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CLASSIFICATION OF METAL-DEFICIENT DWARFS IN THE VILNIUS PHOTOMETRIC SYSTEM

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Abstract. Methods used for the quantitative classification of metal-deficient stars in the *Vilnius* photometric system are reviewed. We present a new calibration of absolute magnitudes for dwarfs and subdwarfs, based on *Hipparcos* parallaxes. The new classification scheme is applied to a sample of Population II visual binaries.

Key words: techniques: photometric – stars: fundamental parameters (classification) – stars: Population II

1. INTRODUCTION

The possibilities of the *Vilnius* seven-color photometric system for identification and quantitative classification of metal-deficient stars were shown in several papers (see Bartkevičius & Lazauskaitė 1996 and references therein). In the present paper we review briefly the methods used in this photometric system for the determination of astrophysical parameters for such stars. Also, the new calibration of absolute magnitudes for dwarfs and subdwarfs, based on *Hipparcos* parallaxes, is presented. Using the methods described and the new M_V calibration, we have classified 25 suspected visual binaries that are supposed to belong to Population II. On the basis of the results of this classification, the visual components of the systems are assigned to the following categories: members of visual binaries, suspected members and nonmembers.

2. METHODS OF PHOTOMETRIC CLASSIFICATION

For the classification of metal-deficient stars in the *Vilnius* photometric system several methods are used:

(1) Comparison of program and standard stars (Figure 1). Here, the program stars are those whose parameters are to be estimated and the standard stars are stars with well-known astrophysical parameters. The measured quantities used in this method are color indices (CI) or reddening-free Q parameters. To choose the standard stars whose observational quantities match most closely those of a given program star, the σ-criterion is used. The final astrophysical parameters of the program stars are then calculated by averaging the parameters of the closest standard stars.

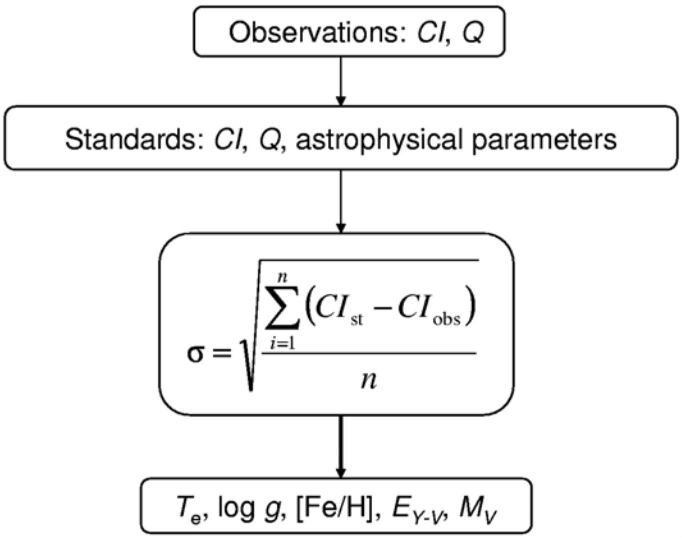

Fig. 1. The scheme of classification of metal-deficient stars in the Vilnius photometric system (the comparison method).

(2) Metallicity calibration of Bartkevičius & Sperauskas (1983), applicable to F–M stars. The accuracy of [Fe/H] estimation is about 0.2 dex.

(3) Effective temperature and surface gravity calibrations of Tautvaišienė (1987) and Tautvaišienė & Lazauskaitė (1993) which apply to metal-deficient giants. The accuracy of estimations is ± 85 K for T_e and 0.3 dex for $\log g$.

(4) Absolute magnitude calibration for dwarfs and subdwarfs given by Lazauskaitė (1995). It is based on the parallaxes measured before the *Hipparcos* mission and allows one to estimate M_V with a

standard deviation of ±0.6 mag. In the next section the new M_V calibration based on the *Hipparcos* parallaxes will be presented.

3. M_V CALIBRATION FOR DWARFS AND SUBDWARFS

Photometric observations for the new calibration were taken from the General Photometric Catalogue of Stars Observed in the *Vilnius* System (Straižys & Kazlauskas 1993) and from the Supplement to this Catalogue (Kazlauskas 2003). Also, our own new and as yet unpublished observations were included. All these observations were crosschecked with the *Hipparcos* Main Catalogue (ESA 1997). In total, 5124 stars were selected. From these, variable stars and binaries were rejected, as well as stars with $\sigma\pi/\pi > 0.175$.

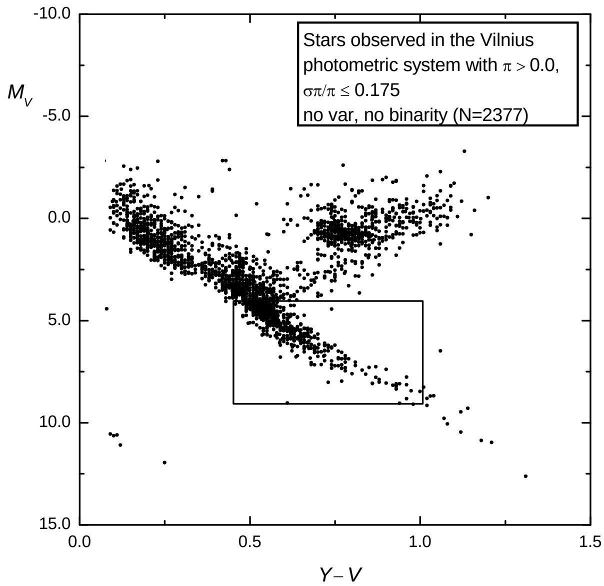

Fig. 2. Selection of stars for M_V calibration of dwarfs and subdwarfs in the *Vilnius* photometric system.

The HR diagram of the selected stars is shown in Figure 2. Only stars in the region marked by the rectangle, i.e., populated with dwarfs and subdwarfs, were used for M_V calibration. They are displayed also in Figure 3, but denoted by different symbols according to their metallicity. No corrections that would eliminate the data selection effects were added to the absolute magnitudes calculated from the *Hipparcos* parallaxes.

To determine the calibration curves we divided our sample stars into five [Fe/H] intervals (see Figure 3). For the stars in each interval,

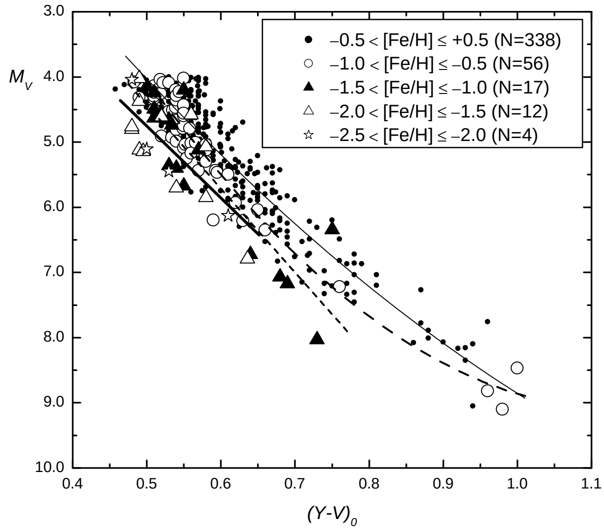

Fig. 3. HR diagram for the sample dwarfs and subdwarfs. The calibration curves are drawn for [Fe/H] intervals –0.5 to +0.5 (thin solid line), –1.0 to –0.5 (dashed line), –1.5 to –1.0 (short dashed line), and –2.0 to –1.5 (thick solid line).

except for the four stars with the lowest [Fe/H] values, the following formula was proved:

$$M_V = a_0 + a_1 \cdot (Y - V)_0 + a_2 \cdot (Y - V)_0^2. \qquad (1)$$

Here, $(Y–V)_0$ is the intrinsic color index of the *Vilnius* photometric system and a_0, a_1 and a_2 are the constants of the fit. If the coefficient a_2 was small in comparison with its error $\sigma(a_2)$, or, to be more specific, $a_2 < 3\,\sigma(a_2)$, the square term was rejected from the formula. The coefficients a_0, a_1 and a_2 for the different metallicity ranges are given in Table 1. In the last two columns, the standard deviation σ_{M_V} and the correlation coefficient R-square for each equation are given.

Table 1. The coefficients a_0, a_1 and a_2 of relation (1) for different ranges of [Fe/H].

[Fe/H] range	a_0	a_1	a_2	$(Y-V)_0$	σ_{M_V}	R-square
–0.5 to 0.5	–3.238	16.984	–4.891	0.45 – 0.96	0.36	0.87
–1.0 to –0.5	–6.963	28.191	–12.364	0.50 – 1.00	0.30	0.93
–1.5 to –1.0	–1.986	12.836	–	0.50 – 0.75	0.54	0.81
–2.5 to –2.0	–0.752	11.014	–	0.50 – 0.64	0.52	0.56

In Figure 4, the absolute magnitudes calculated using our new calibration are compared with those determined using the pre-*Hipparcos*

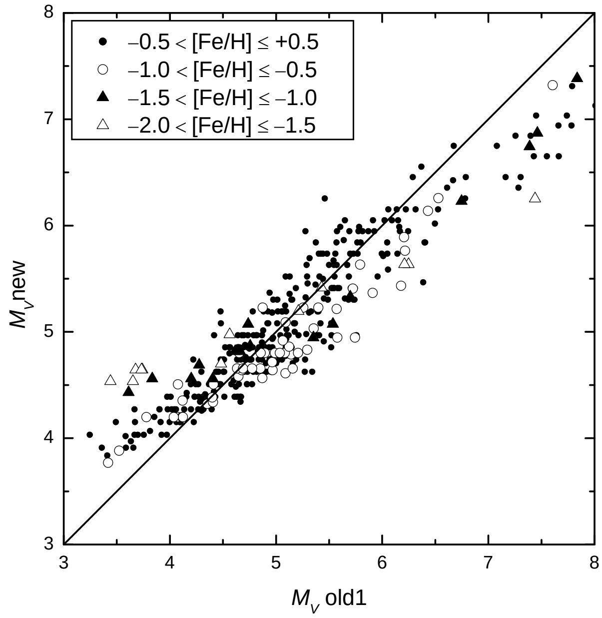

Fig. 4. Comparison of the absolute magnitudes M_V calculated using the old (pre-*Hipparcos*) calibration (formula (1) of Lazauskaitė 1995) and the new calibration given in this paper.

calibration of Lazauskaitė (1995). The differences between the old and the new M_V for the intrinsically brightest and faintest stars in the sample reach 1 mag. Such differences could be due to quite different star samples used for both calibrations. It must be emphasized that our present sample is also affected by selection effects. It does not provide a complete magnitude- or volume-limited sampling but is simply drawn from the *Hipparcos* stars common to available *Vilnius* observations.

4. CLASSIFICATION OF POPULATION II VISUAL BINARIES

Using the methods described in Section 2 and the new M_V calibration given in Section 3, we have classified 25 visual binaries observed by one of us (S.B.) in 1996–1998 with the 1 m telescope at the Maidanak Observatory. These stars were selected for observations from the list of suspected visual binaries compiled by Bartkevičius (2000), as satisfying either criterion for Population II star status: metal-deficiency or large tangential velocity.

The 25 visual binary systems are listed in Table 2, together with the results of our classification: photometric spectral type, [Fe/H], temperature-sensitive intrinsic color index $(Y{-}V)_0$, absolute magnitude M_V and distance r to each component. The distance errors were calculated using the formula

$$\sigma_r = 0.46 \cdot \sqrt{{\sigma_V}^2 + {\sigma_{M_V}}^2} \cdot r, \tag{2}$$

assuming the following uncertainties: $\sigma_V = 0.01$ mag and $\sigma_{M_V} = 0.6$ mag. The interstellar reddening for all stars was found to be negligible (within 0.02 mag) and the error in extinction A_V was therefore ignored in the calculation of distance errors. In the M_V column, label "c" indicates that a given value of M_V is determined from the method of comparison (Section 2), not by using formula (1) which was not applicable due to $(Y{-}V)_0$ or M_V falling outside the calibration range.

Table 2. Results of classification of Population II visual binaries.

No.	Star	Spectral type	[Fe/H]	$(Y{-}V)_0$	M_V	r(pc)	Mem.
1.	HD 224930AB	MD-G1 V	–0.43	0.59	5.08	14±4	
	HD 224930C	G0 IV, CH?	0.16	0.62	2.41c	307±85	NM
	HD 224930D	G0 V	–0.14	0.54	4.51	825±228	NM
	HD 224930D1	sd F3, BS	–1.01	0.51	4.56	514±142	NM
2.	HD 3266AB	MD-G3 V	–0.39	0.59	5.08	37±10	
	G 69-004C	MD-K0 III–IV	–0.25	0.75	2.00c	824±228	NM
3.	HD 23439AB	sd K1	–0.81	0.66	5.84	23±6	
	HD 23439C	K2 V	–0.06	1.10	6.40c	106±29	NM
4.	BD +37°878AB	K1 V	–0.07	0.69	6.15	16±4	
	G 39-001CD	MDG-K2	–0.87	1.08	–0.31c	594±164	NM
5.	HD 134942A	F6 V	–0.07	0.50	4.03	144±40	
	HD 134942B	G5 V	0.01	0.60	5.19	85±24	M?
6.	HD 135101A	G2 V	0.09	0.59	5.08	21±6	
	HD 135101B	G7 V	–0.10	0.62	5.41	26±7	M
7.	HD 139341A	K1 V	–0.05	0.70	6.25	13±3	
	HD 139323B	K1 V	–0.09	0.74	6.65	16±4	M
8.	BD +57°1621A	MD-F7 V	–0.39	0.50	4.03	170±47	
	BD +57°1621B	G1 V, CH?	–0.13	0.54	4.51	171±47	M?
9.	HD 153557A	K3 V	–0.07	0.73	6.55	18±5	
	HD 153525B	K3 V	–0.02	0.74	6.65	18±5	M
10.	LDS 585A	K7 V	0.00	0.82	7.40	12±3	
	LDS 585B	sd K5	–0.83	1.16	7.94c	26±7	NM

Table 2 (continued)

No.	Star	Spectral type	[Fe/H]	$(Y{-}V)_0$	M_V	r(pc)	Mem.
11.	LDS 4741A	K3 V	–0.06	0.77	6.94	154±43	
	LDS 4741B	K5 V	0.00	0.95	8.48	90±25	M
12.	LDS 995A	MD-G0 V	–0.36	0.55	4.62	59±16	
	LDS 995B	G5 V, MD	–0.15	0.60	5.19	79±22	M
13.	BD +74°719A	G8 V	0.02	0.63	5.52	84±23	
	BD +74°718B	G8 V	0.02	0.63	5.52	85±23	M
14.	HD 165908AB	sd F8	–0.51	0.52	4.35	14±4	
	HD 165908C	RR-F4, RHB	–0.75	0.54	1.14c	1716±474	NM
	HD 165908D	G8 V	0.07	0.64	5.63	257±71	NM
	HD 165908E	F5 V, MD	–0.38	0.47	3.66	700±193	NM
	HD 165908F	MD-G0 V, CH?	–0.48	0.61	5.30	246±68	NM
	HD 165908G	G8 V	0.20	0.64	5.63	144±40	NM
15.	HD 169822A	MD-G5 V	–0.33	0.59	5.08	36±10	
	HD 169889B	G8 V	–0.10	0.63	5.52	36±10	M
16.	LDS 1014A	sd G5	–0.57	0.60	5.50	170±47	
	LDS 1014B	K3 V, MD?	–0.17	0.75	6.75	209±58	NM
17.	HD 185657A	K0 III–IV	–0.11	0.77	0.95c	127±35	
	HD 185657B	K0 III–IV	–0.05	0.78	3.12c	578±159	NM
	HD 185657CD	K0 III–IV	0.00	0.74	0.66c	1055±291	NM
18.	HD 188268A	K1 V	–0.01	0.68	6.05	35±10	
	HD 188311B	K2 V	–0.15	0.70	6.25	34±9	M
19.	BD +30°4470A	G3 V	0.11	0.59	5.08	98±27	
	BD +30°4470B	G3 V	0.06	0.60	5.19	120±33	M
20.	LDS 760A	sd K1	–1.05	0.69	6.87	53±15	
	LDS 760B	MD-K4 V pec	–0.49	0.80	7.22	111±31	NM
21.	LDS 5955A	K3 V	–0.07	0.80	7.22	147±41	
	LDS 5955B	K3 V	–0.18	0.75	6.75	190±53	M
22.	BD +38°4955A	sd G5 extr	–2.11	0.62	6.08	98±27	
	BD +38°4955B	F3 V	–0.19	0.54	4.51	168±46	NM
	BD +38°4955C	K2 III	–0.18	0.92	1.11c	857±237	NM
	BD +38°4955D	K2 III	–0.05	0.99	1.70c	935±258	NM
	BD +38°4955E	MD-F3 IV	–0.42	0.53	2.83c	1152±318	NM
23.	HD 221170A	MDGE-K0	–2.10	0.89	–1.41c	664±183	
	HD 221170B	K0 III, MD?	–0.31	0.89	1.16c	1192±329	NM
24.	LDS 6055A	sd K7	–0.81	1.11	9.44c	48±13	
	LDS 6055B	sd K7	–0.66	1.17	9.07c	64±18	M
25.	LDS 6057A	G3 V, MD	–0.38	0.65	5.74	171±47	
	LDS 6057B	sd F6 extr pec	–2.10	0.60	1.58c	2167±598	NM

According to the difference in distance to the components of the systems, the stars were grouped into three categories: members of visual binaries (M), suspected members (M?), and nonmembers (NM). We note that the mean difference in [Fe/H] found between the members of 11 visual binary systems (group M) is 0.11 dex, which is even smaller than a typical error of photometric [Fe/H] determination. This suggests the possibility that the members may be physically connected.

5. SUMMARY

The methods used for the classification of metal-deficient stars in the *Vilnius* photometric system were summarized. The new calibration of absolute magnitude for dwarfs and subdwarfs, based on *Hipparcos* parallaxes, was presented. The standard deviations of M_V estimations are from ± 0.30 mag to ± 0.54 mag, depending on the metallicity range. Using the methods described, we classified 25 suspected Population II visual binaries observed in the *Vilnius* photometric system. Among them, we found 11 systems with probable members and 2 systems with suspected members. The visual components of the remaining 12 systems photometrically show no any indication of their membership.

Further analysis of our photometric results on possible members of visual binaries, with inclusion of astrometric and radial velocity data, will be presented in a forthcoming paper.

REFERENCES

Bartkevičius A. 2000. Lists of suspected Population II binary stars (unpublished)

Bartkevičius A., Lazauskaitė R. 1996, Baltic Astronomy, 5, 1

Bartkevičius A., Sperauskas J. 1983, Bull. Vilnius Obs., No. 63, 3

ESA 1997, *The Hipparcos and Tycho Catalogues* (ESA SP-1200)

Kazlauskas A. 2003, *Photometric Catalog of Stars Observed in the Vilnius System (Supplement)*, private communication

Lazauskaitė R. 1995, Baltic Astronomy, 4, 48

Straižys V., Kazlauskas A. 1993, *General Photometric Catalog of Stars Observed in the Vilnius System*, Baltic Astronomy, 2, 1

Tautvaišienė G. 1987, Bull. Vilnius Obs., 78, 3

Tautvaišienė G., Lazauskaitė R. 1993, Baltic Astronomy, 2, 256