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OPTICAL VARIATIONS OF THREE CARBON STARS WITH SILICATE DUST SHELLS

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Abstract. Light variations studied photographically in the red, visual and blue bandpasses are presented for the carbon stars EU And, V778 Cyg and BM Gem. Periodic component was found only in the variations of V778 Cyg, observations of which cover an interval of 15 years. For two other stars the 2.5-year interval of observations revealed only irregular light changes. Magnitudes and finding charts for comparison stars are presented.

Key words: carbon stars – variable stars

1. Introduction

The variables EU And, V778 Cyg and BM Gem were among the first carbon stars found to have the oxygen-rich dust in their circumstellar shells (Little-Marenin, 1986; Willems and de Jong, 1986). These objects still belong to the revised list of seven carbon stars with silicate dust shells (Lloyd Evans, 1990).

These three stars are the only named variable stars among the seven objects. In the General Catalogue of Variable Stars, Edition IV (Kholopov et al., 1985-1990) they are classified as semi-regular (EU And, SR; BM Gem, SRb) or irregular (V778 Cyg, Lb). Willems and de Jong (1986) suggested, that the carbon stars with silicate dust shells ought to be semiregular or irregular pulsators.

2. Observations

The three stars were monitored with the Baldone Schmidt telescope of the Radioastrophysical Observatory to study their light variations in a similar way as it was previously done for a number of carbon stars in this observatory (see e.g. Alksnis and Alksne, 1988).

EU And.

B- and V-magnitudes for comparison stars Nos. 1–13 (Table 1) are based on photoelectric observations made by O. Paupers and one of the authors (D.Ž.) with the 1-meter telescope of the Institute of Theoretical Physics and Astronomy (Vilnius, Lithuania) situated on the Maidanak Mountain in Uzbekistan. $R(0.63)$-magnitudes are derived from B- and V-magnitudes by the relation $R = V - 0.44(B - V) - 0.266$ (Alksne et al., 1991). For comparison stars Nos. 14–23 B-magnitudes have been obtained by photographic transfer of the sequence from a field of the open cluster NGC 7686 (Hoag et al., 1961) on six plates. EU And and its comparison stars are identified in Fig. 1.

$R(0.63)$-, V- and B-magnitudes of EU And are plotted in Fig. 2 versus time in Julian Days. Crosses are photoelectric magnitudes obtained by Kižla (1991). Up to the time J.D.2448100 light variations are small, although, there seems to be some slight slow brightening of the star in V, and possible declining in B. A faster brightening (about 0.5 mag in B in 50 days) in all three colours take place after the time mentioned and is followed by a smaller declining at least in B and $R(0.63)$. The frequency of our observations is too low to judge more definitely on the characteristics of variations of this star, but EU And seems to be irregular variable star with a small amplitude.

V778 Cyg.

This star occured to be on photographs of the field with the center $l = 94°$, $b = +10.5°$ taken systematically with the Baldone Schmidt telescope from 1975 to 1987. Therefore, observations of V778 Cyg cover much longer time interval than those of two other stars. B-magnitudes of comparison stars (Table 1, Fig. 3) are based on the photoelectric sequence of comparison stars near NGC 6964 (Buta, 1982). For determination of V-magnitudes the sequence in the field of NGC 6939 (Chincarini, 1963) was added, and for $R(0.63)$-magnitudes also B- and V-photoelectric magnitudes of the stars HD 198654 and HD 195066B (Blanco et al., 1968) were used.

Table 1. Sequences of the comparison stars

No.	BD	$R(0.63)$	V	B	No.	B
			EU And			
1	+46°4003	8.12	8.56	9.07	14	13.02
2	+46°4008	8.93	9.38	9.91	15	13.12
3	+46°3995	9.18	9.95	11.05	16	13.15
4	+46°4013	9.24	10.01	11.10	17	13.27
5	+46°3997	9.28	9.52	9.81	18	13.39
6	-	9.90	10.84	12.12	19	13.72
7	-	10.06	10.38	10.74	20	13.77
8	-	10.13	10.48	10.89	21	14.20
9	-	10.15	10.88	11.99	22	14.30
10	-	10.51	10.92	11.41	23	14.47
11	-		11.00	11.67		
12	-		11.21	10.42		
13	-		11.56	12.18		
			V778 Cyg			
1	+59°2270	7.93			11	13.98
2	+59°2263	8.47	9.64		12	14.30
3	-	9.27	10.03		13	14.57
4	-	9.54	10.41		14	14.63
5	-	9.73	10.11		15	13.43
6	-		10.56	11.51:	16	13.82
6A	-		11.37	11.98:	17	13.87
7	-			13.30	18	13.51
8	-			13.28	19	12.76
9	-			13.87	20	13.21
10	-			13.78	21	15.20
					22	15.47
			BM Gem			
1	+26°1510	6.47				
2	+27°1356	7.49				
3	+25°1613	7.77				
4	+26°1532	6.97	7.81			
6	+26°1517	7.48	7.87			
7	+25°1652	8.12	9.22			
8	+24°1627	8.22	9.05			
9	+25°1636	8.27	8.61			
10	+25°1649	8.45				
11	+25°1654		9.16	9.66		
12	+25°1645		9.43	9.47		
13	+25°1651		9.42	9.38		
14	-		9.73	10.38		
15	-		10.29	10.84		
16	+25°1653		10.09	11.24		
17	+25°1648		9.80	11.28		

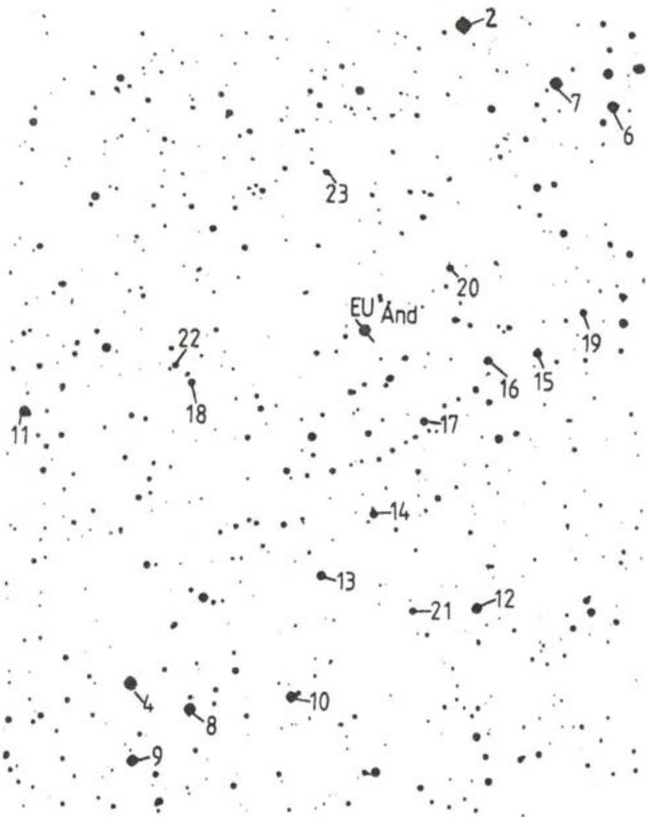

Fig. 1. Finding chart for EU And and comparison stars. North is at the top, west to the right as is also for Figs. 3 and 6. The stars Nos. 1, 3 and 5 are out of borders of the field.

The light curve of V778 Cyg (Figs. 4–5) is far from being regular; a periodic component, however, can be suspected. We found its period to be 289.5 days, with a light maximum at J.D.2442700. The periodic component of the variations in B, V and $R(0.63)$ is shown in Fig. 6. It represents the second approximation derived after the first approximation of the secondary variations has been subtracted from the observed magnitude values. The second approximation of the secondary variations, i.e. the observed magnitude residuals from the periodic component, is shown in Fig. 7 for all three colours.

The amplitude of the periodic component is the largest in B (0.8 mag) as is usually observed for carbon stars (Alksnis and

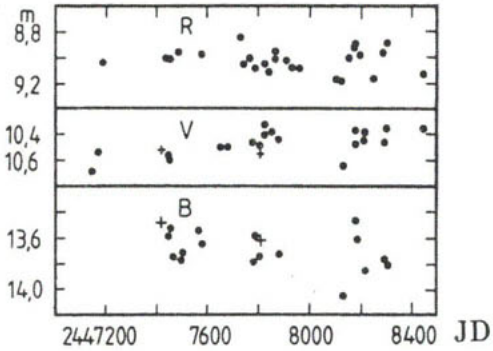

Fig. 2. $R(0.63)$-, V- and B-magnitudes for EU And versus time in Julian Days. Crosses are photoelectric observations by Kižla (1991).

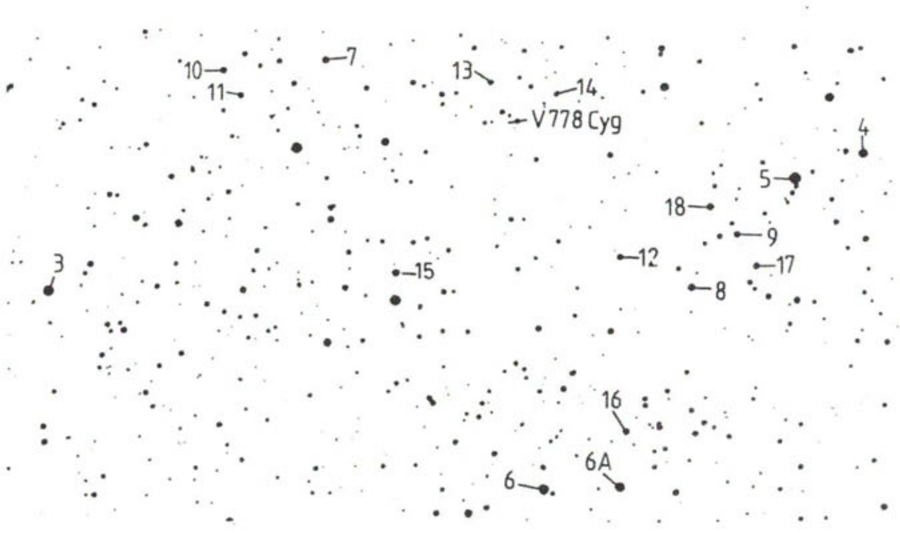

Fig. 3. Finding chart for V778 Cyg and comparison stars. The stars Nos. 1 and 2 are out of the field.

Table 2. Magnitudes of carbon stars

JD 244...	mag	JD 244...	mag	JD 244...	mag
		EU And			
	R(0.63)		R(0.63)		B
7186.29	9.03	8446.47	9.13	7449.37	13.58
7436.46	9.00	8558.21	9.07	7455.45	13.52:
7452.47	9.01	8581.49	9.08	7472.42	13.74
7485.34	8.95			7496.27	13.76:
7475.22	8.98		V	7505.33	13.71
7731.50	8.84	7146.34	10.68	7566.21	13.54
7746.52	9.04	7171.28	10.54	7582.27	13.64
7766.57	9.01	7447.36	10.56	7780.56	13.78
7788.50	9.08	7453.41	10.59	7788.51	13.58
7825.31	9.05	7566.22	10.50	7806.40	13.74
7842.29	9.11	7580.26	10.50	7881.31	13.72
7866.32	9.01	7780.53	10.46	8130.51	14.05
7868.24	8.97	7806.39	10.49	8179.43	13.46
7911.36	9.02	7825.41	10.33:	8187.31	13.60
7934.20	9.07	7827.38	10.39	8216.21	13.85
7959.26	9.08	7850.45	10.38	8290.21	13.76
8099.52	9.16	7881.30	10.43	8304.23	13.80
8117.52	9.18	8130.52	10.65		
8151.46	8.99	8179.45	10.37		
8168.48	8.93	8182.22	10.47		
8157.46	8.90	8209.35	10.45		
8193.45	8.98	8216.19	10.38		
8248.28	9.16	8290.21	10.46		
8286.21	8.96	8304.21	10.35		
8304.20	8.89	8446.46	10.35		
		V778 Cyg			
	R(0.63)		R(0.63)		R(0.63)
1919.46	8.63	3108.16	9.86	4573.18	8.87
2018.19	8.65	3117.29	8.91	4592.16	8.96
2252.45	8.58	3139.19	9.00	4609.17	8.85
2265.43	8.74	3160.18	8.89	4750.48	8.72
2541.53	8.69	3161.18	8.93	4759.42	8.78
2549.46	8.82	3329.43	8.50	4795.40	8.69
2567.40	8.74	3383.32	8.68	4827.51	8.86
2598.42	8.75	3409.33	8.78	4922.27	8.92
2616.39	8.68	3446.23	8.96	5185.44	8.88
2644.35	8.56	3481.15	8.78	5245.36	9.03
2651.37	8.48	3530.19	8.47	5892.42	8.74
2655.43	8.50	3664.48	8.77	7391.34	8.93
2678.27	8.55	3691.46	8.75	7415.39	8.98
2699.21	8.42	3741.32	8.81	7435.23	8.91
2725.18	8.37	3743.34	8.71	7448.23	8.88
2764.17	8.79	3765.27	8.79	7489.15	8.59
2888.56	9.04	3794.22	8.54	7757.53	8.73
2911.48	9.01	3858.19	8.55	7784.33	8.60
2940.42	8.61	4125.26	8.59	7790.42	8.54
2955.41	8.63	4147.56	8.68	7799.19	8.65
2986.38	8.51	4450.42	8.53	8226.27	8.52
3003.36	8.50	4457.39	8.66	8281.17	8.56
3030.37	8.66	4462.36	8.62	8369.55	8.86
3038.45	9.02	4479.31	8.69	8440.45	8.59
3068.40	8.98	4511.31	8.96	8558.19	8.68
3085.19	8.95	4558.21	8.98		

Table 2 (continued)

JD 244...	mag	JD 244...	mag	JD 244...	mag
		V778 Cyg			
	V		*V*		*B*
1161.20	10.35	8130.47	10.24	3768.28	13.76
2631.45	10.01	8175.32	10.18	3779.24	13.51
2686.18	9.85	8182.21	10.20	4128.22	13.76
3074.21	10.31:	8216.18	10.10	4147.49	13.92
3162.22	10.15	8281.18	10.38	4555.32	14.72
3379.43	10.21	8369.55	10.46	4827.48	14.06
3395.32	10.13	8446.45	10.35	7448.29	14.43
3397.37	10.19			7498.34	14.33
3437.21	10.28:		*B*	7779.37	13.76
4147.50	10.05	2667.32	12.88	8023.39	14.17
4158.34	10.21	2684.20	12.86	8106.49	13.96
4208.50	10.54	2744.16	13.00	8130.49	14.00
4555.30	10.50	3067.25	13.91:	8153.39	13.69
4604.19	10.43	3070.25	13.70	8175.31	13.62
4844.50	10.56	3073.24	14.03	8187.29	13.59
7455.42	10.61	3376.38	13.63	8216.21	13.59
7877.27	10.12	3397.37	13.67	8281.20	13.65
8015.49	10.46	3424.26	13.53		
8099.38	10.31	3429.26	13.39		
8118.32	10.24	3750.38	13.76		
		BM Gem			
	R(0.63)		*V*		*B*
7187.25	6.86	7152.52	8.24	7211.32	10.77
7257.28	6.90	7269.40	8.28	7268.38	10.65
7258.27	6.82	7451.64	8.40	7446.58	10.74
7435.57	6.97	7455.65	8.47	7463.63	11.06
7497.66	7.09	7474.62	8.40	7472.66	11.14
7582.39	7.04	7487.55	8.56	7487.54	11.21
7637.38	7.06	7566.46	8.60	7566.48	11.18
7789.54	6.91	7582.34	8.51	7855.53	11.32
7849.68	6.91	7615.32	8.48	7855.54	11.23
7855.55	6.80	7621.28	8.42	7866.49	11.29
7866.49	6.86	7641.34	8.50	7881.49	11.26
7876.42	6.85	7825.44	8.61	7965.38	10.95
7932.54	6.87	7855.51	8.41	7976.30	10.91
7954.35	6.89	7866.48	8.21	7991.44	10.98
7978.27	6.92	7881.47	8.34	7999.44	10.84
7991.43	6.79	7946.46	8.36	8003.32	10.96
7992.32	6.85	8218.49	8.17	8010.36	10.84
8003.31	6.89	8281.41	8.40	8164.60	10.98
8015.34	6.83	8305.47	8.32	8192.63	10.57
8019.32	6.77	8358.30	8.28	8218.48	10.44
8164.62	7.00			8281.40	10.55
8168.57	6.89			8305.47	10.71
8173.65	7.00			8345.34	10.38
8202.52	6.75				
8218.53	6.81				
8231.63	7.08				
8262.50	6.80				
8281.35	6.72				
8286.35	6.80				
8287.41	6.70				
8319.35	6.84				
8343.42	6.84				
8359.30	6.70				
8369.30	6.95				

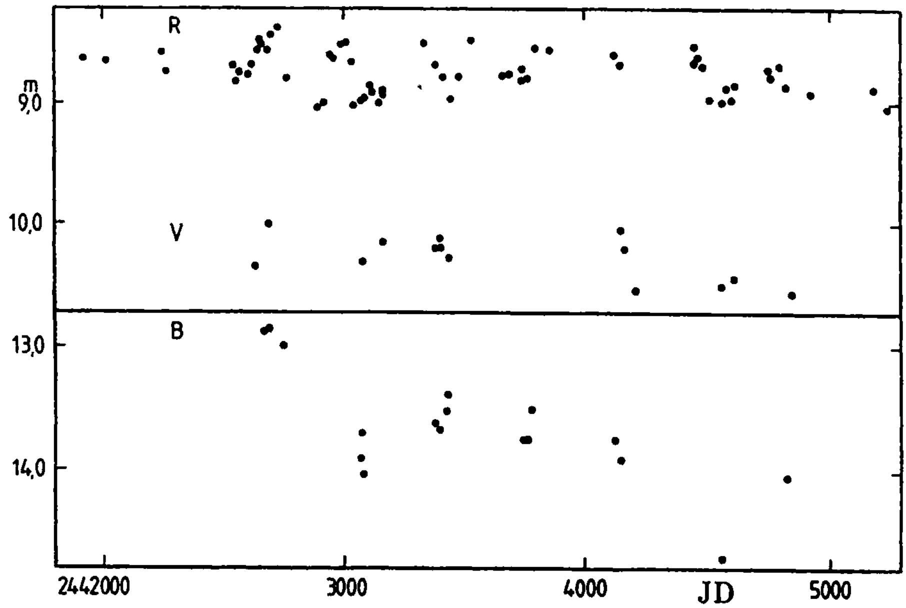

Fig. 4. $R(0.63)$-, V- and B-magnitudes for V778 Cyg before J.D.2445300.

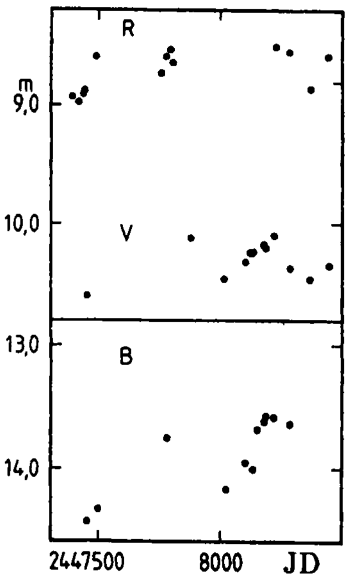

Fig. 5. $R(0.63)$-, V-- and B-magnitudes for V778 Cyg after J.D.2447300.

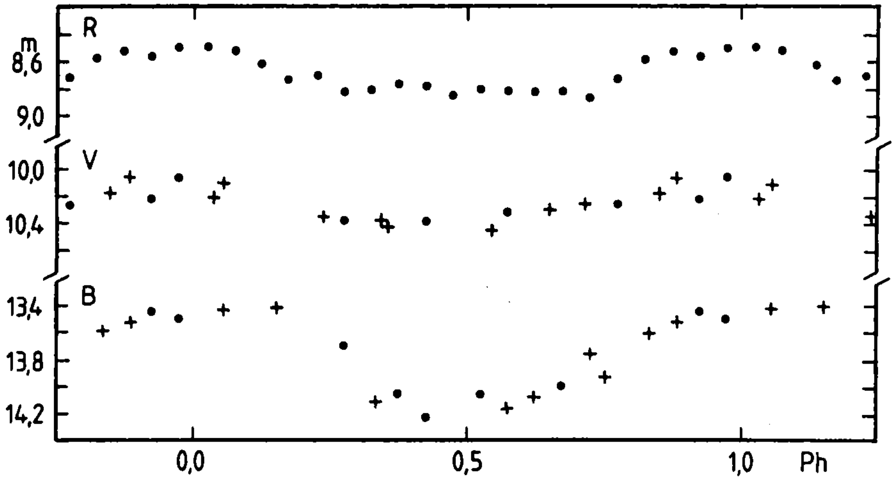

Fig. 6. Periodic component of variations for V778 Cyg, $P = 289.5$ d, Max_0 = J.D.2442700. Dots are the mean magnitudes for 0.05 phase intervals, crosses are individual magnitudes corrected for the smooth curve of secondary variations.

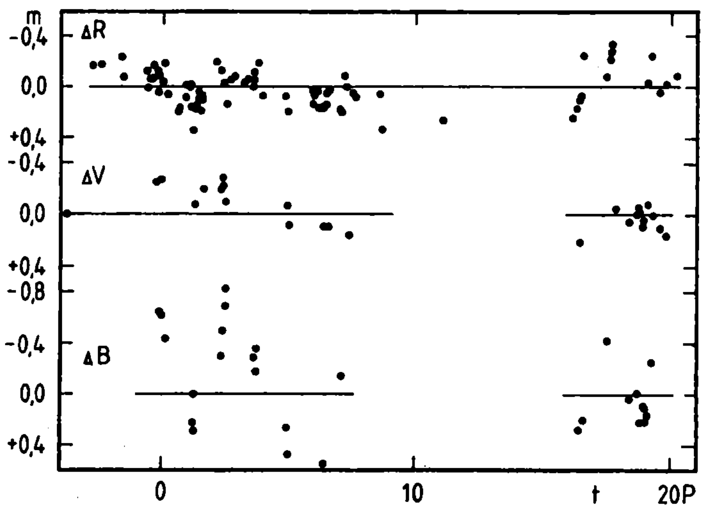

Fig. 7. Deviations of the observed $R(0.63)$-, V- and B-magnitudes for V778 Cyg from the respective light curves of the periodic component versus time ($P = 289.5$ d).

Alksne, 1988); both in V and $R(0.63)$ the amplitude is much smaller ($\sim$ 0.3 mag).

The secondary variations are of nearly the same amplitude (Fig. 7). Unusual seems to be a relatively small amplitude in V, which is even a little smaller than in $R(0.63)$. This conclusion, however, might be influenced by a large difference in the number of observations in V and R.

Waves in the secondary variations of the $R(0.63)$- and B-magnitudes with a cycle length approximately $3P$ are observed at least in the first part of the time interval of our observations, when the frequency of observations was higher than afterwards.

According to our observations the carbon star V778 Cyg ought to be considered as a semiregular variable star.

BM Gem.

$R(0.63)$-, V- and B-magnitudes of comparison stars for BM Gem (Fig. 8) listed in Table 1 are based on B- and V-magnitudes of the stars HD 56224, HD 56513 and HD 55458 (Blanco et al., 1968) and of stars in the field P365 of the HST guide star photometric catalogue (Lasker et al., 1988). The three mentioned HD stars were also used as comparison stars for $R(0.63)$-photometry, their magnitudes being calculated as in the case of EU And.

A long term (very slow) variation is clearly seen in all three light curves of BM Gem (Fig. 9), the minimum light being around J.D.2447600–7700. Besides, faster changes, mainly in B, are present at some intervals (J.D.2447450–750, 2448180–8300). One photoelectric observation by Kižla (1991) shown as a cross at the beginning of the V- and B-curves indicates either a systematic difference between his photoelectric and our photographic magnitudes or the presence of another faster variation just before our series of observations.

3. Results

The mean values of $R(0.63)$-, V- and B-magnitudes for the three carbon stars are given in Table 3 together with the number of observations n and the standard deviation s. The mean colour indices $B-V$ and $V-R(0.63)$ in Table 4 are based on individual values of $B-V$ or $V-R(0.63)$ formed from observations of the magnitudes made at one and the same night or within the time interval not more than two days for $B-V$ and one day for $V-R$.

What do we know about the light variations of other four carbon stars with silicate dust listed by Lloyd Evans (1990)? For the

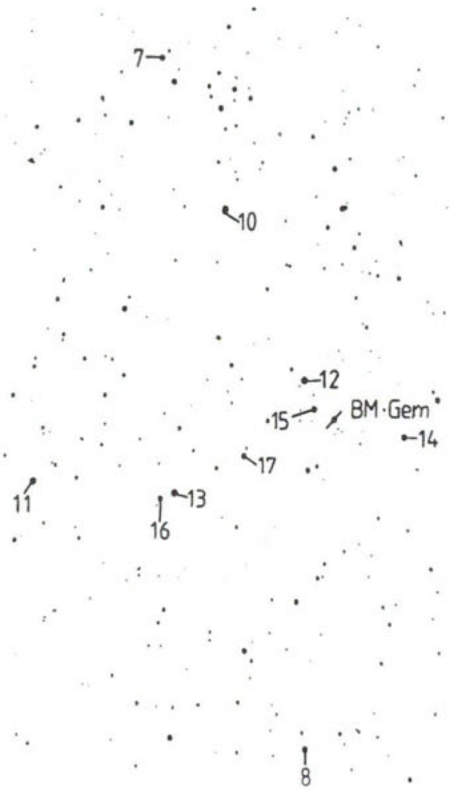

Fig. 8. Finding chart for BM Gem and comparison stars. The stars Nos. 4, 6 and 9 are out of the field.

Table 3. Photometric characteristics

Star	R	n	s	V	n	s	B	n	s
EU And	9.02	27	0.08	10.47	20	0.10	13.70	17	0.14
V778 Cyg	8.74	78	0.17	10.26	26	0.17	13.75	28	0.41
BM Gem	6.89	25	0.09	8.40	20	0.12	10.91	23	0.27

Table 4. Colour characteristics

Star	$B-V$	n	s	$V-R$	n	s
EU And	3.22	12	0.18	1.38	4	0.17
V778 Cyg	3.58	9	0.35	1.50	4	0.23
BM Gem	2.61	9	0.31	1.53	4	0.13

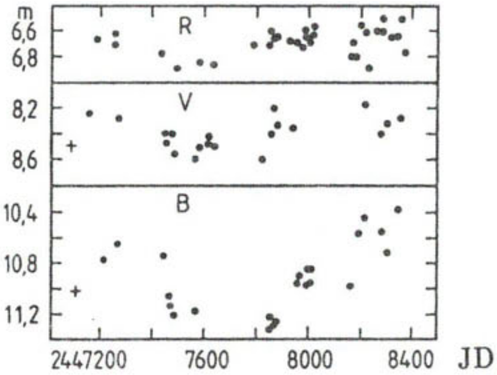

Fig. 9. $R(0.63)$-, V- and B-magnitudes versus time for BM Gem, crosses are for photoelectric observation by Kižla (1991).

fourth northern star NC83 we have got some observations. From six measured plates it follows, that $\langle R(0.63)\rangle = 10.40$ mag and $s = 0.06$ mag, suggesting negligible variations. From the only measured B-plate we derived $B = 14.69$ mag; thus colour index $B - R(0.63) = 4.29$ is similar to that for BM Gem.

As for the three southern stars, Le Bertre et al. (1990) from a small number of observations detected a weak variability (about 0.1 mag in J-band) for CCS 1003 and FJF 270, and no variability for MC79-11. However it is difficult to compare these results with those of this paper; it seems that from the seven stars, V778 Cyg has the largest amplitude of variations and is the only semi-regular variable. Others are either irregular variables as suggested by Willems and de Jong (1986) or nonvariables.

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