The 15-inch Equatorial Reflector by Thomas Grubb at Armagh Observatory

C.J. Butler

Introduction

The giant 4-foot diameter reflecting telescope designed and built by William Herschel in England in the early 19th century and its even larger successor, the 6-foot diameter reflector built by Lord Rosse in Ireland in the 1840s, are well known to historians of science. Both of these telescopes employed what are essentially, alt-azimuth mountings, though in the case of the latter, its azimuthal movement was severely restricted by the masonry walls which supported the immense weight of the instrument. In order to keep the celestial objects in view for more than a few seconds, these cumbersome telescopes needed to be moved non-uniformly in both altitude and azimuth by manually operated machinery. The next great step in telescope design required a mounting about which the motions of the sky were uniform - that is an equatorial mounting. With such a construction, the motive power to drive the telescope could be supplied by a machine, normally in the early days - clockwork. A proposal for a clock-driven equatorial telescope was first made by Hooke in the late 17th century.[1] However, it was not until the second half of the 18th century that a practical instrument of this type was constructed by Jesse Ramsden.[2] Indeed the initial plans for Dunsink Observatory, near Dublin incorporated a dome which was intended to house such an instrument.[3] Sadly, neither the dome nor the instrument were actually built.

Finally, a successful clock-driven equatorially mounted telescope was built by Fraunhofer in Dorpat (*c.* 1824). However, this was a 9.5-inch refractor of relatively light construction compared to the giant reflectors of Herschel and Rosse. The first successful equatorially mounted and clock driven reflector was built for Armagh Observatory by Thomas Grubb of Dublin and erected there in 1835.[4] This innovative instrument was a crucial link in the evolution of Grubb's telescope design that lead to the Great Melbourne Telescope (GMT) and other large Grubb reflectors that became the workhorses of a number of observatories around the world during the first half of the 20th century. It gained this position, not from the observational work it enabled (in the cloudy, wet climate of Ireland) but in the inspiration and practical expertise it gave to Thomas Romney Robinson who was able to expound its virtues to the growing scientific community in the UK and, in particular, to the Committee set up by the Royal Society to promote the construction of a large reflector in the Southern Hemisphere.

Fig. 1 *Thomas Grubb. Photo Mrs Violet Coburn*

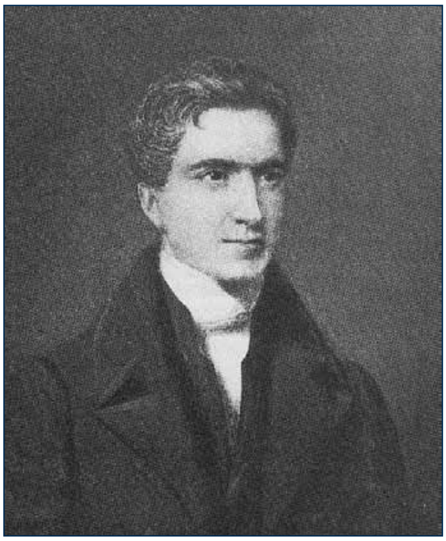

Fig. 2 *Thomas Romney Robinson.*

Grubb, Robinson and Cooper

Thomas Grubb (1800 -1878) (Fig. 1) ran a successful engineering company in Dublin specialising in such diverse products as cast iron billiard tables and machines for printing banknotes.[5] He became a close friend of Thomas Romney Robinson (Fig. 2), a former Fellow and lecturer in physics at Trinity College, Dublin, who subsequently, in 1823, was elected to the position of Astronomer at Armagh Observatory. Grubb was interested in optics and built himself a nine-inch reflecting telescope which he opened to the public in Dublin.[6] Thus began one the most successful telescope manufacturing companies of the 19th and 20th centuries. His first substantial commission in telescope construction was a mounting for a lens belonging to Edward Cooper (1798-1863) of Markree Castle, County Sligo.

Cooper, the son of a wealthy landowner, attended as a boy, the Royal School, Armagh.[7] During this time, he is believed to have visited the Observatory there and became interested in astronomy. When he inherited Markree Castle and its estate in 1830 he decided to build an observatory of his own. In due course it came to be recognised as one of the best equipped private observatories in the World and, together with Andrew Graham his industrious assistant, Cooper compiled and published a catalogue of the positions and magnitudes of 60,000 stars near the ecliptic.

In 1830, Cooper heard that Cauchoix in Paris had succeeded in making two large telescope objectives, one of 12-inches diameter which was bought by Sir James South and the other of 13.5 inches. Cooper bought the larger of the two and, on the advice of Robinson, ordered from Thomas Grubb an equatorial mounting with a clock drive. An excellent engraving of this instrument, as it appeared in 1834, showing Grubb's characteristic tapered cone polar axis, the rolled iron tube and the circular gear wheel for the drive, survives in the library of Trinity College Cambridge and is reproduced by Glass (1997).[8]

So when Robinson asked Grubb to build him an equatorial mounting and reflecting telescope for Armagh, Grubb already had a clear idea of what was required; several features of the Markree mounting are similar to those for the Armagh telescope. In fact, it appears that the mounting of the Armagh reflector (supplied in 1835) probably predates the Markree mounting as Robinson (1842) remarks in a footnote to his report to the Governors:

> '*The East Equatorial is a reflector of 15 inches aperture, used either as Cassegrain or Newtonian, by Mr Grubb of Dublin; its mounting was constructed as an experimental model of Mr Cooper's great Equatorial, but only calculated to bear a ten feet Newtonian of Sir William Herschel; it is, however, abundantly strong for its present load. The circles, being only intended as Finders, are but 9 and 10 inches diameter, but it is capable of giving absolute places*

to a few seconds. It has a very effective clock movement and micrometer; its optical power is such, that I have seen the 6th star of the Trapezium in Orion's Nebula.'

As the Markree telescope was erected in 1834, it therefore seems likely that the mounting of the Armagh telescope was made in 1832 or 1833. This would suggest that parts of the Armagh 15-inch reflector are the earliest surviving parts of a Grubb telescope. However, another early Grubb mounting, very similar to that in Armagh, has recently been found in University College, Galway for which the provenance is unknown.[9]

The Optical Design of the Armagh 15-inch Reflector

Unfortunately for the historian of telescope design, no comprehensive description, drawing or photograph, of Grubb's 15-inch telescope is known to survive, if indeed any were ever produced. Thus we may resign ourselves to rediscovering the telescope from the surviving parts and various notes and references in archives and correspondence, particularly those between Robinson, Grubb and Lord Rosse. Much of this information derives from discussions between members of the committee set up by the Royal Society to consider the proposal for a Great Southern Telescope (GST) which in due course was to materialise as the GMT.[10]

For instance, in a report published by the Royal Irish Academy in 1853[11], Robinson compares the Newtonian and Cassegrain configurations and gives arguments why he prefers the latter to the former for the GST. This is clearly based on his experience with the 15-inch Grubb at Armagh which could adopt either form. By building a telescope that could be operated in both configurations, Robinson was able to assess the merits of both and make recommendations based on his own experience and knowledge, in as far as they went.

Referring to the proposal to erect a large southern telescope, Robinson[12] wrote:

'I suggested that it might be desirable to try the Cassegrain: this was thought deserving of attention, and, in the hope that it may be acted on, I offer some rules for determining the dimensions of its parts, which will not be unimportant in so gigantic an experiment. They were investigated by me many years ago, when directing the arrangements of that which Mr Grubb constructed for the Armagh Observatory which is 15-inches aperture, and its performance is such as to justify an expectation that this form may be made of much greater magnitude. The Cassegrain has been but little used; in fact I know of two besides that referred to, which have been made of larger aperture than 6-inches: one of 18-inches by Lord Rosse, who however uses it as subsidiary to his larger telescopes, and has not given special attention to its improvement. The other was made by the elder Tulley about 1800: it was 15-inches aperture, and 7 feet focus; but it appears to have been indifferent; for, according to the notes of William Walker (a competent judge) it showed Rigel like a shilling, and the companion was not seen at all. At that time, however, the proper method of supporting the great speculum was not known.'

Robinson goes on to describe the disadvantages and advantages of the Cassegrain system, compared particularly to the Newtonian. He notes the following disadvantages: (1) the excessive size of the Cassegrain image; 4-5 times larger than that of a Newtonian. This would be particularly important for extended objects such as nebulae. (2) The light must pass three times through the tube, as opposed to twice with the Newtonian, which leads to a greater image disturbance from convection currents. (3) The secondary mirror is larger and thereby blocks a larger proportion of the light.

Against these, Robinson notes the following advantages of the Cassegrain configuration: (1) The tube is shorter. This could be particularly important for instruments that are housed in a dome. (2) The observer is near the ground, thereby eliminating the necessity for elaborate apparatus to support him at the top of the tube. (3) Any error in the figuring of the primary mirror can be corrected by the figure of the secondary. He mentions that, in the case of the Armagh 15-inch, the primary was made parabolic so that it could be used as a Newtonian and the secondary worked to compensate for any deviation from the Cassegrain form. (4) The field of the Cassegrain for a given magnification is flatter than the Newtonian. (5) The greater magnification of the Cassegrain facilitates micrometrical measurements.

The Physical Characteristics of the 15-inch Telescope

Having described the background to the 15-inch telescope from contemporary and retrospective comments, we move on to describe the physical dimensions, the materials used as far as is known, and its basic characteristics as they were initially in 1835, how they are now and the modifications made at various intermediate times.

Fig. 3 *The cut stone pier of 'Armagh Marble' as it appeared prior to the restoration of the 15-inch telescope showing the recesses for the clock drive in its earlier and later positions and for the weights.*

From the beginning, Thomas Romney Robinson favoured the 'German' mounting with a single pier rather than the 'English' mounting in which the two ends of the polar axis are supported by separate piers. Following roughly the appearance of the Markree telescope, the Armagh 15-inch had a single stone supporting pier which survives to this day in the 1827 Dome at Armagh. In Fig. 3, we show the pier as it appeared before the recent restoration. The pier is a single block of Armagh limestone of overall height, depth (N-S) and width (E-W) of 1690, 1010 and 300 mm respectively.

The south side of the pier is cut parallel to the Earth's axis at the latitude of Armagh (54° 21' N) and the north side at right angles to this. Two substantial rectangular holes have been cut into the stone pier, one on the south side, approximately 325 mm from the top, and the other, a little north of the middle of the pier. The latter cavity housed the driving clockwork in its ultimate form and the other, on the south side, may have held an earlier version of clockwork which was later replaced. (see 'The Clockwork Drive Section'). An inclined channel, parallel to the north side, approxi-

Fig. 4 *The 9-lever, 18-point, mirror support cell for the 15-inch telescope*.

mately 180 mm wide at its southern end, was cut through the pier to allow a sector to connect the telescope with the second clockwork drive.

On the inclined south side of the pier, four studs are set into the stone to support a rectangular cast iron cradle. This in turn supports the telescope's polar axis and incorporates the various weight relieving kinematic devices designed by Thomas Grubb to reduce wear on the bearings. These are possibly later additions as Robinson[13], while commenting on the suggestion to use friction wheels to support the polar axis of the Great Melbourne Telescope, states:

> '*The method of making the principal bearing of the polar axis run on friction wheels, I here will not answer. It will produce what Mr Sheepshanks once called "floating motion". Troughton's beautiful Equatorial at Armagh has it; that of my 15-inch Cassegrain, which was constructed by Mr Grubb as an experimental model of Mr Cooper's had it, till the friction wheels were removed, 'Y's substituted and counterpoise levers applied.*'

The telescope tube is nowhere described, either its form or composition. All we know with certainty is that the focal length of the primary mirror was around 9 feet (2.74m) and the aperture 15 inches (0.38m) giving an f-ratio for the Newtonian of f/7.2. Though high for a modern telescope this was normal at that time. We presume that the tube was circular and probably of rolled iron similar to the Markree Telescope.

The primary mirror of speculum metal, was supported in its cell by a system of levers designed to evenly distribute its weight. This was an innovation which Robinson states was invented by Grubb and was used here for the first time.[14] It was reported that, in his original support for this telescope in 1835, Grubb used a 12-point system; however this showed evidence for flexure which disappeared with eighteen (Fig. 4).[15] Similar precautions were taken to mitigate movement or distortion from changes in the edge support of the primary mirror. Robinson (1857) states:

> '*Mr Grubb supported his specula (almost all of which were for equatorials) in a metal hoop sufficiently flexible to distribute the pressure round the lower semi-circle, and supported by three or four equidistant screws, passing through holes in the speculum box which have play enough for the springing of the back supports.*'

Grubb's lever support systems for primary mirrors were copied and developed in later telescopes by Lord Rosse, Lassell and others.[16]

The Clockwork Drive

Early attempts to use clockwork to drive telescopes with an equatorial mounting foundered on the unsuitability for this purpose of contemporary mechanisms used to measure time. Whereas in a timepiece, the hands move in small discontinuous jumps regulated by an escapement, a telescope required smooth equitable motion. Also the power delivered by the gears of a clock for the movement of its hands, was orders of magnitudes too weak to drive a telescope. Grubb's solution to this problem followed developments in governors for steam engines which used centrifugal forces to control the speed. This type of drive, with the appropriate gearing, could provide sufficient power to move a well-balanced telescope.

In the drive for the Markree Refractor and probably in the initial configuration of the Armagh 15-inch reflector, Grubb meshed the worm-wheel directly to a circular gearwheel which was placed near the bottom of the polar axis. It is likely, though not certain, that the Armagh telescope was first driven this way as it still has the 360-degree gear-wheel in place, though it is now redundant (Fig. 5).

Fig. 5 *The cradle holding the polar axis mounted on the south side of the stone pier. Note the now redundant circular brass gearwheel which it is believed may have been meshed with the driving clock in the original configuration.*

An invoice from T. Grubb, dated 18 December 1837, lists the provision on 29 April 1837 of a '*New Clock, Radial Bar and Sector for the Equatorial Stand of Large Reflector.*'[17] These most likely are the sector, connecting bar and the early Grubb clock now re-fitted to the telescope (see Fig. 6). In all probability, the simple circular gear-

Fig. 6 *The driving clock for the 15-inch telescope, minus its governor, in its second, final, position in the middle of the stone pier. Note the sector, appearing in the cutaway stone to the right and the short worm-wheel immediately to its left attached to the clock drive.*

wheel would have been too coarse to drive the telescope uniformly without backlash. A sector, though usable for only a short time, would have significantly increased the leverage and the uniformity of the motion.

Once having invented a suitable clockwork telescope drive, Grubb proceeded to make a number of copies. The early Grubb drives at Armagh (1837), Greenwich (1838), Westpoint (1840) and Dunsink (date unknown) are all closely similar in appearance (Figs 7 and 8).

The Optics: (a) Primary Mirror

The first primary mirror installed in the 15-inch telescope was manufactured by Thomas Grubb. The figure was made parabolic so that the telescope could, by changing the secondary mirror, work either as a Newtonian or Cassegrain. In a summary of Robinson's address to the Royal Irish Academy in 1849 he reported that '*the able artist who had it made was two years polishing it before he was satisfied with it.*' Illustrating subsequent progress in mechanisation, Robinson goes on to say that such work could then (in 1849) be accomplished in a matter of hours.

In 1843, Lord Rosse presented Robinson with a second 15-inch speculum which was sent to Grubb for grinding and figuring. Around the same time, Robinson had a polishing machine made by the Gardner's Foundry in Armagh which could serve for any disk up to 26 inches diameter.[18]

In Spring 1868, the original primary mirror was found cracked. However, by this time the mirror had deteriorated so much from repeated grinding and polishing that it was described as useless.[19] Robinson asked for the mirror to be recast by Grubb. In early September, 1868, Howard Grubb, the youngest son of Thomas Grubb, came to Armagh with Charles Faris, Robinson's new assistant. Together, they cleaned the telescope and readjusted its component parts. Howard, made drawings for altering Robinson's polisher according to his father's plan and, in January 1869, the remodelled machine was ready for reassembly.

In a surviving 'Journal of Work and Repairs'[20], descriptions of the methods employed for cleaning and realigning the primary and secondary mirrors were recorded. The surfaces of the primary and secondary specula were first rubbed with a cut lemon and then washed with cold pump water (free of organic matter) until all trace of acidity was absent. Following cleaning, Robinson found the focal length of the pri-

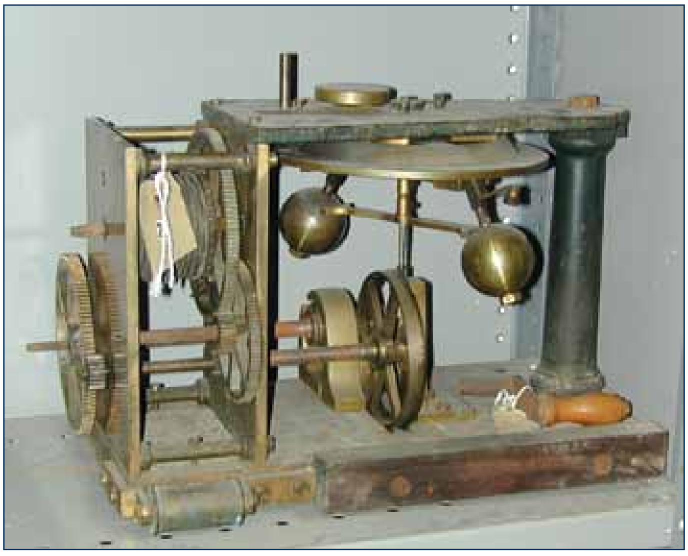

Fig. 7 *An almost identical driving clock by Grubb at Dunsink Observatory to that for the Armagh 15-inch telescope. This version has its original governor. The short worm-wheel is behind and to the left of the gear connecting to the governor.*

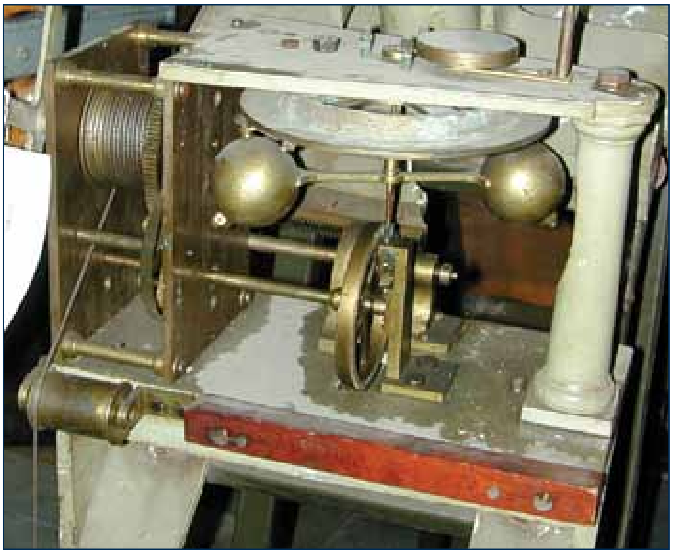

Fig. 8 *The driving clock by Grubb made for the Sheepshanks Telescope at the Royal Greenwich Observatory.*

mary to be 109.31 inches on 8th June, 1869. This compares with a focal length of 112.3 inches in December 1840. Whilst we have no guarantee that these measurements were of the same mirror it is feasible that a difference of this magnitude could originate in the frequent repolishing required to maintain the reflectivity.

The realignment of the Cassegrain mirrors is described as follows:

> '*Adjusted the mirror. As I do not think I have recorded my process, I give it here. As I am nearsighted I use a Galilean Achromatic which fits into the tube of the fourth power (single lens). With No 1 of this (power = 8) I look at the small mirror, in which is seen an image of the large one, with its central aperture, surrounded by a dark ring. If this dark ring be of uniform breadth throughout the small mirror is right, if not it must be made so by turning the three screws behind it. Turning in one of these makes the bright image move away from it. Having done this, look with No 4 of the Galilean power (power = 27) at the image of the central hole. If the large mirror be right, this image will be a black circle surrounded by a bright ring of equal breadth all round; if this ring be of not equal breath, it must be made so by the screws in the speculum box. This test is very delicate.*'

A very similar procedure was used to make the final alignment test of the primary and secondary mirrors of the Armagh-Dunsink-Harvard Baker Schmidt Telescope at Boyden Observatory, South Africa.[21] However, in this case the images of the primary reflected in the secondary were recorded photographically using significantly out-of-focus stellar images.

(b) Secondary Mirrors

In its original form, the Armagh 15-inch reflector had both Cassegrain and Newtonian foci. This enabled Robinson to become familiar with the merits of both and lead to his frequently expressed preference for a Cassegrain design for the Great Melbourne Telescope. Amongst the surviving parts of various telescopes at Armagh are two parts of secondaries which are probably from the 15-inch telescope; namely ID 2013.81, the housing for a Newtonian flat, and ID 393, a convex secondary speculum. This latter item was tested by David Sinden, a former Chief Optician with Grubb-Parsons, and subsequently head of the Sinden Optical Company of Tyne and Wear, England. From spherometer measurements he found the mirror to have a radius of curvature circa 46.6 inches (1185 mm). However, he found the measurement difficult and remarked '*it could easily vary a little from that*'. According to Robinson (1866)[22], the radius of curvature of the Cassegrain secondary was a quarter of that of the primary. With a radius of curvature for the primary of 2 x 109.31 inches we would expect the radius of curvature of the secondary to be *circa* 54 inches, i.e. about 1.17 times that measured by Sinden. Nonetheless, considering the difficulty in measuring the radius of curvature of the secondary and the possibility (probability) that the figure of both the primary and secondary would, through repeated polishings have become progressively further from the specifications, we can be reasonably sure that the surviving secondary comes from the 15-inch telescope.

Robinson states that the first secondary mirrors for the telescope were made by Thomas Grubb, however, subsequently, Robinson, using a model of Lord Rosse's polishing machine made by an Armagh watchmaker was able to figure his own secondaries.[23] He remarks that this enabled him to correct errors in the figure of the primary by modifying the 'hyperbolic figure' of the secondary. He appears to have made several secondary Cassegrain mirrors during subsequent years. In January 1841, he wrote to Lord Rosse:

> '*May I beg for a small speculum, my present pair are quite solid blocks of speculum metal which are awkward to polish from the difficulty of attaching them to anything. The axes of the present are 2.2 and 3 inches, and there should be a little allowance for the mounting.*'[24]

Initially, the secondary mirrors were supported in the tube by three equally spaced (120 degrees) vanes. However, it was found that these produced troublesome diffraction spikes on the images of bright stars and so were replaced by a single supporting vane.[25]

(c) Eyepieces, Finder and Other Items

It is evident from an inventory compiled by Robinson in 1853 that a number of different eyepieces were used on the 15-inch telescope, some of which may be amongst the miscellaneous unidentified eyepieces which survive in Armagh. The inventory for the contents of the 1827 Dome includes: a clock by Sharp[26], a set of steps curved to fit the interior of the dome wall, and a press (cupboard) with two shelves, the upper of which contained the accessories for the Cassegrain form and the lower for the Newtonian form of the 15-inch telescope. In the upper section were four eyepieces, the large one in the telescope had a moveable disk to hide bright objects when looking for faint companions. In addition, there were two eyepieces belonging to the Short Telescope with an adapter. These latter may have been made (*circa* 1768) by Dollond and were part of the Kew Collection presented to Armagh Observatory by Queen Victoria. The telescope to which they originally belonged was specially made for George III to observe the Transit of Venus in 1769.

In the lower compartment of the press, there were three negative eyepieces for a 46-inch achromatic telescope, a micrometer by Dollond, two other eyepieces and a triple eyepiece invented by Robinson.

In addition to the eyepieces, the inventory mentions that the Finder for the 15-inch telescope was a 7 1/2 feet achromatic with the object glass of the Kew Transit, 3.8 inches aperture. This telescope (ID 530) which still remains in the Observatory Instrument Store has a wooden (mahogany) tube with brass fittings. Robinson found it useful to supplement the use of the circles because of the lateral movement of the primary mirror. In October 1843, Robinson (1843) records

> '*Two micrometers have been applied to the declination Circle of the East Equatorial and its cast iron axis (declination) which seemed too slight has been replaced by a stronger one.*'

In spite of his earlier comments on the accuracy of the circles attached to the 15-inch telescope, in 1865[27], Robinson remarks:

> '*In making some observations of spectra of the fixed stars with the large reflector, I found that the declination movement, though quite sufficient for ordinary work, was neither sufficiently delicate or steady.*'

Astronomical Observations Made with the 15-inch Reflector

When surveying the many references to the 15-inch reflector in Robinson's correspondence and publications, one is struck by the relative absence of information on its use for observational astronomy. The construction and modification of the telescope evidently had taken up a lot of Robinson's time and effort and yet no log book of observations with it can be found. In excuse for this we could mention that Robinson was fully occupied for much of his long tenure in making and reducing accurate positions of stars and planets with the Jones Transit Instrument and Mural Circle at Armagh. This so called *grinding of the* *meridian* was the basic *raison d'etre* for observatories in the 19th century.[28] Nevertheless, we know Robinson was interested in some of the outstanding astronomical issues of his day, such as whether or not the nebulae were gaseous or merely conglomerations of distant stars. Also he was aware of, and most probably interested in, the developing field of astrophysics, in particular how spectroscopy could contribute to our understanding of stars and galaxies. There are occasional references to the use of a spectroscope on the 15-inch telescope; e.g. in 1865 when he used it to observe the spectra of the fixed stars and on 6 January 1866 when he observed the spectrum of Jupiter. However, as time moved on, Robinson suffered from deteriorating vision which, in those pre-photographic astronomy days, severely limited what could be done with a visual spectroscope on a 15-inch telescope.

So, in essence, Robinson realised that his 15-inch, apart from the frequent necessity of repolishing its mirror, was not large enough for the observations he needed to make and, in 1853, he states in his report to the Governors that, though the present reflector is a '*capital instrument*', it would be nice to have one of 36 inches aperture. Regrettably, with its total annual income of around £300, even in those days the provision of such an instrument would have been well beyond the resources of Armagh Observatory.

Though the instrument saw less and less use as Robinson's eyesight deteriorated, after he died in 1882, his successor, J.L.E. Dreyer, included it as one of only two instruments at the Observatory at that time, capable of producing good results. He reported to the Governors that the 15-inch had furnished a good observation of the Transit of Venus on 6th December 1882 which was published in the journal *Copernicus*.[29]

In spite of this accolade, it appears the telescope was little used after Dreyer's appointment, he preferring to use the new 10-inch refractor purchased in 1885 from Howard Grubb. It's ironic that a refractor was chosen as a memorial to Robinson when for much of his life he had championed the Cassegrain reflector over both the Newtonian and refractor. Perhaps Dreyer, having been assistant at Birr, felt he had spent enough time polishing speculum mirrors! As luck would have it, though Robinson had strongly opposed the disestablishment of the Church of Ireland, it was the government compensation for the loss of income that followed from that Act, that financed the purchase of the telescope that bears his name - The Robinson Memorial Telescope.

The Dismantling of the Telescope and the Dispersal of its Parts

Dreyer, with very limited financial resources and little prospect of further purchase of equipment became progressively involved in cataloguing earlier observations. On the stellar side, he completed the publication of Robinson's meridian observations, and on nebulae he produced his best known work, the NGC and Index Catalogues. In the 1890s, he became progressively involved in historical studies, in particular the early work of his fellow Dane, Tycho Brahe. Throughout the 1890s and the first decade of the 20th century, the 15-inch remained unused. Indeed, when Ellison was elected to Dreyer's former post in 1917, he soon dismissed Robinson's great reflector as '*both obsolete and useless*'.[30] In 1920 or thereabouts, the telescope suffered the ultimate rejection, it was dismantled and the tube and fittings were sold as scrap metal.[31] The mounting, the clock drive, the finder and some of the optics were retained. The mounting now carried a 6½-inch refractor by Ellison. As it had been so totally dismembered, the remains of the 15-inch telescope lost credibility and the story of the crucial part they had played in the design of the Great Melbourne Telescope was forgotten. In retrospect, it is possible that the fall in the reputation of that great instrument may also have contributed to the demise of its predecessor.[32]

At some time in the late 1950s or early 1960s, the mounting, clock drive and sector were given to a local school. In the mid-1980s, following an interest shown in Irish astronomical archives by Cambridge historians of science, Michael Hoskins visited Armagh to compile with the author a list of the surviving manuscripts at Armagh Observatory.[33] This lead to a greater appreciation of the historical value of Robinson's equatorial reflector and a search began for any remaining parts. An initial search of the Royal School found nothing and for several days it was believed that all was lost. However, several days later a telephone call informed us that some metal objects had been found in the boiler room under the Chemistry Lab. Could these be parts of the missing telescope? In fact, they were and the following day they arrived at the front door of the Observatory.

With the Armagh Observatory approaching its bicentenary in 1990/91, there was an increasing appreciation of the institution's long history and its heritage. This came to public notice in a series of talks, conferences, concerts, publications, exhibitions and a documentary film. Following this period of unparalleled public exposure, there was an increasing understanding of the necessity to conserve its heritage for posterity. An application to the Heritage Lottery Fund was successful and the restoration of both the 1827 Dome and its former occupant, the 15-inch equatorial, were included. The telescope was to be rebuilt by the Sinden Optical Company using as many of the original parts as possible.

The Restoration

David Sinden was, from the beginning, delighted to be able to contribute to the restoration of the 15-inch telescope. He had, whilst at Grubb-Parsons, the commercial descendants of Thomas Grubb of Dublin, been closely involved with the design and manufacture of the optical parts of some of their last great instruments: the Isaac Newton Telescope, the Anglo-Australian Telescope and the UK Schmidt Telescope amongst them. Now he was to make the optics for the restored version of Grubb's first reflector, the prototype 15-inch. He talked of the project as his '*alpha to omega*' encompassing the whole range of Grubb's telescope work over a century and a half. As it turned out, due to his increasing infirmity, the work he did on the Armagh telescopes (including the 10-inch refractor and the 18-inch Calver Reflector as well as the 15-inch Grubb reflector) was to be one of his last completed projects. His contributions to astronomy were recognised by the International Astronomical Union by the naming of an asteroid in his honour.

It was the intention from the outset to rebuild the telescope as closely as possible to the original design using the surviving mounting, clock-drive, pier and mirror cell. Because of its fragility, the original Cassegrain secondary was not incorporated but, instead, replaced with a modern aluminized glass mirror. Also, the finder was not re-attached to the telescope, though this would be possible at some future date. Fittings, such as focus racks, clamps and adjusters, which had been scrapped in the 1920s, were replaced where possible by others of similar type (according to the judgement of David Sinden), or remade anew. One feature that could not be accurately ascertained or reinstated was the balance position along the tube. This depended on the relative masses of the speculum primary and the original tube, neither of which were known. The new primary mirror was made of glass, figured and polished on an early machine formerly at Grubb-Parsons, Newcastle upon Tyne and then at the Sinden Optical Company. Sadly, the clock-drive, when returned from the Royal School in 1988, had lost its governor and so far, it has not been possible to restore it to full work-

Fig. 9 *The restored Grubb 15-inch reflector in the 1827 dome at Armagh Observatory.*

ing order. With so many of the original features unknown, the restored telescope can never be considered a fully authentic copy. Nevertheless, enough of the original material has survived and been incorporated for the telescope to be worthy of preservation as an example of an early clock-driven equatorial reflector (Fig. 9).

Conclusions

This paper attempts to piece together what is known of the first clock-driven equatorial reflector, the 15-inch telescope made by Thomas Grubb for Armagh Observatory and erected there in 1835. Because of its novel features, this telescope represents a crucial step in the evolution of telescope design in the 19th century. Thomas Romney Robinson, one of the select committee of astronomers and engineers appointed by the Royal Society to oversee the proposal to build a large telescope in the Southern Hemisphere, was closely involved with, and based many of his recommendations on his experiences with, the Armagh 15-inch telescope. In many respects, the optical design of the Great Melbourne Telescope that was proposed by Robinson and Grubb and chosen by the Royal Society Committee, was similar to that of the Armagh reflector; only the size was different. The GMT was designed to have a 48-inch diameter primary mirror, figured with a focal length of 30.4 feet (f/7.6)[34], whereas the Armagh reflector had a 15-inch primary, with a a focal length varying from 109 to 112 inches (f/7.2 - f/7.5). Similarly, both had an f/36 to f/40 focal ratio at the Cassegrain focus.[35]

In retrospect, this choice would be questionable, to say the least, as more modern telescopes favour much shorter focal lengths and smaller focal ratios. For a telescope that was intended for observation of extended objects such as nebulae, a lower focal ratio would have been desirable, particularly for the rapidly developing use of photography for astronomical studies. Robinson, it appears, had little experience with photography at the telescope and, when the design for the Great Southern Telescope was first considered in the mid-1850s, photography was in its very early stages. By the time the Great Melbourne Telescope was under construction at Grubb's workshop in Dublin in 1868, photographic techniques had developed sufficiently to allow the imaging of astronomical objects; a possibility that had not been provided for in the original optical design. However, it was to be another 12-15 years before stellar photography became a practical alternative to visual observation. In defence of Robinson and the decision of the Royal Society Committee to adopt Grubb's design, it should be noted that the steeper profiles in the figure of the primary mirror required for shorter focal lengths, would have been much more challenging for the opticians of the time. With the requirement to build a practical telescope which was to operate at a location far from the centres of astronomical expertise, a well-tried design would obviously have more appeal. In this sense, the GMT was just another member, albeit much more technically advanced, in the succession of large aperture and long focal length reflectors by Herschel, Lassell and Lord Rosse.

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Author's address:
Armagh Observatory, College Hill
Armagh BT61 9DG, N. Ireland, UK
email: cjb@arm.ac.uk

Current and Future Events

Details of future events, meetings, exhibitions, etc. should be sent to the Editor. For up-to date information of Society's events, see the SIS website, www.sis.org.uk.

Until 29 July 2016 London, UK

Exhibition: 'Scholar, courtier, magician: the lost library of John Dee' at the Royal College of Physicians, 11 St Andrew's Place, Regent's Park, London NW1 4LE. Their library holds more than 100 volumes stolen from John Dee during his lifetime, the largest single collection of Dee's books in the world. John Dee (1527–1609) was one of Tudor England's most extraordinary and enigmatic figures – a Renaissance polymath, with interests in almost all branches of learning. He served Elizabeth I at court, advised navigators on trade routes to the 'New World'.

Until 4 September 2016, London UK

Exhibition: 'Leonardo da Vinci: The Mechanics of Genius' at the Science Museum in South Kensington: Exhibition Road London SW7 2DD (www.sciencemuseum.org.uk). This brings Leonardo's ideas to life through original drawings, 3-D models and interactive displays. The show also includes 39 historical constructions originally made in Milan in 1952 to mark the 500th anniversary of the polymath's death. Some of these models have been widely circulated but it is well worth seeing them again.

Sunday 3 July, Summer Event and AGM at Cambridge, UK

Venue the Whipple Museum of the History of Science, Free School Lane, Cambridge CB2 3RH. Because of the limitations on parking in the centre of Cambridge we will be providing transport from and to Maddingley Park and Ride, which is to the west of the city close to M11, arriving at the Whipple at 10.10. The Annual General Meeting scheduled at 11.30, is followed by lunch at the nearby Zizzi Italian restaurant, returning at 13.45 for a hand-on session at the Whipple. At 15.10 the delegates will survey the internationally significant collection of vintage computers and other memorabilia (24,000 items) at the Centre for Computing History, Rene Court, Coldhams Road, Cambridge CB1 3EW, and will depart for home at 16.30. See the flyer in the March *Bulletin* for details.

Sunday 4 September-Friday 9 September International Study Tour to Sicily

On arrival there will be an evening reception, in Palermo, which will be our base for the week. In Palermo itself there is a wealth of different scientific institutions, The Astronomical Observatory Museum, housing a famous Ramsden Circle, The Department of Chemistry, The Institute of Physics, The Museum of Radiology, The Museum of Engines and Mechanisms, The Museo Archeologico with a collection of astrolabes and sundials, The Museo del Mare, The Instituto Technico, The Instituto Nautico, and others. Elsewhere on the island there are instrument collections in Museo del Liceo di Cefalù, Museo del Liceo di Caltagirone and Museo del Liceo di Alcamo. A visit to Mount Etna is also planned. Members who have expressed an interest will be contacted by our Executive Officer, Peter Thomas when the itinerary has been finalized. Please direct any enquiries to the SIS Executive officer. Flyer in last December's *Bulletin* No. 127.

Sunday 23 October 2016, London UK

Autumn Antique Scientific Instrument Fair at the Double Tree by Hilton, 92 Southampton Row, London WC1 4BH from 10.00am to 3.00pm. Further details: http://www.tideswel.demon.co.uk/ASIF/ and scientific-fair.blogspot.com

A Sundial by Dollond

A large and precision Equinoctial Sundial by *Dollond, London* from about 1850. Its chapter ring is 112mm in diameter and the dial is housed in a wooden box.

For precision levelling there are two spirit levels in the compass bowl.

A latitude arc on the left allows it to be set from 0° to 80°+.

It includes a needle lifter to avoid transit damage to the jewelled bearing.

This is one of the Sundials featured in a series of articles by Mike Cowham that starts in the September issue. He will concentrate mostly on Portable Dials but will include some Garden Dials and occasionally fixed Vertical Dials.

The equatorial mount built by Grubb in 1832 was very solid compared to the equatorial of the great Dorpat refractor. The refractor was erected in 1834 on a triangular pier made of black marble (Figure 3). This telescope was not housed. 1.Â In 1850 the largest refractors were the 15-inch (38 cm) instruments at Pulkovo and Harvard (Figure 4). These two telescopes were built by Merz & Mahler (Munich). In the middle of the nineteenth century the largest reflector was the Leviathan of Parsonstown built in 1845 by William Parsons, third Earl of Rosse (Birr Castle, Ireland).Â Only after the introduction silver-glass mirrors the reflector was able to compete with the refractor as far as precision work at the observatory is concerned.