AGB stars V

(Why galaxies also care about AGB stars)

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Overview Talk

- The AGB conference series
- AGB stars in high-redshift galaxies
- AGB stars as distance indicators
- Conclusions and Prospects

AGB 1..2..3..4..5

Conference	Stellar Evolution	Nucleosynthesis	CSE/Chemistry/Mass-loss	Pulsation/dust formation/surface	Disc/binarity/[P-AGB]	Resolved stellar populations	Participants
AGB V - 2025	5	8	24	19	25	19	120
AGB IV - 2018/IAUS 243	8	8	15	21	21	28	48T+98P/4d
AGB III - 2014	0	17	23	21	19	19	135
AGB II - 2010	5	23	23	21	5	28	100
AGB I - 2006	5	14	26	16	2	37	130
IAUS 191 - 1998	5	5	24	35	21	11	245

Division over different topics (percentages)

IAUS 191 "Asymptotic Giant Branch Stars", first conference dedicated to AGB

Six people in the audience indicated to have attended all these 6 conferencess

AGB stars and the high-z Universe

Unresolved stellar populations

Understand better:

- Resolved stellar populations
  mass-loss rates, dust production rates
- Low-metallicity nearby analogs (Sextans A, I Zw 18)

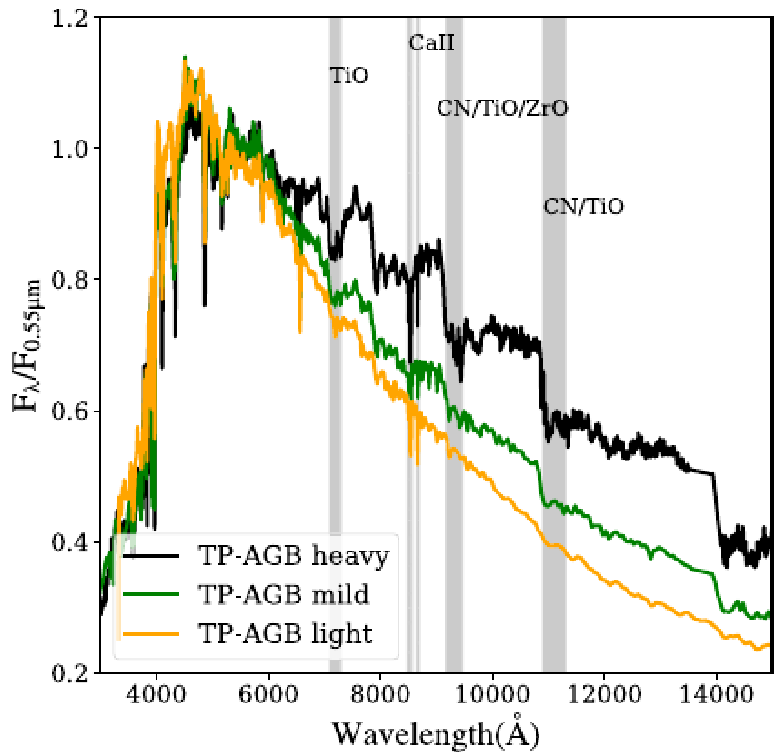
HST, now JWST

(Dell'Agli, Boyer)

AGB stars at high-z: I

Liu & Luo 2023, RAA 23

177 post-starbust galaxies, $z = 0.2 - 0.7$



HST grism spectroscopy ($R \sim 100$)

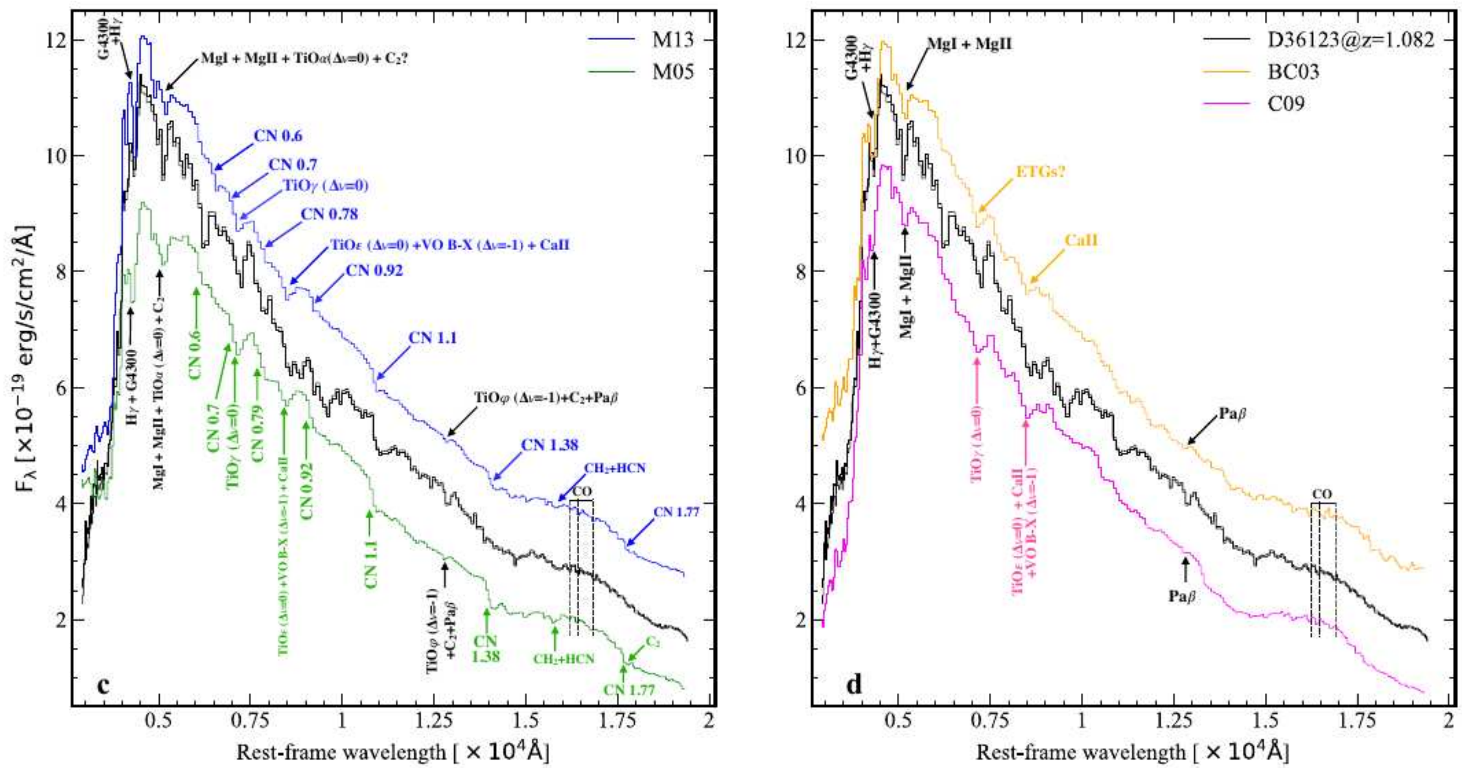
"A majority ($\pm$70%) of galaxies in the sample show features indicative of TP-AGB stars, while ... others ... are well fit by TP-AGB light models."

".. a tentative trend ... more TP-AGB heavy galaxies are observed in the higher redshift PSB galaxy population."

Note: TP-AGB heavy (Maraston 2005), mild (Noël et al. 2013), light (Bruzual & Charlot 2003)

AGB stars at high-z: II

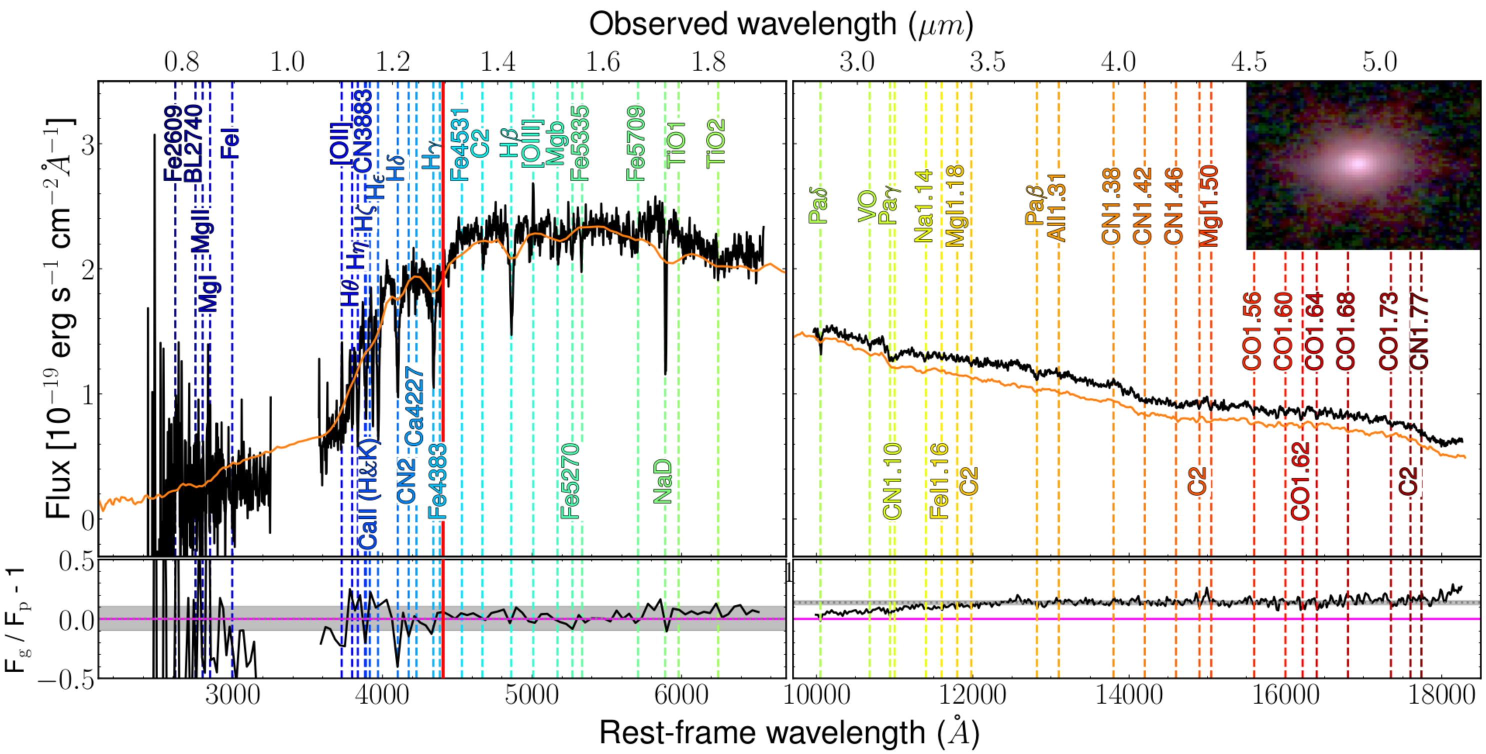
Lu, Daddi, Maraston et al. 2025 Nat. Astr. 9, 28
quiescent galaxy D36123 at $z = 1.082$ (~ 1Gyr, $\sim 10^{10}$M$_{\odot}$)
JWST/NIRSpec



TP-AGB heavy (Maraston 2005), mild (Maraston 2013), light (Conroy+ 2009), poor (Bruzual & Charlot 2003)

AGB stars at high-z: III

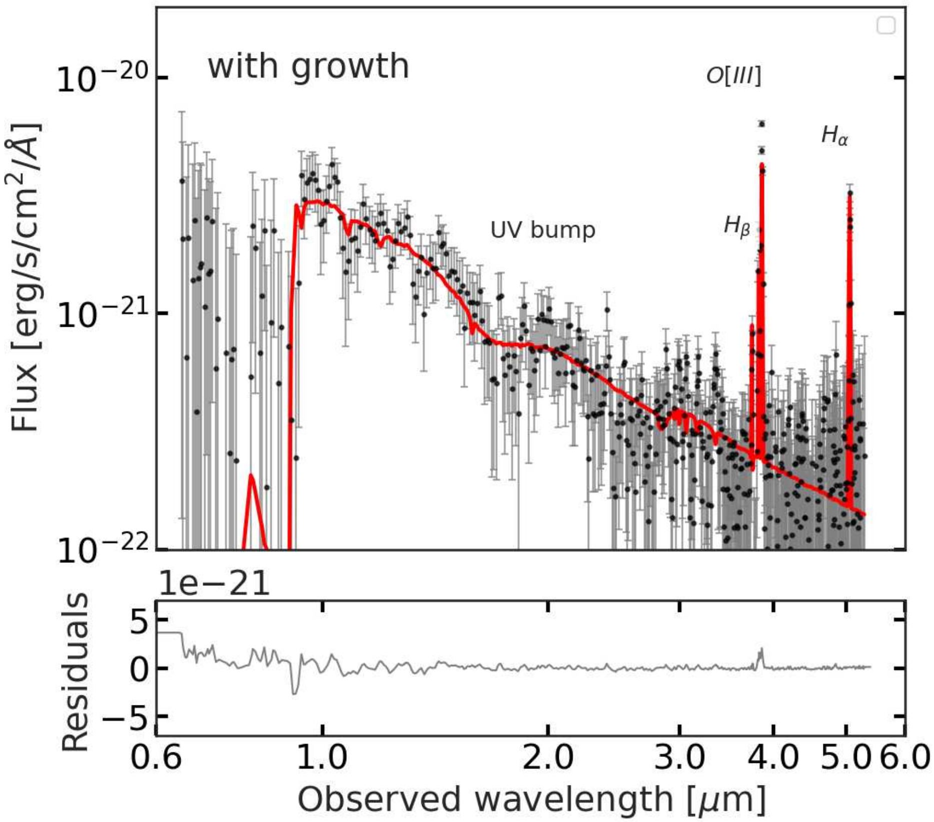
Bevacqua et al. 2025, A&A 699, A203
J-138717, post-starburst galaxy, $z \sim 1.9$ (~ 0.9 Gyr, [M/H] ~ -0.4)



CO and CN absorption lines, tracing TP-AGB stars, "These results imply that the contribution of TP-AGB stars to the spectrum of J-138717 is low, or mild at best."

AGB stars at high-z: IV

Nanni et al. 2025, ApJ 988, L5
JADES-GS-z6-0, $z \sim 6.7$ (800 Myr)
UV bump indicative of a large quantity of hydrocarbon grains.



(1) synthesis in the circumstellar envelopes of AGB stars, (2) shattering of large grains in the ISM.

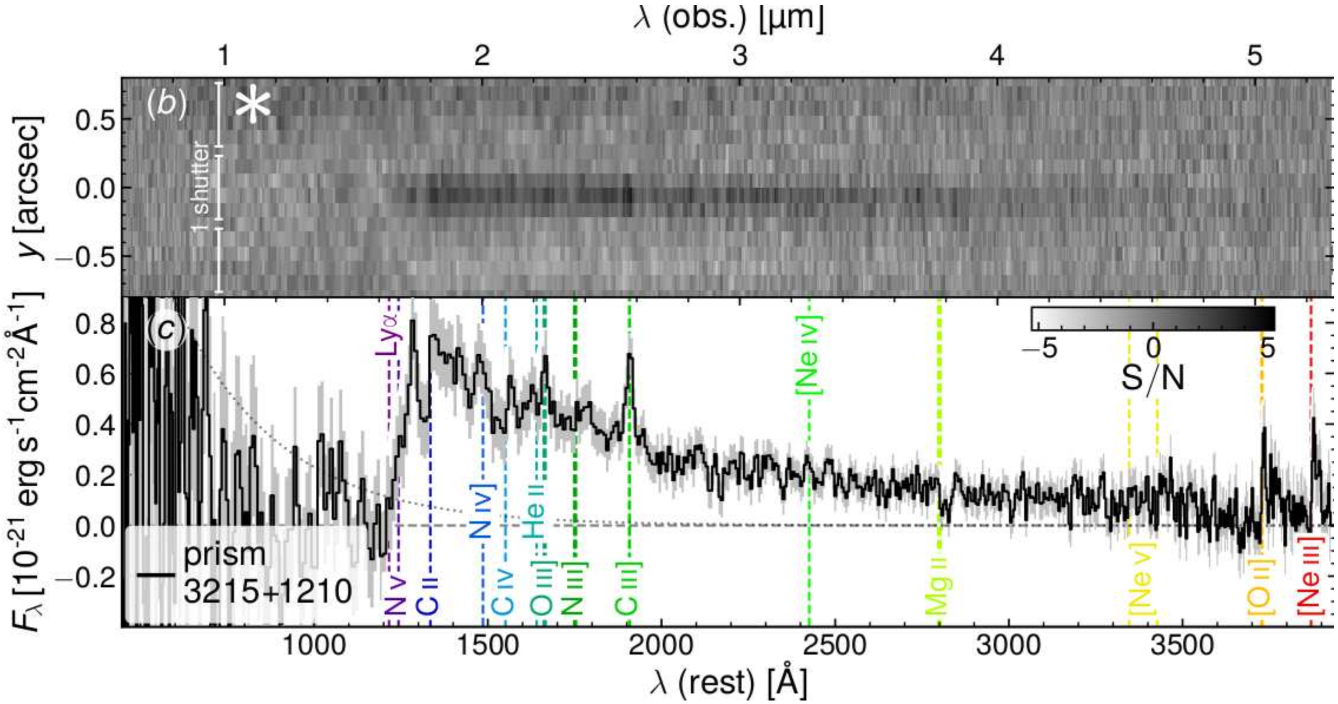
Neither process alone can produce PAH.

Winds of carbon-rich Wolf Rayet stars and/or Type II SNe are likely necessary.

AGB stars at high-z: V

D'Eugenio et al. 2024, A&A 689, A152

GS-z12, $z \sim 12.5$ (~ 350 Myr, [C/O]= 0.06 $\pm$ 0.07 dex)



C iii]$\lambda\lambda$1907,1909. Modelling the emission lines.

"AGB stars can hardly contribute to the carbon enrichment at these early epochs and low Z. Such a high C/O ... may thus be explained by the yields of extremely metal-poor stars, and may even be the heritage of the first generation of SNe from Pop. III progenitors."

AGB stars and the high-z Universe: Conclusion

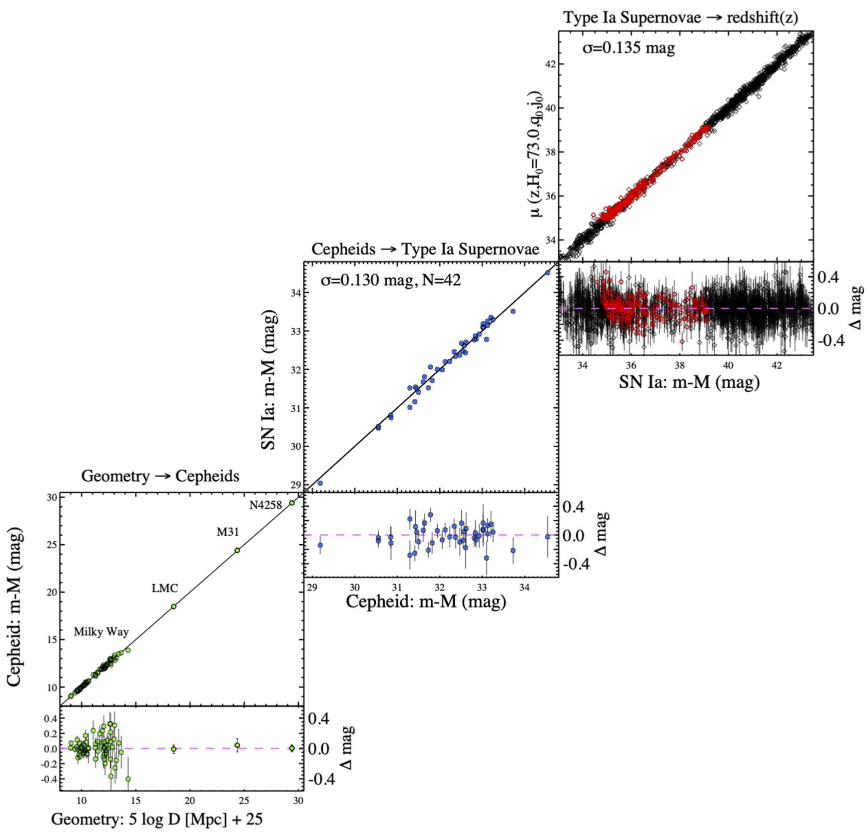
- AGB contribution seems to decline with higher redshifts.
- Carbon is present and enriched.
- Up to $z \sim 2$ AGB contribution is clearly visible; Interpretation in terms of 'poor', 'light', 'middle', 'strong' remains qualitative and uncertain.
- All these models are rather old. Cant we improve ??

AGB stars and the distance scale

H_0 tension

classical path: Cepheid - SNIa

CMB: 67.4 ± 0.5 73.2 ± 0.9 km/s (Breuval et al. 2024)



Riess et al. (2022)

AGB stars and the distance scale

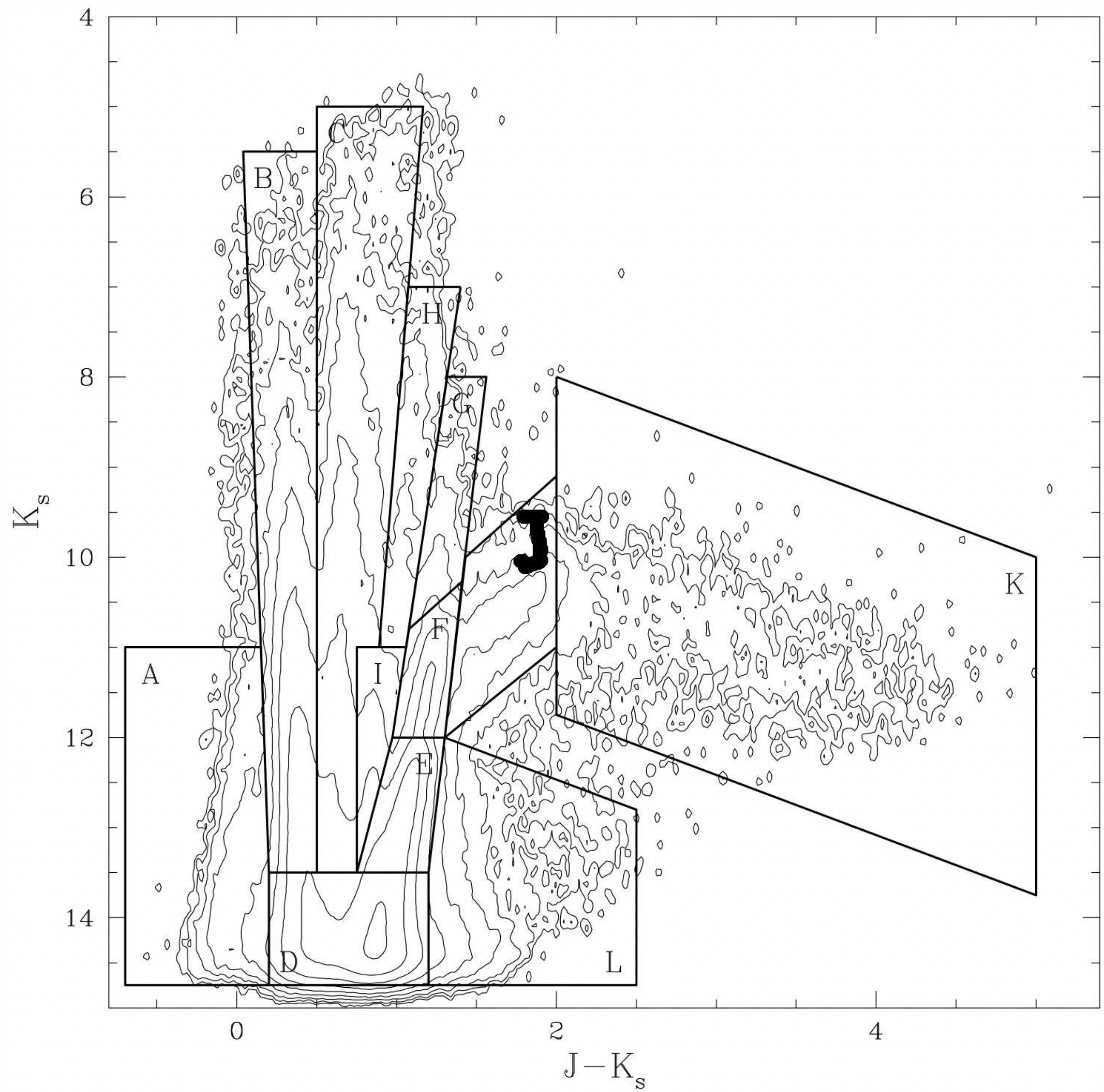
Four anchors:
MW (*Gaia* parallaxes),
SMC, LMC (dEBs),
NGC 4258 (megamaser)

Alternatives: RR Lyrae, Type-II Cepheids, TRGB (Tip of the RGB), SBF (Surface Brightness Fluctuations), TFR (Tully Fisher Relation)

Cross-checks:

- JAGB method
- Mira PL-relation

JAGB - history



2MASS CMD LMC

Nikolaev & Weinberg (2000)

(region J contains mainly C-stars.

JAGB stars NOT TO BE CONFUSED with

J-type AGB stars !)

History

N&W (2000), W&N (2001)

Based on 14 C-Miras with $1.4 < (J - K_\mathrm{s}) < 1.9$ in region J:

$$K_\mathrm{s} = -(0.99 \pm 0.80)\,(J - K_\mathrm{s}) + (12.36 \pm 1.33)$$

From this it actually follows that

$$K_\mathrm{s} + 0.99\,(J - K_\mathrm{s}) \approx J = 12.36$$

with DM of 18.5 one finds that $M_\mathrm{J} \approx -6.14$ mag

Astrophysical Journal, 899:66 (7pp), 2020 August 10 https://doi.org/10.3847/1538-4357/aba(

Astrophysical Distance Scale: The AGB *J*-band Method. I. Calibration and a First Application

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Abstract

A near-infrared, color-selected subset of carbon-rich asymptotic giant branch (C-AGB) stars is found to have tightly constrained luminosities in the near-infrared *J* band. Based on *JK* photometry of some 3300 C-AGB stars in the bar of the Large Magellanic Cloud (LMC) we find that these stars have a constant absolute magnitude of $\langle M_J \rangle = -6.22$ mag, adopting the detached eclipsing binary (DEB) distance to the LMC of 18.477 ± 0.004

History - Methodology

Reference	Gal.	$(J-K)_0$	$(M_\mathrm{J})_0$	method
Madore & Freedman (2020)	LMC	1.3- 2.0	-6.22 $\pm$ 0.04	mean
	SMC	1.3- 2.0	-6.18 $\pm$ 0.05	mean
Freedman & Madore (2020)	MCs	1.3- 2.0	-6.20 $\pm$ 0.04	mean; applied to 14 galaxies
Lee et al. (2022)	MW	1.4-2.0	-6.14 $\pm$ 0.12	mean; 2 catalogs of C-stars
Madore et al. (2022)	MW/OC	(1.2-2.0)	-6.40 $\pm$ 0.40	mean, 17 stars
			-6.20 $\pm$ 0.02	average of MCs & MW
Ripoche et al. (2020)	LMC	1.4-2.0	-6.284 $\pm$ 0.004	median
	SMC	1.4-2.0	-6.16 $\pm$ 0.02	median
	MW	1.4-2.0	-5.60 $\pm$ 0.03	median
Zgirski et al. (2021)	LMC	1.3- 2.0	-6.21 $\pm$ 0.01	Gaussian
	SMC	1.3- 2.0	-6.20 $\pm$ 0.01	Gaussian
Parada et al. (2023)	LMC	1.4-2.0	-6.33 $\pm$ 0.01	Lorentzian, $s=-0.47$
	SMC	1.4-2.0	-6.18 $\pm$ 0.01	Lorentzian, $s=+0.02$
Magnus et al. (2024)	LMC	1.5-2.0	-6.252 $\pm$ 0.004	weighted mean
	SMC	1.5-2.0	-6.199 $\pm$ 0.013	weighted mean
	MW	1.5-2.0	-5.90 $\pm$ 0.02	weighted mean
	LMC	1.5-2.0	-6.310 $\pm$ 0.007	Lorentzian, $s=-0.42$
	SMC	1.5-2.0	-6.173 $\pm$ 0.019	Lorentzian, $s=+0.04$
	MW	1.5-2.0	-5.83 $\pm$ 0.09	Lorentzian, $s=0$ FIXED

- mean, median, functional form, ...
- Blue limit of the $(J-K)$ selection box
- Milky Way

Magnus et al. - Data

1) Lebzelter+ 2022 LPV catalogue (1.7M objects). Contains an C-star classifier based on *Gaia* Bp/Rp-spectra

2) Correlate with 2MASS, only retaining objects with 'AAA' [difference with Lee et al. 2022]

3a) SMC, LMC selected according to positional and proper motion cuts (4900, 39000 sources)
Distances from dEB (Pietrzynski+2013, Graczyk+2020)
Reddening Skowron+2021 maps
3b) MW
$R_{\rm plx} \equiv (\pi + 0.1)/\sigma_\pi >= 5$ (258 000 sources all-sky)
Actual distance from Bailer-Jones+2021
Sources in MCs, Sgr dSph, M31, M33 are removed.
Reddening from STILISM-maps (Lallement+ 2018)

Magnus et al. - Quantities

1) select range in $J-K$
2) select range in J
3) other selection in the data (photometric errors, *Gaia* parameters, MW: $E(B-V)$, parallax)

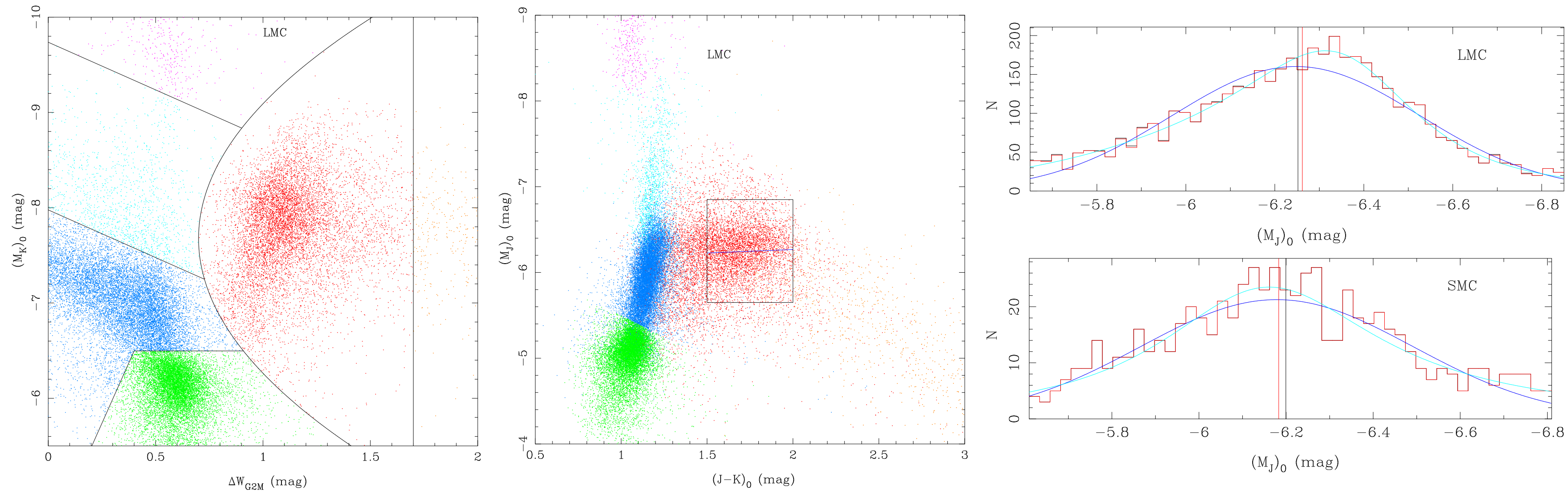
4) mean, median, $J(@(J-K)=1.6)$, peak of the distribution

$$G = \frac{N}{\sqrt{2\,\pi}\,\sigma}\exp\left(-\frac{1}{2}\left(\frac{x-\mu}{\sigma}\right)^2\right) + \\ +b + c\,(x-x_0) + d\,(x-x_0)^2$$

$$L = \frac{N}{1+\left(\frac{x-\mu}{w}\right)^2 + s\,\left(\frac{x-\mu}{w}\right)^3 + k\,\left(\frac{x-\mu}{w}\right)^4} + \\ +b + c\,(x-x_0) + d\,(x-x_0)^2$$

Magnus et al. - Results MCs

In short: as previous results ....



$$\Delta W_{\rm G2M} = W_{\rm Bp,Rp} - W_{\rm K,J-K_s}$$

$$W_{\rm Bp,Rp} = Rp - 1.3 \cdot (Bp - Rp), W_{\rm K,J-K_s} = K_{\rm s} - 0.686 \cdot (J - K_{\rm s})$$

mean, peak of the Gaussian distribution/mode, $J(@(J-K) = 1.6)$ agree within 0.03 mag between SMC and LMC.

LFs are not the same, as evidenced by the Lorentzian distribution (and the median)

Magnus et al. - Results MW

In short: problematic ...

$1.2 < J - K < 2.0$ M-star contam. 13% (SMC), 34% (LMC)
$1.5 < J - K < 2.0$ M-star contam. 4% (SMC), 1% (LMC)
MW: M-star contamination below 10% only for
$1.5 < J - K < 2.0$ mag.

Issues:

- Closest-by AGB stars (with best parallaxes) saturate in 2MASS
- 3D reddening maps
- parallax zero-point offset - BJ2021 (prior?)

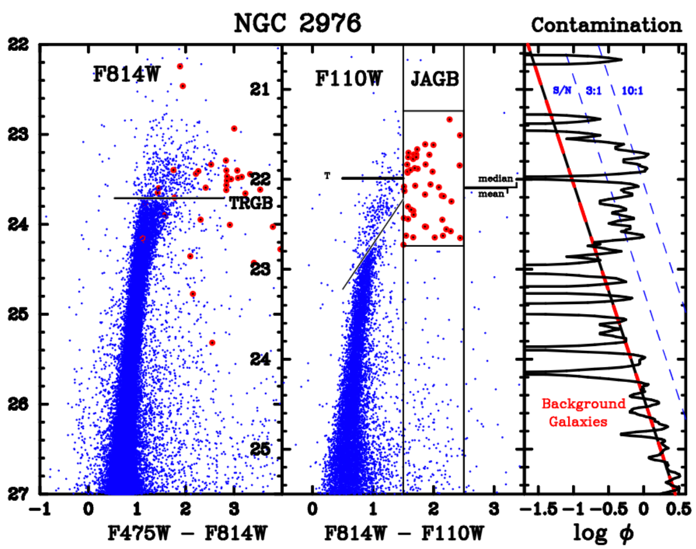
In the end, MW LF is based on 126 stars only

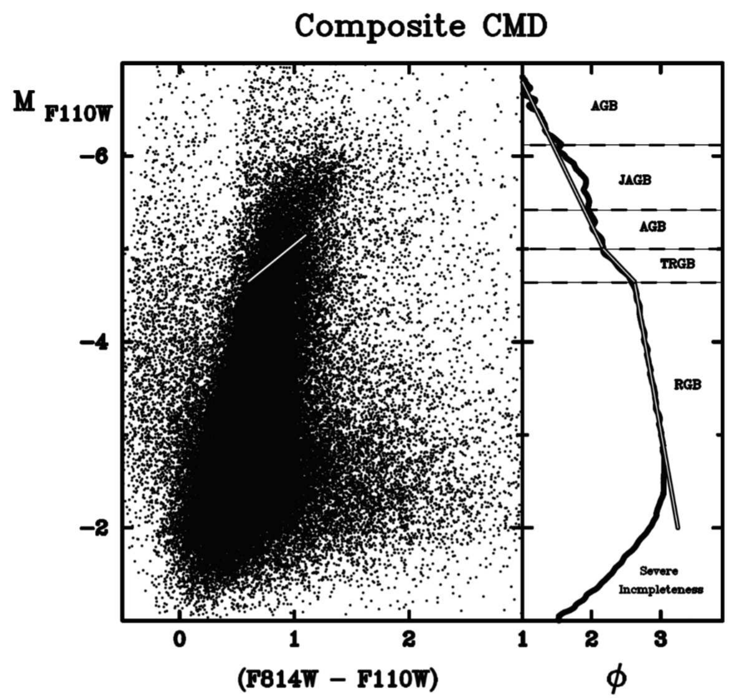
JAGB and HST/JWST

HST and JWST have no classical J-band filter

Madore, Freedman & Lee 2022

F110W, 20 galaxies with TRGB distances





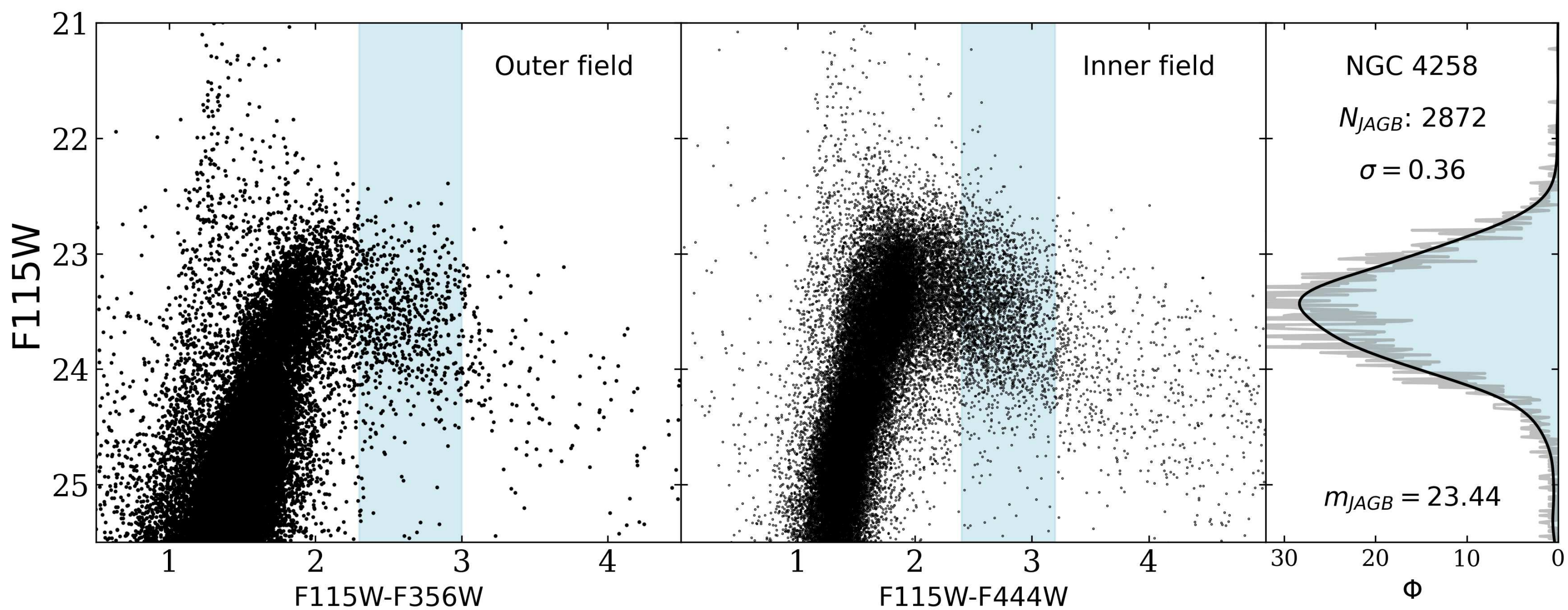
453 JAGB stars
mode $M_{\rm F110W} = -5.77 \pm 0.02$ mag (no LF is shown, metallicies not discussed)

JAGB and the JWST

Lee, Freedman, Madore et al. 2025

F115W (F356W or F444W)

7 SNIa host galaxies, tied to NGC 4258



$M_{\rm F115W} = -5.98 \pm 0.05 \pm 0.04$ mag

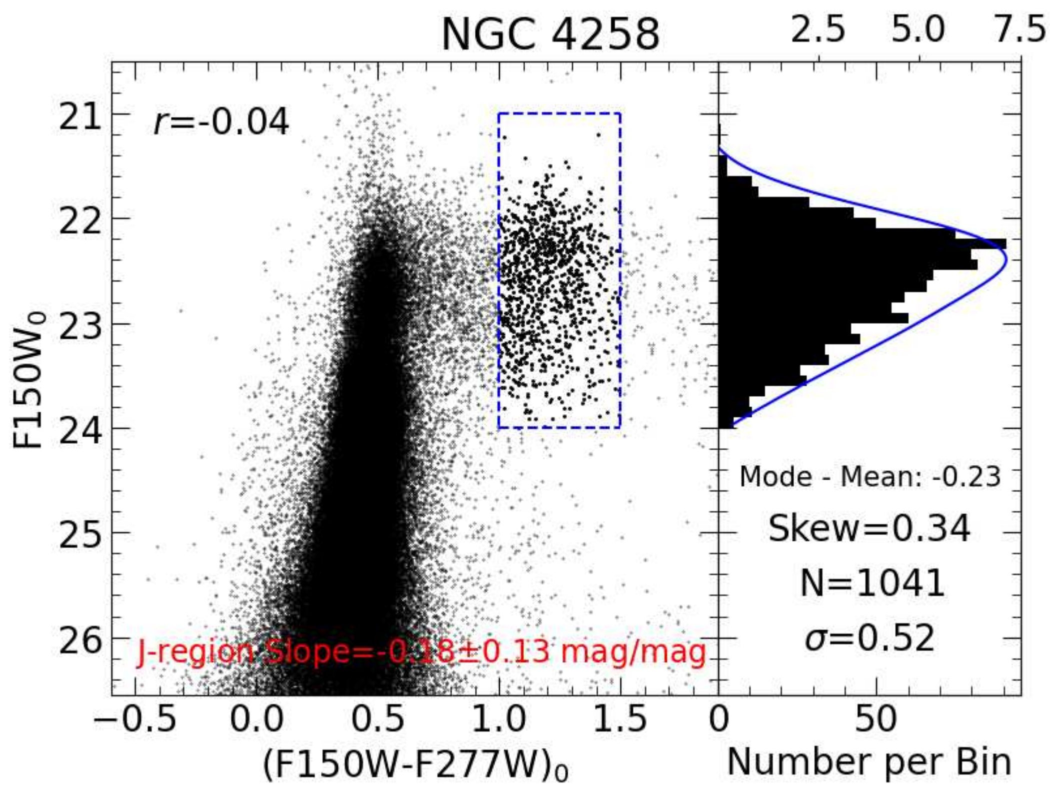
$H_0 = 67.80 \pm 2.17 \pm 1.64$ km/s/Mpc

JAGB and the JWST

Li, Riess, Scolnic et al. 2025

F150W (F2776W or F444W)

6 SNIa host galaxies, tied to NGC 4258



$M_{\rm F150W} \sim -6.9 \pm 0.1$ mag

$H_0 \;=\; 73.3 \pm 1.4 \pm 2.0$ km/s/Mpc

JAGB: Conclusions

- Methodology and understanding needs more work !

  Theoretical predictions

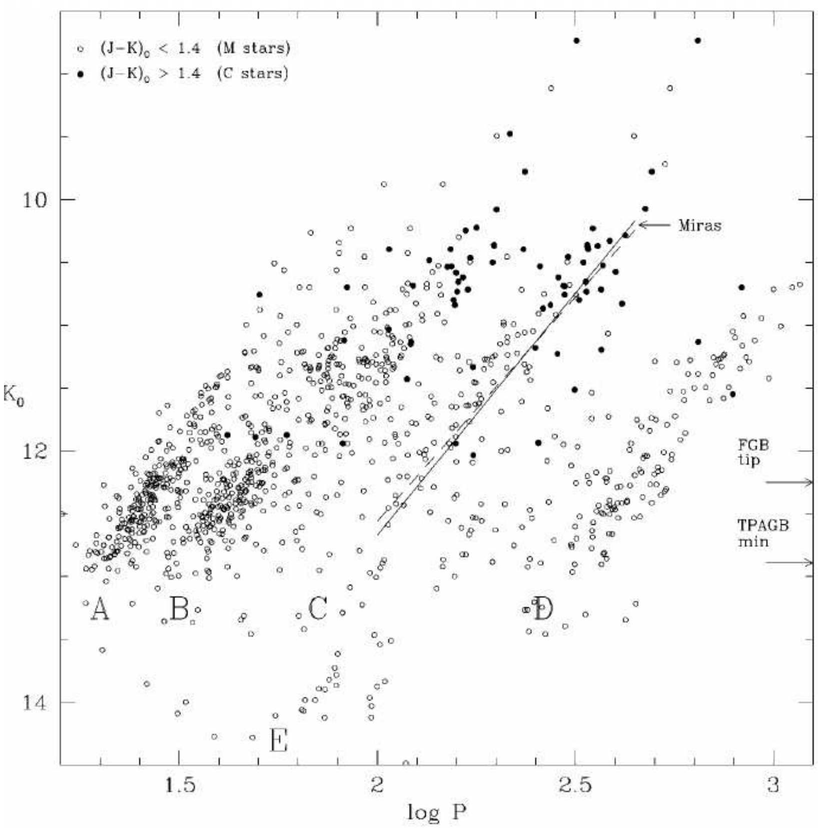
- SMC and LMC LF are not symmetric
- LF MW is uncertain
  (saturation, incompleteness, *Gaia* parallaxes)

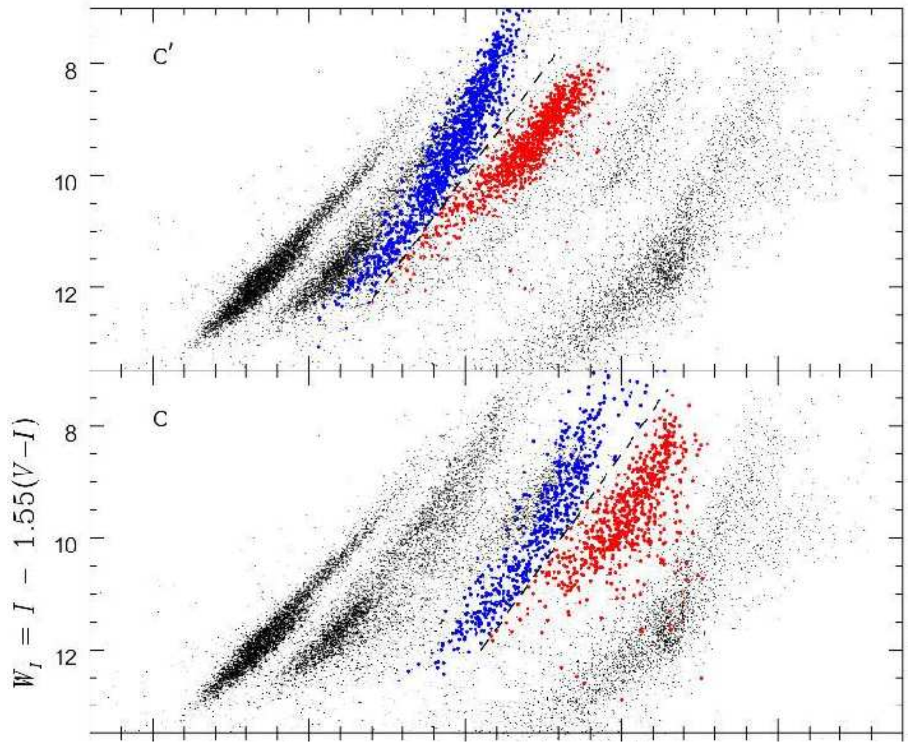
  REMEDY: Use small telescope to observe a few hundred well-selected AGB stars in JK

- JWST calibration has potential, but can not be based on 4 standard anchors and will be in another filter

Mira PL-relation

Long history: Glass, Lloyd-Evans, Feast, Whitelock





MACHO: Wood (1990) OGLE: Soszynski (2005)

(Trabucchi, Abdollahi)

Miras and the Distance Scale

C. Huang
"The Hubble Constant Tension" (Springer 2024)
(many chapters are on the ArXiv)

Anchors: LMC, NGC 4258
SNIa hosts: M101, NGC 1559

LMC:
OGLE-III sample of O-rich Miras, 2MASS J, H, K
Transform F160W = $H + 0.39(J - H)$
$M_{\mathrm{F160W}} = (-6.27 \pm 0.03) - 3.35 \cdot (\log P - 2.3)$

adopt LMC slope

O-rich Miras
(minimize C-rich Miras, minimize effect of dust)

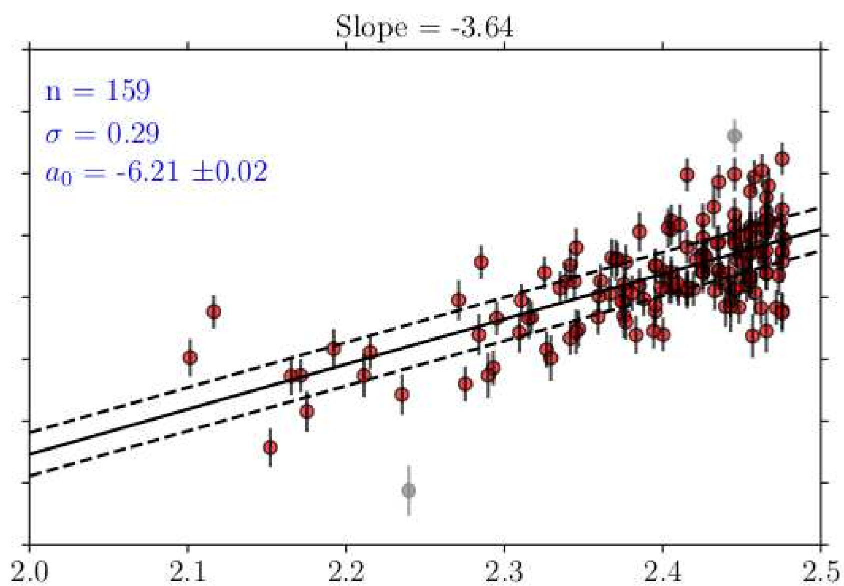
Miras and the Distance Scale

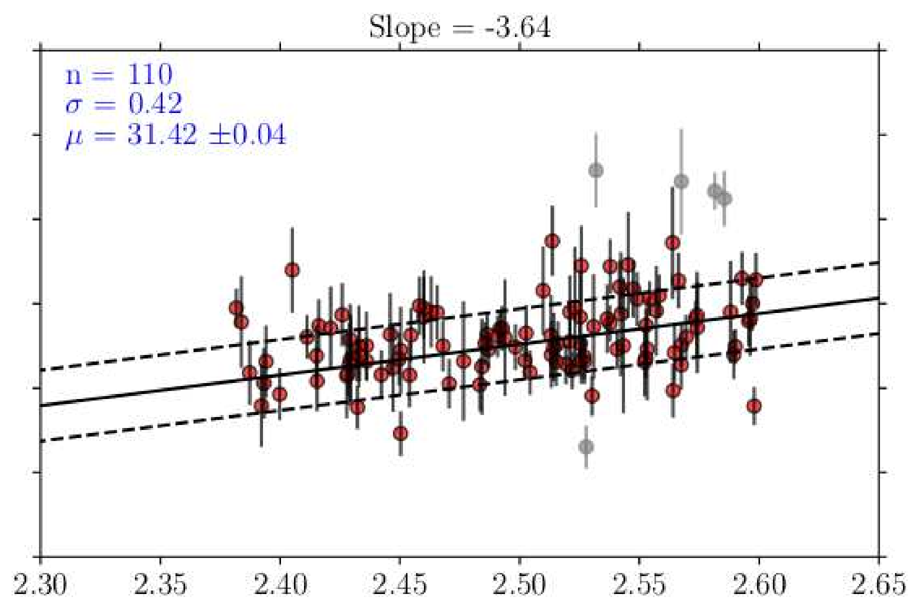
	Period Cut	Amplitude cut	Colour cut
LMC	$P < 400$ d	$0.4 < \Delta H < 0.8$	
M 101	200 d $< P <$ 500 d	$0.4 < \Delta F160W < 0.8$ mag	$m_{F110W} - m_{F160W} < 1.3$
NGC 1559	240 d $< P <$ 400 d	$0.4 < \Delta F160W < 0.8$ mag	
NGC 4258 (gold)	$P < 300$ d	$0.4 < \Delta F160W < 0.8$ mag	$m_{F125W} - m_{F160W} < 1.3$

N 1559: 10 epochs, baseline ∼1 yr, 115 Miras

N 4258: 12 epochs, baseline ∼1 yr, 139 Miras

M 101: 13 epochs, baseline 2900 d, 211 Miras





($H_0 = 72.37 \pm 2.97$ km/s/Mpc)

Conclusions and Prospects

- JWST is a game changer
  (many ongoing studies and accepted proposals)
- high-z. Carbon-rich dust is present. Origin ?
  Role of AGB stars at intermedeate redshifts?
  Improve models.
- JAGB. Potentially powerfull.
  Methodology and theoretical understanding need more work.
- Mira. Equally interesting, but always requires multi-epoch data.

THE END