Armagh Observatory's meridian marks

John Butler surveys the extant and vanished meridian marks of Armagh Observatory and explains their significance for 18th and 19th century observations.

1 The meridian mark at Tullyard for the transit instrument from the northwest. Note the elliptical holes (subsequently blocked) which formed the first stage of alignment and the vertical slits for the second stage. Metal discs mounted on the pinnacles on the top of the arch provided the third stage.

The observatory at Armagh in Northern Ireland was founded in 1790 by the Church of Ireland Archbishop Richard Robinson as part of his wider scheme to develop the fabric and institutions of the city following a prolonged period of strife and neglect. Conscious of the value of education, he envisaged that the observatory would in due course form part of a new university, but his plans were never implemented. Nevertheless, the observatory had been incorporated by an Act of the Irish Parliament at the time of Robinson's death (see Bennett 1990) and its principal activity for the next 90 years was measurement of the positions of stars and planets.

In order to do so, the observatory required astronomical instruments, clocks and the means to maintain the alignment of the instruments. The construction of accurate meridian marks (figure 1) was then believed to be essential for precise measurement of stellar coordinates; individual surviving marks can be found for both Greenwich and Paris observatories. At Cambridge the observatory itself was reputedly positioned so that the tower of Grantchester Church could support a meridian mark. It is unusual for more than one mark at any particular observatory to survive, although there are two at Richmond Observatory, Kew – but Armagh has three. The decline in the population of Ireland in the 19th century and the resultant lack of growth of the city of Armagh perhaps contributed to their survival. They remain as testament to the meticulous observing practices of the 18th and 19th century at Armagh Observatory (figure 2).

Instruments

In the late 18th century, the measurements of the celestial coordinates, right ascension (RA) and declination, were usually made separately with two different instruments. Declination, the angle between the star and the celestial equator, was commonly determined with a quadrant set up to observe in the meridian. In practice, however, rather than measure the declination directly, it was normal to measure the zenith distance and convert to north polar distance (NPD), the converse of declination.

> **"Meridian marks were believed essential for precise measurement of stellar coordinates"**

As techniques developed, larger, more accurate and less portable instruments were designed and, for stability and protection from the elements, they were placed in specially constructed buildings. One such improvement was the mural circle, an instrument that was fastened to a wall exactly in the north–south plane. Examples are to be seen at Greenwich, Oxford and other observatories, including Armagh.

2 A photograph of Armagh Observatory from the north, believed to have been taken in 1883, which shows the slits in the roof of the single storey Transit and Mural Circle Rooms through which the instruments viewed the sky. The slits have shutters; the left one for the mural circle is open. The central panels of the windows below these shutters could be removed to allow the instruments to view the distant meridian marks.

1 The meridian marks of Armagh Observatory

townland	Irish grid *x, y*	instrument	dates	references	notes
Tullyard	287803, 347938	transit	1793–present	1, 3, 7, OS1	stone arch west pinnacle
Corkley	288102, 332179	transit	1793–?	OS1	stone arch east ellipse
Tullyard	287783, 347906	equatorial	1796–1850	2, OS1	design unknown
Corkley	288111, 332173	mural circle	1830–?	OS1	design unknown
Tullyard	287816, 347933	mural circle	1864–present	4, 5, 6	cast-iron obelisk
Palace Demesne		equatorial	1796–1810?	1	possibly moved to Ballyheridan
Ballyheridan	287899, 342803	transit	1810–present	7, OS1	ashlar stone pier on base

References: (1) Transits at the observatory of Armagh, 1796–1798, M126.1. (2) Letter from John Stanley, 25 November 1851. (3) Observation record book, 1793–1796, M129. (4) Thomas Romney Robinson, Annual Report to the Governors 1863, M136. (5) ibid 1864. (6) ibid 1865. (7) T R Robinson (1859), Places of 5,345 Stars observed from 1828 to 1854 at the Armagh Observatory, Dublin (first *Armagh Catalogue of Stars*) pxvi,xvii.

Astronomers also needed to measure the RA (celestial longitude). In principle, all that was required was the time of transit of the object (star, Sun or planet) as it crossed the meridian. As the star crossed the north–south line – the meridian – in the telescope (marked with a crosswire), the exact time was noted, usually to a precision of about one tenth of a second, accomplished by interpolating between the ticks of a nearby clock rated to sidereal time.

To keep the instruments accurately aligned to the meridian, it was common practice to observe a point on the horizon at dusk which indicated the exact location of the meridian. Any error in the alignment of the instrument would be corrected before observations began. The meridian was defined to about 1 second of arc, which is about the limit imposed by the accuracy of the instruments and the stability of the atmosphere. For checks during hours of darkness, when the meridian marks could not be seen, local illuminated marks were set up in the observatory grounds.

At some time or other, there have been meridian marks at seven different locations near Armagh. They are referred to here by the names of the townlands in which they were situated. There were three at Tullyard, close to Grange, north of the city; two at Corkley, near Darkley to the south; one at Ballyheridan south of the Bishop's Palace; and the last at an uncertain location in the Palace Demesne. A short description of each follows; details are given in table 1.

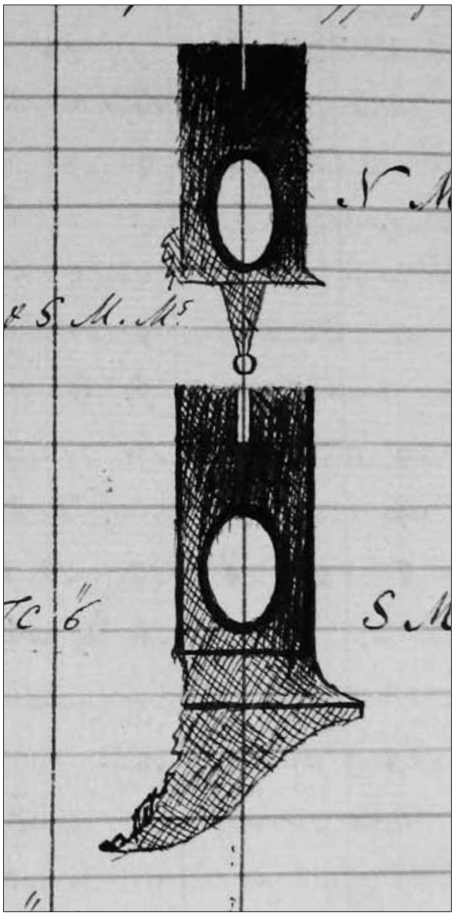
Tullyard

One of the first meridian marks was built at Tullyard and is a free-standing arch which still stands there today (figure 1). It was constructed around 1793 and was probably the work of Francis Johnston, at that time architect to Archbishop Richard Robinson. Johnston had in the previous three or four years been responsible for the design and erection of the observatory. This meridian mark was constructed for the transit instrument, with its west pier aligned due north of the west window of the Transit Room.

The arch is symmetrical with narrow slits cut through each pier in a north–south direction at about one third of their height. Above these slits are elliptical holes, which provided the first stage in the alignment; the slits provided the second stage. The third stage in the alignment was given by a metal disc 20 cm (8 inches) across, fitted to the top of the pinnacle above the west pier of the arch. The disc had a triangular hole in its centre; the apex of the triangle provided the final precise alignment.

Architecturally, one of the interesting features of the Tullyard mark is the incorporation of ellipses in the design. Elliptical structures are relatively rare. According to Curl (1992), the first use of the ellipse in a building in Ireland was in Ballyhaise House, Co. Cavan, which incorporated an elliptical saloon. Curl suggests that the introduction of the form came through the architect Richard Cassells who was responsible for several Palladian mansions in Ireland, and who was aware of its previous use in Germany. Here, in Armagh, in a building intended for practical astronomy, one could speculate that Johnston was using the ellipse to allude to the shape of planetary orbits. We cannot be sure that this was truly the motivation behind Johnston's choice of the elliptical form, but it was also a practical choice: the ellipses, with their major axis vertical, provided a clear and unmistakable illuminated area of sky which could be reasonably accurately bisected by the cross-wires of the transit instrument. Once the instrument was set on the major axis of the ellipse, the telescope would then be moved vertically to align with the slit below and then to the apex of the triangle in the disc above. An almost identical arrangement of ellipses and slits was also incorporated in the southern meridian mark on Corkley Mountain (see below). Johnston subsequently used elliptical openings in his design for the outbuildings of Glanmore Castle, Co. Wicklow, and possibly elsewhere. The elliptical plan of his ecclesiastical masterpiece, St Andrew's Church, Dublin, is well known, but this probably derives in part at least from the shape of a previous structure on this site (McParland 1969).

The elliptical openings of the north meridian mark at Tullyard are currently blocked by masonry. It has been reported



3 A sketch from the observation record book showing the northern (Tullyard) and southern (Corkley) meridian marks for the transit instrument, upside down as seen in the telescope. Note the elliptical holes and narrow slits in both marks, but only the northern mark has the metal disc on top of a pinnacle for the final alignment stage.

by a local resident, Mr Seamus Toner, that they were blocked to prevent children climbing through them, falling and injuring themselves. Perhaps, now that children are reputedly less adventurous, there is an opportunity to reinstate these openings so their original shape is clear and we have a more visible reminder of Johnston's innovative design. The masonry of the north meridian mark was restored by the Department of the Environment in 1990 and the fallen pinnacles re-erected.

In December 1795, the principal instrument of the Archbishop's new observatory, the Troughton equatorial telescope, arrived at Armagh (see box "Equipping Armagh Observatory 1790–1888"). The first director, James Archibald Hamilton, spent the next few months engaged in attempts to bring it into proper adjustment. For this he needed a second set of meridian marks, one at Tullyard, and the other in the Archbishop's demesne about a mile south of the observatory. While we have no direct reference in the archives for the erection of the former, we know that the latter was erected on 23 March 1796 and it is reasonable to assume that the northern one was set up at roughly the same time. We have no knowledge of the design of the meridian mark for the equatorial at Tullyard. The only incontrovertible evidence that it existed is given by its location on the first edition of the 6-inch Ordnance Survey map and a letter dated 25 November 1851 from the farmer of the land on which it stood, asking if the director would like the stones from the mark, now demolished, transported to the observatory for safe keeping. There is no indication whether or not this was done.

The third surviving meridian mark at Tullyard is a single cast-iron obelisk in the Egyptian style, on the meridian of the mural circle. It is similar in design to the meridian marks at Chingford, Essex in 1822 for the Greenwich Observatory and the meridian marks at Kew for the private observatory of George III. The obelisk at Tullyard was manufactured locally by Gardner's Foundry, Armagh and was erected in November 1864.

The mural circle, built by Jones of London, was delivered in 1830, posing the question of why its north meridian mark was erected so long after the delivery of the circle itself? The answer lies in the fact that the mural circle was originally intended for the measurement of north polar distance (NPD) and for this purpose the south meridian mark at Corkley was probably all that was required. The necessity for a north meridian mark came about through the later decision of the third director, Thomas Romney Robinson, to use the mural circle for both NPD and transit observations. His established procedure for the latter required an extra accurate north mark.

Robinson occasionally complained in his reports that the marks at Tullyard had been damaged by stones thrown by vandals or even hit by shot. To discourage this, his new cast-iron meridian mark incorporated an innovation. Near to the top of the mark, in the sloping metal plate forming the apex of the obelisk, a diamond-shaped hole in the northern and southern sides allowed light to pass through; this could be seen from the observatory, but was not apparent close to the mark. Inside the obelisk, a metal plate was mounted vertically on a rack in an east–west plane, similarly perforated by a diamond-shaped hole with a sharp angle at the top for accurate alignment. This meridian mark was completely renovated ~1995 by the Department of the Environment.

"Robinson complained the marks had been damaged by stones thrown by vandals"

Corkley

Neither of the meridian marks on Corkley Hill have survived to the present day and, as a result, we know relatively little about them. One of them, the transit mark, was in use from 1793 to the 1880s when astrometry was the principal occupation of the observatory staff. There are frequent references in the observation record books to alignment using the Corkley marks.

The earliest of the Corkley marks was apparently a free-standing arch, similar to its northern equivalent at Tullyard and probably also the work of Johnston. It was erected in 1793 for the transit instrument. In figure 3, we show a drawing of the relevant parts of the two transit meridian marks, at Tullyard and Corkley, as they appeared (upside down) in the telescope. Whereas the northern mark had a stone pinnacle on top surmounted by a perforated metal disc, the southern mark had just the two primary alignment features: the elliptical holes and the narrow slits. Here the slit provided the final alignment check. The very much larger distance (circa 16 km) of the marks on Corkley Hill from the observatory compared to those at Tullyard (2 km) meant that checks with the ellipse and slit were sufficient for alignment.

The second mark at Corkley, that for the mural circle, is of unknown date but we assume that it was erected around 1830 when the mural circle was first set up; it is shown on the 1846 OS 6-inch map and was referred to by Robinson in a paper in 1836. We have no knowledge of its appearance or construction. Nevertheless, we know that it was in continuous use throughout the middle of the 19th century from references in the circle observation record books. Regular meridian observations for the positions of stars were discontinued shortly after Dreyer took up his appointment in 1882. From then on, the books record only occasional transit observations to regulate the observatory's clocks. Exactly when the meridian marks on Corkley Hill were removed, we do not know. The first and second editions of the OS 6-inch maps, surveyed in 1828–1835 and 1831–1904 respectively, show both meridian marks, but they are absent from subsequent editions. They were seldom used after the 1880s; it is likely that, once the landowners became aware of this, the marks were demolished.

Ballyheridan and the Palace Demesne

The sole remaining south meridian mark associated with Armagh Observatory lies in the townland of Ballyheridan, close to the Newtownhamilton Road and just a short distance from the southern extremity of the palace wall (figure 6). It is shown on the first edition of the Ordnance Survey 6-inch map as "Old South Meridian Mark". The origin of this mark poses a puzzle that we cannot conclusively solve, though we

Equipping Armagh Observatory 1790–1888

At the time of the foundation of Armagh Observatory in 1790 and the appointment of its first director, the Revd James Archibald Hamilton, a complete set of the latest and most up-to-date instruments was proposed (Bennett 1990). Orders were placed for a transit and a meridian circle from Ramsden, the prominent London maker, and for an equatorial telescope from Troughton, also in London. In addition, Nevil Maskelyne, the Astronomer Royal who had tutored Hamilton on his occasional visits to Greenwich, had agreed to arrange for the provision of accurate clocks. However, it was common at that time for suppliers of astronomical equipment to take an inordinate amount of time to come up with the goods; Dunsink Observatory near Dublin, which had also ordered a meridian circle from Ramsden, had to wait 20 years for delivery. In Armagh's case, the delay was critical: Archbishop Robinson died in 1794 and his heirs and successors cancelled as much as they could of the order for the instruments. They were not able to stop the delivery of the Earnshaw regulators or the Troughton equatorial telescope, which became Hamilton's principal instrument (figure 4).

Troughton's innovative but unusual equatorial was one of the earliest attempts to combine the measurement of both coordinates in one instrument. If it had been successful, it would undoubtedly have represented a significant step forward in telescope design; it allowed the coordinates to be measured at any time of the night when the object was above the horizon, rather than just when on the meridian, as with the standard transit instrument, meridian circle or mural quadrant. This would be a distinct advantage at a cloudy site such as Armagh, where poor weather could delay the measurement of a particular star for weeks or even years.

Troughton had designed and constructed a truly novel instrument, one that Thomas Romney Robinson, Armagh's third director, described as magnificent, "but I need scarcely say that it fell short of his [Troughton's] promise". One of its principal deficiencies was a lack of rigidity as a result of the development of cracks in the supporting structure. These developed following work hardening of the brass during manufacture and led to stress corrosion – poorly understood at that time. The sulphurous atmosphere of London during manufacture is believed to have been a contributory factor.

Hamilton struggled with the alignment of the new telescope and, after three months with his whole time devoted to it, he wrote in the record book on 10 March 1796 that it was now as well adjusted as he could make it. Though he subsequently used it to measure the NPDs of several stars, he was reluctant to use it for RA. For this, he continued to use a standard transit instrument, although not the Ramsden instrument originally ordered. Hamilton had purchased a similar instrument from James Waugh, a local clockmaker from Armagh. It was with this instrument that he and his assistant Robert Hogg made many thousands of transit observations of stars, comets, the Sun and planets; they were never published, possibly because of the high cost of printing. Some of Hamilton's observations with the Troughton equatorial telescope were published by Pond in Greenwich.

4 The Troughton equatorial telescope.

6 The southern meridian mark for the transit instrument at Ballyheridan from the northwest. The stone base and the metal fiducial mark on top were renovated in 1999.

believe we have a plausible explanation.

The mark is in the form of a neo-classical pier designed to reflect its intended use in astronomy, mounted on a substantial base of random rubble. It is rectangular in cross-section and is surrounded about a metre from the top by a decorated stone band which features four eight-pointed stars, each one centred and facing a cardinal direction. Above this band, and just below the cap, carved stone pyramids at each corner point horizontally to the NE, SE, SW and NW directions. On top of the pier, a small mechanical device allows a cast-iron metal plate to move in an east–west direction. Through this, a round hole of three inches diameter has been drilled, which provided the fiducial point for the observatory instrument. From its location and references in the observation record books at the observatory, we know that it was used from the early 19th century to mark the southern meridian of the transit instrument. Why, one might ask, were two meridian marks required to the south of the same instrument? It appears that the earlier mark on the horizon at Corkley Hill was occasionally obscured by mist and a closer one was deemed desirable. Though the nearer one must necessarily be seen against pasture below the horizon, its proximity meant that it could be more frequently observed during daylight hours.

The puzzle is that this well-executed stone mark is mounted on a coarse and rough base, at odds with the design and craftsmanship of the mark. Two possibilities come to mind: either it was intended to surround the base with an earthen mound so that the pier stood on a small hill, or the pier was originally designed for another location without the rough stone base and it was subsequently moved and raised to its current location. We believe the second option is correct.

Though we cannot be certain, we believe this mark is the one that was originally erected for the Troughton equatorial telescope in the Palace Demesne in March 1796, that is, about three months after the arrival of that telescope. A comment in the transit record book for 23 March 1796 notes: "Stone MM put up in Demesne for Eql." No sign of a mark in the Palace Demesne can be found today. However, on 8 July 1810, a further note in the transit record book relates: "New SMM now finishing – found correct." We believe that, once Hamilton realized that the Troughton equatorial telescope was not able to provide accurate measurements of right ascension, he removed the old meridian mark for the equatorial from

5 The Jones mural circle in its original configuration.

From the beginning, Armagh Observatory had two regulators by celebrated clockmaker Thomas Earnshaw, a significant bonus to its programme of observation. The clocks used in observatories are usually referred to as "astronomical regulators" and are constructed on much more demanding principles than ordinary domestic and public clocks. Those made for Armagh were specially ordered and tested by the Astronomer Royal Nevil Maskelyne and made by Thomas Earnshaw, a famous name in horology. Like John Harrison and John Arnold, Earnshaw was one of the recipients of the £20 000 prize offered by the Board of Longitude for an accurate marine chronometer. Earnshaw was primarily a watchmaker and it was his version of the marine chronometer that eventually became the standard model. An essential requirement of an astronomical regulator was that it should not just keep time over an integral number of days (i.e. have a small cumulative error) but it should also keep a uniform rate throughout the 24 hours. This could only be achieved by a clock with cogwheels that had teeth uniformly distributed around the wheels. Earnshaw was renowned for his exceedingly fine workmanship, for the large number of teeth on each wheel and his copious use of jewelled bearings. Robinson, the third director of the observatory, believed Earnshaw's first regulator at Armagh to be the most accurate in the world at that time.

It was not until 1822, when a new Archbishop of Armagh was elected, namely John George Beresford, that funds became available to re-equip the observatory. Shortly after his arrival, Beresford appointed Robinson as director of the observatory, a young and dynamic man who would set the institution on the path to national and international recognition. Robinson was no relative to the former archbishop, but the son of an English portrait painter, Thomas Robinson.

Robinson lost no time in taking advantage of the new archbishop's munificence and ordered a new transit instrument and mural circle (figure 5) from Jones of London. It was with these instruments that the great bulk of data on stellar positions were obtained from 1827 to 1883. Within the first five years of the arrival of the new transit instrument in 1827, three volumes of stellar coordinates from Armagh had been published. These were followed by two other large volumes. The first *Armagh Catalogue* was published in 1859, involving a huge amount of tedious hand calculation; Robinson's dutiful assistant, Neil McNeil Edmondson, is said to have remarked to him, "it has made old men of us". The second catalogue was published after Robinson's death in 1882, by his successor J L E Dreyer in 1886.

The publication costs had been borne by the Royal Society of London and, in appreciation of his contribution to science, Robinson was awarded their Gold Medal in 1862. The observatory at Armagh was now finally recognized nationally and even internationally as a serious professional institution. J L E Dreyer, T R Robinson's successor, was to continue with this type of work and in 1888 produced his most important work at Armagh, *The New General Catalogue of Nebulae and Clusters of Stars*, the famous NGC by which most of the bright galaxies in the sky are known to astronomers to this day.

the palace grounds and placed it nearby on a rough stone base to serve as an alternative southern mark for the transit instrument, which he had realized was his only reliable piece of apparatus (see box). Under this scenario, the original southern meridian mark for the equatorial, also probably the work of Francis Johnston, was retained after 1810 for the Waugh transit instrument and after 1827 for the new transit instrument by Jones. This interpretation could also explain why the Ordnance Survey labelled it "Old South Meridian Mark".

We have traced the line of the meridian for the Troughton equatorial telescope through the Palace Demesne to see if any signs of the mark placed there survive, but found nothing to confirm the former location of the mark. If any maps of the demesne from the period 1796–1810 survive, it would be of interest to look for further evidence.

Armagh's astrometric legacy

The astrometric work carried out at Armagh, from the foundation of the observatory in 1790 to 1882, was part of a concerted effort to increase the accuracy and reliability with which the positions of stars were known. Although the early observations made before 1827 were never published, the more reliable data obtained with the instruments made by Jones were published in a series of catalogues culminating in the first (Robinson 1859) and second (Robinson & Dreyer 1886) *Armagh Catalogues of Stars*. According to Dreyer, the Armagh positions of stars were in frequent use by the astronomers of the day who were attempting to compile an internationally agreed fundamental catalogue of stellar positions. This was required, not only for navigation but also to define a fundamental inertial reference frame against which the motions of planetary bodies could be measured.

"The meridian marks stand as a visible reminder of this great international project"

Throughout the second half of the 19th century and through the 20th, the accuracy of stellar positions improved. However, the significant proper motions of stars within our galaxy imposed new limitations; in recent decades positions of distant galaxies from radio telescopes have superseded those of stars determined with ground-based telescopes. Now astrometric satellites such as Hipparcos and Gaia have taken over; astronomical positions to milliarcsecond accuracy are commonplace.

While the stellar position measurements made by the astronomers at Armagh are now of historical interest only, they played their part in the progress of this field of science which came to fruition through a worldwide collaboration of astronomers. Armagh's meridian marks stand today as a visible reminder of this great international science project. ●

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