VY Mon—THE TWIN OF Z CMa?

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Abstract:
In 1985-1990 we obtained photometric, polarimetric and spectroscopic observations of the peculiar emission-line star VY Mon. These observational data were compared with those of Z CMa. To our opinion the similarity of the observational features of these stars is due to their similar nature.
Key Words: Emission-line stars, Young stars, Circumstellar matter.

Article:

I. INTRODUCTION

The investigations of VY Mon have already been a long story to the present time. Herbig (1962) has noted that the spectral class of the object was G:e. Maffey (1966) has published some photographical observations of this star, through blue and red filters, and has shown its remarkable variability ($\Delta B \sim 4^m$). Later VY Mon was listed in the catalogue of possibly young stars, published by Herbig and Rao (1972) with the spectral class G :e. Iijima and Ishida (1978) have obtained the multicolor photometry of VY Mon in the range of 0.36-3.5 μm and the spectrum with the objective prism. They classified this object as M6 :star. Cohen and Kuhi (1979) in the survey of the Pre-Main-Sequence objects on the basis of the scanner observations with a 7 Å resolution have shown that its spectrum is almost continuous but some absorbtion lines suggest that the spectral class of the star is 09. The photometric data from 0.3 μm to 6 cm have been published in the following papers: Bastian and Mundt (1979), Cohen and Schwarz (1976), Herbst et al. (1982), Cohen (1975, 1980), Gezari et al. (1987), Felli et al. (1982). Recently, a remarkable polarization of VY Mon in the B-band (~10%) was discovered by Pavlova and Rspaev (1985). Schevchenko (1988) considers this object as a Herbig Ae/Be star. However, in spite of a wide spectral region, where observations of VY Mon were obtained, they give no opportunity to definitevely classify this object.

II. OBSERVATIONS

UBVR-observations of VY Mon were obtained in 1985-1990 with the 60-cm telescope on the Majdanac mountain. In 1986-1990 we made the BVRIJHK-photometry and R-polarimetry with a 1-m telescope of Assy. 14" and 18" diaphragms were used respectively. The results of the photometry and polarimetry of the VY Mon are given in Tables 1 and 2. Three spectroscopic observations of the VY Mon were obtained in 1989-1990 using 1000-channels scanner on the 6-m telescope. The spectra were obtained with the linear dispersion of 100 Å mm^{-1} (Jan., 14,1989, 3810-5560 Å) and 50 Å mm^{-1} (Jan., 16, 1990, 4040-5040 Å and Dec., 8, 1990, 3950-4950 Å).

III. ANALYSIS OF THE OBSERVATIONS

As a rule there are three levels of the VY Mon brightness: V ~ $12.^m9$, $13.^m7$ and $14.^m3$ (Figure 1). During our observations, the object had the maximum and the minimum level twice. The temporal interval between the respective stages was 1100^d-1200^d. These variations may be regular. Earlier observations in maximum (Cohen and Schwarz, 1976) and in minimum (Bastian and Mundt, 1979) are in agreement with this suggestion.

The optical color-indices change with brightness in general (Figure 2). However, these relations have a different character at different times. On the one hand (B-V) ~ V and (V-R) ~ V are similar to that of Herbig Ae/Be stars with the Algol-type minima (Voshchinnikov et al., 1988). But sometimes the star shows a strong variation of the color-index without significant brightness variations. The synchronous observations in the optics and near infrared including earlier papers (Ijima and Ishida, 1978; Cohen and Schwarz, 1976) show a strong correlation between the variations in V and K (Figure 3).

Table 1 Photometric observations of the VY Mon. First part: Majdanac photometry. Mean errors: in *U-B* $\sim 0^{m}.15$, in other color-indices and in $V \sim 0^{m}.015$. Second part: Assy photometry. Mean errors: in *B* and $J \sim 0^{m}.1$, in other bands $\sim 0^{m}.05$.

JD	*V*	*U-B*	*B-V*	*V-R*	*JD*	*V*	*U-B*	*B-V*	*V-R*
6335.441	12.89	1.39	1.45	1.81	7540.416	13.69		1.52	
6338.440	12.83	0.71	1.57	1.84	7543.340	13.62	1.32	1.59	1.81
6339.441	12.83	0.55	1.65	1.79	7612.131	12.92	0.39	1.60	1.71
6713.508	14.25	1.46	1.54	1.79	7778.480	13.68		1.60	1.80
6730.470	14.24	1.31	1.50	1.82	7779.491	13.68		1.68	1.82
6733.491	14.28	0.45	1.50	1.81	7780.493	13.73		1.87	
6739.414	14.31	0.50	1.49	1.89	7781.493	13.66		1.69	
7060.503	13.68		2.25	1.98	7782.495	13.73		1.76	
7061.494	13.73		1.79	2.00	7784.491	14.09		0.95	
7064.484	13.74		1.67	1.99	7788.492	14.08		1.61	
7065.505	13.74		2.02	2.03	7791.492	14.20		1.77	1.86
7071.506	13.59	1.10	1.89	1.93	7794.468	14.17		1.59	1.79
7133.403	13.73		1.45	1.92	7799.498	13.85		1.73	1.83
7135.443	13.72		1.87	1.92	7803.497	13.70		1.65	1.85
7141.553	13.39			1.80	7805.494	13.83		1.62	
7152.544	13.86		1.63	1.97	7806.491	13.75		1.68	1.78
7422.492	13.34		1.74		7807.486	13.75	1.31	1.61	1.86
7423.494	13.31		1.82		7808.492	13.77		1.66	1.87
7425.841	13.18		1.72		7815.498	13.90		1.61	1.79
7428.468	13.08		1.58		7817.500	13.85		1.50	1.85
7429.495	13.06		1.50		7818.472	13.68		1.36	1.78
7431.480	13.04	0.70	1.52	1.76	7825.516	13.67		1.60	
7433.492	13.03		1.56		7832.532	13.96		1.53	
7439.483	13.03	0.98	1.63	1.83	7833.529	13.84		1.93	1.86
7443.448	12.95	1.11	1.67	1.79	7834.532	13.81		1.60	1.88
7444.483	12.99	0.84	1.64	1.82	7835.526	13.94		2.02	1.99
7447.391	12.96	0.88	1.67	1.81	7836.519	13.77	0.88	1.66	1.85
7448.424	12.96	0.92	1.64	1.82	7836.531	13.81		1.62	1.89
7449.446	13.01	1.10	1.61	1.83	7839.517	13.73		1.63	1.86
7452.425	13.09	1.02	1.60	1.73	7843.515	13.53		1.48	
7454.493	13.10	1.02	1.60	1.77	7845.515	13.66		1.80	
7458.467	13.01		1.60		7850.466	13.58	0.72	1.65	1.93
7459.472	12.97	0.27	1.56	1.77	7853.476	13.61	1.02	1.70	1.87
7461.480	12.97	0.85	1.54	1.76	7857.491	13.73	0.58	1.66	1.89
7462.409	13.02		1.55		7858.502	13.70	1.02	1.64	1.84
7467.520	13.18		1.59		7860.503	13.69	0.84	1.64	1.89
7469.497	13.17	0.84	1.65	1.82	7861.455	13.71	0.86	1.64	1.84
7476.448	12.94	0.98	1.69	1.85	7880.371	13.94		1.73	1.94
7482.409	12.84	0.26	1.73	1.81	7881.426	14.04	0.59	1.69	1.91
7483.488	12.88	1.08	1.65	1.85	7885.427	14.10	0.72	1.69	1.88
7498.395	12.77	1.00	1.65	1.78	7940.285	14.34	0.64	1.68	1.86
7499.442	12.79	0.82	1.60	1.76	7941.290	14.40	1.24	1.56	1.79
7507.354	12.89	0.92	1.63	1.78	7951.246	14.22	0.63	1.61	1.82
7521.340	13.72	2.35	1.71	1.46					

JD	*V*	*B-V*	*V-R*	*V-I*	*V-J*	*V-H*	*V-K*
6440.34	12.88	1.03	—	—	4.85	5.90	—
6443.27	12.90	1.03	1.07	2.14	—	—	—
6450.32	12.91	0.96	0.93	1.80	—	—	—
6806.39	13.82	—	2.25	3.98	5.71	7.19	8.49
6807.39	13.52	—	2.06	3.66	5.50	6.97	8.37
6846.32	13.20	—	1.85	3.49	4.66	6.42	8.17
6847.31	13.87	—	2.24	3.85	5.10	7.07	8.62
6850.24	13.62	—	2.27	3.78	5.35	6.67	8.35
7883.42	14.49	—	2.14	3.82	—	7.03	8.40
8176.41	13.62	1.46	1.96	3.53	5.08	6.85	8.04

Table 2 Polarimetric observations of the VY Mon in the R-band.

*JD*244...	*p*, %	Θ,°
6846.32	10.6 ± 0.2	9 ± 3
6850.24	11.2 ± 0.2	4 ± 2
6852.22	10.4 ± 0.2	4 ± 3
6854.17	8.9 ± 1.0	4 ± 1
6855.20	13.9 ± 1.8	8 ± 3
7883.42	9.8 ± 0.7	9 ± 5

Two spectra (Jan., 1989 and Jan., 1990) obtained in the low level of the star brightness ($V \sim 13.^{m}7$ and $14.^{m}1$ respectively) are very similar, and contain many absorption lines (Table 3). A list of these lines is practically identical to that of Z CMa. The spectrum of Z CMa was obtained with the same instrumentation as a spectra of VY Mon Jan., 14, 1989 (dispersion 100 Å mm^{-1}, 3810-5560 Å, Figure 4). Also the spectrum of Z CMa was published by Covino et al. (1984). VY Mon has a redder continuum than Z CMa. In the spectrum of VY Mon, one can recognize different absorption lines near λ 4300 Å, while in the spectrum of Z CMa the G-band is clearly visible. Some authors consider the identification of He I lines in the spectrum of Z CMa doubtful (Finkenzeller and Mundt, 1984). On one of these lines (λ 4922 Å) we can see the spectra of VY Mon. Without these lines we may consider it as an F-star. The equality criteria of the spectral classification (Morgan and Keenan, 1961) leads us to the following conclusions:

(i) The spectral class of the VY Mon is earlier than F6 (absence of G-band),

(ii) The luminosity is sufficiently high (deep lines near λ 4300 and λ 4174 Å).

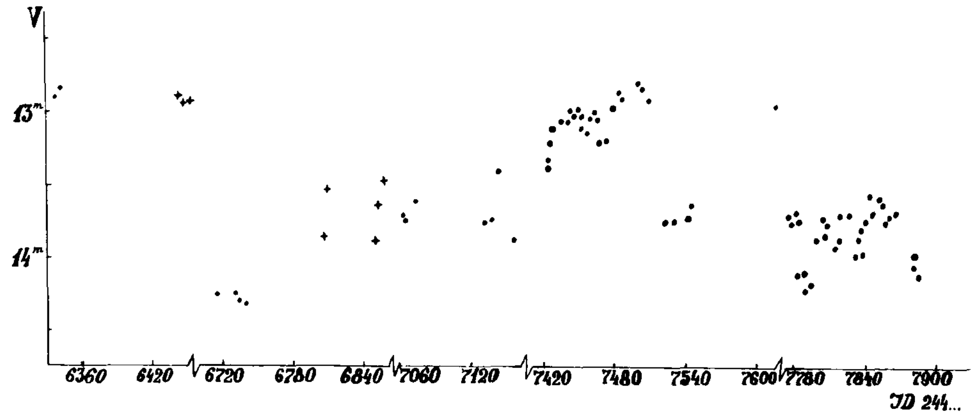

Figure 1 Light curve of the VY Mon. The designations: dots—Majdanac observations, crosses—Assy observations.

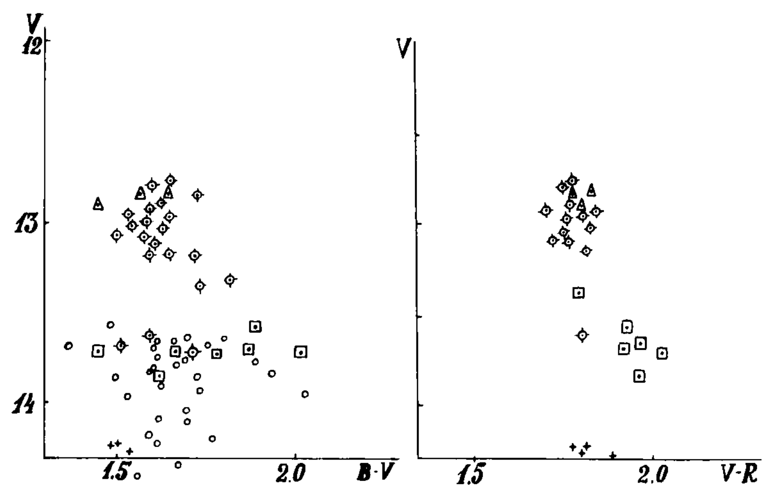

Figure 2 The color-magnitude diagrams of the VY Mon. The designations; triangles—1985, squares—1987, open circles with dots—1988, open circles—1989.

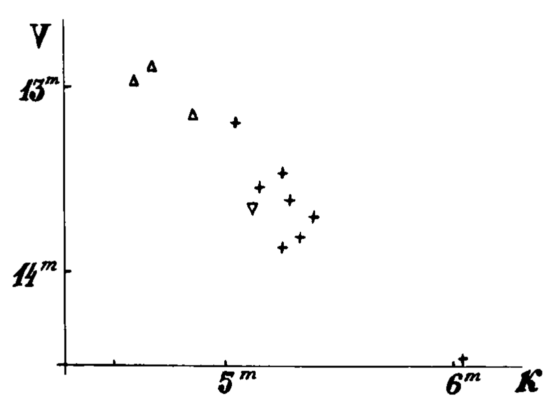

Figure 3 Relation between the light variations of the VY Mon in the *V* and *K* bands. The designations: triangles—Cohen and Schwarz (1976), reversed triangle—Ijima and Ishida (1978), crosses—this paper.

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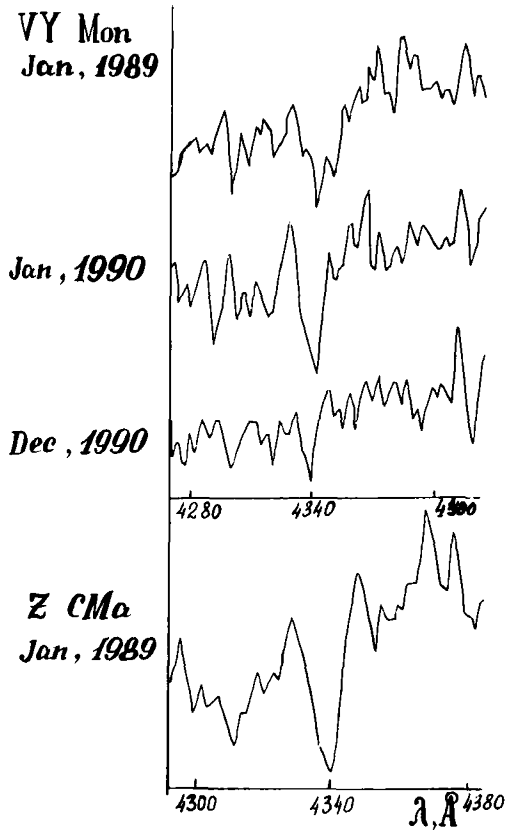

(a)

Figure 4 Spectra of the VY Mon and Z CMa, obtained on the 1000-channels scanner of the 6-m telescope. a-H_γ region, b-H_β region.

The equivalent widths of Hydrogen (5.2 and 6.4 Å for H_γ; 3.6 and 4 Å for H_β in Jan., 1989 and Jan., 1990 respectively) are closer to those of supergiants than of dwarfs, and giants using spectral class earlier than F6 (Wright et al. , 1966; Mustel et al., 1958; Kopylov, 1960). The same conclusion about Z CMa is made by another criteria by Hartman et al. (1989).

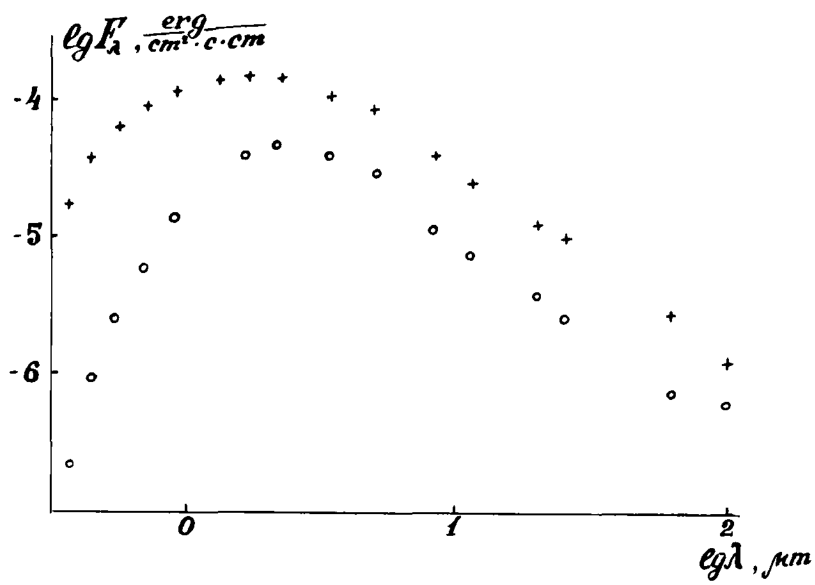

Figure 5 Mean energy distributions of the VY Mon (open circles) and Z CMa (crosses).

IV. DISCUSSION

The analysis of our observations shows that some details of the photometric and spectroscopic behavior of VY Mon are very similar to those of Z CMa. Let us continue to compare the observational features of these objects.

The consideration of the mean energy distributions shows an equal slope on the wavelengths $\lambda > 2\ \mu$m (Figure 5). It may be due to the close nature of its IR excesses. The possibly regular light variations of VY Mon may be due to its duplicity. This is suggested for Z CMa also (Koresko et al., 1989). There are some differences in the behaviour of these objects:

(i) the variability of VY Mon in the U-band is much more intensive than that of Z CMa;

(ii) the relations such as in Figure 3 show Z CMa in the brightness level of $V > 9.^{m}5$ (Bergner et al., 1990). There is no correlation between V and K in the brighter state of Z CMa. However, this similarity of the observational features of these objects may be due to the close physical nature. Hartmann et al. (1989) have showed that the spectral features and energy distribution of Z CMa in the range of 0.3-1 μm may account for the model of F6—F9 supergiant with an accretion disc. It is difficult for us to make such evaluations for VY Mon because we have no spectrum in the red range on the basis of which Z CMa was studied. Furthermore, this model does not provide the observational value of the IR excess. However Hartmann et al. (1989) have not considered the circumstellar dust that may produce the IR excess.

The differences mentioned above may be associated with the different orientation of possible components of these objects to the line of sight (accretion disc, counterpart's orbit, and so forth). Hence, VY Mon may be a FU Ori star as well as Z CMa. In particular, the simultaneous increase of brightness of VY Mon and the appearance of the emission components of the hydrogen lines may be due to the ejection of the object of Herbig—Haro type observed near Z CMa (Poetzel et al., 1989).

V. CONCLUSIONS

On the basis of the photometric and spectroscopic observations of the variable star VY Mon and comparison with that of FU Ori star Z CMa, we show that the behaviour of these objects is very similar. Since the group of FU Ori stars remains small, a study of any possible candidate is very interesting. We consider that for the further progress in the study of VY Mon we need to obtain at least the following observations:

(i) multicolor photometry and polarimetry in the wide spectral region at all levels of the optical brightness;

(ii) high-resolution spectroscopy near the light maximum;

(iii) CCD-survey of the environments of VY Mon similar to that for Z CMa (Poetzel et al., 1989).

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