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RR Lyrae-based calibration of the Globular Cluster Luminosity Function

M. Di Criscienzo[1,2] , F. Caputo[3], M. Marconi[1] and I. Musella[1]

[1] Istituto Nazionale di Astrofisica – Osservatorio Astronomico di Capodimonte, via Moiariello 16, I-80100 Naples, Italy
[2] Universitá di Roma "TorVergata", via della Ricerca Scientifica 1, I-00133 Rome, Italy
[3] Istituto Nazionale di Astrofisica – Osservatorio Astronomico di Monte Porzio Catone, via di Frascti 33, I-00040 Rome, Italy e-mail: dicrisci@na.astro.it

Abstract. Using the properties of RR Lyrae stars we have calibrated the Galactic Globular Cluster Luminosity Function (GCLF) and tested the constancy of itspeak absolute magnitude $M_V(TO)$.

Key words. Stars, variable; clusters, globular.

We have investigated the universality of the GCLF and the use of the peak magnitude for reliable distance determinations to external galaxies. The main results may be summarized as follows:

1. Concerning the dependence of the Milky Way GCLF on the adopted M_V-[Fe/H] relation to get the cluster distances, we find no significant effects on the absolute peak magnitude $M_V(TO)$ (see Table 1), with the exception of the one based on the revised Baade-Wesselink method (Fernley et al. (1998)), that provides a fainter magnitude by about 0.15 mag. Moreover, we have shown that the selection of the GC sample may influence the peak magnitude. In particular, for each given $M_V(RR)$-[Fe/H] relation, using only GCs with reddenings $E(B-V) \leq 1.0$ mag and Galactocentric distances $2 \leq R_{GC} \leq 35$ kpc, as earlier suggested by Secker (1992) to treat the Galaxy as if it were viewed from the outside, yields that the peak magnitude becomes systematically brighter by about 0.2 mag. As a whole, the combined effects of the adopted $M_V(RR)$ calibration and selective criteria are the main reason for the discordant Galactic peak magnitudes presented in the relevant literature.
2. Grouping the Galactic clusters by metallicity, the peak magnitude of the metal-poor ([Fe/H]< -1.0) subsample is brighter than that of the metal-rich ([Fe/H]> -1.0) one by about 0.36 mag. This empirical result meets, also in a quantitative way, the theoretical metallicity effects suggested by Asman et al. (1995) on the basis of synthetic GC populations with similar age and mass-function. As for the dependence on the Galactocentric distance, we found that the shape of the GCLF is broader for the outer halo ($R_{GC} > 8$ kpc) than for the inner one, but with no significant effect on the peak luminosity.

Send offprint requests to: M. Di Criscienzo

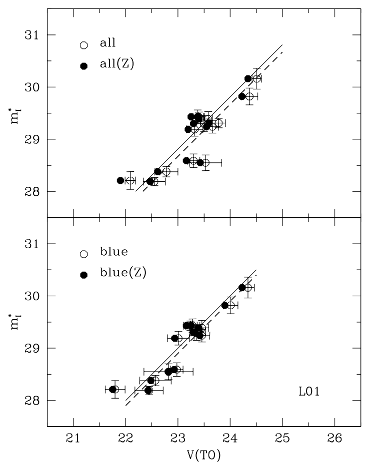

Fig. 2. SBF measurements versus GCLF peak magnitudes for the external galaxies studied by Larsen et al. (2001). The upper panel refers to the combined samples of GCs, while the lower one deals with blue (metal-poor) clusters. Open and filled circles depict observed and metallicity corrected peak magnitudes, respectively.

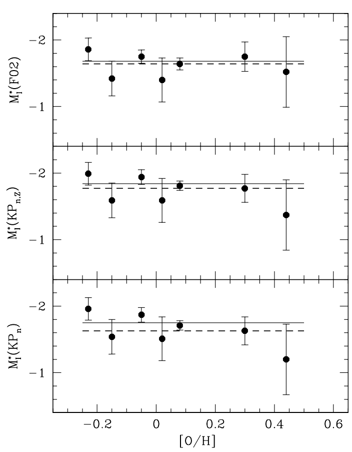

Fig. 3. SBF absolute magnitudes of calibrating galaxies as a function of the galaxy oxygen abundance. The three panels deal with the revised Cepheid distances by Freedman et al. (2001) without metallicity correction (KP_n) and adopting either the empirical correction ($KP_{n,Z}$) or the theoretical one (F02). Dashed and solid lines show the median value and the weighted mean, respectively.

Table 1. $M_V(TO)$ and σ values of GGCs as based on the $M_V(RR)$-[Fe/H] relations (H96: Harris (1996); S93: Sandage (1993); F98: Fernley et al. (1998); G03: Gratton et al. (2003); B03: Bono et al. (2003)). The results are based on the Harris catalog of GGCs with (a) denoting the full sample and (b) the Secker (1992) selection (see text).

Sample	$M_V(RR)$	$M_V(TO)$	σ
H96(a)	H96	−7.40±0.09	1.11±0.12
N=144	S93	−7.46±0.11	1.14±0.13
	F98	−7.26±0.08	1.11±0.10
	G03	−7.40±0.11	1.14±0.12
	B03	−7.40±0.09	1.14±0.11
H96(b)	H96	−7.58±0.11	1.00±0.11
N=100	S93	−7.66±0.11	1.04±0.12
	F98	−7.47±0.10	1.00±0.11
	G03	−7.62±0.11	1.02±0.12
	B03	−7.64±0.12	1.00±0.11

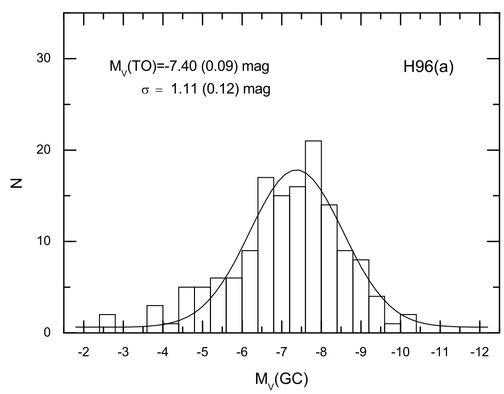

Fig. 1. GCLF for Galactic clusters in our full sample H96(a).

3. For the data by Barmby, Huchra & Brodie (2001) for metal-poor GCs in M31, we find a close agreement with the metal-poor Galactic sample results, as obtained according to the Secker's selection and using the same $M_V(RR)$ calibration to get cluster distances.
4. Concerning external galaxies with available deep photometry and close enough to have apparent GCLF extending below the turnover, we use the sample provided by Larsen et al. (2001) which contains galax-

ies showing a bimodal distribution of the GC color (and consequently of the metallicity). Given the absence of RR Lyrae stars to measure the galaxy distances, we use the I-band SBF measurements (Tonry et al. 2001) to evaluate the difference between the apparent peak magnitude $V(TO)$ and the SBF magnitude m_I^*, as adjusted to the fiducial color $(V-I)_0 = 1.15$ mag. In this way, we show that the blue (metal-poor) cluster component peaks at the same luminosity within ~ 0.2 mag, while the GCLFs of the full samples show constant values within ~ 0.3 mag as a consequence of the quite scattered peak magnitudes of the red globular clusters (see Fig. 2). The adoption of the theoretical metallicity correction by Asman et al. (1995), does not significantly modify these results, thus suggesting that, in external galaxies, blue and red globular clusters may have different ages and/or mass distributions.

5. Following the universally accepted assumption that the absolute calibration of the SBF m_I^* magnitude depends only on a zero-point, we analyze the Cepheid distances to the calibrating galaxies, as determined by Freedman et al. (2001) within a Cepheid distance scale based on $\mu_0(LMC) = 18.50$ mag. We show that the SBF absolute magnitude M_I^* of the calibrating galaxies becomes brighter with decreasing the galaxy oxygen abundance, suggesting the occurrence of a metallicity effect on the Cepheid distance scale. Once the Cepheid distances are corrected using either the empirical (Freedman et al. (2001)) or the theoretical (Fiorentino et al. (2002)) metallicity corrections, the trend is reduced (see Fig. 3). In particular, we find that the peak absolute magnitude of the extragalactic metal-poor clusters is practically identical to the Milky Way and M31 values, provided that the Secker's selection of Galactic clusters and the theoretical metallicity corrections on both the GCLF peak magnitude and the Cepheid distance are adopted.
6. Finally, *within a Cepheid and RR Lyrae distance scale calibrated on μ_0(LMC)=18.50 mag*, the three sets of metal-poor GCs give $M_V(TO)=-7.66\pm0.11$ mag (Milky Way), -7.65 ± 0.19 mag (M31), and -7.67 ± 0.23 mag (extragalactic clusters), i.e. a universal value of -7.66 ± 0.09 mag (weighted mean), with any modification of the LMC distance modulus producing a similar variation of the GCLF peak luminosity.

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