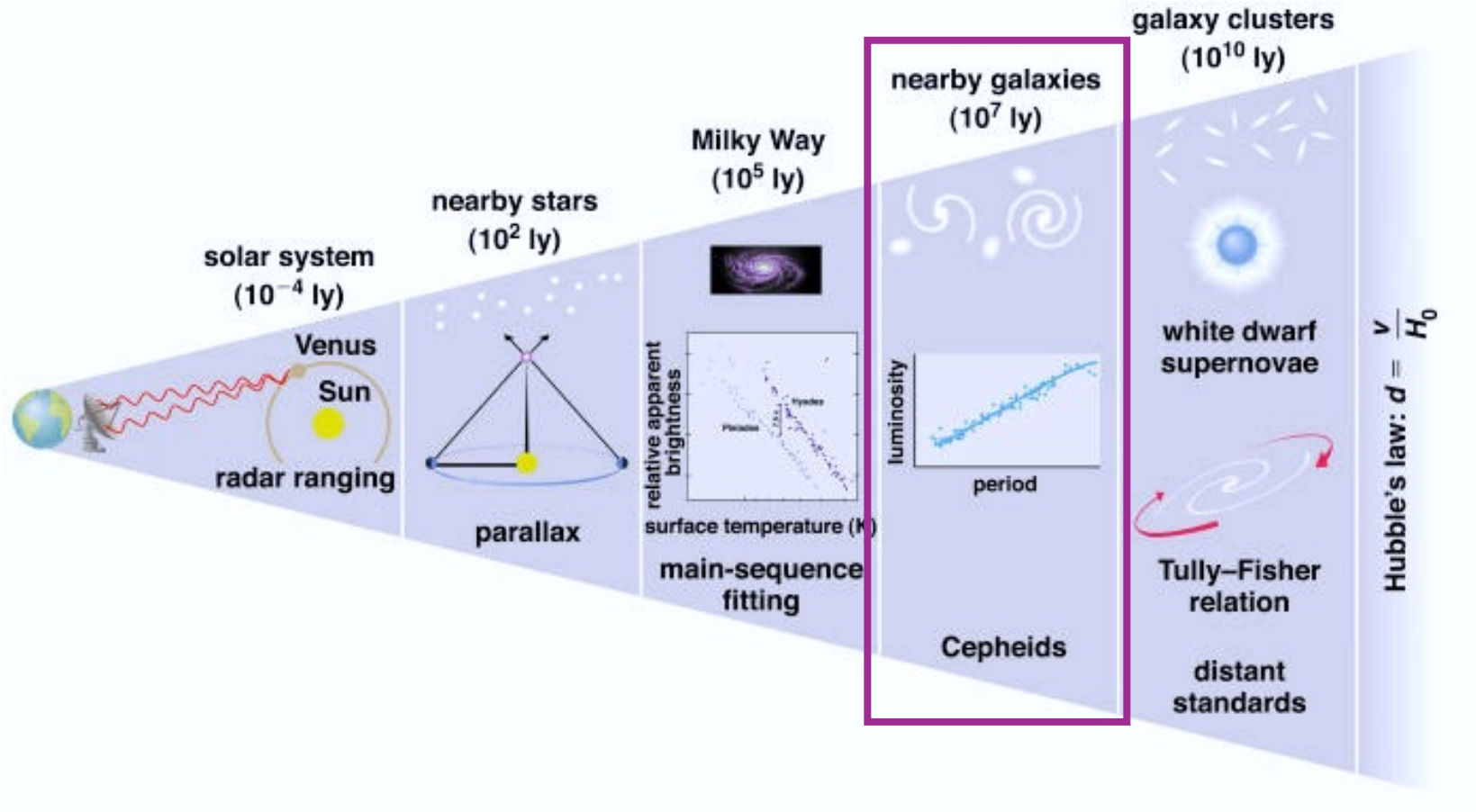
Distance Indicator from:
Cepheids and RR Lyrae stars

Sebastián Carrazco Gaxiola
04.16.2023
ASTR-8400


galaxy clusters
(10^{10} ly)
nearby galaxies
(10^{7} ly)
Milky Way
(10^{5} ly)
nearby stars
(10^{2} ly)
solar system
(10^{-4} ly)
Venus
Sun
radar ranging
parallax
relative apparent brightness
surface temperature (K)
main-sequence fitting
luminosity
period
Cepheids
white dwarf supernovae
Tully–Fisher relation
distant standards
Hubble's law: $d = \frac{v}{H_0}$

Introduction

Period Luminosity Relation / Leavitt's Law

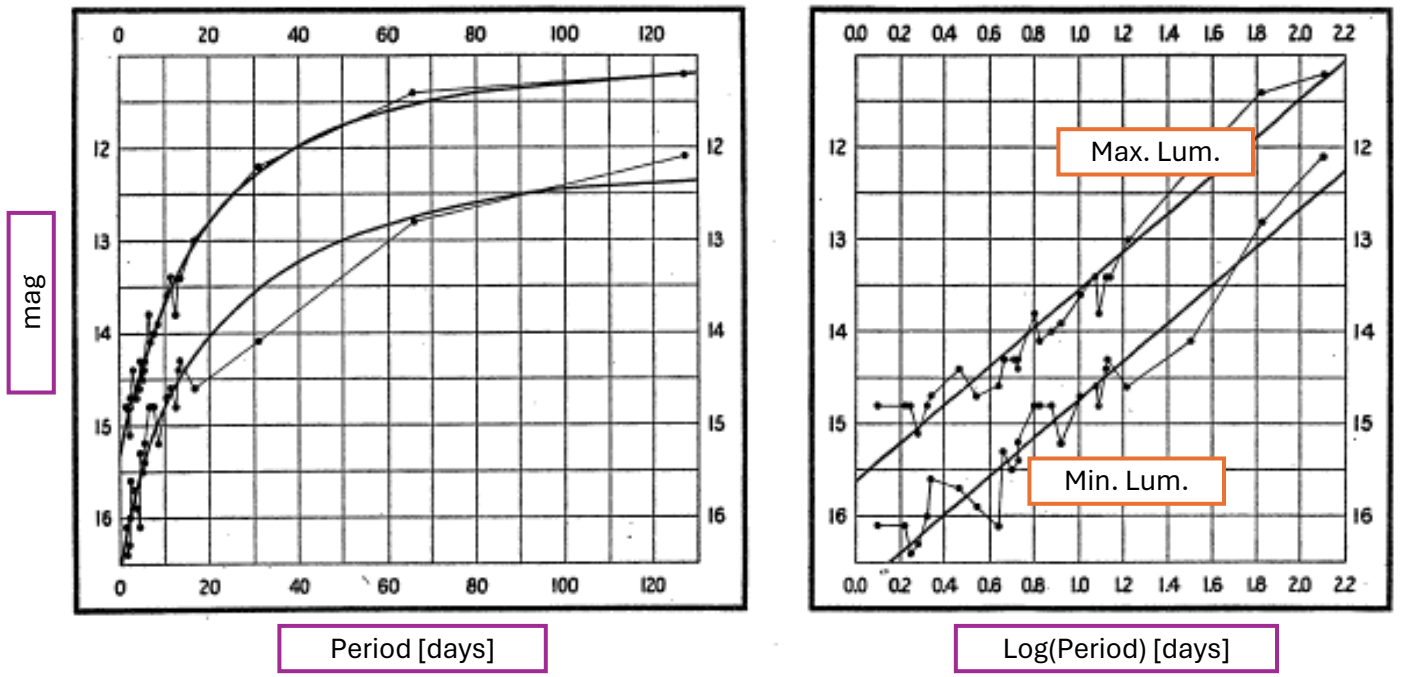
Henrietta Leavitt

Harvard College Observatory in Arequipa, Peru

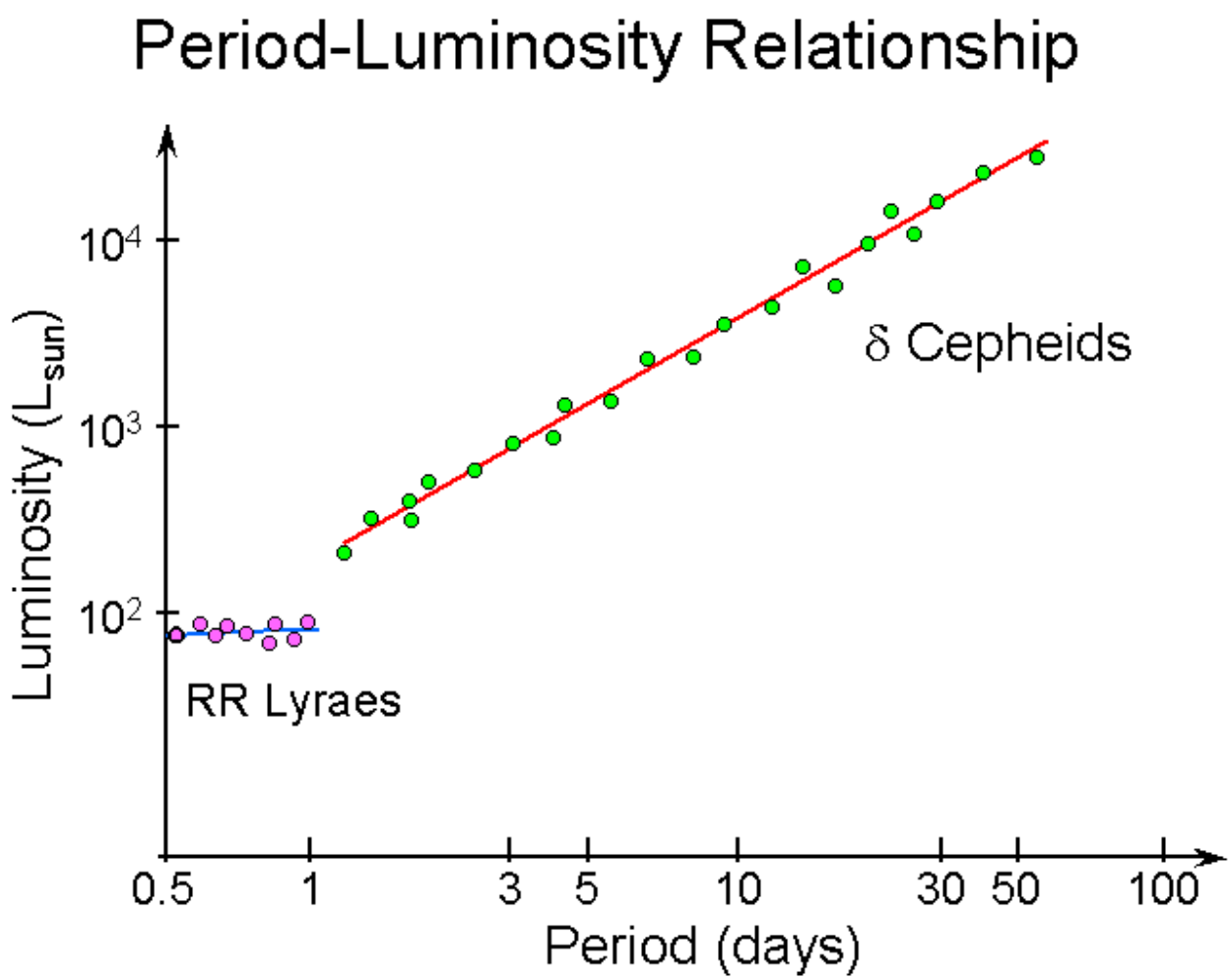
Introduction

Period Luminosity Relation / Leavitt's Law

Henrietta Leavitt



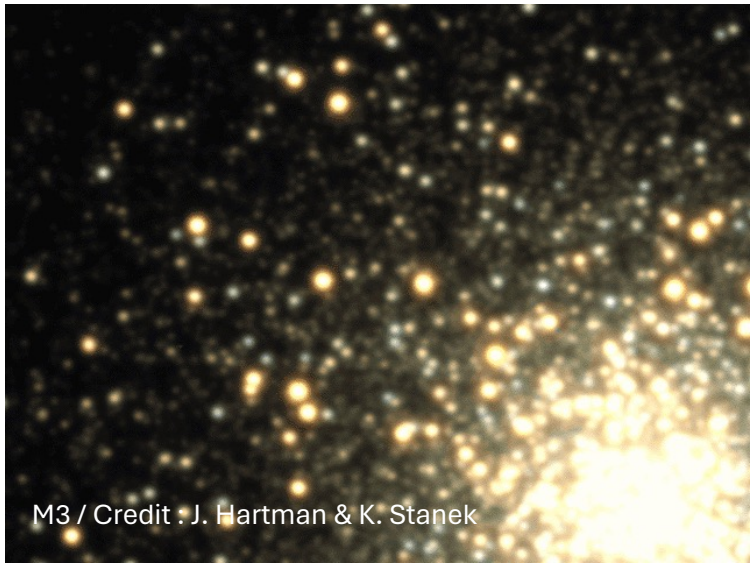
Leavitt, H. S., & Pickering, E. C. (1912).


Period-Luminosity Relationship
Luminosity (L_{sun})
10^4
10^3
10^2
δ Cepheids
RR Lyraes
0.5
1
3
5
10
30
50
100
Period (days)

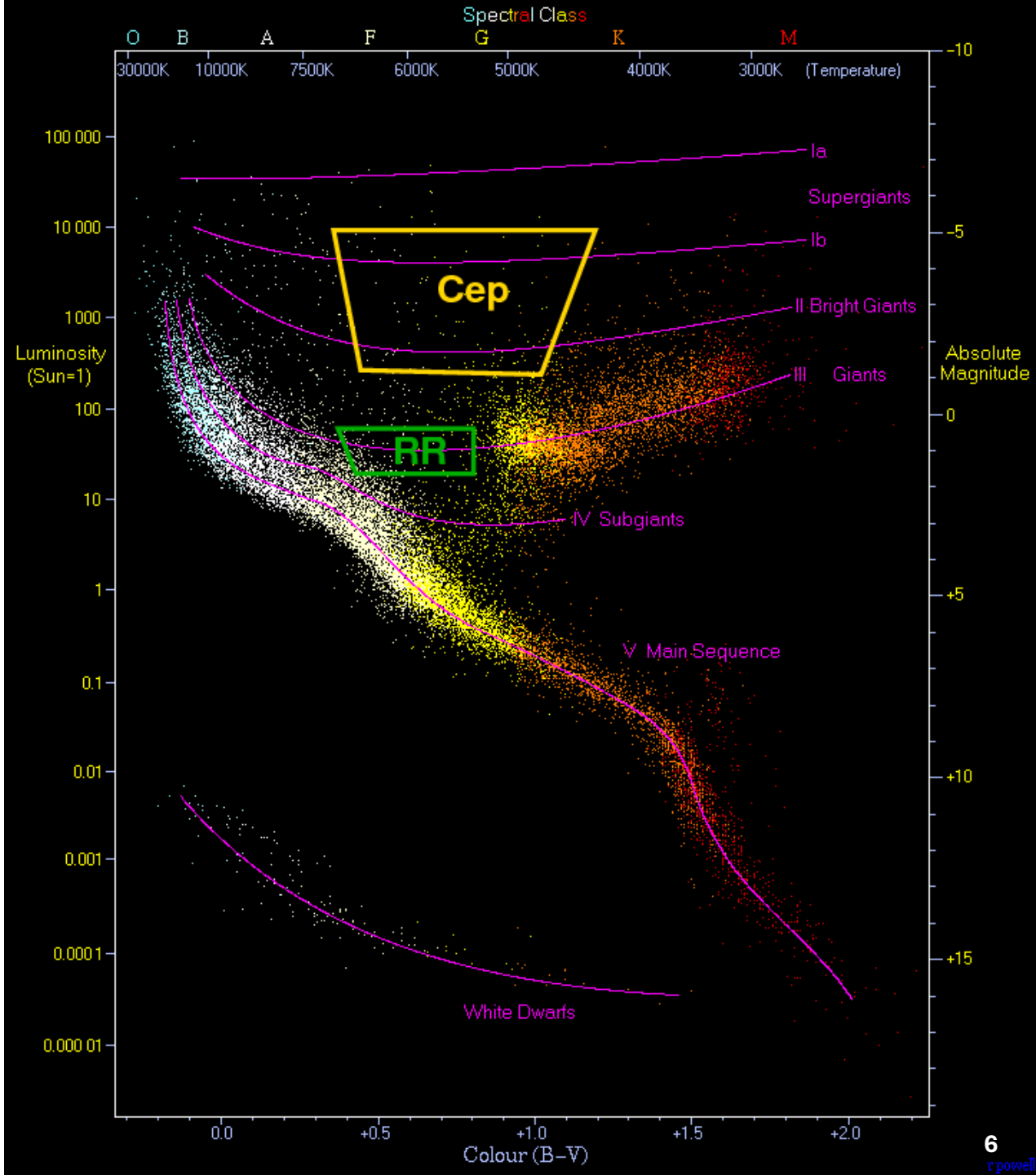
Introduction

RR Lyrae

- Low mass < 0.7 Msun
- HB stars in helium burning phase
- Population II stars
  - Old Metal Poor
- Period ~< 1d
- Pulsation brightness amplitude of Δm ≈ 1m.



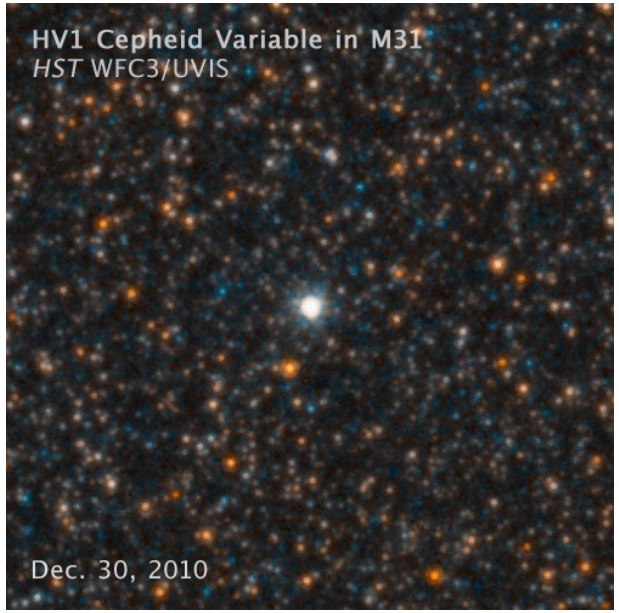
M3 / Credit : J. Hartman & K. Stanek

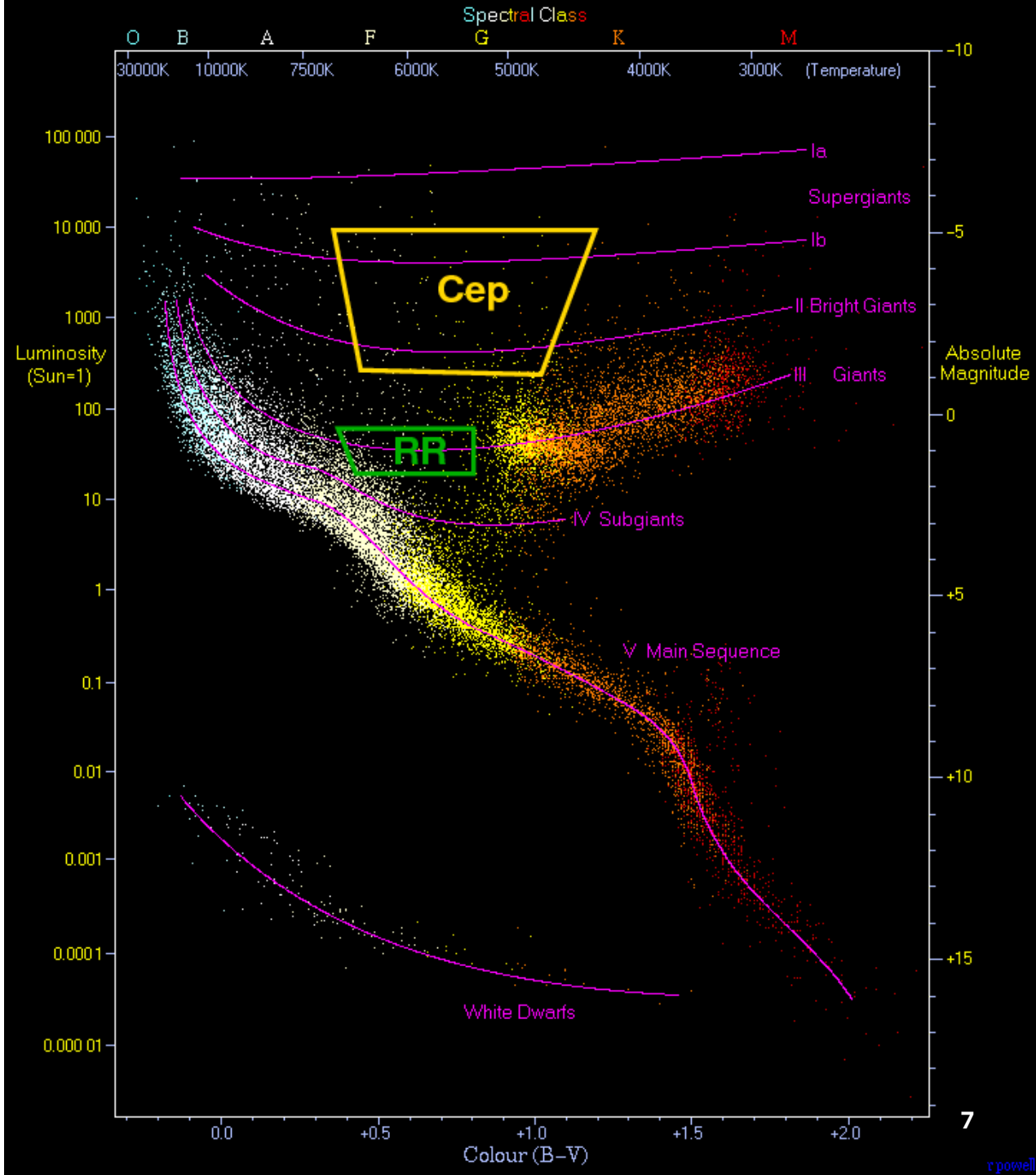


Introduction

Cepheids

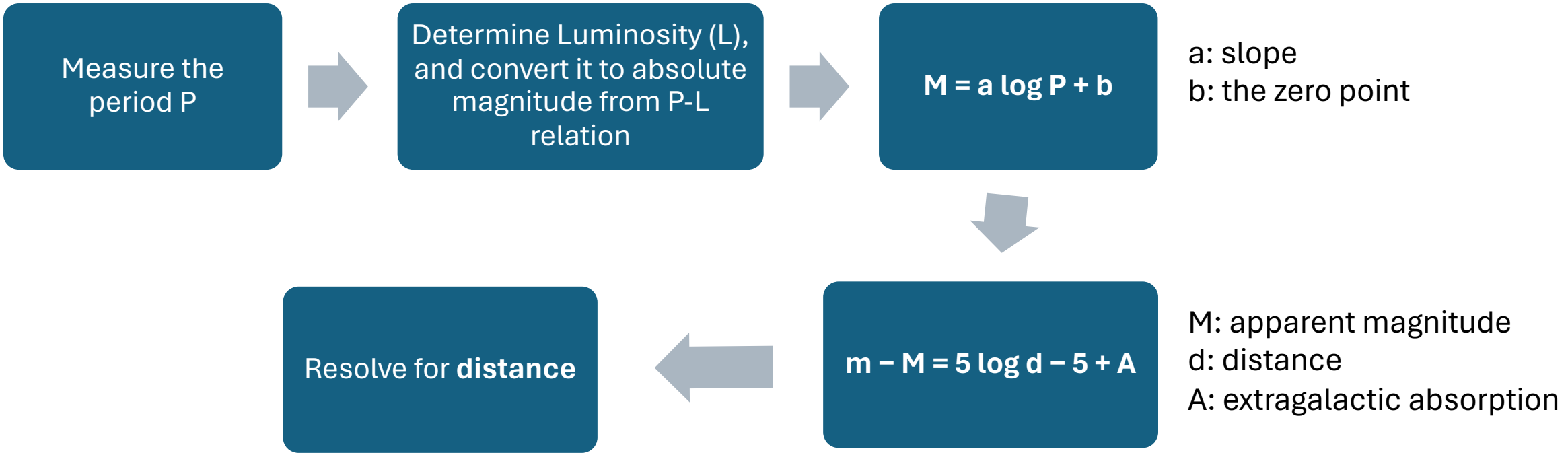
- Evolved High Mass stars
  - Super Giants
- Population I stars
  - Younger Metal Rich
- Period 1d ≤ P ≤ 40d



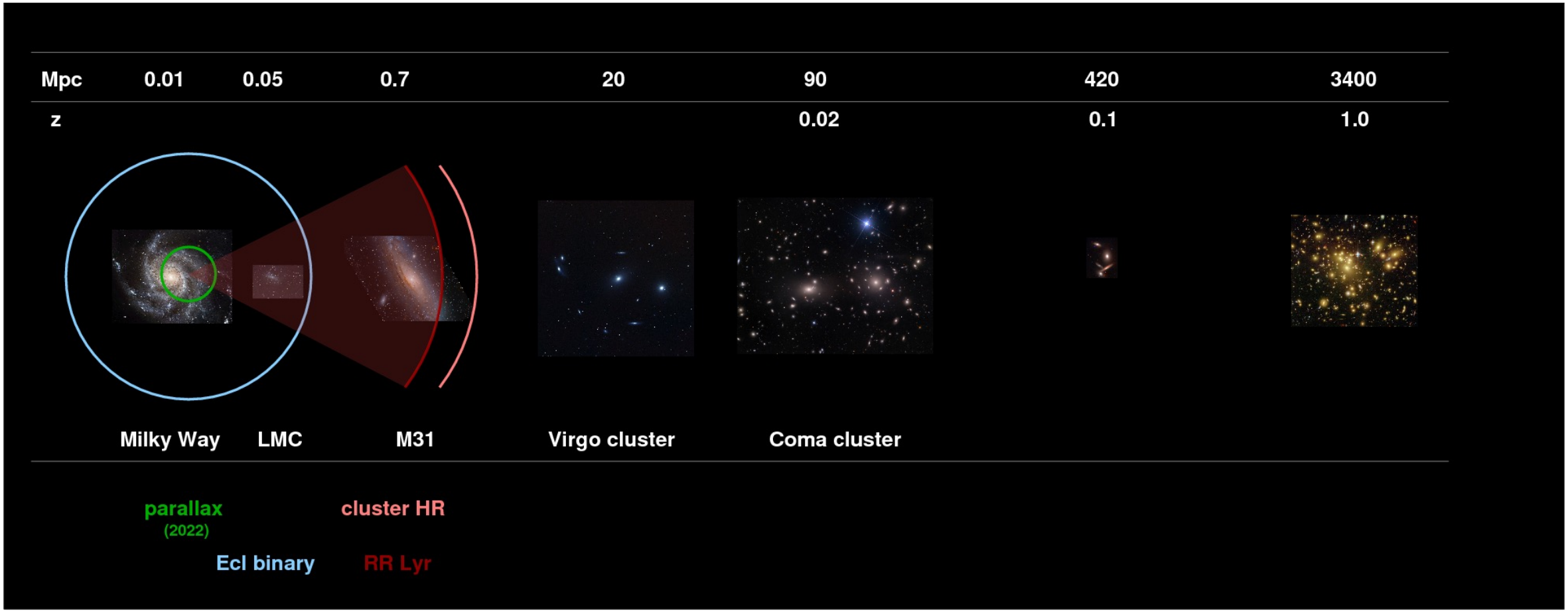


Basic Technique

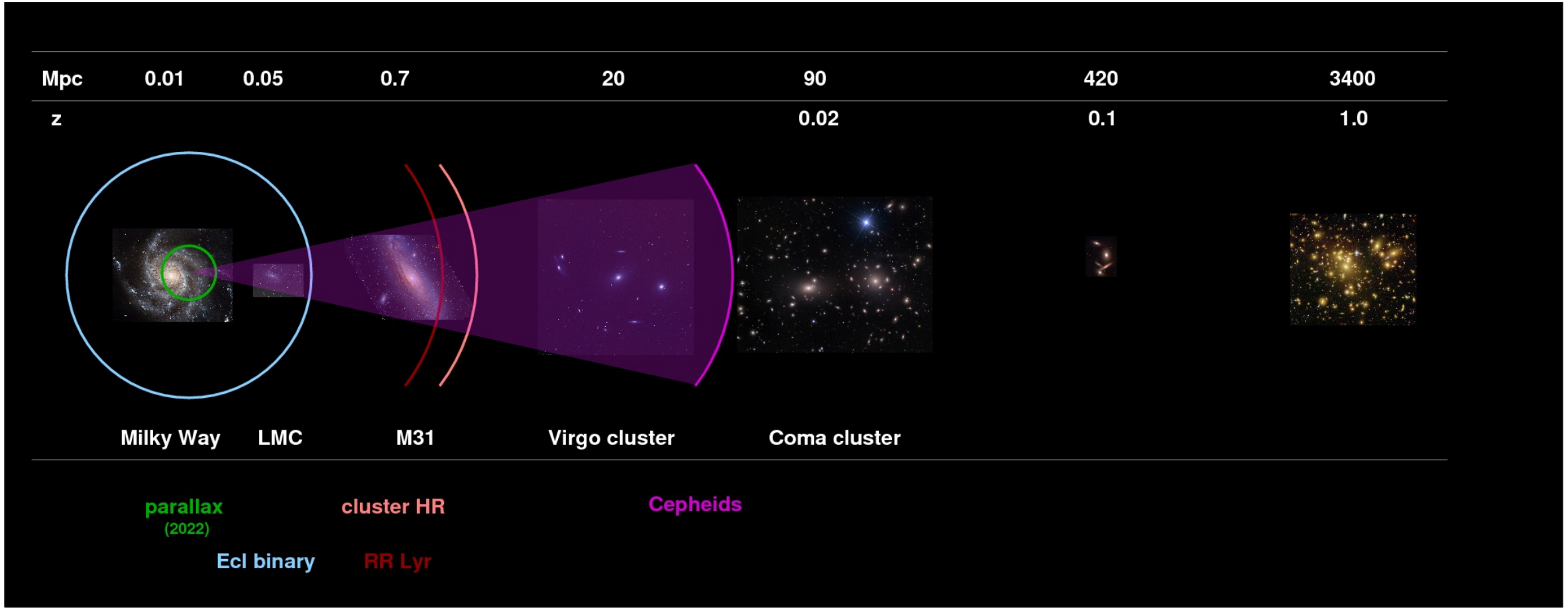
Musella I., 2016, MmSAI, 87, 382



RR Lyrae usable within…



Cepheids usable within…



Problems and Sources of Error

Cepheids

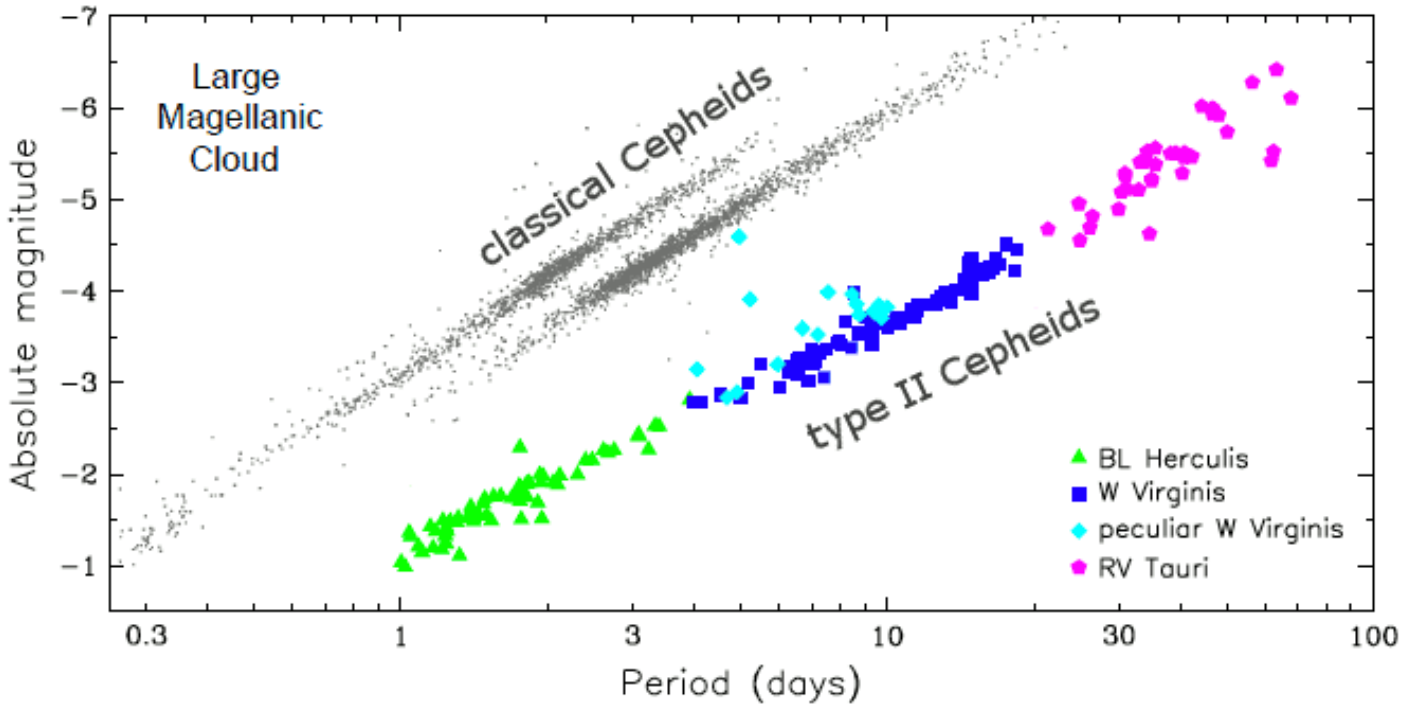
Two types of Cepheids

- Different P-L for each

LMC and SMC best laboratories

- Bias from reddening and metallicity spread

Sampling



Soszyński et al. 2018

Problems and Sources of Error

RR Lyrae

Dependance in Fe/H

- Adoption of Z in models create uncertainties

RR Lyrae P-L relation:

- Optical vs NIR (K band)
- MK = a + b log P + c[Fe/H]

Faint that Cepheids

Problems and Sources of Error

Distance and Metallicity indicators

RR Lyrae

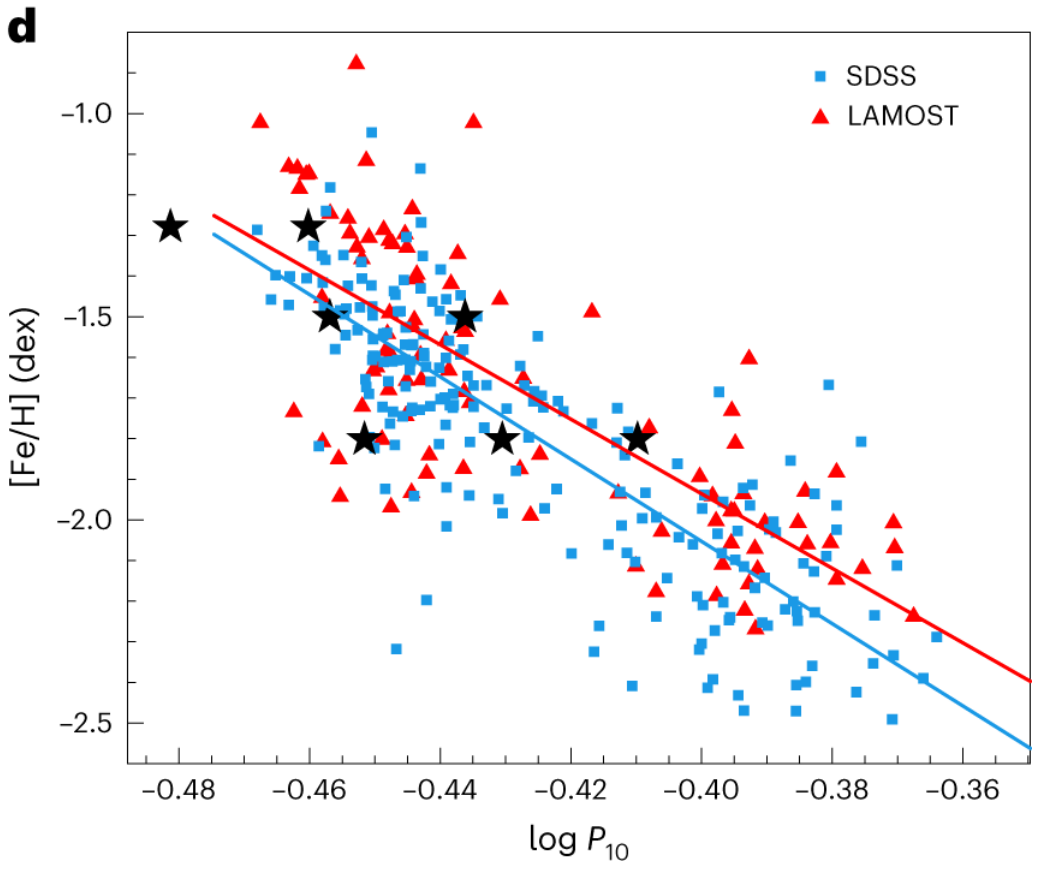
Dependance in Fe/H

- Adoption of Z in models create uncertainties

RR Lyrae P-L relation:

- Optical vs NIR (K band)
- $M_K = a + b \log P + c[Fe/H]$

Faint that Cepheids



Chen et al. 2023. Nature Astronomy volume 7, pages 1081–1089

Recent results… with JWST

OPEN ACCESS

Crowded No More: The Accuracy of the Hubble Constant Tested with High-resolution Observations of Cepheids by JWST

Adam G. Riess[1,2], Gagandeep S. Anand[1], Wenlong Yuan[2], Stefano Casertano[1], Andrew Dolphin[3], Lucas M. Macri[4], Louise Breuval[2], Dan Scolnic[5], Marshall Perrin[1], and Richard I. Anderson[6]

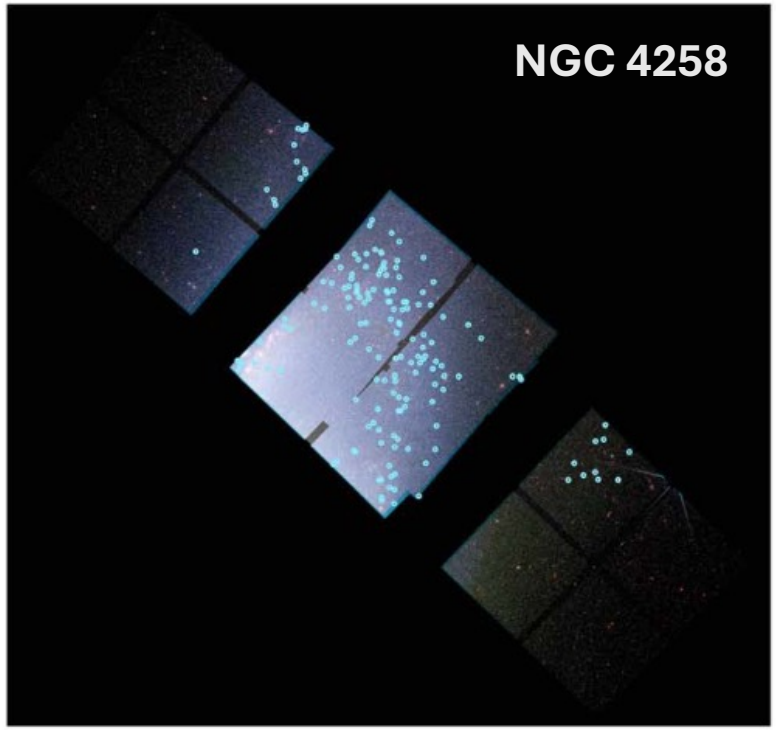
Published 2023 October 16 • © 2023. The Author(s). Published by the American Astronomical Society.

The Astrophysical Journal Letters, Volume 956, Number 1

Citation Adam G. Riess *et al* 2023 *ApJL* **956** L18

DOI 10.3847/2041-8213/acf769

Targeted galaxies



NIRCAM RGB images (F090W/F150W/F277W)

P-L Relation with JWST

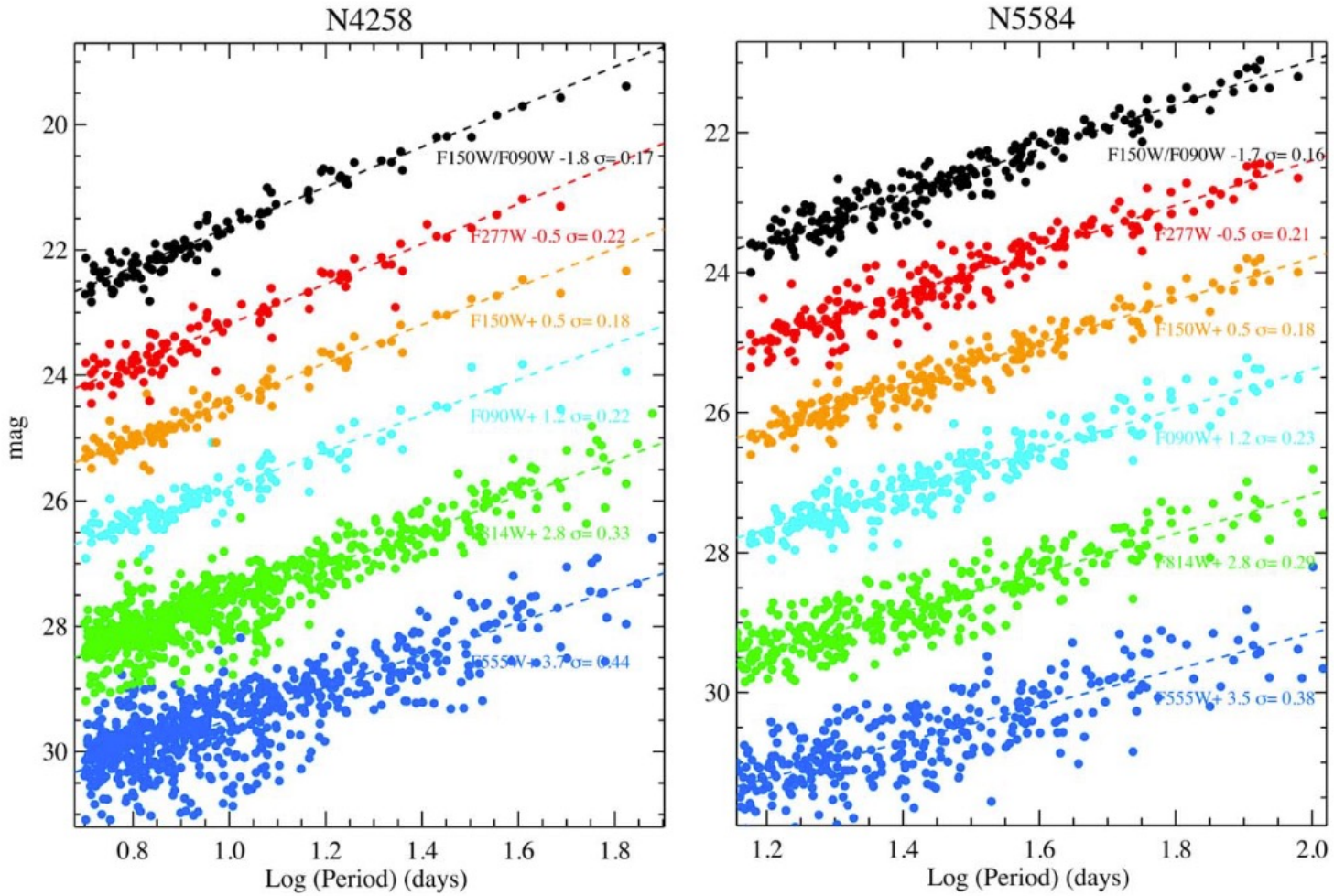


Figure 13. Period–luminosity relations from bluest (bottom) to least reddened (top). The bottom two, F555W and F814W, are from HST, and the others are from JWST. The top set in black is a dereddened or Wesenheit magnitude, F150W-R(F090W–F150W). Magnitude offsets are applied as indicated for ease of view, and the dispersion for each is given.

P-L Relation with JWST

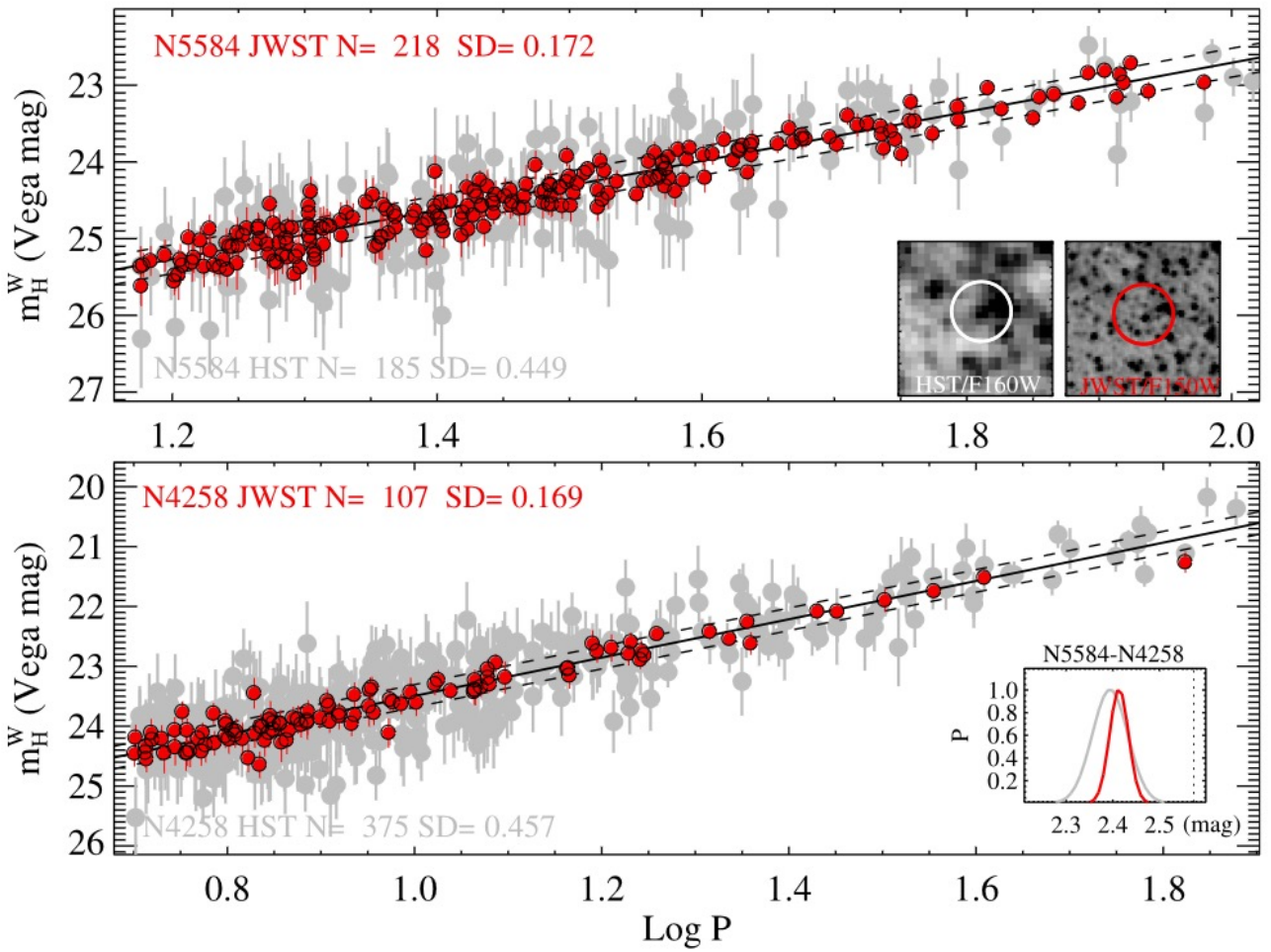


Figure 14. Comparison between the standard (SH0ES: R22) magnitude $W_{V,I}^H$ period–magnitude relation used to measure distances. The red points use JWST F150W, and the gray points are from HST F160W, including a small transformation F150W–F160W = 0.033+0.036[(*V*–*I*)-1.0]. The upper panel is NGC 5584, with the inset showing image stamps of the same Cepheid seen in the *H* band by each telescope. The lower panel is NGC 4258, with the inset showing the difference in distance moduli between NGC 5584 and NGC 4258 measured with each telescope.

P-L Relation
JWST vs HST

JWST has reduced any uncertainties down to their smallest values ever.

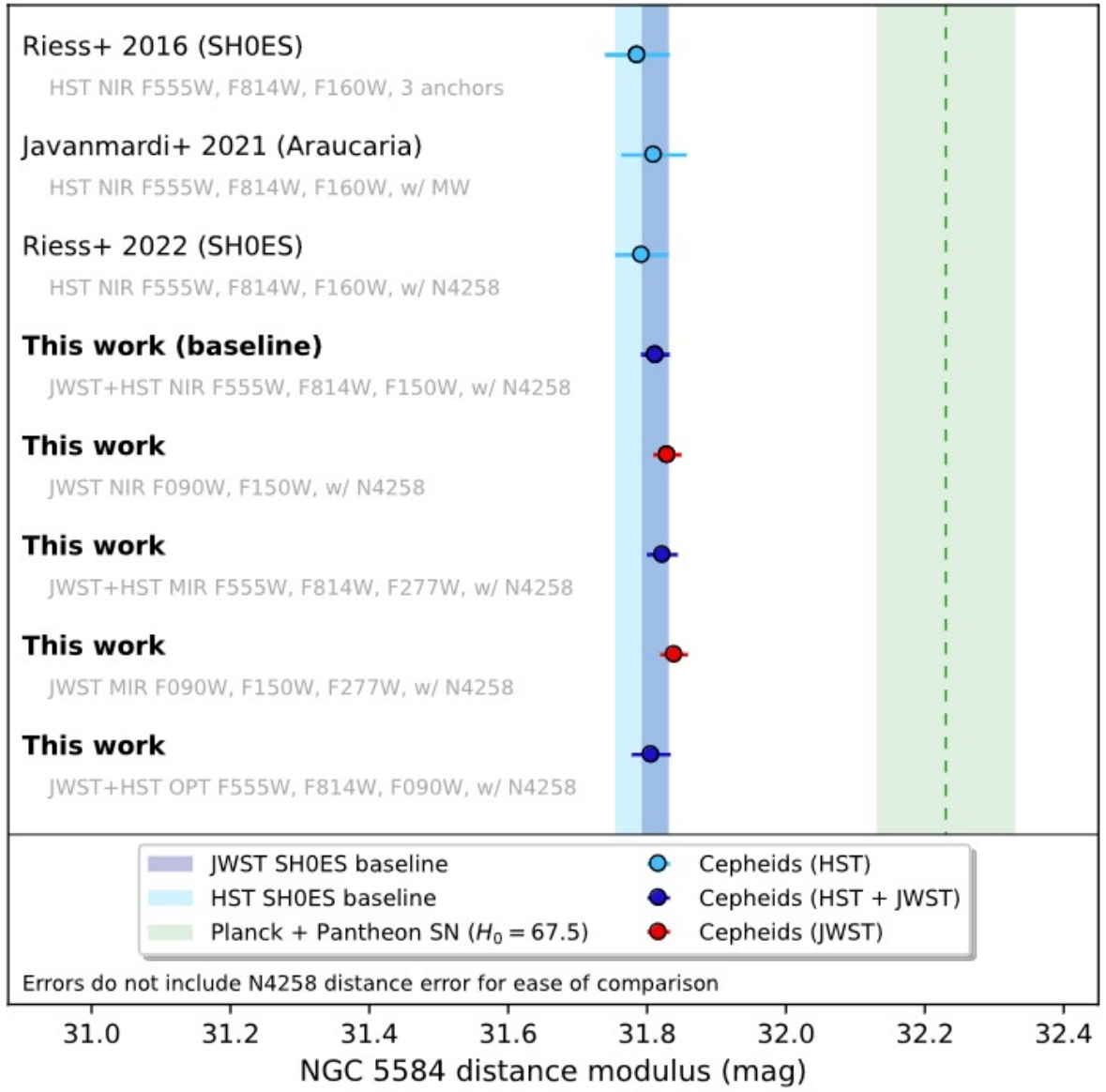
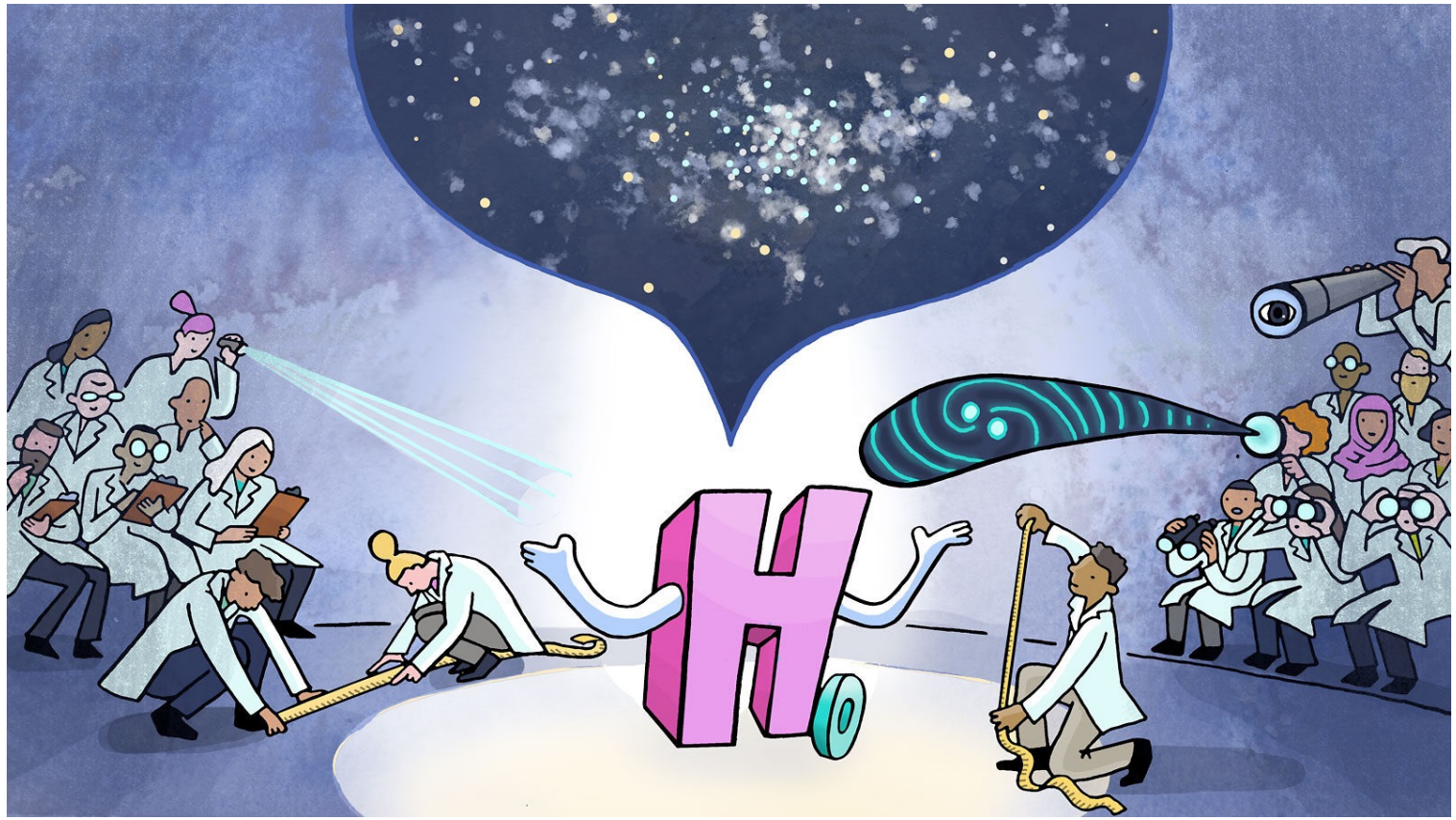


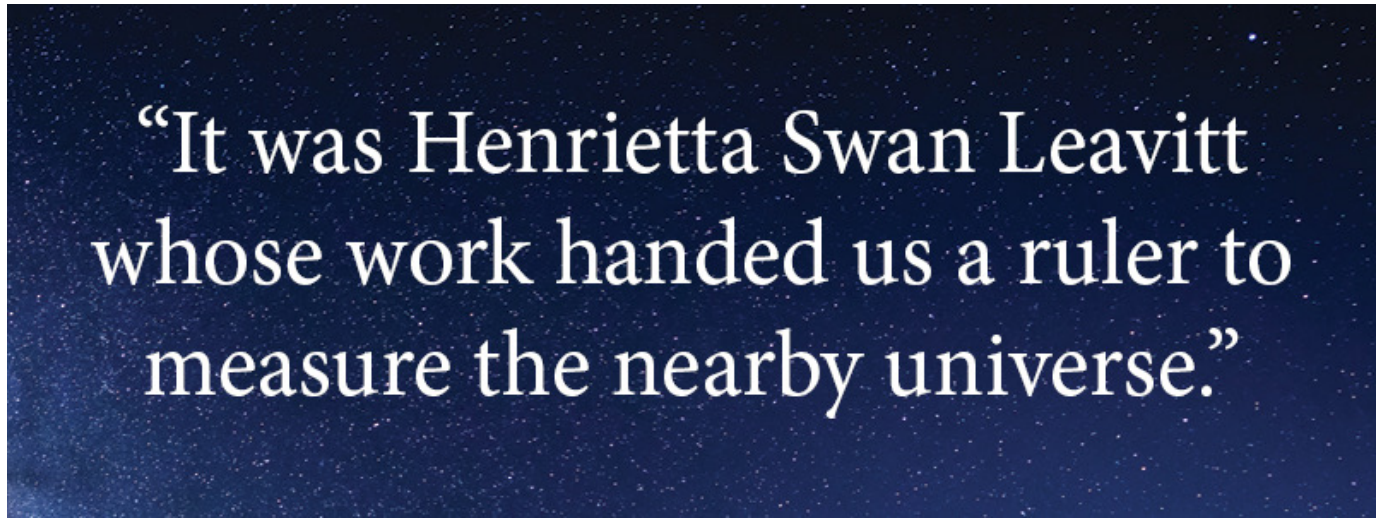
Figure 15. A comparison of Cepheid distance measures to NGC 5584.

Hubble Tension???

- Authors conclude that HST Cepheid photometry does not have a significant role in the present Hubble Tension.



Credit: Sandbox Studio, Chicago with Corinne Mucha



Credit: Floris Books

References

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