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RR Lyrae Variables in Local Group Galaxies: LMC, Leo I. New Results and Distances to these Galaxies[1]

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Abstract. We present new results on a sample of RR Lyrae variables in the bar of the Large Magellanic Cloud (LMC), and report on the first detection of RR Lyrae in the dwarf spheroidal galaxy Leo I. Emphasis is given to the discussion of the distances to these galaxies as derived from their RR Lyrae populations, and of the impact on the "short" and "long" distance scale dichotomy.

1. Introduction

RR Lyrae are primary distance indicators in the Local Group. In galaxies where both RR Lyrae and Population I indicators (e.g. Cepheids, clump stars, etc.) coexist, a direct comparison can be made between the related distance scales.

In order to use the RR Lyrae as distance indicators, one needs to know (i) the average apparent luminosity of the RR Lyrae in the given system, (ii) the average metallicity of the sample (since the absolute magnitude of the RR Lyrae is known to depend on metal abundance), (iii) the reddening; finally, (iv) a value is required for the absolute luminosity of the RR Lyrae and for the slope of its dependence on metallicity. Once these quantities are known the distance of the hosting system is derived from the relation existing between apparent luminosity, absolute magnitude and distance. In the following, we present our new results on the RR Lyrae in the LMC bar and in Leo I, and discuss the distance to these galaxies they imply.

2. The Large Magellanic Cloud

The LMC is the first step on the extragalactic distance ladder. However, the problem of its actual distance is far from being settled. Distances to the LMC

[1]Based on observations made with the 1.5 m Danish and the 2.2 m ESO-MPI telescopes, at La Silla, Chile.

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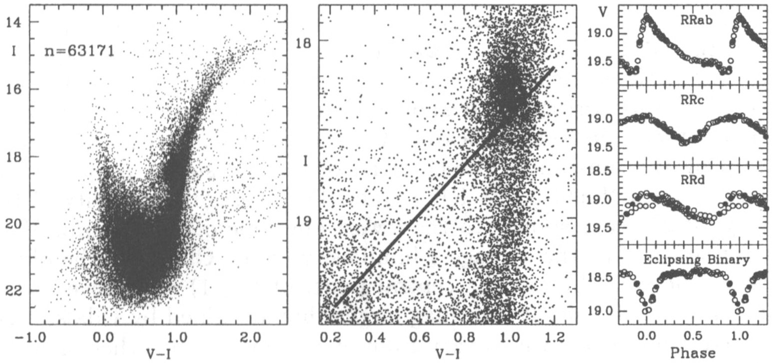

Figure 1. HR diagram of LMC Field A, an enlargement of the Clump region with the solid line showing the HB of the old stellar component, and some examples of our light curves. Open circles are from Clementini et al. (2001), filled dots are the new data points.

from Population II objects are based on the luminosity of the RR Lyrae. New time series B, V, I photometry has been obtained for the sample of about 130 RR Lyrae in the bar of the LMC studied by Clementini et al. (2001) using the 1.5 Danish telescope, in January 2001. Variables are in two 13×13 arcmin^2 areas (namely, Field A and B) contained in field #6 and #13 of the MACHO (Alcock et al., 1996) microlensing experiment. Field A also has a 40% overlap with OGLE II field LMC_SC21 (Udalsky et al., 2000). The left and central panels of Fig. 1 show the I *vs* $(V-I)$ diagram of Field A and an enlargement of the Clump region, respectively. V light curves for some of the variables in our sample are shown in the right panel. The average properties, the metallicity (Bragaglia et al., 2001) and the reddening inferred from the RR Lyrae in our sample are summarized in Table 1. The small difference in the average luminosities of the RR Lyrae in the

Table 1. Average properties of the LMC RR Lyrae in our sample

$\langle P_{ab} \rangle$	Oo-type	$V(RR)_{FieldA}$	$V(RR)_{FieldB}$	[Fe/H]	E(B−V)
0.573	OoI/OoII	19.369±0.023	19.314±0.025	-1.5 ± 0.2	0.10

two fields suggests that a 0.02 mag differential reddening may exist between the two areas. Our average apparent V luminosity of the RR Lyrae *not corrected for reddening* (19.34 mag) is in good agreement with OGLE II's (19.37 mag), and Walker's (1992) value for the LMC cluster RR Lyrae (19.31 mag), and is 0.06-0.07 mag brighter than MACHO's. Particularly important is the comparison of the average luminosities of RR Lyrae and Clump stars in the I band, since the I luminosity of the Clump is the method which provides the shortest distance to the LMC (μ_{LMC}(Clump)=18.24 mag, Udalski, 2000). Our average I luminosity for the clump stars is 18.28 mag, to compare with Udalski's (2000) 18.25 mag.

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However, it should be reminded that the Clump of a composite population, as the one in the LMC, has a complex structure resulting from the superposition of stellar populations with different masses and ages. Strong evolutionary and age effects are then present and should be properly accounted for when the Clump is used as a distance indicator. On the other hand, the contribution to the Clump by the horizontal branch (HB) of the *old stellar population* in the LMC is very well defined by its RR Lyrae. The average luminosity of the RR Lyrae very clearly corresponds to the lowest envelope of the Clump. If we use the RR Lyrae to trace the average I luminosity of the Clump of the old stellar component (the solid line in the central panel of Fig. 1) we derive a distance modulus for the LMC about 0.15 mag larger than obtained by Udalski (2000).

The reddening is known to vary from one region to the other of the LMC. Reddening in our two fields was derived from the comparison of the colours of the edges of the instability strip defined by the RR Lyrae in our sample, with those of the Galactic globular cluster (GGC) M3 based on Corwin & Carney (2001) photometry. We derive values of 0.09 and 0.07 mag for Field A and B, respectively, and an upper limit average value of 0.10 mag. Our estimate is 0.044 mag smaller than derived by Udalski et al. (1999) in the same area, and its adoption contributes further to lengthen by 0.14 mag the distance modulus of the LMC. Finally, if we assume for the absolute magnitude of the RR Lyrae either the HB luminosity derived from the new and still unpublished Main Sequence Fitting distances of NGC6397 and NGC6752 by Gratton and collaborators, based on their ESO-VLT Large Program on GGCs, or, alternatively, values from the revised Baade-Wesselink analysis of Cacciari et al. (2000), we obtain a distance modulus for the LMC of 18.47 mag, in better agreement with the "long" distance scale.

3. The dwarf spheroidal galaxy Leo I

Leo I is a dwarf spheroidal galaxy about 250 Kpc from us. It has long been considered to host no old stellar population until Held et al. (2000) detected a well populated HB in the outer regions of the galaxy. Following that study we have undertaken a search for RR Lyrae in Leo I using time series B, V, I photometry of the galaxy taken with the Wide Field Imager of the 2.2 m ESO-MPI telescope. We have detected 74 variables stars in the 2 CCDs which host the main body of the galaxy, of which 54 are RR Lyrae (see Held et al. 2001 for details). The light variations of the RR Lyrae allowed us to pick up the old stellar component of Leo I even in the most central and crowded region of the galaxy. Examples of the v and b differential light curves of *ab*- and *c*-type RR Lyrae detected in Leo I are shown in Fig. 2 (central and right panels), along with their position on the HR diagram of the galaxy (left panel). Variable search is being performed on the remaining 6 chips of the mosaic. According to the period distribution of the RR Lyrae's detected so far, Leo I is an "Oosterhoff intermediate" galaxy, similar to other dwarf galaxies in the Local Group and the LMC. From the average period of the *ab*-type RR Lyrae we derived an average metallicity of the sample of [Fe/H]=-1.82 dex, using Sandage (1993) formulae, in very good agreement with previous metallicity estimates. The average luminosity of the RR Lyrae in our sample is $\langle V(RR)\rangle = 22.60\pm0.12$ mag. This value, combined with literature

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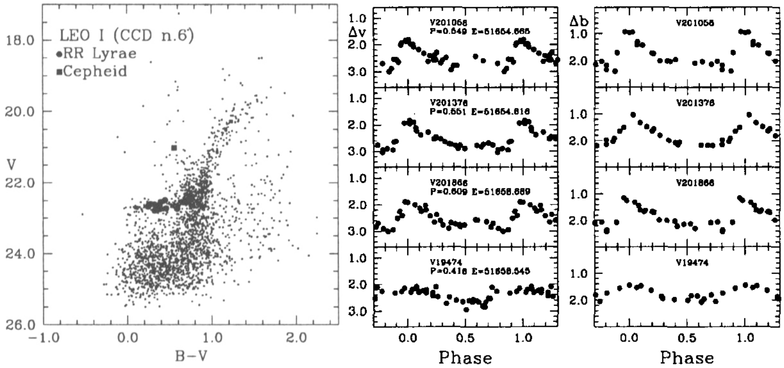

Figure 2. HR diagram of Leo I from data in CCD #6 and some examples of our light curves.

values for the reddening, and with our metallicity estimate leads to a distance modulus of 22.04±0.14 mag for Leo I on the "long" distance scale.

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Discussion

D. Laney : If you use your actual $E(B-V)$ values (0.07 and 0.09), your LMC distance modulus is in even better agreement with the modulus from Cepheids.

G. Clementini : My adoption of the upper limit value of $E(B-V) = 0.10$ is a caution since the absolute photometric calibration of our data is still preliminary.

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