New Astronomy 52 (2017) 112–121

Contents lists available at ScienceDirect

New Astronomy

journal homepage: www.elsevier.com/locate/newast

Photometry of some neglected bright cataclysmic variables and candidates☆

Albert Bruch*

Laboratório Nacional de Astrofísica, Rua Estados Unidos, 154, Itajubá, CEP 37504-364, MG, Brazil

HIGHLIGHTS

- The light curves of CZ Aql, BO Cet, V380 Oph and EF Tuc are dominated by strong flickering.
- The absence of flickering in Lib 3 permits to exclude the star from the list of CV candidates.
- Orbital variations are observed in BO Cet and V380 Oph but not in CZ Aql and EF Tuc.
- CZ Aql may exhibit superhump-like variations.
- Circumstantial evidence points at a possible magnetic nature of CZ Aql.

ARTICLE INFO

Article history:
Received 3 October 2016
Accepted 23 October 2016
Available online 1 November 2016

Keywords:
Stars: novae
Cataclysmic variables – Stars: individual:
CZ Aql - BO Cet - V380 Oph - EF Tuc - Lib 3

ABSTRACT

As part of an effort to better characterize bright cataclysmic variables (CVs) which have received little attention in the past light curves of four confirmed systems (CZ Aql, BO Cet, V380 Oph and EF Tuc) and one candidate (Lib 3) are analyzed. For none of these stars time resolved photometry has been published previously. While no variability was found in the case of Lib 3, which thus cannot be confirmed as a CV, the light curves of all other targets are dominated by strong flickering. Modulations on hourly time scales superimposed on the flickering can probably be related to orbital variations in BO Cet and V380 Oph, but not in CZ Aql and EF Tuc. Variations on the time scale of 10 min in CZ Aql, while not yet constituting convincing evidence, together with previous suspicions of a magnetically channeled accretion flow may point at an intermediate polar nature of this star. Some properties of the flickering are quantified in an effort to enlarge the data base for future comparative flickering studies in CVs and to refine the classification of the target stars.

1. Introduction

Cataclysmic variables (CVs) are binary stars where a Roche-lobe filling late-type component (the secondary) transfers matter via an accretion disk to a white dwarf primary. It may be surprising that even after decades of intense studies of CVs there are still an appreciable number of known or suspected systems, bright enough to be easily observed with comparatively small telescopes, which have not been studied sufficiently for basic parameters such as the orbital period to be known with certainty. In some cases even their very class membership is not confirmed.

Therefore, I started a small observing project aimed at a better understanding of these so far neglected stars. First results have been published in Bruch (2016) and Bruch and Diaz (2017). Here, I discuss light curves of some further targets of the project for which no time resolved photometry has yet been published. They were observed in order to verify the presence of flickering typically observed in CVs and to try to measure the orbital period photometrically (or to confirm suspected periods).

It is well known that accretion of mass via a disk onto a central object normally leads to apparently stochastic brightness variations termed flickering. It occurs to a more or less obvious degree in objects as diverse as Active Galactic Nuclei (Garcia et al., 1999), certain stages of star formation (Herbst and Shevchenko, 1999; Kenyon et al., 2000; Scaringi et al., 2015), x-ray binaries (van der Klis, 2004) or some (but not all) symbiotic stars (Gromadzki et al., 2006). The time scales of such variations and the spectral range in which they most prominently appear depend on the nature of the particular system. In the optical range flickering is by far most conspicuous in CVs where it leads to variability typically on time scales of the order of minutes and with amplitudes which can range from a few millimagnitudes to more than an entire magnitude. For a general characterization of flickering in CVs, see Bruch (1992).

☆ Based on observations taken at the Observatório do Pico dos Dias/LNA.

* Tel: +553536298111; Fax: +553536298192.
E-mail address: albert@lna.br

http://dx.doi.org/10.1016/j.newast.2016.10.013
1384-1076/

While the strength of the flickering, as measured by its total amplitude, depends heavily on the individual system and its momentary photometric state no photometric observations of well established CVs obtained with a suitable time resolution and signal-to-noise ratio, of which the present author is aware, ever showed the absence of flickering, unless the respective system was in a state of (temporary) suspension of mass accretion onto the white dwarf. Thus, the presence of flickering appears to be a necessary (but not sufficient) condition for a star to be classified as a cataclysmic variable.

While flickering by itself is a fascinating and still not well understood phenomenon, it can also be a severe obstacle to find and characterize modes of variability in CVs which may have similar amplitudes but are due to different mechanisms. Thus, orbital variations caused by the changing aspect of the system around the orbit may easily be masked by flickering. This is the case in particular in systems with a low or intermediate orbital inclination where such variations remain small and in the presence of flickering may only be detected when observations over many cycles are averaged.

The objects discussed in the present paper are four systems taken from the most recent on-line version of the Ritter & Kolb catalogue (Ritter and Kolb, 2003) which have only unconfirmed or uncertain orbital periods. These are CZ Aql, BO Cet, V380 Oph and EF Tuc. To these I add Lib 3 (= Preston 874124), an unconfirmed CV listed in the catalogue of Downes et al. (2005) and classified as being of UX UMa subtype.

In Section 2 the observations and data reduction techniques are briefly presented. Sections 3–7 deal with the individual objects of this study, focusing on orbital variations, while in Section 8 the rapid variations observed in four of the five targets are collectively quantified. Finally, a short summary in Section 9 concludes this paper.

2. Observations and data reductions

All observations were obtained at the 0.6-m Zeiss and the 0.6-m Boller & Chivens telescopes of the Observatório do Pico dos Dias, operated by the Laboratório Nacional de Astrofísica, Brazil. Time series imaging of the field around the target stars was performed using cameras of type Andor iKon-L936-B and iKon-L936-EX2 equipped with back illuminated, visually optimized CCDs. In order to resolve the expected rapid flickering variations the integration times were kept short. Together with the small readout times of the detectors this resulted in a time resolution of the order of 5^s. In order to maximize the count rates in these short time intervals no filters were used. Therefore, it was not possible to calibrate the stellar magnitudes. Instead, the brightness is expressed as the magnitude difference between the target and a nearby comparison star. This is not a severe limitation in view of the purpose to the observations. A rough estimate of the effective wavelength of the white light band pass, assuming a mean atmospheric extinction curve, a flat transmission curve for the telescope, and a detector efficiency curve as provided by the manufacturer, yields $\lambda_{eff} \approx$ 5530 Å, very close to the effective wavelength of the Johnson V band (Allen, 1973, 5500 Å).

A summary of the observations is given in Table 1. Some light curves contain gaps caused by intermittent clouds or technical reasons. Basic data reduction (biasing, flat-fielding) was performed using IRAF. For the construction of light curves aperture photometry routines implemented in the MIRA software system (Bruch, 1993) were employed. The same system was used for all further data reductions and calculations. Throughout this paper time is expressed in UT. However, whenever observations taken in different nights were combined (e.g., to search for orbital variations) time was transformed into barycentric Julian Date on the Barycentric Dynamical Time (TDB) scale using the online tool provided by Eastman et al. (2010) in order to take into account variations of the light travel time within the solar system. Timing analysis of the data employing Fourier techniques was done using the Lomb–Scargle algorithm (Lomb, 1976; Scargle, 1982; Horne and Baliunas, 1986) unless specified otherwise. The terms "power spectrum" and "Lomb–Scargle periodogram" are used synonymously for the resulting graphs.

Table 1
Journal of observations.

Name	Date	Start (UT)	End (UT)
CZ Aql	2014 Jun 17	3:31	8:54
	2014 Jun 19	2:40	8:31
	2014 Aug 25/26	22:46	4:06
	2014 Sep 21/22	22:16	2:28
	2014 Sep 22	21:44	23:12
	2014 Sep 23	21:47	23:13
	2014 Sep 24	21:56	23:22
BO Cet	2014 Sep 23	5:21	8:14
	2014 Sep 24	5:12	8:10
	2014 Oct 23	1:31	3:10
	2016 Aug 11	5:49	8:51
	2016 Aug 12	5:55	8:44
Lib 3	2016 Jun 27/28	21:16	2:55
V380 Oph	2014 Jun 18	1:00	6:37
	2014 Jun 20	4:36	6:05
	2014 Jun 22	2:37	4:30
EF Tuc	2014 Jun 18	8:02	8:44
	2014 Jun 23	4:06	8:56
	2014 Aug 26	4:50	8:43
	2014 Sep 22	2:39	8:13
	2014 Sep 22/23	23:20	5:11
	2014 Sep 23/24	23:22	5:05
	2014 Sep 24/25	23:27	2:19
	2015 Aug 11	7:40	8:47
	2015 Aug 12	7:18	8:41
	2015 Aug 13	6:52	8:51
	2015 Aug 14	7:06	8:59
	2015 Aug 15	7:01	8:41

3. CZ Aql

CZ Aql was discovered as a variable star by Reinmuth (1925) who did not provide a classification. Based on spectroscopic evidence, Cieslinski et al. (1998) considered the star to be a dwarf nova and suspected an orbital period of 4.8 h. This is confirmed by Sheets et al. (2007) who find $P_{orb} = 0.2005$ days = 4.812 h but cannot distinguish between aliases ranging between 4.798 and 4.826 h. Based on a detailed spectroscopic analysis they suspect CZ Aql to contain a magnetically channeled accretion flow.

CZ Aql was observed in seven nights between 2014, June 17 and September 24. Representative light curves, drawn on the same time and magnitude scale to ease comparison, are shown in Fig. 1. Differential magnitudes are given with respect to the comparison star UCAC4 415-122382 (Zacharias et al., 2013, $V = 14^{m}_{.}122$;). This translates into a rough average nightly magnitude of CZ Aql between $15^{m}_{.}0$ and $15^{m}_{.}3$ which is on the faint end of the distribution of the few magnitude estimates in the data base of the American Association of Variable Star Observers (AAVSO).

The light curves are dominated by flickering superposed on more gradual variations on the time scale of several hours, most clearly visible on 2014, Aug 25 (Fig. 1). In fact, adjusting a sine curve to the data of that night alone gives a best fit at a period of 4.704 h, just slightly shorter than but still compatible with the spectroscopic period determined by Sheets et al. (2007). In order to investigate if the variations can be explained as a periodic mod-