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The Araucaria Project: Precise distances to Local Group galaxies from near-infrared photometry of RR Lyrae stars

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Abstract. We present results of the Araucaria Project's investigation of RR Lyrae stars as distance indicators in nearby galaxies. With an aid of near-infrared period-luminosity-metallicity relations available in the literature we determined distance moduli to five Local Group galaxies with the uncertainty of about 5%.

1 Context

The main goal of the Araucaria Project is to improve the calibration of the cosmic distance scale by studying various stellar distance indicators in nearby galaxies. Special attention is paid to RR Lyrae stars (RRLs), which are found in abundance in many galaxies of the Local Group: Sculptor, Carina, Fornax, LMC, SMC, and more. Near-infrared (NIR) photometry of RRLs, while minimizing the influence of both interstellar extinction and metallicity on the RRL luminosity, reveals a linear relationship between the luminosity and the metallicity and the logarithm of pulsational period, i.e. the period-luminosity-metallicity (PLZ) relation.

2 Methodology and results

Within the Araucaria Project, we adopted a methodology to determine distance moduli from NIR photometry of RRL stars, and used it consistently in order to secure homogeneity and equally high quality of our results. Data collected with world-class infrared cameras SOFI/NTT and HAWK-I/VLT were reduced and calibrated with a pipeline tailored for the purpose of the Araucaria Project ([1, 2]), and yielded random-phase measurements of RRL apparent magnitudes. Using pulsational periods from the literature, we plotted the RRL apparent magnitudes against their log periods (Fig. 1), and performed the linear least squares fitting. The slope of the fit was intentionally fixed using a set of PLZ relations ([3–6]), so the uncertainty of the free parameter – zero point of the calibration – could be substantially reduced. The zero point of the calibration, corrected for the effect of metallicity and interstellar extinction (both from the literature), yielded the true distance modulus.

The PLZ relations, applied to high quality NIR photometry of RRL stars, allowed us to determine distance moduli to five Local Group galaxies: Sculptor ([7]), LMC ([8]), SMC ([9]), Carina ([10]), and Fornax ([11]), all with an uncertainty of about 5% (Table 1). The results agree very well with other determinations available in the literature, but are of considerable better precision.

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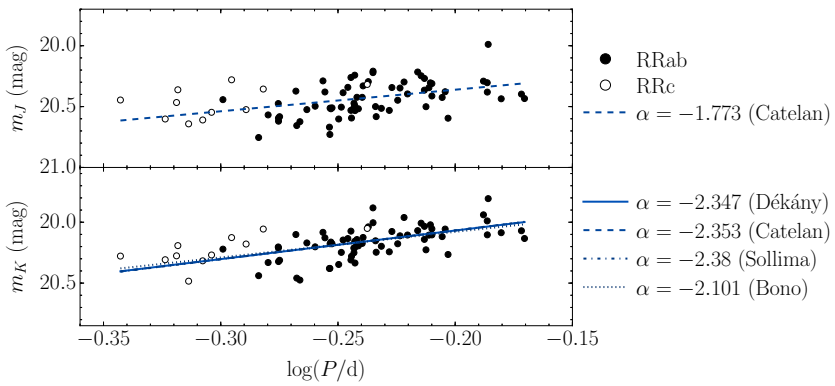

Figure 1. Apparent magnitudes of Fornax RRL stars as a function of their log pulsational period. Lines denote different slopes of PLZ relations, α, extracted from the literature ([3–6]).

Table 1. Distance moduli to five Local Group galaxies determined within the Araucaria Project.

Galaxy	$n_{\rm RRL}$	$(m-M)_0 \pm \sigma_{\rm syst.} \pm \sigma_{\rm stat.}$	Reference
Sculptor	78	$19.67 \pm 0.02 \pm 0.12$	[7]
LMC	65	$18.58 \pm 0.03 \pm 0.11$	[8]
SMC	34	$18.97 \pm 0.03 \pm 0.12$	[9]
Carina	33	$20.118 \pm 0.017 \pm 0.110$	[10]
Fornax	77	$20.818 \pm 0.015 \pm 0.116$	[11]

The effort put in reducing the statistical error and controlling the systematic error of standard candles, as shown in the case of RRL stars, can significantly improve the accuracy of secondary distance indicators, and ultimately contribute to the refinement of the Hubble constant.

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