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BX Mon as a long-period eclipsing binary system

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Summary. Continuing the series of spectroscopic observations of symbiotic stars, it was found out that the spectrum of BX Mon varies with a period of 1380 or 1374 days. Usually, BX Mon shows an absorption spectrum of an intermediate M type giant and strong emission lines of H I, He I, Fe II etc. The emission line of He II 4686 was observed in November 1981–March 1982 (Phase 0.5–0.6) and its intensity rapidly varied during the period. A weak trace of the nebular emission line [O III] 5007 was detected in October 1982 (Phase 0.75). On the other hand, in January–February 1980 and in October–November 1983 (Phase 0.01–0.04) only Hα and Hβ were recorded as weak emission and the absorption bands of TiO were extremely deep. The depth of TiO bands varied periodically but no spectral characteristic of Mira variables was found. High dispersion spectra show that Hα has two emission peaks cut by an extraordinarily deep absorption core. The blueward emission peak was more intense than the redward one in January 1984 (Phase 0.076) and a reversal ratio was observed in February 1985 (Phase 0.358).

These results suggest that BX Mon is a long-period eclipsing binary system consisting of a non-Mira type M 5 $\sim$ 6 III and a hot component, the latter is brightened up by a mass accretion process. The binary system may have an eccentric orbit, because the mass accretion rate onto the hot component seems to vary periodically. A serious inconsistency, however, still remains between this model and the light variation of BX Mon in the years from 1890 to 1940.

Key words: stars: individual – spectra: optical – symbiotic star – eclipsing binary – mass accretion

1. Introduction

BX Monocerotis (HV 10446, AS 150, M Hα 61 – 12; $7^h22^m53^s$, $-3°29.8'$ (1950)) was noticed at first as the longest long-period (Mira type) variable by Mayall (1940), who derived the following elements from the analysis of 887 Harvard photographic plates covering the years from 1890 to 1940:

$$\mathrm{JD\ (Max)} = 2412490 + 1380\ (\mathrm{day}) \times E,$$

$$m_{pg}(\mathrm{Max}) = 10.02,\ m_{pg}(\mathrm{Min}) = 13.05.$$

A slightly different period is reported by Kukarkin et al. (1958):

$$\mathrm{JD\ (Max)} = 2430345 + 1374\ (\mathrm{day}) \times \mathrm{E}.$$

Its spectrum has been classified as M type with peculiarly strong hydrogen emission lines (M 4 ep: Mayall, 1940; Merrill and Burwell, 1950; Bidelman, 1954). While Bidelman (1954) classified BX Mon as a symbiotic star, its detailed properties have not been well known. It has not been obvious if this star satisfies the criteria for symbiotic stars, namely if it has nova-like outbursts, absorption spectrum of a late type star, and emission lines from highly ionized ions such as O III or He II (Boyarchuk, 1975). Especially the last criterion has been problematic for BX Mon (Allen, 1979).

In the recent years some new observations have been carried out in ultraviolet (Michalitsianos et al., 1982; Sahade et al., 1984), in optical (Allen, 1984; Iijima, 1984; Viotti et al., 1985), in infrared (Whitelock and Catchpole, 1983) and in radio wave region (Seaquist et al., 1984). Whitelock and Catchpole (1983) showed that the energy distribution of BX Mon in J, H, K, and L bands does not fit with that of Mira variables or of symbiotic stars with a Mira type component (Feast et al., 1977; 1983), but fits well with that of a normal M 5 III. Michalitsianos et al. (1982) found out highly excited emission lines such as C IV, N III], O III], Si III], and C III] in the ultraviolet region and proposed a binary model consisting of an M giant and a hot component with spectral type F0 II–III. More recently Viotti et al. (1985) proposed a binary model consisting of an M 7 III and a hot component of A 7–F0 type.

In this paper, results of spectroscopic observations carried out from October 1979 to the present days are reported. According to these results, it is proposed a model of a long-period eclipsing binary system with eccentric orbit. A serious inconsistency between the binary model and the light curve published by Mayall (1940) is discussed in Sect. 5.

2. Observations and results

Almost all observations were carried out with the 122 cm reflector of the Astrophysical Observatory of the University of Padova in Asiago. The one-prism spectrograph with S-20 Carnegie Image Tube was used. The spectral range is $\lambda\lambda$ 3800 – 7800 Å and the dispersion is 60 Å mm^{-1} at Hγ ($\Delta\lambda/\lambda = 8 \times 10^{-4}$). Two high dispersion spectra (10 Å mm^{-1}, $\Delta\lambda/\lambda = 8 \times 10^{-5}$, $\lambda\lambda$ 5800 – 6600 Å) were taken with the Echelle spectrograph mounted on the 182 cm reflector at Cima Ekar station of the Asiago Observatory and a photographic photometry was made with the 65 cm Schmidt telescope using the emulsion-filter combination of 103a-O + GG 13. Journal of the observations is given in Table 1. In the table, Ph(Ma) is the phase according to the elements of Mayall (1940).

Table 1. Journal of observations

Plate No.	Date	J D	Ph(Ma)	Exp. time (min.)	
12827	Oct. 17, 1979	4164.7	0.953	14	
12842	Oct. 24, 1979	4171.7	0.958	20	
12855-6	Nov. 2, 1979	4180.6	0.964	45,17	
12914	Nov. 27, 1979	4205.7	0.984	45	
13124	Feb. 11, 1980	4281.6	0.037	50	
13130	Feb. 12, 1980	4282.5	0.038	100	
13517	Oct. 21, 1980	4534.7	0.221	50	
13603	Nov. 22, 1980	4566.6	0.244	50	
13647	Dec. 5, 1980	4579.7	0.253	30	
13771-2	Dec. 28, 1980	4602.6	0.270	10,42	
13901-2	Jan. 11, 1981	4616.6	0.280	10,60	
14003	Jan. 26, 1981	4631.6	0.291	25	
14031-2	Feb. 8, 1981	4644.4	0.300	40,10	
14318-9	Nov. 7, 1981	4916.7	0.498	15,40	
14387-8	Nov. 22, 1981	4931.7	0.509	10,35	
14507	Jan. 19, 1982	4989.5	0.550	10	
14525	Jan. 21, 1982	4991.5	0.552	30	
14554	Jan. 28, 1982	4998.5	0.557	10	
14602	Feb. 12, 1982	5013.4	0.568	12	
14623	Feb. 27, 1982	5028.4	0.579	10	
14662-3	March 15, 1982	5044.4	0.590	10,35	
14670	March 16, 1982	5045.4	0.591	60	
14702	April 27, 1982	5087.4	0.621	60	
14940	Oct. 14, 1982	5257.7	0.745	20	
14967	Oct. 27, 1982	5270.7	0.754	35	
15056	Dec. 11, 1982	5315.6	0.787	40	
15061	Dec. 12, 1982	5316.6	0.787	110	
15076	Jan. 12, 1983	5347.5	0.810	40	
15127	Feb. 17, 1983	5383.5	0.836	30	
15169-70	March 4, 1983	5398.4	0.847	20,60	
15422	Oct. 19, 1983	5627.7	0.013	50	
15532	Nov. 16, 1983	5655.7	0.033	65	
15619	Nov. 30, 1983	5669.7	0.043	50	
15649	Dec. 13, 1983	5682.6	0.053	60	
15711	Jan. 11, 1984	5711.5	0.074	20	
3303	Jan. 15, 1984	5715.4	0.076	60	Echelle
15771	March 5, 1984	5765.4	0.113	40	
15807	March 22, 1984	5782.4	0.125	60	
16077	Oct. 3, 1984	5977.7	0.266	65	
16119	Oct. 21, 1984	5995.7	0.280	70	
16163	Nov. 1, 1984	6006.7	0.287	80	
12773	Jan. 27, 1985	6093.5	0.350	5	Photo.
3600	Feb. 6, 1985	6103.5	0.358	20	Echelle

J D : Julian day 2440000 +

In the following, the elements of Mayall are used to make easy the comparison between the spectroscopic results and the mean light curve presented by Mayall (1940). Table 2 gives equivalent widths of prominent emission lines and depths of TiO absorption bands relative to the local continuum level. The observational error is estimated of the order of ±20% in the equivalent widths and about ±15% in the depths of TiO bands. Values with lower accuracy are denoted by a colon. The last column of Table 2 gives the intensity ratio of He II 4686/Hβ. Spectrophotometric corrections were made by using spectra of ε Ori (Code, 1960) taken in the same nights. Intensity traces of some selected medium dispersion spectra are shown in Figs. 1 and 2. In these figures "N.S." indicates emission lines of the night sky. Figure 3 shows the profiles of Hα emission line in the high dispersion spectra. The numbers on the peaks indicate respective radial velocity in km s^{-1}. Figures 4–7 show the equivalent width of selected emission lines and the depth of TiO absorption bands. The upper panels show their time variations while their phase dependence is shown in the lower panels. Figure 8 shows the intensity ratio of He II 4686/Hβ and the mean depth of TiO bands in the period between JD 2444644 and 5044. Heliocentric radial velocities of Hβ, Hγ, Hδ and He II 4686 are given in Table 3. The observational error in an individual value is about ±20 km s^{-1}. Figure 9 shows the radial velocity of He II 4686 and the mean of those of the hydrogen emission lines. Visual estimates of BX Mon in the years from 1979 to 1983, collected by AAVSO (Mattei, private communication), are shown in Fig. 10. The mean light curve of Mayall (1940) is reproduced in Fig. 11. The result of our photographic photometry, giving $m_B = 10.8 \pm 0.1$ on January 27, 1985 (Phase 0.35), is indicated by a cross in Fig. 11. The cross in parentheses indicates another probable position for the same observation (see Sect. 5).

3. Interpretation

3.1. Medium dispersion spectra

As seen in Figs. 1, 2 and 4–7, the spectrum of BX Mon varies for a large extent, and the variations seem to occur according to the period of 1380 days (Mayall, 1940). In January–February 1980 and October–November 1983 (Phase 0.01–0.04) only Hα and Hβ were seen weak in emission together with large depth of TiO absorption bands (Figs. 1, 2, 7). On the other hand, the emission line of He II 4686 was observed during November 1981–March 1982 (Phase 0.5–0.6) and at that time the bands of TiO were very shallow (Figs. 1, 6, 7). In the next observational season from October 1982 to March 1983, the emission line of He II 4686 was not observed and a weak emission of [O III] 5007 was noticed (Fig. 2).

The equivalent width of Hβ has a deep minimum at phase near zero and a smaller minimum at phase 0.57 (Fig. 4). The equivalent width of He II 4686 decreased more distinctly at phase 0.57–0.58 (Fig. 6). The depths of TiO bands in 1979 were much weaker than those expected from their periodical variation after that time (Fig. 7). This weakness may be due to an accidental outburst, because as seen in Fig. 10, BX Mon was unusually bright at that time.

Except for the spectra at phases near zero and 0.5–0.6, BX Mon usually shows an absorption spectrum of an intermediate M type star and emission lines of H I, He I, Fe II etc. (Figs. 1, 2). Nearly the same features are seen in spectra taken on November 3, 1967 (Phase 0.79; Mammano, private communication) and on November 18, 1977 (Phase 0.45; Allen, 1984). Weak emission-like features are seen at λ 6830 Å on some spectra (Figs. 1, 2). It is not obvious, however, if those correspond to the unidentified emission band at λ 6830 Å of symbiotic stars which usually associated with high excitation level (Allen, 1980). Sometimes also normal M type stars show such a weak emission-like feature at λ 6830 Å which may correspond to a window in absorption bands (Allen; Mammano; private communications). The peculiarity of the intensity of hydrogen Balmer series, which is known among Mira variables, was not observed.

The radial velocities of hydrogen emission lines seem to vary according to the period of 1380 days (Fig. 9). A tentative result of an analysis of the radial velocities is given in Table 4. These values are derived assuming that the radial velocity of the hydrogen emission lines represents that of the orbital motion of the hot component. Results of detailed analyses will be reported in a forthcoming paper.

Table 2. Equivalent width of emission lines (Å) and depth of TiO bands

No.	J D	Ph(Ma)	Ti O 5167	HeI,FeII 5017	Ti O 4955	HeI,FeII 4923	Hβ 4861	Ti O 4761	He II 4686	He I 4471	He I 4388	Hγ 4340	He II/Hβ
12827	4164.7	0.953	0.47	2.0	0.49	3.1	18.7	0.39	0	3.2		8.1	
12842	4171.7	0.958	0.46	2.3	0.51	3.1	21.9	0.32	0	3.3	1.9	11.7	
12856	4180.6	0.964	0.54	3.3	0.51	1.7	24.8	0.38	0	4.0	3.5	22.9	
12914	4205.7	0.984	0.45	4.5	0.47	4.6	22.6	0.33	0	3.9	4.4	15.8	
13124	4281.6	0.037	0.85	0	0.87	0	8 :	0.90					
13130	4282.5	0.038		2.3	0.81 :	0	6.3	0.73	0				
13517	4534.7	0.221	0.44	4.4	0.48	2.7	OE	0.37	0	3.0	3.3	15.0	
13771	4602.6	0.270	0.37	5.4	0.44	2.3	24.8	0.33	0	1.5		9.8	
13901	4616.6	0.280	0.37	5.2	0.43	2.7	29.0	0.46	0	2.9	2.3	14.9	
14003	4631.6	0.291	0.33	4.7	0.47	5.2	26.0	0.43	0	5.0		11.1	
14031	4644.4	0.300	0.35	3.8	0.37	2.1	26.1	0.39	0	2.9	2.2	23.8	
14318	4916.7	0.498	0.36	3.2	0.39	2.4	21.9	0.18	5.7	2.2	2.0	9.1	0.31±0.09
14387	4931.7	0.509		3.6	0.43	2.8	OE	0.31	4.3	2.9	2.3	8.2	
14507	4989.5	0.550	0.29	2.7	0.30	1.5	13.9	0.24	3.1	3.3	1.8	10.8	0.22±0.07
14554	4998.5	0.557	0.39	2.7	0.35	3.4	16.3	0.25	3.3	3.3	2.9	13.4	0.20±0.06
14602	5013.4	0.568	0.30	2.0	0.31	1.3	9.6	0.28	2.0	2.0	1.1	6.9	0.22±0.07
14623	5028.4	0.579	0.33	1.7	0.36	2.4	13.0	0.28	1.5	2.7	1.8	9.5	0.11±0.03
14662	5044.4	0.590	0.41	2.8	0.43	2.7	21.0	0.45	6.9	3.1	2.1	13.0	0.27±0.08
14967	5270.7	0.754	0.59	4.9	0.60	2.3	24.9	0.46	0		3.2	27 :	
15056	5315.6	0.787	0.61	3.9	0.66	2.4	26.9	0.63	0	2 :		11 :	
15076	5347.5	0.810	0.55	3.4	0.63	3.2	20.3	0.64	0			28 :	
15127	5383.5	0.836	0.51	2.9	0.64	2.8	25.1	0.51	0			9 :	
15169	5398.4	0.847	0.65	4.4	0.74	3.0	31.1	0.63	0	5 :	3 :		
15422	5627.7	0.013	0.79	0	0.87	0	3.2	0.83	0				
15532	5655.7	0.033	0.82	0	0.82	0	3.3	0.81	0			2.8 :	
15619	5669.7	0.043	0.82	3.0	0.84	0	10.2	0.74	0				
15649	5682.6	0.053	0.78	0	0.77	0	15.7	0.74	0			10 :	
15711	5711.5	0.074	0.68	1.9	0.76	2.7	28.0	0.75	0	5 :		25 :	
15771	5765.4	0.113	0.75	6.6	0.84	1.8	45 :	0.9 :					
16077	5977.7	0.266	0.46	4.2	0.44	2.1	23.7	0.37	0	2.6		16 :	
16119	5995.7	0.280	0.40	2.3	0.44	0	16.8	0.29	0	0.8		9.6	
16163	6006.7	0.287	0.37	3.2	0.47	3.1	21.1	0.26	0	2.4		15.3	

J D : Julian day 2440000 +

OE : over exposed

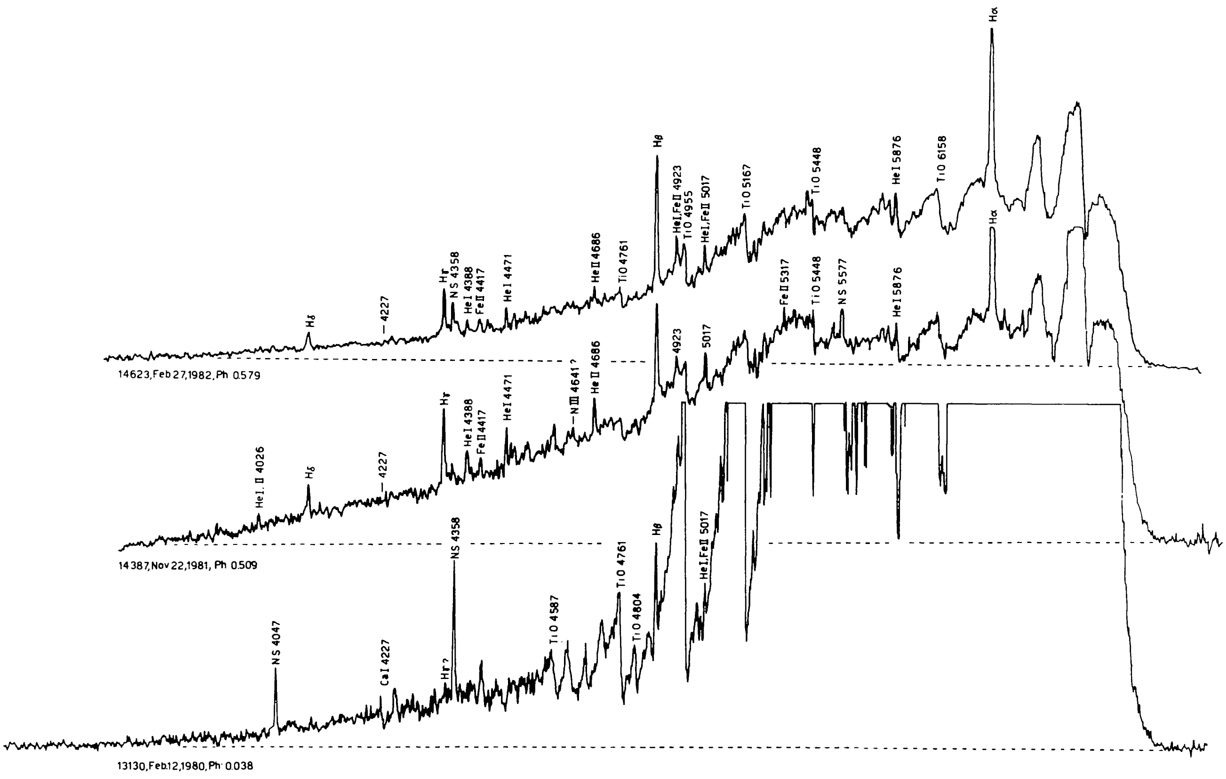

Fig. 1. Intensity traces of selected medium dispersion spectra

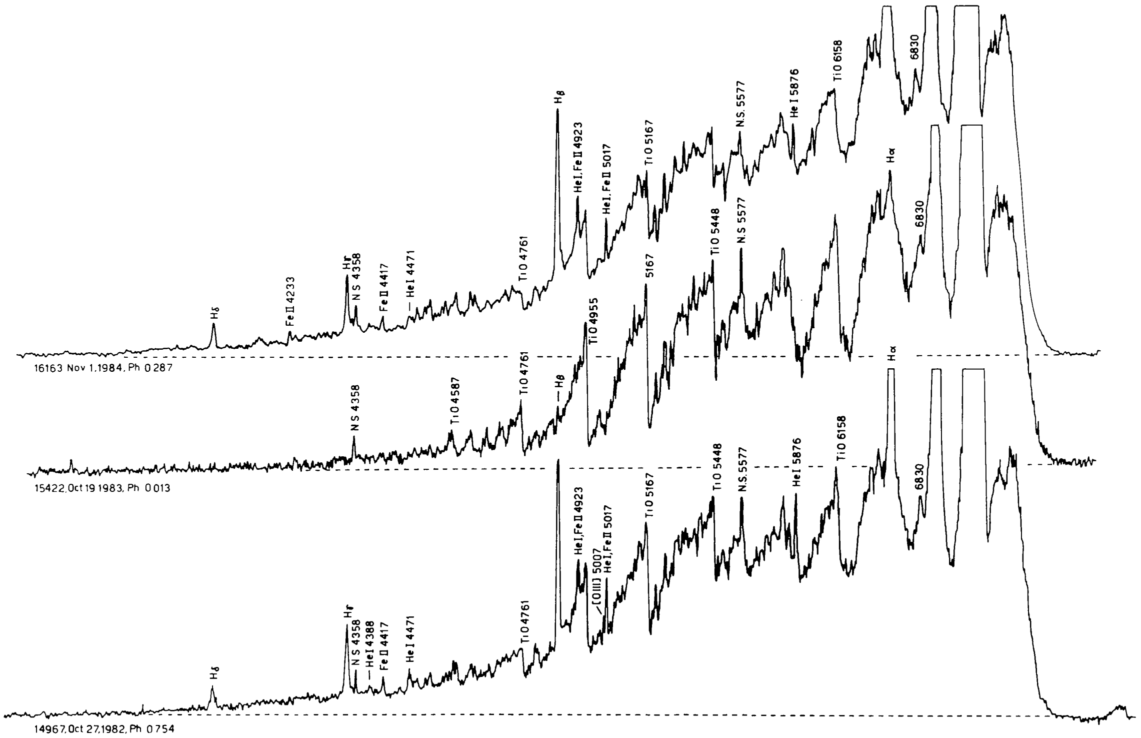

Fig. 2. The same as in Fig. 1

3.2. *High dispersion spectra*

The high dispersion spectra show that Hα of BX Mon has two emission peaks cut by an extraordinarily deep central absorption core (Fig. 3). Viotti et al. (1985) took a high dispersion spectrum in the region of Hα on February 3, 1984, that is 19 days later than our first observation. No significant change was found between these two spectra. The blueward emission peak was more intense than the redward one on January 15, 1984 (Phase 0.076) and on February 3, 1984 (Phase 0.09) then a reversal ratio was found on February 6, 1985 (Phase 0.358). Similar profiles and variations of the profiles have been known on Hα and Hβ of the symbiotic star CH Cyg (Anderson et al., 1980; Faraggiana and Hack, 1971), and on Hα of the shell star 48 Lib (Underhill, 1960).

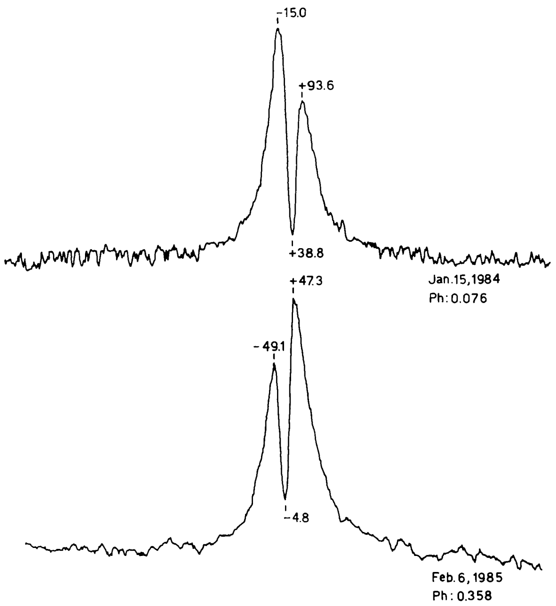

Fig. 3. Hα profiles from high dispersion spectra. The numbers indicate heliocentric radial velocities in $\mathrm{km\,s^{-1}}$

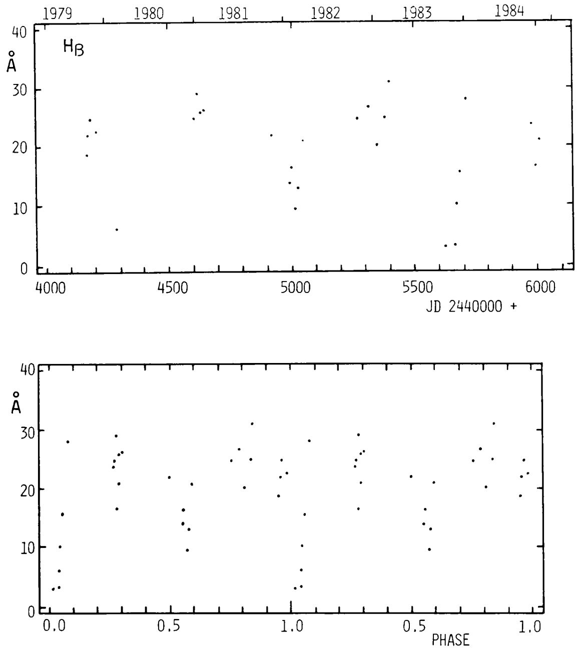

Fig. 4. Equivalent width of Hβ (up) and its phase dependence (down). Observational error is about ±20%

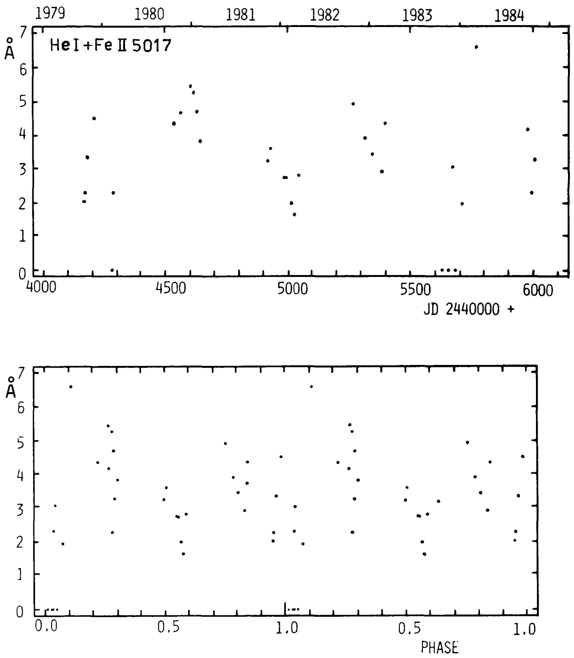

Fig. 5. Equivalent width of He I + Fe II 5017 Å (up) and its phase dependence (down). Observational error is about ±20%

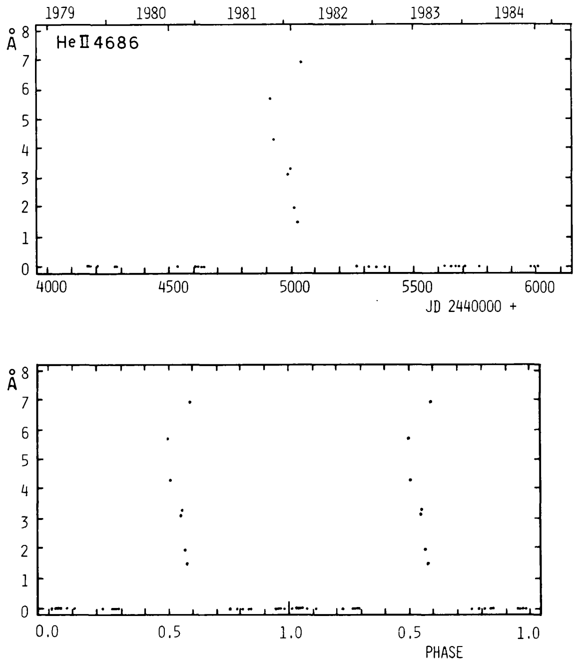

Fig. 6. Equivalent width of He II 4686 Å (up) and its phase dependence (down). Observational error is about ±20%

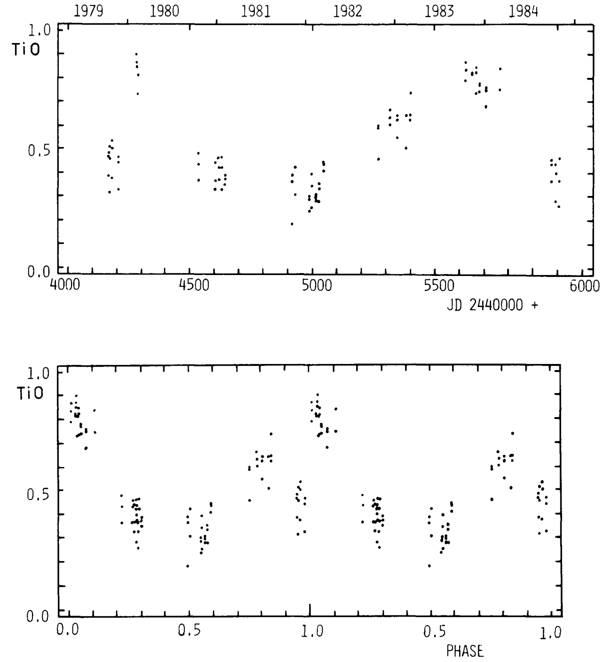

Fig. 7. Depth of TiO absorption bands (up) and its phase dependence (down). Observational error is about ±15%

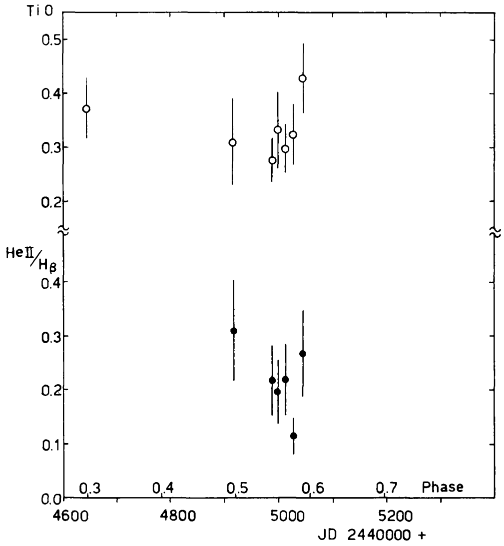

Fig. 8. Intensity ratio of He II 4686/Hβ and mean depth of TiO bands

In 48 Lib the variation of the intensity ratio between the two peaks is explained as the result of a shift of the central absorption core (Underhill, 1960). Because of the lack of radial velocity measurements, a definite explanation is not given for CH Cyg, but the authors (Anderson et al., 1980; Faraggiana and Hack, 1971) suggest that the same explanation could be applicable. In the case of BX Mon, again as in 48 Lib, the variation of the intensity ratio is mainly due to the shift of the absorption core, because it significantly blue-shifted between January 15, 1984 and February 6, 1985 (Fig. 3). This phenomenon may reflect gas motions in the system of BX Mon. These profiles of Hα are also different from those of Mira variables (Gillet et al., 1983).

Table 3. Heliocentric radial velocity of emission lines (km s^{-1})

No.	J D	Ph(Ma)	Hβ	He II 4686	Hγ	Hδ	H I
12827	4164.7	0.953			+26		+26±20
12855	4180.6	0.967			+29		+29±20
13130	4282.5	0.038	+32				+32±20
13517	4534.7	0.221	+5		+28	+33	+21±15
13603	4566.6	0.244	+15		+30	+8	+18±15
13647	4579.7	0.253			+31		+31±20
13772	4602.6	0.270			−2	+5	+2±15
14031	4644.4	0.300	+32		+12	+33	+25±15
14387	4931.7	0.509	+56	+10	+74:		+56±20
14525	4991.5	0.552	+39	+36	+49		+44±15
14662	5044.4	0.590	+37	0	+44	+58	+46±15
14670	5045.4	0.591	+25	−3	+54	+37	+39±15
14702	5087.4	0.621	+37	+46			+37±20
14940	5257.7	0.745	+39		+59	+23	+40±15
15061	5316.6	0.787	+45		+54		+49±15
15076	5347.5	0.810			+60	+60	+60±15
15170	5398.4	0.847			+46	+50	+48±15
15619	5669.7	0.043	+18		+49		+34±25
15771	5765.4	0.113			+24		+24±20
15807	5782.4	0.125			+14		+14±20
16119	5995.7	0.280			+12		+12±20
16163	6006.7	0.287			+31		+31±20

J D : Julian day 2440000 +

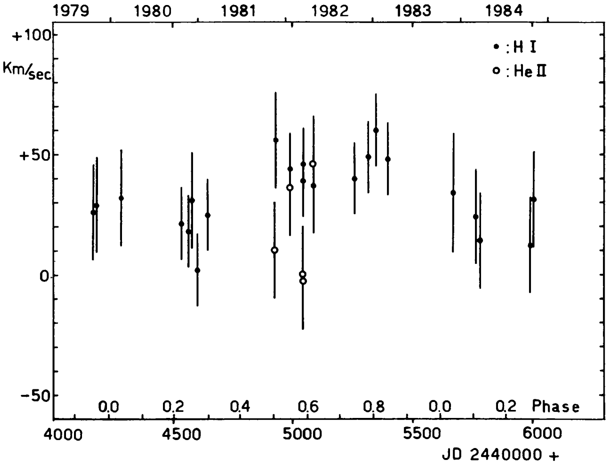

Fig. 9. Heliocentric radial velocity of He II 4686 and H I

4. Discussion

4.1. Binary model

As mentioned in the previous section the optical spectra of BX Mon do not show the typical characters of Mira variables. Also Viotti et al. (1985) do not find any characteristics of Mira variables in their infrared and optical observations. These results are consistent with the infrared observations of Whitelock and Catchpole (1983). On the contrary the absorption line of Ca I 4227 is barely perceptible in the spectra taken at phase 0.5–0.6 (Fig. 1), which means that an appreciable fraction of the blue continuum does not come from the M type component. It is necessary to assume another source with higher temperature for the blue continuum of BX Mon. The existence of a hot component has been suggested also from the ultraviolet observations (Michalitsianos et al., 1982; Sahade et al., 1984). Moreover the emission line of He II 4686 suggests that a mass accretion process exists in the system of BX Mon. All of these results thus support the binary models consisting of an M type giant and a hot component (Michalitsianos et al., 1982; Whitelock and Catchpole, 1983; Viotti et al., 1985).

The unusually low excitation states in January–February 1980 and in October–November 1983 are similar to the phenomenon which was observed in the well established symbiotic binary system CI Cyg during the eclipse in 1980 (Mikołajewska and Mikołajewski, 1983). In both cases recombination emission lines

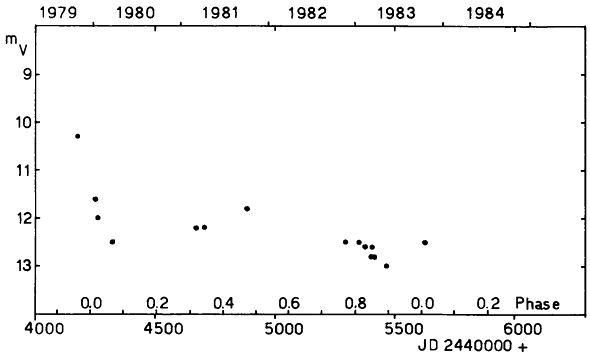

Fig. 10. Visual estimates of BX Mon collected by AAVSO

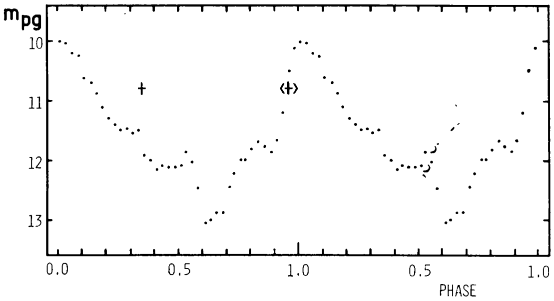

Fig. 11. Mean light curve given by Mayall (1940). A result of our photographic photometry is given by a cross. See section 5 for the cross in parentheses

Table 4. A tentative result for orbital parameters of BX Mon binary system

Period	1380	days	(assumed)
Eccentricity	0		(assumed)
$A \sin i$	380 ± 60	$R_\odot$	
Semi-amplitude	14.0 ± 2	km s^{-1}	
Baricentric velocity	32.8 ± 2	km s^{-1}	

became fainter, or completely disappeared, and the absorption spectra of the late type components were very distinct. The interval between the two low excitation states of BX Mon is about 1360 days (Fig. 7) which agrees with the photometric period, that is 1380 days (Mayall, 1940) or 1374 days (Kukarkin et al., 1958). These periods may relate to that of the orbital motion of the binary system of BX Mon. The unusually low excitation states could be due to eclipses of the hot component by the M type component.

The mean light curve of BX Mon (Fig. 11) is not similar to that of usual eclipsing binaries, but rather similar to that of Mira variables. If BX Mon is not a Mira variable, how such a light variation is possible? Mayall (1940) showed that the periodicity and the amplitude of the light variation in the *photographic* band were stable during the years from 1900 to 1940. On the other hand it is difficult to find such periodical variation in the *visual* estimates of AAVSO in the years from 1979 to 1983 (Fig. 10). The visual brightness is roughly constant except in 1979. As seen in Fig. 1, however, the star was bluer at phase 0.5–0.6, than at phase near zero. Therefore, it is likely that observations in blue or photographic band would show light variations also in the present days. The light variations of BX Mon may be mainly due to the hot component, because they seem to be more distinct in the blue region. The variation of the depth of TiO bands gives another piece of evidence for the periodical light variation of the hot component (Fig. 7). In this argument the points in 1979 are omitted because they are affected by the outburst. If, as suggested by Whitelock and Catchpole (1983), the M type component is not variable, the depth of TiO bands may reflect a contribution from the hot component, in the sense that the shallower are the bands, the brighter is the hot component. The periodical variation of the depth of TiO bands suggests that the brightness of the hot component varies according to the phase and becomes brighter at phase 0.3–0.5 (Fig. 7).

Since, in general, an early type star does not show by itself a periodical long term light variation, the hot component may be brightened up by an external energy source which is periodically changing. The mass transfer and accretion in a binary system with an eccentric orbit is one of acceptable models. In such a system the mass transfer rate, which relates to the luminosity of the hot component, can vary with phase. If the M type component fills its Roche lobe on the periastron passages of the companion, the accretion rate will become high enough to give rise to He II 4686 emission line. A slow mass transfer from the extended atmosphere of the M type component will produce the emission lines of H I, He I, Fe II etc. A schematic diagram of the model is shown in Fig. 12. The spectral type of the late type component M 5 ~ 6 III was deduced from the depth of TiO bands at their maxima.

This model can explain qualitatively the variation of the profile of Hα in the high dispersion spectra. The first spectrum was taken at phase 0.076, namely, when the hot component was located nearly behind the M type component. The emission region of the hydrogen lines around the hot component was probably seen through the stream of accreting matter. On the other hand, the second spectrum was taken at phase 0.358, when significant gas motion may not have existed along the line of sight to the hot component. The slight blue shift of the absorption core in the second spectrum could be due to a gas outflow from the hot component, while its red shifted position in the first spectrum may reflect the radial motion of the accreting gas stream.

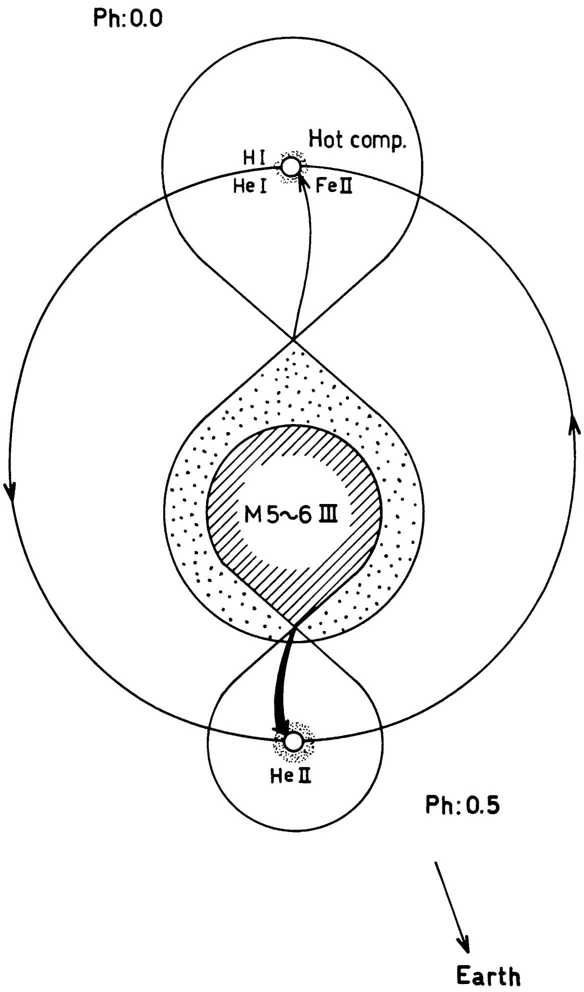

Fig. 12. Schematic diagram of BX Mon binary system

4.2. Instability in mass accretion process

As seen in Figs. 4 and 6 the equivalent widths of He II 4686 and Hβ decreased in January–February 1982 (JD 2444916–5028) then recovered in March 1982 (JD 2445028–5044). The variation of the intensity ratio of He II 4686/Hβ (Fig. 8) suggests that these phenomena are mainly due to the temperature variation of the excitation source of these emission lines (Ambartsumyan, 1932; Iijima, 1981). In the period between JD 2444916 and 5028, the intensity ratio of He II 4686/Hβ decreased, that is, the excitation temperature decreased. This phenomenon may be due to an expansion of the excitation source or a decreasing of the mass accretion rate. Unfortunately, because of the lack of accurate photometric data, it is not possible to decide which of the mechanisms was at work. On the other hand, when the intensity ratio of He II 4686/Hβ increased between JD 2445028 and 5044, the depth of TiO bands apparently increased, which means that the excitation temperature increased and the brightness of the hot component in the optical region decreased. Probably the hot component shrinked and the shrinking induced the higher temperature of the excitation source. This phenomenon suggests that some instabilities occurred at that time in the mass accretion process, for example a collapse of the accretion disk.

5. Inconsistency between the light curve and the binary model

The binary model presented in the previous section presumes that the eclipses occur at phase zero. In the light curve of Mayall (1940), however, the phase zero corresponds to the photometric maximum. This is the serious inconsistency which was anticipated in the introduction. As mentioned in the previous sections, BX Mon can be fainter in the photographic band at phase zero than at phase 0.3–0.6. Therefore the binary model is consistent with the observed phenomena of BX Mon at least in the years from 1980 to 1985. It may be possible to consider two probable answers to explain the inconsistency. The first is a change of the phase dependence of the light variation between 1940 and 1980, which is a possibility not to be ruled out. The second is some mistakes in the representation of Mayall's light curve. If we can suppose that the phase was counted from the photometric minima and a typing error was made when the work was published, the mean light curve could still agree with the results of the recent observations, as follow: (i) The shape of the photometric minima is similar to that observed on eclipses of Algol type system (Fig. 11). (ii) The duration of the photometric minima is about 100 days (Fig. 11) which agrees with that of the unusually low excitation states. (iii) The result of the photographic photometry in January 1985, the cross in Fig. 11, does not agree with the light curve of Mayall (Fig. 11). However, if the phase is to be counted from the photometric minima, the point will shift in phase by an amount of 0.61 (Mayall, 1940). The shifted position, the cross in parentheses, would well agree with the light curve of Mayall (Fig. 11).

Even though Kukarkin et al. (1958) list nearly the same elements, they do not quote a source for their values. Their results might mainly depend on the same work of Mayall (1940). Reanalysis of old photographic plates and investigation of light variation in photographic or blue band after 1940 are therefore badly needed.

If there was no mistake in the representation of Mayall's light curve, the phase dependence of the light variation of BX Mon had to be completely changed in the years between 1940 and 1980. If the period of the variation is not 1380 days but about 1350 days, the phase can be reversed between 1940 and 1980. Such a large discrepancy, however, may not be probable, because the elements of Mayall (1940) are based on the light variation in the years from 1890 to 1940 which include 13 full periods. The phase dependence had to be changed discontinuously. It is difficult to explain such a phenomenon with the model presented in this paper. BX Mon must be an extremely peculiar object. It seems to be better to wait for new photometric data before a more detailed discussion could be presented.

6. Conclusion

The detection of He II 4686 emission line confirmed the symbiotic nature of BX Mon. This is a matter of interest concerning the galactic distribution of symbiotic stars, because BX Mon ($1^{II} = 220°$, $b^{II} = +6°$) and the newly found ZZ CMi ($1^{II} = 208°$, $b^{II} = +11°$; Iijima, 1984; Bopp, 1984) are located at the ending point of the gap in the distribution of symbiotic stars along the galactic longitude (Wallerstein, 1981).

The observed spectroscopic characteristics suggest that BX Mon is a long-period eclipsing binary system consisting of a non-Mira type M 5 ~ 6 III and a hot component. The light variation with a period of 1380 days (Mayall, 1940) or 1374 days (Kukarkin et al., 1958) can be explained by the binary model (Fig. 12) with the following assumptions: The light variation of BX Mon is mainly due to that of the hot component which is brightened up by mass accretion from the M type component. Owing to the eccentric orbit of the binary system, the accretion rate, which may be roughly proportional to the luminosity of the hot component, varies periodically. The light variation around the photometric minima is due to the eclipse of the hot component by the M type component.

A serious inconsistency, however, still remains between this binary model and the light curve in the years from 1890 to 1940 (Mayall, 1940).

After the first version of this manuscript, some new observations were made in our observatory. The absorption bands of TiO were nearly veiled by continuum light in spectra taken in February 1985 (Phase 0.36–0.37). At the same time absorption lines of Ca II, Fe I, Fe II etc., but not the *G* band, appeared in the blue part of the spectra ($\lambda < 4500$ Å). Although it is difficult to indicate an accurate spectral type, because hydrogen Balmer lines are in emission, these features are consistent with a late A or early F type. These phenomena indicate that the hot component brightened up in this period, and therefore support the binary model presented in this paper. In these spectra, however, the intensity of all emission lines decreased and no trace of He II 4686 emission line was found. Also a spectrum taken by Allen (1984) at phase 0.45 does not show any traces of He II 4686 emission line. The temperature of the hot component likely decreased, or at least not increased, at the phase of its maximum luminosity (Phase 0.3–0.4). The phase of the maximum temperature (Phase 0.5–0.6) seems to arrive after that period. It will be necessary to consider some delicate mechanisms in the mass accretion process. It will be very important to see whether BX Mon will show He II 4686 emission line again in the next phase 0.5–0.6, that is, in the period from August 22, 1985 (JD 2446300) to January 7, 1986 (JD 2446438). Careful observations are requested. A finding chart is given by Allen (1984).

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References

Allen, D.A.: 1979, in IAU Colloquium No 46, Changing Trends in Variable Star Research, eds. F. Bateson, J. Smak and I. Urch, Univ. Waikato Press, Hamilton, New Zealand, p. 125
Allen, D.A.: 1980, *Monthly Notices Roy. Astron. Soc.* **190**, 75
Allen, D.A.: 1984, *Proc. Astron. Soc. Australia* **5**, 369
Ambartsumyan, V.A.: 1932, *Circ. Glav. Astron. Obs.* **4**, p. 8
Anderson, C.M., Oliversen, N.A., Nordsieck, K.H.: 1980, *Astrophys. J.* **242**, 188

Bidelman, W.P.: 1954, *Astrophys. J. Suppl.* **1**, 175
Bopp, B.W.: 1984, *Publ. Astron. Soc. Pacific* **96**, 894
Boyarchuk, A.A.: 1975, in Variable Stars and Stellar Evolution, IAU *Symp* No 67, p. 377
Code, A.D.: 1960, in Stellar Atmospheres, ed. J.L. Greenstein, The University of Chicago Press, Chicago, p. 83
Faraggiana, R., Hack, M.: 1971, *Astron. Astrophys.* **15**, 55
Feast, M.W., Robertson, B.S.C., Catchpole, R.M.: 1977, *Monthly Notices Roy. Astron. Soc.* **179**, 499
Feast, M.W., Whitelock, P.A., Catchpole, R.M., Roberts, G., Carter, B.S.: 1983, *Monthly Notices Roy. Astron. Soc.* **202**, 951
Gillet, D., Maurice, E., Baade, D.: 1983, *Astron. Astrophys.* **128**, 384
Iijima, T.: 1981, in Photometric and Spectroscopic Binary System, eds. E.B. Carling and Z. Kopal, D. Reidel Publ. Co., Dordrecht, p. 517
Iijima, T.: 1984, *Inf. Bull. Var. Stars* No 2491
Kukarkin, B.V., Parenago, P.P., Efremov, Yu.I., Kholopov, P.N.: 1958, General Catalogue of Variable Stars, The USSR Academy of Science, Moscow
Mayall, M.W.: 1940, *Bull. Harvard College Obs.* **913**, 8
Merrill, P.W., Burwell, C.G.: 1950, *Astrophys. J.* **112**, 72
Michalitsianos, A.G., Kafatos, M., Feibelman, W.A., Hobbs, R.W.: 1982, *Astrophys. J.* **253**, 735
Mikołajewska, J., Mikołajewski, M.: 1983, *Acta Astron.* **33**, 403
Sahade, J., Brandi, E., Fontenla, J.M.: 1984, *Astron. Astrophys. Suppl.* **56**, 17
Seaquist, E.R., Taylor, A.R., Button, S.: 1984, *Astrophys. J.* **284**, 202
Underhill, A.B.: 1960, in Stellar Atmospheres, ed. J.L. Greenstein, The University of Chicago Press, Chicago, p. 411
Viotti, R., Altamore, A., Ferrari-Toniolo, M., Friedjung, M., Persi, P., Rossi, C., Rossi, L.: 1985 preprint
Wallerstein, G.: 1981, *The Observatory* **101**, 172
Whitelock, P.A., Catchpole, R.M.: 1983, *Inf. Bull. Var. Stars* No. 2296