New Astronomy 16 (2011) 311–316

Contents lists available at ScienceDirect

New Astronomy

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

# The orbital and superhump periods of the dwarf nova HS 0417+7445 in Camelopardalis

J.H. Shears [a,*], B.T. Gänsicke [b], S. Brady [c], P. Dubovský [d], I. Miller [e], B. Staels [f]

[a] BAA, "Pemberton", School Lane, Bunbury, Tarporley, Cheshire CW6 9NR, UK
[b] Department of Physics, University of Warwick, Coventry CV4 7AL, UK
[c] AAVSO, 5 Melba Drive, Hudson, NH 03051, USA
[d] Astronomical Observatory on Kolonica Saddle, Slovakia
[e] BAA, Furzehill House, Ilston, Swansea SA2 7LE, UK
[f] CBA Flanders, Patrick Mergan Observatory, Koningshofbaan 51, Hofstade, Aalst, Belgium

ARTICLE INFO

*Article history:*
Received 11 October 2010
Accepted 6 November 2010
Available online 15 December 2010

Communicated by E.P.J. van den Heuvel

*Keywords:*
Stars: dwarf novae
Cataclysmic variables
Accretion disks

ABSTRACT

We present the 2005–2010 outburst history of the SU UMa-type dwarf HS 0417+7445, along with a detailed analysis of extensive time-series photometry obtained in March 2008 during the second recorded superoutburst of the system. The mean outburst interval is 197 ± 59 d, with a median of 193 d. The March 2008 superoutburst was preceded by a precursor outburst, had an amplitude of 4.2 magnitudes, and the whole event lasted about 16 days. No superhumps were detected during the decline from the precursor outburst, and our data suggests instead that orbital humps were present during that phase. Early superhumps detected during the rise to the superoutburst maximum exhibited an unusually large fractional period excess of $\epsilon = 0.137$ ($P_{sh} = 0.0856(88)$ d). Following the maximum, a linear decline in brightness followed, lasting at least 6 days. During this decline, a stable superhump period of $P_{sh} = 0.07824(2)$ d was measured. Superimposed on the superhumps were orbital humps, which allowed us to accurately measure the orbital period of HS 0417+7445, $P_{orb} = 0.07531(8)$ d, which was previously only poorly estimated. The fractional superhump period excess during the main phase of the outburst was $\epsilon = 0.037$, which is typical for SU UMa dwarf novae with similar orbital period. Our observations are consistent with the predictions of the thermal-tidal instability model for the onset of superoutbursts, but a larger number of superoutbursts with extensive time-series photometry during the early phases of the outburst would be needed to reach a definite conclusion on the cause of superoutbursts.



## 1. Introduction

In cataclysmic variables (CVs) a white dwarf primary accretes material from a secondary star via Roche lobe overflow. The secondary is usually a late-type main-sequence star (Warner, 1995). In the absence of a significant white dwarf magnetic field, material from the secondary is processed through an accretion disc before settling on the surface of the white dwarf. In CVs with low to intermediate mass transfer rates, dwarf nova outbursts with amplitudes of 2–8 mag and durations of days to weeks are observed. The outbursts are thought to be caused by a thermal instability in the accretion disc associated with partial ionisation of hydrogen (Meyer and Meyer-Hofmeister, 1981; Smak, 1982; Cannizzo et al., 1982), and such time-dependent models for accretion disc evolution have been applied to a variety of astrophysical environments, e.g. AGN (Burderi et al., 1998) or young stellar objects (Bell et al., 1994). Dwarf novae of the SU UMa family occasionally exhibit superoutbursts which last several times longer than normal outbursts and may be up to a magnitude brighter. During a superoutburst the light curve of a SU UMa system is characterised by superhumps. These are modulations in the light curve which are a few percent longer than the orbital period. They are thought to arise from the interaction of the secondary star orbit with a slowly precessing eccentric accretion disc. The eccentricity of the disc arises because a 3:1 resonance occurs between the secondary star orbit and the motion of matter in the outer accretion disc. The actual trigger of the superoutbursts is still debated (Osaki et al., 2003; Schreiber et al., 2004).

HS 0417+7445 (hereafter HS 0417), also known as 1RXS J042332+745300, was independently identified as a CV by Wu et al. (2001) in the course of follow-up spectroscopy of objects from the ROSAT Bright Source Catalogue (Voges et al., 1999), and by Aungwerojwit et al. (2006) because of the presence of strong Balmer emission lines in its optical spectrum in the Hamburg Quasar Survey (HQS, Hagen et al., 1995). HS 0417 showed large amplitude variability on the HQS spectroscopic plates, between $B \simeq 18.0$ and $B \simeq 13.7$, suggesting a dwarf nova classification of the object.

* Corresponding author. Tel.: +44 151 373 5882; fax: +44 1829 260707.
*E-mail address:* bunburyobservatory@hotmail.com (J.H. Shears).

1384-1076/$ - see front matter © 2010 Elsevier B.V. All rights reserved.
doi:10.1016/j.newast.2010.11.002

Further observations of HS 0417 by Aungwerojwit et al. (2006) between December 2000 and January 2005 showed the object near to a mean magnitude of ~17.5, except during January 2001 when the system was found in outburst near $B \simeq 13.5$. Photometry during this outburst revealed superhumps that identify HS 0417 as a SU UMa type dwarf nova. Two possible superhump periods were identified, $P_{sh}$ = 108.3 or 111.2 min (0.0752 or 0.0772 d). Analysis of the quiescent data revealed a double-humped light curve with two possible values of the orbital period, $P_{orb} \simeq 105.1$ or 109.9 min (0.0723 or 0.0763 d). Brief descriptions of two superoutbursts in 2008 and 2010 were given by Kato et al. (2009, 2010).

Here we report a detailed analysis of time-series photometry obtained in 2008 during the second superoutburst of HS 0417, from which we determine accurate orbital and superhump periods. We also discuss the possible mechanisms triggering superoutbursts, and how pre-cursor outbursts, such as detected in our data, can help to distinguish between the competing models.

## 2. Observations

We detected HS 0417 in outburst on 2008 March 3.977 at a filterless magnitude of 14.5C. Time resolved photometry was conducted during the course of the outburst according to the observation log shown in Table 1. Raw images were dark-subtracted and flat fielded before being measured using differential aperture photometry relative to comparison stars with *V*-band photometry given by Henden (2010). We will generally refer to dates in the truncated form JD = JD − 2454000. From the overall light curve of the superoutburst shown in Fig. 1 it is apparent that the superoutburst was preceded by a precursor outburst. Detailed views of the individual light curves are shown in Fig. 2.

**Table 1**
Log of the observations.

| Date 2007 (UT) | Start time (JD-2454000) | Duration (h) | Filter | Observer |
|---|---|---|---|---|
| March 4 | 530.304 | 4.8 | C | JS |
| March 4 | 530.363 | 5.3 | V | IM |
| March 5 | 531.337 | 0.5 | C | BS |
| March 6 | 531.558 | 7.0 | C | SB |
| March 6 | 532.247 | 10.0 | V | PD |
| March 7 | 532.546 | 7.5 | C | SB |
| March 7 | 533.237 | 5.8 | V | PD |
| March 7 | 533.302 | 4.1 | V | IM |
| March 7 | 533.398 | 3.2 | C | JS |
| March 7 | 533.441 | 4.6 | C | BS |
| March 8 | 533.707 | 1.0 | V | IM |
| March 8 | 534.295 | 4.4 | C | JS |
| March 8 | 534.370 | 5.0 | C | IM |
| March 9 | 535.292 | 2.2 | C | JS |
| March 9 | 535.304 | 0.4 | C | IM |
| March 9 | 535.337 | 6.7 | C | BS |
| March 10 | 536.369 | 2.1 | C | JS |
| March 11 | 536.506 | 7.9 | C | SB |
| March 12 | 538.463 | 1.7 | C | IM |
| March 13 | 538.511 | 6.6 | C | SB |
| March 16 | 542.319 | 3.3 | C | IM |
| March 17 | 543.325 | 4.0 | C | IM |
| March 18 | 543.512 | 7.3 | C | SB |

Notes on the equipment used for the observations. JS: 0.28 m SCT plus Starlight Xpress SXV-M7; SB: 0.4 m reflector plus SBIG ST-8XME; PD: 0.265 m reflector plus Meade DSI Pro; IM: 0.35 m SCT plus Starlight Xpress SXVF-H16; BS: 0.28 SCT plus Starlight Xpress MX716.

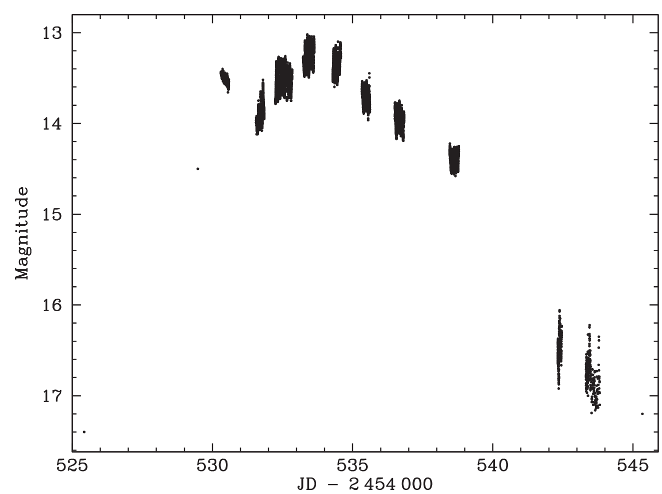


**Fig. 1.** Light curve of HS 0417 during the 2008 March outburst.

## 3. Analysis and results

### 3.1. Outburst history

Examination of the AAVSO International Database (Henden, 2010), supplemented with data from the authors, reveals at least 11 outbursts of HS 0417 between April 2005 and October 2010 (Table 2). Two of the outbursts are definitely superoutbursts as superhumps were recorded: the one in March 2008 outburst discussed in this paper and the 2010 Sep discussed by Kato et al. (2009, 2010). In both cases the outburst lasted about 16 days.

The April 2005 outburst lasted ~8 days and the star showed a rapid decline with no superhumps confirming this to be a normal outburst. Similarly, the absence of superhumps during the October 2007 outbursts suggests it too was a normal outburst. Whilst we are not aware of any time series photometry conducted during the other outbursts, their short outburst duration (less than 6–8 days) suggests they too were normal outburst.

Dwarf novae are known to exhibit quasi-periodic outbursts. In the case of HS 0417, the mean outburst interval between the 11 outbursts was 197 ± 59 d and the median interval was 193 d. Although observational coverage of HS 0417 has been good since the 2005 outburst, there are nevertheless 43 gaps in the data of more than 6 d during which further outbursts might have been missed. We note that the normal outbursts of HS 0417 have a rather long duration compared to other SU UMa dwarf novae. Close monitoring of this object should continue to improve the statistics of the outburst frequency and duration.

### 3.2. The March 2008 superoutburst

Fig. 1 shows the overall light curve of the outburst, from its discovery at 14.5C on JD 529. Photometry conducted the next night (JD 530) showed that the star had brightened to ~13.4C, but that it was fading at an average rate of 0.50 mag $d^{-1}$. By contrast, the following night (JD 531) the star, although considerably fainter at ~14.1C, was re-brightening rapidly at 0.91 mag $d^{-1}$. Superhumps were plainly visible at this point, suggesting this to be the start of the superoutburst. It appears that the activity on JD 529–530 represented a normal outburst which was the precursor, perhaps even the trigger, for the superoutburst (see Section 4). At its brightest on JD 533 the star reached magnitude 13.2 (averaged over the superhumps). An approximately linear decline followed between maximum on JD 533 and JD 538 at 0.14 mag $d^{-1}$, which is typical of a dwarf nova in decline from a superoutburst. There was then a 4 d gap in the record until JD 542 when the star was at 16.5C; hence it is not possible to conclude whether there was a gradual or a sudden fade in the intervening period. Finally the star was found at magnitude 17.2C, close to its quiescence magnitude of 17.4C, on JD 545