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ORIGINAL ARTICLE

Photometric study of the FUor star V 1735 Cyg (Elias 1-12)

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Abstract Results from optical photometric observations of the PMS star V 1735 Cyg are reported. The star is located in the IC 5146 dark cloud complex—a region of active star formation. On the basis of observed outburst and spectral properties, V 1735 Cyg was classified as a FUor object. We present data from *BVRI* CCD photometric observations of the star, collected from March 2003 to January 2009. Plates from the Rozhen Schmidt telescope archive were scanned for a brightness estimation of the star. A sequence of sixteen comparison stars in the field of V 1735 Cyg was calibrated in *BVRI* bands. The data from photographic observations made from 1986 to 1992 show a strong light variability ($\Delta V = 1\overset{\mathrm{m}}{.}2$). In contrast, the recent photometric data obtained from 2003 to 2009 show only small amplitude variations ($\Delta I = 0\overset{\mathrm{m}}{.}3$). The analysis of existing photometric data shows a very slow decrease in star brightness—$1\overset{\mathrm{m}}{.}8$ (R) for a 44 year period. The possibilities for future photometric investigations of V 1735 Cyg using the photographical plate archives is discussed briefly.

Keywords Pre-main sequence stars · T Tauri stars · V 1735 Cyg

1 Introduction

The photometric variability is a common property of Pre-Main Sequence (PMS) stars (Herbst et al. 1994). A very rare phenomenon, but with a great significance in PMS evolution, is the FU Orionis (FUor) outburst. The prototype of FUors is the variable star FU Orionis, located in the Orion star-forming region. The star was brightened by 6 magnitudes in 1936 and for a long time was the only one object of its kind (Wachmann 1939). FUors are defined as a class of young variables by Herbig (1977) after the discovery of two new FUor objects: V 1057 Cyg and V 1515 Cyg. The prototypes of FUors seem to be low-mass PMS objects (T Tauri stars) with massive circumstellar disks. Herbig (1989) demonstrated that FUor eruptions almost certainly occur repetitively in all T Tauri stars in the course of their evolution. Hartmann and Kenyon (1985) have proposed that the flare-up is a result of a major increase of accretion from a circumstellar disk on the stellar surface (up to $10^{-4}\ M_{\odot}/\mathrm{yr}$). This accretion disk model can account for the main properties of FUors. According to Reipurth (1990) the main characteristics of FUors are their location in star-forming regions and their association with reflection nebulae. Photometrically, classical FUors exhibit a rapid rise in visual brightness of about 4-6 mag, followed by a slow decay. Spectroscopic properties of FUors are F-G supergiant spectra with a strong Li I 6707 line, P Cygni profiles at Hα and Na I 5890/5896 lines, and the presence of CO bands in the near infrared spectra. Another spectral feature of FUors is the gradual change from earlier to later spectral type from the blue to the infrared.

From all objects associated to the group of FUors only three (FU Ori, V 1057 Cyg and V 1515 Cyg) have detailed photometric observations taken during the outburst and during the set of brightness (Clarke et al. 2005). For a few objects, V 1735 Cyg (Elias 1978), V 346 Nor (Graham and Frogel 1985) and V 733 Cep (Reipurth et al. 2007), the presence of an optical outburst is also documented and they

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are joined to the group of classical FUors. About ten objects have spectroscopic properties similar to the classical FUors, but there is no evidence for an outburst in the optical wavelengths. This objects are termed FUor-like (Reipurth and Aspin 1997) and only partial photometric observations were published for them.

V 1735 Cyg (Elias 1-12) was discovered by Elias (1978) in an infrared survey of the IC 5146 dark cloud complex. The object was classified as FUor on the basis of an observed outburst, spectroscopic properties (Bastian and Mundt 1985) and association with a molecular outflow (Levreault 1983). The measurements made with the multichannel spectrometer on the 5-m Hale telescope show that V 1735 Cyg has $R = 15\overset{m}{.}0$ in 1977 (Elias 1978). However, on the red plate from the POSS-I obtained in 1952 V 1735 Cyg is under the limit ($R > 20^m$). Rodriguez et al. (1990) found a plate taken on October 16, 1957, with the 66-cm Schmidt telescope of the Tonantzintla Observatory that does not show V 1735 Cyg. The first evidence for an outburst observation is a plate from the Hale Observatory taken on July 5, 1965, where the object has a brightness similar to that in the Elias survey (Elias 1978). The star appears to have brightened by 5 mag sometime between 1957 and 1965. Subsequently, only few optical photometric estimations of V 1735 Cyg were published (Goodrich 1987 and Levreault 1988) and the light curve around and after the outburst is still undetermined. Ábrahám et al. (2004) documented a flux decrease of 40% for a 30 years period in the infrared K band similar to other classical FUor stars. On the basis of X-ray detection Skinner et al. (2009) concluded that the central object in V 1735 Cyg is a high-luminosity and respectively high-mass ($M \geq 1.7 M_{\odot}$) single T Tauri star.

Recent CCD photometric observations and results from archival photographic plate measurements are reported in the paper. We try to study the long-term photometric variability of V 1735 Cyg in comparison with the other FUor objects.

2 Observations

Our photometric CCD data were obtained in two observatories with three telescopes: the 2-m Ritchey-Chrétien-Coudé and the 50/70/172-cm Schmidt telescopes of the National Astronomical Observatory Rozhen (Bulgaria) and the 1.3-m Ritchey–Crétien telescope of the Skinakas Observatory[1] of the Institute of Astronomy, University of Crete (Greece).

Observations with the 2-m RCC telescope were made with the Photometrics AT-200 CCD camera (1024 × 1024 pixels) and with Vers Array 1300B CCD camera (1340 × 1300 pixels) from March 2005. Observations with the 1.3-m RC telescope were made with the Photometrics CH-360 CCD camera (1024 × 1024 pixels) and with the ANDOR CCD camera (2048 × 2048 pixels) from July 2007. Observations with the 50/70-cm Schmidt telescope were made with the SBIG ST8 CCD camera (1530 × 1020 pixels) and with the SBIG ST11000 CCD camera (4008 × 2672 pixels) from March 2008. All frames were taken through a standard Johnson–Cousins set of filters. Twilight flat fields in each filter were obtained each clear evening. All frames obtained with the Photometrics, ANDOR and Vers Array cameras have been bias subtracted and flat fielded. CCD frames obtained with the ST8 and ST11000 cameras have been dark subtracted and flat fielded. Aperture photometry was performed using DAOPHOT routines.

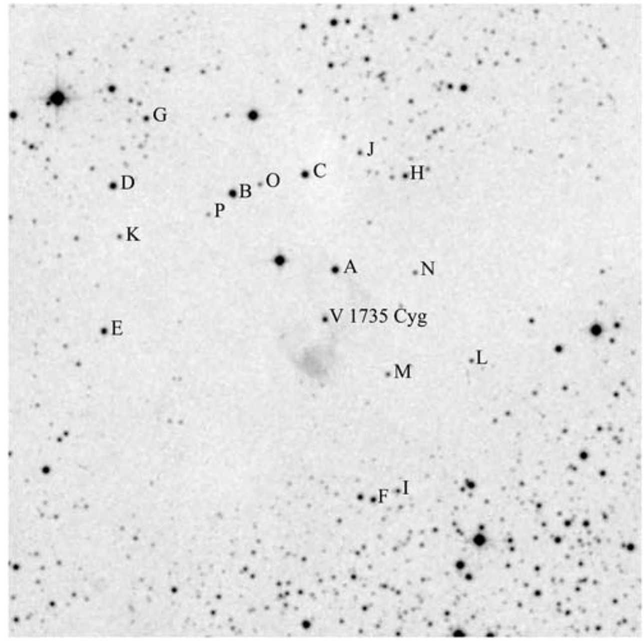

Fig. 1 A finding chart for the *BVRI* comparison sequence around V 1735 Cyg

In order to facilitate transformation from instrumental measurement to the standard Johnson–Cousins system, sixteen stars in the field of V 1735 Cyg were calibrated in *BVRI* bands. Calibration was made during fourteen clear nights in 2004, 2006, 2007 and 2008 with the 1.3-m RC telescope of the Skinakas Observatory. Standard stars from Landolt (1992) were used as reference. The finding chart of the comparison sequence is presented in Fig. 1. The comparison stars are labeled from A to P in order of their V magnitudes. The field is $10' \times 10'$, centered on V 1735 Cyg. North is at the top and east to the left. The chart is retrieved from the STScI Digitized Sky Survey Second Generation Red. Table 1 contains the co-ordinates and the photometric data for the *BVRI* comparison sequence. The corresponding mean errors of the mean are listed, too.

[1] Skinakas Observatory is a collaborative project of the University of Crete, the Foundation for Research and Technology—Hellas, and the Max-Planck-Institut für Extraterrestrische Physik.

Table 1 Photometric data for *BVRI* comparison sequence

Star	R.A. (2000)	DEC. (2000)	I	σ_I	R	σ_R	V	σ_V	B	σ_B
A	21:47:19.63	47:32:50.7	14.12	0.01	14.58	0.02	15.08	0.02	15.93	0.02
B	21:47:28.82	47:34:07.0	13.56	0.04	14.28	0.03	15.09	0.02	16.32	0.02
C	21:47:22.07	47:34:21.8	14.12	0.06	14.59	0.02	15.12	0.02	16.04	0.02
D	21:47:40.02	47:34:17.4	13.84	0.04	14.70	0.03	15.60	0.02	16.97	0.03
E	21:47:41.33	47:31:59.6	14.98	0.03	15.63	0.02	16.30	0.02	17.42	0.03
F	21:47:16.61	47:29:12.6	14.86	0.04	15.74	0.03	16.57	0.02	17.93	0.02
G	21:47:36.72	47:35:19.2	14.60	0.07	15.90	0.04	17.12	0.03	18.98	0.05
H	21:47:12.66	47:34:16.8	14.79	0.07	16.09	0.04	17.35	0.02	19.34	0.07
I	21:47:14.32	47:29:20.6	15.99	0.06	17.04	0.05	17.99	0.03	19.50	0.04
J	21:47:16.87	47:34:41.1	15.45	0.08	16.96	0.04	18.28	0.03	20.09	0.11
K	21:47:39.51	47:33:29.3	16.34	0.06	17.37	0.03	18.38	0.05	19.95	0.05
L	21:47:07.11	47:31:20.2	15.74	0.07	17.38	0.05	18.42	0.05	20.13	0.10
M	21:47:14.85	47:31:09.3	16.46	0.09	17.45	0.03	18.49	0.04	20.04	0.11
N	21:47:11.99	47:32:44.8	16.49	0.08	17.71	0.06	18.71	0.03	20.30	0.09
O	21:47:26.23	47:34:13.3	16.63	0.11	17.79	0.04	18.84	0.05	20.40	0.15
P	21:47:31.43	47:33:47.0	16.41	0.12	18.40	0.08	20.19	0.12	–	–

The CCD photometric *BVRI* data presented in this paper were collected from March 2003 to January 2009. The results of our photometric observations of V 1735 Cyg are summarized in Table 2. The columns give the Julian date, *BVRI* magnitudes, and telescope used. The *BVRI* light curves of V 1735 Cyg during the period of our observations are plotted in Fig. 2. The mean values of the instrumental errors are $0\overset{m}{.}015$ (I) and $0\overset{m}{.}019$ (V) for observations made with nitrogen cooled CCD cameras, Photometrics, ANDOR and Vers Arrey, and $0\overset{m}{.}022$ (I) and $0\overset{m}{.}029$ (V) for observations made with the electric cooled CCD cameras, ST-8 and ST-11000.

The plate archive of the 50/70-cm Schmidt telescope of Rozhen Observatory contains 82 photographic plates centered on IC 5146. The plates were obtained in the period 1984–1994 and most of them are blue plates (ORWO ZU21 emulsion with B filter). The visual inspection of these plates does not indicate the presence of V 1735 Cyg (the typical plate limits are $17\overset{m}{.}5$–$18\overset{m}{.}0$). The plates obtained on Kodak IIa-D emulsions with V filter and on Kodak 103a-F and 103a-E emulsions with R filter have been scanned with Epson Expression 1640 XL scanner, 1600 dpi resolution, corresponding to 10×10 µm pixel size. Aperture photometry of the digitized plates used DAOPHOT routines. The *BVRI* comparison sequence reported in the paper was used as a reference. The data from the photometry of V 1735 Cyg made on the plate scans are summarized in Table 3. Five plates taken with the 100/150-cm Schmidt telescope in the Byurakan Astrophysical Observatory (Armenia) have also been inspected for the presence of V 1735 Cyg. One of them, obtained on September 8, 1980, shows the star, and its measured magnitude is $B = 20\overset{m}{.}4 \pm 0.4$.

The digitized plates from the Palomar Schmidt telescope, available via the website of the Space Telescope Science Institute, have also been inspected for the presence of V 1735 Cyg. The blue and red plates from POSS I obtained in 1952 do not show the star. On the plate scans from Quick-V and POSS II sky surveys, V 1735 Cyg is detectable and its magnitudes were measured using our comparison sequence. The corresponding values are $V = 17\overset{m}{.}4 \pm 0.1$ (Sept. 5, 1983), $R = 15\overset{m}{.}64 \pm 0.05$ (Jul. 20, 1988), $B = 20\overset{m}{.}8 \pm 0.2$ (July 10, 1989), $I = 13\overset{m}{.}77 \pm 0.03$ (September 25, 1992).

3 Results and discussion

We try to construct the historical light curve of V 1735 Cyg and to study the photometric behavior of the star around the optical outburst and in the time of set in brightness using the collected data from photographic and CCD observations. In contrast to the three FUor objects with well defined light curves, V 1735 Cyg is relatively less bright. While FU Ori and V 1057 Cyg have in the maximum light $R \sim 8^m$, and for V 1515 Cyg it is $R \sim 11^m$, the maximum registered magnitude of V 1735 Cyg is only $R \sim 15^m$. The difference in brightness grows still more for the V and B pass bands. Therefore, we need to collect observations from relatively big telescopes made with longer exposures, in order to realize our photometric study.

In Fig. 3 we plot the R and V light curves from all available observations of V 1735 Cyg. The filled triangles denote photographic data from the Rozhen Schmidt telescope, the filled diamonds our CCD observations, the filled squares photographic data from the Palomar Schmidt telescope, the

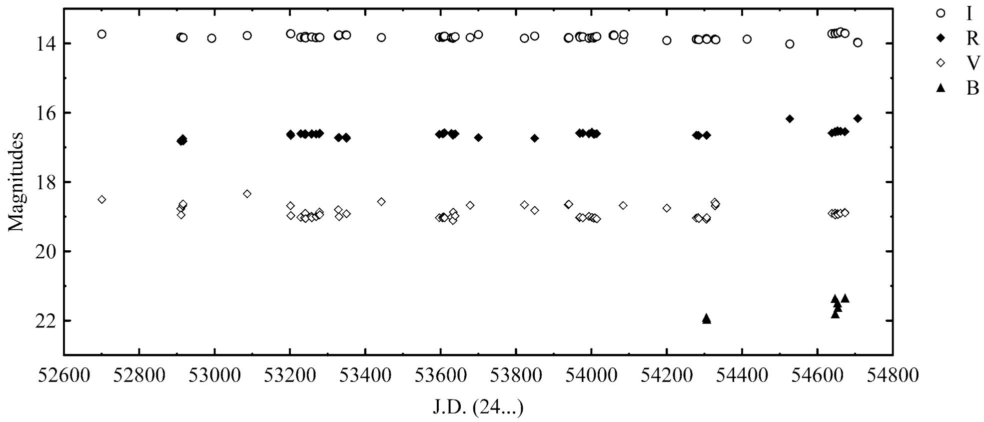

Fig. 2 *BVRI* light curves of V 1735 Cyg in the period March 2003–January 2009

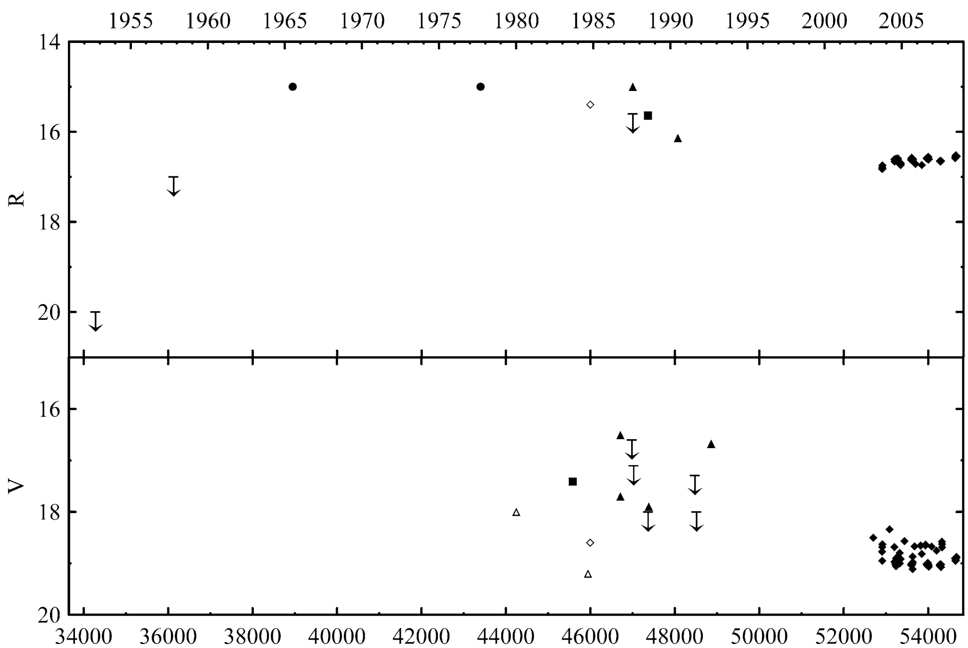

Fig. 3 *R* and *V* light curves of V 1735 Cyg in the period 1952–2009

filled circles the data from Elias (1978), the open triangles magnitudes published by Levreault (1988), and the open diamonds magnitudes published by Goodrich (1987). The arrows mark the upper limits from photographic observations made with the Palomar, Tonantzintla and Rozhen Schmidt telescopes.

The analysis of the available photometric data for V 1735 Cyg leads to some important conclusions. The time of rise in brightness and the star magnitude in the maximum light are still under discussion. The data from photographic observations made with the 50/70-cm Schmidt telescope from 1986 to 1992 show a strong light variability ($\Delta V = 1\overset{m}{.}2$). Taking into account the magnitudes from Goodrich (1987) and Levreault (1988) the registered amplitude of V 1735 Cyg in the period 1980–1992 is $\Delta V = 2\overset{m}{.}7$. In contrast, the recent photometric data obtained from March 2003 to January 2009 (Fig. 2) show only small amplitude variations ($\Delta I = 0\overset{m}{.}3$). Such a change of the photometric activity during the period of set in brightness was not observed for the other FUor objects. The analysis of existing photometric data shows a very slow decrease in star brightness—$1\overset{m}{.}8$ (R) for a 44 year period.

The shape of the observed light curves of FUors may vary considerably from object to object. While the time of rise for FU Ori and V 1057 Cyg is in the order of 1 year, for V 1515 Cyg it is considerably longer: ~ 25 years. The rate of decrease in brightness is quite different for each of them. While the brightness of V 1057 Cyg reaches the pre-outburst level after ~ 30 years, the decrease in brightness of FU Ori and V 1515 Cyg goes much slower. The available photometric data for V 1735 Cyg are not enough at present to determine the time of rise to the maximum brightness, but the rate of decrease in brightness is definitely similar to the ones observed in the cases of FU Ori and V 1515 Cyg. Our data show that V 1735 Cyg must be added to the group of long-lived FUors and that the

Table 2 *BVRI* CCD photometric observations of V 1735 Cyg

JD (24...)	*I*	*R*	*V*	*B*	Telescope	JD (24...)	*I*	*R*	*V*	*B*	Telescope
52700.604	13.73	–	18.50	–	2-m	53940.467	13.84	–	18.64	–	2-m
52910.346	13.82	16.83	18.77	–	Schmidt	53968.524	13.80	16.58	19.03	–	1.3-m
52911.315	13.82	16.79	18.95	–	Schmidt	53969.480	13.83	16.60	19.01	–	1.3-m
52915.420	13.84	16.75	18.68	–	Schmidt	53977.512	13.81	16.59	19.04	–	1.3-m
52916.366	13.83	16.82	18.63	–	Schmidt	53993.538	13.85	16.61	18.99	–	1.3-m
52992.204	13.85	–	–	–	Schmidt	54001.409	13.83	16.56	19.02	–	1.3-m
53086.598	13.78	–	18.34	–	2-m	54006.402	13.84	16.62	19.05	–	1.3-m
53201.407	13.72	16.61	18.69	–	Schmidt	54009.411	13.81	16.62	19.03	-	1.3-m
53202.433	13.72	16.66	18.97	–	Schmidt	54014.395	13.80	16.61	19.07	–	1.3-m
53228.531	13.82	16.61	19.02	–	1.3-m	54057.313	13.77	-	–	–	Schmidt
53238.367	13.83	16.62	19.04	–	1.3-m	54058.421	13.77	–	–	–	Schmidt
53240.533	13.80	16.61	18.90	–	1.3-m	54059.320	13.75	–	–	–	Schmidt
53241.445	13.84	16.63	19.06	–	1.3-m	54060.261	13.77	–	–	–	Schmidt
53257.289	13.81	16.62	18.99	–	1.3-m	54084.330	13.90	–	–	–	2-m
53258.282	13.81	16.61	19.03	–	1.3-m	54086.306	13.74	–	–	–	Schmidt
53269.418	13.83	16.62	19.00	–	1.3-m	54200.559	13.92	–	–	–	2-m
53277.263	13.82	16.61	18.95	–	1.3-m	54278.488	13.88	16.65	19.04	–	1.3-m
53278.272	13.83	16.60	18.87	–	1.3-m	54283.423	13.88	16.65	19.02	–	1.3-m
53279.309	13.82	16.59	18.95	–	1.3-m	54285.492	13.89	16.66	19.06	–	1.3-m
53328.296	13.78	16.72	18.80	–	Schmidt	54305.356	13.86	16.65	19.08	21.91	1.3-m
53330.264	13.76	16.71	19.00	–	Schmidt	54306.352	13.88	16.65	19.02	21.96	1.3-m
53348.220	13.76	16.71	–	–	Schmidt	54327.366	13.88	–	18.58	–	2-m
53349.255	13.75	16.70	–	–	Schmidt	54328.363	13.88	–	18.69	–	2-m
53350.220	13.76	16.74	18.92	–	Schmidt	54330.329	13.90	–	18.63	–	2-m
53442.611	13.83	–	18.57	–	2-m	54413.351	13.88	–	–	–	2-m
53596.445	13.82	16.63	19.03	–	1.3-m	54526.733	14.02	–	–	–	Schmidt
53605.307	13.82	16.61	19.04	–	1.3-m	54638.403	13.72	16.59	18.90	-	1.3-m
53606.308	13.80	16.60	19.00	–	1.3-m	54646.442	13.71	16.55	18.90	21.36	1.3-m
53609.401	13.80	16.58	19.02	–	1.3-m	54647.446	13.72	16.56	18.96	21.81	1.3-m
53610.395	13.79	16.58	19.04	–	1.3-m	54653.407	13.70	16.52	18.91	21.49	1.3-m
53628.422	13.84	16.60	19.01	–	1.3-m	54654.440	13.70	16.54	18.94	21.62	1.3-m
53632.476	13.85	16.65	19.11	–	1.3-m	54661.446	13.67	16.54	18.90	–	1.3-m
53633.479	13.83	16.63	18.87	–	1.3-m	54672.458	13.70	16.55	18.88	–	1.3-m
53638.463	13.80	16.61	18.98	–	1.3-m	54673.450	13.71	16.54	18.89	21.35	1.3-m
53678.263	13.83	–	18.67	–	2-m	54706.481	13.97	–	–	–	Schmidt
53700.269	13.74	16.72	–	–	Schmidt	54707.425	13.98	–	–	–	Schmidt
53822.575	13.85	–	18.66	–	2-m	54761.325	13.96	16.64	–	–	Schmidt
53849.553	13.79	16.74	18.82	–	Schmidt	54763.252	13.96	16.63	–	–	Schmidt
53938.431	13.85	–	18.65	–	2-m	54791.210	13.96	16.67	–	–	Schmidt
53939.470	13.83	–	18.65	–	2-m	54844.199	13.95	16.66	–	–	Schmidt

time scale of the FUor phenomenon must be much longer than the one assumed in previous studies (Herbig 1977; Reipurth 1990).

Due to the small number of objects known as FUors their classification is very difficult. In some cases, stars originally classified as FUors in the detailed spectral and photometric study were identified as variables of other types. Such an example is the case with V 1184 Tau, initially considered as a FUor, but according to the recent published results it is more likely a star of UX Ori type (Barsunova et al. 2006; Semkov et al. 2008). The photometric data for V 1735 Cyg collected up to the present have confirmed its FUor classi-

Table 3 Photometric data from the photographic observations of V 1735 Cyg with the Schmidt telescope of Rozhen Observatory

Plate No.	Bandpass	Date	JD (244...)	Magnitude
3761	*V*	1986 Oct. 08	6712.316	16.5±0.1
3762	*V*	1986 Oct. 08	6712.351	17.7±0.2
3829	*V*	1987 Jun. 27	6973.500	>16.6
3836	*V*	1987 Jun. 29	6976.444	>16.6
3864	*V*	1987 Jul. 25	7002.361	>17.1
4462	*V*	1988 Jul. 20	7362.503	>18.0
4486	*V*	1988 Aug. 10	7384.471	17.9±0.3
5947	*V*	1991 Aug. 10	8479.352	>17.3
6006	*V*	1991 Sep. 14	8514.310	>18.0
6377	*V*	1992 Sep. 27	8862.303	16.7±0.1
3861	*R*	1987 Jul. 25	7001.514	>15.6
3873	*R*	1987 Jul. 26	7003.430	15.0±0.2
5478	*R*	1990 Jun. 30	8072.502	16.1±0.1

fication. A strong decrease in brightness by about $1\overset{\text{m}}{.}5$ (B) in a few months was registered in the light curve of V 1515 Cyg. This minimum in brightness was explained by an obscuration from dust material ejected from the star (Kenyon et al. 1991). The strong light variability of V 1735 Cyg observed during the period from 1986 to 1992 may be due to similar processes.

The results from photographic observations with the Rozhen Schmidt telescope, reported in the present paper, show the importance of archival plate collections for long-term photometric studies of PMS stars. In order to construct the historical light curve of V 1735 Cyg a search for archived photographic observations in the Wide-Field Plate Database (WFPDB) was made. The WFPDB (Tsvetkov et al. 1997) contains (1) a catalogue of all known archives of wide-field ($\geq 1°$) plates and (2) a merged catalogue of wide-field plates. Our search in the database, limited to a clear telescope aperture, ≥ 40 cm, shows the possibility to find archival photographic observations of V 1735 Cyg in the plate collections of the following telescopes: the 67/92-cm and the 40/50-cm Schmidt telescopes at Asiago Observatory (Italy), the 105/150-cm Schmidt telescope at Kiso Observatory (Japan), the 60/90-cm Schmidt telescope at Campo Imperatore (Italy), the 134/200-cm Schmidt telescope at Tautenburg (Germany) and the 40-cm Astrograph at Sonneberg Observatory (Germany).

4 Conclusion

We consider the photometric studies of FUor and FUor-like objects as very important for their exact classification. The problems with the duration and the possible recurrence of the FUor stage can be solved by collecting photometric data from the photographic plate archives and with photometric monitoring in the present time. Another disputed point that can be solved by photometric monitoring of star-forming regions is the percentage of PMS stars passing through a FUor outburst.

A possible future study along with the next photometric observations is the reconstruction of the historical light curve of V 1735 Cyg. This should be an international cooperation study, because the archival photographic plates of this region have been stored in different countries. We are convinced that such a study would be very interesting and fruitful, as was the investigation of the suspected FUor star V 1184 Tau (Semkov et al. 2008).

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References

Ábrahám, P., Kospal, A., Csizmadia, Sz., et al.: Astron. Astrophys. **428**, 89 (2004)
Bastian, U., Mundt, R.: Astron. Astrophys. **144**, 57 (1985)
Barsunova, O.Yu., Grinin, V.P., Sergeev, S.G.: Astr. Let. **32**, 924 (2006)
Clarke, C., Lodato, G., Melnikov, S.Y., Ibrahimov, M.A.: Mon. Not. R. Astron. Soc. **361**, 942 (2005)
Elias, J.H.: Astrophys. J. **223**, 859 (1978)
Goodrich, R.W.: Publ. Astron. Soc. Pac. **99**, 116 (1987)
Graham, J.A., Frogel, J.A.: Astrophys. J. **289**, 331 (1985)
Hartmann, L., Kenyon, S.J.: Astrophys. J. **299**, 462 (1985)

Herbig, G.H.: Astrophys. J. **217**, 693 (1977)
Herbig, G.H.: In: Reipurth, B. (ed.) ESO Workshop on Low-Mass Star Formation and PMS Objects, p. 233. ESO, Garching (1989)
Herbst, W., Herbst, D.K., Grossman, E.J., Weinstein, D.: Astron. J. **108**, 1906 (1994)
Kenyon, S.J., Hartmann, L.W., Kolotilov, E.A.: Publ. Astron. Soc. Pac. **103**, 1069 (1991)
Landolt, A.U.: Astron. J. **104**, 340 (1992)
Levreault, R.M.: Astrophys. J. **265**, 855 (1983)
Levreault, R.M.: Astrophys. J. Suppl. Ser. **67**, 283 (1988)
Reipurth, B.: In: Mirzoyan, L.V., Petterson, B.R., Tsvetkov, M.K. (eds.) IAU Symp. 137, Flare Stars in Star Clusters, Associations, and the Solar Vicinity, p. 229. Kluwer, Dordrecht (1990)
Reipurth, B., Aspin, C.: Astron. J. **114**, 2700 (1997)
Reipurth, B., Aspin, C., Beck, T., Brogan, C., Connelley, M., Herbig, G.H.: Astron. J. **133**, 1000 (2007)
Rodriguez, L.F., Hartmann, L.W., Chavira, E.: Publ. Astron. Soc. Pac. **102**, 1413 (1990)
Semkov, E.H., Tsvetkov, M.K., Borisova, A.P., et al.: Astron. Astrophys. **483**, 537 (2008)
Skinner, S.L., Sokal, K.R., Gudel, M., Briggs, K.R.: Astrophys. J. **696**, 766 (2009)
Tsvetkov, M.K., Stavrev, K.Y., Tsvetkova, K.P., et al.: Baltic Astr. **6**, 271 (1997)
Wachmann, A.A.: IAU Circ. 738 (1939)