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TIME SERIES PHOTOMETRY OF THE CATACLYSMIC VARIABLE SYSTEMS VY AQUARII AND V2491 CYGNI

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ABSTRACT

We present an analysis of time-series photometry of the cataclysmic variable systems VY Aquarii and V2491 Cygni. We produced a lightcurve for VY Aquarii during its superoutburst and calculated a superhump period of 92.81 minutes. The decline of the superoutburst was also examined in VY Aquarii. The new classical nova V2491 Cygni was examined. A Fourier analysis revealed no significant periodicity.

Subject headings: stars: cataclysmic variables

1. BACKGROUND

Cataclysmic variable stars (CVs) are binary systems containing a white dwarf primary star and typically a lower main sequence secondary star undergoing mass transfer from the latter to the former. The secondary star fills its Roche lobe, and matter flows through the L1 inner Lagrange point. The orbiting material will form an accretion disk, which is typically the most luminous component of the system. The accretion disk produces many of photmetric features observed in CV systems.

There are several different types of cataclysmic variable stars (Warner 1995; Hellier 2001). The main focus of this work is on the SU UMa class which is a subset of the dwarf nova (DN) category. The SU UMa stars undergo superoutbursts during which they display a periodic photometric signal known as superhumps. A superoutburst is an outburst that lasts a few times longer and is up to a magnitude brighter than a normal dwarf nova outburst. The physical origin of the superhump photometric signal is the oscillation of the accretion disk, and which is driven by the rotating tidal field of the secondary star (e.g., Simpson & Wood 1998; Wood, Thomas & Simpson 2009). Superhump oscillations can be excited if the outer disk can extend to radius of the inner Lindblad resonance – near the 3:1 co-rotation resonance. Superhumps have periods a few percent longer than the orbital period (Patterson 2005; Wood et al 2009).

1.1. *VY Aquarii*

VY Aquarii is classified as an SU UMa star. The orbital period from spectroscopy is 0.06309 ± 0.00004 d (Thorstensen & Taylor, 1997), and Thorstensen (2003) estimates the distance to be 89 pc. We report on observations obtained during the 2008 July superoutburst.

1.2. *V2491 Cygni*

The outburst of V2491 Cygni was reported by Nakano et al. (2008), using data obtained on unfiltered CCD images taken 2008 April 10.728UT at which time the system was at magnitude 7.7. Follow-up observations (e.g., Page et al. 2009) have focused on the UV and X-ray evolution – no periodic photometric signals have been reported.

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TABLE 1
V2491 Cyg.Journal of Observations

UT Date	Object	Site	Observers	Exp	Frames
080606	V2491 Cyg	FIT	PSW[a]	20 s	397
080607	V2491 Cyg	FIT	PS[b]	20 s	340
080608	V2491 Cyg	FIT	PS	30 s	270
080611	V2491 Cyg	SARA	PSWM[c]	20 s	497
080612	V2491 Cyg	SARA	PSWM	5 s	1204
080613	V2491 Cyg	SARA	PSWM	5 s	1108

[a] Piwowar, Schwieterman, Wood
[b] Piwowar, Schwieterman
[c] Piwowar, Schwieterman, Wood, May

TABLE 2
VY Aqr. Observations

Telescope	Observer
CBA-Pretoria 30 cm	B. Monard
CBA-Nelson 35 cm	R. Rea
WPO[a]-Arizona 30 cm	G. Roberts
CBA-Indiana 25 cm	D. Starkey

[a] Whispering Pines Observatory

2. OBSERVATIONS

Observations of V2491 Cyg were obtained at The Florida Institute of Technology (FIT) Ortega 0.8-m Telescope, Melbourne, Florida, and Southeastern Association for Research in Astronomy (SARA) 0.9-m Telescope, Kitt Peak National Observatory (KPNO), Arizona. We observed the nights of 2008 July 6, 7, and 8 UT at FIT and 2008 July 11, 12, and 13 UT at SARA-KPNO. The Journal of Observations is given in Table 1. FIT has a Finger Lakes Instrument IMG-1042s CCD camera with 24 μm pixels. Observations were made without a filter and with the CCD temperature set at -30°C. The SARA telescope is equipped with an Apogee Alta U42 CCD camera. Observations were done with an infrared-blocking (IRB) filter, 2x2 binning (yeilding 27 μm pixels), and CCD temperature set at -20°C.

The VY Aquarii data were obtained from the Center for Backyard Astrophysics (CBA). CBA collects data from observatories around the world for purpose of producing complete light curves. The observers are listed in Table 2.

3. DATA REDUCTION

The V2491 Cygni data obtained at FIT and SARA were reduced using *IRAF*[2]. Master darks, flats, and biases were created and applied to the original images. The target star was then compared to constant field stars to get a differential magnitude. We used *Period04* (Lenz & Breger 2004) and our own discrete Fourier transform code during the analysis.

The VY Aquarii data were reduced with *IRAF* and examined with *Period04* the same way as V2491 Cygni.

[2] IRAF is distributed by the National Optical Astronomy Observatories, which are operated by the Association of Universities for Research in Astronomy, Inc., under cooperative agreement with the National Science Foundation

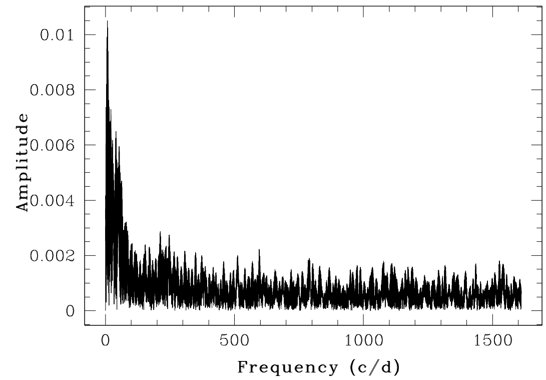

Fig. 1.— V2491 Cygni Fourier Transform. No significant periodicities are present.

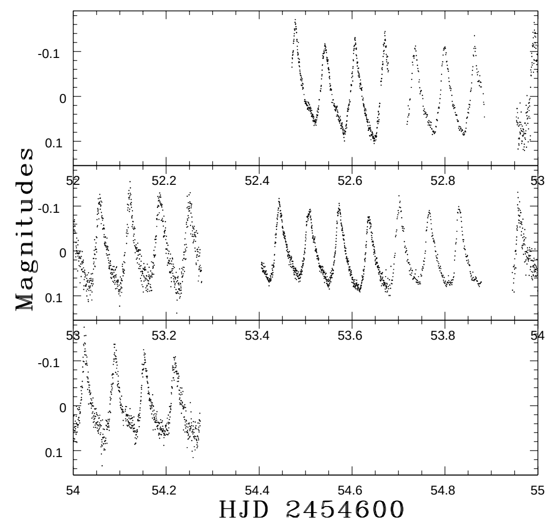

Fig. 2.— VY Aquarii lightcurve during superoutburst.

TABLE 3
VY Aquarii Superhump

Day	Frequency (cycles/day)	Frequency σ	Period (days)	Period (min)
6	15.53	0.0053	0.06440	92.74
7	15.48	0.0050	0.06462	93.05
All	15.52	0.0018	0.06445	92.81

4. RESULTS

The V2491 Cygni data produced inconclusive results. No significant periodicities were found in the Fourier transform (Figure 1).

VY Aquarii was analyzed during its superoutburst and its decline. A sample of the light curve is shown in Figure 2. Note the high amplitude pulse shapes characteristic of newly excited superhumps (e.g., Patterson et al. 2005).

The VY Aqr superhump periods were 92.74 min and 93.05 min for 080705UT and 080706UT respectively. The combined average superhump period was 92.81 min which is in agreement with Patterson et al. (1993) su-

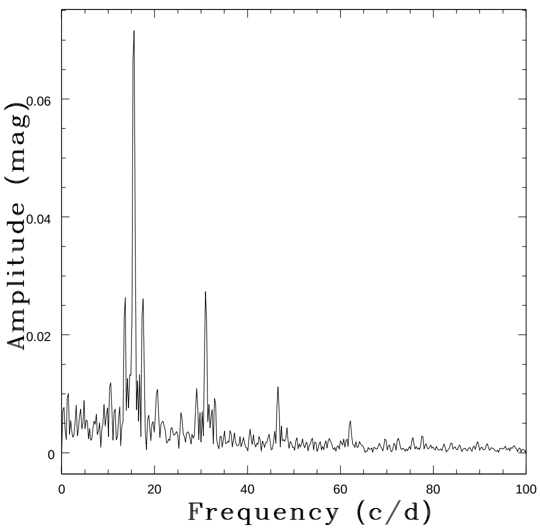

FIG. 3.— VY Aquarii Fourier transform showing superhump harmonics.

TABLE 4
VY AQUARII MONTE CARLO SIMULATION

Harmonics	Freq. (cycles/day)	Freq. σ	Calc. Freq. (cycles/day)
1:1	15.51	0.0018	15.51
2:1	31.01	0.0062	31.02
3:1	46.56	0.014	46.53
4:1	62.07	0.028	62.04
5:1	77.63	9.79	77.55

perhump period of 92.70 ± 0.12 min to within the errors. Table 3 combines these data together. The Fourier transform of the combined data produced several harmonics of the primary peak as seen in Figure 3. The harmonics counted were 2:1, 3:1, 4:1, and 5:1. A Monte Carlo simulation was used to check error range of the harmonics. The results are seen in Table 4.

The decline of the superoutburst appeared during JD 24546664.4. The lightcurve can be seen in Figure 4. Rebrightening occurred on JD 2454669.38 to a magnitude of 12.2. It quickly dropped to a 15 magnitude by JD 2454671. A plot of the magnitudes over the decline of the superoutburst is seen in Figure 5[2]. The superhump period was visible in the light curve and Fourier analysis.

5. CONCLUSION

We found the superhump period of VY Aqr to be 92.81 min which is in agreement with the superhump period of 92.70 ± 0.12 min reported by Patterson et. al (1993). VY Aqr had a superoutburst in July of 2008 which declined from a 12th magnitude to a 15th magnitude in only a couple of days. The nova cataclysmic variable V2491 Cyg showed no significant photometric periodicity following it's 2008 outburst.

[2] Courtesy of The AAVSO.

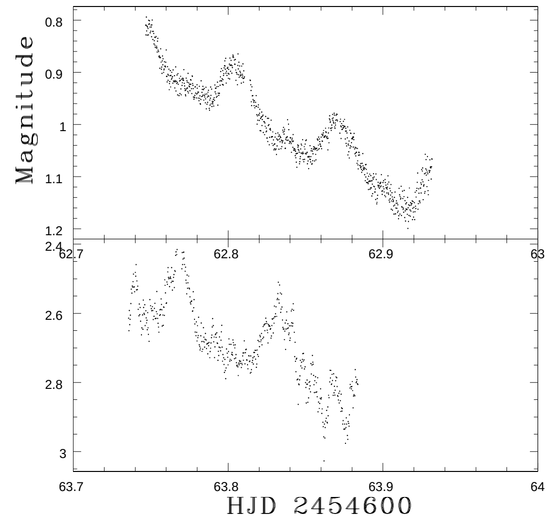

FIG. 4.— VY Aquarii lightcurve declines after superoutburst.

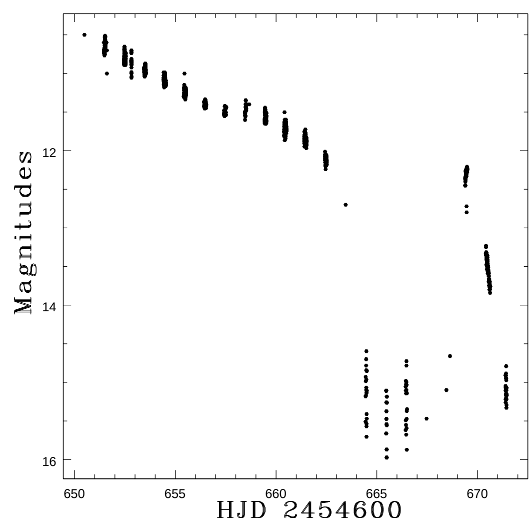

FIG. 5.— VY Aquarii magnitudes.

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