Publ. Astron. Soc. Aust., 1996, 13, 258–67

William Edwin James: Designer and Maker of Astronomical Optics

H. C. Bolton[1] and D. W. Coates[2]

[1]Department of History and Philosophy of Science, University of Melbourne, Parkville, Vic. 3052, Australia
[2]Department of Physics, Monash University, Clayton, Vic. 3168, Australia
dcoates@sci.monash.edu.au

Received 1996 May 31, accepted 1996 August 18

Abstract: We give an account of the life and work of William James, including his many contributions to astronomy in Australia mainly through his skill in designing, figuring and testing aspheric surfaces.

Keywords: instrumentation: miscellaneous

1 Introduction

After the war of 1939–45, astronomy in Australia displayed a large increase in activity. This was achieved not by the traditional State Observatories which had existed as Colonial Observatories before 1901, but by the vigour of the astronomers in the two Commonwealth bodies, the Mount Stromlo Observatory in the Australian Capital Territory and the Radio Research Board. A survey of the work of these two bodies has been given by Gascoigne (1988). In addition other centres around Australia started doing optical astronomical research and at the time of writing there seems to be a steady demand for precision optical equipment. The late William Edwin (Bill) James was at the forefront of the production of this optical equipment in Australia from about 1968 onwards. The good reputation of all observatories and indeed of all laboratories depends jointly on the skills of instrument makers and on the abilities of observers and experimenters. This was neatly stated in the last years of James' life when the photographer at the Anglo-Australian Observatory, David Malin, published his book (Malin 1993); he sent a copy to James with the inscription 'For Bill James with best wishes and deep respect. Without your skills, mine could not have been so well used.'

2 Formative Years

William James was born on 6 March 1931 at Yeovil, Somerset, England. His father was Victor M. K. James, who on demobilisation after the 1914–18 war had a dentistry practice in Ilminster, Somerset, where he married Ida Rose Relleen, accountant. Victor James studied externally at Manchester College, Oxford, for the Unitarian ministry while being a lay pastor at the Unitarian Church in Yeovil. Completing his studies in 1932, he moved to Aberdare, South Wales, in 1933 as a Minister of the Unitarian Church. Victor James built a workshop in which his son was encouraged to practise. Victor had an inquiring mind, was a keen reader and had a passionate interest in science; as a dentist he experimented with new materials and gave his son and daughter, Avril, a chemistry set. The children watched their father make and repair radio sets, a common exercise for home electricians before the 1939–45 war. Victor James had contributed occasionally to *The Inquirer*, the journal of the Unitarian Church in the United Kingdom before the 1939–45 war, and after his family came to Melbourne in July 1947 he edited and wrote articles for the *Beacon*, the weekly journal of the Melbourne Unitarian Church. He broadcast talks on the 'Unitarian Half Hour' on the Melbourne radio station 3XY and wrote two pamphlets explaining his religious stance (James, V. 1973; the other of unknown date). Unitarians stand on the edge of orthodox Christian thought and Victor met the difficult task of explaining his views with characteristically robust argument. His autobiography (James, V. 1981) was privately printed. Victor James was a Radical in politics and had visited China and Vietnam.

William James had been shown how to use tools responsibly and had spent much time in the home workshop. He also had an understanding headmaster who taught him mathematics at primary school and encouraged him to draw plans for model aeroplanes; in 1946, when he was fifteen, one of his models won a prize. William received his School Certificate, approximately equivalent to the present GCE O level.

When the family arrived in Melbourne in 1947, James at first did not want to continue at school and took an apprenticeship at Macpherson's in the

1323-3580/96/030258$05.00

workshop. After two years he returned to school, attending University High School in Melbourne, and in 1951 he passed his Leaving Honours examination in science subjects. Before going to the University of Melbourne, James spent a year working with Power Tools, which was owned by a friend of the family, Charles Pauer Halik, who demanded a high standard of workmanship, a fact which appealed to James. About this time he began to make telescopes for himself. From 1951 to 1954 he took various subjects at the University of Melbourne, all in science, but did not graduate. In the summer vacations he worked for the Forestry Department, now called Conservation and Natural Resources, on fire-watching duties in remote areas of Victoria.

James had a good deep baritone singing voice and acting talent. He took singing lessons during his initial employment and education; he had the same teacher as John Luck with whom he collaborated scientifically later in their careers. About 1954–55 he was offered parts in 'Salad Days' and 'My Fair Lady' and played in repertory theatre touring Victoria. In the 1950s actors were not paid during rehearsals so to earn money he made and sold lenses. He had them tested in CSIRO (probably at the Division of Chemical Physics). When touring with 'My Fair Lady' in New Zealand he had his lenses tested at a DSIR Laboratory and it was from this Laboratory that he was encouraged to extend his work as a lensmaker. We can at this point read James himself describing how he was attracted to this work.

Figure 1—William Edwin James.

In 1993 James was invited to deliver the Lloyd Rees Lecture at the Australian Academy of Science, which he gave on 30 September in the Ian Wark Conference Room of the CSIRO Division of Chemicals and Polymers, Clayton. This division is next door to the former Division of Chemical Physics (now Materials Science and Technology) whose chief was Lloyd Rees. Lloyd Rees was involved in James' optical career, as we shall see. The title of James' talk was 'Beyond the Fringe—Making Optics for Astronomy' (James, W. 1994a, 1994b). He started with a story, very probably autobiographical, of an English migrant on holiday in the Australian bush when he saw for the first time the glorious Australian night sky:

> With no moonlight and far away from city lights, he was overwhelmed by the spectacle of the Milky Way and the profusion of faint stars invisible to the city dweller ... this sight was a revelation. As the night wore on he watched above the distant dark hills the slow swing of the sky. The experience was a quiet epiphany. With the aid of binoculars, more stars appeared. He looked at the planets Jupiter and Saturn but to his disappointment he could see little detail; the instrument was simply not made for this purpose. [He] wanted a good telescope, but even a modest refractor was beyond his means. Back in Melbourne [he] found the book *Amateur Telescope Making, Vol 1* (1946). This is a compendium of articles by professional and amateur telescope makers and astronomers which inspired [him] to make his own reflecting telescope.

James goes on to describe how the young man worked on the kitchen table (with pointed comments from his parents) and when polishing the mirror surface, 'the fine polishing rouge got everywhere and our young man was banished from the kitchen.' The young man set up the Foucault knife edge test described in the book and so discovered that more work was needed on the surface. This done, the mirror was aluminised and mounted with a secondary prism in a Newtonian configuration. 'The apprenticeship had begun.' Many young people have got this far along the path of mirror making, but few match what James was to achieve.

James read widely as a young man and some of his reading strengthened his interest in astronomy. In Newton's *Optics* he read about the making of Newton's first speculum mirror and about the early astronomers Herschel and Lassell and their telescopes. The popular books in astronomy just after the 1939–45 war were the Pelican paperbacks by Jeans (1937, 1939), Eddington (1940) and Hargreaves (1948); the latter had started his own firm in England with the encouragement of the then Astronomer Royal, Sir Harold Spencer-Jones. The firm was at Kingswood, south of London, in long tunnels, formerly air-raid shelters, under the chalk of the South Downs. James worked with Hargreaves' firm from late 1961 until May 1962 when he moved to Imperial College London. The work of Hargreaves' firm is described in one of its pamphlets (Anon., undated) which James possessed and which will be included in a collection for the University of Melbourne Archives. One of the firm's specialists, J. V. Thomson, had worked in the optical shop at the California Institute of Technology on the production of the 5-metre Hale Telescope (Thomson 1952).

Letters from Hargreaves to James (Hargreaves 1962–64) reveal that by this time Hargreaves accepted James as an authority. Hargreaves asks for advice on aberrations in optical systems, the design of test methods for mirrors and on technical matters such as the best way to cement lens components. James' ability in the calculations necessary for the design of lenses and mirrors was ahead of that of Hargreaves. Thus in July 1963 Hargreaves asks James to do a calculation, 'I think you could do the sum in a few minutes .... My knowledge of maths wasn't anywhere near adequate.' Hargreaves has accepted James as at least an equal in his profession.

One of the instruments that James worked on at Imperial College was a camera for the National Bubble Chamber Project. The leader of this work was Professor W. T. Welford of the Applied Optics Department. The camera was to measure particle tracks for the High Energy Nuclear Physics Research Group at the Rutherford Laboratory, Harwell, UK. The photographs had to be sharp over a wide field of view and simple spherical optical surfaces were inadequate. It was necessary to use aspherics and this was James' introduction to advanced lens design. He had met Michael Waterworth, then on leave at Imperial College from the Physics Department, University of Tasmania, Hobart. They wrote a paper describing a method for testing aspheric surfaces (James, W. & Waterworth 1965). The test method was derived from a consideration of refraction by a 'Cartesian Oval', first described by Descartes. The methods used to solve this problem, based on the classical ideas of geometrical optics, are typical of James' later approach to design and testing.

After Imperial College, James went under the Colombo Plan to the Indian Institute of Technology in Delhi to establish an optical workshop and to give the inaugural lectures. The Colombo Plan was an organisation of the British Commonwealth to provide aid to developing countries. James also helped with UNESCO projects in India and Pakistan. James probably did not feel at home at the Institute; his combination of theoretical understanding and practical experience was not suited to the Institute where, in a comment to his parents, he said that he found academic staff with no practical experience and technicians with no theoretical knowledge.

In 1965 he returned to Australia and became a part-time optical technician in the Physics Department at the University of Tasmania. There he started making the 1-metre mirror for the University's telescope and also components for a far-infrared spectrometer in the Chemistry Department at the University. He was promoted to senior technical officer, a position he kept from November 1965 until March 1968 when he resigned.

3 The Mature Years: James Optics

By 1968 he felt confident enough to start his own company, James Optics, in the Melbourne suburb of Hartwell. His workshop was on the ground floor of a building housing offices. Later he moved house in Hawthorn and the workshop was moved to a separate building in the garden. His optical techniques were now well established. He understood the physics of aspheric surfaces and with the steady improvement in computers and software he was able to refine his numerical techniques. Also he insisted on monitoring the progress of his figuring and polishing with test experiments which eventually involved interferometric methods which showed errors to a very small fraction of the wavelength of light. He found a source of advice and information about computing problems in J. K. Mackenzie of the then CSIRO Division of Chemical Physics, Clayton, Victoria, and he acknowledged this later in one of his articles on his testing methods (James, W. 1990a). He wrote, 'Thanks to J. K. Mackenzie ... for extensive computer analysis of various testing methods for prime-focus correctors.' He also acknowledges the 'enthusiastic support' of his work by A. L. G. (Lloyd) Rees, then chief of the CSIRO Division of Chemical Physics. This is only one example of the successful interaction of this vigorous research division with scientists working in other laboratories. James was careful about cleanliness in his workshop. He knew that the presence of the slightest piece of abrasive grit or sand while an optical surface was being worked could cause damage; he would not visit a beach lest he brought back sand on his hands and clothes.

In the late 1960s Monash University took the opportunity of purchasing a 0·4-metre Newtonian telescope from the estate of L. Jeffree of Bendigo. Jeffree had not completed the telescope before he died and James was chosen to figure the mirror; the instrument was installed at a small observatory in the Dandenong Ranges east of Melbourne. James later made the primary and secondary mirrors for a 0·46-metre Cassegrainian telescope as a replacement for the original Jeffree telescope. A steady flow of publications has come from work with these instruments on pulsating stars and stars with active chromospheres. A spectrograph designed with the help of James has now been added to the observatory's equipment.

The Physics Department at Monash University also has the 0·3-metre telescope originally belonging to E. J. Hartung, formerly Professor of Chemistry at the University of Melbourne. After his retirement he used the telescope at his small observatory near his home at Woodend northwest of Melbourne. The Hartung telescope and observatory were moved to the roof of the Physics Department at Monash and used for teaching. The mirror for this telescope was made by Hargreaves (Hartung 1968).

When the Anglo-Australian 3·9-metre Telescope (AAT) was being built in the early 1970s at Siding Spring Mountain, James competed against optical companies worldwide and won the contract to construct the prime-focus corrector lenses designed by C. G. Wynne, which increased the field of good definition at this focus. The competition included the well known firms of Grubb Parsons of the UK and Perkin–Elmer of the USA. It was W. H. (Beattie) Steel, formerly of the CSIRO Division of Applied Physics in Sydney, who had introduced James to the astronomers involved in work on the AAT. The description of this important work is taken from James' Lloyd Rees Lecture (James, W. 1994a, 1994b) and is reproduced in Section 2 of the Appendix.

The University of Wollongong, NSW, had a 0·4-metre telescope with a mirror made by James. He also made the 0·4-metre mirror and an optically flat plate for a telescope owned by the Physics Department at the University of Melbourne. This telescope was used for teaching by R. H. Wilkinson at Rock Top Observatory, Bacchus Marsh, west of Melbourne, opened in about 1975.

James' expertise with aspherical surfaces meant that he was called on to make the 0·15-metre Schmidt camera for the optical spectrograph of the 2·3-metre telescope at Siding Spring Mountain in NSW. Figuring and testing the complex corrector plate for a Schmidt camera is notoriously difficult. Also for the ANU Observatories he made the Schmidt camera of 0·4-metre focal length for the coudé spectrograph of the 1·8-metre telescope at Mount Stromlo, Canberra. Components were also made for the Sydney University Stellar Interferometer (SUSI) of Hanbury Brown and John Davis. These components were of high precision and had a surface tolerance of 1/40 wavelength for reflecting elements and a transmitted wavefront tolerance of 1/20 wavelength for transmission elements. The components were flat mirrors up to 150 mm in diameter, vacuum windows, right-angled prisms, beam splitters and off-axis paraboloidal mirror segments. Professor John Davis has said, 'The success of the project owed much to his fine work' (Davis, J. 1990).

When Supernova 1987A appeared in February 1987 it was the first opportunity ever to observe a nearby supernova using modern astronomical equipment. Because of its southern latitude the Anglo-Australian Telescope was ideally placed to observe 1987A and an emergency program of observations was set up very quickly. Included in this program was a very high-resolution spectrograph designed and built in a few days using ideas contributed by James. The resolution was of the order of 5×10^5. A description was given by Cannon (1987).

For the CSIRO Solar Physics Group in Sydney, James made a 0·4-metre solar telescope and gave advice and assistance to Lloyd Rees' Division of Chemical Physics.

The Australian satellite Optus AUSSAT B1 was launched on a Chinese Long March Rocket in 1993. Its orbital height of some 36,000 km above the earth is monitored by an optical laser-ranging system based at the Orroral Space Ranging Observatory in the ACT, which is presently headed by John Luck. James won the contract to make the three reflectors (for a series of three satellites), each of which is an array of 14 cube-corner retro-reflector prisms. These prisms for the ranging system were made by James under sub-contract to British Aerospace in Adelaide for the Hughes Corporation. Each prism is nearly a cube with one corner cut off [the normal to the new surface is in the (111) direction to use a crystallographic notation]. If the prism were exactly a cube, a beam of light entering the new surface would be reflected back along its original direction, which is the well known principle of the 'cat's eye' reflectors on roads. But the satellite is in a geostationary orbit and the light from the laser source on the earth takes about 0·25 s on its round trip. Because of the rotation of the earth in this time, the satellite sees the receiver at an angle of 18 μrad (3·7 arcsec) from the source. The reflector must return the beam as a cone with 18 μrad semi-angle. The design of the reflectors was the joint effort of John Luck, James, W. H. Steel and N. O. J. L. Evans, the latter of British Aerospace Australia. A paper by the latter three gives the details (James, W. et al. 1990). The rear faces of the prisms had to have a dihedral offset, or the defect from perpendicularity had to be 0·8 arcsec. This very small angle involved a fine feat of optical workmanship and testing from James. The errors in the 126 angles in the prisms for the three sets had a standard deviation of 0·2 arcsec. The final performance tests of the first array were done at the Laboratory of the Defence Science and Technology Organisation in Salisbury, South Australia; the experiment was designed by James and Steel. The array on Optus B1 was in action on 24 July 1993 after only three nights of trying. About 200 readings were taken of the distance to the satellite and their standard deviation was 28 mm. The satellite B3 gave good returns on the first laser shots.

Optus B2 crashed after take-off and has never been recovered. A remnant went into orbit and by ironic chance was expected to disintegrate in the earth's atmosphere either on the day of James' funeral (1 June 1995) or the day afterwards. A photograph of James working on one of the prisms appeared in the *Australian Physicist* (Anon. 1990). For this project James constructed 50 retroreflector prisms in total.

4 James' Contribution to the Wider Field of Optics

James was always ready to discuss his work and to share his experiences with others. He gave a course on precision optics at the Royal Melbourne Institute of Technology to students who were mainly going into the spectacle-making industry and for a time was a member of the Subject Committee for Year 12 Physics in Victoria. But above all was his warm interaction with other professionals in the field of optics and his time was freely given.

He was always sympathetic to amateur astronomers of whom there are many in each generation and especially in Australia with its clear skies. He made the 0·2-metre doublet lens for a telescope at the Old Melbourne Observatory in the Domain, now part of the Museum of Victoria; there has long been a possibility for this to be re-opened as a public display centre. The Bedford Observatory in South Australia commissioned from him a 0·76-metre mirror, possibly the largest ever commissioned by an Australian amateur. Previously the largest was the 0·66-metre mirror made by Henry Evans Baker (1816–90) for his Newtonian telescope in about 1886 (Davis, M. E. 1990). This telescope has recently been renovated for public viewing in Ballarat, Victoria.

The Astronomical Society of Victoria commissioned a 0·51-metre mirror for its Le Marquand Telescope. The mirror was rough ground by members of the Society and James carried out the final figuring.

James received several honours. In 1975 he was awarded a Churchill Fellowship to work with Professor H. H. Hopkins in the Physics Department of Reading University. He was elected to Fellowship of the Australian Institute of Physics, until then an honour reserved for professional physicists with major research experience and many publications. In 1989 he was awarded Membership of the Order of Australia (AM) 'for services to the field of applied optics'.

In 1993 he was made an Honorary Research Associate of the Science Faculty at Monash University and was attached to the Physics Department. The first such associate of the department had been John J. McNeill. It was hoped that James would be able to contribute to the optical and astronomical thinking in the department but he was always a busy man and his final illness prevented the association from bearing fruit. He was preparing a research colloquium for the department at the time of his death.

In 1994 the Australian Optical Society established a medal. James was the inaugural recipient with the citation 'for excellence in optics, especially for contributions to optics in Australia using the design and production of aspheric surfaces' (Bolton 1995). The president of the society, Chris Walsh, said that James' work had served the practice of optics for a wide cross section of scientists and institutions in Australia. The brief ceremony was held in the Peter MacCallum Cancer Institute on 23 March 1995. The influence of James' work was reflected in the wide range of interests of his friends at the ceremony: Alan Walsh, formerly of the CSIRO Division of Chemical Physics; Peter Hannaford and Clyde Mitchell of the CSIRO Division of Materials Science and Technology; George Smith of the Department of Optometry at the University of Melbourne; John Morris, chief executive officer of the Peter MacCallum Cancer Institute, formerly a fellow student of Peter Hannaford at the University of Melbourne.

James' interest in geometrical optics made him the ideal person for one of us (HCB) to approach about understanding the action of the 'Killer Whale' *Orcinus orca* in its spectacular dashes up pebble beaches to catch seal pups as its prey. The problem arose from viewing the popular TV program 'Wolves of the Sea' which had been shown on the ABC program 'Natural History of Australia' with a commentary by David Attenborough. The photography was by the Australian couple David Parer and Elizabeth Parer-Cook (Parer and Parer-Cook 1994). The vision of the whale's eye is restricted to the circular aperture above it known as 'Snell's Window' and the geometrical image of a pup within this window is very distorted (Bolton & James, W. 1995). Little is known about the optics of the seal's eye apart from its visual acuity of 5 arcmin from external experiments. Samples of fresh seal's eyes are very rare! Fish eyes are known to have a spherically symmetrical lens with a radial refractive index gradient which reduces image aberrations (Jagger 1992).

James had published short articles on aspects of his work. One was an analysis of a photograph taken during the interferometric testing of the corrector plates for the prime focus of the Anglo-Australian Telescope (James, W. 1990a). The pattern on the photograph looked remarkably like a koala in full face and had been named 'Blinky Bill' by one of James' sons. The other article was a description of the work needed for the retro-prisms for the Optus satellites (James 1990b).

During his last years James also wrote several short unpublished notes on optical problems. He may have intended his published articles and these notes to be part of a larger body of work on lens and mirror grinding, polishing and testing, but equally they could have been directed to an assistant or possible successor. The titles and dates given here are of those notes found in his papers (they will be assembled in the archive on James):

Rubbing up Schmidt Plates (1995)
A Simple Demonstration Interferometer (2 November 1994)
The Cartesian Oval Revisited (21 July 1993), an extension of the joint work with Michael Waterworth (James, W. & Waterworth 1965)
(1) Null testing telescope mirrors using a spherical mirror.
(2) Null testing Schmidt camera corrector plates using a spherical mirror (August 1992)
An Interferometer to Measure Right Angles (September 1990)
Figuring and Testing of Astronomical Optics (no date)
Axial Wavefront Aberration (25 August 1986).

James never had a long-term assistant in his workshop, but there were times when he needed short-term assistance. Among his assistants were Arthur Coombs, now a physics teacher; T. C. (Charlie) Alldis, after his retirement as technical assistant to John McNeill of the CSIRO Division of Chemical Physics (Bolton 1983); and PhD students from the University of Melbourne and Monash University awaiting examiners' reports on their theses. John Luck of the Orroral Space Tracking Observatory sent some of his staff to work alongside James in order to benefit from his skill and wisdom. During his last year it became clear that James could spend only a decreasing amount of time in his workshop, a source of great disappointment to him. His commitment to his tasks was such that he was restless under his illness. While none of his assistants succeeded to his firm or the position he established in Australia, there was one person with whom he was closely enough involved to be able to say that the master–protégé link had been closely established. This is Gabe Bloxham of the Optical Workshop at Mount Stromlo and Siding Spring Observatories. Their friendship and professional links were strengthened in the last year of James' life when Bloxham was encouraged by his own workshop to visit and stay with James to learn his skills. James had, over a long period of time, been supplying an unfailing stream of advice to Mount Stromlo. One of James' last professional comments was to John Luck: 'Bloxham was one of the very few persons with the drive and persistence to become a master optician' (Luck 1995).

James was working on a new secondary mirror for the Orroral Telescope just before his last illness began. By March 1995 he was in hospital but still trying to get back to his workshop. The need for the new mirror arose because of shortening the distance between the primary and secondary mirrors which had altered the Ritchey–Chrétien system. The new mirror has been completed by Gabe Bloxham in the optical workshop at Mount Stromlo.

Gabe Bloxham is also completing the work started by James on the two 255-mm diameter, f/0·7 Schmidt corrector plates for spectrographs to be used with the Two-Degree-Field system of the Anglo-Australian Telescope.

In one of the curiosities of family history James was not the first in his wider Australian family to have an international reputation in optics. His wife's mother's family name was Thom and she was related to Alfred Marshall Graeme Thom (1886–1943) who started in Australia as an amateur making optical surfaces and who had written an article on the technique of grinding surfaces (Thom 1938). Thom had gone to the UK in 1938, just before war broke out, to work with the optical firm of Hilger and Watts, then run by the well known optical designer and maker F. Twyman. Thom was returning to Melbourne by sea with his wife in 1943 to take up a position for the war-time Optical Munitions Panel. The ship was torpedoed and all aboard were lost (Bolton 1991). The nephew of Thom, Dr Alec Thom, was present at James' funeral. The work of the Optical Munitions Panel was surveyed in Mellor (1958) and further analysis is given in Bolton (1990).

Perhaps the best summary of James' work has been given by Professor Alex Rodgers (1990) who wrote, referring to the contribution James has made to astronomy in Australia,

> It is not only because Bill has been based in Australia, it is because he has had such a genuinely interactive role with his astronomical customers that there have been so many successful conclusions to the projects on which he has worked.

And from the same source:

> The ANU operates an Optical Shop within Mount Stromlo and Siding Spring Observatories. Mr James has made continual inputs in terms of advice on techniques, materials and design procedures which have been of enormous benefit to Mount Stromlo and Siding Spring Observatories.

5 Some Personal Details

James met his future wife Sue Eggleston with the Eggleston family when he was returning to Melbourne from Delhi. He was introduced to the family on the railway station and they travelled by train to

Bombay and thence on the P & O liner *Iberia* to Melbourne. Sue James is now librarian at Wesley College, Melbourne. They had three sons: Kit, an anaesthetist, Tim, a musician, and Will, a science student at the University of Melbourne. James was devoted to his family and to his profession. He gave much time, often over the phone, to discussions with clients and users of his equipment about their problems. His profession gave him long-lasting friendships, with professional respect on both sides. Among such friends were J. J. McNeill, Alan Walsh, Peter Hannaford, Lloyd Rees, Pat Francis and J. K. Mackenzie of CSIRO Chemical Physics, Damien Jones, an optical designer now in Queensland, W. H. Steel of CSIRO Applied Physics and John Luck of the Orroral Space Observatory, Canberra.

A book about which he spoke appreciatively and which may express his own inner feelings was Richard Dawkins' *The Blind Watchmaker* (1986). He was aware of the need for scientific continuity, especially in the use of high-quality instruments, and he watched the loss of public sympathy for science in the latter decades with some sorrow. As an example of his interest in the continuity of scientific usefulness, he was always sad when any of the instruments to which he had contributed became under-used.

In scientific and technical discussions he was always straight to the point and often assumed that his listeners knew and understood as much as he; flattering but very often not true. This was seen when he tried out on one of us (HCB) his first drafts of lectures he was to give. Gradually James responded to suggestions to slow down the presentation. His home in Hawthorn, Melbourne, was, with its workshop, an ideal environment for James, who liked to be close to both his family and his work. He leaves behind his family and many friends who now feel the world to be emptier. He also leaves a legacy of successful scientific instrumentation in Australia that must be seen as an inspiration to a new generation of optical workers.

James had a favourite photograph taken with instruments containing components he had fabricated. It was described in his Lloyd Rees lecture, not in the published version (James, W. 1994a, 1994b) but in his script for the lecture now in the University of Melbourne Archives:

> The AAT picture that I treasure most is the 'first light' photograph of the globular cluster Omega Centauri taken on the evening of 22 June 1974. This one-hour exposure was taken using the triplet corrector before the 4-metre primary mirror was aluminised.

We reproduce part of this photograph in Figure 2.

The funeral was held on 1 June 1995. The service was taken by the Reverend Ken Lindsay, a friend of the James family. Lindsay gave an introduction to the service which had three technical appreciations, from HCB, Peter Hannaford and John Luck, each of whom spoke on various technical aspects of the work of James. The talks were interspersed with pieces of his favourite music: the overture to Gilbert and Sullivan's 'Iolanthe', guitar music played by John Williams, Aled Jones singing the *Pie Jesu* of Fauré and at the conclusion of the service the chorus from Wagner's *Tannhäuser*. Peter Hannaford spoke about the relationship between James and the CSIRO Division of Chemical Physics, especially about the troubled times in which the three corrector lenses were completed for the Anglo-Australian Telescope. John Luck discussed the making of the retro-reflector prisms for the Optus Satellites and it was a moving moment when he displayed the one remaining prism which James had only recently given him. John Luck is a capable singer, as was James, and John ended his eulogy with a song. In a long tradition of adding new words to the familiar songs of Gilbert and Sullivan,

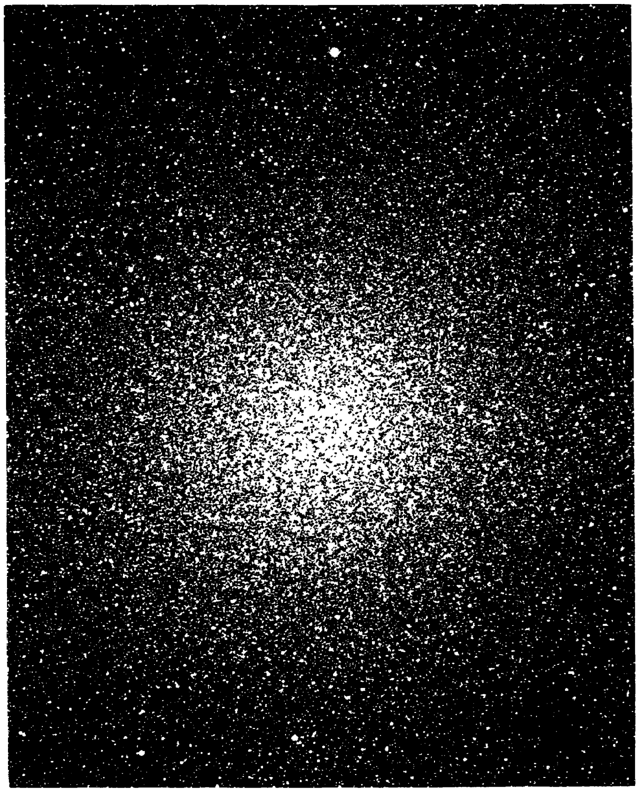

Figure 2—The Globular Cluster Omega Centauri, NGC 5139, taken at the prime focus of the Anglo-Australian Telescope on 22 June 1974 before the primary mirror had been aluminised. The triplet corrector fabricated by James was used; it yields a corrected field one degree in diameter. This particular photograph only covers an area of approximately 23 arcmin by 18 arcmin.

John sang in honour of Bill James a version of Don Alhambra's song from 'The Gondoliers', 'There lived a king as I've been told':

There lived a Bill—let's all behold
His mirror-working ways of old—
Whose heart was coated fine with gold,
A twentieth-lambda fellow!
Beyond the fringe you'd find his face
With chinks of light in every place
Like his exit pupils, and many a trace
Of green and Sodium-D yellow.
His only interfering's been
With Michelson and Twyman-Green.
His Perpendicularity Defect's been
In Retros—not in body.

(He was very upright, in carriage and in character.)

We wish all men like him could be—
No optical illusion he!
He sat at the top of the optics tree
Beloved by everybody!
Now that's the kind of Bill for me,
No optical illusion he!
He sat at the top of the optics tree
Beloved by everybody!

Acknowledgments

We wish to thank the following persons for supplying information about Bill James and his career or commenting on earlier drafts of this paper. Sue James, his widow (née Eggleston); Mrs Avril Mitchell, his sister, for notes on the family history; Dr John Luck of the Orroral Space Tracking Observatory, Canberra; Dr Bruce Poppleton, CSIRO Division of Materials Science and Technology; Dr Robert Leckey, Australian Institute of Physics, for information about James' Fellowship; Dr Russell Cannon, Director of the Anglo-Australian Observatory; Professor S. C. B. Gascoigne, Mount Stromlo and Siding Spring Observatories; Peter Gillingham, one-time Officer in Charge of the AAT; Dr David Malin, photographic scientist of the Anglo-Australian Observatory; Professor John Davis, Chatterton Astronomy Department, University of Sydney; Mrs Pamela Wendell-Smith, Archivist, University of Tasmania Library; Professor Alex W. Rodgers, Mount Stromlo and Siding Spring Observatories; Dr Sean Ryan, Anglo-Australian Observatory.

Amateur Telescope Making—Advanced 1946, Vol. 1, published by Scientific American Inc., Munn and Co. Inc., USA

Anonymous (no date, but after 1947). Optos, a pamphlet describing the work of F. J. Hargreaves' firm. [Photographs of several telescopes made by the firm. Its address was Cox, Hargreaves and Thomson Ltd, Mirastelle, Ringwood, Surrey, England. The pamphlet came from W. E. James and will be included in an archival collection for the University of Melbourne Archives.]

Anonymous 1990, Precision-optics firm wins satellite contract. Australian Physicist 27, opp. 167. [Educational Supplement p. 4 has a photograph of James working on one of the retro-prisms.]

Bolton, H. C. 1983, J. J. McNeill and the development of optical research in Australia. Historical Records Aust. Science 5 (4), 55–70

Bolton, H. C. 1990, Optical instruments in Australia in the 1939–45 War: Successes and lost opportunities. Australian Physicist 27 (3), 31–43

Bolton, H. C. 1991, A. M. G. Thom: Crossing the gap between amateur and professional science. The Victorian Historical Journal 62, 51–9

Bolton, H. C. 1995, The Australian Optical Society's Medal is awarded to W. E. (Bill) James AM, FAIP. Australian & New Zealand Physicist 32 (5), 81–2

Bolton, H. C., & James, W. E. 1995, What the killer whale sees. Australian & New Zealand Physicist 32 (4), Educational Supplement 3–6 [This is the last article written by James.]

Cannon, R. 1987, Observing the Supernova in the Large Magellanic Cloud'. Australian Physicist 24, 216–21

Davis, J. 1990, Chatterton Astronomy Department, School of Physics, University of Sydney, in a letter of 26 July 1990 to one of the authors (HCB)

Davis, M. E. 1990, Henry Evans Baker: A Brave, Able, Original Man (Privately published by the author, Brisbane, Queensland)

Dawkins, R. 1986, The Blind Watchmaker (London: Longman Scientific and Technical)

Eddington, A. S. 1940, The Expanding Universe (London: Pelican Books), A70

Gascoigne, S. C. B. 1988, Australian astronomy since the Second World War, in Australian Science in the Making, ed. R. W. Home (Cambridge Univ. Press), 345–73

Gascoigne, S. C. B., Proust, K. M., & Robins, M. O. 1990, The Creation of the Anglo-Australian Observatory (Cambridge Univ. Press), Ch. 6, p. 96 and Ch. 10, p. 168

Hargreaves, F. J. 1948, The Size of the Universe (London: Pelican Books), A193

Hargreaves, F. J. (1962–64). Letters to Bill James, May 1962 to June 1964. [Available in Adolph Basser Library, Australian Academy of Science. Manuscripts, James, W. E. MS 137. See also note in Historical Records Aust. Science (1986) 6 (3), 424. Photocopies of these letters are to be presented to the University of Melbourne Archives.]

Hartung, E. J. 1968, Astronomical Objects for Southern Telescopes (Melbourne Univ. Press), 33

Jagger, W. S. 1992, The optics of the spherical fish lens. Vision Research 32 (7), 1271–84

James, V. 1973, This Religion Business (Melbourne: Beacon Publications)

James, V. (date unknown), Why I am a Unitarian

James, V. 1981, Windows on the Years (privately printed)

James, W. E. 1990a, An exercise in practical optics. Australian Physicist 27, 59–60

James, W. E. 1990b, Note on polishing a cube. Australian Physicist 27, Education supplement, p. 4 [opp. p. 167]

James, W. E. 1994a, Beyond the fringe—Making optics for astronomy. Newsletter of the Australian Academy of Science No. 25

James, W. E. 1994b, Australian & New Zealand Physicist 31, 226–30

James, W. E., Steel, W. H., & Evans, N. O. J. L. 1990, Design and testing of a cube-corner array for laser ranging. Soc. Photo-Optical Instrumentation Engineers, Optical Fabrication & Testing 1400, 129–36

James, W. E., & Waterworth, M. D. 1965, A method for testing aspheric surfaces. Optica Acta 12, 223–7

Jeans, J. H. 1937, The Mysterious Universe (London: Pelican Books), A10

Jeans, J. H. 1939, The Stars in their Courses (London: Pelican Books), A59

Luck, J. 1995, Eulogy delivered at the funeral of W. E. James, 1 June 1995
Malin, D. 1993, A View of the Universe (Cambridge Univ. Press)
Mellor, D. P. 1958, The Role of Science and Industry in Australia in the War of 1939–1945 (Canberra: Australian War Memorial), Series 4, Number 5, Ch. 12
Parer, D., & Parer-Cook, E. 1994, The complicated killer, Wildlife Magazine of BBC 12 (3), 38–46
Rodgers, A. W. 1990, Letter of July 1990 to one of the authors (HCB)
Thom, A. M. G. 1938, Hints on the polishing, figuring and after-care of high-grade optical surfaces. Laboratory Journal of Australia 1, 128–31 [Reprinted in the standard text of Twyman, F. 1952, Prism and Lens Making: A Textbook for Optical Glassworkers (London: Hilger and Watts), 44–8]
Thomson, J. V. 1952, An account of the grinding, figuring and testing of the 200-inch mirror for the Hale Reflector, in Twyman, F. 1952, Prism and Lens Making: A Textbook for Optical Glassworkers, 2nd edn (London: Hilger and Watts), 568–76

Appendix

(1) *Extract from James' Curriculum Vitae dated 8 March 1995*

Born 6 March 1931, Yeovil, Somerset, England. Lived in Aberdare, South Wales, 1933–47. Arrived in Australia July 1947. Educated at Grammar School, Aberdare and University High School, Melbourne. Matriculated, Melbourne, 1950. Taught mathematics and science at junior High School level—Victorian Education Department 1952 to 1955 ...

The following is a brief resumé of some of the more interesting optical projects carried out during the last twenty-five years:

(1) Anglo-Australian Telescope: prime focus correctors (tender won against overseas bids).
(2) 1-metre telescope: University of Tasmania.
(3) 0·75-metre telescope: Bedford Observatory, SA.
(4) 0·5-metre telescope: SA Jubilee telescope.
(5) 0·5-metre TV acquisition telescope: AAT.
(6) 0·45-metre telescope: University of Wollongong.
(7) 0·45-metre telescope: Monash University.
(8) Re-figured 0·4-metre mirror for Monash University.
(9) 0·4-metre telescope: University of Melbourne.
(10) 0·4-metre telescope: CSIRO Solar Physics Group.
(11) 0·6-metre paraboloid: Fairey Australasia, SA, for off-axis paraboloids.
(12) 0·4-metre convex hyperboloidal mirror: AAT chopping secondary.
(13) Optics for prototype stellar interferometer: University of Sydney.
(14) 150-mm aperture Fabry–Perot interferometer plates: Mawson Institute, SA.
(15) 200-mm aperture Mach–Zehnder interferometer optics: ANU School of Physics.
(16) f/1·6 Schmidt spectrographic camera: MSSSO.
(17) f/1·6 Schmidt spectrographic camera: MSSSO, later redesigned and reworked to accommodate a new detector system.
(18) Two f/1 Schmidt plates for spectrographic cameras: MSSSO.
(19) f/2 Schmidt spectrographic camera: AAT.
(20) 200-mm aperture Twyman–Green interferometer optics: Fairey Australasia.
(21) Multi-Spectral Scanner optics: Fairey Australasia.
(22) Endeavour telescope and CVU Optics: AUSPACE (Shuttle launch date January 1992).
(23) Cube Corner Retroreflector prisms for OPTUS B1, B2 satellites. A laser-ranging facility—made 50 off.
(24) Singlet lens, 325-mm diameter, figured null for CSIRO, NPL Fizeau interferometer.
(25) Baker–Nunn camera. Reground, polished and aspherised the front surface of the corrector lens.
(26) 0·5-metre ASV primary mirror.

Work in progress:

(27) New 0·4-metre hyperboloidal convex secondary mirror for the 1·5-metre laser-ranging telescope at Orroral Valley Observatory.
(28) Two 255-mm diameter f/0·7 Schmidt corrector plates for the AAO.

In addition to the above optics I have done production runs of optical components for industry. This work has included many hundreds of precision optical items—lenses, optical flats, mirrors, prisms, etc.

Consultancies:

(1) Cox, Hargreaves and Thompson.
(2) Colombo Plan: I.I.T. Delhi.
(3) UNESCO: three-month consultancy, Pakistan, 1979.
(4) MSSSO: Design of various spectrographic cameras.
(5) STARLAB: Oblique reflector corrector.
(6) CSIRO.
(7) Department of Science and Technology: Large Earth-Based Solar Telescope, report no. 21—Manufacture and testing of optical mirrors.
(8) Fairey Australasia: Design of Multi-Spectral Scanner optics.
(9) Auspace.
(10) Department of National Mapping: Laser-Ranging Telescope.
(11) Electro Optic Systems Pty Ltd.
(12) British Aerospace Australia.

Publications:

A method for testing aspheric surfaces. With M. D. Waterworth. Optica Acta, Vol. 12, No. 3, July 1965, pp. 223–7.
Oblique Reflector Corrector. An analysis in the STARLAB phase B studies, 1983.
Line diffraction test. With R. Hariharan. Applied Optics, Vol. 25, 1 November 1986, pp. 3806–7.
Manufacture and testing of the LEST mirrors. Technical Report No. 21 in the LEST FOUNDATION technical report series, published at the Institute of Theoretical Astrophysics, University of Oslo, 1986.
Design and testing of a cube corner array for laser ranging. With W. H. Steel and N. O. J. L. Evans. Proceedings of SPIE Conference, Singapore, Volume 1400, 1990, pages 129–36.
Prime focus correctors for the spherical mirror. With D. J. Jones. Applied Optics, Vol. 31, No. 22, August 1992, pp. 4384–8.

(2) *Note on the AAT Prime-Focus Correctors.*

The following quotations are from James' Lloyd Rees Lecture (James, W. 1994a, 1994b):

The optical system of the AAT follows the Ritchey–Chrétien design, with the primary mirror figured to a hyperboloid. This system gives an extremely well corrected field at the f/8 Cassegrainian focus. The price paid for this advantage is that the f/3·3 prime focus is uncorrected on axis by about 70 wavelengths and needs to be corrected with ancillary lens systems placed before the focal plane to provide suitable field coverage. Three such correctors were made: a singlet aspheric plate covering a field of 10 arcmin, a doublet lens to cover a field of 25 arcmin and a triplet lens with a field of 60 arcmin.' The three correctors are shown in Figure 6·4 on page 77 of Gascoigne, Proust & Robins (1990).

After coating of the triplet lens corrector, the lenses had to be reworked because of a failure in the coating procedure. The lenses were taken interstate to the only vacuum coating plant that could handle the lens sizes. The surfaces were anti-reflection coated with magnesium fluoride and the person doing the coating ... deposited white-hot globules of aluminium (present as a contaminant) on the lens surfaces. This created a scatter of tiny craters which in some cases required the lens surfaces to be re-ground and all the surfaces re-polished. As you can imagine, my return trip to Melbourne was not a happy one.

A few days after my return I rang John McNeill [see Bolton 1983] of CSIRO Chemical Physics and told him what had happened. He came straight over and examined the lenses. John McNeill was as hurt ... as I was. Later the same day he rang to say that he had discussed the situation with Lloyd Rees and that, if I girded my loins as it were, and re-worked the lenses, then the Division of Chemical Physics would undertake to coat the surfaces. This magnificent offer, made so promptly, put me back on track and the painful process of re-grinding the previously fine-polished surfaces was started.

In the meantime the Division built a new coating chamber large enough to take the lenses and the optical workshops also assisted in re-building a tiled smoothing tool for the surface that was most badly affected. This help was given by a young Pat Francis who, I'm sure, remembers well the occasion.

John McNeill, with the assistance of Ray Carter and Keith Haberle, experimented with coating and thickness monitoring and, in due course, John McNeill successfully coated the lenses which were then mounted in the cell.

The completed triplet corrector was duly acceptance-tested by S. C. B. Gascoigne and Peter Gillingham and delivered to Siding Spring. The correctors were the largest built in Australia up to that time; the largest component is a 0·46-metre diameter lens. The correctors worked from the day they were installed.

The first real observations were made on the night of 27 an 28 April 1974 by S. C. B. Gascoigne (Gascoigne et al. 1990): a ten-minute exposure of the Globular Cluster NGC 6266 done with the mirror not yet aluminised. The plate showed good star images about 1 arcsec in diameter across the full one-degree field of view. The aluminising plant did not reach Canberra from England until months later and the telescope was not fully available until July 1975.'

In June 1974, still before the primary mirror was aluminised, a plate was made by Gascoigne of the globular cluster Omega Centauri, NGC 5139, the central part of which is reproduced in Figure 2.