Carbon Stars as Standard Candles

An Independent Measurement of the Hubble Constant with JWST

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XIV Torino Workshop on AGB Stars
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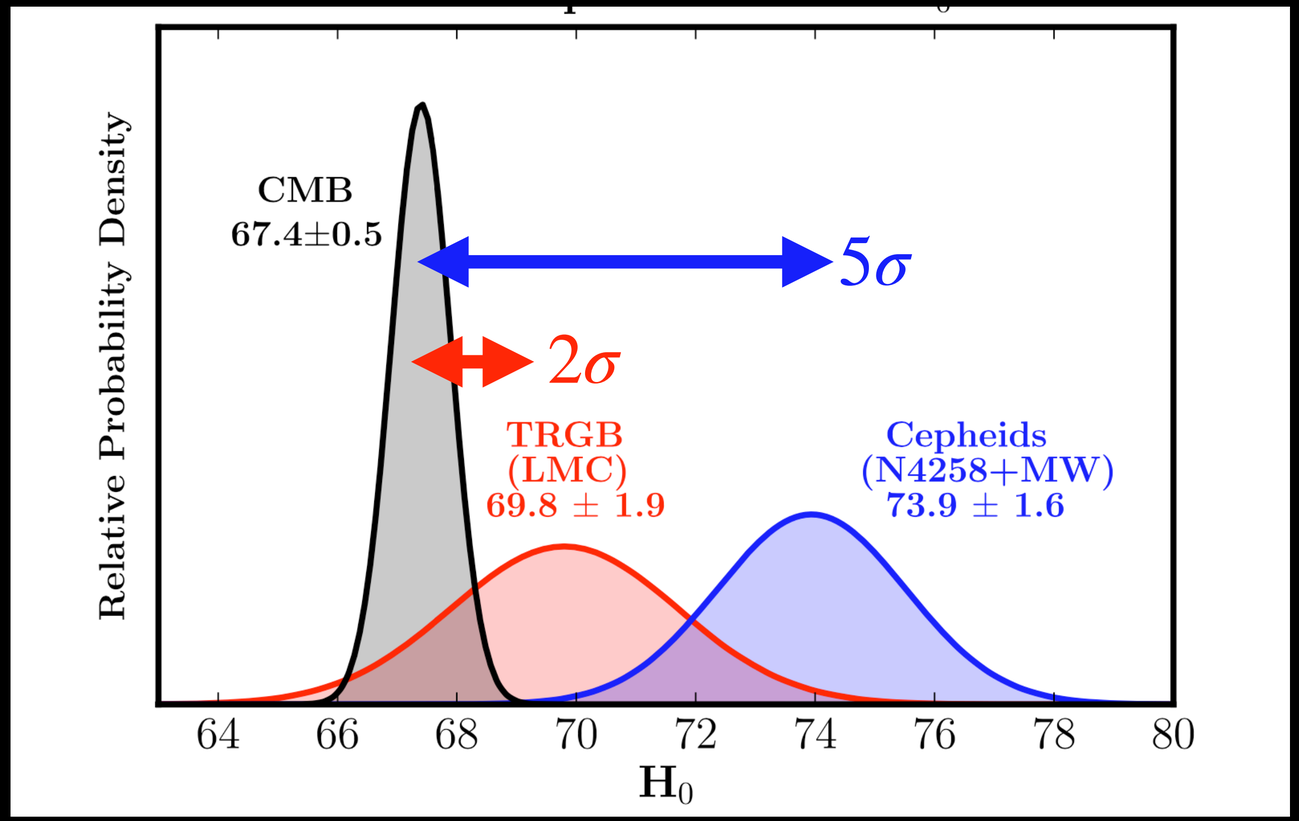
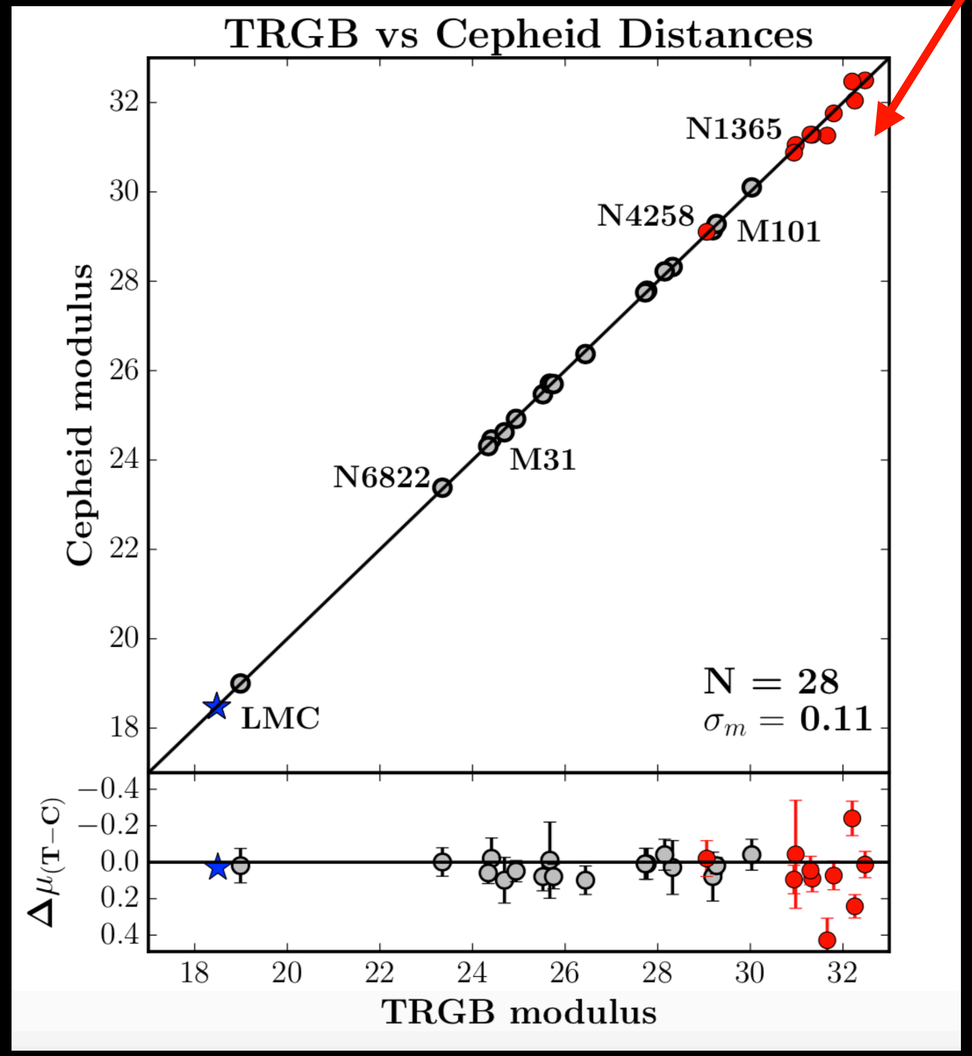
Disagreement between Cepheids vs. TRGB

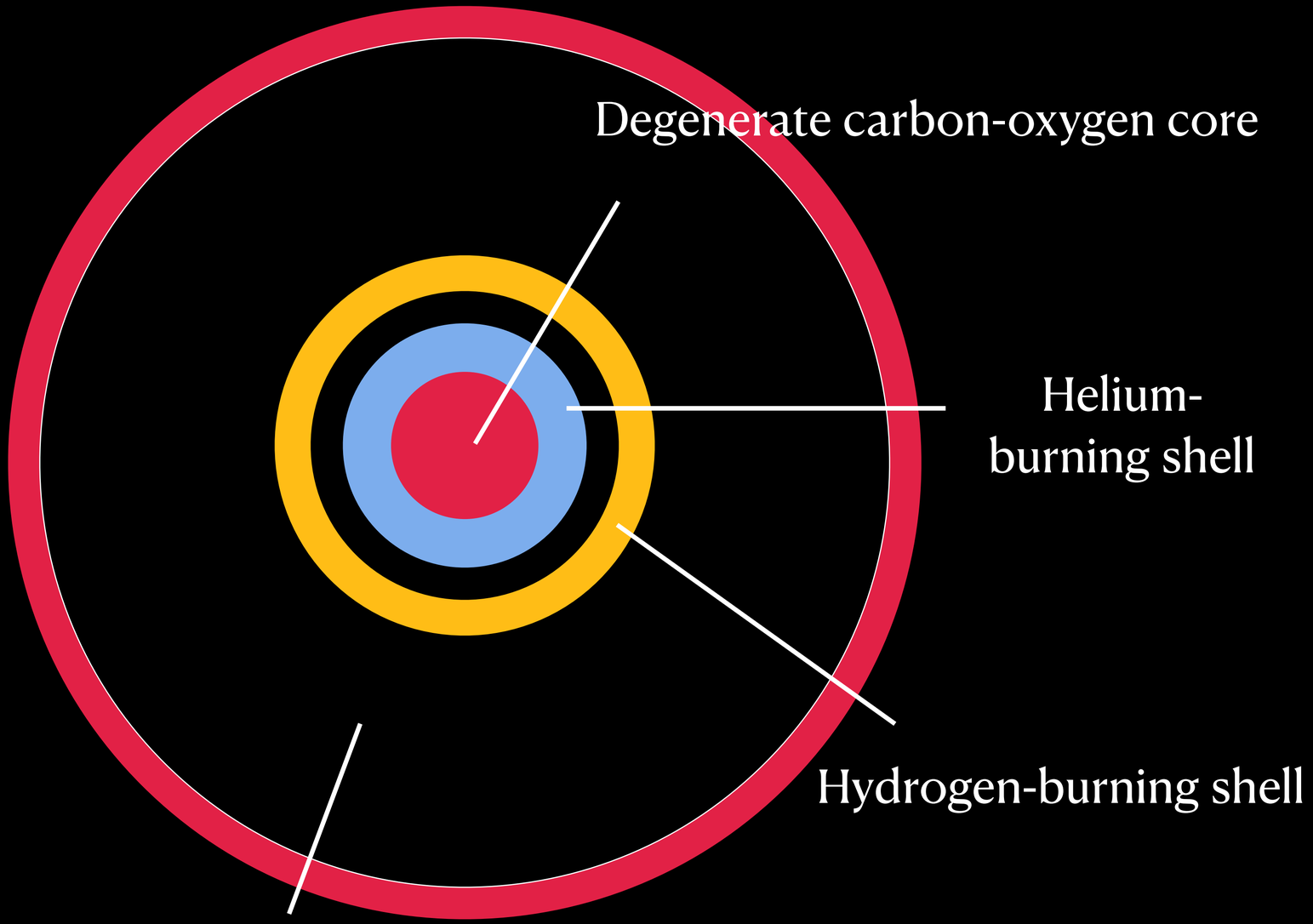


SNe Ia host calibrating galaxies



Freedman+ 2019

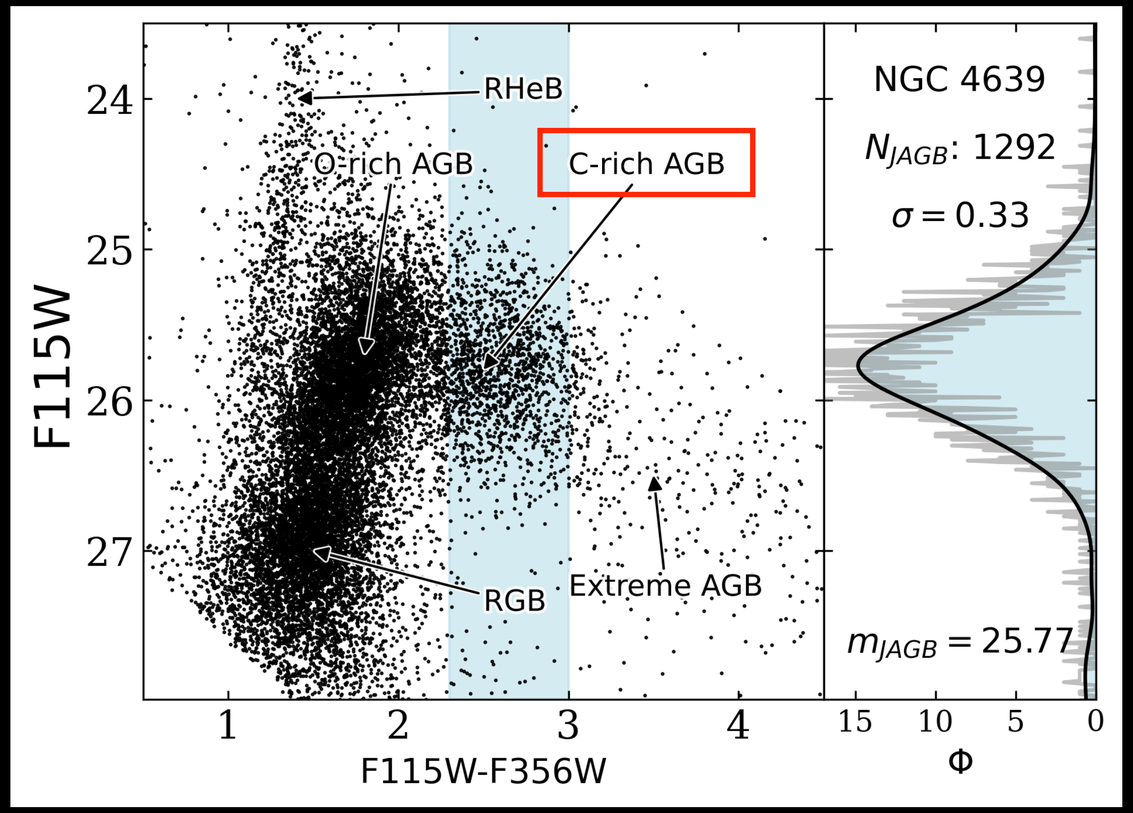
Astrophysical Distance Methods: Carbon Stars as Standard Candles



*Not to scale

- "Dredge-up" episodes responsible for creating carbon stars only effective for a narrow range of masses and thus, luminosities of AGB stars (see Habing & Olofsson 2004 for a review)
- ≈1.5-4 M◉

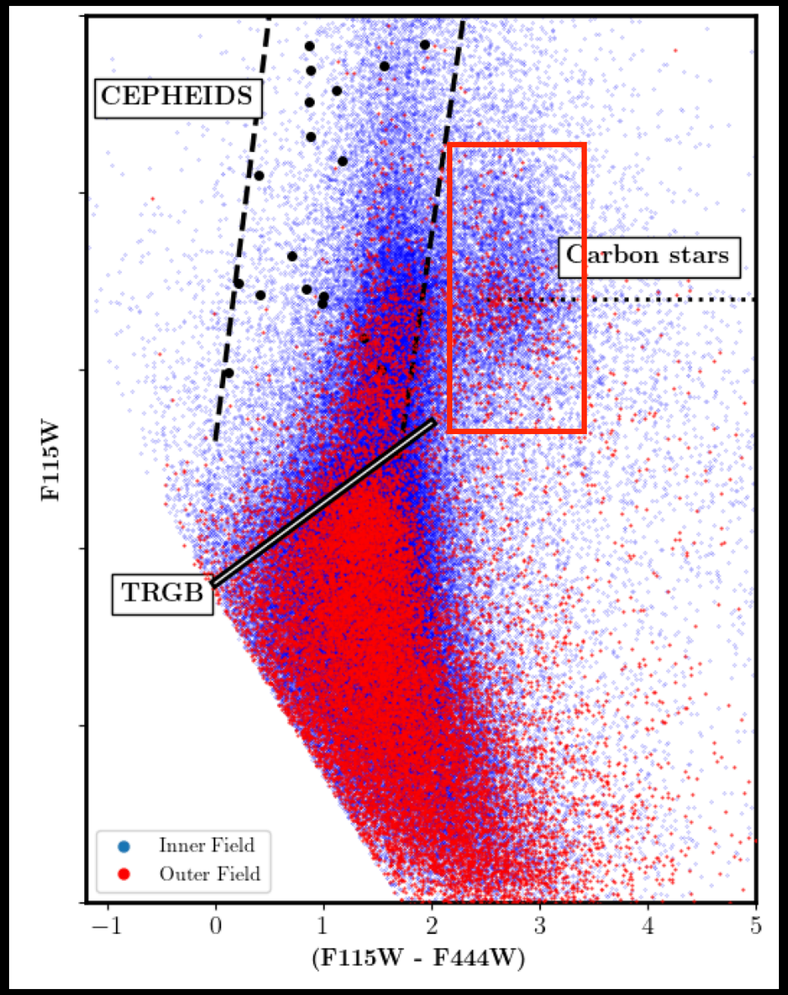
The J-region Asymptotic Giant Branch (JAGB) Method



Lee+24c (submitted)

- ★ JAGB stars are intermediate-mass, carbon-rich AGB stars
- ★ JAGB stars are **photometrically** selected using near-infrared colors
- ★ The mode of the JAGB luminosity function is constant from galaxy to galaxy and therefore an effective standard candle (Freedman & Madore 2020, **Lee**+2021a, Zgirski+2021, **Lee**+2022, Madore+2022, Parada+2023, **Lee**+2024b)
- ★ Comparable accuracy and precision to the TRGB and Cepheids

Comparison of Brightnesses Between Distance Indicators



Brighter

Cooler

Freedman & Madore 2023

The JAGB Method

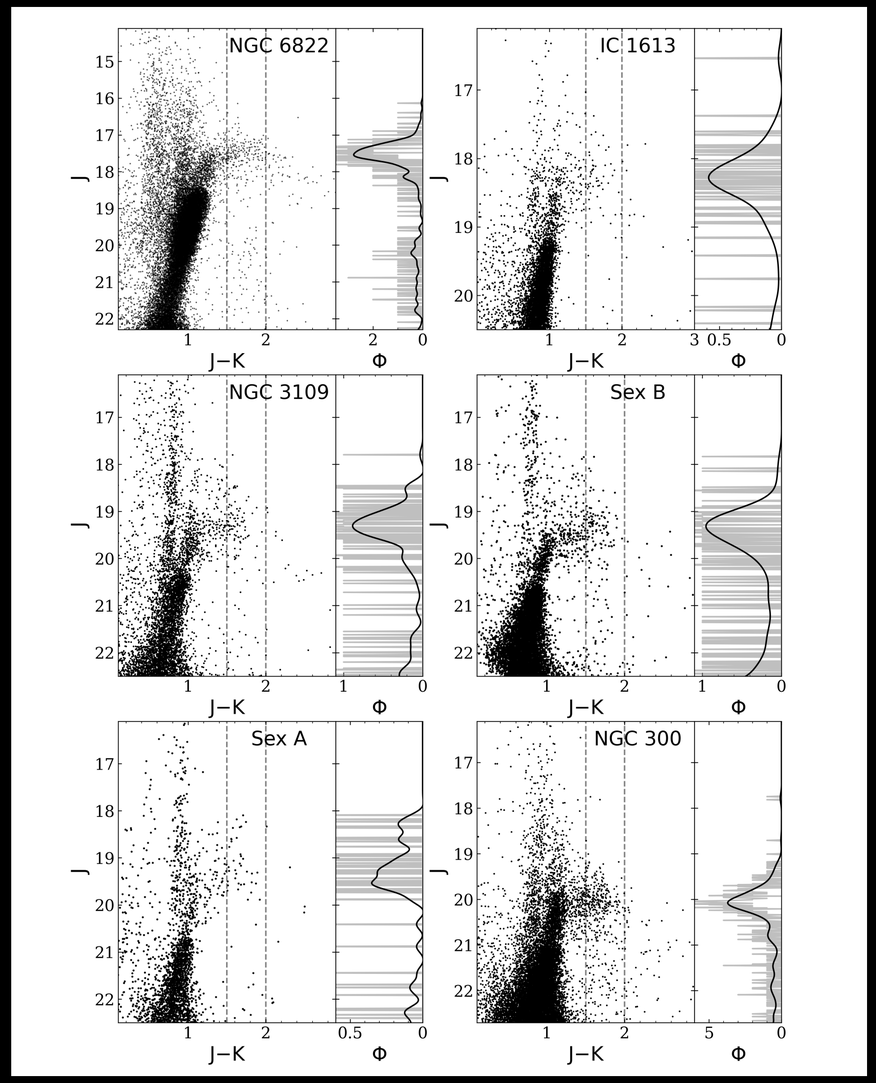
Advantages:

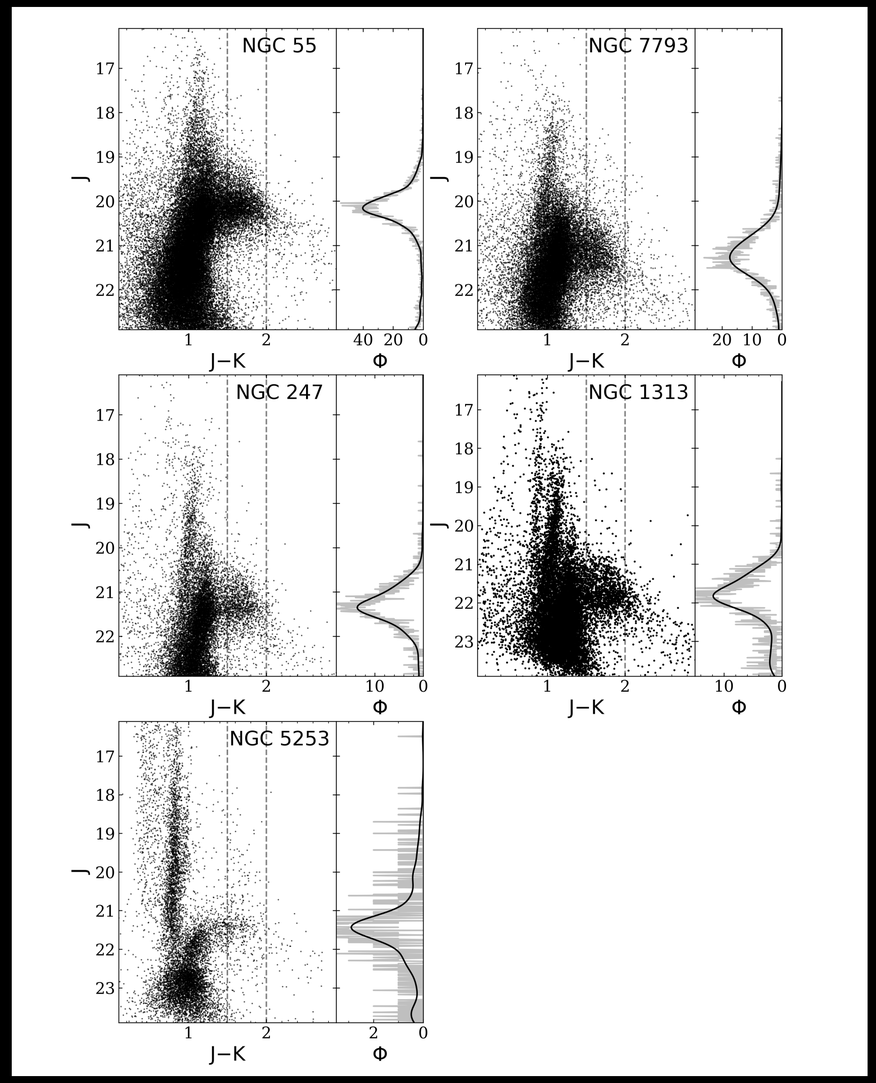
- ★ JAGB stars are distinctive and easily identifiable on the basis of their color
- ★ JAGB stars are ubiquitous and can be found throughout all galaxy morphologies and inclinations
- ★ Near-infrared observations decreases line-of-sight extinction
- ★ Only require 1 epoch of observations for measurement

Potential sources of systematic errors:

- ★ How does the shape and mode of the JAGB star luminosity function depend on the host galaxy's star formation history or metallicity?

NIR Observations of JAGB stars



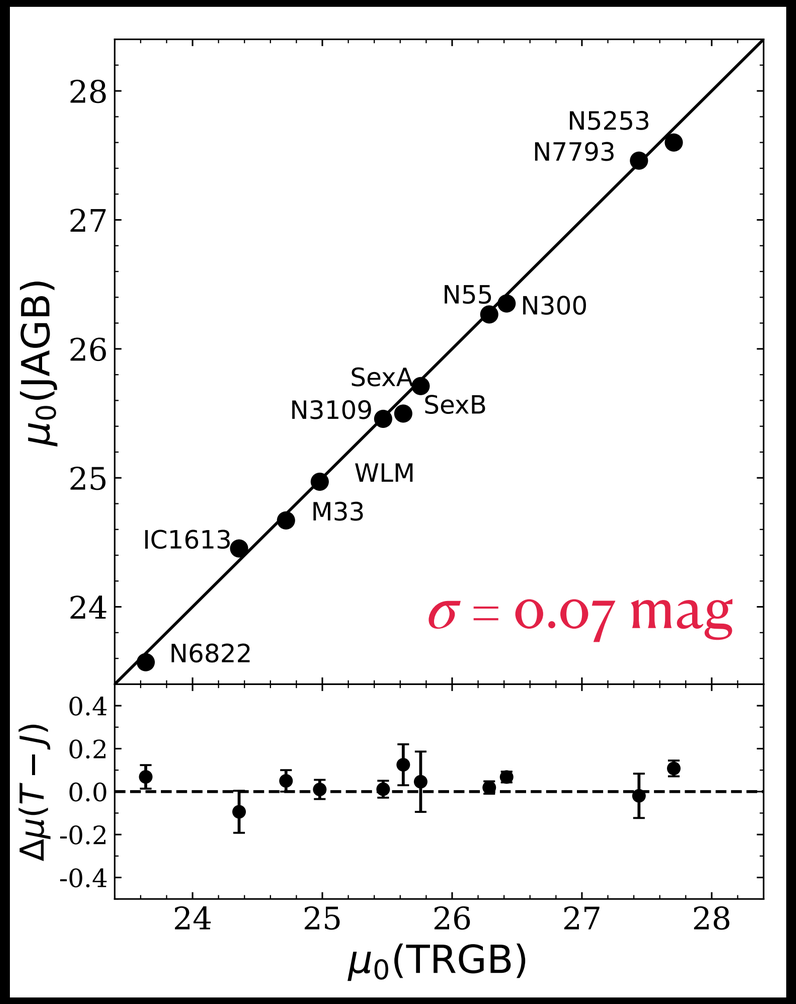


- 104 nights of JHK observations acquired from the Baade-Magellan telescope
- Data are publicly available

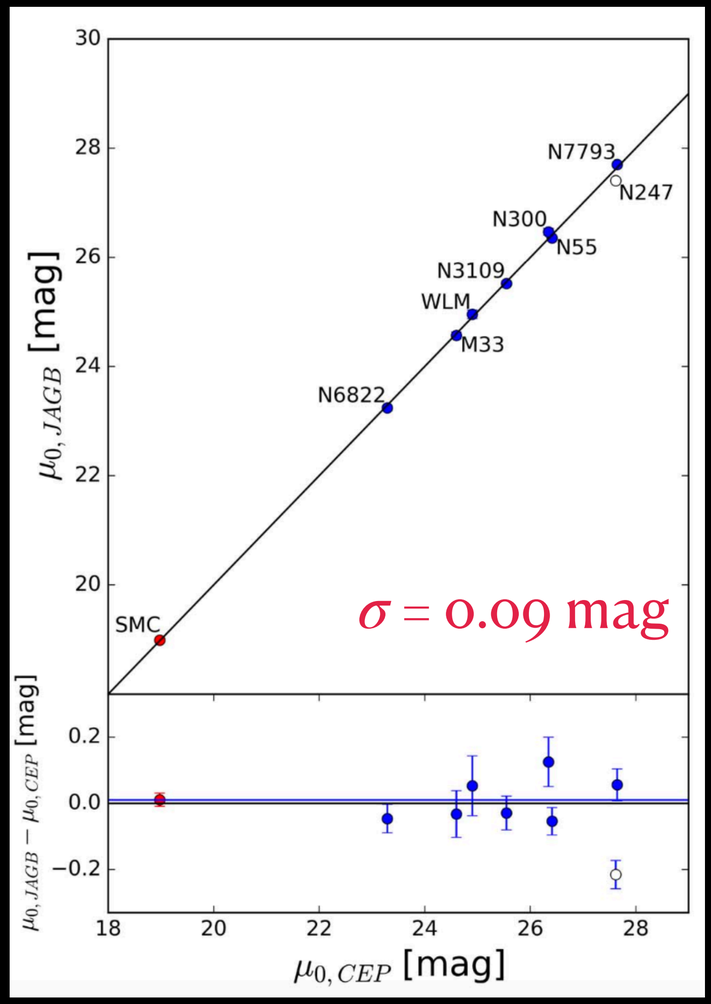
doi: 10.5281/zenodo.10989065

Lee+ 2024b

TRGB vs. JAGB vs. Cepheid Distances

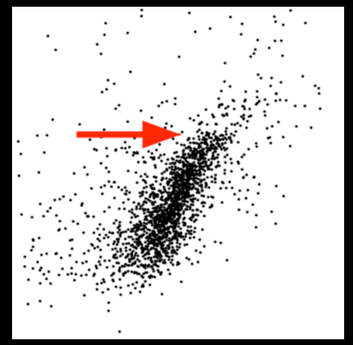


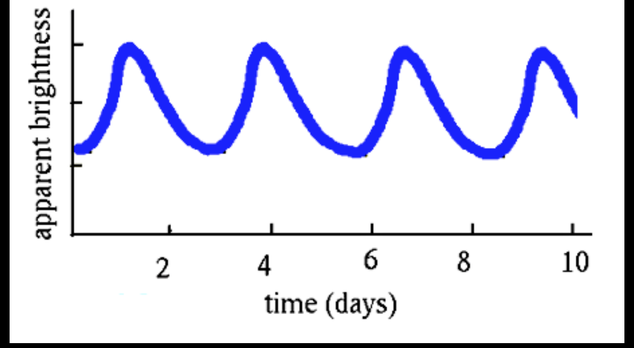
Lee+ 24b

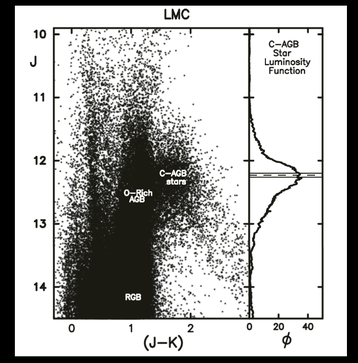


Zgirski+ 21

The JAGB method agrees well with the TRGB and Cepheid P-L relation at the 4% level in nearby galaxies (d < 4 Mpc)







TRGB

- ★ Measured in stellar halo
- ★ Older stellar population (>4 Gyr)
- ★ Helium Flash

Cepheids

- ★ Measured in the star-forming disks
- ★ Younger stellar population (<100 Myr)
- ★ Mechanical pulsation cycles

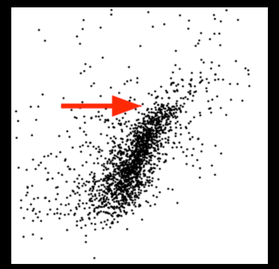
JAGB

- ★ Measured in the outer disks
- ★ Intermediate-age stellar population (300 Myr-1 Gyr)
- ★ Third Dredge-up

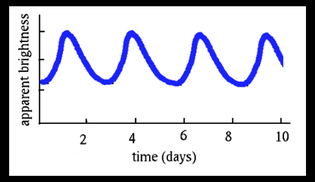
Potential sources of systematic errors for each distance indicator are independent, and can be unearthed through inter-comparison

The Chicago-Carnegie Hubble Program (CCHP)

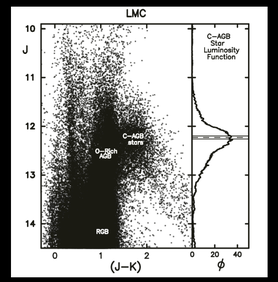
How can the JWST help us improve measurements of H_0?



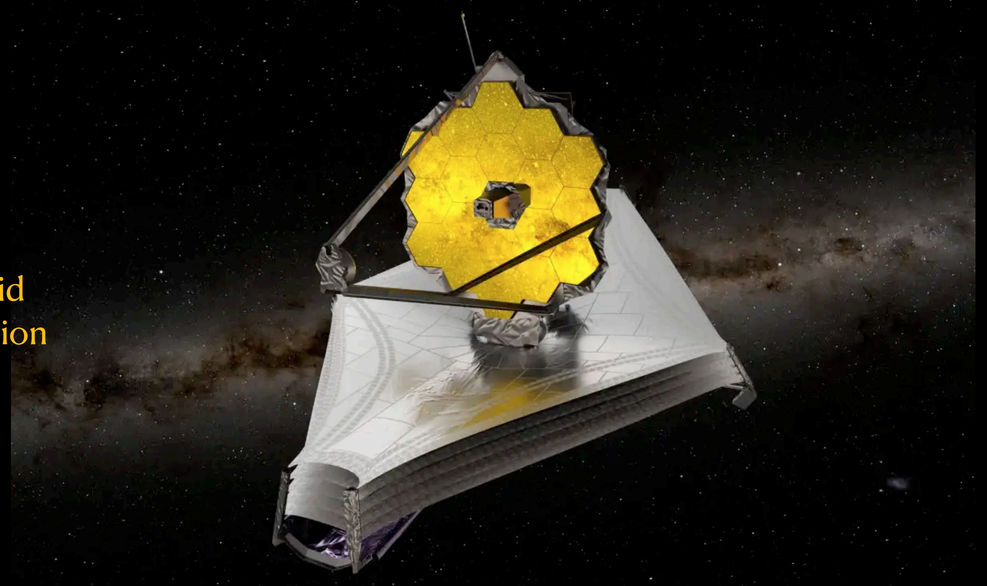
TRGB



Cepheid
P-L relation



JAGB
Method



Wendy Freedman

Barry Madore

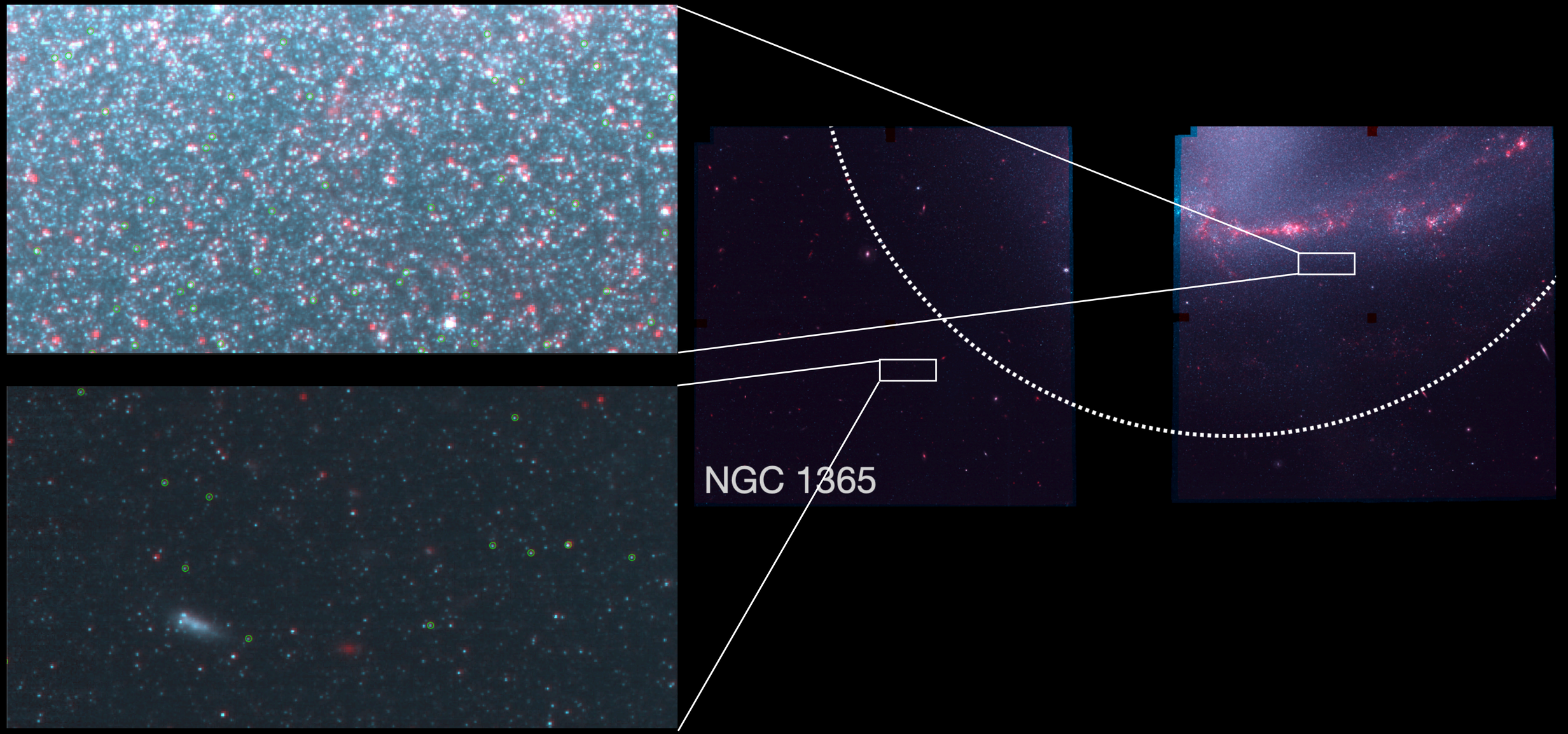
In Sung Jang

Taylor Hoyt

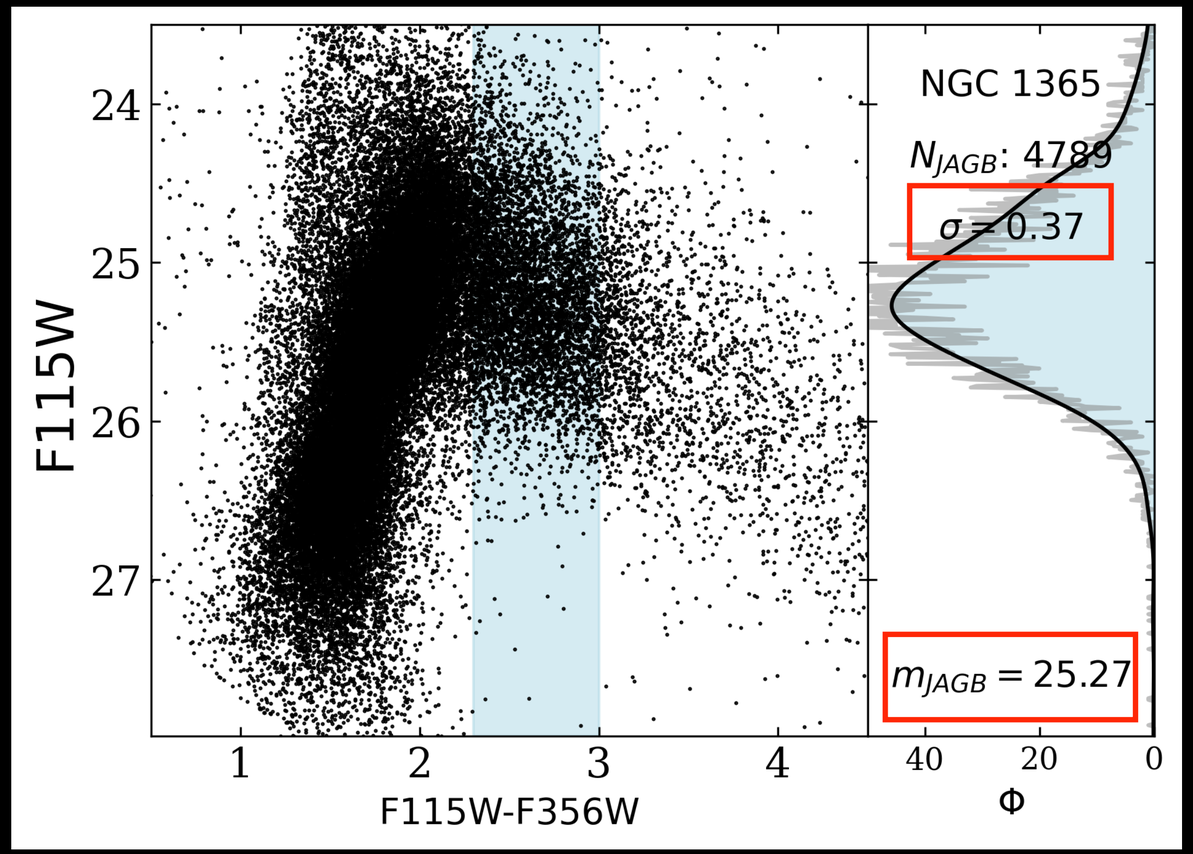
Abby Lee

Kayla Owens

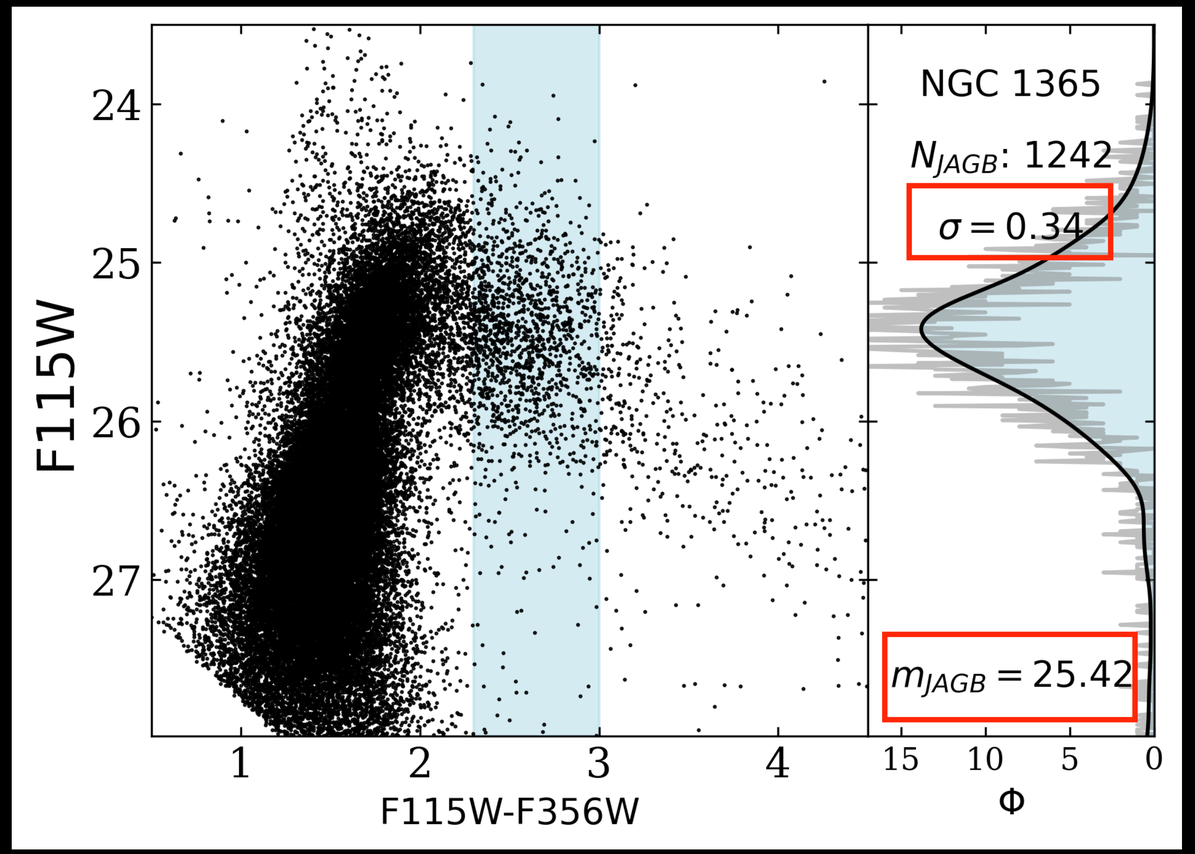
Crowding



“Inner disk”

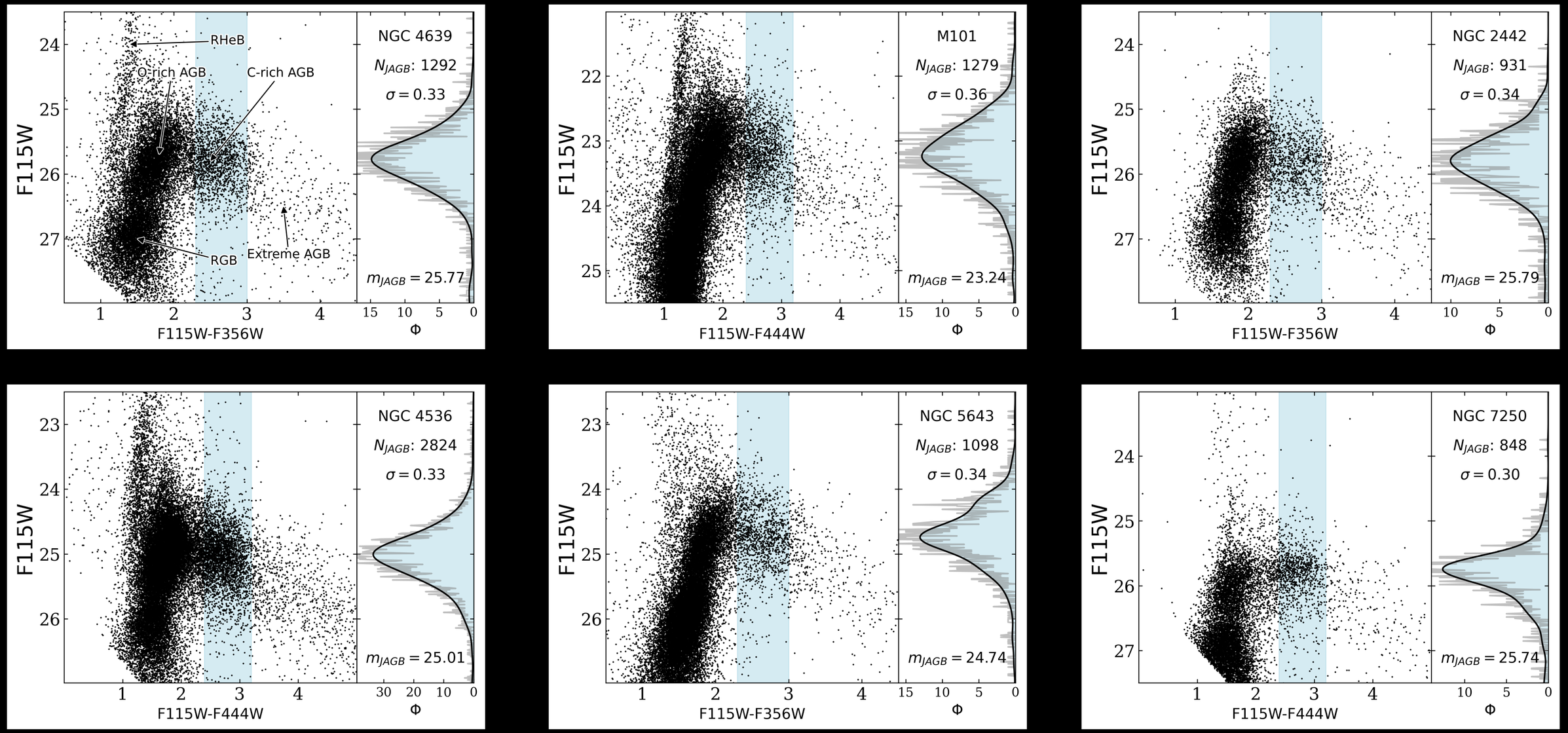


“Outer disk”



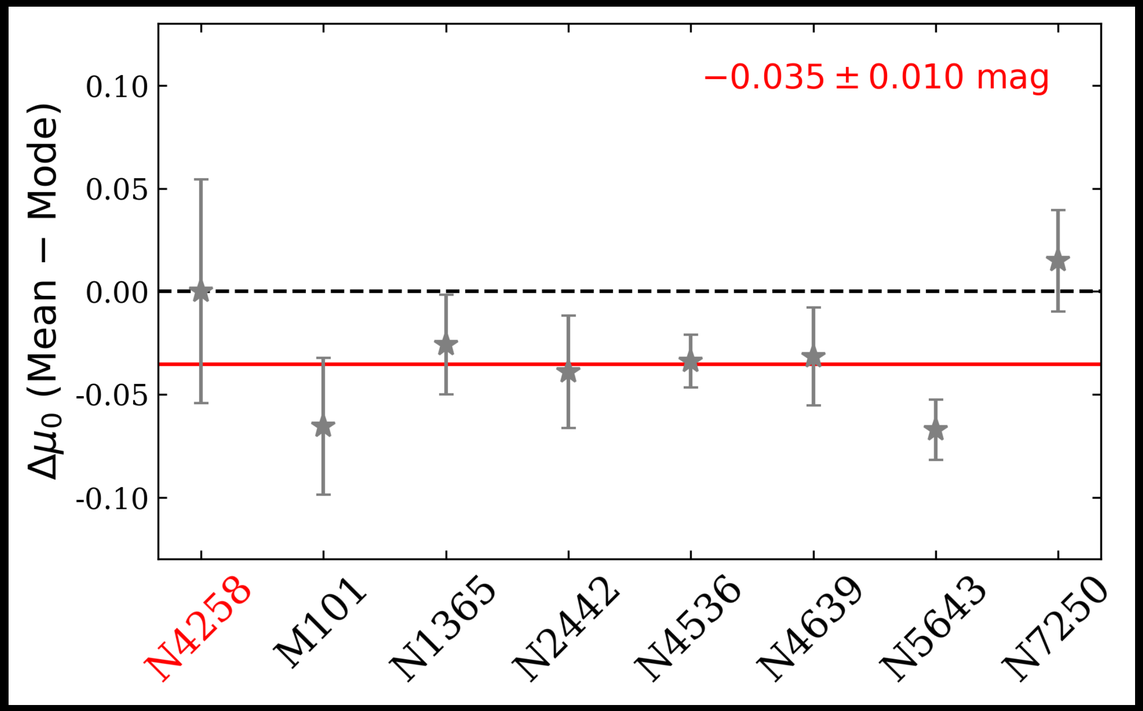
JAGB LF in inner disk exhibits brighter mode and larger dispersion

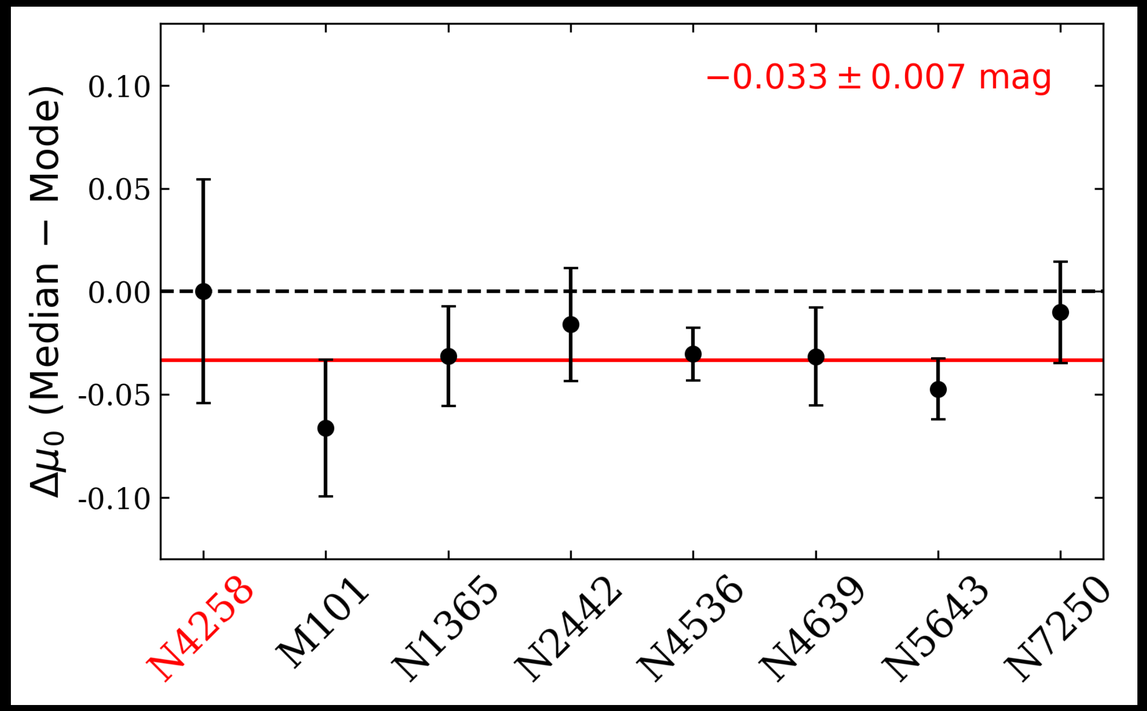
Lee+ 24c (submitted)



Lee+ 24c (submitted)

Mean vs. Median vs. Mode





- Mean/Median systematically predicts ~0.03 mag closer distances than Mode
- We adopted a conservative uncertainty of 0.05 mag that accounts for this (2% uncertainty in distance)
- JAGB method promising— but more work to be done to get 1% H_0!

Lee+ 24c (submitted)

Summary

- The JAGB method is a new standard candle based on carbon-rich AGB stars
- The JAGB method agrees well with the Cepheid Leavitt law and the TRGB in nearby galaxies (d < 4 Mpc)
- The SN Ia JAGB calibration is currently being finalized. JAGB H_0 paper will be posted to the arXiv in the next couple weeks!