THE CHANGING ROLE OF THE 'CATTS TELESCOPE': THE LIFE AND TIMES OF A NINETEENTH CENTURY 20-INCH GRUBB REFLECTOR

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Abstract: An historic 20-in (50.8-cm) Grubb reflector originally owned by the London amateur astronomer, Henry Ellis, was transferred to Australia in 1928. After passing through a number of amateur owners the Catts Telescope—as it became known locally—was acquired by Mount Stromlo Observatory in 1952, and was then used for astrophysical research and for site-testing. In the mid-1960s the telescope was transferred to the University of Western Australia and was installed at Perth Observatory, but with other demands on the use of the dome it was removed in 1999 and placed in storage, thus ending a century of service to astronomy in England and Australia.

Keywords: Catts Telescope, Henry Ellis, Walter Gale, Mount Stromlo Observatory, Mount Bingar field station, photoelectric photometry, spectrophotometry, Lawrence Aller, Bart Bok, Priscilla Bok, Olin Eggen, Don Faulkner, John Graham, Arthur Hogg, Gerald Kron, Pamela Kennedy, Antoni Przybylski, David Sher, Robert Shobbrook, Bengt Westerlund, John Whiteoak, Frank Bradshaw Wood.

1 INTRODUCTION

One of the roles of the Historic Instruments Working Group of the IAU is to assemble national master lists of surviving historically-significant telescopes and auxiliary instrumentation, and at the 2000 General Assembly in Manchester I presented a paper listing such instruments (and historically-significant astronomical archives) for Australia and for New Zealand (Orchiston, 2000; see, also, Orchiston, 2004a).

In my initial investigation of the Australian and New Zealand telescopes I encountered some difficulty in determining precisely where the cut-off point should lie for instruments that are deemed to be 'historically-significant'. All instruments pre-dating 1850 were automatically included in the master list—reflecting a criterion sensibly adopted by the late Derek Howse (1986, 1994) when he assembled the 'Greenwich List of Observatories'—as were those telescopes associated with notable astronomers, or that represented significant innovations in design. Thus, the Gregorian reflector supposedly associated with Solander and Cook's first voyage to the Pacific (Orchiston, 1999) and the various instruments used at Parramatta Observatory (Lomb, 2004) all belonged on the list, as did the 'Fletcher Telescope', with the world's first all-metal English equatorial mounting (Orchiston, 2001), and the Melbourne Observatory Dallmeyer photoheliograph, one of very few surviving and functional instruments of this type (Clark and Orchiston, 2004). Also on the list was the 8-in (20.3-cm)Grubb refractor that was used very effectively and over a long period of time by Australia's foremost nineteenth century astronomer, John Tebbutt, and then did further excellent service in the Cook Islands and in New Zealand whilst under Frank Bateson's care (Orchiston, 1982).

The problem lay in deciding on those telescopes that made a 'notable contribution to astronomy or astrophysics'. Some telescopes, such as the historic 9-inch (22.9-cm) Cooke photovisual refractor at Carter Observatory, made a long-term international contribution to both observational astronomy and (in its later years) astronomical education in England and New Zealand (Orchiston, 2002) and deserved to be on the list, but what of other telescopes, like the 20-in (50.8-cm) 'Catts Telescope'? After passing from amateur ownership to Mount Stromlo Observatory in 1952, this was used over the following twelve years to make a valuable contribution to astrophysics and to provide data for five different Ph.D. theses. Because of its short life-time as a 'cutting-edge' research instrument and its long period of inactivity (in both England and Australia) whilst in amateur hands, I originally passed over the Catts Telescope when assembling my 2000 IAU paper, but in hindsight I now regard this as a mistake. I believe that the Catts Telescope does belong on my Australian master list, but after reading this paper let you be the judge.

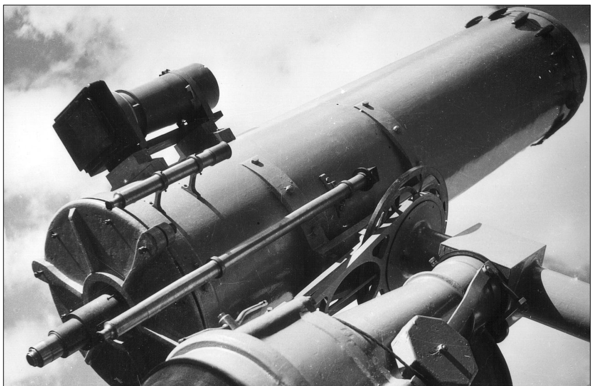

Figure 1: The 20-in 'Catts Telescope' (Orchiston Collection).

2 THE EARLY YEARS IN ENGLAND

The Catts Telescope began life as a 20-in (50.8-cm) f/4.5 Cassegrainian reflector, on a German equatorial mounting (Figure 1), complete with a 6-in (15.2-cm) guide scope. It is not known precisely when it was manufactured or for whom, but a 1947 Sydney newspaper article (While wives are asleep, 1947) suggests the last decade of the nineteenth century. This article discusses a stand-alone 6-in Grubb refractor, stated at the time to be "… at least 50 years old, [which] once

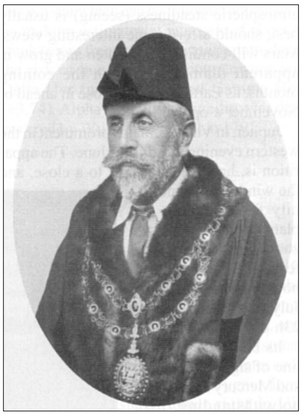
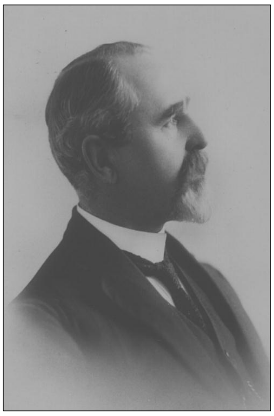

Figure 2 (left): Henry Ellis, 1858–1927, first known owner of the 'Catts Telescope' (after Marriott, 2005).
Figure 3 (right): Walter Gale, 1865–1945 (courtesy: British Astronomical Association Library).

belonged to the late Walter Gale of Waverley [Sydney], 'grand old man' of Australian astronomy." Elsewhere I have demonstrated that this instrument was originally the guide scope on the Catts Telescope (Orchiston, 1997b).

The first documented owner of the telescope was a well-known British amateur astronomer named Henry Ellis (Figure 2), who for many years was the Treasurer of the British Astronomical Association. He was born in 1858, and at the age of 16 joined the Indemnity Mutual Marine Assurance Company, and went to live just north of London at Potters Bar. He remained with the company until his retirement in 1909 and then moved to Lyme Regis on the south coast of England where he died in 1927.

An Obituary published in *Monthly Notices of the Royal Astronomical Society* merely states that "While at Potters Bar, he acquired a 20-inch reflecting telescope by Grubb, for which he built an observatory." (A.E.L., 1928). So an acquisition date in the 1890s is possible, and it is perhaps also relevant that Ellis was elected a Fellow of the Royal Astronomical Society in 1898.

Whatever the actual circumstances, Ellis seems to have made remarkably little use of this telescope. The first published mention of it dates to 1908, when slides of six photographs of Comet C/1908 R1 (Morehouse) taken with the instrument were exhibited at meetings of the British Astronomical Association (*Journal of the British Astronomical Association*, 1908). Then, in 1911, Ellis showed further comet photographs—this time of C/1911 O1 (Brooks)—at a meeting of the Association (see *Journal of the British Astronomical Association*, 1911). And although he published four short papers in the *Journal*, none of these related to the Grubb telescope.

3 TRANSFER TO THE ANTIPODES

The next owner of the telescope was Walter Gale of Sydney (Figure 3), one of Australia's most prominent early amateur astronomers. Gale was born in Sydney in 1865 (for Australian localities mentioned in the text refer to Figure 4), and after completing his schooling worked for five years in the insurance and commercial fields before joining the Savings Bank of New South Wales in 1888. He remained with the Bank until 1925, rising to the position of Manager and Chief Inspector at Head Office (Wood, 1981). He then worked as Manager of the Hoskins Investment Company, founded by George Hoskins (1883–1953), a wealthy industrialist and prominent amateur astronomer (see Orchiston and Bembrick, 1997). Gale died in 1945, and was remembered by his many friends for his "... personal qualities of helpfulness, enthusiasm, kindness, tolerance and understanding ..." (Obituary, 1945).

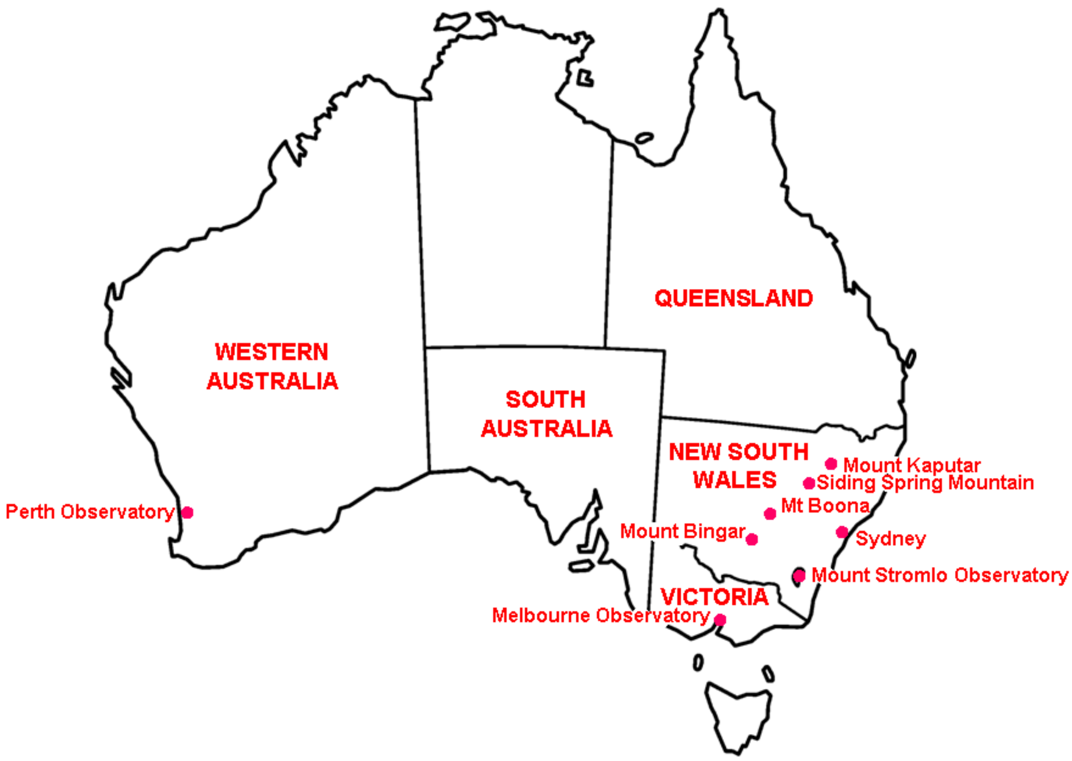

Figure 4: Australian localities mentioned in the text.

Gale inherited an early interest in astronomy from his father, but the Great Comet of 1882 (C/1882 R1) made a major impact (see Finds Venus Unexciting, 1943). He also acknowledged that newspaper articles written by John Tebbutt enticed him to seriously take up astronomy as a hobby (Gale, 1886). In 1884 he made a 17.8cm reflecting telescope (Gale, 1928), which was destined to be the first of many (Wood, 1981). The largest had an aperture of 12 inches (Obituary, 1945).

Unlike some amateur telescope-makers, Gale made effective use of his instruments, observing the planets, but particularly Mars, Jupiter and Saturn (Wood, 1981). He believed that the so-called 'canals' of Mars were genuine naturally-occurring surface features and that the planet "... may be inhabited by a race of sentient beings, perhaps not cast in the same mould as we are, but of a type suited to the conditions of the planet ..." (Gale, 1921). Like Tebbutt, Gale was addicted to comet-searching and independently discovered seven different comets, three of which (C/1894 G1, C/1912 R1 and 34P/Gale) now bear his name (Wood, 1946). He also discovered a number of double stars and a planetary nebula (Wood, 1981), experimented successfully with astronomical photography (Obituary, 1945), and participated in a number of solar eclipse expeditions (ibid.). In addition to publishing in the *Journal of the British Astronomical Association*, he made a point of promoting astronomy locally by writing for the Sydney newspapers and presenting popular public lectures (see Orchiston, 1997a).

Gale also promoted amateur astronomy by forming and developing one of Australia's earliest formal astronomical groups (Orchiston, 1998). In 1892 he teamed with R.T.A. Innes (1861–1933) to investigate the possible formation of an Australian Astronomical Society (Orchiston and Bhathal, 1984), deciding ultimately not to proceed, but in 1895 they succeeded in founding the New South Wales Branch of the British Astronomical Association in Sydney (Orchiston, 1988). Gale served as the inaugural Secretary and for many years was President of the Branch (Orchiston, 1990b; Orchiston and Perdrix, 1990). In 1935 he emulated Tebbutt by receiving the Jackson-Gwilt Medal and Gift from the Royal Astronomical Society, for his "... discoveries of comets and his work for astronomy in New South Wales." (Wood, 1981).

During the twentieth century, Gale was one of Australia's leading amateur 'telescope-brokers' and supposedly "... knew the history and characteristics of every astronomical instrument in Australia, and could tell many anecdotes relating to them." (Obituary, 1945). Over the years a large number of professionnally-made instruments passed through his hands, and these included the ex-Tebbutt 8-in Grubb refractor (see Orchiston, 1982), an 18-in (45.9-cm) Calver reflector (see Orchiston and Bembrick, 1995), and the Henry Ellis 20-in reflector. A letter by Gale in the library and archives of the British Astronomical Association in London documents his acquisition of the Ellis telescope, and states (*inter alia*):

> After an endeavour to reduce my equipment, I have increased it again by purchasing the outfit of the late Hy Ellis, to which you were good enough to refer me a few years ago ... I hope to get the telescope working somehow pretty soon after its arrival in a few months time ... The 20 in reflector will be principally employed in making long exposures upon the most interesting nebulae – if not by me then by some one who will come after ... I have not mentioned my intentions to any other as too much might then be expected of me. (Gale, 1928).

Despite good intentions and his excellent observational track record, Gale appears never to have used the Grubb reflector for any serious work. According to the late Con Tenukest (see Orchiston, 1990a), the figure of the primary mirror was not ideal, and this may have been the principal reason, especially since Gale was already making regular use of his 18-in equatorial reflector which reportedly had "… exceptional optics …" (C. Tenukest, pers. comm.).

At some date prior to his death in 1945, Gale sold the Grubb reflector to an unknown purchaser, and in 1945 or 1946 a Sydney astronomer named Horace Pinnock made a successful bid for it at the auction of this man's estate (ibid.). Pinnock had the telescope for a short time, selling it in 1947, but only after removing the 6-in guide scope—which he then proceeded to set up as a stand-alone telescope in his observatory, complete with English equatorial mounting (ibid.). It is this instrument which is discussed in the aforementioned 1947 newspaper article.

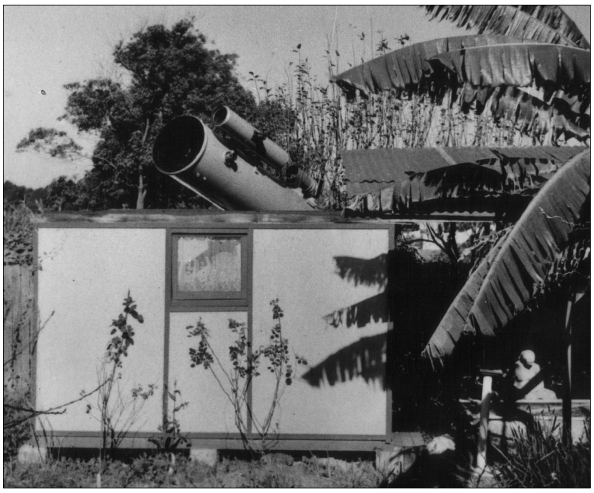

Figure 5: The 20-in reflector in Tenukest's Observatory in Sydney, ca. 1950 (Orchiston Collection).

The new owner of the 20-in Grubb reflector was Dr Con Tenukest of Sydney. Tenukest (1906–1989) was responsible for the Precision Optical Laboratory at the University of Technology in Sydney and was

> … one of Australia's most distinguished amateur astronomers during the 1940s and 1950s … [He] made important contributions in the fields of planetary observational astronomy, telescope-making (through his University of New South Wales classes) and astronomical education (mainly via the planetarium at the Museum of Applied Arts and Sciences in Sydney). He was a stalwart of the New South Wales Branch of the British Astronomical Association, and a number of large telescopes, both reflectors and refractors, passed through his hands. Some of the reflectors were historically significant instruments. (Orchiston, 1990a: 154).

The 20-in Grubb reflector could be counted as one of these "… historically significant …" telescopes, and it was installed in a roll-off roof observatory (Figure 5)

Figure 6: The Catts Telescope roll-off roof observatory at MSO (courtesy: Mount Stromlo and Siding Spring Observatories).

in the back yard of Tenukest's property. When he acquired this telescope, Tenukest was Director of the Planetary Section of the New South Wales Branch of the British Astronomical Association, and he used it for planetary observations (Orchiston, 1990a), but he was not happy with the condition of the primary mirror and had it refigured by the late Ron Schaefer who was employed by the CSIRO's Division of Physics (C. Tenukest, pers. comm.).

Tenukest believed that Sydney's sky conditions did not allow the Grubb reflector to be used to its full potential (ibid.) and so in 1951 he sold the instrument to another Sydney-based Branch member, J.H. Catts (*British Astronomical Association NSW Branch Bulletin*, 1952), but on the understanding that when he wished to part with it Catts would offer Tenukest first right of refusal (C. Tenukest, pers. comm.). Catts proceeded to install the telescope in an observatory at his home,

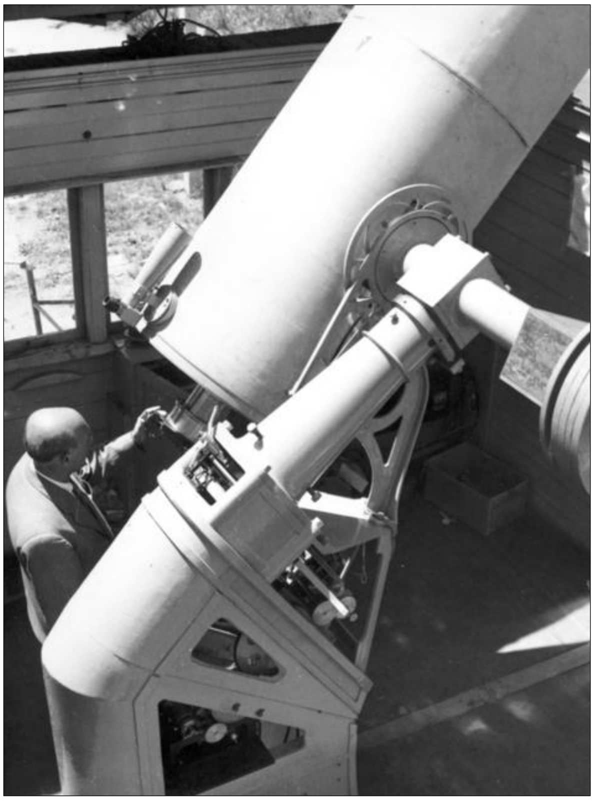

Figure 7: Arthur Hogg is shown with the Catts Telescope at Mount Stromlo (courtesy: Mount Stromlo and Siding Spring Observatories).

but had little opportunity to carry out any useful astronomical work as he died in the following year.

4 THE STROMLO ASSOCIATION

4.1 Photometry at Mount Stromlo

Much to Tenukest's chagrin, in 1952 Mrs Catts sold the 20-in reflector to Mount Stromlo Observatory (henceforth MSO) for a substantial profit (ibid.; cf. Haynes et al., 1996: 162-163, who incorrectly state that the telescope was gifted to MSO), but in fact it was only through this action that its true research potential could be realized (see Orchiston and Bembrick, 1995). At this time, this historic Grubb reflector came to be known colloquially as the 'Catts Telescope'.

MSO was located near the nation's capital, Canberra (see Figure 4), and by this time was Australia's foremost professional optical observatory. The decade following WWII was a critical one (see Davies, 1984; Frame and Faulkner, 2003; Gascoigne, 1984, 1988, 1992; and Hyland and Faulkner, 1989), and under the innovative leadership of Richard Woolley (1906–1986) the institution gradually shifted its research focus from solar to galactic and extra-galactic astronomy, acquired new telescopes and auxiliary instrumentation, recruited new staff, and became a *de facto* Department of Astronomy of the Australian National University (ANU) by offering courses in astronomy and attracting graduate students (as a prelude to later formally transferring from the Government's Department of the Interior to the University) (Woolley, 1968).

Vital in this renaissance were larger and more modern telescopes, to serve as company for the aging 30-in (76.2-cm) Reynolds Reflector, then Australia's largest telescope. Two telescopes were decided on, a new Grubb-Parsons 74-in (1.88-m) reflector and a 50-in (1.27-m) reflector, representing an extensively rebuilt and modified version of the notorious nineteenth century 'Great Melbourne Telescope' (see Gascoigne 1996). Since neither of these instruments was operational when the Catts Telescope came up for sale, it was seen as a particularly attractive short-term option —at least until the two new telescopes were ready in 1955.

On 17 March 1952 Woolley and his deputy, Arthur Hogg (1903–1966), went to Sydney, inspected the Catts Telescope and arranged for its immediate purchase. By the time it arrived at MSO on 15 April work had already started on its roll-off roof observatory, a converted old solar radiation hut. The completed observatory is shown in Figure 6. The telescope itself was installed on 12 May but the condition of the mirror caused some concern and in July it was repolished, refigured and realuminised (see Mount Stromlo Diary, 1951-1956). By late 1952 Stromlo finally had a new research telescope "… erected primarily to further a programme for photoelectric observations of eclipsing variables and other objects." (Hogg, 1953: 7), and shortly after this Hogg (1954: 54) wrote that the telescope (see Figure 7) was "… in continuous operation on photoelectric programmes." It was used in the f/18 Cassegrain mode (Buscombe, 1958), and its limiting magnitude for these 'programmes' would have been about 13 (Woolley, 1954b). Woolley (1953b) summarised the situation in his 1952 Report to the MSO Board of Visitors (my italics):

> A 20 inch equatorially mounted reflector by Grubb was purchased from the estate of the late Mr. J.H. Catts and removed from Sydney in April. The telescope was erected in an existing small building with sliding roof. The primary mirror was refigured and aluminised and a new secondary mirror (Cassegrain) in "Pyrex" was made and installed. An EMI photo-multiplier has been mounted on the telescope and with the loan of a Brown recording potentiometer from the Yale-Columbia Southern Station *a most useful photoelectric installation is now available*.

As it happened, the purchase was a fortuitous one for delays in the satisfactory completion of the 74-in and 50-in telescopes meant that the Reynolds and Catts reflectors would remain the mainstays of the Observatory's observational programs for somewhat longer than anticipated. While the Catts Telescope was dedicated to photometry, the larger Reynolds reflector was used both for photometry and for spectroscopy.

As might be inferred from the foregoing paragraphs, Arthur Hogg was the principal user of the Catts Telescope during its short time at Mt Stromlo (see Photoelectric observations … 1953-1954), although only two research papers based on his observations appeared in print. In one of these, Hogg (1955) reported Johnson *B* and *V* observations at a large number of points in the Large and Small Magellanic Clouds. In addition to deriving mean values for both Clouds (see Table 1), he produced isophote plots in *B* for both Clouds (Figure 8) and noted that

> The colour of the Small Cloud is found to be systematically bluer in the brighter central regions than nearer the edge. The Large Cloud shows no regular variation of colour over its surface. (Hogg, 1955: 473).

For the SMC, this effect is reflected in the *B–V* values listed in Table 1. Hogg (1955: 477-478) has more to say about this interesting effect:

> The distribution of colour in the Small Cloud is difficult to account for by absorption due to dust intermingled with the stars in any regular fashion. The distribution suggests that the hotter stars are concentrated towards the centre of the Cloud. The overall colour of the Small Cloud does not support the idea of a Type II population …

This photometric study of the Magellanic Clouds was an important contribution to astrophysics, but Hogg was also interested in the properties of stars that lay within our Galaxy. One of these was ς Scorpii, which is a binary star with an 8.7 magnitude companion 20″ distant. The brighter component is both a spectroscopic binary (with a period ~34 days) and a β Canis Majoris type variable with a period of about 0.25

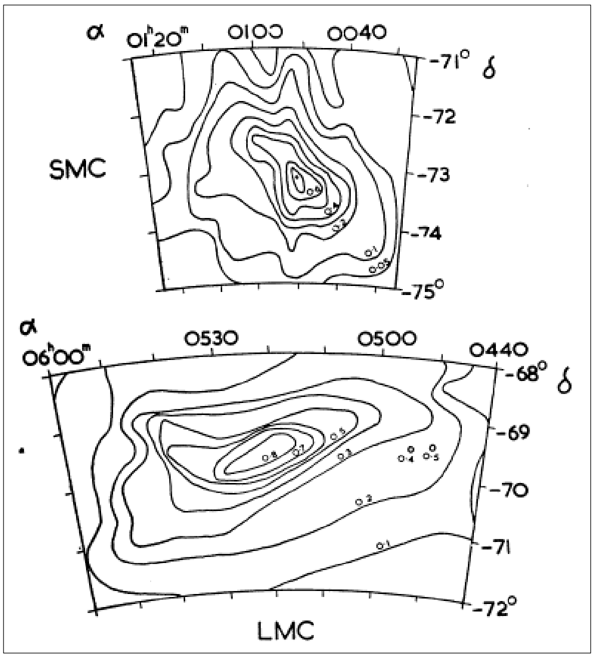

Figure 8: *B* system isophotes for the LMC and SMC. The contours refer to the magnitude differences between the central regions of the Clouds and the total light received from object + sky (after Hogg, 1955: 475).

days. In 1954 and 1955 Hogg carried out *UBV* photometry of this system at MSO while Otto Struve (1897–1963) and his colleagues conducted radial velocity measures in the USA. In all, Hogg (1957: 96) was able to assemble seven "… substantially complete light curves (i.e. curves covering the whole of one cycle with readings of the variable at average intervals of 12 minutes) …", and some of these are reproduced here in Figure 9. Detailed examination of the photometric observations revealed the existence of a beat period of 8.028 days superimposed on the known short-period variation of 0.246846 days.

The arrival of the Catts Telescope at MSO was fortuitous in that the Observatory was rapidly expanding its doctoral program. The first Ph.D. scholar to use

Table 1: Surface photometry of the Large and Small Magellanic Clouds (after Hogg, 1955: 473).

Parameter	LMC	SMC
Area measured (square degrees)	27.5	10.8
B magnitude	+1.4	+2.6
B–V	+0.33	+0.1 to +0.6
Central brightness (mag.sec^{-2})	21.4	21.4

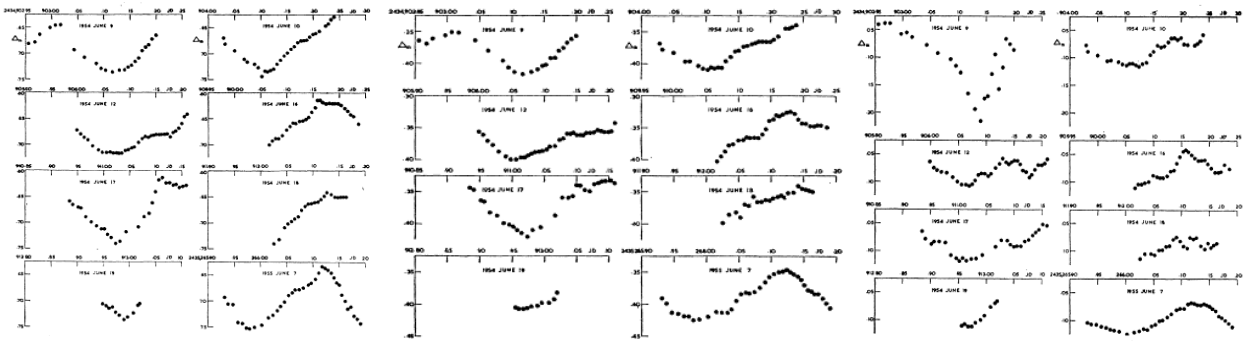

Figure 9: Short-period light variations in the β Canis Majoris-type variable, ς Scorpii. Two left columns: *U* magnitude; two centre columns: *B* magnitude; two right columns: *V* magnitude (after Hogg, 1957: 96-97).

Table 2: Three colour amplitude variations of SX Phoenicis in 1957 (after Wood, 1959b: 224).

Date JD 2436000+	Magnitude Variation		
	Yellow	Blue	Ultraviolet
158	0.43-0.47	0.58-0.64	
175	0.40-0.44	0.45-0.48	0.27-0.32
176	0.56-0.60	0.64-0.68	0.39-0.56
183	0.68-0.72	0.75-0.79	0.55-0.64
184	0.48-0.54		

the telescope for thesis-related observations was John Whiteoak (1937–), who began a photometric study of selected clusters in the southern Milky Way. This study would continue after the relocation of the Catts Telescope to Mount Bingar in 1959 (see Section 4.2).

The third local person to use the Catts Telescope during its sojourn at Mt Stromlo was the 'Uppsala Schmidt' astronomer, Bengt Westerlund (1921–2008),[2] who began a *UBV* survey of early type stars near the South Galactic Pole. This study would conclude once the refitted Catts Telescope was located at Mount Bingar.

Apart from Stromlo-based astronomers, at least two overseas visitors—Frank Bradshaw Wood and Olin Eggen—used the Catts Telescope.[3] Professor Wood (1915–1997) was from the Flower and Cook Observatory at the University of Pennsylvania, and from July 1957 to mid-1958 he spent his Sabbatical Leave at MSO while on a Fulbright Fellowship (Bok, 1958; Wood, 1958). Wood made photometric observations of the following Algol-type variables: ST Car, RS Lep, TZ CrA and V Tuc. They had known periods of 17-30 hours and deep primary eclipses with durations of 3-6 hours, and these stars were of special interest to him (Wood, 1959a: 56) because

> The short periods mean either extraordinarily large masses or small distances between the components. Similar systems which have undergone detailed analysis have shown normal masses for the brighter components; this, plus the short period, calls for a distance between components so small that the radii of the brighter components can only be about ½ those of normal A stars; this in turn locates the A components below their normal place in the HR-diagram. The secondary components in such cases have frequently been found to fill the limiting Jacobian surface and hence are in an interesting evolutionary stage. Lack of appreciable light change between eclipses, in such close systems can be most simply explained by a large mass-ratio. If this explanation survives detailed analysis, the fainter components of these systems must have abnormally low masses.

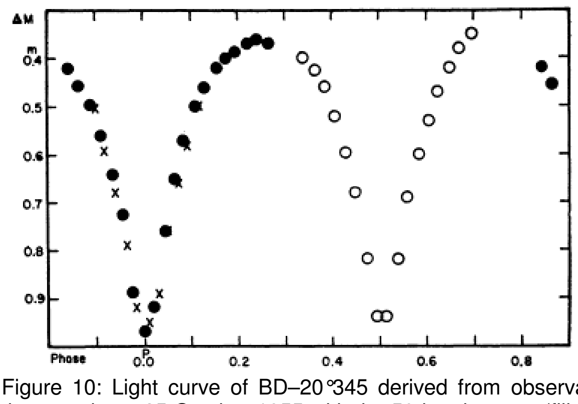

Figure 10: Light curve of BD–20°345 derived from observations made on 25 October 1955 with the 50-in telescope (filled circles), and with the Catts Telescope on 17 October (open circles) and 19 October (crosses) (after Eggen, 1956: 143).

Another star that Wood observed with the Catts Telescope and an EMI type 5060 photomultiplier was the short-period variable, SX Phoenicis. This was known to have a period ~80 minutes and a variation in magnitude ranging between 0.3 and 0.8. Wood carried out 2- or 3-colour observations on 3 nights in 1957 and recorded the magnitude ranges listed in Table 2.

He also found that

> By 1957 the beat phenomenon had shifted in phase so that the variations in phase and amplitude arrive about 0.1 beat-period earlier than in 1952. Thus the beat-period has shortened and this suggests that the period, P_0, has increased relatively more than the period P_1. (Wood, 1959b: 224).

In concluding his paper, Wood (1959b: 226) pointed to the need for further observations made simultaneously with two or more telescopes. Regrettably, the Catts Telescope was not to be a part of such a program, and no further papers by Wood involving observations with this telescope were found during an ADS search, notwithstanding Whiteoak's recollection (pers. comm., 2010) that

> … when I started at Mt Stromlo in March 1958 … the biggest user [of the Catts Telescope] was Frank Bradshaw Wood … who gobbled up as much time as possible. I had to scrounge a few days a month … Because of Frank's interest, the time was always fully booked!![4]

The other overseas visitor who used the Catts Telescope in the 1950s was Olin J. Eggen (1919–1998) from the Lick Observatory (at that time—somewhat later he would become a Director of Mount Stromlo and Siding Spring Observatories). Eggen used the 20-in and 50-in telescopes to study RR Lyrae variables (Woolley, 1955).

Presumably most of Eggen's time was spent on the 50-in, for an ADS search produced just one solitary paper listing Catts Telescope data. The stars in question were BD–20°345, HD273211 and HD206379, all of which had been identified as variables by Cuno Hoffmeister (1892–1968) in the 1930s and 1940s.

From photometric observations made in 1955 with the 20-in and 50-in telescopes, Eggen (1956) was able to show that BD–20°345 was a W Ursae Majoris-type variable with a period of ~7.5 hours and the light curve shown in Figure 10. On 8 December 1955 Eggen carried out photometry on the RR Lyrae variable HD273211 using the Catts Telescope, and found the magnitude varied between 9.50 and 10.85. Since the star was followed almost continuously and the comparison star was observed only occasionally, all Eggen could do was determine the basic form of the light curve, which is shown in Figure 11. HD206379 was observed with the Catts Telescope on 16 and 18 October 1955 and the period was shown to be ~3.5 hours. The magnitude varied between 7.65 and 8.22. Because of continuous monitoring, once again only the basic form of the light curve was determined (see Figure 12).

4.2 Photometry, Spectrophotometry and Sky-Monitoring at Mount Bingar

Once the Grubb-Parsons 74-in reflector and the refurbished 50-in Great Melbourne Telescope were operational at MSO the Catts Telescope was no longer in great demand, but a new project awaited its attention.

Richard Woolley left Canberra at the end of 1955 to become the thirteenth Astronomer Royal, and he was replaced by the inimitable Bart Bok (1906–1983) who soon realized that

> … the climate at Mt. Stromlo left a great deal to be desired, that with the growth of Canberra, conditions could not but deteriorate, and that a search should accordingly be made for a site where a field station could be established in the fairly near future. (Gascoigne, 1968: 65)

After considering possible localities in Western Australia, South Australia, Victoria and New South Wales, five sites were selected for detailed investigation (Bok, 1960a). In 1959, the number of sites to be monitored for evening cloudiness was increased to twenty, including Mount Bingar near Griffith, and Siding Spring Mountain near Coonabarabran, both in New South Wales (see Figure 4). Bok and his staff then decided to set up a provisional field station

> … so as to have a control for the testing programme, and to gain experience of operations remote from Mount Stromlo. The location chosen was Mount Bingar, which had topped the previous year's statistics for highest quality nights, and which became a firm favourite with Bok. (Hyland and Faulkner, 1989: 220).

The Catts Telescope was assigned to this project, but only after the 20-in primary mirror was replaced by one of 26 inches aperture, "… a thick-ribbed, honeycomb disk of pyrex … made available to us by courtesy of Dr T. Dunham Jr. and the Fund for Astrophysical Research of the U.S.A." (Bok, 1960b: 202).[5] A 10-in secondary was ground and polished in the MSO optical shop, and the original telescope mounting was modified to accommodate a new larger tube (Figure 13 lower insert). The upgraded Catts Telescope, with an

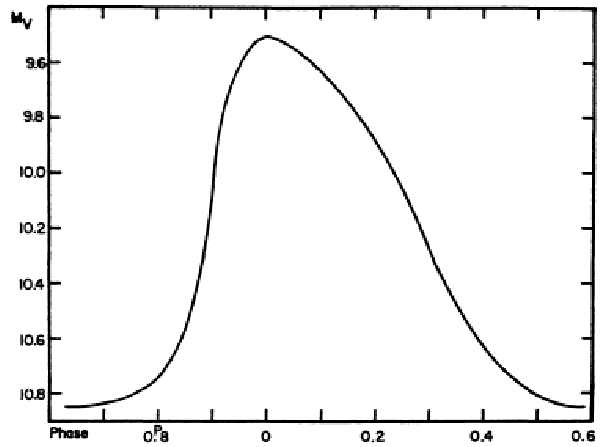

Figure 11: Basic form of the light curve of HD273211 (after Eggen, 1956:144).

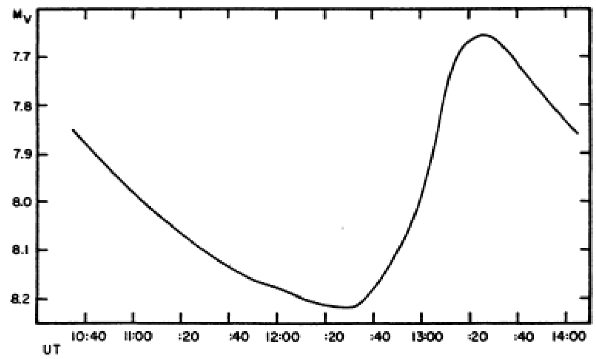

Figure 12: Basic form of the light curve of HD206379 (after Eggen, 1956:144).

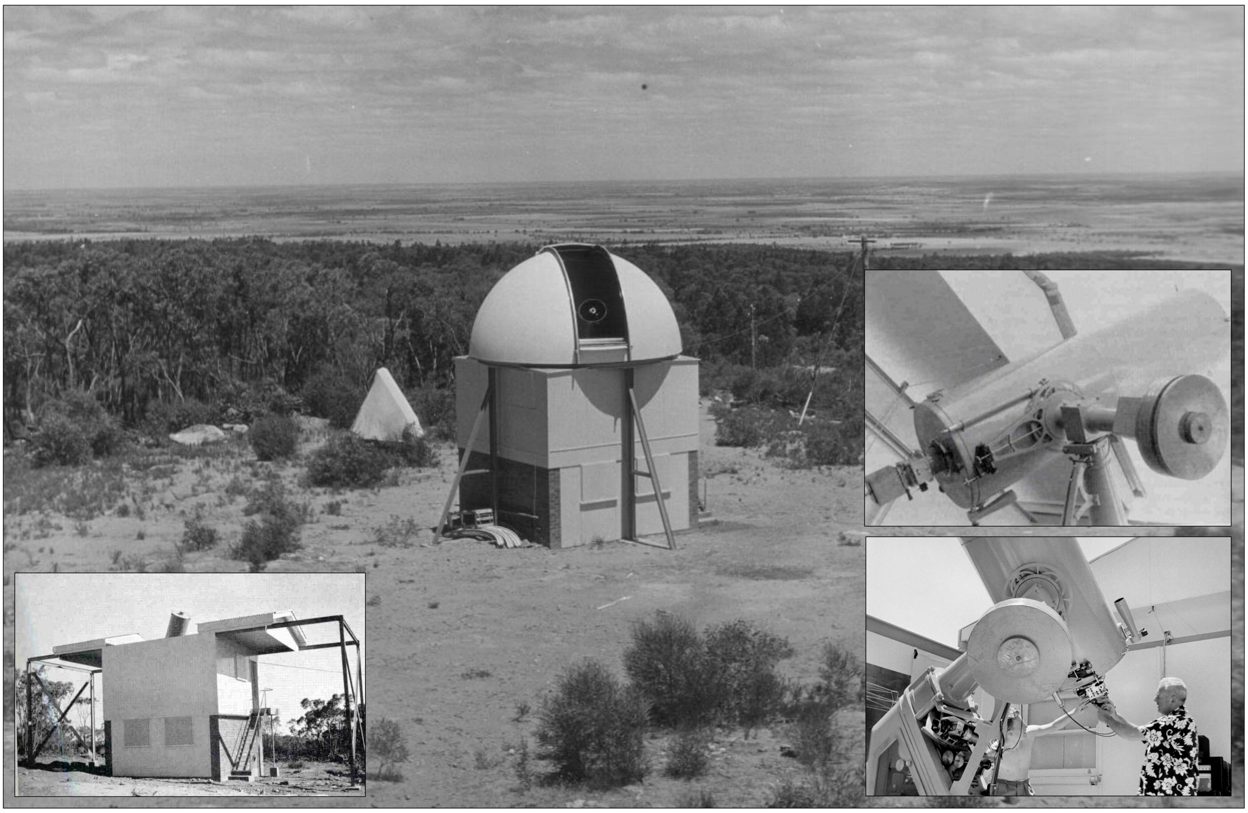

Figure 13: Mount Bingar field station and the final version of the 26-in Catts Telescope observatory. The original observatory is shown in the bottom left inset and the telescope itself in the upper right inset (courtesy: Mount Stromlo and Siding Spring Observatories). The lower right inset shows Bob Shobbrook (left) and Bart Bok at the telescope (courtesy: Bob Shobbrook).

Table 3: Mean integrated magnitudes and colours for two OB associations in the LMC (after Bok et al, 1962: 495).

OB association	V_0	$(B-V)_0$	$(U-B)_0$
NGC 1955	8.98 ± 0.03	−0.22 ± 0.02	–1.11 ± 0.02
NGC 1968-1974	8.79 ± 0.03	−0.27 ± 0.02	–1.13 ± 0.02

f/12 Cassegrainian configuration, was then installed in a roll-off roof observatory at Mount Bingar in 1959 (Figure 13 upper insert), and as the main image in Figure 13 illustrates, in February 1961 this facility was replaced by a 7.6m dome (see Mount Bingar, 1961). The first observations at Mount Bingar were carried out on Christmas Night, 1959, with sky monitoring proceeding throughout 1960. Although it proved favourable for photoelectric work (Bok, 1961), by the end of that year it was becoming obvious that the site was just far enough south to experience the northern extremities of the storm centres that formed to the south of the Australian continent.

Despite, this, Mount Bingar remained in contention as the possible MSO outstation, along with Siding Spring, Mt. Boona (near Condobolin) and Mt. Kaputar (north of Gunnedah) (for these localities see Figure 4). The last two sites were subsequently eliminated, and the final choice was made in 1962. Although Bok strongly favoured Mount Bingar, other staff opted for Siding Spring, which won the day—but only after the intervention of the University's Vice-Chancellor (see Gascoigne, 1968; Hyland and Faulkner, 1989). Initially, 16-in and 40-in Boller & Chivens reflectors were installed, and later they were joined by other ANU instruments, including the 2.3m New Technology Telescope. Siding Spring Mountain also became home to the 3.9m Anglo-Australian Telescope and the 1.22m U.K. Schmidt (see Gascoigne, Proust and Robins, 1990).

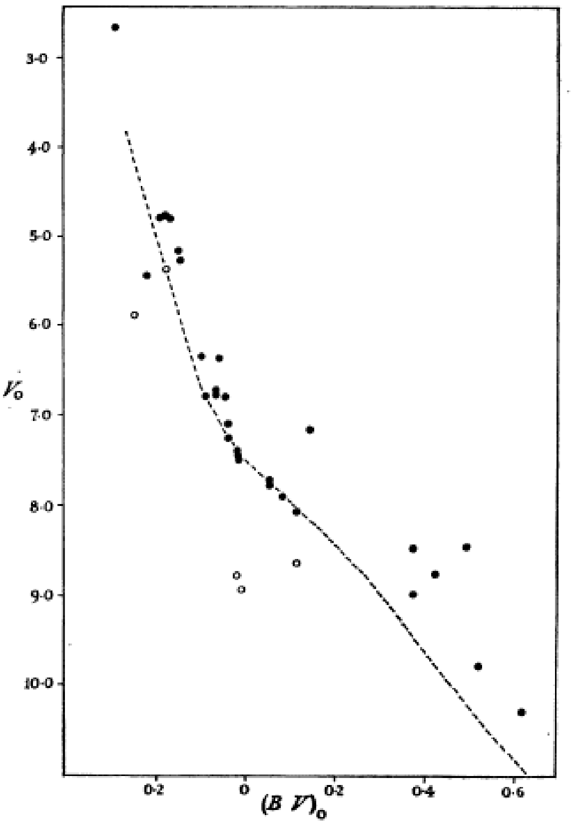

Figure 14: Colour-magnitude diagram for IC 2602 cluster members (after Whiteoak, 1961b: 251).

Apart from its sky-monitoring role, whilst stationed at Mount Bingar the refurbished Catts Telescope was used extensively by some MSO staff and graduate students for astrophysical research. Initially it was furnished with a *UBV* photometer that was constructed at MSO under the direction of Ben Gascoigne, and was modeled on the design of the Lick Wide Field Photometer.

John Whiteoak was one of the MSO doctoral students to use the refurbished Catts Telescope at Mount Bingar, and his thesis, "The Structure of the Southern Milky Way" (Whiteoak, 1961a) contains MSO and Mount Bingar observations.

One of the projects that Whiteoak (1961b) began at MSO but continued with the 26-in at Mount Bingar was a photoelectric, spectroscopic and photographic investigation of the galactic cluster IC 2602, near θ Carinae. Most of the photoelectric observations were made at Mount Bingar, initially with the EMI photometer, but this was subsequently replaced by one with a refrigerated RCA 1P21 photomultiplier tube. *UBV* photometric data were obtained for 67 different stars; spectra existed for about half of these, and most were either B- or A-type stars. Five stars stood out as more reddened than the others, and these were identified as background stars and not members of the cluster. After a correction for interstellar absorption was applied, a colour-magnitude diagram was prepared for the 34 stars with spectra, and this is shown in Figure 14 (where the non-cluster members are indicated by open circles). The dashed curve is the fitted 'zero-age' main sequence, displaced vertically by 5.95m, the distance modulus of the cluster. This equates to a distance of 155 parsecs (Whiteoak, 1961b: 251). The luminosity function of the cluster was also investigated, and stars of absolute magnitude +3 and +4 were shown to be under-represented (Whiteoak, 1961b: 253). Two different methods were then employed to derive the age of the cluster, yielding values of 1.2×10^7 years and 8×10^6 years; Whiteoak (1961b: 254) regarded the former figure as more accurate. On the basis of its age and its distance, Whiteoak (1961b: 255) concluded that "… IC 2602 may be a local condensation of the Scorpio-Centaurus Association."

Foremost among the MSO staff users of the Mount Bingar facility was Observatory Director, Bart Bok (see Figure 13) who, along with his wife Priscilla (1896–1975), was interested in photometric properties of young associations in the Large Magellanic Cloud. In Bok, Bok and Basinski (1962) they report *UBV* photometry of six OB stars in NGC 1955 and five stars in NGC 1968-1974, two distinctive concentrations of young stars and associated nebulosity. A preliminary survey showed

> … the fields to be remarkably free from overlying obscuration. Within the confines of the areas of high surface density of stars, the percentage of foreground stars should be relatively small … Because of the presence of irregular emission nebulosity, special care

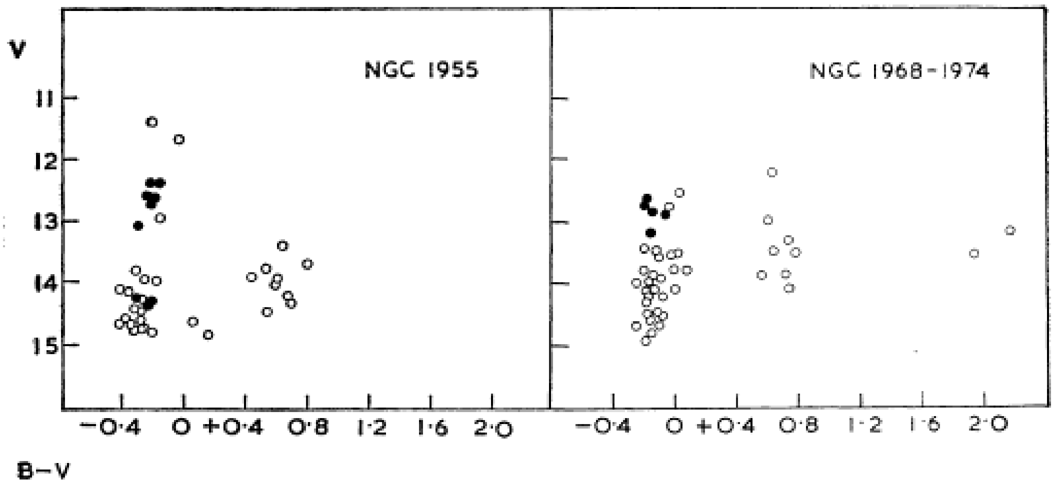

Figure 15: Colour-magnitude diagrams for NGC 1955 and NGC 1968-1974. Open circles represent photographic magnitudes and the filled circles the Mount Bingar photoelectric magnitudes (after Bok et al., 1962: 492).

> had to be taken in the execution of the photoelectric and photographic photometry. (Bok et al., 1962: 487).

The eleven stars subjected to photometric investigation at Mount Bingar ranged in V magnitude from 12.33 to 13.13, and the mean values for $B-V$ and $U-B$ were −0.22 and −0.17 respectively for stars in NGC 1955 and −0.97 and −0.91 respectively for stars in NGC 1968-1974. In an extension of the Mount Bingar study, 33 different stars in NGC 1955 and NGC 1968-1974 were subjected to photographic photometry at MSO using the 74-in reflector or the 20/26-in Uppsala Schmidt, and Bok et al. then combined the MSO and Mount Bingar data to produce the two colour-magnitude diagrams shown in Figure 15 (where the Mount Bingar stars are represented by filled circles). Bok et al. (1962: 492) noted that

> The two arrays exhibit the pattern which is by now familiar for Large Magellanic Cloud groupings, of very blue stars with colour indices mostly between −0.1 and −0.4 over the range $11 < V < 15$ and of a smaller number of stars with colour indices between +0.4 and +0.8. The absence of stars with colour indices between −0.1 and +0.4 is strikingly shown in these figures; the few stars which fall in the gap are most likely foreground stars or Magellanic Cloud field stars.

Following an August 1961 IAU Symposium at Santa Barbara (California), a decision was made to measure the integrated photometric magnitudes and colours of NGC 1955 and NGC 1968-1974, and observations were carried out over six nights in October 1961. After applying corrections for space reddening, Bok et al. derived the mean values listed above in Table 3.

Bok et al. (1962: 496; my italics) conclude their paper with the following pertinent remarks:

> It is quite evident that in the present study we are dealing with two very young stellar groups, whose probable ages since formation are almost certainly less than 10^7 years. These groups of young and luminous supergiants merit further study, in particular by extending the colour-magnitude arrays beyond the present limit of $V = 15$ to $V = 20$ or 21 and by eliminating foreground stars by means of future radial velocity and spectral studies. *In all of this work the great potential of (U−B) colours in addition to (B−V) colours should be realised.*

At the 1961 IAU Symposium in Santa Barbara, Dr B.E. Markarian (1913–1985) urged Bok and his MSO colleagues to measure the integrated magnitudes and colours of young associations in the LMC. Bart and Priscilla Bok responded by using the 26-in telescope at Mount Bingar to measure the 14 different associations listed in Table 4.

After applying a minor correction for absorption, Bok and Bok (1962: 443; their italics) concluded that "… through the use of these young associations, *readily identified by their UBV colour characteristics,* we are in a position to extend and make more precise the techniques of distance calibration suggested by Gum and de Vaucouleurs (2) and Sersic (3, 4) …" Furthermore,

> It should be a simple matter to locate and identify these young associations in galaxies at distances of the order of 6000 kiloparsecs. A large Schmidt telescope or modest reflector should permit the observer to establish their non-stellar appearance and, with m = 18, they should be within reach for photoelectric studies of their photometric properties in *UBV*. With the aid of large reflectors, and with refined photoelectric and photographic techniques, it should be possible to identify them with some certainty in galaxies as far distant as 25000 kiloparsecs. (ibid.).

Table 4: Mean integrated magnitudes and colours for OB associations in the LMC (after Bok and Bok, 1962: 438-439).

OB association	*V*	*(B−V)*	*(U−B)*
NGC 1770	9.06	−0.04	−0.96
NGC 1805	10.42	+0.06	−0.54
NGC 1814-1816-1820	8.80	+0.23	−0.60
NGC 1818	9.36	+0.16	−0.51
NGC 1929-1934-1935-1936-1937	8.46	−0.06	−0.99
NGC 1955	9.10	−0.18	−1.10
NGC 1968-1974	9.07	−0.17	−1.07
NGC 1962-1965-1966-1970	8.36	0.00	−0.84
NGC 1983	8.32	+0.11	−0.62
NGC 2004	9.07	+0.19	−0.64
NGC 2011	9.65	+0.05	−0.78
NGC 2014	8.61	+0.09	−1.00
NGC 2074	8.62	+0.06	−0.91
NGC 2100	9.08	+0.23	−0.50

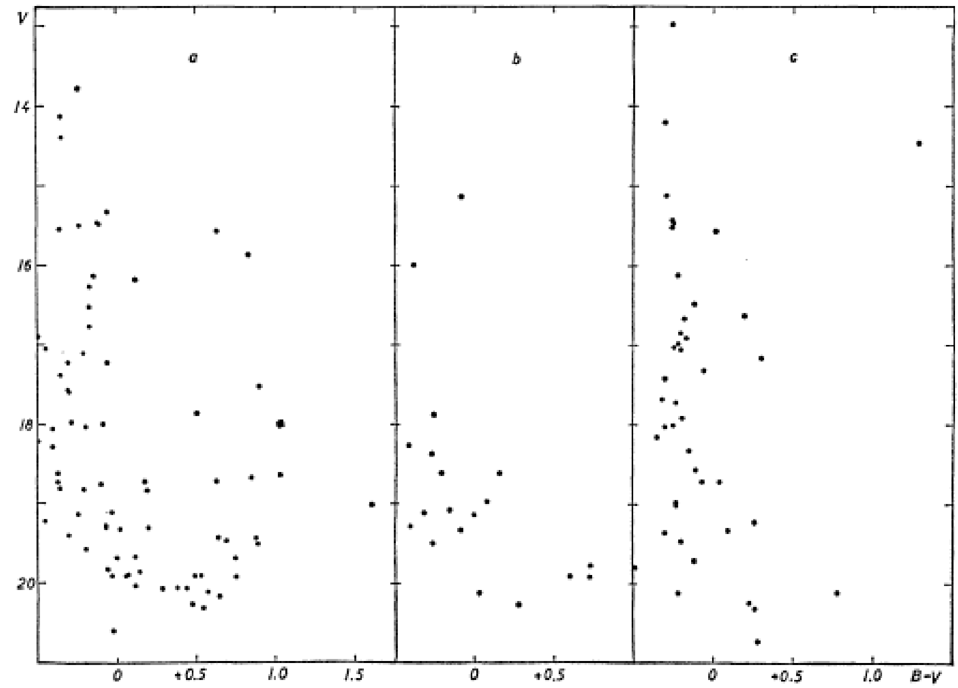

Figure 16: Colour-magnitude diagrams for NGC 602a, NGC 602b and NGC 602c respectively (after Westerlund, 1964: 439).

Complementing the Boks' study of young associations in the LMC was Westerlund's investigation of stars in the Wing of the SMC.

In Westerlund, Danziger and Graham (1963) they report on eight supergiants in the region of NGC 456-60-65 which were investigated to determine whether they were members of the SMC. *UBV* data obtained by Westerlund at Mount Bingar were combining with *Hβ* measures taken by Graham with the 50-in and 30-in telescopes at MSO. Spectroscopic observations were also made by Danziger at MSO. The authors concluded:

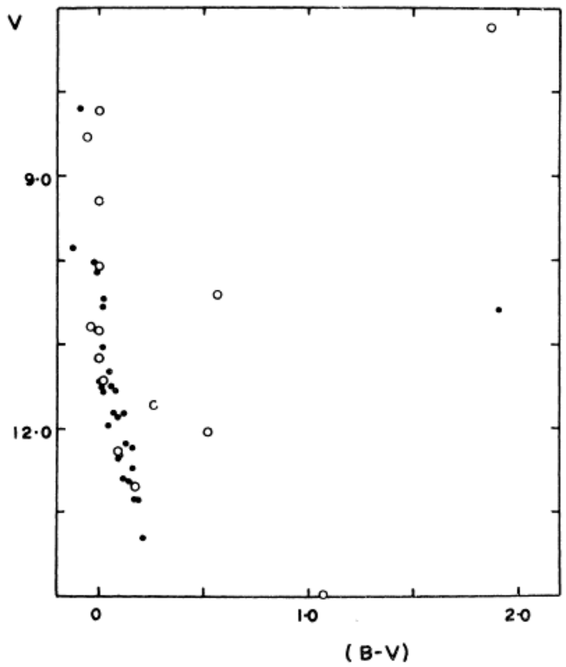

Figure 17: Colour-magnitude diagram for NGC 3766, uncorrected for absorption. The photometric observations are shown by open circles (after Sher, 1962: 64).

> It is evident from all our data that the eight stars are members of the Small Magellanic Cloud. They are all supergiant stars and have evolved away slightly from the zero-age main sequence … Our investigation also confirms previous results … that the Magellanic Cloud early-type supergiants are similar to those in our Galaxy.
>
> The present eight stars can hardly belong to a single association of normal size; if the distance of the Clouds is assumed to be about 55,000 parsecs, our stars No. 1 and No. 8 are about 2500 parsecs apart.
>
> However, it appears quite possible that the whole wing has an identical evolutionary history and, in spite of its size, may be treated as a unit. Judging from the present stars, its age is probably younger than 10^7 years. (Westerlund et al., 1963: 78-79).

Westerlund (1964) followed up with a photometric study of three further concentrations of blue stars in the wing of the SMC, which he designated NGC 602a, NGC 602b and NGC 602c. *UBV* photometry was carried out at Mount Bingar on 26, 7 and 15 stars respectively in the three groups, and photographs were obtained at MSO with the 74-in reflector and the Uppsala Schmidt. Colour-magnitude diagrams were prepared for the three groups of stars and, as Figure 16 indicates, there is

> … a well-defined main sequence going vertically at about $B-V = -0.25$ mag. This blue mean colour indicates that hardly any interstellar absorption occurs in the region … the main sequence termination points in the diagrams all appear at about $V = 14$ mag. This value corresponds to an age of about 10^7 years … We conclude … [that] the blue field stars [in the wing of the SMC] and the concentrations NGC 602a, b and c form one association ... (Westerlund, 1964: 439-442).

Apart from the Magellanic Clouds, Bart and Priscilla Bok were also interested in young associations in our Galaxy. In Bok, Bok and Graham (1963) they discuss 17 OB stars that lie within one degree of l = 327° and b = 0°. When *UBV* data obtained by the Boks at Mount Bingar were combined with *Hβ* values obtained by

Graham with the 50-in reflector at MSO, Bok, Bok and Graham were able to identify two separate groupings of stars. Eleven stars of spectral type O or early B yielded a mean distance modulus of 12.0 ± 0.3, corresponding to a distance of 2,500 ± 300 parsecs. The authors noted that "… the dispersion of the individual distance moduli is small for this group. It is probable … that these stars form a physical system." (Bok, Bok and Graham, 1963: 517). The authors conclude that if the estimated distance was realistic, then this young association was situated in the Sagittarius spiral arm.

In a later study, Bok, Bok and Graham (1966) report on a *UBV* and *Hβ* photometric study of the I Scorpii association, which they describe as "… one of the most striking concentrations of blue supergiant stars to be found in the whole Milky Way ...." (Bok, Bok and Graham, 1966: 247). The Boks obtained most of the *UBV* measures with the 26-in telescope at Mount Bingar, while Graham made the *Hβ* observations with telescopes at MSO. Forty-three possible members of the association were investigated, and after corrections were made for interstellar absorption two different techniques were employed to derive the distance modulus of the group. Both values were similar, and the adopted mean value of 11.25 corresponded to a distance of 1,800 ± 200 parsecs. This result lay comfortably within the range 1,400-2,300 published by other researchers. Reflecting on their earlier LMC studies, Bok et al. (1966: 251) observed that

> It is instructive to note the general similarity between the I Scorpii group and the young associations in the Large Magellanic Cloud. At a distance of 55000 parsecs, the I Scorpii association would have an angular diameter of approximately 4′ by 2′. The brightest star in the association, ζ^1 Scorpii, would have an apparent magnitude of about 10.5, while there would be several stars in the group brighter than apparent magnitude 12.5. The HII ring would have an apparent diameter of about 8′. These general specifications can be applied to many of the young associations in the Large Magellanic Cloud.

John Graham, one of the authors of the two aforementioned studies, was a MSO doctoral student, and his thesis topic was "The Application of Hydrogen Line Photometry to Milky Way Research." Graham (1963) was particularly interested in early-type stars, and carried out *Hβ* photoelectric photometry with the 30-in and 50-in reflectors at MSO, but—as we have seen—in a number of published studies his photometric data were combined with those obtained by the Boks at Mount Bingar.

Graham (1965) also published a research note on the distances of the η Carinae and I Scorpii early type associations, on the basis of absolute magnitudes of seven Wolf-Rayet stars observed in *UBV* and *Hβ* at Mount Bingar and MSO. The absolute magnitudes of these stars ranged from –5.2 to –7.1 (with a mean of –6.4), and the derived distances of the η Carinae and I Scorpii associations were 2,800 parsecs and 1,800 parsecs respectively (ibid.; cf. Bok, Bok and Graham, 1966). Graham (1965: 197) makes an important point at the end of his short paper:

> It is interesting to note that Westerlund has found a mean visual magnitude of 12.63 for the Wolf-Rayet stars in the young associations of the Large Magellanic Cloud. Adopting an apparent distance modulus of 19.0 for the Large Cloud, the corresponding mean absolute magnitude for this particular class of Wolf-Rayet stars in −6.4, in good agreement with the present result.

This nicely complements the remarks made by Bok, Bok and Graham at the end of their 1966 paper.

David Sher (1936–) was another doctoral student with an interest in galactic open clusters, and he wrote a thesis titled "Distances of Some Open Clusters near Eta Carinae" (Sher, 1963). In his first published paper (which he calls a "note"), Sher (1962) reports on the distance of NGC 3766, on the basis of *UBV* photometry carried out at Mount Bingar and with the MSO 50-in telescope and photographs taken with the Uppsala Schmidt. A colour-magnitude diagram was prepared and is shown here in Figure 17. The distance of the cluster was found to be 1,900 parsecs and the age ~10^7 years (Sher, 1962: 63).

Sher (1965) later used data obtained at Mount Bingar with the EMI photometer, along with readings from MSO, to investigate the ages of five open clusters located near η Carinae in the southern Milky Way. Table 5 lists the different clusters and the numbers of stars observed photometrically at Mount Bingar, while Figures 18 and 19 display colour-magnitude and two-colour diagrams for NGC 3603 and Melotte 105 respectively. In Figure 18 the solid line represents Blaaw's initial main sequence, adjusted for a colour excess of 1.42 and a distance modulus of 17.0, but

Table 5: Data on five open clusters investigated by David Sher (1965).

Cluster	Stars observed at Mount Bingar	Distance (kpcs)	Age (yrs)
NGC 3496	3	1.1	10^9
NGC 3603	3	3.5	10^6
NGC 3766	9	1.9	10^7
Melotte 105	2	2.1	10^8
Trumpler 17	5	1.4	10^7

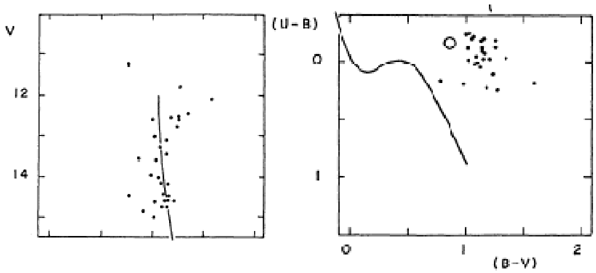

Figure 18: Colour-magnitude and two-colour diagrams for stars in the core of NGC 3603. The large open circle in the latter plot represents the integrated colours of the cluster (after Sher, 1965: 252).

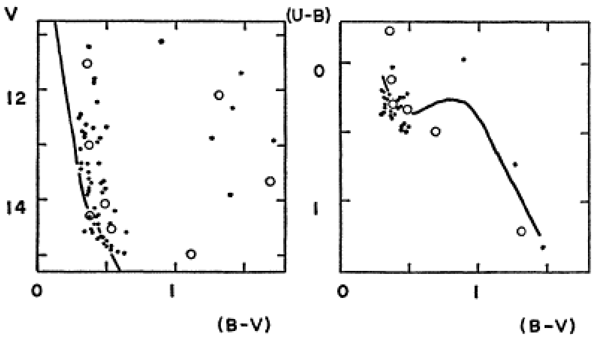

Figure 19: Colour-magnitude and two-colour diagrams for stars in Melotte 105 (after Sher, 1965: 256).

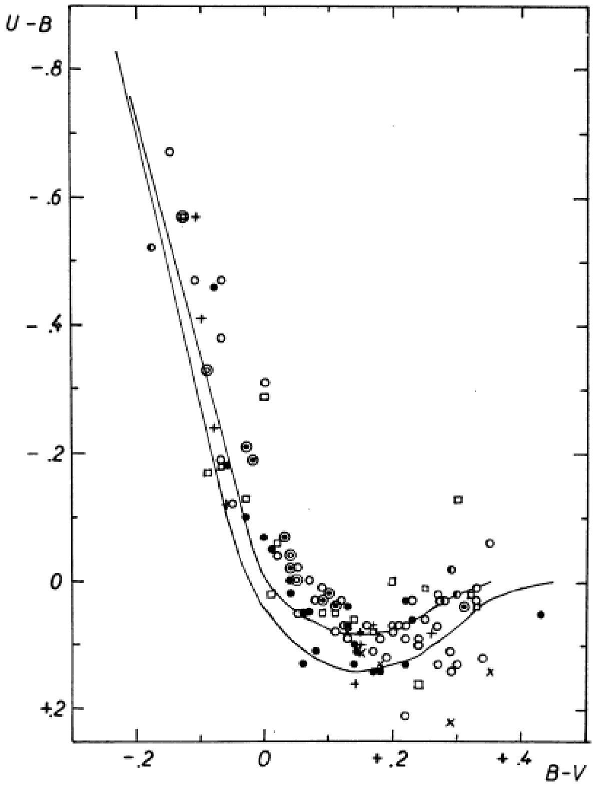

Figure 20: Two-colour diagram for stars near the South Galactic Pole (after Westerlund, 1963c: 93).

Sher points out that if the total absorption adopted throughout his paper is correct then the real distance modulus is 12.7. Meanwhile the solid line in Figure 19 is based on a colour excess of 0.38 magnitudes and a distance modulus of 12.7.

Derived ages and distances for the five clusters are included in Table 5.

Whilst all five asterisms listed in Table 5 were described initially as 'clusters', the scatter of points in the colour-magnitude and two-colour diagrams prepared for NGC 3496 and Trumpler 17 led Sher (1965: 260) to raise doubts about these two groupings:

> If Tr 17 is merely a chance collection of field stars, NGC 3496 must either be a cluster or a sample of field stars of an entirely different character as shown by the occurrence of so many red stars. If NGC 3496 is a cluster, and if it does indeed contain the red stars shown in Figure 14 [in his paper], it has a remarkably richly populated branch of K giants. It would nevertheless be advisable to await further proof of their reality as clusters before accepting any particular interpretation of the observations.

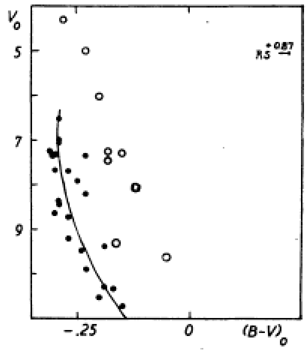

Figure 21: Colour-magnitude diagram for OB stars near RS Puppis. Dots represent members of the association and open circles field stars. RS Puppis is indicated by the star (adapted from Westerlund, 1963a: 76).

The Uppsala Schmidt observer, Bengt Westerlund, was another Stromlo astronomer who used the Mount Bingar facility to investigate OB associations and early-type stars in our Galaxy. After observing stars near the North Galactic Pole he turned his attention to the southern sky and carried out *UBV* photometry of 110 B- and A-type stars near the South Galactic Pole. The project was started when the Catts Telescope was still sited at Mount Stromlo, but continued at Mount Bingar. In addition, a few observations were made with the 30-in reflector at MSO. A two-colour diagram was prepared and is shown in Figure 20. The two lines delineate the distribution of the stars near the North Galactic Pole; the very different pattern for the South Galactic Pole stars is explained by blanketing effects and the presence of interstellar reddening in the southern region (Westerlund, 1963c: 93).

Westerlund (1963a) then carried out a study of RS Puppis and nearby OB stars, drawing on spectra obtained with the 20/26-in Uppsala Schmidt at MSO and *UBV* photometric data obtained at Mount Bingar. The initial photometry was carried out with an EMI photomultiplier tube, but this was later replaced by an RCA 1P21 tube. Thirty-one stars were observed, and when a colour-magnitude diagram was prepared (see Figure 21) all but 8 of these were seen to be members of an OB association. The distance modulus of this association was 11.2, corresponding to a distance of 1,700 parsecs.

Westerlund also used the Mount Bingar telescope to conduct *UBV* photometry on the Cepheid variable, RS Puppis, deriving the light curve shown in Figure 22 (where the cross and open circles represent observations made by other astronomers). Photometric properties of the star are listed in Table 6. A mean absolute magnitude of −6.1 was derived on the basis that the variable is also a member of the OB association, and this is in close accord with the value of −5.8 based on the period-luminosity relations of Cepheids in the LMC and SMC. RS Puppis and the OB stars form an association, and

> … are situated in a volume of space which is rich in dust as well as gas. The age of the association is about 4×10^6 years … [and] The Cepheid is probably the most evolved star in it. It appears quite likely that stars not yet on the main sequence or even in the stage of formation may be found in the region. (Westerlund, 1963a: 80).

Finally, in a paper presented at an international conference in Indonesia, Westerlund (1963b) reviewed his recent studies involving Mount Bingar photometry with the 26-in telescope and low dispersion spectroscopy with the 20/26-in Uppsala Schmidt at MSO.

After the Boks, Antoni Przybylski (1913–1986) and his MSO colleague Pamela Kennedy were the next most productive MSO astronomers to use the Mount Bingar 26-in telescope for astrophysical research. Their primary interest was in high velocity stars, and their overall aim was to secure data on 500-600 southern stars, thereby extending to the southern hemisphere a similar northern sky survey that had been carried out by N. Roman. In their second paper in this series, Przybylski and Kennedy combined spectra taken at

MSO on the 74-in reflector with *UBV* photometric measures made at Mount Bingar and reported observations of 52 southern stars with unusually large proper motions. Fifty-six percent of these showed ultra-violet excesses >0.10, indicating they were subdwarfs (Przybylski and Kennedy (1965a: 68). Twelve of the stars in the survey were early-type stars (i.e. with spectra up to F0), and most of these had low radial velocities. Two of these stood out: one was "… a peculiar A0 star with strong lines of strontium and chromium and … [the other was] a metallic line star with strengthened lines of the same elements. Other early type stars show no spectral peculiarities." (ibid.).

In the next paper in the series, Przybylski and Kennedy (1965b) present a long table listing spectral classifications and radial velocities for 127 high velocity southern stars and 39 low velocity stars. *UBV* measures—mostly taken with the Mount Bingar 26-in and the EMI photometer—are included for 149 of these stars, and the Australian photometric results are compared with data published by other researchers.

The last project Przybylski carried out with the Mount Bingar telescope was an investigation of HD 176387, which in the course of the southern high velocity survey was found to be a variable star. However, *UBV* observations made at Mount Bingar in 1961-1963 "…were insufficient for the determination of either the period or the light curve." (Przybylski, 1967: 185), and this information only became available when subsequent observations were carried out with the 30-in Reynolds reflector at MSO. HD 176387 proved to be the brightest-known c-type RR variable, with a period of 0.316899 days and an amplitude of $V = 0.6$, from 8.68 to 9.28 (ibid.).

A fourth graduate student who used the Mount Bingar telescope for doctoral research was the late Don Faulkner (1937–2004), whose thesis was titled "A Study of the 30 Doradus and Eta Carinae Nebulae" (Faulkner, 1963).

Unlike other MSO staff and students, Faulkner worked in collaboration with visiting Postdoctoral Fellow Lawrence Aller (1913–2003) to carry out photoelectric spectrophotometry with the 26-in telescope; some observations were also conducted with the 30-in and 50-in reflectors at MSO. The spectrophotometer had been constructed by William Liller (1927–), and was on loan from the University of Michigan. Aller et al. (1966: 1074) discuss the advantages of this type of instrument:

> A spectrum scanner has certain advantages for measuring monochromatic magnitudes. First, a precise wavelength internal λ_1 to $\lambda_1 + \Delta\lambda$ can be selected so that the effective wavelength is firmly fixed, regardless of spectral class. Second, the very nearly rectangular character of the "transmission function" involved makes it easy to interpret the measurements, particularly if scanner tracings are supplemented by slit spectrograms, so that the energy subtracted by absorption lines from the star's continuum can be properly measured. Third, since no integration over a long-wavelength interval is involved, atmospheric extinction coefficients can be accurately determined. Fourth, it is possible (Willstrop 1960) to calibrate the monochromatic magnitudes in units of flux, a task which is much more difficult for broad-band-pass measurements.
>
> A significant advantage of the spectrum scanner is that one can select the wavelength λ and interval $\Delta\lambda$, or one can scan the entire spectrum. A variety of slot and diaphragm sizes provides flexibility to the entire program. In studies of gaseous nebulae, for example, precise line ratios can be measured, and one can determine surface brightnesses in monochromatic radiations …

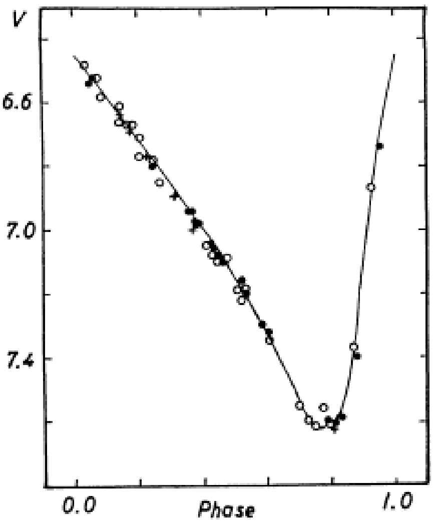

Figure 22: V light curve for RS Puppis (after Westerlund, 1963a: 78).

Table 6: Photometric parameters of RS Puppis (after Westerlund, 1963a: 79).

Parameter	V	$B-V$	$U-B$
Maximum	6.45	+1.10	+0.80
Minimum	7.62	+1.73	+1.79
Amplitude	1.17	0.63	0.99

Faulkner, of course, *was* interested in gaseous nebulae, and in 1965 he and Lawrence Aller published a paper about the prominent southern galactic nebula, η Carinae, and about 30 Doradus in the LMC. However, the Mount Bingar telescope was only used to establish line intensities for η Carinae. The resulting values, after correction for interstellar absorption using Whitford's (1958) reddening curve, are listed in Table 7. By using the values for [OIII] shown here, and an [OIII] figure for λ4363 derived from MSO observations, Faulkner and Aller (1965: 400) found a value of 620cm^{-3} for the electron density (N_e) of η Carinae and 10,200 ± 700 K for its electron temperature (T_e). They also concluded (ibid.: 402) that collectively the O^+ and O^{+2} ions accounted for ~90% of all oxygen in this nebula, and they obtained an oxygen abundance, N(O)/N(H), of $1.8 \pm 0.6 \times 10^{-4}$.

Later in their paper, Faulkner and Aller (1965: 405) used corrected line intensities for Hγ, [OII] at λ3726 and λ3729, and [OIII] at λ4959 and λ5007 obtained

Table 7: Relative line intensities for η Carinae (adapted from Faulkner and Aller, 1965: 398).

Element	λ (Å)	Intensity (corrected)
[OII]	3726	86
[OII]	3729	89
H	3970	18.5
H	4102	27.5
H	4340	47.6
H	4861	100
[OIII]	4959	66
[OIII]	5007	200

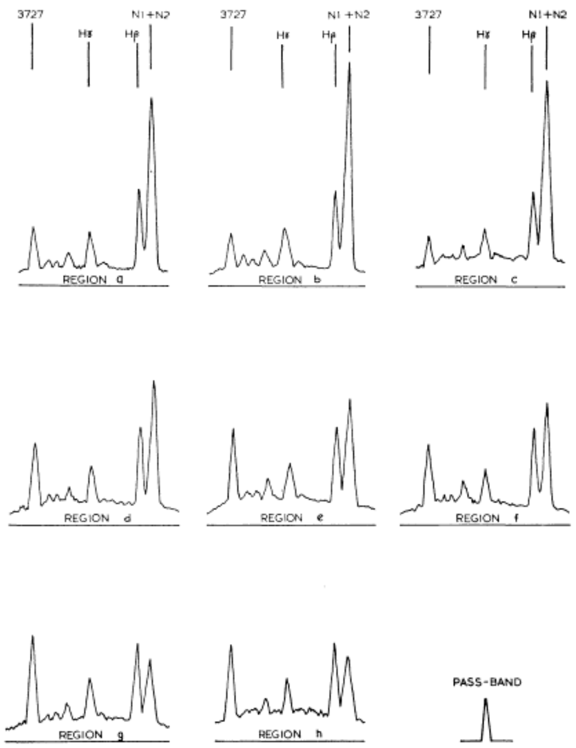

Figure 23: Low resolution spectral scans of eight different regions in Eta Carinae (after Faulkner and Aller, 1965: 396).

from the low resolution spectrograms shown in Figure 23 to calculate the electron temperature (T_e) at eights different locations within the η Carinae nebula. The

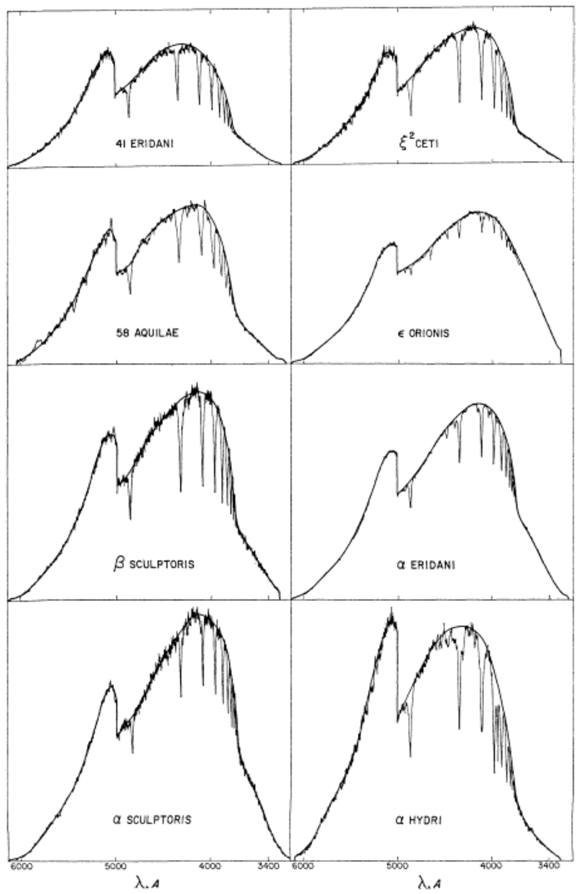

Figure 24: Spectral scanner tracings for selected southern stars made at Mount Bingar and/or MSO in 1960-1961 (after Aller at al., 1966: 1079).

derived values showed little variation, ranging from 9,600 to 10,400 K.

In addition to their spectrophotometric investigation of η Carinae, Faulkner and Aller wanted

> … to establish a number of Southern Hemisphere stars as spectrophotometric standards, to measure the energy distributions in a number of stars of special interest (e.g., ζ Puppis, γ Velorum, and η Carinae), and to tie our spectrophotometric system as closely as possible to the system established in the Northern Hemisphere. (Aller, Faulkner and Norton, 1966: 1075).

Consequently, between 28 September 1960 and 16 March 1961 Aller teamed with Faulkner and R.H. Norton (1966) and they used the Mount Bingar telescope to examine the spectral-energy distributions of selected southern stars. They also carried out comparable observations with the 50-in reflector at MSO in August 1961 and from 20 December 1961 to 11 February 1962. In Table 2 in their paper Aller et al. (1966: 1077) list the spectral type, *V* magnitude, *B–V* and *U–B* colours and other values for the 28 stars observed at Mount Bingar and MSO, and in Figures 2-4 they reproduce the actual spectral tracings for 24 of these stars (e.g. see Figure 24), but nowhere do they identify which of the 28 target stars were actually observed at Mount Bingar.

Another MSO graduate student to use the 26-in reflector at Mount Bingar was Robert Shobbrook (1937–; see Figure 13) who in 1963 submitted a Ph.D. thesis titled "Photographic, Spectrographic and Photometric Studies of Southern Galaxies."

UBV photometric observations of 43 southern galaxies in Centaurus, Dorado, Grus and Telescopium were conducted at Mount Bingar with the 26-in telescope, one galaxy was observed at MSO with the 50-in reflector and nine galaxies were observed with both telescopes (Shobbrook, 1966a). During the 2.5-yr observing period, the following photomultipliers were used at Mount Bingar: an EMI type 5 659, 11 stage 950 V; an EMI 9 524S. 11 stage, 900 V; and a Lallemand blue sensitive, 19 stage, 1,300 V. For these observations, the 26-in telescope was used near its limiting magnitude of ~14 (Shobbrook, 1966a: 361).

Shobbrook (ibid.) also noted that

> … there was a significant dependence of the mean errors of observation on magnitude … Galaxies measured 2, 3, 4 or 5 times were used in the determination of the errors in the 10th, 11th, 12th and 13th magnitude intervals. The mean errors from one observation range from ±0.02 mag at the 10th magnitude to ±0.05 mag at the 13th magnitude in *V* and *B–V*, and from ±0.03 to … as high as ±0.10 mag [in *U–B*].

After correcting for interstellar absorption, Shobbrook produced scatter diagrams of $(U-B)_c$ vs $(B-V)_c$ for all of the observed elliptical and S0 galaxies (see Figure 25) and for spiral galaxies (Figure 26). The globular cluster NGC 6752 is also included in Figure 25. Because of the larger uncertainty in the Centaurus (*U–B*) colours and the large corrections for galactic absorption and redshift these galaxies (Cen E and Cen S0) are distinguished in Figure 25 from those galaxies for which more accurate data are available. The thin lines in Figures 25 and 26 connect points for different diaphragm measures of the same galaxy, with the direction of the arrow indicating increasing aperture, while the curved lines show the mean relations found previously by de Vaucouleurs (1961) and Hodge (1963) for comparable types of northern galaxies. These diagrams show that the galaxies observed from Mount Bingar and MSO do not differ appreciably from comparable galaxies in the northern sky, but Shobbrook (1966a: 363) offers a final word of warning: "However … observations should [also] be made of northern and southern galaxies using one telescope and photomultiplier, in order to check that all the galaxies are on the same system."

In yet another paper, Shobbrook (1966b) draws on photometric data in the above-mentioned paper and MSO spectral data presented in an earlier paper to examine the distances of the 53 southern galaxies, using the distance of the Virgo cluster for comparison. The southern galaxies were assumed to belong to four discrete clusters of galaxies located in Centaurus, Dorado, Grus and Telescopium, and their distances—after correction for galactic absorption—were calculated as 21.2 ± 3, 8.8 ± 0.2, 14.1 ± 1.1 and 15.9 ± 1.5 Mpc respectively. While these values were seen to be 'state-of-the-art' at the time, we now know that the distance to the Virgo cluster is ~16.5 Mpc (Mei et al., 2007) not the value of 9.7 Mpc adopted by Shobbrook.

Apart from MSO staff and graduate students, at least one visiting astronomer also used the Catts Telescope while it was at Mount Bingar. During an 8-month visit to MSO Gerald Kron (1913–) from the Lick Observatory used the 74-in, 50-in and 30-in telescopes at MSO in his research on southern Cepheids, but between October 1960 and April 1961 he also visited Mount Bingar and used the Catts Telescope and the RCA 7102 photometer to observe *l* Carinae, *β* Doradus, *κ* Pavonis and W Sagittarii (Breckinridge and Kron, 1963). This project was designed to extend his study of colour excesses in northern Cepheids to the Southern Hemisphere.

By the time Faulkner, Graham, Sher and Shobbrook completed their Ph.D.s, they and the astronomers at MSO not only had access to the 50-in reflector at MSO, but the 74-in reflector was also fully operational. This to some extent took the focus away from the 26-in reflector at Mount Bingar, and the decision to site the MSO outstation at Siding Spring Mountain in northern New South Wales rather than at Mount Bingar effectively sounded the death-knell for this particular telescope which, up to that point, had been regarded by MSO staff and graduate students as a useful complement to the MSO 50-in for *UBV* photometry.

4.3 The Fate of the Catts Telescope

Initially, the intention was that the Catts Telescope would remain at Mount Bingar and continue to play a role in astrophysical research—with a smaller primary mirror (Bok 1961)—but a decision was later taken to renovate the instrument so it would "… be ready for erection on Siding Spring Mountain *should demand warrant this*." (Bok, 1963: 233; my italics).

When the Mount Bingar field station was closed in 1963 the 26-in telescope was dismantled and the mirror was returned to the Fund for Astrophysical Research. Bok (1964: 253) then announced that "New optics for this telescope are being ordered … [so that it can] be moved to Siding Spring Observatory." However, this course of action was reversed the following year when it was decided that a 24-in Boller & Chivens reflector would be ordered for Siding Spring Mountain in place of the revitalized Catts Telescope, and that this new instrument would be dedicated to the study of polarization of starlight (Bok, 1965).

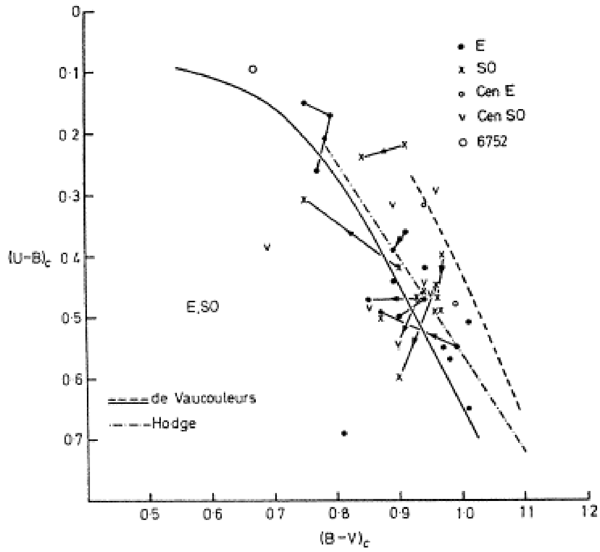

Figure 25: Scatter diagram of $(U-B)_c$ vs $(B-V)_c$ for elliptical and S0 galaxies (after Shobbrook, 1966a: 361).

With the imminent arrival of the new Boller & Chivens reflector there was no further need for the Catts Telescope, and MSO decided to donate it (minus the original 20-in mirror) to the University of Western Australia in Perth.

5 THE PERTH YEARS

After the acquisition of a new 16-in (40.6-cm) mirror, the new-look Catts Telescope was fabricated in the workshop of the Physics Department under the direction of Dr S.E. Williams (1919–1979) (Burman and Jeffery, 1992).

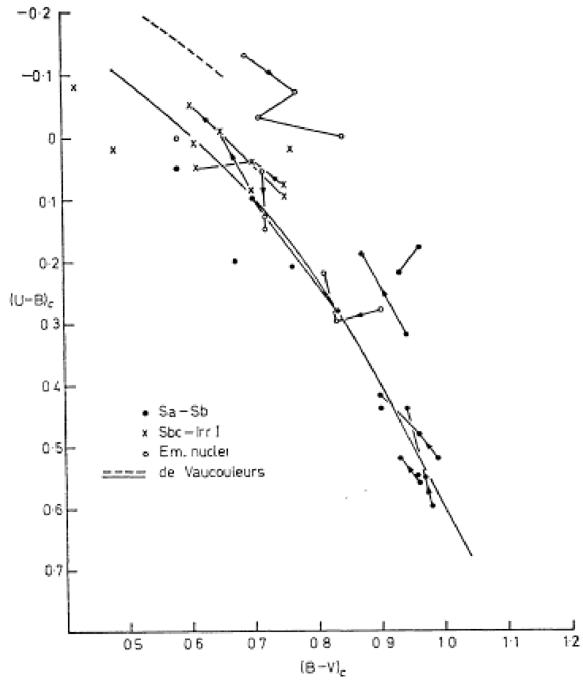

Figure 26: Scatter diagram of $(U-B)_c$ vs $(B-V)_c$ for spiral galaxies (after Shobbrook, 1966a: 362).

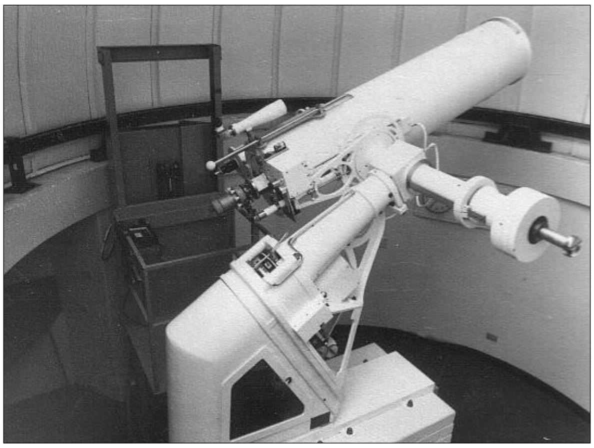

Figure 27: The refurbished 16-in Catts Telescope at Perth Observatory (Orchiston Collection).

The intention was to produce an instrument that could be used for photometric and spectroscopic research (Hunter, 1976), and in 1969 the completed telescope (Figure 27) was installed in a new dome at the Perth Observatory (*Review of Observatories*, 1978). Figure 28 shows this dome. Williams then used the telescope intermittently for photoelectric photometry of variable stars (Figure 29) from 1969 up until his retirement in 1975 (Burman *et al*., 1990), but it saw little use after this except on occasions by Perth Observatory staff and students from Murdoch University.

Two undergraduate students from the University of Western Australia used the telescope during the 1985-86 apparition of Comet 1P/Halley, and this led to a revival of research interest in the telescope from staff at that University and it was used in July-August 1987 to obtain photoelectric observations of flares on Proxima Centauri with the aid of a Gencom Starlight Photometer on loan from the Perth Observatory (Kroupa et al., 1989).

The plan then was to automate the telescope and use it for systematic supernova searches, but when observing time became available on the Perth Observatory's 24-in Boller & Chivens reflector in 1987 the program was transferred to that instrument. This successful program involved astronomers from the Observatory, the University of Western Australia, Curtin University and Murdoch University, operating under the acronym PARG (the Perth Astronomy Research Group), a collaboration that was formally established in 1988 (see Burman *et al*., 1990).

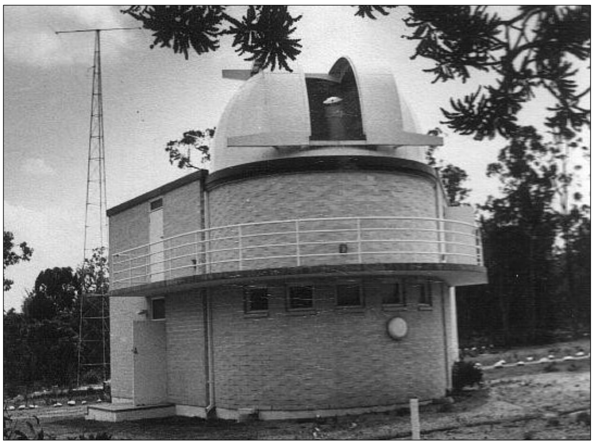

Figure 28: The Catts Telescope in its new dome at the Perth Observatory (Orchiston Collection).

The transfer of the supernova search program to the 24-in telescope ended the research role of the Catts Telescope, and in 1998, when Perth Observatory required the dome for a new telescope, the University decided to formally donate the 16-in reflector to the Observatory. The telescope was then removed from the dome and placed in storage. In 1999, James Biggs and Peter Birch reported that this telescope "… will be refurbished, as workshop time allows, and employed in the public star viewing sessions." They emphasized that upgrading the instrument to automatic operation was not a viable option as it would require a complete rebuild of the mounting.

6 DISCUSSION

6.1 The Research Potential of Small Reflectors

During the nineteenth century, prior to the emergence of astrophysics, telescopes with apertures comparable to and even considerably smaller than the Catts Telescope were eagerly acquired by professional observatories and amateur astronomers, and were used effectively for research (e.g. see Orchiston 1985; 1992; 2004b). However, the advent of astrophysics changed all this, and 'aperture-fever' and the quest for increasingly more sophisticated instrumentation permeated professional astronomy (e.g. see van Helden, 1984).

Nonetheless, even as recently as the 1950s and 60s modest instruments like the Catts Telescope were still capable of producing valuable results if placed in the hands of competent astronomers and directed towards viable research projects (such as those based on photoelectric photometry). This is clearly evidenced by the use of the Catts Telescope when it was located at MSO, and even though its transfer to Mount Bingar—complete with expanded optics—was primarily for site survey purposes, whilst there it also was able to fulfill an important research role. Without ongoing access to this telescope the research programs of a number of MSO staff and Ph.D. students would have been seriously compromised.

6.2 Glass' Master List of Grubb Telescopes

South African astronomer Ian Glass (1939–) has researched Grubb telescopes worldwide, and in 1997 published an invaluable book titled *Victorian Telescope Makers: The Lives and Letters of Thomas and Howard Grubb.* This book includes a master list of Grubb telescopes in decreasing order of aperture, and data are presented on three different 20-in reflectors:

1) Isaac Roberts' well-known twin 20-in reflector/7-in refractor, which was used for pioneering astronomical photography (e.g. see McNally and Hoskin, 1988; Roberts, 1893).
2) A speculum-metal reflector which was made in about 1851 and erected in Glasgow, Scotland.
3) The 16.5-in Grubb reflector made in about 1887 and transferred to Poona, India. In 1894 the original mirror was replaced by a 20-in figured by A.A. Common. In 1912 this instrument was transferred to the Kodaikanal Observatory.

Conspicuously missing from this list is the 20-in Catts Telescope, and it is to be hoped that data presented in this paper will justify its inclusion when a revised edition of Glass' book is published.

7 CONCLUDING REMARKS

The Catts Telescope was manufactured a little over a century ago, and witnessed three distinct phases of ownership. During the 'Amateur Era', which extended to 1952, its research potential was largely squandered, even though it had the potential to contribute in a meaningful way to science if placed in capable hands and directed to viable research projects.

The 'Stromlo Era' lasted from 1952 to 1963 and during this 12-yr interval the Catts Telescope was first used at MSO in its original 20-in Cassegrainian configuration and from December 1959 as a refurbished 26-in Cassegrainian reflector at the Mount Bingar field station. During the critical 'Stromlo Era' the Catts Telescope was used very effectively by ten MSO astronomers and visiting astronomers and by five different Ph.D. students for photometry or spectrophotometry of stars in our Galaxy and for photometry of clusters of southern extragalactic nebulae. These investigations resulted in the publication of twenty-six research papers based *in toto* or in part on observations made with the Catts Telescope, and these were published mainly in *The Astronomical Journal*, *The Astrophysical Journal*, *Monthly Notices of the Royal Astronomical Society*, *The Observatory* and *Publications of the Astronomical Society of the Pacific*. Apart from its valuable contribution to astrophysics, while at Mount Bingar the Catts Telescope also was the mainstay of the site-survey program that led ultimately to the establishment of a MSO outstation at Siding Spring Mountain.

The Mount Bingar field station was closed in 1963, thus ending a 12-yr period during which the Catts Telescope had been used extensively for photoelectric photometry. In the light of this record of achievement it is surprising that its research role is not mentioned in some historical papers about the Observatory (e.g. see Gascoigne, 1984; 1992; Hyland and Faulkner, 1989).

The final phase in the history of the Catts Telescope is the 'Perth Era', which extends from about 1965 to 1999. During this period, the refurbished 16-in Catts Telescope was based at Perth Observatory but was only used intermittently for astrophysical research. Finally, the telescope was removed from its dome in 1999 and placed in storage, thus ending a century of service to science, first in a primarily educational and recreational role, and later, during the 'Stromlo Era' as an instrument that made a meaningful contribution to Australian astronomy and to international astrophysics. In this context, the Catts Telescope certainly deserves to be included in the next edition of Glass' book on historic Grubb telescopes.

8 NOTES

1. An abbreviated version of this paper titled "The Role of the 'Catts Telescope' at Mount Stromlo and Mount Bingar: A Southern Hemisphere Analog to the Crossley Reflector" was presented at the Donald E. Osterbrock Memorial Symposium which was held at the University of California, Santa Cruz, on 2-3 August 2007. In utilizing this title, Dr William Sheehan (one of the Symposium organizers) and I wanted to pay homage to Don Osterbrock's long association with the Lick Observatory and his recognition that telescopes of modest aperture—like the 20-inch Catts Telescope and the 36-inch Crossley Reflector—were (and indeed still are) capable of being used for serious research. This paper is a companion paper to the contributions by Sheehan (2008), Misch (2008) and Pearson and Orchiston (2008) from that Symposium, which were published in the March 2008 issue of this journal.
2. Westerlund was in charge of Uppsala University's Southern Station at Mount Stromlo, which boasted a 20/26-in (50.8/66.0-cm) Schmidt.

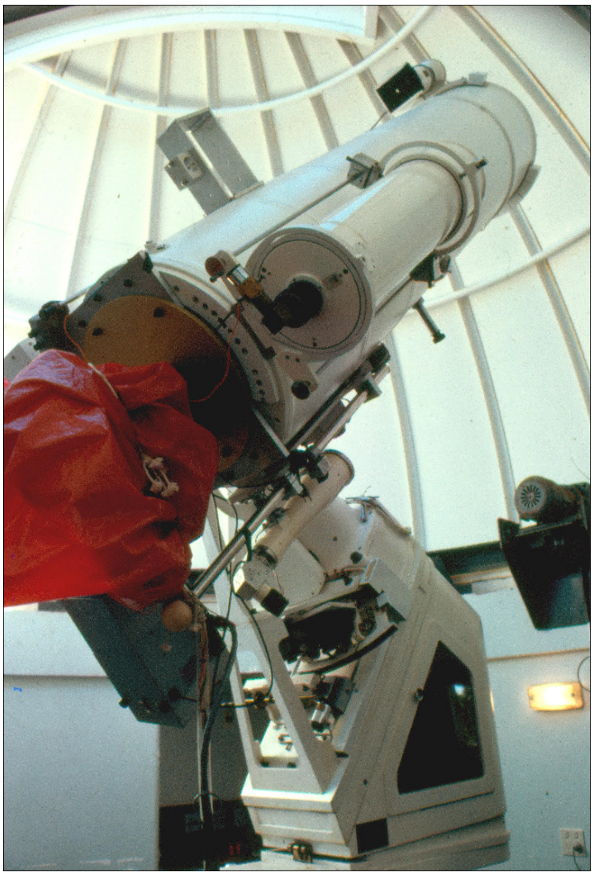

Figure 29: A later view of the Catts Telescope at Perth Observatory, complete with photoelectric photometer and a large new guide scope (courtesy: Graeme White).

3. Apart from Wood and Eggen, according to the Annual Report of the Observatory for 1952 (Woolley, 1953a), another overseas visitor to MSO was Professor J. Schilt (1894–1982) from Columbia University who arrived to spend about a year at MSO, "… making arrangements for the Yale-Columbia station and carrying out photoelectric observations of colours of southern stars." Later in 1952 he was joined by Cyril Jackson (1903–1988). In the next annual report, Woolley (1954a) writes about the acquisition of the Catts Telescope, and that this instrument was "… made available for a considerable part of the year to the Yale-Columbia observers, Professor Schilt and Mr. J. Jackson [sic.]." It is therefore surprising that an ADS search of publications by Schilt and Jackson for the period 1952-1969 (inclusive) failed to produce even a single paper incorporating Catts Telescope observations.
4. This coincides with John Graham's recollections: "When I was a summer student in 1957-58, Frank

Bradshaw Wood used it [the Catts Telescope] a lot and I remember spending a number of hours there while he was mumbling into his finding charts." (pers. comm., April 2002).

5. For some unknown reason Sher (1962: 63) erroneously gives the aperture of the Mount Bingar reflector as 36 inches.

9 ACKNOWLEDGEMENTS

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Finally, I wish to dedicate this paper to the two Dons: Faulkner and Osterbrock. Before he died, Don Faulkner took a personal interest in my Catts Telescope Project, chasing up photographs and information for me from the Stromlo archives (in the period before the disastrous January 2003 fire) and from a number of retired staff members; he also read the first draft of this paper and supplied many useful comments. For his part, the late Don Osterbrock was an unstinting supporter of the *Journal of Astronomical History and Heritage*, and his interest in and papers on historic telescopes were a constant source of inspiration to me. Don was very aware that 'modest' telescopes were capable of making valuable research contributions if placed in the right hands, and I know that he would have enjoyed learning about the Catts Telescope had he been in a position to attend the Santa Cruz Symposium.

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