The Great Melbo

Ragbir Bhathal traces the chequered history of the Great Melbourne Telescope in Australia, from initial disappointment to recent research success.

The Great Melbourne Telescope (figure 1) has probably had the most eventful history of any in the world, from its inception in London in the 1850s to its final demise as a result of a bushfire in 2003. It was conceived as a powerful instrument for studying the southern hemisphere, but problems in manufacture and operation led to many years of wrangling across the continents, after which it was overtaken by new technology. Yet after it moved to Mount Stromlo near Canberra in the 1940s, the venerable instrument was rejuvenated and played a key part in 20th-century astronomy, in the search for MACHOs.

It all began with an ambitious idea among the elite of UK science and astronomy, of designing and building a large southern telescope to be located at the Cape of Good Hope, to observe and make drawings of the southern nebulae so that they could be compared with Sir John Herschel's 1830s sketches and look for differences. The idea was vigorously discussed by a Royal Society Telescope Committee comprising, among others: Lord Rosse; Thomas Robinson, the Director of Armagh Observatory; George Airy, Astronomer Royal; Edward Sabine, a long-serving secretary of the British Association, foreign secretary of the Royal Society and scientific advisor to the Admiralty; and the well known telescope maker Thomas Grubb. While there were disagreements on the design of the telescope, they agreed it should have a speculum mirror of approximately 48 inches diameter, with lattice tube and clock drive to track the revolving night sky (Perdix 1992, Royal Society of London 1871, Warner 1982). They were an influential group with the right connections with the political elite and the government of the day, but they were not influential enough. They were unable to convince the government to grant them funds to build their dream machine. It was the Crimean War that thwarted their ambitions: the government needed money for the war effort.

A change of plan

A solution came from the "colonial boys" in Victoria, Australia. Victoria was enjoying a gold rush and had plenty of money to spend on arts and sciences. It also had ambitions of becoming the Paris or London of the southern hemisphere. The young, energetic and newly appointed professor of mathematics at the University of Melbourne, William Wilson, seized the opportunity to further the cause of the large southern telescope (Serle and Ward 1976). Through his contacts with Britain's scientific leaders he resurrected the plans and the Great Melbourne Telescope was built by Grubb in Dublin, reaching Melbourne Observatory on 6 November 1868, ready to observe nebulae.

It was the second largest telescope in the world and arrived in Melbourne with much fanfare and publicity. However, the telescope failed to live up to expectations (Hyde 1987). The problems were plentiful: the mirror had a mealy appearance because the wrong solvent had been used to remove the shellac from its surface, and the eye-stops for the telescope eyepieces had been incorrectly changed. Thus began the "GMT wars", in which the blame game was played out in the press in Australia and England.

The development and establishment of the GMT in Melbourne had involved three parties: the committee of the British scientific elite, Thomas Grubb of Dublin, and the scientists and bureaucrats in Melbourne. The President of the Royal Society, Sir Edward Sabine, placed the blame for the non-functioning of the telescope squarely on the inexperience of the colonials. In his annual address of 30 November 1869, he said: "Its performance since erection does not appear to have given altogether the same satisfaction at Melbourne that it did in Dublin; but the defects complained of may arise partly from imperfect knowledge of the principles of the instrument and inexperience in the use of so large a telescope, partly from experimental alterations made at Melbourne, and partly from atmospherical circumstances," (Royal Society of London 1871). This was despite the fact that the UK had sent one of their own – Albert Le Sueur – to erect and commission the telescope in Melbourne.

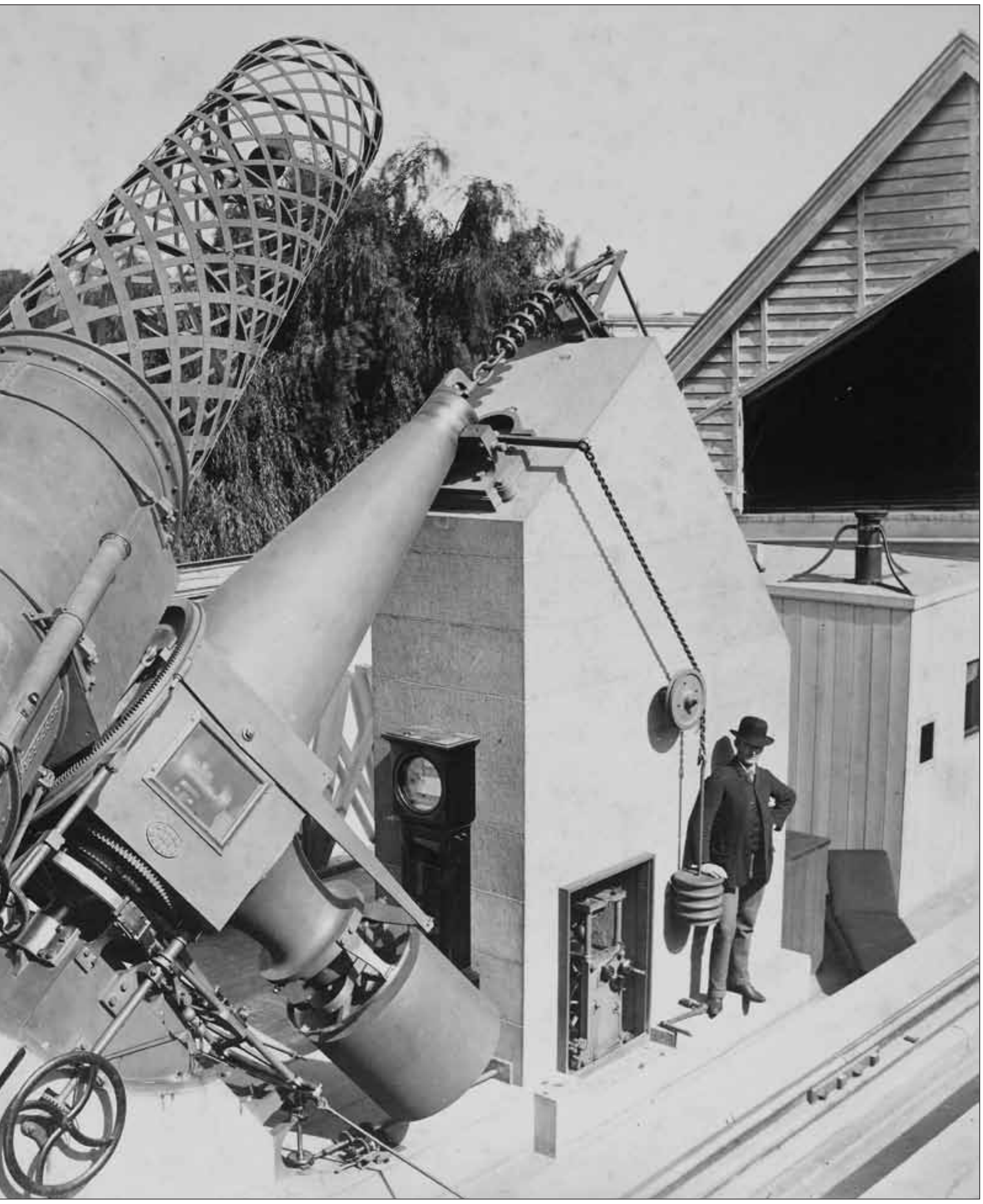
Le Sueur had been a wrangler at Cambridge in 1863 and had studied under George Stokes, the Lucasian Professor of Mathematics. Stokes recommended Le Sueur for the Great Melbourne Telescope project even though he had only a theoretical understanding of astronomy. He was given astronomical coaching by mathematician and astronomer John Couch Adams, and later Walter De la Rue trained him in celestial photography. His training was topped by working for a few months in Grubb's workshop in Dublin.

Le Sueur was very much in charge in Melbourne. All correspondence regarding the erection, functioning and progress of the telescope was between Le Sueur and the Telescope Committee in Britain, according to Robert Ellery, director of the Melbourne Observatory. Ellery was virtually left out of the picture and wrote to George Verdon, the agent general in London for the state of Victoria: "All communications, accounts of progress, parcels, etc. are addressed to Mr Le Sueur. No communications whatever comes to me and on several points I have been unable to take action where action was required," (Gillespie 2011). It would appear that the chain of command had not been followed by the committee, which contributed to the problems faced by the telescope.

In the GMT wars, the blame for the problems that beset the Great Melbourne Telescope was laid squarely at the feet of Le Sueur. He successfully repolished Mirror A, the focus of the acrimonious debate between the British Tele-

1: The Great Melbourne Telescope, circa 1880. The astronomer is probably Joseph Turner, GMT observer from 1873–83. (Museum Victoria)

urne Telescope



scope Committee and the Melbourne staff, but in August 1870 he left Melbourne and never returned to the British scientific community. He spent his remaining days teaching mathematics.

The GMT wars rumbled on and in 1871 the Royal Society of London published *Correspondence Concerning the Great Melbourne Telescope In Three Parts: 1852–1870* to justify and defend its stand on various matters concerning the telescope.

Results at last

Despite the shortcomings of the GMT, some of its defects were corrected in the following years by Ellery. In October 1871, Farie MacGeorge, a Melbournian who had replaced Le Sueur, was able to catalogue 109 stars in a small area near the star Eta Carinae, an area where John Herschel had recorded only 39 stars. Ellery saw this as a triumph for the power of the Great Melbourne Telescope and wasted no time in informing Edward Sabine. In his presidential address to the Royal Society of London in November 1871, Sabine said: "As the existence of the Great Melbourne Telescope is in no small degree owing to the exertions of Members of this Society, and to their influence, you will be glad to hear that it is now in regular and successful work, after several difficulties and misadventures, such as often occur in the early trials of uncommon instruments or new sorts of observations," (Gillespie 2011).

In 1885, Ellery published the *Observations of the Southern Nebulae made with the Great Melbourne Telescope from 1869 to 1885*. By this time most of the members of the committee had passed away, except for Walter De la Rue, and the controversy that the Great Melbourne Telescope had generated had all but been forgotten. But, by this time, the telescope was no longer a technological marvel. A review of the annual reports of Melbourne Observatory reveal that very little scientific work was performed with the GMT after 1885, in part because of deterioration in the instrument. Ellery tried repolishing the mirrors but was unsuccessful in getting them back to their original state. But the telescope also became less used because it was not suitable for new technologies such as photography. Fast gelatin plates were being introduced for astronomical photography – spelling the end of pencil sketches – and the GMT could not be used for the long exposures necessary.

Ben Gascoigne, who used the GMT in the 1950s and 60s, was correct in his assessment of the telescope when he noted: "The real problem was that the telescope had been built for the explicit purpose of making hand-and-eye drawings of the southern nebulae. This was a difficult technique at which the Melbourne observers became surprisingly adept, but it was flawed for reasons and to an extent not sufficiently appreciated at the time, and the technique could make no real contribution to the problem of classifying nebulae … the telescope could do neither photography nor spectroscopy, and it fell into disuse. Even if the mirror had been made of silver-on-glass, it would have made no difference," (Gascoigne 1995).

Gascoigne made a comparison of the photographs of NGC 1365, NGC 5128 (Centaurus A) and NGC 5236 (M83) with the drawings of these objects made by Herschell, Lassell, Joseph Turner (an observer employed by Melbourne Observatory; figure 1) and Pietro Barrachi (who succeeded Ellery as the director of the observatory). He found that the drawing technique only captures the broad features and not the details of the complex structure of the objects. After an analysis of the drawings, Gascoigne (1995) came to the conclusion that it was not the staff at Melbourne Observatory who were to blame for the failure of the telescope, but "the body who put it forward in the first place, the Royal Society Committee".

A futher problem was that the observatory joined the Carte du Ciel project in 1890. This tremendous project eventually led to the demise not only of the Melbourne Observatory, but also of the other state observatories because of the long drawn-out observing and cataloguing of the southern sky. The observatory's major programme was meridian astronomy – mainstream astronomy at that time – rather than the work needed for the Carte du Ciel, which consumed much of the time and energy of observatory personnel. The financial crash of the 1890s didn't help the observatory's finances, either. The observatory was closed down by the Victoria government on 8 March 1944 and the GMT was bought by Richard Woolley, the director of the Commonwealth Solar Observatory at Mount Stromlo.

At Mount Stromlo

On arrival at Mount Stromlo, the Great Melbourne Telescope was extensively modified. The original speculum metal mirror was replaced with a new 1.27 m aluminized Pyrex mirror, the polar axis was lengthened, the tube shortened and the drive and controls motorized. Ben Gascoigne became the first big user of the telescope, in the 1950s and 1960s, for his photoelectric observations of cepheids in the Magellanic Clouds and the Milky Way with the American astronomers Olin Eggen (who became director of Mount Stromlo Observatory from 1966 to 1977) and Gerald Kron, a photometer expert. Their papers influenced ideas about the intrinsic colours of the cepheids and provided improved distance moduli for the Magellanic Clouds (Eggen *et al.* 1957, Gascoigne and Eggen 1957, Gascoigne and Kron 1965). But with the arrival of the 74-inch at Mount Stromlo in the mid-1950s, and the Anglo-Australian Telescope at Siding Spring in the early 1970s, the GMT was used less and less by astronomers. It was decommissioned in 1973 when its declination bearing failed.

The GMT came into prominence once again following the appointment of Alex Rodgers as director of the observatory in 1986. Rodgers was an exceptional instrumentalist and enjoyed nothing more than spending time in the observatory's workshops with the technical staff, getting his hands dirty. Engineering was his passion, especially optical engineering. He was involved in the design and development of several pieces of equipment for use in the observatory's research programmes. One of his first development projects was to design and build a spectrophotometer for the Great Melbourne Telescope. This instrument was used for several interesting PhD theses by astronomers such as Michael Bessell and John Norris, who went on to establish themselves at the international frontiers of astrophysics.

Rodgers kept the observatory's instrumentation up to date, thus enabling it to remain at the competitive edge of international astronomy. However, his greatest challenge came when he had to refurbish the Great Melbourne Telescope and convert it into a computer-controlled and wide-field imaging telescope for use in answering one of the most intriguing questions in astrophysics: what is dark matter?

For a long time, astronomers had believed that the mass in galaxies was distributed in the same way as the light that came from them. Thus, the rotational velocities of stars would decline as one moved away from the centre of the galaxy. However, much to their surprise, observations of spiral galaxies showed that the rotational velocities remain much higher than predicted out to the most distant measured parts of the galaxies; in 21 cm radiation from neutral hydrogen, these high velocities are maintained well outside the visible disc. This was quite a surprise. Mount Stromlo astronomers also found these discrepancies in their observations. John Norris and Mike Hawkins from the Royal Observatory in Edinburgh carried out observations of the motions of stars in our galactic halo, extending to 200 000 light-years. They found the influence of gravity from unseen material extended to at least half this distance (Norris and Hawkins 1991). With his student Claude Carignan, Ken Freeman studied four key galaxies (the Sm galaxy NGC 3109 and the Sd galaxies NGC 7793, NGC 247 and NGC 300 in the Sculptor Group) and found evidence that they had dark halos of mass comparable to their luminous material (Carrignan and Freeman 1985). In fact, Freeman was cited as one of the first astronomers to suggest that the rotation curves of some spiral galaxies seem to imply the presence of invisible matter (Freeman 1970).

On a visit to Princeton in 1984, Freeman met Bohdan Paczynski who proposed that it would be possible to test which of the two most popular theories about dark matter was correct by performing a gravitational lensing experiment (Paczynski 1986). There were two competing ideas for the nature of the dark matter: MACHOs or WIMPS. MACHOs is an acronym for massive (astrophysical) compact halo objects, WIMPS an acronym for weakly interacting massive particles that was coined by particle physicists. For gravitational lensing to work there has to be almost perfect alignment between a distant star, a dark-matter object and an observer. The mass of the dark matter would act as a lens and increase the brightness of the distant star by several orders of magnitude. The greater the mass in dark matter, the greater the effect, so this technique was expected to be able to detect MACHOs. According to Paczynski: "In any nearby galaxy one star out of a million is strongly microlensed by a 'dark' object located in the galactic halo, if the halo is made up of objects more massive than about 10^{-8} solar mass. Monitoring the brightness of a few million stars in the Magellanic Clouds over a timescale between two hours and two years may lead to a discovery of 'dark halo' objects," (Paczynski 1986). He also noted that the "observational project is not simple". The best place to try this was in the southern hemisphere, using the Magellanic Clouds, and Mount Stromlo Observatory was an ideal place to carry out the project.

This idea fired the imagination of US astronomers Charles Alcock from the Lawrence Livermore National Laboratory (LLNL) and Chris Stubbs from the University of California Centre for Particle Astrophysicists (CFPA) at Berkeley. Freeman was instrumental in getting the observatory involved in the project. The MACHO programme involved "the monitoring of the light intensity of millions of stars in the Large Magellanic Clouds, Small Magellanic Clouds and the galactic bulge fields each night to detect the amplification that may occur through gravitational lensing when a massive object passes close to the sight line to the background star", according to Hart (Hart *et al.* 1996). The programme required a "dedicated telescope of significant aperture and wide field to ensure detection of enough lensing events for statistically useful analysis of the mass spectrum of the lenses and to characterize the structure of the dark halo".

The Great Melbourne Telescope was the ideal choice for the project. It was lying idle because it had suffered a catastrophic mechanical failure in 1973 and there was no money available to fix it. This is where Rodgers, as director of the observatory, came into the picture. He was the key to the project, according to Alcock: "Alex went out on a long limb in committing MSSSO (Mount Stromlo and Siding Spring Observatories) to MACHO, at a time when most of the astronomical establishment believed that the project would not succeed. He clearly recognized the potential for MACHO to be very important and he acted on this judgement decisively. He did this at a career stage when most of our colleagues are much more risk averse," (Freeman 1997).

Refurbishment

Rodgers agreed to refurbish the telescope completely and assign it to the project for the next four years – later extended. Alcock ran the project while Stubbs built the detector, which was one of the first cameras to use mosaic CCDs. The responsibility for developing two detector mosaics, each comprising four 2048 × 2048-pixel CCDs, was given to the Centre for Particle Astrophysics in California (Stubbs *et al.* 1993). The completed instrument had a field half a degree across – about the size of a full Moon. The provision of computer resources and the development of the software codes needed to handle the enormous amount of data reduction generated by the experiment was given to the Lawrence Livermore group. Ken Freeman, Bruce Peterson, Peter Quinn and Alex Rodgers represented the Mount Stromlo team, which was made up of a dozen researchers. Observations began in July 1992.

There was great excitement in the astronomical community when the first year's observations of microlensing objects were published in *Nature*, which featured the story with a

Repurposing the Great Melbourne Telescope… again

Following the fire at Mount Stromlo in 2003, only the original cast iron structure of the GMT remained. This suffered further neglect, being exposed to the elements for five years. But the remains of the GMT were returned to Melbourne in 2008 and work has begun to rebuild it, aided by more than 50 volunteers. The plan is that the restored GMT will have state-of-the-art 50-inch optics, making it one of the biggest telescopes in the world dedicated to public use, as well as having a capability for some useful scientific work and for use over the internet. It is hoped it will become a major tourist attraction in Melbourne. The restoration is a joint project between Astronomical Society of Victoria, Museum Victoria and Royal Botanical Gardens of Victoria.

http://greatmelbournetelescope.org.au

2: The GMT at Mount Stromlo shortly after the 2003 bushfire. (Australian National University)

cover. Writing in the journal, Alcock said: "We report a candidate for such a microlensing event, detected by monitoring the light curves of 1.8 million stars in the Large Magellanic Cloud for one year. The light curve shows no variation for most of the year of data taking, and an upward excursion lasting over one month, with a maximum increase of ~2 mag. The most probable lens mass, inferred from the duration of the candidate lensing event, is ~0.1 solar mass," (Alcock *et al.* 1993). This mass made it an excellent MACHO candidate.

The project wound up in December 1999, by which time more than 200 000 million individual measurements had been made. The results indicated that about 15 microlensing events had been observed for the Large Magellanic Cloud, two for the Small Magellanic Cloud and several hundred towards the centre of the Milky Way, the latter probably caused by normal stars. In reviewing the results of 5.7 years of microlensing observations, Alcock said: "One of our most important conclusions is that a 100% all-MACHO Milky Way halo is ruled out at the 95% confidence level for a wide range of reasonable models," (Alcock *et al.* 2000).

Two other groups (Aubourg *et al.* 1993, Udalski *et al.* 1993) that had taken up the challenge also reported their results in 1993. In the end, the MACHO and similar experiments elsewhere have not solved the problem of dark matter. In fact, they have raised more new questions than provided answers. According to Georg Raffelt (2001): "The early excitement about the apparent discovery of some or all of the galactic dark matter has given way to a more sceptical assessment – the apparent mass range of the observed events simply does not seem to make sense. Perhaps the least troublesome interpretation is that one is not seeing MACHOs but normal stars as lenses, which is possible if there is an unrecognized population of stars between us and the Large Magellanic Cloud themselves if their distribution is different from what had been thought. Thus, while the observed microlensing events are no doubt real, the question of where and what the lenses are remains for now wide open."

The end of the GMT

On a hot summer's day in 2003, the observatory suffered an unforeseen catastrophe. Fires had been burning in nearby rural areas for some time and extensive preparations had been made to protect life and property. However, on the afternoon of 18 January, more than one fire front converged on Mount Stromlo, leaving an unprecedented trail of devastation. According to Penney Sackett, the then director of the observatory: "When the damage was assessed it was clear that we had lost all of our research facilities – that is, all of our research telescopes, all of our library facilities, and our workshop where we had built instruments for our own telescopes and telescopes for other organizations," (Bhathal 2013). The fires had engulfed the Great Melbourne Telescope and the aluminium dome had melted (figure 2).

It was a sad day for Australian astronomers and astronomy. It was the end of a great telescope, unfortunately born at a time when new developments in optical technology and the new astronomy called astrophysics were just emerging. In hindsight it would appear that the originators of the idea of the great telescope were timid men who were not willing to take a gamble on the new optical technology. Yet the GMT acquired a life of its own in the nation's astronomical heritage. ●

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