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HIGHLIGHTS FROM THE GOLDEN AGE OF THE AUCKLAND OBSERVATORY'S STELLAR PHOTOMETRY PROGRAMME

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Abstract: Auckland Observatory has a proud history of variable star research that extends back more than half a century. In this paper we briefly outline events leading up to the founding of the Observatory and discuss its construction, before summarizing highlights from the Observatory's stellar photometry program with the Zeiss 50-cm Edith Winstone Blackwell Telescope.

Key Words: photoelectric photometry, variable stars, astronomical outreach, professional-amateur collaborations

1 INTRODUCTION

1.1 It Began With a Generous Gift

On a partly cloudy evening in February 1967, the Auckland Observatory (AO) was opened by the Governor General, Sir Bernard Ferguson, thus providing a home for the Auckland Astronomical Society (AAS) in its 44th year. Most of New Zealand's well-known astronomers attended, and the weather improved so that attendants were able to see some beautiful astronomical objects through what was, by far, the country's largest and best optical telescope. Over the next 25 years this 50-cm diameter Edith Winstone Blackwell Telescope and its associated high-quality accessories, operated by amateur members of the AAS and with assistance from the University of Auckland Physics Department (UAPD), performed leading-edge photometry in a variety of stellar and other areas.

It all began in 1955. At that time, Ronald (Ron) McIntosh (1904–1977; Orchiston, 2016: 523–561), a notable amateur lunar, planetary and meteor observer, was President of the AAS. He received a phone call from a Mrs Blackwell who wished to donate a telescope to the Society. Ron duly visited this caller, though without high expectations. 'Auntie', as she was called by most of her young relatives, wished for a larger telescope "… suitable for an important city like Auckland." When Ron mentioned the cost of housing such an instrument he was assured "… my family will look after the costs." Ron discovered that this was the Winstone family. The benefactor requested only that the facility be named the Edith Winstone Blackwell Telescope and used by as many people as possible.

Ron was associated with the Auckland Birthday Carnival, the Chairman of which was Lawrence Nathan. Being approached for advice, Nathan suggested the formation of an Auckland Observatory and Planetarium Trust, with strong links to the AAS. A subsidiary group of Directors was set up once the project began. By the time of the opening, Arthur Partridge, then Society President, was also Chairman of the Trust, while Ronald McIntosh and John Orr were fellow Directors.

But what sort of telescope would it be and where would it be located? After much argument and many alternative proposals, the One Tree Hill Borough Council offered a site on the southern slopes of Maungakiekie. A 50-cm reflecting telescope was then ordered from Carl Zeiss of Jena. That manufacturer was interested to see one of their products operating in the Southern Hemisphere, so the price was accommodating. The project was on its way!

1.2 Building the Observatory and Setting Up the Telescope

Building involved all the normal contributors, but the specific purpose of an astronomical observatory meant close links with the AAS. The Winstone and Blackwell families provided the finance as well as the architectural design, coordination and supervision of the construction. The AAS provided several thousand pounds from the Bostock Bequest. What resulted was an attractive building in a beautiful environment: the gently sloping south western slopes of Maungakiekie that the local Council maintains as a public park (see Figure 1). Easy access encouraged its popularity and use in the manner envisaged by Mrs Blackwell. One inter-

Figure 1: The Auckland Observatory, now called Stardome, as seen from the south west with the obelisk on the 184-metre Maungakiekie, an extinct volcanic cone, in the left background. The area on the right end with the grey roof contains a planetarium, and was added in the early 2000s (Photograph courtesy: https://upload.wikimedia.org/wikipedia/commons/7/76/Stardome_Observatory_Cornwall_Park.jpg).

contributor was Peter Read (1923–1981), a popular New Zealand artist and astronomical broadcaster, who designed and painted a mural for the large main entryway.

The next step was to put the two tonnes of telescope and associated controls together and make certain of its functioning. At this point, the Observatory received a great favour from Kurt Gottlieb (1910–1995) of Mt Stromlo Observatory, who sacrificed much of his annual vacation to visit Auckland and supervise the assembly of the massive telescope, then connect the various electronic controls and dome rotation motors, and finally ensure a fair degree of alignment. There would be still many months of settling time. Prior to this, the pier was designed, the ground excavated to bedrock and many cubic metres of concrete in the pier allowed to harden. After Gottlieb left, local AAS member Harry Williams supervised the general equipment maintenance, and fellow-member Trevor Rounthwaite the final alignment.

Figure 2: This shows the open dome with the 50-cm Edith Winstone Blackwell Telescope illuminated. It is an offset German equatorial design with the upper part of the pier aligned with the south celestial pole and a counterweight visible slightly behind and to the right (photograph: Walker Collection).

The result was a very user-friendly equatorially mounted telescope (see Figure 2). But on the opening night it appeared few people in the Society were familiar with this system of sky coordinates. Stan Walker, the first author of this paper (henceforth SW), was one of these, and he was duly called in to activate the telescope. Manual operation of this telescope turned out to be satisfactorily fast.

1.3 Application

Now there was a large working telescope—but what to do with it. A variety of fortunate circumstances led to a path that proved very rewarding. In no particular order, these were:

- The strong group of local planetary observers was familiar with their own telescopes and found no particular advantage from the new telescope (henceforth simply referred to as the EWB Telescope). They resolved to observe more regularly with their home arrangements.
- Several types of variable star were attracting astrophysical interest, and radio astronomers were seeking optical observations of

stellar radio sources.

- Professor Brian Warner (1939–2023) from the University of Cape Town had called attention to the problematic dwarf novae with their remarkable changes of brightness on various time-scales.
- The IP21 tube was widely used as a sensitive electronic detector that with suitable filters attached proved faster and more accurate than conventional photographic plates. Even better, the EMI series of photomultiplier tubes was easily available.
- Drs Harold L. Johnson (1921–1980) and William W. Morgan (1906–1994) had, in the early fifties, devised the U (ultra-violet), B (blue) and V (visual) set of glass filters to allow measures. The Vs would form a quantitative reference scale for stellar magnitudes. The magnitude differences U–B, B–V, (colours) would provide additional information about stars and the interstellar medium. R (red) and I (infrared) filters were later added.
- In an influential paper in *Astronomical Techniques*, Professor R.H. Hardie (1964) spelled out the reductional procedures involved in putting measures from different equipment and different observatories onto a uniform footing.

This forms the background to much of the rest of this paper. It took time for the stellar photometry programme to become established. In Auckland, it started from a group of visual observers with just pencil and paper. In this context, the pioneering work of Ken Adams (1992) and especially George Eiby (1949) in Wellington should not be forgotten. Adams was employed by Carter Observatory, and in 1948 he built a photometer and used this with both the 5.5-inch Grubb refractor in the Thomas King Observatory and the Carter Observatory 9-inch Cooke refractor. The following year, Eiby built a photometer with a 931-A photomultiplier tube as an MSc project at Victoria University of Wellington, and then carried out observations with the 9-inch telescope, assisted by Adams. These were the first photoelectric photometry projects conducted in the Southern Hemisphere, but they produced results of limited astrophysical value (see Hearnshaw, 1996; Orchiston, 2016: 259–260 and 358; Orchiston, 2022).

2 THE AUCKLAND MARK I PHOTOMETER

After a few months, it became clear that visual measures were not accurate enough for the serious pursuits intended. The way ahead involved a few lucky chances. Professor F.B. (Brad) Wood (1915–1997), who had an important role in the early days of Mt John Observatory after its opening in 1965, had produced *Photoelectric Photometry for Amateurs* (Wood, 1964), a copy of which was in the Auckland Public Library where it was frequently perused by SW. He proposed that a photometer, as discussed by Wood, be made with the support of the AAS.

Bob White and Alec Chisholm from the UAPD then reached out to the AAS and offered help. The Royal Astronomical Society of New Zealand (RASNZ) bestowed a grant of £400 to cover the cost of two efficient photomultiplier tubes made by EMI™. Harry Williams offered to make the body of the photometer if the AO covered material costs. An alternative suggestion was to utilize the proven IP21 side-window tube, and obtain a chart recorder. Manual measurement of stellar fluxes would then be carried out along the lines of the procedure followed at Mt John Observatory. At this stage, Clive Rowe from the Canterbury Astronomical Society contacted the AAS. He had constructed a photometer in his workshop using an EMI6256 pm tube. He had designed and constructed an analogue/digital converter, based on a Schmidt trigger circuit, to produce pulses that could be measured by a digital frequency meter. He requested a trial run on the EWB Telescope. Two of his colleagues, Bob Evans and Stefan Mochnacki, came to Auckland and could demonstrate this photometer. The visit was successful and most of the doubters agreed the plan would work, although budgeting arrangements were not clear.

The UAPD then stepped in and provided a very stable high voltage supply and a digital frequency meter, as well as guaranteeing maintenance if the project went ahead. AAS member Brian Marino and SW set down specifications for the photometer. Harry Williams machined the components. Mt John Observatory supplied a set of UBV filters, Clive Rowe an A/D converter—the prospects looked good. The UAPD ran the PM tubes at the recommended voltages for days on end to check stability. White and Chisholm contacted Dr Robert Shobbrook at the University of Sydney for comments. Such responses were very helpful.

At this point, a problem surfaced. How were the magnitude and colours of measured stars determined? Norman Rumsey from the Department of Scientific and Industrial Research and the RASNZ provided answers. Two astronomers, A.W.J. Cousins and Dr R.H. Stoy, from the South African Astronomical Observatory, were using the Johnson UVBRI photometric system (mainly UBV at that time). Rumsey drew attention to the *Royal Observatory Bulletins*, of which *ROB 64* contains a catalogue of UBV magnitudes and colours of several hundred bright stars, carefully reduced to a standard reference system, that was also consulted. Cousins and Stoy had previously published notes of existing photometric systems such as the SPv and SPg system in two earlier *Bulletins*.

By mid-1969 the photometric system (PEP) was up and running and able to produce high quality V, B–V and U–B measures of stars down to magnitude 13 (see Figure 3). The limit was not imposed by the system itself, but rather a consequence of the observer's ability to position a star in the 30 arcsec input pupil of the photometer. For many years this EWB Telescope system carried out stellar photometry to fainter limits and with higher accuracy than any other in the country. This was from a convenient city site with an inevitably bright sky background. A presentation of some of the more notable successes follows. Unfortunately, the selection is necessarily incomplete, and we apologize to those whose worthy contributions have been omitted in this review. A key intention is to note the excitement and enjoyment of the observational and related activities at the AO, particularly in the last quarter of the twentieth century.

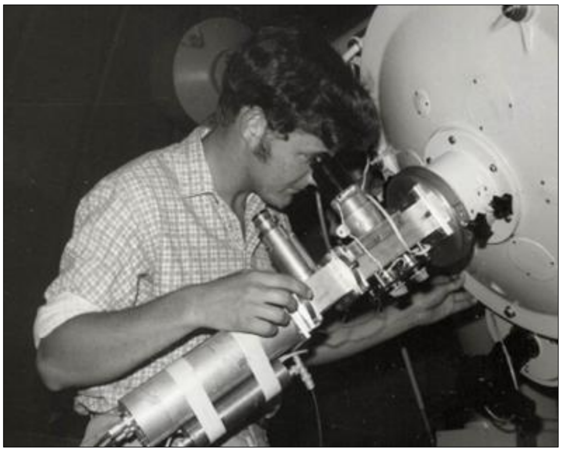

Figure 3: The Mark I photometer with the analogue/ digital A/D converter underneath. Roger Feasey is looking through the main field eyepiece with his hand on the aperture inspection eyepiece and filter assembly (Walker Collection).

3 STELLAR PHOTOMETRY

Although the Observatory opened in February, 1967, little thought had been given to its operation by either the Directors or the AAS. This was resolved over the succeeding months, with McIntosh and Orr retiring as Directors, and SW being appointed with responsibility for observational research. Operational financing was necessary and Arthur Partridge assumed control of fund-raising, mainly through regular openings for the public and other group visits.

The accession of SW to the Observatory Directorship resulted in a more liberal attitude to use of the EWB Telescope and regular meetings of the new variable star observers were encouraged. Observing began after photocopies of Series 1 and 2 of the RASNZ Variable Star Section (VSS) charts were distributed at a meeting where methods of making accurate visual measures were presented.

Targets included the long period, large amplitude, Mira stars, with some semi-regulars and R Coronae Borealis objects, that display occasional dramatic declines in brightness. The area which the Auckland observers became noted for, dwarf novae, was yet to be addressed. Some dedicated observers who began at this stage were Dick Hull, Barry Menzies, Brian Marino, Deryck Fisher, SW and others. Later, more appeared, such as Daphne Patterson and Frank Ives. Not all were observers: Jean Aldiss, Kathy Barrow, Lynn Duff and several others were involved in plotting the observations, punching computer input cards for analysis of targets: initially flare stars and later a variety of other objects. Later Leslie and John Beuning were engaged in similar work using the Observatory's TRS80 and other personal computers.

The first major impetus to research-level work came via a request from Dr Bruce Slee (1924–2016; Orchiston, 2004), from the Commonwealth Scientific and Industrial Research Organisation in Australia, for visual monitoring of flare stars during specific periods in the expectation that radio events detected with the Parkes Radio Telescope could be supported by visual measures. After a few months it was clear that visual observations were not accurate enough for this. The technique used—i.e. a quick estimate every 30 seconds—was, in theory, useful when taken by an experienced observer, but the monitoring sessions tended to become social events with more than two persons in the dome creating 'poor seeing' and too many distractions. After three or four such collaborations, it was clear that greater precision than the visual observers could provide was needed. Other methods of data-gathering then started to be discussed.

3.1 Flare Stars

Although, for the most part, a relatively inconspicuous component of the galactic stellar population, these 'cool stars', with masses but a few tenths that of the Sun, occasionally show outburst phenomena that pose interesting problems for theoretical physics. These are the UV

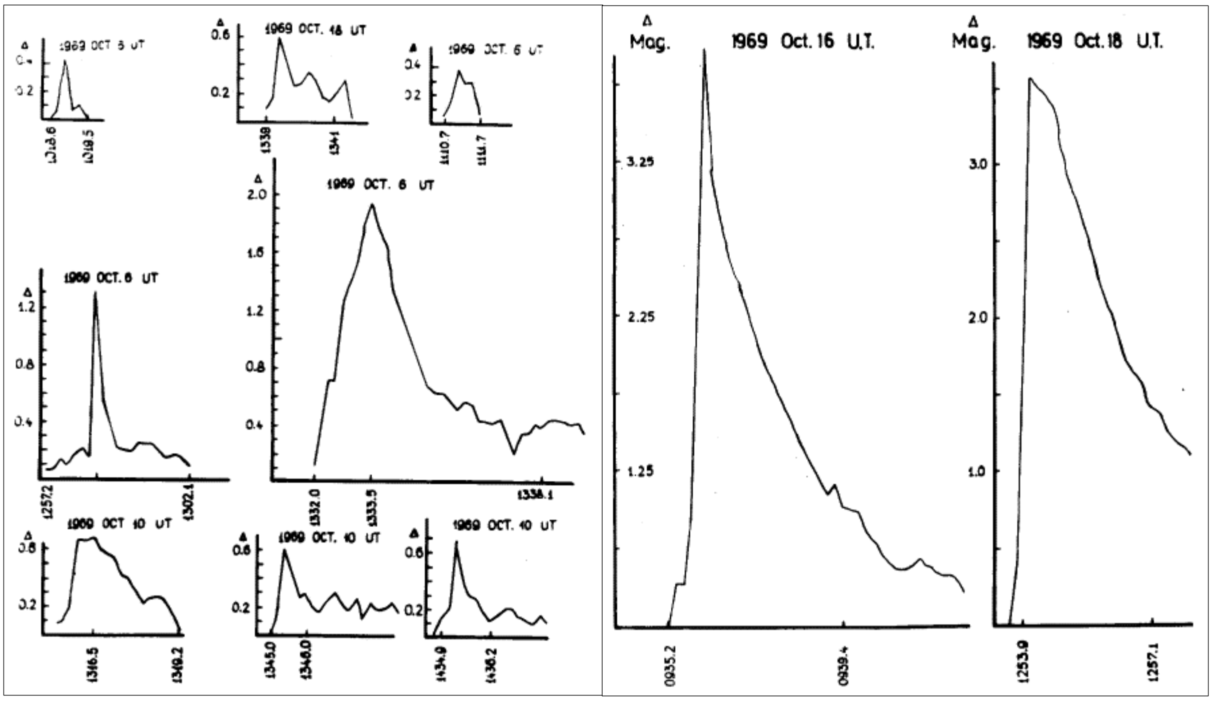

Figure 4: Some UV Ceti flares during a programme in October, 1969. Most of the flares are not all that bright but one on 6 October had an amplitude in the B filter of 1.95 magnitudes and two on 16 October about 3.5. These latter two had extremely sharp rises (after Bateson et al., 1970: 2–3).

Ceti type variables, also known as flare stars; the latter name suggestive of comparisons made with the Sun's more directly observable flashes of magnetodynamic 'activity'. Flare stars undergo dramatic episodes of energy release across the whole electromagnetic spectrum, from γ-rays to radio waves, and lasting over hours to a day or two. UV Ceti, the prototype of this class, was presented in this connection by Joy and Humason (1949), who reported its steep increase in brightness of >4 magnitudes in an hour or so, followed by a slower decline, usually within less than one day.

A development, having repercussions at AO, occurred with the confirmation of the link to transient phenomena detected by radio astronomers at Jodrell Bank (Lovell and Solomon, 1966). Follow-up surveys were made at Culgoora near Narrabri, in Australia (see e.g. Nelson et al., 1979). 'Multiwavelength campaigns', involving sizeable teams of linked groups and individuals, have been undertaken to widen out the record on this kind of object (e.g. Butler et al., 2015; Vilhu et al., 1993). These have included data contributions from AO and similar locations (see Figure 4), resulting in an improved physical understanding of the flare mechanism. This has used concepts like large scale reconnection of magnetic field lines in the outer regions of UV Ceti stars. More than a thousand such sources have been identified within a few tens of parsecs from the Sun.

3.2 Widening Fields of Interest

Around this time (late 1960s to early 1970s) a request was received from the VSS to provide accurate comparison star sequences for visual observers. With the acquisition of an impersonal photometer this could become an important part of the Observatory's activities. The topic is pursued in the next Subsection.

Meanwhile, Ronald McIntosh continued as an adviser. He remarked that dwarf novae of varying types were attracting a lot of astronomical attention, thus sparking interest in this area. Frank Bateson (FMB), Director of the RASNZ's Variable Star Section, confirmed this, and advised searching for eclipses to determine orbital periods. He recommended VW Hydri and BV Centauri as likely candidates. To these were added EX Hydrae, a known eclipsing binary star that was subject to periodic outbursts.

Some of the AAS observers were interested in photography, and one in particular, Ronald Welch, was successful in finding new variable stars. In 1969, he discovered a nova in Sagittarius as well as the unique behaviour of the Mira star BH Crucis, that shows double maxima similar to those of R Cen and R Nor.

Another famous star was η Carinae, which in the 1840s was the second brightest star in the sky, before fading by nine magnitudes (Frew, 2004). It then began slowly brightening and became a visual target. The photometric monitoring later found one of its comparison stars also to be variable. This object—now known as the massive system QZ Carinae—has turned out to be one of the most complex stellar systems known: a central quadruple star with a six-day period eclipsing binary and a massive spectroscopic binary, together with several lower mass companions. The system, comprising more than a hundred solar masses, is almost naked eye at ~7000 light years. The age is put at just a few million years. The system is discussed in Section 3.8 below.

3.3 Visual Star Sequences

The early 1970s saw a dramatic increase in the numbers of visual observers in a wide range of astronomical studies. Of course, visual star observers have been around for centuries, but the major observing groups for variable stars do not go back that far. Among the first was that of the British Astronomical Association (BAA), formed in 1890 (Toone, 2012). Then the American Association of Variable Star Observers (AAVSO) was set up in 1911 (Williams and Saladyga, 2011). In New Zealand, the RASNZ's Variable Star Section started in 1927 (Jones and Walker, 2012). Prolific observers in the 1960s, when AO came on the scene, included Frank Bateson (Bateson, 1989), Albert Jones (Toone, 2016), Merv Jones in Queensland (Anderson, 2024) and Colin Venimore. Other contributors to VSS activities included AAVSO members, Tom Cragg (Waagen et al., 2011) and Danie Overbeek (Mattei and Fraser, 2002).

These observers used a wide range of published values for their comparison stars. A prolific observer from 1890 to 1920 was Alexander Roberts of the BAA, who worked in South Africa (Snedegar, 2015). Roberts appears to have relied on the *Cape Photometric Durchmusterung* for photographic 'pg' reference magnitudes. European observers were more likely to use the visual measures of the *Cordoba Durchmusterung* (CoD), published in the 1860s, and still highly regarded for comparison star data, even in the 1960s.

A meeting and correspondence between Frank Bateson of Tauranga, Albert Jones of Nelson and Barry Menzies of Auckland resulted in the AO management agreeing to a project to measure comparison star sequences for use by VSS observers. Initially, the project was led by Barry Menzies, and later Peter Gordon became a co-leader. This began in 1969, when it became clear that the photoelectric photometer was accurate and the transformations were allowing the derivation of reliable magnitudes. The project's importance was realised, and the Saturday night of each week was officially allocated; such allocations to take precedence except for important international joint urgencies. Measures were made through B and V filters, thus providing a V value for visual comparisons and a B–V value to check the suitability of the star, insofar as colour was concerned. The limiting magnitude was V ≈ 14.0: a great extension of the range for variable star magnitude quantification.

In each field two main stars were selected with V magnitudes and B−V colours from the *Royal Observatory Bulletin 64* catalogue, compiled by the Cape observers Cousins and Stoy. Derived magnitudes were rounded to the nearest 0.1 mag for the visual observers. As these sequences were to be used mainly for visual observations of Mira and similar stars, often with ranges of 6–8 magnitudes or more, the selection of suitable comparisons was important. Sequences were to have several stars through each magnitude interval without gaps or duplicated magnitudes. These guidelines produced sequences that were excellent for the purpose, and the selection criteria made the charts showing these values to be competitively reliable.

The first published sequence was for the Mira star U Crucis in January 1970 (Bateson et al., 1970). Records are still readily available for the first few dozen of such sequences. The project carried on for some years, but the number of target stars grew alarmingly large, so that recourse to other published magnitudes became expedient. Unfortunately, many of the later brightness data were not adequately transformed to the standard UBV system.

As a result of these calibrations, a considerable systematization of the visual data on variables was achieved. Plots of brightenings and fadings allowed the properties of individual stars to be determined. The main results were:

- Amplitude from minimum to maximum.
- Period of each individual star.
- Rise time as a percentage of the period.
- Idiosyncrasies of individual stars.
- Stability of the period.

3.4 Miras and 'Red Stars'

According to standard theory of stellar evolution, those red giant variable stars, typified by ο Ceti ('Mira'), are located on the 'asymptotic giant branch' (AGB)—a relatively late evolutionary stage—where they manifest a persistent instability that shows up in a sequence of visual brightness changes. These vary through several magnitudes over a cycle that lasts for hundreds of days. Miras may have a quite wide range of masses, but surface temperatures are

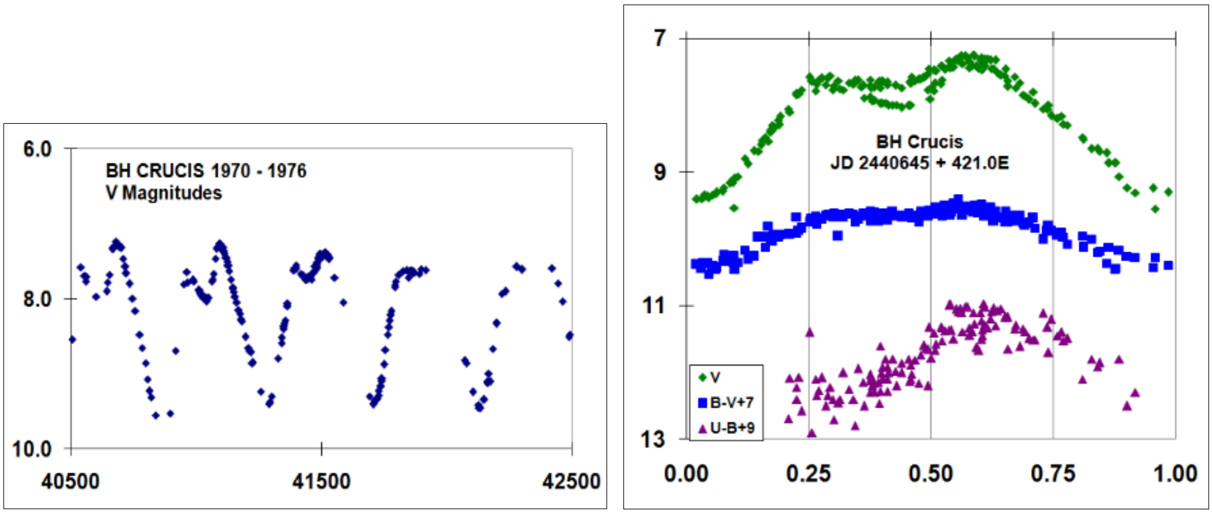

Figure 5: At the left the V measures of BH Crucis show the dual maxima, on the right the B–V colour indicates substantial temperature variations. The U–B colour is puzzling, but may indicate a circumstellar gas cloud, replenished each cycle by increased mass loss at minimum when the surface gravity of the distended star is at a minimum. The phase delay is an indication of the distance from the star of the circumstellar disk (after Walker, 2022).

generally below 5000 K (Mattei, 1997; Willson, 2006). The light variation ('pulsation') period has been reported to be somewhat variable, as noted in the *General Catalogue of Variable Stars* (GCVS) for almost all Miras with periods of over 200 days. Bateson gathered information on these period changes and Ranald McIntosh provided VSS records of 88 Miras with data covering more than 50 years.

The AO stellar photometry group selected 20 Miras with periods ranging from 200 to 400 days. Earlier data had produced conflicting results. Sterne and Campbell (1937) had concluded only three of 300 Mira stars showed true period changes. Percy et al. (1990) considered the changes mentioned in the GCVS to be random. Mean light curves were derived for each star and epochs of maximum determined from the best fits. These were then compared with other derived epochs and the method was checked for self-consistency. 'Observed minus calculated' reference times plotted against epoch ('O–C diagrams') for each star were determined and analysed. Results were presented at the IAU General Assembly in Kyoto, Japan, in 1997 (Walker et al., 1998). The findings showed that periods mostly alternated between two extremes within about 1% to 3% of the main period. Extreme deviations in the O–C diagrams lay between 9% and 20% of the mean period. The fluctuations were not random. In two cases, the period variation was surmised to relate to evolutionary effects. Subsequently, unpublished analyses have suggested that almost all Miras with periods exceeding 400 days show period changes that may reflect their evolutionary stage (for BH Crucis see below).

Regarding variable red stars, Norman Rumsey from the DSIR Optical Division helped the project greatly by drawing attention to useful catalogues, such as those of the Cape Observatory, published in the *Royal Observatory Bulletins* series. AO observers subsequently veryfied the variability of Rumsey's selected targets.

Ronald Welch discovered the unusual Mira type variable BH Cru, also known as Welch's red star, in 1969 (Bateson, 1974). Photoelectric measures at AO commenced on 10 October that year, with initial values determined as: V = 8.54, B–V = 2.81(!), U–B = 1.9(!). A phased light curve showing cyclical colour changes is shown in Figure 5. The graph demonstrates BH Cru's unusual properties. When discovered, and for a decade thereafter, there were two maxima. Some analyses suggested a period of half the generally accepted one of 421 days, but this was belied by the colour variations. The B–V varies from ~2.5 to 3.5 over 421 days. Such values point to an unusually cool Mira. Whilst the U–B data is noisy (U ~ 17 at minimum), there is no doubt that the period in U is also close to 421 days. Walker (2022) reviewed the main properties of BH Cru as: (1) subject to major period changes; (2) probable alternations of period; (3) dual maxima persist for some time; (4) changes from a double maximum to a regular single hump Mira; (5) the mean brightness has increased since discovery by about 0.7 mag; (6) the spectral classification changes from the cool, carbon-strong SC type, to the C-type (showing the Swan bands of C_2), featuring s-process elements in the spectrum; (7) BH Cru has appeared to cool as it brightened, indicating a large radial expansion.

Internal helium flashes may occur during AGB evolution. These are thought to cause a reduction of the pulsation period by up to 30% over one or two centuries. About 6 to 10 Miras have been reported to show this behaviour. But BH Crucis and the comparable star LX Cygni have shown period increases of up to 25% over two- to three-decades time intervals.

At the time of discovery of BH Crucis there were only two other known examples of Mira stars with two maxima per cycle: R Centauri and R Normae; the latter with a mean period of 490 days and the former ~548 days. However, recent data indicate that the period of R Cen is currently a little under 500 days.

A fourth such star, V415 Velorum, has been reported by Variable Stars South observers together with several other candidates, mainly in the Southern Hemisphere and around the Crux star-formation region. One puzzle is that for R Cen the first maximum seems to be the more stable one, but for BH Crucis the reverse holds. Recent data have shown that this star brightened near the phase of its second hump, similar to many of the longer period (>400 days) Miras.

3.5 Cepheids

A programme to check on the times of maximum light and determine any change in the ephemerides of cepheid type variable stars was in place at AO from at least 1984. Observations were in the standard UBV system, although there are not as many data points in U as for B and V. Bos et al. (1996) concentrated on R and S Mus, noting irregularities in the timings, which they surmised could be due to an unresolved binary companion in the case of R Mus. The known companion of S Mus would have too long an orbital period to associate with a light-travel time effect. However, the companion could have some inherent instability to account for the light curve irregularities.

Towards the end of the twentieth century, NZ photometrists were producing a *Communique* series, in which their activities could be locally and swiftly published. Issues 2 and 3 contained a review of observations and analysis of classical cepheids (Williams et al., 2001a, 2001b), that included detailed studies of β Dor and S Mus. The Baade–Wesselink technique was employed for system parametrization. This involves a phased set of radial velocities of the stellar photospheres, that were available in the literature on these two cepheids. The spectroscopically obtained radial velocity curves were integrated to yield the cyclic variations in size of the stars. These data were combined with the AO observations of B–V colours, the latter being used in an empirical equation relating colour to temperature. Having both the measures of size and temperature, the V magnitudes of the stars could be calculated and compared with the AO observations. The two sets of magnitudes were then matched in a computer-based parameter-optimization program (cf. Budding and Demircan, 2007).

As a result, reference values of the phase-zero radii, temperatures, source distance and gravity-dependence of the colour-temperature relation were obtained. The parameters for β Dor were determined to be about 70 solar radii (size at phase zero), 7500 K (reference temperature), 310 pc (distance—just a few pc different from the Hipparcos value). A comparable set of results were found for more distant, hotter and somewhat smaller S Mus, although the match of temperature to the colour data was compromised by the early type companion to S Mus that was included in the photometry.

3.6 Short Period Pulsating Stars

Two younger VSS-members, Grant Christie and Roger Feasey, became interested in stars of the δ Scuti type, particularly those with large amplitudes such as AI Velorum. This has a period 0.11157 days and an amplitude of ~0.6 magnitudes, though the amplitude is found to show systematic variations. Walraven (1952) suggested the star may have two periods that interact, resulting in a beat period of 0.37917 days.

Regrettably, these AO data have not yet been published. This emphasizes the importance of effective communication of observations. This sometimes meets with discouraging delays. A similar situation affected the observations by SW and Marino of RS Columbae, whose close binary nature was not recognized until some 34 years after Hofmeister's discovery of the variability in 1935.

3.7 Active Cool Stars

The advantage of long-term surveillance of stars that exhibit comparatively mild variations in brightness (compared to flare stars), but otherwise have near-normal properties, becomes apparent in the case of the 'RS CVn type' (magneto-dynamically active, often binary) stars. These stars are characterized, photometrically, by showing the effects of large surface 'starspots' (maculation). Here amateur observers have a distinct 'edge' over headline-seeking, large astronomical institutes. The southern active system CF Tucanae is a good illustration. AAS member Trevor Rounthwaite steadily collected broadband photometry of this object over the last couple of decades of the twentieth century, and 25 separate light curves, over the in-

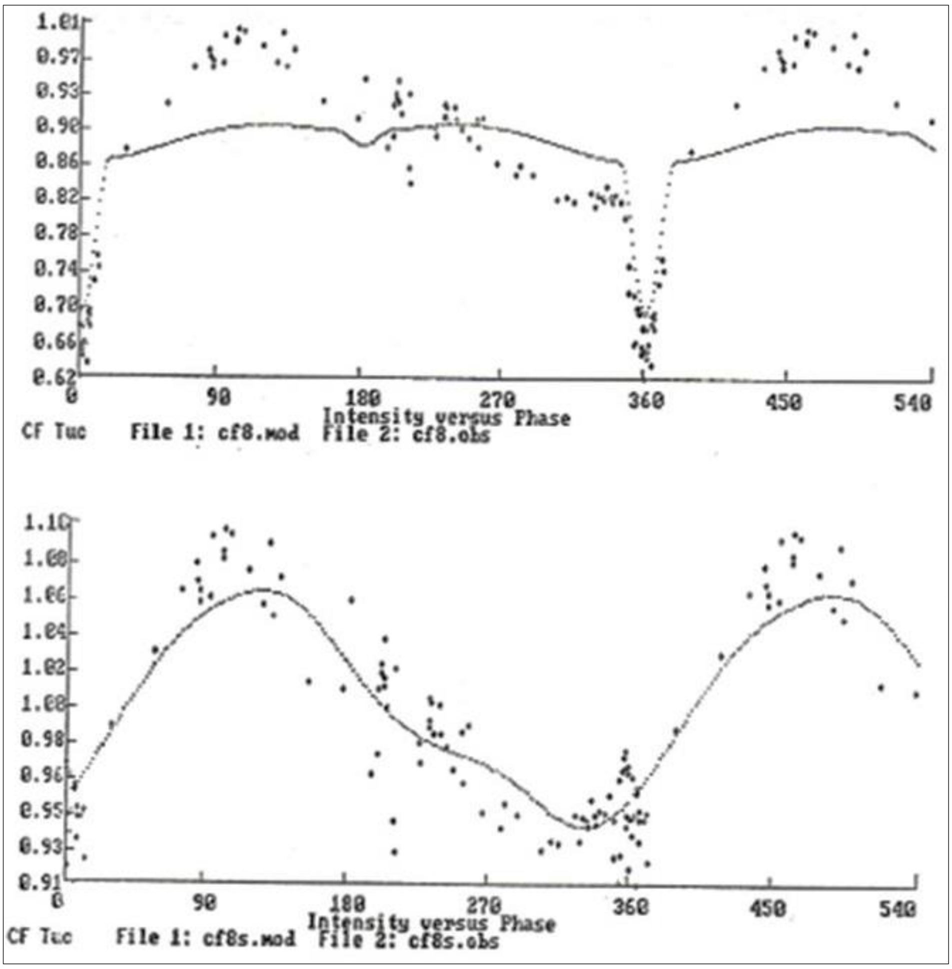

Figure 6: V light curve of CF Tuc (= HD5303) collected during late-1985–early-1987. The observations are plotted with a standard model light curve in the top panel. The lower panel shows the 'difference curve' modelled by a simple representation of the maculation effects (after Budding and Zeilik, 1994: 78).

terval 1978–1994, were studied for trends in surface maculation.

The data-sets were divided into four intervals of more continuous records. From these the following effects were found: (1) Maculation tended to concentrate in certain restricted regions of longitude, so that distinct 'waves' could often be seen. These maculation waves can be modelled with one or two large dark starspots, plausibly at higher latitudes, in comparison with the familiar solar case. (2) Such a spot often preferred a longitude close to, but frequently a little before, the central meridian at primary minimum. Intermediate latitudes (±40–50 degrees) were feasible at this stage. (3) From this position the spot would tend to drift to lower phases over the timescale of a year or so, and at a rate of typically 30–50 degrees/year. (4) Such a spot tended to drift to a lower latitude during this process. (5) After a given large spot had drifted back to a phase near second quadrature, a new formation would typically appear around the primary conjunction phase. (6) At, or a little after, this, the maculation effects could become quite complex, without a small number of predominating features. (7) A near-conjunction feature subsequently tended to predominate as at (2). This behaviour allows an activity 'cycle' (2) → (7) → (2) taking around five to six years to be proposed. These results (see Figure 6) suggested that CF Tuc should be the target of a continuous and dedicated campaign of photometric monitoring to help substantiate or improve on this picture and increase our knowledge of the RS CVn type syndrome.

Such extended data series helped stimulate further follow-up work on this and similar examples of magnetodynamically 'active' stars (Budding and Zeilik, 1995; Budding et al., 1999). Another Southern Hemisphere active binary, comparable to CF Tuc, is the somewhat longer period pair of Sun-like dwarfs TY Pyx (Allen et al., 1993)—see Figure 7. Having recognized the interest in active star monitoring, AO members engaged with photometric back-up of this and other similar stars.

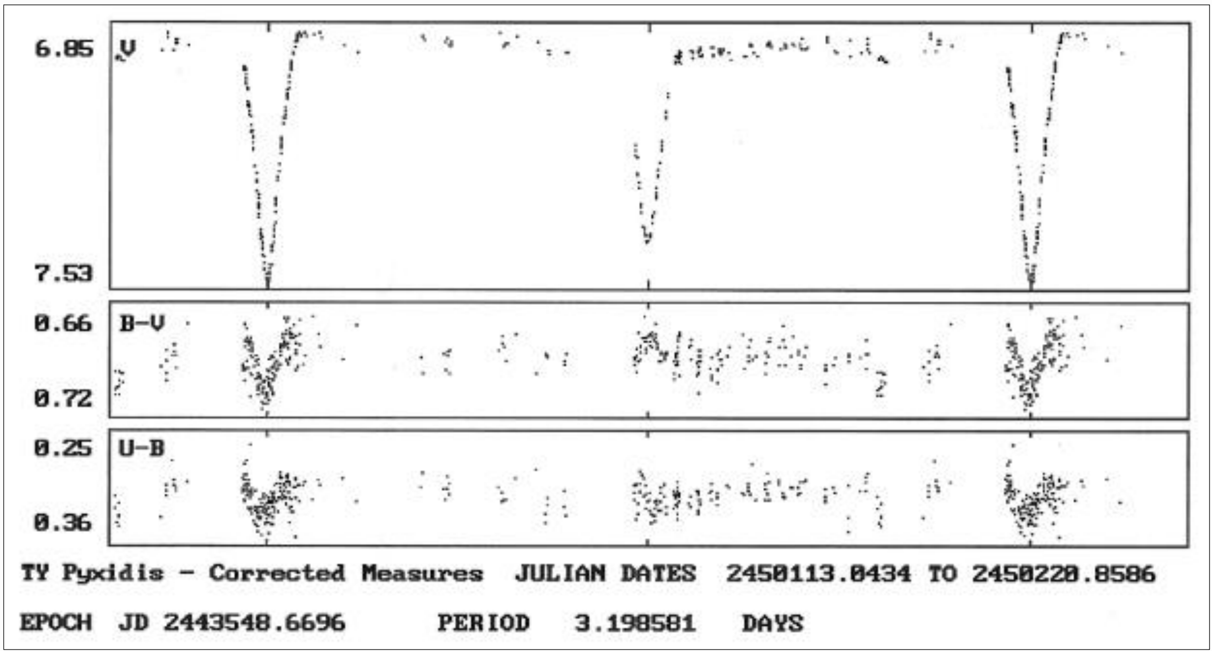

Figure 7: UBV light and colour curves of TY Pyx. The asymmetries visible in the trend of the out-of-eclipse light are attributed to starspot effects. The rotation of the TY Pyx stars is appreciably lower than in CT Tuc; this is perhaps reflected in the lower scale of maculation (cf. Allen et al., 1993; Williams et al., 1996).

3.8 Eclipsing Binaries

Although CF Tuc and TY Pyx were referred to in connection with their surface maculation, the two binaries do undergo eclipses, the plane of their orbit being close enough to the line of sight. This circumstance gave rise to the classic 'royal road' to knowledge of the basic para-meters of stars. This is associated with the combination of photometric and spectroscopic techniques, particularly in the hands of H.N. Russell and others at start of the twentieth century. By now, many thousands of eclipsing binary stars are known, though most of them have not been studied in much detail. AO photometry of eclipsing binaries was limited to a few of the more interesting objects, or those where other investigators were seeking data. This type of collaboration is outlined by Walker et al. (2022) in the case of the massive multiple system, QZ Carinae. The discovery of this ob-ject has an interesting background.

Whilst η Car is a massive binary, it does not show eclipses. It does, however, display intrinsic light variations, as do those similar massive stars known as the Luminous Blue Variables (LBVs), also called S Dor stars. For the reasons discussed above, η Car was on the target list as soon as the photometer was ready for use. At that time, its visual brightness was about sixth magnitude. Four other stars were used as brightness comparisons: HD 93131, HD 93206, HD 93695 and HD 93737. After a while, there was convincing evidence that either HD 93206 or HD 93131 also was variable. This was later established, but in three stars, not just one! HD93131 turned out to be a Wolf-Rayet star that is variable at around 1%. HD 93737 is an A star with a V brightness range of about 8%, now listed as V522 Car—an α Cyg type variable—while HD 93206 showed a range of ~0.25 V mag. Even HD 93695, a foreground B5 star, has been listed in the NSV catalogue, but that turned out to be incorrect and it was adopted as the main comparison star for η Car. This star was later found to be a spectroscopic binary (Mayer et al., 2022), but with less than 1% changes in brightness.

3.8.1 HD 93206 (QZ Car)

Of these three variables, HD 93206 had the greatest amplitude, and excited the most curiosity. It became clear that its period of close to exactly 6.0 days created problems. From any one observing site over an interval of six months, a normal observing season for a typical sky object, it will show six similar clumps of brightness measures. Fortunately, at the time of discovery, the system was aligned so that the primary eclipses were visible at AO. At any one site, the phases slowly change over a cycle of about eleven years. After two seasons, an ephemeris was published (Walker and Marino, 1972). Later observations produced the more accurate light elements: Min I = JD 2441033.033 + 5.99857 days. There remains a slight disparity between the ephemerides adopted by different groups studying this binary (cf. Mayer et al., 1998).

Early spectroscopic and photometric studies of QZ Car (Leung et al., 1979; Morrison and Conti, 1980) led to the model that remains similar to that of the present-day. In this picture, QZ Car consists of four massive early-type stars, arranged as two close binaries that revolve around a common centre of gravity in a period of several decades. The closer eclipsing pair forms QZ Car B, while QZ Car A is a spectroscopic binary with a period of 20.73 days. More recent data suggest that there may be as many as 5 more stars with lower masses in the system. Overall, the total mass is thought to be around 120 times that of the Sun. The VSS arranged for follow-up observations in South Africa, Australia and New Zealand, resulting in an improved period. BRITE satellite photometry was also organized by VSS members that yielded a continuous, improved light curve, allowing fuller coverage to find epochs of light minimum. These, in turn, led to the date at which the wide orbit of the two binaries returns to the arrangement when the close binary was first discovered. The period of the wide orbit thence being known, the masses of the A and B systems can be independently estimated. Further details are found in Walker et al. (2017) and Mayer et al. (2020).

3.8.2 RS Columbae

Bond and Landolt (1969) identified RS Columbae as a W UMa type ('contact') binary, but reported an ambiguity about the period determination. The AO light curve, with supporting comments from G. Hill, helped resolve this issue, and their longer period of ~0.672355 d is now accepted (Marino and Walker, 1971).

3.8.3 HD 153919 (X Ray binary 3U 1700-37)

With this extraordinary object AO photometry extended its compass to include the 4-colour uvby system (cf. Crawford and Barnes, 1970). Results were reported in Marino and Walker (1976).

3.8.4 KZ Pavonis and RW Doradus

AO-based photometry of these binaries was carried out in 1988 after a request from the second author of this paper (henceforth EB), who was working with Dr D.J. Sullivan from the Physics Department at Victoria University Wellington. Spectroscopy was carried out at Mt Stromlo Observatory near Canberra, Australia. Subsequent analysis of the relevant data on these systems can be found in Budding et al. (2001) and Marino et al. (2007).

3.8.5 V777 Sagittarii

In 1985, AO received a request to observe an eclipse of the binary V777 Sagittarii. This giant binary shows eclipses every ~940 days, having a close similarity to the prototype ζ Aurigae (cf. Ake and Griffin, 2015). Such binaries are characterized by an A or B spectral type Main Sequence photometric primary and a supergiant secondary. The decline into eclipse occurs as a result of a steadily increasing obscuration in the line of sight as the hot star sinks behind the dense atmospheric layers of the supergiant. The process offers a means to probe the atmospheric structure. A short account of this type of system is given in Section 7.4 of Budding and Demircan (2022). Data on the ingress and egress of V 777 Sgr in 2018 are available from SW.

The contrast as the hot star is eclipsed is naturally much greater in U and B than V. Thus, in V the eclipses are 0.08 mag deep; they are 0.333 in the B filter, and 1.438 deep in the near ultraviolet U filter. Unfortunately, commonly used CCD cameras are not sensitive to the U signal and a significant part of the B. Even the photomultiplier type detector of the Mark I photometer tended to show considerable noise in the U region, in the case of V777 Sgr. The B data probably offers the best signal/noise ratio for the kind of data collected. Another eclipse is expected in December 2023.

3.9 Cataclysmic Variables (CVs)

CVs are a diverse category of objects characterized by occasional and sudden explosive increases in brightness that may reach to the order of 10 magnitudes. The bright stage would usually be relatively short-lived compared to the interval between brightenings: a few days would be characteristic for the well-known example U Geminorum. The bright stage may be accompanied by rapid 'flickering' light variations. This is followed by a slower decline to a quiescent state that would usually be relatively faint compared with typical stars in the Henry Draper catalogue (cf. Warner, 1995).

This latter point implies that many CVs were first picked up by relatively small-scale facilities—a point that naturally arouses the attention of amateurs. The development of 'fast' photometric techniques in the sixties fur-nished a means to study the finer details of CV properties. There subsequently burgeoned a large literature on this class of object. The underlying evolved-binary-star nature of CVs, one component being a collapsed object (such as a white dwarf), became clear in this process.

3.9.1 EX Hydrae

Bateson encouraged attention towards the photometry of CVs, including EX Hydrae and VW

Hydri, to find eclipses that could establish their orbital periods. Monitoring began with EX Hydrae, which was known to show eclipses, although the period was uncertain. It was discovered later that EX Hydrae was an 'intermediate polar' type of CV, characterized by strong magnetic fields. Even with the 50-cm EWB Telescope and the ability to measure to magnitude V = 15, these two, together with BV Cen, were the only southern CVs that could be checked at AO in the quiescent phases. The technique of eyeball estimates every 30 seconds, when plotted, produced a well-defined bright period in the middle phases of the cycle. This led to the idea that flaring might be more common amongst CVs than was realised (cf. Walker and Marino, 1969). Later observers deduced that this flare-like effect was related to the spin cycle of the white dwarf component.

This productive field attracted international attention and soon became the main research programme at AO. AO was then for many years engaged in the study of CVs, with the bright VW Hydri being the main target. Measures began in mid-1968, but it was a full decade before the nature of the two types of VW Hydri outbursts was presented, on the basis of AO data, at IAU Colloquium 46 (Walker et al., 1978).

CVs were the subject of many presentations at that meeting. As a result, Professor Christiaan Sterken organised a collaborative programme, involving professional and amateurs, to observe the dual periods of EX Hydrae. Linked observations were made for eight days in April 1979, with participants from New Zealand, Australia, South America and South Africa (see Sterken et al., 1983). By the end of the twentieth century, it was clear that both eclipses and the rotation rate of the accreting white dwarf could be determined. Various attempts had been made to establish definite periods, but this proved difficult. Walker and Allen (2000) provided better agreements by fitting the data to a system with abrupt small changes at regular intervals rather than a continuous change. The Center for Backyard Astrophysics has continued with observations of this star and further refinements to our knowledge of the components' physical behaviour are anticipated.

3.9.2 VW Hydri

This CV belongs to the subgroup known as the SU UMa type, characterized by short orbital periods and occasional 'superoutbursts' that are brighter and last longer than the more typical dwarf nova eruptions. Even with only visual measures at quiescence (V ~13.5) a repetitive nature to the light variations could be seen. By late 1968 an epoch and period—JD 2440128.0222 + 0.0742711 days—had been determined from the AO data. A curious development occurred when similar variations during the bright supermaxima were noticed. The period for these variations appeared to be slightly longer at ~0.0768 days. The possibility was considered that the adopted method of determining orbital periods was unreliable. Several years of collecting more data failed to clarify this question. In late 1973, the issue was brought to a head when 16 anomalous hump effects were reported (Marino and Walker, 1974). This drew a quick response from Brian Warner (1974), who proposed that these 'superhumps' were a consequence of the precession of an elliptical disc. This stimulated much further research into the energetics of SU UMa type variables.

Photoelectric (UBV and unfiltered) monitoring of this star continued at the AO, particularly during the normal, more frequent, outbursts. Certain features in the data drew attention to the early stages of superoutbursts (Figure 8). This led to a presentation at the Paris Conference on Novae and Related Stars in September 1976, detailing the colour and magnitude changes. Meanwhile, an earlier review had appeared in *Southern Stars* (Walker and Marino, 1974).

3.10 Targets of Opportunity

From time to time unusual events—Targets of Opportunity—are important enough to interrupt normal observatory programmes. The AAS included keen photographers, who made interesting discoveries. Barrie Ward (2022) reported several new variables, of which CR Muscae attracted attention (Marino and Walker, 1975). Ron Welch's discovery of the unusual Mira BH Cru was mentioned above. Templeton et al. (2005) discussed the sudden changes in spectral signature of BH Cru in connection with evolutionary models (cf. Walker, 2009).

Welch also observed the outburst of Nova Sgr, 1969, noticing that the brightness of the image increased by about 5 magnitudes during June–July of that year. John Orr, from the AAS, helped with these observations. In addition, 17 sets of UBV monitorings of Nova CrA were reported (cf. McNaught, 1987); 46 of Nova Ara (1983); and similar data on the recurrent nova RR Pic. In 1981, the AO contributed nine sets of UBV magnitudes of the supernova in NGC 1316.

Harry Williams called attention to the central star in the planetary nebula NGC 2346 that showed occasional eclipse-like diminutions of light (see Marino and Williams, 1982). These

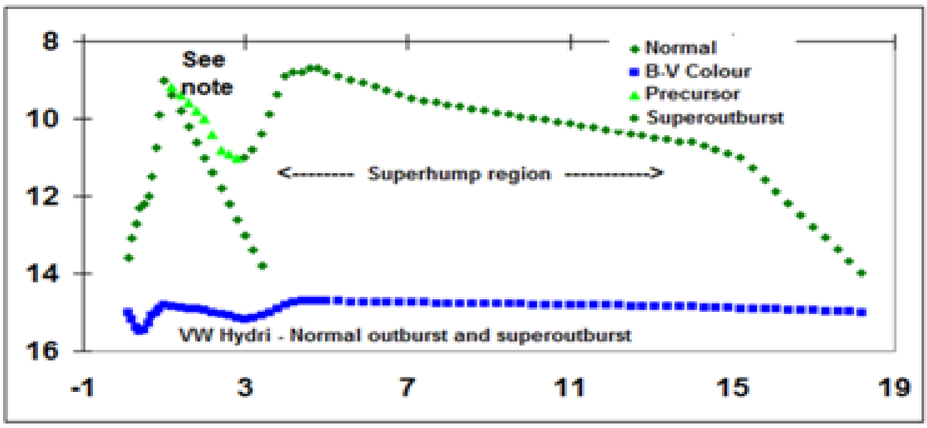

Figure 8: A VW Hydri superoutburst begins with an ordinary event which usually reaches V ~9.0. Then the slower fading orbital humps, enhanced ~30 times, but with the same period as at quiescence, are observed. This is the precursor, which triggers the main outburst after an interval of an hour or two, to as much as a day or two. The superoutburst is signalled by the onset of superhumps with amplitudes of ~0.5 magnitudes but a period ~3% longer. The amplitude and period of these superhumps gradually shortens for the next ~12 days, after which the star returns to about normal, although with complex small-scale after-effects. One feature of the normal outburst is a change in B–V from ~0.1 to 0.5 at V = 12. This is associated with the collapse of an accretion disc around the receiving white dwarf star, which temporarily obscures the very blue radiation from that object, which reaches B–V ~ –0.05 at maximum (diagram: Stan Walker; cf. .Walker and Marino, 1982: 172).

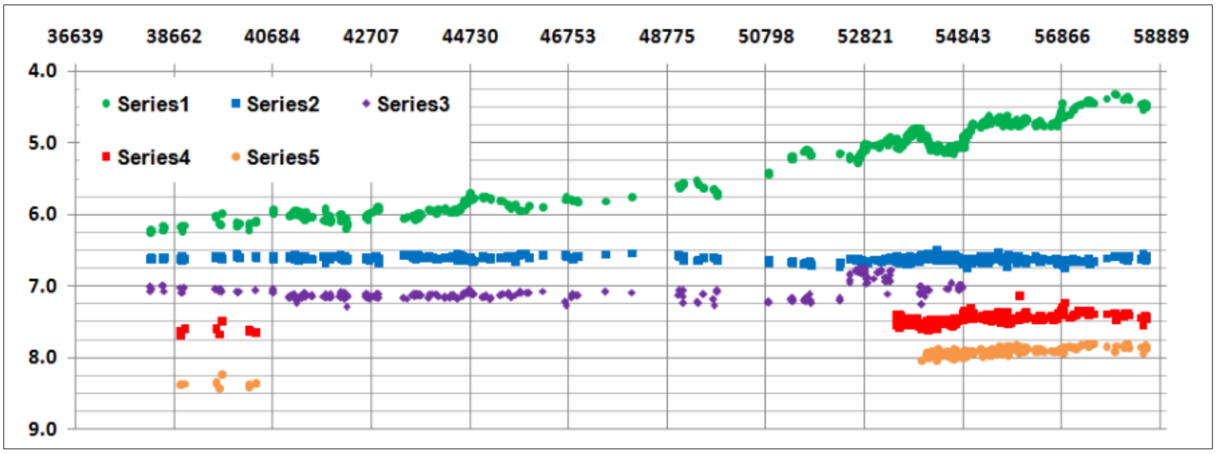

Figure 9: Measures of η Carinae from the following five sites: 1. Feinstein and Marraco, South America, JD 2438181–2441769; 2. AO, JD 2441030–2448051; 3. H.O. Williams, Milton Road, Auckland, NZ, JD 2448998–2452322, 4. W.H. Allen, Blenheim, NZ, JD 2452506–2454826, and 5. Giorgio di Scala, New South Wales, Australia, JD2453469–2458602. The vertical bars mark the times of periastron passage. The colours represent different filter passbands: green is V, similar to visual; blue is B–V; purple is U–B; red is V–R; and orange V–I. The main result is that as the central nebula expands the system brightens, with an increase in the UV radiation but a slight cooling of the disc resulting in a larger B–V (diagram: Stan Walker).

have been associated with passing dust clouds: remnants of a bygone era of inter-active evolution, when the present subdwarf component of the nebula's central binary was a giant shedding its envelope. As well, several minor planet transient events were timed at AO during the 1969–1995 interval.

3.10.1 η Carinae

Eta Carinae—a potential supernova in our own Galaxy—was initially regarded as a visual observers' target as it had changed little over the preceding decade. But there were reports of 'flares', calling for independent confirmation. Constancy of the sometimes-used comparison star HD 93206 was also in doubt. This object turned out to be the QZ Car system (see above).

Figure 9 shows the photometric data, with the vertical lines indicating times of periastron passage. Dates are expressed in JD 2400000. The measures included the Homun-

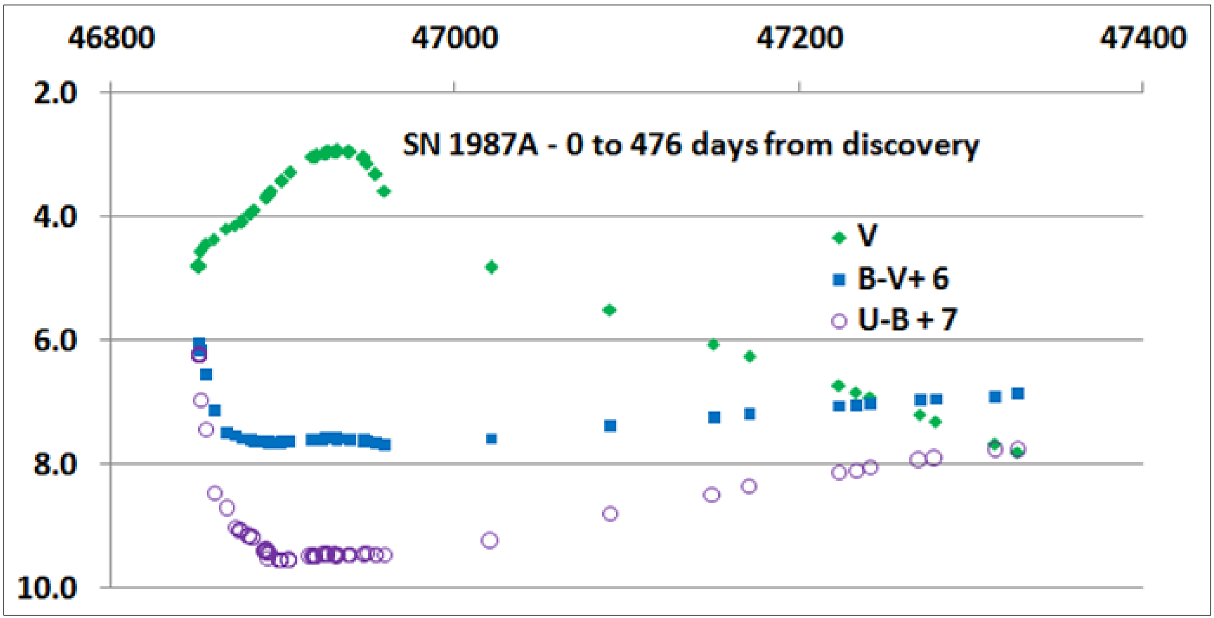

Figure 10: This shows the unusually slow brightening of SN1987a. At discovery the magnitude and colours reached V = 4.793, B–V = 0.036, U–B = –0.792. Over the next 23 hours these changed to Day 1 = 4.568, 0.142, –0.051. By Day 30 it was 3.942, 1.605, 2.143, Day 48 = 3.415, 1.625, 2.535, Day 80 = 2.928, 1.580, 2.463; and eventually Day 476 = 7.803, 0.846, 0.775. These numbers are, of course, the magnitudes and colours of the expanding shell—not the remnant of the star itself that should have formed a neutron-star pulsar. This has not yet been unambiguously identified, though debris from the original star and surrounding material may be masking the collapsed object (diagram: Stan Walker).

culus condensation in the Great Carina Nebula (cf. Burnham, 1978). They were made with a 31-arcsec focal plane aperture, which included flux from three other relatively bright condensations in the nearby sky. A net brightening in V was largely absent for the first decade, although there are indications of a flux increase near each periastron passage. The Homunculus feature has become slightly redder and cooler during its steady expansion, as shown in both the B–V and U–B colours. Measures at AAO were discontinued in 2001, when the project was transferred to W.H. Allen in Blenheim.

Interest in η Car continues. Recently, SW received a request from Elizabeth Waagen of the AAVSO to estimate the accuracy of the 19.2 years of AO data and Harry Williams' 9.1 years of Milton Road Observatory observations, that were to be included in an updated analysis in 2022.

3.10.2 Supernova 1987A

This was a relatively unusual example that did not follow more typical supernova behaviour. The initial explosion was observed in South America, but the well-known visual observer Albert Jones, of Nelson, had independently noticed this within a few hours of the first report. A request was subsequently made later that night to AO for confirmation. The first UBV photometry at AO started at 1050 UT on 23 February 1987. Results were recorded as follows: V = 4.793, B–V = 0.036 and U–B = –0.792.

Measures were repeated the following night. With the assumption that the expanding shell was still dense and opaque, and its temperature could be estimated from the apparent B–V colour, the relationship $L = R^2T^4$ yields an indication of the radius of the emitting surface. This produced an expansion rate of order 8500 km/sec, as well as confirming that the object was part of the Large Magellanic Cloud and not a foreground object.

SN 1987A took 28 days to brighten to V = 4.0, a further 17 to reach V = 3.50, and another 25 to reach V = 3.0 (see Figure 10). It peaked at V = 2.931, B–V = 1.578, U–B = 2.468 on 14 May 1987. At this brightness, the photon-counting system of the AO photometer was showing significant saturation effects, even with high response speed components, and appropriate corrections had to be made. In all 90 measures were made at AO over an interval of 476 days, until 13 June 1988 (Walker and Marino, 1992).

4 HUMAN FACTORS

4.1 The Photometry Section

Photoelectric photometry was not suitably placed within the largely visual RASNZ Variable Star Section. Accordingly, a separate RASNZ

Photometry Section was set up in 1980 with Brian Marino and SW as Directors. W.H. (Bill) Allen soon joined this new Section. The organization was effective and became a strong supporter of the New Zealand Photoelectric Photometry (PEP) conferences. With the revival of the RASNZ VSS in late 2008, stimulated by a meeting with the new Director of the AAVSO, Arne Henden, after the 2006 RASNZ Conference in New Plymouth, the Photometry Section was wound up and its funds transferred to the new Variable Stars South.

4.2 Active Members

These could be divided into two groups: (1) the visual observers, measuring a large number of stars, particularly CVs. They reported any CVs in outburst to the AO; (2) others, with their own photometric equipment. This latter group included Auckland's Marc Bos and Harry Williams, both with good data collection systems. Later, they were joined by Jennie McCormick (also from Auckland), who used a CBA ST6 CCD camera before moving to more sensitive equipment.

4.2.1 H.O. (Harry) Williams and the Milton Road Observatory

Harry Williams (1911–2008; Christie, 2008) began by constructing a 53-cm Cassegrain telescope at his private observatory in Milton Road, Auckland. He also constructed a photometer similar to the original AO one, but economic considerations saw him choose the 12-stage EMI 9924 detector. He used the photometer very effectively until he was in his mid-nineties. Harry's targets included bright Cepheids, but his main project was with Professor John Percy of the AAVSO, in the measurement of small amplitude red variables (SARVs, cf. Eggen, 1973).

Harry is remembered at the AAS as the winner of a photographic competition, but his activities in that field were limited. They included photographs of Comet 1P/Halley around its perihelion passage in 1986–1987 and images of the planetary nebula NGC 2346. But his more prolonged observing efforts concerned the SARVs, of which he made UBV observations of more than one hundred objects.

One of the stars he tracked photometrically was L^2 Puppis. This was from 1990 onward, when measures at AO ceased. The programme was then carried on by Harry, and by SW at Waiharara. They made more than 200 observations between 1984 and 1999.

4.2.2 Frank and Barbara Ives, and L^2 Puppis

Frank and Barbara Ives were both active in the AO research programmes. Barbara was part of the Cepheid-monitoring team, along with Marc Bos and Gordon Herdman with a project to collect UBV measures of the seven Cepheids: R, S, T, X, AD, AG and BG Cru, data being directed to the AAVSO database. Frank was a visual observer of bright stars employing a useful 3-inch refractor. An analysis of Frank's visual measures of L^2 Puppis, the second nearest giant star at 64 parsecs, showed that it had the alternating periods typical of certain Mira-like, semi-regular, stars. The main period of 141 days was derived. Like other such variables, however, it also shows a secondary period, in this case of ~103 days, i.e. about ⅔ of the main one.

Visual photometry from 1891 together with 42 UBV measures made at AO during the period 1984–1985 were collected and analyzed (Walker et al., 1992). A period change around 1967 was found and it was argued, from the colour data, that the star was likely to be a binary. A further 162 UBV observations covering the period 1993–1999 were made by Williams at Milton Road. When the star's variations were originally detected they were from around 2.5 to 6.0 visual magnitude. However, in the 1990s it faded dramatically, perhaps as a result of obscuration by local dust concentrations. There were three earlier reported instances of this behaviour, but this 1990s one was the deepest and the most prolonged. Subsequent measures suggested, inconclusively, recovery to the original brightness.

Kervella et al. (2017) used the SPHERE/ZIMPOL instrument on the VLT at Cerro Paranal in Chile to make extensive high-resolution images of L^2 Pup. Their results showed an edge of the dust cloud partially obscuring the star itself. Kervella et al. also noted that Hipparcos observations suggested that L^2 Pup may be a binary star (confirming the earlier suspicions at AO).

4.3 Collaborations

The flare star programmes led to the development of a high-speed data-recording system with the UAPD. One of their doctoral students, Bruce Griffiths, volunteered to work on this. The photometer would be potentially very effective in observing CVs. This project took several years and involved the construction of another photometer with a variety of automatic controls and linkages. Photon counts were to involve a readable tape punch but this latter idea did not eventuate, with Cold War restrictions on components and an export ban given as an explanation. A teletype recorder from NZ Post was eventually adapted to the purpose.

The electronics were housed in a special cabinet, allowing portability. The photometer was later used at Mt John and Black Birch.

As a side issue, this usage allowed some inter-comparisons of these alternative observing locations. These expeditions were organised by another UAPD doctoral student, Rodger Freeth and later Ian Bond. Both worked in conjunction with the AO, whose research continued chiefly with CVs, although a wide range of stars were able to be covered. An example of such collaboration was Jennie McCormick's adoption of the ST6 CCD camera on loan from Joe Patterson of the Centre for Backyard Astronomy (CBA), operated from Columbia University in New York. This camera had been originally loaned to SW several years after his move to Waiharara. in 1994, where it scored a hit with the discovery of the ~23 h outburst period for V803 Centauri; a helium dwarf pair with an orbital period of a few minutes (Patterson et al., 2000).

Of course, the long-standing role of Dr Frank Bateson and the RASNZ's Variable Star Section cannot be overlooked. In the early seventies Bateson initiated a series of articles about individual stars in the Section's 'Publications'. Rather than continuing the observations of various long period variable stars (LPVs) indefinitely, on the basis that these would prove valuable at some future date, the emphasis changed. After a few cycles it was decided to present the main characteristics of a particular star. The data could then be compiled, and results compared with others, taking into account the ascribed type of variability. In due course, the organization of the VSS and its routine communications were helped along by two other prominent observers, Albert Jones and Ranald McIntosh (NB not the Ronald McIntosh of earlier years).

4.4 Promotion of Stellar Photometry

AO, with help from a wide range of people, including UAPD, introduced a new concept to amateur astronomy in New Zealand, namely, that it could include a moderate level of practical astrophysics. Not only did UBV photometry allow measures to be made to an accuracy of ~1% down to V mag ~14, thus vastly increasing the *number* of possible target stars, but it allowed inferences on *temperatures* to be made. From this, source radii and other physical attributes of stars could be ascertained. As well, the extension of measures to the near UV was a clue towards mass ejection or transfer in highly evolved objects. It did not, at that stage, move into the more complex field of spectroscopy, but empirical B–V and U–B relationships allowed spectral classes to be approximately assigned.

An important aspect was cost. Mechanical construction was within the capabilities of many 'backyard engineers'; the photomultiplier tube for signal detection was not over-expensive for many; and supporting electronics could be supplied from among the community of amateur radio enthusiasts. Clive Rowe's design of an analogue digital (A/D) converter provided a simple method of digitising the output, while local university departments could help with certain items of equipment no longer in regular use. At the time, in the stellar photometry programme of AO reduction procedures were still largely manual. The effects of atmospheric extinction were calculated by hand. Such challenges were met by concerted efforts. In Christchurch, the Canterbury Astronomy Society used its West Melton Observatory, while in Australia Harold Kennedy and Arthur Page both worked at separate sites in Queensland.

The situation changed drastically in 1977, with the mass distribution of the 'personal computer'. The TRS 80 from Radio Shack, the Commodore, the Apple and various others, all appeared around the same time. By today's standards, these were very crude and unsophisticated devices, but they pointed the way forward for stellar photometry. The communication of results was still difficult, but by 1983 the internet was widely available, allowing greater and faster progress. Ranald McIntosh introduced observers to the powerful Quick Basic computer programming language. This allowed a transition from Auckland University's facilities to data reductions on personal computers. SW wrote a series of programs that handled the necessary data transformations and produced a series of displays to make the presentations simpler and more flexible. These were used by both the visual and photoelectric observers and are still in use today, although the change from 32 to 64-bit registers limits the computers they can be used on.

For a decade or two after 1980, there was a close relationship with the International Amateur Professional Photoelectric Photometry group (IAPPP), set up by Professor Doug Hall and Russ Genet in the USA (Genet, 1983). B. Marino and SW were invited to become life members and publish reviews in their journals. The invitation was well-received, though it lost impetus around the turn of the century.

4.5 The PEP Conferences

These began when Dr Murray Lewis, the newly appointed Director of Carter Observatory in Wellington, suggested that interested persons meet

Figure 11: Some of the participants at PEP 3. From left: SW, Derek Robinson (U.S. Naval Observatory), Jim Hughes (U.S. Naval Observatory), Mike Bessell (Mt Stromlo and Siding Spring Observatory) and EB (Carter Observatory), obviously enjoying a pre-dinner discussion (courtesy: Bill Allen).

and discuss astronomical research in New Zealand. At the time, the amateur operations at AO were seen as a strong focus for this.

4.5.1 PEP 1, Carter Observatory, Wellington, 1976

This inaugural conference attracted 15 participants. It was a fairly informal gathering—the 'Conference Banquet' comprised fish and chips from the local takeaway—but it did provide an opportunity for observers to discuss their work. The Auckland group presented 9 papers, largely about variable stars and the AO photometer. The occultation events associated with 1580, Betulia, and the lunar occultation of β Scorpii on 11 September 1975, were also presented. (cf. Marino, 1976).

4.5.2 PEP 2, Auckland 1982: Photoelectric Photometry with Small Telescopes

The venue was the Rocklands Hall, Auckland Training College. in Epsom. This four-day conference attracted 44 participants including Col Bembrick and Keith Thompson from Australia and Professor Ed Nather from the USA. Also present were two University of Canterbury postgraduate students, David Buckley and Andrew Collier.

Professor Paul Edwards from the University of Otago chaired the Scientific Organising Committee, which contained, amongst others, Frank M Bateson, Dr Richard J. Dodd, Russ Genet, Dr Denis Sullivan, Dr Joe Trodahl and David Buckley. Thirty papers were presented. For the proceedings see Woodgear (1982).

4.5.3 PEP 3, Blenheim 1989: Toward the Global APT Network

Influenced by the burgeoning of computerized systems and the Internet, this memorable meeting looked daringly forward to a more cyberlinked world. In so doing, it generated a shared mood of cheerful excitement and thoughtful anticipation. There were 59 registered participants, including 13 from overseas countries (three of whom are shown in Figure 11, along with both authors of this paper). In all, 31 papers were presented at the meeting. The proceedings eventually appeared as a 211-page double issue of *Southern Stars* (Budding and Richard, 1991), and was therefore available to all RASNZ members, whether they had attended the conference or not. The proceedings also was marketed by Fairborn Observatory in Phoenix, Arizona.

The longish time interval after PEP2 was occasioned by the holding of an IAU-supported meeting in Canterbury in 1985, featuring 'small' telescopes with primary mirrors or objectives of one metre and less (see Hearnshaw and Cottrell, 1986). This conference was also strongly supported by New Zealand observers, amateur and professional, as well as a sizable overseas contingent. At the conference the Auckland photometrists encountered professionals working on Miras and associated fields. One of these overseas astronomers was Dr Emilia Belserene, Director of the Maria Mitchell Observatory in Nantucket, USA, who drew attention to relatively new methods of period determination.

4.5.4 PEP 4 Hanmer Springs, 1993: Photometry in the Electronic Age – The Second Century

Thirty-six papers were presented over this 4-day interesting and enjoyable meeting in the picturesque setting of this North Canterbury tourist destination. There were 50 registered participants (excluding partners), including 29 from abroad. Proceedings were published in *Experimental Astronomy* (see Budding, 1994). The meeting was supported by the Carter Observatory, the RASNZ, the Kingdon–Tomlinson Astronomical Trust, the NZ Lottery Science and the Royal Society of New Zealand. The four main sessions were loosely arranged under the headings of 'New Observations', 'New Techniques', 'New Arrangements' and 'New Ideas'.

Topics ranged from discussions of the future of the *IBVS* and its backlog of data on variable stars, to the effect of aerosols from the Philippines' Mt Pinatubo eruption on the extinction at Black Birch; from the monitoring of eclipsing binaries in the Magellanic Clouds, to the use of speckle interferometry at the National Observatory of China; from the Education and Science programme of the AAVSO, to speculation on the long-term future of stellar photometry —and many more topics besides.

The outstanding role that the late Bill Allen played in organizing both the PEP3 and PEP4 Conferences is very well remembered by participants from near and far.

4.5.5 PEP 5 Toowoomba, Queensland, Australia, 1996

Arthur Page, Professor Brad Carter and Dr Jim O'Mara were prominent in the setting up of this Trans-Tasman meeting at the University of Southern Queensland (USQ). Topics included historical perspectives, photometric observations and spectrophotometry, developments in instrumentation and techniques, existing and new observations, and light pollution. It included a two-day tour of observing sites such as the USQ field station, the Australia Telescope National Facility and the SUSI stellar interferometer at Narrabri, New South Wales, and a visit to the observatories at Siding Spring. Proceedings were published in the *Australian Journal of Astronomy* (see Page et al.,1996).

A PEP 6 conference was scheduled for Auckland in 2000, but, with the health-related resignation of Marino in that year, it was replaced by the RASNZ Annual Conference of 2002.

5 CONCLUDING REMARKS

For a quarter of a century amateur astronomers of the Auckland Astronomical Society and Observatory were internationally recognized leaders in amateur research and professional-amateur ('proam') collaboration. The gift from Edith Winstone Blackwell and the Winstone Family had been used to the full in the manner that Mrs Blackwell envisaged. When combined with high-quality photoelectric equipment and the use of UBV filters observational results were achieved of genuine astrophysical interest.

The closure of the planetarium in the Auckland War Memorial Museum, however, created an incentive to set up a planetarium more closely associated with AO. The return of Comet 1P/Halley in the mid-eighties saw Pam Dale employed as a full-time Secretary/Manager, and upon her retirement a grant of $250,000 from Po-Shing Woo allowed a salaried astronomer to be employed as her successor. Around 1990, the AAS took over responsibility for research at AO, appointing Dr Grant Christie in an organizational role. 'Citizen science' continued in private observatories, as noted above in Section 4. Usage of the EWB Telescope in variable star research started to decline after the restructuring of AO, although Christie carried out photometry of QZ Carinae at the request of P. Meyer (1998). The emphasis at AO shifted towards education. With strong financial support from a wide range of citizens and organisations this resulted in an extension of the Observatory building, the installation of a planetarium and a more delineated overall operation under the 'Stardome' name. The sense of participation in scientific discovery associated with the Observatory's first 25 years, as well as the intention of a permanent home for the AAS, appear to have been deprioritized. The implication is that the shared satisfaction coming from direct contact with usable scientific data production has dropped, in comparison to the early days of the EWB bequest.

As to the present and future, discussions at the RASNZ Annual Conference in 2006 chaired by Pauline Loader, acting as an unofficial secretary for the dormant RASNZ Variable Stars Section, led to Australia's Professor Tom Richards offering his services as Director of the Section. It was proposed, though, that the name be changed to 'Variable Stars South' (still with the acronym VSS), which was widely accepted. At the time of writing, the VSS is directed by Mark G. Blackford of the Congarinni Observatory in New South Wales (Australia). The VSS encourages observational projects with a distinctly finite lifetime, with quickly publishable results, after due peer-review. Many of its members make freely scheduled measures of a variety of variable stars, and other objects, with data often submitted to the internationally accessible database, maintained by the AAVSO.

Whilst research is encouraged by these organisations, results appear not as widely available at present as they were in the 1970s and 1980s. The Auckland group made great use of the RASNZ publications, particularly *Southern Stars*, section publications and also local society newsletters, particularly that of the AAS. With the improved technology of today, amateurs are venturing into other areas, such as spectroscopy, astrometry and deep sky photography, often working in collaboration with professionals. But they do not support local publications in the way described above. Unfortunately, the level of participation, despite the doubling of the general New Zealand population, looks to have fallen to around a quarter of what it was, with the associated publications at an even lower level.

But are we seeing the beginnings of a welcome recovery? Under the guidance of the new RASNZ President, Nalayini Davies, elected in June 2022, the national society's publications and its website have been reorganised, and a survey has been conducted of members' research backgrounds, desires and equipment. In order to recover to and beyond the level described above, members need to communicate more and publish their findings. This should result in the interchange of ideas and encourage more people to actively engage in astronomical science.

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W.S.G. (Stan) Walker was born in Lower Hutt, New Zealand, in 1932 but moved to Auckland in 1940 where he spent the next 54 years before moving to Waiharara in the Far North. Interest in astronomy began at an early age but a variety of other interests, athletics and golf, intervened until 1962 when his first telescope, a 20-cm reflector, was bought. A casual link with the Auckland Astronomical Society (AAS) was later stimulated by the opening of the Auckland Observatory in 1967 with its 50-cm Zeiss reflecting telescope.

This provided an opportunity to become involved in serious research and Stan was elected to the AAS Council in 1967 and then as one of three Observatory Directors later that year. Exciting new developments were taking place in astronomy: better equipment, better understanding in a wide range of areas, even better interchange of

ideas, although not at today's pace. With Brian Marino and Harry Williams a state-of-the-art photoelectric photometer was developed and Stan became one of the Observatory's two Research Co-ordinators or Directors.

An invitation to join the International Astronomical Union as an amateur saw him appointed to that body in 1970 with special interests in variable stars generally, but especially close binaries and photoelectric photometry. Over the next 25 years more than 100 research papers were published by the Auckland group, mainly in *Southern Stars* (the main journal of the Royal Astronomical Society of New Zealand), but also in many refereed international journals. Related to this, Stan became the main speaker at the Auckland Observatory weekly public nights, and with Pam Dale and Brian Marino wrote a weekly newspaper article on astronomy for more than 20 years.

When he moved to the Far North of New Zealand in 1994 Stan operated a small photometer and carried on this work for several years before joining the Centre for Backyard Astronomy operated by Professor Joseph Patterson of Columbia University. Initially using a CCD camera provided by that group but later another bought from a New Zealand Lottery Fund grant he worked in the cataclysmic variables field until the camera failed in 2007. Since then he has collaborated with other amateur observers or used the International Database measures to continue writing either popular astronomical articles or scientific research papers. Most of this latter work is not covered in this review.

Dr Edwin (Ed) Budding was born in Chadderton, near Manchester, UK, in 1943, where he lived until moving to London to study for his first degree at University College London in 1961. That was in the Astronomy Department of Professor C.W. Allen (renowned for his *Astrophysical Quantities*). This followed up on a deep interest in the subject, developing from early childhood.

After graduation, Ed moved to the Jeremiah Horrocks Observatory (JHO), Preston (now part of the University of Central Lancashire) to work with V. Barocas, particularly on wide-field observations made with the 15-inch Wilfred Hall Astrograph. There was also a focus on public information and education services at the central park setting of the JHO. The astrograph's plates were processed in the measuring laboratory of Z. Kopal's Astronomy Department in Manchester. In due course, this led to a transfer from Preston to Manchester, where Ed enrolled in the postgraduate course supervised by Professor Kopal, with the topic of close binary stars as a priority.

In this environment, Ed encountered a great wealth of professional experience with visits to leading facilities at home and abroad. In Manchester, he was to meet M. Kitamura of the National Observatory of Japan, and, after completing his PhD in 1972, Ed moved to work with Professor Kitamura, carrying out photometric and spectroscopic observations at Dodeira and Okayama Observatories. In 1974, he accepted a teaching position in Kopal's Department and moved back to Manchester. The Department maintained a good rapport between 'town and gown', cultivated through public lectures, local societies and the Workers Education Authority.

In 1982, Ed accepted a position at Wellington's Carter Observatory, which was then known as the National Observatory of New Zealand, under the direction of Dr R.J. Dodd. This lead to many new experiences in a Southern Hemisphere setting. Public and educational functions of the Observatory were also in view, with a close connection between the Observatory and local and national astronomical societies. Later, after a few years at the former Central Institute of Technology (in nearby Upper Hutt), Ed renewed his main research field on close binaries with another former Kopal student, Professor Osman Demircan, and his astronomy group at Çanakkale in Turkiye (COMU). Ed last returned from working in COMU in 2016.

Ed has been enriched by the multi-faceted experience of following his childhood aspirations, and is grateful to the many teachers, friends, supporters, colleagues, students, general enthusiasts and, of course, family, who enabled this starlit path to materialize.