A&A 462, 591–597 (2007)
DOI: 10.1051/0004-6361:20066076

Astronomy & Astrophysics

CCD photometric search for peculiar stars in open clusters

VIII. King 21, NGC 3293, NGC 5999, NGC 6802, NGC 6830, Ruprecht 44, Ruprecht 115, and Ruprecht 120⋆,⋆⋆,⋆⋆⋆

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Received 20 July 2006 / Accepted 4 October 2006

ABSTRACT

Context. We continue our survey of magnetic chemically peculiar (CP2) stars in galactic open clusters to shed more light on their origin and evolution.

Aims. To study the group of CP2 stars, it is essential to find these objects in different galactic environments and at a wide range of evolutionary stages. The knowledge of open cluster ages and metallicities can help for finding a correlation between these parameters and the (non-)presence of peculiarities, which has to be taken into account in stellar evolution models.

Methods. The intermediate band Δa photometric system samples the depth of the 5200 Å flux depression by comparing the flux at the centre with the adjacent regions with bandwidths of 110 Å to 230 Å. It is capable of detecting magnetic CP2 and CP4 stars with high efficiency, but also the groups of (metal-weak) λ Bootis and classical Be/shell stars can be successfully investigated. In addition, it allows the age, reddening, and distance modulus to be determined with appropriate accuracy by fitting isochrones.

Results. From the 1677 observed members of the eight open clusters, one Ae and twenty-five CP2 stars were identified. Furthermore nineteen deviating stars are designated as questionable for several reasons. The estimated age, reddening, and distance for the programme clusters were compared with published values of the literature and discussed in this context.

Conclusions. The current paper shows that CP2 stars are continuously present in very young (7 Myr) to intermediate age (500 Myr) open clusters at distances greater than 2 kpc from the Sun.

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

1. Introduction

In continuation of our CCD Δa photometric survey to detect chemically peculiar (CP) stars of the upper main sequence, eight more open clusters were chosen, including very young ($\log t = 6.8$) to old ($\log t = 8.7$) aggregates lying at distances up to 4.8 kpc from the sun.

Sampling their characteristic flux depression at 5200 Å (cf. Kupka et al. 2003, 2004), the Δa photometric system is capable of detecting CP and related objects in an easy and economic way. Paunzen et al. (2005a) re-examined recently the efficiency of this system, resulting in a detection probability of up to 95% for all relevant magnetic CP stars. Furthermore, the groups of λBootis and classical Be/shell stars systematically exhibit negative Δa values.

The formation and evolution of CP stars is still a matter of debate; unambiguous detection or even non-detection of those groups in different galactic environments will therefore help to shed more light on that topic. The latest study of the incidence of peculiar objects was carried out by North (1993) on the basis of 57 open clusters, which is still a small number considering the quantity of ∼1700 known clusters in the Milky Way (Dias et al. 2002). The Δa system is therefore the best solution for extending the examined sample. It also serves as a kind of pre-selection for further studies. Recently, Bagnulo et al. (2006) for example used Δa results to obtain spectropolarimetry at the ESO VLT.

However, if one aims to cover clusters at galactic environments different from the solar neighbourhood, a lack of deeper investigations, especially of membership analysis, becomes evident, necessary for segregating possible peculiar stars among nonmembers. We are therefore planning to obtain additional UBV photometry, wherever applicable, during future observations.

⋆ Based on observations at CASLEO, CTIO (Proposal 2003A-0057), and OSN. The Observatorio de Sierra Nevada is operated by the Consejo Superior de Investigaciones Científicas through the Instituto de Astrofísica de Andalucía (Granada, Spain).

⋆⋆ Photometric data are only avaialable in electronic form at the CDS via anonymous ftp to cdsarc.u-strasbg.fr (130.79.128.5) or via http://cdsweb.u-strasbg.fr/cgi-bin/qcat?J/A+A/462/591

⋆⋆⋆ Full Fig. 1, Tables 1 and 3 are only available in electronic form at http://www.aanda.org

† Visiting Astronomer at Complejo Astronómico El Leoncito operated under an agreement between Consejo Nacional de Investigaciones Científicas y Técnicas de la República Argentina and the National Universities of La Plata, Cordoba, and San Juan.

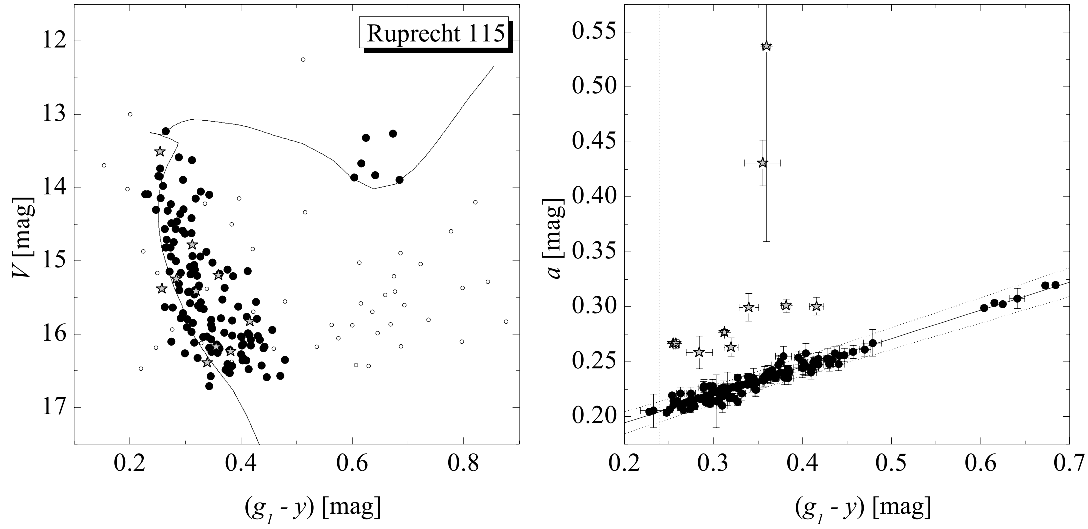

Fig. 1. As an example, the observed a versus $(g_1 - y)$ and V versus $(g_1 - y)$ diagrams for the cluster Ruprecht 115 is presented. *Left panels*: the solid lines represent the corresponding isochrones taken from Claret et al. (2003) and Claret (2004), which are based on the Δa photometric system. The derived ages, reddenings, and distance moduli are given in Table 2. *Right panels*: the solid line is the normality line, whereas the dotted lines are the confidence intervals corresponding to 99.9%. The error bars for each individual object are mean errors. The detected peculiar objects are marked by stars. Only members (filled circles) have been used to derive the normality lines, their coefficients can be found in Table 4. The dotted vertical lines represent the colour index for spectral type A0.

Beside detecting CP stars, we are also able to determine cluster parameters such as age, reddening, and distance, using isochrones for the Δa system (Claret et al. 2003; Claret 2004), which were compared with already published parameters. Since Paunzen & Netopil (2006) show that the accuracy of parameters for a lot of open clusters is still far from satisfactory, this additional capability of Δa is very important. More data sets will contribute to minimising the errors for individual clusters, which then helps for examining the galactic structure more accurately, among other possibilities.

In the currently presented sample of eight galactic clusters (King 21, NGC 3293, NGC 5999, NGC 6802, NGC 6830, Ruprecht 44, Ruprecht 115, and Ruprecht 120) we detected 25 CP2, 1 Ae, and 19 objects showing peculiar behaviour due to doubtful membership, variability, or binarity.

2. Observations, reduction, and used methods

Observations of the eight open clusters were performed at three different sites and telescopes:

- 0.9 m telescope (CTIO), direct imaging, SITe 2084 × 2046 pixel CCD, 13′ field-of-view;
- 2.15 m RC telescope (CASLEO), direct imaging, EEV CCD36-40 1340 × 1300 pixel CCD, 9′ field-of-view;
- 1.5 m RC telescope (OSN), direct imaging, RoperScientific VersArray 2048 × 2048 pixel CCD, 8′ field-of-view.

The observing log with the number of frames in each filter is listed in Table 1. The observations were performed with two different filter sets, both with the following characteristics: g_1 (λ_c = 5007 Å, *FWHM* = 126 Å, T_P = 78%), g_2 (5199, 95, 68) and g_3 (5466, 108, 70), whereby T_P indicates the transmission efficiency.

The basic CCD reductions and a point-spread-function fitting were carried out within standard IRAF V2.12.2 routines on personal computers running under LINUX. The way of calculating the normality line, deriving the errors, the calibration of our $(g_1 - y)$, and y measurements, is the same as in previous works (see Netopil et al. 2005 and Paunzen et al. 2006 for example) and will not be repeated here in detail. Our measured y magnitudes, as well as the $(g_1 - y)$ colour indices were directly converted into standard *UBV* magnitudes on the basis of already published values. The transformation coefficients can be found in Table 4.

The isochrones shown in Fig. 1 were taken from Claret et al. (2003) and Claret (2004), which are based on the Δa photometric system. The derived ages, reddenings, and distance moduli, together with their errors are listed in Table 2. The fitting procedure takes advantage of the available *UBV* measurements for all programme clusters, which means that the results were compared to those of the colour–magnitude diagrams for the *UBV* photometric system. However, our determination is based on the Δa measurements alone, which is another important application of this photometric system.

The tables with all the data for the cluster stars, as well as nonmembers, are available in electronic form at the CDS, at WEBDA (`http://www.univie.ac.at/webda/`) or upon request from the first author. These tables include the cross identification of objects from the literature, the X and Y coordinates within our frames, the observed $(g_1 - y)$ and a values with their corresponding errors, V magnitudes, the $(B - V)$ colours from the literature, as well as the Δa-values derived from the normality lines based on $(g_1 - y)$ (disregarding nonmembers).

The diagnostic diagrams for all eight open clusters are shown in Fig. 1, partly available in electronic form only. As an example, the cluster Ruprecht 115 is presented. Furthermore, the normality lines and the confidence intervals corresponding to 99.9% are plotted. The detected peculiar objects are marked by stars. Only members have been used to derive the normality lines. Membership was attributed according to their location in the colour–magnitude diagrams, the distance from the cluster centres, and additional information from the literature (proper motions and radial velocities) taken from WEBDA.

Table 2. Summary of results: the age, distance modulus, reddening, and thus the distance from the Sun derived by fitting isochrones to the Δa photometry.

Name	King 21 C2347+624	NGC 3293 C1033−579	NGC 5999 C1548−563
l/b	115.95/+0.68	285.86/+0.07	326.01/−1.93
$E(B-V)$ (±0.05)	0.85	0.29	0.48
$m_V - M_V$ (±0.2)	15.3	13.1	13.2
d [kpc]	3.41(56)[a]	2.76(45)	2.20(36)
R_{GC} [kpc]	9.98(38)	7.72(2)	6.30(26)
$\|z\|$ [pc]	41(7)	4(1)	74(12)
$\log t$ (±0.1)	7.2	7.0	8.5
Tr-type[b]	I 2 p	I 3 r	I 2 m
n(member)	115	241	227
n(none)	144	96	1960
n(frames)	30	30	30
CP No. (Webda): $\Delta a/(B-V)_0/M_V$ [mmag]	55(−):+59/+113/+832 85(−):+85/+242/+1020 137(−):+41/+6/−465 151(−):+84/+358/+2335 *152(11)[c]:+36/0/−895		1570(119): +92/+223/+1509 1642(148): +72/+421/+1721 1693(−): +78/+405/+2217
Name	NGC 6802 C1928+201	NGC 6830 C1948+229	Ruprecht 44 C0757−284
l/b	55.33/+0.92	60.14/−1.80	245.75/+0.48
$E(B-V)$ (±0.05)	0.89	0.48	0.58
$m_V - M_V$ (±0.2)	14.4	12.9	15.2
d [kpc]	2.13(35)	1.92(31)	4.79(79)
R_{GC} [kpc]	7.01(13)	7.24(10)	10.88(57)
$\|z\|$ [pc]	34(6)	60(10)	40(7)
$\log t$ (±0.1)	8.7	8.3	6.8
Tr-type	I 1 m	II 2 p	IV 2 m
n(member)	279	92	379
n(none)	401	311	66
n(frames)	30	30	15
CP No. (Webda): $\Delta a/(B-V)_0/M_V$ [mmag]	*208(−): +41/+635/+2769 *314(42): +46/+1360/−1470 *345(100): +155/+230/+90 *395(138): +119/+460/+480 427(−): +27/+233/+1870	117(38): +38/+255/+50 *164(9): −21/+170/−1900 *175(180): +42/+365/+1395 257(166): +35/−65/+290 *324(159): +36/+485/+1245	16(−): +68/+149/−784 *17(235): +39/−370/−2680 *143(162): +52/−380/−2900 381(−): +69/−197/−825 383(−): −132/+133/+814 394(−): +45/−9/−70 436(−): +49/−6/+369 443(−): +46/−49/−1235 444(−): +58/+136/−1380
Name	Ruprecht 115 C1609−522	Ruprecht 120 C1631−482	
l/b	330.96/−0.85	336.39/−0.49	
$E(B-V)$	0.74	0.65	
$m_V - M_V$ (±0.2)	13.8	13.5	
d [kpc]	2.00(33)	1.98(33)	
R_{GC} [kpc]	6.33(26)	6.24(28)	
$\|z\|$ [pc]	30(5)	17(3)	
$\log t$ (±0.1)	8.6	8.0	
Tr-type	III 1 p	II 3 p	
n(member)	142	202	
n(none)	50	549	
n(frames)	30	27	
CP No. (Webda): $\Delta a/(B-V)_0/M_V$ [mmag]	*54(30): +302/+487/+1484 *58(93): +60/+514/+2422 65(63): +38/+297/+1618 *73(3): +197/+430/+2095 81(38): +43/+208/+1464 90(−): +53/+206/+980 92(7): +58/+64/−282 98(11): +57/+79/1564 132(178): +69/+431/2610 *139(57): +51/+639/2029	485(34): +53/−49/−411 487(35): +52/−51/−536 *490(−): +17/+387/+1906 600(38): +66/−49/−769 *604(−): +22/+970/+3728 *616(−): +18/+607/+3623 *623(−): +22/+854/+3209 *663(116): +19/+480/+1980	

[a] The errors of the last digits are always given in parenthesis.
[b] The Trumpler classification was taken from Lyngå (1987).
[c] Questionable peculiar stars are marked by asterisks.

Table 4. The regression coefficients for the transformations and normality lines.

Cluster	V, $(B-V)$, a_0[a]	N
King 21	$-0.42(16)+1.00(1)\cdot y$	19
	$0.61(1)+2.09(24)\cdot(g_1-y)$	19
	$0.277(3)+0.267(16)\cdot(g_1-y)$	110
NGC 3293	$-5.31(8)+1.00(1)\cdot y$	72
	$0.75(3)+2.63(11)\cdot(g_1-y)$	67
	$0.352(1)+0.203(5)\cdot(g_1-y)$	241
NGC 5999	$-5.35(6)+1.00(1)\cdot y$	278
	$0.64(1)+2.42(5)\cdot(g_1-y)$	273
	$0.279(1)+0.100(3)\cdot(g_1-y)$	222
NGC 6802	$-0.15(19)+1.06(1)\cdot y$	98
	$0.96(1)+2.96(9)\cdot(g_1-y)$	92
	$0.301(1)+0.273(6)\cdot(g_1-y)$	274
NGC 6830	$0.93(15)+0.98(1)\cdot y$	35
	$0.81(1)+2.76(7)\cdot(g_1-y)$	35
	$0.314(1)+0.274(11)\cdot(g_1-y)$	87
Ruprecht 44	$-5.32(10)+1.00(1)\cdot y$	75
	$0.71(1)+2.84(12)\cdot(g_1-y)$	75
	$0.271(1)+0.273(1)\cdot(g_1-y)$	370
Ruprecht 115	$-4.30(7)+1.00(1)\cdot y$	72
	$0.08(3)+2.76(7)\cdot(g_1-y)$	72
	$0.143(2)+0.256(5)\cdot(g_1-y)$	132
Ruprecht 120	$-6.38(9)+1.05(1)\cdot y$	93
	$0.92(1)+2.27(6)\cdot(g_1-y)$	93
	$0.265(1)+0.270(4)\cdot(g_1-y)$	194

[a] The absolute values and errors vary due to the inhomogeneous "standard" observations (photographic, photoelectric and CCD) found in the literature as well as the dependence on the magnitude range in common, i.e. a broader range guarantees a small error. The errors of the last digits are given in parenthesis.

3. Results

In the following we present the results for the individual open clusters and compare them with the literature. The cluster parameters and their errors are listed in Tables 2 and 3, and the significant deviating cases are discussed in more detail. The ratio of total-to-selective extinction R_V was set to 3.1, and for the distance of the Sun from the galactic centre a value of 8.0 kpc was used. Averaged $(B-V)$ and V values were taken from the literature, corrected by the obtained distance modulus and interstellar reddening. If not available, we used the transformed Δa photometry (see Table 4). Star numbers are based on ascending (X, Y) coordinates on the CCD frames. In Table 3, one can also find the star numbers according to WEBDA, if available.

3.1. King 21

The only available photometric study about King 21 was performed by Mohan & Pandey (1984). They measured 26 stars in the cluster area only down to about $14\overset{\text{m}}{.}5$, biasing the determination of the distance modulus. This explains the large difference in distance compared to our result, as is seen in Table 3. Furthermore, they estimated the cluster age according to the method by Mermilliod (1981), settling it between the very young groups of NGC 2362 and NGC 457. This would correspond to an age around $\log t = 7.0$. Five possible chemically peculiar stars (#55, 85, 137, 151, 152) with Δa indices between +36 and +85 mmag were found within this aggregate, all lying in the typical spectral range of CP2 stars, according to their colour indices. However, star #152 has to be treated with caution, since it is part of a close pair. Together with object #155, it represents the star #11 according to Mohan & Pandey (1984). Some other stars are lying somewhat outside the determined confidence interval, but are considered insignificant due to their errors. The authors of the foregoing study report a nonuniform reddening across the cluster, which could be responsible for the location of the five detected peculiar stars in the colour–magnitude diagram: all objects deviate slightly from the cluster main sequence. Thus, a definite conclusion about their membership cannot be made yet due to the scarcity of information. Moreover, we are unable to confirm the variability of object #94 reported by Mohan & Pandey (1984) (#19 therein), because of our shorter observing period.

3.2. NGC 3293

Due to its brightness, several studies were performed on the young cluster NGC 3293, including an extensive spectroscopic survey by Evans et al. (2005) using the telescopes VLT (Flames) and ESO 2.2 m (FEROS). Its location in the area of the Carina Nebula (NGC 3372) enhances its attractivity. Although the detection limit of our Δa photometry is very low for that cluster, we did not find any peculiar object. However, several stars showing Hα emission have already been identified in the former investigations by Baume et al. (2003) and McSwain & Gies (2005). Furthermore, the survey by Evans et al. (2005) resulted in the detection of five Be/Ae objects, as well as one definite Si star and an object showing peculiar He I lines. The Si star is located outside of our field-of-view and is a probable nonmember due to its large distance from the cluster centre, whereas Evans et al. (2005) note for the other object (#22 according to our photometry, $\Delta a = +3$ mmag) that the peculiar appearance is probably due to a hotter, though less luminous, companion. Astonishing is the non visibility of the large number of likely Be/Ae objects in Δa. Inspecting the indicated emission stars of the three studies mentioned above, one can notice that, among the nine targets in common, no detection coincides in all investigations. Just two stars (WEBDA # 12 and 117) were designated as emission objects in at least two studies. These stars exhibit Δa indices of −8 and −1 mmag respectively. McSwain & Gies (2005), for example, note that their results are likely contaminated by the background Hα emission, as well as emission from pre-main sequence stars. Furthermore, the phases of emission can be replaced by shell and normal phases of the object. Such behaviour was investigated e.g. by Pavlovski & Maitzen (1989) using Δa photometry. The determined cluster parameters are in perfect agreement with the literature values (Table 3). For the sake of a better presentation of the diagnostic Δa diagram (Fig. 1), only main-sequence stars were plotted. Nevertheless, the single red giant shown in the colour–magnitude diagram of NGC 3293 in Fig. 1 is found close to the normality line.

3.3. NGC 5999

Beside the search for variable stars within the OGLE survey (Pietrzynski et al. 1998), the only in-depth investigation of the open cluster NGC 5999 was carried out by Piatti et al. (1999). Their results are in perfect agreement with the parameters obtained in this work, in contrast to Santos & Bica (1993) who found a much younger age ($\log t = 8.0$) based on integrated spectra and template matching. Additionally, they also obtained a slightly higher age of ~230 Myr using Balmer lines and a metallicity of [Fe/H] = 0.18 from Ca II triplet lines. However, we assumed solar metallicity for the isochrone-fitting procedure, since the more recent work by Santos & Piatti (2004) list [Fe/H] = 0.0(2). Although apparent red giants seem to be present in the innermost region of NGC 5999, the obtained parameters are based only on main sequence stars, because neither their spectral type nor their membership is known. Also the two brightest "main sequence" stars of our sample, #1326 (WEBDA #36) and #1465 (WEBDA #53), were disregarded for determining the cluster parameters, since we have obtained much redder colours (up to $\sim 0\overset{m}{.}2$) compared to Piatti et al. (1999) and their $(B-V)$ and $(V-I)$ colours, whereas the V magnitudes agree with previous work. A reinvestigation of these stars is necessary in order to determine their cluster affiliation. If they turn out to be members, a much younger age has to be set for the cluster. Because of the small cluster diameter compared to the available field-of-view and the high star density in that field, a lot of nonmembers have to be rejected for further analysis (see Table 2, Fig. 1). The detection of three extremely deviating objects can be reported (#1570, 1642, and 1693). They exhibit Δa indices between +72 and +92 mmag and are, due to their colours, early/mid F type stars, just on the cool end of the spectral range where CP stars are expected. Since no membership analysis is available in the literature, the only hint can be delivered by the present colour–magnitude diagram, which does not contradict membership, although they do deviate slightly from the main sequence.

3.4. NGC 6802

Within the oldest cluster in the current sample, we were able to detect five possibly peculiar stars, but no classical ones except for one (#427). Although that star exhibits a moderate Δa index of 27 mmag, it lies just slightly outside the confidence interval due to the large scatter among the cluster members. One other suspicious star (#208) is, on the one hand, too cool to be a CP2 object; on the other hand, it clearly deviates from the main sequence, suggesting a questionable membership status. All other stars are placed along the giant branch, but their membership is uncertain. Evolved objects of luminosity classes III to I can also show the same Δa behaviour as CP2. In addition, two of them (#345, 395) exhibit exceptional Δa indices of more than 100 mmag. The clear visible giant clump in the colour–magnitude diagram allows the cluster parameters to be determined more accurately, but the obtained distance of 2.13 kpc is in part considerably higher than in the literature. By inspecting the photometry by Hoag et al. (1961), one can notice numerous brighter stars in an extended area around NGC 6802 that also form a cluster main sequence. Including them in an analysis will result in a much lower distance. However, it is up to later observations to clarify whether those brighter stars mimic a cluster sequence or build a foreground cluster.

3.5. NGC 6830

According to earlier investigations, ages between $\log t = 7.5$ and 8.0 were found for the cluster NGC 6830, whereas we have obtained a much older age of $\log t = 8.3$, which represents the best fit to the current data. Grubissich (1960) notes, that the brightest cluster stars are probably not physical members. This objects are not measured by us, because of saturation or lying outside of our field-of-view. If they are included in an analysis, a much younger age will be derived, of course. The above-mentioned stars (#2, 5, and 72 according to WEBDA) have spectral types of B9 IIIe, B7 V, and B9.5 III (Hoag & Applequist 1965), respectively. The authors determined a true distance module of $10\overset{m}{.}7$ based on photometric UBV, Hγ, and spectrographic observations of six bright cluster stars in total, which is $0\overset{m}{.}7$ lower than the one obtained by us on the basis of the whole main sequence. This seems to confirm the assumption by Grubissich (1960). Due to a large scatter of the cooler stars within the Δa diagram, probably caused by nonmembers and/or the photometric errors of the fainter stars, they were truncated at about $(B-V) = 1.0$, since CP stars are no longer expected at cooler temperatures. Five deviating objects were found in the remaining domain, whereas the only negative star (#164) is questionable due to its larger error, but the spectral type of A9 III by Turner (1976) did not contradict its membership status. Two of the four objects showing a positive Δa index (#175 and 324) have an adopted spectral type of mid F and are already at the cool end of CP stars, exhibiting the largest deviation from the main sequence, whereas the remaining two objects (#117 and 257) are candidates for classical, chemically-peculiar stars. One star (#226, WEBDA #24) of our sample is also included in the catalogue of Hα emission-line stars by Kohoutek & Wehmeyer (1999), showing a Δa index of −16 mmag, just lying within the confidence interval. Restricting ourselves to the hotter portion ($(g_1 - y) < -0.05$), the calculation of the normality line and its confidence interval would yield an outlying position below it.

3.6. Ruprecht 44

Ruprecht 44 is another very young cluster in the current survey. However, it is most difficult to fit isochrones to data of such young aggregates, because of the nonexistence of a giant clump or a turn-off point to determine an accurate distance module. Due to ongoing star formation, differential reddening can be an additional difficulty. We therefore used only the innermost region to determine the cluster parameters, which well agree with the literature values. Only Moffat & FitzGerald (1974) and FitzGerald & Moffat (1976) obtained much larger distances. These discrepancies already have been discussed by Turner (1981). Nine possible peculiar objects were found within this cluster, which are all well separated in the Δa diagram. There is only one star (#383) that exhibits a huge negative Δa index (−132 mmag), whereas its photometric index implies an Ae nature. Unfortunately, a spectroscopic confirmation will be challenging due to its close position to the bright star #383 ($V = 9\overset{m}{.}48$). Furthermore, the objects #17 (A7:) and 143 (B8:) are nonmembers according to Moffat & FitzGerald (1974). All other stars are magnetically peculiar candidates with Δa indices between 45 and 69 mmag. We have to note that, although the cluster is extended ($\sim 12'$ in diameter), filling nearly the whole available field-of-view, most of the detected peculiar stars are lying at the assumed cluster border. Another interesting behaviour is the concentration of the probable CP2 objects, and four of them are located in an area of about $2 \times 2'$. On the basis of these findings, a reinvestigation of the whole Δa survey will be necessary to answer the question of whether local fluctuations are possibly affecting the formation of the CP phenomenon.

3.7. Ruprecht 115

The cluster parameters obtained for Ruprecht 115 partly agree with results found in the literature. Piatti et al. (1999) have studied the cluster via BVI photometry and integrated spectra. They have determined an age that is only slightly older than our value. The differences in the results for interstellar reddening $E(B-V)$ can be explained by their combined values for the determinations via photometry and integrated spectra, whereas they have obtained a comparable value via photometry (0.65), but a lower one (0.50) using the spectra template method. However, when inspecting their reddening result $E(V-I) = 0.9$ and the ratio $E(V-I)/E(B-V) = 1.25$ by Dean et al. (1978), our result of $E(B-V) = 0.74$ seems to be in good agreement, assuming a normal extinction law. The stars in the apparent red giant clump are probable members, since they all lie directly on the normality line, suggesting a similar reddening. In total, ten possible peculiar objects were found, two of them (#54 and 73) showing extreme Δa indices of +302 and +197 mmag, respectively. These are rather unusual values by implying nonmembership or more probably variability, since a comparison of our calibrated V and $(B-V)$ magnitudes with the previous investigation exhibits differences up to $\sim 0\overset{m}{.}3$, but further investigations are necessary. One of them (#54) also has a large error, mainly caused by the results for the g_2 filter, which covers the 5200 Å flux depression. These objects, together with two other stars (#58 and 139) that are too cool to be classified as CP members, were therefore marked as questionable in Table 2. The six other positive detections exhibit Δa indices in the "normal" range between +38 and +69 mmag, as well as colour indices hotter than spectral type F5. However, a membership analysis is not available for the detected objects, but none (also the extreme cases) deviates in the colour–magnitude diagram.

3.8. Ruprecht 120

We have found eight possibly peculiar objects within the cluster Ruprecht 120. The photometric indices for three of them (# 485, 487, 600) suggest late B-type nature. The range of their positive Δa indices (52 to 66 mmag) is indicative of their bona fide CP2 nature (Paunzen et al. 2005a). The remaining five CP candidates have moderate Δa indices up to +22 mmag, but are too cool for classical CP objects, except #490, an early/mid F-type star, lying just on the border of the confidence interval, therefore designated as questionable. The obtained cluster parameters agree with the work by Piatti et al. (1999), but they have determined a slightly greater distance. A lot of field stars, designated as nonmembers due to their distance to the cluster centre (a diameter of 7′ was assumed), show a similar behaviour to the cluster main sequence. Such an appearance of galactic field stars was already discussed for example by Piatti et al. (1999).

4. Conclusions

Within the presented sample of eight galactic open clusters, 5254 objects (1677 cluster members) on 222 frames using three different sites were investigated, resulting in the detection of twenty five CP2 stars and one object of a probable Ae nature. Another nineteen deviating stars are designated as questionable for to several reasons (e.g. uncertain membership status) as indicated in the respective cluster section. Due to the poor available membership information, we also studied their behaviour in the $(B-V)_0/M_V$ diagram (Fig. 2) using the values given in Table 2. The star closest to the ZAMS is object #381 in Ruprecht 44, the youngest aggregate of the current sample. No other distinctive features can be found if taking the differential reddening of some clusters into account, but the most outstanding objects are

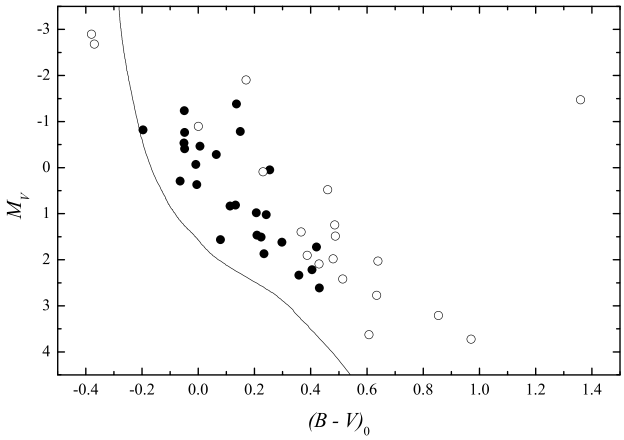

Fig. 2. The detected probable (filled circles) and questionable (open circles) peculiar stars within the $(B-V)_0/M_V$ plane as given in Table 2. The solid line represents the ZAMS relation from Schmidt-Kaler (1982).

#117 (NGC 6830), as well as #16 and 44 (Ruprecht 44), which exhibit the largest deviations from the ZAMS.

As an important application of the Δa photometric system, isochrones were fitted to the colour–magnitude diagrams (V versus (g_1-y)) of the programme clusters. A comparison of our results yields excellent agreement with the corresponding parameters from the literature.

The programme clusters are all located at distances ≥2 kpc from the sun, widely distributed in galactocentric distances (6.2 to 10.9 kpc) and ages (6 to 500 Myr), thus helping to cover different environments and evolutionary stages for a deeper investigation of the incidence of peculiar stars. Of special interest is the influence of metallicity, taking its gradients within the galactic disc into account (Chen et al. 2003). Together with NGC 3105 and Berkeley 11 of earlier Δa investigations (Paunzen et al. 2005b; Paunzen et al. 2006), the cluster Ruprecht 44 in the current sample is farthest from the galactic centre (~10.7 kpc), applying a value of $R_0 = 8.0$. We have to note that the R_{GC} data for NGC 3105 in Paunzen et al. (2005b) was wrongly given as 11.4 instead of 11.0 using $R_0 = 8.5$. Examining their CP stars content in respect to the investigated total members, lead to 1.6, 2.1 and 5.6% for Ruprecht 44, NGC 3105, and Berkeley 11, respectively, neglecting questionable candidates. However, only Ruprecht 44 and NGC 3105 represent clusters of comparable age ($\log t = 6.8$ and 7.3) and galactic coordinates, whereas Berkeley 11 deviates by age ($\log t = 8.0$) and position. On account of the small number, we want to enhance our efforts with clusters situated in outer regions, but also in the opposite direction, since the solar neighbourhood has been investigated up to now a lot via photoelectric and CCD Δa photometry as well as spectroscopy.

Acknowledgements. This research was performed within the projects *P17580* and *P17920* of the Austrian Fonds zur Förderung der wissenschaftlichen Forschung (FwF) and also benefited from financial contributions from the City of Vienna (Hochschuljubiläumsstiftung project: H-1123/2002). I.Kh. Iliev acknowledges the support by the Bulgarian National Science Fund under grant F-1403/2004 and the Pinehill Foundation. Use was made of the SIMBAD database, operated at the CDS, Strasbourg, France and the WEBDA database, operated at the University of Vienna. This research made use of NASA's Astrophysics Data System.

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Online Material

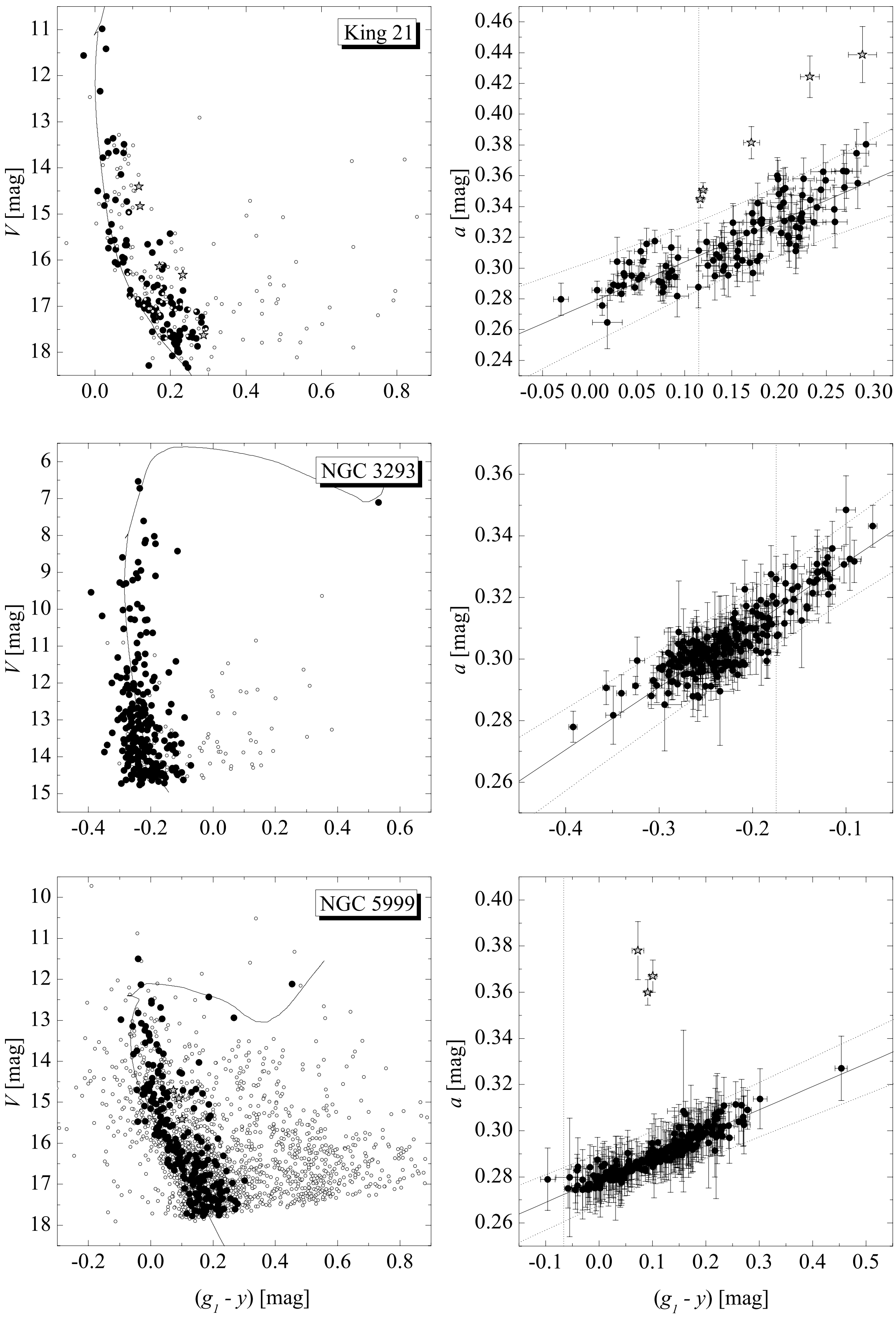

Fig. 1. The observed a versus $(g_1 - y)$ and V versus $(g_1 - y)$ diagrams for the clusters King 21, NGC 3293, and NGC 5999.

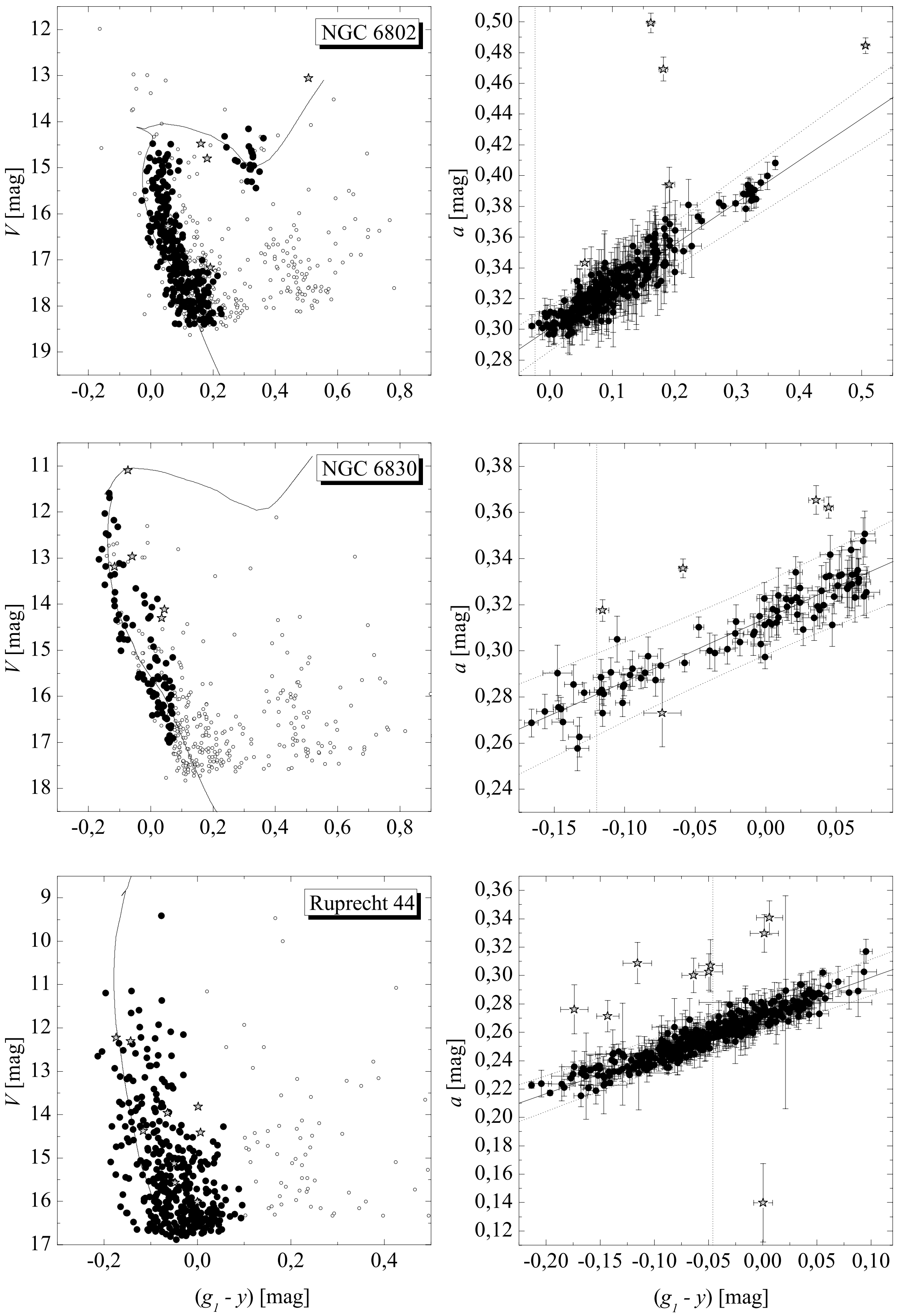

Fig. 1. Continued. The observed a versus $(g_1 - y)$ and V versus $(g_1 - y)$ diagrams for the clusters NGC 6802, NGC 6830, and Ruprecht 44.

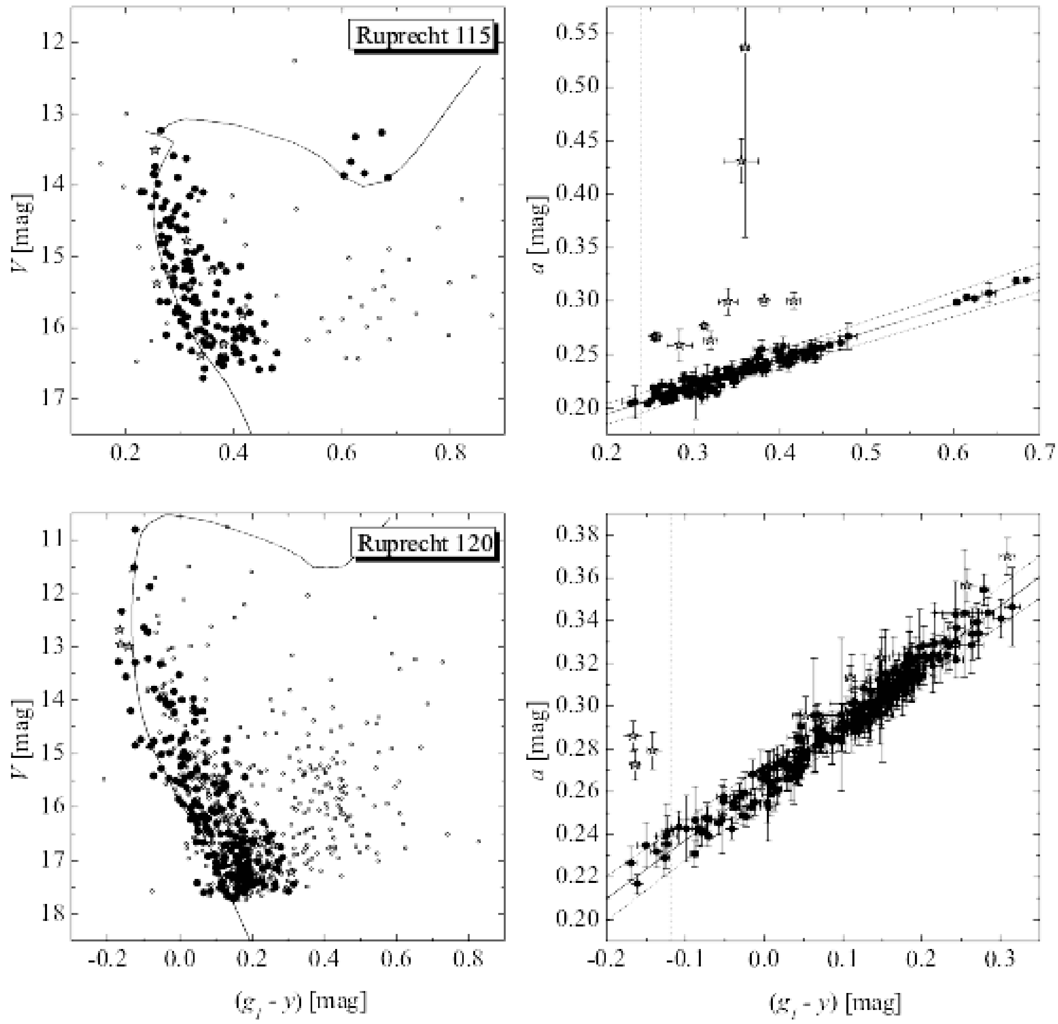

Fig. 1. Continued. The observed a versus $(g_1 - y)$ and V versus $(g_1 - y)$ diagrams for the clusters Ruprecht 115 and Ruprecht 120.

Table 1. Observing log for the programme clusters with the number of frames in each filter. The exposure time per frame is given in seconds.

Cluster	Site	Date	$\#g_1/g_2/y$	Exp.time	Observer
King 21	OSN	August 28, 2005	10/10/10	180/360	V. Casanova
NGC 3293	CTIO	April 21, 2003	10/10/10	5/10	H.M. Maitzen
NGC 5999	CTIO	April 21−23, 2003	10/10/10	300	H.M. Maitzen
NGC 6802	OSN	August 22, 2005	10/10/10	180/360	V. Casanova
NGC 6830	OSN	August 24, 2005	10/10/10	180/360	V. Casanova
Ruprecht 44	CTIO	April 22, 2003	5/5/5	100/200	H.M. Maitzen
Ruprecht 115	CASLEO	June 26−27, 2003	10/10/10	300	O.I. Pintado
Ruprecht 120	CTIO	April 22−23, 2003	9/9/9	300	H.M. Maitzen

Table 3. Comparison of our results (indicated by bold face) to already published cluster parameters.

Cluster	log t	$E(B-V)$	d [kpc]	Ref
King 21	**7.20**(1)[a]	**0.85**(5)	**3.41**(56)	
		0.89	1.91	Mohan & Pandey (1984)
	7.16	0.89	2.10	Dias et al. (2002)
N 3293	**7.00**(1)	**0.29**(5)	**2.76**(45)	
	6.70	0.33	2.50	Turner et al. (1980)
	7.00	0.31	2.60	Feinstein & Marraco (1980)
	7.00	0.25[b]	2.75	Balona (1994)
	6.90	0.29	2.75	Baume et al. (2003)
	6.94	0.25	2.47	Kharchenko et al. (2005)
	7.01	0.26	2.33	Dias et al. (2002)
N 5999	**8.50**(1)	**0.48**(5)	**2.20**(36)	
	8.00	0.44		Santos & Bica (1993)
	8.60	0.45	2.20	Piatti et al. (1999)
	8.60	0.45	2.05	Dias et al. (2002)
N 6802	**8.70**(1)	**0.89**(5)	**2.13**(35)	
		0.83	0.91	Hoag & Applequist (1965)
		0.80	0.82:[c]	Becker & Fenkart (1971)
	9.18:	0.80	1.84	Kaluzny & Shara (1988)
	9.00	0.94	1.43	Sirbaugh et al. (1995)
	8.87	0.85	1.12	Dias et al. (2002)
N 6830	**8.30**(1)	**0.48**(5)	**1.92**(31)	
			1.68	Barkhatova (1957)
		0.51	1.38	Hoag & Applequist (1965)
		0.58	1.47	Becker & Fenkart (1971)
	8.00	0.56	1.70	Moffat (1972)
	7.52	0.50	1.64	Kharchenko et al. (2005)
	7.57	0.50	1.64	Dias et al. (2002)
Ru 44	**6.80**(1)	**0.58**(5)	**4.79**(79)	
		0.64	4.60	Turner (1981)
		0.68	6.80	FitzGerald & Moffat (1976)
	6.00	0.70	6.60	Moffat & Fitzgerald (1974)
	7.33	0.62	4.66	Kharchenko et al. (2005)
	6.94	0.62	4.73	Dias et al. (2002)
Ru 115	**8.60**(1)	**0.74**(5)	**2.00**(33)	
	8.70	0.60	2.50	Piatti et al. (1999)
	8.78	0.65	2.16	Dias et al. (2002)
Ru 120	**8.00**(1)	**0.65**(5)	**1.98**(33)	
	8.00	0.65	2.30	Piatti et al. (1999)
	8.18	0.70	2.00	Dias et al. (2002)

[a] The errors of the last digits are always given in parenthesis.
[b] Interstellar reddening was transformed according $E(b-y) = 0.74E(B-V)$ (Crawford 1978).
[c] Indicates an uncertain result in the respective reference.