High speed photometry of faint cataclysmic variables - VI. Car2, V1040 Cen, Hα075648, IL Nor (Nova Nor 1893), HS Pup (Nova Pup 1963), SDSS J2048-06, CSS 081419-005022 and CSS 112634-100210

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Accepted 2009 November 27. Received 2009 November 24; in original form 2009 April 22

ABSTRACT
We have observed 8 faint cataclysmic variable stars photometrically. The nova-like Car2 was extensively sampled but showed little variability. V1040 Cen was observed near the end of a dwarf nova outburst and possessed dwarf nova and quasi-periodic oscillations. Hα075648 has strong large amplitude flickering and a possible orbital modulation at 3.49 h. The correct identification for the nova remnant IL Nor (Nova Nor 1893) has been established. HS Pup (Nova Pup 1963) has a possible orbital period of 3.244 h. SDSS J2048-06 is a low mass transfer dwarf nova that in quiescence shows slow variations at 7.67 h (though poorly sampled with our observations) and an orbital modulation at 87.26 min. The dwarf nova CSS 081419-005022 has an orbital period of 1.796 h and the eclipsing dwarf nova CSS 112634-100210 has an orbital period of 1.8581 h.

Key words: techniques: photometric – binaries: eclipsing – close – novae, cataclysmic variables

1 INTRODUCTION
In five previous papers (Woudt & Warner 2001, 2002, 2003; Woudt, Warner & Pretorius 2004; Woudt, Warner & Spark 2005a) we have presented results of high speed photometry of faint cataclysmic variables (CVs; see Warner 1995 for a review) that had only previously been poorly studied. Here we give light curves and analyses of a further 8 stars. We again emphasize that this work is in the nature of a survey – many of the stars will require further study.

As with the earlier work we used the University of Cape Town CCD photometer, as described by O’Donoghue (1995), in frame transfer mode and with white light, on the 1.9-m (74-in) and 1.0-m (40-in) reflectors at the Sutherland site of the South African Astronomical Observatory. Our magnitude scale was derived using hot white dwarf standards, but because of the non-standard spectral distributions of CVs and the use of white light our magnitudes approximate a V scale only to ∼0.1 mag.

In Section 2 we give the results of our observations. Section 3 gives brief conclusions from our work.

2 OBSERVATIONS
2.1 Carinae 2 (Car2)
Car2, alias BPM 18764, although long recognized as an object of some interest, has not been dignified with a variable star designation because hitherto there was no evidence that it varies in brightness. It is listed as a white dwarf suspect by Eggen (1969), who made only one photometric measurement and hence did not detect its variability. Wickramasinghe and Bessell (1977) recognized its true character when they noticed broad, shallow absorption lines accompanied by emission cores in Hα and Hβ, found it to be close to an X-Ray source, and thought it might be an old nova. The spectral emission features ensured that it entered the CV catalogue1 (Downes et al. 2001), designated as Car2. Kawka et al. (2007) find that in fact there is no X-Ray candidate in the ROSAT database at the position of Car2, but from infrared colours deduced that it is probably a white dwarf with a cool companion, the latter having a spectral type M3-4 V. Hoard et al. (2007) similarly find evidence of a companion, probably of type M2-3 V.

Our photometric runs are listed in Table 1 and the best
three long light curves are shown in Fig. 1 (run S7587 is truncated because of poor observing conditions). There are mean variations $\sim 0.1$ mag from year to year, and some variations of similar amplitude during individual nights. A low amplitude cyclic variation may be suspected in the longer runs. A Fourier transform (FT) of the combined January 2008 runs has a peak at 104.2 min which is probably not significant.

2.2 V1040 Centauri

V1040 Cen was first found as an X-Ray source in the ROSAT Galactic Plane Survey (Motch et al 1998) and designated
RX J1155.4-5641. It was classified as a CV, but no spectrum has been published. Photometry was carried out in a superoutburst in April 2002, and later in quiescence (Patterson et al. 2003), from which a superhump period of 1.492 h and an orbital period of 1.446 h were deduced, typical values for an SU UMa type dwarf nova. Recently Longa-Pe±a (2009) has found a spectroscopic period of 1.452 h. No other periods have been noticed.

Our observing runs are listed in Table 1. The AAVSO (American Association of Variable Star Observers) light curve of V1040 Cen shows normal outbursts to V ~ 12.3 with recurrence time ~ 35 d and infrequent superoutbursts to V ~ 11.6, reaching 10.8 on one occasion; Kato et al. (2003) give the average time between superoutbursts as 211 d. At the time of our observations V1040 Cen was returning to quiescence from a normal outburst that reached maximum about 4 days earlier than our first observation.

Our light curves are shown in Fig. 2; the FTs contain only a few significant features, in particular that of run S7802 has a weak signal at 17.4 s and a stronger signal at 223 s – see Fig. 3. The ratio of these is 13, which is similar to the ratio of QPO to DNO periods seen in dwarf novae during outburst (Warner, Woudt & Pretorius 2003). In run S7800 there is a modulation at ~ 225 s near the central part, which doubles to ~ 455 s in the final third. Again, period doubling is commonly seen in DNO and QPO signals (Warner & Woudt 2006).

2.3 Hα 075648

In a survey of CV candidates based on Hα emission, Pretorius & Knigge (2008) found 14 confirmed CVs and an additional two candidates. The B ~ 18.3 star Hα 075648 showed very strong and rapidly variable Hα emission but despite more than 7 h of spectroscopic coverage no plausible periodicity was detected. A short (~ 2 h) lightcurve obtained in poor conditions showed the expected flickering but no sign of orbital modulation. At the suggestion of Retha Pretorius we added Hα 075648 to our observing list. Our photometric runs are listed in Table 1, and the light curves are displayed in Fig. 4.

The star shows large scale flickering, which makes certain detection of any periodicity difficult, but an FT of the combined data set has a peak and window function at 3.49
2.4 IL Normae (Nova Normae 1893)

IL Nor was discovered in 1893 and reached a peak magnitude of 7.0 in July of that year (Duerbeck 1987). It was a moderately fast nova \((t_3 = 108 \text{ d})\) which faded to less than 18th magnitude and has not been subsequently identified (Downes et al. 2001), being described by Duerbeck as coinciding with a blend of three stars, indicated on Duerbeck’s chart and encircled in the Downes et al. (2001) catalogue. To obtain good light curves for the components of the blend requires particularly good seeing, which we have achieved on only one occasion. Our observing runs are listed in Table 1 and two light curves are given in Fig. 5, of which the first was able to show which component varies but only the second gave a satisfactory result. There is evidence for a modulation on a time scale \(\sim 6000 \text{ s}\). A finding chart made from one of our CCD images is given in Fig. 6. IL Nor was 18.5 mag in 2003 but \(\sim 0.5\) mag fainter in 2004.

h with an amplitude of 48 mmag. This is at best only a tentative suggestion of an orbital period.

2.5 HS Puppis (Nova Puppis 1963)

HS Pup was the second nova to appear in the constellation of Puppis in 1963, reaching maximum at \(V = 8.0\) on 23 December of that year (Strohmeier 1964). It was a moderately fast nova, decaying with \(t_3 = 65 \text{ d}\), and is classified as possibly of type B, meaning that the decline light curve (which was not well observed) may have had irregularities in it (Duerbeck 1981, 1987). The shell ejected during the nova explosion has been imaged (Gill & O’Brien 1998) and the spectrum of the nova remnant shows \(\text{H} \alpha\) in emission (Zwitter & Munari 1995). HS Pup has no counterpart in the ROSAT All-sky Survey.

The apparent magnitude of the remnant is variously given as \(m_{pg} = 20.5\) (Duerbeck 1987), \(V = 18.06\) (Szkody 1994), \(V = 19.1\) (Zwitter & Munari 1995) and \(J = 16.32\) (Hoard et al. 2002). There is no published time-resolved photometry of this nova remnant.

Our photometric observations of HS Pup are detailed in Table 1. The 2008 light curves are shown in Fig. 7. There is a lot of flickering in the light curves of HS Pup, with some excess power in the range of 600-700 \(\mu\text{Hz}\) (\(\sim 1500 \text{ s}\)). Despite extensive sampling of HS Pup with numerous 7-hour runs, there appears to be little coherency in the \(\sim 1500 \text{ s}\) modulation. The FT of the combined 2008 observations, detrended by subtracting the individual means, shows a marginal peak near 85.62 \(\mu\text{Hz}\) (3.244 h), with an amplitude of 16.1 mmag. We tentatively assign this to an orbital frequency.

2.6 SDSS J204817.85-061044.8

SDSS J2048-06 was discovered during the Sloan Digital Sky Survey as a \(g = 19.35\) mag CV with strong double hydrogen emission lines and indications of underlying broad absorption lines (Szkody et al. 2003). It is evidently a low \(M\) dwarf nova, but no outburst has yet been observed. No follow-up observations had been made before our own photometric work, which is listed in Table 1, initial reports on which were published in Woudt et al. (2005b) and Warner & Woudt (2005).

A selection of long, individual light curves of the 2004 August observations is shown in Fig. 8. The FT of the August 2004 light curves is shown in upper panel of Fig. 9 and...
shows a strong peak at 7.67 h with an amplitude of 112 mmag. This periodicity is poorly sampled with the present data, given our data length limitations (our three longest runs are 7.2, 5.8 and 5.7 hours, respectively) and should therefore be regarded with caution. Nonetheless, it does not appear to be the result of differential atmospheric extinction corrections, as the colours of SDSS2048-06 and the chosen reference star are fairly similar and given identical airmass ranges on the three consecutive nights shown in Fig. 8.

After prewhitening the 2004 data with this periodicity, the FT, seen in the lower panel of Fig. 9, contains modulations consisting of a fundamental and its first harmonic modulation, but with an alias ambiguity. The two possibilities are 179.417 ± 0.007 µHz (92.89 min) and 191.001 µHz (87.26 min), both at amplitude 56 mmag. Comparison of separate FTs of our August and September 2004 light curves gives a slight preference for the shorter of the two periods. The orbital ephemeris for maximum light is

$$HJD_{\text{max}} = 245 3228.3656 + 0.060597 (2) \ E. $$ (1)

The 87.26-min periodicity is almost certainly the orbital period – its high stability over our 41 d baseline supports this. The mean light curve at the orbital period is shown in Fig. 10 and may contain a grazing eclipse of the disc, superposed on an orbital hump.

Figure 8. Individual light curves of SDSS 2048-06. The light curve of run S7373 is displayed at the correct brightness. Runs S7376 and S7380 have been displaced vertically by 0.7 and 1.4 mag, respectively, for display purposes.

Figure 9. The Fourier transform of the 2004 August data (upper panel) and the combined 2004 August/September data (lower panel). The former is detrended by removing nightly means. The 7.67-h periodicity is marked by the vertical bar. The lower panel shows data prewhitened with the 7.67-h periodicity; the fundamental frequency of the orbital modulation and its first harmonic are marked by the vertical bars.

Figure 10. The average light curve of SDSS 2048, folded on the ephemeris given in Eq. 1.

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We first observed this star in the hope that it would have a non-radially pulsating white dwarf primary (e.g. Warner & Woudt 2005), but we have found no evidence for such pulsations at a level of 1 mmag. Nor are there any signs of DNOs or QPOs.

2.7 CSS 081419-005022

This is the first of two CVs that we have observed, sourced from the Catalina Sky Survey (CSS)² for near-earth objects (Drake et al. 2009), where it was listed as 19.0 at quiescence but with outbursts up to mag 14.8. It was listed in the SDSS survey but not recognized as a CV. Our observations are listed in Table 1 and the light curves of the three longest runs are shown in Fig. 11. The FT of all observations (detrended by subtraction individual means) is given in Fig. 12, in which we see a strong orbital modulation. A simultaneous sinusoidal fit of fundamental and first harmonic gives an orbital period of 1.796 h at an amplitude of 98 mmag. The mean light curve at this period is shown in Fig. 13. The ephemeris for maximum of the orbital hump is

$$HJD_{\text{max}} = 245 4911.385 + 0.07485 (2) \ E. $$ (2)

2.8 CSS 112634-100210

This star is listed in the CSS at 18.6 mag with a note that it is an eclipsing system. It was detected in the SDSS but no spectrum nor resulting identification as a CV was made. Our observations are listed in Table 1 and the light curves are shown in Fig. 14. There are deep eclipses, with period 1.8581 h, following the ephemeris for mid-eclipse:

$$HJD_{\text{min}} = 245 4893.49325 + 0.077422 (2) \ E. $$ (3)

² See also http://nesssi.cacr.caltech.edu/catalina/AllCV.html
We noticed that the orbital variations can be divided into two types of behaviour, one with almost no modulation out of eclipse and one with a double hump per orbit, in the style of the low $M$ dwarf nova WZ Sge. We show these behaviours in Fig. 15 as averages of runs S7841, S7857 and S7838, S7844 respectively. The former have slightly deeper eclipses. There is little indication of any single hump per orbit contribution from a bright spot, and the profiles of the eclipses show only slight effects of a bright spot.

3 CONCLUSIONS

The use of small or modest-apertured telescopes continues to be fruitful in the identification of CVs that will be worthy of follow-up observations with larger instruments. Our latest contribution includes our first photometric follow-up...
of faint dwarf novae detected in the Catalina Sky Survey (CSS) demonstrating the need for well-sampled photometric observations of transients detected in wide-area surveys. The two CSS dwarf novae presented here have orbital periods of 1.796 h (CSS 081419-005022) and 1.8581 h (CSS 112634-100210), respectively, where the latter shows deep eclipses.

Further observations were presented of two nova remnants (HS Pup and IL Nor). The nova remnant IL Nor has been unambiguously identified, and extensive photometry of HS Pup has resulted in a tentative identification of the orbital period in this system (3.244 h).

The low mass transfer dwarf nova SDSS 2048-06 was extensively studied with the aim of identifying non-radial pulsations of the accreting white dwarf primary. No pulsations were detected to a level of 1 mmag, but a (poor sampled) long-period variability was seen (∼7.67 h), and the orbital period has been securely identified (1.454 h).

ACKNOWLEDGMENTS

Both authors acknowledge support from the University of Cape Town and from the National Research Foundation of South Africa. We thank the anonymous referee for useful comments which helped to improve this paper. PAW in addition thanks the School of Physics and Astronomy at Southampton University for financial assistance. We kindly acknowledge Denise Dale for obtaining some data of SDSS 2048-06.

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