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Chemically peculiar stars in the field of NGC 2244*

H. Hensberge[1], **M. Vrancken**[1], **and W. Verschueren**[2,**]

[1] Royal Observatory of Belgium, Ringlaan 3, B-1180 Brussel, Belgium
[2] University of Antwerp (RUCA), Astrophysics Research Group, Groenenborgerlaan 171, B-2020 Antwerpen, Belgium

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Abstract. Low-resolution long-slit spectra of reference stars, including MKK standard stars and well-known chemically peculiar stars, are used to develop a spectroscopic method for the detection of the 5200 Å flux depression in CP stars. This new method is shown to be as sensitive a detection tool as the photometrical techniques, and provides a higher resolution view of the excess blocking. Application to stars in the field of NGC 2244 allows us to estimate and eliminate reddening effects. CP stars detected in this field include two members (# 334 and # 276) of the very young stellar group NGC 2244 (age $\approx 3 \times 10^6$ yr) and two or three foreground stars (# 381, # 625 and maybe # 629). # 334 and # 625 are strongly peculiar.

Key words: stars: chemically peculiar – stars: magnetic fields – techniques: spectroscopic – open clusters and associations: individual: NGC 2244

1. Introduction

The broad flux depression around 5200 Å in magnetic chemically peculiar (mostly CP2) stars was first noticed by Kodaira (1969) and has been measured photometrically for more than 20 years with the purpose of identifying Ap stars. Recently, CCD photometry was used for the first time (Maitzen et al. 1997). Maitzen (1976) developed especially for the measurement of this flux depression his g_1, g_2, y filter system, but the feature is also detectable in intermediate band systems (e.g. Geneva, Vilnius) which were not especially designed for its study. Adelman & Pyper (1979) pointed out that g_1 (at 5020 Å) and y (at 5465 Å) are still within the wings of the feature. Therefore, they use 4785 Å and 5840 Å as reference wavelengths in their spectrophotometrical description. A two-component structure of the feature, changing with temperature, became evident from spectrophotometry with 10 Å resolution of a very small sample of magnetic stars (Maitzen & Seggewiss 1980). However, considering large samples, the spectrophotometric series on CP stars by Adelman and co-workers (Adelman & Pyper 1993 and references therein) at $25-50$ Å resolution offers still the most detailed view. The origin of these features has been attributed to various bound-free ionization edges, autoionization features and differential line blocking. Most recently, Adelman et al. (1995) concluded from synthetic spectra with different metallicities that at least part of the feature around 5200 Å is due to differential line blocking.

The obvious problems related with the normalization of spectra in the presence of shallow, broad flux depressions has demotivated spectroscopic studies. In this paper we show that high signal-to-noise low-dispersion spectroscopy can be successfully used to detect magnetic stars from the 5200 Å region, while it provides at the same time superior information on the shape of the flux depression. We show that a "normality line", describing how the excess blocking around 5200 Å relative to some reference wavelengths varies with temperature for non-magnetic stars, can be accurately defined over the whole spectral type range of interest. Magnetic stars can then be separated from the non-magnetic stars as clear as in the best photometric studies.

The paper is organized as follows: Sect. 2 describes the observed sample of stars and the quality of the spectra. The spectrum analysis is presented in Sect. 3. In Sect. 4 the influence of interstellar reddening on the resulting blocking excess diagrams is discussed and the normality line is defined. The detection of magnetic stars in the field of the very young cluster NGC 2244, using these diagrams as well as more detailed spectral information, is discussed in Sect. 5. Finally, the conclusions are put in a broader perspective in Sect. 6.

2. Observations

The spectra were obtained between January 1987 and December 1990 using the long-slit spectrograph CARELEC (Lemaitre et al. 1990) at the 1.93 m telescope at OHP. With the 150 lines/mm grating and the RCA-type CCD #1, they cover a wavelength range from below the Balmer jump to beyond Hα, at 15.5 Å two-pixel resolution. The sample consists of two subsets: almost 300 reference stars, including many MKK standards covering the spectral types O–M and all luminosity classes on the one

Send offprint requests to: H. Hensberge, (Herman.Hensberge@oma.be)

* Based on observations obtained at the Observatoire du Haute–Provence (OHP), France

** Postdoctoral Fellow of the Fund for Scientific Research (NFWO) - Flanders (Belgium)

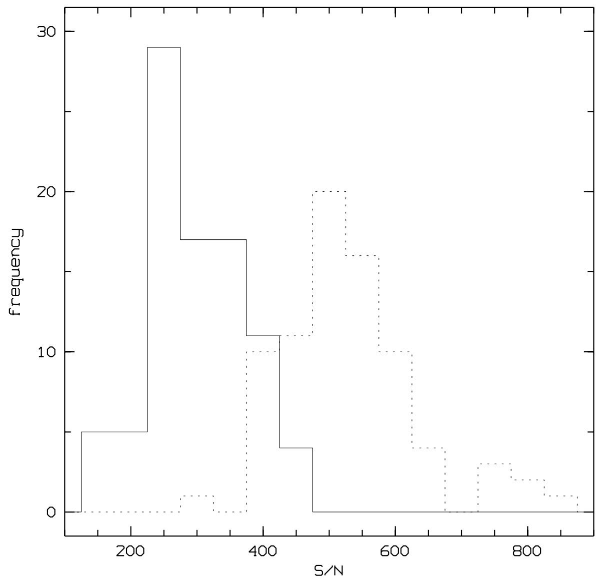

Fig. 1. Histogram of the signal-to-noise ratio of the mid-B to early-F spectra in the 5200 Å region. The full line refers to stars in the field of NGC 2244, the dashed line to the reference stars

hand, and about 250 stars in the field of NGC 2244 on the other hand. The second subset includes the stars in the central part of the cluster studied by Ogura & Ishida (1981), except those with a very low membership probability according to Marschall et al. (1982), and about 20 stars in each of two concentric rings at $27' \pm 3'$ and $38' \pm 2'$ from the centre of the cluster. The magnitude limit is approximately $B = 13$ in the rings and $U = 14$ in the core. Details about this sample can be found in Verschueren (1991). Information on the data reduction procedure, based on optimal extraction including an error analysis, is published by Hensberge & Verschueren (1992). The long-slit mode allows an efficient subtraction of the nebular background in the direction of NGC 2244. In this paper, our attention is focussed on the stars in the spectral range from mid-B to early-F. For these stars, the S/N ratio is at least 200 in the 5200 Å region for all but 6 stars (Fig. 1).

3. Spectrum analysis technique

3.1. Methodology

At low resolution, it is evident that there are no continuum windows. Hence, at most a reference level can be defined, relative to which differential blocking will be measured. For reasons of consistency and robustness, the spectral windows chosen for this purpose should be independent of spectral type, and also the change of line blocking in these windows relative to each other should not be very dependent on it. Obviously, a choice of windows with little absorption in late-B to early-F stars would be ideal. Robustness requires that sufficiently large windows are selected, situated at both sides of the feature to be measured.

Given the choice of the spectral windows, the reference level can be defined either on the extracted spectra, or after removing partly or completely the instrumental response and the atmospheric absorption from the data (see Fluks & Thé (1992) for the involved factors). We decided to use straightforwardly the extracted spectra, because in our case the gain to be expected from the removal of the instrumental and atmospheric signature is small. The observations, primarily made with spectral classification as objective, were obtained without the proper observing strategy one would follow when aiming for spectrophotometrical quality: a broad range of weather conditions and different slit orientations (to gain efficiency in the cluster observations) would require specific corrections for each frame and not all involved factors are accurately known. Moreover, the wavelength dependence of the stellar flux, the instrumental sensitivity and the low dispersion combine favourably to produce for most mid-B to early-F stars a reasonably flat unnormalized spectrum.

In the adopted empirical approach, there is no need to normalize the *whole* spectrum, from the Balmer jump to beyond H_α, since the reference level will be used only over a short part of the spectrum. A much simpler mathematical form may represent *locally* sufficiently accurate the low-frequency wavelength dependence of the extracted spectrum. The success of a specific local mathematical representation depends obviously on instrumental characteristics, and should therefore not be applied blindly to other sets of spectra. The extracted spectra are introduced in the normalization procedure as vectors of unnormalized relative intensities $I(p)$ in pixel space, with a wavelength associated with each element. All subsequent measurements are done in pixel space, but further on in the text wavelengths are mentioned rather than pixels in order to enhance the comprehensibility.

3.2. Reference level

Because of the occasional presence of a “knee” in the instrumental sensitivity near 5650 Å, trials to find a useful reference level have been limited to the wavelength region shortward of this knee. We speculate that the observed knee might be due to the difference in instrumental sensitivity for parallel and perpendicular polarization. It is well-known that the efficiency of gratings is not a smooth function of wavelength for perpendicularly polarized light. Depending on the degree and the mode of polarization of the received light, modified by the instrument, a knee might be observable in the instrumental response.

As a first test, we used the spectral regions well within the passbands of the g_1 and y filters for the definition of a reference level. In our case, the stellar flux distribution and the instrument/detector sensitivity combine to a maximum response near 5000 Å, such that a quadratic fit to $I(p)$ is a minimum requirement. In the case of the normal reference stars, such a fit is reasonable, although the appearance of strong absorption lines in the core of the g_1 passband for the cooler stars results in a reference level that is further from the continuum at 5000 Å than at 5550 Å. But for peculiar stars in the reference sample, larger problems arise because of the influence of line blocking on the local spectral gradients. A quadratic fit through two wavelength intervals then turns out to be not sufficiently robust (Fig. 2).

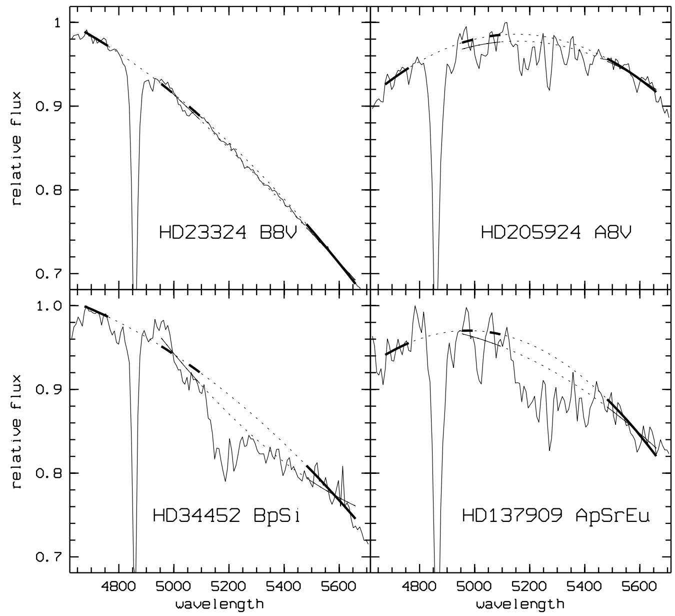

Fig. 2. Reference level determination (original test: shorter interval; final choice: longer interval) in normal reference stars (upper panels) and peculiar reference stars (lower panels) respectively. In the wavelength intervals used in the fitting procedure, the reference level is drawn as a full line instead of a dotted line; the thicker lines refer to the final choice

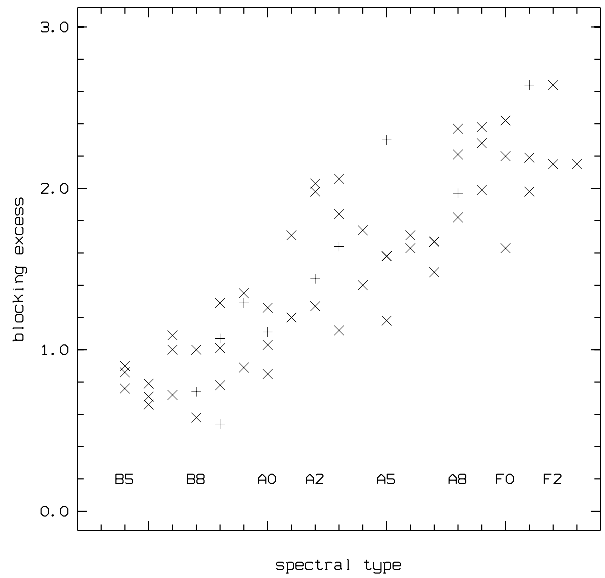

Fig. 3. The blocking excess b_{5200} for not heavily reddened normal reference stars ($E_{B-V} < 0.25$). Crosses refer to luminosity class III–V stars, pluses to bright giants and supergiants

Hence, the spectra of the non-magnetic stars in the spectral range B3–F5 were inspected, looking for a (longer) baseline from which the curvature of the response should be retrievable without strong interference of local line blocking. This lead to the final choice of the wavelength intervals which define the reference level $C(p)$: $\lambda\lambda\ 4672-4765, 4950-4997, 5051-5098, 5477-5663$. Basically, the core of the g_1 region was replaced by an interval shortward of Hβ with relatively low line blocking throughout the spectral range of interest. Fig. 2 shows the much better similarity obtained between the reference level in peculiar and normal stars of comparable temperature, although the fit for peculiar stars remains less satisfactory than for the normal reference stars. For hot peculiar stars, our reference wavelengths are in the wings of the flux depression and particularly the interval $\lambda\lambda\ 5051-5098$ forces the reference level lower than ideal. In cooler magnetic stars, the absorption in the $\lambda\lambda\, 4672-4765$ interval is not negligible, but its influence on the reference level in the 5200 Å region seems to be acceptably small. A comparison with the available spectrophotometry (Figs. 2 and 3 in Pyper & Adelman 1985; Fig. 1 in Maitzen & Muthsam 1980) for HD 34 452 and HD 137 909 elucidates these statements. In both cases, the gain made by reducing the influence of the region covered by the g_1 passband is evident. For peculiar stars, it would be more correct to disregard the $\lambda\lambda\ 5051-5098$ interval, but at present we choose to retain it because it provides more robustness for the reference level determination in non-peculiar stars. It should be emphasized that the reference level is not the continuum level (hence, equivalent widths cannot be derived), and that the low-frequency shape of the feature may be somewhat distorted.

The quantity $b_{5200} = 100 < 1 - \frac{I}{C} >$, where the average is taken over the pixels in the wavelength interval $\lambda\lambda\, 5113-5462$, is used as a measure for the excess blocking in the 5200 Å region relative to the blocking in the reference spectral ranges. As shown in Fig. 3, b_{5200} increases slowly towards the later spectral types, without a prominent dependency on luminosity class. This is consistent with our knowledge about the metal spectra in this spectral region, and similar to the behaviour of the photometrically observed normality lines. The scatter at a given spectral type is of the order of 1.0 at the $3\,\sigma$ level, which is comparable to the $3\,\sigma$ detection level of ≈ 0.01 mag found in photometric and spectrophotometric studies (both indicating a one percent deviation from the "normal" flux).

4. Interpretation of blocking excess diagrams

The blocking excess diagram shown in Fig. 3 is intrinsically equivalent to the peculiarity excess diagrams obtained through photometry (a, Z, ...). In both cases, the measured excess depends on temperature and reddening. In diagrams constructed from photometry, the temperature estimator used is a colour index (conventionally $b-y$, but see Maitzen & Vogt (1983) for the validity of this index as a temperature estimator for late-A stars), which can be obtained simultaneously with the peculiarity index. It is natural to use in a spectroscopic method the spectral type as a temperature indicator, as it can be obtained from the low dispersion spectra under investigation. The method is then independent from external (photometric) data sets, which might not be available. For peculiar stars, the spectral type as well as the colour index are undoubtedly less accurate temperature indicators than for normal stars, and this should be taken

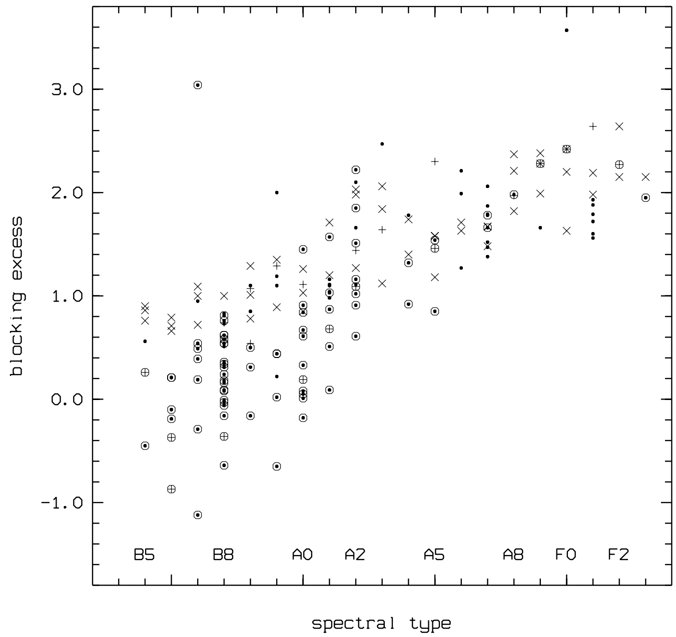

Fig. 4. The blocking excess b_{5200} for normal reference stars and all programme stars. Crosses refer to luminosity class III–V reference stars, pluses to reference bright giants and supergiants, dots to stars in the field of NGC 2244. The more heavily reddened stars ($E_{B-V} > 0.25$) are encircled

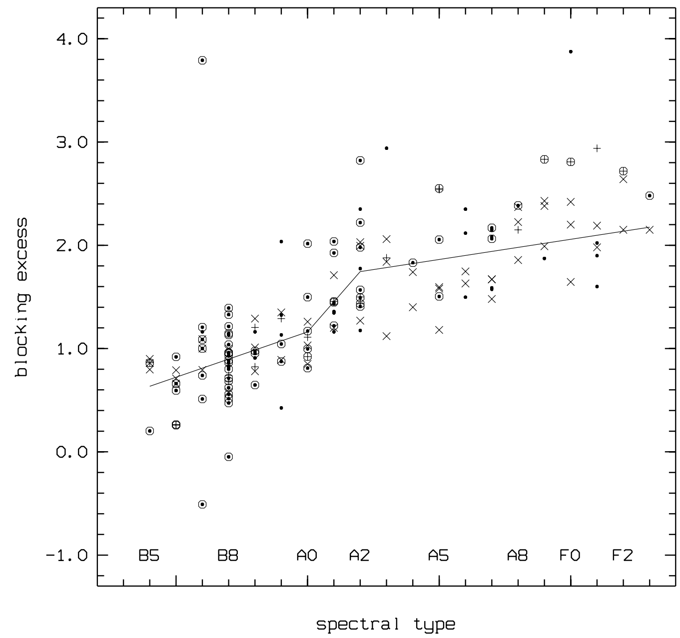

Fig. 5. The blocking excess b_{5200} corrected for reddening, and the adopted normality line. The symbols have the same meaning as in Fig. 4

into account when deciding on the significance of the deviation from a normality line.

The effect of interstellar reddening is present in both kinds of excess diagrams, but in a different way. In diagrams constructed from photometry, the temperature indicator should be dereddened, while the spectral type determination is reddening-independent. In practice, photometrical studies have often used a specific normality line for a group of equally reddened stars (e.g. a cluster), rather than to determine the reddening for the cluster or star by star. Maitzen (1976) has defined his photometrical index in such a way that it is in first order reddening-free, and hence $\Delta\, a$ does not depend on reddening when measured against $(b-y)_0$ or against a reddening-specific normality line. Other photometric indices suffer from reddening, but were seldomly used to measure substantially reddened stars. The reddening-dependence of the spectroscopic excess index defined in this paper needs to be investigated. At present, we prefer to estimate the effect in an empirical way (Sect. 4.1), rather than to correct the spectra for reddening before applying our spectrum analysis technique. Indeed, the standard reddening law might not be strictly applicable in a region of recent star formation (Pérez et al. 1989). However, in principle, for many star samples a classical reddening correction would be preferable rather than an empirical procedure.

Finally, one should keep in mind that the position of the normality line also depends on the chemical composition of the "normal" stars, but there are no indications that the reference stars and the members of NGC 2244 would have significantly different metallicities (Vrancken et al. 1997).

4.1. Reddening correction

The sample shown in Fig. 3 is extended by adding the *reddened* (normal) reference stars and the stars observed in the field of NGC 2244 (Fig. 4). It is clear from this figure that the substantially reddened stars have a lower blocking excess than the unreddened stars of the same spectral type. The effect is noticeable, but small, such that a simple correction proportional to the amount of reddening and independent of spectral type proves to be sufficiently adequate. The proportionality coefficient ϵ was derived in an iterative way, requiring that the residuals of the excess blocking relative to the normality line (that defines the average blocking excess for normal, unreddened stars of each spectral type) are statistically independent from the degree of reddening.

In order to do this, we need for individual, non-magnetic stars:

– an estimate of the amount of reddening. For the stars in the field of NGC 2244, we used our $VBLUW$ photometry (Verschueren 1991); for the reference stars, we derived the reddening from Geneva photometry (Rufener 1988). In both cases, the result was converted to Johnson's E_{B-V}. For 19 stars in NGC 2244 (almost exclusively stars in the core of the cluster with an apparent visual magnitude fainter than 13), we have spectra in which the strength of the diffuse interstellar bands allowed us to decide whether they are appreciably reddened or not, but for which no photometry is available. These stars are included in Fig. 4, but not in the dereddening procedure and the subsequent figures.
– the expectation value of b_{5200} for unreddened stars of the considered spectral type, say b^0_{5200}, or shortly b^0.

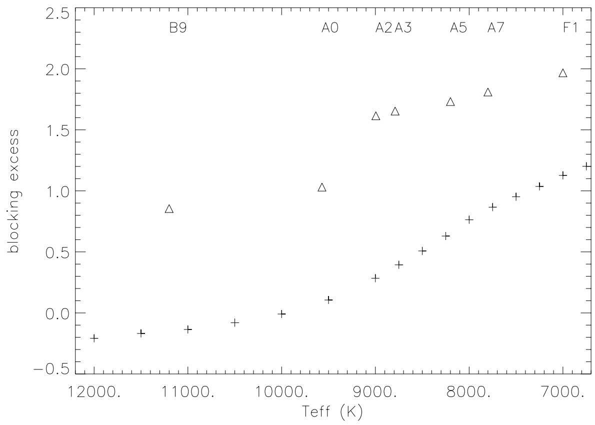

Fig. 6. Comparison between the normality line as predicted by the synthetic spectra (pluses) and the empirical one (triangles). The spectra were computed with solar abundances, $\log g = 4.0$ and $v_{\rm turb} = 2$ km s^{-1}. The calibration of Flower (1977) is used to link spectral types with temperature

An initial estimate of b^0 was obtained from the (almost) unreddened normal reference stars. Previous photometric studies suggest that b^0 varies nearly linearly with temperature. Given the run of b^0 over the considered spectral type interval, ϵ may be derived from a least-squares fit to the relation

$$b_{5200} - b^0 = \epsilon E_{B-V} \ .$$

The preliminary reddening correction then allows to include the reddened stars in the next iteration defining a better normality line $b^0(\rm sp.type)$; the value of ϵ is thereafter improved using the newly estimated b^0.

In practice, this procedure converges very fast. However, it turned out to be useful to check for subsets of stars that deviate in a systematical way from the normality line. The final estimate $\epsilon = 1.37$ and the piecewise linear normality line shown in Fig. 5 (see also Sect. 4.2) were derived from all luminosity class III–V stars, except emission line stars and candidate magnetic stars. The latter were identified by their large positive residual with respect to the fitted relation and removed iteratively. While most emission line stars occupy a position near the normality line, some do lie significantly below it. For consistency, the few emission line objects were all excluded from the fit. Similarly, most bright giants and supergiants appear to obey the derived reddening relation. However, the cooler ones tend to lie above the normality line and this appears to be rather an intrinsic characteristic than that it would be the consequence of an inadequate reddening correction.

4.2. Normality line

The definition of the normality line is based on sufficient stars to investigate whether a linear relation with a temperature parameter (e.g. spectral type) is adequate. There is significant evidence for a faster increase in b^0 between the spectral types A0 and A2. Therefore we adopted, in the final iteration in the dereddening procedure, a piecewise linear dependence of b^0 on spectral type: one for the B-stars (including A0), one for the early-A stars (A0–A2) and one from A2 on (Fig. 5). The influence on the b_{5200} blocking excess is nowhere larger than 0.3, as compared to the use of a linear relation over the whole spectral range, and hence the decision on the complexity of the normality line is not very critical.

LTE synthetic spectra in the temperature range 7 000–12 000 K were computed for comparison of the theoretically predicted normality line with the empirical one (Fig. 6). Classical LTE line blanketed atmosphere structures, having a solar composition and $v_{\rm turb}$=2 km s^{-1}, were taken from the grid of Kurucz (1992, 1993). LTE synthetic spectra, consistent with these atmospheres, were then computed with the program SYNSPEC (Hubeny et al. 1994) which takes Kurucz line list (Kurucz & Bell 1995) as input. The increase of b^0 with decreasing temperature is reproduced globally, but there is an offset of about 1.0 in b^0, in the sense that the theoretical spectra have not enough absorption in the 5200 Å region relative to that in the reference wavelengths. Hence, also the detailed run of the theoretical normality line with temperature might show inaccuracies that are larger than those associated with the, admittedly subjective, choice made for the empirical representation. The present uncertainty on how to draw the normality line implies primarily that marginally peculiar stars in the spectral range A1–A3 could be somewhat easier missed than for other spectral types.

5. Chemically peculiar stars in NGC 2244

Fig. 7 shows the residuals Δb of individual stars relative to the normality line, after applying the dereddening correction discussed in Sect. 4.1. Threshold levels ($3\,\sigma$) are shown as dashed lines. For clarity, only the stars in the field of NGC 2244 and the known peculiar reference stars are shown. Two stars in the field of NGC 2244, # 334 and # 625, are clearly above the detection threshold, while two (# 276 and # 381) are slighter above it and two more (# 124 and # 629) are essentially on the detection threshold. # 74 and # 116 deviate significantly from the normality line in the opposite sense. Relevant data on these stars are given in Table 1.

Inspecting this table, one might have the impression that the reddening for # 334 is overestimated, which would not be uncommon when applying a classical dereddening procedure to a strongly peculiar star. However, Verschueren (1991) observes a reddening pattern over the cluster that relates to the position of the star inside the central hole of the Rosette nebula, or outside of it. The central hole is characterized by a median E_{B-V} = 0.42 (almost all stars have $E_{B-V} < 0.50$), while the halo ($> 20'$ from the centre) has a median E_{B-V} = 0.59 (almost all stars have $E_{B-V} > 0.50$). Nearer to the centre, but outside of the central hole, stars with $0.4 < E_{B-V} < 0.7$ intermingle in a complicated way. # 276 as well as # 334 belong to this latter subgroup. Hence, the reddening value for # 334 is not suspiciously high. Moreover, even assuming quite arbitrarily a low true reddening excess of 0.4, the effect on $\Delta\, b$ would be small ($\Delta\, b$ = 2.85 instead of 2.99).

Table 1. Stars in the field of NGC 2244 significantly deviating from the normality line. Identifications are from to Ogura & Ishida (1981) and coordinates from Marschall et al. (1982), converted to 2000.0, for identification numbers smaller than 400. All other information is taken from Verschueren (1991)

object	$V_{\rm J}$	α (2000)	δ (2000)	member	E_{B-V}	sp. type	Δb
74	12.37	6 31 29.72	4 54 48.3	yes	0.45	B7 V:e	−1.31
116	12.75	6 31 54.56	4 59 22.0	yes	0.43	B8 V	−0.93
124	13.00	6 31 51.25	4 56 16.2	yes	0.41	A0 IV	+0.87
276	12.46	6 32 26.32	4 44 56.2	yes	0.44	A2 IV	+1.09
334	12.93	6 32 51.79	4 47 16.2	yes	0.55	Bp	+2.99
381	8.94	6 31 16.78	4 37 24.5	no	0.03	B9 III	+0.98
625	10.30	6 31 39	4 20.4	no	0.22	F0p	+1.83
629	9.62	6 30 15	4 26.6	no	0.09	A3 V	+0.82

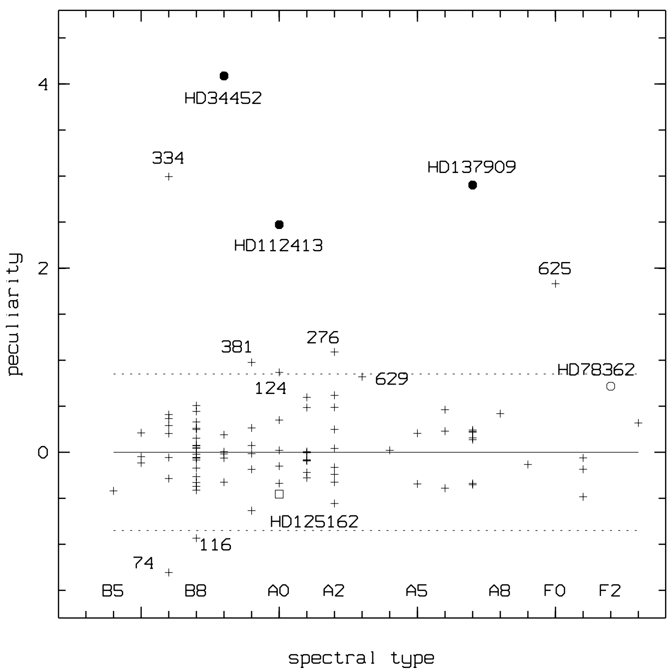

Fig. 7. The peculiarity parameter Δb for the stars in the field of NGC 2244 (+) and for known peculiar reference stars (CP2: dots, Am: circle, λ Boo: square)

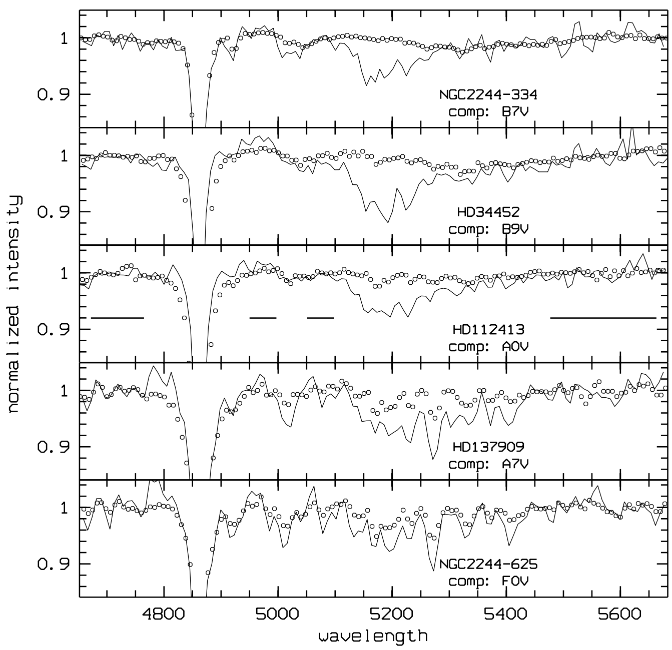

Fig. 8. Detailed view of the 5200 Å region in detected and known magnetic stars (full line), compared to normal stars (circles; from top to bottom: HD 21 071, HD 45 380, HD 103 287 = γ UMa, HD 87 696 = 21 LMi and HD 58 946 = ρ Gem). The reference wavelengths, used to rectify all spectra, are indicated by horizontal bars

334 is a very probable member (96% probability, Marschall et al. 1982) situated 17′ SW of the core of the cluster, and was already recognized as a peculiar star during the classification of our spectra. A detailed view of the 5200 Å region relative to the reference level is given in Fig. 8, with comparison to the hottest peculiar reference stars HD 34 452 and α^2 CVn (HD 112 413). We emphasize that each panel of this figure shows the local line blocking *excess* of both a peculiar and a non-peculiar star of similar temperature. The zero-excess level is (roughly) the average line blocking observed over the reference wavelength regions of the considered star. In an absolute sense, the line blocking in the peculiar star is at all observed wavelengths likely to be stronger than that in the non-peculiar star.

625 is a foreground star of the outer observed ring. It was recognized in the classification study as peculiar, but without the present study of the 5200 Å region it had been impossible to distinguish at this low dispersion between a metallic line (Am) or a magnetic star. The large Δb strongly favours the latter interpretation.

The only star clearly below the normality line, # 74, shows emission in Hα (eq. width ≈ 40 Å) and in many Fe II lines, the most prominent ones being situated near $\lambda\lambda$ 5018, 5169, 5276 and 5317. Six of the emission line stars detected in NGC 2244 have a spectral type in the range of interest of this study, and all but # 74 are close to the normality line: four of them with a low emission measure give $\Delta b = 0.33$ with a rms of 0.06 while # 319 (eq. width Hα ≈ 30 Å) is at $\Delta b = -0.37$. All this

Table 2. Indices measured spectropscopically (Δb), spectrophotometrically (ΔWS_2) and photometrically ($\Delta a, \Delta(V1-G)$). Data are taken from Adelman & Pyper (1993), Maitzen et al. (1998), Maitzen (1976), Maitzen & Hensberge (1986), Rufener (1988) and Schnell & Maitzen (1994). Spectral types are from Gray (1988) and Gray & Garrison (1989a, 1989b) or are copied from Renson (1991)

HD	name	MKK	Δb	ΔWS_2	Δa	$\Delta(V1-G)$
34 452	–	B9 Si	4.09	31.5	–	0.047
78 362	τ UMa	kA3 hF2 mF5 (Ib)	0.72	–	0.000	0.009
112 413	α^2 CVn	A0 Eu Si Cr	2.47	–	0.040	0.027
125 162	λ Boo	A0 Va λ Boo	-0.46	–	-0.010	-0.006
137 909	β CrB	knA7hA7 Sr Eu	2.90	20.7	0.023	0.004

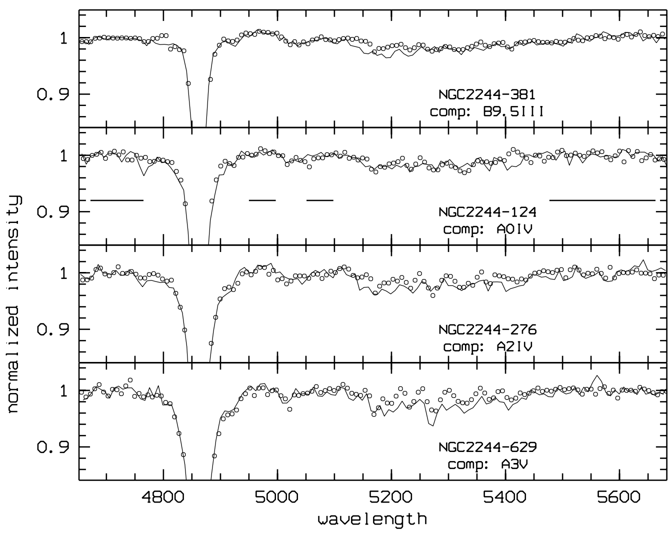

Fig. 9. Detailed view of the 5200 Å region in candidate magnetic stars in the field of NGC 2244 (full line), compared to normal stars (circles; from top to bottom: HD 186 882 = δ Cyg, HD 210 419, HD 1 280 = θ And and HD 102 647 = β Leo). The reference wavelengths, used to rectify all spectra, are indicated by horizontal bars

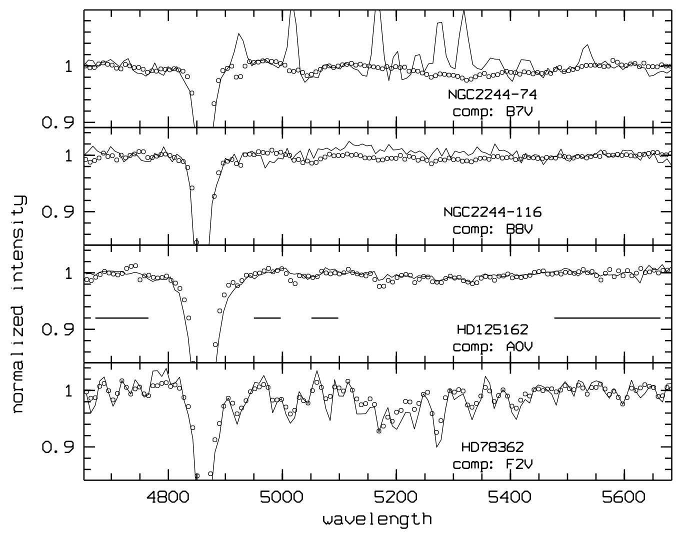

Fig. 10. Detailed view of the 5200 Å region, from top to bottom panel, full lines: two stars in the field of NGC 2244 with a negative differential blocking index, λ Boo (=HD 125 162), a metallic line (δ Del) star; all compared to normal stars (circles; from top to bottom: HD 21 071, HD 23 324 = 18 Tau, HD 103 287 = γ UMa and HD 113 139 = 78 UMa). The reference wavelengths, used to rectify all spectra, are indicated by horizontal bars

corroborates the conclusion of Pavlovski & Maitzen (1989) that emission line stars usually do not deviate significantly from the normality line; and when they do, they are more often below than above the normality line. Our spectroscopy shows that the position below this line is related to the strength of the iron emission lines around 5200 Å (Fig. 10). Their effect on Maitzen's (1976) photometric parameter Δa will be quantitatively somewhat different, since one of the strong emission lines lies in the centre of the g_1 passband.

116 star lies below the normality line for a different reason: its spectrum is the only late-B type that shows significant absorption in the $\lambda\lambda\, 4950-5000$ interval, while the flux at these reference wavelengths is relatively high in all other spectra. It is this absorption, the origin of which is currently unknown, that forces the reference level somewhat below the observed flux level in the 5200 Å region.

For a correct interpretation of the position of the four stars near the detection threshold (none of which is obviously peculiar at low resolution), we checked whether pre-defined subsets of stars showed larger-than-average residuals. Subsets were defined according to S/N and to the strength and the complexity of the background that was subtracted from the raw spectra, but no significant dependency on these parameters was found. At best, there is a slight indication that the scatter may increase marginally for the lowest S/N spectra (S/N $<$ 250).

All stars near the detection threshold were observed with a S/N $>$ 300, except # 124. Fig. 9 shows that in the case of # 629, # 276 and # 381 the contributions to a positive Δb come indeed from the wavelength points that also contribute in the stars showing a stronger feature. These three stars are thus good candidate magnetic stars, albeit with a weak 5200 Å peculiarity, whose character should be confirmed by higher resolution spectroscopy and a search for light variability. Only one of them is a probable member of NGC 2244, i.e. # 276, at $13'$ SW of the cluster core. Hence, it is in the same part of the cluster as the more prominent peculiar star # 334. It is not excluded that the classification of # 276 and # 381 as (sub-)giant is related to their peculiarity rather than to their luminosity (a well-known confusion in classification). Si stars also appear too blue for their spectral type, which might have contributed to the low measured reddening of # 381 as compared to its apparent brightness.

For # 124, the evidence for the presence of the λ 5200 feature is unconvincingly weak. Moreover, a classification error of only one sub-class would bring it well inside the "normality" region. Since it is a likely member, right in the core of the very young cluster, further studies that might clarify whether it is peculiar or not are still of considerable interest.

Finally, the sample of 19 stars without accurate reddening estimates was checked for outliers. None of them qualifies as a magnetic star, even not when assuming the highest reddening measured over the whole cluster. It appears that # 137 (the low point at spectral type B9.5 V in Fig. 4) might remain significantly below the normality line. Applying a dereddening corresponding to the average value in the core of NGC 2244 results in $\Delta b \approx -1.1$ and a differential blocking pattern similar to that of # 116, shown in Fig. 10.

6. Discussion and conclusions

Two probable members of NGC 2244 and three foreground stars in the field towards this cluster were identified as magnetic stars. The stars # 334 and # 276 in NGC 2244 are only a few million years old and hence among the youngest CP2 stars known. An extensive set of reference stars was used to show that the spectroscopically defined parameter Δb separates the magnetic stars from "normal" and other peculiar stars, although cooler supergiants and metallic line stars tend to lie slightly above the normality line as defined by the luminosity class III–V reference stars. B-type emission line stars that show emission in the Fe II lines near 5200 Å are situated below the normality line.

The spectroscopic method is as a detection tool as sensitive as the photometric methods. A S/N of 250 turned out to be more than sufficient. Undoubtedly, improvements can be made to the spectrum analysis technique; in the first place to the choice of the reference intervals, and probably also to the representation of the reference level when precautions are taken during the observations to exploit a physical model for instrumental and atmospheric response. In our opinion, the use of a slightly better resolution and the availability of a depolarizer unit in front of the grating would contribute particularly to an improved reference level.

The excess blocking measurements presented in this paper for known peculiar stars correlate well with the (spectro)photometric indices for the 5200 Å feature. As shown in Table 2, the spectroscopic Δb index singles out better the cooler magnetic stars than do the photometric indices, and gives relatively lower excesses for the hotter stars which, however, remain the easier recognizable ones. This has two reasons. On the one hand, the excess is averaged over a broader wavelength interval ($\lambda\lambda$ $5113 - 5462$). On the other hand, regions with considerable absorption distort less the wavelength dependence of the reference level in the (normal) late-A to early-F stars than in the (peculiar) late-B to early-A stars. The Δb index is primarily sensitive to the strength of the narrower absorption component centred on $\approx$ 5175 Å in the hotter peculiar stars, while it measures the global enhancement of the differential line blocking over the whole $\lambda\lambda\ 5113 - 5462$ interval in cooler peculiar stars.

In addition, the spectroscopy provides insight into the location of the excess absorption and its dependence on temperature or chemical peculiarity, although the defined reference level distorts the feature in a different way in hotter and cooler magnetic stars. The principal distortion is the suppression of the broader underlying component of the 5200 Å feature in the hotter peculiar stars. In all cases, our reference level lies more below the continuum than the spectrophotometric one on which the ΔWS_2 index (Adelman & Pyper 1993) is based. More work needs to be invested in the definition of the reference level. In spite of this caveat on the low-frequency distortion of the feature, the spectra are useful to distinguish the contribution of different blocking factors to the feature. Obviously, a large sample of magnetic stars needs to be observed (preferably at a twice higher resolution) to exploit fully this advantage, but some trends can already be indicated.

In the stars of spectral types A3 and later, the structure of the normalized blocking seen in normal stars is reflected in the peculiar stars. Hence it appears that an important part of the excess blocking in cooler peculiar stars is due to the enhanced strength of lines also common in normal star spectra. There is also structure visible in the 5200 Å feature in hotter peculiar stars, but it does not reflect the wavelength dependence of the blocking in normal stars, which at those temperatures is much less pronounced than in the cooler normal stars. An important part of the absorption in the spectra of the hotter peculiar stars is apparently due to lines which do not produce significant absorption in normal stars of similar temperatures. Part of the excess blocking might be due to one or several intrinsically broad features, insofar as no bins with small absorption are observed over a broad wavelength region. We note that also in a cooler peculiar star as β CrB, a larger excess absorption relative to the normal stars, in comparison to the excess measured in other wavelength regions, is observed over a quite broad interval ($\lambda\lambda\ 5140 - 5320$). It is thus not excluded that a rather weak, very broad underlying feature persists over the whole spectral interval studied, albeit less apparent in cooler stars because of the superimposed line blocking structure. On top of this broad feature many hotter strongly peculiar stars have a sharper, deeper feature in the range $\lambda\lambda\ 5120 - 5270$ on which structure is superimposed. This is most clear in the case of HD 34 452. It will be interesting to investigate whether this feature dissolves in narrower ones at higher resolution.

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