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B[e] stars

VIII. MWC 342*

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Abstract. On the basis of spectroscopic CCD material obtained at the Haute Provence Observatory, we provide line identifications and equivalent width measurements in the wavelength region 4095 − 8935 Å of the spectrum of MWC 342. Two hundred eighty emission features are identified and eighteen absorption features. Nine interstellar bands could be identified. Some of the remaining absorption lines correspond to a B0 type star. The cooler emission lines correspond to a spectrum of an early A-type star. The temperatures derived from both spectral types (29 000 and 9 000 K) are in excellent agreement with the temperatures derived by photometrists.

Key words: stars: emission line, B[e]; MWC 342; variables stars; peculiar

1. Introduction

The object MWC 342 was discovered as an emission line object by Merrill & Burwell (1933). On the basis of the spectrum, the star was classified Be and this classification is retained also by Stock et al. (1960) and Perraud (1961). A description of the spectrum was published by Swings & Struve (1943), who mention double emission components in the Balmer series, with narrow absorption cores characteristic of shells and numerous emission lines of Fe II and [Fe II]. Andrillat & Swings (1975) provided a description of the near infrared spectrum and Brosch et al. (1978) gave a description of the spectrum in 1974-75 based upon image tube spectra obtained at 75 and 223 Å/mm. Allen & Swings (1976) show a spectrum of the star and point out an important infrared excess.

The near infrared spectrum from IRAS observations was classified by Volk & Cohen (1989) as being of type "U"= unusual. The nature of most of these sources is unknown.

Polarization was investigated by Zickgraf & Schulte-Ladbeck (1989) who found intrinsic polarization and by Yudin (1994) who confirmed the intrinsic polarization and found it to be variable with a period of half the photometric period (66 days). The detailed behavior could be explained by the presence of a compact X-ray source in a binary system. Using data from Amnuel et al. (1979) he found an X-ray source whose position coincides within the error box with MWC 342.

Bergner et al. (1990) made a photometric study based upon observations in the $UBVRIJHK$ bands, whose conclusion can be summarized as follows. A model is proposed in which the star has a temperature of 28 000 K, whereas the temperatures of gas and dust are respectively 9 000 K and 800 K. The spectral type of the star should correspond to B0-B0.5 on the ZAMS. With a visual absorption of 2.1 magnitudes, a distance of 1.1 kpc is obtained. A long term photometric variability of 132 days is also found, which seems to be related to the variable polarization. In no band the variation over the period is larger than 0.65 magnitudes.

The aim of the present study as well as of others of this series is to provide a complete line identification based upon the largest possible wavelength region, as well as a description of the spectrum and a comparison with previous work.

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* Based on observations obtained at the Haute Provence Observatory (CNRS).

** Table 2 is only available in electronic form at the CDS via anonymous ftp to cdsarc.u-strasbg.fr (130.79.128.5) or via http://cdsweb.u-strasbg.fr/Abstract.html

Table 1. Observational data

Wavelength Region	Date
4095−4963 Å	21-7-1997
4890−5758	22-7-1997
5590−6457	25-7-1997
6280−7148	19-7-1997
7110−7958	24-7-1997
8067−8935	19-7-1997

The wavelength region is given in Angström and the date in day-month-year.

2. Material

The star was observed at the Haute Provence Observatory (OHP) of the CNRS in 1997. The wavelength regions and dates of observation are given in Table 1.

The observations were made with the 152 cm telescope, in July 1997. The spectrograph used was Aurélie (see Gillet et al. 1994) with a Thomson 7832 double bar detector, with 2048 photodiodes ($750 \times 13\ \mu$). The grating used had 300 grooves/mm, blazed at 6000 Å. The original dispersion is 33 Å/mm, with a resolution of 1.3 Å, equivalent to 65 $\mathrm{km\,s^{-1}}$ at 6000 Å.

Calibrations were made with a tungsten lamp for flat field and in wavelength by means of a hollow cathod of thorium and argon for the blue and the red and thorium-neon for the near infrared.

3. Line identifications

These were made in the traditional way, paying attention to both wavelengths and line intensities within the multiplets. The identifications were made with the help of the table of Moore (1959); for Fe II we also used Johansson's (1978) compilation. In addition we have used the Meinel et al. (1969) catalogue, for lines which we could not identify (see notes to Table 2).

On our spectra are present 270 emission features. The complete list of identifications is given in Table 2. Parts of the spectrum are reproduced in Fig. 1.

4. Emission lines

As mentioned before, we have measured a total of 270 emission lines and identified 251, i.e. 93%. Of these, two thirds correspond to Fe II and [Fe II]. The elements present are discussed in what follows.

- **Hydrogen.** Unfortunately we have only Hδ, Hγ, Hβ and Hα of the Balmer series. Hα is a broad line, about 6000 $\mathrm{km\,s^{-1}}$ wide at the continuum level, Hβ is 2400 $\mathrm{km\,s^{-1}}$ wide and Hγ 1100 $\mathrm{km\,s^{-1}}$ wide. The Hδ line is too near to the plate limit to be able to say something meaningful. No line has an indication of a P Cyg structure.

  The Paschen series is visible up to $n = 28$, with a clear progression from $n = 25$ downwards. The emissions are sharp and narrow at our resolution and show no trace of underlying absorption lines.
- **Helium.** Lines of the ^{3}S, ^{3}D, ^{1}S and ^{1}D series are present, but not of the ^{1}P^0 series. The lines are sharp and in single emission, except λ6678 which shows a P Cyg structure, with a separation between absorption line and emission line peaks of 170 $\mathrm{km\,s^{-1}}$.
- **Carbon.** Ionized carbon is present with lines from M.2 and 45.
- **Oxygen.** Neutral oxygen is represented by lines from M.1, 4, 10, 21, 22, 23 and 34. Lines from M.1 of [O I] are also present.
- **Nitrogen.** Neutral nitrogen is well represented by lines from M.1, 2, 3, 8, 9 and 21.
- **Magnesium.** Neutral magnesium is represented by lines from M.2, 8, 11 and 22, whereas singly ionized magnesium is present with lines from M.4 and 8.
- **Aluminium.** Singly ionized aluminium is perhaps present with lines from M.3 and 21.
- **Silicon.** Ionized silicon is represented by lines from M.2, 4 and 5.
- **Calcium.** Ionized calcium is represented by lines from M.2 which can be seen only through the deformation of the Paschen progression.
- **Titanium.** Ionized titanium is represented by lines from M.41, 50 and 82. There exist also lines of [Ti II] from M.15.
- **Chromium.** May be present with a line from M.30.
- **Manganese.** Ionized manganese has lines from M.13, 19 and the line at 8783. We regard the presence of this element as dubious.
- **Iron.** Ionized iron is represented by many lines from M.25, 27, 28, 37, 38, 40, 41, 43, 46, 48, 49, 55, 72, 73, 74, 186, 200 and 211. Also [Fe II] is represented by many lines from M.3, 4, 6, 7, 13, 18, 19, 20, 21, 33, 34, 36 and 39.
- **Nickel.** Ionized nickel may be represented by two lines from M.9.

In summary we have evidence for the presence of species of 11 elements, whereas the presence of three more elements must be regarded as doubtful (Al, Cr and Mn).

5. Comparison with other authors; spectroscopic variability

The most extensive work on this star was performed by Brosch et al. (1978) who identified the following elements: H, He I, O I, [O I], Mg II, Si II, Fe II and [Fe II]. They remark that few [Fe II] lines are present and that except for [O I] no other forbiden lines are seen. Another point is that they were unable to see absorption lines. Although part of

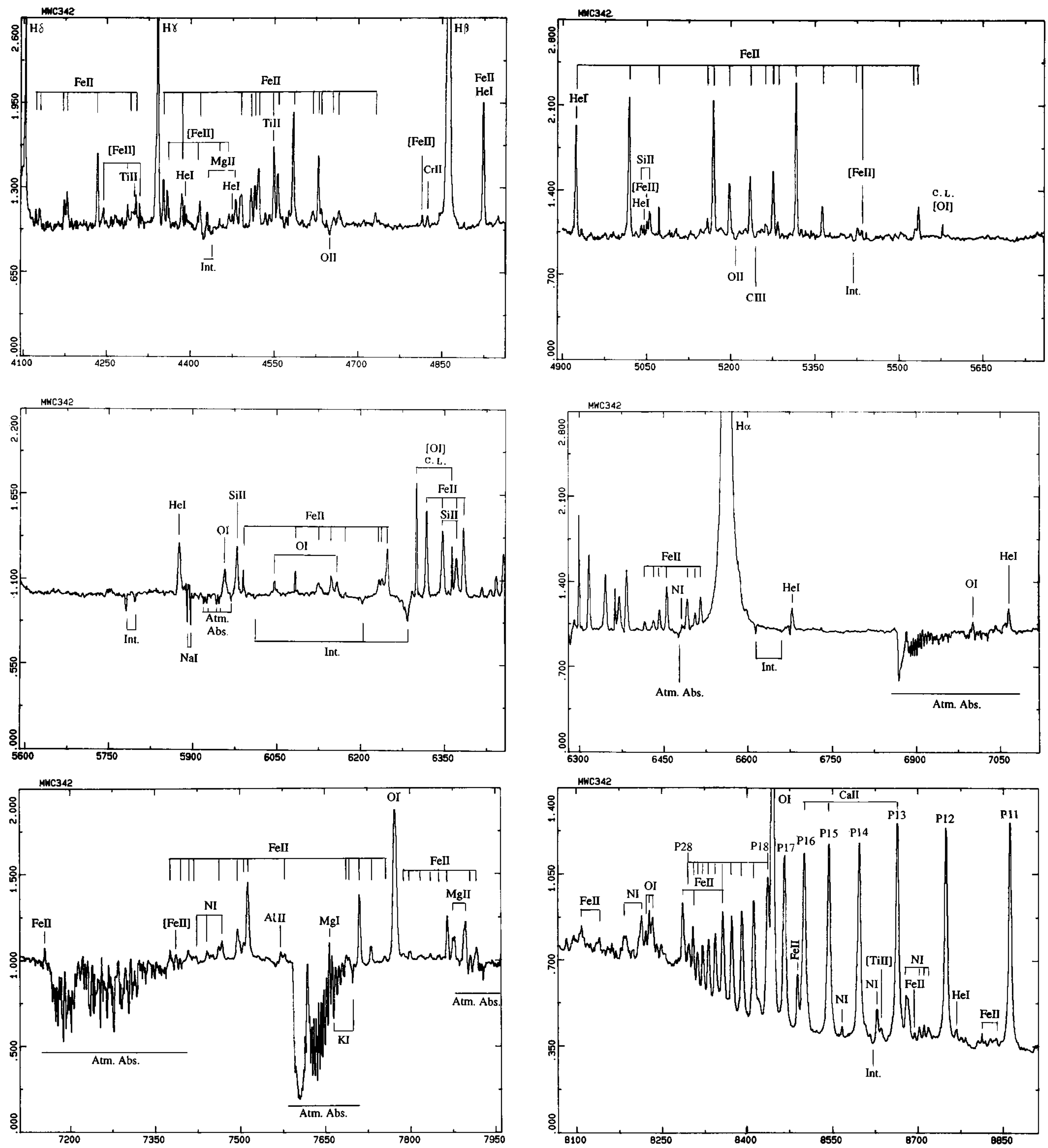

Fig. 1. Reproduction of CCD spectra MWC 342. Abscissae: wavelengths in Angström. Ordinates: intensities. The continuum is set to unity. Identifications of important lines are provided

Table 3. Absorption lines present in MWC 342

λ	W	$\lambda(L)$	Identification
4422.6	0.43	4428	IB Herbig
4437.0	0.22	4428	IB Herbig
4649.4	0.35	9.14	O II 1
5208.0	0.21	6.73	O II 32
5242.8	0.09	4.50	C III 4
5419.2	0.10	5420	IB Herbig
5780.8	0.28	5780	IB Herbig
5796.4	0.15	5797	IB Herbig
5890.0	0.13	9.95	Na I 1
5896.0	0.28	5.92	Na I 1
6010.0	0.04	6010	IB Herbig
6065.2	0.05	5.5	N II
6202.6	0.325	6203	IB Herbig
6283.6	1.45	6283 (large band from 6264 to 6290)	IB Herbig
6613.6	0.02	6613	IB Herbig
6659.2	0.14	6660	IB Herbig
7664.4	4.90		K I 1
7698.0	8.98		K I 1
8620.0	0.28	(band from 17.8 to 23.8)	IB Sanner et al.

Notes: The first column provides the observed wavelength, the second the equivalent width, the third the theoretical wavelength and the last the identification. IB = interstellar band; Herbig = Herbig (1975); Sanner et al. = Sanner et al. (1978).

this may be attributed to their low resolving power, the absence of Ca II in absorption is striking. Furthermore Kuhi in 1976 quoted a number of higher Balmer lines in absorption (Brosch et al. 1978), which in Brosch appear in emission. Since on our spectra we are limited to $\lambda > 4095$ Å, we see only Hδ, Hγ, Hβ and Hα in emission, so that our spectra agree with the description by Brosch et al. (1978). A further point of agreement with their description is that we see no other forbidden emissions except those of [O I] and [Fe II]. The difference is that we see many lines of the latter species, although none has an equivalent larger than 0.80.

We may also compare with the verbal description by Swings & Struve (1943). They found double emissions in the Balmer series, with $R \gg V$ and deep absorption cores, characteristic of shells. These features extend at least up to $n = 13$. They observe also strong permitted lines of Fe II, all of which are somewhat diffuse but show no duplicity; the strongest Fe II lines have P Cyg type profiles. Mg II is weakly in emission, Si II $4128-30$ absent and Ca II shows a relatively weak interstellar absorption line. Several moderately strong emission lines of [Fe II] are also present.

From the descriptions, we see that changes in the spectrum of the star have taken place. Due to the lack of coverage of the star, we are however unable to establish when these changes took place.

6. Absorption lines

We have listed in Table 3 all absorption features appearing in our spectra. Half of them belong to well known interstellar bands, whereas the remainder is composed by lines belonging to a hot star. Among the interstellar lines we find those corresponding to NaI (M.1) and K I (M.1) which cannot be resolved into components due to lack of resolving power. We can thus not decide if they come from the interstellar or from the circumstellar medium. If the observed equivalent widths of the interstellar lines are taken at face value, we can use Herbig's (1975) relation between strength and $B-V$ color excess to derive an estimate of the latter. From four features, we derive 0.41 ± 0.48 which speaks in favor of a rather low value of $E(B-V)$. It should be added that the large uncertainty attached to our result is quite natural when dealing with equivalent width-color excess relations. Brosch et al. (1978) had found a value of 0.5, whereas Bergner et al. (1990) found 2.1. However all values have a rather large uncertainty attached.

Among the lines attributable to the hot component, we find lines belonging to CIII and O II. Such lines are observable in stars of spectral types between O 7-B 0.5 (C III) and O9-B3 (O II). As a compromise we adopt a spectral type of about B 0. Nothing can be said on the luminosity of the star, since both elements show a positive luminosity effect. The spectral type found agrees well with the 28 000 K star found by Bergner et al. (1990).

7. Emission line spectrum

The emission line spectrum is produced in the shell and because of the presence of C II, Mg I and Ca II it corresponds probably to an early A type star. This would correspond to a temperature of about 9 000 K, which can be compared to the 9 000 derived photometrically by Bergner et al. (1990). Observe also that no He II lines are observed, which are the habitual signature of an X-ray source.

8. Analogies with other stars studied in this series

We have remarked that the lines of [Fe II] are weak and this characteristics makes the object to stand out among the others studied in this series where [Fe II] lines tend to be strong and numerous. The [Fe II] weakness is only paralleled by HD 50138, where one also finds numerous but weak [Fe II] lines.

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