

Araucaria PROJECT

Weronika Narloch
on behalf of the Araucaria members

18-20 March 2026, The Young Astronomers Meeting, Warsaw 2026

The Araucaria Project: Over 25 years of history...

Gieren et al. (2001, Msngr, 106, 15):

“There are, however, still a number of important systematic uncertainties affecting both Cepheid variables and other secondary methods of distance measurement which have so far prevented a truly accurate calibration of the extragalactic distance scale.”

“The astrophysical consequence of such limitation include a larger uncertainty on the Hubble constant than we hope for (...).”

“The currently weakest link in the whole process of setting up the distance scale is our limited capability to measure truly accurate distances to nearby galaxies which provide the zero point calibration for the extragalactic distance scale. Our difficulties (...) are best reflected by the current dispersion of the distance values derived for the LMC (...).”

“As an added benefit, we will significantly improve our knowledge of many astrophysical properties of the object classes used for distance determination.”



credit: W. Gieren

The Araucaria Group:

2013



The Araucaria Group:

2013



2017



The Araucaria Group:

2013



2017

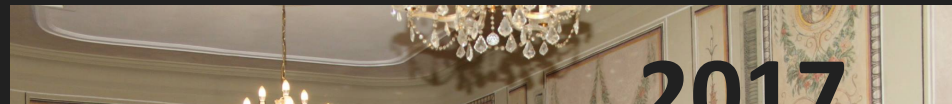


The Araucaria Group:

2013



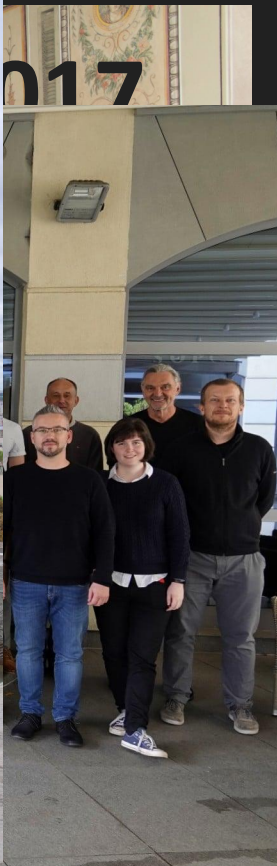
2017



2021



The Araucaria Group:



The Araucaria Project:

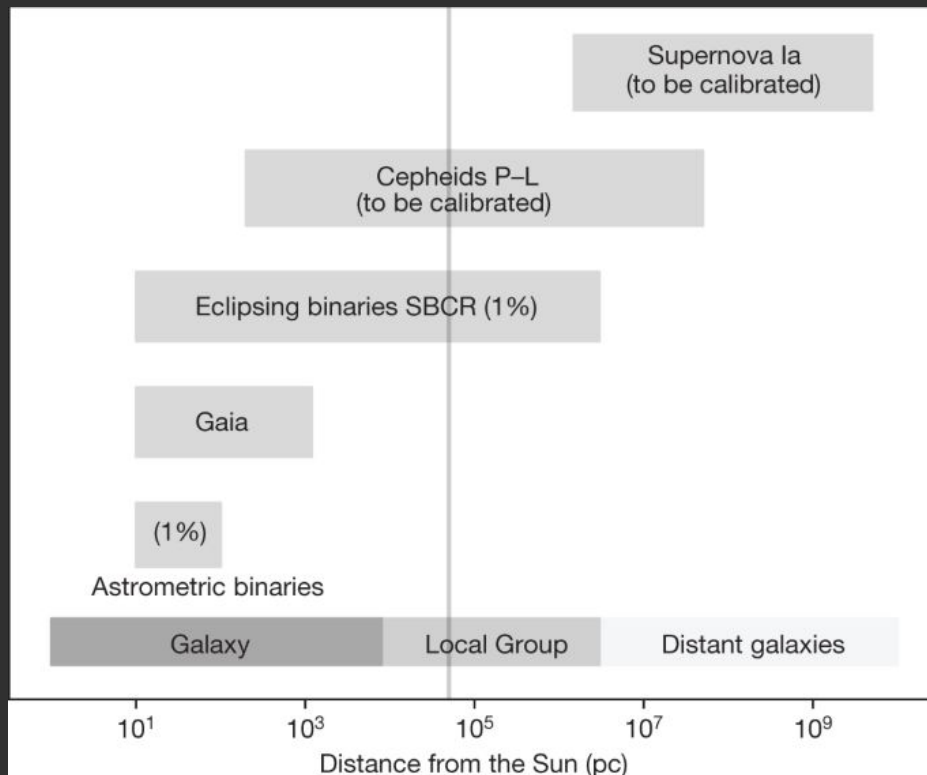
The main goal of the Araucaria Project is to improve the calibration of the cosmic distance scale in the local Universe. We trace down environmental dependencies on the brightness of various standard candles by comparing distances to their host galaxies and clusters, obtained with different methods. We also seek to reduce systematic uncertainties in the extragalactic distance scale.



The Araucaria Project:

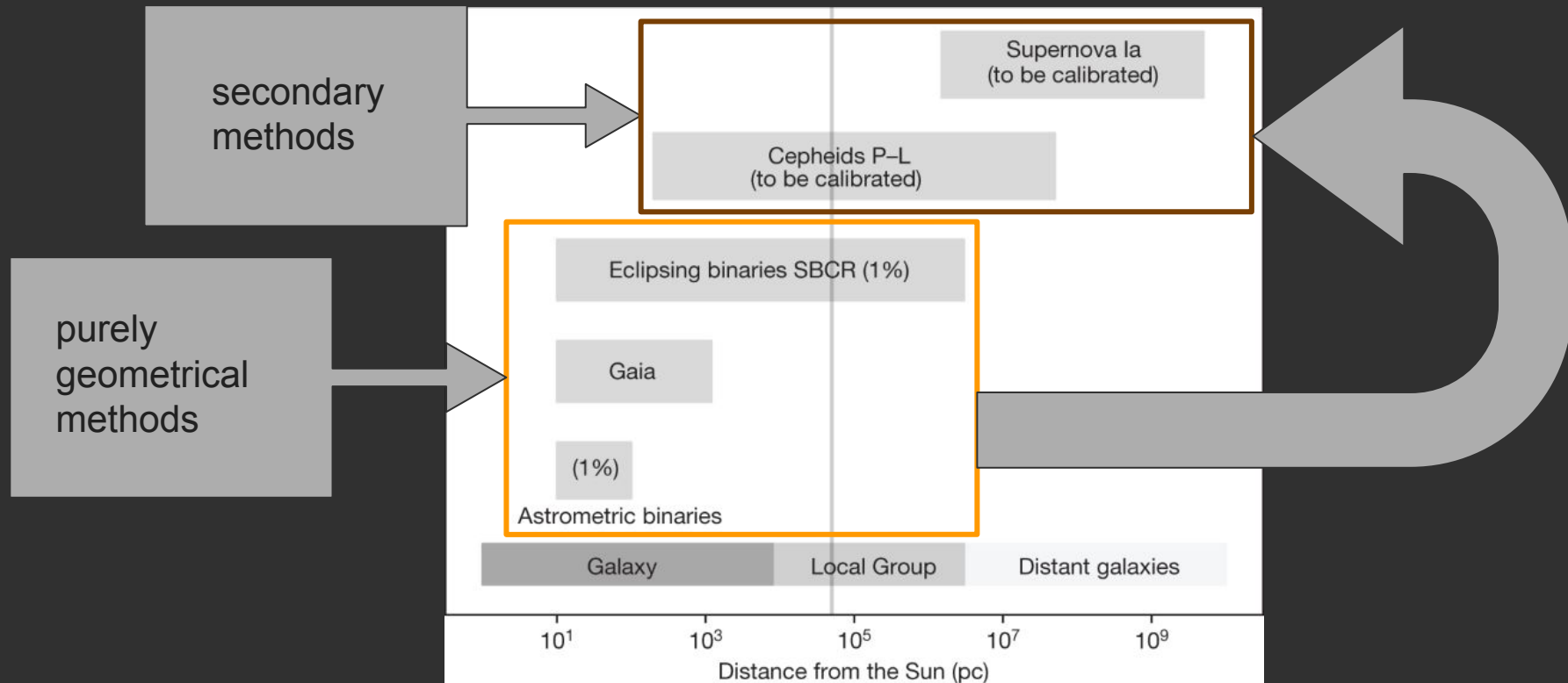
Measuring distances in the universe

Pietrzyński et al. (2019), Fig. 3

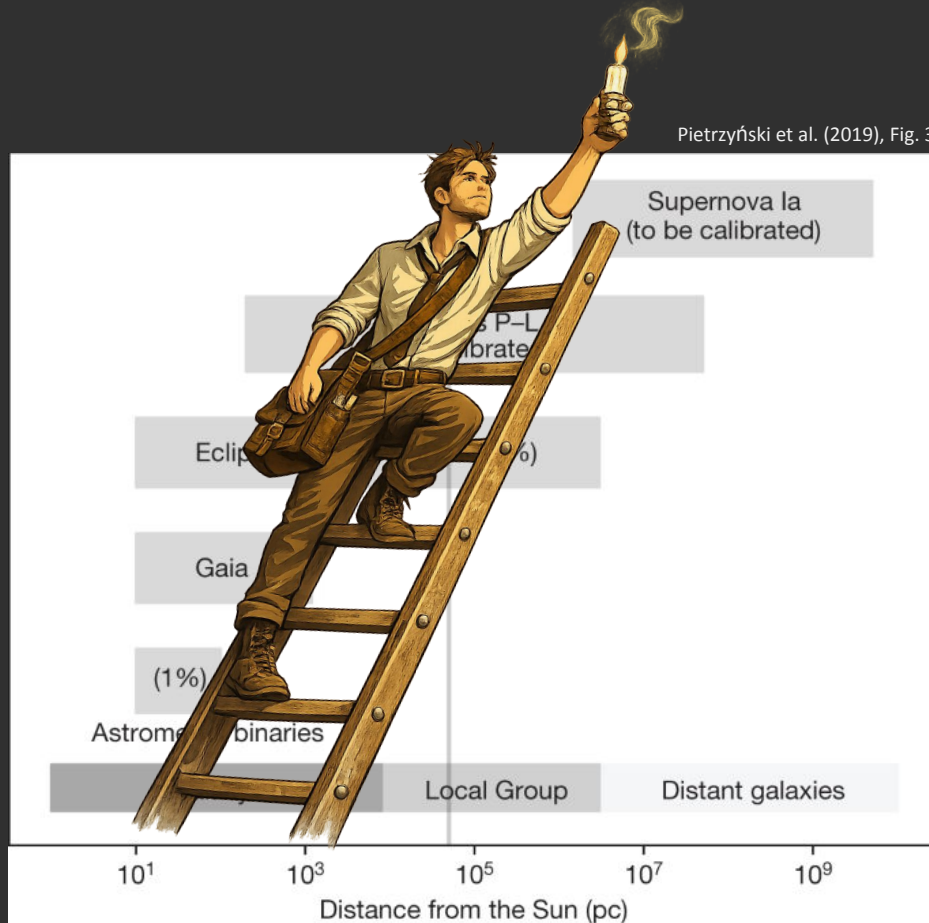


The Araucaria Project: Measuring distances in the universe

Pietrzyński et al. (2019), Fig. 3



Cosmic distance ladder:



Cosmic distance ladder:

H_0

- eclipsing binaries (surface brightness - color relation),
- Baade-Wesselink method.

- period - luminosity relations (PLR) for pulsating stars,
- tip of the red giant branch (TRGB),
- J-AGB stars.

Eclipsing binaries:

Surface brightness - color relation (SBCR)

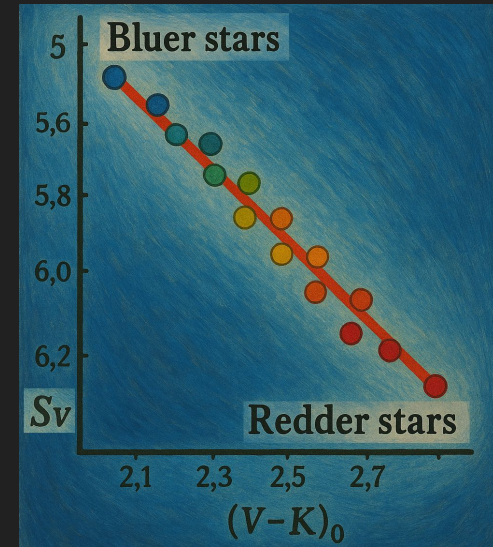
Surface brightness - color relation (SBCR) - a simple relation being a powerful tool for predicting the **angular diameters** of stars. It describes how surface brightness (brightness per unit area) of a star changes with color.

Surface brightness:

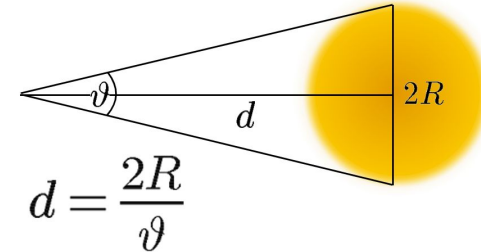
$$S_V = V_0 + 5 \log \theta$$

where V_0 is the V band magnitude corrected for the reddening and θ is the stellar angular diameter.

When the **distance** (or the trigonometric parallax) to a particular star is known, application of an SBCR immediately gives its **radius**. When the **radius** of a star is known, an application of SBCR gives a robust **distance**.



credit: chatGPT

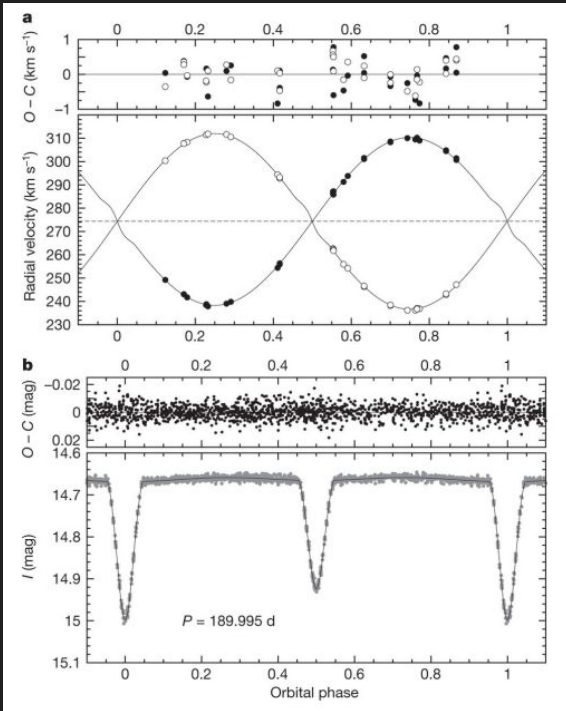


$$d = \frac{2R}{\theta}$$

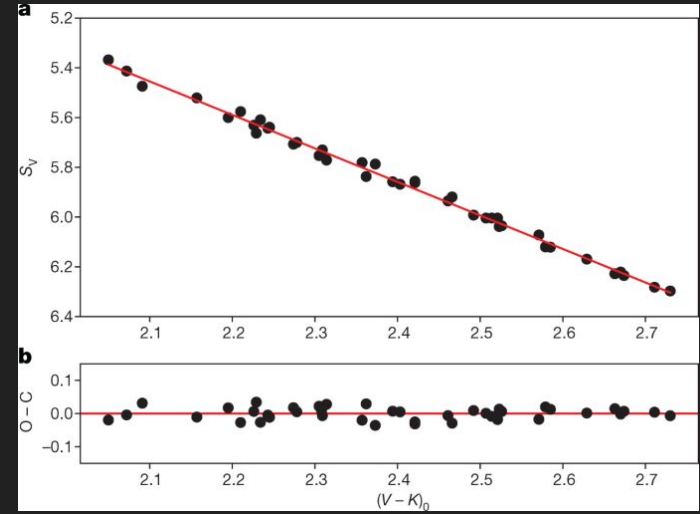
$$d[\text{pc}] = 9.2984 \times \frac{R[R_{\odot}]}{\theta[\text{mas}]}$$

Eclipsing binaries: Surface brightness - color relation (SBCR)

$$S_V = V_0 + 5 \log \theta$$



Pietrzyński et al. 2013 (Nature 495, 76)



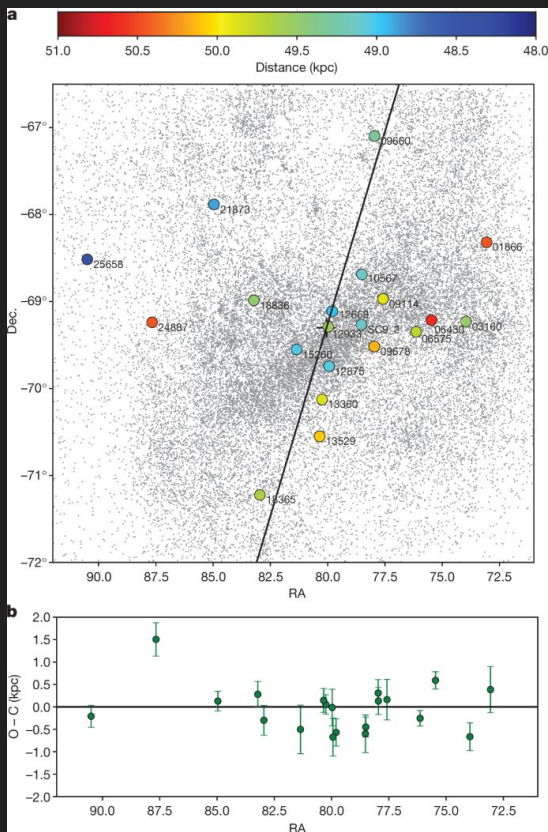
Pietrzyński et al. 2019 (Nature 567, 200), Fig. 1

The following relation was obtained from a least-squares fit:

$$S_V = (1.330 \pm 0.017) \times [(V-K)_0 - 2.405] + (5.869 \pm 0.003) \text{ mag}$$

Eclipsing binaries: Surface brightness - color relation (SBCR)

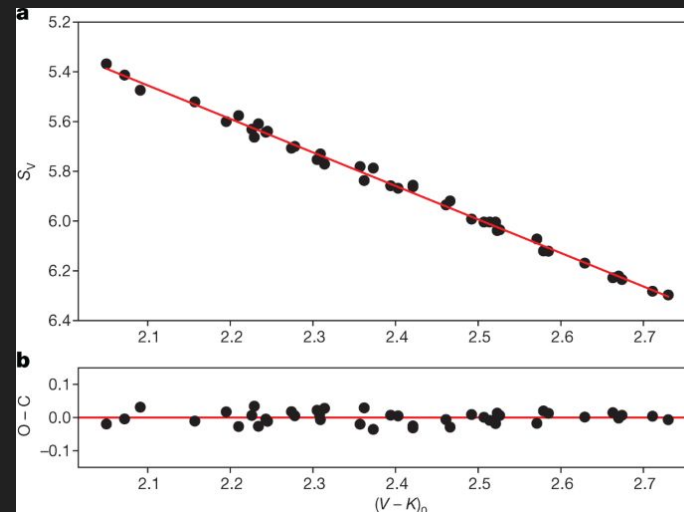
$$S_V = V_0 + 5 \log \theta$$



Distance:

$$d = 9.2984 \times R (R_{\odot}) / \theta \text{ (mas)},$$

$$\text{where } \theta = 10^{0.2(S_V - V_0)}$$



Pietrzyński et al. (2019), Fig. 1

Final distance:

49.59 ± 0.09 (statistical) ± 0.54 (systematic) kiloparsecs

18.477 ± 0.004 (statistical) ± 0.026 (systematic) mag

Pietrzyński et al. (2019), Fig. 2

Eclipsing binaries:

Surface brightness - color relation (SBCR)



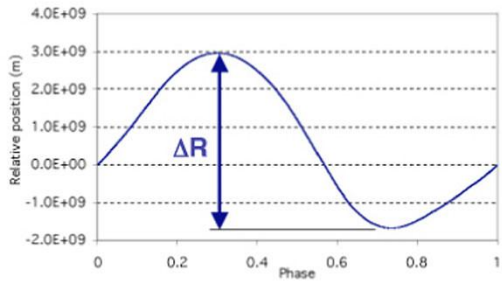
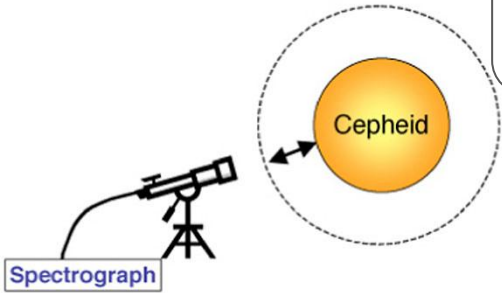
1% accuracy!!!

3 4 5 6 7 8 9 10 1 2 3 4 5 6 7 8 9 10 1 2 3 4 5 6



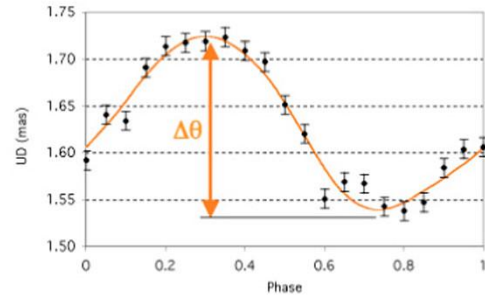
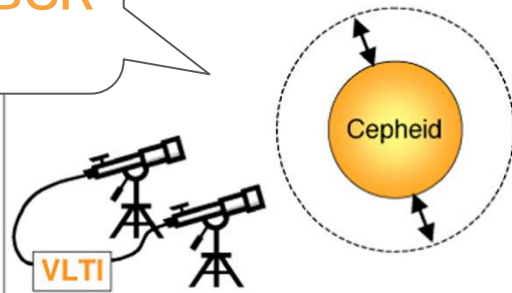
Baade - Wesselink method (BWM):

Integrated radial velocity
spectroscopy



SBCR

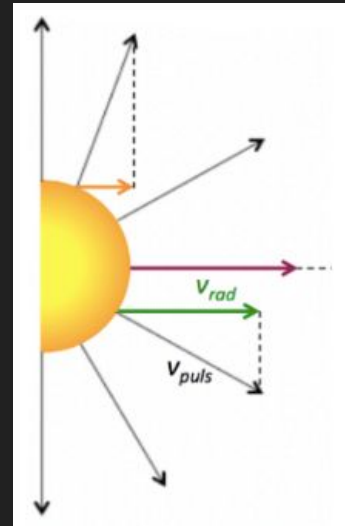
Angular diameter
interferometry



$$d \text{ [pc]} = 9.305 \Delta R \text{ [R}_{\odot}] / \Delta \theta \text{ [mas]}$$

Credit: ESO

Distance determination method for stellar objects, for which the photosphere can be approximated as a spherically moving (expanding) shell.



$$p = \frac{v_{\text{puls}}}{v_{\text{rad}}}$$

$$\Delta R = \int p v_{\text{rad}}(t) dt$$

Baade - Wesselink method (BWM):

A&A 597, A73 (2017)
DOI: 10.1051/0004-6361/201629400
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Astronomy
&
Astrophysics

HARPS-N high spectral resolution observations of Cepheids I. The Baade-Wesselink projection factor of δ Cep revisited*

N. Nardetto¹, E. Poretti², M. Rainer², A. Fokin³, P. Mathias^{4,5}, R. I. Anderson⁶, A. Gallenne^{7,8}, W. Gieren^{8,9},
D. Graczyk^{8,9,10}, P. Kervella^{11,12}, A. Mérand⁷, D. Mourard¹, H. Neilson¹³, G. Pietrzyński¹⁰,
B. Pilecki¹⁰, and J. Storm¹⁴

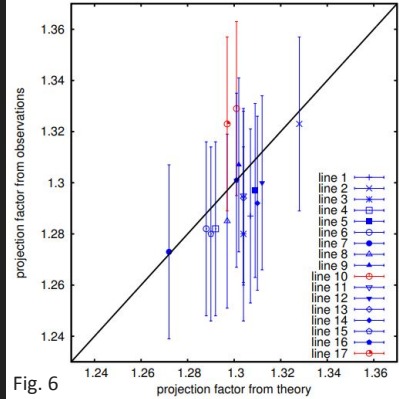


Fig. 6

A&A, 689, A241 (2024)
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Astronomy
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Astrophysics

Projection factor and radii of Type II Cepheids BL Her stars

P. Wielgórski^{1,*}, G. Pietrzyński^{1,2}, W. Gieren², B. Zgierski², M. Górski¹, J. Storm³, N. Nardetto⁴,
P. Kervella⁵, G. Bras⁶, G. Hajdu¹, V. Hodeč⁶, B. Pilecki¹, W. Narloch¹, P. Karczmarek², W. Pych¹,
R. Chini^{1,6,7}, and K. Hodapp⁸

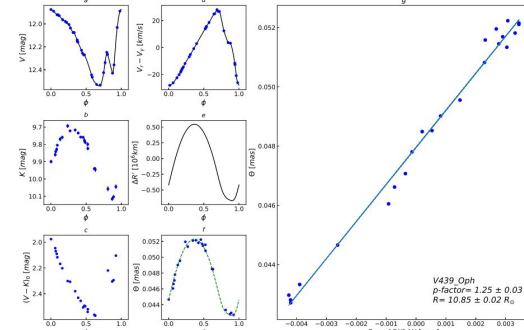


Fig. 3. Baade-Wesselink analysis of V439 Oph. Panels a, b, and d show our V , K , and radial velocity measurements, respectively. Panel e shows the unreddened colour index curve. Black lines in these plots are Akima splines fitted to the measurements. Panel e shows the integrated radial velocity curve. Panel f shows the angular diameter measured using the K04b SBRC. The green line in this panel is the curve from panel e, rescaled using equation 4 and measured values of the p -factor and the mean radius. Panel g shows the relation between angular diameters from panel f and corresponding values of the integrated radial velocity from panel e, rescaled using equation (4). The slope of this relation is the p -factor, and the zero point is the mean angular diameter used to calculate the mean radius of the star.

A&A, 706, A268 (2026)
https://doi.org/10.1051/0004-6361/202556144
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Astronomy
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Astrophysics

Distance to the globular cluster M 3 from the infrared surface brightness technique applied to RR Lyrae stars

Bartłomiej Zgierski^{1,*}, Wolfgang Gieren¹, Grzegorz Pietrzyński², Gergely Hajdu³, Piotr Wielgórski²,
Marek Górski², Jesper Storm³, Nicolas Nardetto⁴, Alexandre Gallenne⁵, Garance Bras⁶,
Pierre Kervella^{6,7}, Paulina Karczmarek², and Weronika Narloch²

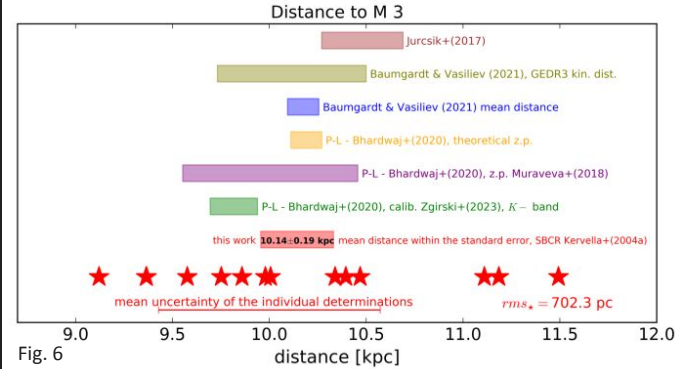
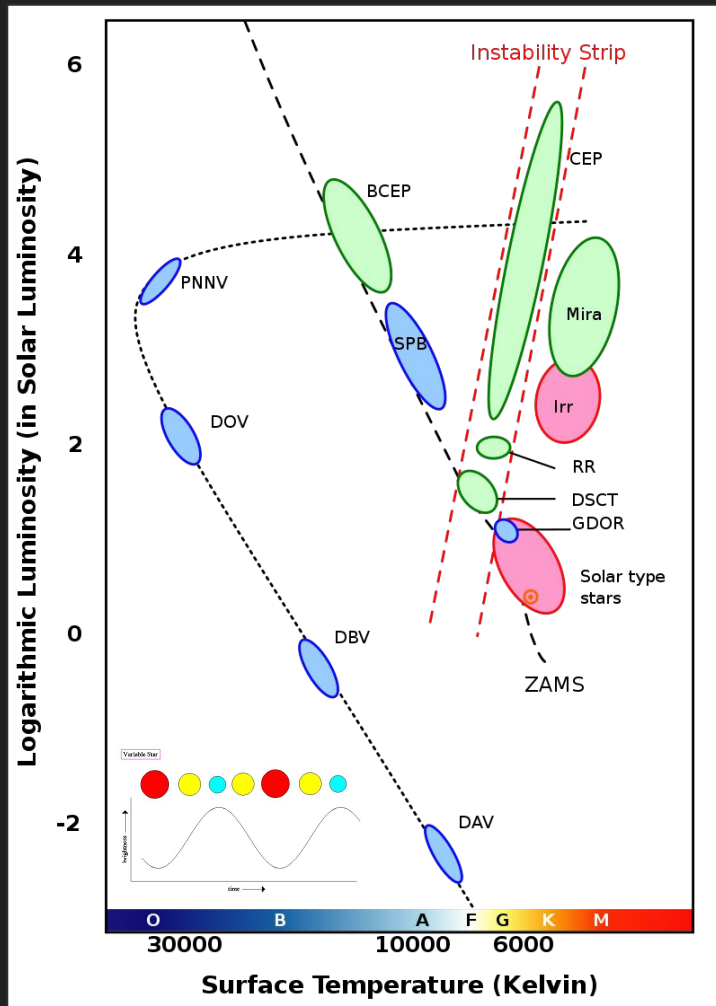
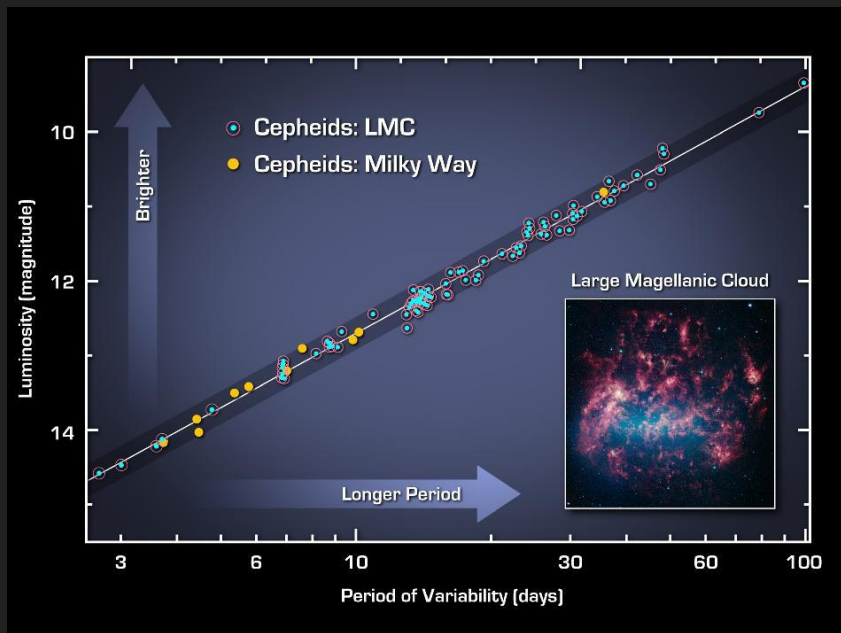


Fig. 6

Period - luminosity relation (PLR): Cepheids, Type II Cepheids, RR Lyr stars

PLR method base on an assumption that pulsating stars serve as standard candles.



Period - luminosity relation (PLR): calibration, application, systematic errors...



A Precision Determination of the Effect of Metallicity on Cepheid Absolute Magnitudes in *VIJHK* Bands from Magellanic Cloud Cepheids

Piotr Wielgórski¹, Grzegorz Pietrzyński^{1,2}, Wolfgang Gieren^{2,3}, Marek Górski^{2,3}, Rolf-Peter Kudritzki⁴, Bartłomiej Zgierski¹, Fabio Bresolin⁴, Jesper Storm⁵, Noriyuki Matsunaga⁶, Dariusz Graczyk^{1,2,3}, and Igor Soszyński⁷

Table 3
Metallicity Effect on Cepheid *P-L* Relations in *VIJHK*, W_{VI} , and W_{JK} Bands

Filter	R_0	$\Delta(m - M)$	$\Delta(m - M)_{\text{IGP}}^{\text{IGP}}$	$\Delta(m - M)_{\text{IGP}}^{\text{IGP}} - \Delta(m - M)_{\text{IGP}}^{\text{IGP}}$	γ
V	3.134	0.340 ± 0.017	0.481 ± 0.017	0.009 ± 0.031	-0.022 ± 0.076
I	1.894	0.393 ± 0.012	0.478 ± 0.012	0.006 ± 0.029	-0.015 ± 0.071
J	0.892	0.449 ± 0.010	0.489 ± 0.010	0.017 ± 0.028	-0.042 ± 0.069
H	0.553	0.452 ± 0.009	0.477 ± 0.009	0.005 ± 0.028	-0.012 ± 0.069
Ks	0.363	0.463 ± 0.008	0.479 ± 0.009	0.007 ± 0.028	-0.017 ± 0.069
W_{VI}	...	...	0.482 ± 0.008	0.010 ± 0.027	-0.025 ± 0.067
W_{JK}	...	...	0.481 ± 0.008	0.009 ± 0.027	-0.022 ± 0.067



Period-Luminosity Relations for Galactic Classical Cepheids in the Sloan Bands*

Weronika Narloch^{1,2}, Gergely Hajdu², Grzegorz Pietrzyński^{1,2}, Wolfgang Gieren¹, Piotr Wielgórski², Bartłomiej Zgierski², Paulina Karczmarek¹, Marek Górski², and Dariusz Graczyk²

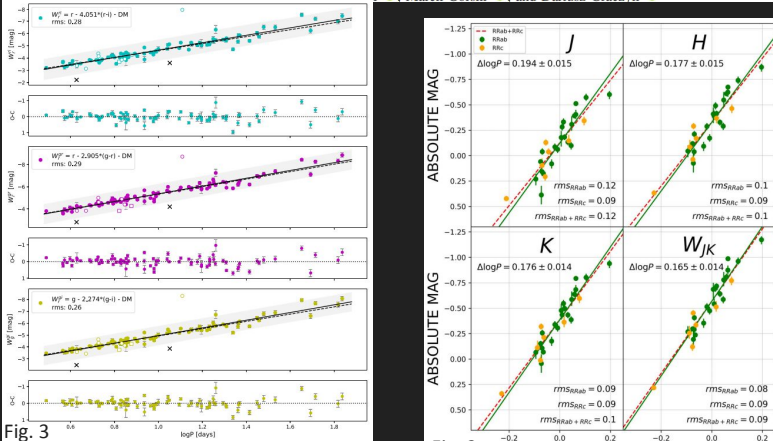


Fig. 3

OPEN ACCESS



Synthetic Population of Binary Cepheids. II. The Effect of Companion Light on the Extragalactic Distance Scale

Paulina Karczmarek^{1,2}, Gergely Hajdu², Grzegorz Pietrzyński², Wolfgang Gieren¹, Weronika Narloch¹, Radosław Smolec², Grzegorz Wiktoriańczyk², and Krzysztof Belczynski²

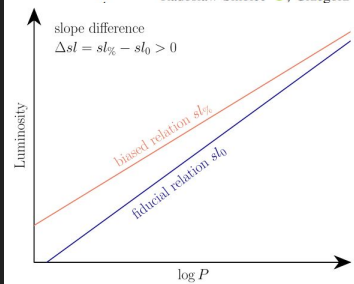


Figure 2. Qualitative representation of the effect companions have on the slope of the PLR.

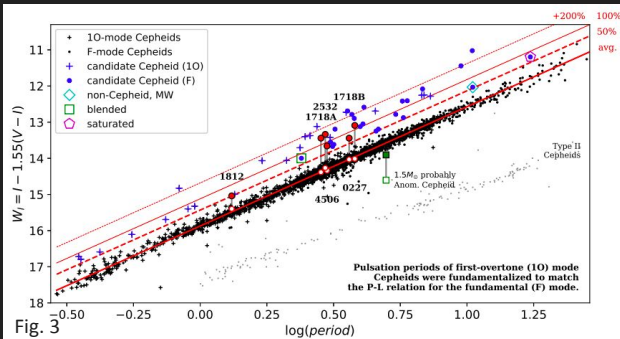
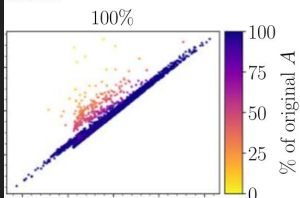


Fig. 3



New Near-infrared Period-Luminosity-Metallicity Relations for Galactic RR Lyrae Stars Based on Gaia EDR3 Parallaxes

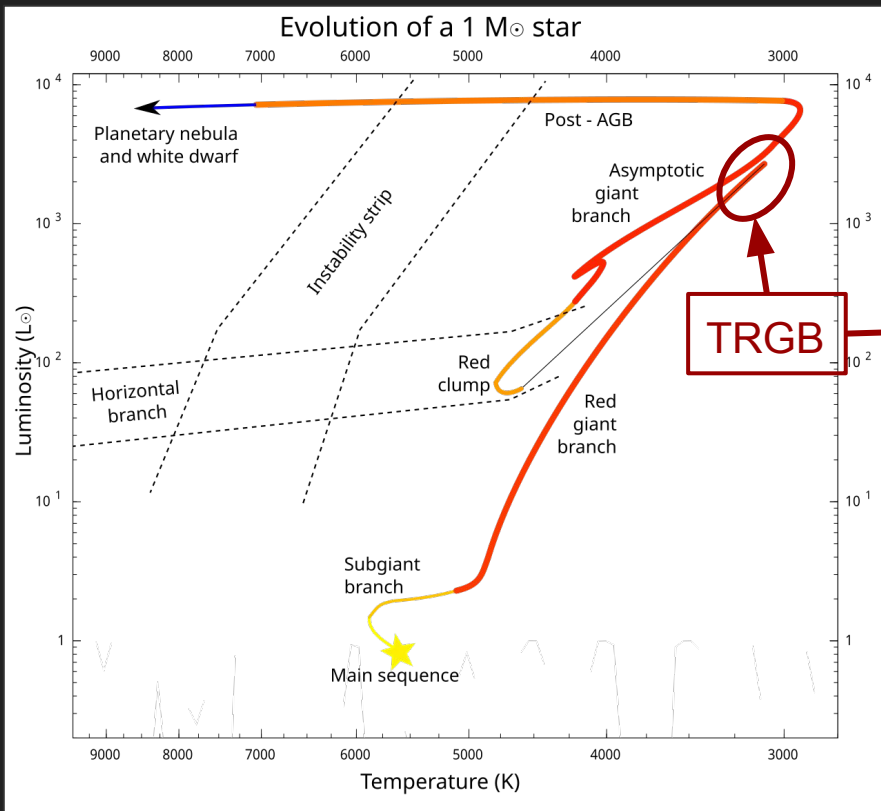
Bartłomiej Zgierski¹, Grzegorz Pietrzyński^{1,2}, Marek Górski¹, Wolfgang Gieren², Piotr Wielgórski¹, Paulina Karczmarek², Gergely Hajdu¹, Megan Lewis³, Rolf Chini^{1,3,4}, Dariusz Graczyk², Mikołaj Kaluszynski¹, Weronika Narloch², Bogumił Pilecki¹, Gonzalo Rojas García¹, Ksenia Suchomska¹, and Mónica Taormina¹



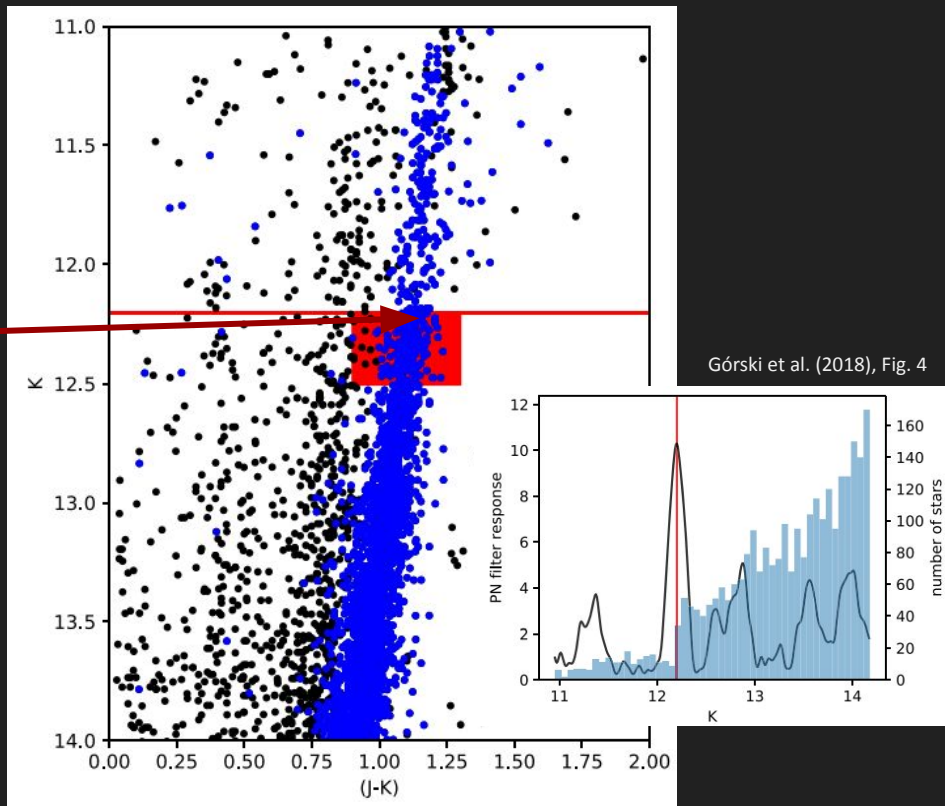
Cepheids with Giant Companions. I. Revealing a Numerous Population of Double-lined Binary Cepheids*

Bogumił Pilecki¹, Grzegorz Pietrzyński¹, Richard I. Anderson^{2,3}, Wolfgang Gieren⁴, Mónica Taormina⁴, Weronika Narloch⁴, Nancy R. Evans⁵, and Jesper Storm⁶

Tip of the red giant branch (TRGB):

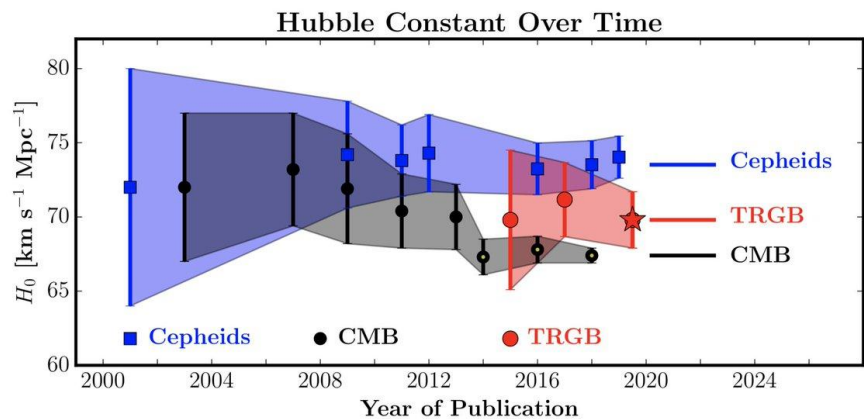


Górski et al. (2018), Fig. 1

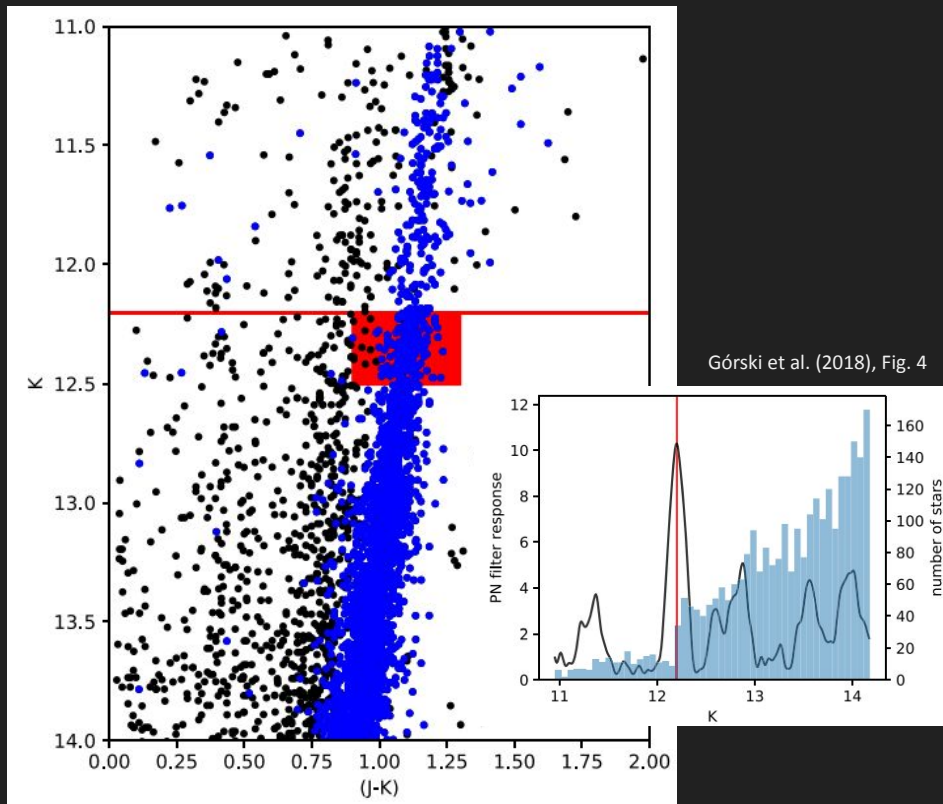


Tip of the red giant branch (TRGB):

Górski et al. (2018), Fig. 1

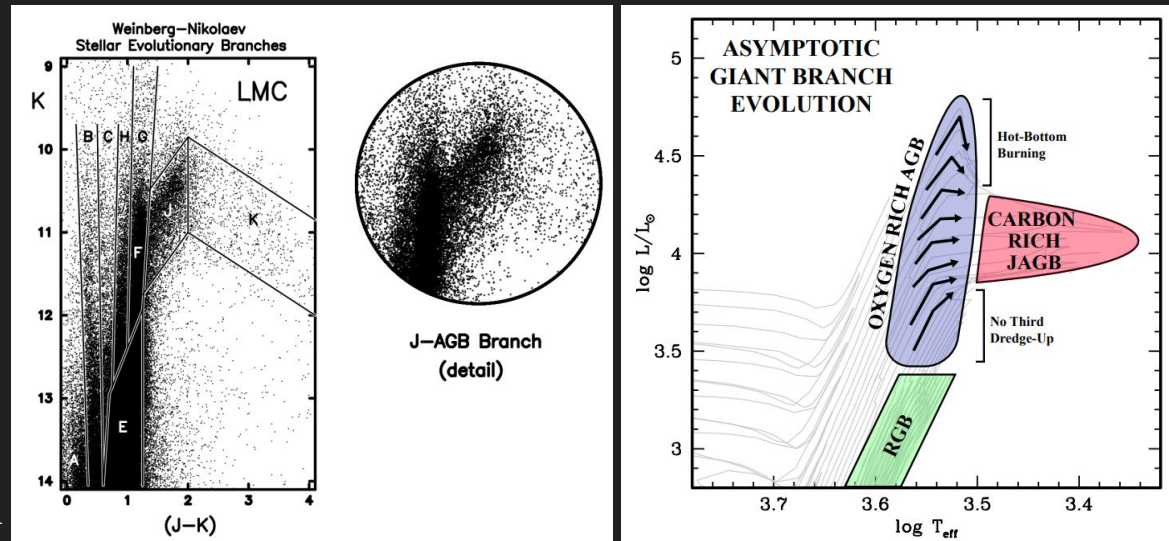


Freedman et al. (2019), Fig. 17

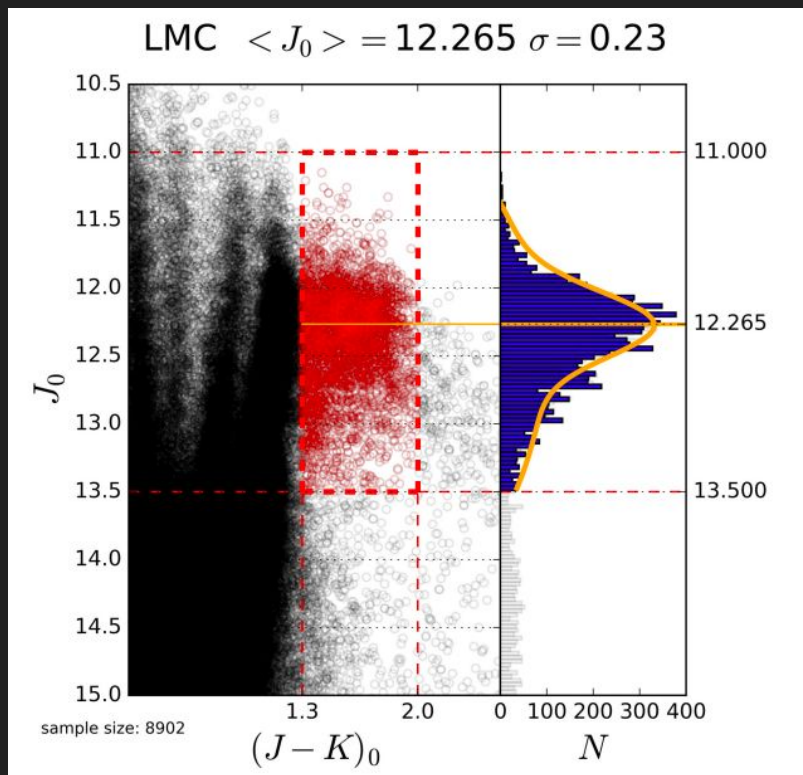


J-AGB stars:

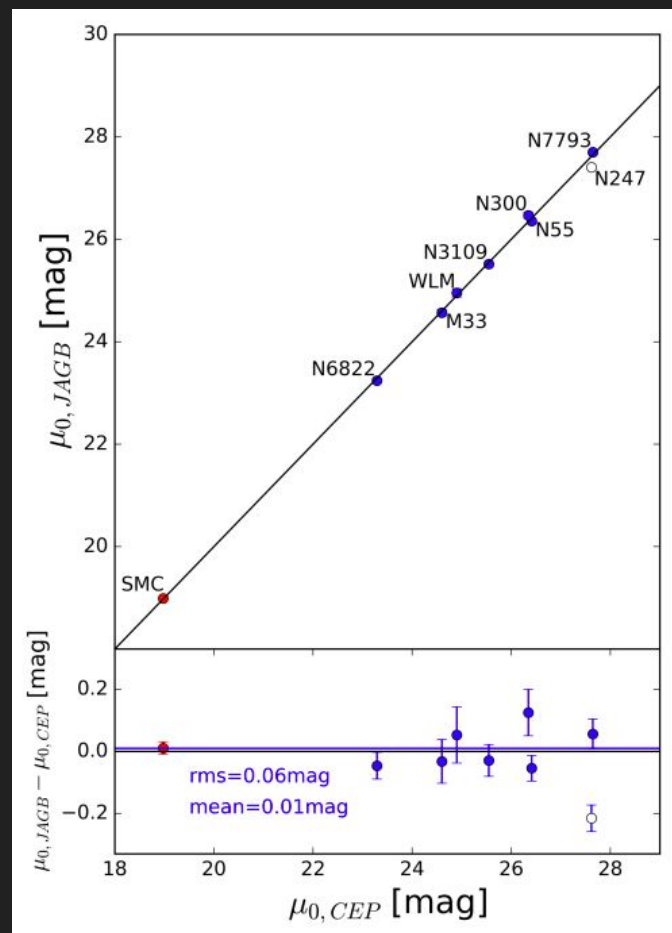
J-Type Asymptotic Giant Branch (JAGB) - they are thermally pulsating AGB stars with the convective envelope, which is being enriched in carbon, brought to the surface via thermal pulses from the helium-burning shell. Carbon stars have their masses in a small range, which translates to their constant luminosity, making them useful standard candles.



J-AGB stars:



Zgirski et al. (2021), Fig. 2



Zgirski et al. (2021), Fig. 10

Other projects:

Reddening maps

THE ASTROPHYSICAL JOURNAL, 889:179 (13pp), 2020 February 1
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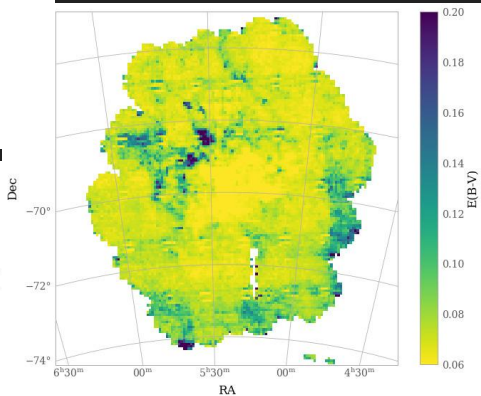
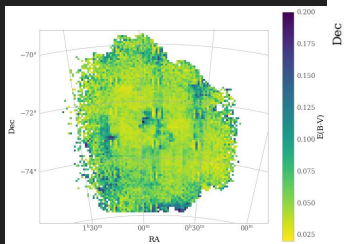
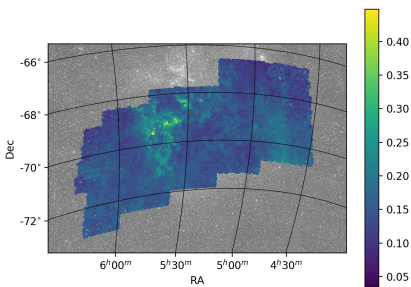
<https://doi.org/10.3847/1538-4357/ab65ed>



Empirical Calibration of the Reddening Maps in the Magellanic Clouds

Marek Górski¹, Bartłomiej Zgirski², Grzegorz Pietrzyński^{1,2}, Wolfgang Gieren¹, Piotr Wielgórski², Dariusz Graczyk^{1,2}, Rolf-Peter Kudritzki^{3,4}, Bogumił Pilecki^{1,2}, Weronika Narloch¹, Paulina Karczmarek^{1,5}, Ksenia Suchomska², and Mónica Taormina²

Górski et al. (2020), Fig. 5



Netzel et al. (2026),
submitted

Physics of stars

Circumstellar emission of Cepheids across the instability strip: Mid-infrared observations with VLT/MATISSE*

V. Hodge^{1,*,}, A. Matter², N. Nardetto², A. Gallenne^{3,4}, P. Kervella⁵, A. Mérand⁶, G. Pietrzyński¹, W. Gieren⁷, J. Lefley², S. Robbe-Dubois², B. Lopez², M. C. Baillieu², G. Bras², R. Smolec¹, P. Wielgórski¹, G. Hajdu¹, and A. Afanasiev⁷

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<https://doi.org/10.1051/0004-6361/202557724>
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Astronomy
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Astrophysics

RR Lyrae stars with variable mean magnitudes

G. Hajdu^{1,*}, J. Jurešik², M. Catelan^{3,4}, G. Pietrzyński^{1,5}, V. Hodge⁶, I. Soszyński⁶, A. Udalski⁶, C.-U. Lee⁷, and D.-J. Kim⁷

Extended envelopes around Galactic Cepheids

V. Multi-wavelength and time-dependent analysis of IR excess*

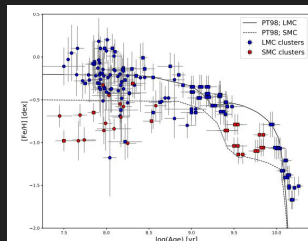
A. Gallenne^{1,2,3}, A. Mérand⁴, P. Kervella⁵, G. Pietrzyński¹, W. Gieren², V. Hodge⁶, L. Breuval¹, N. Nardetto⁶, and E. Lagadec⁶

peculiarities and side projects

RR-Lyrae-type pulsations from a 0.26-solar-mass star in a binary system

G. Pietrzyński^{1,2}, I.B. Thompson³, W. Gieren¹, D. Graczyk¹, K. Stepien², G. Bono^{4,5}, P. G. Prada Moroni^{6,7}, B. Pilecki^{1,2}, A. Udalski³, I. Soszyński², G. Preston³, N. Nardetto⁸, A. McWilliam³, I. Roederer³, M. Górski^{1,2}, P. Konorski^{1,2}, J. Storm⁹

2012. Nature. 484. 75



A&A 666, A80 (2022)
<https://doi.org/10.1051/0004-6361/202243378>
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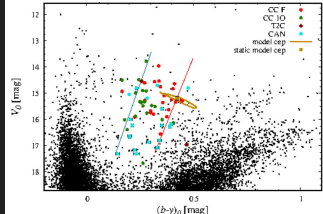
Metallicities and ages for star clusters and their surrounding fields

W. Narloch¹, G. Pietrzyński^{1,2}, W. Gieren¹, A. E. Patti^{3,4}, P. Karczmarek¹, M. Górski^{1,2}, D. Graczyk¹, R. Smolec¹, G. Hajdu², K. Suchomska², B. Zgirski², P. Wielgórski², B. Pilecki², M. Taormina², M. Kaluszynski², W. Pych², G. Rojas García², and M. O. Lewis²

Monthly Notices
ROYAL ASTRONOMICAL SOCIETY
MNRAS 000, 1-25 (2019)
Advance Access publication 2019 August 1
doi:10.1093/mnras/mtz2113

Candidates for non-pulsating stars located in the Cepheid instability strip in the Large Magellanic Cloud based on Strömgren photometry

Weronika Narloch^{1,2,3}, G. Pietrzyński^{1,3}, Z. Kołaczowski^{1,3}, R. Smolec^{1,3}, M. Górski^{1,2}, M. Kubiak⁵, A. Udalski³, I. Soszyński³, D. Graczyk^{1,2,6}, W. Gieren^{1,2}, P. Karczmarek^{1,5}, B. Zgirski³, P. Wielgórski³, K. Suchomska³, B. Pilecki³, M. Taormina³ and M. Kaluszynski³



Astronomy
&
Astrophysics

Rolf Chini Cerro Murphy Observatory:



**Talk of
Paulina Karczmarek!**

What we offer?:

- Summer practice for bachelor and master students.
- Observational practice in the OCM for CAMK's PhD students.

Who we are hiring next year?:

- 1 PhD position,
- 2 postdoc positions,
- 1 student.



Thank you for your attention!

Questions?