FIRST STEPS IN CCD PHOTOMETRY

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Introduction

The aim of this article is to relate some of my initial experiments in CCD photometry, in the hope that other people may be encouraged to try. Previously, I had some experience of CCD imaging of deep sky objects for pleasure, but I wanted to achieve some more scientifically useful results from my work. Having attended the Pro-Am symposium on CCD photometry at Northampton in 2004 May, I was stimulated to investigate variable star photometry. I had tried visual variable star observing many years ago, but struggled with locating the objects, and my enthusiasm waned.

The Observatory

I have recently returned to the UK after living overseas for 12 years in various countries. This provided the opportunity to realise my childhood dream of setting up a permanent observatory. The first thing to do, was to work out where to buy a house. The estate agents thought my requirements were slightly unusual. They could understand my wanting to live not too far from work, schools and other amenities, but they thought it a little odd when I added minimal light pollution to the list. However, I backed this up with light pollution maps downloaded from the web, which showed I was serious, and enabled us to identify a *triangle of opportunity* of semi-rural skies in south Cheshire, where we eventually found a house in the village of Bunbury. Since the property was still under construction, I asked the developer to lay a concrete pad, as part of the garden landscaping, ready to accept a 7 ft (2.1 m) dome which was ordered from Pulsar Optical in Cambridgeshire. In the meantime, I applied for planning permission from the local authority; because Bunbury is a conservation area, all construction, even small sheds, needs formal approval. Fortunately, the project was approved, so my prospective neighbours obviously did not raise any significant objections (and have subsequently shown quite a bit of interest in my nocturnal activities).

Figure 1. The Bunbury Observatory, Cheshire

The main telescope is a Takahashi FS102, a 102 mm apochromatic fluorite refractor with a focal length of 820 mm. This is mounted on a Vixen Great Polaris DX, controlled by a Skysensor 2000 GOTO unit, and the whole lot is supported by a very solid pillar from BCF Astroengineering. The CCD camera is a Starlight Xpress MX716. The set up can be seen in Figure 1

First Attempts at Photometry

First light was in early June 2004, and in August I began to experiment with photometry of variables, having purchased the AIP4WINsoftware at the BAA Exhibition meeting at Cambridge. Roger Pickard guided me through the photometry options in AIP4WIN. The first few stars I measured were from the *VSS Basic CCD photometry target list*, using unfiltered photometry. The main problem was that these stars were a little faint for my system, being at quiescence. For example, I was regularly recording **V1363 Cyg** (range 13.0p to 16.7V) below magnitude 16C, but this was too faint for reliable photometry. I have yet to spot **V1454 Cyg** (range 13.9-20.5V) and **V650 Ori** (15.5-19.2V), although I can see a magnitude 16.7 star near the position of the latter.

To keep my interest going, I added a few other brighter stars to my programme, including **Mis1147 Cep**, **TZ Per**, **GK Per** and the AGN, **3C66A And** (a time series on the latter on 2004 Dec 26, 17.37 to 22.53UT, suggested an irregular variation of about 0.1 magnitudes, but the amount of scatter in the data means that no definite conclusion can be drawn; this is one to follow up on in the future).

Having almost sorted out the basics, I realised I should really be doing routine photometry using a proper filter. At the VSS meeting in Preston, I purchased a V-filter from Norman Walker. I have made some observations with this, but the loss of up to 2 magnitudes is a little disappointing. Clearly I will need to adapt my observing programme to include some brighter stars, and suggestions of suitable targets are always welcome. In an attempt to extend my magnitude limit, I carried out some experiments with a C8 f/6.3, in place of the Tak FS102. Using my typical exposure time of 60 s, I found that the ADU counts for a range of stars were, on average only 1.85 times higher with the C8. This implies that the photometric light gathering power of the C8 is about equivalent to a 136 mm refractor. Given the Tak FS102 is lighter and the focal length is shorter than the C8, both contributing to better tracking accuracy, I have decided to optimise my technique with the refractor for the time being.

Photometry of Supernovae

During 2004 there were two particularly bright SNe: **SN2004dj** in NGC2403 and **SN2004et** in NGC6946. Both galaxies are great targets for CCD imagers, and that was my starting point (Fig 2). Later I began to perform photometry on the images, which were submitted regularly to Guy Hurst, and combined with many other people's observations to build an overall light curve of these SNe. However, for my own pleasure I have produced my own light curves and that for SN2004dj is shown in Fig 3.

Photometry of Cataclysmic Variables

One area that I wanted to have a go at is time series photometry on CVs, especially with the aim of detecting superhumps in possible UGSU stars. I guess I wanted to have a go at a target that *did something*. My first attempt was with **Var79 Peg** on 2004 Oct 30, but I used the V-filter, and the reduced sensitivity resulted in appreciable scatter (around magnitude 14.7V). I also worked on **Var80 Per** on 2004 Nov 13; I suspected some variation, but again there was too much scatter in the data. At this point I decided to cut my teeth on a known superhumper.

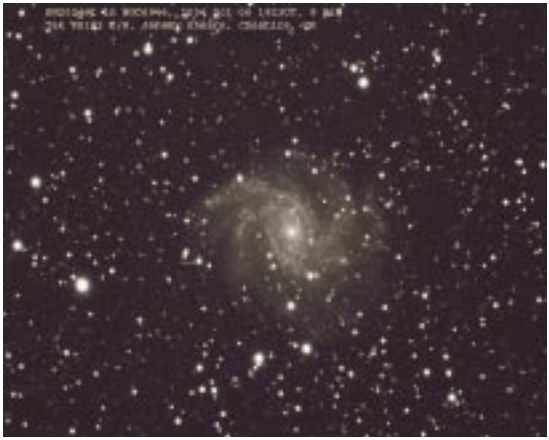
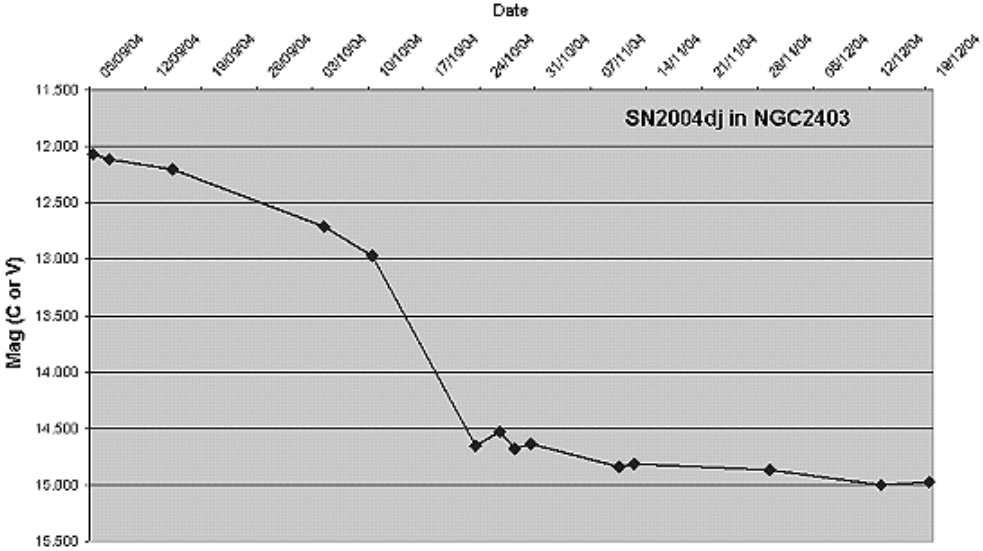


Figure 2(left), SN2004et in NGC6946. 2004 Oct 6, 9 min exposure (mag

Figure 3 (below), Light curve of SN2003dj in NGC2403.
All are unfiltered measurements, except for those on 2004 Oct 26, 28 and 30, which are V. Start date is 05/09/04, end date 19/12/04, time intervals are one week. Start magnitude is 15.5, end magnitude is 11.5, interval units of 0.5 magnitude.



V1113 Cyg

The first success was on **V1113 Cyg** on 2004 Dec 2. I learnt from Gary Poyner that the star was in outburst, so I carried out a 4 h time series of consecutive 1 min exposures. Photometry was performed using the *Multiple-images* option in AIP4WIN. The raw measurements were then imported into the VSS Excel spreadsheet for reduction. Here, at last, I was able to detect superhumps! The variation was about 0.25 magnitudes, with a mean near magnitude 14.7C. Tonny Vanmunster kindly reanalysed the data using his Peranso software (www.peranso.com; Figs 4 and 5), and found a superhump Period, Psh, of 0.077d. This is within 3% of the published value of 0.0792 d (Kato, T., Nogami, D., Masuda, S. and Hirata, R., 1996, Publ. Astron. Soc. Japan 48, 45-49). Whilst my observation did not represent original science, it did give me confidence in my observing techniques, and fuelled my enthusiasm to continue.

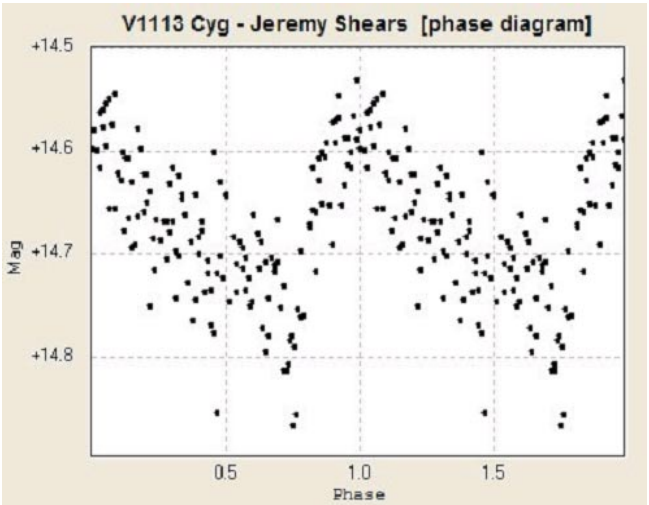


Figure 4. Light curve of V1113 Cyg on 2004 Dec 2, 19.13 to 21.51UT.

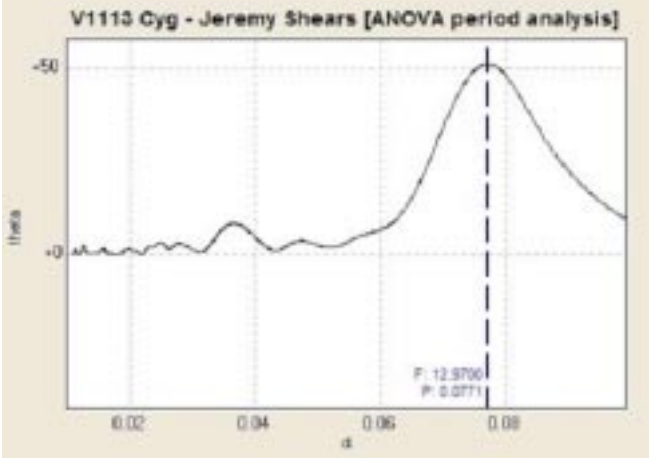


Figure 5. Period analysis of V1113 Cyg.
The data used to plot Figure 4 were used for this analysis. With thanks to Tonny Vanmunster.

V542 Cyg

According to Downes et al. in the online Catalogue and Atlas of Cataclysmic Variables (http://icarus.stsci.edu/~downes/cvcat/index.html), V542 Cyg is a probable UGSS star, hence I was not expecting superhumps. It has a range of 13.0P to 18.3P. Given the apparent uncertainty of classification, I thought it was worth a couple of hours of photometry when it went into outburst. However, the results of a 2 h run on the evening of 2004 Dec 19 show no variation in brightness, at 13.5C (Fig. 6)

IW And

IW And is listed in Downes et al. as a UGZ star, although a comment on the Yahoo CV discussion forum suggested that this was not certain, and that a time series photometry run would be worthwhile. To this end, I carried out a run of about 4h 40 min on 2005 January 4, 17.58 to 22.39UT, at which time the star was in outburst (14.0C). However, over this period no variation (eclipses, superhumps) was noted.

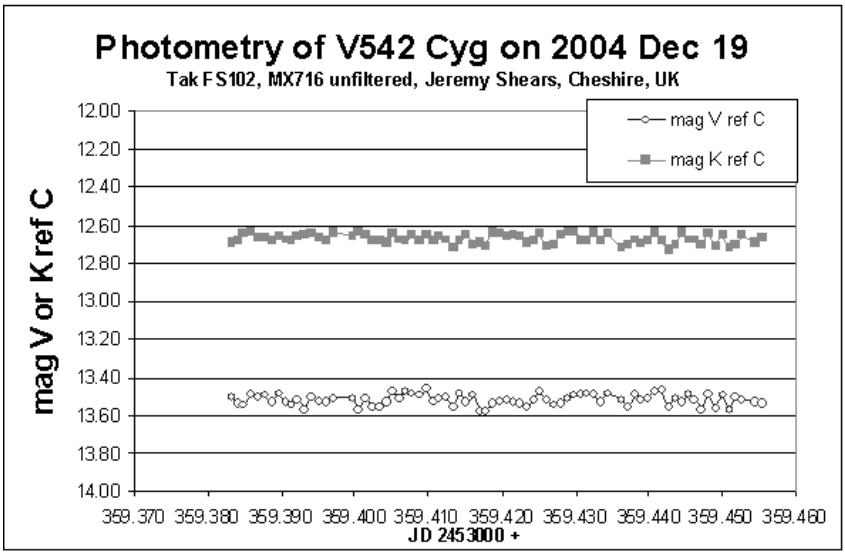


Figure 6. Photometry of V542 Cyg on 2004 Dec 19, 21.11 to 22.55UT. Star C is the star marked 129 on the AAVSO f-chart (preliminary chart, 7/95) NE of V542 and K is star 127 located N of V542

GX Cas

GX Cas was also in outburst in early 2004 January. A 3h 20min time series on 2005 Jan 4 (Fig 7 on inside back cover), shows a complete cycle with a superhump crest-to-trough magnitude range of about 0.3. This is similar to the variation observed during the 2004 Aug outburst, recorded by Nick James (http://www.theastronomer.org/gxcas/aug2000.html). According to Downes et al. GX Cas is a UGSU with a period of 0.089 d. Analysis of my data by Tonny Vanmunster showed a period of 0.090 d.

GY Cnc

This is a star which really does *do something*! It's a deeply eclipsing UG star. The star was in outburst in early 2005 Jan, and I caught a couple of these eclipses. The main challenge to precision photometry is the huge magnitude range of the eclipse. Whilst in outburst the star is pretty bright, about magnitude 13.9, but at mid eclipse it was well below magnitude 16, which is really too faint for my set-up (poor signal-to-noise ratio). Anyway, a typical eclipse is shown in Figure 8 on the inside back cover of this circular.

Acknowledgements

I would like to thank the people who have provided copious quantities of advice and encouragement in my efforts to move up the CCD photometry learning curve, especially Roger Pickard, Gary Poyner, Richard Miles, Guy Hurst and Tonny Vanmunster. There have been others who have also been generous with their time and patience. Thanks to all of you; I didn't believe it was possible to have so much fun in one's back garden with a 4 inch telescope! I'd certainly encourage others to have a go at CCD photometry.