

Adjusting the distance scales of old and intermediate-age tracers via statistical parallaxes

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Abstract. The method of statistical-parallax determination is used to adjust the photometric distance-scale zero points and test the selection of several samples of old and intermediate-age tracer objects in the Milky Way, including RR Lyrae- and Mira-type variables, blue and red horizontal-branch stars, and red giants. We obtain reasonable and stable absolute-magnitude (and, hence, photometric distance-scale) corrections for all samples except for the red horizontal-branch stars, which appear to be significantly contaminated by main-sequence turn-off and subgiant stars.

Keywords. stars: distances, stars: luminosities, stars: kinematics, stars: classification, stars: horizontal-branch, stars: variables: other

1. Introduction

We use the method of statistical-parallax determination in its rigorous maximum-likelihood version suggested by Murray (1983, p. 297) to analyze five tracer samples consisting (or supposedly consisting) of RR Lyrae variables, Mira variables, red-giant stars, and blue and red horizontal-branch (BHB, RHB) stars.

2. RR Lyrae-type variables

We use a bimodal version of the statistical-parallax method (for details, see Dambis 2009) to set the zero point of the metallicity- and period–luminosity (PL) relations, respectively, for Galactic field RR Lyrae-type variables. Our sample is composed of 368 stars with heliocentric distances ≤ 6.5 kpc, *bona fide* proper motions, radial velocities, and phase-corrected 2MASS *K*-band magnitudes (Cutri *et al.* 2003), as well as UCAC4 proper motions (Zacharias *et al.* 2012) and 355 stars with average *V*-band magnitudes. The resulting relations are

$$\langle M_V \rangle = +1.17(\pm 0.09) + 0.214[\text{Fe}/\text{H}] \quad (2.1)$$

and

$$\langle M_K \rangle = -0.80(\pm 0.08) - 2.338P_F, \quad (2.2)$$

where the slopes have been adopted from Gratton *et al.* (2004) and Frolov & Samus' (1998), respectively. Here, P_F is the period of fundamental-mode pulsation.

3. Mira-type variables

Our Mira sample is based on the catalog of Galactic Mira-type variables of Kharchenko *et al.* (2002), supplemented with radial-velocity data from Feast & Whitelock (2000) and

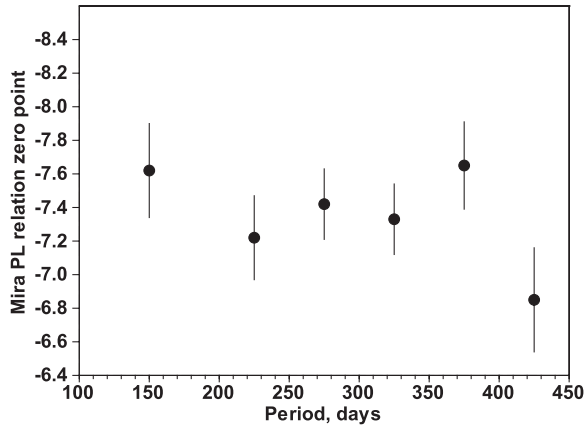


Figure 1. Zero point of the PL relation for Galactic Miras as a function of period.

Menzies *et al.* (2006), average K -band magnitudes adopted from Menzies *et al.* (2006), Whitelock *et al.* (2006, 2008), and 2MASS (Cutri *et al.* 2003), and proper motions from the UCAC4. The provisional distances to our sample Miras are based on the $\log P$ – M_K relation of Whitelock *et al.* (2008), $\langle M_K \rangle = -7.15 - 3.51(\log P - 2.38)$. Using our inferred zero point, the relation has the following form:

$$\langle M_K \rangle = -7.41(\pm 0.10) - 3.51(\log P - 2.38). \quad (3.1)$$

The absence of any apparent trend in the zero-point correction in the ~ 120 – 400 day period interval (see Fig. 1) implies that the slope of the PL relation for Galactic field Miras does not differ significantly from the corresponding slope for Miras in the Large Magellanic Cloud.

4. Red giants

Our third sample consists of 2519 red giants identified using SDSS/SEGUE data (Martell *et al.* 2011) with photometric distances based on absolute-magnitude calibration derived using 12 Gyr-old Dartmouth isochrones (Dotter *et al.* 2008). Fig. 2 shows the inferred zero-point correction of the adopted absolute-magnitude calibration as a function of metallicity. The adopted calibration and selection procedure appear robust given the moderate absolute-magnitude correction ($\Delta M_g = +0.17 \pm 0.06$ mag) and the lack of any apparent metallicity trend.

5. Blue horizontal-branch stars

Our fourth sample consists of 1955 rigorously selected blue horizontal-branch halo stars from SDSS data release (DR) 6 (Adelman-McCarthy *et al.* 2008) with photometric distances based on the calibration of Sirko *et al.* (2004) and radial velocities determined within the framework of the SEGUE project (Yanny *et al.* 2009). We adopted this sample from Xue *et al.* (2008) and supplemented it with absolute proper motions from the SDSS DR7 (Abazajian *et al.* 2009) database. We applied a single-mode version of the statistical-parallax method, parametrizing the variation of the velocity-ellipsoid parameters as a function of Galactocentric distance in terms of the model of Sommer-Larsen *et al.* (1997) and found the absolute-magnitude correction to be small ($\Delta M_g = -0.12 \pm 0.06$ mag) and highly stable across the entire metallicity range of BHB stars considered (see Fig. 3).

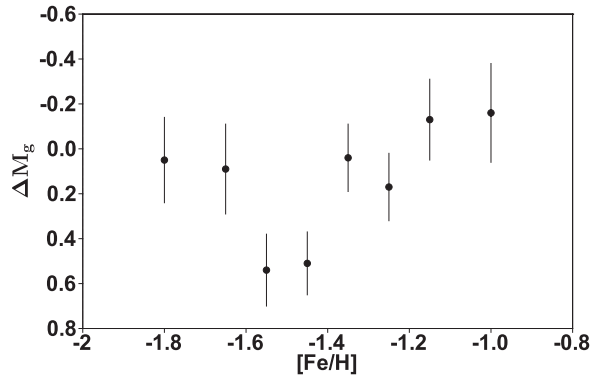


Figure 2. Zero-point correction of the absolute-magnitude calibration for red-giant stars based on the 12 Gyr-old Dartmouth isochrones as a function of metallicity.

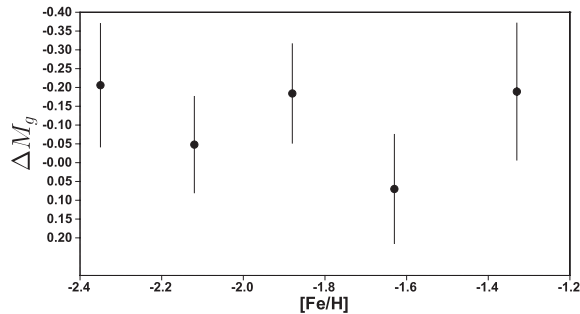


Figure 3. Zero-point correction to the absolute-magnitude calibration for BHB stars as a function of metallicity.

6. Red horizontal-branch stars

Our fifth sample consists of presumed field red horizontal-branch stars (5391 objects) selected by Chen *et al.* (2010) based on SDSS photometry and SEGUE spectroscopy using positions of stars in the metallicity–color and $T_{\text{eff}}\text{--}\log g$ diagrams. The surprising result is the average factor-of-two reduction in the adopted distances, implying a factor-of-four reduction in the adopted luminosities of the sample stars, rendering the horizontal-branch nature of most of the sample and the underlying selection procedure doubtful. To further investigate this issue, we determined the average absolute magnitudes, M_V , of stars in this sample in $(B - V)_0$ color bins and show the resulting color–magnitude diagram in Fig. 4, where the $[(B - V)_0, M_V]$ data points corresponding to our subsamples are superimposed on the 12 Gyr-old Dartmouth isochrone (Dotter *et al.* 2008). Our results appear to imply that the sample should consist mostly of main-sequence turn-off and subgiant stars and is perhaps only slightly contaminated by RHB stars, except for the metal-richest part.

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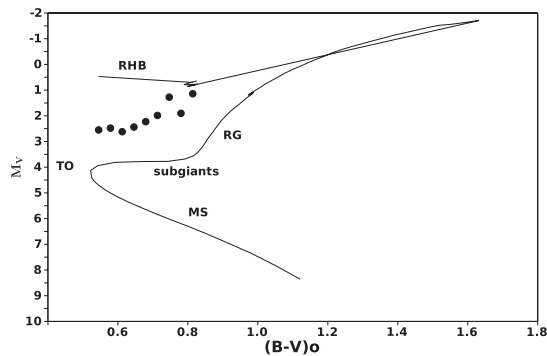


Figure 4. Inferred average positions of color-binned RHB subsamples (dots) on the $(B - V)_0$ versus M_V color-absolute-magnitude diagram. Also indicated are the loci of main-sequence (MS), main-sequence turn-off (TO), red-giant (RG), and RHB stars, and the $Z = 0.004$, 12 Gyr-old Dartmouth isochrone.

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