

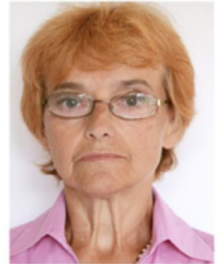
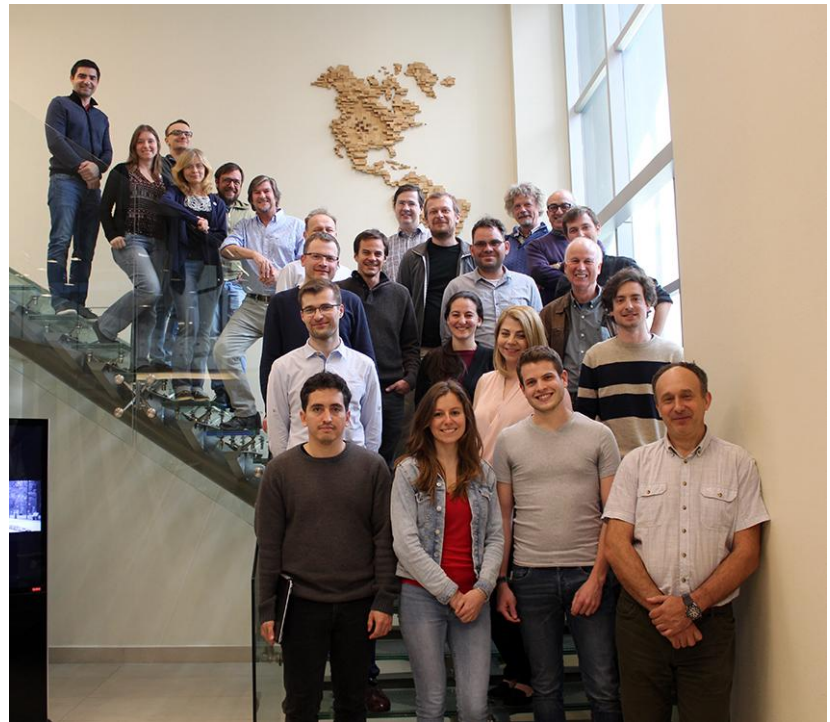
Distance measurements in the **Araucaria Project**

Marek Górski
XLI ZJAZD PTA
Toruń, 13.09.2023



Araucaria Project

- International Collaboration
Warsaw, Concepcion, Paris



Araucaria Project - distance scale calibration

- distances
- energy scale
- Hubble constant

eclipsing binaries (late, early),

C Cep, type II Cep, RR Lyr,

RC, JAGB, TRGB

- range and natural limitations
- precision
- accuracy - systematic errors



Araucaria Project - distance scale calibration

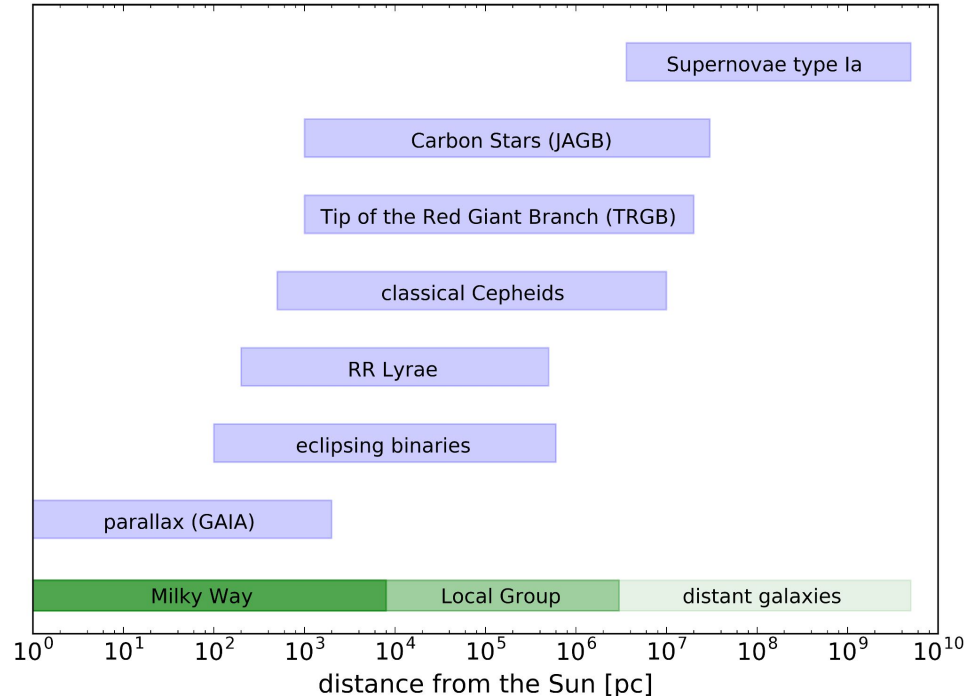
- distances
- energy scale
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eclipsing binaries (late, early),

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distance scale - distance discrepancies

Distance to LMC (1%)

Hubble Constant (1-3%) [?]

systematic <TRGB-CEP> = 0.2 mag

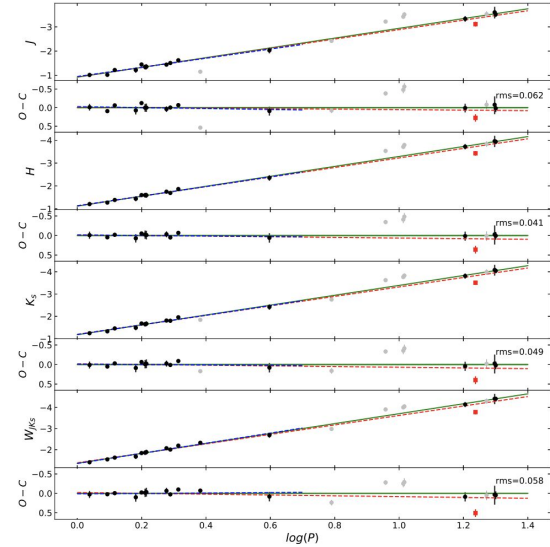
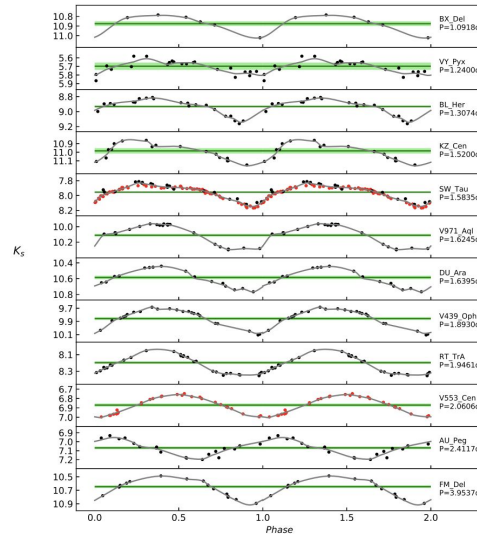
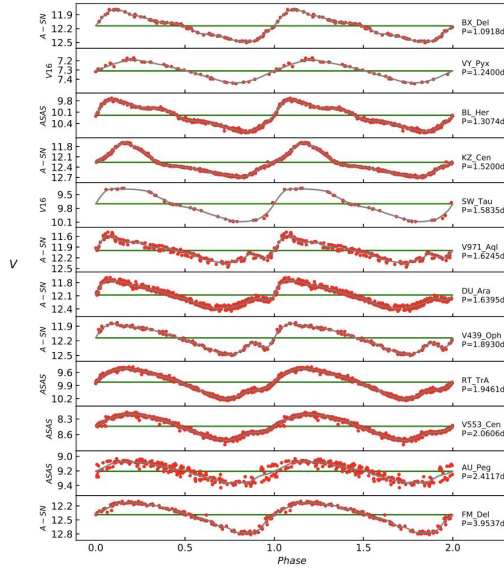
rms <TRGB-CEP> = 0.1 mag

M33 (different methods): rms = 0.14 mag

- Cep: 24.56 - 24.65
- TRGB: 24.5 - 24.84
- RR Lyr: 24.67
- Miras: 24.8
- HB: 24.84
- FGLR: 24.93
- JAGB: 24.57

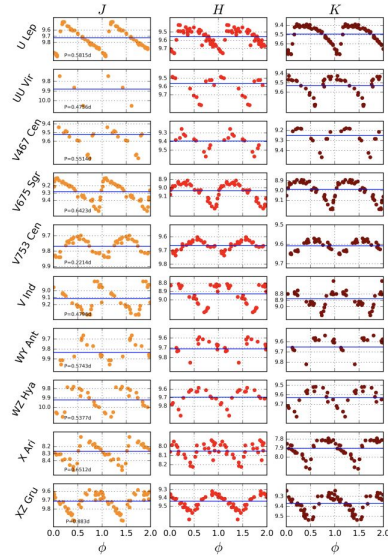
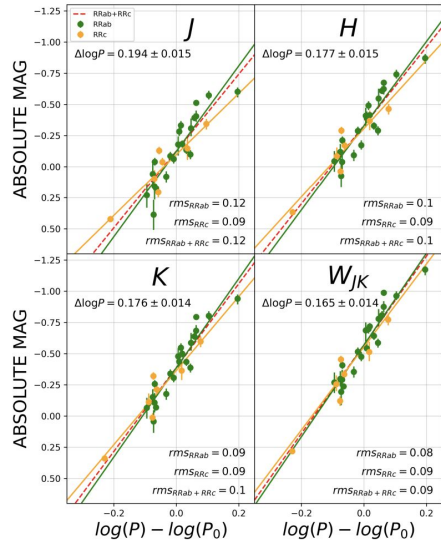
OBJECT	TRGB	Cep
WLM	24.925	24.85
NGC 3109	25.66	25.45
IC1 613	24.35	24.29
NGC 300	26.65	26.37
M33	24.84	24.62
NGC 7793	27.96	27.66

distance scale - improvements - Type II Cep



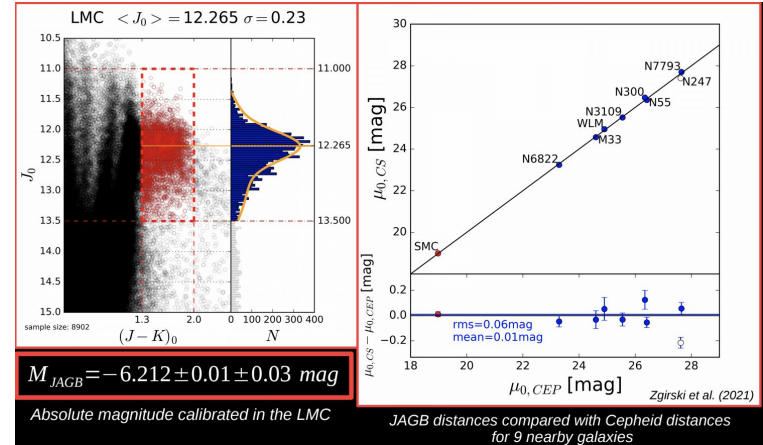
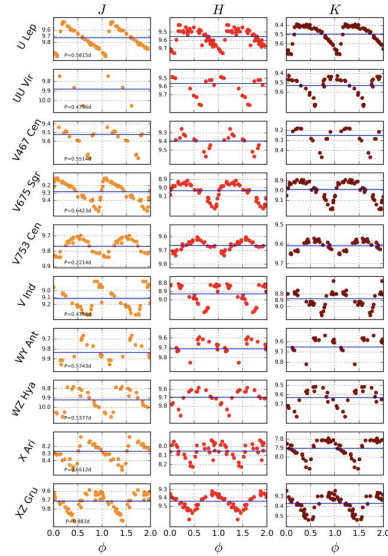
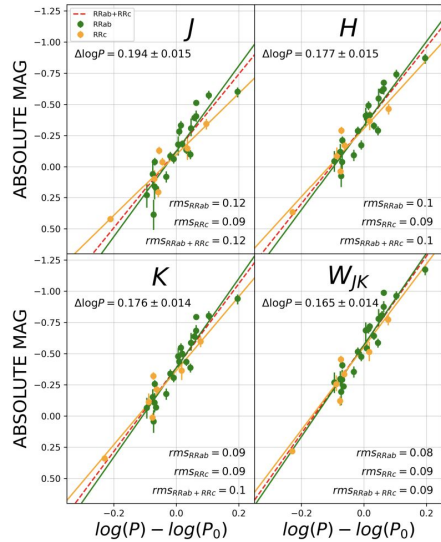
21 nearby type II Cepheids (EDR3) - J, H, Ks PLRs
(Wielgórski et al. 2022)

distance scale - improvements - RR Lyrae



28 nearby RR Lyrae (EDR3) - J, H, Ks PLRs
(Zgirski et al. 2023)

distance scale - improvements - JAGB

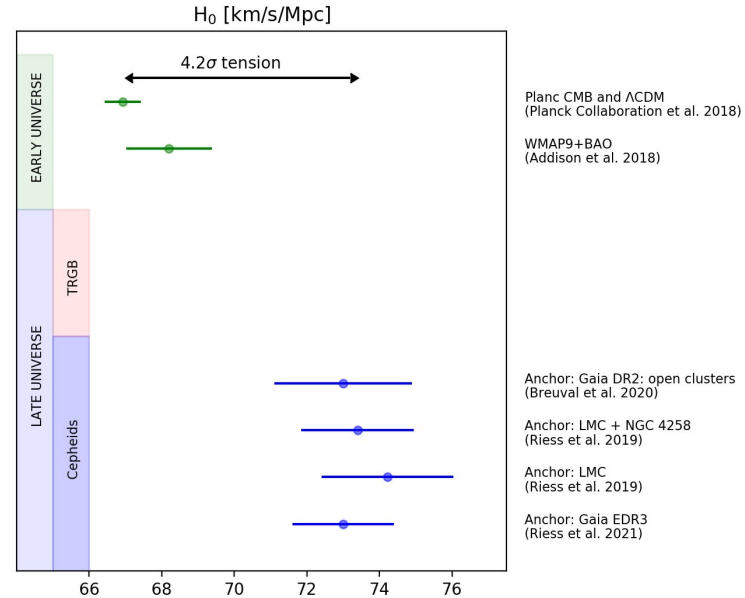


Distances to 9 Galaxies with the JAGB
(Zgirski et al. 2023)

distance ladder - Hubble tension

Any theory that would explain different H_0 value measurements for the early and late Universe will have to modify the standard Λ CDM model.

Before new physics will be necessary, **it is crucial** not only to improve Hubble constant measurements with the distance ladder, but what is even more important, **to confirm beyond any doubts that the Hubble tension is not the effect of systematic errors of the distance measurements.**

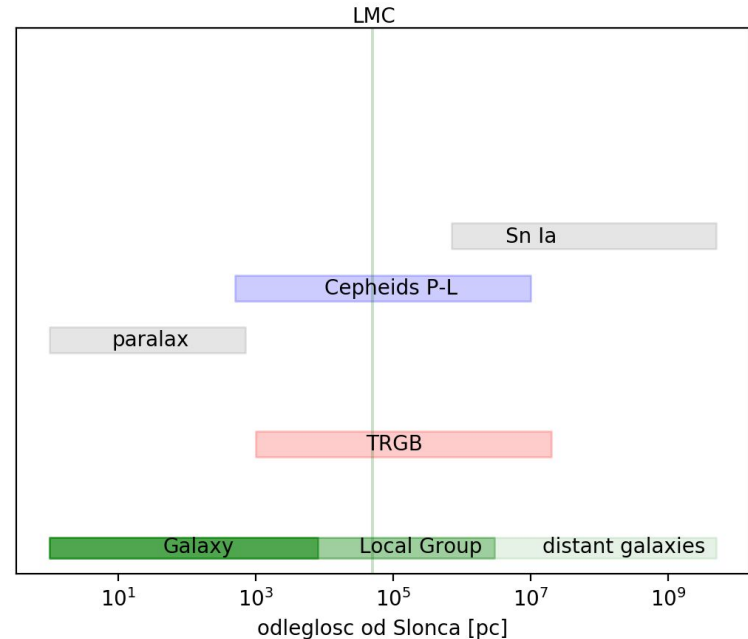


distance ladder - Hubble tension

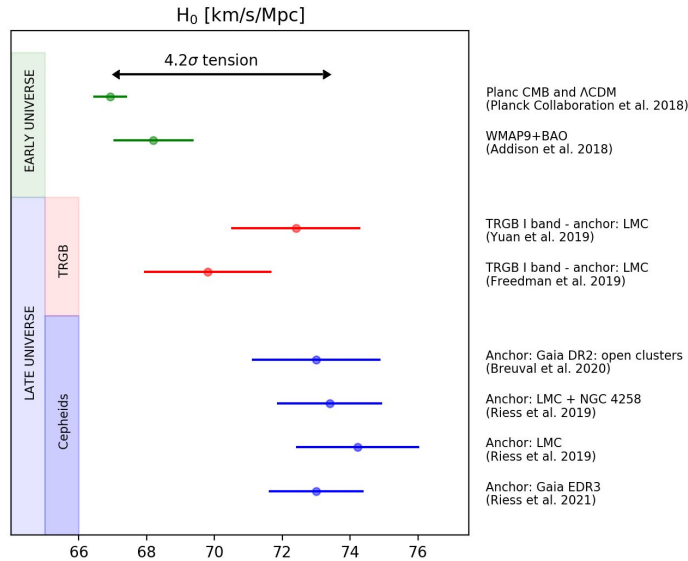
Cepheids:

- zero point
- reddening
- metallicity effect
- blending/crowding
- PL break
-

Even if all mentioned systematic errors are well understood and controlled, **it is impossible to confirm how accurate is the Hubble constant derived with the Cepheid distance scale, without using other, independent and precise distance measurement technique.**

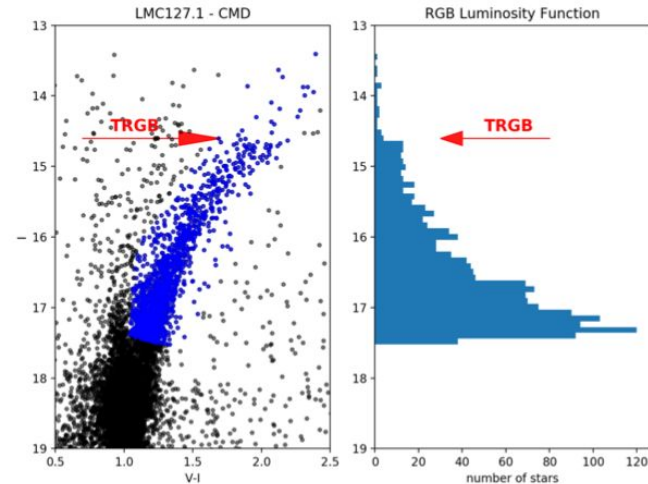


Hubble tension - TRGB

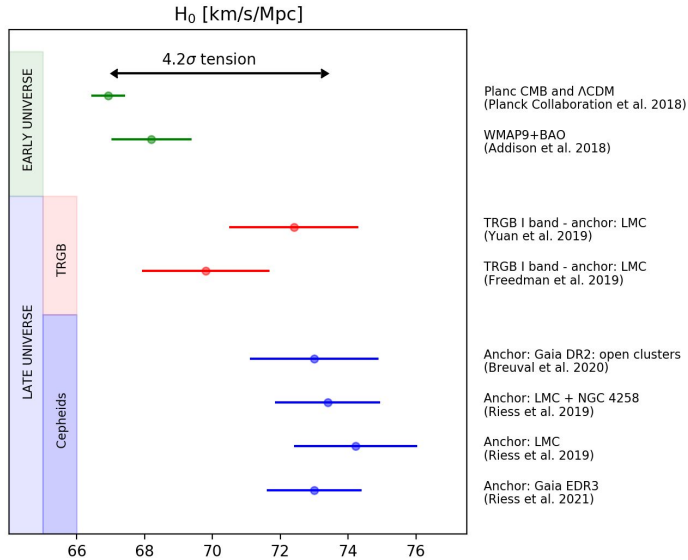


TRGB (I-band): sharp cut-off of the stellar luminosity function of the red giant branch (RGB). It marks the final stage (helium flash) of the evolution of stars on the RGB.

More than 300 galaxies up to 17 Mpc



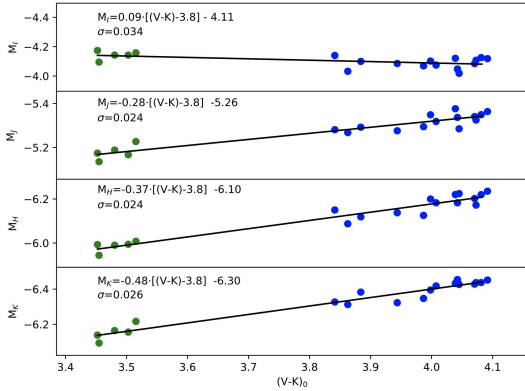
Hubble tension - TRGB



TRGB (I-band)

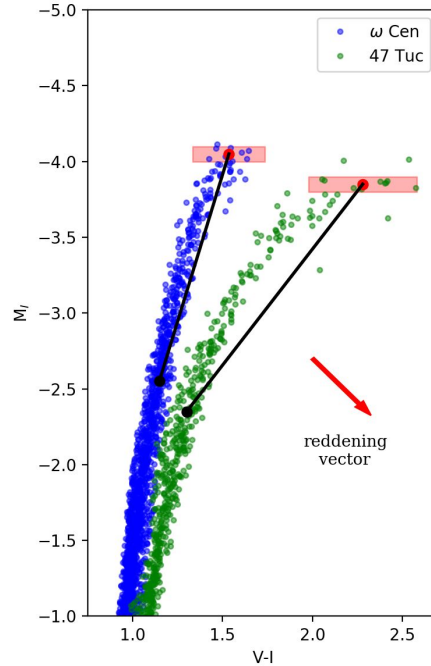
- statistical uncertainty
- zero-point
- reddening
- metallicity
- population effects (intermediate age population)

Hubble tension - TRGB



J, H, K TRGB depends:

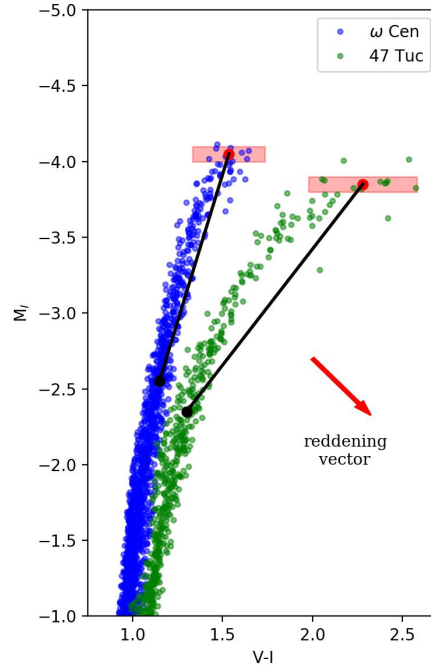
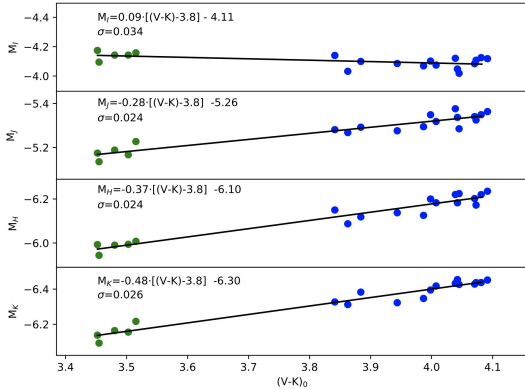
- metallicity
- RGB tip color
- shape of the RGB



TRGB (I-band)

- statistical uncertainty
- zero-point
- reddening
- metallicity
- population effects (intermediate age population)

Hubble tension - TRGB



J, H, K TRGB depends:

- metallicity
- RGB tip color
- shape of the RGB

Multiband TRGB technique

Calibration of the I,J,H,K band TRGB

- distance to LG (LMC, NGC 6822, IC 1613)
- reddenings

Verification - comparison with other techniques (Local Group, HST)

distances HST, JWST



THANK YOU FOR ATTENTION!