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New spectroscopic observations of the B[e]/K binary system MWC 623

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Abstract. The B[e]/K binary system MWC 623 was reinvestigated using new spectroscopic observations. The absorption lines of the K and the B star do not exhibit any significant radial velocity variations over a time interval of 14 years. The spectral classification using a recent echelle spectrum yielded spectral types of K2II-Ib and B4III. The luminosity class of the K star gives an estimate of the distance towards MWC 623 of $2.4^{+1.4}_{-0.9}$ kpc. This is consistent with the kinematic distance of $2.0^{+0.6}_{-0.3}$ kpc. The masses derived from the locations of the binary components in the H–R diagram are $7 \pm 1.5\ M_\odot$ and $7.5 \pm 2.5\ M_\odot$ for the B and K star, respectively, i.e. the mass ratio is close to 1. Both stars are coeval with an age of 50^{+10}_{-20} Myr as shown by the comparison with isochrones. The high luminosity of the K star excludes a pre-main sequence evolutionary phase as explanation for the strong Li Iλ6708 absorption line observed in the late-type component. Rather, the high lithium abundance is a consequence of the young age. Likewise, the B[e] star is a slightly evolved object starting it post-main sequence evolution.

Key words. stars: circumstellar matter – stars: early-type – stars: late-type – stars: emission-line – stars: evolution

1. Introduction

The emission-line object MWC 623 was described by Allen & Swings (1976) as a peculiar Be star with a strong near-infrared excess. The spectrum they discussed was dominated by strong emission lines of the Balmer series and numerous permitted and forbidden emission lines of Fe II, [Fe II], and [O I]. Absorption lines were not reported. Zickgraf & Stahl (1989) (hereafter referred to as Paper I) obtained high resolution spectroscopic observations of this object. In addition to the rich emission line spectrum they detected early-type and late-type absorption features, namely He I absorption lines and numerous absorption features of Fe I, Li I, Ca I, etc. The analysis of these spectroscopic properties and of the continuum energy distribution lead Zickgraf & Stahl to the conclusion that MWC 623 is actually a binary system consisting of a B2- and K2-type component.

Polarimetry of MWC 623 carried out by Zickgraf & Schulte-Ladbeck (1989) revealed the presence of intrinsic polarization. These observations were interpreted as being due to a bipolar wind structure as suggested for B[e]-type stars e.g. by Zickgraf et al. (1985) (cf. also the review by Zickgraf 1998, on B[e]-type stars). The presence of intrinsic polarization was considered indicative for an inclination angle deviating significantly from pole-on.

A puzzling discovery was the existence of a strong absorption line of lithium, Li Iλ6708 Å. Because it seemed unlikely that the late component in MWC 623 is a T Tauri star Zickgraf & Stahl proposed that the high lithium abundance of the K star might be produced during He-flashes occuring when the K star evolves along the giant branch or alternatively that the object is just not old enough to have the lithium completely depleted.

In this paper new spectroscopic observations of MWC 623 are presented. The purpose here is to investigate for the first time variability of the spectrum and to rediscuss the evolutionary scenario for MWC 623 based on a revised spectral classification of the binary components. The outline of the paper is as follows. The observations are described in Sect. 2. Radial velocity measurements are discussed in Sect. 3. In Sect. 4 spectroscopic variability is investigated. The stellar parameters and evolutionary status are discussed in Sect. 5. Finally, conclusions are summarized in Sect. 6

2. New spectroscopic observations

MWC 623 was observed on October 21, 1998 and June 16, 2000. The observations in 1998 were obtained with the spectrograph AURELIE at the 1.5 m telescope of the Observatoire de Haute Provence. A description of the

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spectrograph can be found in Gillet et al. (1994). The spectra were observed with grating No. 2 with 1200 lines mm^{-1} giving a reciprocal linear dispersion of 8 Å mm^{-1}. The detector was a double-barrette Thomson TH7832 (2048 pixel with 13 μm pixel size). The spectra cover the wavelength interval from 6540 Å to 6740 Å. The resolution of the spectra is 20 000. Wavelength calibration was obtained with neon and argon lamps.

The spectrum of June 2000 was observed with the echelle spectrograph FOCES (cf. Pfeiffer et al. 1998) at the 2.2 m telescope of Calar Alto Observatory. The spectrograph was coupled to the telescope with the red fibre. The detector was a 1024×1024 pixel Tektronix CCD chip with 24 μm pixel size. With a diaphragm diameter of 200 μm and an entrance slit width of 180 μm a spectral resolution of 34 000 was achieved. Wavelength calibration was obtained with a ThAr lamp.

The spectra were reduced with the standard routines of the ESO-MIDAS software package (contexts *longslit* for the AURELIE spectra and *echelle* for the FOCES data).

3. Radial velocities

3.1. Absorption lines

The radial velocity of the late-type component was determined from the spectra by means of a cross-correlation technique, i.e. by measuring the shifts of the spectra relative to radial velocity standard stars. For this purpose first the mean continuum was subtracted from the normalized spectra. Then the spectra were rebinned on a logarithmic wavelength scale. The relative shift was finally measured by cross-correlation. The standard stars used had been observed with AURELIE during the run in October 1998. The selected stars were HD 212943 (K0, $v_{\rm rad} = 53.8$ km s^{-1}), HD186791 (K3, $v_{\rm rad} = -2.1$ km s^{-1}), and HD 204867 (G0, $v_{\rm rad} = +6.5$ km s^{-1}) (Duflot et al. 1995). In order to obtain consistent measurements of the radial velocities also for the spectra of 1986-88 discussed in Paper I, the same procedure was applied also to these data and the radial velocities were redetermined with the same set of standard star spectra.

The section of the spectra used for the measurement was 6600–6730 Å. This region is completely dominated by the lines of the late-type component and is free of emission lines. For the spectrum of 1987 a smaller interval of 6660–6710 Å had to be used due the smaller wavelength interval covered by the spectrogram of this observing run (cf. Paper I). Measurement errors were estimated from the scatter of the results for the three standard stars and from the scatter of the individual spectra available for each observing campaign (2–3 spectra per observing run). Note, that only minor differences in the redetermined velocities were found relative to the results given in Paper I.

The velocities of the He I absorption lines (and of the emission lines, see below) were determined by measuring directly the wavelengths instead of using the cross-correlation method.

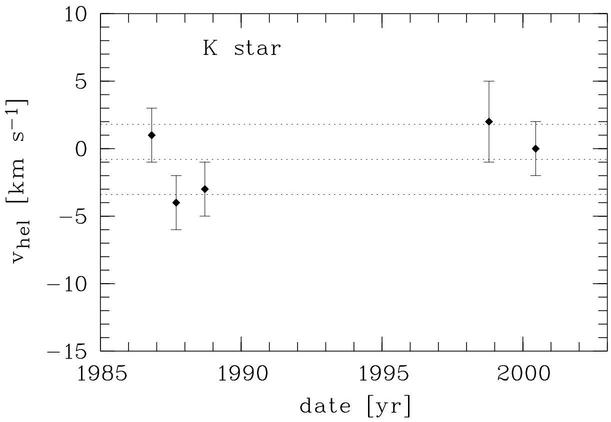

Fig. 1. Heliocentric radial velocity of the K component. The interval of $\sigma = 2.6$ km s^{-1} is marked by the upper and lower dashed lines.

In Table 1 the resulting heliocentric radial velocities are listed. The velocities measured from absorption lines of Fe I, Li I, and Ca I are summarized as "K star abs.". Within the errors of the measurements no significant radial velocity variations of the absorption lines of the K star could be detected between 1986 and 2000. This also holds for the He I lines attributed to the B star component. In Fig. 1 the heliocentric radial velocities of the K star are plotted for the different observational epochs. The mean velocity of the K star calculated from the five measurements is $v_{\rm K} = -0.8 \pm 2.6$ km s^{-1}. The standard deviation of the mean velocity is of the same order as the individual errors of the measurements.

3.2. Emission lines

The radial velocities of the emission lines are also summarized in Table 1 including the results from Paper I. In constrast to the absorption lines the emission features exhibit some variability. [O I] shows some variation on the order of 6 km s^{-1}. In 2000 the lines of Fe II and [Fe II] had a slightly more negative velocity than in the 1980s. The mean difference is $\sim$−6 km s^{-1}. Likewise, the Balmer lines in 1998 and 2000 exhibit a more negative velocity by the same amount as the singly ionized iron lines. The variable velocities of the Balmer lines could be related to line profile variations discussed in the next section.

4. Spectroscopic variability

4.1. Emission lines

The emission line of Hα is clearly variable. This is shown in Fig. 2. In the recent spectra the line is a factor two weaker than in the late 1980s. Also small changes in the line profile are discernible, in particular in the blue wing which showed a more pronounced dip in the 1998 and 2000 spectra. The spectrum of 1998 additionally shows a dip also on the red wing (weakest line in Fig. 2).

The emission lines of Fe II and [Fe II], however, do not exhibit this variability pattern. Rather, these lines seem

Table 1. Heliocentric radial velocities of emission and absorption lines between 1986 and 2000. The velocities of the emission lines for the years 1986-88 are from Paper I.

date	Fe II em.	[Fe II]	[O I]	Hα	Hβ	Hγ	Hδ	He I abs.	C II abs.	K star abs.
1986	-5 ± 2	-6 ± 1	-5 ± 4	$+26 \pm 3$			$+8 \pm 3$	-4 ± 4	-8 ± 3	$+1 \pm 2$
1987		-8 ± 2	-12 ± 2	$+18 \pm 2$						-4 ± 2
1988	-6 ± 4		-6 ± 4	$+22 \pm 2$						-3 ± 2
1998				$+13 \pm 2$						$+2 \pm 3$
2000	-11 ± 2	-13 ± 2	-11 ± 2	$+13 \pm 2$	$+11 \pm 2$	$+3 \pm 2$	-5 ± 2	-2 ± 3	-3 ± 3	$+0 \pm 2$

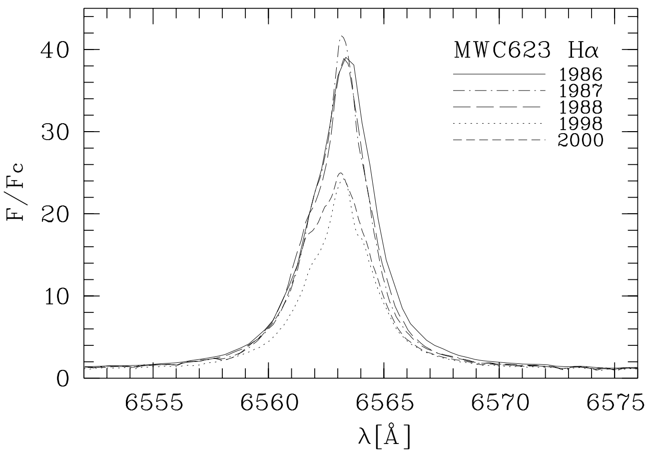

Fig. 2. Line profile variations of Hα. During 1986–1988 the emission line was nearly twice a strong as in 1998 and 2000.

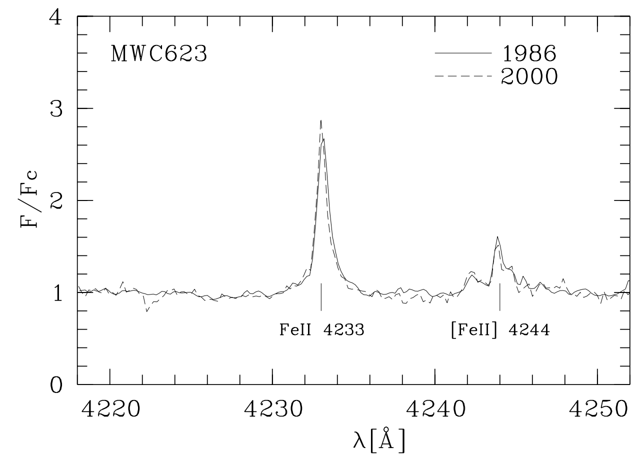

Fig. 3. Comparison of the lines Fe II and [Fe II] in 1986 and 2000. No significant variation of the line strengths is discernible.

to be constant in intensity, at least for the two epochs of 1986 and 2000 (only these two observations of the blue spectral region are available). This is depicted in Fig. 3. Note, that the spectrum of 2000 has been rebinned to the same resolution as that of 1986 for this comparison.

4.2. Absorption lines

In Fig. 4 a section of the spectrum of MWC 623 around the line of Li I λ6708 Å are shown for the five epochs of observation. Obviously, the strengths of the K star absorption features are variable to some extent. The measured equivalent widths W of some characteristic lines of Fe I, of Li I, and of Ca I are listed in Table 2. In addition, the sum of the three Fe I lines is listed, which has a smaller relative error than the individual lines.

Table 2. Equivalent widths W of absorption lines around 6710 Å (given in mÅ). The error of the individual measurements is of the order of 10 mÅ. The last column gives the sum of the equivalent width of the three Fe I lines listed. Its error is about 20 mÅ.

date	Li I λ6708	Ca I λ6719	Fe I λ6703	Fe I λ6705	Fe I λ6710	Σ Fe I
1986	192	123	68	60	95	223
1987	200	140	74	36	100	210
1988	298	142	67	62	88	217
1998	135	91	61	20	44	125
2000	200	137	81	53	82	216

Comparing the measured equivalent width in the different years which are plotted in Fig. 5 one realizes a significant weakening of the strength of all lines in 1998 while in the other years the line strengths are similar except the line of Li I which shows a significant maximum in 1988.

The comparison of the relative line strength, i.e. W(Li I)/W(Ca I), W(Li I)/W(Σ Fe I), and W(Ca I)/W(Σ Fe I), however, does not reveal the drop in 1998. This is depicted in Fig. 6. Rather, the line ratios are constant within the errors. However, the Li I line again deviates significantly in 1988 in the sense of being stronger than in the other years.

An explanation for the variation of the measured equivalent widths in 1998 could be a varying relative brightness of the B and the K star. This would change the relative continuum level and consequently the equivalent widths of intrinsically constant lines. The weakening of the K star absorption lines in 1998 would thus correspond either to a fading of the K star or to a brightening of the B star. Bergner et al. (1995) published *UBVRIJHK* photometry for MWC 623 obtained in 1989–1994. Their mean V magnitude was 10.89 ± 0.06 as compared to 10.5 measured by Allen & Swings (1976). This shows that MWC 623 which is also known as V2028 Cyg is photometrically variable at least on a 0.3–0.4 magnitude level in V. The mean $B - V$ colour of Bergner et al. is $+1.21 \pm 0.05$ which is

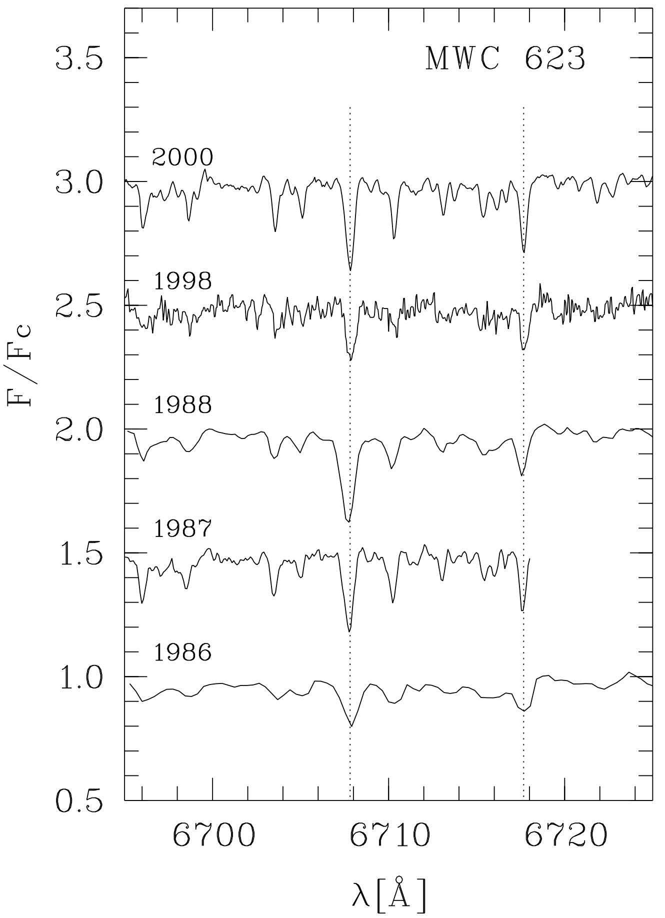

Fig. 4. Sections of the spectrum around the absorption of Li I λ6708 Å. The dashed line mark the positions of Li I λ6708 Å and Ca I λ6717 Å.

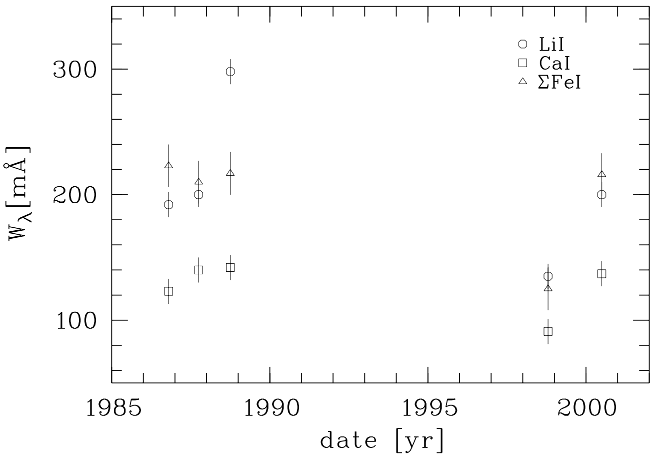

Fig. 5. Variations of the equivalent widths of Li I, Ca I, and the sum of the three Fe I lines listed in Table 2. Note the weaker lines in 1998.

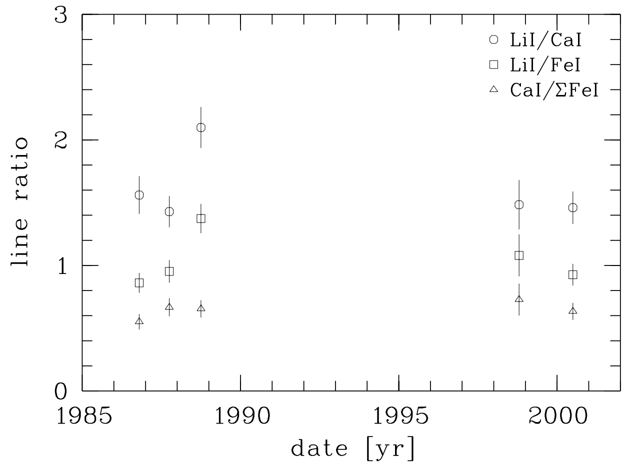

Fig. 6. Ratio of the equivalent widths listed in Table 2. Whereas the ratio of Ca I and Fe I is constant, even in 1998, a significant variation of the Li I line is discernible in 1988 relative to both, Ca I and Fe I.

similar to +1.3 given by Swings (1981). Unfortunately, the photometry available so far does not allow to decide which of the components is variable although there might be some weak indication that the object appears bluer when it is weaker. This would suggest that the K star became fainter.

The behaviour of the Li I line remains puzzling. Whereas the ratio of Ca I and Fe I is constant suggesting that no change of the effective temperature of the K star has occured, the observation of 1988 seems to indicate a real increase of the Li I equivalent width although no explanation for such a behaviour can be give at this time. Certainly, further monitoring of the spectrum is necessary in order to investigate this phenomenon in more detail.

5. Discussion

5.1. Distance towards MWC 623 and stellar parameters

As discussed in Paper I the continuum energy distribution can be well fitted with the superposition of the energy flux distribution of a B star, a K star, and a black body with $T_{\rm bb} \approx 930$ K, assuming a reddening of $E_{B-V} = 0.8 \pm 0.2$. The spectral types adopted for the fit were B2V and K2III. The relative brightness of the components lead to dereddened V magnitudes of $V_0 = 8.6$ and 9 for the K and the B star, respectively. The uncertainty of V_0 due to E_{B-V} is of the order of 0.6 mag.

In the following a new estimate of the spectral types of the components is obtained by making use of the wider spectral coverage provided by the FOCES echelle spectrum compared to the short spectral sections observed with the coudé spectrograph in 1986–1988.

5.1.1. Spectral types of the binary components

The late-type component of MWC 623 was re-classified by comparison with high resolution spectra of late G to K stars retrieved from the stellar library of Prugniel & Soubiran (2001). This library is part of the HYPERCAT[1] data base. Note that the resolution of the spectra in HYPERCAT is similar to that of the FOCES spectra.

[1] *URL*: `http://www-www-obs.univlyon1.fr/hypercat/11/spectrophotometry.html`

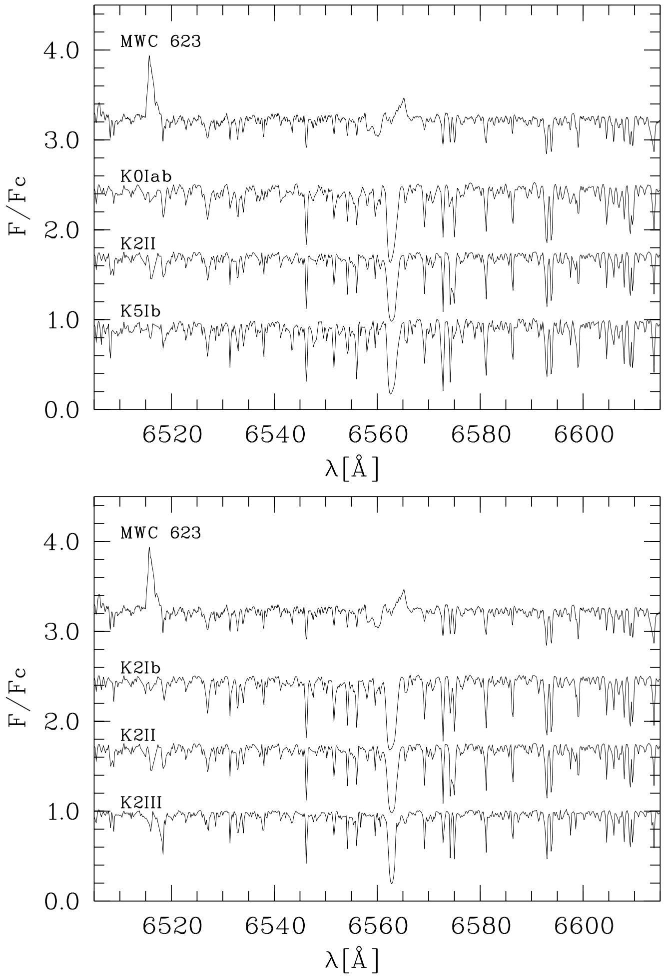

Fig. 7. Spectrum of MWC 623 together with spectra of stars with spectral types between K0Iab and K5Ib (upper panel) and between K2III and K2Ib (lower panel). The Hα emission line of MWC 623 has been removed by normalization. The comparison shows good agreement of the K component of MWC 623 with the K2II and K2Ib star. A spectral type of K2II-Ib is therefore adopted for MWC 623. The K star spectra were obtained from the HYPERCAT data base of Prugniel & Soubiran (2001).

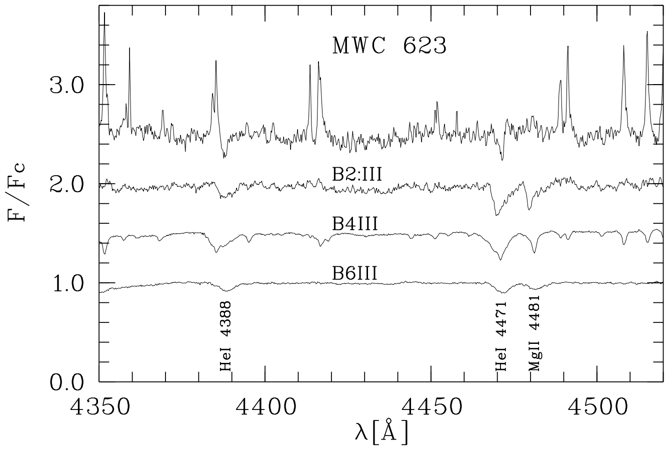

Fig. 8. Spectrum of MWC 623 together with spectra of stars with spectral types between B2 and B6. Note, that in MWC 623 Mg IIλ4481 is in emission. The B star spectra were obtained from the stellar library of Prugniel & Soubiran (2001).

The comparison with stars of spectral types between G8 and K5 and of luminosity classes V to I yields the best agreement for spectral type K2II-Ib, which will be adopted in the following. The uncertainty of the spectral type is about 1–2 subclasses. Luminosity class V can be definitely excluded. Likewise, luminosity class III yields a significantly poorer agreement than the higher luminosity spectra. Figure 7 depicts the comparison of the late component of MWC 623 with various K stars and with K2 stars of luminosity class III, II, and Ib (HD 5234, HD 39400, and HD 206778, respectively).

Likewise, the reclassification of the early-type component of MWC 623 was aided by the comparison with B type spectra from the stellar library of Prugniel & Soubiran. The classification of the late component suggests a luminosity class III for the hot component (see below). A section around He Iλ4388 and He Iλ4471 of the spectra is shown in Fig. 8. The spectral type of the B component can be confined between B2 and B6 from the relative strengths of the He I lines, by taking into account that the lines of Si III$\lambda\lambda$4553, 4568, 4575 are absent, and from the ratio of the very weak absorption feature at λ4075 and of CIIλ4267. In the following a spectral type of B4 will be adopted with an uncertainty of 2 subclasses. This is somewhat later than adopted in Paper I, however, with only weak effects on the continuum fit as carried out in Paper I. In particular, the intrinsic colours are not much different and therefore the conclusions on the relative fluxes of the components and the dereddened magnitudes from Paper I are adopted also here in the following.

To summarize the result of the spectral classification it can be stated that the spectral types of the two components are K2II-Ib and B4.

5.1.2. Kinematic distance estimate

As discussed in Paper I the projected position of MWC 623 in the plane of sky at $l = 67\overset{\circ}{.}64$ and $b = 1\overset{\circ}{.}26$ lies between the Vul OB1, OB4 ($l \approx 60°$) and the Cyg OB3 A, B and OB1 associations ($l \approx 73°$ and $76°$, respectively). The distances of these associations are $d = 1.21$, 2.54, 1.37, 1.82, and 2.31 kpc respectively. The association data were taken from Melnik & Efremov (1995) who in addition to the location also give the approximate extension of the associations. In Fig. 9 the position of MWC 623 in galactic coordinates and the associations located in the immediate (projected) neighborhood are plotted. MWC 623 obviously is too far from each of these associations to be considered as a member of one of them. Rather, MWC 623 seems to be located somewhere in the field. Melnik & Efremov also give radial velocities for some associations, e.g. for Cyg OB3A, B, and OB1 −9, −17, and −6.5 km s^{-1}, respectively, however, with considerable scatter of 7–10 km s^{-1} rendering a comparison with MWC 623 meaningless.

An independent estimate for the distance may be obtained from the galactic rotation curve if it is assumed that

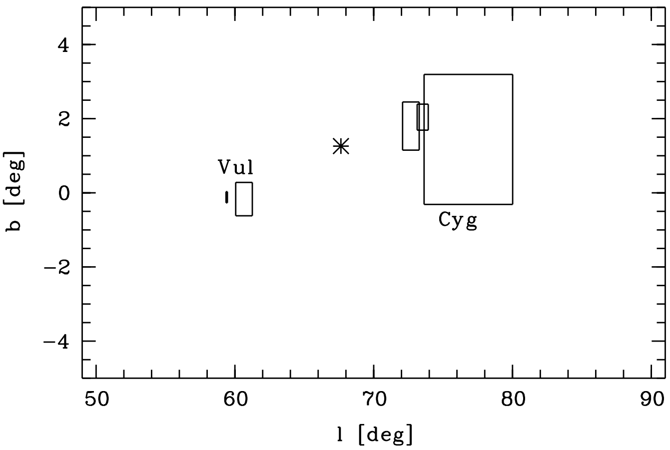

Fig. 9. Position of MWC 623 in the sky (⋆ symbol) in galactic coordinates and the locations of the (projected) nearby associations Vul OB4, OB1, Cyg OB3 A, B, and Cyg OB1.

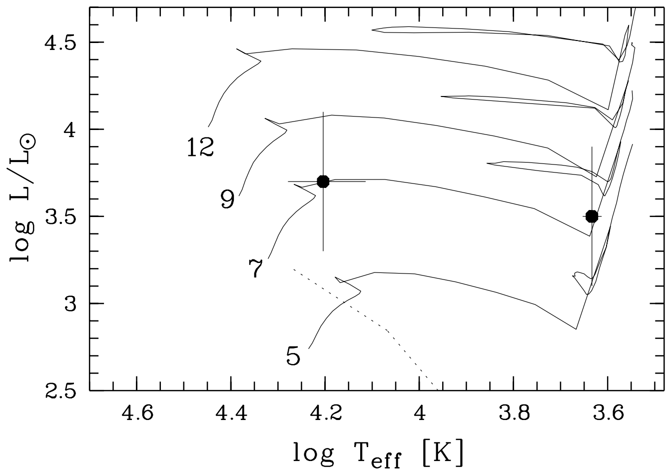

Fig. 10. H–R diagram showing the locations of the B and the K component of MWC 623. Evolutionary tracks are from Schaller et al. (1992) for metallicity $Z = 0.020$. ZAMS masses are indicated for each track. The dashed line represents the stellar birth line from Palla & Stahler (1993).

the star is comoving with the field at its given location in the Milky Way.

With a second order expansion of the galactic rotation curve the velocity of MWC 623 in the local standard of rest (LSR) frame, $v_{\rm LSR}$, is given by

$$v_{\rm LSR} = -2\,A\,\Delta R \sin l \cos b - 2\,A_2 (\Delta R)^2 \sin l \cos b \qquad (1)$$

where

$$v_{\rm LSR} = v_{\rm helio} + v_{\odot} \qquad (2)$$

and $\Delta R = R - R_0$, with R and $R_0 = 8.5$ kpc being the galacto-centric distances of the star and the sun, repectively, l and b the galactic longitudes and latitude, respectively, and the constants $A = 16.1$ km s^{-1} kpc^{-1} and $A_2 = -0.7$ km s^{-1} kpc^{-2} (cf. Dubath et al. 1988). The solar motion is given by

$$\begin{aligned} v_{\odot} \;=\; & 19.5 \text{ km s}^{-1} (\cos\alpha_{\odot} \cos\delta_{\odot} \cos\alpha \cos\delta \\ & + \sin\alpha_{\odot} \cos\delta_{\odot} \sin\alpha \cos\delta + \sin\delta_{\odot} \sin\delta) \end{aligned} \qquad (3)$$

where α and δ are the right ascension and declination of the star, and $\alpha_{\odot}(1900) = 18^{\rm h}$ and $\delta_{\odot}(1900) = +30°$ are the standard solar apex (Lang 1980).

The systemic velocity of MWC 623 should, of course, be derived from the velocity of the centre-of-gravity of the binary system. However, the orbital parameters of the system are still unknown. Therefore, as an estimate for the centre-of-mass velocity the mean of the velocities of the photospheric lines of the B and the K star in 1986 and 2000 was used, i.e. $v_{\rm helio} = -1.3 \pm 2$ km s^{-1}. Note that the mass estimates obtained below yielding a mass ratio of close to 1 justifies this approximation. In this way $v_{\rm LSR} \approx +16.7$ km s^{-1} with $v_{\odot} = +18$ km s^{-1}, and $\Delta R = -0.55$ kpc is obtained from Eq. (1). At the given galactic longitude two solutions for the distance exist, $d_1 = 2.0^{+0.6}_{-0.3}$ kpc and $d_2 = 4.4^{+0.4}_{-0.5}$ kpc. The uncertainties given here result from the statistical error of the adopted radial velocity of 2 km s^{-1} only. No systematic errors like peculiar velocity were taken into account. The distances correspond to distance moduli of $m - M = 11.5^{+0.5}_{-0.4}$, and $m - M = 13.2^{+0.2}_{-0.3}$, respectively. Note that both distances are consistent with the extinction $A_V \approx 1.9$–3.1 which in the direction towards MC 623 occurs at distances larger than 2–3 kpc (Neckel & Klare 1980).

5.1.3. Distance and stellar parameters

The spectral classification of the late component yielded a spectral type of K2II-Ib which leads to an absolute visual magnitude of $M_V = -3.3 \pm 1$ (Schmidt-Kaler 1982). With the dereddened V magnitude derived in Paper I of $V_0 = 8.6$ this yields $m - M = 11.9 \pm 1$ or $d = 2.4^{+1.4}_{-0.9}$ kpc. Note the good agreement with the short kinematic distance d_1. The long kinematic distance of 4.4 kpc corresponds to $M_V = -4.6^{+0.2}_{-0.3}$ for the K star which would still marginally be consistent with the spectroscopic distance, although the overall agreement of spectroscopic and kinematic distance is better for the short distance. Therefore in the following the spectroscopic distance of 2.4 kpc is adopted. The dereddened visual brightness of the early-type component of $V_0 = 9$ then leads to luminosity class III for the B star, i.e. a spectral type B4III. The stellar parameters of the components of MWC 623 derived for $d = 2.4$ kpc are summarized in Table 3. Bolometric corrections were taken from Schmidt-Kaler (1982).

In Fig. 10 the location of the components of MWC 623 on the H–R diagram are shown. Evolutionary tracks were taken from Schaller et al. (1992) for metallicity $Z = 0.020$. The masses estimated from the tracks are 6–9 $M_{\odot}$ and 5–10 $M_{\odot}$ for the B and the K star, respectively (see Table 3). The resulting mass ratio is $M_{\rm K}/M_{\rm B} = 1.07 \pm 0.4$.

5.2. Evolutionary status

A possible model for MWC 623 could involve interaction in a close binary system. However, this was already

Table 3. Stellar parameters of MWC 623 for the distances $d = 2.4$ kpc, corresponding to $m - M = 11.9$.

comp.	Sp. type	$T_{\rm eff}$ [K]	M_V	$M_{\rm bol}$	$\log L/L_\odot$	$R/R_\odot$	$M/M_\odot$
B	B4III	17200 ± 3000	-2.9 ± 1.0	-4.4 ± 1.0	3.7 ± 0.4	8^{+11}_{-4}	7.0 ± 1.5
K	K2Ib-II	4300 ± 200	-3.3 ± 1.0	-3.9 ± 1.0	3.5 ± 0.4	100^{+74}_{-42}	7.5 ± 2.5

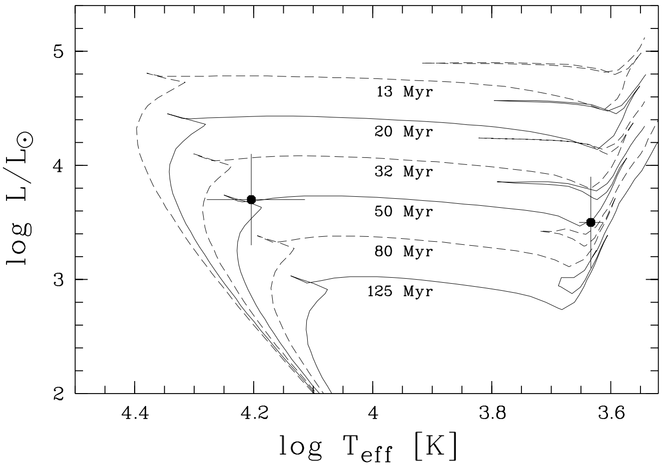

Fig. 11. Isochrones from Bertelli et al. (1994) for metallicity $Z = 0.020$ with the positions of the B and the K component of MWC 623. Ages are indicated for each track.

rejected in Paper I based on observations covering about 2 years. The absence of significant radial velocity variations of the photospheric absorption lines of the B and the K star on an even longer timescale of 14 years as discussed in Sect. 3 indicates that the orbital period is actually on the order of longer than 14 years unless the small radial velocity variation is due to a low inclination angle. This seems, however, to be inconsistent with the observed polarization. Rather, the inclination angle is expected to be intermediate to large.

If the assumption is made that the scattering plane responsible for the observed polarization is correlated with the orbital plane of the binary, the presence of strong intrinsic polarization suggests that the inclination angle i deviates significantly from pole-on. Because the polarization is proportional to $\sin^2 i$ the inclination should be intermediate to large, i.e. i should be of the order of $\gtrsim$30–45°. Otherwise, the observed degree of intrinsic polarization, $p_{\rm obs} = p_{\rm true} \sin^2 i$ of about 2% (Zickgraf & Schulte-Ladbeck 1989) would lead to unreasonably high true polarization $p_{\rm true}$.

Assuming a minimum separation of the components on the order of the radius of the K star, i.e. 100 $R_\odot$, the masses determined above would lead to a period of ~30 days from

$$P = \frac{a^{3/2}}{M^{1/2}}\ {\rm yr} \qquad (4)$$

with the separation a (in AU) and the total mass $M = M_1 + M_2$ (in $M_\odot$) of the system. In this case the velocity amplitude would be of the order of 80 km s^{-1}. This is inconsistent with the observations because even within a few days of observation as in 1988 (cf. Paper I) significant velocity variations should have been detectable. On the other hand, the small observed velocity variation $\Delta v \sin i \lesssim 2$–3 km s^{-1} over a time interval of 14 years suggests that the orbital period P is longer than ~14 years. This leads to $a \gtrsim 14$ AU $\approx 3000\ R_\odot$. The velocity amplitude would then be of the order of $\lesssim$15 km s^{-1}. Taking $\sin i$ into account expected velocity variations are thus on the order of at most a few km s^{-1}, which is consistent with the observations.

The linear separation of the components of 14 AU corresponds to an angular separation of ~5 mas. By taking into account the different colours of the components a positional shift should be directly measurable with the forthcoming astrometric space missions DIVA and GAIA by comparing observations in different colours.

These estimates suggest that MWC 623 is a wide binary system. In this case each component evolved like a single star. From the evolutionary timescales for single stars it is expected that the B star is less massive than the K star which then would evolve faster. This is in agreement with the mass estimates given above. Figure 11 shows the H–R diagram with isochrones from Bertelli et al. (1994) for metallicity $Z = 0.020$. The positions of the B and K component confirm that both are coeval within the error bars. Both stars lie on the 50 Myr isochrone within an uncertainty range from ~30 to ~125 Myr for the K star and ~30 to ~60 Myr for the B star. The B component thus constraints the age to 50^{+10}_{-20} Myr.

These findings shed new light on the question of origin of the strong lithium line in MWC 623 which, in principle, could indicate a pre-main sequence status for the K star. However, the spectroscopic characteristics exclude a low-luminosity K star and lead instead to a luminosity which is more than 2 orders of magnitudes above the stellar birth line (cf. Palla & Stahler 1993) which for $T_{\rm eff} = 4300$ K is located at $\log L/L_\odot \approx +1$. The K star is therefore clearly in a post-main sequence evolutionary phase.

The estimated age of 50 Myr is younger than that of the Pleiades (80–100 Myr). The lithium abundance of the late-type stars in this cluster is still high due to the young age. The high lithium abundance of the late component of MWC 623 can therefore quite naturally be explained by the age in the sense that the primordial lithium is not yet destroyed.

The B[e] star in MWC 623 is located slightly off but still close to the main sequence and could thus be related to the class of (near) main-sequence B[e]-type stars discussed by Lamers et al. (1998) and Zickgraf (1998) for which HD 45677 and HD 50138 are examples. For this type of B[e] star it is unclear whether they are still in a pre-main sequence phase of evolution or if they are already in the core-hydrogen burning phase. The first possiblity would place them on contraction tracks of Herbig Ae/Be stars towards the main-sequence instead of post-ZAMS evolutionary tracks. For MWC 623 is was possible for the first time to obtain a reliable age estimate. It clearly excludes the pre-main sequence option at least for this object. Note also that both components of MWC 623 are located above the stellar birth line (cf. Fig. 10). This is also inconstent with a pre-main sequence status. The conclusion is that the B[e] component in MWC 623 is a slightly evolved object starting its post-main sequence evolution. The similarities with the mentioned (near) main-sequence B[e]-type stars suggest that this conclusion might also hold for the latter class.

The B[e] component in MWC 623 might even belong to the subgroup of post-main sequence B[e] stars discovered in the Magellanic Clouds at luminosities $\log L/L_{\odot} \approx 4$ (Gummersbach et al. 1995). These objects are located in the H–R diagram below the luminous B[e] supergiants described by Zickgraf et al. (1986) and extend the class of B[e] supergiants towards lower luminosities into the range of classical Be stars.

6. Conclusions

New spectroscopic observations were used to reinvestigate the B[e]/K binary system MWC 623. Neither the K nor the B star absorption lines were found to exhibit significant radial velocity variations over a time interval of 14 years suggesting that the orbital period is longer than 14 years.

The spectral classification using a recent echelle spectrum yielded spectral types of K2II-Ib and B4III. The luminosity class of the K star was used to estimate the distance towards MWC 623 to 2.4 kpc which is consistent with the kinematic distance of 2.0 kpc.

Placing the binary components in the H–R diagram allows to derive masses of 7 and 7.5 $M_{\odot}$ for the B and K star, respectively, yielding a mass ratio close to 1. Both stars are coeval with an age of 50 Myr as shown by the comparison with isochrones.

The high luminosity of the K star excludes a pre-main sequence evolutionary phase as explanation for the strong Li I λ6708 absorption line. Rather, the high lithium abundance is a consequence of the young age. Likewise, a pre-main sequence Herbig Ae/Be phase of the B[e] star can be excluded. Instead it is a slightly evolved post-main sequence object.

In order to determine the orbital parameters of MWC 623 and to investigate in more detail the variablility indicated by the presently available observations it is clearly desirable to monitor this object spectroscopically and photometrically also in the future.

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