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Time resolved spectroscopy and photometry of three little known bright cataclysmic variables: LS IV −08° 3, HQ Monocerotis and ST Chamaeleontis☆

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HIGHLIGHTS

- The spectra of all investigated systems are as expected for their respective class.
- The orbital ephemeris of LS IV −08° 3 have been improved.
- Doppler mapping of LS IV −08° 3 reveal distinct emission sites (outer accretion disk and illuminated secondary star).
- Tentative orbital periods of 0.21462 days and 0.229 days are derived for HQ Mon and ST Cha, respectively.
- Light curves of all systems are discussed.

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ABSTRACT

As part of a project to better characterize comparatively bright but so far little studied cataclysmic variables in the southern hemisphere, we have obtained spectroscopic and photometric data of the nova-like variables LS IV −08° 3 and HQ Mon, and of the Z Cam type dwarf nova ST Cha. The spectra of all systems are as expected for their respective types. We derive improved orbital ephemeris of LS IV −08° 3 and map its accretion disk in the light of the Hα emission using Doppler tomography. We find that the emission has a two component origin, arising in the outer parts of the accretion disk and possibly on the illuminated face of the secondary star. The light curve of LS IV −08° 3 exhibits a low level of flickering and indications for a modulation on the orbital period. Spectroscopy of HQ Mon suggests an orbital period of $\approx 5^{h}.15$ which is incompatible with previous (uncertain) estimates. The light curves show the typical low scale flickering of UX UMa type nova-like systems, superposed upon variations on longer time scales. During one night a modulation with a period of $\approx 41^{m}$ is observed, visible for at least 4 hours. However, it does not repeat itself in other nights. A spectroscopic orbital period of $\approx 5^{h}.5$ is derived for ST Cha. A previously suspected period of $6^{h}.8$ (or alternatively $9^{h}.6$), based on historical photographic photometry is incompatible with the spectroscopic period. Moreover, we show that our new as well as previous photometry does not contain evidence for the quoted photometric period.

1. Introduction

Cataclysmic variables (CVs) are interactive binaries where a late type, low mass star which is normally on or close to the main sequence transfers matter to a white dwarf. For a general and encompassing introduction to CVs, see Warner (1995) or Hellier (2001). The number of known systems of this kind has grown enormously in recent years mainly due to numerous detections of CVs in large scale surveys. However, most of these newly discovered systems are rather faint in their normal brightness state. Therefore, the characterization of their individual properties is expensive because is requires large telescopes.

On the other hand, it is much easier to perform detailed studies of the brighter CVs, most of which are known for a long time. It is therefore surprising that even among these stars an appreciable number has not yet been adequately characterized to be certain about basic parameters such as the orbital period. In some cases even the very class membership is not confirmed.

We therefore started a small observing program aimed at a better understanding of these so far neglected stars. For this purpose we selected a number of little studied southern CVs and

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

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suspected CVs bright enough ($m_{vis} \leq 15^m$) to be easily observed with comparatively small telescopes. The emphasis of this program lies on photometry with a high time resolution aimed at the detection of short and medium time scale variations such as flickering and orbital variability. However, in a few cases the photometric observations could be complemented by spectroscopic time series. The first results of this program, concerning the dwarf nova MU Cen, were recently published by Bruch (2016).

Here, we report on three stars for which spectra were taken in addition to light curves. These are the nova-like variables LS IV -08° 3 and HQ Mon, and the Z Cam type dwarf nova ST Cha. Nova-like variables are CVs with accretions disks in a bright state which do not show outbursts such as the dwarf novae (or, alternatively, may be considered to be in permanent outburst). Sometimes, they are subdivided into UX UMa stars which always remain on approximately the same brightness level, and VY Scl stars which occasionally assume a low state at much fainter magnitude than normal. The Z Cam stars are systems which, instead of alternating between quiescent and outburst states due to a limit cycle instability in their accretion disks as is usual with dwarf novae, sometimes get stuck for some time at a brightness just below the outburst level. This phenomenon in known as "standstill".

HQ Mon and ST Cha entered the observing program mainly because no time resolved photometry was ever published and because the orbital periods as quoted in the most recent on-line edition of the Ritter & Kolb catalogue (Ritter and Kolb, 2003) are uncertain and require confirmation. On the other hand, LS IV -08° 3 was quite thoroughly characterized by Stark et al. (2008). It entered the observing program only as a backup target. However, as it turns out, the present additional observations nicely complement those of Stark et al. (2008).

In Section 2 we report briefly on the observations and data reductions. The results for the individual objects are then dealt with in turn in Sections 3 – 5. We summarize the most important conclusions in Section 6.

2. Observations and data reductions

All observations were obtained at the Observatório do Pico dos Dias (OPD), operated by the Laboratório Nacional de Astrofísica, Brazil. For photometry the 0.6-m Zeiss and the 0.6-m Boller & Chivens telescopes were used. Spectroscopy was performed using the 1.6-m Perkin Elmer telescope.

Time series imaging of the field around the target stars was performed using cameras of type Andor iXon EMCCD DU-888E-C00-#BV and iKon-L936-B 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 was 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 summary of the photometric observations is given in Table 1. Not all of them were useful. Parts with an elevated noise level due to passing clouds will not be regarded here.

The spectra were taken in 2015, February and March, using the Boller & Chivens spectrograph of OPD. Details are given in Table 2. An Andor iKon-L936-BR-DD camera was employed. Integration times were 15 ^{m} throughout. Exposures of a He-Ar lamp for wavelength calibration were taken after every second stellar exposure. From the FWHM of the lines in the comparison spectra a spectral resolution of ≈ 4 Å is estimated. The spectral range of the March data encompassed Hα and Hβ. However, due to an error of the instrumental configuration, Hα was not included in the February spectra. The observing conditions were quite variable, ranging from photometric to periods heavily affected by clouds. Therefore, some of the spectra remained severely underexposed and are only of limited usefulness. In view of these difficulties no attempt was made to flux calibrate the data.

Table 1
Journal of photometric observations.

Name	Date	Start (UT)	End (UT)	Time Res. (s)	Number of Integr.
LS IV −08° 3	2015 May 20	1:10	6:16	6	3 449
	2015 May 21	3:35	6:52	6	1 971
HQ Mon	2014 Mar 26	23:19	23:52	5.5	346
	2014 Mar 28/29	23:05	1:52	5.5	2 094
	2014 Nov 21	3:20	7:34	5	2 923
	2015 Feb 13	0:59	5:02	5	2 645
ST Cha	2014 Mar 29	2:52	5:22	5.5	1 466
	2014 Apr 30	21:38	22:00	5	256
	2014 Jun 17/18	21:25	0:18	5	1 800

Table 2
Journal of spectroscopic observations.

Name	Date	Start (UT)	End (UT)	Number of Spectra	Spectral Coverage (Å)
LS IV −08° 3	2015 Mar 24	5:33	8:35	11	4704 – 6796
	2015 Mar 25	4:35	8:21	12	4705 – 6797
	2015 Mar 26	4:24	6:00	6	4706 – 6798
	2015 Mar 27	4:06	8:27	16	4707 – 6799
	2015 Mar 28	4:34	7:31	9	4709 – 6801
HQ Mon	2015 Fev 13	0:57	4:46	12	4342 – 6448
	2015 Fev 14	2:48	4:31	6	4343 – 6449
	2015 Mar 24	21:51	22:07	1	4708 – 6800
	2015 Mar 25	21:39	22:50	2	4709 – 6801
	2015 Mar 26/27	21:37	1:56	15	4708 – 6800
ST Cha	2015 Fev 13	4:54	7:11	4	4339 – 6445
	2015 Mar 23/24	23:54	5:22	14	4702 – 6794
	2015 Mar 24/25	22:40	3:30	16	4702 – 6794
	2015 Mar 25/26	22:58	4:14	18	4704 – 6798
	2015 Mar 27	2:01	3:56	6	4707 – 6799

Basic reductions of the data (bias subtraction, flat-fielding, spectral extraction) were performed with IRFF. All further data reduction and analysis was done using the MIRA software system (Bruch, 1993), with the exception of the Doppler mapping (Section 3.1) for which an IRAF/SPP user code was employed.

Aperture photometry was applied to the images of the target stars, the primary comparison stars and several check stars in the field. The time axis of the resulting light curves is expressed in UT throughout this paper, unless stated otherwise. In contrast, the times of mid-exposure of the spectra, used to measure the orbital motion of the target stars, were transformed into barycentric Julian Dates, following (Eastman et al., 2010). In order to remove the instrumental response curve from the uncalibrated spectra, they were normalized to the continuum. The raw spectra contained strong absorption features in particular in the wavelength ranges λλ 5860 – 6020 Å (mostly just to the red of the Na D lines), λλ 6260 – 6340 Å and λλ 6450 – 6620 Å (to the blue and around Hα). They can be attributed to atmospheric absorptions. Therefore, the normalized spectra were divided by a suitably scaled normalized atmospheric transmission spectrum (degraded to match the observed spectral resolution). This procedure was optimized for the strong absorptions close to Na D and around Hα, at the expense of an imperfect elimination of the absorptions in the third range, resulted in spurious structures centred on $\lambda \sim$ 6280 Å in LS IV −08° 3 and HQ Mon. With few exceptions which will be appropriately specified below radial velocities of lines in