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CCD TIME-RESOLVED PHOTOMETRY OF FAINT CATACLYSMIC VARIABLES. IV.

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ABSTRACT

We observed 15 faint stars, known or suspected to be cataclysmic variables, obtaining CCD time-resolved photometry in *V*, *B*, and the near-IR. The stars are: WX Cet, CP Eri, XZ Eri, V592 Her, TT Ind, AO Oct, BE Oct, CT Ser, V2276 Sgr, KK Tel, DR UMa, RW UMi, PG 0917+342, PG 2240+193, and 2138-453. All of the stars were observed for ~ 2 or more hours, with the average time-series length being over 3 hrs. We find orbital periods for the stars KK Tel and 2138-453 and a likely period confirmation for RW UMi. CP Eri is a probable DQ Her star, showing an optical modulation of 29 min. Nine other stars show photometric evidence which likely confirms them as cataclysmic variables, while the true natures of PG 0917+342 and PG 2240+193 are not yet revealed.

Key words: cataclysmic variables–binary periods–CCD photometry

1. Introduction

This paper is the fourth in a series of our continuing project to obtain CCD time-resolved photometry of faint cataclysmic variables (CVs) (Paper I: Howell & Szkody 1988; Paper II: Szkody et al. 1989; Paper III: Howell et al. 1990). Cataclysmic variables are close binaries in which a mass-losing secondary (a late main-sequence dwarf) is in orbit with a white-dwarf primary. Typical dimensions for these systems are of the order of a solar diameter, and accordingly they have periods that are very short: a little over 1 hr to about 15 hrs. The material that is lost from the secondary usually accumulates in a disk around the primary with eventual accretion onto its surface. This transfer of material to the disk can be responsible for flickering (random low-level variations of order 0.1–1.0 mag) and periodic variations due to viewing the hot spot created at the stream/disk interface. An increase in the transfer rate of material from the secondary to the disk, or a disk instability leading to increased transfer of material through the disk, is thought to be the cause of the usual 2–5 mag outbursts observed in the dwarf novae type of CVs (see the review by Wade & Ward 1985). All dwarf novae with periods below the period gap show, at times, enhanced outbursts called superoutbursts. During the superoutbursts there are photometric humps present at a period a few percent longer than the orbital period. These stars belong to a subgroup of CVs known as the SU Ursae Majoris stars (reviewed by Warner 1985).

The stars we observe in this continuing project generally have little or no previous information other than some hint of being likely candidates for CVs. The goals of obtaining CCD photometry on such binaries and determining their colors are (1) to search for variability and periodicities related to the orbital periods and the spin periods of magnetic white dwarfs, and (2) to look for long-term changes in the quiescent properties of these stars (see Paper III). The major focus of this study is on

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stars with evidence for short periods (less than 4 hrs) and CVs that are at high galactic latitudes as described in Howell & Szkody 1990. Other faint unstudied and/or interesting systems are also included. Detailed analysis of interesting systems and synthesis of our collected data are published separately.

Using CCDs as our detectors, we can gather time-series data with one- to ten-minute time resolutions for stars from ~14 magnitude down to magnitude 20–22 with 1–2 meter class telescopes. For the faintest stars ($V > 17$–18) we are usually providing the first such data available. Papers I through IV contain data on a total of 52 stars and over 100 time-series data sets.

2. Observations

The data presented here were obtained with the Perkins 1.8-m telescope of the Ohio State and Ohio Wesleyan Universities at Lowell Observatory, the Kitt Peak National Observatory No. 1 0.9-m telescope, and the Cerro Tololo Inter-American Observatory 0.9-m telescope. The data from Kitt Peak and CTIO were reduced either with the "cdphot" package available on the instrument computer at the telescope or with the APPHOT package in IRAF[4]. The Lowell data were reduced with the IRAF/APPHOT package. Table 1 gives an observing log for the data presented here.

Our general observing policy for these types of data is to observe a few photometric standards each night to determine rough offsets between instrumental and real magnitudes. We obtain single color measurements directly before or after our time-series data. The standards are then used to give the average magnitude values listed in Table 1, with an error of $\sim \pm 0.1$ mag. The time-series data sets were reduced and have their errors determined as given in Howell et al. 1988a.

All the data sets were searched for periodic modulations using the technique of Phase Dispersion Minimization (PDM) developed by Stellingwerf 1978. The PDM technique provides the user with a test statistic for each determined period that yields a confidence level via an (two-sided) F-test. We indicate that no periods were seen if our PDM analysis fails to reveal any period at all with a confidence level of > 70%–80%. Between ~80% and 90% confidence level (CL) we generally will mention the result, as it may possibly be of some interest or get confirmed later. We define a period to be real if it gives an acceptable (usually ≳ 95%) confidence level, and we believe it to be stable if it is seen on more than one night at this high CL. Table 2 gives a list of the periods seen in our 15 stars from this paper which fall into the "real and stable" category. Many CVs do, however, show nightly changes in average magnitude level and flickering characteristics, which may lead to erroneous "periods" being determined. The less confident periods, that may or may not be real, are listed in the individual discussion for each star presented in the next section.

3. Results

3.1 *WX Ceti*

Paper II presented our initial work on this star. A possible period of 127 ± 5 min (in the near-IR) was seen, but with low confidence since the data set length was short. We present here two new data sets taken in V and B (see Fig. 1). Our V data set shows no indication of any periods and shows simply a flickering light curve. Our B data set, however, shows indications of periods at 43.5 ± 8 and 90.9 ± 7 min. These periods are at confidence levels of 80% and 85%, respectively. These periods are certainly shorter than that of 6.98 hrs suggested by van Paradijs, van der Klis & Pedersen 1990, based on spectroscopic studies.

Recently, O'Donoghue 1990 observed WX Cet during superoutburst. His determined superhump period is likely to be 73, 76, or 81 min, leading to a probable orbital period (see Warner 1985) of 72–80 min. The periods seen in our B data are in general agreement with the orbital period found by O'Donoghue, with the 44-min period being a likely harmonic. The superhumps observed and our photometric evidence almost certainly indicate a short orbital period for WX Cet, likely to be near 75 ± 5 min.

We note that there may be a decrease in photometric flickering amplitude with color (0.3 mag in B and 0.1 mag in R (see in Paper II)), although our data were obtained more than a year apart. In order to determine the source of this photometric modulation, multicolor photometry would be useful. These observations could differentiate between a hot-spot structure (decreasing amplitude in the red) and general flickering.

3.2 *CP Eridani*

In Paper II we presented a time-series light curve for this star. It was seen to be at an average magnitude of $V = 17.8$ and showed a slight increase of 0.2 mag over the 2.7 hrs of monitoring. There was no indication of any periodic modulations. We observed CP Eri again in September 1989 and in August 1990. During these observations CP Eri was at a magnitude of 19.7 and showed a very distinct modulation in both B and V light (Fig. 2). The B data show large-amplitude (0.2–0.4 mag) modulations and a clearly defined period of 28.6 ± 1.3 min, while the V data had smaller (0.1–0.2 mag), less well-defined modulations yielding a period of 29.5 ± 1.5 min. The V data set also shows a strong harmonic at 13.6 ± 1.5 min.

We conclude that the Paper II observation was proba-

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TABLE 1
OBSERVING LOG

Object	UT Date	UT[a] Start	N[b] obs.	t[b] sec.	dt[b] sec.	T[b] hrs.	CCD[c]	Filter[d]	Average[e] mag.	Sigma[f]
WX Cet	01Sep89	08:29:13	60	180	23	3.4	TI6	B	17.8	0.02
		08:28:40						V	17.6	
	03Nov89	06:16:40	29	300	13	2.5	RCA	V	17.7	0.03
CP Eri	04Sep89	09:16:37	30	320	23	2.9	TI6	B	19.3	0.05
		09:12:30						V	19.7	
	26Aug90	08:25:56	21	300	29	1.9	TI3	V	19.8	0.03
XZ Eri	04Nov89	08:14:20	55	220	13	3.8	RCA	V	18.7	0.06
V592 Her	20Apr90	09:06:10	15	400	13	1.7	RCA	WR	—	0.10
								V	20.5	
TT Ind	27Aug90	00:50:14	100	120	29	4.1	TI3	V	—	0.12
		23:52:00						B	16.8	
		23:58:00						V	16.6	
	28Aug90	00:01:00						R	16.1	
AO Oct	25Aug90	04:10:11	10	360	29	1.1	TI3	V	21.1	0.14
		03:42:18						B	21.0	
		03:55:00						V	20.9	
		04:02:00						R	20.7	
		23:44:33						R	20.2	
		23:51:38						V	20.9	
		23:58:34						B	20.6	
	26Aug90	00:06:37	37	360	29	4.0	TI3	V	20.9	0.09
BE Oct	27Aug90	05:48:26	45	300	29	4.1	TI3	V	19.4	0.03
		09:47:05						B	19.6	
		09:53:19						R	19.3	
CT Ser	14Apr90	08:59:10	25	180	13	1.3	RCA	V	16.4	0.06
		08:43:41						B	16.2	
V2276 Sgr	29Aug90	02:53:05	28	300	29	2.6	TI3	V	20.1	0.07
		02:40:41						B	19.9	
		02:46:45						R	20.1	
KK Tel	27Aug90	00:26:50						B	19.5	
	28Aug90	00:21:11	86	180	29	5.7	TI3	V	19.2	0.03
		00:08:37						B	19.4	
		00:14:52						R	18.8	
		23:46:01	41	180	29	2.4	TI3	B	19.4	0.05
		23:41:14						V	19.3	
DR UMa	07Jun89[g]	07:30:19	66	250	13	3.4	RCA	V	20.2	0.06
		07:28:10						B	20.7	
	16Apr90	08:42:19	16	600	13	2.7	RCA	WR	18.9	0.01
		08:29:23						V	19.1	
	19Apr90	05:01:00	29	600	13	4.9	RCA	WR	19.2	0.04
		09:45:03						V	19.2	
RW UMi	01Sep89	05:46:49	29	240	23	2.1	TI6	B	18.9	0.04
PG0917+342	16Apr90	03:29:27	230	45	13	3.7	RCA	WR	13.1	0.05
		07:05:09						V	14.1	
PG2240+193	31Aug89	07:23:41	153	60	23	3.5	TI6	V	15.9	0.03
2138-453	28Aug90	05:51:40	44	300	29	4.1	TI3	V	20.2	0.06
		05:38:30						B	20.3	
		05:45:30						R	20.0	
	29Aug90	05:47:03	35	300	29	3.2	TI3	B	20.2	0.05
		05:39:21						V	19.9	
		09:04:20						V	20.2	

a) Time is for midpoint of first exposure in series.
b) N = number of integrations, t = integration time, dt = dead time between integrations (varies between computers and sometimes with number of frames stored on disk), T = total observation interval (including any gaps).
c) TI6 = KPNO TI6 CCD, Format 400X400 (2X2 pixel summed), Read noise = 8e⁻, Gain = 4.0e⁻ADU.
TI3 = CTIO TI3 CCD, Format 400X400 (2X2 pixel summed), Read noise = 8.3e⁻, Gain = 8.3e⁻/ADU.
RCA = Lowell RCA CCD, Format 256X256, Read noise = 60e⁻, Gain = 13e⁻/ADU.
d) B, V, R, and I are Johnson filters, WR (Wide R) has central wavelength = 7009A and FWHM 2601A.
e) Standard stars were observed nightly, usually near the beginning and/or end of a time series. No corrections for color terms and/or air mass differences were made. Errors are approximately 0.1 mag (see Howell et al. 1988). The listed magnitude for the time series is an average magnitude over the series length. The other magnitudes are single measurements made directly before or after the series. WR magnitudes are estimated from spectrophotometric standards.
f) Sigma calculated from Eq. 4, Howell et al. 1988.
g) The CCD frames were co-added in this time series to yield the equivalent of 500 sec exposures.

TABLE 2
PERIODS EVIDENT IN DATA

Object	Period (min)	Sigma[a] (min)	Confidence[a] Level (%)	Period Type
CP Eri	29	1.4	99	magnetic
KK Tel	121	5	95	orbital
RW UMi	113	10	95	orbital
2138-453	93	11	88[b]	orbital

a) As given in Stellingwerf (1978)
b) See text

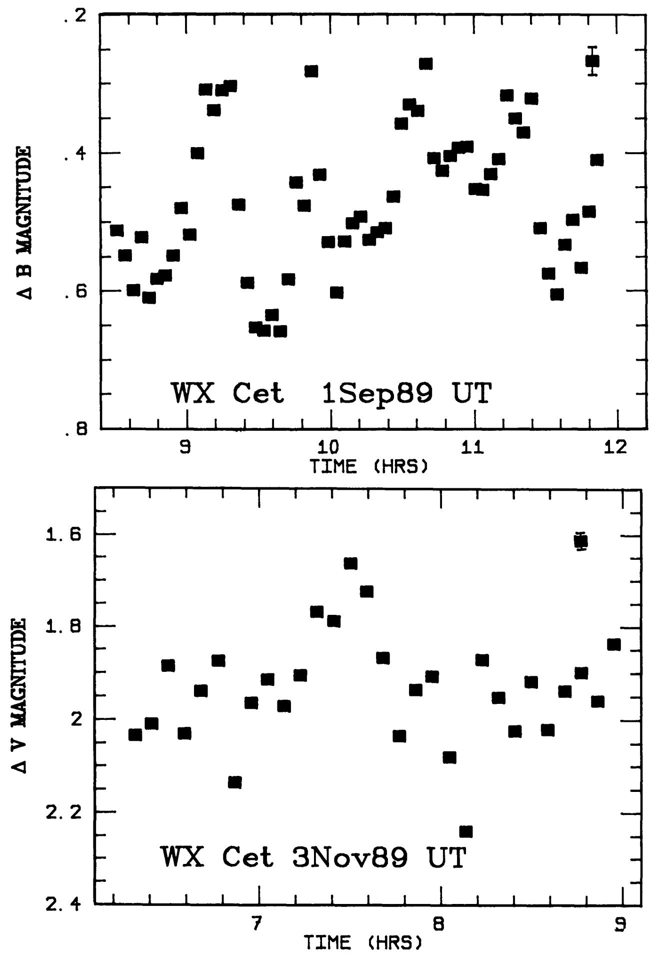

FIG. 1–The light curve of WX Cet taken in (a) *B* on 1989 September 1 and (b) *V* on 1989 November 3. Note the amplitude is smaller in *V* and the light curves appear very dissimilar. Each point represents a differential magnitude measurement relative to a comparison star from the same CCD frame. The points are plotted at the midexposure time of each integration with the first point being at the time given in Table 1 for the UT start. The magnitude listed in Table 1 for each series corresponds to the average magnitude seen during the observations. The error bars shown are ± 1σ and are displayed with a sample data point. They are equal to the sigma value listed in Table 1. If no error bar is shown, the error is smaller than the size of the plotted symbol.

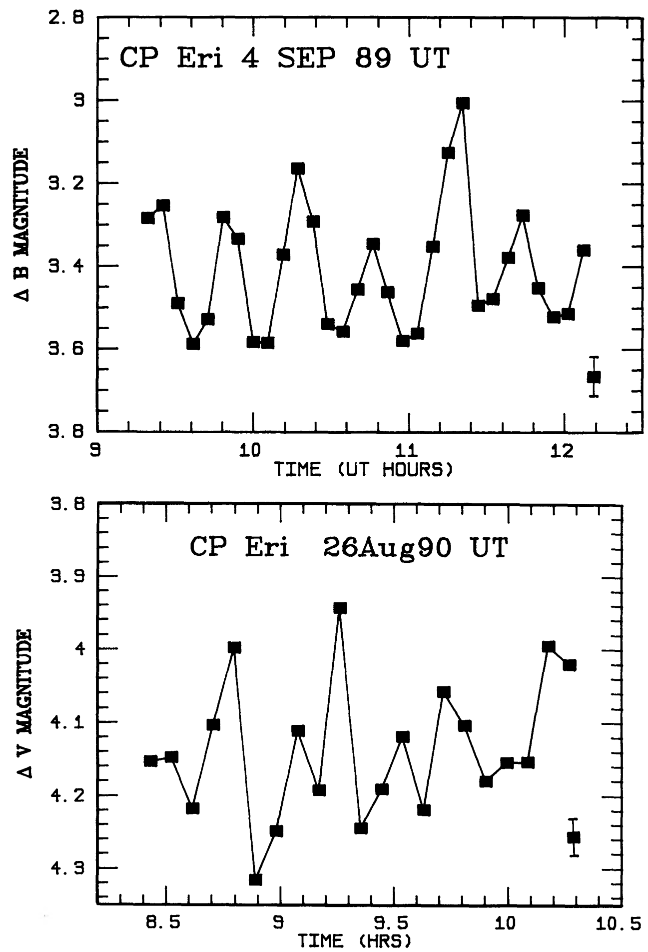

FIG. 2–Light curves in (a) *B* and (b) *V* for the DQ Her system CP Eri. See Figure 1 caption for a complete description.

bly made during a rise to outburst during which the light-curve modulations presented here were completely masked. The determined period of 29 min for CP Eri, being too short to be an orbital period (Nelson, Chan & Rosenblum 1985), suggests that this star is likely to be a new DQ Herculis system.

3.3 *XZ Eridani*

Noticed by Shapley & Hughes 1934 to be a variable with a magnitude range of from 14.6 to fainter than 17.5, this star was a likely candidate to be a CV. We obtained ~4 hrs of time-series photometric data, during which time it was at a mean magnitude of $V = 18.7$. The light curve (Fig. 3) shows flickering at the 0.4 mag level, characteristic of a CV, but no indications of periodic modulations were found. A radial-velocity study of this star at minimum is likely to be needed to determine its orbital period.

3.4 *V592 Herculis*

This star is listed as a nova of type NA in the GCVS and as type UG? or XND? in Duerbeck 1987. It was discovered by Richter 1968 on Sonneberg plates and found to have a magnitude range of $m_{pg} = 12.3$ to greater than 20. The light curve during decline appeared similar to that of the X-ray nova V616 Monocerotis, and the object is blue in color at maximum. Duerbeck suggests that these latter two properties make classification as a classical nova unlikely.

We observed the entire field shown in Duerbeck, including his marked candidate stars 1 and 2, and found that only star 1 showed any significant variability during the 1.7-hr time series. Figure 4 shows the light curve obtained when the star (Duerbeck's candidate 1) was at a V magnitude of 20.5. No periodic modulations were seen, but large-amplitude flickering of 0.4–0.6 mag is clearly visible. We therefore feel fairly certain that candidate 1 is the star associated with V592 Her and the "nova" observed in 1968. Further study at minimum is needed to determine the true nature of this star.

3.5 *TT Indi*

This star was discovered at magnitude 14.0 by Gessner & Meinunger 1974. We observed this star when at minimum, $V = 17.0$. This observation gives the first measurement of this star at quiescence and shows it to have an outburst amplitude of at least 3 mag.

Our 4-hr time-series light curve (Fig. 5) taken in August 1990 showed typical CV behavior with flickering of ~0.2 mag, but no indication of any periodic modulations.

3.6 *AO Octantis*

Listed in the GCVS as a UG:-type variable, this CV was discovered by Gessner & Meinunger 1974 during an outburst at magnitude 13.5. Their quiescent value listed m_{pg} 21, which agrees well with our determined value of $V = 20.9$. The outburst amplitude of this star is quite large (7.5 mag), making it a very interesting system to study.

Two photometric data sets of 1 and 4 hrs (see Fig. 6) were obtained. Large-amplitude flickering of 0.5–0.65 mag was observed but no modulations of a periodic nature were found.

3.7 *BE Octantis*

BE Oct is listed in the GCVS as a UGSU-type variable with a magnitude range of 15.4 to >17.5. Petit 1970 noted

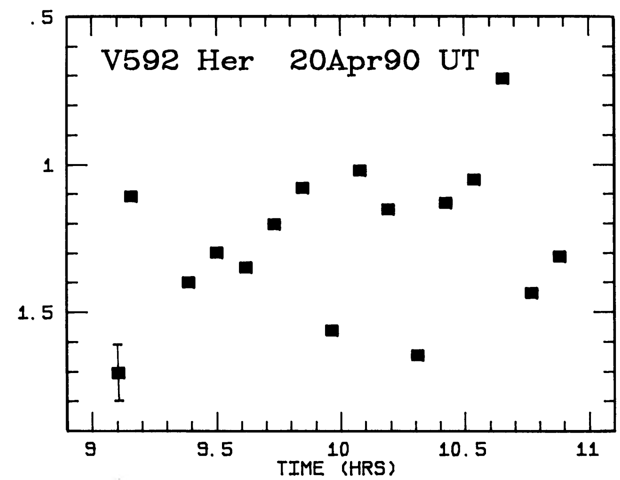

FIG. 4–Light curve for V592 Her taken on 1990 April 20. See Figure 1 caption for a complete description.

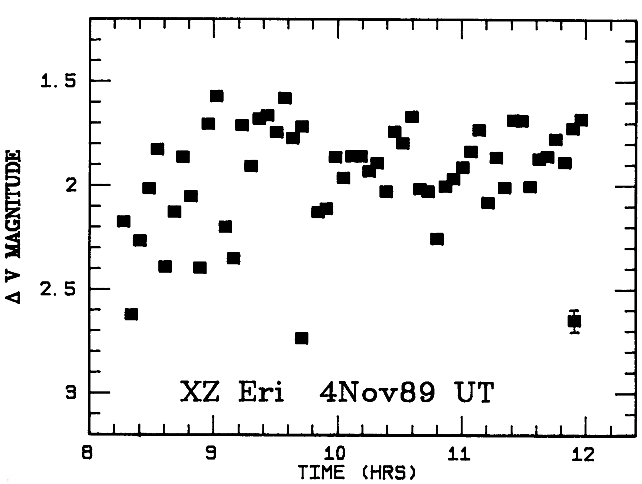

FIG. 3–Light curve of XZ Eri taken on 1989 November 4. See Figure 1 caption for a complete description.

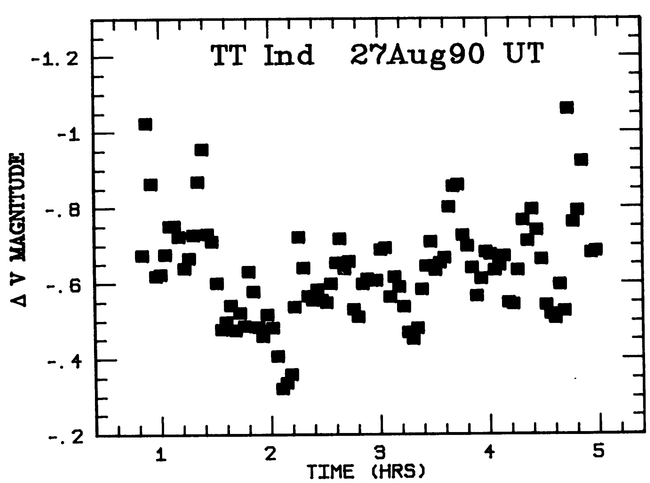

FIG. 5–Light curve of TT Ind taken on 1990 August 27. See Figure 1 caption for a complete description.

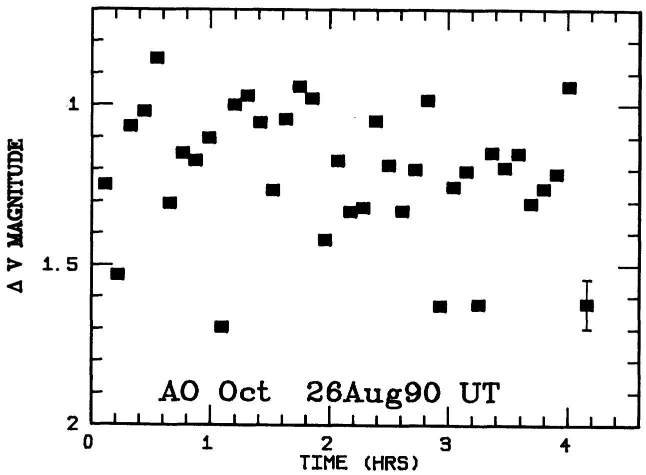

FIG. 6–Light curve of AO Oct taken on 1989 November 4. See Figure 1 caption for a complete description.

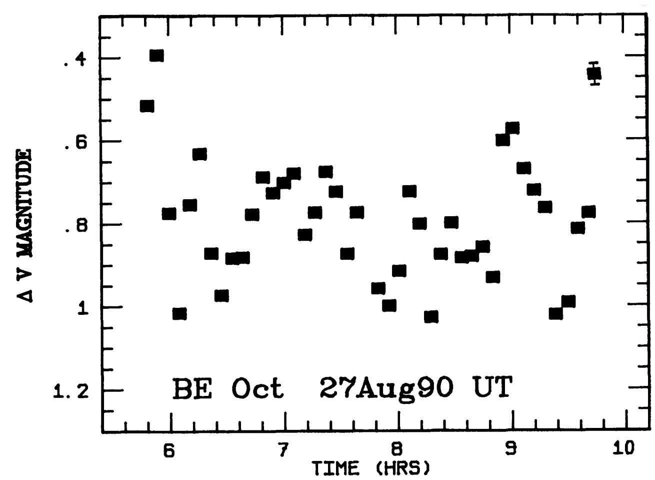

FIG. 7–Light curve of BE Oct taken on 1989 November 4. See Figure 1 caption for a complete description.

an apparent extended outburst time and suggested that this object is a dwarf nova of the SU UMa subclass.

Our 4-hr light curve (Fig. 7), obtained when BE Oct was at a *V* magnitude of 19.4, showed 0.2 mag flickering, typical for CVs in quiescence, but presents no orbital or other periodic modulations.

3.8 *V2276 Sagittarii*

Petit 1970 describes this star as a UG-type object with an outburst period of <30 days. The GCVS lists it as having a maximum magnitude of 14.4, with minimum being fainter than 16.7. Our observations, made at quiescence, showed it to have a *V* magnitude of 20.1. A single time-series data set (Fig. 8) reveals typical flickering usually associated with a CV at minimum, but shows no periodic modulations.

3.9 *CT Serpentis*

In Paper III we indicated that CT Ser might show periodic modulations of order 13 and 65 minutes. We therefore reobserved it to see if these possible periods were still present, thereby indicating their reality.

Our new photometric data set shows a light curve that is essentially flat, with only small-amplitude (<0.1 mag) modulations. A period search found no indication of any period, particularly the ones suggested in Paper III. We therefore conclude that either the periods seen were quasi-periodic in nature or were simply flickering modulations masquerading as periods.

3.10 *KK Telescopii*

Noted as a variable blue object by Hoffmeister 1963, KK Tel is listed as having a magnitude range from m_{pg} = 13.5 to ~19.7. Hoffmeister suggested that the nature of the variations he observed indicated that this star is a likely member of the UG class of variables.

Our two photometric light curves (Fig. 9) show quite clear evidence for a periodic modulation. The two data sets shown were taken on consecutive nights in *V* and *B*,

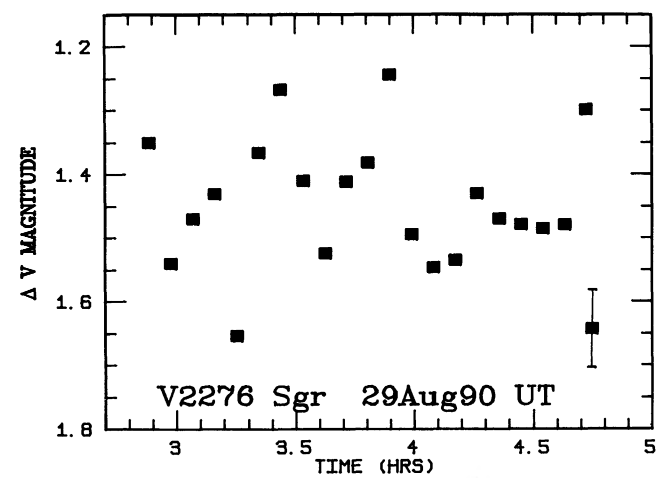

FIG. 8–Light curve of V2276 Sgr taken on 1989 November 4. See Figure 1 caption for a complete description.

respectively. The data from the first night show a period of 121±5 min. The two nights together gave the same period with a CL of 95%, but with a larger error (±14 min). The different shape of the hump seen in *B* is the likely cause of this larger error. The 121-min period extrapolated to the second night predicts the peak midpoint to be at 0.82 hr (see Fig. 9b), while the real midpoint appears at about 1.06, the difference being 14.4 min. This modulation is very likely to be from a hot spot, thereby indicating the orbital period of KK Tel, with the difference in phasing on the two nights possibly being due to hot-spot changes in size or location. We see that even within a single night (see Fig. 9a), the hot-spot hump shows different shapes and is not always symmetric.

In order to investigate the properties of our light-curve data in detail, we have phased together the *V* data obtained on the first night (Fig. 10). These data may show some evidence for an additional hot spot, offset by 0.45 in phase from the main (typical) hot spot. Additional spots of this kind have been seen in a few other systems, such as DV Ursae Majoris (Howell et al. 1988b). Further extended photometric observations of KK Tel are planned in order to confirm the phenomena discussed here.

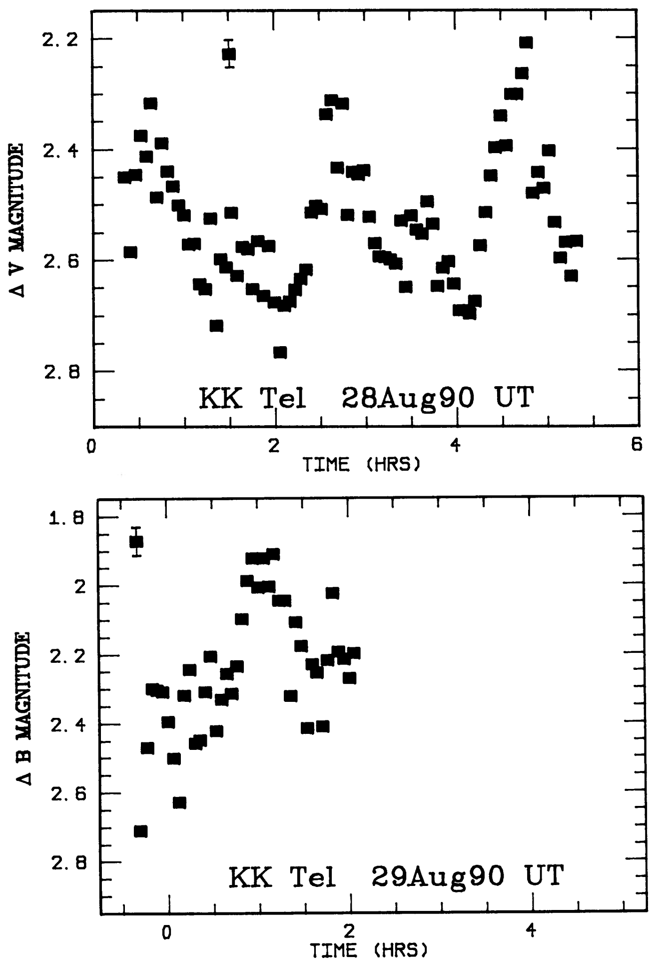

FIG. 9–*V* and *B* light curves for the star KK Tel. These data were taken on consecutive nights and generally have the same appearance. See Figure 1 caption for a complete description.

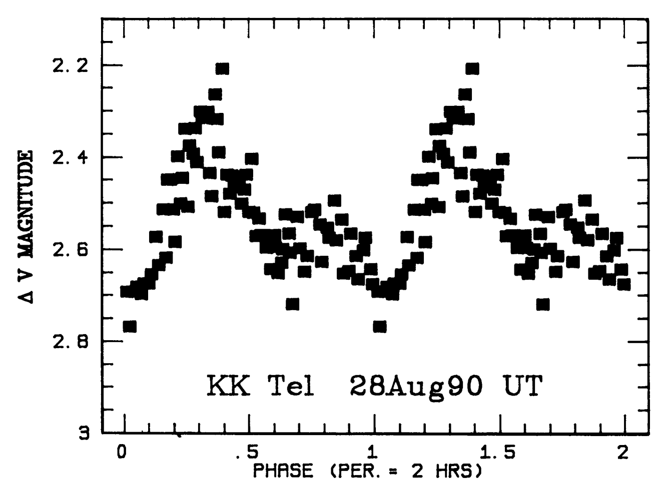

FIG. 10–KK Tel *V* data from 1990 August 28 orbitally phased on a determined orbital period of 2 hrs. Note the possible existence of a secondary hot-spot hump, offset in phase from the primary by 0.45 in phase. See text for details.

3.11 *DR Ursae Majoris*

Romano 1979 discovered this star while searching near M 101 for high galactic latitude variables. He noted that it had a range of 17.5 to fainter than 18.2 and a $(B-V)$ magnitude of +0.1 to +0.5. This evidence led him to the conclusion that this star is a likely CV candidate.

Using the chart provided by Romano, we looked for this object in June 1989 and found no object in the field at or near his marked position that was blue, or that showed significant variation down to a *V* magnitude of ~18.5. Almost one year later, in April 1990, we again looked for this star and found it at a magnitude of V = 19.1. A reexamination of our original data from approximately one year earlier revealed that the star was indeed present but that its magnitude was fainter, being $V = 20.2$. Summing our original 1989 frames in groups of two gave us poorer time resolution, but did allow us to construct a light curve with reasonable signal-to-noise characteristics. Two of the light curves from 1989 and 1990 are shown in Figure 11.

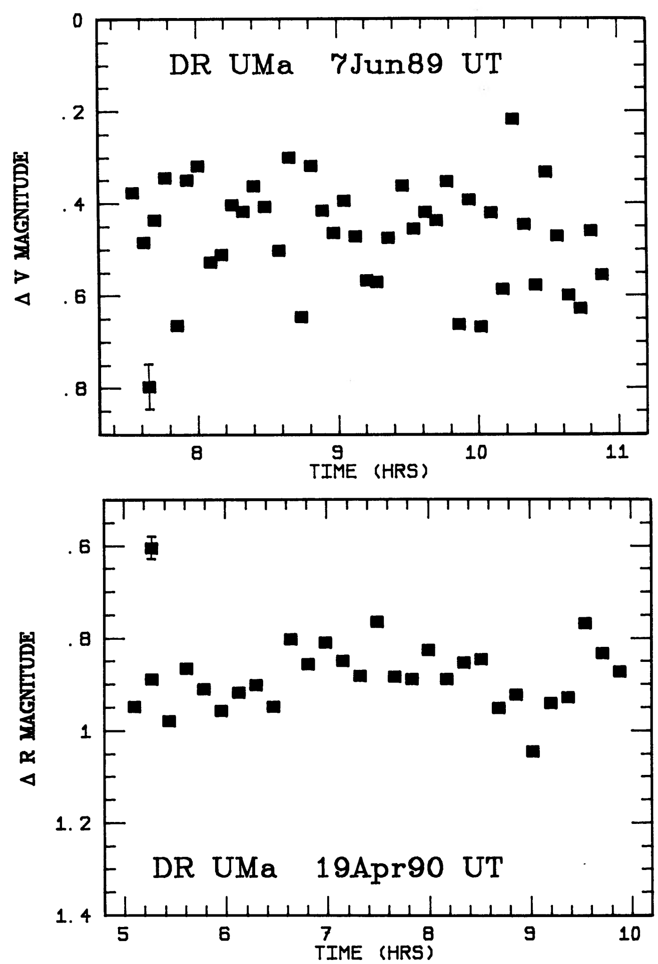

FIG. 11–Light curves for DR UMa from (a) 1989 June 7 in *V* and (b) 1990 April 19 in *R*. See Figure 1 caption for a complete description.

A period search of each data set independently, as well as the two sets from April 1990 combined, revealed no significant periods. Our three time-series data sets do, however, show >0.2 mag variations throughout. For DR UMa we presume a typical CV nature can explain our observations.

3.12 *RW Ursae Minoris*

Paper II showed the first time-series light curve for this star. It indicated a 117±5 min periodicity in the near-IR, but confirmation was needed since we only had data from a single night. The modulation seen in the near-IR looked sinusoidal and, if it represented the changing aspect of a Roche-lobe-filling secondary (ellipsoidal variations), it would indicate an orbital period of ~234 min.

We present here new time-series photometry, taken in *B*, in hopes of distinguishing between the possible confusion of the true period being once or twice the observed photometric period. Since this star has a very high declination (+77 degrees), it is difficult to study it for extended time periods due to the construction of most equatorial mounted telescopes. Our 2.1-hr *B* dataset (see Fig. 12) shows a modulation which has a similar peak-to-peak amplitude and overall appearance to the near-IR data shown in Paper II. The *B* data show a period of 106±20 min, consistent with the period of 117±5 min found in the data we presented in Paper II.

If the modulation seen is due to the ellipsoidal nature of the secondary, the correct explanation of the photometric data indicates an orbital period for RW UMi of ~4 hrs. However, the nonsinusoidal shape and amplitude of the *B* data suggest its origin is not the changing aspect of the secondary but a large bright portion of the disk (hot spot?), coming into view once each orbital period. Our best guess so far is that the orbital period of RW UMi is ~1.9 hrs, but we believe a better interpretation can result only from a simultaneous multicolor or spectroscopic study at minimum.

3.13 *PG 0917+342*

PG 0917+342 was found during the Palomar-Green Survey (PG Survey; Green, Schmidt & Liebert 1986) and identified as a CV candidate by Green et al. 1982. It has also been suggested to be the missing Nova Lynx 396 AD (Shara 1989). Green et al. 1982 mention that the star was observed in both emission and absorption states and that, while in an emission state, the line strengths appear to look like those of a typical dwarf nova, although He lines are not present.

Our single ~4-hr light curve (Fig. 13) shows the star to be constant within the errors throughout the entire data set. This type of light curve is atypical for dwarf nova in that it does not show the normal flickering behavior, but would be typical for an old nova, possibly indicating a thick disk. PG 0917+342 does, however, show two dissimilar-looking ~0.1 mag humps in its light curve. These features are not greater than 3σ but their cohesive appearance is compelling. If these humps represent an orbital modulation, then the orbital period would be ~2 hrs. Further photometric observations, particularly in *B*, are planned.

3.14 *PG 2240+193*

This star was also identified in the PG Survey and described by Green et al. 1982. The spectrum Green et al. describe has Hα in emission but the higher Balmer lines in absorption. They also mention that it might have an Fe II spectrum and that no He lines appear. We observed this star for 3.5 hrs and the light curve (Fig. 14) is constant to within ± ~0.05 mag, possibly indicating that PG 2240+193 has a period longer than 3.5 hrs.

3.15 *2138-453*

Hawkins & Veron 1987 discovered this object during their search for faint variable quasars. They present a spectrum (4000 Å–7000 Å) taken when 2138-453 was at $B = 20.4$. It looks fairly typical for a dwarf nova at mini-

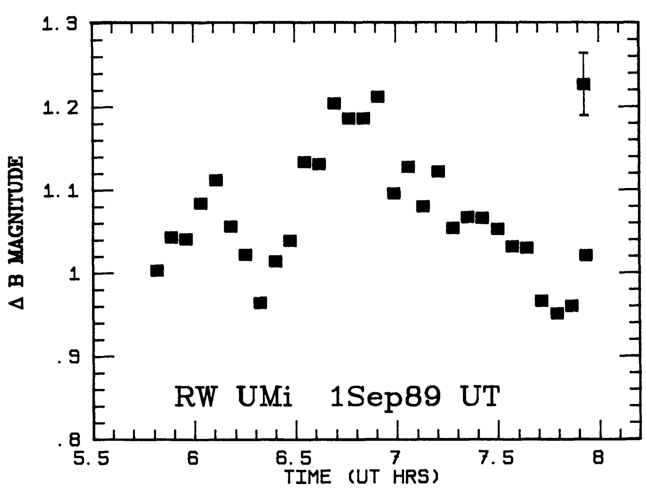

FIG. 12–*B* photometry of RW UMi taken on 1989 September 1. See Figure 1 caption for a complete description.

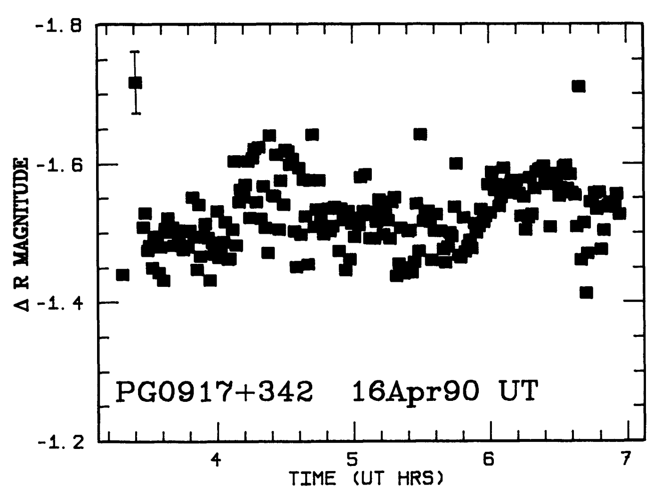

FIG. 13–*R* light curve of PG 0917+342 obtained on 1990 April 16. See Figure 1 caption for a complete description.

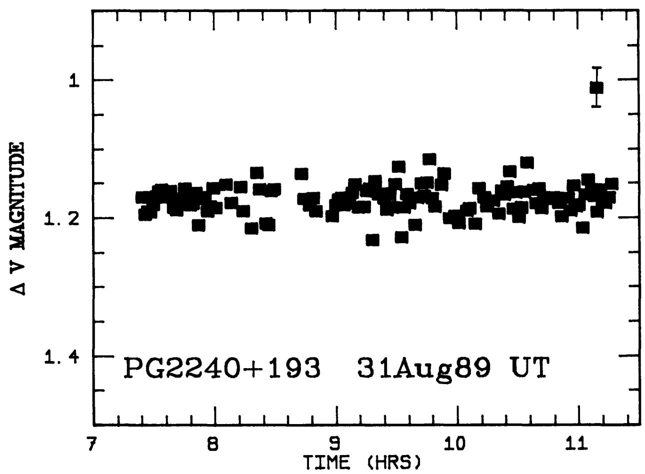

FIG. 14–V light curve of PG 2240+193 taken on 1989 August 31. On this particular night the observations were made during a period of passing thick clouds. The light curve has less data during these cloudy times, particularly near 8.3 and 10 hrs UT.

mum, with the Balmer lines and He I λ5876 in emission. The Balmer lines are double peaked, with Hα having a separation of 900 km sec^{-1}. We therefore added this object to our observing list.

Our time-series observations obtained in V and B are shown in Figure 15. The V data set shows a fairly typical hot-spot modulation and some marginal evidence for an additional hump offset by 0.6 in phase. The system shows large flickering in both data sets.

Each data set was searched for periods independently. We found a period of 93 ± 11 min (CL of 88%) in the V data set and 88 ± 11 min (CL of 86%) in B. We then combined the data sets in hopes of better refining the period. What we found, however, was that each of the two periods above remained and there was no indication of any single period common to both sets. Plots made of the data of both nights phased together on either period are not convincing but show a much better fit to the periodic modulations found in the V data set. Also, taking the 93-min period and extrapolating it to the second night shows a reasonable fit to the two larger peaks seen. We therefore list the period of 2138-453 as 93 ± 11 min in Table 2 and believe it to be real, within our errors, based on its repeatability. The large flickering seen may mask a good determination of the true orbital period, particularly on the second night. Longer-term multicolor light curves are needed.

4. Summary

We have presented CCD photometry time-series data for eleven new stars and further data for four stars. Two new orbital periods have been found for the stars KK Tel and 2138-453, and CP Eri is a likely DQ Her star. WX Cet is likely to have an orbital period of 72–80 min, and the orbital period of RW UMi is probably near 113 min.

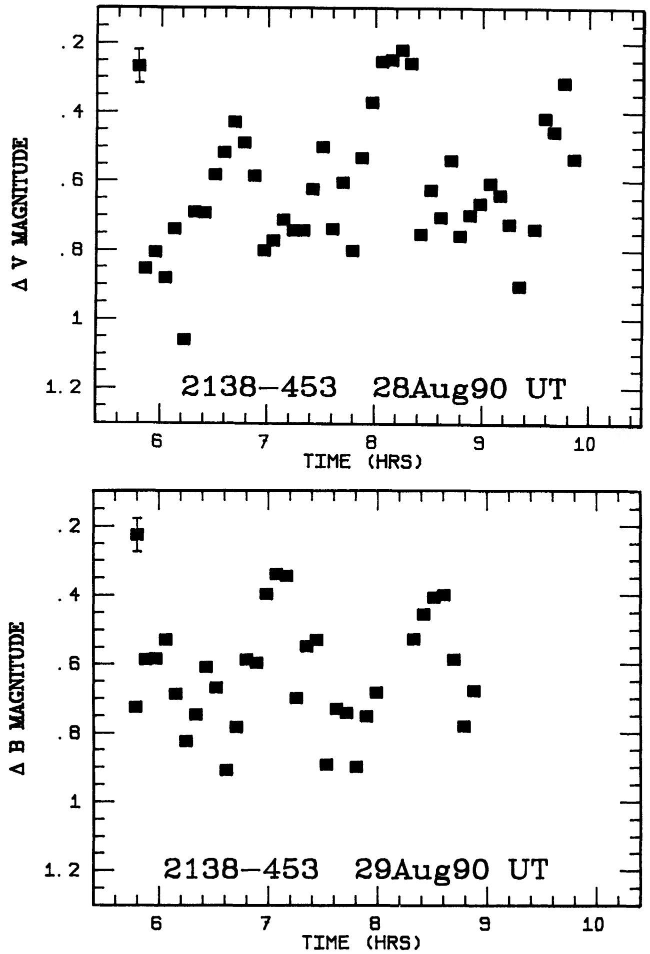

FIG. 15–Light curves of the star 2138-453 in (a) V and (b) B obtained on successive nights in August 1990. See Figure 1 caption for a complete description.

In Paper III we pointed out the fact that some of our program CVs show temporal magnitude changes at quiescence. DR UMa is yet another example and gives us a hint of the time scales involved as it changed by one magnitude on a time scale of no longer than ten months. We also know that for the time period of three days (1990 April 16 to 19) it stayed within 0.1 mag of $V = 19.1$.

Our four papers in this series so far have presented CCD light curves for 52 previously unstudied stars known or suspected to be cataclysmic variables. These data have consisted of 120 time-series light curves, 47 of duration >3 hrs. Of the 52 different stars that have been observed, we have found 22 which show modulations indicative of orbital periods (19) or magnetic pulses (3). Most of the other 30 stars have shown photometric evidence which supports their inclusion as cataclysmic variables.

We are continuing our CCD photometry project of obtaining data on faint CVs and pursuing follow-up study on the interesting systems we have already discovered. Distances and radial-velocity studies are of high priority in order to ascertain the true absolute magnitudes of the faint CVs and provide measurements of their intrinsic properties.

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