Astron. Astrophys. 327, 636–639 (1997)

ASTRONOMY AND ASTROPHYSICS

Research Note

First CCD measurements in the Δa system for detecting CP2 stars*

H.M. Maitzen, E. Paunzen, and M. Rode

Institut für Astronomie der Universität Wien, Türkenschanzstr. 17, A-1180 Wien, Austria (surname@astro.ast.univie.ac.at)

Received 28 April 1997 / Accepted 24 June 1997

Abstract. This is the first time that CCD-photometry in the three filter Δa system (Maitzen 1976) was carried out after two decades of classical photoelectric photometry. The aim is to extend the successful search for chemically peculiar stars to more and distant open clusters as well as far galactic fields. In this paper we present CCD-photometry for a sample of 25 field stars with published spectroscopic peculiarity types. 22 of them show discordance between their Michigan catalogue types (non-peculiar) and the Bidelman & MacConnell (1973; BC) peculiarity assignments. Eight stars are peculiar in Δa (five of them also in the Geneva index $\Delta(V1-G)$) thus supporting BC, mainly among their Silicon star discoveries.

Considering cases where Silicon line enhancements were interpreted as peculiar instead as indicator of higher luminosity by BC, and the perfect detection of the three unambiguous peculiar stars, in addition to the achievement of an accuracy of 0.003 mags, we are justified to conclude that the performance of our CCD-Δa photometry perfectly matches the requirements of the conventional photometric technique and thus opens the way to observations of fainter stars.

Key words: stars: chemically peculiar – stars: early type – techniques: photometric

1. Introduction

Since 20 years, the Δa photometric system has been very successful in detecting new chemically peculiar (CP) stars. This three filter system samples the 5200 Å flux depression which is characteristic for CP2 and part of the CP4 (for the definition see Preston 1974) stars. Still, the question of the origin of this feature has been unsolved. A series of up to now 14 papers (see Maitzen 1993) has been dedicated to a photometric survey in open clusters using the Δa criterion.

In the past all measurements were obtained by classical photoelectric photometry employing circular diaphragms and photomultiplier tubes. This way observations had to be restricted to well separated ($d > 20''$) and rather bright ($V < 11$ mag) stars.

For the first time, we have used the advantages of CCD observations together with the Δa system. The possibility of performing point-spread-function photometry and increasing the integration time for a given field makes this technique especially interesting for more distant (and thus more crowded) open clusters.

In order to prove the capability of the 'new' photometric system, we present CCD observations of galactic field stars. Bidelman & MacConnell (1973, BC hereafter) and the Michigan Spectral Catalogue (Houk & Cowley 1975; Houk 1978, 1982; Houk & Smith-Moore 1988, MC hereafter) have classified about 800 southern hemisphere stars as CP2 based on exactly the same objective prism plates. We noticed, however, that for more than 70 stars the spectral classifications of both sources are discordant concerning peculiarity. We have chosen 22 of these stars in order to test our 'new' photometric system. They all are peculiar according to BC, but have non-peculiar types, often with higher luminosity, in MC. We call them 'CP2 candidate stars' in this paper. In addition, eight standard, two well-known CP2 and one λ Bootis star were measured.

2. Observation and reduction

Observations were performed with the 61 cm Bochum telescope at ESO-La Silla on three photometric nights from May 29-31, 1995. The telescope was equipped with a liquid nitrogen cooled Thompson 7882 CCD (384x576 pixel) resulting in a field of view of about $3'$ by $4'$. Three Schott interference filters ($\varnothing$ 50mm) g_1, g_2 and y were used, their characteristics are listed in Table 1. Typically, three frames per filter were obtained for each star, integration times ranged from 30 to 120 seconds. The sequence of filters was always g_1, g_2 and y.

The basic CCD-reduction steps (bias-subtracting and flatfielding) have been performed with standard IRAF-routines. For our actual situation, i.e. well separated field stars, we decided to

Send offprint requests to: H.M. Maitzen

* Based on observations obtained at ESO-La Silla

Table 1. Filter system

Filter	λ_c[Å]	FWHM [Å]	transmission
g_1	5027	222	66 %
g_2	5205	107	50 %
y	5509	120	54 %

perform only aperture photometry using the package APPHOT. It turned out that the images of our programme stars spread over 2″ covering about 20 pixels. This corresponds to a seeing of 1.5″.

Averaging the magnitudes derived for each filter we obtain an intrinsic error of 3 mmag in Δa for our programme and standard stars which are generally in the brightness interval 8.5 to 9.5 mag.

Programme and known CP stars (Tables 2 and 3) were taken from BC and Paunzen et al. (1997). In order to establish a reference line of normality for deriving the deviations Δa, we have chosen standard stars from the MC (Table 4) and as temperature index the $(B2-V1)_0$ from the Geneva photometric system (Rufener & Nicolet 1988). We are aware that we add thereby the effect of the depression feature on V1 to its temperature information. But this occurs in a similar way as using b-y in foregoing papers, since also y is influenced by the depression. The sum effect of this procedure is a slight enhancement of Δa values in case of peculiar stars. The individual values of the Geneva system were taken from Rufener (1988) in order to derive intrinsic colours following Meylan et al. (1980). From eight standard stars for which intrinsic colours had to be derived from their MC spectral types (Table 4) we obtain the normality line as:

$$a_0 = 0.666 + 0.092\,(B2-V1)_0$$

Since the errors of the standard stars around the normality line follow a normal distribution, we have calculated confidence intervals (Rees 1987) of 90 and 99 percent (Fig. 1), respectively. The confidence intervals are curved since they include the uncertainty in the slope of the line. The curvature is of course smaller if one has more standard stars to define the normality line. When the original system was introduced (Maitzen 1976) there were so many normal stars that the curvature was negligible.

We regard a star as photometrically peculiar if: $\Delta a \geq 0.014$ or $\Delta a \leq -0.014$ mag. To check peculiarity found this way the Geneva photometric system criterion $\Delta(V1-G) > 0.010$ mag (North & Cramer 1981) may be applied. We were unable to find here a significant influence of interstellar reddening on the a-values which might be expected from the relatively blue wavelength of g_2 compared to those of g_1 and y. Obviously the rather low amounts of reddening did not succeed in producing sensible differential effects on the a-values.

3. Results

According to our detection limit, eight candidate stars (HD 84629, HD 86170, HD 128075, HD 129460, HD 142778,

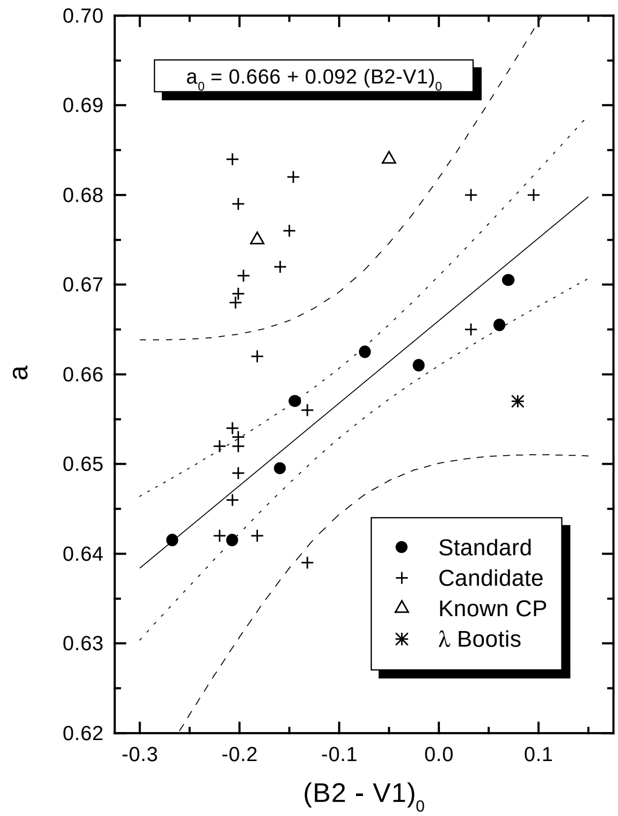

Fig. 1. a vs. $(B2-V1)_0$ for all observed stars

HD 142960, HD 152044 and HD 167444) are to be regarded as photometrically peculiar. Five of them (HD 84629, HD 128075, HD 142778, HD 142960 and HD 167444) are confirmed by the Geneva photometric system (Table 2) and HD 129460 misses the detection threshold by only 0.001 mag.

As expected, the λ Bootis star, HD 107233 exhibits a significant negative Δa value.

There is one object which was already measured by conventional photoelectric photometry in the Δa system: *HD 156869*, classified as Sr by MC was in the sample of Maitzen & Vogt (1983) and yielded exactly the same Δa value (0.025).

Two objects deserve further interest:

HD 87432: This star was classified as A2 IV by MC and has a significant negative Δa value, which is not supported by the Geneva system. Reinvestigation is therefore desirable.

HD 134185: It was classified as F0/2 V according to MC, but Si in BC. The Geneva colours support the F-type, so we tend to assume that a typographical error (perhaps it should read 'Sr') is the reason for this striking discrepancy. Otherwise it would be a very exotical object. Photometrically, it is a non–peculiar star.

Comparing the classification performances of both sources (BC and MC) with the help of the new available photometric evidence, one notes in Table 2 that for eleven B-type stars with giant MC classification, the BC-peculiarity assignments are in better agreement with our results (six cases) than the MC-types.

Table 2. CP2 candidate stars

HD	Durchm.	MC	BC	m_{pg}	$(B2-V1)_0$	$E(B2-V1)$	a	Δa	Δ (V1 – G)	log g
79718	CD−56 2052	A0/1 Vn	Si	9.7	−0.182	0.077	0.642	−0.007	−0.015	4.2
84629	CD−55 2893	B9.5 II	Si	9.5	−0.196	0.113	0.671	+0.023	+0.016	3.7
86170	BD−01 2324	A2*	SrCrEu*	8.3	−0.150	0.103	0.676	+0.024	+0.002	4.3
87432	CD−45 5717	A2 IV	CrEu	8.9	−0.132	0.114	0.639	−0.015	+0.005	4.2
100570	CD−46 7181	B9 V	Sr	9.3	−0.207	0.112	0.646	−0.001	+0.008	4.2
103671	CP−55 4727	B8 III	Si	8.7	−0.220	0.006	0.652	+0.006	+0.006	4.1
115000	CP−61 3532	B9 III	Si	9.8	−0.201	0.272	0.649	+0.001	−0.006	3.6
121208	CP−57 6394	A9 V	Sr	9.5	+0.032	0.052	0.665	−0.004	−0.004	3.5
128075	CP−66 2588	B9 II/III	Si	8.8	−0.201	0.052	0.679	+0.031	+0.032	3.8
128997	CP−66 2616	B9 V	Si	8.9	−0.207	0.143	0.654	+0.007	+0.008	3.5
129460	CP−53 6083	B9 III	Si	10.1	−0.201	0.098	0.669	+0.021	+0.009	4.0
132319	CP−53 6186	A0/1 V	Si	9.6	−0.182	0.143	0.662	+0.013	−0.004	3.7
133428	CP−76 977	A2 V	Si	9.0	−0.132	0.117	0.656	+0.002	−0.011	4.0
133755	CP−52 7861	B9 II/III	Si	8.7	−0.201	0.168	0.653	+0.005	+0.006	3.3
134185	CD−51 8801	F0/2 V	Si	9.6	+0.095	0.098	0.680	+0.005	−0.008	3.5
142778	CP−60 6256	B9 II	Si	9.3	−0.146	0.064	0.682	+0.029	+0.024	3.8
142960	CP−60 6280	B9 IV	SrCrEu	9.3	−0.207	0.196	0.684	+0.037	+0.019	4.1
149334	CD−33 11273	A9 IV	Sr	9.2	+0.032	0.184	0.680	+0.011	−0.007	4.0
152044	CP−52 10302	A1 V	SrCrEu	8.7	−0.159	0.156	0.672	+0.021	+0.006	4.3
156791	CP−52 10606	B9 III/IV	Si	9.2	−0.201	0.161	0.652	+0.004	−0.004	3.8
167444	CD−42 13073	B9 IV	Si	8.8	−0.204	0.037	0.668	+0.021	+0.015	4.1
168163	BD−16 4806	B8 III	Si	8.9	−0.220	0.263	0.642	−0.004	−0.009	3.6

* classification taken from Renson (1991)

Table 3. Known CP stars

HD	Durchm.	Spt	m_{pg}	$(B2-V1)_0$	$E(B2-V1)$	a	Δa	Δ (V1 – G)	log g
107233	CD−47 7538	λ Bootis	7.3	+0.079	0.000	0.657	−0.016	−0.012	4.1
117227	CD−46 8677	Ap(SrCr)	9.3	−0.050	0.097	0.684	+0.023	−0.012	4.5
156869	CD−52 8109	Ap(SrCr)	8.2	−0.182	0.086	0.675	+0.025	+0.023	4.0

The latter agree only in three cases with the log g values (calculated in the Geneva system following the relation given in Table VI of North & Cramer 1984) typical for giants and photometric non-peculiarity, whereas in two cases luminosity is not far from class V, and MC is in accord with photometry only concerning non-peculiarity.

For the eight A-type stars we notice one substantial and two mild positive Δa detections supporting BC. Since half of the A-type stars were classified as Silicon stars in BC, a reinspection or reobservation would be helpful. The current evidence underlines once again the problem of spectroscopic peculiarity classification among the cooler types, especially for faint stars.

Summarizing, the precision of our standard star measurements, the agreement of our Δa with the Geneva peculiarity index Δ(V1 – G) values and the comparison of Geneva log g values with the discordant spectroscopic types including the photometric peculiarity indices enable us to state that the first CCD-photometric observations in the Δa system have proved to exhibit the same level of performance as conventional photoelectric photometry.

Table 4. Standard stars

HD	Durchm.	MC	m_{pg}	$(B2-V1)_0$	a	Δa
84655	CD−55 2895	A1/2 Vn	9.5	−0.144	0.657	−0.004
88225	CD−51 4510	A5/7 IV	9.2	−0.020	0.661	+0.003
91819	CD−39 6510	A1 V	9.4	−0.159	0.650	+0.002
115033	CD−61 3711	B9 IV/V	9.7	−0.207	0.642	+0.005
129611	CD−54 5846	B5 V	9.5	−0.267	0.642	0.000
134184	CD−51 8802	A4 V	8.4	−0.074	0.663	−0.003
143793	CD−45 10409	F0 IV/V	9.7	+0.070	0.671	+0.002
149333	CD−33 11274	F0 V	8.6	+0.061	0.666	+0.006

Therefore we are encouraged to proceed finding photometric peculiar stars also at lower brightness levels in open clusters and galactic fields.

Acknowledgements. We are greatly indebted to the Astronomisches Institut der Ruhr-Universität Bochum (head: Prof. Dr. R. J. Dettmar) for granting us observing time at the Bochum telescope on La Silla. HMM acknowledges financial support from the Hochschuljubiläumsstiftung der Stadt Wien (project *Wiener Zweikanalphotome-*

ter). This research was partly carried out within the working group *Asteroseismology-AMS* with funding from the Fonds zur Förderung der wissenschaftlichen Forschung (project *S7303-AST*). We would like to thank Dr. H.G. Grothues for logistical support. In addition, we are indebted to Dr. A. Erikson and Dr. S. Mottola for helping us with the data handling. Use was made of the Simbad database, operated at CDS, Strasbourg, France.

References

Bidelman W.P., MacConnell D.J., 1973, AJ 78, 678
Houk N., 1978, University of Michigan Catalogue of Two-Dimensional Spectral Types for the HD Stars, Volume II, Astronomy Dept., Univ. Mich., Ann Arbor, Michigan
Houk N., 1982, University of Michigan Catalogue of Two-Dimensional Spectral Types for the HD Stars, Volume III, Astronomy Dept., Univ. Mich., Ann Arbor, Michigan
Houk N., Cowley A.P., 1975, University of Michigan Catalogue of Two-Dimensional Spectral Types for the HD Stars, Volume I, Astronomy Dept., Univ. Mich., Ann Arbor, Michigan
Houk N., Smith-Moore M., 1988, University of Michigan Catalogue of Two-Dimensional Spectral Types for the HD Stars, Volume IV, Astronomy Dept., Univ. Mich., Ann Arbor, Michigan
Maitzen H.M., 1976, A&A 52, 223
Maitzen H.M., 1993, A&AS 102, 1
Maitzen H.M., Vogt N., 1983, A&A 123, 48
Meylan G., Python M., Hauck B., 1980, A&A 90, 83
North P., Cramer N., 1981, In: Upper Main Sequence CP Stars, 23rd Liege Astrophys. Coll. Université de Liège, p. 55
North P., Cramer N., 1984, A&AS 58, 387
Paunzen E., Weiss W.W., Heiter U., North P., 1997, A&AS 123, 93
Preston G.W., 1974, ARA&A 12, 257
Rees D.G., 1987, Foundations of Statistics, Chapman & Hall, London, p. 244
Renson P., 1991, Catalogue Général des Etoiles Ap et Am, Institut d'Astrophysique Université de Liège
Rufener F., 1988, Catalogue of Stars measured in the Geneva Observatory Photometric system (fourth edition), Observatoire de Genève
Rufener F., Nicolet B., 1988, A&A 206, 357

This article was processed by the author using Springer-Verlag LaTeX A&A style file *L-AA* version 3.