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ASTRONOMY AND ASTROPHYSICS

Revealing the nature of the B[e] star MWC 342

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Abstract. We carried out an analysis of existing multicolor photometry and optical spectroscopy of MWC 342, a B[e] star with an uncertain evolutionary state. The star shows a gradual brightening in the optical and near-IR regions, while its Balmer lines demonstrate a relative stability of their shapes over the last 50 years. Recent high-resolution spectroscopic observations did not reveal the presence of photospheric lines. The hypotheses about the nature of MWC 342 suggested in the literature are briefly discussed. It is shown that the object's properties, such as the Balmer line profiles and shapes of the IR excess, are similar to those of several other B[e] stars including MWC 84 = CI Cam, which underwent a strong outburst in April 1998. We suggest that MWC 342 is likely to be an evolved object, perhaps a binary system with a compact secondary, which may also undergo an outburst in the nearest future.

Key words: techniques: photometric – techniques: spectroscopic – stars: circumstellar matter – stars: emission-line, Be – stars: individual: MWC 342

1. Introduction

MWC 342 is an emission-line star (Merrill & Burwell 1933) which is located close to γ Cyg. Its spectrum was first discussed in detail by Swings & Struve (1943), who noted bright Balmer lines and numerous Fe II emission lines in it. The infrared (IR) excess was discovered in course of the AFCRL survey (Low 1970) and later confirmed by Allen (1973). Allen & Swings (1976) listed MWC 342 among peculiar Be (latterly known as B[e]) stars because of several forbidden lines seen in its spectrum (e.g., [O I] 5577, 6300 and 6363 Å) and the IR excess. Brosch et al. (1978) studied its medium-resolution optical spectrum and suggested that MWC 342 is a B3 III star surrounded by a dense gaseous envelope and an optically thin dusty shell. They also pointed out that absorption components of the emission lines, which were observed by Swings & Struve (1943), were absent in 1974–1975. The IR emission of the object was detected by *IRAS* as a point source 20212+3920 at 12, 25, and 60 μm. Additionally an almost featureless *IRAS* LRS spectrum was recorded (Volk & Cohen 1989). Spectrophotometric observations in the optical region were carried out by Arkhipova & Ipatov (1982), who suggested that MWC 342 is a binary system consisting of an early B-type dwarf and an early M-type giant, which is 1^m brighter in the V-band than the hot companion. However, they have detected no feature of late-type stars. Thus, the studies of MWC 342 published before the end of 1980-s resulted in the finding that it had a variable spectral appearance. Several hypotheses about its nature were proposed, but none of them has been definitely proved. Recently Lamers et al. (1998) trying to improve classification of B[e] stars listed MWC 342 as an unclassified object.

A new impulse to the studies of MWC 342 was given by Bergner et al. (1990), who undertook a photometric and polarimetric monitoring of the object in 1986–1989. These authors found quasi-periodic brightness variations with a period of 132^d, which are most prominent in the U-band, and polarimetric variability in the R-band with a period twice as small as the above value. Lately Mel'nikov (1997) made Fourier analysis of the quoted below much larger data set of $UBVR$ photometry obtained for MWC 342 in Uzbekistan and found that the most reliable period of the observed cyclic variations is 18.52 days. At the same time, this author mentioned that the 66^d period is also present in this data set. It is not clear yet what causes such a cyclic behaviour of the object's brightness.

Bergner et al. (1990) suggested MWC 342 to be a pre-main-sequence Herbig Ae/Be star (HAEBEs) due to its early spectral type and the presence of the emission lines, UV and IR excesses. However, this hypothesis was not justified enough, because the star is not clearly connected to a star forming region and does not display any variability type detected in HAEBEs (e.g., Algol-type variations common in isolated HAEBEs). Finally, its IR excess does not imply the presence of a large amount of cold dust, which is always found in pre-main-sequence stars and which seems to be a remnant of the protostellar cloud. Instead, the described variations may indicate the presence of a secondary component in the system, which can be a Be/X-ray binary as was lately suggested by Miroshnichenko (1991). The photometric and polarimetric variations cited above with the same period ratio are expected for binary systems with a compact source of high-energy radiation (Dolginov et al. 1995).

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Table 1. New photometric observations of MWC 342

JD 24...	V	$U-B$	$B-V$	$V-R$	$R-I$	J	H	K
49949.29	10.59	−0.20	1.20	1.33	0.81	7.26	5.99	4.81
49952.31	10.38	−0.12	1.23	1.31	0.74	6.99	5.94	4.72
49953.29	10.41	−0.19	1.27	1.24	0.82	7.01	6.10	–
50671.38	10.56	−0.11	1.22	1.27	0.75	7.26	–	4.82
51042.30	10.50	−0.14	1.28	1.26	0.77	–	–	–
51043.32	10.62	−0.19	1.19	1.31	0.75	–	–	–
51047.23	10.46	−0.06	1.27	1.26	0.75	7.07	6.29	4.76
51048.25	10.41	−0.09	1.32	1.25	0.80	7.12	6.01	4.70
51052.29	10.55	−0.09	1.29	1.32	0.82	6.87	6.02	4.63
51054.27	10.49	–	1.17	1.23	0.71	–	–	–
51057.38	10.52	−0.02	1.24	1.28	0.74	–	–	–
51155.02	10.37	−0.12	1.20	1.27	0.73	–	–	–
51156.02	10.30	−0.15	1.26	1.27	0.79	–	–	–
51157.02	10.27	–	1.29	1.24	0.80	–	–	–
51161.02	10.46	−0.21	1.30	1.36	0.79	–	–	–
51168.03	10.45	–	1.25	–	–	–	–	–

A large number of new observations of MWC 342 has been obtained meanwhile. Nearly 650 $UBVR$ photometric observations were carried out in 1989–1994 by V. S. Shevchenko's group from the Ulugbek Astronomical Institute in Uzbekistan (Herbst et al. 1994). A group from the Pulkovo Observatory led by Yu. K. Bergner and A. S. Miroshnichenko continues the $UBVRIJHK$ photometric monitoring of the star until the present time. In total 119 optical and 86 near-IR observations have been obtained by them so far. Partial results of this program were briefly considered in Bergner et al. (1995). Recently the star was included to the General Catalog of Variable Stars as V1972 Cyg (Kazarovets & Samus 1997). Other photometric and spectroscopic data obtained in 1986–1998 are presented here.

The purpose of this paper is to present high-resolution spectra of MWC 342, discuss its photometric and spectroscopic variations as well as its possible evolutionary state, attract more attention to this remarkable object, and show the importance of its further monitoring.

2. Observations

In addition to the published data mentioned above, we carried out the following observations of MWC 342. $UBVRIJHK$ photometric measurements in the Johnson system were obtained at the Tien-Shan Observatory (Kazakhstan) between August 1995 and December 1998 with a 1-m telescope and a two-channel photometer-polarimeter through a 26″ diaphragm (Bergner et al. 1988). The results are presented in Table 1. The mean error of the optical photometry is 0.02 mag., while those of the near-IR one are 0.1 mag. in the J-band, 0.06 mag. in the H-band, and 0.04 mag. in the K-band.

Medium-resolution spectra were taken at the 6-meter telescope of the Special Astrophysical Observatory (SAO) of the Russian Academy of Sciences (Northern Caucasus) with a 1024-channel TV scanner in October 1986, July 1989, December 1990, and July 1991. Three high-resolution spectra were taken with a fiber-fed spectrograph ÉLODIE at the 1.93-m telescope of the Observatoire of Haute-Provence (south of France) in August and November 1994 and August 1995 in the framework of an extended search for spectroscopic binaries among young early-type emission-line stars (Corporon & Lagrange 1999). The log of spectroscopic observations is presented in Table 2.

Table 2. Journal of the spectroscopic observations

JD 24...	Instrument	Spectral range (Å)	R	Exposure time (s)
46715.21[a]	TV scanner	6545–7450	7000	1722
46716.25[a]	TV scanner	6544–7450	7000	1388
47708.53	TV scanner	3750–5600	2500	1066
48233.17	TV scanner	3936–5000	4300	990
48456.35	TV scanner	4185–5230	4400	2380
48457.31	TV scanner	5983–7010	6100	1028
49594.40	ÉLODIE	3906–6811	42000	3600
49677.31	ÉLODIE	3906–6811	42000	3600
49948.44	ÉLODIE	3906–6811	42000	3600

R is the mean resolving power $\frac{\lambda}{\Delta\lambda}$,
[a] the Hα line is saturated

3. Results

3.1. Photometric variations

There are probably three more types of photometric variations displayed by the star in addition to the quasi-periodic changes described above. The first one was occasionally found by Bergner et al. (1990), who discovered a 1^m brightening of MWC 342 (V=9.65, B=10.69) on September 29, 1965 detected on a photographic plate of the Sternberg Astronomical Institute collection. Nothing is known about the duration of this event. The second one, a long-term brightening in both the optical and

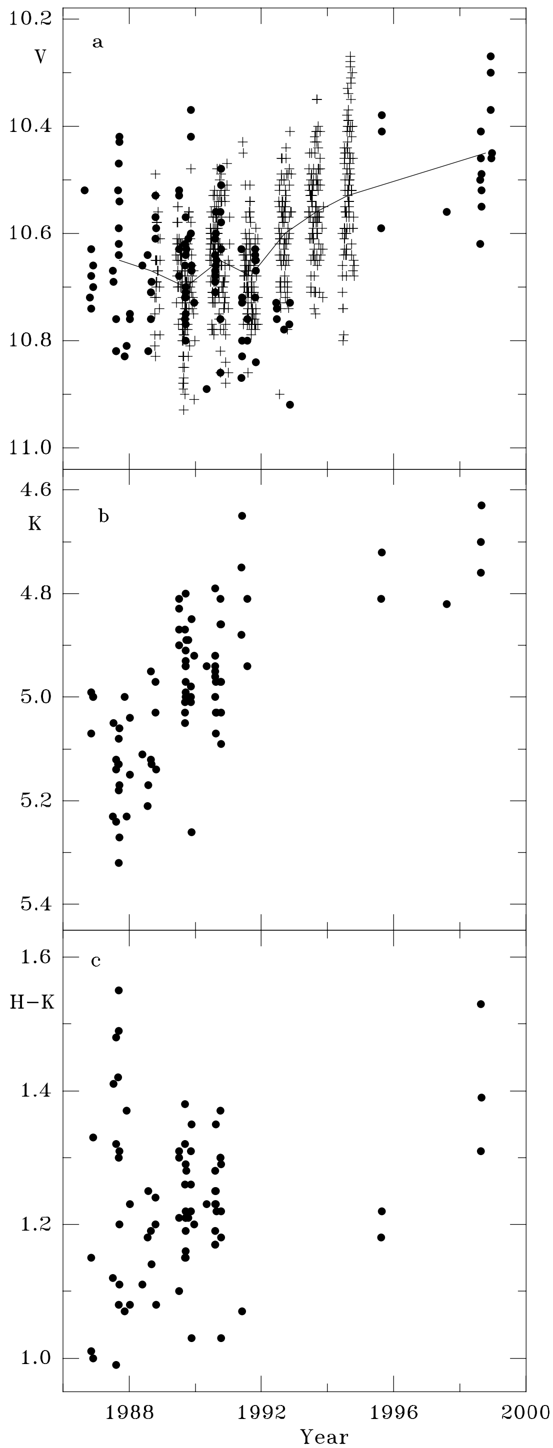

Fig. 1a–c. Light curves of MWC 342 in 1986–1998 in the V- **a** and K-band **b** and $H-K$ color-index **c**. Filled circles represent the data from Bergner et al. (1990, 1995) and this work, while crosses are the data by Shevchenko's group from Herbst et al. (1994). Yearly averaged V-band data are shown in the upper panel by a solid line

near-IR region, was recently noticed by Miroshnichenko (1998). The last one is the non-regular variations up to 0.4 mag. in a few days.

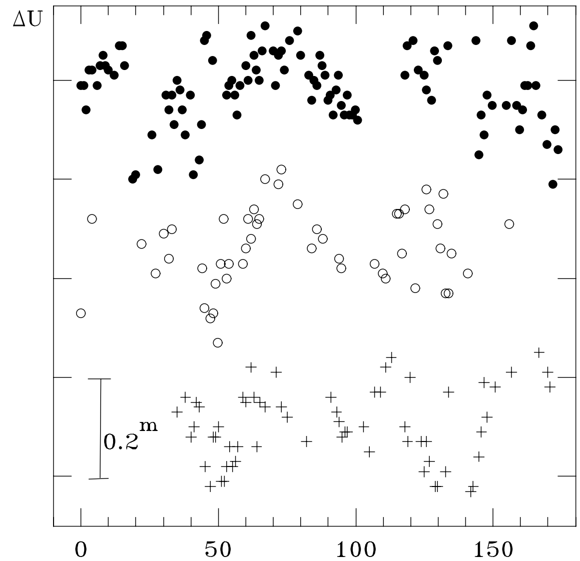

Fig. 2. Variations of MWC 342 in the U-band. The data sets were obtained during the observing seasons of 1990 (filled circles), 1991 (open circles), and 1992 (crosses) by V. S. Shevchenko's group. Both the magnitude and time axis have arbitrary zero-points

The light curve of MWC 342 in the V and K bands since 1986 including the most recent data described in Sect. 2 is shown in Fig. 1ab. The mean brightness in the V-band increased from 10.7 to 10.4 between 1986 and the present time, while that in the K-band from 5.15 to 4.75. However, the brightening in the optical and near-IR regions was not simultaneous. The main rise in the HK-bands occured between July 1987 and August 1991, when the averaged optical brightness was mostly constant. After that time the mean fluxes in the $UBVRIJ$-bands began to increase. The mean value of the $H-K$ color-index gradually increased with time (except for a short-time rise of this color-index occured in August 1987) and reached 1.4 mag. in 1998 (Fig. 1c).

Such a behaviour might be due to an increase of the dust formation rate in the star's envelope. The HKL observation obtained by Allen (1973) back in early 1970-s (K=4.90, $H-K$=1.06, $K-L$=1.91) indicates that the IR-excess was similar to that in the present time, i.e. the dust already existed around the star. The overall K-band brightening indicates that the dust optical depth increase is small. The optical brightness constancy in 1987–1991 may be explained by an increase of both extinction, which causes reddening and fading, and scattering, which is responsible for blueing and brightening. The photometric behaviour since August 1991 implies that the dust formed was moving outwards which resulted in a decrease of its optical depth (seen as the optical brightness rise) and mean temperature (increase in $H-K$).

The cyclical variations are seen thanks to the good photometric coverage provided by V. S. Shevchenko's group (see Fig. 2). The cycle duration was nearly 132^d in 1990 (upper data set in Fig. 2), while it tended to decrease later. The average cycle amplitude is $\sim$ 0.3 mag. in the V-band. $U-B$ and $V-R$ are $\sim$

Table 3. Color-indices in the cycle minima and maxima

Minima					Maxima				
JD24...	V	$U-B$	$B-V$	$V-R$	JD24...	V	$U-B$	$B-V$	$V-R$
47500	10.79	−0.17	1.21	1.63	47475	10.61	−0.32	1.24	1.55
47760	10.88	−0.10	1.18	1.60	47690	10.58	−0.23	1.21	1.57
48098	10.78	−0.19	1.21	1.75	48135	10.48	−0.27	1.24	1.52
48476	10.86	−0.24	1.21	1.65	48500	10.51	−0.28	1.25	1.53
48910	10.78	−0.33	1.22	1.59	48950	10.56	−0.39	1.23	1.50
49220	10.75	−0.30	1.22	1.58	49235	10.41	–	1.22	1.43
49620	10.64	−0.09	1.23	1.52	49610	10.28	−0.15	1.25	1.44

The data obtained by V.S. Shevchenko's group are used

Table 4. Parameters of the Balmer lines

Line	No.	V_{be}	V_a	V_{re}	I_{be}	I_a	I_{re}	EW (Å)
Hα	1	−136	−82	−6	9.14	5.38	47.58	199
	2	−149	−88	−11	10.83	3.70	40.44	170
	3	−133	−83	−7	18.13	4.58	49.49	221
Hβ	1	−214	−73	+8	1.91	0.74	9.17	25.6
	2	−137	−85	−4	3.01	0.57	7.31	24.1
	3	−128	−77	+27	4.93	0.56	10.66	30.7
Hγ	1	−218	−69	−2	1.32	0.50	3.96	8.9
	2	−130	−71	−13	2.30	0.48	3.64	10.9
	3	−123	−72	+3	2.41	0.25	4.52	10.8
Hδ	1	−223	−65	−12	1.28	0.50	2.78	5.3

Line identification is given in column 1, sequential number of the ÉLODIE spectrum in chronological order in column 2, heliocentric radial velocities of the blue emission peak, central absorption, and red emission peak in columns 3–5 respectively, their intensities in continuum units in columns 6–8, the Hα line equivalent width (EW) in Å in column 9.
An additional absorption distorts the blue emission peak of the Hβ–Hδ lines in the first spectrum. The data listed in the table relate to the largest intensity in this region

0.1 mag. bluer in the cycle maxima, while $B-V$ is $\sim$ 0.02 mag. redder (see Table 3 for a sample of the color-indices observed in the cycle minima and maxima). This might imply the presence of an additional source of radiation, which has a larger effective temperature than the visible star. We should note that the same color behaviour (except for the blueing in $V-R$) is expected from an increase of free-free and free-bound radiation, however this is not confirmed by our spectroscopic data (see discussion in Sect. 3.2.1).

Thus, the photometric variations of MWC 342 show a complicated behaviour, which is probably due to several mechanisms acting altogether. Nevertheless, hypotheses about the nature of some of them can be suggested. The presence of an additional hot-temperature source of radiation and the recent circumstellar dust formation episode are among them.

3.2. Spectral features

The spectrum of MWC 342 has been recently discussed in detail by Jaschek & Andrillat (1999). Since the ÉLODIE observations were not aimed at obtaining a list of spectral lines, we will describe the spectrum briefly and discuss only the features, which were revealed due to its high resolution.

3.2.1. Balmer lines

The spectrum of MWC 342 contains bright Balmer lines. Swings & Struve (1943) obtained the visible star's spectrum with a resolution of 20–30 Å mm^{-1} and described the Balmer line profiles as double-peaked with the red component 2–3 times stronger than the blue one, detached by a narrow absorption. This shape was also reported by Kuan & Kuhi (1975), who observed the star in 1970 with the same dispersion. The spectra obtained in 1974–1975 with a dispersion of 75 Å mm^{-1} and a poorer signal-to-noise ratio (Brosch et al. 1978) appeared remarkably different. No absorption components of the Balmer lines were detected at all: the profiles turned out to be almost symmetric. Our observations at the 6-m telescope (dispersion 50 and 100 Å mm^{-1}) also showed symmetric profiles. The higher resolution ÉLODIE data revealed the absorption components again. The sample profiles of Hα–Hδ from our data sets are shown in Fig. 3. In the ÉLODIE spectra the absorption component is seen at the velocities between −70 and −90 km s^{-1} in all the lines. Convolution of these data with Gaussian profiles of different width showed that at resolutions poorer than about 1.5 Å the absorption components can be completely missed. Therefore, the profile shape changes reported by different authors are most likely not real.

The Balmer line profiles are variable. The ratio of the V and R peak intensity as well as that of the peak intensity to that of the absorption component show significant variations (see Table 4). Sometimes the blue peak shows a complicated structure as it is seen in Fig. 3. Such a behaviour may be due to the local changes in the density structure of the circumstellar gas. At the same time, the Hβ line profile detected in 1994 is similar to that presented by Kuan & Kuhi (1975) both in shape and intensity, that demonstrating a long-term stability of the overall mass distribution in the envelope. This conclusion is supported by the results of our observations at the 6-meter telescope. The equivalent widths of the Balmer lines detected in these spectra are presented in Table 5 and are very similar to those measured in the ÉLODIE spectra and in the spectra obtained by Jaschek &

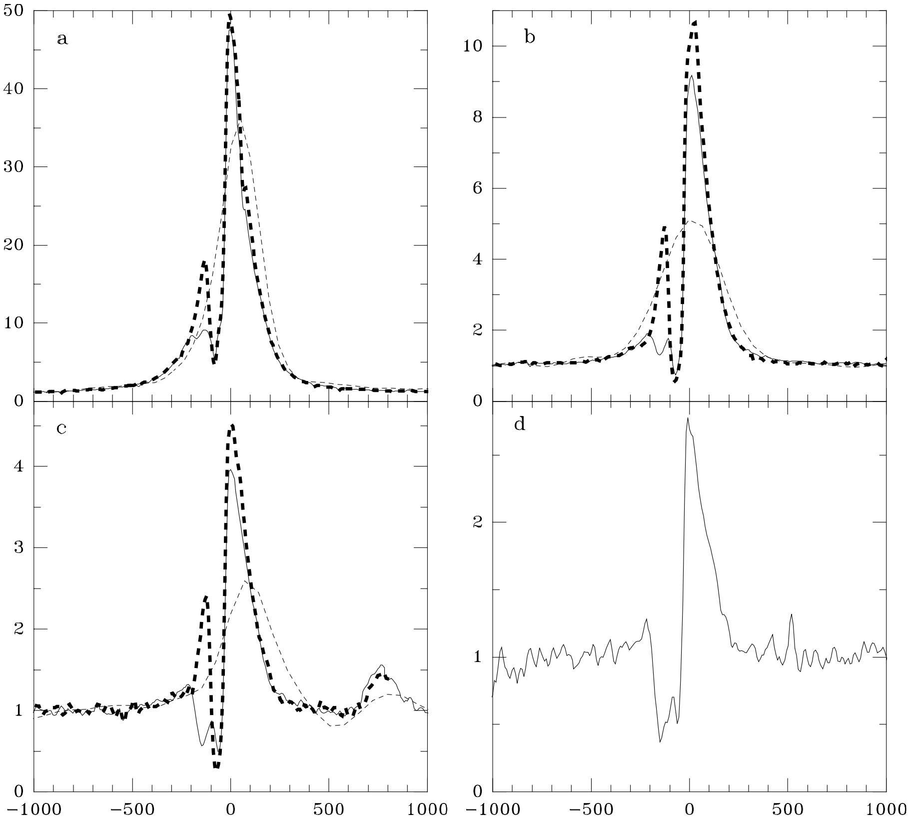

Fig. 3a–d. Balmer line profiles of MWC 342. **a** Hα, **b** Hβ, **c** Hγ, **d** Hδ. Abscissa is heliocentric velocity (km s^{-1}), ordinate is intensity normalized to the continuum. The ÉLODIE data are shown by solid line (spectrum No. 1 at JD2449594.40) and dotted line (No. 3, JD2449948.44), the 6-m telescope data are shown by dashed line (JD2448456/7)

Table 5. Characteristics of the Balmer lines measured in the medium-resolution spectra

Date	Line	Peak Intensity ($I_{cont} = 1$)	EW (Å)
1991 Jul 19	Hα	36.1	246
1989 Jul 01	Hβ	4.4	34.0
1990 Dec 07	Hβ	7.0	35.4
1991 Jul 18	Hβ	5.1	29.2
1989 Jul 01	Hγ	1.9	8.9
1990 Dec 07	Hγ	2.6	9.3
1991 Jul 18	Hγ	2.1	10.8

Andrillat (1999) in July 1997. This fact indicates that the mass loss rate is essentially stable over the last three decades.

3.2.2. Lines of other elements

The lines of neutral helium are seen in emission in both our medium- and high-resolution spectra. Three weak emission lines of singly ionized helium at 4541, 4686, and 5411 Å are present as well (Fig. 4). The latter line is the strongest among them. No photospheric lines were detected reliably. The strongest forbidden lines detected are those of [O I] 5577, 6300, and 6364 Å as well as that of [N II] at 5755 Å. Numerous weak [Fe II] lines were detected as well. A number of diffuse interstellar bands (hereafter DIBs) were found in our spectra. Their characteristics are presented in Table 6.

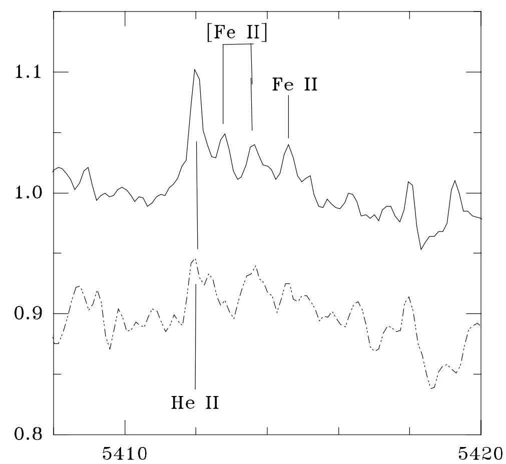

Fig. 4. The spectral region containing the He II 5411 Å line. The first (upper) and third (lower) ÉLODIE spectra are shown. The wavelengths are given in Angstroems. The intensities are normalized to the continuum, while the spectra are shifted by 0.1 continuum intensity with respect to each other

4. Main parameters of the star and its envelope

4.1. Interstellar extinction and luminosity

High-resolution and high signal-to-noise spectroscopic data published in recent years for B[e] stars made possible to constrain their detailed line profile shapes and improve stellar parameters (see review by Jaschek 1998). A close look at these results shows a striking similarity of the Balmer line profiles of

Table 6. Parameters of the diffuse interstellar bands

λ_{obs}	Peak Intensity ($I_{cont}=1$)	EW (Å)	V_a (km s^{-1})
5705.49	0.95	0.07	+15
5719.43	0.97	0.03	−2
5780.39	0.83	0.29	−8
5796.90	0.86	0.16	+5
5849.64	0.93	0.06	−8
5889.77[a]	0.03	0.53	−9
5895.74[a]	0.02	0.50	−9
6195.67	0.95	0.03	−14
6202.92	0.93	0.09	−10
6269.67[b]	0.96	0.06	
6278[c]	0.76	1.52	
6379.03	0.93	0.04	−9
6613.63	0.87	0.15	−9
6660.60	0.97	0.02	−18

[a] Na I,
[b] three absorption components,
[c] blend with 6283 Å

such B[e] stars as HD 45677 (Israelian et al. 1996), HD 50138 (Pogodin 1997), and MWC 342. Another object with similar properties is CI Cam = MWC 84. Miroshnichenko (1995) reported strong and symmetric Balmer lines purely in emission in its medium-resolution spectrum, however, at higher resolution a central depression is clearly seen (Clark 1999). The profile shape similarity indicates that the envelope kinematics is essentially the same in all the stars, however their effective temperatures are different. Since the photospheric features are not visible in MWC 342, its temperature may be estimated from the Balmer and He I line strengths. In MWC 342 and CI Cam (spectral type B0) the Balmer lines are the strongest, while the He I lines appear in emission, however they all are stronger in CI Cam. In HD 45677 (B2) and HD 50138 (B5–8) no components of the He I lines are seen in emission. These facts suggest that the spectral type of MWC 342 is between B0 and B2. The He II lines in emission discussed in Sect. 3.2.2 constrain the temperature of the underlying star at about 26000 K (Schmutz et al. 1991), which is in agreement with the estimated spectral type.

Different authors estimated the interstellar extinction (A_V^{IS}) towards MWC 342. From a spectrophotometric analysis, Brosch et al. (1978) and Arkhipova & Ipatov (1982) gave almost the same values, A_V^{IS} = 1.5 and 1.4 mag. respectively. Trying to take into account possible circumstellar reddening Bergner et al. (1990) derived A_V^{IS} = 2.1 mag., while Zorec (1998) found A_V^{IS} = 1.6 mag. The best fit of the spectral energy distribution (SED) in the range 0.3–60 μm by Ivezić et al. (1998), who assumed that MWC 342 is a 30000 K star surrounded by an optically thin spherical dusty envelope, resulted in A_V^{IS} = 4.6 mag. This model did not take into account the gaseous contribution to the SED that may reduce the derived interstellar extinction.

All the above estimates are model dependent, while our spectral data make possible the direct determination of this value from the strengths of the interstellar features. Almost saturated interstellar components of the Na I $D_{1,2}$ lines and a number of noticeable DIBs in our spectra (see Table 5) imply a strong interstellar reddening towards MWC 342. We applied a calibration by Herbig (1993) to the equivalent widths of the strongest DIBs (5780, 5797, 6203, and 6613 Å) and derived $E_{B-V}^{IS} = 0.7 \pm 0.2$ mag. This result, which we finally adopt for the object, is consistent with most of the above estimates and implies a distance (D) of about 1 kpc according to the interstellar extinction law in the vicinity of the star (Bergner et al. 1990, Zorec 1998).

In order to estimate the luminosity of MWC 342 we have to put constraints on the circumstellar contribution to the object's SED. Its strong emission-line spectrum suggests an additional continuum emission in the visual and IR regions and, in particular, a reddening in $B-V$ (E_{B-V}^{ff}) due to free-free and free-bound radiation of the circumstellar gas. Waters et al. (1987) showed that in classical Be stars even with strong Hα emission lines (EW $\sim$ 50 Å) $E_{B-V}^{ff} \leq 0.1$ mag., while the additional emission in the V-band (ΔV^{ff}) ≤ 0.25 mag. The double-peaked shape of the Balmer line profiles observed in MWC 342 is similar to those of classical Be stars. It indicates that the density distribution in the object's stellar wind is non-spherical and allows to use a model suggested by Pogodin (1989) for simultaneous calculation of the Balmer line and continuum emission from the star plus wind.

The model assumes that the star is surrounded by a hydrogen disk with a certain velocity or density profile, which are linked to each other by the continuity equation. In order to calculate the line profiles, the populations of 12 lowest levels of hydrogen are computed taking into account all radiative and collisional processes (non-LTE case) in the Sobolev approximation. After that, the radiative transfer equation is solved by numerical integration throughout the stellar wind in both the lines and continuum. We did not try to reproduce the shape of the Balmer lines as it is a difficult task, which has not been solved yet even for classical Be stars (e.g., Stee & Araujo 1994). Instead, we derived a relationship between the line equivalent widths and continuum emission at different wavelengths which is not sensitive to the velocity profile responsible for the line shapes. We found that E_{B-V}^{ff} and $\Delta V^{ff} \sim$ 0.3 mag. and 1 mag., respectively, correspond to the equivalent widths listed in Tables 4 and 5.

Another component of the circumstellar medium is dust, which brings an additional reddening and extinction in the visual region. Since the overall $E_{B-V} \sim$ 1.5 mag. for MWC 342 which is determined as a difference between the averaged observed $B-V$ and intrinsic $B-V$ for a B1 dwarf (e.g., Straizhys 1977) and $E_{B-V}^{IS} + E_{B-V}^{ff}$ = 1.0±0.2 mag., one can derive the reddening due to the circumstellar dust as E_{B-V}^{d} = 0.5±0.2 mag. Adopting the interstellar ratio of the total extinction to selective, R=A_V/E_{B-V}=3.1, the overall (interstellar and circumstellar) extinction is then A_V=3.7±0.6 mag.

Thus, adopting the averaged V=10.5 mag., D=1 kpc, and the above A_V, we find $M_V = -3.2$ mag. for MWC 342. The error of this value may be estimated as nearly 1 mag. taken into account the uncertainties of the determination of the overall extinction and the distance. Within the uncertainty this estimate coincides with that derived by Bergner et al. (1990), $M_V = -3.3$ mag, and translates to the bolometric luminosity log $L_{bol}/L_{\odot}$ = 4.2±0.4, assuming the effective temperature estimated above. With these parameters, the star is located near the zero-age main sequence (ZAMS) which, however, does not imply its youth. Such stellar parameters are typical, for example, for Be/X-ray binaries (e.g., Negueruela 1998) as well as some of the object's properties discussed below.

4.2. Circumstellar dust

Let us now discuss characteristics of the circumstellar dust around MWC 342. No attention to this issue has been paid in the past except for the consideration by Bergner et al. (1990), who assumed that the star is surrounded by a spherical gaseous and isothermal dusty envelope. In the framework of this extremely simple model these authors estimated the overall optical depth of the dust, τ_V=2.2, by fitting the observed SED in the region from 0.3 to 5 μm. Since the dust optical properties for astronomical silicate were used (Draine 1985), the emergent spectrum should display a noticeable silicate emission feature at 9.7 μm. Recently Ivezić et al. (1998) assumed that the dusty envelope of MWC 342 is spherical and contained standard interstellar dust grains with the MRN size distribution (Mathis et al. 1977). The theoretical SED was calculated using the radiation transfer code DUSTY (Ivezić et al. 1997). The best fit was obtained for τ_V=0.14; a power-law density distribution proportional to $r^{-1.8}$, where r is the distance from the star within the envelope; and the ratio of the outer and inner envelope's radii, Y_{out}=700. The emergent model spectrum contains a strong silicate emission feature at 9.7 μm much stronger than indicated in the IRAS LRS spectrum. Thus, both models are not consistent with the observed properties of MWC 342.

An almost featureless SED in the 10 μm region can be produced in the following cases:

1. the dust contains small silicate particles, but the optical depth is large enough so that the feature is in transition from emission to absorption;
2. the dust optical properties do not contain such features (e.g., amorphous carbon);
3. the IR excess in this region is dominated by emission from an extremely optically thick formation, such as an accretion disk, so that the spectrum is described by blackbody radiation;
4. the dust particles responsible for the emission have a large size.

The first option implies optical depths of the order of 10 in the spectral region, where the stellar light dominates the SED (e.g., Yorke & Shustov 1981), and a strong wavelength dependence of circumstellar extinction, which, in turn, produces a high reddening. To check the second option we calculated a grid of models with power-law density distributions using the DUSTY code quoted above. The MRN size distribution and optical properties of amorphous carbon (Hanner 1988) were employed. No satisfactory fit to the observed SED, which was constructed using the averaged photometric data for 1986–1987 (Bergner et al. 1990) and the *IRAS* data, was obtained even for $\tau_V \le 0.1$ since these grains have a rather large emissivity in the near-IR and a significant additional reddening is required to fit the SED slope in the optical region. The same problem arises for both the large-sized grains and the optically thick formation which additionally produce an almost grey extinction. In the case of a very large optical depth, the dust should not obscure the star, otherwise we can not see it at all.

The above analysis shows that it is difficult to explain all properties of the observed SED of MWC 342 in the framework of a single-component dusty envelope. Perhaps, this could be done with a combination of a compact dusty envelope, which produces near-IR excess and reddening (similar to that suggested by Bergner et al. 1990), and an optically thick disk, which gives a featureless mid-IR spectrum and a steep decrease of the far-IR flux with wavelength. However, this suggestion requires a thorough study and is out of the scope of this paper.

5. Discussion

The analysis of our high-resolution spectroscopic data allows us to constrain the nature of MWC 342. The absence of late-type stellar features in the spectrum (such as absorption lines of neutral metals or molecular bands) rules out the possibility that it has a cool companion with the brightness ratio predicted by Arkhipova & Ipatov (1982). It is not a symbiotic star either, because it does not display emission lines of high excitation and [O III] lines. MWC 342 can hardly be classified as a pre-main-sequence star because of the lack of pronounced far-IR excess, which is typically observed in this object class and originates in the nearby protostellar dust. Besides that, early B-type pre-main-sequence stars usually show weak brightness variations (e.g., Bibo & Thé 1991). The star is most likely not a post-AGB object evolving towards the planetary nebula phase since such objects usually display only far-IR excesses (e.g., García-Lario et al. 1997) and significantly weaker emission lines in their spectra.

We mentioned above the similarity of the Balmer line profiles in MWC 342, HD 45677, HD 50138, and CI Cam. Different strengths of the Balmer lines in these objects seem to be dependent on parameters of the underlying star and density of the circumstellar gas. Another property similar in all the four objects is the shape of the IR excess in the *IRAS* wavelength region. They display a steep decrease of the observed flux longward of 25 μm. The spectral slope in this region, $\lambda F_\lambda \propto \lambda^{-3}$, is expected for the optically thick dust at $\lambda \ge 4$ mm/T_{out}, where T_{out} is the temperature of the coolest dust (cf., Lynden-Bell & Pringle 1974). Hence, T_{out} of about 150 K can be derived from the *IRAS* data for the sources which implies that the dusty region is very compact ($\le$ 1000 radii of its central object). As we pointed out above, such a region should not obscure the star and, therefore, have a disk-like form. It can potentially surround the visible star (excretion disk) or an invisible secondary (accretion disk, see below).

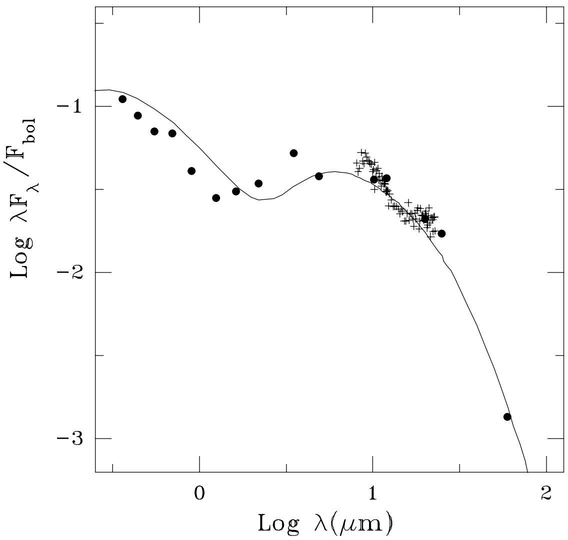

Fig. 5. The dereddened SED of MWC 342 (filled circles) constructed from the averaged photometric data in 1987. The mid-IR photometry (at 3.5–20 μm) is taken from Allen (1973), Low (1970), and Simon (1974). The *IRAS* LRS spectrum is shown by crosses. The theoretical SED of the optically thick disk is shown by the solid line. The fluxes are given as fraction of the bolometric flux (F_{bol}) integrated over the entire SED

Fig. 5 represents the SED of MWC 342 dereddened with A_V = 3.7 mag. and a typical spectrum of the optically thick disk with T_{out} = 150 K, which was calculated using formulae presented by Bertout et al. (1988). It is seen that such a disk can account for the most of the IR radiation of the object. A weak 10 μm emission feature seen in its *IRAS* LRS spectrum indicates that the contribution of the optically thin dust is very small.

There are some more similarities between CI Cam and MWC 342 in addition to those mentioned above. Their optical and near-IR color-indices are close to each other (Bergner et al. 1995), they both show extremely strong emission-line spectra (Miroshnichenko 1995). The recent multiwavelength outburst of CI Cam strongly favors the presence of a compact object (neutron star or white dwarf) in this system (Frontera et al. 1998). The brightening of MWC 342 in 1965 might be evidence of a similar event. The cyclic variations of its brightness and polarization discovered by Bergner et al. (1990) as well as those described in Sect. 3.1 are consistent with the hypothesis that MWC 342 is a binary system. In particular, the blue radiation seen in the photometric maxima might relate to the accretion disk around the secondary component. The lack of stability of the cycles period is also observed in other known Be/X-ray systems (e.g., X Per, Roche et al. 1997). Furthermore, recent analysis of the observed properties of known Be/X-ray binaries by Negueruela (1998) showed that their optical components have spectral types earlier than B2, which is consistent with the spectral type of MWC 342 derived above.

In this case, its strong emission-line spectrum would be a result of an intensive mass transfer from the visible star to the compact companion. The fact that the photospheric lines were not detected even at a high spectral resolution may indicate that they are veiled by the circumstellar emission. The gradual brightening of MWC 342 at the present time might not be a result of the expansion of the newly formed dust only, but also a consequence of an increasing contribution of the disk to the SED that would not last for a long time. Material accumulated in the disk might be released in an outburst due to interaction with the compact secondary (e.g., Negueruela 1998).

We should note here that known Be/X-ray systems do not show the presence of circumstellar dust in their SEDs (e.g., Telting et al. 1998). However, their emission-line spectra are significantly weaker than those of MWC 342 and CI Cam. This implies that the mass loss rate in the objects exhibiting dusty emission is much larger which makes the possibility of the dust formation in their winds quite real. The disk extent might be limited by the Roche lobe size of the visible star. One can suggest that the objects in question undergo a specific short-time evolutionary phase or that their appearance reflects certain parameters of the binary system (e.g., a large orbital period). This suggestion is in qualitative agreement with a recent finding by Reig et al. (1997) that Be/X-ray binaries with larger orbital periods have stronger Hα emission. For example, if we assume a typical radius of the B0-type ZAMS star (5 $R_{\odot}$), a Roche lobe size of 500 star's radii, the star's mass 10 $M_{\odot}$, and neglect the mass of the secondary, the orbital binary period would be of the order of 40 years. This is roughly the time passed since the 1965 brightening of MWC 342. If we assume that it was due to the periastron passage of the secondary, which has an eccentric orbit, one can expect an increase of the mass loss rate in the nearest future.

The Be/X-ray hypothesis might also be applicable to HD 45677, a B2-type star, whose nature is not yet known (e.g., de Winter & van den Ancker 1997). However, another explanation ought to be searched for HD 50138 which has a lower temperature. In any case, we selected here a group of low-luminosity B-type stars with a mass loss significantly stronger than that in other emission-line objects in the same domain of the Hertzsprung-Russell diagram (e.g., classical Be and Herbig Ae/Be stars) and a steep decrease of the IR flux, that is consistent with the presence of an optically thick and a compact non-spherical envelope. Two more similar objects, MWC 657 (Miroshnichenko et al. 1997) and AS 78 (Miroshnichenko et al. 1999), which have been poorer-studied so far, can be added to this list. This group certainly deserves further attention, which might result in more detailed understanding of stellar evolution.

6. Conclusions

In this paper we summarized the information for a B[e] star MWC 342 obtained so far. The photometric data show that the star started to increase its near-IR brightness in 1987, while that in the optical region began to rise in 1991. The cyclic behaviour of the optical brightness first detected by Bergner et al. (1990) is confirmed on a larger data set. A gradual increase of the $H-K$ color-index over the last decade is noticed. These phenomena suggest the presence of an additional radiation source with a higher temperature than that of the visible star and the dust formation event, which occurred in 1987.

Our high-resolution spectroscopy revealed the fine structure of the Balmer line profiles, confirmed its long-term stability, allowed to detect DIBs and estimate the interstellar reddening toward the object independently, and helped to constrain the stellar temperature. We noted some similarities in the properties of MWC 342 and several other B[e] stars including CI Cam, which recently displayed a strong multiwavelength outburst and was suggested to be a binary system with a compact object (a white dwarf or a neutron star). We suggest the same explanation for MWC 342 as its properties are not consistent with those of most of the other classes of early-type emission-line stars surrounded by circumstellar dust. We realize that this explanation may not be unique and certainly needs further verification. We also stress that the current brightening of MWC 342 is an unusual phenomenon that requires further study and may probably end with an outburst.

To make further progress in understanding the nature and properties of MWC 342 the following observations are desirable:

1. Multiwavelength photometric monitoring is important as the star may show significant brightness variations already in the near future;
2. High-resolution spectroscopy to study possible radial velocity variations;
3. X-ray observations to detect radiation of the suggested secondary and/or possible outbursts, which may not be accompanied by optical brightenings.

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