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A SET OF STANDARDS FOR STELLAR CLASSIFICATION OF METAL-DEFICIENT STARS IN THE VILNIUS SYSTEM

A. Bartkevičius and R. Lazauskaitė

Institute of Theoretical Physics and Astronomy, Goštauto 12, Vilnius 2600, Lithuania

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Abstract. A new set of 580 metal-deficient standard stars is presented, which is used for stellar classification in the Vilnius photometric system by the method of comparison of intrinsic colour indices or reddening-free Q-parameters of the observed and standard stars. While compiling this set of standards, emphasis was placed on the absolute magnitudes of stars.

Key words: techniques: photometric – stars: fundamental parameters – stars: Population II

1. Introduction

For the classification of stars in the Vilnius photometric system, a method similar to the Geneva photometric "boxes" is often used. It is based on the assumption that stars with closely similar colour indices or reddening-free Q-parameters have nearly the same astrophysical parameters T_e, [Fe/H] and $\log g$ or M_V. To classify stars in this way, we need a set of standard stars for which both the Vilnius photometry and the astrophysical parameters are available. Clearly, the classification accuracy depends on the accuracy of the parameters of standard stars and on the completeness of the set of standards. For the sake of accuracy, the set of standards should cover all types of the stars studied. Up to now, the classification of metal-deficient stars in the Vilnius system has relied on a set of standards compiled by Bartkevičius and Sperauskas (1983). Since the number of observations in the Vilnius system and the number of stars with reliably estimated astrophysical parameters have increased, we have attempted to form a new set of standards, containing more metal-deficient stars with known astrophysical parameters than the previous set.

2. The groups of standard stars

The metal-deficient stars for our set were selected from the General Catalogue of the Vilnius Photometric System (Straižys and Kazlauskas 1993). Of about 1000 stars selected previously, only 580 stars with astrophysical parameters collected from the literature or calculated by us have been included into our set. The set stars was divided into groups (Table 1) according to their metallicity, luminosity and peculiarity by using the criteria described by Bartkevičius and Sperauskas (1983), Bartkevičius (1984a, 1984b) and Šleivytė and Bartkevičius (1990).

The distribution of all of the standard stars by metallicity is shown in Fig. 1. The histogram is divided into two parts. One part

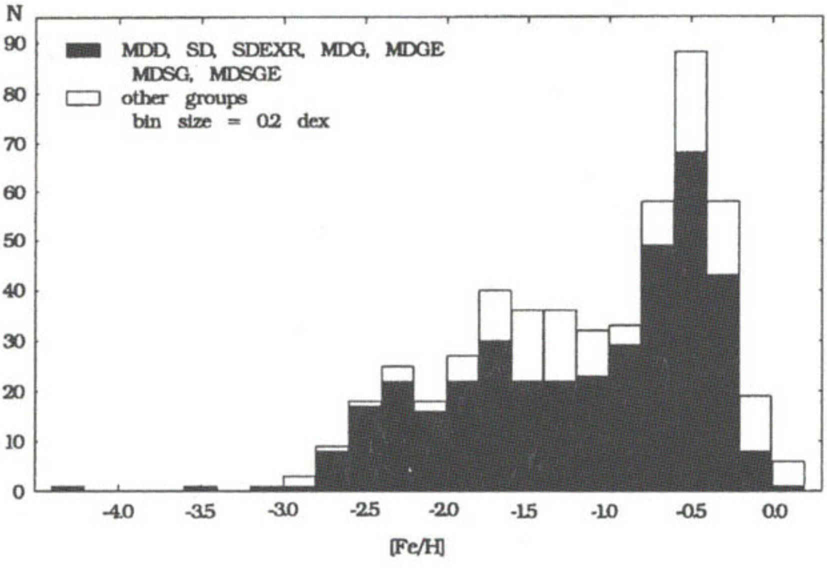

Fig. 1. Distribution of standard stars by metallicity.

includes dwarfs with moderate metal deficiency, subdwarfs, metal-deficient giants and subgiants, while its other part embraces stars in the remaining groups.

Table 1. The groups of standard stars

No.	Group	Abbreviation	N
1.	Dwarfs with moderate metal deficiency ($-0.2 \leq$[Fe/H]<-0.6; $M_V \geq 4.0$)	MDD	84
2.	Subdwarfs ($-0.6<$[Fe/H]≤ -1.3; $M_V \geq 4.0$)	SD	100
3.	Extreme metal-deficient subdwarfs ([Fe/H]<-1.3; $M_V \geq 4.0$)	SDEXTR	66
4.	Metal-deficient giants ($-0.3 \leq$[Fe/H]≤ -1.3; $M_V \leq 2.0$)	MDG	57
5.	Extreme metal-deficient giants ([Fe/H]<-1.3; $M_V \leq 2.0$)	MDGE	67
6.	Metal-deficient subgiants ($-0.3 \leq$[Fe/H]≤ -1.3; $2.0<M_V<4.0$)	MDSG	13
7.	Extreme metal-deficient subgiants ([Fe/H]<-1.3; $2.0<M_V<4.0$)	MDSGE	6
8.	Asymptotic giant branch stars	AGB	7
9.	CH giants	CH	37
10.	Carbon variables of RV Tau-type	CH-RV	5
11.	CH subdwarfs	SDCH	5
12.	CH subgiants	CH-SG	3
13.	Metal-deficient barium stars	MD-BA	9
14.	Weak G-band stars	WG	4
15.	Blue horizontal-branch stars	BHB	13
16.	Red horizontal-branch stars	RHB	27
17.	RR Lyrae-type stars	RR Lyr	10
18.	SX Phe-type stars	SX Phe	2
19.	λ Bootis-type stars	λ Boo	5
20.	Blue stragglers	BS	5
21.	O-B subdwarfs	SDOB	10
22.	Helium-rich stars	HE	10
23.	R CrB-type stars	R CrB	2
24.	UU Herculis-type stars	UU Her	10
25.	RV Tau-type stars	RV Tau	4
26.	SRd-type stars	SRd	6
27.	White dwarfs	WD	13

3. The values of T_e, [Fe/H] and $\log g$ of the standard stars

228 stars of the set of standards have estimations of T_e, [Fe/H] and $\log g$. The values of these parameters were mostly taken from the Catalogue of Mean [Fe/H], T_e and $\log g$ Values of Population II F–M Stars (Bartkevičius and Lazauskaitė 1992b). The data in this catalogue are based mainly on the estimations from high-resolution ($\leq$ 20 Å/mm) spectra. In order to compile data for a greater number of metal-deficient stars, some estimations from intermediate-resolution spectra were also included. The average standard deviations of a single determination in this Catalogue are 0.16 dex, 116 K and 0.29 dex in metallicity, temperature and surface gravity, respectively.

For horizontal branch stars, RR Lyrae-type stars, blue stragglers and λ Boo-type stars, the [Fe/H], T_e and $\log g$ values have been taken from Sperauskas (1987). For UU Herculis-type stars, the astrophysical parameters come from Bartkevičius (1992).

4. Absolute magnitudes of the standard stars

Since the accuracy of the absolute magnitude estimation for metal-deficient stars from the previous calibration (Bartkevičius and Sperauskas 1983) is not satisfactory (about $\pm$ 1 mag), we attempted to include into our set of standards as many stars with known absolute magnitudes as possible. As it is well known, the absolute magnitudes can most accurately be calculated from trigonometric parallaxes. The parallax values of the standard stars were taken from the preliminary General Catalogue of Trigonometric Stellar Parallaxes (van Altena et al. 1991). In order to eliminate systematic errors in the absolute magnitude, Lutz and Kelker (1973) statistical corrections were added, taking into account the ratio of the parallax error to the parallax itself. However, only 43 stars from the set have sufficiently accurate parallaxes ($\sigma_\pi/\pi \leq 0.175$). The main part of these are subdwarfs; for the remaining stars we have five giants, one metal-deficient barium star and six white dwarfs.

To extend our set, we have also used less reliable determinations of the absolute magnitudes. For the estimation of the absolute magnitudes of metal-deficient giants, the branches of globular clusters of different metallicities can be used. Unfortunately, until now only a few brightest stars of some globular clusters have been observed in the Vilnius system, and the accuracy of these observations is not satisfactory. Therefore, for the estimation of M_V of metal-deficient stars of our set we used the giant branches of globular clusters from the literature. Then the $(B-V)_0$ indices (after correcting the observed values for reddening) were taken from the *UBV* Photoelectric Photometry Catalogue (Mermilliod 1986) or, in some cases, were derived from the $(Y-V)_0$ index of the Vilnius system by using the relation between these two colours from Bartkevičius and Lazauskaitė (1992a). By this method, we adopted the standard deviation of a single estimation of M_V to be $\pm$ 0.8 mag.

The absolute magnitudes of RR Lyrae-type stars were calculated taking into account their metallicity. By using different methods, different slopes of the relation between the absolute magnitude and metallicity, varying from 0.17 to 0.40, were obtained (Buonanno et al. 1990, Sandage and Cacciari 1990). For RR Lyrae-type stars observed near the minimum phase, we have used the relation between M_V and [Fe/H] derived by Liu and Janes (1990) by the Baade-Wesselink method:

$$\langle M_V(\mathrm{RR})\rangle = 1.05 + 0.20\ [\mathrm{Fe/H}].$$

But the phase interval used by Liu and Janes was $0.30 - 0.80$. We have not applied any corrections to our M_V due to two reasons noticed by Cacciari et al. (1992): no simple relation exists for transforming the Baade-Wesselink method solutions to the other phase interval; the slope of the relation between M_V and [Fe/H] vary according to the phase interval used for analyses by the Baade-Wesselink method only slightly, while the zero point remains almost the same. The standard deviation of M_V calculated in this way is about 0.3 mag.

For blue horizontal-branch stars, we adopt, as it was done by Beers et al. (1990),

$$M_V = 1.040 - 4.423\ (B-V) + 17.740\ (B-V)^2 - 37.700\ (B-V)^3.$$

In order to achieve the consistency with our M_V values of RR Lyrae-type stars, we have to add to M_V of each star a correction which depends slightly on metallicity, e.g., when [Fe/H]=0.0, this correction is equal to 0.45; when [Fe/H]=–1.0, the correction is 0.25.

31 stars from our set are members of old moving groups. Their absolute magnitudes were taken from Eggen's papers, with the standard deviation adopted to be $\pm$0.3.

For CH stars, the absolute magnitudes were taken from the Catalogue of CH and Metal-Deficient Barium Stars (Šleivytė and Bartkevičius 1990). In this case the accuracy of M_V is about $\pm$1.0.

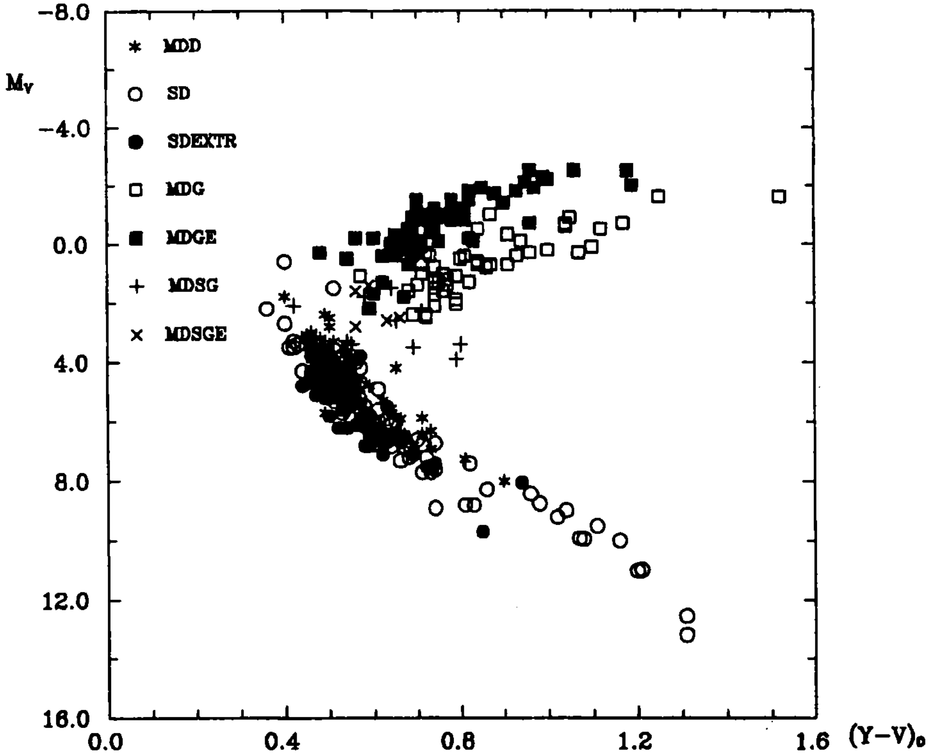

Fig. 2. The HR diagram for dwarfs with moderate metal deficiency, subdwarfs, metal-deficient giants and subgiants. $(Y-V)_0$ is the intrinsic colour index of the Vilnius photometric system, M_V is the absolute magnitude obtained from the literature sources described in Section 2.

The absolute magnitudes of blue stragglers were assumed with respect to their metallicity according to their mean location in the HR diagram of globular clusters published by Fusi Pecci et al. (1992).

For λ Boo-type stars, the absolute magnitudes were calculated from $\log g$ given by Sperauskas (1987). After analyzing positions of this type of stars in the $\log g, T_e$ diagram with evolutionary tracks (Stürenburg 1993) we assumed that their masses are 2 $M_\odot$.

For helium-rich stars as well as for R CrB-type stars, the absolute magnitudes were estimated from the diagram M_V, $\log T_e$ (Drilling 1986).

The individual values of M_V for O-B subdwarfs have been collected from the existing literature data. Following Downes (1986), for

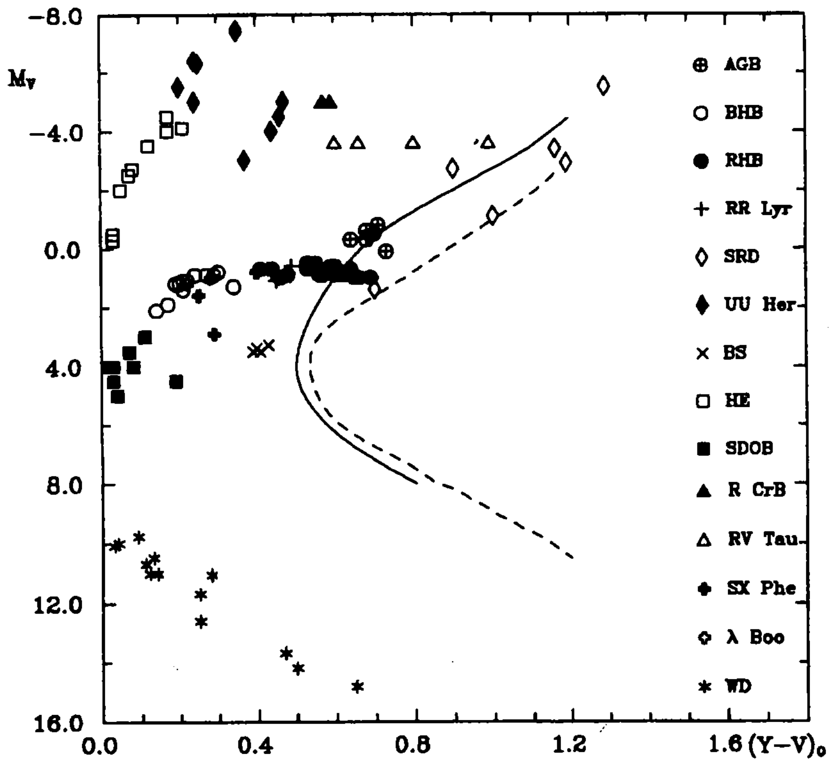

Fig. 3. The HR diagram for the remaining groups of stars except CH, MD-Ba and WG stars. The dashed line is the mean sequence of subdwarfs and giants with moderate metal deficiency ($[Fe/H] \geq -1.3$). The solid line is the mean sequence of subdwarfs and giants with large metal-deficiency ($[Fe/H] < -1.3$).

some of this type of stars, the mean absolute magnitudes were adopted as follows: $M_V = 4.0$ for sdB; $M_V = 4.5$ for sdO.

The absolute magnitudes for stars of other types were collected from the literature in which spectroscopic or photometric determinations, mostly in the DDO, *RI* and *uvbyβ* systems, were available.

Except for the absolute magnitudes of stars with known trigonometric parallaxes and also of RR Lyrae-type stars, M_V values determined by various methods were averaged with the weights inversely proportional to the standard deviations of estimated absolute magnitudes. For averaging, we used only those M_V values which were consistent to within 2 magnitudes.

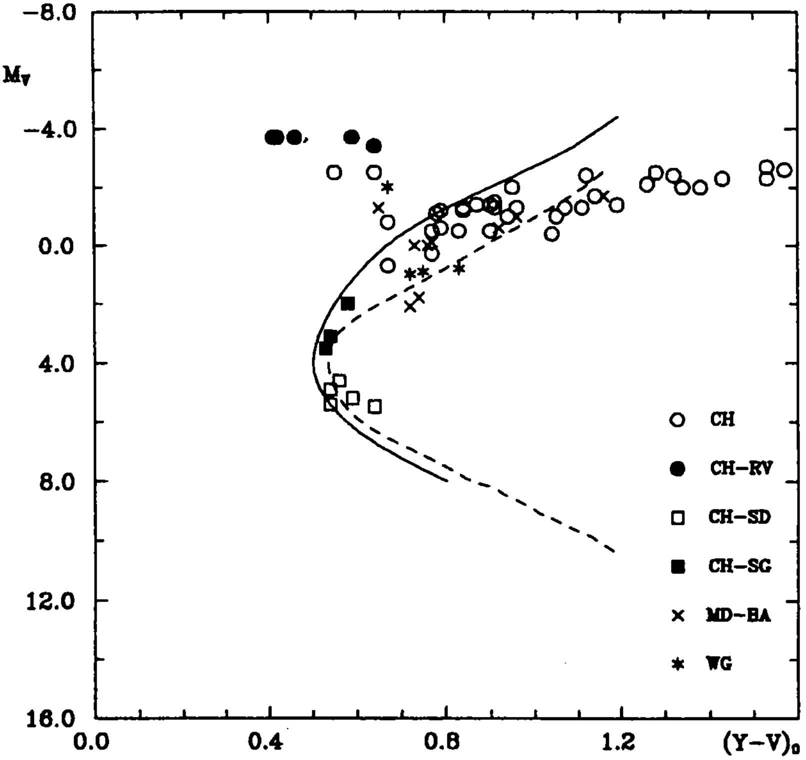

Fig. 4. The HR diagram for CH, MD-Ba and WG stars.

Thus, we have in our set a total of 575 stars with estimated absolute magnitudes. The HR diagrams for these stars divided into the adopted groups are shown in Figs. 2, 3 and 4. The mean standard deviation of a single estimation of M_V for the total sample is 0.45 mag, and the average number of M_V estimations for one star is 2.2. The described set of metal-deficient stars is used for classification of stars of the above-mentioned types in the Vilnius photometric system by the method of comparison of intrinsic colour indices of the program and the standard stars.

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