BVI$_c$ observations of the flickering in the cataclysmic variable KR Aur

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Abstract. We present CCD observations of the flickering of the cataclysmic variable (double star with accretion disk) KR Aur. We obtained that the amplitude short scale brightness variations depends on the mean flux as $\triangle F \propto F^k$ with k=0.70-0.75 in B, V and I_c bands.

Key words: cataclysmic variables, flickering, individual - KR Aur

BVI$_c$ наблюдения на фликеринг при катаклизмичната променлива KR Aur

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Представени са CCD наблюдения на фликеринга на катаклизмичната променлива (двойна звезда с акреционен диск) KR Aur. Получена е зависимост между амплитудата на бързите промени на блясъка и средния поток от звездата от типа $\Delta F \propto F^k$ с k=0.70-0.75 в B, V и I$_c$ филтри.

Introduction

KR Aurigae is a binary system consisting of a white dwarf and M2-3V star. with orbital period 3.907 hour (Shafter, 1983).

It is a nova-like cataclysmic variable (CV) of VY Scl type (anti-dwarf nova). In normal state such systems accrete at high mass transfer rate. At random intervals deep fades occur, which can last from days to years, suggesting that most or even all of the accretion disk disappears during the low state.

The brightness of CVs varies on minute-to-hour time scale with an amplitude of a few tenths of magnitude - flickering.

In this note we investigate the behaviour of the flickering amplitude on the base of CCD observations in B,V and I$_c$ bands.

1 Observations

Our observations are obtained from February 1999 to January 2007 with 3 different telescopes equipped with CCD cameras: the 60 cm Cassegrain telescope of the Belogradchik Astronomical Observatory (SBIG ST-8), 50/70cm Schmidt telescope (SBIG ST-8) and the 2.0 m telescopes of the Rozhen National Astronomical Observatory (Photometrix and VersArray CCDs).

The CCD frames were corrected for dark, bias, flat field and a standard aperture photometry was performed to obtain the stellar magnitudes.

As comparison stars we have used USNO-B1.0 1185-0114546 (B=13.77; V=12.84; I$_c$ =11.82) and USNO-B1.0 1185-0114438 (B=16.74; V=15.60; I$_c$ =14.28). All magnitudes have been transformed to Landolt's system from our observations. On each night, we measured the average magnitude, the amplitude of the flickering, the minimum and maximum flux during the night. The fluxes were calculated using the calibrations of Bessell (1979).

Usually, KR Aur has a brightness $V \sim 13-14^m$. However, during the last low state (1994 – 2001) it reached as low as $V \sim 19^m$. The minimum brightness ever observed in KR Aur is V= 19.02 ± 0.05 (10 Sept. 1997), B= 19.5 ± 0.5 (17 Sept. 1997), and I$_c = 17.9 \pm 0.25$ on 22 Jan. 1999 (see also Boeva et al. 2006). As a first approximation

Table 1. Journal of observations and results

HJD(start)	T h:mm	Npts	mean [mag]	err [mag]	A [mag]	stddev [mag]	$\log \Delta F$	err	$\log F_{av}$	err
B band										
2451516.412	1:18	25	16.87	0.04	0.83	0.18	-17.097	0.033	-16.967	0.032
2451520.512	1:21	36	16.94	0.08	1.05	0.23	-16.936	0.018	-16.999	0.051
2452994.326	5:42	51	13.36	0.01	0.52	0.12	-15.835	0.001	-15.508	0.005
2452995.338	0:46	21	13.37	0.01	0.36	0.09	-15.978	0.012	-15.513	0.004
2453763.260	1:51	8	13.64	0.01	0.32	0.12	-16.149	0.023	-15.637	0.005
2453764.219	7:59	8	13.74	0.02	0.41	0.13	-16.106	0.021	-15.680	0.009
2453766.228	2:27	10	13.67	0.01	0.30	0.09	-16.229	0.028	-15.648	0.005
2453995.524	2:42	71	13.61	0.02	0.48	0.12	-15.951	0.046	-15.627	0.009
2454035.460	4:47	17	13.60	0.01	0.43	0.12	-16.025	0.020	-15.623	0.005
2454040.439	5:25	28	14.10	0.02	0.45	0.09	-16.177	0.037	-15.821	0.009
2454111.486	2:15	9	13.67	0.01	0.28	0.11	-16.220	0.023	-15.650	0.005
V band										
2451258.268	1:27	30	17.22	0.11	1.21	0.37	-17.273	0.074	-17.425	0.058
2451512.464	0:43	12	18.80	0.13	0.39	0.11	-18.412	0.265	-18.695	0.275
2451516.447	1:02	30	17.01	0.11	0.67	0.15	-17.437	0.179	-17.322	0.055
2451607.330	1:11	38	15.49	0.04	0.48	0.12	-16.964	0.082	-16.650	0.017
2452995.285	0:32	60	13.51	0.01	0.29	0.07	-16.414	0.029	-15.849	0.004
2453761.293	0:59	6	13.31	0.01	0.16	0.06	-16.594	0.053	-15.771	0.004
2453763.265	1:48	8	13.14	0.01	0.29	0.11	-16.286	0.029	-15.702	0.004
2453764.225	7:52	7	13.26	0.01	0.29	0.11	-16.319	0.029	-15.752	0.004
2453766.232	2:24	10	13.07	0.01	0.25	0.09	-16.303	0.035	-15.673	0.004
2453995.516	1:22	18	13.38	0.01	0.35	0.11	-16.280	0.038	-15.797	0.004
2454035.465	4:46	17	13.18	0.01	0.45	0.13	-16.097	0.019	-15.719	0.004
2454040.443	5:21	28	13.74	0.01	0.43	0.09	-16.317	0.020	-15.942	0.004
2454111.491	2:10	9	13.45	0.01	0.20	0.06	-16.583	0.043	-15.827	0.004
I_c band										
2451237.235	3:04	3	15.73	0.05	0.46	0.23	-17.578	0.077	-17.266	0.027
2451607.405	0:59	32	14.62	0.06	0.31	0.09	-17.305	0.148	-16.781	0.029
2451914.452	1:19	5	17.28	0.24	0.80	0.32	-17.915	0.172	-18.183	0.263
2451916.558	1:02	4	16.99	0.31	1.02	0.48	-17.759	0.221	-17.951	0.239
2452995.591	1:00	109	13.18	0.01	0.29	0.07	-16.746	0.021	-16.192	0.050
2453764.198	8:36	253	13.01	0.01	0.50	0.09	-16.453	0.017	-16.125	0.005
2453765.224	4:59	194	13.00	0.01	0.49	0.11	-16.458	0.019	-16.119	0.005
2453766.236	2:24	10	12.86	0.02	0.38	0.09	-16.510	0.023	-16.058	0.009
2453995.531	1:19	251	13.15	0.01	0.39	0.10	-16.588	0.022	-16.175	0.005
2454035.481	4:27	16	12.86	0.01	0.27	0.08	-16.673	0.031	-16.059	0.005
2454040.449	5:16	28	13.27	0.01	0.28	0.08	-16.807	0.030	-16.226	0.005
2454111.474	2:38	12	13.28	0.02	0.27	0.08	-16.828	0.030	-16.230	0.009
2454112.295	7:20	326	13.00	0.02	0.63	0.12	-16.340	0.019	-16.119	0.009

we will accept that at the minimum there is no contribution from the accretion disk and the total flux of the system is formed from the white and red dwarfs. During the calculations, we remove the contribution of the red and white dwarfs.

Journal of observations together with the measured quantities are presented in Table 1. In the columns are given the Julian day of the start of the run, the duration of the run, number of the data points, the mean magnitude, the typical error of the measurements, the total amplitude of the variability, standard deviation of the run, $\log \Delta F$, the error of $\log \Delta F$, $\log F$, the error of $\log F$. ΔF is the difference between the maximum and minimum flux in each night. F is the mean flux during the night, corrected for the contribution of the red and white dwarfs (the minimum brightness).

2 Flickering amplitude

We search for relations of the type $\Delta F \propto F^k$, as it is done for CH Cyg (Mikolajewski et al. 1990) and for T CrB (Zamanov et al. 2004).

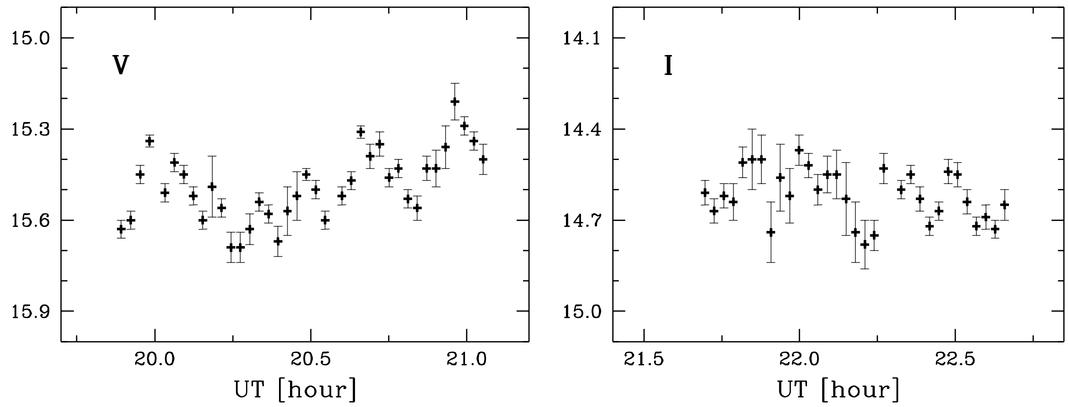

Fig. 1. Example of the light curve in V and I$_c$ bands observed on March 3rd, 2000

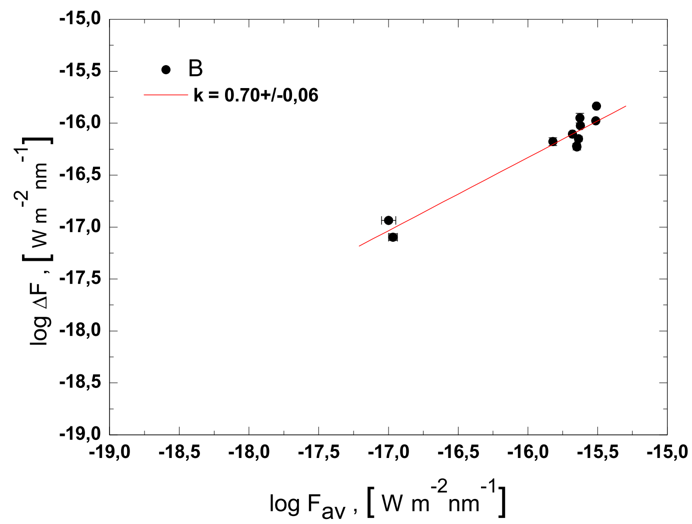

Fig. 2. The behaviour of the flickering amplitude versus the average flux in B

The data not corrected for the contribution of the red and white dwarfs give us k$_B = 0.72 \pm 0.06$, k$_V = 0.76 \pm 0.06$, k$_I = 0.80 \pm 0.07$ in B,V and I$_c$ filters respectively. Using all filters we get k$_{all} = 0.81 \pm 0.04$.

After the correction for the contribution of the red and white dwarfs, we calculate $k_B = 0.70 \pm 0.06$, $k_V = 0.68 \pm 0.03$, $k_I = 0.68 \pm 0.06$ and for all points $k_{all} = 0.72 \pm 0.03$. Graphic representations of the relations are given in Fig.2 The correlation coefficients (linear Pearson correlation, Spearman's rank, Kendalls's rank) are in the range 0.62-

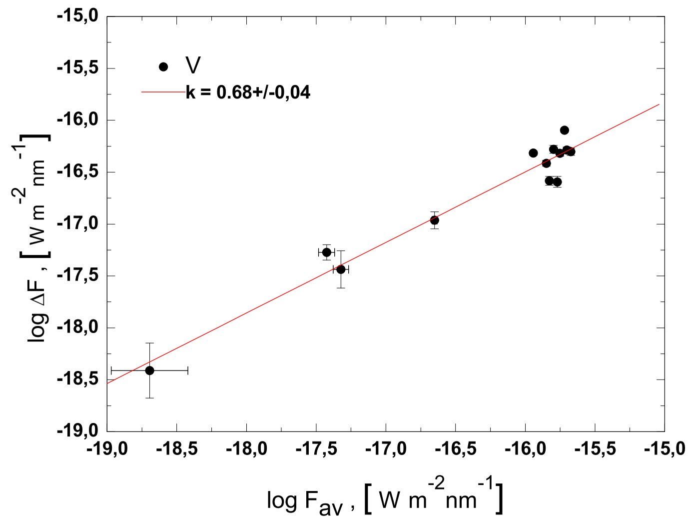

Fig. 3. The behaviour of the flickering amplitude versus the average flux in V

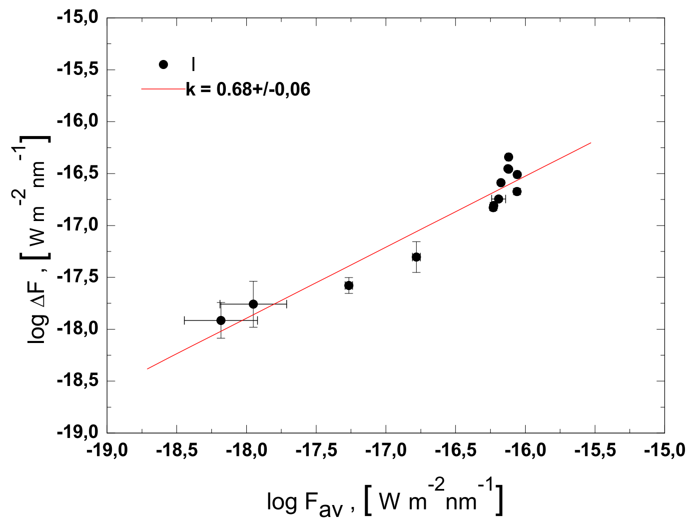

Fig. 4. The behaviour of the flickering amplitude versus the average flux in I_c

0.97, using the B,V and I_c bands. This indicates that there is a strong correlation between $\log F$ and $\log \Delta F$.

It is worth noting that the calculated contribution of the red and white dwarfs to the system brightness are probably slightly overestimated.

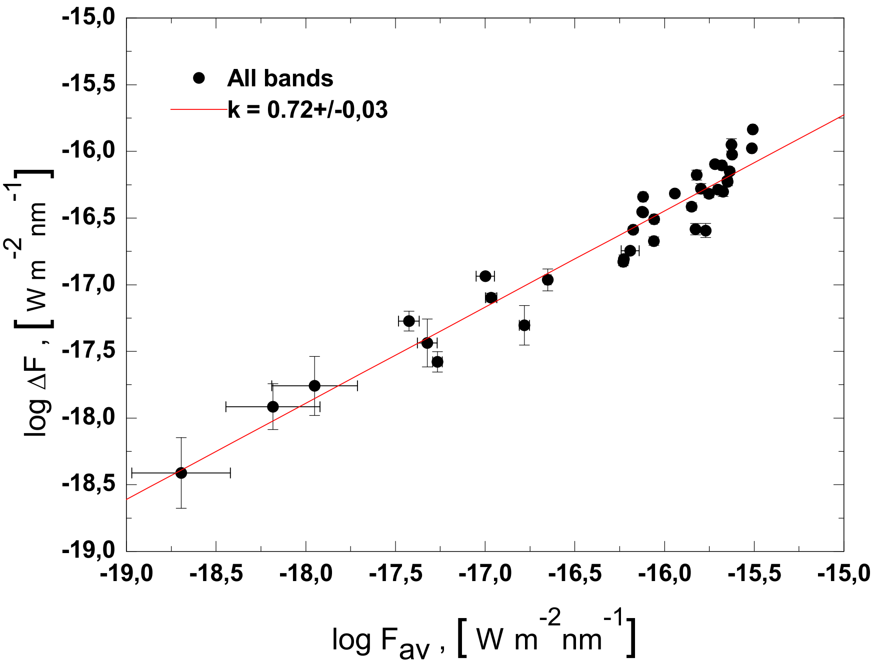

Fig. 5. The behaviour of the flickering amplitude versus the average flux in all bands together

However, there is not a considerable difference between the value of k obtained with and without subtraction of the contribution of the red and white dwarf. On average, for KR Aur we calculate the value of $k \approx 0.70 - 0.75$. Remarkably, this value is practically the same in all three (B,V,I$_c$) bands, indicating that this is a parameter of the flickering in KR Aur, which does not depend of the wavelength of the observations (at least in the optical bands).

For the symbiotic star CH Cyg, Mikolajewski et al. (1990) obtained in U band $k = 1.40 - 1.45$. Zamanov et al. (2004) obtained $k = 1.03 \pm 0.09$ for the recurrent nova T CrB, and no correlation for MWC 560. Here for KR Aur we get a lower value $k = 0.70 - 0.75$.

The origin of the flickering is not clear still. Bruch (1992) and Bruch & Duschl (1993) identify the boundary layer between the accretion disk and the white dwarf as the probable place for its origin. In this connection, possible reasons for the different behaviour of these three flickering sources (KR Aur, T CrB and CH Cyg) can be: (i) changes of the size of the boundary layer; (ii) changes of the position of the inner edge of the accretion disk; (iii) changes of the mass/size of accreting blobs.

Conclusion

We have observed the flickering of the anti-dwarf nova KR Aur in 11 nights in B band, 13 – in V, and 13 – in I$_c$ band, during the period 1999-2007, when the star brightness varied from $V \sim 13^m$ to $V \sim 19^m$. We obtained that the flickering amplitude depends on the mean flux ($\Delta F \propto F^k$, with k=0.70-0.75) in B, V and I$_c$ bands.

Our results pose the question: is there a systematic difference in the behaviour of the flickering amplitude between different objects and different classes (nova-like, dwarf novae, symbiotic stars, etc)?

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