Photoelectric search for peculiar stars in open clusters XV. Feinstein 1, NGC 2168, NGC 2323, NGC 2437, NGC 2547, NGC 4103, NGC 6025, NGC 6633, Stock 2, and Trumpler 2

Paunzen, E.; Netopil, M.; Maitzen, H.M.; Pavlovski, Krešimir; Schnell, A; Zejda, M.

A&A 564, A42 (2014)
DOI: 10.1051/0004-6361/201423521

Astronomy & Astrophysics

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XV. Feinstein 1, NGC 2168, NGC 2323, NGC 2437, NGC 2547, NGC 4103, NGC 6025, NGC 6633, Stock 2, and Trumpler 2*

E. Paunzen[1], M. Netopil[1,2], H. M. Maitzen[2], K. Pavlovski[3], A. Schnell[2], and M. Zejda[1]

[1] Department of Theoretical Physics and Astrophysics, Masaryk University, Kotlářská 2, 611 37 Brno, Czech Republic
e-mail: epaunzen@physics.muni.cz
[2] Universitätssternwarte, Türkenschanzstr. 17, 1180 Wien, Austria
[3] Department of Physics, Faculty of Science, University of Zagreb, Bijenička cesta 32, 10 000 Zagreb, Croatia

Received 28 January 2014 / Accepted 20 February 2014

ABSTRACT

Context. The chemically peculiar (CP) stars of the upper main sequence are mainly characterized by strong overabundances of heavy elements. Two subgroups (CP2 and CP4) have strong local magnetic fields which make them interesting targets for astrophysical studies. This star group, in general, is often used for the analysis of stellar formation and evolution in the context of diffusion as well as meridional circulation.

Aims. In continuation of a long term study of CP stars (initiated in the 1980s), we present new results based on photoelectric measurements for ten open clusters that are, with one exception, younger than 235 Myr. Observations in star clusters are favourable because they represent samples of stars of constant age and homogeneous chemical composition.

Methods. The very efficient tool of Δa photometry was applied. It samples the flux depression at 5200 Å typically for CP stars. In addition, it is able to trace emission line Be/Ae and λ Bootis stars. Virtually all CP2 and CP4 stars can be detected via this tool, and it has been successfully applied even in the Large Magellanic Cloud. For all targets in the cluster areas, we performed a kinematic membership analysis.

Results. We obtained new photoelectric Δa photometry of 304 stars from which 207 objects have a membership probability higher than 50%. Our search for chemically peculiar objects results in fifteen detections. The stars have masses between 1.7 $M_{\odot}$ and 7.7 $M_{\odot}$ and are between the zero- and terminal-age-main-sequence. We discuss the published spectral classifications in the light of our Δa photometry and identify several misclassified CP stars. We are also able to establish and support the nature of known bona fide CP candidates.

Conclusions. It is vital to use kinematic data for the membership determination and also to compare published spectral types with other data, such as Δa photometry. There are no doubts about the accuracy of photoelectric measurements, especially for stars brighter than 10th magnitude. The new and confirmed CP stars are interesting targets for spectroscopic follow-up observations to put constraints on the formation and evolution of CP stars.

Key words. stars: chemically peculiar – stars: early-type – techniques: photometric – open clusters and associations: general

1. Introduction

More than a century ago, Maury (1897) detected a subclass of A-type stars with peculiar lines and line strengths, which thereafter became known as Ap stars. Later on, the spectral range was widened and the class become known as chemically peculiar (CP) stars of the upper main sequence. These stars revealed other peculiar features, for example the existence of a strong global magnetic field (CP2 and CP4 objects) with a predominant dipole component located at random with respect to the stellar rotation axis and the centre of the star as well as overabundances with respect to the Sun for heavy elements such as silicon, chromium, strontium, and europium. The peculiar surface abundances for CP stars have been explained either by diffusion of chemical elements depending on the balance between gravitational pull and uplift by the radiation field through absorption in spectral lines or by selective accretion from the interstellar medium via the stellar magnetic field (Szklarski & Arlt 2013). Therefore, the correlation of stellar magnetic field strengths with astrophysical processes like diffusion and meridional circulation as well as their evolutionary status can be very well studied with this stellar group (Glagolevskij 2013).

Nearly four decades ago, Maitzen (1976) introduced the Δa photometric system in order to investigate the flux depression at 5200 Å typically for CP stars. An overview of the system and its applications can be found in Paunzen et al. (2005). The a index samples the depth of this flux depression by comparing the flux at the centre with the adjacent regions. The final intrinsic peculiarity index Δa was defined as the difference between the individual a-values and the a-values of non-peculiar stars of the same colour (spectral type). It was shown (Paunzen et al. 2005) that virtually all CP2 and CP4 stars have positive Δa-values up to 95 mmag. Extreme cases of the non-magnetic CP1 and CP3 objects may exhibit marginally positive Δa values, whereas emission line Be/Ae and λ Bootis stars exhibit significant negative values. Since the detailed study of Pleione (Pavlovski & Maitzen 1989), it is known that Be stars can change their Δa values from

* Photometric data are only available at the CDS via anonymous ftp to cdsarc.u-strasbg.fr (130.79.128.5) or via http://cdsarc.u-strasbg.fr/viz-bin/qcat?J/A+A/564/A42

Table 1. Fundamental parameters of the target clusters taken from Paunzen & Netopil (2006) and Zejda et al. (2012).

Cluster		$\alpha(2000)$	$\delta(2000)$	l	b	$d_{\odot}$ [pc]	$E(B-V)$ [mag]	Age [Myr]	$\mu_{\alpha}\cos\delta$ [mas/yr]	μ_{δ} [mas/yr]
Feinstein 1	C1103−595	11 05 56	−59 49 00	290.03	+0.39	1180	0.41	5	−6.1	+2.9
NGC 2168	C0605+243	06 09 00	+24 21 00	186.59	+2.22	830	0.23	100	+1.5	−2.9
NGC 2323	C0700−082	07 02 42	−08 23 00	221.67	−1.33	895	0.23	100	+0.4	−2.0
NGC 2437	C0739−147	07 41 46	−14 48 36	231.86	+4.06	1495	0.16	235	−5.0	+0.4
NGC 2547	C0809−491	08 10 09	−49 12 54	264.47	−8.60	430	0.05	45	−7.7	+5.0
NGC 4103	C1204−609	12 06 40	−61 15 00	297.57	+1.16	1810	0.25	30	−5.6	−0.5
NGC 6025	C1559−603	16 03 17	−60 25 54	324.55	−5.88	725	0.28	75	−3.3	−3.1
NGC 6633	C1825+065	18 27 15	+06 30 30	36.01	+8.33	335	0.18	505	+0.2	−1.2
Stock 2	C0211+590	02 15 00	+59 16 00	133.33	−1.69	300	0.33	130	+16.6	−13.5
Trumpler 2	C0233+557	02 37 18	+55 59 00	137.38	−3.97	605	0.32	120	+1.0	−4.6

Table 2. Observations log.

Cluster	Observatory	Telescope	Time	Reference
Feinstein 1	ESO	Bochum 0.61 m	89/04	Maitzen (1993)
NGC 2168	Hvar	0.65 m	89/01, 89/02	Maitzen & Pavlovski (1987)
NGC 2323	ESO	0.5 m	85/02, 85/03	Maitzen & Schneider (1987)
NGC 2437	ESO	1.0 m	84/02	Maitzen (1993)
NGC 2547	ESO	1.0 m	84/02	Maitzen (1993)
NGC 4103	ESO	1.0 m	84/02	Maitzen (1993)
NGC 6025	ESO	Bochum 0.61 m	89/04	Maitzen (1993)
NGC 6633	ESO	Bochum 0.61 m	89/04	Maitzen (1993)
Stock 2	Hvar	0.65 m	84/12, 85/12	Maitzen & Pavlovski (1987)
Trumpler 2	Hvar	0.65 m	85/12, 86/10, 86/11	Maitzen & Pavlovski (1987)

Notes. The description of the used equipment can be found in the last column.

significantly positive at their shell to negative at their emission phase.

Starting with the paper by Maitzen & Hensberge (1981), fourteen parts of a large photoelectric Δa survey to detect CP stars in open clusters and stellar associations were published. Observations in star clusters are preferable because they represent samples of objects of constant age and homogeneous chemical composition, suited to the study of processes linked to stellar structure and evolution, and to fixing lines or loci in several very important astrophysical diagrams such as the colour–magnitude diagram (CMD), or the Hertzsprung-Russell diagram (HRD).

In this paper, we present new photoelectric Δa data for the ten open clusters Feinstein 1, NGC 2168, NGC 2323, NGC 2437, NGC 2547, NGC 4103, NGC 6025, NGC 6633, Stock 2, and Trumpler 2. All aggregates, with the exception of NGC 6633, are younger than 250 Myr (Table 1). The detection of CP stars in young open clusters will help us to understand the formation and evolution of these objects and their magnetic fields.

2. Target selection, observations, and reduction

This work was initiated by the European working group on chemically peculiar stars of the upper main sequence (Mathys et al. 1989). The regular photoelectric observations of this programme were performed until 1991. Soon afterwards, the, for that time new, technique of CCD photometry was employed (Maitzen et al. 1997). Nevertheless, there are no doubts about the accuracy of the photoelectric measurements. Furthermore, we also have time series of CP stars in our archive, which are very important for filling gaps when determining rotational periods (Mikulášek et al. 2011). These data will be published in a separate paper.

We have chosen ten open clusters for which no Δa observations are yet available. The fundamental parameters of the target clusters taken from Paunzen & Netopil (2006) and Zejda et al. (2012) are listed in Table 1. The observations log is listed in Table 2. The details of the used equipment and basic reduction processes can be found in Maitzen & Schneider (1987), Maitzen & Pavlovski (1987), and Maitzen (1993).

To deredden the programme stars, we made use of photometric data in the Johnson, Geneva, and Strömgren systems, compiled from the open cluster database WEBDA[1]. For the first two systems, the well-known calibrations based on the X/Y parameters (Cramer 1999) and Q-index (Gutierrez-Moreno 1975), respectively, applicable for O/B-type stars were applied. Objects with available Strömgren data were treated with the routines by Napiwotzki et al. (1993), allowing the dereddening of cooler type stars. For member stars without sufficient photometry, the mean cluster reddening was adopted. There are only a few non-member stars (fifteen in total), for which we were not able to derive individual reddening values; these were therefore rejected in the subsequent analysis. If several estimates for a particular object are available, a mean value was calculated. Since all clusters are rather near to the Sun, a strong reddening especially for cool-type stars is hardly expected.

Since the a index is slightly dependent on temperature (increasing towards lower temperatures), the intrinsic peculiarity index Δa had to be defined as the difference between the individual a-values and those of non-peculiar stars (a_0) of the same colour. The locus of the a_0-values has been called the normality line. Because of the reddening, the normality line is shifted by $E(B-V)$ to the red and by a small amount $E(a)$ to higher a-values (Maitzen 1993). The mean ratio of these shifts $f = E(a)/E(B-V)$ was determined as $f \approx 0.035$. The final

[1] http://webda.physics.muni.cz

Table 3. Final results.

	Feinstein 1	NGC 2168	NGC 2323	NGC 2437	NGC 2547
$a_{\rm corr} = b + c(B-V)_0, N$	17(2)/55(6)/24	29(2)/47(17)/21	−34(4)/35(17)/17	123(1)/61(6)/37	122(1)/82(6)/29
3σ	±8	±9	±14	±12	±9
$N(>50\%)/N(<50\%)$	22/6	19/8	9/9	36/12	16/17
#CP/Δa/Prob	W16/+16/99	W244/+16/93	W171/+51/82	W172/+34/80	W8/+16/8
	W17/+15/59	W336/+17/37		W457/+26/76	
		W364/+23/69		W469/+38/63	
				W476/+19/50	
$\log T_{\rm eff}$ / $\log L/L_\odot$	4.350/3.36	4.126/2.32	4.105/2.07	3.993/1.67	4.124/2.245
	−/−	4.060/2.25		4.018/1.82	
		4.086/2.77		3.978/1.98	
				3.985/1.72	
	NGC 4103	NGC 6025	NGC 6633	Stock 2	Trumpler 2
$a_{\rm corr} = b + c(B-V)_0, N$	129(5)/151(25)/34	27(2)/101(16)/24	19(2)/70(11)/38	125(4)/118(21)/31	−47(2)/60(14)/12
3σ	±14	±13	±14	±15	±20
$N(>50\%)/N(<50\%)$	21/13	23/5	28/12	24/10	9/5
#CP/Δa/Prob			W48/+47/65	W6/+20/0	W30/+42/66
				W77/−24/4	
$\log T_{\rm eff}$ / $\log L/L_\odot$			3.919/0.92	3.988/1.49	4.069/2.12
				−/−	

Notes. All photometric values are given in mmag. For Feinstein 1 W17 and Stock 2 W77, we were not able to derive reliable astrophysical parameters (see text). The errors in the final digits of the corresponding quantity are given in parentheses.

values were calculated as $a_{\rm corr} = a({\rm obs}) - f E(B-V)$. For the subsequent analysis, we used the dereddened diagnostic $a_{\rm corr}$ versus $(B-V)_0$ diagrams (Fig. 1). The mean $(B-V)$ values have been calculated from the data included in WEBDA.

The normality line for each cluster was determined using the photometric data of member and non-member stars, which is justified because of the use of individually dereddened colours. Objects deviating more than 3σ were rejected in an iterative process. The final coefficients of $a_{\rm corr} = b + c(B-V)_0$ together with their errors are listed in Table 3. We consider an object as positively (or negatively) detected if its Δa value, taking into account the observational error, lies above (or below) the 3σ limit of the corresponding normality line.

The Δa, $a_{\rm corr}$, and $(B-V)_0$ data of all stars (Fig. 1) are available from the first author and/or via CDS. In the following, we will use the numbering system from WEBDA (W no.).

For the membership probabilities of the individual stars, we employed the method given in Balaguer-Núnez et al. (1998). In addition, we compared the results with those of the algorithm published by Javakhishvili et al. (2006), yielding excellent agreement. The first method takes both the errors of the mean cluster and the stellar proper motions into account. The mean proper motions of the target clusters were taken from Zejda et al. (2012) and are listed in Table 1. The proper motions of the individual stars were taken from the following sources, sorted by the priority:

- TYCHO-2 (Høg et al. 2000);
- UCAC4 (Zacharias et al. 2013);
- PPMXL (Röser et al. 2010).

For the complete sample, kinematic data are available. Because the mean proper motions of NGC 2547 and Stock 2 deviate strongly from the background, a definite membership determination should be straightforward. A comparison with the results published by Baumgardt et al. (2000) yields an excellent agreement.

To place the detected CP candidates in the HRD (Fig. 2), we applied the effective temperature calibrations and bolometric corrections for CP stars by Netopil et al. (2008) on the available photometric data in the Johnson, Geneva, and Strömgren systems. The luminosities were derived using the cluster parameters listed in Table 1 regardless of the kinematic non-membership in order to obtain an additional membership criterion. In general, we adopt an uncertainty for the derived temperatures of 500 K and 700 K for CP2 and CP4 stars, respectively (see Netopil et al. 2008). The errors in luminosity were derived using a standard error in distance of 10%, 0.1 mag for bolometric correction, and 0.02 mag for brightness and interstellar reddening.

By comparing the derived absolute magnitudes and temperatures with available spectral types, and the position of the stars in the HRD with the adopted cluster ages, we conclude that all kinematic non-members, except NGC 2547 W8, can be also considered cluster non-members from the photometric point-of-view.

One exceptional case is Feinstein 1 W17 which is a kinematical member, but from photometry we conclude the contrary. A detailed analysis for it is given in Sect. 3.1.

3. Discussion

From our final $a_{\rm corr}$ versus $(B-V)_0$ diagrams (Fig. 1), we find fifteen stars that deviate significantly from the corresponding normality lines. About one third of them seem not to be members of the associated star cluster. However, since we have dereddened each star individually, these stars are still very good candidates for being true CP stars. In the following, we discuss the results for the open clusters in more detail.

3.1. Feinstein 1

This aggregate is an accumulation of brighter stars around the β Cephei variable and helium star HD 96446 (W20). If this is indeed a true star cluster, it is very young and all A- and F-type stars should still be in there Pre-Main-Sequence phase (Feinstein 1964). Since its initial discovery, it has hardly been studied.

We find two stars, HD 305941 (W16) and HD 306034 (W17), significantly above the normality line. Garcia (1993) classified W16 as B2 IV/V ($\upsilon \sin i$ of 80 km s^{-1}) and W17 as

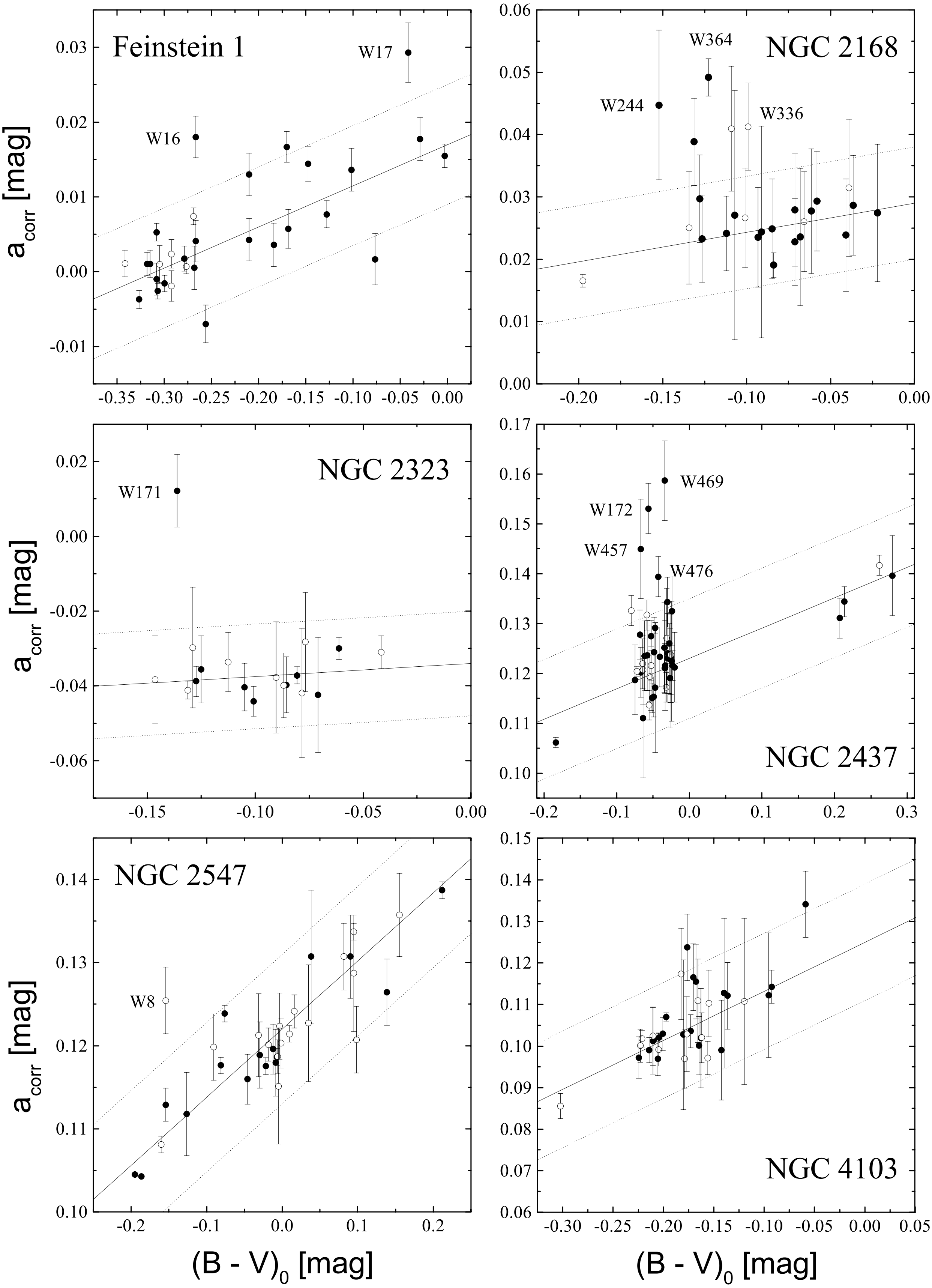

Fig. 1. a_{corr} versus $(B - V)_0$ diagrams for target clusters. Filled circles denote stars with a kinematical membership probability of more than 50%, open circles less than 50%. Stars with a statistical significant Δa value, are denoted with their WEBDA numbers (W no.). The solid line is the normality line and the dotted lines are the confidence intervals corresponding to 99.9%.

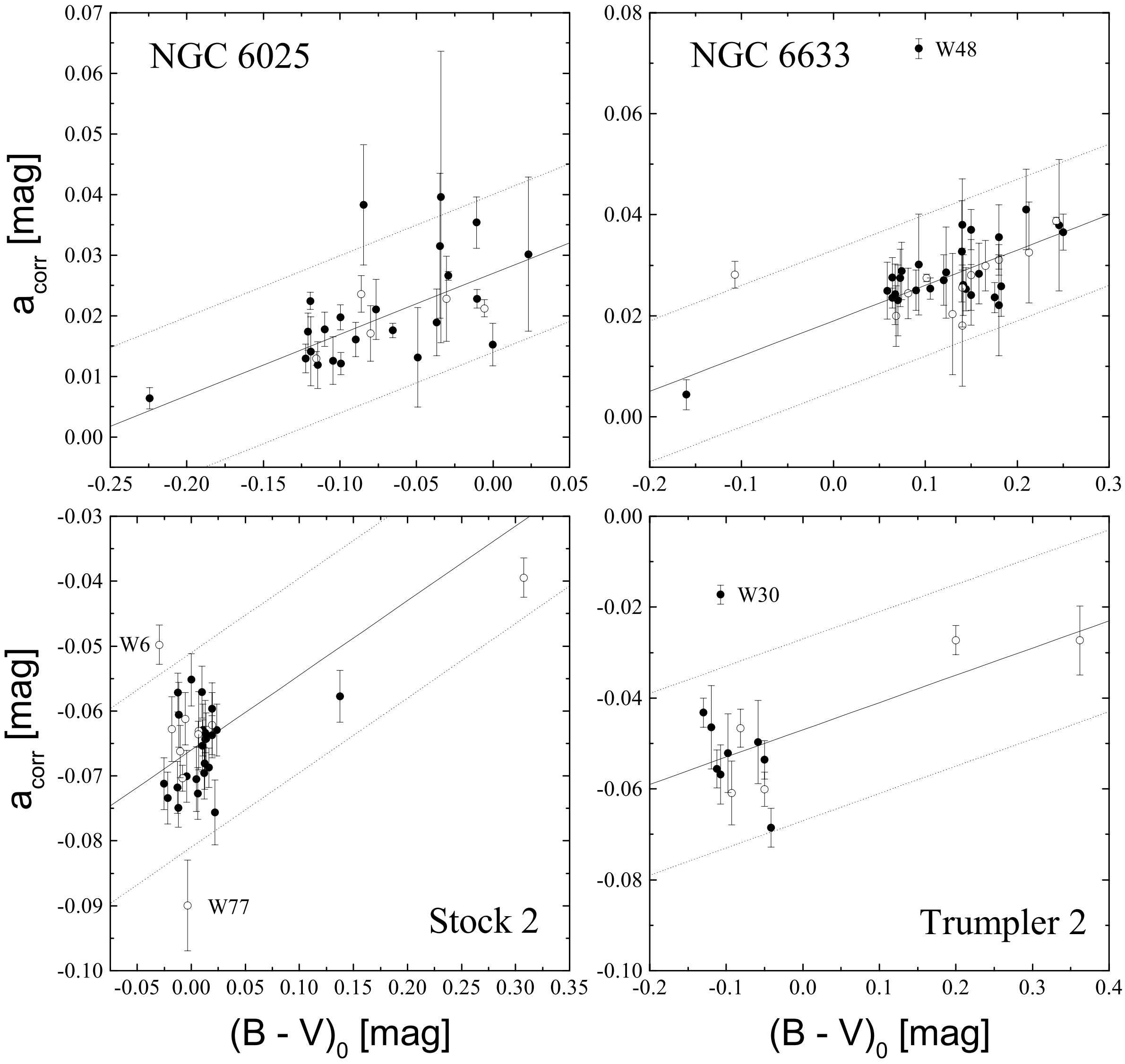

Fig. 1. continued.

Am (kA2 IV, mF6 III/IV). The projected rotational velocity of W16 is exceptionally low for an early B-type star which already points to a CP nature. They also noted that "He II at 4009 Å presents intensity variations". From the classification of W17 it is already clear that this is a very extreme CP1 star.

From the kinematic data, we derive membership probabilities of 99% and 59%, respectively. Therefore, we calibrated these stars using the reddening and distance of Feinstein 1 (Table 1). This resulted in $T_{\rm eff}$ and $M_{\rm Bol}$ of [22 400 K, −3.7 mag] and [10 300 K, −1.6 mag] for W16 and W17. While the values for W16 are perfectly in line with the spectral type, they are not compatible for W17 even if we assume a pre-main-sequence status. For W17, we chose a different approach on the basis of Johnson UBV photometry. Taking the standard relation for $(B-V)$ versus $(U-B)$ from Schmidt-Kaler (1982) and the observed values, we estimated the reddening assuming that the object follows the standard relation. As a result, we get $E(B-V) = 0.15$ mag. With this reddening value, we calibrated the $T_{\rm eff}$ as 7800 K. This value is well in line with the spectral type (Am (kA2 IV, mF6 III/IV)). As a last step, we kept the $T_{\rm eff}$ value fixed and calculated the distances which place the star either at the zero- or terminal-age-main-sequence within the evolutionary grids by Schaller et al. (1992). The derived values are between 300 pc and 850 pc which establishes it as being a foreground star. Recalculating the Δa value using the reddening given above and the relation from Table 3 yields +10 mmag. However, this peculiar object is worthwhile for follow-up spectroscopic observations. We conclude that W17 is not associated with Feinstein 1, although its kinematic characteristic is, to a certain degree, compatible with the mean cluster proper motion.

From the location in the HRD, we infer that W16 is a CP4 (He-strong) star with about 7.7 $M_\odot$. This star is the most massive and most luminous star among our CP candidates (Fig. 2). Cidale et al. (2007) presented a similar diagram for a sample of CP4 stars (see Fig. 7 therein). Comparing both diagrams, we find that this star is among the youngest CP4 objects known so far. We encourage follow-up observations in order to detect a possible stellar magnetic field.

3.2. NGC 2168

For this open cluster, two CP star candidates are listed in the literature (Niedzielski & Muciek 1988): W364 (HD 252405) and W547 (HD 252459). The source of the corresponding information is not known to us. Both stars are classified in Hoag & Applequist (1965) as B6 III: and A3 V, respectively. The star

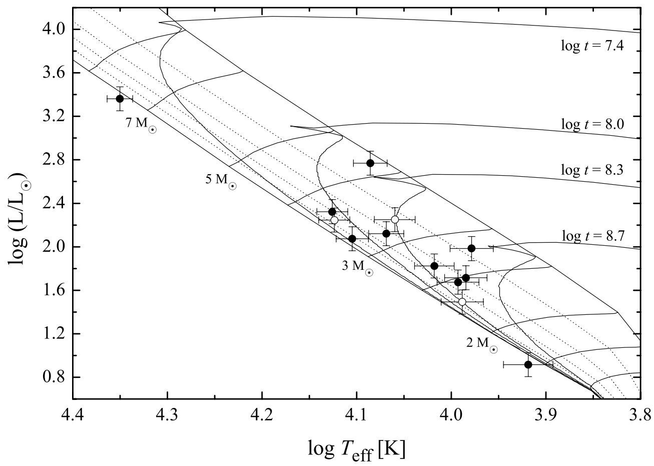

Fig. 2. Hertzsprung-Russell diagram for the bona fide CP stars listed in Table 3. The dotted lines represent the lines of equal fractional ages calculated from the evolutionary grids by Schaller et al. (1992). The stellar mass, relative to each track, in units of solar masses, is indicated in the plot. Both isochrones and evolutionary tracks are for solar metallicity. Kinematic non-members are represented by open symbols.

W364 has a measured Δa value of +23 mmag therefore, we confirm its peculiar nature. For W547, we get +17 mmag, but the error of the mean is too large to make it statistically significant. One could argue that this is caused by an apparent photometric variability due to spots and rotation. However, according to the kinematical data, W547 is not a member (1% probability) of NGC 2168. On the other hand, W364 is a member of the cluster. It is close to the terminal-age-main-sequence with a mass of about 4.1 $M_{\odot}$. This would correspond to a probable B7 Si-type star.

In addition, two other stars from our sample are significantly above the normality line, namely W244 (TYC 1877−356−1, +16) and W336 (HD 252427, +17). For neither of these objects are spectral classifications available (Skiff 2013). The kinematical data supports the membership of W244 (93%), but not for W336 (37%). They both have masses between 3 $M_{\odot}$ and 4 $M_{\odot}$ and would be therefore classified as late B-type Si stars. We note that HD 252427 is incorrectly identified as W335 in SIMBAD/CDS. For W336, the star HD 252458 is listed.

The only known emission-type object in the cluster area (Kohoutek & Wehmeyer 1999), HD 41995 (W781), was not measured.

3.3. NGC 2323

The known CP candidate stars within NGC 2323 are HD 52965 (W3) and BD−08 1708 (W51). Bychkov et al. (2009) listed upper limits of the magnetic fields for these objects of 89 G and 49 G, respectively. They list a spectral classification of B8 Si, taken from Renson & Manfroid (2009), for HD 52965 which is probably wrong. The only found reference in this respect is from Young & Martin (1973) which lists "B9 p: Si II (4128/4130) slightly enhanced". We measured a Δa value of +3 mmag. This value together with the non-detection of a magnetic field suggests that this object is not a CP star. The same authors published the spectral type of "B9p:: Hg II 3984 Å weak" for BD−08 1708. A classification which is not typical for a CP3 object. However, we have not measured this star.

For the star CD−08 1704 (W171) we find a significant positive Δa value of +51 mmag. Its membership probability is 82%. There are some recent investigations of NGC 2323 that include photometric but no spectroscopic data (Clariá et al. 1998; Sharma et al. 2006; Frolov et al. 2012). Clariá et al. (1998) list $E(B-V) = 0.23$ mag for W171 which corresponds to the mean value of the cluster (Table 1). Its location within the HRD (Fig. 2) is consistent with the isochrone of NGC 2323. The star W171 is therefore a 100 Myr old, 3.4 $M_{\odot}$ (late B-type), probable Si, star.

3.4. NGC 2437

The open cluster NGC 2437 has been studied photometrically several times because it might host a planetary nebula (Majaess et al. 2007). However, there is no detailed spectroscopic analysis available in the literature. Neither CP nor Be stars within the cluster area have been detected so far.

We detected four stars that lie above the normality line, namely W172 (TYC 5422−967−1, $\Delta a = +34$ mmag), W457 (TYC 5422−2127−1, +26), W469 (BD−14 2133, +38), and W476 (TYC 5422−305−1, +19). For none of these objects are spectral classifications available in the literature. All stars are, within the errors, well represented by the isochrone for NGC 2437 with a distance of 1500 pc and an age of 235 Myr. The derived masses range from 2.4 $M_{\odot}$ to 2.9 $M_{\odot}$ which corresponds to early A-types. The overall metallicity of NGC 2437 is solar (Paunzen et al. 2010).

3.5. NGC 2547

The star HD 68074 (KW Vel, W8) is a known CP2 star with a rotational period of 1.1822 d (North 1987). Our measured Δa value of +16 mmag is slightly higher than that published by Maitzen & Vogt (1983), +9 mmag. It is the only star measured by them in the cluster area. The values of the peculiar indices in the Geneva system (Hauck & North 1982), $\Delta(V1-G) = +3$ mmag and $Z = -12$ mmag, are intrinsically consistent. Because of the large amplitude of the rotational induced variability, variations of the Δa are also expected. From the current available kinematical data, we deduce that W8 is not a member of NGC 2547 (probability of 8%), a result that is in line with the study by Baumgardt et al. (2000), who listed a probability of 0%. According to the different photometric diagrams, it appears to be a member (Clariá 1982) because neither the cluster nor the star exhibits a reddening larger than 0.05 mag. Therefore, it is essential to use proper motions for a membership determination.

Niedzielski & Muciek (1988) listed HD 68275 (W35) as a CP1 star on the basis of the classification as A3(m) by Houk (1978). However, Hartoog (1976) listed a spectral type of A2 V for this object. We find $\Delta a = +2$ mmag. Even, if the CP1 nature can be confirmed, it is not a member of NGC 2547 on the basis of the proper motions (probability of 1%). Therefore, NGC 2547 seems not to host any classical CP stars.

3.6. NGC 4103

The object CD−60 3984 (W12) is a well-known emission-type star that could be still in the pre-main-sequence phase (Henize 1976). We measured a Δa value of −4 mmag, which is not significant according to our criteria. From the kinematical data, a membership probability of 49% was calculated.

In total, we measured 34 stars in the cluster area, but found no significant deviating Δa values for this young (30 Myr) and rather metal-poor (−0.47(10) dex; Paunzen et al. 2010) aggregate.

3.7. NGC 6025

Tetzlaff et al. (2011) list an age of 40±11 Myr for the emission-type star (Henize 1976) HD 143448 (W1). Although their derived age is only marginally compatible with that of NGC 6025 (75 Myr), but our derived membership probability is 94%. It was therefore previously identified as a blue straggler by Mermilliod (1982). The Δa value of +2 mmag for W1 is not significant. We did not measure CD−60 6028, which was classified as A2 Vp (Paunzen et al. 2001).

Two objects, CD−60 6011 (W13) and CD−60 6002 (W38), have positive Δa values but with large errors. Grosso & Levato (2011) listed the following spectral types and projected rotational velocity for these two stars: B8 V, 185 km s^{-1} and A0 V. The high $v \sin i$ value of W13 is clearly not in line with the values found for CP stars. If we assume that W38 is a bona fide CP star candidate, the large error of $a_{\rm corr}$ could be caused by rotational induced variability.

3.8. NGC 6633

Levato & Abt (1977) published spectral types of stars in the cluster area. Among their sample, they identified five CP1 stars (W67, W75, W87, W88, and W161) and one CP2 star (W39). From these objects, we measured four CP1 stars: W67 ($\Delta a = -5$ mmag), W75 (−3), W87 (+3), and W88 (−8). The non-detection of CP1 stars is consistent with previous results for this group (Maitzen et al. 1998). However, we are not able to draw any further conclusions from our measurements about the true nature of these objects.

Levato & Abt (1977) also identified HD 170054 (W77) as a blue straggler with a spectral type of B6 IV. Later on, Abt (1985) changed the classification to B6 IVp (Si). Bailey & Landstreet (2013) used this object as a "standard star" for determining Si II and Si III elemental abundances in B-type stars. They found no significant deviation from the solar abundance for it. We measured $\Delta a = -3$ mmag, which is consistent with the values of peculiar indices of the Geneva system, $\Delta(V1 - G) = -16$ and $Z = +5$ mmag. We conclude that this object is not chemically peculiar and that it has been misclassified.

There is one star, HD 169959 (W58), that is just on the limit of the detection level. It is a non-member and has been classified as A0 III by several authors (Abt 1985).

We find a significantly positive Δa of +47 mmag for star W48 (BD+06 3755). In terms of kinematic data, it is a member of NGC 6633. Unfortunately, no further information other than $uvby\beta$ photometry is published in the literature. Its location in the HRD (Fig. 2) suggests that it is, within the errors, very close to the zero-age-main-sequence with a mass of about 1.7 $M_\odot$. This would correspond to a rather cool late A-type CP2 star, probably with enhancements of chromium, strontium, and europium. Such objects are rare (Pöhnl et al. 2005) and are very important for the study of the early formation and evolution of the local stellar magnetic field.

3.9. Stock 2

There are two CP stars listed in the catalogue by Renson & Manfroid (2009), namely HD 13402 (W34) and HD 13412 (CP1, W31). The first star is a high-mass supergiant (B0.5Iab) with a very small proper motion and is probably misclassified (Skiff 2013). The proper motion of HD 13412 (−14.73/+3.96) also disagrees with the mean cluster motion. As a consequence, (Baumgardt et al. 2000) concluded that both stars are non-members. However, we did not measure these objects.

The star HD 13112 (W6) is catalogued as a blue straggler by Ahumada & Lapasset (1995) and was classified as B8 III (sharp hydrogen lines) by McCuskey (1974). The latter could be a hint of a CP nature because of the generally low rotational velocities of these objects which were often misidentified as sharp lined giants (Preston 1974). The location in the HRD (Fig. 2) is clearly in favour of it being on the main sequence. The derived astrophysical parameters (Table 3) are typical for an A2-type star, whereas $(B - V)_0 = -0.03$ mag is consistent with a B8-type object. Again, this irregular behaviour is typical of CP stars. The final decision about its true nature can only be drawn on the basis of further observations, for example, classification resolution spectroscopy.

For HD 13631 (W77) we find $\Delta a = -24$ mmag, which is the only significant negative value in the complete sample presented in this paper. In the literature, two different spectral classifications, namely B9 V (Voroshilov et al. 1985) and A1 II: (hydrogen lines sharp; McCuskey 1974) have been published. Based on the colours of this star and the absolute magnitude of a class II bright giant, this object would be located at a distance of about 2 kpc. This would imply a much higher interstellar reddening and a proper motion much closer to zero. We therefore conclude that the classification as B9 V is more likely. However, both spectral types and proper motion contradict membership. Since Voroshilov et al. (1985) has not noticed any emission in the spectra, we suggest that W77 is a good candidate for being a hot λ Bootis-type star.

3.10. Trumpler 2

The only known Be star in this cluster (Schild & Romanishin 1976), W8 (HD 16080), has a Δa value of +7 mmag. It seems that it was measured in its shell phase. The star W30 (BD+55 664) was detected as a CP (Ap) star of Si-type by Zelwanowa (1971) on the basis of prism spectroscopy. From kinematical data, it was confirmed as member of Trumpler 2 in the aforementioned paper. We derived $\Delta a = +42$ mmag, which supports the classification as a classical CP2 star. The recent and more accurate proper motions establish this star as being a true member of Trumpler 2.

4. Conclusions

We presented new photoelectric Δa photometry of 304 stars in ten open cluster fields. From a detailed kinematical analysis, we concluded that 207 stars of the sample have a membership probability higher than 50%.

The ten clusters (Feinstein 1, NGC 2168, NGC 2323, NGC 2437, NGC 2547, NGC 4103, NGC 6025, NGC 6633, Stock 2, and Trumpler 2) are young to intermediate age aggregates (5 Myr < age < 500 Myr) with distances from 300 pc to 1800 pc from the Sun.

Our search for chemically peculiar objects results in fifteen detections from which ten objects seem to be true member of the corresponding star cluster. Of the remaining five stars, four are probable field CP objects and one is a λ Bootis-type candidate. The objects have masses between 1.7 $M_\odot$ and 7.7 $M_\odot$ and are dwarf stars (luminosity class V).

We discussed the already published spectral classifications in the light of our Δa photometry and identified several misclassified CP stars. On the other hand, we were also able to establish and support the nature of known bona fide CP candidates.

The newly detected CP stars, close to the zero-age-main-sequence, will help to understand the formation and evolution of this phenomenon. To this end, follow-up observations, for example, to detect and trace the local stellar magnetic fields, as well as an abundance analysis are needed.

Acknowledgements. This project is financed by the SoMoPro II programme (3SGA5916). The research leading to these results has acquired a financial grant from the People Programme (Marie Curie action) of the Seventh Framework Programme of EU according to the REA Grant Agreement No. 291782. The research is further co-financed by the South-Moravian Region. It was also supported by the grants GA ČR P209/12/0217, 14-26115P, 7AMB12AT003, 7AMB14AT015, and the financial contributions of the Austrian Agency for International Cooperation in Education and Research (BG-03/2013, CZ-10/2012, and CZ-09/2014). This research has made use of the WEBDA database, operated at the Department of Theoretical Physics and Astrophysics of the Masaryk University. This work reflects only the author's views and the European Union is not liable for any use that may be made of the information contained therein.

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