel weights, etc.

› What are the 'right' choices?

› Different defensible choices → different measured TRGB → different H_0



Scolnic+23

Systematic 4: Methodological Variations (cont'd)

Suggested approach — remain agnostic & build into errors:

› Make all choices explicit and document them

› Run sensitivity tests (τ, color limits, scale_factor)
→ record the range of TRGB

› Report that range as σ(method) — a separate term in the error budget

Section 3

The Major TRGB Analysis Programs

CCHP — Carnegie Chicago Hubble Program

e.g. Freedman+19

› Led by Wendy Freedman (Univ. Chicago) & Barry Madore (Carnegie)

› Goal: measure TRGB H_0 TRGB independently of Cepheids; probe Hubble Tension

The Astrophysical Journal, 882:34 (29pp), 2019 September 1 https://doi.org/10.3847/1538-4357/ab2f73

CrossMark

The Carnegie-Chicago Hubble Program. VIII. An Independent Determination of the Hubble Constant Based on the Tip of the Red Giant Branch*

Wendy L. Freedman[1], Barry F. Madore[2], Dylan Hatt[1], Taylor J. Hoyt[1], In Sung Jang[3], Rachael L. Beaton[4], Christopher R. Burns[2], Myung Gyoon Lee[5], Andrew J. Monson[6], Jillian R. Neeley[7], M. M. Phillips[8], Jeffrey A. Rich[2], and Mark Seibert[2]
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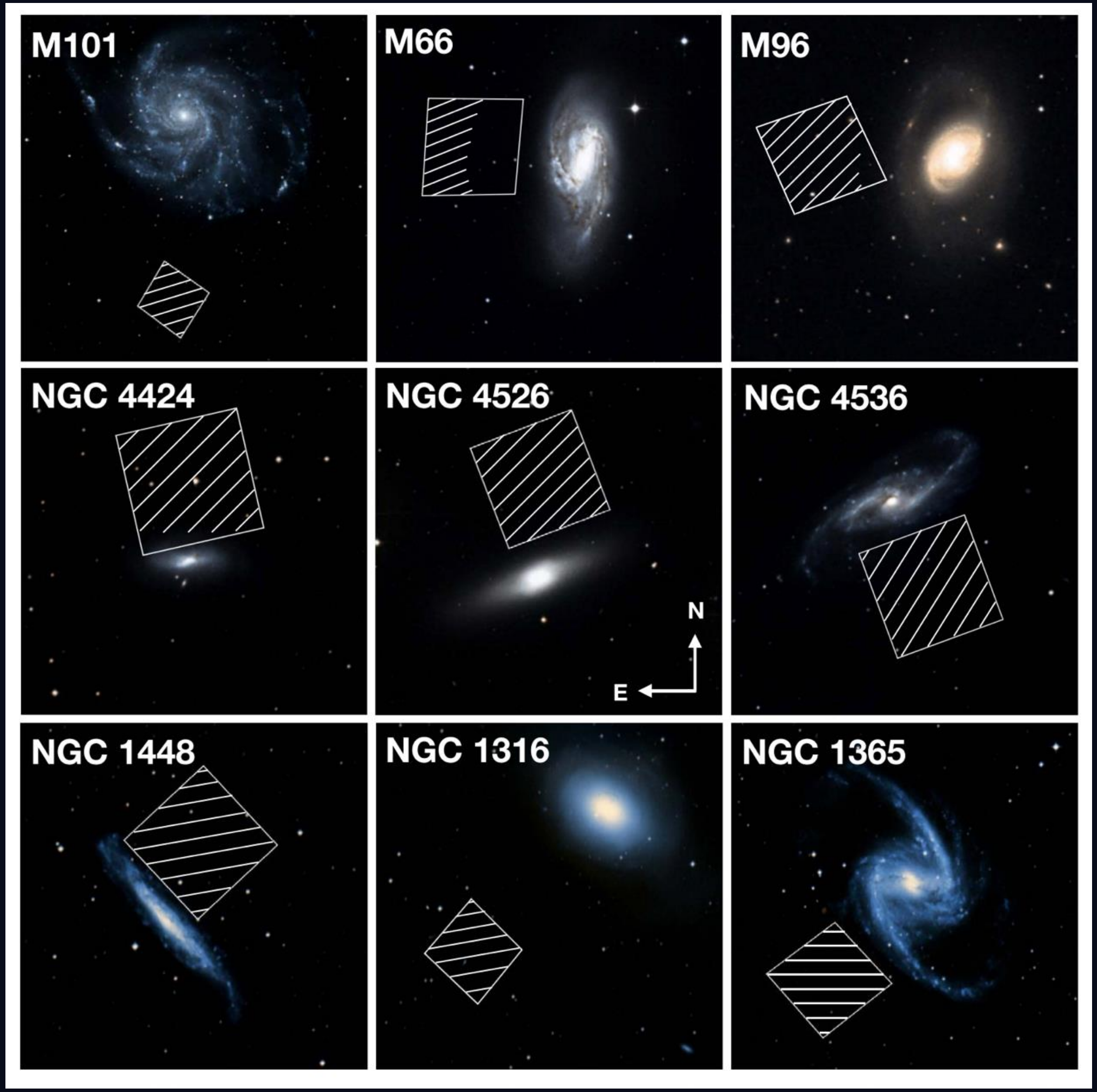
Received 2019 April 25; revised 2019 June 22; accepted 2019 July 3; published 2019 August 29

CCHP — Carnegie Chicago Hubble Program (cont'd)

e.g. Freedman+19

- **Calibration anchor:** LMC DEBs (Pietrzyński+2019)
- Edge detection: Sobel filter
- Photometry: custom pipeline w/ DAOPHOT
- SN Ia sample: CSP supernova photometry



Freedman+19

CCHP — Carnegie Chicago Hubble Program (cont'd)

Freedman, Madore et al.; first TRGB-based H_0 (2019)

› Freedman et al. 2019 (ApJ 882):

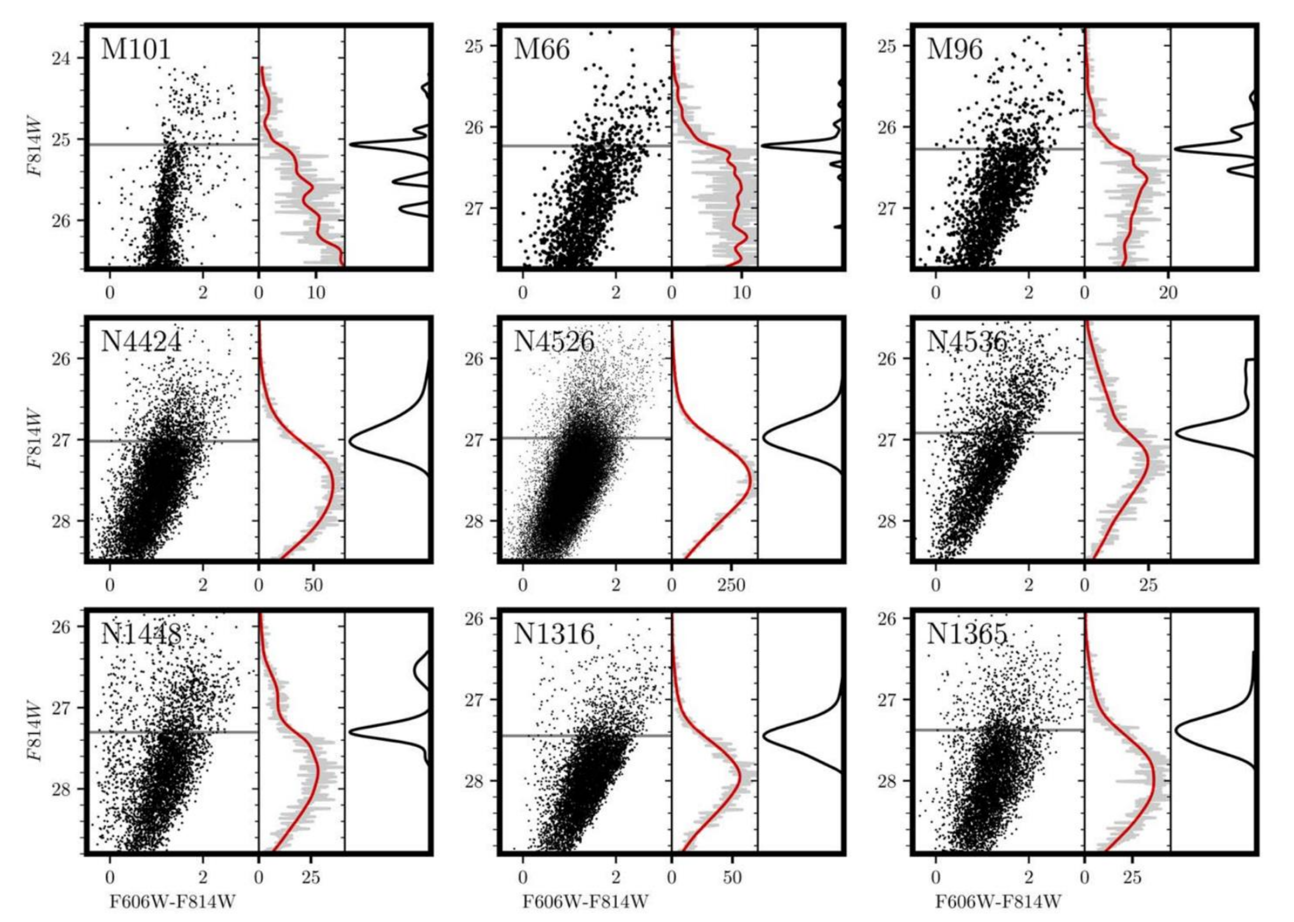
H_0 = 69.8 ± 0.8 (stat) ± 1.7 (sys)

› Freedman et al. 2021 (ApJ 919):

H_0 = 69.6 ± 0.8 (stat) ± 1.7 (sys)

› Freedman+2024 (JWST TRGB):

H_0 = 69.1 ± 1.6 km/s/Mpc



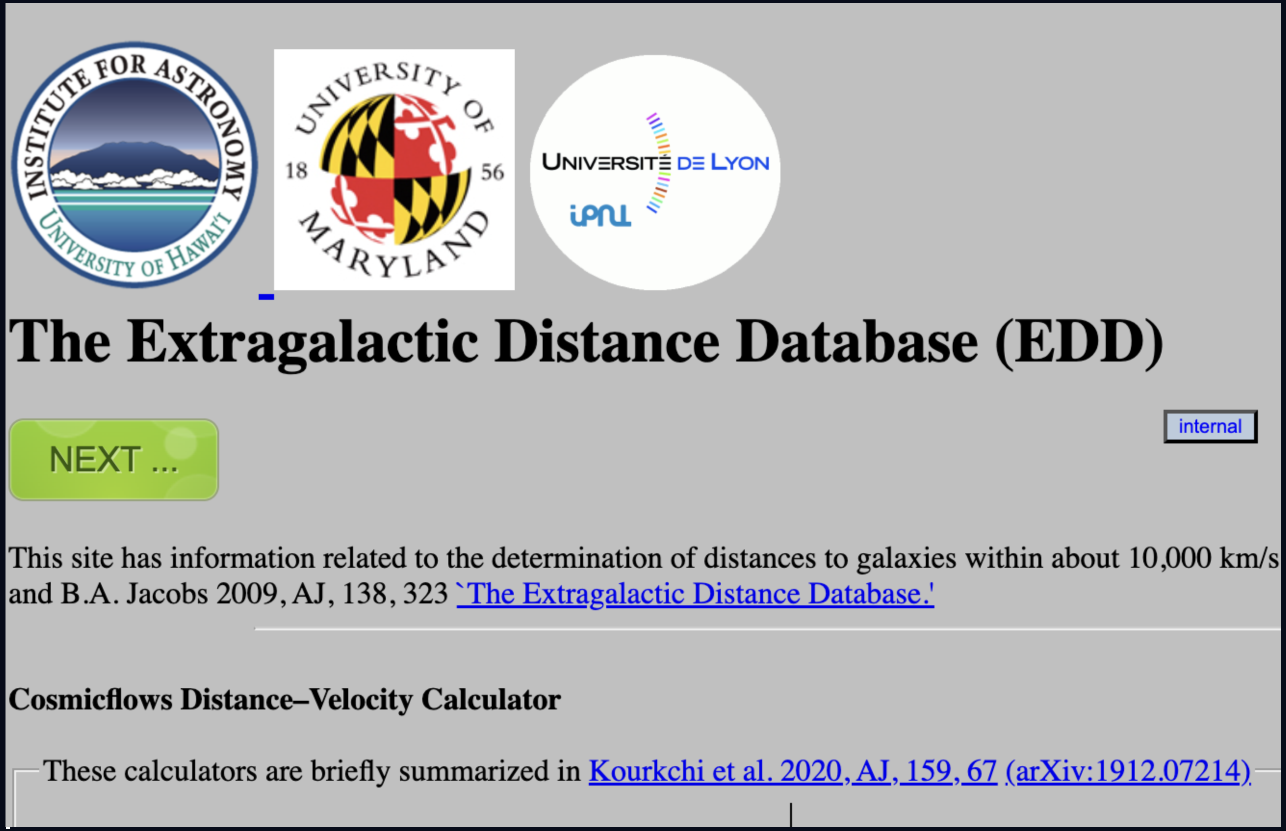
Freedman+19

EDD — Extragalactic Distance Database

Program overview:

› EDD = Extragalactic Distance Database (Tully+09)

› Anand+22: systematic re-analysis of all archival HST TRGB data



EDD

EDD — Extragalactic Distance Database (cont'd)

Methods:

› Calibration: own TRGB calibration in multiple photometric bands

› Model fit to luminosity function; maximum likelihood and least-squares

› Photometry: DOLPHOT

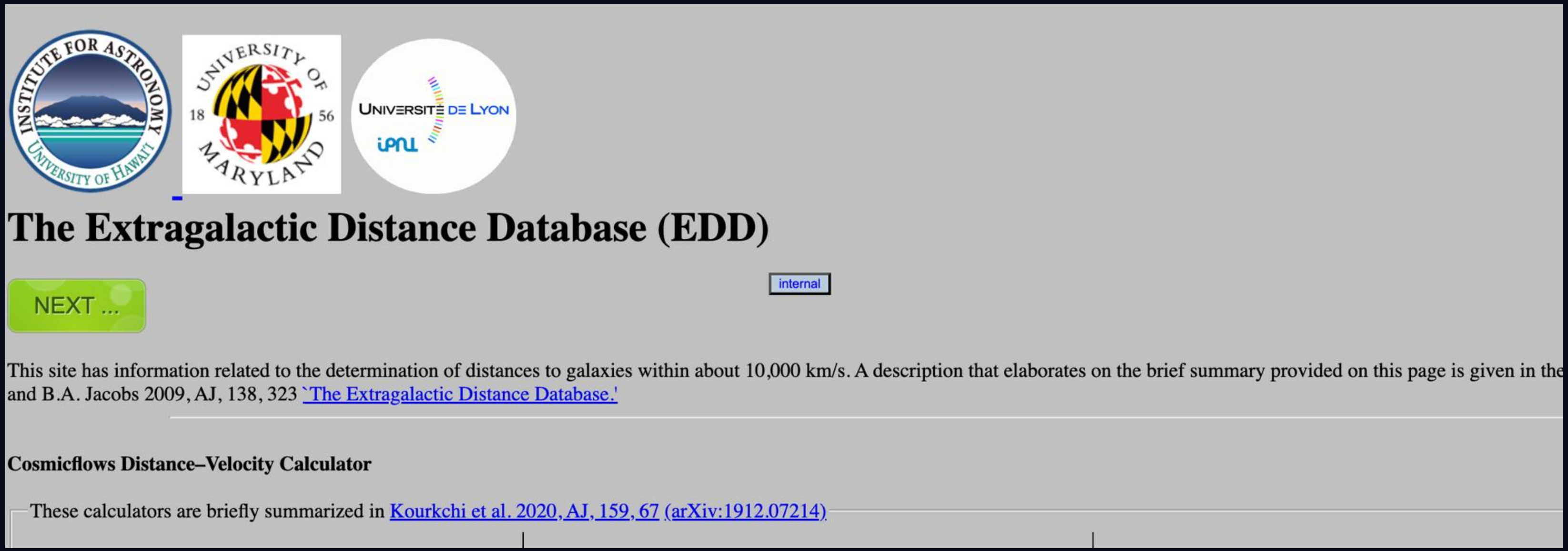
› **All photometry is public**; used in data challenge

EDD — Extragalactic Distance Database (cont'd)

All data is public! Anyone can download the photometry

@ https://edd.ifa.hawaii.edu/

Data challenge photometry drawn from here

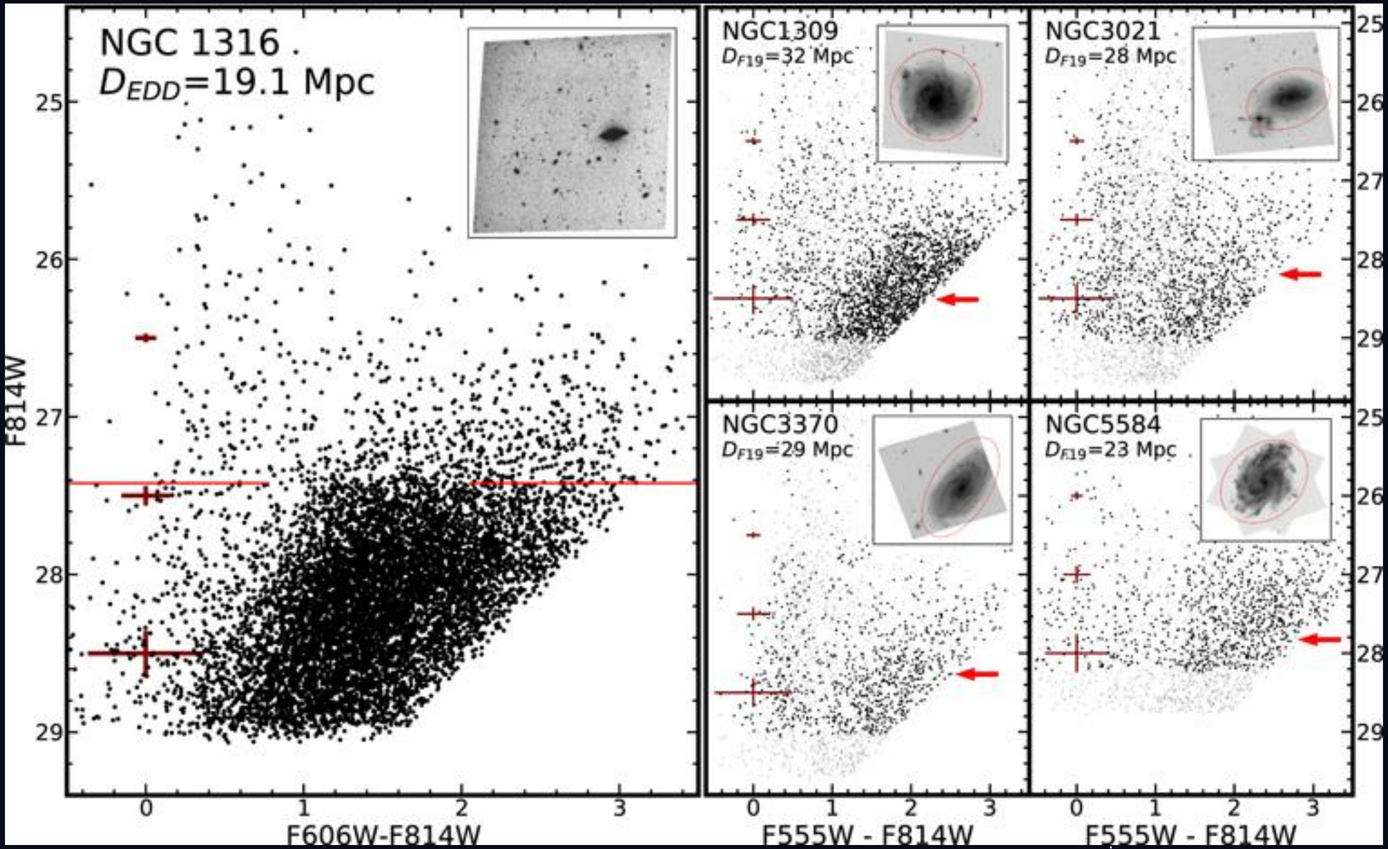


EDD — Extragalactic Distance Database (cont'd)

Key differences from CCHP:

› Concluded four datasets → irrecoverable TRGB

› Different photometry pipeline, measurement approach, color corrections, calibration



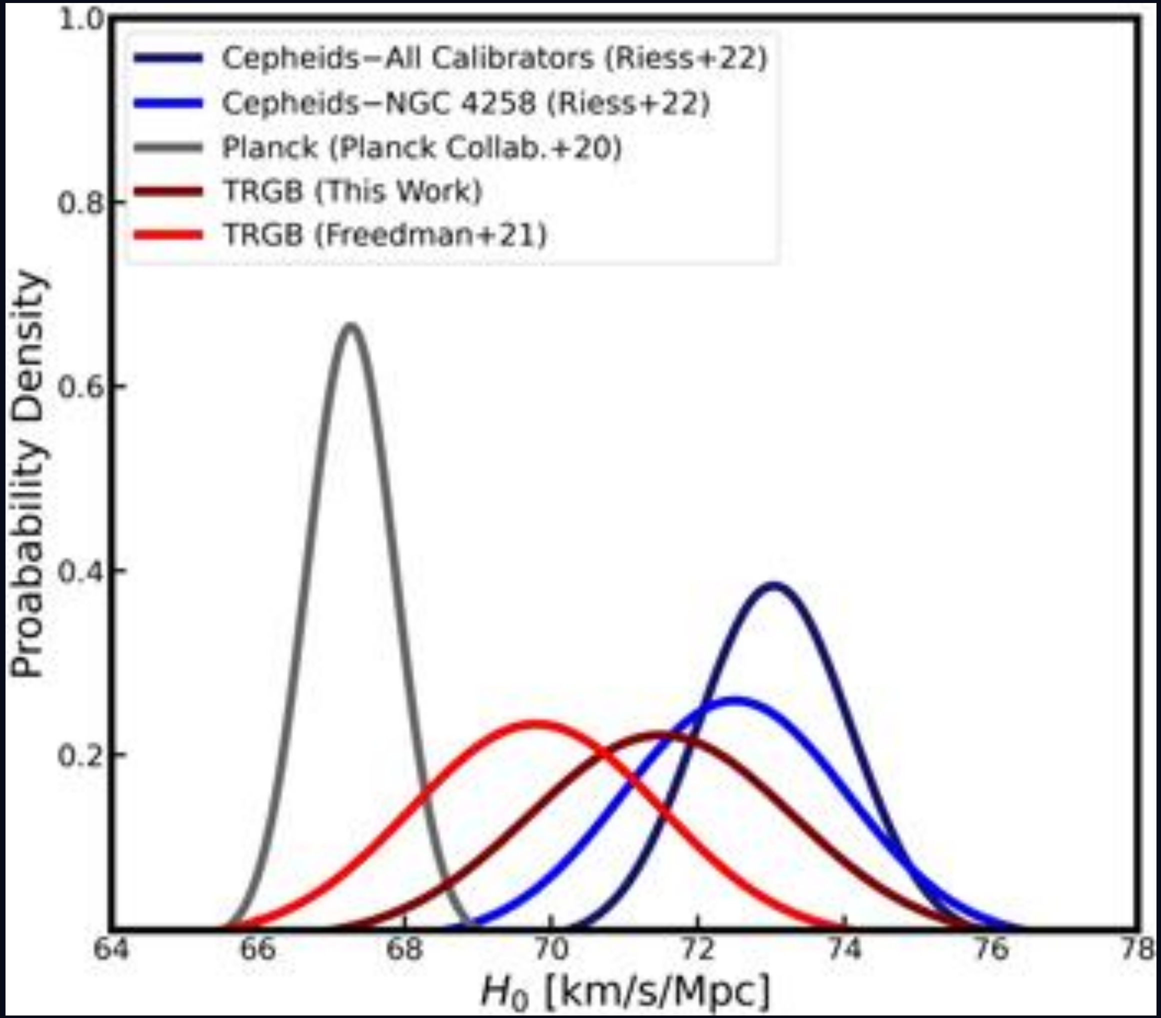
Anand+22

EDD — Extragalactic Distance Database (cont'd)

› Anand+22: $H_0 = 71.5 \pm 1.8$ km/s/Mpc

› ~5σ tension with CMB (Planck 2018: $H_0 = 67.4 \pm 0.5$ km s^{-1} Mpc^{-1})

› All distances publicly available at edd.ifa.hawaii.edu



Anand+22

CATS — Comparative Analysis of TRGBs

Program overview:

› TRGB H_0 measured independently from Cepheids

› Develop a standard measurement pipeline → consistent measurement choices across all galaxies

› Investigate intrinsic variations; apply additional standardization

CATS — Comparative Analysis of TRGBs

Pipeline:

› EDD public photometry

› Unsupervised TRGB algorithm (Wu+22) — no subjective parameter tuning

Key result:

H_0 = 73.22 ± 2.06 km s^{-1} Mpc^{-1} (Scolnic+23, calibrated w/ Li+23)

You will also be able to work with the CATs dataset in the data challenge!

Section 4

The Hubble Tension from the TRGB Perspective

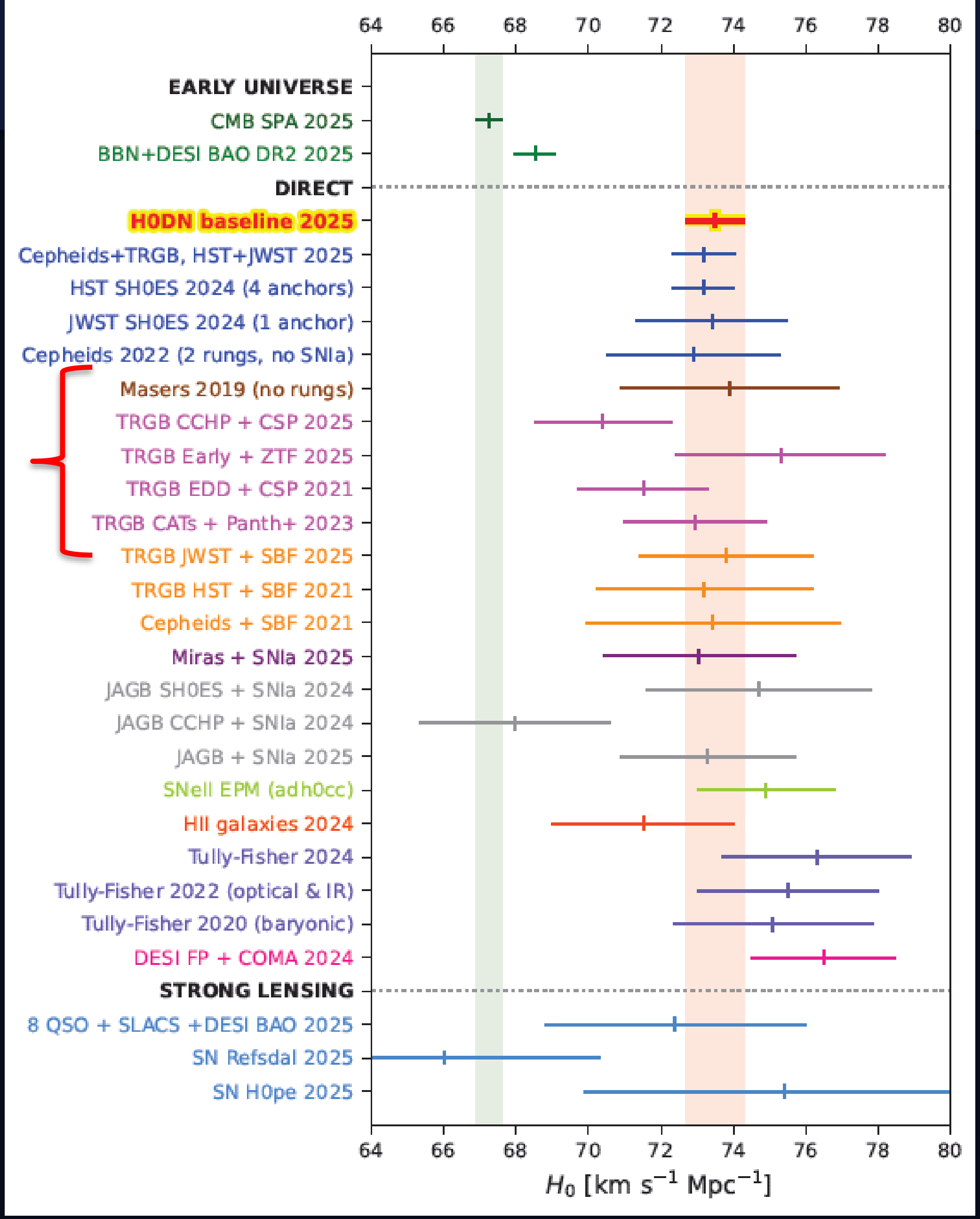
The Current H_0 Landscape

H_0 from multiple teams
→ Many H_0 using independent methods;
*Note SBF vs SN Ia

Where do differences come from?

→ Documented in literature (e.g. Anand+21, Scolinic+23, Freedman+25, Casertano+25, Li+26)

→ A chance for YOU to explore in the data challenge!



Casertano+25

TRGB H_0 Differences Explained

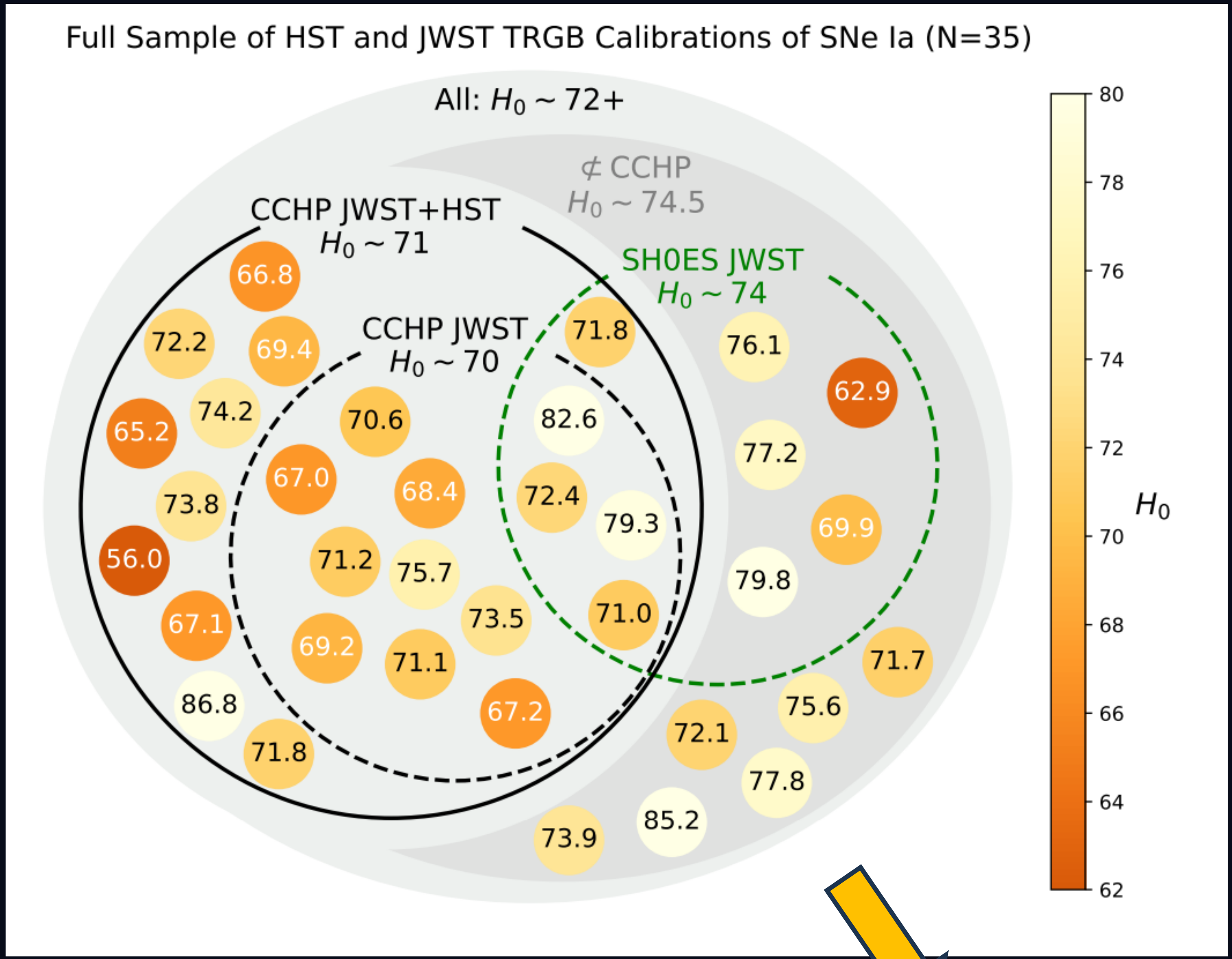
› Difference between H_0: **traceable**

› e.g. CATS to EDD & CCHP:
SN Ia/host galaxies, peculiar velocity corrections, contrast ratio correction

Table 5. Sources of Differences in H_0 between TRGB Analysis by CATS (Here), CCHP, and EDD (in H_0)

Term	ΔCCHP	ΔEDD
	(km s^{-1} Mpc^{-1})	(km s^{-1} Mpc^{-1})
SN-related		
(1) Include SNe 2021pit, 2021rhu, 2007on	0.6	1.3
(2) No TRGB detected in N5584, N3021, N1309, N3370	0.0	0.0
(3) Peculiar flows (Pantheon+)	0.4	0.0
(4) Hubble flow surveys (Pantheon+)	1.1	0.0
SN subtotal	2.0	1.3
TRGB-related		
(5) Fiducial TRGB calibration/tip-contrast relation	1.4	−0.3
Total	3.4	1.0

Subsample Selections



- Each distance can give single values of H_0
- Dispersion expected; intrinsic variations
- Past studies do not include the full available sample

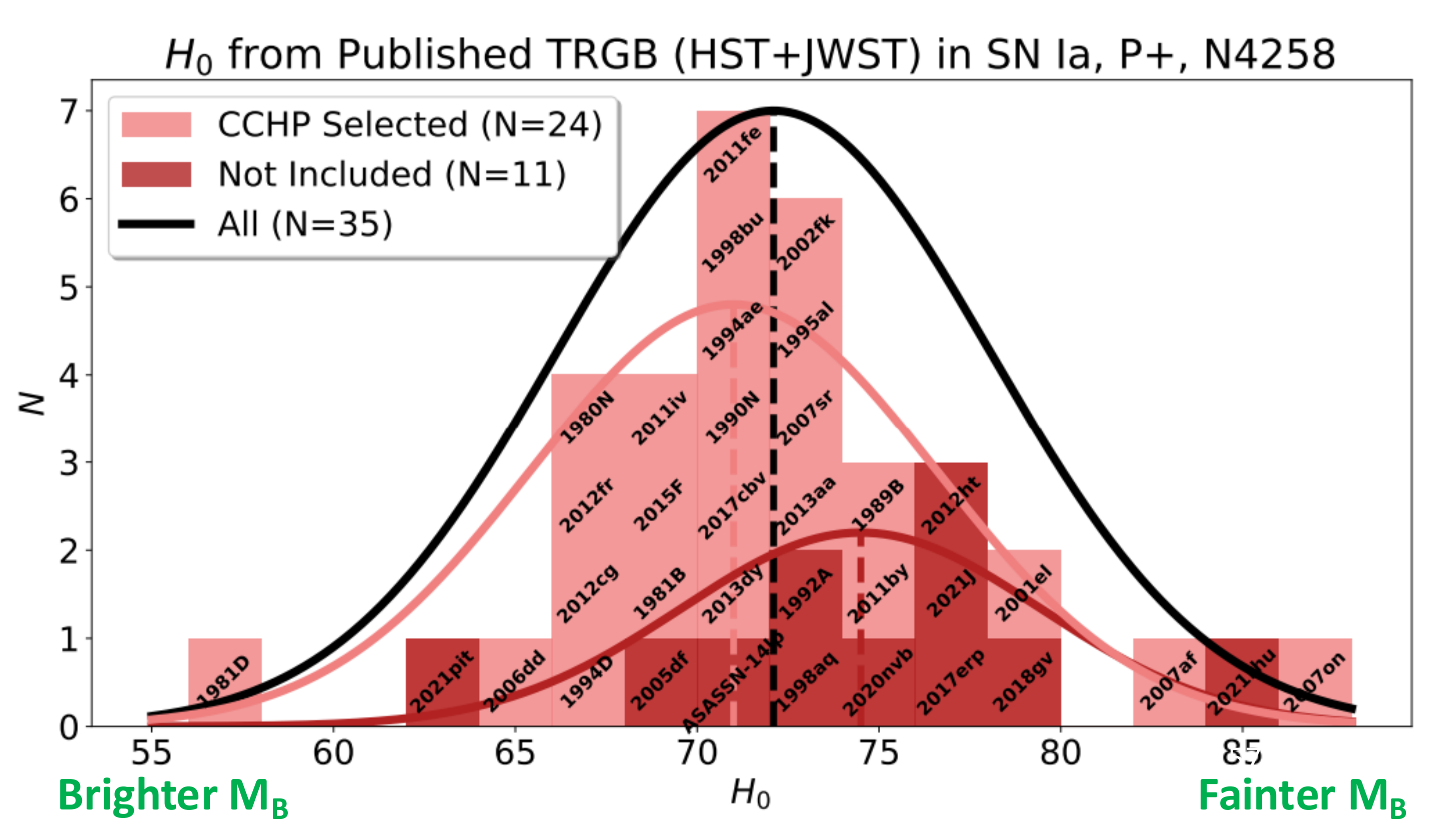
$$5\log(\mathrm{H}_0/72.5) = M_B^0 - (-19.29)$$

Li+26; created by: Y. Murakami

A Reversion to the Mean

- All (N=35) SNe Ia included → 72.1 km/s/Mpc, excellent agreement with HST Cepheid H_0
- Can reproduce lower measures in the literature w/ subsample selection

Question to you: Is knowing SN Ia luminosities → H_0…confirmation bias in this kind of application? Under what circumstances would it be so?



Li+25b

Section 5

The Road Forward

JWST & Roman — Next Generation TRGB

How new telescopes will transform the measurement

JWST NIRCAM (operational since 2022):

- F090W (I-band), F115W (J-band), F150W (H-band)
- Less blending: 6× less crowding than HST at same distance
- Reaches to 30 Mpc at similar precision to HST at 20 Mpc
- See e.g. Freedman+25, Hoyt+25, Anand+25, Li+26, etc.

JWST & Roman — Next Generation TRGB (cont'd)

How new telescopes will transform the measurement

Roman Space Telescope (planned launch this year!):

› 2.4m mirror (same as HST) but 100× wider field

› 18 × 18 arcmin FOV vs 3.4 × 3.4 arcmin for HST/ACS

› Can observe multiple halo fields simultaneously

› Could increase TRGB calibrator sample by factor 5–10

The CosmoVerse Data Challenge

How the challenge enables your own TRGB H_0 measurement

The Hubble tension: a community effort

› Real HST photometry catalogs

› Each participant applies the TRGB pipeline independently

› Results aggregated

› Tests reproducibility and method sensitivity

How does TRGB H0 change w/ your different measurement choices?

The CosmoVerse Data Challenge (cont'd)

How the challenge enables your own TRGB H_0 measurement

What your notebooks do (Lecture 3 / Tutorial):

› Reads DOLPHOT output catalog (Thank you to Kayla & contributors!)

› Runs Sobel filter measurement approach

› Measures TRGB magnitude + bootstrap uncertainty

› Converts to distance modulus

› Feed results into SN Ia notebook (Thank you to Yukei & contributors!)

› Submit result to the challenge

Lecture 2 Complete

Next: Tutorial — CosmoVerse Data Challenge Notebook

Questions?