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Strömgren metallicity calibration: the m_1, $b - y$ relation

A. Calamida[1], G. Bono[1], P. B. Stetson[2], L. M. Freyhammer[3], S. Cassisi[4], F. Grundahl[5], A. Pietrinferni[4], M. Hilker[6], F. Primas[6], T. Richtler[7], M. Romaniello[6], R. Buonanno[8], F. Caputo[1], M. Castellani[1], C. E. Corsi[1], I. Ferraro[1], G. Iannicola[1], and L. Pulone[1]

[1] INAF-OAR, via Frascati 33, Monte Porzio Catone, Italy
e-mail: calamida@mporzio.astro.it
[2] DAO, HIA, National Research Council, Victoria, BC, Canada
[3] University of Central Lancashire, UK
[4] INAF-OACTe, Teramo, Italy
[5] Department of Physics and Astronomy, Aarhus University, Denmark
[6] ESO, Garching, Germany
[7] Universidad de Concepcion, Concepcion, Chile
[8] Universitá di Roma Tor Vergata, Rome, Italy

Abstract. We performed a new calibration of the Strömgren metallicity index m_1 based on the $b - y$ color of cluster red giant stars. The current Metallicity-Index-Color (MIC) relation is not linear in the color range $0.40 \lesssim b - y \lesssim 1.0$, but provides iron abundances of cluster and field red giants with an accuracy of ~ 0.25 dex.

Key words. globular clusters: general — stars: abundances — stars: evolution

1. Introduction

Empirical calibrations of the Strömgren metallicity index $m_1=(v - b) - (b - y)$ were usually based either on field stars (Anthony-Twarog & Twarog 1998, hereafter ATT98) or on a mix of cluster and field stars (Schuster & Nissen 1989; Hilker 2000). However, empirical spectroscopic evidence suggest that field and cluster stars present different heavy element abundance patterns (Gratton, Sneden & Carretta 2004). Moreover, the occurrence of CN and/or CH rich stars in globular clusters (GCs, Grundahl, Stetson, & Andersen 2002) along the red giant (RG, Hilker 2000) and the subgiant branches, and the main sequence (Kayser et al. 2006) opens the opportunity for an independent calibration of the Strömgren metallicity index only based on cluster stars.

Calamida et al. (2007, hereafter CA07) provided new empirical calibrations of the m_1 metallicity index based only on cluster RG stars. The new Metallicity-Index-Color (MIC) relations have been validated by adopting GC and field RGs with known spectroscopic iron abundances in the Zinn & West (1984) scale, and provide metallicity estimates with an accuracy ≤ 0.2 dex. The main advantage of CA07 MIC relations compared to similar relations available in the literature is that they adopt the $u - y$ and $v - y$ colors instead of the $b - y$.

The main advantage of the $u-y$ and $v-y$ colors is the stronger temperature sensitivity, and the MIC relations show a linear and well-defined slope in the $m_1,\ u-y/v-y$ planes (see CA07). We now perform a new empirical metallicity calibration based on the $b-y$ color, and show that the $m_1,\ b-y$ relation for cluster RGs is not linear over the color range $0.42 < (b-y)_0 < 1.05$. We then compare the new metallicity calibration with the CA07 $m_1,\ v-y$ MIC relation.

2. Metallicity estimates

In order to calibrate the metallicity index m_1 we selected four GCs, namely M92, M13, NGC 1851, NGC 104, that cover a broad range in metallicity ($-2.2 < [Fe/H] < -0.7$), are marginally affected by reddening ($E(B-V) \leq 0.04$), and for which accurate u, v, b, y Strömgren photometry well-below the Turn-Off region is available. The reader interested in details concerning the observations, data reduction and calibration procedures is referred to CA07[1]. We selected stars from the tip to the base of the RGB for each cluster in our sample. However, in order to avoid subtle systematic uncertainties in the empirical calibration, current cluster RG stars have been cleaned for the contamination of field stars. To accomplish this goal we used optical-Near-Infrared (NIR) color planes to split cluster and field stars. All cluster samples were reduced by $\approx 40\%$ after the color-color plane selection. We derived a MIC empirical relation that correlate the iron abundance of RG stars to their metallicity (m_1) and $b-y$ color. We assumed $E(b-y) = 0.70 \times E(B-V)$, adopting the reddening law from Cardelli et al. (1989) and $R_V = 3.1$. Reddening values for the selected clusters are from Harris (2003) and Schlegel et al. (1998). We applied a multilinear regression fit, by adopting cluster metallicities, to estimate the coefficients of the MIC relation. Note that the $m_1,\ b-y$ relation is not linear in the selected color range ($0.42 < (b-y)_0 < 1.05$) and we had to include a quadratic color term. The metallicities adopted in the fit are in the Zinn & West scale.

In order to validate the new empirical calibration we decided to apply it to five GCs for which accurate Strömgren photometry, absolute calibration, and sizable samples of RG stars are available. They are NGC 288, NGC 362, NGC 6752, NGC 6397, and M71. Fig. 1 (top panel) shows NGC 288 RG stars plotted in the $m_0,\ (b-y)_0$ plane after the optical-NIR color–color selection. The bottom panel of Fig. 1 shows the metallicity distribution obtained for the RGs using the new MIC relation between m_0 and $(b-y)_0$. The distribution was fitted with a Gaussian function, with a peak value of $[Fe/H]_{phot} = -1.30$ dex and a dispersion of $\sigma = 0.12$ dex (dashed-dotted line). This cluster metallicity estimate agrees quite well with the spectroscopic result ($[Fe/H]_{spec} = -1.40 \pm 0.12$, see Table 1). We find a similar agreement also for the other four GCs we adopted to validate the MIC relation. Fig. 2 shows the comparison between the mean photometric metallicity estimates (listed in Table 1) and the spectroscopic measurements (bottom panel). Data plotted in this figure indicate that they agree with each other within 1σ errors. Together with the validation based on GC stars we decided to test the accuracy of the new MIC relation using a sample of field RG stars. Strömgren photometry, spectroscopic abundances, and reddening estimates for these stars were retrieved by Anthony-Twarog & Twarog (1994; 1998, CA07 and references therein). We selected only RGs in the metallicity range $-2.4 < [Fe/H] < -0.5$ and in the color range $0.42 < (b-y)_0 < 1.05$. Fig. 2 shows the comparison between CA07 $m_1,\ v-y$ MIC relation and current $m_1,\ b-y$ relation (top panel) and a linear $m_1,\ b-y$ relation (middle panel). It is clear that the parabolic trend between the photometric $[Fe/H]_{vy}$ and $[Fe/H]_{by}$ metallicities decreases when adopting a quadratic $b-y$ color term in the MIC relation. The bottom panel of Fig. 2 shows the difference between the photometric and spectroscopic metallicities for the 85 field RGs as a function of their spectroscopic iron abundances. This figure shows that on average there is a systematic shift of ~ -0.1 dex towards

[1] The Strömgren catalogs adopted in this investigation can be retrieved from the following URL: http://www.mporzio.astro.it/spress/stroemgren.php

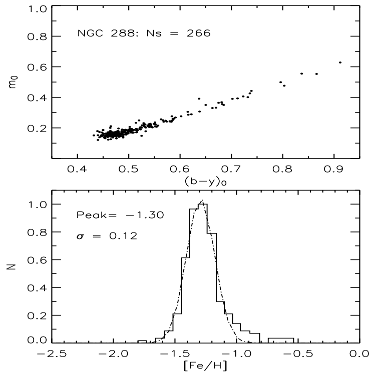

Fig. 1. Top: RGs in NGC 288 plotted in the (m_0, $(b-y)_0$) plane. Candidate cluster stars were selected according to the optical-NIR color plane. Bottom: Metallicity distribution obtained applying the $m_{10}, (b-y)_0$ MIC relation to the RGs of the top panel. The distribution was fitted with a Gaussian (dashed-dotted line). The peak value and the dispersion are labeled.

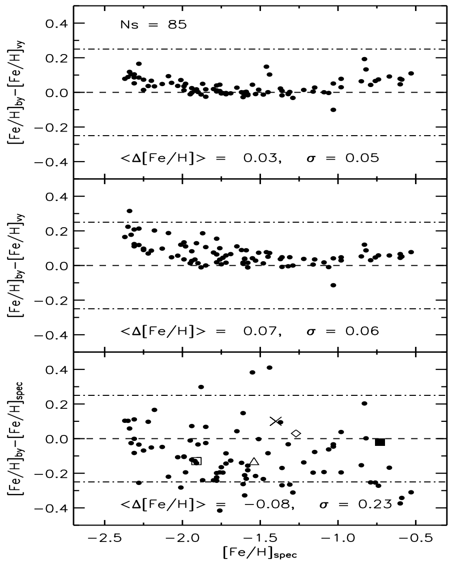

Fig. 2. Difference between photometric $[Fe/H]_{vy}$ and $[Fe/H]_{by}$ metallicities for the 85 field RGs by ATT98. The $[Fe/H]_{by}$ metallicities are estimated adopting a quadratic (top panel) and a linear (middle) $b-y$ color term. Bottom: Difference between photometric ($[Fe/H]_{by}$, quadratic) and spectroscopic metallicities plotted versus $[Fe/H]_{spec}$ for the 85 RGs. Different symbols show the metallicity estimates of the five validation GCs: -empty square: NGC 6397, -empty triangle: NGC 6752, - cross: NGC 288, -empty diamond: NGC 362, -filled square: M71.

Table 1. Spectroscopic measurements from Rutledge et al. (1997) and photometric metallicity estimates for the GCs adopted to validate the Strömgren metallicity index.

GC	$[Fe/H]_{spec}$	$[Fe/H]_{phot}$
NGC 6397	-1.91 ± 0.14	-2.04 ± 0.15
NGC 6752	-1.54 ± 0.09	-1.67 ± 0.18
NGC 288	-1.40 ± 0.12	-1.30 ± 0.11
NGC 362	-1.27 ± 0.07	-1.24 ± 0.30
M71	-0.73 ± 0.05	-0.48 ± 0.34

more metal-poor values, as already found for the m_1, $v-y$ MIC relation by CA07. In spite of this systematic difference and the mild residual parabolic trend, the intrinsic dispersion is smaller than 0.25 dex.

3. Conclusions

We present a new empirical calibration for the Strömgren m_1 metallicity index based on the $b-y$ color. We included a quadratic color term in the MIC relation in order to account for the non-linearity of the m_1, $b-y$ relation for RG stars in the color range $0.42 < (b-y)_0 < 1.05$. The new MIC relation provides metallicity estimates for both cluster and field RGs with an accuracy of $\sim$ 0.25 dex.

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