Grubbs of Dublin: telescope-makers to the world

IAN ELLIOTT

Although lacking a formal education in engineering, Thomas Grubb (1800–78) established a unique high-technology enterprise in Ireland. The Grubb instrument firm was continued by his son, Howard, and constructed many of the world's largest and best telescopes as well as producing a wide range of precision optical and mechanical instruments.[1] This paper examines the development of the Grubbs' reputation and successful business, a business that was aided by the support of prominent Irish astronomers such as Thomas Romney Robinson and William Parsons, third earl of Rosse. At the start of the twentieth century, Grubbs' business shifted towards the development of military technologies, as demand for large-scale telescopes in the British Isles and the empire declined. The long-standing relationship with the Parsons of Birr enabled yet another transformation of the business to Grubb-Parsons in 1925 and this company continued to manufacture telescopes until 1985.

THOMAS GRUBB

Thomas Grubb was born on 4 August 1800 near Portlaw in Co. Waterford, the son of William Grubb and his second wife, Eleanor Fayle, both members of the Society of Friends.[2] In 1826, Thomas married Sarah Palmer (1798–1883) in Kilkenny. As his wife was not a Quaker, he was immediately disowned by the Society of Friends.[3] Nothing is known about Thomas' education or how he became so knowledgeable about mechanical engineering. It is possible that he may have been employed at Malcolmson's cotton mill in Portlaw or in the shipyards that flourished in Waterford at the beginning of the nineteenth century.[4] Alternatively, he may have gained practical experience in some British engineering works.[5]

By 1832, Thomas Grubb (Fig. 3.1) had established an engineering works near Charlemont Bridge by the Grand Canal on the south side of Dublin.[6] He produced

1 C. Mollan, *Irish national inventory of historical scientific instruments* (Dublin, 1995), pp 481–3. **2** Uncatalogued archives, Dublin Friends Historical Library. **3** Disownment 312, Dublin Friends Historical Library. **4** B. Irish, *Shipbuilding in Waterford, 1820–1882* (Bray, 2001). **5** H. Andrews, 'Grubb, Thomas' in J. Maguire and J. Quinn (eds), *Dictionary of Irish Biography* (Cambridge, 2009) online ed. (dib.cambridge.org.elib.tcd.ie, accessed 15 Sept. 2010). **6** I.S. Glass, *Victorian telescope makers: the lives and letters of Thomas and Howard Grubb* (Bristol, 1997), p. 10.

3.1 Thomas Grubb.

small machine tools, telescopes and cast iron beds for billiard tables. He took up optics as a hobby and constructed a small observatory with a 9-inch reflecting telescope and a transit telescope; visitors were admitted for a charge of one shilling.[7] Grubb's reflector came to the attention of the Revd Thomas Romney Robinson (1792–1882) who was director of Armagh Observatory from 1823 until his death fifty-eight years later. Robinson was a mathematician and physicist with a keen interest in optical instruments; he was a fellow of Trinity College Dublin and well-established in Irish and British scientific circles.[8] He was well acquainted with William Parsons (1800–67), then Lord Oxmantown and later third earl of Rosse, who invented new techniques for making large speculum mirrors. By 1840, Parsons had constructed a 36-inch reflector and by March 1845 his famous 72-inch reflector, the Leviathan of Parsonstown, was bringing distant galaxies into view.

Robinson soon became responsible for Grubb's first major commission. About

7 D. Kelly, *Four roads to Dublin* (Dublin, 1955), p. 98. **8** J.A. Bennett, *Church, state and astronomy in Ireland: 200 years of Armagh Observatory* (Armagh, 1990), p. 85.

1831, Robinson learned that the largest refractor in existence had been erected at Markree Castle, near Sligo, in north-west Ireland.[9] The proud owner of this instrument was a wealthy landowner, Edward Joshua Cooper (1798–1863). Cooper had purchased the 13.3-inch objective lens from Robert-Aglaé Cauchoix in Paris.[10] However, the telescope did not perform well as it had been mounted on a temporary alt-azimuth stand of wood. Robinson persuaded Cooper to order a tube and equatorial mounting from Thomas Grubb. Both the tube and the sturdy mounting were made of cast iron and weighed 2,387kg. The telescope was erected in 1834 on a triangular pier of limestone blocks and the polar axis was driven by a clockwork mechanism. There was no dome but the lens was covered when not in use and the observer was protected from the wind by a circular wall sixteen feet high and thirty-six feet in diameter.

Work on the Markree telescope led Grubb to develop several innovations that would later be put to good use in other telescopes. As part of the preparations for making the Markree telescope, Grubb had constructed a trial equatorial mount; Robinson later purchased this mount to support a 15-inch clock-controlled Cassegrain reflector for Armagh Observatory. This was the first time that a large reflecting telescope had been given a proper equatorial mount with a clock drive. Another innovation was the use of a lever support system for the primary mirror whereby the supporting pressure was evenly distributed over the back surface of the mirror by eighteen support pads on three triangular plates, thereby avoiding strain on the mirror and consequent distortion of the image. This design feature was used by Lord Rosse for his 72-inch reflector, which had eighty-one support points and it has been adopted in various ways for large telescopes ever since. Grubb also supplied eyepieces and a micrometer for the 72-inch telescope.[11]

Grubb began to gain a reputation in scientific circles, which led to further commissions. The 1835 meeting of the British Association for the Advancement of Science in Dublin, when Thomas Grubb became a member, seems to have marked the beginning of his active engagement in the scientific life of the city. In 1836, he read a paper to the Royal Astronomical Society about a method for illuminating cross-wires in the field of a reflecting telescope to facilitate micrometer measurements.[12] About the same time, he received two important commissions for instruments from Trinity College Dublin. The first, from the mathematician Professor James MacCullagh (1809–48), was for an optical instrument to study the reflection of light from metals.[13] The second, from Prof. Humphrey Lloyd (1800–81), was for twenty sets of magnetometers for the global network of magnetic observatories then being established in the British colonies.[14] In 1839, Grubb was elected a

9 Glass, *Victorian telescope makers*, p. 13. **10** W.G. FitzGerald, *Strand Magazine*, 12 (1896), 369–81. **11** Glass, *Victorian telescope makers*, p. 28. **12** T. Grubb, 'On illuminating the wires of telescopes', *MNRAS*, 3 (1836), 177–9. **13** J. MacCullagh, 'On a new optical instrument', *PRIA*, 1 (1836–40, read 9 Apr. 1838), 158–60. **14** H. Lloyd, *Account of the magnetical observatory of Dublin, and of the instruments and methods of observations employed there* (Dublin, 1842).

member of the Royal Irish Academy on 14 January; this was a considerable honour as he did not have an academic background or formal education.

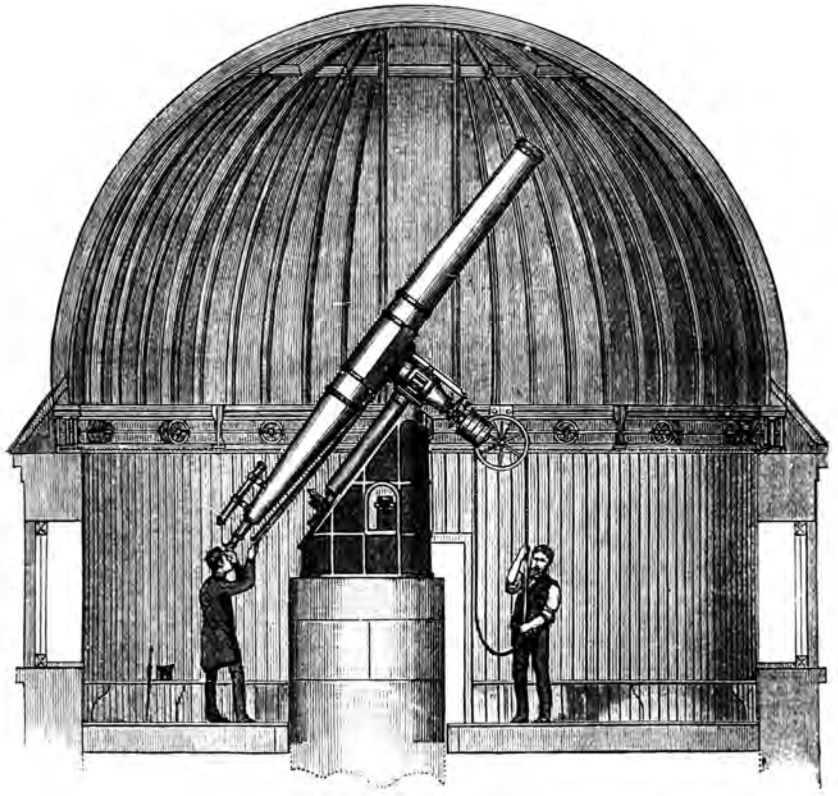
While Grubb achieved notable success in building scientific instruments, his main source of income arose from the commercial need for banknotes. About 1840, he became 'Engineer to the Bank of Ireland', where he was responsible for designing and constructing machinery for engraving, printing and numbering banknotes.[15] At that time, banknotes were usually produced manually from copper-plate engravings. After spreading ink over the plates, the surplus was removed to leave ink only in the grooves. Then the plates were pressed firmly against paper for the actual printing. Starting from the type of machine used by the Bank of England, Grubb introduced a number of cams to eliminate, as far as possible, the need for a human operator. He was employed by the Bank of Ireland until his death in 1878 when his son Henry took over his position. Several of Grubb's machines were still in use in the 1920s.

During the 1850s and 1860s, Grubb consolidated his reputation as Ireland's pre-eminent telescope manufacturer. He received numerous commissions for telescopes from the moderately sized 6.75-inch Sheepshanks refractor for the Royal Greenwich Observatory to the enormous Great Melbourne Telescope with its 4-foot speculum mirror. Grubb's position within the scientific community also became more significant and Robinson's support continued to be influential in his success.

In 1853, the Dublin Industrial Exhibition took place on the Leinster Lawn premises of the Royal Dublin Society and Grubb exhibited a 12-inch equatorial refractor; this telescope was exhibited also at the London exhibition of 1862. When Sir James South presented his 11.75-inch Cauchoix lens to Trinity College Dublin, Grubb mounted it on the equatorial and erected it at Dunsink Observatory in 1868 (Fig. 3.2). A novel feature of this telescope is the method adopted for reducing friction. For stability Grubb used large-diameter bearings on the polar axis and he reduced the friction on each bearing by applying sideways pressure with counterpoised rollers. This feature was used in the Melbourne and Vienna telescopes and became obsolete only when large roller bearings became available.[16]

Grubb's innovations in optics became a matter for scientific discourse as well as the basis of new instruments. During the 1850s, he published a series of papers in the *Proceedings of the Royal Irish Academy* and in the *Journal of the Royal Dublin Society* that demonstrate his ability to design optical systems. In a paper on spherical aberration in a microscope, he states that for several years he had been using ray tracing methods to gain insight into the effects of various combinations of optical components.[17] His ray-tracing diagrams were drawn on a scale ten times the actual size and he made measurements with a magnifier to 1/500th of an inch. By combining mathematical and practical approaches, he was able to estimate the overall aberrations of a lens

15 T. Grubb, 'Description of the banknote printing machine at the Bank of Ireland', *PIME* (1865), 166–78. **16** P.A. Wayman, *Dunsink Observatory, 1785–1985: a bicentennial history* (Dublin, 1987), pp 96–9. **17** T. Grubb, 'A new method of determining, approximately, the spherical aberration of a combination of lenses for microscopic purposes', *PRIA*, 6 (1853–7, read 27 Feb. 1854), 59–63.



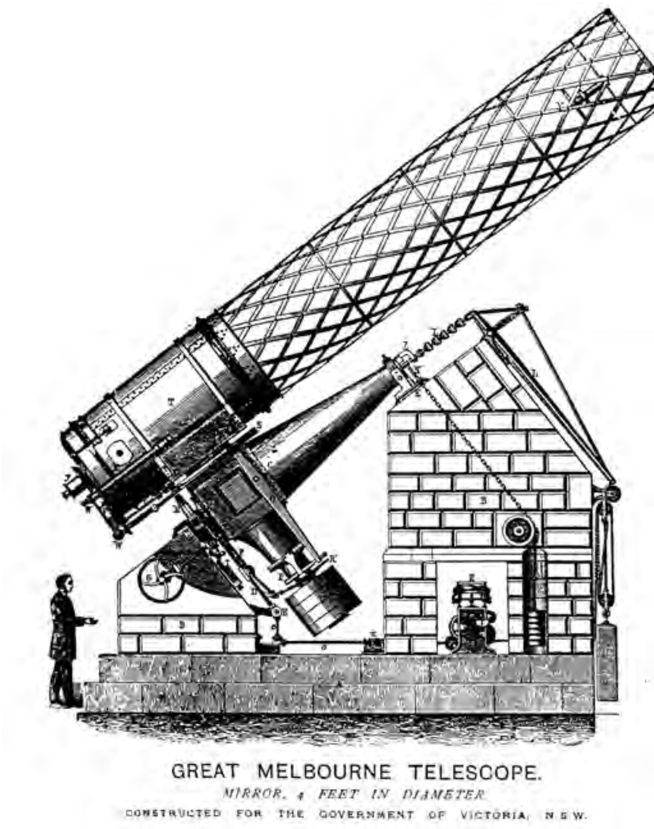
3.2 The James South 12-inch refractor at Dunsink Observatory.

system. Other investigations led to his invention of a wide-angle achromatic portrait lens which he patented and about which he read a paper at the Royal Dublin Society in March 1858.[18]

THE GREAT MELBOURNE TELESCOPE

The success of Thomas Grubb in achieving a reputation as the preeminent scientific telescope maker in the United Kingdom during the nineteenth century is demonstrated by the story of the Great Melbourne Telescope. The influence of Robinson and Lord Rosse was paramount. In the late 1840s, efforts were made by Sir Edward Sabine, Robinson and others to persuade the British government to fund a large astronomical telescope in the southern hemisphere. These suggestions were chan-

18 T. Grubb, 'On a new patent compound view lens for photographic cameras', *JRDS*, 2 (1858), 27–9.



3.3 The Great Melbourne Telescope.

nelled through the British Association and later, the Royal Society of which Lord Rosse was then president. In 1852, the Royal Society set up the Southern Telescope Committee which included G.B. Airy, T.R. Robinson, J.C. Adams, Lord Rosse, J. Nasmyth, E.J. Cooper and J. Herschel. In July 1853, the committee agreed to ask the government for funds to enable Thomas Grubb to construct a 4-foot reflector. However, the Crimean War caused the proposal to be put aside until 1862, when a proposal for a large telescope came from the University of Melbourne. Despite the fact that J.B.L. Foucault (1819–68) had demonstrated the feasibility of silver-on-glass mirrors, it was decided that a metal mirror would be the safest option (Fig. 3.3).[19]

Grubb received the order for the telescope in February 1866 and immediately withdrew his youngest son Howard (Fig. 3.4) from Trinity College Dublin, where he was a third-year student of engineering. Grubb senior bought a piece of land in

19 T. Grubb and T.R. Robinson, 'Description of the Great Melbourne Telescope', *PTRS*, 159 (1869), 127–61.

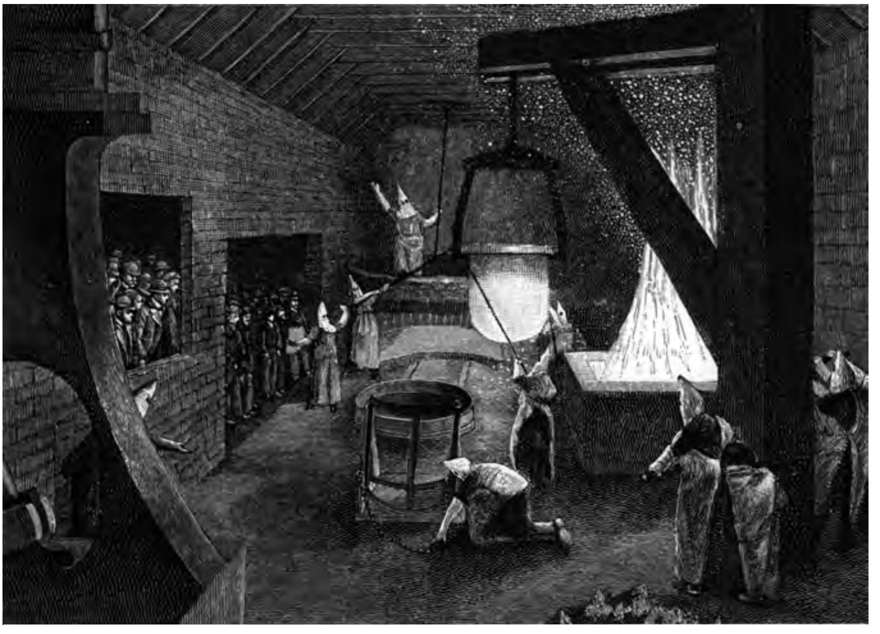
3.4 Howard Grubb at 35.

Rathmines and erected workshops, machinery and furnaces suitable for casting a 4-foot speculum mirror.[20] The procedure for casting two speculum mirrors followed closely that pioneered by the third earl of Rosse at Parsonstown. The Great Melbourne Telescope was completed in February 1868 and shipped to Australia (see Fig. 3.5 and jacket). Regular observing started in August 1869 but, despite its acclaim as a technical triumph, it became an embarrassing failure. The main reason for the failure was the lack of adequate expertise in Melbourne to maintain the surfaces of the speculum mirrors.[21]

Despite its failings, the construction of the Great Melbourne Telescope brought the Grubbs international recognition. Thomas Grubb's achievements were recognized in 1864 by his election as a Fellow of the Royal Society. He developed further scientific contacts, including Sligo-born George Gabriel Stokes (1819–1903), Lucasian Professor of Mathematics at Cambridge and great-grandson of Gabriel Stokes, a Dublin instrument maker. Stokes, who had married Robinson's daughter in 1859, gave the Grubbs advice on theoretical optics over many years.[22]

The Great Melbourne Telescope also marked a turning point in the Grubb business. From 1868, the firm was run as a partnership of father and son and renamed 'Messrs Grubb & Son (formerly Thomas Grubb)'. Howard adopted a more empir-

20 H.C. King, *The history of the telescope* (Dover, 1955), pp 264–7. **21** T. Grubb, *The Great Melbourne Telescope: an examination of and reply to the official reports from Melbourne respecting the instrument, its erection at Melbourne etc. etc.* (Dublin, 1870). **22** Glass, *Victorian telescope makers*, p. 64.



3.5 The casting of the speculum for the Great Melbourne Telescope.

ical approach to design than his father and took advantage of the latest advances in precision measurement. By 1873, the elderly Thomas appears to have withdrawn from the business and the firm was called 'Howard Grubb (late Grubb & Son)'. In 1871, Howard Grubb married Mary Hester Walker, who was born in 1854 in New Orleans of Irish parents. Her father, George Hamilton Walker, was born in Kells, Co. Meath. Howard and Mary had six children, of whom four survived to adulthood. The youngest surviving son was named Romney Robinson, an indication of the high regard of the Grubbs for the Armagh astronomer.[23]

In April 1869, Grubbs received an important order from the Royal Society, whose president was then the Dublin-born Sir Edward Sabine. In order to promote the new field of astronomical spectroscopy that had been pursued very successfully by William Huggins of Tulse Hill in London, and his neighbour, the chemist W. Allen Miller, the society decided to equip Huggins with a Grubb 15-inch refractor and an 18-inch reflector. In 1871, Grubbs supplied Huggins with a multi-prism spectrograph for solar work.[24] Howard Grubb also introduced Huggins to Margaret Lindsay Murray of Dublin, a young woman nearly twenty-five years his junior who became his wife and skilled collaborator. It remained a standing joke between the two men that however correctly they settled their business accounts, Huggins still remained indebted to Grubb for introducing him to the future Mrs Huggins.[25]

23 Glass, *Victorian telescope makers*, p. 69. **24** H. Grubb, 'Automatic spectroscope for Dr Huggins' sun observations', *MNRAS*, 31 (1871), 36–8. **25** C.E. Mills and C.F. Brook, *A*

3.6 Completion of Grubb's optical and mechanical works in 1875.

THE GREAT VIENNA TELESCOPE

Howard Grubb, now fully in charge of the firm, benefited from the reputation that his father had established. In 1873, Howard received an enquiry from Vienna Observatory about supplying a large refractor for a new observatory to be built on high ground 5km from the centre of Vienna. The observatory was to be a very large building in the shape of a cross with a 45-foot dome at the centre and three smaller domes on each of the arms. After a representative of Vienna Observatory had examined observatories and engineering works in Europe and America, he recommended that Grubb should be asked to build the telescope and four domes. In June 1875, Howard Grubb signed a contract with the Austro-Hungarian government for a 27-inch refractor and the four domes at a cost of £8,000. To build the largest refracting telescope in the world was quite a challenge for a man only thirty years old.[26]

Howard Grubb immediately rebuilt the engineering works in Rathmines. The new building had a large twelve-sided central hall 42 feet wide and 42 feet high (Fig. 3.6). The hall was surrounded by workshops containing machinery for grinding and polishing lenses and for constructing the components of the telescopes and the domes. The factory was known as 'The Optical and Mechanical Works, Rathmines' and was situated on Observatory Lane, which exists to this day.[27]

sketch of the life of Sir William Huggins, KCB, OM (London, 1936). **26** H. Grubb, 'Grubbs equatorial telescope', *Engineering*, 28 (1879), 278; H. Grubb, 'The Vienna Equatorial', *Engineering*, 29 (1880), 114–16,199–202, 309–11, 391, 409, 467–9; 30 (1880), 314–15, 424–8. **27** H. Grubb, 'Sir Howard Grubb's works, Dublin', *Engineering*, 46 (1888), 571–3.

A local committee, including many of the Grubbs' scientific contacts, was set up to monitor the building of the telescope. It consisted of Prof. R.S. Ball, the earl of Crawford, W. Higgins, Prof. J.E. Reynolds, the earl of Rosse, Prof. G.G. Stokes, Dr G.J. Stoney and Mr Richard Walsh, the Austrian consul in Dublin. The telescope was to be delivered within three years of the delivery of the lens blanks. The mechanical work on the telescope and mounting progressed rapidly. The forty-five-foot dome had a double skin of riveted steel plates for stiffness and to keep the temperature of the interior constant. The total weight of the dome was fifteen tons, yet a force of only 70 pounds was required to move it. The domes were sent to Vienna and erected at the end of 1878.[28]

The Vienna Telescope was completed towards the end of 1880 and was ready for testing on the stars. It was approved by the local committee in March 1881 and was declared 'a splendid success'. Despite governmental red tape, which delayed the delivery of the telescope, it was commissioned and in full working order by the end of 1883, just ten years after it was first conceived. The Vienna Telescope was briefly the largest refractor in the world until one of 30-inch aperture was completed for Pulkovo Observatory in 1885.[29]

Howard Grubb continued in the tradition of his father by maintaining contacts in the scientific community through the Royal Dublin Society and the British Association for the Advancement of Science. He had strong interactions with his customers, especially David Gill of the Royal Observatory, Cape of Good Hope. He received recognition from Trinity College Dublin in 1876, when he was awarded the honorary degree of Master of Engineering. In 1883, he was elected a Fellow of the Royal Society and in 1887 he was knighted.

HECTIC TIMES

During the 1880s and 1890s, Howard Grubb extended and enhanced the international reputation that his father had built, by building telescopes for countries beyond Europe and the British Empire. By 1888, he was employing between thirty-five and forty men at the Rathmines works. He made about ninety objective lenses ranging from five to twenty-eight inches in diameter and most of the required mountings and controls. The countries to which he exported telescopes included South Africa, India, the USA, Germany, Mexico, Australia, Spain, Venezuela, Belgium, Bulgaria, New Zealand and Turkey, and many telescopes were also sold in Ireland, England and Scotland. It was said that Grubbs exported to every continent except Antarctica.[30]

The Rathmines works frequently accommodated overseas visitors who were considering ordering a telescope. Among these, in February 1875, was Simon Newcomb of the US Naval Observatory in Washington DC. Newcomb was scien-

28 H. Grubb, 'The Great Vienna Telescope', *Nature*, 24 (1881), 11–14. **29** Glass, *Victorian telescope makers*, p. 93. **30** W.G. FitzGerald, *Strand Magazine*, 12 (1896), 369–81.

tific advisor to the board of trustees of the Lick Observatory to be established at Mount Hamilton in California. At the end of a tour of European optical workshops, Newcomb judged that Howard Grubb was the only person outside the United States who had any chance of successfully building the instruments for Lick Observatory.[31]

Grubb had ambitious plans for the new Lick Observatory. He envisaged a 40-inch refractor in a dome 70 feet in diameter, a 72-inch reflector with a special sliding roof as well as a meridian room with a meridian circle and a transit instrument. One important feature was the provision of a rising floor, controlled hydraulically. He presented a plaster model of the proposed scheme to the Lick trustees.[32]

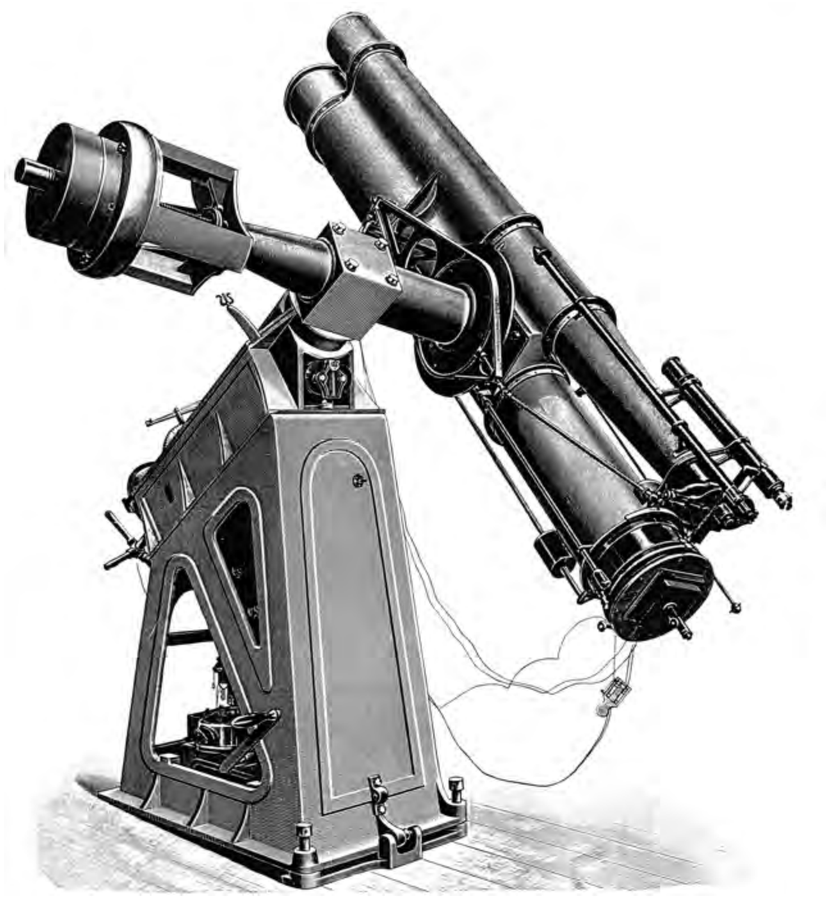
Grubb's chief competitor was the firm of Alvan Clark and Sons of Cambridge, Massachusetts, then widely regarded as the best lens makers in the world. However, Clark did not undertake mechanical work. Alvan Graham Clark visited Grubb in 1879 and the two men debated the pros and cons of refractors and reflectors. Clark believed that his refractors were superior to reflectors double their aperture and Grubb tried to convince him of the benefits of reflectors. In December 1880, the Lick trustees awarded the contract for a 36-inch lens to Alvan Clark at a cost of $50,000 and Grubb, despite his disappointment, offered to build a tube and mounting. The project was delayed for want of suitable glass blanks, which were not available until December 1885.[33]

In April 1886, Grubb delivered a lecture at the Royal Institution in London on 'Telescope Objectives and Mirrors, their Preparation and Testing', in which he described his plans for Lick Observatory.[34] An important feature of his design was that despite the size of a large telescope in a seventy-foot dome, he could arrange for it to be operated single-handed by the observer. In the end, the Lick trustees awarded the contract for an equatorial mount and dome to Warner and Swasey of Cleveland, Ohio. The design incorporated Grubb's idea of a hydraulically operated rising floor and he was compensated by the payment of $600.

In 1882, David Gill, Her Majesty's Astronomer at the Royal Observatory, Cape of Good Hope, attached an ordinary portrait camera to his six-inch equatorial telescope to take photographs on the new 'dry plates' of the great comet then visible. With exposures up to one or two hours duration, he obtained fine photographs not only of the comet but of the background stars. He realized that it would be possible to use photography to make star maps free from personal errors and avoiding the great labour of observing by eye. He obtained an f/9 lens of six-inch aperture from Dallmeyer and began a sky survey known as the *Cape Photographic Durchmusterung*.[35]

The potential of photography for recording star positions was also recognized by the Henry brothers, opticians at Paris Observatory. They built a special photographic refractor and the successful trials of this telescope led Admiral Mouchez, director of

31 Glass, *Victorian telescope makers*, p. 96. **32** Glass, *Victorian telescope makers*, p. 100. **33** Glass, *Victorian telescope makers*, p. 110. **34** H. Grubb, 'Telescope objectives and mirrors; their preparation and testing', *PRI*, 11 (1887), 413–32. **35** D. Gill, *Cape Photographic Durchmusterung*, 1, ix.



3.7 Grubb's 13-inch astrographic telescope.

Paris Observatory, and Gill to organize an international congress in Paris in April 1887.[36] Fifty-six astronomers from nineteen countries attended the congress and a permanent commission was set up to promote the *Carte du Ciel* (Map of the Sky). The plan was to make a photographic map of the sky showing stars to the fourteenth magnitude and, by measuring the photographs, to make a precise catalogue of stars to the eleventh magnitude. It would require exposing over 10,000 plates and would give rise to a catalogue of over four million star positions; in the event, it was not completed until 1964. Each of the eighteen participating observatories mapped a particular declination zone. The Henrys' telescope was chosen as the standard instrument for the survey; with an aperture of 33 centimetres and a focal length of 343 centimetres, it gave a plate scale of one minute of arc per millimetre.[37]

36 Glass, *Victorian telescope makers*, p. 133. **37** H.H. Turner, *The great star map, being a brief*

While continental observatories chose to order their astrographic telescopes from the Henrys, British institutions preferred to deal with Howard Grubb, and he obtained orders for seven telescopes (Fig. 3.7). Designing lenses for photographic use raised new problems and Grubb had to carry out much experimental work before he was in a position to manufacture the telescopes. As the early dry plates were most sensitive to the violet and ultra-violet region of the spectrum, the lenses had to be in focus for these wavelengths. Grubb sent his lenses to Oxford Observatory for testing on the stars and the list of defects guided him in making corrections. The work progressed slowly but surely and by 1889, the first telescope had been completed.[38]

In constructing the drives for the astrographic telescopes, Grubb had to pay special attention to avoid periodic errors in the worm screws which transmitted the driving torque. He devised a new machine especially for cutting these screws. For cutting the teeth of the driving sectors he used a dividing engine and as each tooth was cut it was watched under a microscope. He also devised a precise sidereal drive that was locked to the beats of a seconds pendulum. It was in effect a phase-locked clock drive and was provided with all his photographic telescopes after 1888.[39]

The seven observatories that Grubb supplied with astrographic telescopes were Oxford, Sydney (lens only), Melbourne, Tacubaya (Mexico), Greenwich, Cape of Good Hope and Perth. Some of these instruments were later used for some very important observations. In 1919, Arthur Eddington organized expeditions to observe a total eclipse of the Sun at Principe Island off the coast of West Africa and at Sobral in north Brazil. The objective of the Oxford astrographic telescope was used at Principe and the Greenwich one was used at Sobral. With these and with a long-focus lens and an eight-inch coelostat made by Grubb and owned by the Royal Irish Academy, Eddington and Dyson confirmed the bending of starlight as predicted by Einstein's general theory of relativity and overnight Albert Einstein became an icon of science.[40]

A NEW CENTURY AND NEW TECHNOLOGIES

In the early years of the twentieth century, Howard Grubb turned his attention to military and surveying instruments. This change in direction may have been caused by the declining economy of Britain and Ireland and the rising prosperity of the United States, where there were prosperous benefactors willing to fund large tele-

general account of the international project known as the astrographic chart (London, 1912). **38** H. Grubb, 'The construction of telescopic object-glasses for the international photographic survey of the heavens', *TRDS*, 4 (1891), 475–80. **39** H. Grubb, 'On the latest improvements in the clock-driving apparatus of astronomical telescopes', *PIME* (1888), 308–16. **40** F.W. Dyson et al., 'A determination of the deflection of light by the sun's gravitational field, from observations made at the total eclipse of May 29, 1919', *PTRS*, 220 (1920), 291–333.

scopes. In Europe, telescope-making came to be dominated by the Schott glassworks and by the firm of Carl Zeiss of Jena in Germany.

The last big refractors made by Grubb were ordered before the First World War but were not delivered until long after it ended. In 1909, the Transvaal Observatory in Johannesburg ordered a 26.5-inch refractor and the Chilean National Astronomical Observatory ordered a 24-inch refractor. These instruments incorporated several improvements in design. Instead of sectors that had to be rewound every few hours, the telescopes had continuous circular worm wheels. Apart from the advantage of avoiding interruption to the observations, the wear on the gears was more uniform. In addition, ball bearings were used in the friction relief systems for the first time. These changes may have been due to Cyril Young (1875–1949) who joined the Dublin firm in 1910. A delay in obtaining blanks for lenses was extended by the outbreak of the First World War and work on the telescopes ceased in 1914.[41]

Even before the outbreak of war, Howard Grubb seems to have recognized a new market for his skills in the development of military devices. Between 1900 and 1916, Howard Grubb filed a score of patents items such as periscopes, gun-sights and range finders. A 1901 patent shows drawings for a periscope and the first effective submarine periscope was made by Grubb in Dublin. Initially, there was some difficulty in making the early periscopes watertight but successful trials were reported to the British Admiralty in 1902. Grubb supplied most of the periscopes for the British submarines in the First World War. These were made at first at the Rathmines and Charlemont Bridge works. However, for security reasons, the Admiralty insisted on moving production to St Albans, some twenty miles north of London. The thirty-foot steel tubes for the periscopes were made at Vickers works in the north of England and had to be transported across the Irish Sea. In addition, growing political unrest in Ireland put the Rathmines works at risk and it had to be guarded night and day by the military.[42]

The end of the war created considerable turmoil for Howard Grubb's business. In November 1918, the move to St Albans was only partially completed, yet it was impossible to reverse it. By March 1919, some three hundred tons of machinery still had to be moved across the Irish Sea. Moreover, wages had risen by a factor of two or three and many workers were on strike.[43]

Howard Grubb tried to complete the telescopes that had been ordered before the war, but ran into great difficulties from the rising wages and the lack of glass blanks. Eventually, in January 1925, the firm went into liquidation. However, by April the same year it was rescued by Sir Charles Parsons and re-established as 'Sir Howard Grubb, Parsons and Co.' at Heaton, Newcastle-on-Tyne in north-east England. Charles Parsons (1865–1931), inventor of the steam turbine, was the youngest son of the third earl of Rosse, who had been associated with Thomas Grubb many years before.[44]

41 Glass, *Victorian telescope makers*, p. 211. **42** Glass, *Victorian telescope makers*, p. 213. **43** Glass, *Victorian telescope makers*, p. 214. **44** G.M. Sisson, 'Sir Howard Grubb, Parsons and Company', *PRS*, Series A, 230 (1955), 147–57.

After the St Albans works closed, Sir Howard Grubb retired to Monkstown in south Dublin where he lived in a house overlooking the sea. Lady Grubb died in April 1931 and Sir Howard died only a few months later on 16 September 1931 at the age of 87.

The firm of Grubb-Parsons went on to build many large astronomical telescopes. These included the 74-inch reflectors at Pretoria Observatory in South Africa, Helwan Observatory in Egypt and Mount Stromlo Observatory in Australia. The firm also supplied the tube and optics of the Anglo-Australian Telescope and the UK Schmidt at Siding Spring in New South Wales. Grubb-Parsons telescopes at the Spanish observatory on La Palma in the Canary Islands include the Carlsberg Automatic Transit Circle, the 1-metre Jacobus Kapteyn Telescope, the 2.5-metre Isaac Newton Telescope (originally erected in 1967 in England) and the 4.2-metre William Herschel Telescope. The firm of Sir Howard Grubb, Parsons & Co. finally closed in 1985.

CONCLUSION

It seems probable that few Dublin citizens appreciated the achievements of the high-precision engineering firm at the end of Observatory Lane in Rathmines. Yet the quality of design and construction gained a worldwide reputation for Thomas and Howard and enabled them to sustain a high level of employment at their works. Indeed, it is only with hindsight that we can see the impact that their innovative ideas had on the general progress of telescope technology in the nineteenth and twentieth centuries. Grubb telescopes were characterized by sturdy mechanical design, precision optics, reliable tracking and ease of use. It is still not widely known that the crucial test of Einstein's General Theory of Relativity in 1919 relied on optical components made entirely by Grubbs. Around the world, many Grubb telescopes continue to scan the heavens and help astronomers probe the secrets of the universe.