Measurements of the Hubble Constant: Tensions in Perspective

Freedman (2021)

Illustration by Sandbox Studio, Chicago with Corinne Mucha

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Astro Student Seminar, 2021-09-24

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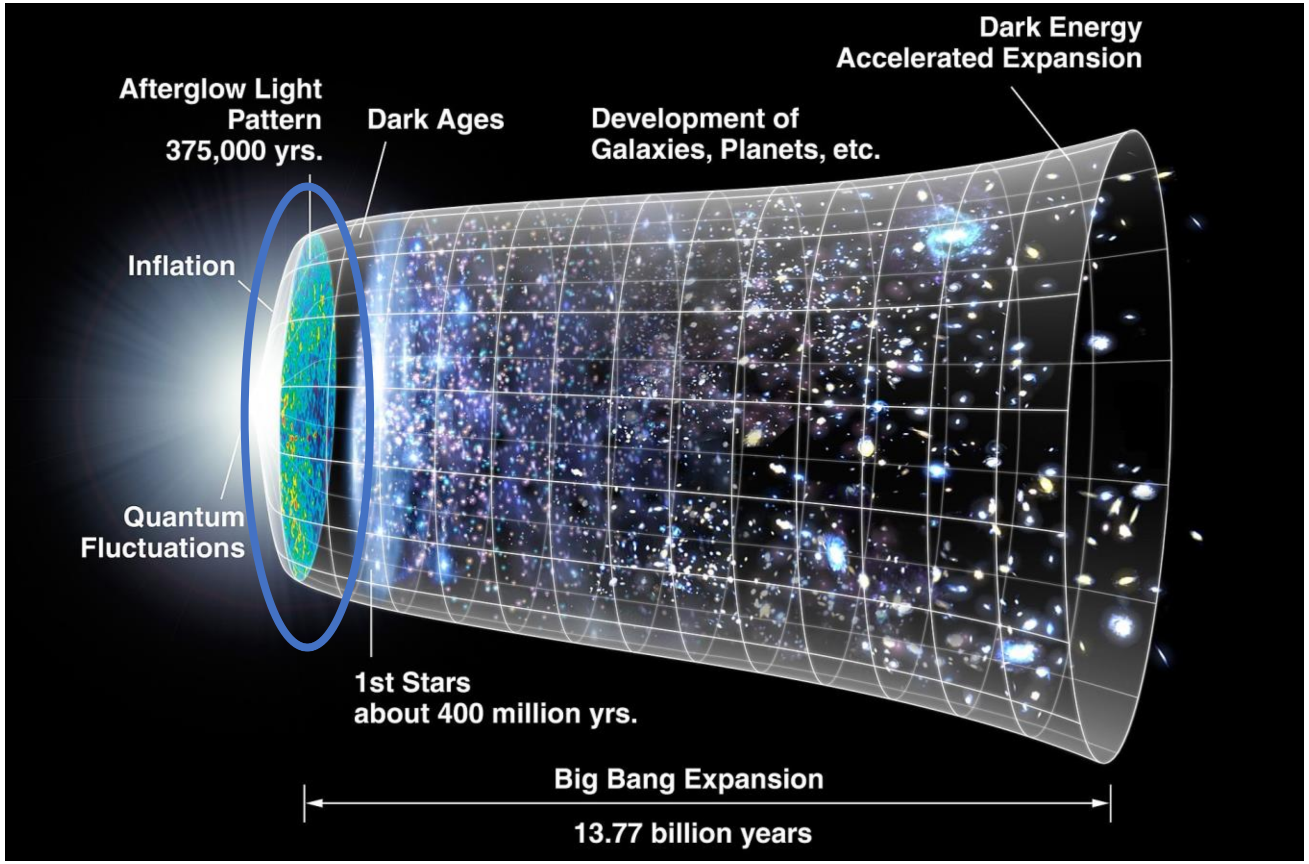
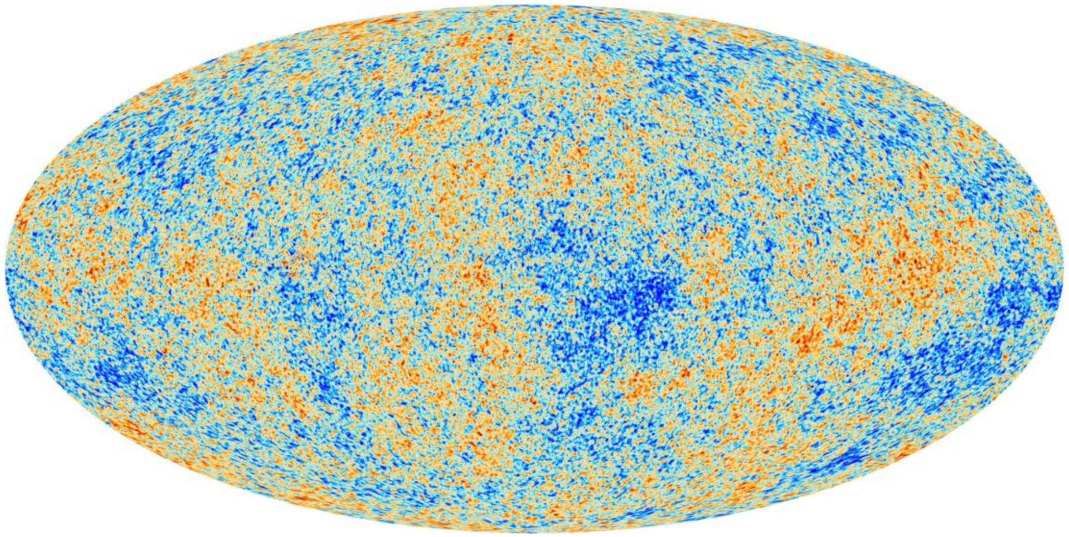
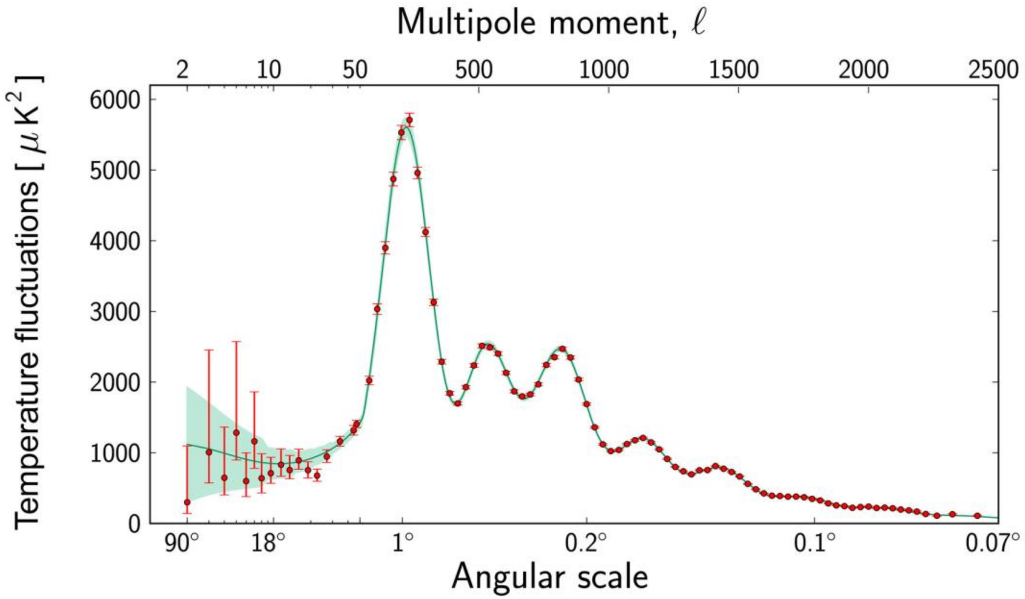
Outline

- Hubble tension & TRGB method
- Freedman (2021)
- My comments
- Summary

Early universe H_0







H_0 = 67.66+-0.42 km/s/Mpc (Planck 2018)

Image credit: NASA/ESA

Late universe H_0

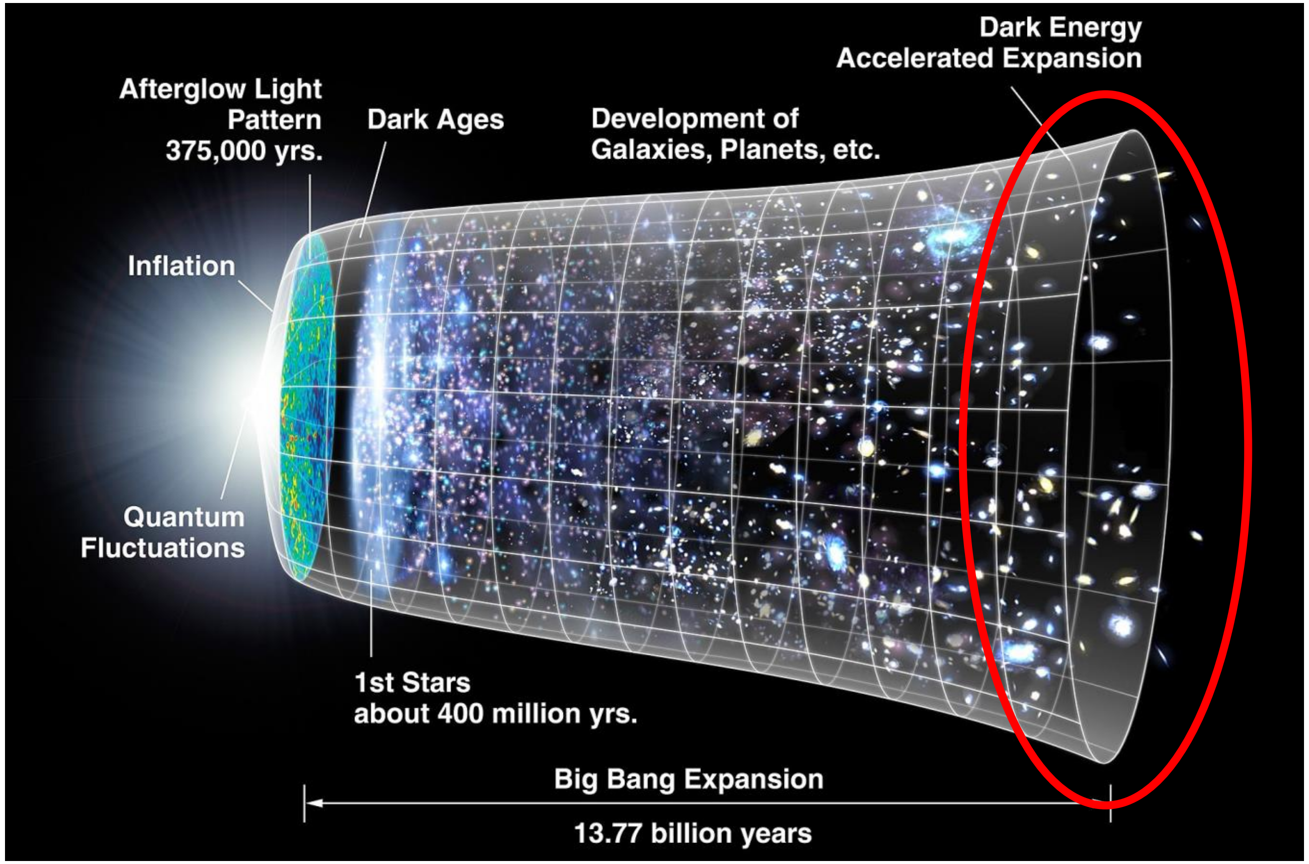


Image credit: NASA/ESA

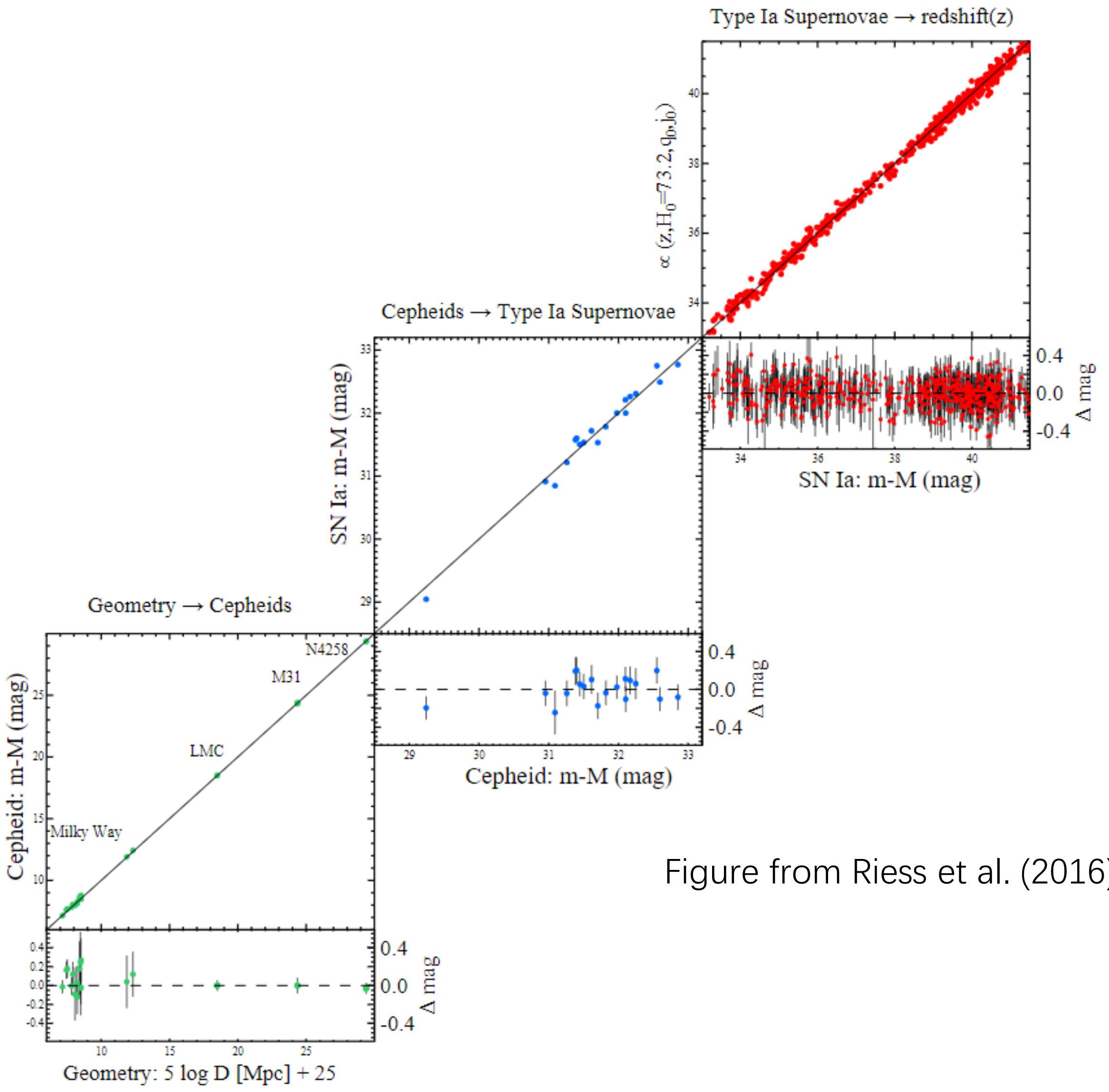
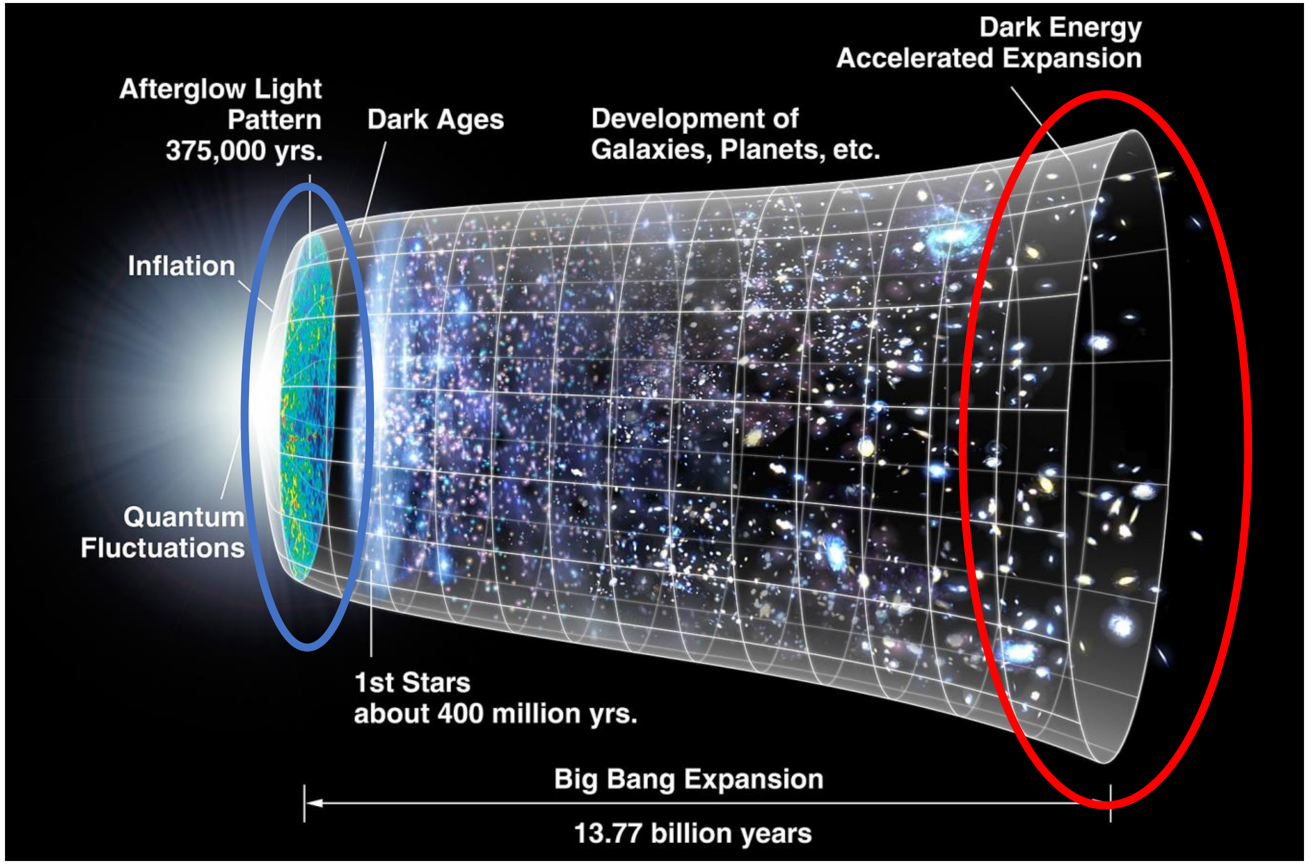
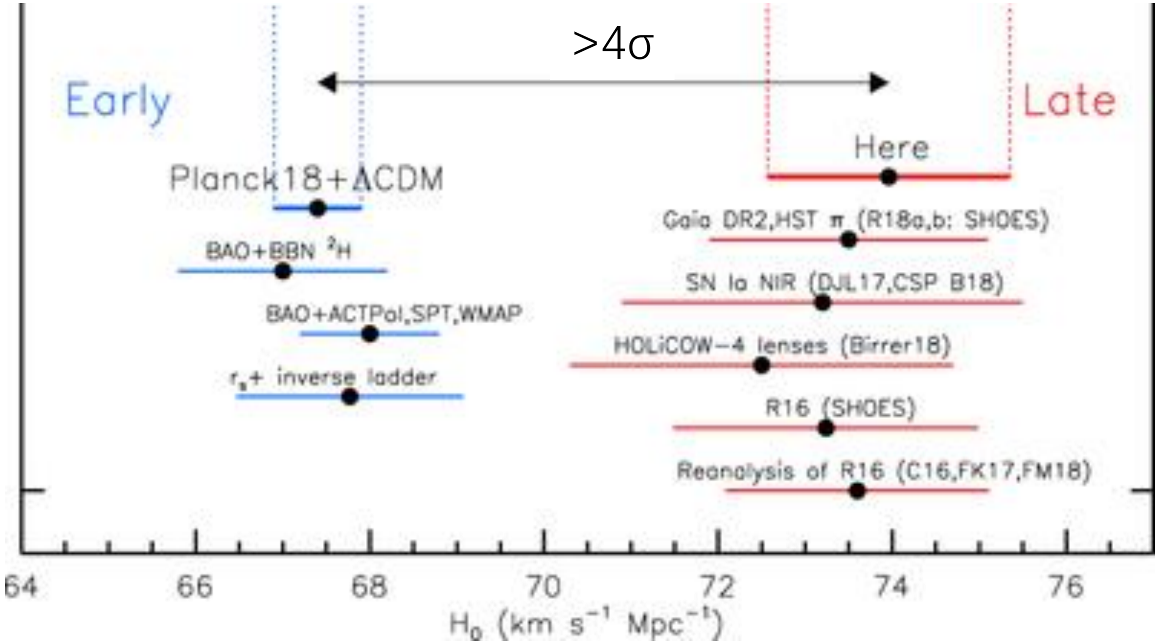


Figure from Riess et al. (2016)

H_0 = 73.2+-1.3 km/s/Mpc (Riess et al. 2021)

Hubble tension





Riess et al. (2016, 2019, 2021)

New physics? Or Systematics?

Image credit: NASA/ESA

TRGB method

- Helium flash in low-mass stars → Tip of the Red Giant Branch (TRGB) as a standard candle (especially in I band).

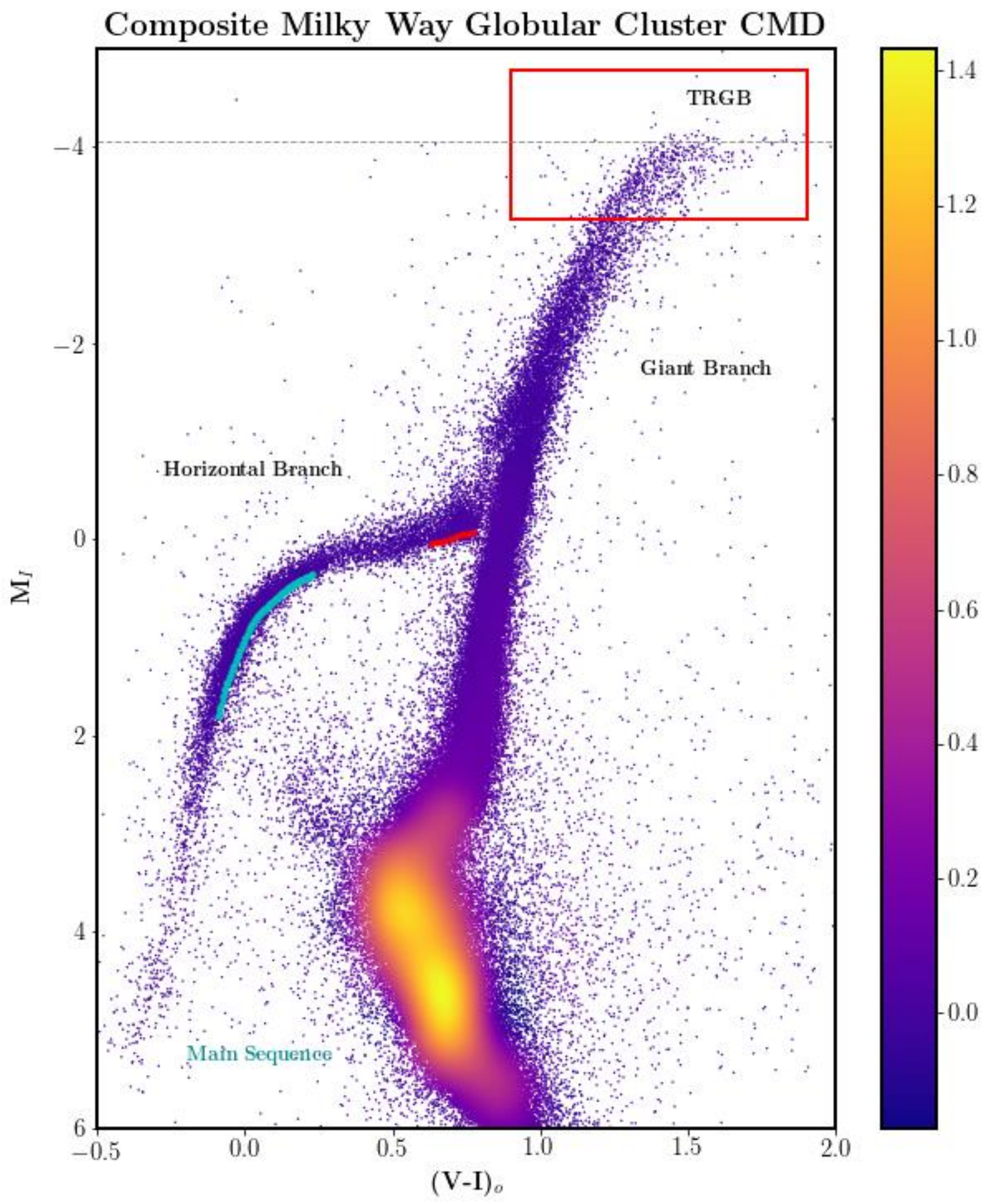


Figure from Freedman (2021)

TRGB method

- Helium flash in low-mass stars → Tip of the Red Giant Branch (TRGB) as a standard candle (especially in I band).

- **Replacing Cepheids with TRGB in the distance ladder → H_0**

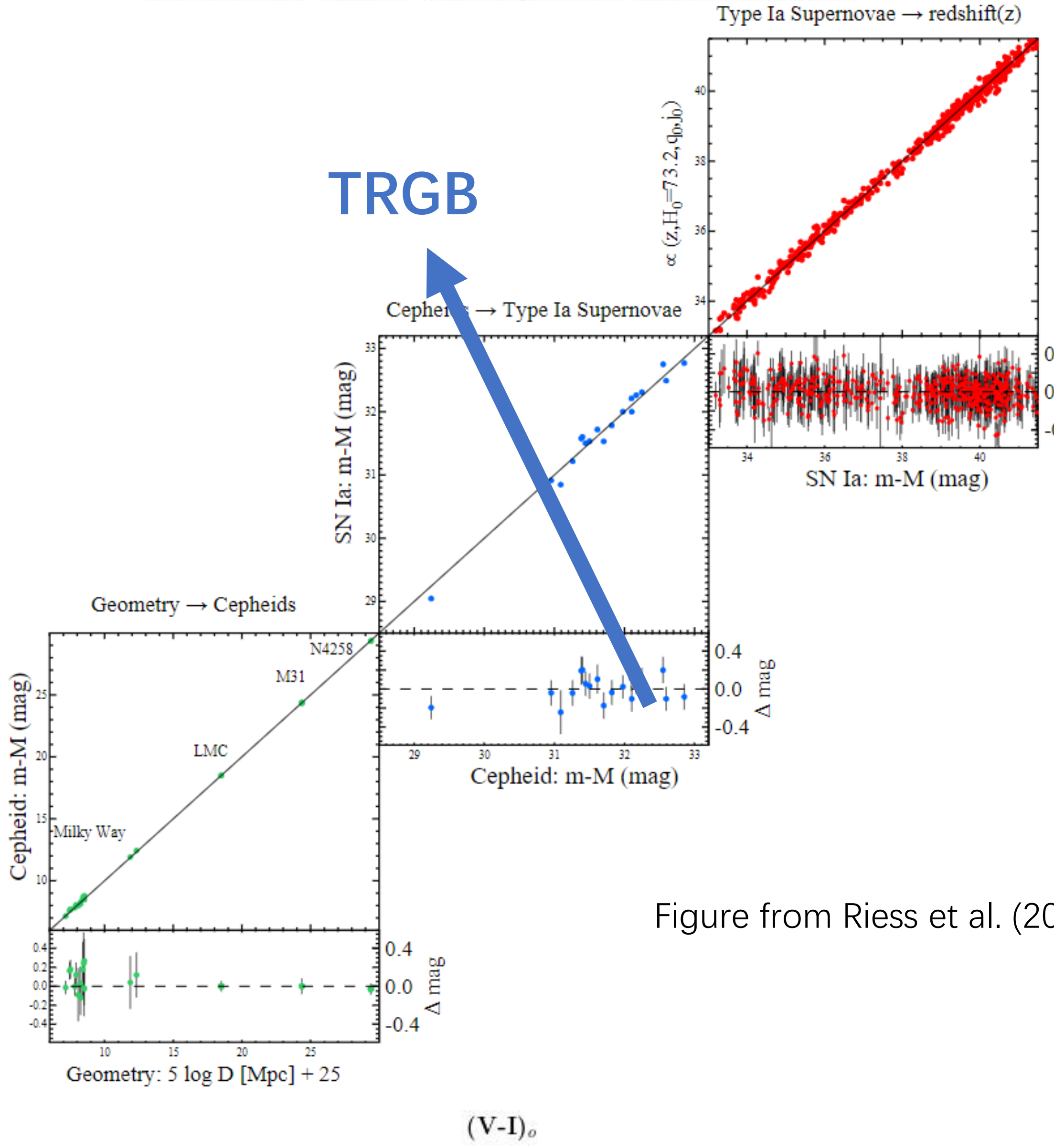


Figure from Riess et al. (2016)

TRGB method

- Helium flash in low-mass stars → Tip of the Red Giant Branch (TRGB) as a standard candle (especially in I band).
- Replacing Cepheids with TRGB in the distance ladder → H_0
- **Different calibrations of the TRGB method → different TRGB zero point M_I → different H_0**

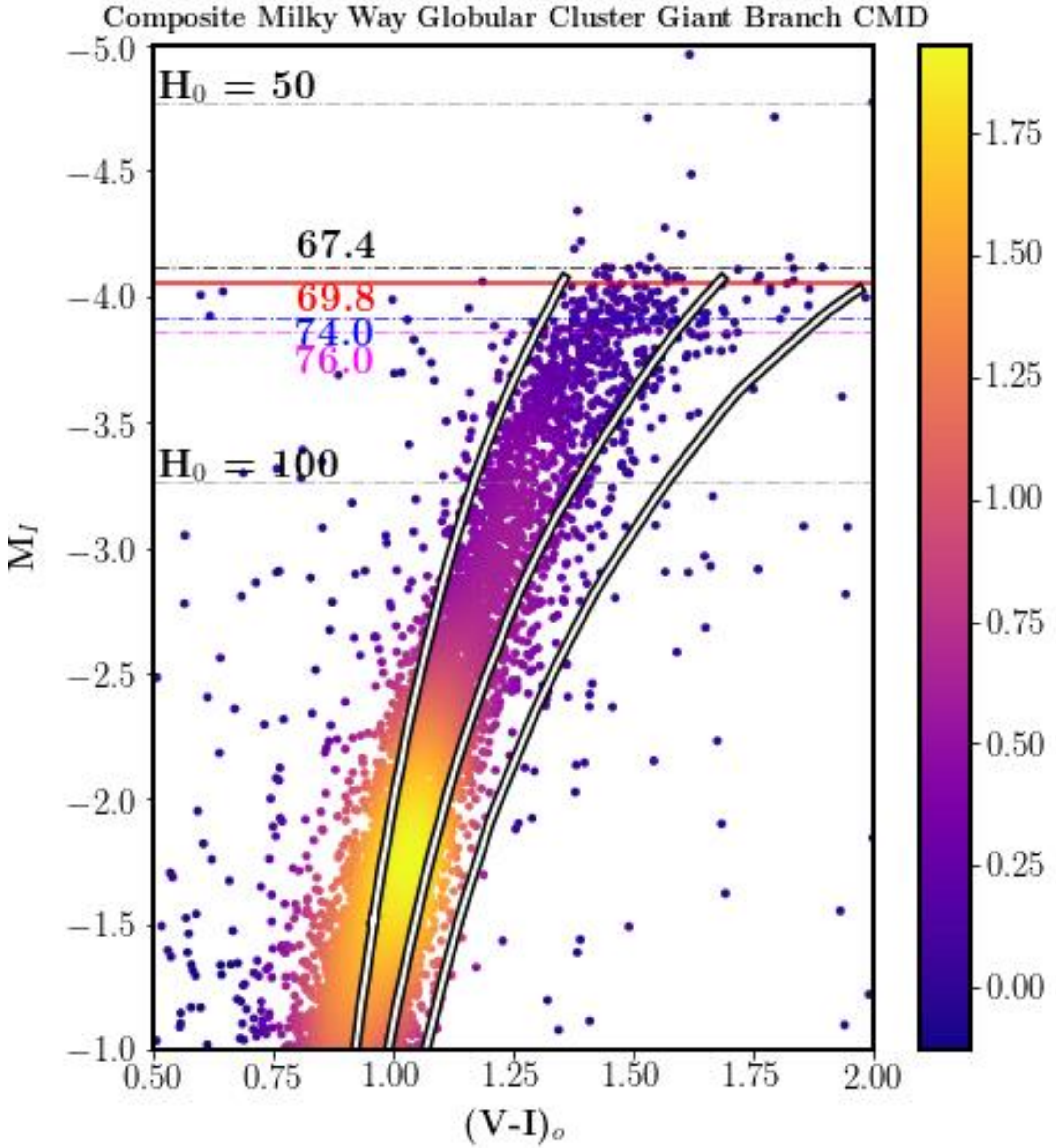


Figure from Freedman (2021)

Outline

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- **Freedman (2021)**
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Take-home message

Freedman (2021): Local measurement of H_0 from TRGB is more consistant with the early universe result.

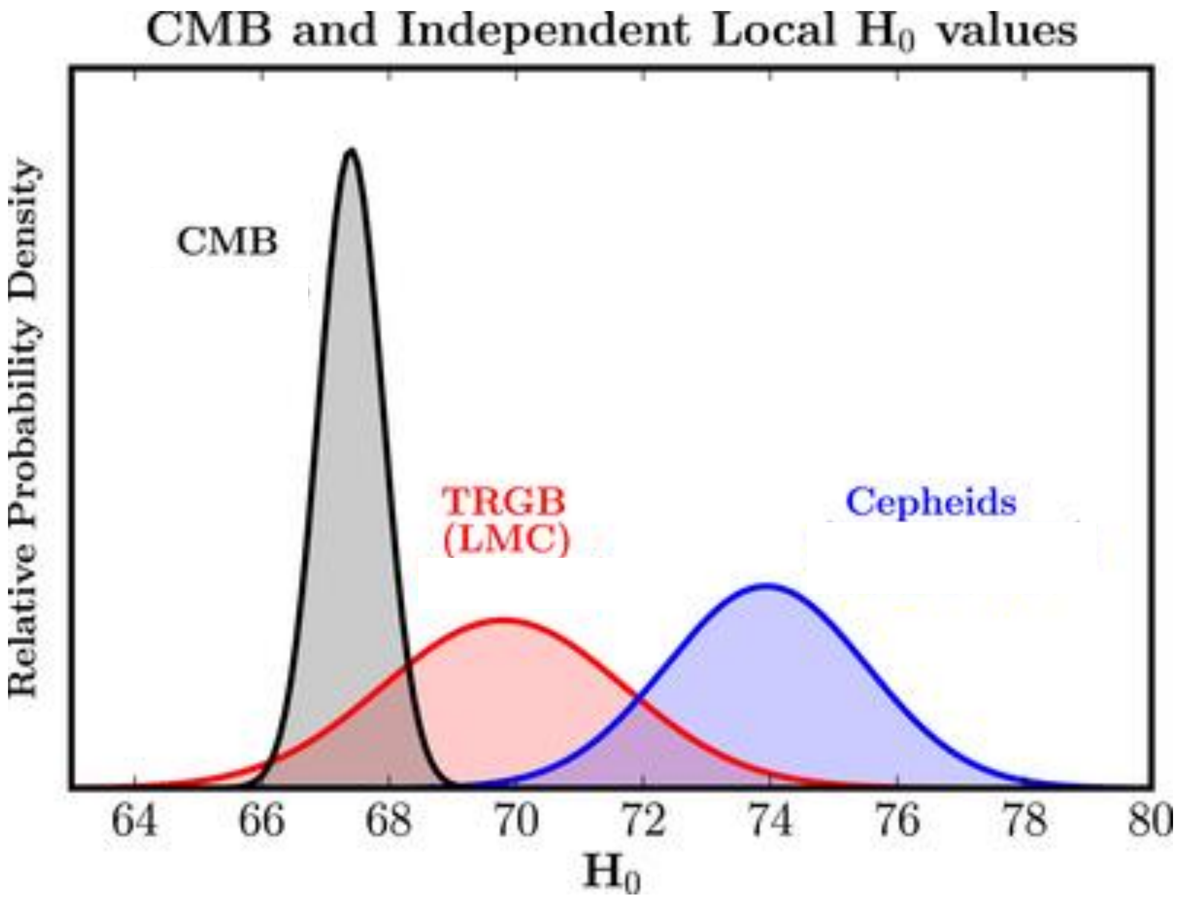
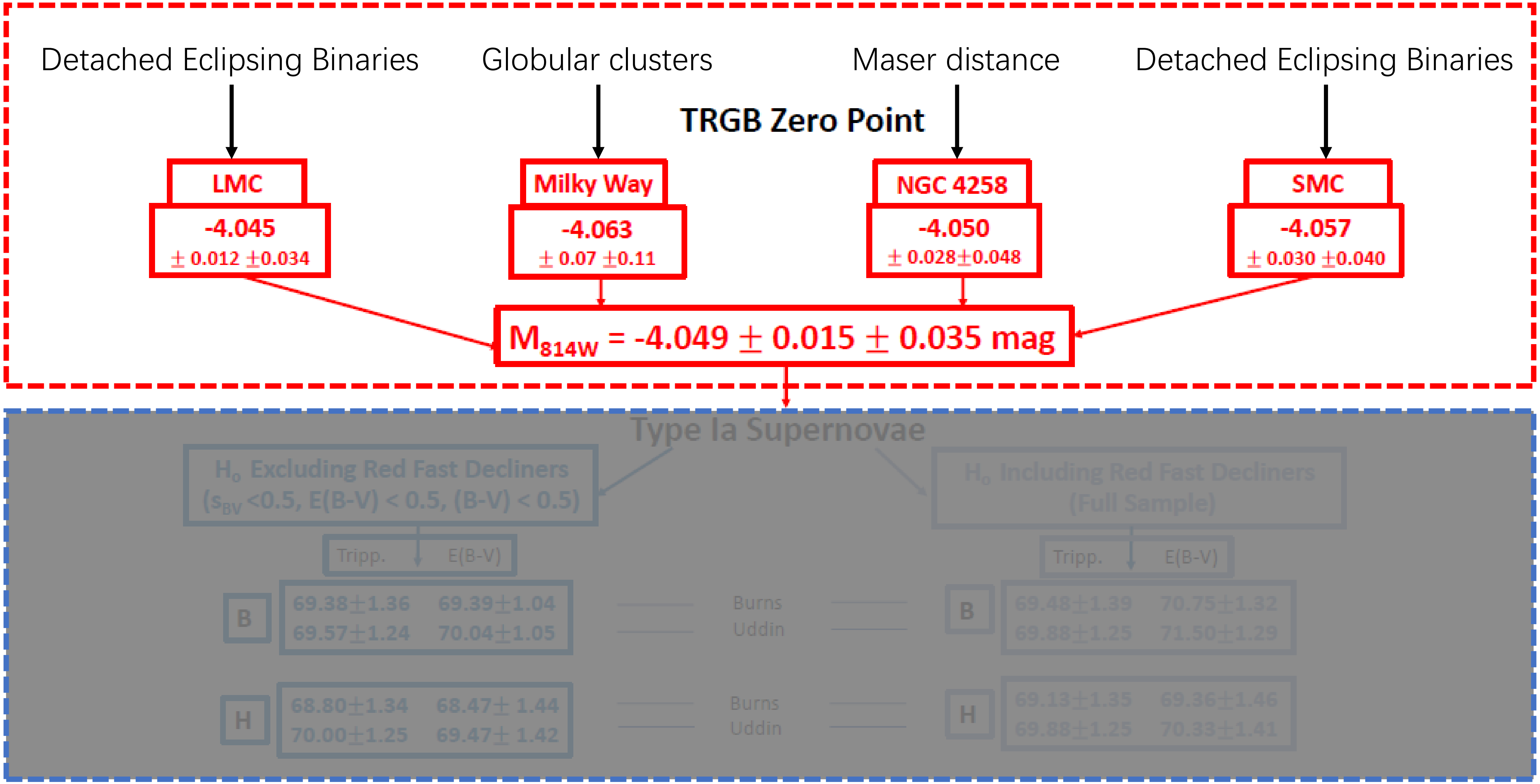
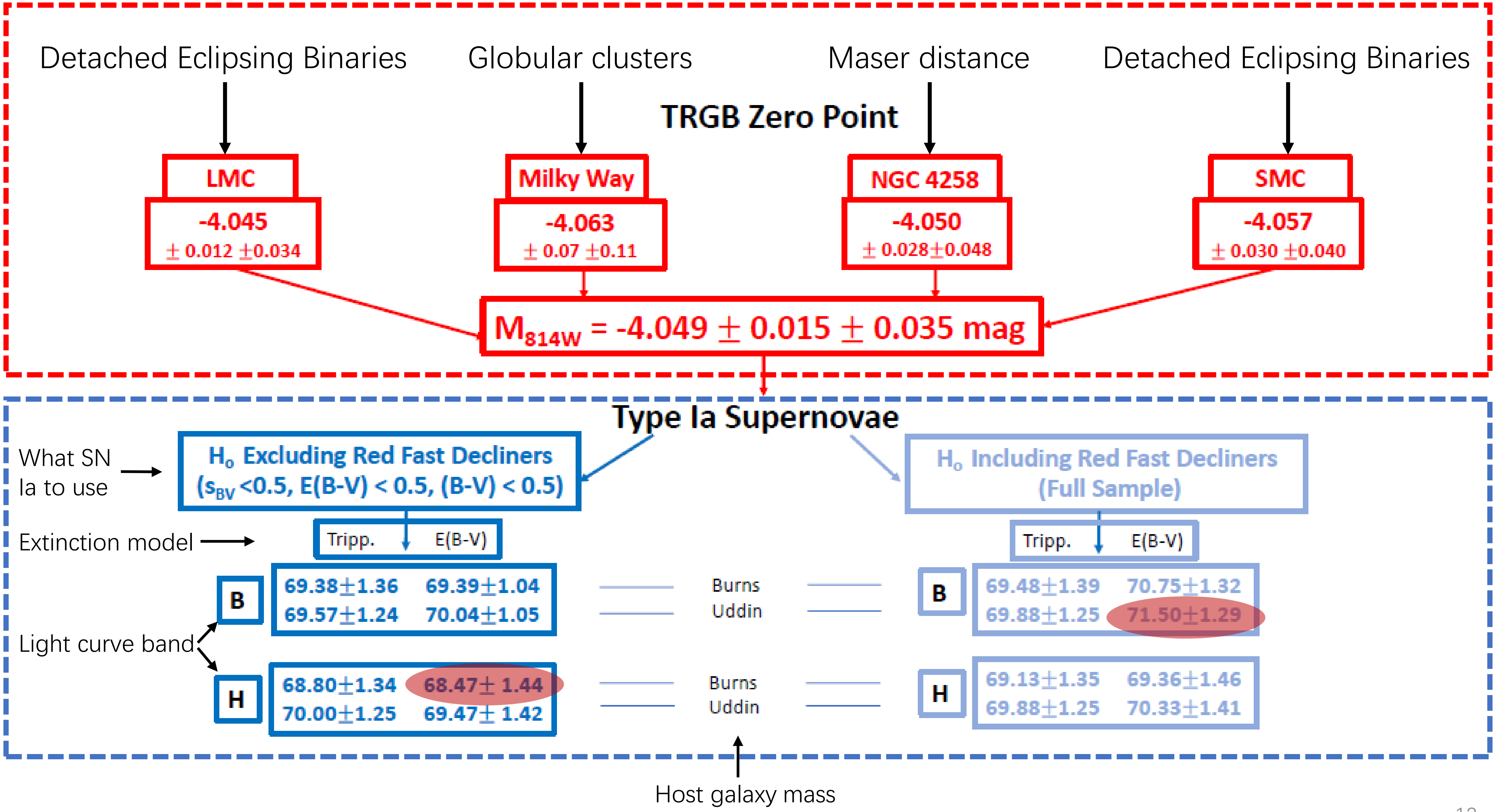


Figure adapted from Freedman et al. (2019)

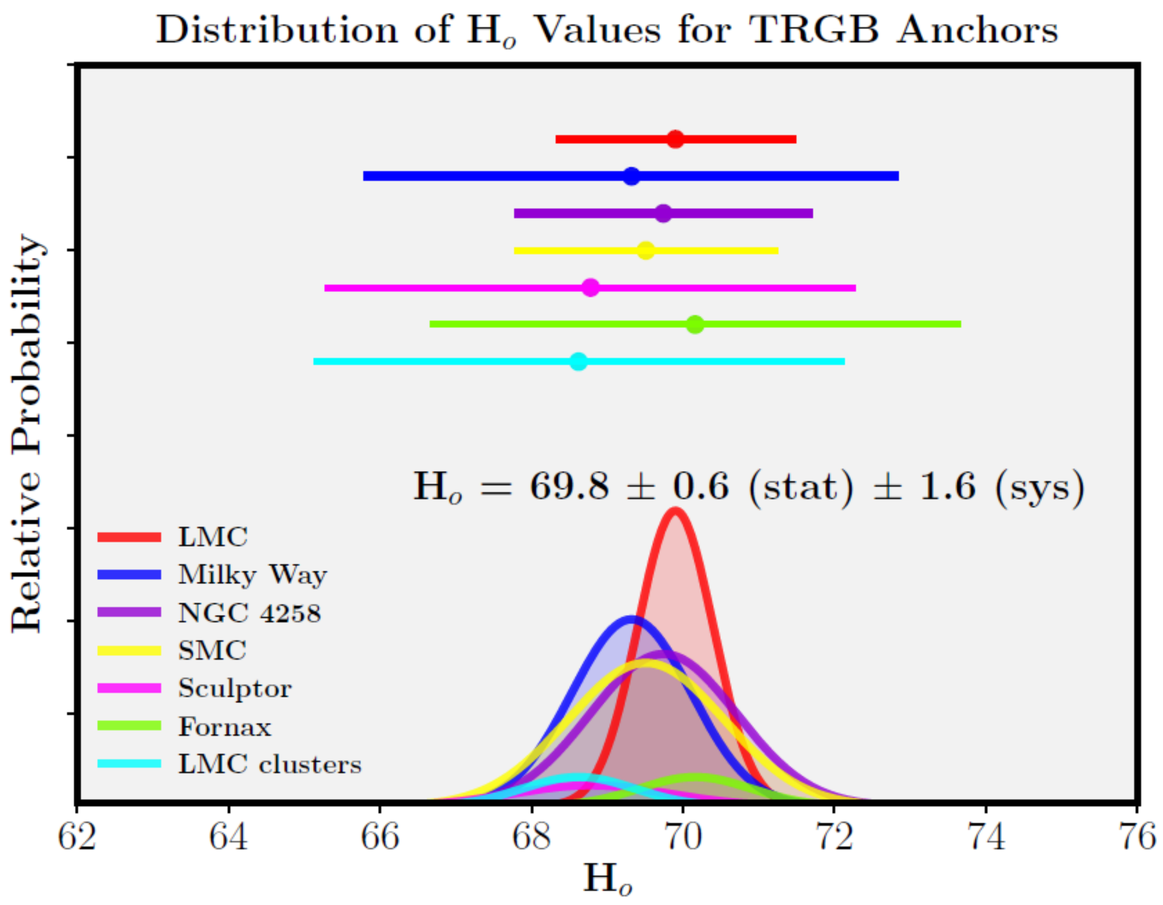


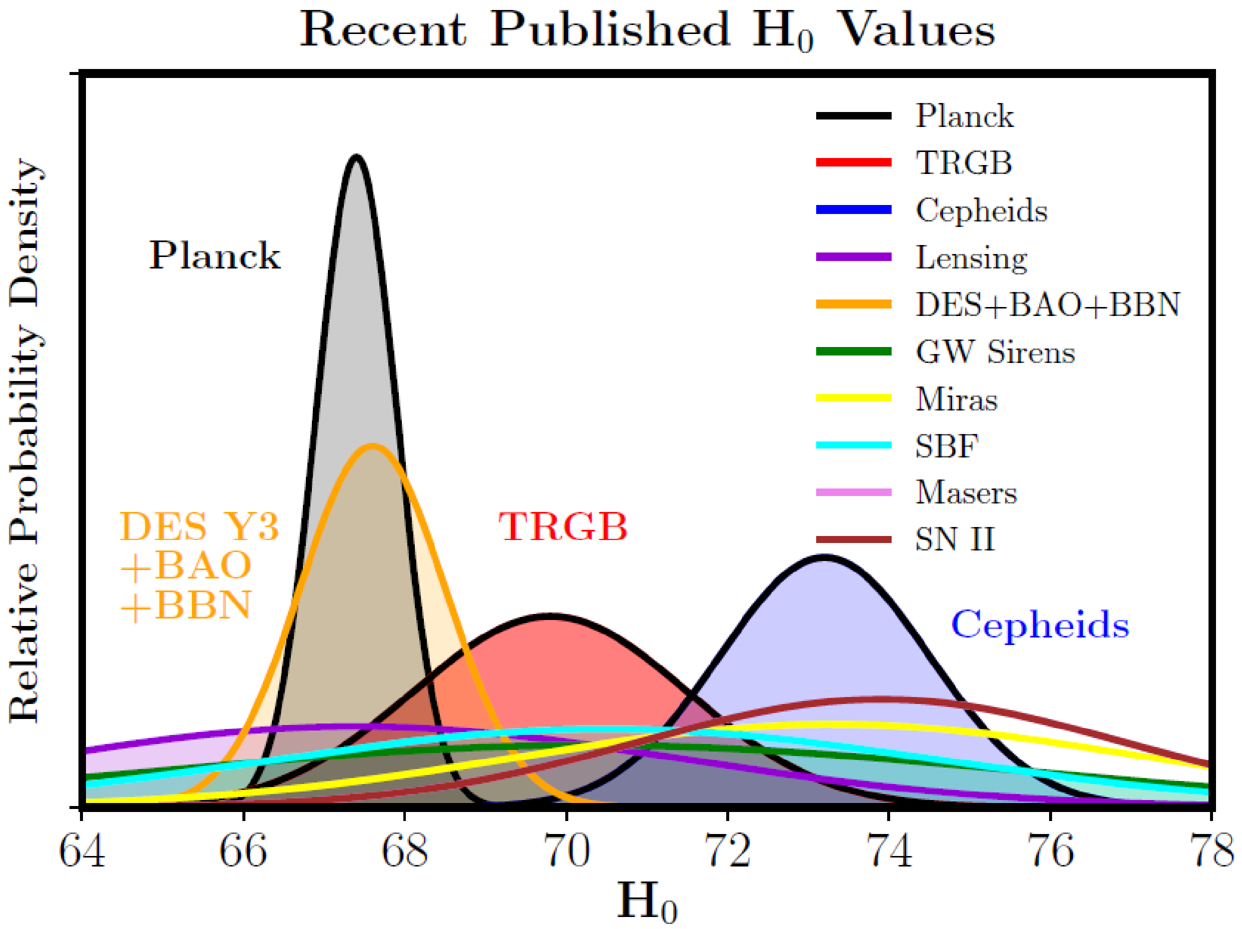
Freedman (2021)



Freedman (2021)

H_0 from TRGB method





Freedman (2021)

3. My comments

- Robustness of the empirical determination of H_0.

- Cepheid vs. TRGB calibrators

Calibrator	TRGB	Cepheids
LMC	DEB[a]	DEB[a]
NGC 4258	masers[b]	masers[b]
Milky Way	ω Cen DEB[c]	EDR3 parallaxes[d]
SMC	DEB[e]	...

[a] Pietrzyński (2019)
[b] Reid et al. (2019)
[c] Thompson et al. (2001)
[d] Riess et al. (2021)
[e] Graczyk et al. (2020)

Summary

- Hubble tension: Early and late universe probes result in >4-sigma difference in the Hubble constant (67 vs. 73 Km/s/Mpc).

- Using four anchors to calibrate the TRGB method, Freedman (2021) derived

$$H_0 = 69.8 \pm 0.6 \text{ (stat)} \pm 1.6 \text{ (sys)} \quad \mathrm{km\,s^{-1}\,Mpc^{-1}}$$

  This is more consistent with the early universe measurements.

- The discrepancy in the late universe probes (TRGB and cepheid) needs to be resolved in order to understand the nature of Hubble tension.

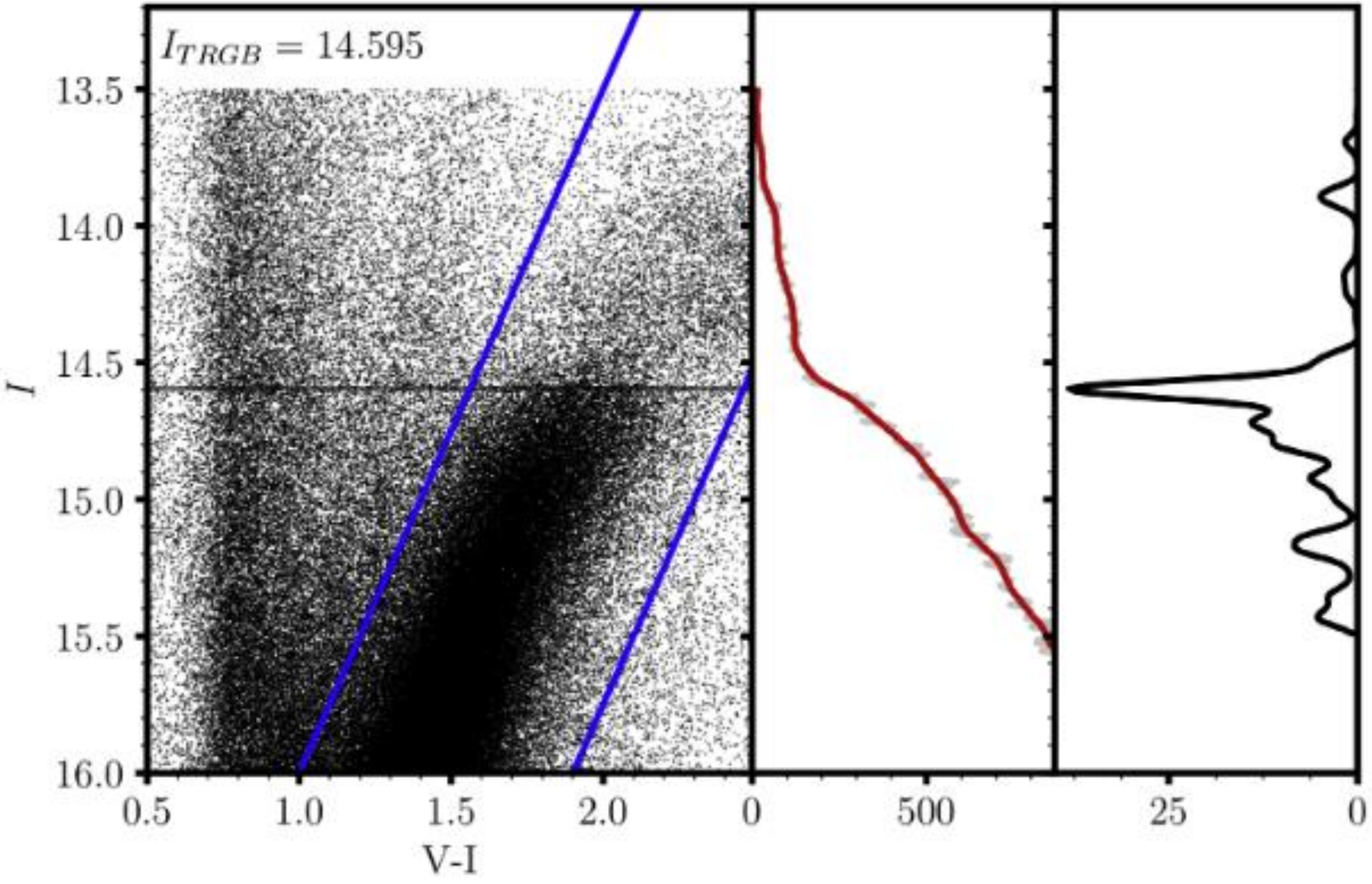
Questions I would ask as an audience

1. What types of galaxies can TRGB method apply to? How is it compared to the cepheid method?
2. What is the advantage of TRGB method over cepheid method?
3. Why is TRGB independent of stellar metallicity?
4. How will future (larger) telescopes help in resolving the discrepancy?

Back-up slides

How to determine the TRGB

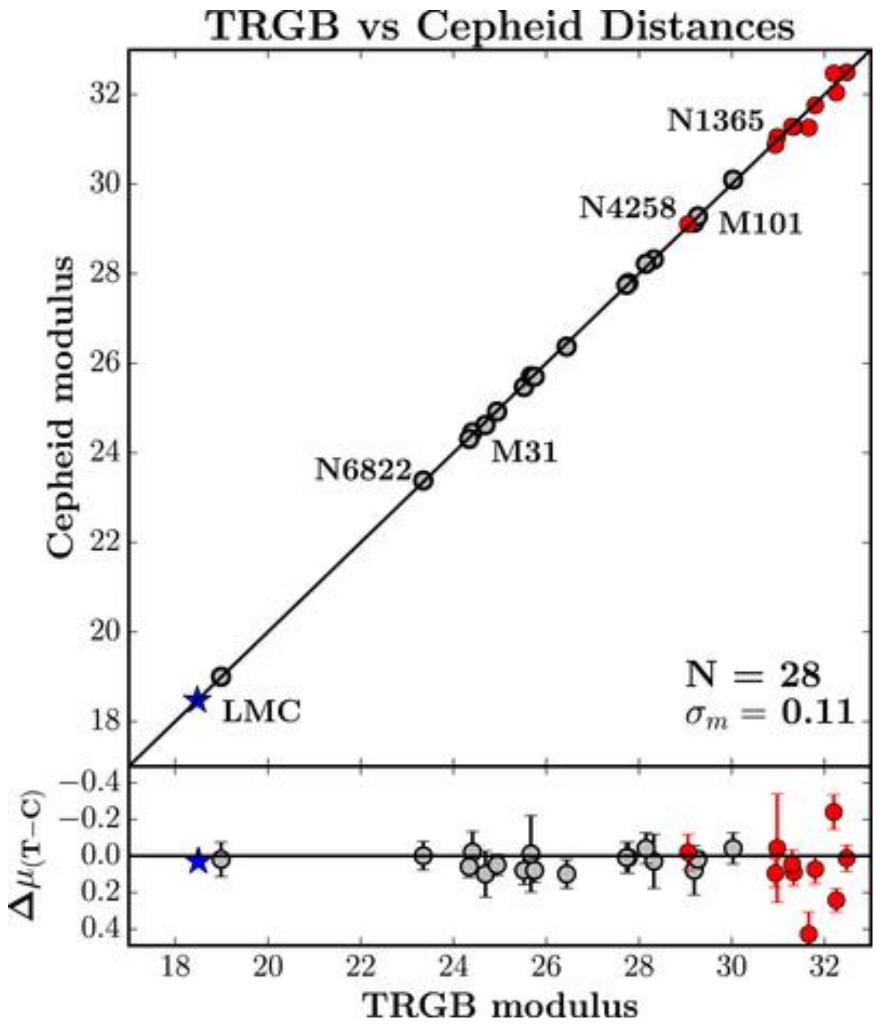
- Sobel edge-detection filter.



Freedman et al. (2019)

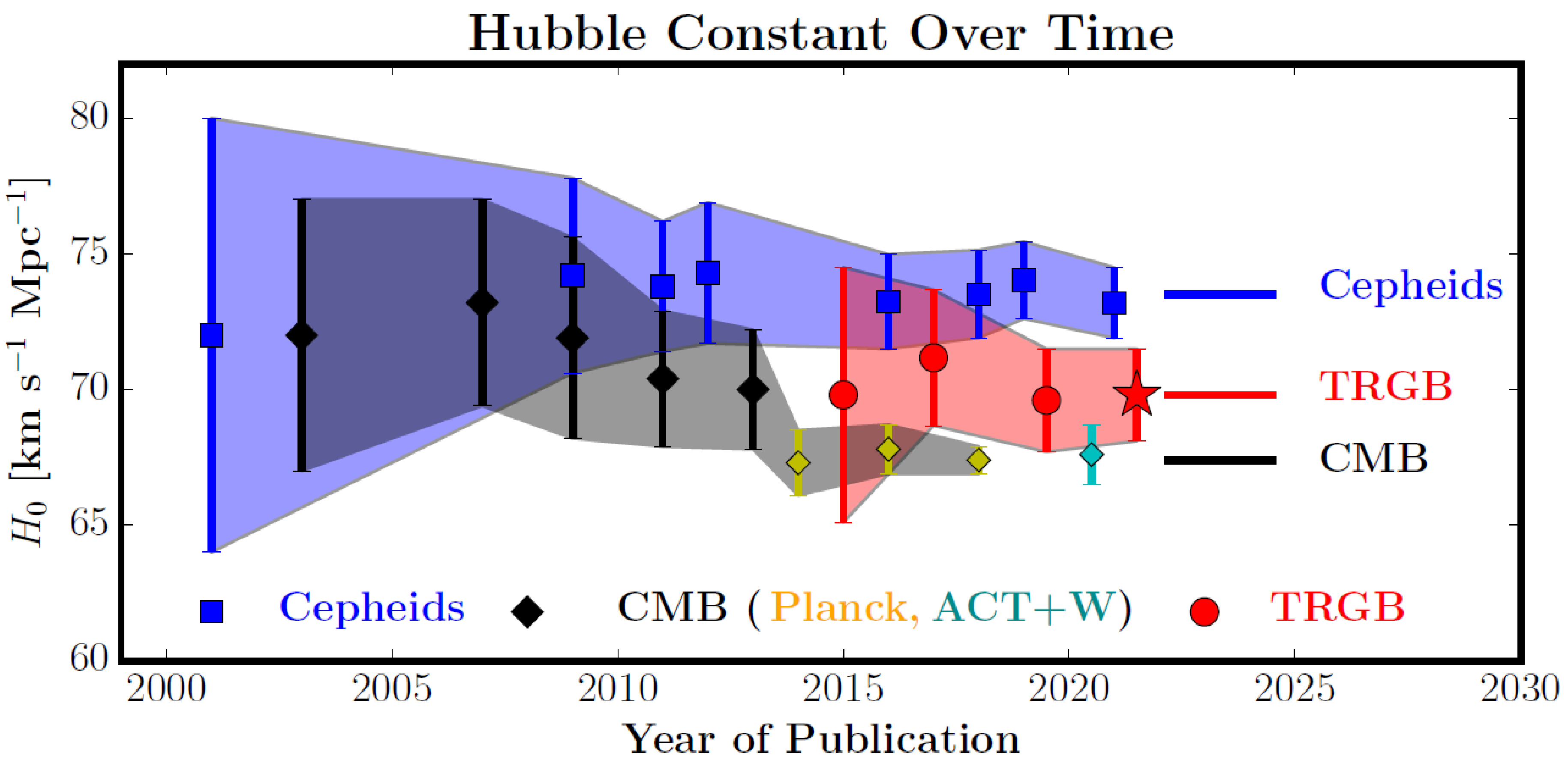
Common hosts of cepheid and TRGB

- Comparison of published TRGB and Cepheid distance moduli for 28 nearby galaxies. The distances span a range from 50 kpc to 30 Mpc.



Freedman et al. (2019)

Hubble constant measurements over time



Freedman (2021)