Optical flickering of the symbiotic star CH Cyg

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Abstract. Here we present quasi-simultaneous observations of the flickering of the symbiotic binary star CH Cyg in U, B and V bands. We calculate the flickering source parameters and discuss the possible reason for the flickering cessation in the period 2010–2013.
Key words: stars: binaries: symbiotic – accretion, accretion discs – stars: individual: CH Cyg

1 Introduction

Symbiotic stars are interacting binaries. They consist of an evolved red giant or Mira-type variable, and a hot component — white dwarf, subdwarf, neutron star or main-sequence star. The hot component accretes material from the stellar wind of the donor (Sokoloski 2003). The wind is ionized by the hot component, causing the rise of a nebula. Orbital periods of the symbiotic stars range from years to decades.

CH Cyg is an eclipsing symbiotic star composed of a M6-7 III star and an accreting white dwarf, so the system belongs to the S-type symbiotics. The binary separation is $8.7^{+1.1}_{-0.7}$ AU (Mikołajewska et al., 2010). The masses of the components are $M_{\rm rg} = 2^{+1}_{-0.5}\,{\rm M}_{\odot}$ and $M_{\rm wd} = 0.70^{+0.22}_{-0.09}\,{\rm M}_{\odot}$ (Mikołajewska et al., 2010). Based on *Hipparcos* satellite measurements, the distance to CH Cyg is estimated to $d = 244^{+49}_{-35}$ pc (van Leeuven 2007). CH Cyg ejects collimated bipolar outflows with velocity of $\sim$700 km s^{-1}, detectable in the radio (Taylor, Seaquist & Mattei 1986; Crocker et al., 2001). The system is detectable also in X-rays (Galloway & Sokoloski 2004). The orbital period of CH Cyg is $\sim$15.6 yr (Hinkle, Fekel & Joyce 2009). The light curve of CH Cyg is very complex. The detected variability varies from dozens of years caused by the orbital motion and dust obscuration events (Bogdanov & Taranova 2001), through periodicity with periods of several hundred days caused by pulsations of the giant (Mikolajewski, Mikolajewska & Khudyakova 1992), to flickering activity with time-scales of a few minutes (Dobrzycka, Kenyon & Milone 1996).

Flickering is broad-band stochastic light variations on time-scales of a few minutes with amplitude from a few$\times$0.01 mag to more than one magnitude. Flickering activity is detected in only 10 symbiotic stars — RS Oph, T CrB, MWC 560, V2116 Oph, CH Cyg, RT Cru, *o* Cet, V407 Cyg, V648 Car and EF Aql (Dobrzycka, Kenyon & Milone 1996; Sokoloski, Bildsten & Ho 2001; Gromadzki et al. 2006; Angeloni et al. 2012; Zamanov et al., 2017).

The flickering of CH Cyg was first detected by Wallerstein (1968) and Cester (1968) and it was studied in detail later (Skopal 1988; Mikolajewski et al. 1990; Mikolajewski et al. 1992; Panov & Ivanova 1992; Kuczawska, Mikolajewski & Kirejczyk 1992; Hric et al. 1993; Dobrzycka, Kenyon & Milone 1996; Sokoloski & Kenyon 2003). CH Cyg is an eclipsing system (Mikolajewski, Mikolajewska & Tomov 1987), and the flickering activity disappears during the eclipses (Sokoloski & Kenyon 2003). In 2010, the flickering from CH Cyg became non-detectable (Sokoloski et al., 2010) until it renewed its activity in 2014 (Stoyanov et al., 2014). CH Cyg probably enters a new active stage in 2017 (Iijima 2017).

Here we present photometric observations of the flickering of CH Cyg and calculations of the flickering source parameters.

2 Observations

The observations are performed with the following three telescopes equipped with CCD cameras:

- the 60 cm Cassegrain telescope of Rozhen NAO
- the 50/70 cm Schmidt telescope of Rozhen NAO
- the automated 41 cm telescope of the University of Jaén, Spain (Martí, Luque-Escamilla, & García-Hernández 2017)

In Fig. 1 are plotted the light curves from a few nights. The observations consisted of repeated exposures in U, B and V bands, or in B and V bands. On 20110609 the total duration of the run is 86 minutes; 20141001 — 90 minutes; 20170724 — 66 minutes; 20170809 — 147 minutes; 20170811 — 284 minutes.

The data reduction was done using IRAF (Tody 1993) following standard procedures for aperture photometry. A few comparison stars from the list of Henden & Munari (2006) have been used, bearing in mind that SAO 31628 is an eclipsing binary (Sokoloski & Stone 2000).

The journal of observations is given in Table 1. In the table are given the telescope, band, number of exposures, exposure time, average magnitude, minimum and maximum magnitude during the run, and typical observational error.

3 Flickering source parameters

In our observations obtained during the period 2010–2013 the flickering of CH Cyg was not detectable (see Table 3 and Fig. 1). It re-appeared in August 2014. After that CH Cyg exhibited variability on a time scale of 1–30 minutes with amplitude 0.2 – 0.3 mag in V. The amplitude increases in B and U bands.

Bruch (1992) proposed that the light curve of CVs can be separated into two parts — constant light, and variable (flickering) source. We assume that all the variability in each night is due to flickering. In these suppositions the flickering light source is considered 100% modulated. Following these assumptions, we calculate the flux of the flickering light source as $F_{\rm fl} = F_{\rm av} -$

$F_{\rm min}$, where $F_{\rm av}$ is the average flux during the run and $F_{\rm min}$ is the minimum flux during the run (corrected for the typical error of the observations). $F_{\rm fl}$ has been calculated for each band, using the values given in Table 1 and the Bessel (1979) calibration for the fluxes of a zero magnitude star.

A modification of this method is given in Nelson et al. (2011), which proposed to use the $F_{\rm fl} = F_{\rm max} - F_{\rm min}$, where $F_{\rm max}$ is the maximum flux during the run. Adopting these, we find that the flickering light source contributes about 4% in V, 6% in B, and 8% in U (October 2014).

The calculated colours of the flickering light source are given in Table 2, where $T_{(B-V)_1}$ is calculated using F_{av} and $T_{(B-V)_2}$ is calculated using F_{max}.

Assuming that the flickering source radiates as a black body, for the colours of the black body we use the calibration given in Straižis (1977). The use of other formulae (e.g. Ballesteros 2012) could introduce a difference of about ± 500 K.

An independent estimate of the black body temperatures from the B-V colour using an analytic approximation (Ballesteros 2012) provides similar results with a difference not exceeding 1000 K.

The radius is calculated for B-V colour and B band flux, assuming effective wavelength of B band $\lambda = 4400$ Å, the temperature calculated from the B-V colour, assuming black body, spherical form of the flickering source, and a distance $d = 244pc$.

In a comparison of the temperatures, calculated using the method of Bruch (1992) and Nelson et al. (2011), we find that the temperatures are in agreement.

As expected, the method of Nelson et al. (2011) gives higher values for the size of the flickering source, because it uses greater flux.

In Table 2 are summarized the calculated flickering source parameters: (1) date of observations; (2) U-B colour of the flickering source calculated following Bruch (1992); (3) temperature corresponding to the U-B colour; (4) B-V colour of the flickering source calculated following Bruch (1992); (5) temperature corresponding to B-V colour; (6) radius of the flickering source calculated following Bruch (1992); (7) U-B colour of the flickering source calculated following Nelson et al. (2011); (8) temperature corresponding to the U-B colour; (9) B-V colour of the flickering source calculated following Nelson et al. (2011); (10) temperature corresponding to B-V colour; (11) radius of the flickering source calculated following Nelson et al. (2011).

4 Discussion

Parameters of the flickering source

The temperature of the flickering source is similar to the temperature of the bright spot in cataclysmic variable stars (e. g. Marsh 1988; Wood et al., 1989; Zhang & Robinson 1987) and it is significantly lower than the temperature of the boundary layer. This is a hint that the flickering probably originates from the bright spot, but its nature is still unknown. For comparison, the temperatures and radii of the flickering source in other symbiotic stars are comparable with those that we estimate for CH Cyg. For RS Oph, Zamanov et al. (2010) give $T_{fl} = 9500 \pm 500$ K and $R_{fl} = 3.5 \pm 0.5 R_{\odot}$.

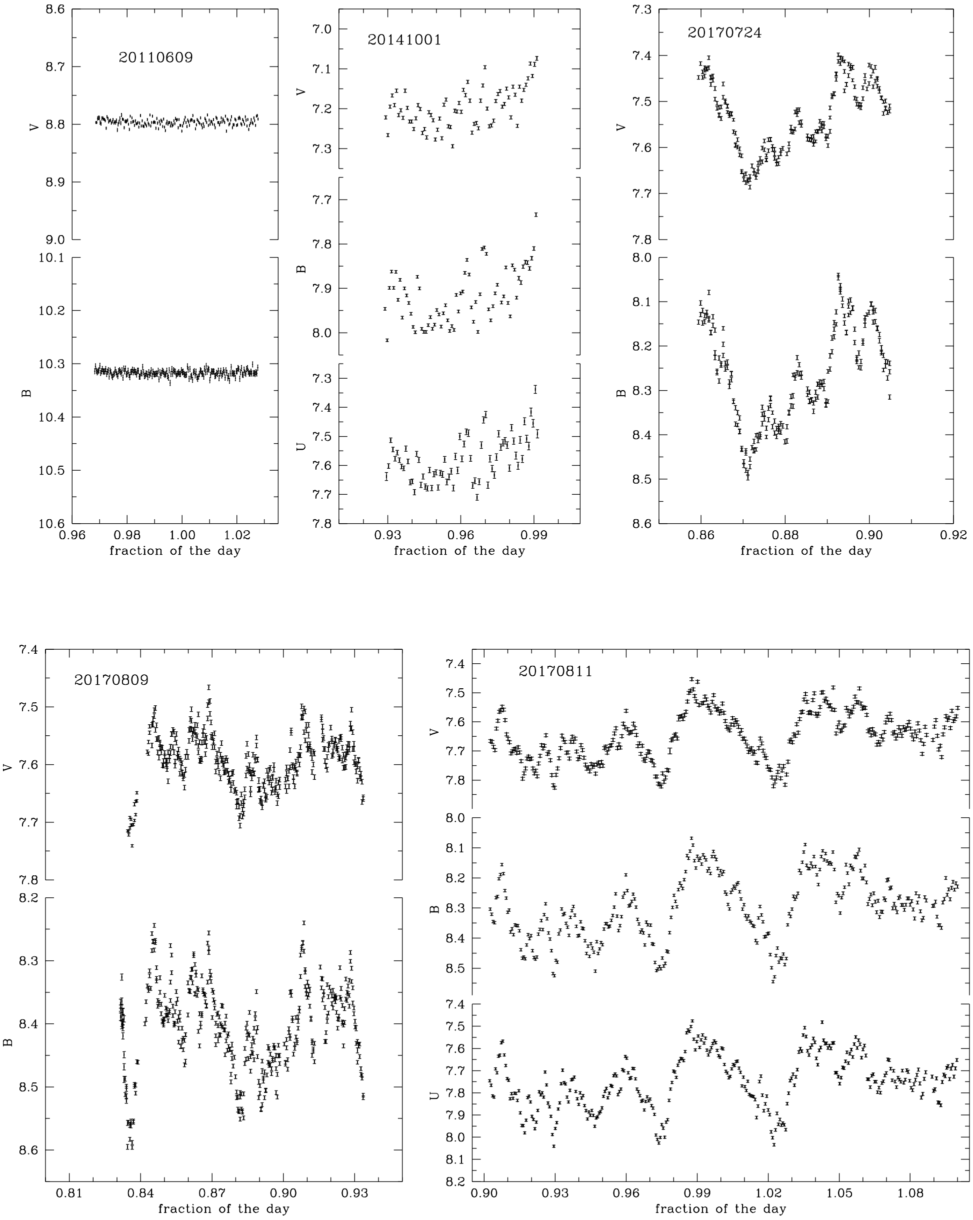

Fig. 1. Flickering of CH Cyg in U, B and V bands.

Table 1. Journal of observations.

date-obs	telescope	band	exposures	average	min	max	merr
20110609	60cm Roz	B	191 × 10s	10.317	10.301	10.336	0.005
20110609	60cm Roz	V	190 × 5s	8.796	8.784	8.812	0.002
20141001	60cm Roz	U	69 × 15s	7.578	7.344	7.714	0.009
20141001	60cm Roz	B	71 × 10s	7.916	7.735	8.017	0.003
20141001	60cm Roz	V	71 × 4s	7.197	7.074	7.294	0.004
20170724	41cm Jaen	B	200 × 3s	8.264	8.040	8.497	0.009
20170724	41cm Jaen	V	196 × 2s	7.533	7.399	7.686	0.005
20170809	41cm Jaen	B	417 × 6s	8.410	8.248	8.600	0.003
20170809	41cm Jaen	V	389 × 2s	7.666	7.547	7.827	0.004
20170811	50/70cm Roz	U	318 × 20s	7.748	7.476	8.041	0.007
20170811	50/70cm Roz	B	318 × 4s	8.298	8.068	8.545	0.005
20170811	50/70cm Roz	V	318 × 2s	7.649	7.453	7.826	0.005

Table 2. Flickering source parameters.

date-obs	$U-B$	$T_{(U-B)_1}$	$B-V$	$T_{(B-V)_1}$	$R/R_\odot$	$U-B$	$T_{(U-B)_2}$	$B-V$	$T_{(B-V)_2}$	$R/R_\odot$
1	2	3	4	5	6	7	8	9	10	11
20141001	-0.6439	9292	0.6782	5554	1.94	-0.6441	9284	0.4212	6992	2.07
20170724	—	—	0.3126	7895	1.20	—	—	0.2161	9049	1.42
20170809	—	—	0.5430	6231	1.62	—	—	0.5322	6299	2.24
20170811	-0.7134	9834	0.3211	7824	1.23	-0.7353	10723	0.3966	7195	2.10

Table 3. List of observations of CH Cyg. The last column indicates if the flickering is present or not.

date-obs	bands	flickering	date-obs	bands	flickering
20100430	BV	no	20110918	B	no
20100501	UB	no	20111006	B	no
20100502	B	no	20111118	B	no
20100506	B	no	20120618	B	no
20100507	UB	no	20120820	B	no
20100509	BV	no	20130514	BV	no
20100816	UB	no	20130703	B	no
20100817	BV	no	20130803	B	no
20100818	UB	no	20140814	B	yes
20100909	BV	no	20141001	UB	yes
20101029	UB	no	20170724	BV	yes
20101030	BV	no	20170809	BV	yes
20110529	B	no	20170811	UBV	yes
20110609	BV	no			

For MWC 560, Zamanov et al. (2011) give $T_{fl} = 13550 \pm 500$ K and $R_{fl} = 1.68 \pm 0.16 R_{\odot}$.

Why was the flickering missing for 4 years?

Flickering is expected to arise in the vicinity of the accretion disc around the white dwarf companion in CH Cyg. Its absence during a nearly four year time interval is most naturally interpreted as a major disruption of the inner disc structure. This is probably due to reduced supply of mass flow from the M-type giant across the L_1 Lagrangian point of the system. This situation, lasting in the period 2010–2013 according to Table 3, renders now difficult other alternative interpretations for the lack of flickering based on an eclipse configuration (Stoyanov et al. 2014). The required eclipse duration, at least four years, appears to be too long unless a highly eccentric system is invoked. Interestingly, in the CH Cyg case there is observational evidence based on infrared observations for episodic creation and dissipation of a dust envelope around it (Taranova & Shenavrin 2004). Such a behavior has been observed in the past. The creation and dissipation of a dust envelope is connected with a change of the mass-loss of the giant, which underwent a significant reduction during the 2010–2013 time interval. The time scale reported by Taranova & Shenavrin (2004) for previous dust envelope creation and dissipation events is ~ 10 yr. The cessation of the flickering is consistent with the giant undergoing a reduced mass-loss episode with a shorter, few year duration. Unfortunately, no contemporaneous infrared observations are available to us to confirm this hypothesis.

Conclusions

We performed quasi-simultaneous multicolour observations of the flickering of the symbiotic star CH Cyg in Johnson U, B and V bands. We calculated the flickering source parameters — the temperature is in the range $5000 < T < 11\,000$ K and the radius is in the range $1.42 < R/R_{\odot} < 2.24$. We briefly discuss the disappearance and re-appearance of the flickering.

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