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Faint CV Monitoring at CBA Pretoria

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Abstract

The regular monitoring of faint cataclysmic variables (CV) is one of five observing programs that are run at CBA Pretoria. It started off in 2002 with about 120 CVs and related objects in the program. The intention was to observe those targets as often as possible with unfiltered CCD. There were continuous additions of more CVs by digging deeper in the CV atlas, new finds, and reclassified stars while some were taken off the list. At the end of 2004 the number of CVs in the observing program exceeded 200. With only one telescope and one observer and so many other things to observe, the actual number of snapshot CV observations have been much less than hoped. Despite this, the program has shown to be very successful. Publications have been referring to reported findings from this program while even more publications resulted from observing campaigns (time resolved photometry) dedicated to CVs that were found in outburst by observations at CBA Pretoria. In most cases they were the first real-time outburst detection of that CV. The present paper will not deal with those published or alerted finds but will show observing results of other CVs from the list just to give an indication of the broader meaningfulness of such a program. A selection of fifteen light curves obtained after three years of monitoring will be shown and discussed. The choice of the 15 stars was based on their possible interest and the fact that they have been positively observed on most occasions, since they were mostly brighter than magnitude 18 CR (unfiltered with red zero-point).

1. Introduction

CBA Pretoria is housed at the Bronberg Observatory, 40 km East of Pretoria Centre at coordinates 25 º 54' 32" S, 28º 26' 18" E and an altitude of 1590m.

The site is located on top of the Bronberg ridge, which stretches from Pretoria to just east of the observatory.

The observatory was built in 2001 to initially provide shelter and an observing platform for visual observations with a 32cm Newtonian telescope and with the aim of later housing a SCT with CCD camera for dedicated participation in the CBA network. The first real observing success came on 16 Sep 2001 with the visual discovery of supernova SN 2001el in NGC 1448.

Beginning in 2002, the observatory was equipped with a 30cm Meade LX200 classic (Schmidt-Cassegrain GOTO) telescope with CCD camera SBIG-ST7. Combined with a focal reducer (3.3x) it gives an effective f/3.7. A filter wheel with BVRI filters was added in Dec 2004.

The observing instrumentation was pier mounted and polar aligned for easy access and immediate observing.

2. Observing Programs at CBA Pretoria

Unless mentioned differently observations are done with unfiltered CCD.

2. 1. Time series photometry

The program started at the beginning 2002 as part of the CBA network to study the behaviour of CVs from observations taken over periods of weeks at different time zones. Observations were also done in collaboration with VSNET campaigns and simultaneously with satellite observations as organized by AAVSO, VSNET, or individual astronomers. Regularly, exploration targets are measured, usually one year old novae, newly found bright CVs, exoplanets for eventual transits, a minor planet, and even a comet that happened to pose on the images of the observed CV.

2. 2. SN Searching

The present search program consists of about 1500 galaxies, of which 100 are primary and 600 are secondary targets. This classification is based on the expected SN production of the listed galaxies and the frequency of observations is planned accordingly.

2. 3. Faint CV Monitoring

This program started off with 170 targets in early 2002 and extended to over 220 targets in 2005. It is further being optimized for maximum value. The idea was to observe those CVs as often as possible.

The plan for the future is to prioritize, to settle for a smaller number of listed CVs, and to observe those more often.

2. 4. TOO

Observations to follow up on transients – XT, GRB, novae, etc. – and unusual objects when alerts are made via the Internet. Bright objects are usually observed filtered in V and R_c. Astrometry is sometimes applied on the images to improve the reported coarse coordinates or in case of nova confirmations. GRB observations are reported to AAVSO-HEN.

2. 5. Southern Symbiotic Stars

Started at the end 2004, this project aims to monitor monthly all known and suspected Z And systems in the Southern Hemisphere in the V band. About 200 targets are presently listed. Not much is known about most of those symbiotic stars. In addition to light curves, some interesting developments (eclipsing systems, Mira pulsations of the secondary, symbiotic novae) will be observed in the years to come.

3. Faint CV Monitoring Program

The purpose is to produce long term light curves of the program stars by regular monitoring of their brightness in terms of unfiltered CCD magnitudes (CR) relative to reference stars with a constant brightness and calibrated/derived R_c magnitude. Of specific interest are the evolution between low and high activity states of magnetic CVs (polars and intermediate polars), the occurrence of outbursts in dwarf novae and novalikes, fading episodes of VY Scl type CVs, and activity of Xray binaries.

Long term lightcurves will assist the astrophysicists with type characterization of lesser known or 'uncertain' CVs. In cases of an uncertain identification of the suspect CV, the stored images taken over a long period will eventually allow pinpointing the actual CV on the basis of brightness variations or outbursts.

The targets selected for this program originate from the CV atlas, X transient catalogs, and alerts. Only stars south of Declination +10 were considered.

The mixture of CV types on the observing list has been varied. Beginning in 2006, the list comprised 211 targets.

44	Non-typed CVs
49	Known and suspected dwarf novae (ug)
10	Known and suspected DQ Her stars (IP, dq)
49	Known and suspected polars (am)
7	LMXB and XN
6	Novalikes (ux, nl, vy, sw sex, non-types)
4	Known and suspected AM CVn types (ibwd)
10	Known and suspected recurrent novae (nr)
9	Young novae (often monitored to see if modulation revealing time series are possible after more than one year after the explosion)
25	Known and suspected old novae for recurrence or other brightenings (non-cv sometimes)

Note that some CVs are documented with more than one possible classification. Therefore, in this case, the sum of parts is larger than the total.

In March 2006, the number of program CVs was reduced to 163. CVs scrapped from the list were mainly of type ug with outburst magnitudes brighter than 15 and young novae that became too faint.

4. Observations

4. 1. Procedure

Observing is done manually via a PC and the telescope control keypad. Images are taken using CCDOPS 5 and are stored in the FITS format. AIP4WIN is used for image calibration (dark and flat) and data processing (image stacking and differential photometry). Usually 2 to 5 images are taken per target depending on the expected brightness. After the calibration, images of acceptable quality are stacked for improved S/N and increased limiting magnitude. In this way, most CVs are monitored at the 18 to19th magnitude level. Still, a fair amount of such observations remain negative most of the time.

4. 2. Photometric Accuracy

Although the observations are regularly reported and will possibly be kept in databases, the magnitudes cannot be considered very accurate. In the observing reports, it is stated that the derived CR magnitudes result from differential photometry to non-red comparison stars with R magnitudes. Those magnitudes are taken directly or derived from published photometric data or, lacking any thing better, UCAC2 magnitudes of constant comparison stars that are selected on the basis of non-red colour and reliability of the data.

In the latter case, R magnitudes of selected reference stars for the sequence are derived by the empirical formula:

$$R = O - 0.3\ (J\text{-}K)$$
$$V = O + 0.7\ (J\text{-}K)$$

O being the tabled UCAC2 magnitudes and J and K being published NIR magnitudes. The assumption is made that J-K = V-R, which is approximately valid. The advantage of differential (aperture) photometry is that without loss of accuracy (but gain in precision!) comparison stars can be selected that are about two magnitudes brighter than the measured star. In addition, this allows for an improved accuracy since validation can be sought by comparing the derived V values to those of ASAS3 data, which typically shows agreement to about 0.1V. The reference sequence is further improved by regularly checking the magnitude differentials between the major comparison stars on the acquired field images. This has been applied to a large extent to the V sequences of star fields for the symbiotic stars monitoring program.

Estimated uncertainties (errors) for observations in the CV program are typically 0.2-0.5 mag in accuracy and 0.1-0.3 mag in precision, much of this depending on the source of reference for the photometry and the faintness of the measured star.

In view of the program objectives, the precision is particularly important since it allows monitoring the small night-to-night variations in the magnitudes of the observed CVs. Since most of the brighter observed CVs have known orbital modulation amplitudes, actual changes in activity of the CV can be noticed from the data. In some cases, the cycle modulation amplitude of bright CVs (magnitude 17 or less) has been derived from time series photometry at CBA Pretoria.

Note: The drawbacks of unfiltered observing of CVs must be well understood in that the red/IR excess sometimes determines the measured brightness. This mostly concerns CVs that are strongly reddened or where the red light from the secondary is dominant during quiescence. This red/IR light is readily picked up by the NIR tail of the Si photosites, showing the CV much brighter than it would from behind a V filter.

Even in those cases, the increased activity of the system manifested by means of an increased brightness at shorter wavelengths might still be picked up in unfiltered mode and certainly in the case of outbursts.

4. 3. Observing Frequency

Observations are done as often as time, weather, and other observing priorities allow. Special efforts are made to follow up on interesting episodes or unusual behaviour of some of the program stars. Occasional flare-ups of stars like UZ can be picked up by dense monitoring. The past years have shown that due to other observing priorities, most program CVs have been under observed.

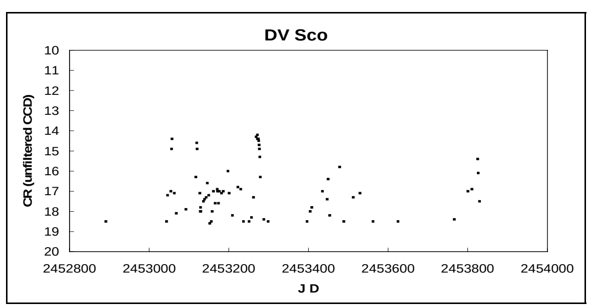
4. 4. Past Successes

Most of the discoveries made by this observing program can be found in alerts, publications and timestudies. Timestudies of lesser known CVs that were observed to be in outburst at were also made at CBA Pretoria. Examples are: 2QZ J021927-3045, BZ Cir, DV Sco, V663 Ara and CTCV J0549-4921.

5. Discussion of Results After Three Years

Light curves of 15 faint CVs made over about three years are presented. They are tabled in alphabetical order in the table below with data from the CV atlas (Downes, Feb 2006). Findings are discussed and comments are given on the individual CVs. Quoted magnitudes refer to unfiltered magnitudes with red zero-point (CR) unless stated differently.

5. 1. DV Sco

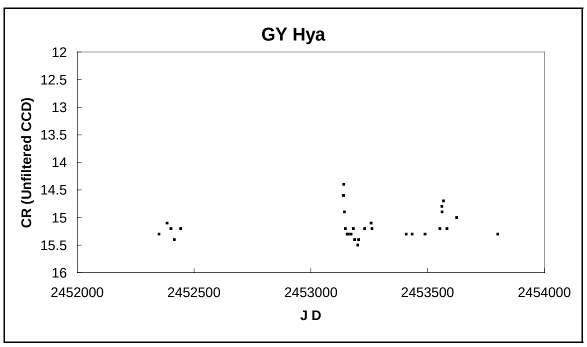


This star has regular outbursts around magnitude 14 and a quiescent magnitude below 18.

Name	Alternate Name	RA	DE	Type	Magnitude range	Period (d)
DV Sco	HV 4225	16:50:27.93	-28:07:58.6	ugsu	13.8 B - <18.4 B	-
GY Hya	S 6576	14:30:30.47	-25:52:38.0	ug	14 p - 16 p	0.347237
QS Tel	RE 1938-461	19:38:35.80	-46:12:56.6	am	15.2 V - 17.4 V	0.097187
UW Pic	RX J0531-4624	05:31:35.59	-46:24:05.9	am	16.4 V - 17.2 V	0.09264
V662 CrA	Plaut 3-1235	18:35:30.53	-36:56:44.7	ug	15.7 p - <19.6 p	-
V834 Cen	1E 1405-451	14:09:07.30	-45:17:16.2	am	14.2 v - 17 v	0.070498
V895 Cen	EUVE J1429-38	14:29:27.22	-38:04:09.5	am	16.5 v - 17.5 V	0.198553
V1025 Cen	RX 1238-38	12:38:16.38	-38:42:46.0	dq	16.1 V -	-
V1043 Cen	RX J1313-3259	13:13:17.14	-32:59:12.2	am	16 V -	0.174592
V2839 Sgr	Plaut 3-281	18:16:19.29	-31:42:09.8	UG:	15.3 p - 17.2 p	-
V3608 Sgr	Plaut 3-1233	18:35:24.55	-35:32:04.5	UG	15.6 p - 18.7 p	-
V3774 Sgr	Plaut 3-1453	18:41:41.18	-32:54:33.9	ug	14.7 p - 17.7 r	-
VW Tuc	HV 6327	00:20:19.11	-73:52:08.1	UG:	15.4 p - <16.5 p	-
VX Ret	EC 04030-5801	04:04:05.70	-57:53:26.6	ug	14.7 B - 18.1 B	-
WX Pyx	1E 0830.9-2238	08:33:05.74	-22:48:32.2	am:/dq	16.2 V - 17.7 V	0.2307

Short runs of time series photometry at CBA Pretoria during a long outburst in September 2004 showed the distinct shape of superhumps. There is a need for further dense monitoring to better establish the outburst frequency and to conduct longer time series photometry during a future superoutburst.

5. 2. GY Hya



The mean magnitude in quiescence is around 15.2. The long term light curve shows outbursts or active states around magnitude 14.3.

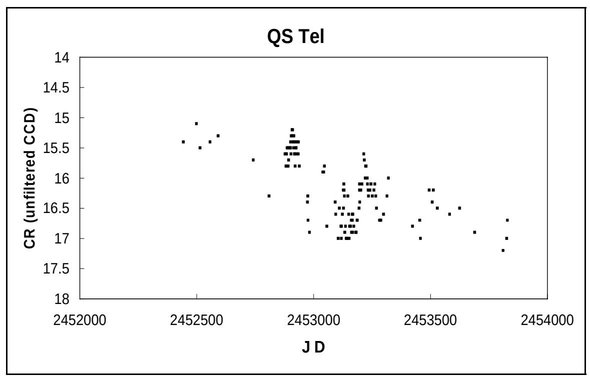
Time series photometry of long duration at CBA Pretoria during a spotted outburst in May 2004 showed the eclipsing nature of the system and gave a good indication of the orbital period. In comparison to time series photometry made during quiescence, the orbital light curve shows deeper eclipses during outburst, which hinted at the WD region as the eclipsed region. However, the mean unfiltered magnitude over the cycle didn't change much (< 1 magnitude) from quiescence to outburst.

Follow up time series at later epochs did improve the accuracy of the orbital period down to the resolution given in the CV atlas and which is in close agreement with the spectroscopically determined period by Peters, C.S. (2005).

Multicolour time series light curves might show even deeper eclipses at the shorter wavelength bands.

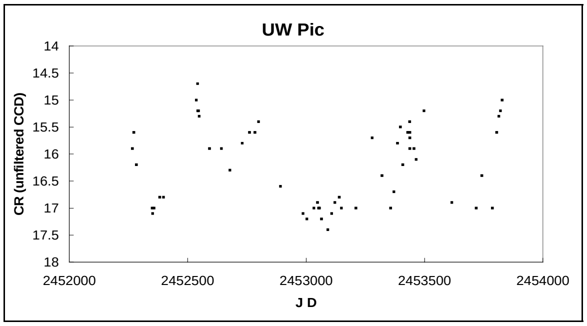
The main characteristics of this long period CV seem to be well established and its continuous monitoring was stopped in favour of other targets.

5. 3. QS Tel



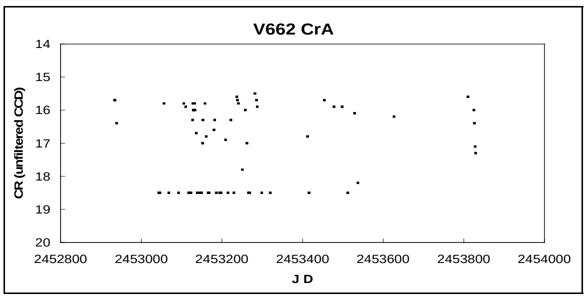
This star has been in the active phase at the start of observations in 2002. The mean magnitude was around 15.5. The active phase seems to have ended during Aug 2003. Arguably a transition state occurred for nearly two years. The low state has continued up to date. Further monitoring is planned.

5. 4. UW Pic



This is a polar alternating steadily between high and low states. Time series unfiltered photometry was done during the active phase. More observations are needed to derive a cycle of states.

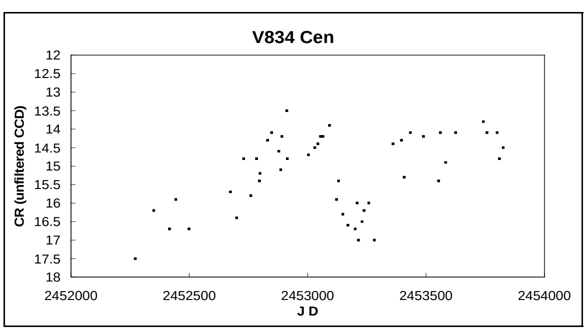
5. 5. V662 CrA



Despite its large outburst amplitude, this CV has lots of them. They are mostly of short duration while the long outbursts last a couple of weeks. On two occasions (6 May and 23 Aug 2004) time series photometry was done about midway through such long outbursts. No humps appeared in the light curve. This is possibly this is an ugss type.

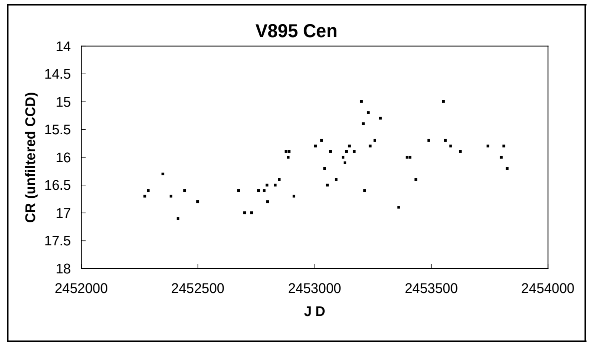
The frequency of short and long outbursts will be further researched by continuous dense monitoring.

5. 6. V834 Cen



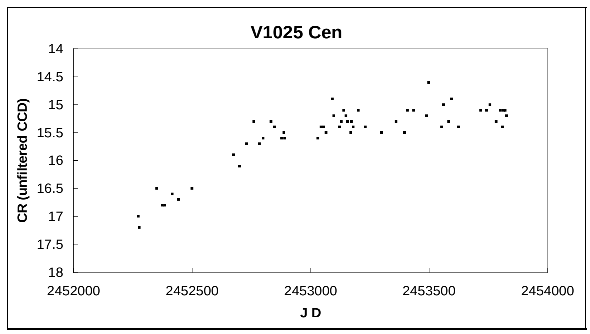
The difference between low and high states is about 2.5 magnitudes (16.5-14.0). There is a hint of a cycle period around 800 days.

5. 7. V895 Cen



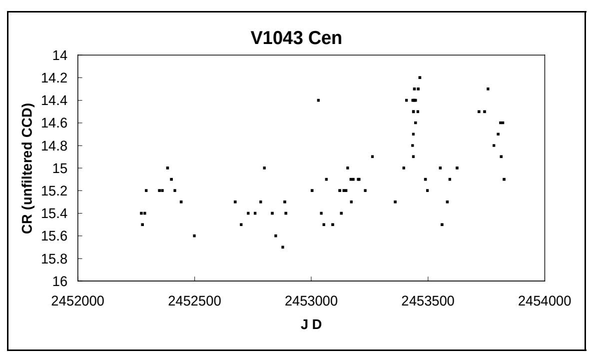
The mean magnitude has increased from 16.7 to 15.7 over the period 2003 to 2006. Is this part of a periodic cycle?

5. 8. V1025 Cen



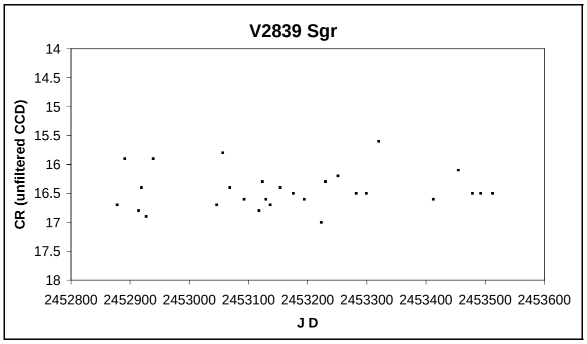
The star has reached the high state since the beginning of 2003 and remained there until now.

5. 9. V1043 Cen



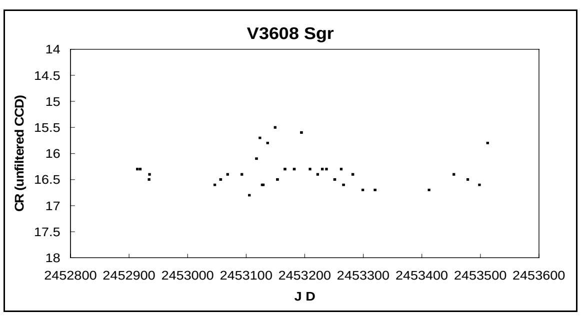
Observations reported by Thomas et al. in their 2000 paper showed this star to be close to 16.0V. The mean brightness has increased considerably since then and this trend continues. Two outburst stages were recorded in 2005-2006, with magnitudes around 14.4. It is difficult to predict how this polar will further evolve in the years to come. One way to find out is a more dense coverage at CBA Pretoria. Sporadic filtered photometry might be considered.

5. 10. V2839 Sgr



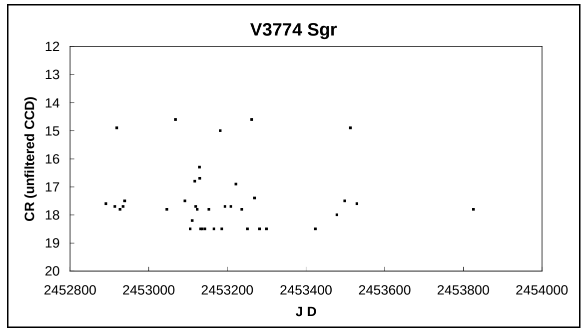
Initially the ID of this suspect CV was uncertain, indicated by a circled area on a field image in the CV atlas. Observations over one year pinpointed the suspect on the basis of variability. In order to probe the orbital period and eventual type of the suspect CV, time series photometry was conducted in 2004. It established the RRab nature of this variable with a period close to 1d or, more likely, 0.5d. No further observations were done.

5. 11. V3608 Sgr



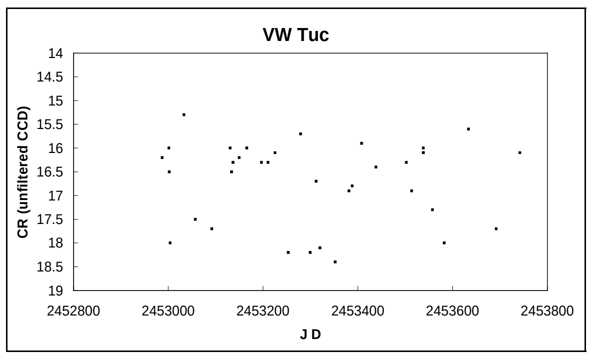
This is similar to V2839 Sgr, i.e,. another RRab star with a similar light curve and period.

5. 12. V3774 Sgr



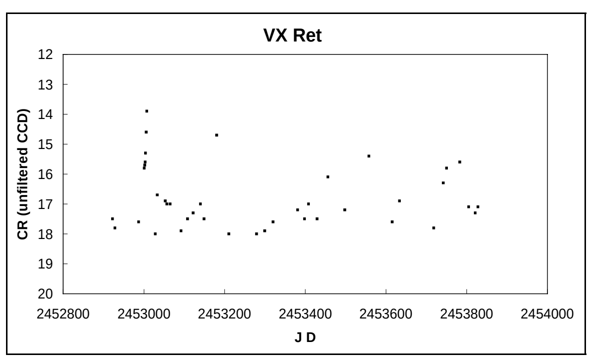
This star has shown outbursts at regular intervals. Short time series photometry during outbursts did not reveal any clear modulation. More data are needed.

5. 13. VW Tuc



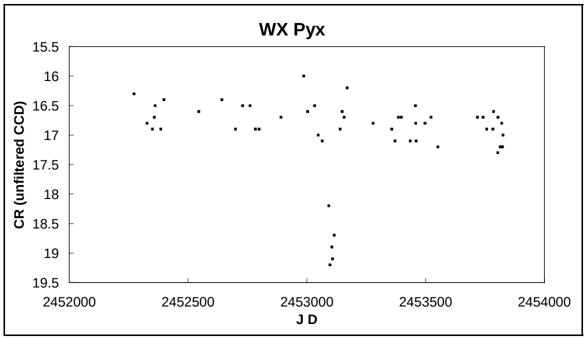
VW Tuc has usually been observed around magnitude 16.2 but with fadings beyond mag 18. This star has an uncertain 'UG:' classification. There is a need for more dense coverage, including filtered observations and time series photometry, to see if there is a pattern,. This could be an interesting star.

5. 14. VX Ret



A long outburst was detected in Jan 2004. Short time series did not reveal any obvious modulations. More dense coverage is planned.

5. 15. WX Pyx



WX Pyx has been showing a small gradual fading since observations started in Feb 2002. The scattering of nightly data points largely reflects the brightness amplitude during the orbital light curve, which is around 1 magnitude. In April 2004 WX Pyx showed a deep fade of more than two magnitudes during a period of two weeks. Is this a recurring phenomenon? This looks interesting and this polar will be more densely monitored.

6. Conclusions

The first three years of the faint CV monitoring program observing can be considered successful, having made the following achievements:

1. Outburst detection and characterization of suspected or unknown dwarf novae
2. Identification of suspected variables
3. Characterization of non-CVs
4. Evolution of activity states of magnetic CVs. It is clear that much longer monitoring is required to probe for the existence of cycles
5. Shortcomings observed are related to insufficient density of the monitoring.

With regard to specific types of targets, it is difficult and even speculative to report any findings. However, it is clear that in the case of polars, changes in activity states differ considerably from target to target.

The discussed observing period is much too short to show the long-term behaviour of each of those CVs. The changes in activity states and their frequency of occurrence and repeatability of magnitudes need considerably more data.

7. Future of the CV Monitoring Program at CBA Pretoria

There will be a continuous review of the observing list. More dense monitoring of a select few stars along with periodic monitoring for most other listed CVs is the present strategy.

The faint CV monitoring program must be seen as complementing the organized observing programs by associations such as the AAVSO, BAA, RASNZ, and others. It differs in that the target selection is not based on the availability of historical data but rather on recent findings. Organized observing programs of those associations are still catering mainly for visual observers, while those same targets are also presented to CCD observers with the aim of providing more accurate filtered photometry.

The initiative to monitor faint CVs and transient sources often at the limit of an unfiltered CCD camera/small scope combination without much accuracy and without third party validation of the results is not really in line with the mandate of most of those organisations.

Therefore, monitoring faint CVs must be considered a “niche field” for amateurs with an interest in exploring the CV zoo.

8. Acknowledgments

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Dr Arne Henden (now AAVSO Director) and Brian Skiff (Flagstaff) for their efforts to provide accurate photometric references

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Brigitte, my wife and companion for over thirty years, for her patience and always support.

No grants or financial subsidies were received for any of the observing programs at CBA Pretoria.

9. References:

CV atlas now archived at
http://archive.stsci.edu/prepds/cvcat/index.html

CBA site at
http://cba.phys.columbia.edu/

AAVSO at
http://www.aavso.org/

VSNET (semi-dormant) at
http://vsnet.kusastro.kyoto-u.ac.jp/vsnet/index.html

VIZIER at
http://vizier.u-strasbg.fr/viz-bin/VizieR

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