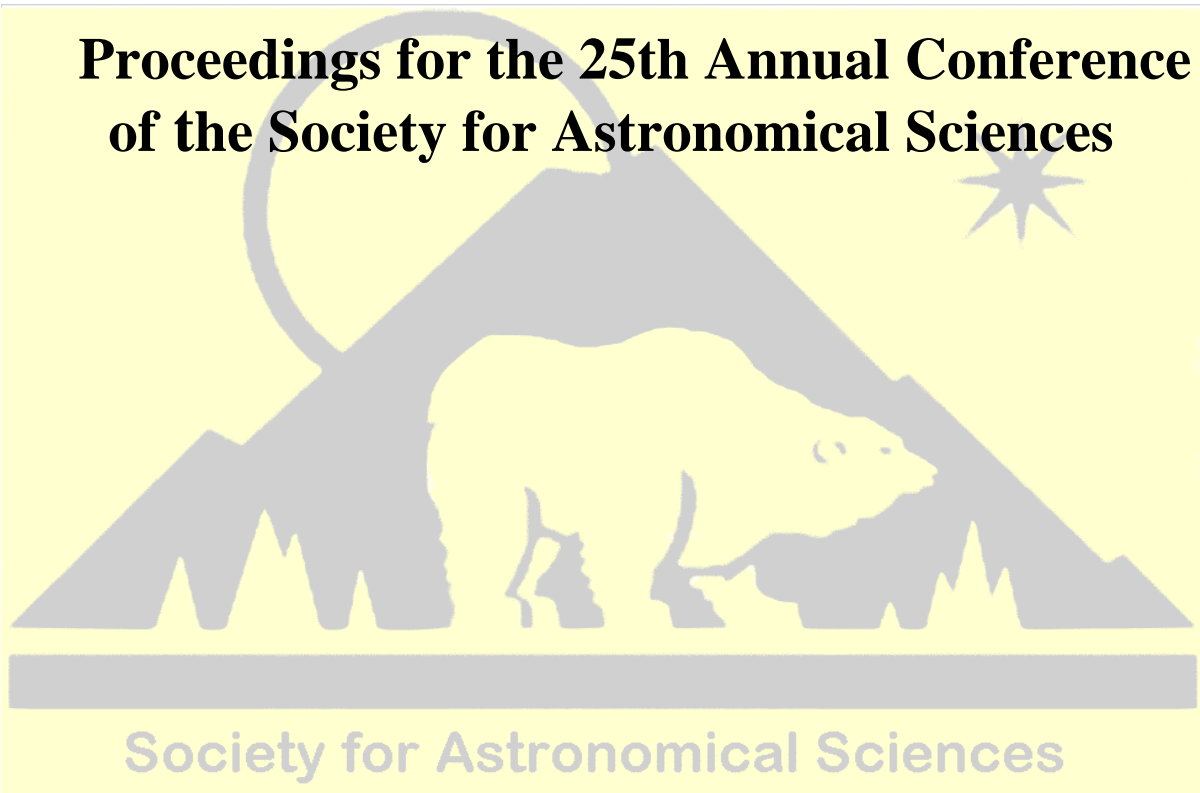

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CCD Photometry from a Small Observatory in a Large City

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Abstract

Since 2000, Farm Cove Observatory in Auckland New Zealand has contributed observational data to several international collaborative teams. During this time, the author has supplied 1339 hours of data to the Center for Backyard Astrophysics, directly contributed to the co-discovery of the extra-solar planet, OGLE-2005-BLG-071 and has discovered three new eclipsing binary stars. The observational data from FCO has now been used in a number of peer-reviewed scientific publications. This paper describes the observatory equipment, the software used, and provides details on the observations carried out for the international collaborative teams. The paper demonstrates what can be achieved using a small telescope in a large city. © 2006 Society for Astronomical Sciences.

1. Introduction

Farm Cove Observatory (FCO) is situated in New Zealand's largest city, Auckland, (population ~1.3 million) and is sited close to sea level on the banks of the Waka-aranaga Reserve in the eastern suburb of Pakuranga.

The observatory was constructed in 1999 and has clear unobstructed views of the eastern, northern, and northwestern skies. Unfortunately, the house, neighboring structures, and trees obscure a large area of the southern sky below 40° elevation.

The observatory is privately owned and operated by the author and currently contributes data to several international research collaborations (Figure 1).

Since 2000, the primary research has been time series photometry of Cataclysmic Binary stars for the Center for Backyard Astrophysics (CBA) (Patterson 1997). Professor Joseph Patterson from Columbia University, New York heads the team. Farm Cove Observatory is known within the group as CBA Pakuranga.

In 2004, observations commenced on gravitational microlensing events for the Microlensing Follow-up Network (MicroFUN) (Gould 2006). This group consists of an international collaboration of professional astronomers supported by a small group of amateurs. In 2005, FCO took part in the co-discovery of OGLE-2005-BLG-071, the second extra-solar planet discovered using the gravitational microlensing technique (Udalski 2005). Farm Cove Observatory is known within this group as MicroFUN Farm Cove. Professor Andrew Gould from

Ohio State University (OSU) leads the MicroFUN team.

Since December 2005, FCO has contributed regular magnitude measures on Blazer OJ+287 for the British Astronomical Association (BAA) (Pietila 1998).

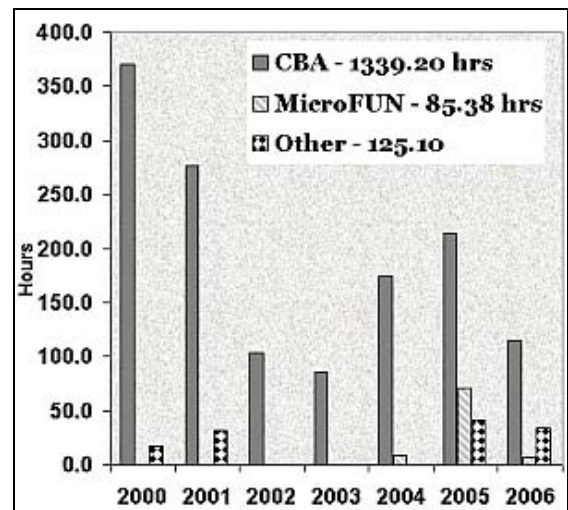


Figure 1. FCO data acquisition since January 2000.

2. Observatory Equipment

FCO operates one of the first Go-To telescopes manufactured by Meade - an LX200 25cm f/10 telescope (Figure 2). A focal reducer is not used with this system. The telescope is mounted on a custom-made wedge and supported by a permanent pier. This particular telescope has proven to be a very reliable re-

search tool and to date, no operational or electronic problems have been encountered.

The recent purchase of a DewZee dew control and light baffle (Resource International, San Jose, CA) for the optical tube has proved successful. A small number of modifications were made to the baffle to allow for extra rigidity and a snug fit over the tube. This product was purchased solely as a light baffle to reduce stray light entering the telescope from neighboring properties. It is also used in conjunction with a Kendrick Dew Remover. (Kendrick Astro Instruments, Toronto.)



Figure 2. Meade LX200 25cm / SBIG ST7e

An SBIG ST7E dual chip CCD camera is on permanent loan from the CBA. The separate auto-guiding chip is an important feature of this camera because it allows for accurate tracking during long exposures on faint MicroFUN targets. The longest exposures used routinely are 300s duration. All data are currently acquired without filters.

The small CCD chip, 765 x 512 pixels, gives a field of view of 9.6 x 6.4 arc-minutes when operating at f/10. The size of the chip does not produce any significant disadvantages to the work carried out at FCO. All comparison and check stars can be found within the field of view making the need for a larger chip unnecessary. The major advantage of the smaller image size is the shorter image download time and smaller FITS files for ease of handling and storage.

The image scale is 0.75as/pixel in 1x1 binned mode (2.25as/pixel with 3x3 binning).

All CBA and magnitude measure photometry is imaged in 3x3 binning mode and matches well the typical seeing Full Width Half Maximum (FWHM) of 2.5-3.5arc-sec (Figure 3). Only in fields of very high stellar density are 1x1-binned images used.

The telescope and computers are networked to the house, making it possible to monitor and control the CCD camera and telescope from a warm and comfortable environment. The dome is rotated by hand; this requires regular repositioning over the course of the night.

3. Data Acquisition and Telescope Control

Several software packages are used for data acquisition, telescope control, and data processing. The ability to pick and choose the best features from each package is essential because no single product is currently available to satisfy all these requirements.

The images are acquired using CCDSoft V (Software Bisque, Golden CO). This package has a user-friendly interface, allowing for efficient control of both the camera and guide chip. The only disadvantage encountered with this product is an inability to display a large display window giving FWHM values and other important information during focusing.

The Sky Version 5 (Software Bisque, Golden CO) is used for telescope control, image recognition and is an excellent aid for check star identification. This software integrates closely with the Meade LX200 and has proven to be a very stable and reliable program.

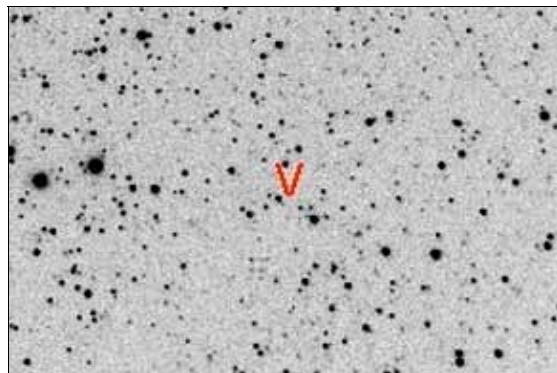


Figure 3. Calibrated 3x3 binned 20s CCD image of WX Cen (north up, east left)

4. Calibration Procedures

All dark and flat field frames are calibrated and stored in libraries as masters. These are typically used

over a period of 60 days. Each master frame consists of approximately 30 median averaged frames and in the case of flat fields, the appropriate master dark frame is subtracted.

Flat fields are produced using a 5mm white plastic sheet, which is fitted securely into place over the light baffle (Figure 4). A red darkroom light is used to illuminate the interior surface of the dome. This has proved to be a quick and effective procedure when time constraints are present and it consistently produces evenly illuminated calibration frames.



Figure 4. Flat field board fitted to the telescope.

5. Photometric Reductions

Almost all photometry carried out at FCO is done differentially. Given that a full night observing run can produce ~1000 FITS format data frames, a reliable and versatile reduction program is essential. The primary requirement is the ability to automatically calibrate each FITS image frame and then measure the differential magnitude of all stars within the field.

This is accomplished using the freeware Windows software MuniWin/C-MuniPack (Motl). It has been specifically designed for efficient reduction of up to 1000 frames for time series photometry and has a simple, intuitive user interface. All CBA data is processed through this software package.

CCD Soft V5 is used for quick and easy flat field and dark frame calibration on numerous folders of images. It is especially useful when MicroFUN requires calibrated frames immediately for gravitational microlensing events.

MaxIm DL (Diffraction Ltd, Ottawa, Canada) complements both MuniWin and CCDSoft. This package allows for comprehensive image analysis on all frames where necessary, and handles individual accurate photometric reductions when required.

Reduced data are submitted by email in simple text format while calibrated CCD frames are uploaded to a nominated FTP server if necessary.

6. Target Selection

There are benefits to being an independent observer. Perhaps the two most important of these are the freedom to pick and choose observational projects of interest and the ability to re-assign all telescope time at short notice. With this in mind, it is possible to observe two or even three targets over the course of a night. Naturally, this depends on what observations are required and the rise and set times of each object.

The CBA communicates monthly observation target lists for both northern and southern hemisphere observers. In the case of FCO, the small aperture size of the telescope often dictates which target will be observed. For many of the CBA targets, short exposure times are preferred as the stars commonly exhibit phenomena on time scales of a few hours and in many cases, a few minutes.

Short exposure times are required to adequately sample high frequency signals in data (e.g rotation rate of a white dwarf), but unless the star is bright, this reduces the signal-to-noise ratio (SNR). In most cases achieving both an acceptable SNR and an adequate sampling frequency requires a compromise. In practice at FCO, if the white light magnitude lies in the range 13-15 then exposure times of 15-30s still gives a useful SNR. Any fainter than this and longer exposures become essential.

Moreover, if the expected amplitude of the signal is large, then accepting a lower SNR (and hence allowing a faster sampling frequency) may be a better option.

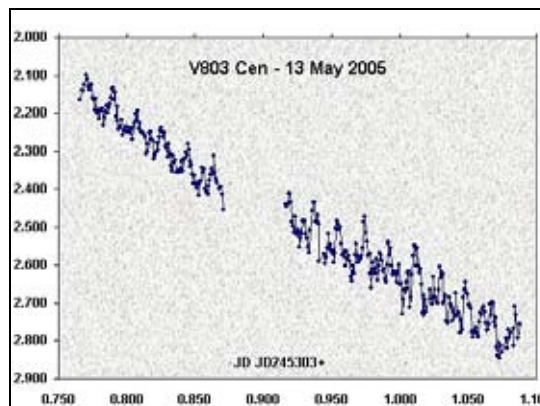


Figure 5. Example of V803 Cen (Patterson 2000) light curve from FCO showing a strong periodic signal.

MicroFUN gravitational microlensing targets are seasonal due to the visibility of the galactic bulge. All

observations are made in this region of sky because of its high stellar density, increasing the probability of detecting gravitational microlensing events. Accessibility of the galactic bulge in early autumn (March), allows for limited observations from 3.00am local time. During the winter months (April through August) the bulge passes almost overhead in Auckland and is accessible throughout most of the night.

Due to the limited size of the telescope, only high magnification events are observable at FCO. However, these are the times when the sensitivity to detecting planets is at its greatest. Typically, targets as faint as magnitude 18 in white light are observable. At these faint magnitudes, exposures of 300s are used together with the autoguider. This guarantees accurate tracking will be continually maintained throughout the observations.

Working in the galactic bulge can cause problems due to the crowded fields. However, this is offset by the numerous stars available for auto-guiding, allowing long exposures.

In very crowded fields aperture photometry is impractical. Instead, the calibrated images are uploaded by FTP and processed through the OSU photometry pipeline, which uses DOPHOT (Schechter 1999).

Magnitude measures and other observations can be made at any time during a CBA or MicroFUN observing run. The observations carried out on Blazer OJ+287 (Pietila 1998) for the BAA consist of approximately twenty 60s integrations. These are calibrated and then averaged to obtain a single accurate magnitude measurement. Such a short interruption during primary observations has, thus far, caused no major inconvenience to the primary observing programmes.

Three new eclipsing binary stars were discovered while observing CBA targets in 2005 and 2006. (McCormick 2005) Each of the discoveries were found in a CBA target field, a task made possible by MuniWin and its ability to extract differential photometry for all stars in a CCD image (Figure 6).

7. Conclusions

Despite the disadvantages of an urban location and a small telescope, Farm Cove Observatory has been able to contribute observations to several astronomical research collaborations. These have proven to be successful partnerships as many of the observations obtained are used and published in peer-reviewed journals.

The flexibility to change observing programs at short notice is a key factor to the successes obtained

as demonstrated by the co-discovery of extra-solar planets using gravitational microlensing techniques.

CCD photometry presents constant challenges and offers a wide variety of observational opportunities. It is a particularly stimulating field to work in, providing both a high level of personal satisfaction as well as the opportunity to make a useful contribution to the science of astronomy.

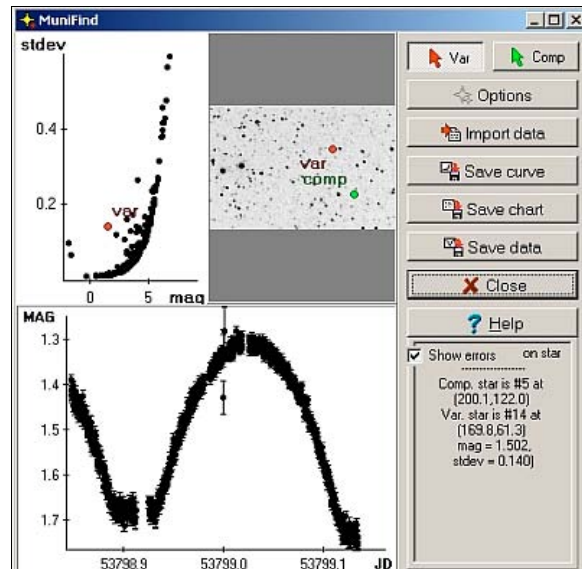


Figure 6. MuniWin extractive photometry (Find Variable) window.

8. Acknowledgements

Professor Joseph Patterson, Center for Backyard Astrophysics at Columbia University, for the permanent loan of the SBIG ST7e CCD camera and his many kind words of encouragement and support.

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9. References

Gould, A., Udalski, A., An, D., Bennett, D.P., Zhou, A.Y., Dong, S., Rattenbury, N.J., Gaudi, B.S., Yock, P.C.M., Bond, I.A., Christie, G.W., Horne, K., Anderson, J., Stanek, K.Z., DePoy, D.L., Han, C., McCormick, J., et al. Microlens OGLE-2005-BLG-169Lb Implies Cool Neptune-Like Planets are Common, *ApJ*, to appear (2006)

McCormick, J., Christie, G.W. New Eclipsing Binary Star USNO-A2.0 0675-31638784, IBVS 5700, No 54 (2005)

Motl, D. C-MUNIPACK package of software utilities for reducing astronomy CCD images. <http://integral.sci.muni.cz/cmunicipack/index.html>

Patterson, J., Kemp, J., Skillman, D., Harvey, D., Vanmunster, T., Jensen, L., Fried, R., McGee, P., Walker, W.S.G., Retter, A. Cataclysmic Variables with the CBA, AAS (1997)

Patterson, J., Walker, W.S.G., Kemp, J., O'Donoghue, D., Bos, M. and Stubbings, R. V803 Centauri, A Helium-Rich Dwarf Nova. PASP 112, 625 (2000)

Pietila, H. Possibilities and Predictions of the OJ 287 Binary Black Hole Model, ApJ 508, 669 (1998)

Schechter, P.L., Mateo, M., Saha, A. DOPHOT, a CCD photometry program, description and tests. PASP 105, 693 (1999)

Udalski, A., Jaroszynski, M., Paczynski, B., Kubiak, M., Szymanski, M.K., Soszynski, I., Pietrzynski, G., Ulaczyk, K., Szewczyk, O., Wyrzykowski, L., Christie, G.W., DePoy, D.L., Dong, S., Gal-Yam, A., Gaudi, B.S., Gould, A., Han, C., Lepine, S., McCormick, J., Park, B.G., Pogge, R.W. et al. A Jovian-mass Planet in Microlensing Event OGLE-2005-BLG-071, ApJ 628, L109 (2005)

