Flickering amplitude of the cataclysmic variable star MV Lyrae in different states

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Abstract. We present CCD observations of the short time brightness variations (flickering) of the cataclysmic variable MV Lyr in low and high state. We show that the amplitude of the flickering correlates with the average flux of the accreting component as $\Delta F \sim F^k$ with $k = 0.80$ in U, B, V, R and I bands. The relation is ascertained in a large range of brightness variations, as the mean flux changes about 1000 times from low to high photometric state.
Key words: cataclysmic variables, flickering, individual - MV Lyr

Амплитуда на фликеринга при катаклизмичната променлива звезда MV Lyrae в различни състояния

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Ние представяме CCD наблюдения на бързите вариации на блясъка (фликеринг) на катаклизмичната променлива MV Lyr в ниско и високо състояние. Получена е зависимост на амплитудата на фликеринга от средния поток от вида $\Delta F \sim F^k$ с показател $k = 0.80$ за U, B, V, R и I филтри. Тази зависимост е добре изразена в широк диапазон на промяна на блясъка, тъй като средният поток има изменение от около 1000 пъти между ниско и високо фотометрично състояние.

Introduction

MV Lyr is a typical member of VY Scl stars - a semidetached close binary system consisting of a white dwarf and a red dwarf with orbital period of 3.20 hr (Schneider et al. [1981]). This cataclysmic variable is usually in high photometric state $V \sim 12.5\ mag$ with high mass transfer rate and a stable bright accretion disk but occasionally it drops to very fade state $V \sim 18\ mag$, when the disk disappears.

There were two previous very deep minima observed for this system - the first one lasting from 1979 to 1989 (Rosino et al. [1993]) and another one lasting from 1995 to 2003 (Honeycutt, Kafka [2004]). The new brightness drop of the system started in April 2007 and continued for about 3 years.

We present flickering (short term stochastic variations of the brightness) observations of MV Lyr including data from different states. We obtained a relation between the flickering amplitude and the average flux of the system.

1 Observations

Our observations covered the period from the beginning of the latest minimum in 2007 to the end of 2010 when MV Lyr was in the high photometric state. The observations were obtained with 3 telescopes of National Astronomical Observatory - Rozhen: 2 m RCC telescope equipped with CCD camera (Photometrics CE200A or VersArray 1330B) or with the dual channel focal reducer FoReRo2 (CCD cameras Photometrics for the blue channel and VersArray for the red channel - Jockers et al.[2000]), 50/70 Schmidt telescope (with a CCD camera SBIG ST-8E, SBIG STL-11000M or FLI PL16803), 60 cm Cassegrain telescope (FLI PL09000) and 60 cm Cassegrain telescope at Astronomical Observatory Belogradchick (SBIG ST-8 or FLI PL09000).We obtained 4 sets in U, 13 in B, 32 in V, 8 in R and 12 in I bands (about 3200 frames in all bands) in 36 nights. The total duration of the patrol observations is about 102:30 h.

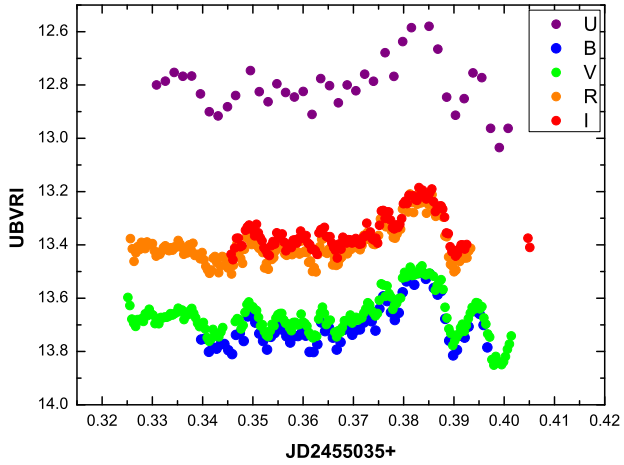

Fig. 1. $UBVRI$ observations of the flickering of MV Lyr on July 22, 2009.

All frames were reduced and standard aperture photometry was performed to extract the stellar magnitudes. As comparison stars we used standard 4 (U=14.60; B=13.58; V=12.49; R=11.69; I=11.05) and standard 8 (U=13.68; B=13.60;
V=13.05; R=12.61; I=12.24) following Andronov et al.[1993].

The log of observations and the calculations of the average flux and the flickering amplitude for $UBVRI$ bands are presented in Tables 1 - 5. The Julian day of the start of the run, the telescope, the duration of the run, number of the data points, the exposure of the frames, the mean magnitude, the typical error of the measurements, the logarithm of average flux (the mean flux in each set corrected for the contribution of the red and the white dwarfs) with the error estimations, the minimal and maximal magnitudes of the set, the total amplitude of the variability in magnitudes and the logarithm of the flux of flickering amplitude ($\Delta F = F_{max} - F_{min}$ for each set) with the error estimations are given in the table columns.

A part of the patrol sets were obtained simultaneously in 2 to 5 different filters. Fig.1 is an example of 5 color light curve obtained during an intermediate state on July 22, 2009.

Table 1. U band

HJD start 2450000+	Tel	Δt	N	exp [s]	M_{av} [mag]	err [mag]	$log F_{av}$	err	M_{min} [mag]	M_{max} [mag]	A [mag]	$log \Delta F$	err
4999.452	60r	1:24	22	120	13.485	0.010	-20.787	0.004	13.726	13.312	0.414	-21.200	0.010
5035.330	2m	1:43	39	120	12.810	0.030	-20.509	0.012	13.035	12.580	0.455	-20.874	0.030
5036.424	2m	1:16	30	120	12.850	0.030	-20.526	0.012	12.970	12.735	0.235	-21.181	0.050
5424.436	sh	1:36	31	180	12.134	0.010	-20.234	0.004	12.221	12.000	0.221	-20.911	0.020

Table 2. B band

HJD start 2450000+	Tel	Δt	N	exp [s]	M_{av} [mag]	err [mag]	$log F_{av}$	err	M_{min} [mag]	M_{max} [mag]	A [mag]	$log \Delta F$	err
4210.477	2m	1:06	11	240	16.570	0.020	-21.959	0.008	16.710	16.180	0.530	-22.065	0.020
4303.509	2m	0:46	10	240	17.580	0.025	-22.805	0.010	17.610	17.550	0.060	-23.470	0.140
4305.430	2m	0:53	10	300	17.600	0.025	-22.837	0.010	17.620	17.590	0.030	-23.781	0.220
4655.420	2m	1:30	15	300	17.420	0.060	-22.595	0.024	17.540	17.080	0.460	-22.474	0.060
4999.454	60r	1:23	23	90	14.290	0.010	-20.912	0.004	14.582	14.127	0.455	-21.296	0.020
5034.447	sh	1:20	40	60	13.693	0.010	-20.666	0.004	13.894	13.508	0.386	-21.107	0.020
5035.339	sh	1:23	74	60	13.700	0.010	-20.669	0.004	13.815	13.500	0.315	-21.179	0.020
5036.402	sh	1:54	103	60	13.760	0.010	-20.694	0.004	13.870	13.575	0.295	-21.234	0.020
5057.494	sh	2:52	60	90	13.455	0.010	-20.569	0.004	13.647	13.237	0.410	-20.977	0.020
5111.263	60b	2:12	65	60	13.003	0.010	-20.386	0.004	13.264	12.776	0.488	-20.732	0.020
5126.257	sh	3:23	111	60	13.144	0.010	-20.443	0.004	13.442	12.949	0.493	-20.797	0.020
5424.444	60r	1:22	26	120	12.946	0.005	-20.363	0.002	13.029	12.810	0.219	-21.042	0.020
5447.457	60r	1:33	24	120	12.838	0.005	-20.319	0.002	12.943	12.699	0.244	-20.956	0.020

2 Results and discussion

For each night we measured the average magnitude, the amplitude of the flickering, the minimum and the maximum flux during the set using the calibrations of Bessell [1979] for the flux of a zero magnitude star. We searched for relations of the type $\Delta F \sim F_{av}^k$. Usually the brightness of MV Lyr has been about 12.5 in V. The main part of the luminosity of the system in a high state is due to the bright accretion disk. In the low states we accepted the assumption that the accretion disk is absent. We estimated the total contribution from the white and the red dwarfs by the minimum values of the brightness of MV Lyr obtained from our observations in this faint state - $U \sim 17$, $B \sim 17.9$, $V \sim 17.8$, $R \sim 17.6$, $I \sim 17.2$. In our calculations we removed this minimal flux in each band to eliminate the contribution of the red and white dwarfs.

Fig. 2 presents our results, showing that the flickering amplitude strongly depends on the average flux of the system. Using all flickering runs we find the following relation: $\Delta F_{fl} \sim F_{av}^{0.80 \pm 0.03}$. This value could be slightly higher if the contribution of the white and the red dwarfs had been overestimated. The relation is valid for average flux changes of about 1000 times. As far as F_{av} is a measure of the photometric state of MV Lyr we plot two individual

dependances for the flickering amplitude on the mean flux. Figure 3) refers to the high state (brighter than 15 mag in V) and Figure 4) - the low state. The obtained coefficients are $k = 0.96 \pm 0.06$ and $k = 0.94 \pm 0.12$ respectively. These values are slightly higher than 0.80 for all present flickering points. This difference could be explained by two facts. First, there is not a distinct border between the average fluxes in maximum and minimum state and we use the limit $V \sim 15\ mag$ as an approximately mean value of the brightness of MV Lyr.

Table 3. V band

HJD start 2450000+	Tel	Δt	N	exp [s]	M_{av} [mag]	err [mag]	$logF_{av}$	err	M_{min} [mag]	M_{max} [mag]	A [mag]	$log\Delta F$	err
4210.543	sh	0:42	15	150	16.200	0.025	-22.037	0.010	16.590	15.890	0.700	-22.123	0.020
4230.479	60b	0:54	13	240	17.600	0.080	-23.258	0.032	17.750	17.350	0.400	-22.895	0.070
4231.467	60b	0:50	12	240	17.590	0.060	-23.235	0.024	17.680	17.410	0.270	-23.065	0.080
4234.469	sh	1:05	16	240/300	17.600	0.080	-23.258	0.032	17.720	17.470	0.250	-23.119	0.110
4236.411	sh	0:47	8	300	17.660	0.065	-23.425	0.026	17.740	17.590	0.150	-23.369	0.140
4299.433	sh	0:53	10	300	17.575	0.060	-23.202	0.024	17.600	17.540	0.060	-23.730	0.240
4304.507	2m	0:39	12	180	17.640	0.025	-23.363	0.010	17.660	17.600	0.060	-23.754	0.130
4305.360	2m	1:04	15	240	17.710	0.035	-23.627	0.014	17.770	17.590	0.180	-23.296	0.070
4323.321	sh	1:06	12	300	17.620	0.065	-23.308	0.026	17.720	17.560	0.160	-23.331	0.130
4541.531	sh	2:24	70	30/60	13.070	0.010	-20.678	0.004	13.250	12.930	0.320	-21.209	0.010
4564.485	2m	0:39	70	15	13.447	0.010	-20.831	0.004	13.576	13.327	0.249	-21.463	0.020
4619.458	60b	1:31	22	240	16.060	0.020	-21.966	0.008	16.620	15.650	0.970	-21.933	0.010
4620.426	60b	1:53	27	240	15.870	0.020	-21.872	0.008	16.280	15.540	0.740	-21.966	0.010
4651.437	60b	1:26	18	240	16.970	0.060	-22.504	0.024	17.660	16.220	1.440	-22.066	0.020
4653.373	60b	1:44	24	240	16.380	0.080	-22.133	0.032	17.410	15.800	1.610	-21.876	0.020
4889.596	2m	1:31	120	40	14.710	0.010	-21.354	0.004	14.940	14.430	0.510	-21.642	0.010
4914.549	2m	1:07	55	30	14.970	0.030	-21.465	0.012	15.180	14.750	0.430	-21.829	0.030
4946.540	60b	1:01	28	120	14.910	0.030	-21.439	0.012	15.060	14.790	0.270	-22.017	0.040
4977.426	60b	0:49	17	120	14.068	0.010	-21.085	0.004	14.144	13.927	0.217	-21.757	0.020
4982.432	60b	1:08	26	120	14.261	0.010	-21.165	0.004	14.406	14.140	0.266	-21.763	0.020
4983.408	60b	0:59	20	120	14.251	0.010	-21.161	0.004	14.558	14.070	0.488	-21.513	0.010
4991.386	60b	1:18	32	120	14.228	0.010	-21.152	0.004	14.358	14.078	0.280	-21.719	0.020
4999.496	60b	1:38	23	60	14.252	0.010	-21.162	0.004	14.582	14.097	0.485	-21.526	0.010
5034.463	60b	1:12	70	60	13.575	0.010	-20.883	0.004	13.825	13.411	0.414	-21.307	0.010
5035.324	2m	1:51	191	30	13.670	0.005	-20.922	0.002	13.850	13.480	0.370	-21.375	0.010
5036.424	2m	1:19	137	30	13.720	0.005	-20.942	0.002	13.820	13.560	0.260	-21.540	0.010
5057.495	sh	2:51	59	60	13.326	0.010	-20.782	0.004	13.459	13.092	0.367	-21.223	0.010
5111.264	sh	1:27	47	60	12.993	0.005	-20.646	0.002	13.221	12.792	0.429	-21.047	0.010
5126.309	sh	2:09	69	30	13.096	0.010	-20.688	0.004	13.340	12.923	0.417	-21.110	0.010
5154.198	sh	1:28	25	40	12.827	0.015	-20.579	0.006	13.107	12.639	0.468	-20.955	0.010
5424.433	60b	1:39	63	30/60	12.912	0.015	-20.614	0.006	12.985	12.767	0.218	-21.291	0.030
5447.459	60r	1:32	24	90	12.804	0.005	-20.570	0.002	12.893	12.692	0.201	-21.293	0.010

Furthermore the flickering of MV Lyr has sometimes unusual amplitudes in intermediate and low state - there are cases with large amplitudes ($\sim 1.0 - 1.5\ mag$) when the brightness is about 16 - 17 mag, but near the minimum light we observed cases with too low amplitude (less then 0.06 mag). Such behaviour was reported for MV Lyr (Robinson et al.[1981]) and another VY Scl variable - TT Ari (Shafter [1985]). Although we have never observed such flickering amplitudes in the case of a similar cataclysmic KR Aur - its flickering has never stopped completely (Boeva et al.[2010]).

Similar relations are known for other cataclysmic and symbiotic stars: CH Cyg ($k = 1.40 - 1.45$, Mikolajewski et al. [1990]), T CrB ($k = 1.03 \pm 0.09$, Zamanov et al. [2004]), KR Aur ($k = 0.70 - 0.75$, Boeva et al. [2007]) and for V425 Cas ($k = 1.22 \pm 0.12$,Tsvetkova et al. [2010]). The value $k = 0.80 - 0.90$ is close to the one for another VY Scl variable - KR Aur, but differs from the one for an identical variable V425 Cas.

There is possibility that different relations exist for the 5 individual bands. We obtained $k = 0.99 \pm 0.08$ for B, $k = 0.75 \pm 0.04$ for V, $k = 0.79 \pm 0.06$ for R and $k = 0.73 \pm 0.05$ for I. The observational data in U are insufficient. The coefficients k are in fact identical for V, R and I and are slightly larger for B, but only data in V are large enough. However there are good linear dependences for KR Aur, V425 Cas and MV Lyr for all optical bands U, B, V, R and I. It seems that the flickering amplitude does not depend on the wavelengths of observations.

Table 4. R band

HJD start 2450000+	Tel	Δt	N	exp [s]	M_{av} [mag]	err [mag]	$logF_{av}$	err	M_{min} [mag]	M_{max} [mag]	A [mag]	$log\Delta F$	err
4210.573	sh	1:01	25	120	15.980	0.040	-22.151	0.016	16.140	15.810	0.330	-22.554	0.050
4305.488	2m	0:49	15	180	17.440	0.030	-23.487	0.012	17.490	17.400	0.090	-23.707	0.110
4655.427	sh	1:10	13	240/300	17.190	0.030	-23.026	0.012	17.390	16.920	0.470	-22.870	0.030
4999.497	60b	1:38	23	60	14.021	0.010	-21.273	0.004	14.279	13.888	0.391	-21.723	0.010
5035.325	60b	1:38	185	30	13.400	0.010	-21.017	0.004	13.510	13.205	0.305	-21.541	0.010
5036.402	60b	1:49	200	30	13.465	0.015	-21.044	0.006	13.570	13.300	0.270	-21.625	0.020
5111.265	sh	1:23	46	30	12.794	0.010	-20.771	0.004	12.996	12.651	0.345	-21.273	0.010
5424.434	60b	1:39	64	30/40	12.711	0.010	-20.737	0.004	12.788	12.604	0.184	-21.497	0.020

Table 5. I band

HJD start 2450000+	Tel	Δt	N	exp [s]	M_{av} [mag]	err [mag]	$logF_{av}$	err	M_{min} [mag]	M_{max} [mag]	A [mag]	$log\Delta F$	err
4210.490	sh	0:53	22	120	15.750	0.048	-22.345	0.019	15.880	15.490	0.390	-22.628	0.050
4262.417	sh	0:59	7	240	17.010	0.130	-23.510	0.052	17.140	16.940	0.200	-23.462	0.180
4299.497	sh	0:52	12	240	17.023	0.100	-23.543	0.040	17.120	16.940	0.180	-23.504	0.160
4305.542	2m	0:41	13	180	16.910	0.050	-23.306	0.020	16.960	16.870	0.090	-23.759	0.160
4321.319	sh	6:15	63	120/240	16.970	0.130	-23.419	0.052	17.200	16.850	0.350	-23.212	0.120
4655.426	2m	1:23	16	300	16.760	0.020	-23.093	0.008	16.870	16.490	0.380	-23.038	0.020
4999.498	60b	1:38	23	60	13.932	0.015	-21.507	0.006	14.168	13.821	0.347	-22.003	0.020
5034.446	sh	2:14	40	30	13.358	0.020	-21.268	0.008	13.548	13.258	0.290	-21.845	0.030
5035.345	60r	1:08	127	30	13.350	0.015	-21.265	0.006	13.455	13.185	0.270	-21.843	0.020
5036.418	60r	1:26	155	30	13.410	0.015	-21.289	0.006	13.510	13.270	0.240	-21.923	0.030
5111.264	60b	2:11	66	30	12.717	0.010	-21.006	0.004	12.896	12.556	0.340	-21.505	0.010
5424.446	60r	1:21	26	60	12.678	0.015	-20.990	0.006	12.766	12.595	0.171	-21.786	0.040

The flickering and flickering light source of the symbiotic stars differ from such of the cataclysmic variables (Zamanov et al. [2010]) but the detail study

of this phenomenon requires obtaining a large amount of observations in different states for various objects showing fast optical changes.

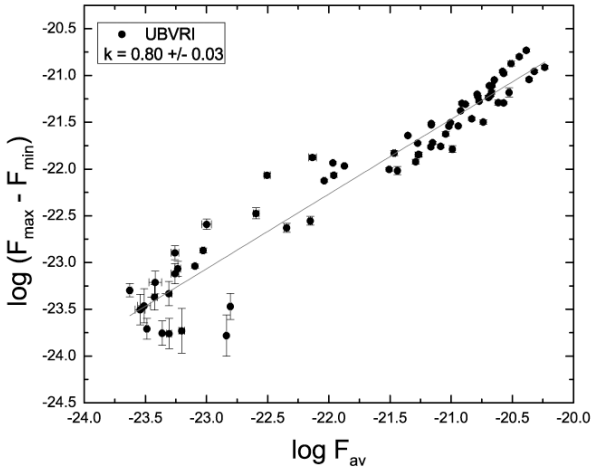

Fig. 2. The flickering amplitude $\Delta F = F_{max} - F_{min}$ versus the average flux in a logarithmic scale. The flux is in units of $Wcm^{-2}\mathring{A}^{-1}$. The contribution of the red and white dwarf has been removed. The solid line is a linear fit for $\Delta F \sim F_{av}^{k}$ dependence, where $k = 0.80 \pm 0.03$.

Conclusion

We observed the flickering of the VY Scl type variable MV Lyr in 36 nights in $UBVRI$ bands during the period 2007-2010, when the star brightness varied from 12.6 to 17.8 in V. We obtained that the amplitude of short time scale brightness variations depends on the mean flux as $\Delta F \sim F^{k}$ with $k = 0.80 \pm 0.03$ ($k = 0.95$ for the high and the low state individually) using all optical bands. We find that the coefficients k does not depend on the wavelength and the photometric state of MV Lyr.

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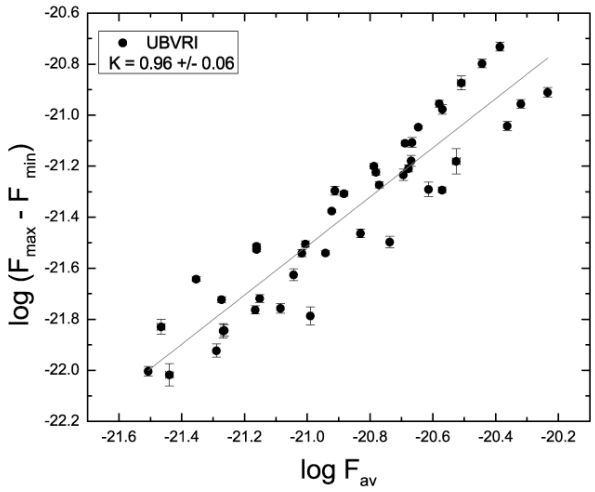

Fig. 3. The flickering amplitude versus the average flux in a logarithmic scale in high state of MV Lyr.

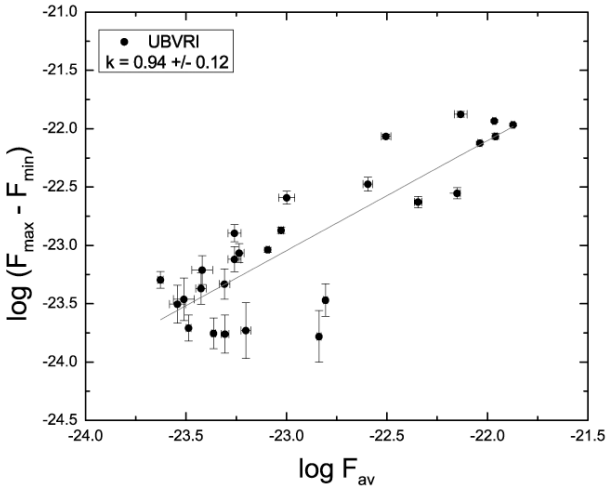

Fig. 4. The flickering amplitude versus the average flux in a logarithmic scale in low state of MV Lyr.

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