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CCD TIME-SERIES OBSERVATIONS OF THE DAV CATACLYSMIC VARIABLE GW LIBRAE

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Abstract. Experiences in using a 'standard' commercial CCD photometer for relatively fast time series photometry are presented.

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1. INTRODUCTION

The dwarf nova GW Librae (González 1983, Duerbeck & Seitter 1987) was recently discovered by Warner & van Zyl (1998) and van Zyl (1998) to contain a pulsating DAV white dwarf primary. The potential of this object to yield significant astrophysical information is quite high: an asteroseismological study of the white dwarf pulsations should provide unique data on both cataclysmic variable structure and the phenomenon of non-radial white dwarf pulsation. Unfortunately, due to the faintness of the object in its quiescent state ($V \approx 18$ mag), the necessary high-speed photometry required for asteroseismology is difficult to achieve. With one meter class telescopes CCD observing is essential, but the CCD systems available at most observatories are not really suitable for fast time-series work. The following sections report on using a 'standard' CCD system to observe GW Lib in "fast" photometry mode. Also see van Zyl et al. (2000).

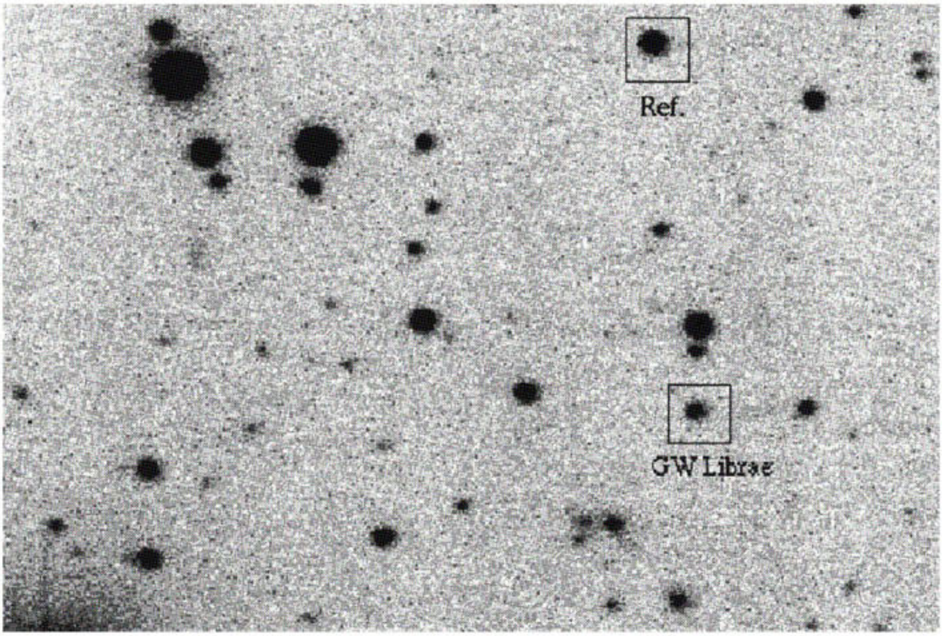

Fig. 1. One of the 30 s CCD images of the field near GW Lib. South is up and east is to the right, the field of view is about 4.7′ (EW) by 3.2′. Data from the marked reference star are given in Fig 2.

2. NEW ZEALAND OBSERVATIONS

CCD time-series observation of GW Lib were carried out at Mt. John University Observatory in New Zealand on four separate nights in 1998. Two nights in May (23, 24) were part of a southern hemisphere multi-site campaign organised by Warner & van Zyl (1998) and two further nights in August (14, 16) represented an attempt to extend the observations. The CCD camera used a 1K×1K SITe chip that formed part of a Photometrics (Tucson, Arizona) 200 series system, and this was attached to the Mt. John 1 m telescope. The CCD system is under the control of proprietary software that runs in a Windows 95 environment. Due to the faint magnitude of the target, no filter was used, so the effective photometric passband of the instrument was defined by a combination of atmospheric absorption and changing CCD detection efficiency.

The Mt. John CCD system is a fairly standard design, and is not optimized for fast time-series work on hot targets: it has no frame transfer mode, there is no on-line reduction and the software control system handles time awkwardly. Nevertheless, the system was made to work in a satisfactory way for this programme.

A subset of the chip (525×300 pixels) was chosen for readout, such that an adequate region around the target was observed (see Fig. 1) and readout time ($\sim$ 10 s) was minimized. Previous fast photometry on the target (van Zyl 1988) had indicated that no periodicities less than about 200 s were present, so an integration time of 30 s was chosen to ensure that (a) no real high frequencies were aliased and (b) the fractional deadtime of the instrument was not too high. A deadtime of $\sim$ 25 % was hardly ideal, but under the circumstances it was deemed satisfactory.

As the CCD system allowed some automatic control, a simple script was written that immediately started the next exposure once the software had read out and stored the previous one. Even though the CCD time system was rather crude by real-time photometry standards, it did allow the recording of an adequately accurate start time for each exposure.

However, as one might expect, the software did not allow computation of stellar magnitudes as the observing proceeded, and one simply sat there watching a boring succession of auto-scaled 30 s exposures. For an experienced Quilt-watcher (or similar time-series display program), this was not very satisfying observing. Ironically, the absence of an autoguider on the telescope "saved the day" (night), as one had to frequently make guiding corrections to ensure that the images remained (nearly) in the same place in pixel space (a good idea, whatever your view about the uniformity of CCD chips).

CCD images were stored on disk for subsequent analysis.

3. ANALYSIS

Experience with this observing program has reinforced the existing prejudices of one author (DJS), that on-line or near on-line analysis is an essential prerequisite to undertaking CCD time-series photometry. During the May runs, the CCD frames were analysed within a few days using control scripts written (by JP) for the MIDAS environment. These preliminary reductions were not entirely satisfactory, and the final reduction had to wait for the completion of a reduction pipeline (AutoPHOT, Reid et al. 1999, Reid 2000) written

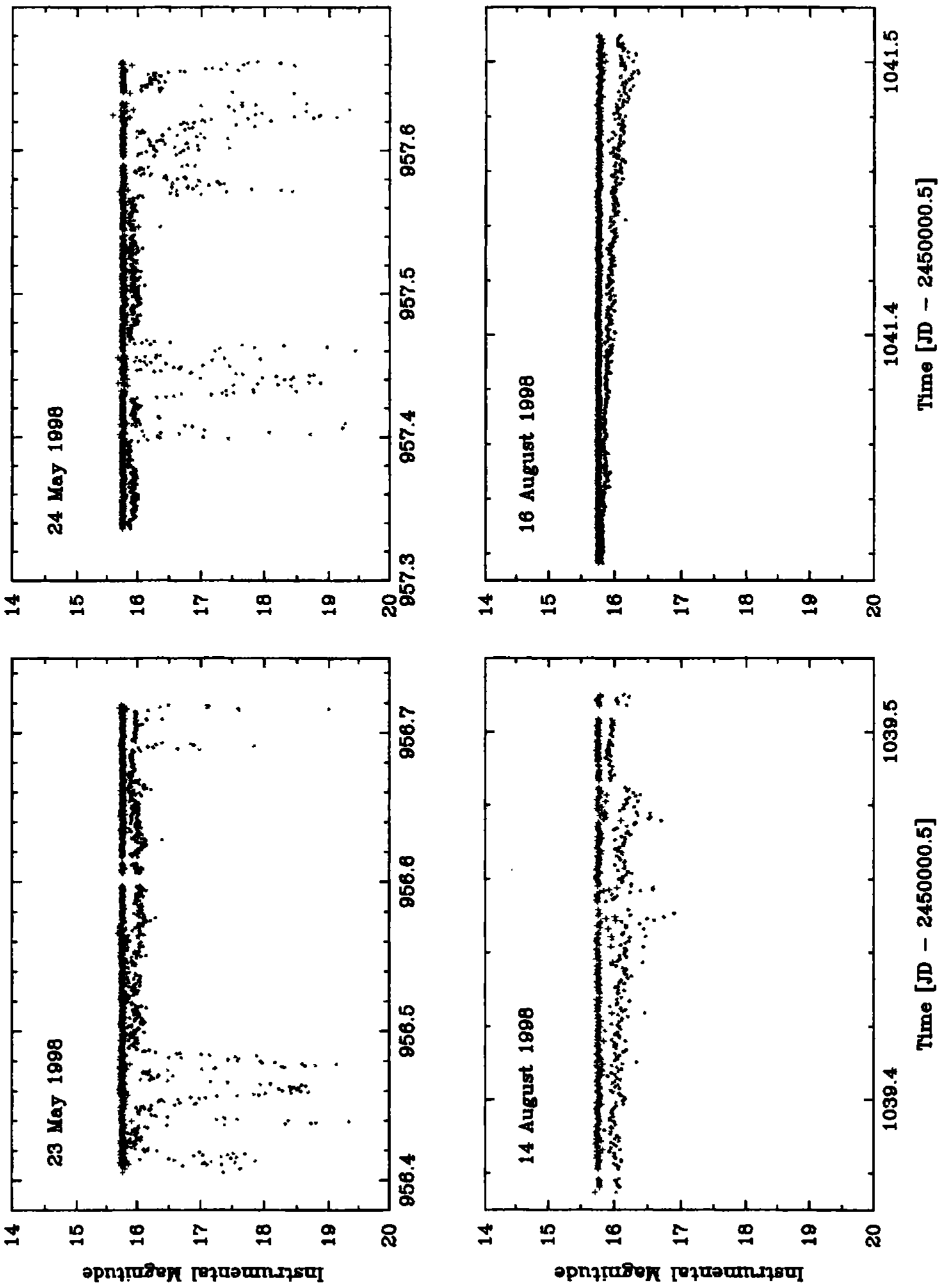

Fig. 2. Instrumental magnitudes of the reference star marked in Fig. 1 for all observations. The (grey) dotted points are the output of the reduction pipeline described in the text that uses DoPHOT, while the crosses are the result of the zero-point correction algorithm also described in the text.

by one of the authors (MLR) for a NZ-based microlensing survey project (Abe et al. 1997, Hearnshaw et al. 1999).

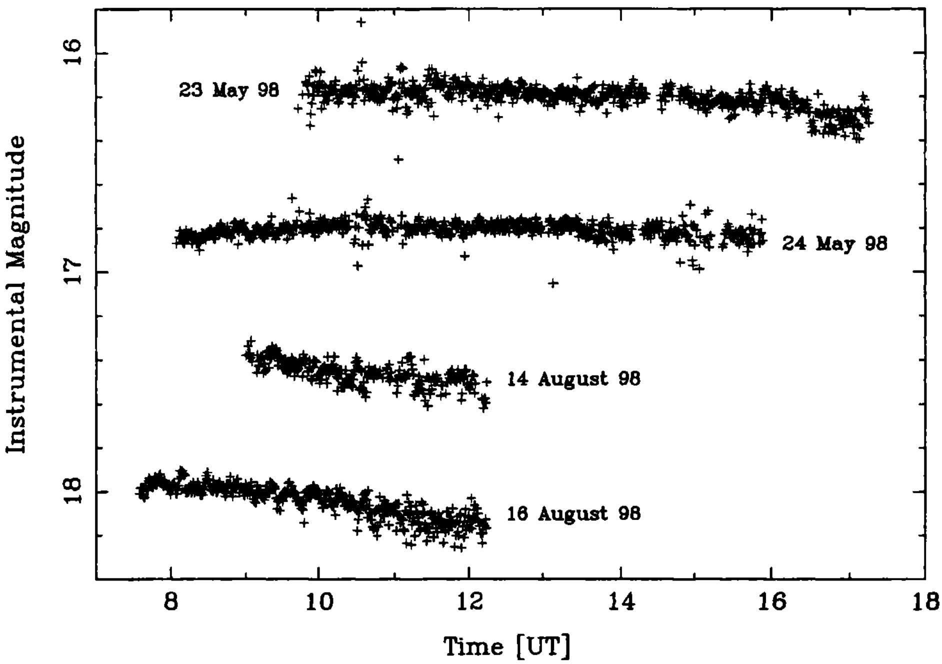

Fig. 3. Zero-point corrected instrumental magnitudes for GW Lib on all four nights. For display purposes, the different nights have been separated by adding different constants.

Currently, AutoPHOT uses the routine DoPHOT (Schechter et al. 1993) to extract instrumental magnitudes from each science frame, but there are plans to incorporate DAOPHOT II (Stetson 1992) as an alternative. AutoPHOT is much more than a simple control program for DoPHOT. In fact, the combination of another control and database program (StarBase) and AutoPHOT automates all the preliminary work, coordinates multi-processor operation, allows star matching of disparate frames, incorporates algorithms to adjust the photometric zero points of different frames, and finally pipes stellar magnitudes into a flexible customized database (Reid et al. 1999, Reid 2000).

The results of using AutoPHOT on the four data sets are shown in Figs. 2 and 3. Fig. 2 shows for each night the raw instrumental magnitudes produced by DoPHOT (grey dots) and the zero-point corrected magnitudes (crosses) that account for atmospheric transparency variations, including clouds. The zero-point correction algorithm uses magnitude differences of ensembles of stars to evaluate corrections for each frame, rather than ensemble averages. The raw magnitudes indicate the presence of significant amounts of clouds during some of the observations, but the corrected magnitudes for the reference star show reassuringly constant behavior.

The corrected instrumental magnitudes for GW Lib on all four nights are plotted together in Fig. 3. Data from different nights have been separated for display purposes by adding arbitrary constants. Except for some cloud-affected points that defied correction, and some residual changing airmass effects, the data from the four nights look (one might even say "more than") acceptable.

Before computing discrete Fourier transforms (DFTs) for each data set, residual airmass effects were removed by subtracting a least squares fitted parabola from each data set. The resulting DFTs are displayed in Fig. 4.

In isolation the DFTs of the shorter data sets are not really that meaningful, but taken together the transforms indicate the presence of unstable power near $\sim$ 650 s (definitely), and near 370 s and 230 s (possibly). The much superior data set obtained from SAAO during the multi-site run and before (van Zyl et al. 2000, van Zyl 1998) shows both that these periodicities are real and that their amplitudes are unstable. This is strongly suggestive of the behavior of the cooler DAV white dwarfs (see Kleinman et al. 1998), which probably reflects the cumulative behaviour of unresolved modes.

4. CONCLUSION

This work has demonstrated that an "off the shelf" CCD photometric system can be utilised for fast photometry programs provided the required integration times are not too short. Exposure durations of about 30 seconds are about the minimum, given current CCD readout times and an effective small chip size.

Before embarking on a similar observing program at least one author (DJS) is strongly of the view that a minimum requirement for the existing CCD system at Mt. John is the availability of a software reduction pipeline, such as the one described here. Ideally, this pipeline would be implemented on a platform separate from the CCD control software and run in parallel with the acquistion process. After each CCD frame is written to disk by the control computer,

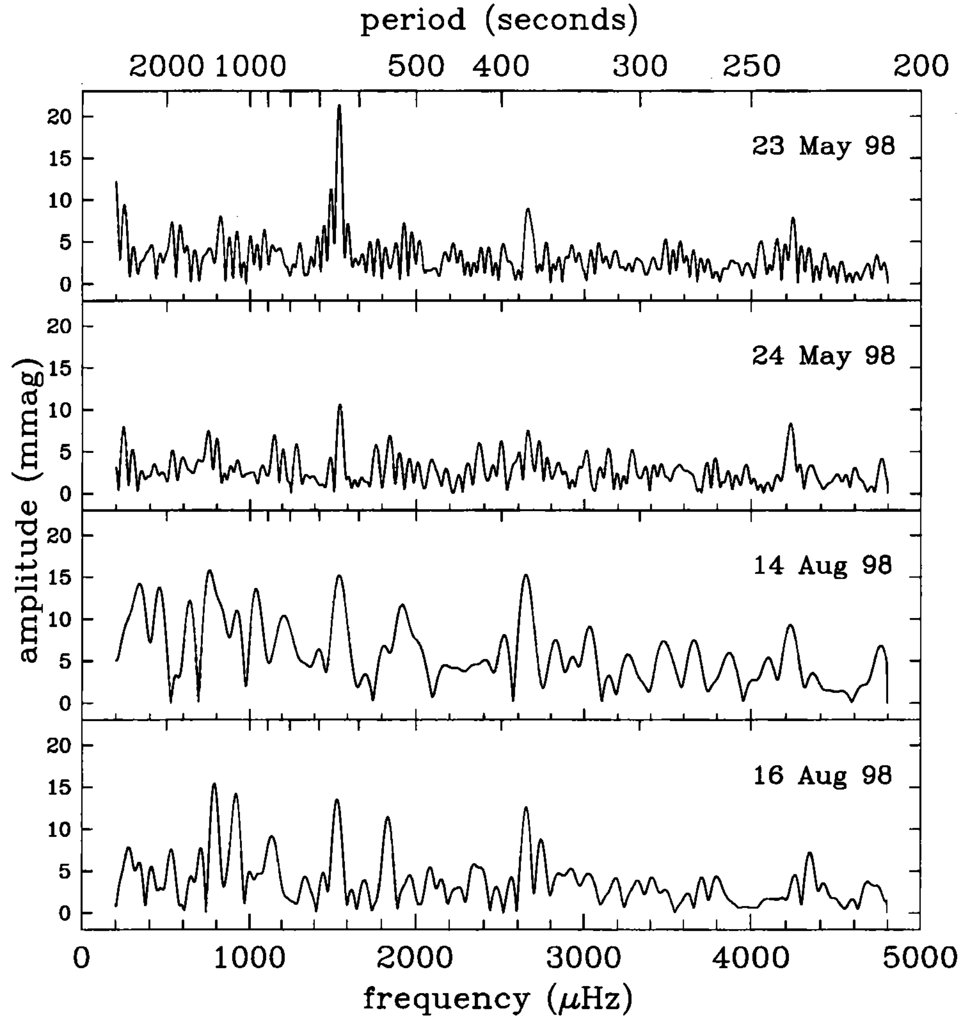

Fig. 4. Individual DFTs of the four nights of GW Lib photometry.

the analysis computer can retrieve the frame and analyze it. At the time of writing, although the authors are aware of system software routines (e.g. in the Linux environment) that would facilitate this, they are not really sure how much additional software effort would be involved in implementing this process at Mt. John.

As things currently stand, the existing reduction pipeline can be implemented with little difficulty at Mt. John, and it would allow efficient reduction of the data at the conclusion of a night's observing: the results would be available for the astronomer's delayed breakfast.

This may be enough to encourage future observing with the current system, *if* the science of the target is compelling.

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