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Studies of the flickering in cataclysmic variables

V. The recurrent nova T Coronae Borealis

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Abstract. The flickering activity in the recurrent nova and symbiotic star T CrB is investigated using light curves taken in the Johnson U band. In order to be able to compare the results with those of other CVs the contribution of the red giant secondary is first estimated and subtracted. It is found to be ≈10% on the average. The U band flux varies considerably over long time scales, but the ratio of the flux of the flickering light source and the quiet part of the primary remains constant. This is in contrast to the behaviour of dwarf novae around the outburst cycle. A wavelet analysis reveils a remarkable constancy of the distribution of flickering energy among different time scales as compared to other CVs. With the exception of the particular, not well understood feature that the activity can disappear temporarily, flickering in T CrB is on the whole indistinguishable from that in normal cataclysmic variables, in particular in classical novae, although the geometrical dimensions are very different. This is one more indication that the vicinity of a white dwarf, being of similar size in all CVs independent of their absolute dimensions, is the site of the flickering.

Key words: stars: individual: T CrB – stars: novae, cataclysmic variables – stars: binaries: symbiotic

1. Introduction

T CrB having undergone two full-fledged nova outbursts in 1866 and 1946 it is by definition a recurrent nova and thus a cataclysmic variable (CV). Its optical spectrum is dominated by a red giant of spectral type M2 III. In contrast, in the ultraviolet range the contribution of a hot component dominates (Selvelli et al. 1992). Moreover, emission lines of H I and sometimes the higher excitation line of He II 4686 in the optical (Iijima 1990) and many more emission lines in the UV (Selvelli et al. 1992) are detected. Thus, T CrB also exhibits the defining hallmarks of symbiotic stars (Allen 1984). There is a dispute in the literature concerning the nature of the hot component (throughout this paper we will refer to the hot component as the primary and to the red giant as the secondary to stay in line with the nomenclature used for CVs): The view of e.g. Kenyon & Garcia (1986) and Webbink et al. (1987) of a main sequence primary is contested by Selvelli et al. (1992) and Belczyński & Mikołajewska (1998) who present strong arguments in favour of the primary being a white dwarf. This question has a decisive bearing on the nature of the outbursts of T CrB: A mass transfer burst from the red giant secondary versus a thermonuclear runaway on the white dwarf as in other recurrent novae.

In both cases, accretion of matter onto the primary is inferred. Bruch (1995) made a case that in all systems where matter is accreted onto a central body stochastic brightness variations known as flickering occur. In most of the systems exhibiting flickering an accretion disk is involved. However, it appears also to be possible that accretion from a stellar wind of a companion star leads to flickering (e.g. CH Cyg, Mikołajewski et al. 1990). The first systematic study of the flickering phenomenon in CVs was performed by Bruch (1992) on the basis of light curves of 14 systems. This study as well as the work of Bruch & Duschl (1993) and Bruch (1996) identify the boundary layer between the white dwarf and the accretion disk as the most probable source of the flickering, while the hot spot – long thought to be the principal site of flickering (Warner & Nather 1971) – may play a subordinate role as a secondary flickering site in some systems. In interpreting the results of the present study this view will be adopted here.

Being a cataclysmic variable, T CrB is no exception to the rule that these stars flicker. Observations of its flickering behaviour have been reported among others by Walker (1977), Ianna (1964), and Bianchini & Middleditch (1976). The observed amplitude in the U band is typically $0\overset{\mathrm{m}}{.}1 - 0\overset{\mathrm{m}}{.}5$ on time scales of minutes. At longer wavelengths the amplitude drops rapidly due to the strong increase of the contribution of the red secondary to the total light. Flickering in T CrB is unusual in the sense that it apparently disappears sometimes (Bianchini & Middleditch 1976, Oskanian 1933, Mikołajewski et al. 1996b). In this contribution we present new observations of U band light curves of T CrB which are used to analyse the flickering behaviour.

2. Observations

The observations have been performed with a single channel photometer attached to the 60 cm telescope of the NAO Rozhen, Bulgaria, in the Johnson U band. HD 142929 and

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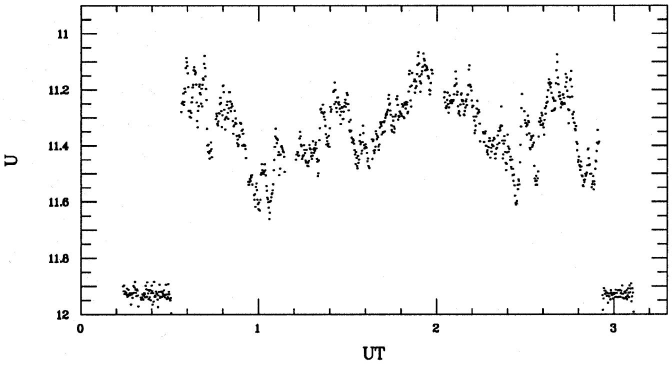

Fig. 1. Flickering light curve of T CrB of 1996, February 28. For comparison, the observations of the check star are shown at the beginning and end.

BD$+26^0$2761 served as comparison stars. Their constancy was checked against GSC 2037.1228. The light curves of T CrB were sampled with a time resolution of $10^{\rm s}$. A journal of the observations is given in Table 1. The Julian Date refers to the middle of the observations; N is the number of integrations. The primary data reduction was done with PDP software (Denchev 1998) while the MIRA software system (Bruch 1993) was used for the subsequent analysis. The accuracy of the reduction to the standard U band is estimated to be better than $\pm0\overset{\rm m}{.}04$, while the internal accuracy (standard deviation of the average of 10 consecutive measurements in regions of low flickering activity) is of the order of $0\overset{\rm m}{.}015 - 0\overset{\rm m}{.}030$. In Fig. 1 the first of the two the light curves of 1996, Feb. 28 is shown as an example of our data. Flickering of the order of a few tenths of a magnitude is evident.

The U magnitudes were converted into fluxes, adopting the zero-point $\log F(U) = -10.378$ Watt m^{-2} nm^{-1} (Bessell 1979). The results are also given in Table 1. $F_{\rm max}$, $F_{\rm min}$, $F_{\rm av}$ are minimum, maximum and average values for the corresponding night. $F_{\rm s}$ is the calculated contribution of the red giant (see Sect. 3.1).

3. Results and discussion

3.1. The contribution of the red giant secondary

Since flickering takes place in the primary component of a CV (Bruch 1995) the contribution of the secondary star (the red giant) to the U band should be subtracted before studying the flickering in T CrB.

The total flux of T CrB can be considered as being composed of 3 components: (1) $F_{\rm s}$, the flux of the secondary, (2) $F_{\rm Fl}$, the flux of the (modulated part of the) flickering light source, and (3) $F_{\rm p,q}$, the flux of the quiet (i.e. not flickering) part of the primary which is basically the light of that part of the accretion disk which is not involved in the flickering activity plus a contribution from the central body. The strong long term variations of T CrB in U (see Table 1) indicate that the latter is small because the white dwarf is not expected to be strongly variable. Each of the three components has its own spectral characteristic.

Let the ratio between the flux of the primary and the secondary component in the U band be

$$R(U) = \frac{F_{\rm p}(U)}{F_{\rm s}(U)} = \frac{F_{\rm p,q}(U) + F_{\rm Fl}(U)}{F_{\rm s}(U)} \tag{1}$$

The average flickering flux in a particular light curve, $F_{\rm Fl} = F_{\rm av} - F_{\rm min}$, can be calculated from the values listed in Table 1. Moreover, $F_{\rm min}$ is obviously the sum of $F_{\rm s}$ and $F_{\rm p,q}$. Thus:

$$\frac{F_{\rm p,q}(U) + F_{\rm s}(U)}{F_{\rm Fl}(U)} = \frac{F_{\rm min}(U)}{F_{\rm av}(U) - F_{\rm min}(U)} \equiv c \tag{2}$$

Using Eq. (1) to eliminate $F_{\rm Fl}(U)$ from Eq. (2) and solving for $F_{\rm p,q}(U)$ yields

$$F_{\rm p,q}(U) = \frac{[cR(U) - 1]\, F_{\rm s}(U)}{c + 1} \tag{3}$$

Since from Eq. (1) we have $F_{\rm Fl}(U) = R(U)\, F_{\rm s}(U) - F_{\rm pq}(U)$, we can express both, the flux of the flickering light source and the flux of the quiet primary component in terms of the flux $F_{\rm s}$ of the secondary star and the parameter $R(U)$.

In order to solve for $R(U)$ a further condition is required. This is given by demanding that the colour $U - V$ of the system must be equal to the observed colour. $U - V$ can be expressed as

$$U - V = -2.5 \, \log \left[\frac{F_{\rm s}(U) + F_{\rm p,q}(U) + F_{\rm Fl}(U)}{F_{\rm s}(V) + F_{\rm p,q}(V) + F_{\rm Fl}(V)} \, \frac{F_{\rm V,0}}{F_{\rm U,0}} \right] \tag{4}$$

where $F_{U,0}$ and $F_{V,0}$ are the calibration constants of the U and V bands for which the values of Bessell (1979) are adopted.

The fluxes of the individual components in the U and V bands are related through their spectral characteristics. The spectrum of the flickering light source is taken to be the mean from Table 4 of Bruch (1992) [disregarding T CrB in order to avoid circular reasoning, and the peculiar system AE Aqr (Bruch & Grütter 1997)]: $c_1 \equiv F_{\rm Fl}(U)/F_{\rm Fl}(V) = 2.99 \pm 0.85$. For the quiet primary component a spectrum of a standard steady state disk is assumed which over a wide range of wavelengths (in particular the range of interest here) can be approximated by $F(\lambda) \sim \lambda^{-7/3}$ (see e.g. Frank et al. 1985), leading to $c_2 \equiv F_{\rm p,q}(U)/F_{\rm p,q}(V) = 2.69$. The corresponding ratio for the secondary star is given by its colours which are assumed to be those of a normal M2 III star ($B - V$=1.60; $U - B$=1.85; Straižys 1979). Then, $c_3 \equiv F_{\rm s}(U)/F_{\rm s}(V) = (F_{\rm U,0}/F_{\rm V,0})\, 10^{-0.4(U-V)} = 0.048$.

In order to obtain robust results we will not try to determine $R(U)$ individually for each light curve but rather derive an average value. The mean, reddening corrected colours of T CrB are $(B - V)_0 = 1.13$ and $(U - B)_0 = 0.00$ (Bruch & Engel 1994), and thus $(U - V)_0 = 1.13$. From Table 1, $c = 6.7 \pm 2.3$ on the average.

With these values a ratio of the primary to secondary flux of $R(U) = 8.8 \pm 0.2$ is calculated. The corresponding ratio for the V band is $R(V) = 0.155 \pm 0.003$.

The error of $R(U)$ was propagated from the errors of c, c_1 and c_3 (in the latter case, an error in $(U - V)_{\rm s}$ caused by an uncertainty of ±1 spectral subclass of the red giant was assumed).

Table 1. Journal of observations of T CrB and monochromatic radiation fluxes in the U band [in 10^{-16} Watt m^{-2} nm^{-1}]

Date	UT from	UT to	JD 2400000+	Orbital phase	N	$F_{\rm min}$	$F_{\rm max}$	$F_{\rm av}$	$F_{\rm s}$
1993 Feb 28	0:17	2:14	49046.55	0.211	371	4.19	5.18	4.72	1.27
1993 Mar 1	1:03	1:23	49047.55	0.215	99	5.37	7.01	6.06	1.28
1994 Apr 10	23:06	23:55	49452.48	0.995	266	2.74	3.58	3.09	0.94
1995 Jun 20	20:24	22:05	49889.38	0.915	456	5.32	8.05	6.49	1.06
1996 Jan 10	4:01	4:32	50092.68	0.809	151	5.18	7.48	6.33	1.29
1996 Feb 28	0:34	2:55	50141.57	0.023	770	9.33	15.49	12.30	0.92
1996 Feb 28	23:46	26:55	50142.55	0.028	924	7.14	11.75	8.84	0.91
1996 Dec 16	2:59	3:38	50433.64	0.307	222	11.75	16.37	13.10	1.27
1996 Dec 18	3:15	3:39	50435.64	0.316	138	11.75	15.07	13.10	1.25
1997 Jan 28	1:19	3:27	50476.60	0.496	689	8.43	12.65	9.99	0.97
1997 Jan 29	1:43	3:22	50477.60	0.500	521	8.67	11.53	9.87	0.97
1997 Jan 30	2:22	3:43	50478.63	0.505	424	8.99	11.86	10.49	0.97
1997 Jan 31	1:17	3:35	50479.59	0.509	704	8.51	11.02	9.72	0.96
1997 Feb 1	0:55	3:25	50480.58	0.513	848	7.76	11.02	9.05	0.96
1997 Jul 21	20:25	21:43	50651.38	0.264	386	10.74	12.78	11.60	1.32
1997 Aug 27	19:57	20:43	50688.35	0.427	203	17.19	25.23	20.65	1.05

It is dominated by the error of c. Assuming a normal error distribution of c, c_1 and c_3, Monte Carlo simulations were performed. The resulting distribution in $R(U)$ is only approximately Gaussian having an extented (but faint) tail to high values. The quoted error is the parameter σ of a Gaussian fit to this only approximately Gaussian distribution and thus underestimates the true uncertainty slightly. Since the possible systematic error inherent in the assumptions leading to this result are not considered, the formal errors should be regarded as a lower limit to the true errors.

The contribution of the red giant in T CrB to the U band is thus of the order of 10%. This refers to the mean light of T CrB. As can be seen from Table 1 the flux averaged over a light curve can vary considerably from night to night and on longer time scales. Moreover, $F_{\rm s}(U)$ is modulated due to the ellipsoidal variations of the red giant. In order to be able to subtract the light of the secondary from each light curve individually, we assume that the value $R(V) = 0.155$ refers to $V = 10\overset{\rm m}{.}08$, i.e. the mean over the ellipsoidal variations according the to the empirical formula of Zamanov & Zamanova (1997). Since these variations are only due to the secondary, its V band flux can then be calculated as a function of the orbital phase. Together with the mean colours of an M2 giant (Straižys 1979) and a colour excess $E_{B-V} = 0.15$ (Cassatella et al. 1982), using $E_{U-V} = 1.7\,E_{B-V}$, this yields the flux of the giant in the U band which is quoted for the individual light curves in Table 1. These values were subtracted from the total light before the further analysis.

3.2. The relationship between flickering and quiet light

In order to investigate the relationship between the fluxes of the flickering light source and of the quiet primary component, we plot in Fig. 2 $F_{\rm Fl}$ (the average flux of the flickering in a particular light curve) as a function of $F_{\rm p,q}$ (the flux of the quiet, i.e. not modulated part of the primary). Following Bruch (1992), the different quantities are defined as:

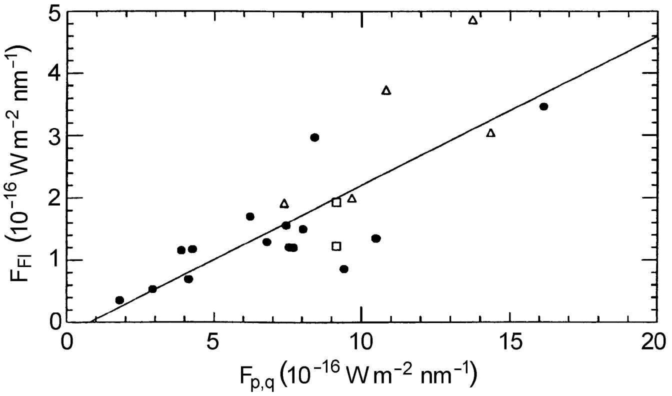

Fig. 2. The average flux of the flickering, $F_{\rm Fl}$, as a function of the average flux $F_{\rm p,q}$ of the quite primary in a light curve. The dots represent the present data, the squares data from Bruch (1992) and the triangles data from Oskanian (1983). The solid line is a formal linear least squares fit.

$$F_{\rm p,q} = F_{\rm min} - F_{\rm s},$$
$$F_{\rm Fl} = F_{\rm av} - F_{\rm min}.$$

The quantities at the right hand side of these equations are taken from Table 1. Additionally, Fig. 2 contains the data of Bruch (1992) (corrected for the dereddening he had applied to his data and for the difference in the zero-point of the flux scale adopted by him and us) and of Oskanian (1983). For the latter data we assume that $\Delta u = 0$ corresponds to $U = 11\overset{\rm m}{.}83$. Only positive detections of the flickering in Oskanian's data were used.

It is, of course, expected that $F_{\rm Fl}$ rises with $F_{\rm p,q}$. However, it is a priori not self-understood that this rise is linear. Although the data points in Fig. 2 scatter considerably[1] there is no indication of a significant deviation from linearity. The flux of the quiet primary is supposed to be due to the accretion disk with a certain contribution of the central star. A linear least squares fit to the data in Fig. 2 yields:

$$F_{\rm Fl} = (-0.19 + 0.24\,F_{\rm p,q})\ 10^{-16}\,{\rm W\,m^{-2}\,nm^{-1}}$$

If the flickering flux is strictly proportional to that of the accretion disk, it must obviously vanish if the latter is zero. The slightly negative zero-point of this relation is in apparent contradiction to this notion. Of course it is easily explained by statistical uncertainties. However, it may also be due to the contribution of the central star to $F_{\rm p,q}$.

Standard disk theory predicts that the luminosity of the disk is proportional to the mass transfer rate. The average U band flux at different epochs, as observed by us, varies by a factor of about 7. Selvelli et al. (1992) even observed flux variations up to a factor of 20 in the integrated UV light. Unless the spectral energy distribution changes significantly with the U brightness, the mass transfer rate through the disk varies by the same amount. It is remarkable that the ratio of flickering to quiet flux remains constant in spite of the large brightness variations. This is not so in all cataclysmic variables: Fritz & Bruch (1998) showed that the amplitude of the flickering in several dwarf novae varies with the square root of the mean system brightness around the outburst cycle. Such systems are not in a steady state during quiescence, receiving more matter from the secondary than is transferred to the central white dwarf, while during outburst the excess matter accumulated in the disk is dumped onto the latter. The different behaviour of T CrB suggests that in this system matter is transferred at the same rate from the secondary through the accretion disk onto the central body. Thus, in this respect T CrB can be regarded as being in a steady state. It is then close at hand to consider mass transfer variations from the secondary as begin responsible for the longer term brightness variations. The inferred time scales of days to weeks appear reasonable for atmospheric activity in the giant star and agree also with the viscous time scale of the accretion disk.

In a model of a radially extended boundary layer, Bruch & Duschl (1993) showed that the ratio $F_{\rm Fl}/F_{\rm p,q}$ is a measure of the size of the boundary layer between the accretion disk and the white dwarf in CVs. The constancy of this ratio then implies – within the limitation of their model – that the size of the boundary layer remains practically constant in spite of a widely varying mass accretion rate.

As a caveat we have to mention that the above considerations are only valid, if the degree of modulation of the flickering light source does not change with its luminosity, since only then the observable flickering (i.e. the modulated part of the flickering light source) will scale linearly with the flux generated in the boundary layer and thus with the mass accretion rate onto the central star. The above mentioned observations of dwarf novae around the outburst cycle may indicate that this is not always true!

3.3. *Wavelet analysis*

Fourier techniques are sometimes applied to study the statistical properties of flickering in CVs (e.g. Elsworth & James 1982, 1986). Fourier transforms being based on sinusoids, such techniques are not ideally suited since the flickering flares have approximately triangular shape rather than resembling sinusoids. Therefore, a wavelet transform – using a mother wavelet with a shape adjusted to that of flickering flares – appears to be more appropriate for this purpose. Recently, Fritz & Bruch (1998, hereafter FB98) have pioneered this method and applied it to a large number of light curves of many CVs.

This is not the place to give a detailed account of this new technique. For a general introduction to the theory of wavelets and its application to stochstic data, we refer e.g. to Jawerth & Sweldens (1993), Chui (1992), and Scargle et al. (1993). The special points to be considered in connection with flickering light curves are discussed in detail by FB98. Here, we will only give a short summary.

The wavelet transform permits the decomposition of a signal according to a localized function, the (finite) carrier of which is tied to the investigated scale. The base functions – the wavelets – are scaled version of a fundamental function, the mother wavelet. The wavelet transform of a time dependent signal is then a representation of the signal in time *and* frequency. However, flickering being a stochastic signal, it is not of much interest to know exactly when a particular event occurs, but rather the distribution of variations among different time scales. For the analysis of such data, Scargle et al. (1993) introduce the scalegram, which is basically a measure of the variances of the wavelet coefficients as a function of the time scale. Suitable normalized (energy normalization; FB98) to permit a direct comparison of results from light curves obtained under different conditions, it describes the variance of the modulated part of the light curve in units of the mean of the square of all data points.

We calculated scalegrams of all suitable light curves of T CrB, using the coiflet C12 (Daubechies 1992) as mother wavelet which was found by FB98 to be most suitable for an analysis of flickering data. Since all light curves were transformed into a well defined photometric system (Johnson U) an energy normalization is in principal not required. The scalegrams are then given as the variances of the wavelet coefficients expressed in absolute units. However, in order to be able to compare the present results with those of FB98, it is preferred to use the normalized scalegrams here.

For each light curve the mean normalized scalegram after 100 bootstrap replications (Efron & Tibshirani 1993) – performed in a way to account for the fact that the points in a flickering light curve are not statistically independent (FB98) – is shown in Fig. 3. With a single exception (the light curve of 1997, July 21) all scalegrams are very similar. They differ somewhat in their vertical location in the diagram, reflecting

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[1] Note that it is not possible to assign errors to the individual points because they are derived from properties of a *stochastically* varying light curve. The determination of errors would require repeated observations of such light curves, T CrB being *in the same state*. This can obviously not be done.

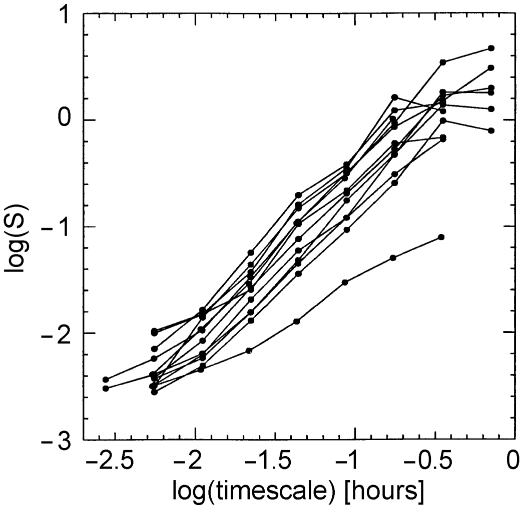

Fig. 3. Scalegrams of the light curves of T CrB.

night to night variations of the strength of the flickering relative to the unmodulated background light (basically the quiet accretion disk), but their shape is remarkably stable. Disregarding the very long time scales where the scalegram is statistically uncertain, and the very short ones where Poisson noise begins to become dominant, the scalegrams rise linearly from small to long time scales on the double logarithmic scale. This is typical for flickering of all CVs (FB98) and reflects the self similar nature of these stochastic variations (Steiman-Cameron et al. 1994).

The linear rise of the scalegrams permits a simple parametrization: For easy comparison with scalegrams of light curves of other systems, its essence can be condensed into two parameters: The first is the inclination α of a straight line fitted to the linear part of the scalegram points in the double logarithmic diagram. The second parameter is $\Sigma = \log S(t_{\rm ref})$, where S is the scalegram value and $t_{\rm ref}$ is a reference time scale (FB98). Thus Σ is a measure of the strength of the flickering, while α describes the distribution of the energy of the flickering signal among different time scales. α is always found to be > 0, reflecting the obvious fact that flickering on long time scales is stronger than on short ones. However, the smaller $|\alpha|$ is, the more similar is the flickering strength on all time scales.

Adopting the same weighting scheme for the scalegram points and the value $t_{\rm ref} = 3^{\rm m}$ as chosen by FB98, the values of α and Σ for the individual light curves of T CrB were calculated and are summarized in Table 2. They are plotted against each other in Fig. 4. It is seen that α is confined to a particularly narrow range, very close to the mean value for all classical novae (see Fig. 11 of FB98). On the other hand there is a larger dispersion in the parameter Σ. Thus the relative contributions of the flickering light varies considerably with time while the distribution among different time scales remains largely constant. The mean value of Σ being larger than that of the mean of other novae is easily explained by the different bands: while the present data were observed in the U band, the bulk of the data of FB98 were observed in B or white light. An adjustment of the order of 0.5 – 1 in Σ – the typical difference of Σ obtained from simultaneous data in U and B (see Fig. 9 of FB98) – brings the Σ values for T CrB well into the range of the bulk of classical novae. Thus, concerning the statistical properties of the flickering T CrB appears to be indistinguishable from classical novae.

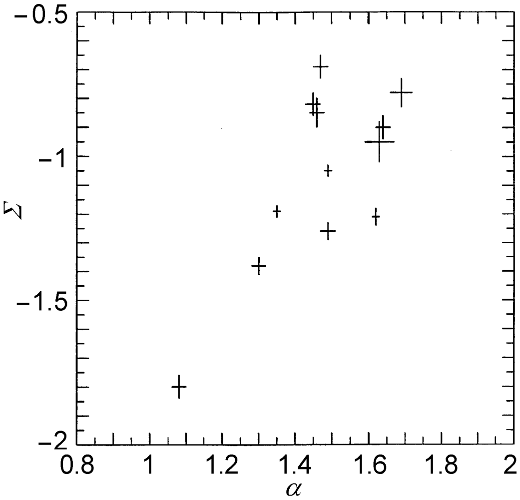

Fig. 4. Scalegram parameter Σ as a function of α for the light curves of T CrB

Table 2. Scalegram parameters α and Σ.

Date	α	Σ
1993 Feb 28	1.63 ± 0.04	−0.95 ± 0.07
1994 Apr 10	1.69 ± 0.03	−0.78 ± 0.05
1995 Jun 20	1.47 ± 0.02	−0.69 ± 0.04
1996 Feb 28	1.45 ± 0.02	−0.82 ± 0.04
1996 Feb 28	1.64 ± 0.02	−0.90 ± 0.04
1997 Jan 28	1.49 ± 0.01	−1.05 ± 0.02
1997 Jan 29	1.62 ± 0.01	−1.21 ± 0.03
1997 Jan 30	1.35 ± 0.01	−1.19 ± 0.02
1997 Jan 31	1.30 ± 0.02	−1.38 ± 0.03
1997 Feb 1	1.49 ± 0.02	−1.26 ± 0.03
1997 Jul 21	1.08 ± 0.02	−1.80 ± 0.04
1997 Aug 27	1.46 ± 0.02	−0.85 ± 0.05

FB98 found for many systems a positive correlation between α and Σ or at least a tendency for Σ to increase with α. As is shown in Fig. 4 this is also the case for T CrB. A formal analysis yields a correlation coefficient of $r = 0.73$ which – at a false alarm probability of 1.9×10^{-3} – is significant. The correlation has an inclination of 1.35. Thus Σ increases with α at a similar rate as other systems listed in Table 2 of FB98, indicating a systematic redistribution of flickering energy between time scales as the strength of the flickering varies.

We searched for correlations of α and Σ with the total system brightness which, however, do not exist. In agreement with the findings of FB98 systematic variations of α and Σ over the years could also not be detected. They rather appear to be stochastic.

3.4. Temporary absence of flickering

Flickering is present in all our observations. However Bianchini & Middleditch (1976), Oskanian (1983), Mikołajewski et al. (1996b) report that sometimes flickering is not detected. The only other CV where a temporary disappearance of flickering occurs is AE Aqr. However, in that case phases of strong variability and quiet phases alternate irregularly on time scales of hours (Bruch 1991, van Paradijs et al. 1989), whereas in T CrB much larger time scales of the order of weeks are involved, suggesting the reasons to be different.

The flickering can disappear either (1) because the flickering light source is screened by some other component of the T CrB system, or (2) because its degree of modulation decreases strongly, or (3) because it is temporarily extinguished. We will discuss these possibilities in turn.

Screening by other system components cannot easily explain the disappearance of flickering. T CrB not being an eclipsing system – Kraft (1958) derived an orbital inclination of $i = 60°$ – the red giant cannot eclipse a flickering light source close to the centre of the accretion disk. If the central body were magnetic and for some reason accretions occurs only onto one limited range of its surface self eclipses by the primary are possible. In that case the disappearance should occur periodically, something which the sparse data do not permit to confirm. However, the involved time scales of weeks would demand a very slowly rotating central star, difficult to envisage if it is indeed a white dwarf (Selvelli et al. 1992). Other possibilities to screen the flickering light source temporarily from view might be thought of (precession and/or a twisted shape of the accretion disk; a flared outer disk rim). However, lacking more substantial evidence for such structures it is premature and highly speculative to consider them further.

The second alternative, a strongly decreased degree of modulation of the flickering light source, would imply a change of the accretion of matter onto the central body from an unsteady to a steady mode. The reasons for such a change are necessarily obscure as long as no convincing model for the details of the accretion process exists. In the picture of a magnetic white dwarf as the central body matter may be accreted from the disk–magnetosphere boundary in form of discrete blobs (Gosh & Lamb 1979). These blobs can fall either more or less intact onto the white dwarf or they break up into smaller pieces (Arons & Lea 1980). In the second case accretion is much more steady and thus the flickering activity should decrease. However, it remains unclear what should cause the change in accretion behaviour.

Finally, the disappearance of flickering could be due to a temporary extinction of the underlying light source. If flickering is indeed due to unsteady mass accretion this would imply that the central body stops accreting matter.

In principle this could happen if the mass transfer from the secondary is cut off e.g. by a temporary detachment of its surface from the Roche limit [but note that Yudin & Munari (1993) did not observe intrinsic variations of the red giant in the IR]. Matter would then drain from the accretion disk without being resplenished. The time scale for the disk to disappear is the time it takes for a particle at the outer disk rim to reach the central body. If the disk radius is of the order of 30% of the component separation as in other CVs (Bruch 1992, see also Selvelli et al. 1992), then standard steady state disk theory (Frank et al. 1985) – assuming a viscosity parameter $\alpha = 0.1$, $M_1 = 1.4\,M_\odot$ and $\dot{M} = 1.5 \times 10^{18}\mathrm{g\,sec}^{-1}$ – predicts a time scale of the order of 30 years for the disappearance of the disk (mainly due to the large dimensions of the T CrB system compared to other CVs); much longer than the observed time scales. However, repeating the same excercise regarding only the optically thick part of the disk with a radius of the order of $1\,R_\odot$ (Sevelli et al. 1992) – disregarding the tenuous outer disk regions – results in a time scale of ∼60 days and thus in a much better agreement with the observations. Without the disk a considerable decrease of the UV brightness is expected, only the central star being left as a UV source. This is observed to a certain degree by Oskanian (1983) and Mikołajewski et al. (1996b), but not by Bianchini & Middleditch (1976).

Mikołajewski et al. (1996a) recently suggested an accretor–propeller model to explain the properties of the symbiotic stars CH Cyg and MWC 560: a rotating magnetic white dwarf undergoes transitions from an accreting state – flickering is then expected and observed – to a propeller state in which the transferred matter is expelled from the system when it reaches the magnetospheric boundary – thus suppressing accretion and hence flickering – and vice versa. They point out that T CrB is another candidate for such a system. This would also be a way to explain the temporary disappearance of flickering.

Which of the discussed scenarios is in fact realized (if any) cannot be decided on the basis of the presently available limited data.

4. Conclusions

No self consistent picture of the mechanism leading to flickering exists as yet. In this contribution we studied the flickering in a CV which is untypical in the sense that its geometrical dimensions are much larger than those of normal CVs. Nevertheless, with the exceptions of the temporary disappearance, the overall flickering behaviour is indistinguishable from that in other CVs, in particular of classical novae.

T CrB containing a red giant which contributes significantly to the (visual) flux of the system, it is important to correct the total light for this contribution before comparing the flickering properties with those of other CVs. It is found that on the average the secondary contributes almost 90% to the radiation in V, but only 10% in the U band where the present observations were made.

We find that the flux F_{Fl} of the (modulated part of the) flickering light source increases linearily with the flux $F_{\mathrm{p,q}}$ of the quiet primary component at least over a factor 7 in $F_{\mathrm{p,q}}$. This is different from the behaviour of dwarf novae in the outburst cycle where the ratio $F_{\mathrm{Fl}}/F_{\mathrm{p,q}}$ generally decreases with increasing $F_{\mathrm{p,q}}$. In the model of Bruch & Duschl (1993) this behaviour indicates that the boundary layer in T CrB is independent of the mass accretion rate.

We have applied a recently developped method to investigate flickering via wavelet transforms to T CrB. It is found that the distribution of the flickering energy among different time scales varies systematically with its strength but remains within narrower limits than observed in most other CVs. In this respect, flickering in T CrB is remarkably stable.

An unusual feature of the flickering in T CrB is its temporary absence. Some possible scenarios to explain this behaviour are discussed, but the available data do not permit to settle down on a particular one.

T CrB being at the same time a CV and a symbiotic star, it is interesting to note that its flickering behaviour is not different from that of normal CVs, in spite of the vastly different dimensions of (most) CVs and symbiotic stars. This suggests strongly that it is related to a structurally similar region in both types of system, which we consider to be the immediate vicinity of a white dwarf.

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