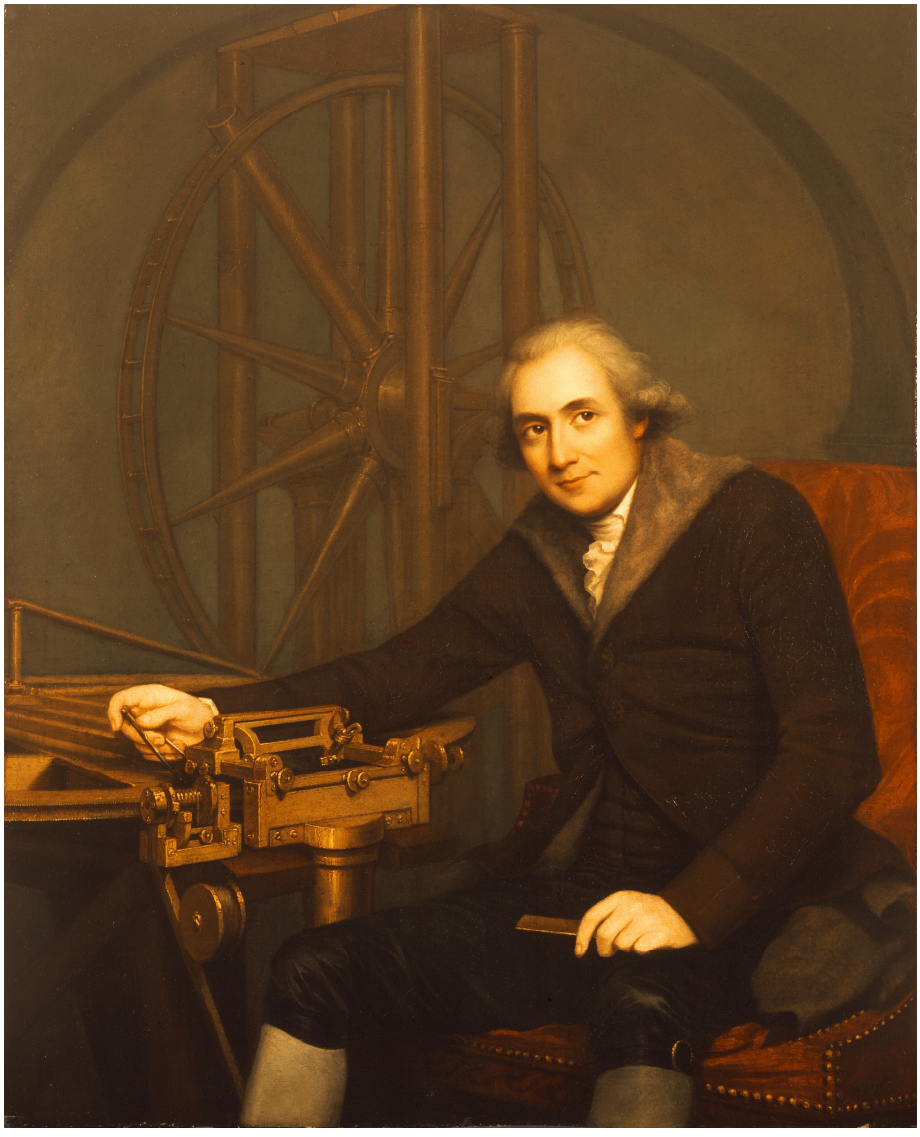
The Antiquarian Astronomer

Journal of the Society for the History of Astronomy



Issue 7 March 2013

ISSN 1740-3677

The Antiquarian Astronomer

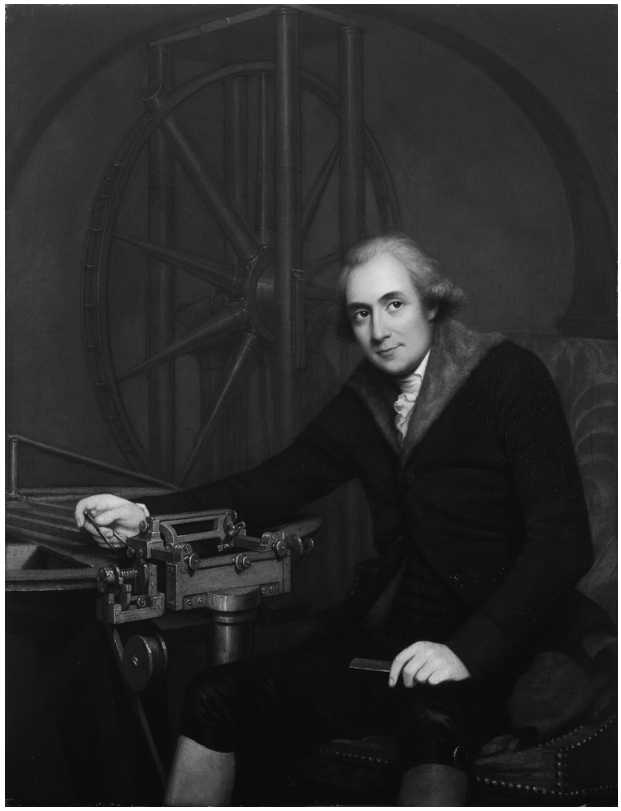
Journal of the Society for the History of Astronomy

The Cover illustration:

Portrait of Jesse Ramsden

The colour plate overleaf shows the best known portrait of the Jesse Ramsden (1735-1800), the celebrated London scientific instrument maker who is prominent in two of the papers in this issue of the journal. The oil painting that resides with the Royal Society, London shows Ramsden with to his two greatest achievements, the Palermo Circle and his famous dividing engine. The former, shown in the background, is a large measuring instrument with precision scales and optics. Ordered by Giuseppe Piazzi (1746-1826) in 1791, it was supplied to the Royal observatory in Palermo, Sicily. In contrast, Ramsden is portrayed seated next to his famous dividing engine, a pioneering device that allowed the angular scales on navigational instruments to be made, both quicker and more cheaply. This innovation earned Ramsden financial reward from the Board of Longitude and his election to the Royal Society London in1786.

Although it might be expected that the portrait was owned by Ramsden, it appears that it was commissioned by the surgeon Sir Everard Home (1756-1832) and painted by his brother, the artist Robert Home (1752-1834) around 1790. Both Ramsden and Sir Everard Home were fellows of the Royal Society and collaborated through their interest in optical devices.[1] The portrait is better known from the mezzotint print of it by John Jones (1745-1797), published London after the original by Home. The Ramsden portrait was subsequently donated to the Royal Society in 1850 by Sir James Everard Home (1798-1853) an eminent naval officer and son of Sir Everard Home. The donation was recorded in a letter from Home.



Sir (James) Everard Home:

> Sir. – I have the honour to offer for the acceptance of the Royal Society. To be suspended in the Meeting Room, two pictures, one of John Hunter, the other of Jesse Ramsden, optician, both of them painted by the late Robert Home Esq…[2]

1. McConnell, Anita, *Jesse Ramsden (1735-1800): London's leading scientific instrument maker* (Aldershot, Ashgate, 2007), 39-51
2. Royal Society Minutes of the Council. Printed CM P/2, 1846-1858. Page 158, meeting of 20 June 1850

Foreword

The current issue of *The Antiquarian Astronomer* has a stimulating selection of papers with a strong focus on the eighteenth century. These range from the role of copyright law in Flamsteed's battle with Newton and Halley to American colonial expeditions to observe the 1769 transit of Venus. In contrast, we also have papers giving an incisive overview of the Neptune controversy and an insight into how the Co-operative Society pioneered astronomical adult education. In addition, a paper giving an account of the English mount and its use is included as a fitting tribute to the memory of Peter Hingley. A project of many years, it involved much fieldwork. Françoise Launay recalls of an expedition to South Kilworth and Shuckburgh in the Midlands with Dr Allan Chapman. On that occasion, Peter drove Allan back to his home in Oxford when it transpired that there were no further trains from Leamington Spa that day and then proceeded to drive all the way to Bridgnorth west of Birmingham.

If you are thinking of publishing your research, much useful advice can be found on the society's website www.shastro.org.uk, in particular, the web pages for the journal and the bulletin. Either way, I recommend you contact me or other members of the society as we can give help and guidance as to the best way of getting your research published. The quality and range of research being undertaken by members will be lost or ignored unless it is in the public domain. It is this sort of research that is becoming increasingly more important for the history of astronomy as the major figures have been investigated exhaustively.

I would like also to thank all those who have helped in bringing the journal to fruition, both the editorial team and all the external reviewers, their effort and expertise is greatly appreciated. Without such support the work of the society would not be possible.

Objectives

The Society for the History of Astronomy was formed in June 2002 with three main aims:

- To provide a forum for those with an interest in the history of astronomy and related subjects;
- To promote interest in the history of astronomy by academics, educators, amateur astronomers and local historians;
- To encourage research into the history of astronomy, especially research by amateurs, and to facilitate its collation, interpretation, preservation, publication and dissemination.

To implement these aims, the Society organises regular meetings and publishes its twice yearly *SHA Bulletin* and annual Journal, *The Antiquarian Astronomer*. This provides a medium to publish research by members and others into any aspect of the history of astronomy and related subjects. It is recognised that because most members were amateur astronomers and amateur historians, most of their research would be local history and was unlikely to be within the scope of professionally journals. The journal therefore provides a means by which the results of that research can be shared with other individuals and groups having interests similar to those of the Society. Papers for journal need not be restricted to local history, but should contain original research, new interpretation, insights of material in the public domain or bring to a wider audience material of limited availability or is available only in dispersed locations. Papers offered to *The Antiquarian Astronomer* should not have been previously published and are subject to external peer review.

Timely information, particularly about forthcoming events, both SHA and other, is now communicated to members via the quarterly *eNews*, which most members will receive by email. The Society also publishes the *Bulletin* (Editor Clive Davenhall; newsletter@shastro.org.uk), which usually appears twice per year. The next issue is scheduled for summer 2013. The scope of the *Bulletin* includes, but is not necessarily limited to: news and developments in the history of astronomy, meeting reports, articles, obituaries, book reviews and members' letters.

Contributions for the *Bulletin* are welcome. Articles can be on any aspect of the history of astronomy and are usually up to 2000 words in length. They normally do not contain significant new research (such research should be published in *The Antiquarian Astronomer*) and are not peer reviewed. Contributions for the *Observatory Scrapbook* series are particularly welcome. These items consist of a brief description (typically 500 words or fewer) and an illustration of some historical observatory. It is prudent to discuss contributions for the *Bulletin*, particularly book reviews, with the Editor in advance to avoid duplication.

Prof. James Stuart and the Rochdale Pioneers: How Astronomy as food for thought became a Co-op dividend

Philip A. J. Barnard

Wolverhampton Astronomical Society

In the mid-nineteenth century, formal education for many people, of all ages and especially the poorer members of society, left much to be desired. The Acts of Parliament needed to redress the deficiency lay in the future. For adults at this time community organisations such as The Rochdale Equitable Pioneers Society, and the Mechanics' Institutes set up by local industrialists and railway companies, became vehicles for self-improvement. James Stuart (1843-1913) of the University of Cambridge became one of the most important advocates of universal education, and he used astronomy as one means of achieving his goal – University Extension.

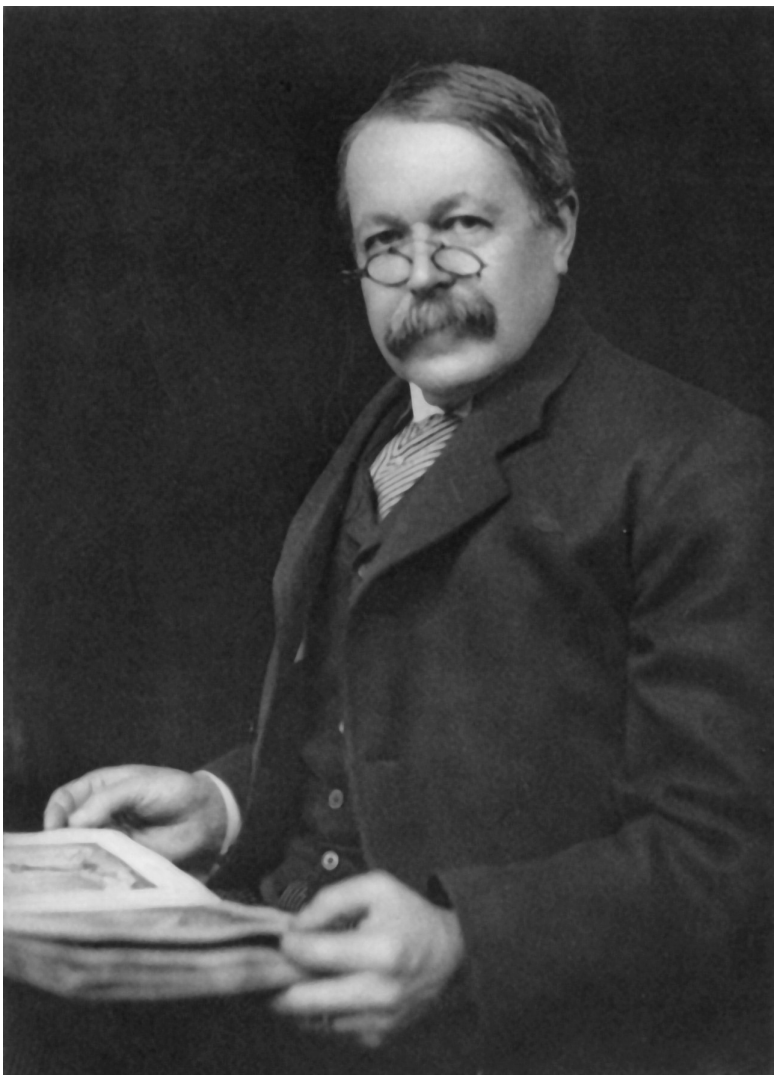


Fig. 1 Portrait of James Stuart in 1900
James Stuart, *Reminiscences* (London: The Chiswick Press 1911)
Courtesy of the University of Cambridge

There were several reasons for the development of co-operative societies in the second quarter of the 19th century, among which were high retail prices, adulteration of produce and the use of credit to render customers in thrall to unscrupulous shopkeepers. Co-operative customers not only owned the shops, but in later years this policy would be extended to the means of production.

The Rochdale Equitable Pioneers Society was not the first co-operative society to be created in the United Kingdom. However, the secure and enduring principles upon which that particular society had been founded ensured its long-term survival. The modern Co-operative movement, developing as it has into a worldwide organisation, claims confidently that its origins date to the shop which opened for business on 21 December 1844 at 31, Toad Lane, Rochdale.[1] The shop is now the Rochdale Pioneers Museum.

Fig. 2 Rochdale Pioneers Museum, Toad Lane, Rochdale, 1994
Photograph by author

My first visit to the museum was in the summer of 1992. Apart from the historical interest, my visit was somewhat influenced by feelings of nostalgia. For many of us growing up in a working class environment during World War II, the Co-op shops are remembered as an important part of the social fabric. However, I was to discover that my interest in astronomy would prove to have another, and rather unexpected, connection. In the museum guide, in a paragraph headed 'Lectures and Classes', was the statement that a Professor James Stuart had delivered a series of lectures on astronomy under the auspices of the Educational Department of the Rochdale Equitable Pioneers Society, and that this had influenced the development of the University Extension system.[2]

My first action was to contact the Institute of Astronomy, University of Cambridge, in the hope that a member of staff would be able to shed some light on the career of Professor Stuart. I very soon received a letter from Dr. David Dewhirst, informing me that Stuart was born at Markinch in Scotland, and listing some references he had gleaned from Stuart's autobiography *Reminiscences*, and advised me to obtain a copy. This memoir has been an invaluable source regarding Stuart's personal life and the development of University Extension, and has been used extensively in this article.[3] Although Dr Dewhirst had not known of Stuart's connection with astronomy, he was aware that the building first occupied by the Department of Extra-mural Studies, a field in which Dr. Dewhirst expressed considerable personal experience, had been named 'Stuart House' in his honour.

An imminent visit to Edinburgh, about 30 miles to the south of Markinch, had been fortuitously arranged a month previously, which gave me the opportunity to carry out further research. At Glenrothes public library, I photocopied an article from the Fife Free Press of 4 October 1958, which listed some of Professor Stuart's accomplishments, as an honoured local celebrity. I was then directed to Kirkcaldy public library, where I was able to make the first photocopies from James Stuart's autobiography and gain some detailed knowledge about his life and work.

Stuart was born at Balgonie, near Markinch, Fifeshire (now Fife), on 2 January 1843, the son of Joseph and Catherine Stuart, who owned flax-spinning mills in the district. As a graduate of St Andrews University, in 1862 he won a minor scholarship to Trinity College, Cambridge. He was elected Fellow of the college in 1866 and as such he lectured on mathematics.

Although remembered at this time by his contemporaries in Rochdale as 'the young professor', it was not until 1875 that he was appointed as the first Cambridge Professor of Mechanism and Applied Mechanics – 'Engineering' would be today's equiva-

lent. He set up the first workshops there, not an easy task in an institution more familiar with theoretical ideas. Instruments were constructed in the workshops for such worthies as John W. Strutt (3rd Baron Rayleigh) and James Clerk Maxwell. Stuart states in *Reminiscences* that he received payment from Maxwell 'for the box in which the Earth was weighed', used by a pupil repeating the famous experiment conducted by Henry Cavendish in 1798.

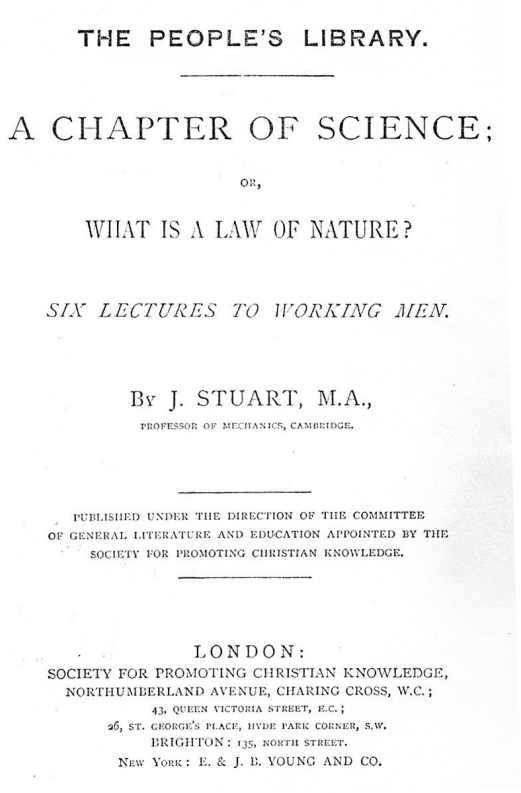
Stuart recounts that he befriended the then Astronomer Royal, George Airy, whose sons Hubert and Osmund were also at the university. Whilst still an undergraduate, he studied astronomy for about two months at the Royal Greenwich Observatory under the personal tuition of Airy, someone who made a great impression on the young man, describing him as, probably the most remarkable man he ever met. As Stuart explains, 'by the power of his intellect and his propensity for developing practical solutions to problems'. Curiously, whilst he describes the Astronomer Royal as being 'very abstemious', he is seemingly, at the same time, very fond of his food and drink. Regarding the latter, he is remembered as a good Saxon yeoman, having a preference for ale over any other beverage and able to sing a humorous song to accompany it!

Stuart was forever a champion of women's rights. To become an educated woman and work in what was still very much a 'man's world', was fraught with difficulties. In the summer of 1867 he was invited by the newly-formed North of England Council for Promoting the Higher Education of Women to give a series of lectures in Liverpool, Manchester, Sheffield and Leeds. It was always Stuart's belief that lectures were best delivered as a *course* and by the same lecturer. The lectures took place during the following autumn, and the subject he chose was astronomy, from Copernicus to Newton, showing how it was possible to formulate a 'law' by a process of observation and reasoning. To overcome what was considered to be a social taboo, of a young lady asking verbal questions of so young a male lecturer, James Stuart had to devise a syllabus and a series of written questions and answers, which resulted in a vast workload of marking, to be completed before the next lecture.

These lectures brought about Stuart's first contact with the Rochdale Pioneers, who were themselves strongly supporting legislation to improve women's rights, especially with regard to ownership of property, including the Co-op dividends paid to members. At that time, most of a wife's estate legally belonged to her husband, an injustice not removed by Act of Parliament until 1882.

However, a prior contact with friend and former colleague, W.M. Moorsom, who was a founder of the London & North Western Railway Mechanics' Institute at Crewe, had already resulted in an invitation to lecture there, the first subject being 'Meteors' in November 1867. Expecting twenty or so people, he was greatly surprised to be confronted by an audience exceeding one thousand, thanks to a fortuitous display of the Leonid meteors the night before, even though this was not the even more remarkable display of the previous year.[4]

The success of this lecture resulted in a return the following year with the same series of lectures he had delivered to the young ladies. These were later published under the banner of the People's Library, with the title 'A Chapter of Science: Six Lectures to Working Men', from notes taken down in shorthand, allowing the present-day reader to gain some idea of his lecturing style. The choice of publisher, the Society for Promoting Christian Knowledge, was very much in keeping with his strongly held beliefs, which always underlined his approach to the subject matter.



THE PEOPLE'S LIBRARY.

A CHAPTER OF SCIENCE;

OR,

WHAT IS A LAW OF NATURE?

SIX LECTURES TO WORKING MEN.

By J. STUART, M.A.,

PROFESSOR OF MECHANICS, CAMBRIDGE.

PUBLISHED UNDER THE DIRECTION OF THE COMMITTEE OF GENERAL LITERATURE AND EDUCATION APPOINTED BY THE SOCIETY FOR PROMOTING CHRISTIAN KNOWLEDGE.

LONDON:
SOCIETY FOR PROMOTING CHRISTIAN KNOWLEDGE,
NORTHUMBERLAND AVENUE, CHARING CROSS, W.C.;
43, QUEEN VICTORIA STREET, E.C.;
26, ST. GEORGE'S PLACE, HYDE PARK CORNER, S.W.
BRIGHTON: 135, NORTH STREET.
NEW YORK: E. & J. B. YOUNG AND CO.

Fig. 3 Title page from *A Chapter of Science* by James Stuart (London, 1883)
Courtesy University of Cambridge

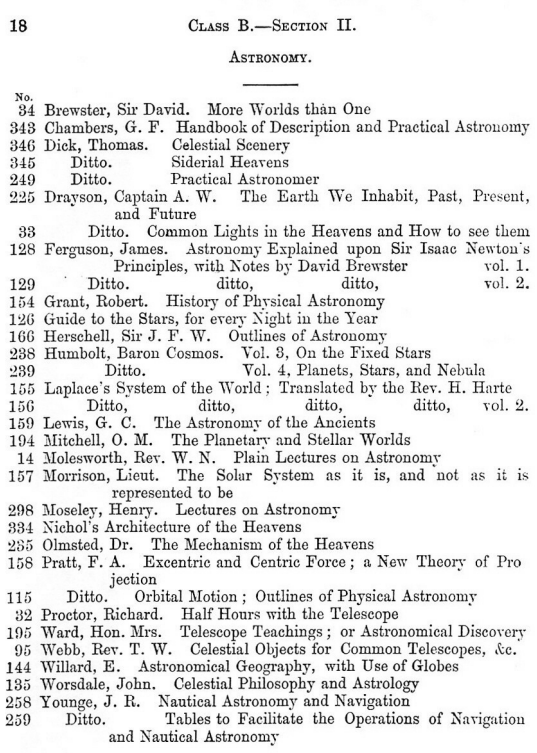
Notions for expanding university teaching beyond the normal confines had been aired both at Oxford and Cambridge Universities even before Stuart's arrival in 1862, but had not resulted in action of the kind Stuart now envisioned. However, his ideas for a peripatetic university, whose professors would circulate among the larger towns to bring teaching to a wider population, which he had first expressed during his early years at Cambridge, were now beginning to come to fruition. The reduction in travelling times across country, from days to hours, had been made possible at this time by the rapidly expanding railway network, which in the 1860s saw a smaller scale version of the 'railway mania' of the 1840s. The Rochdale Pioneers' committee, having learned of Stuart's exploits already undertaken in northern England, invited him to lecture in Rochdale. His agreement to their request would now to add a further impetus to the plan he had been formulating.

Education had become an important aspect of the Rochdale Equitable Pioneers Society from its early years, with 2.5% of the profits being used for this purpose and organised by their Educational Department. They were soon able to boast one of the best libraries in the area, with 6,000 volumes by 1868.[5] As you can see in the accompanying extract from the library's catalogue of December 1868, the list of 32 astronomy books included tomes by Laplace, Sir John Herschel and George F. Chambers together with several exercises on practical astronomy.[6]

Amongst the Society's collection of scientific instruments – the 1868 library catalogue lists some of them, were included two telescopes and a celestial globe. I could find no reference to the telescopes in the Society minute books, but there is a reference stating that the larger one cost £10 and appears to have been a refractor with accessories that could be hired for four pence per day or one shilling per week.[7] The Toad Lane store, now the museum, had part of its roof made level as an observation platform where, to quote one person's recollection – with a nod to Lord Byron, 'Like the Chaldean, they could watch the stars'.[8] A party of visitors from York expressed disappointment when unable to sample it for themselves, because their host was unable to produce the keys.[9] There is no sign of this structure in today's renovated building, but at least the main structure of this rudimentary 'observatory' is still extant.

I could find no records reporting how good the viewing conditions were in the centre of what must have been at that time, the smoke-laden industrial town of Rochdale. Perhaps this was better than one might imagine. A report in the Rochdale Observer newspaper of 17 November 1866 cites a Mr Curtis at a location near Oldham, who observed 600-800 Leonids in a 90 minute period, between clouds, during the exceptional display of that year.

At his own expense, Stuart began lectures in Rochdale on Tuesday 15 December 1868, where he was greeted with gratitude and acclaim. The lectures took place in the Large Assembly Room above the Toad Lane Central Store. To confuse matters, a larger 'Central Premises' had opened in 1867, where the library and newsroom were transferred from Toad Lane in 1870.[10] In the Pioneers' records, it is interesting to note that Stuart's experience at Crewe is repeated at Rochdale, where again he had expected only a small audience. An eye-witness account describes his first lecture in the large Assembly Room, having a capacity for well over 1,000 people, '...crowded from end to end by the cream of the working classes, with bright and intelligent faces', a sight which apparently made Stuart distinctly nervous.[11]



18 CLASS B.—SECTION II.

ASTRONOMY.

No.

34 Brewster, Sir David. More Worlds than One
343 Chambers, G. F. Handbook of Description and Practical Astronomy
346 Dick, Thomas. Celestial Scenery
345 Ditto. Siderial Heavens
249 Ditto. Practical Astronomer
225 Drayson, Captain A. W. The Earth We Inhabit, Past, Present, and Future
33 Ditto. Common Lights in the Heavens and How to see them
128 Ferguson, James. Astronomy Explained upon Sir Isaac Newton's Principles, with Notes by David Brewster vol. 1.
129 Ditto. ditto, ditto, vol. 2.
154 Grant, Robert. History of Physical Astronomy
126 Guide to the Stars, for every Night in the Year
166 Herschell, Sir J. F. W. Outlines of Astronomy
238 Humbolt, Baron Cosmos. Vol. 3, On the Fixed Stars
239 Ditto. Vol. 4, Planets, Stars, and Nebula
155 Laplace's System of the World; Translated by the Rev. H. Harte
156 Ditto, ditto, ditto, ditto, vol. 2.
159 Lewis, G. C. The Astronomy of the Ancients
194 Mitchell, O. M. The Planetary and Stellar Worlds
14 Molesworth, Rev. W. N. Plain Lectures on Astronomy
157 Morrison, Lieut. The Solar System as it is, and not as it is represented to be
298 Moseley, Henry. Lectures on Astronomy
334 Nichol's Architecture of the Heavens
285 Olmsted, Dr. The Mechanism of the Heavens
158 Pratt, F. A. Excentric and Centric Force; a New Theory of Pro jection
115 Ditto. Orbital Motion; Outlines of Physical Astronomy
32 Proctor, Richard. Half Hours with the Telescope
195 Ward, Hon. Mrs. Telescope Teachings; or Astronomical Discovery
95 Webb, Rev. T. W. Celestial Objects for Common Telescopes, &c.
144 Willard, E. Astronomical Geography, with Use of Globes
135 Worsdale, John. Celestial Philosophy and Astrology
258 Younge, J. R. Nautical Astronomy and Navigation
259 Ditto. Tables to Facilitate the Operations of Navigation and Nautical Astronomy

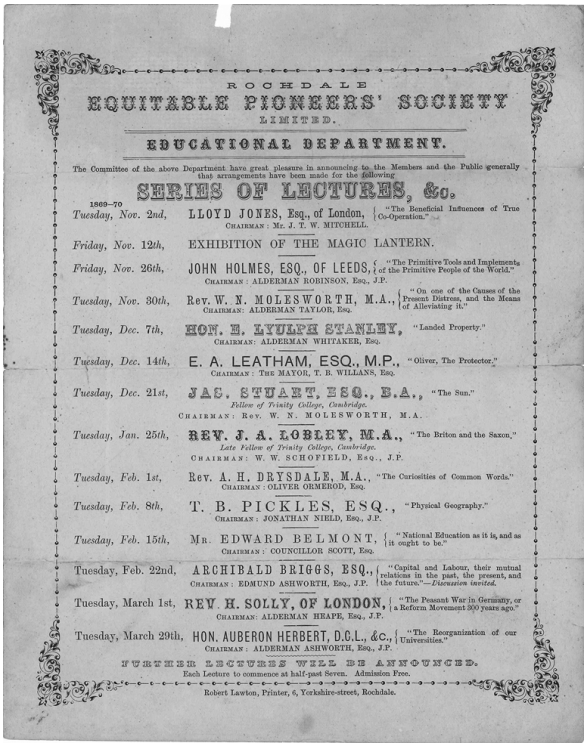
Fig. 4 Astronomy books in the Rochdale Pioneers' Library Catalogue 1868
Courtesy of National Co-operative Archive, Manchester

But young James Stuart was a master of his subject and soon had the audience held by his legendary oratory. These lectures were advertised, and

reported upon in some detail, in the pages of the *Rochdale Observer*, where for one lecture it was possible to find the intriguing headline 'Mr Stuart On The Sun'. The subject matter covered during a period of three years visiting Rochdale also included 'Meteors' and four lectures again outlining the development of astronomy, from the ancients to Newton. Obtaining a syllabus of the subject matter was simple. If you shopped at the Co-op you could obtain one with your purchase prior to the lecture.[12] Stuart claimed these lectures were the first occasions when he lectured to women holding babies in their arms.

After one such lecture, the hall keeper was persuaded to allow some astronomical diagrams to remain on the wall until the next visit. In the meantime, the room was used for a regular monthly Society meeting, whereupon the diagrams became of more interest than the business in hand. So many questions came to the minds of those present that they asked Stuart to come early to the next lecture, when they might receive answers to their questions, and this he agreed to do. In fact, this discussion period proved to be so successful that Stuart decided it should become the model for the University Extension class. He decided to add such a 'class' for those willing to take up the subject more thoroughly. It was frequently reported that one could now use part of the lecture time to 'heckle' the lecturer.[13] This is a term Stuart himself sometimes used, though it should probably be interpreted in the meaning of the word in Stuart's native Scotland – also used for the act of flax-combing, of plying someone with questions, rather than its modern more abusive meaning.

H.J. Mackinder and M.E. Sadler, who were themselves influential in the University Extension system at the University of Oxford, give James Stuart the credit as the 'father' of the Extension Class as it was developed universally, and confirms that it was an outcome of the Rochdale experiment when delivering his lectures on astronomy.[14] In 1871, together with the Northern Council, the Mechanics' Institute at Crewe and the mayor of Leeds, the Rochdale Pioneers presented a memorial to Cambridge University asking for support in expanding this venture, with a supporting letter from Stuart. As a result, Stuart was appointed as secretary of the Syndicate set up to consider the options and although not immediately tackled, Cambridge did take up the challenge in 1873 with lectures in Nottingham, Derby and Leicester, to be followed by Oxford University in 1878, firstly in Birmingham.



ROCHDALE
EQUITABLE PIONEERS' SOCIETY
LIMITED.

EDUCATIONAL DEPARTMENT.

The Committee of the above Department have great pleasure in announcing to the Members and the Public generally that arrangements have been made for the following

SERIES OF LECTURES, &c.

1869–70

Tuesday, Nov. 2nd, LLOYD JONES, Esq., of London, "The Beneficial Influences of True Co-Operation."
CHAIRMAN: Mr. J. T. W. MITCHELL.

Friday, Nov. 12th, EXHIBITION OF THE MAGIC LANTERN.

Friday, Nov. 26th, JOHN HOLMES, ESQ., OF LEEDS, "The Primitive Tools and Implements of the Primitive People of the World."
CHAIRMAN: ALDERMAN ROBINSON, Esq., J.P.

Tuesday, Nov. 30th, Rev. W. N. MOLESWORTH, M.A., "On one of the Causes of the Present Distress, and the Means of Alleviating it."
CHAIRMAN: ALDERMAN TAYLOR, Esq.

Tuesday, Dec. 7th, HON. E. LYULPH STANLEY, "Landed Property."
CHAIRMAN: ALDERMAN WHITAKER, Esq.

Tuesday, Dec. 14th, E. A. LEATHAM, ESQ., M.P., "Oliver, The Protector."
CHAIRMAN: THE MAYOR, T. B. WILLANS, Esq.

Tuesday, Dec. 21st, JAS. STUART, ESQ., B.A., "The Sun."
Fellow of Trinity College, Cambridge.
CHAIRMAN: Rev. W. N. MOLESWORTH, M.A.

Tuesday, Jan. 25th, REV. J. A. LOBLEY, M.A., "The Briton and the Saxon,"
Late Fellow of Trinity College, Cambridge.
CHAIRMAN: W. W. SCHOFIELD, Esq., J.P.

Tuesday, Feb. 1st, Rev. A. H. DRYSDALE, M.A., "The Curiosities of Common Words."
CHAIRMAN: OLIVER ORMEROD, Esq.

Tuesday, Feb. 8th, T. B. PICKLES, ESQ., "Physical Geography."
CHAIRMAN: JONATHAN NIELD, Esq., J.P.

Tuesday, Feb. 15th, Mr. EDWARD BELMONT, "National Education as it is, and as it ought to be."
CHAIRMAN: COUNCILLOR SCOTT, Esq.

Tuesday, Feb. 22nd, ARCHIBALD BRIGGS, ESQ., "Capital and Labour, their mutual relations in the past, the present, and the future."—*Discussion invited.*
CHAIRMAN: EDMUND ASHWORTH, Esq., J.P.

Tuesday, March 1st, REV. H. SOLLY, OF LONDON, "The Peasant War in Germany, or a Reform Movement 300 years ago."
CHAIRMAN: ALDERMAN HEAPE, Esq., J.P.

Tuesday, March 29th, HON. AUBERON HERBERT, D.C.L., &c., "The Reorganization of our Universities."
CHAIRMAN: ALDERMAN ASHWORTH, Esq., J.P.

FURTHER LECTURES WILL BE ANNOUNCED.

Each Lecture to commence at half-past Seven. Admission Free.

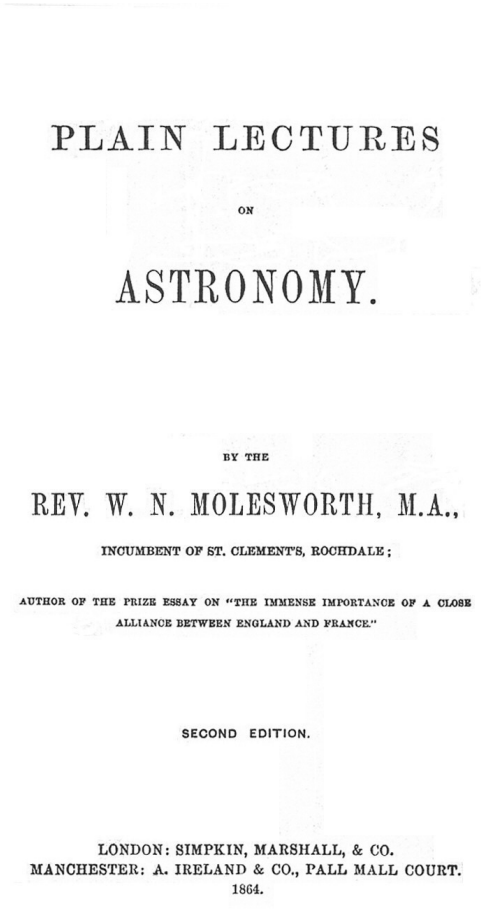
Robert Lawton, Printer, 6, Yorkshire-street, Rochdale.

Fig. 5 Rochdale Pioneers', Lectures Poster
Courtesy of the National Co-operative Archive, Manchester

This period in the 1860s saw the rapid growth in the availability of lectures on all manner of subjects, which were again advertised in the *Rochdale Observer* newspaper. The Reverend W.N. Molesworth MA (1816-1890), vicar of St. Clement's in Spotland, near Rochdale, at whose home Stuart had stayed during visits, also had a close association with the Rochdale Pioneers. He too gave lectures in the town, including astronomy, which was duly reported upon in the local press. In 1864 he had already published the second edition of his own *Plain Lectures on Astronomy*, a copy of which Rochdale Central library managed to unearth for me after a prolonged search.[15]

Plain Lectures is a small 69-page volume aimed at readers with a general interest in astronomy. Of course, it is interesting in retrospect, including as it does sections on the history of astronomy, celestial mechanics and then current ideas regarding the solar system. The final section covers the latest thinking on such questions as the nature of nebulae, at a time when the expression 'other universes' meant star systems external to our own galaxy. Until the mid-nineteenth century, it was not unusual to refer to the planet Uranus as 'Herschel', the name proposed by Jérôme Lalande (1732-1807) in honour of its discoverer. Here it appears as both, probably the result of incomplete editing for the second edition.

Stuart had hoped to accomplish his peripatetic



PLAIN LECTURES

ON

ASTRONOMY.

BY THE

REV. W. N. MOLESWORTH, M.A.,

INCUMBENT OF ST. CLEMENT'S, ROCHDALE;

AUTHOR OF THE PRIZE ESSAY ON "THE IMMENSE IMPORTANCE OF A CLOSE ALLIANCE BETWEEN ENGLAND AND FRANCE."

SECOND EDITION.

LONDON: SIMPKIN, MARSHALL, & CO.
MANCHESTER: A. IRELAND & CO., PALL MALL COURT.
1864.

Fig. 6 Title page from, *Plain Lectures on Astronomy* by W.N. Molesworth (London, 1864)
Courtesy Rochdale Central Library

university with the help of the national Co-operative movement, even suggesting the foundation of a Co-operative University in a letter to the *Co-operative News*. In these terms, now as its President, he addressed the Eleventh Annual Co-operative Congress on 14th April 1879 in Gloucester – and now truly as Professor Stuart. In his long speech, reported verbatim, he set out his vision of how this might be accomplished. At the conclusion, it is recorded that delegates responded to his speech with rapturous applause.[16]

The University Extension system he did so much to promote was to expand rapidly and beyond the United Kingdom. In some cases the Extension movement helped in the foundation of new universities in provincial towns, to the benefit of many generations of students. However, it would not be with the aid of the Co-operative movement in the way he had hoped, which must have been a great disappointment to Stuart, although he did maintain his connections in Rochdale. According to Stuart's autobiography, the main reason was the decision to reduce the Co-operative financial support for education in favour of advertising and increased financial reward to individual members. Parliament was also now enacting legislation which would make available finance from other sources.

James Stuart began what was to be a considerable career in politics in 1884, when for one year he served as Liberal MP for Hackney, after failing in an attempt to represent Cambridge University in 1882. He resigned his professorship in 1889. Further terms as a MP were for the Hoxton division of Shoreditch and finally for Sunderland from 1906 to 1910. He fought a total of nine parliamentary elections and lost on only three occasions. He also served on London County Council including a term of nine years as Alderman. He combined his years in London with a career in journalism as Chairman of the Board of Directors of the Star Newspaper Company, sometimes writing leading articles. He was clearly a man of many talents whose life generally was dedicated to service in the community. Owing to the personal beliefs he held all of his life; it is fair to describe Stuart as a 'radical' politician. His accomplishments and his place in the history of the University of Cambridge have been recognised in a more recent publication, *Cambridge Minds*, in a chapter by Paul McHugh, where the author states that he is happy to include Stuart in the distinguished company of the Darwin family, John Maynard Keynes and Ludwig Wittgenstein.[17]

The final chapter of Stuart's working life effectively began on 16 July 1890, 'cutting the mustard', so to speak, when he married Josephine Colman the eldest daughter of Jeremiah and Caroline Colman, who owned the Norwich company carrying the family name, long famous for its well-known condiment. He became a director of the company in which capacity he managed the business. He was appointed Privy Councillor in 1909. He died on 12 October 1913.[18]

Conclusion

Although this is predominantly a story of social history rather than the technical history of astronomy, James Stuart's pioneering lectures helped to bring astronomy to the working classes and at an important time in the development of education in Britain. One might compare Stuart's career with his contemporary, Sir Robert Stawell Ball (1840-1913), who probably became known to a wider public for his lectures on astronomy. This has continued to the present day and the current President and Vice President of the Society for the History of Astronomy, Dr. Allan

Chapman and Sir Patrick Moore respectively, are surely worthy successors in this field, having literally followed in James Stuart's footsteps, also in print and via the modern communication media of radio and television.

Acknowledgements

I am indebted to the following for their generous help: Dr. David Dewhirst, Institute of Astronomy, University of Cambridge; the local history curators at the Rochdale, Glenrothes and Kirkcaldy Public Libraries; Gillian Lonergan, Librarian at the National Co-operative Archive, Manchester; Mrs Dorothy Greaves, warden of the Rochdale Pioneers Museum and Mark Hurn, SHA Librarian, for facilitating procurement of the digital image of James Stuart from the University of Cambridge; Stuart Williams for helpful advice.

Notes and References

1. Anon., *Rochdale Pioneers Museum Guide* (Manchester, Co-operative Union Ltd.), p.1
2. Ibid., p.19
3. Stuart, James, *Reminiscences* (London: The Chiswick Press, 1911), 302pp; First published for private circulation only, but later published by Casell & Company Ltd., 1912
4. Littmann, Mark, *The Heavens on Fire* (Cambridge University Press, Cambridge, 1998); includes several reports from the United Kingdom.
5. Greenwood, Abraham, *The Educational Department of the Rochdale Equitable Pioneers Society Ltd., its origins and development* (Central Co-operative Board, Manchester, 1971), p.7
6. Anon, *Catalogue, The Library of the Rochdale Equitable Pioneers' Society Ltd.* (December 1868)
7. Greenwood (1971), p.11
8. Anon, *Handbook of the 24th Annual Co-operative Congress, June 1892,* (Co-operative Printing Society Ltd., Manchester, 1892), p.81
9. Ernest Chas., 'A Visit to Rochdale', *The Co-operator*, November 1860, p.79
10. Greenwood (1971), p.8
11. Anon (1892), p.108
12. Ledger, Arthur, *Co-operative Review*, September 1952, p.210
13. Bonner, Arnold, *British Co-operation*. (Co-operative Union Ltd., Manchester, 2nd. Ed., 1970), p.5
14. Mackinder, H.J, and Sadler, M.E., *University Extension, Past, Present and Future* (Cassell & Company Ltd., 1891), p.18
15. Rochdale Central Library, Ref. W59MOL, L04001.RC
16. Pitman, Henry (Reporter) and Neale, E.V. (Ed.), 'Inaugural Address by James Stuart', *The Eleventh Annual Co-operative Congress, 1879* (Manchester; the Co-operative Union 1879). Held in the Corn Exchange, Southgate Street, Gloucester, April 14th, 15th and 16th.
17. McHugh, Paul, 'James Stuart: engineering, philanthropy and radical politics', in Mason, Richard (Ed.), *Cambridge Minds* (Cambridge University Press, Cambridge, 1994), Chap.8, 100-9
18. Anon, 'Obituary: Mr James Stuart', *The Times*, Tuesday, October 14, 1913, p.11

The Author

Philip Barnard MRSC gained an interest in astronomy in 1949 at the age of ten, thanks to his local public library. He has been a member of Wolverhampton Astronomical Society for many years, thirty of them on the governing Council. He studied chemistry at Wolverhampton & Staffordshire Technical College, at the same time beginning a career as a research chemist in the plastics industry. He later moved to the Agricultural Development and Advisory Service, Ministry of Agriculture, Fisheries & Food as an analytical chemist, eventually becoming responsible for automated gas chromatography and high-performance liquid chromatography systems.

The introduction of Copyright Law in England and its effect on the dispute between Newton, Halley and Flamsteed concerning the 'pirated' *Historia Coelestis* 1712

John L Birks

Founder Member of the Society for the History of Astronomy
Former Chairman of Swansea Astronomical Society

In 1712 Sir Isaac Newton and Dr Edmund Halley, acting on behalf of the Royal Society, printed some 400 copies of the star catalogue *Historia Coelestis* under the name of John Flamsteed, including his observations of the positions of nearly 3000 stars made at Greenwich from 1676. Flamsteed had not been allowed to check the proofs of this work before it was published, and he was enraged to see what he considered to be a travesty of his life's work.[1] This became a great scientific scandal of the early eighteenth century, which echoes down to the present day.

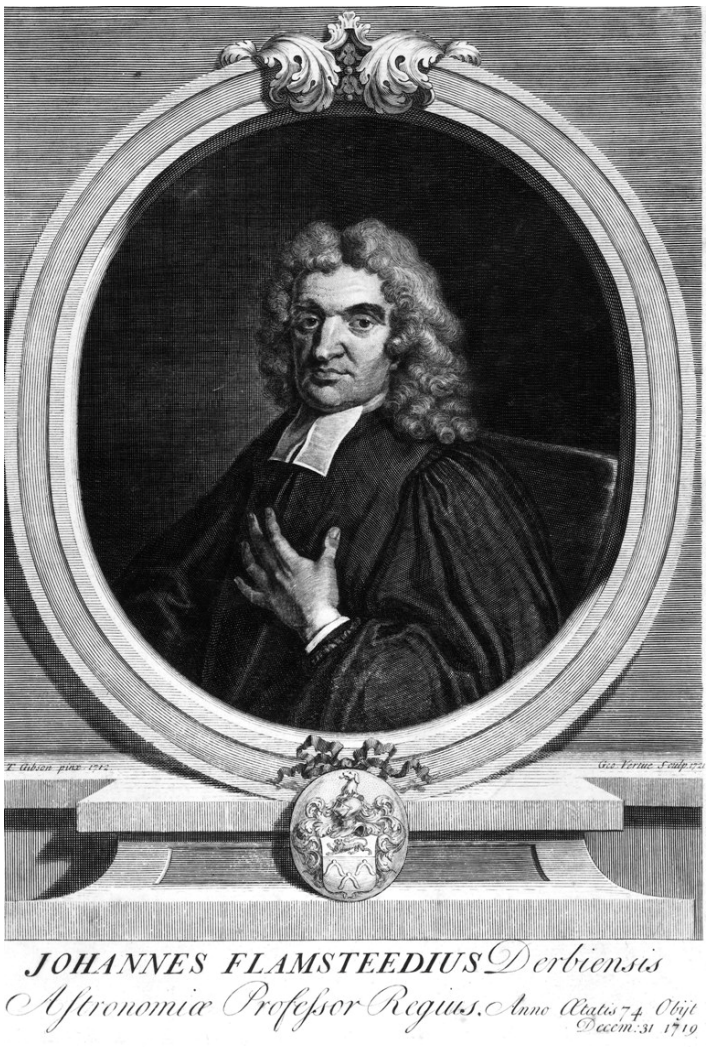


Fig. 1 The frontispiece of Flamsteed's *Historia Coelestis Britannica* of 1725, from the portrait he commissioned in late 1712, when he determined to publish his own correct version of his observations
SSPL Image No. 10285075
Courtesy of the Science Museum, London

Flamsteed protested to the authorities about what he considered was the theft of his life's work and '...making my application by proper persons [I] got his Majesty's [King George's] order to have 300 copies of them delivered unto me…'.[2] It was rather surprising that the elderly and somewhat infirm Flamsteed was able to win his case against the famous Sir Isaac Newton and Dr Edmund Halley, who was Savilian Professor of Geometry at Oxford – both well-known men held in high esteem in the Royal Society and in society in general. The reason seems to be that the *Statute of Anne*, which gave copyright protection to authors for the first time rather than the publishers of books, had just become law in 1710.[3]

The sequence of events which gave rise to the necessity for a copyright law of some kind followed the invention of the printing press by Gutenberg around 1440 and the introduction of printing into England by William Caxton at Westminster in 1476. Writings of dissent and criticism of both State and Church could afterwards be replicated and circulated rapidly. This became a matter of concern to the authorities and consequently steps were taken to restrict the production and duplication of possibly contentious material.

In 1557 a Royal Charter was granted to the Stationers' Company in London, allowing only their members the right to print books, and all such books had to be registered with this Company. This Charter was confirmed by Queen Elizabeth I in 1559, her intention being, 'to prevent divers scandalous malicious schismatical and heretical persons moving our subjects to sedition and disobedience against us….and against the faith of Holy Mother Church…'.[4]

The Licensing Act of 1662 continued to give the Stationers' Company sole right to print and distribute books, and only members of this Company could register a book and hold perpetual copyright over its printing, copying and publication. Authors themselves were not permitted to become members of the Stationers' Company, and they were generally not held in high esteem. This meant that any author's work could be 'pirated' and registered, printed and published by a Stationer, to the financial detriment of the author.

After the 'Glorious Revolution' of 1688, when James II fled to France and William of Orange and Princess Mary assumed co-regency in England, more power in government passed from Royalty to Parliament. The philosopher John Locke returned from political exile on the continent, accompanying Princess Mary on board the royal yacht, and was influential in framing the laws of the new government. Around 1690 he wrote his, *Second Treatise on Civil Government*, where in chapter 11, section 138, he states,

> Men therefore in society having property, they have such right to the goods, which by the law of community are theirs, that nobody hath a right to take their substance or any part of it, from them, without their own consent.

Locke was concerned about the rights of ownership of property, and considered a man's property to consist of those things he had worked hard to acquire, thus including what would nowadays be called 'intellectual property'.

After the death of Mary in 1694 and that of William of Orange in 1702, succession passed to Mary's younger sister, who became Queen Anne – both were daughters of King James II. Thus in the years following 1704, when Sir Isaac Newton, with the backing of the Royal Society, planned to print the data which John Flamsteed had accumulated at Greenwich over a period of some thirty years, there was something of a 'free for all' during which any printer could copy and publish through a member of the Stationers' Company, anything which came into his hands. This was probably the reason that Flamsteed, who was working towards publishing his own catalogue of all the northern stars visible from Greenwich, with associated star charts, was reluctant to give any of his data away without due safeguards. He wanted his catalogue to be as complete and accurate as he could possibly make it, so that it would be a work of reference to last for many years.

In his *Essay on the Press*, 1704, Daniel Defoe, an influential public spokesman and the famous author of the popular adventure story *Robinson Crusoe*, continued the demand for authors to be given more control over their work. Writing on Nov. 8th, 1705, he stated that with the absence of author's copyright,

> One man studies seven years to bring a finished piece into the world, and a pyrate printer reprints his copy immediately, and sells it for a quarter of the price…these things call for an Act of Parliament.

Defoe repeated this complaint in his *Review*, 3rd Dec. 1709, demanding 'a Law in the present Parliament… for the encouragement of Learning, Arts and Industry, by securing the property of books to the Authors or Editors of them'.

The *Statute of Anne*, which was granted Royal Assent on 5th April 1710, was the first real copyright act which provided protection for authors, regulated by the government and the courts. Intended to improve access to public learning and the easy avail-

ability of knowledge, it was described as 'An Act for the encouragement of Learning, by vesting the copies of printed books in the Authors or Purchasers of such copies, during the times therein mentioned'. The period defined was fourteen years, with provision for renewal for a further fourteen years, during which only the author and the printers they chose to register their works could publish the author's creations. The same Act also gave protection to authors of books already in print, with copyright protection for a period of twenty one years in this case.[5]

Fig. 2 Queen Anne and Prince George of Denmark, by Charles Boit, 1706. The Statute of Anne, 1710 first provided authors with copyright protection
SSPL Image No. 10285075
Courtesy of the Royal Collections

From 1704 onwards, Sir Isaac Newton had been keen to see all the work produced by Flamsteed at Greenwich published, so that this data would be readily available to all astronomers and scientists. However, Flamsteed alone knew how much work was entailed in calculating star positions from the original experimental data and ensuring that such data, when published, would be accurate enough for navigational use. He required more 'calculators' to assist him with the task of reducing the raw observational data and ensuring the accuracy of anything printed. With the backing of the Royal Society, Newton approached Prince George of Denmark, consort to Queen Anne, to ask for special funding so that the Greenwich data could be published. A sum of around £1,200 was allocated to the work, of which £125 was given to Flamsteed to pay for assistance, and after some misgivings Flamsteed handed over to Newton the manuscript containing the early results he had obtained using the 7-foot radius Greenwich sextant.

Following more pressure from Newton and the Royal Society, on March 30, 1707, Flamsteed handed over a further 175 sheets of provisional data obtained using his Mural Arc, as a pledge that he would eventually provide fully corrected figures when the work on these had been completed.[6] During these years, Flamsteed was always reluctant to hand over his star observations to Newton and the Royal Society for publication, as he believed they were his own property, obtained 'by labours harder than thrashing'. He thought that this was his own 'intellectual property' and that he should benefit from any profits made by its publication.

Sir Isaac Newton gave the task of editing Flamsteed's incomplete and uncorrected manuscript, and preparing it for the press, to Dr Edmund Halley. The final copy for printing was only revealed to Flamsteed in letters he received from Dr John Arbuthnot, who, as a Royal Society referee, was querying omissions and trying to reconcile differences between Flamsteed's manuscript and Halley's version.[7] As can be imagined, this caused a great deal of friction between Flamsteed and Halley, as Flamsteed was never given opportunity to oversee or check the work before it came into final print. When he saw the published *Historia Coelestis* in 1712, Flamsteed was incensed, and wrote a 'Petition and Remonstrance' to Queen Anne (April 16, 1712) stating his intention to 'publish my catalogue with all convenient expedition', and requesting that 'no encouragement be given to those who are putting out …[a star catalogue in my name]'.

It can be seen that the *Statute of Anne* of 1710, with its protection of author's copyright, came into force at a very timely moment for Flamsteed. It is inconceivable that John Flamsteed, bearing in mind his long-standing concern over the publication of his observations under Halley's editorship, would have been ignorant of the copyright protection granted to authors by the *Statute of Anne*, which is perfectly clear in its intentions. Any legal action that he would take thereafter as an author against the printers of his work would be virtually certain to succeed, seeing that his case was supported under the terms of this new Act. Although I have been unable to trace the records of any actual Court proceedings in this case – it is

Fig. 3 Flamsteed as portrayed in the 'pirated' *Historia Coelestis* of 1712. The baroque engraving appears to show him as a naval captain in armour, with a small telescope, to emphasise his navigational links. It is doubtful if Flamsteed would have approved this portrayal, any more than he did the rest of Halley's work.
Image No. D130699
Courtesy of the Science Museum, London

doubtful if such records exist – the outcome in the case was precisely that outlined by the 1710 *Statute of Anne*. Flamsteed described his actions in a letter to his friend and former colleague Abraham Sharp, written on March 29th, 1715/16, '… making my application by proper persons, [I] got his Majesty's order to have 300 copies of them delivered unto me, and last night my man brought them down to the observatory'. The return of some 300 unsold copies of the 'pirated' *Historia Coelestis* to Flamsteed at Greenwich in March 1716 was in exact accordance with the wording of the *Statute of Anne*, that

> …if any Bookseller, Printer or any other Person whatever,…shall print...any such book...without the consent of the Proprietor...they shall forfeit such book or books to the Proprietor…who shall forthwith… make waste paper of them...

Flamsteed complied precisely with this instruction by burning these copies of his work on a bonfire in Greenwich Park, which he termed 'a sacrifice to heavenly Truth'.[8]

Conclusion

He continued to observe and calculate star positions for his own definitive star catalogue until his death in 1719. His *Historia Coelestis Britannica* was eventually published in 1725, followed by his *Atlas Coelestis* in 1729, due to the efforts of his former colleagues Abraham Sharp and Joseph Crosthwait, who worked on without payment, as a tribute to their former director at the Greenwich observatory.

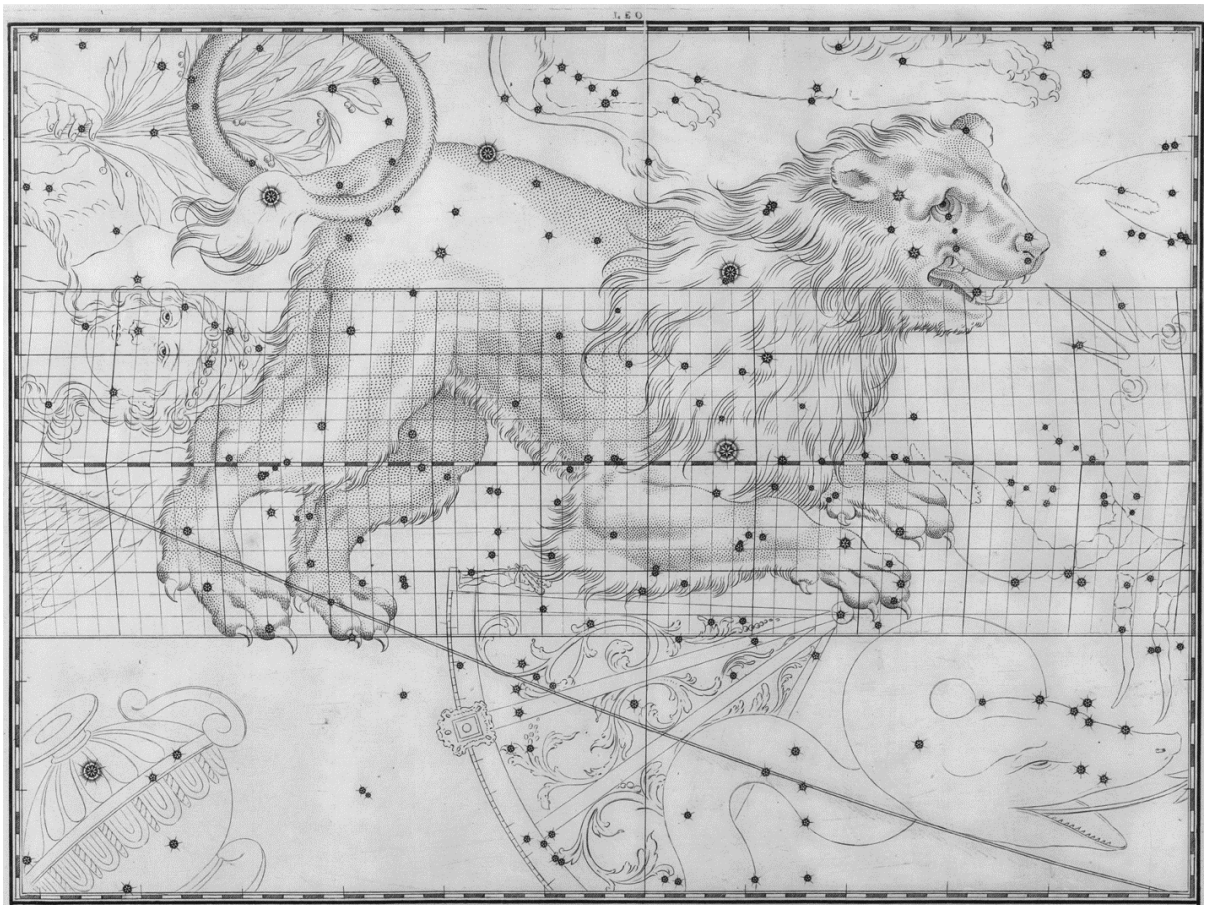


Fig. 4 The constellation Leo, from *Atlas Coelestis* 1729 by John Flamsteed.
Image No. D130703
Courtesy of the Science Museum, London

Acknowledgements

I am grateful for the encouragement of Clive Davenhall and Kevin Johnson during the production of this paper, and for their careful editorial work. Kevin assisted particularly in suggesting that a few images might enlighten the text, and with the procurement of these and addressing copyright issues.

Notes and References

1. Birks, J.L., *John Flamsteed, the first Astronomer Royal at Greenwich* (Avon books, London, 1999), 96-106
2. Letter of John Flamsteed to Abraham Sharp, March 29, 1715/16, see Baily, F., *An Account of the Revd. John Flamsteed* (Dawsons, London, 1966), p 321
3. The original is held at the British Library, 8 Anne. C 19
4. Arber, Edward (ed.), *A transcript of the Registers of the Company of Stationers of London, 1554 – 1640*, vol. I (London: Privately printed, 1875)
5. Bently, L. and Kretschmer, M. (eds.), *Primary Sources on Copyright (1450 – 1900)*, available at www. copyrighthistory.org (accessed 24-August-2012). This website has a facsimile copy of the original Act, taken from the British Library, with a transcription in a more easily read modern script.
6. Baily, Francis, *An Account of the Revd. John Flamsteed* (Dawsons, London, 1966), 727 – 8
7. See letters from Arbuthnot in, *Flamsteed's Correspondence,* dated March 14, 1710/11 and April 16, 1711
8. Birks, J.L., *John Flamsteed, the first Astronomer Royal at Greenwich* (Avon books, London, 1999), 105 – 6

The Author

Before moving to Swansea in 1966, Dr John Birks lived in Denby Village, Derbyshire, which was the birthplace of John Flamsteed, the first Astronomer Royal. He developed an interest in astronomy as a child after being shown the partially eclipsed Sun, using a piece of smoked glass (Do not try this at home!). Following his retirement from a career as a Medical Physicist with the NHS, he continues his interest in astronomy with the Swansea Astronomical Society.

The Shuckburghs of Shuckburgh, Isaac Fletcher, and the history of the English Mounting

Peter D. Hingley

Librarian, RAS (1980-2012)

(See author notes)

This article attempts to document, in three sections, the history of the form of equatorial telescope support known as the 'English Mounting'. This is usually said to have first been successfully applied to a permanently mounted telescope in an instrument made by Jesse Ramsden (1735-1800) for Sir George Shuckburgh-Evelyn (1751-1804), Baronet, of Shuckburgh, Warwickshire. The first part gives the general history of this type of telescope; the second the history of Shuckburgh's famous instrument, and the third that of the fundamental redesign from a fabricated wooden or iron structure to one of cast iron, by Isaac Fletcher (1827-79). The place in astronomical history of these two innovative gentlemen and the current location of their instruments are also recounted. An attempt is also made to reach an improved typology and definition of terms for the English mounting, and a preliminary attempt is made at a listing of all telescopes identifiable as being of this type.

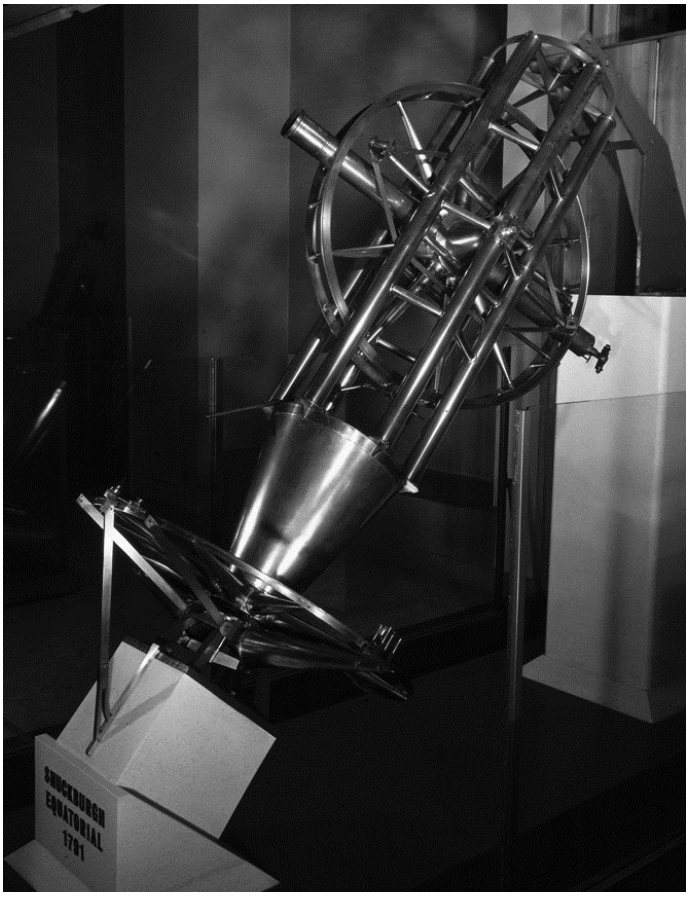


Fig.1 The Shuckburgh Equatorial by Ramsden at the Science Museum. A five foot telescope of 4.2-inch aperture took ten years to build and was not delivered until 1791
SSPL Image No. 10323764
Courtesy of the Science Museum, London

General history of the English Mounting

The English mounting is an elegant and well balanced structure, though it requires a substantial framework to take the top end of the polar axis. The weights are well supported and not cantilevered out beyond their bearings, and the polar axis is supported at both ends; it does not require such elaborate strengthening and massive counterweights, resulting in further danger of distortion, as does its 'Germanic' competitor. The outline history of the configuration has been set out, and its characteristics defined, by Owen Gingerich.[1] Its main disadvantage is that, unless special arrangements are made, stars close to the celestial pole are inaccessible.

Elegant though it is, it could be said that the English mounting got off to a bad start. Its name was coined, along with that of the equivalent 'German' mounting, by George Biddell Airy (1801-92) in a publication of 1844.[2] The Shuckburgh Equatorial, whose history will be recounted in detail later, though apparently used successfully at the eponymous location, was found after its donation to the Greenwich Observatory in 1811, and eventual re-erection there, to have a mounting which was insufficiently rigid, with its long polar axis composed of tubes without triangulated bracing, for serious positional work.[3] This judgement may be a little harsh on the instrument maker Jesse Ramsden (1735-1800), however; twenty years had passed away and the standards of accuracy required for positional observation at Greenwich in Pond's time would doubtless be very different from those of an enthusiastic amateur in a country house observatory! Derek Howse describes the instrument as 'of great historic interest as the world's first large equatorial'.[4] The instrument maker Edward Troughton (1753–1835) is supposed to have made a smaller and improved copy of the Ramsden instrument at a later but unspecified date but this instrument also, though commended at the time, suffered from weakness of the polar mounting.[5]

Huddart telescope

Worse, the second (third, if we include Troughton's variation for Huddart, below) major example of the English mounting, built for, and eventually destroyed by, Sir James South (1785-1867), was at the centre of his notorious legal battle with Troughton and Simms on the grounds of the alleged instability of the mounting.[6] Accounts of this affair have, understandably, centred on the cantankerous, and eventually insane, behaviour of Sir James and the spite and quarrels of his allies and adversaries, rather than the innovatory character of the mounting which Troughton had made for what the Council of the Astronomical Society correctly referred to as 'this gigantic telescope' with its 11¾-inch clear aperture and 19-foot focal length.[7] For much of the early part of this lengthy war South attempted to persuade Troughton and Simms to abandon this structure, with its scantily braced wooden polar axis, and instead to construct, at extra cost which he was prepared to cover entirely, a mount which would have been an enlarged version of that which the Troughtons had made, to the design of Captain Joseph Huddart (1741-1816), for his earlier telescope of 5-foot focal length and 3¾-inch aperture, with which South had made highly successful and sustained observations. This was similar in principle to an English mounting, with

Fig.2 Huddart equatorial built by Troughton with a 5-foot telescope of 3 ¾-inch aperture, 1797.
SSPL Image No. 10196887
Courtesy of the Science Museum, London

a rounded triangular shaped tube. In an age before detailed structural analysis, one may perhaps wonder, with Michael Hoskin, whether a leap of four times in scale of a structure would have been likely to have been successful. At all events, that stage of the battle was fundamentally between an iron and brass mounting and the innovatory, but wooden, English one.[8] A close parallel can be drawn here with the development of girder bridges for the new, larger engineering structures which were beginning to be

needed for railways and the like. A lattice girder structure with square or rectangular cells and no diagonal bracing tends to fail, or just to distort, the spaces becoming lozenge shaped, because the joints are relatively weak in preventing distortion; diagonal braces oppose this by being placed in compression or tension.

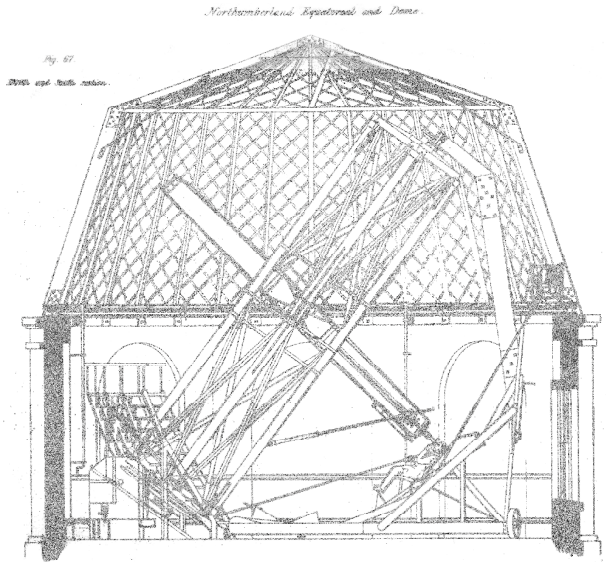


Fig.3 Engraving of the Northumberland Equatorial a 11 ½-inch refractor with mount by Airy, 1844
Airy 1844 (Ref.2)
SPL Image No. C0090536
Courtesy of the Royal Astronomical Society/SPL

It was only after Airy, with his *penchant* for innovative (if not always successful) and robust instrument design, took up the idea, that this form of the English mounting was used for important and successful instruments such as the 11¾-inch Northumberland Equatorial at Cambridge (1833), and the 12¾-inch, (1860), later rebuilt as the current 28-inch (1893), 'Great Equatorial' at Greenwich. It may be noted that both these mountings are very generously braced diagonally. The six main elements of the Northumberland's polar axis are of straight grained Norway Fir, much used in those days for ships' masts, and the entire cross bracings are of wood also, with iron brackets to hold them together. Airy described an advantage of wood in this situation as not being so susceptible as metal to 'quick tremors'. In the Northumberland telescope the declination axis passes through the centre of the polar axis, which means the centre of gravity of the tube coincides with the rotational centre of the axis, and no counterbalancing is needed; while in the Greenwich telescope Airy placed the axis off-centre and notched the upper support, enabling the instrument to reach the celestial pole, but requiring weight to be added to some of the tubes; apparently this was done in the form of loose leaden musket balls, which escaped and rolled all over the floor when the instrument was dismantled for the move to Herstmonceux![9] The main elements of the Greenwich mount are six great iron pipes, again generously braced; one hesitates to accuse the formidable shade of Sir George Airy of 'over-engineering', but when the instrument was re-constructed in 1893 with a new tube of more than twice the aperture, the mounting took it without a murmur! The main part of the mounting was engineered by Ransomes and May of Ipswich, a firm of (mainly) agricultural engineers with whom Airy had both family connections and professional experience, while the optics were by Howard Grubb of Dublin.

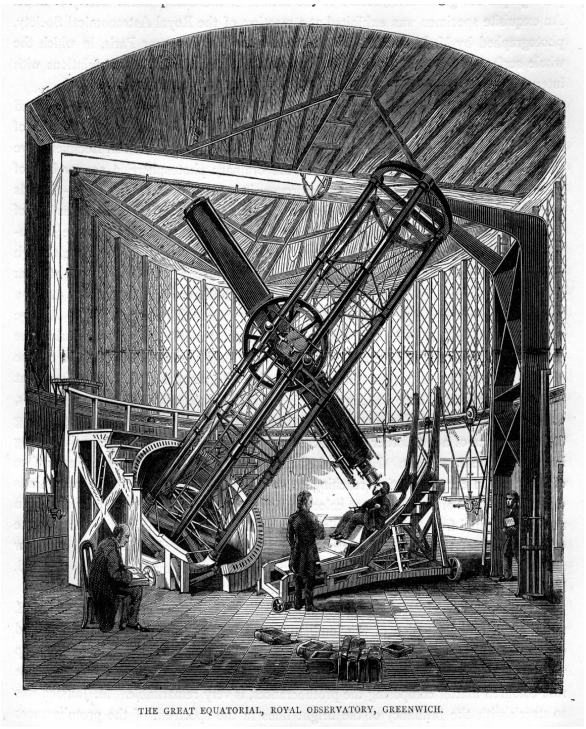


Fig.4 The Great Equatorial Refractor, 12¾-inch object glass, on a large 'English Mount', 1859.
Dunkin, Edwin, *The Midnight Sky* (Religious Tract Society, London, 1879 - Revised Ed.)
Reproduced by Kevin Johnson

David Dewhirst points out that, in contrast to the rigidly braced iron structure of the Greenwich mount, the Northumberland telescope has tensioning screws at top and bottom of the polar axis which place the diagonal braces in compression, this force being opposed by the (original) iron straps in tension round the centre of the axis.[10] He suggests it is a very early

example of a stressed frame structure, and may be the first one ever.[11]

Subtypes of the English Mounting

Airy appears to have applied the term originally to the telescopes as listed above, where the tube passes between, and is pivoted from, two or more structural elements of the polar axis, which means that the declination pivot is supported at both ends; the tube's centre of gravity is more or less coincident with the axis of the right ascension (RA) pivots. I would propose the term 'through axis' for this type, though the later, larger examples are also referred to as 'yoke mounts', as they slightly resemble that rustic device.

A second version seems to have had the name applied to it later, in which the tube is pivoted to one side of the single polar axis and thus needs a counterweight on the other side. This vitiates some of the advantages of the 'pure' English configuration, but was still a highly practical telescope mounting especially in the smaller sizes and has the advantage over the original that the celestial pole is accessible without modification of the upper end of the polar axis. The first recorded use of this principle appears even to pre-date Ramsden's building of the Shuckburgh telescope. Jeremiah Sisson (1720-1783/4) made two 'equatorial sectors' for the Greenwich Observatory where they were set up in the former 'Summer Houses' in 1773.[12] Following Owen Gingerich I refer to this as the 'Cross Axis' type, while Isaac Fletcher, in his 1865 description of his own telescope quoted below, says this was then generally known as the 'Sisson' polar axis type. They seem to have been extremely unsuccessful, though some results were published from them, and are very ill recorded, although a drawing of about 1785 by John Charnock (1756-1807) exists at the National Maritime Museum.[13] The telescopes were of 4-inch aperture and 5-foot focal length; very similar in size to the Shuckburgh instrument's tube. Various attempts were made to improve these by the instrument makers Sisson, Troughton and Simms, and the Dollonds up to 1827. It appears from the title and from the professed mission of the Greenwich Observatory that these instruments were an attempt at a more versatile equivalent of the Transit instruments, rather than a general purpose telescope – able to make precise positional observations out of the meridian.

Allan Chapman has identified another possible ancestor, by locating the components, and making a reconstruction sketch of, the Equatorial Sector made by John Bird for the newly founded (1772) Radcliffe Observatory, Oxford, in 1775, a little later than the Sisson sectors at Greenwich.[14] The major components of this instrument now rest in the Museum of the History of Science at Oxford, though they have not been assembled as an instrument for many long years. The basic configuration is certainly that of a 'cross axis' English mounting, but instead of a large telescope tube it carries a 5-foot radius graduated sector which is used to measure accurately the position of a small aperture telescope tube. The long polar axis, a solid heavy bar of wrought iron without the bracing or multiple structural elements of the 'through axis' mounts described, certainly looks as though it would suffer distortion from the unbalanced loads imposed on it. In truth, however, the instrument seems to have been used relatively infrequently on 'sporadic' targets such as comets and then the method appears to have been that the 3-foot diameter RA and declination (Dec) circles were used to 'point' the instrument at the desired target and then the 28 degree sector arm with its micrometer could measure the position of an object in Dec, relative to known stars, to a claimed accuracy of two arc-seconds.

The conception of a measuring instrument on a fixed equatorial mount, however, goes back even further. Most of the previous equatorials described by Shuckburgh were portable instruments. Robert Hooke (1635-1703) had published in 1674 a conceptual design for a screw quadrant mounted on a long equatorial shaft, to which he added the idea of a clock drive.[15] It is not clear whether this instrument was ever actually built, but it seems unlikely. As the quadrant is depicted as pivoted across one end of a long polar axis with a counterweight this should perhaps be regarded as the primordial 'German' mount.[16]

Earlier instances of this sort of mounting can be seen in the Torquetium of Petrus Apianus (1495-1552) and illustrated in his work, *Astronomicum Caesareum* (1540). The astronomer Johannes Hevelius (1611-1687) also mounted his instruments in a similar fashion as can be seen in his work, *Machinae Coelestis* (Danzig, 1673). A later example, incorporating the telescope, includes the equatorial instrument designed in 1690 by Ole Rømer (1640-1710), which resembled a modified transit instrument.[17]

There is a difficulty of definition between what exactly constitutes a 'measuring instrument, circle, quadrant,' etc. and what an 'equatorial telescope'. The distinction must surely be one of purpose rather than structure; a telescope being for general visual

observation and the other types for accurate positional measurement of objects away from the meridian. Measurements made with a 'telescope' would be by methods which did not require movement of the tube, such as the eyepiece or the later object glass micrometer. The Shuckburgh instrument has received both descriptions.

There was an early group of English mounting telescopes, mostly with wooden polar axes, which Kevin Johnson has dubbed the 'Smythian' in design. The most famous of these was the famous Smyth/Lee 5.9-inch refractor, by this time definitely a 'telescope', originally set up in 1829 at Admiral William Henry Smyth (1788-1865) Bedford observatory, used by him for the observations for his famous 'Bedford Cycle of Celestial Objects'. The

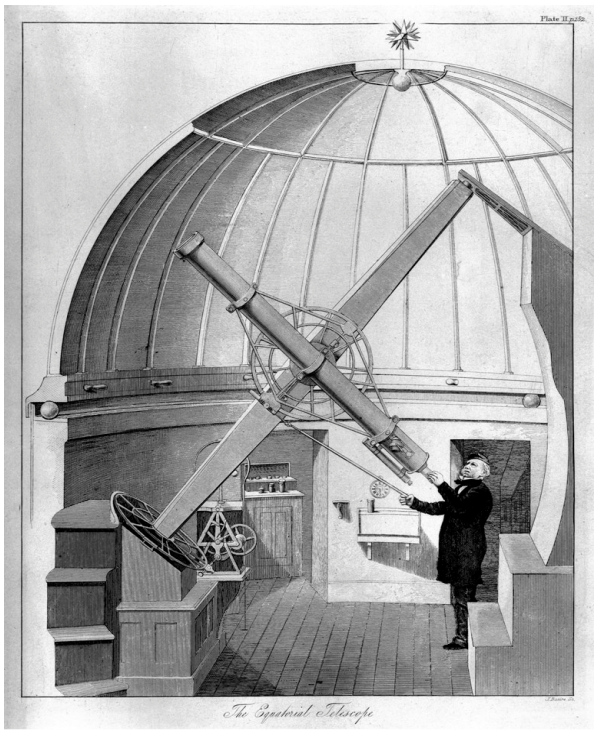


Fig.5 Smyth Telescope at Hartwell Observatory, a 5.9-inch refractor on a mount by G. Dollond and clock drive designed the Rev. Sheepshank
Smyth, W.H., *Ædes Hartwelliance* (London, 1851)
SSPL Image No. 10197320
Courtesy of the Science Museum, London

polar axis of this is a wooden 'box girder' of planks joined at the edges, as later described by Fletcher. He sold it to his friend Dr John Lee (1783-1866) who used it at Hartwell Observatory, Bucks, and after Lee's death it was sold by his executors to the Government for the Transit of Venus expeditions of 1874 and 1882 where respectively it was used at Cairo, Egypt and the West Indies. It was finally used at the Hong Kong observatory before gravitating to the Science Museum, South Kensington and its present location, the museum's stores in West London – by a curious twist of fate, the same location as the Shuckburgh instrument.

Further Smythian Telescopes

The term 'English' is also applied by the writers Henry C. King, Russell W. Porter, and others, to the type of large telescope mounting where the tube is pivoted on a single fork which is itself carried on a pivot aligned towards the celestial pole.[18] The largest example of this type is the 120-inch at Lick Observatory. As Owen Gingerich remarks this stretches the term well outside its normal definition, indeed it has virtually nothing in common with the true 'English Mount'. The correct term should surely be 'fork mount'.

Two telescopes with mounts that closely matched the design of Smyth's mount at Bedford/Hartwell were produced by George Dollond (1774-1865) for amateur astronomers George Bishop (1785-1861) and John Wrottesley (1798-1867). These cross-axis English mounts carried refracting telescopes of 7-inch and 7¾-inch aperture respectively. Bishop had a private observatory erected adjacent to his villa in Regents Park, London where he employed a series of observers to do his observations. Most notable of these paid astronomers included William Rutter Dawes (1799-1868) and John Russell Hind (1823–1895).[19] Wrottesley constructed his observatory in the ground of estate in Staffordshire after his father's death when he took the title of second baron Wrottesley. He also employed a private observer to complete observations of double-stars for a catalogue later published as a memoir of the Royal Astronomical Society.[20]

A curious variant of the English mounting was produced for the Meudon Observatory, France, by Paul Gautier (1842-1909). This reflector completed in 1893 was of 1-metre aperture and the polar axis was supported by a cradle made as a sector of a circle so that the angle could be adjusted for different latitudes. Weighing several tons this could hardly be described as 'portable', but it could have been moved to different locations. It is not clear whether the drive was reversible for use in the southern hemisphere.

'Series Production' of telescopes is relatively rare but two groups of telescopes to the same or similar designs used the English configuration. The telescopes built in France for the 'Carte du Ciel' project, whose 33-cm clear aperture photographic

objectives were designed by the Brothers Henry, of Paris, and mounts built by Gautier, were on through-axis English mounts, while ironically the countries under British influence preferred to buy instruments of the same, internationally agreed, optical design from Grubbs and they were mostly on German mounts, though Sydney's was an exception, on a locally made English mounting. Another semi mass produced group were the reflecting telescopes of about 74-inch aperture built by Grubb, Parsons, for observatories at Toronto – David Dunlap Observatory (Obs.), Pretoria – Radcliffe Obs., Canberra – Mt. Stromolo Obs., St-Michel, Tokyo, and Helwan. John Stanley Plaskett (1865-1941) apparently considered the yoke (or through axis) arrangement for the first of these, but perhaps saw its limitations at Mount Wilson and decided on the cross axis type.[21] This group of instruments has recently been documented by Richard Jarrell.[22] Further reminiscences of their building can be found in an article by George Sisson.[23] Some Schmidt cameras were also mounted thus and the English mounting can be applied equally to supporting refractors, reflectors, and Schmidt Cameras.

Although many of the telescopes described so far have been refractors the last and greatest telescopes to be built using the English configuration were the 82-inch reflector at the McDonald Observatory and the 100-inch 'Hooker' reflecting telescope on Mount Wilson, 'Boiler Plate' variant of the English Mounting as its members are fabricated from steel plate with the contemporary profusion of rivets.

Although the English mount was reasonably popular for medium to large telescopes for over 100 years it could never be said to have attained dominance; the telescopes of William Herschel were all altazimuths as was Lord Rosse's mighty 6-foot aperture 'Leviathan of Birr', and the original incarnation of its predecessor, the 3-foot. This was later re-erected on a fork mount.

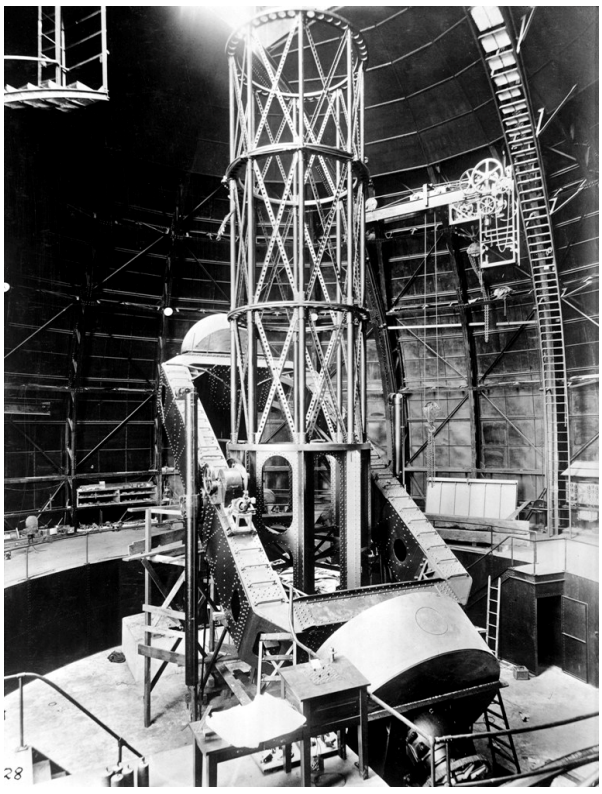


Fig.6 Hooker telescope, Mt. Wilson; not quite the last large telescope built with an English Mount
SSPL Image No. 10197320
Courtesy of the Science Museum, London

Sir George Shuckburgh and an origin in Warwickshire

The village of Lower Shuckburgh, Warwickshire, lies athwart the busy A425 road, just west of the Northamptonshire border. The houses of Upper Shuckburgh were apparently removed to improve the landscaping of Shuckburgh Park, and the estate workers who lived there re-housed in Lower Shuckburgh. The cultivation ridges from the former village's open fields can be clearly seen near the entrance gates of the Park. A little to the east of the present village is Shuckburgh Hall, which is not open to the public, and but few of the motorists who roar past can realise that it was here that Sir George Shuckburgh had erected in 1791 the very first permanently mounted equatorial telescope of the type later christened the 'English' mount.[24] It seems fitting that a configuration with such a name should come to birth at this sequestered location among the rolling countryside of the Midland shires. Shuckburgh Hall is described by Pevsner as 'a proud range of 1844, by Kendall, in front of an older timber-framed house, which may be pre-Reformation....entirely Victorian'.[25]

Fig.7 Shuckburgh Hall, Warwickshire, England
Image No. BB98_01697
Reproduced by permission of English Heritage

Table 1: A preliminary list of major instruments on the English Mount

Date	Owner or sponsor / Builder	Location	Size (aperture & focal length)	Type* (telescope & mount)	Source	Fate /Present location
1788	Sir Geo. Shuckburgh/ Jesse Ramsden	Shuckburgh Hall, Warwickshire, England	4.1-inch/ 5 ½-feet	Refractor/TA	Shuckburgh 1793 (Ref. 51)	Given to the Royal Observatory, Greenwich (1811 ROG)
1789	Armagh Observatory/ Edward Troughton	Armagh Observatory, Armagh, Ireland	2 ½-inches/ 3 ¾-feet	Refractor/TA	Bennett 1990, 24-6	In situ, Armagh Observatory
1797	Joseph Huddart/ Edward Troughton	Highbury, London, England	3 ¾-inches/ 5-foot	Refractor/TA	King 1955, p.160 (Ref.5)	Science Museum, London
1811	Sir Geo. Shuckburgh/ Jesse Ramsden	Royal Observatory, Greenwich, England	4.1-inch/ 5 ½-feet	Refractor/TA	Howse, 1986, 85-89	Science Museum, London
1827	Dr W. Pearson/ George Dollond	South Kilworth, Leices., England	6.8-inch/ 12-foot	Refractor/TA	Smyth, 1844, 373-76	Private observatory, fate of telescope unknown
1829	Capt. W.H. Smyth/G. Dollond & Chas.Tulley	Private observatory, Bedford, England	5.9-inch/ 8 ½-feet	Refractor/XA	King 1955, p.194 (Ref.5)	To John Lee and new observatory (1846 Lee)
1831	James South/ Edward Troughton & Cauchoix	Campden Hill, London, England	11 ¾-inches/ 19-foot	Refractor/TA	King 1955, p. 236 (Ref.18)	Destroyed by South after dispute with Troughton
1832	Cambridge University/ Thomas Jones	University Observatory, Cambridge, England	2 ¾-inches/ 5 -foot	Refractor/TA	Weale 1851, p.671	In situ until 1899, later fate unknown
1833	Duke of Northumber-land/Airy & Cauchoix	University Observatory, Cambridge, England	11 ½-inches/ 19-foot	Refractor/TA	King 1955, p.180 (Ref.5)	In situ, Institute of Astronomy, Cambridge
1836	George Bishop (Senior)/ G. Dollond	Regent's Park, London, England	7-inch/ 10 1/6 feet	Refractor/XA	Howard-Duff 1985, 20-6	Observatory moved to Twickenham (1863 Bishop)
1843	2nd Baron Wrottesley/ George Dollond	Wrottesley Hall, Staffs., England	7 ¾ -inches/ 10 ¾-feet	Refractor/XA	Howse 1986, p.66 & 83	Observatory in ruins, fate of telescope unknown
1845	Liverpool Observatory/ Troughton & Simms	Liverpool Docks, Liverpool, England	8-inch/ 8-foot	Refractor/TA	Howse 1986	Moved to new site at Bidston Hill, Wirral (1866 Bidston)
1846	Lee Telescope/ G. Dollond & Tulley	Hartwell House, Lee, Bucks. England	5.9-inch/ 8 ½-feet	Refractor/XA	King 1955, p.194 (Ref.5)	Sold to ROG in 1869/ Science Museum, London
1847	John Drew/ Geo. Dollond	Windsor Terrace Southampton, England	3 ¾-inch/ 5-foot	Refractor/XA	Weale, 1851, p.689	Private observatory until 1857, fate unknown
1851	E. J. Collingwood/ Troughton & Simms	Lilburn Observatory, Northumberland	6-inch	Refractor/XA	Clucas 2012	In situ, private ownership
1860	Greenwich/ Airy & Merz	Royal Observatory, Greenwich, England	12 ¾-inch/ 18-foot	Refractor/TA	Lowne 1988, 169-82	Replaced with 28-inch refractor. Remounted with reflector (1893 Greenwich)
1863	George Bishop (Junior)/ George Dollond	Meadowbank, Twickenham, London, England	7-inch/ 10 ¼-feet	Refractor/XA	Howard-Duff 1985, p.25	Observations stopped in 1877, telescope given to Royal Naples Observatory
1865	Isaac Fletcher/ T. Cooke & Lowca	Tarn Bank House, Cumberland	9 ½-inch/ 12-foot	Refractor/XA	Orchiston 2001, 29-42 (Ref.64)	Later removed to Wanganui, N.Z. in 1903. Telescope in situ and is still active

Date	Owner or sponsor / Builder	Location	Size (aperture & focal length)	Type* (telescope & mount)	Source	Fate /Present location
1866	Bidston Observatory/ Troughton & Simms, Merz	Bidston Hill, Birkenhead, England	8-inch/ 8-foot	Refractor/TA	Scoffield 2006	Tidal institute from 1946, now vacant / Liverpool City Museum
1869	Melbourne (Victoria)/ Thomas Grubb	Melbourne Observatory, Melbourne, Australia	48-inch/ 28-foot	Reflector/TA	King 1955, 264-7 (Ref.5)	Reconfigured and moved to Mt. Stromolo (1950 Stromlo)
1885	Paris Observatory/ Gautier & Henry Bros.	Observatoire de Paris, Paris, France	33-cm/ 343-cm	Refractor/TA	Lamy 2008	Astrograph built for Carte du Ciel project
1875	Paris Observatory/ Eichens & Secretan	Observatoire de Paris, Paris, France	120-cm/ 720-cm	Reflector/XA	King 1955, p.274 (Ref.5)	Moved to Southern France remounted (1941 Haute-Prov.)
1889	Bordeaux/Gautier & Henry Brothers	Observatoire de Bordeaux. Floirac, France	33-cm/ 343-cm	Refractor/TA	Lamy 2008,	Astrograph built for Carte du Ciel project
1889	Algiers Observatory/ Gautier & Henry Bros.	Observatoire de Algiers, Morocco	33-cm/ 343-cm	Refractor/TA	Lamy 2008	Astrograph built for Carte du Ciel project
1890	Sydney/Howard Grubb & Carl Zeiss	Sydney Observatory, NSW, Australia	33-cm/ 343-cm	Refractor/TA	Nangle 1930	Astrograph built for Carte du Ciel project
1891	San Fernando/ Gautier & Henry Bros.	Observatorio de la Armada San Fernando,Cadiz, Spain	33-cm/ 343-cm	Refractor/TA	Lamy 2008	Astrograph built for Carte du Ciel project
1892	Toulouse/ Gautier & Henry Brothers	Observatoire de Toulouse, France	33-cm/ 343-cm	Refractor/TA	Lamy 2008	Astrograph built for Carte du Ciel project
1892	Vatican/ Gautier & Henry Brothers	Specula Vaticana, Rome, Italy	33-cm/ 343-cm	Refractor/TA	Berget, & Rudaux 1923	Astrograph built for Carte du Ciel project
1893	Greenwich/ Howard Grubb & Merz	Royal Observatory, Greenwich, England	28-inch/ 28-foot	Refractor/TA	Wright 1990	Refractor put on same mounting as earlier one & in situ (1860 Greenwich)
1894	Catania/ unknown	Osservatorio di Catania, Sicily, Italy	33-cm/ 343-cm	Refractor/XA	Lamy 2008	Astrograph built for Carte du Ciel project
1895	Meudon Observatory/ Gautier & Henry	Meudon Observatory, Meudon, Paris, France	100-cm/ 300cm	Reflector/TA	King 1955, p.307 (Ref.5)	In situ at observatory in original dome
1904	Crossley/ Warner & Swasey	Lick Observatory, Mt. Hamilton, CA, United States	36-inch/	Reflector/XA	King 1955, p.278 (Ref.5)	Remounted after being moved to Mt. Hamilton, California
1917	Hooker/ Pease (design) & various	Mt. Wilson Observatory CA, United States	100-inch	Reflector/TA	King 1955, 332-8 (Ref.5)	In situ and still active as research telescope
1918	Plaskett/ Brashear	Dominion Astro-physical Observatory, Victoria, BC. Canada	72-inch	Reflector/XA	King 1955, p.352 (Ref.5)	In situ and still active as research telescope
1920	Yale-Columbia/ McDowell	Yale-Columbia Southern Station, Witwatersrand, South Africa	26-inch	Refractor/XA	King 1955, 351 & 394 (Ref.5)	Moved to Mt Stromlo, Canberra, Australia in1954. Destroyed by fierce bush fire 2003
1928	Bosscha Observatory/ Carl Zeiss	Bosscha Observatory, Lembang, West Java, Indonesia	60-cm/ 1070-cm	Refractor/TA	Observatory website	Established by Dutch colonial authorities

Date	Owner or sponsor / Builder	Location	Size (aperture & focal length)	Type* (telescope & mount)	Source	Fate /Present location
1929	Reynolds/ Richey & Grubb-Parson	Mount Stromolo Observatory, State of Canberra, Australia	30-inch	Reflector/XA	King 1955, p.418 (Ref.5)	Remounted by Grubb-parsons. Destroyed by fierce bush fire in 2003
1930	Pluto Telescope/ Lowell workshops	Lowell Observatory, Flagstaff, AZ, United States	13-inch/ astrograph	Refractor/XA	Kirby-Smith 1976, p.60	In situ at US Naval Observatory outside Flagstaff
1932	Paris Observatory/ Eichens & Secretan	Paris Observatory, Forcalquier, Haute-Provence France	80-cm/ 120-cm	Reflector/XA	Observatory website	Moved, 1945 to St. Michel, Haute-Provence France (1945 H-P Observatory)
1934	Yapp Telescope/ Grubb-Parsons	Royal Observatory, Greenwich, England	36-inch	Reflector/XA	King 1955, p.388 (Ref.5)	Moved to Herstmonceux observatory site after war (1957 RGO)
1935	David Dunlap/ Grubb-Parsons	David Dunlap Observatory, Richmond Hill, Ontario, Canada	74-inch	Reflector/XA	King 1955, p.387 (Ref.5)	Closed as a research institute in 2007. Use being reconfigured
1935	Perkins/ J.W. Fecker & Warner & Swasey	Perkins Observatory, Delaware, Ohio, United States	69-inch	Reflector/XA	Kirby-Smith 1976, 143-4	Moved in 1961 to Lowell Observatory, Flagstaff, Arizona, United States (1961 Lowell)
1939	Katherine Burrell/ Warner & Swasey	Warner & Swasey Observatory, Ohio, United States	24/36-inch/ Schmidt astrograph	Reflector/XA	King 1955, 371-2 (Ref.5)	Moved to Kitt Peak National Observatory
1941	Haute-Provence Observatory/ Eichens & Secretan	Observatoire de Haute-Provence, St. Michel, France	120-cm/ 720-cm	Reflector/XA	King 1955, p.274 (Ref.5)	Mounting & tube rebuilt when moved from Paris
1945	Haute-Provence Observatory/ Eichens & Secretan	Observatoire de Haute-Provence, St. Michel, France	80-cm/ 120-cm	Reflector/XA	Observatory website	In situ and still active as research telescope
1947	Carnegie/ Warner & Swasey	Lick Observatory, Mt. Hamilton, California, United States	20-inch/ double astrograph	Refractor/XA	Kirby-Smith 1976, 81-2	In situ, at Mt. Hamilton, Lick Observatory
1948	Radcliffe/ Grubb-Parsons	Radcliffe Observatory/ Pretoria, South Africa	74-inch/ 111-inch	Reflector/XA	Sisson 1993, p.279	Moved in 1972 to the Sutherland Observatory
1952	Mt. Stromolo Observatory/ Grubb-Parsons	Mount Stromolo Observatory, State of Canberra, Australia	74-inch/ 111-inch	Reflector/XA	Sisson 1993, p.280	Destroyed by fierce bush fire in 2003
1953	Great Melbourne/ Grubb-Parsons	Mount Stromolo Observatory, State of Canberra, Australia	50-inch	Reflector/XA	King 1955, 264-7 (Ref.5); Bell 2012	Rebuilt with 50-inch mirror. Destroyed by fierce bush fire in 2003
1957	Uppsala Southern Station/ Uppsala University workshops	Mount Stromolo Observatory, State of Canberra, Australia	26-inch/ Schmidt astrograph	Reflector/XA	Observatory website	Moved in 1982 to Siding Springs, NSW, Australia. Still active as a research telescope
1957	Haute-Provence Observatory/ Grubb-Parson & Couder/ Texereau	Observatoire de Haute-Provence, St. Michel, France	193-cm/ 286-cm	Reflector/XA	Observatory website	In situ and still active as research telescope

Date	Owner or sponsor / Builder	Location	Size (aperture & focal length)	Type* (telescope & mount)	Source	Fate /Present location
1957	Greenwich Observatory/Grubb-Parsons	RGO, Herstmonceux, Sussex, England	36-inch	Reflector/XA	McCrea 1975, 52-3	In situ at Herstmonceux, now a science Centre
1960	Okayama Observatory/ Grubb-Parsons	Okayama Astrophysical Observatory, Chugoku, Japan	74-inch	Reflector/XA	Sisson 1993, p.280	In situ and still active as research telescope.
1961	Perkins/ J.W. Fecker & Warner & Swasey	Lowell Observatory, Flagstaff, Arizona, United States	72-inch	Reflector/XA	Kirby-Smith 1976, 143-4	In situ and still active as research telescope. Now with larger mirror
1964	Kottamia/ Grubb-Parsons	Kottamia observing Station, Helwan, Egypt	74-inch	Reflector/XA	Sisson 1993, p.280	In situ and still active as research telescope.
1967	Haute-Provence Observatory/ REOSC	Observatoire de Haute-Provence, St. Michel, France	152-cm	Reflector/XA	Observatory website	In situ and still active as research telescope
1970	Haute-Provence Observatory/ REOSC	Observatoire de Haute-Provence, St. Michel, France	87-cm/ Schmidt	Reflector/XA	Observatory website	In situ and still active as research telescope
1972	South African Astronomical (SAAO)/ Grubb-Parsons	Sutherland (SAAO) Observatory, Cape Provence, RSA	74-inch/ 111-inch	Reflector/XA	Sisson 1993, p.279	In situ and still active as research telescope
1979	UKIRT/ Dunford-Hatfields &Grubb-Parsons	Mauna Kea Observatory, Hawaii	150-inch (380-cm)	Reflector/TA	Observatory website	In situ and still active as research telescope, but will close end of 2013

*mount type: XA = Cross Axis; TA = Tube Axis or Yoke

Sources

Bell, E. Trudy, 'Restoration of the Melbourne Telescope', *Bulletin - Society for the History of Astronomy*, **22**, Autumn 2012, 28-33

Bennett, J.A., *Church, State and Astronomy in Ireland…*, (Belfast 1990)

Berget, Alphone & Rudaux, Rucien, Le Ciel (Larousse, 1923)

Clucas, Len, 'Observatory Scrapbook:…', *Bulletin - Society for the History of Astronomy*, **22**, Autumn 2012, 54-6

Howard-Duff, Ian, 'George Bishop (1785-1861)…', *Journal of the British Astronomical Association*, **96** (1985)

Howse, Derek (Ed.), 'The Greenwich list of Observatories', *Journal of the History of Astronomy*, **17/4**, (1986)

Kirby-Smith, H.T., *U.S. Observatories: A Directory and Travel |Guide* (Van Nostrand Reinhold Co., 1976)

Lamy, Jerome, *La Carte du Ciel* (l'Observatoire de Paris, 2008)

Lowne, C.M., 'The Object-Glass of the Greenwich Great Equatorial Telescope', Journal for the History of Astronomy, **19** (3/Aug.), 1988, 169-182

McCrea, W.H., *The Royal Greenwich Observatory* (HMSO, 1975)

Nangle, J., *The Sydney Observatory: its history and work* (Sydney Technical College, 1930)

Scoffield, Joyce, *Bidston Observatory…*, (Countryvise Ltd 2006)

Sisson, George M., 'Grubb Parsons – from War to Peace', in Wall, Jasper V. (ed.), *Optics in Astronomy* (Cambridge University Press, 1993)

Smyth, William Henry, A Cycle of Celestial Objects.., Vol.1 (John W. Parker, London, 1844)

Weale, John, 'The observatories of London & its vicinity', *The Pictorial Handbook of London…* (1854, Henry G. Bohn, London), 630-699

Wright, D.G., 'The 28-Inch Refractor at Greenwich:….', *Quarterly Journal of the Royal Astronomical Society*, **31** (1990), 551-566

Images of English Mounts from Table 1

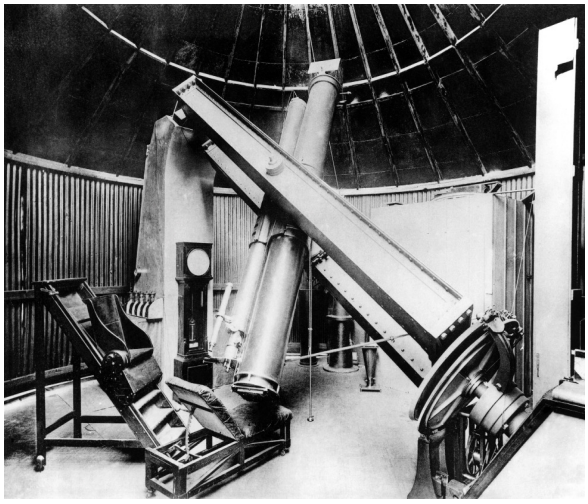


Fig. 8a Astrograph built for the Carte du Ciel project, built by Howard Grubb, Dublin with optics by Carl Zeiss for the Sydney Observatory, Sydney, NSW, Australia, 1890
SPL Image No. C0041864
Courtesy of the Royal Astronomical Society/SPL

Fig.8b The Victoria Telescope, a 72-inch reflector built jointly by Brashear with Warner & Swasey for the Dominion Astrophysical Observatory, Victoria, BC. Canada, 1918
SSPL Image No. 10418889
Courtesy of the Science Museum, London

Fig. 8c The completed Dunlap Telescope a 74-inch reflector in the workshops of Grubb-Parsons in 1933 ready to be moved to its new home, the Dunlap Observatory, at Richmond Hill, Ontario in Canada
SSPL Image No. 10418905
Courtesy of the Science Museum, London

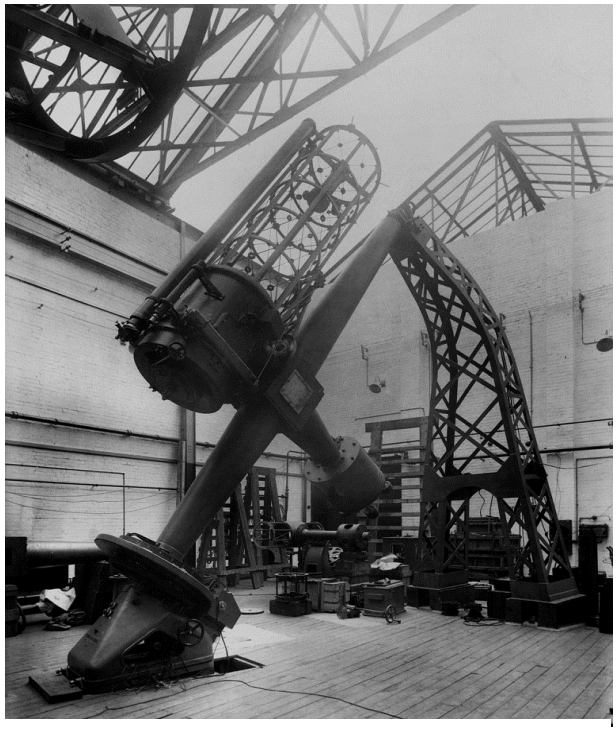


Fig. 8d The completed Yapp Telescope, a 36-inch reflector in the workshops of Grubb-Parsons, ready for transport to the Royal Observatory, Greenwich, London, England, c.1933
SSPL Image No. 10418903
Courtesy of the Science Museum, London

The Shuckburgh Family

The Shuckburghs are a family with deep Warwickshire roots; they are said to have been in Shuckburgh since the 12th Century.[26] Sir Richard Shuckburgh (1596-1656) was MP for Warwickshire in the Long Parliament (1640-1653), but after being questioned by the sergeant-at-arms in 1642 over his evident loyalty to the King, he withdrew to his Warwickshire estates.[27] He supported the Royalist cause in the first major battle of the Civil War, at Edge Hill, in October 1642; he was knighted on the eve of battle in recognition of his presence, and afterwards fortified a position near Shuckburgh Hall. After a fierce battle, Shuckburgh, badly wounded, was captured by the Parliamentarians and imprisoned in Kenilworth Castle, subsequently spending seven years in prison. At the Restoration, in 1660, after Sir Richard's death, his eldest son John was created Baronet by Charles II, to recompense the family for their sufferings in the Royalist cause.

Other distinguished bearers of this patronymic listed in the *Dictionary of National Biography* include Evelyn Shirley Shuckburgh (1843-1906), classical scholar, and Sir John Evelyn Shuckburgh, KCMG (1877-1953), colonial civil servant, while another Sir George Shuckburgh fought with distinction in the Crimea and returned to enhance the grounds of Shuckburgh Hall with a replica of the fort at the Redan, but made of yew hedges.[28]

Life of Sir George Shuckburgh

Sir George Augustus William Shuckburgh was born in 1751 and after attending Rugby School and Balliol College, spent three years of his youth in the 'Grand Tour' of France and Italy, though in his case he concerned himself with scientific as well as artistic matters. He succeeded as sixth Baronet on the death of his uncle in 1773 and was elected as a Fellow of the Royal Society on 22 December 1774. He also belonged to the Society of Antiquaries. He sat as MP for Warwickshire from 1780 until his death. His contributions to science included use of the barometer to determine altitudes of mountains in Savoy (with General William Roy FRS (1726-1790), who, like Shuckburgh, was a patron of the instrument maker Jesse Ramsden), and the improvement of standard measures of length, weight and capacity.

A portrait of Shuckburgh by Gilbert Stuart, which was sold at Sotheby's in 1991, shows him as a strikingly handsome man.[29] When his father-in-law died in 1793 Shuckburgh added his second wife's maiden name, Evelyn, to his own to become Shuckburgh-Evelyn, though his descendants did not continue this. Sir George was awarded the Royal Society's Copley Medal in 1798, but for some reason the Society does not appear to have published an Obituary of him when he died on 11 August 1804.[30] As his only child was a daughter, the Baronetcy passed to his brother. There are monuments to Sir George, ornamented with a Globe and an Armillary

Fig.9 Portrait of Sir George Shuckburgh, by Gilbert Stuart (1755-1828)
Reproduced by courtesy of Sotheby's

Fig.10 Memorial plaque to Shuckburgh in St John the Baptist in the Wilderness at Upper Shuckburgh
By the author

Sphere, and to his first and second wives, all by John Flaxman, in the Parish church of St John the Baptist in the Wilderness at Upper Shuckburgh.[31]

A handsome MS volume *Astronomical Observations made with a Large Equatoreal Instrument at Shuckburgh in Warwickshire…*, covering the years 1791 to 1795, survives at Shuckburgh Hall while a run of observing books covering the years 1774-97 is preserved in Cambridge University Library.[32] The Cambridge observing books were donated to the Library in 1903 by Mrs Prince, the widow of that Sussex surgeon and notable astronomical book collector Charles Leeson Prince (1821-1899), many of whose books rest in the Royal Astronomical Society (RAS) Library and who had donated the printed copy of Sir George's *Account of the Equatorial Instrument…* in 1898.[33] These observational records show Shuckburgh to have been an enthusiastic and fairly regular observer, and there is no sign of his having employed a practical astronomer to do the hard work as was the case with some other wealthy astronomical enthusiasts. The earliest series of observations were made from various locations in Britain and Europe between 1771 and 1780, from locations in London – Norfolk St. and Welbeck St., Calais, Abbeville, Amiens – where he determined the latitude of the Cathedral, Paris, Dijon, Lyons, Geneva, Turin, Bologna, Florence, Leghorn, Rome, Naples, Hafodunes, Denbighshire, the home of his friend John Lloyd – see below, Llanberis, the top of Carne Cwm-Gap, and at last home to Shuckburgh.

On one of his European peregrinations Shuckburgh is said to have had the opportunity, denied to most French astronomers, of trying out an instrument made by that ill recorded figure Dom Noel for Louis XV's 'Optical Cabinet' at La Muette.[34] This was one of the first to have been made to the Cassegrain configuration and had a length of 24 French feet (7.8 m) and 594-mm clear aperture; its maker claimed it enlarged 430 times but Sir George judged it at only 200 times.[35] Before he ordered the 'Great Equatorial' Sir George owned a small portable equatorial instrument, one of four made by Ramsden in 1770-73 for the Earl of Bute, Mr McKenzie, Sir Joseph Banks, and Shuckburgh himself. A 'plate and description' of this instrument – also described as a 'machine', was printed in French in 1773, and reprinted in English in 1779, but no copy is at present to hand. It is also described and illustrated by Vince.[36] Shuckburgh used this instrument for astronomical and geometrical [i.e. surveying] purposes in 1774-75, and praises the accuracy of its divisions, great portability

Fig.11 Portable equatorial similar to four of which were made by Ramsden including one for Sir George Shuckburgh
SCM Image No. 0177
Courtesy of the Science Museum, London

and the advantage of its being equipped with a swinging level. He mentions that it had alternative apertures – really stops, of 2, 1 and ½-inch.

Observations recorded over the years include positions of bright stars such as α Andromedae, α Ceti, α Aquilae, α Aquarii, α Serpentis, ε Ophiuchi, Fomalhaut, and Arcturus; only a few observations of the planets, and meridian positions of the Sun. He observes the occultations of Aldebaran by the Moon on 15 November 1774, by Jupiter on 13 February 1776, and measures and draws a partial solar eclipse on 17 October 1781 [the 'Nautical Almanac', states that it was the 16th, but Jean Meeus gives 17th – old astronomical day?].[37] Routine operations of checking and rating his clocks appear regularly. He also frequently records the results of measurements of the variation and dip of the Earth's magnetic field using 'Martin's Needle' and 'Nairne's Needle'– compass or dip-circle by the instrument maker Benjamin Martin and Edward Nairne, recording that these were set up in the Library at Shuckburgh as well as on the tops of various mountains. Most of these astronomical observations, unlike the geographical ones, do not

seem to have been communicated or used for anything, but by December 1795 he has accumulated 293 observations of the diameter of the Sun which he applies to produce a correction for the tables of Tobias Mayer (1723-1762).

The Shuckburgh Equatorial & its Antecedents

Shuckburgh ordered the instrument from Ramsden in 1781 and it was completed and set up in 1791.[38] The origin of the novel design is not explicitly stated but Ramsden must have known of the Sisson 'Sectors' of 1773 at Greenwich, and probably of the Bird sector for the Radcliffe Observatory, both described below. As Richard Learner pointed out, the mounting can be regarded as a development of Ramsden's great Palermo circle, finally completed in 1789, but converted from an altazimuth to an equatorial by the axis being tilted over at the angle of 90 degrees minus the latitude from the vertical.[39] Howse relates that an equatorially mounted telescope was ordered for the Royal Observatory from Ramsden in 1778 and implies that the order was cancelled by the Royal Observatory, and further suggests that in making the Shuckburgh instrument Ramsden would certainly have used some of the parts from this, though the circles should have been larger for the Greenwich commission.[40] Chapman, however, sheds a less creditable light on Ramsden's actions; he quotes a letter from the Astronomer Royal (Maskelyne) to the Royal Society complaining that Shuckburgh had 'stolen a march' on the Royal Observatory by offering Ramsden an extra £50 on top of the price of £500 agreed with the Board of Ordnance.[41] This would imply that it was actually the same instrument, even if at the time of accepting the higher offer it had no more corporeal existence than an intention in the mind of its builder. These antics certainly differ from the reputation of 'Honest Jesse Ramsden' which seems to be generally held. The total price of £550 would equate to about £30,000 today.[42]

From the detailed description Shuckburgh gives of the rationale behind his telescope and its details it seems likely that his input to the design, backed by his considerable knowledge of scientific instrumentation, would have been far more than merely that of a rich patron ordering the best possible instrument. He describes his aim as to combine in this instrument 'all the properties of a transit instrument with those of a meridian quadrant' and it was clearly intended for positional observations. In his observing books he records the arrival of the 'Great Equatorial' in late August 1791 and on 10 September 1791 he 'Observed the Sun with the great Equatorial for ye 1st time in the Meridian'. The instrument was set up by one of Ramsden's foremen, Mr G. Pope, and a note in his hand giving directions for its lubrication, with charmingly erratic orthography, is preserved with the observing books. It was apparently despatched by canal boat to Lower Shuckburgh wharf, on the Grand Union Canal, and brought up to the Hall by waggon and horses.[43]

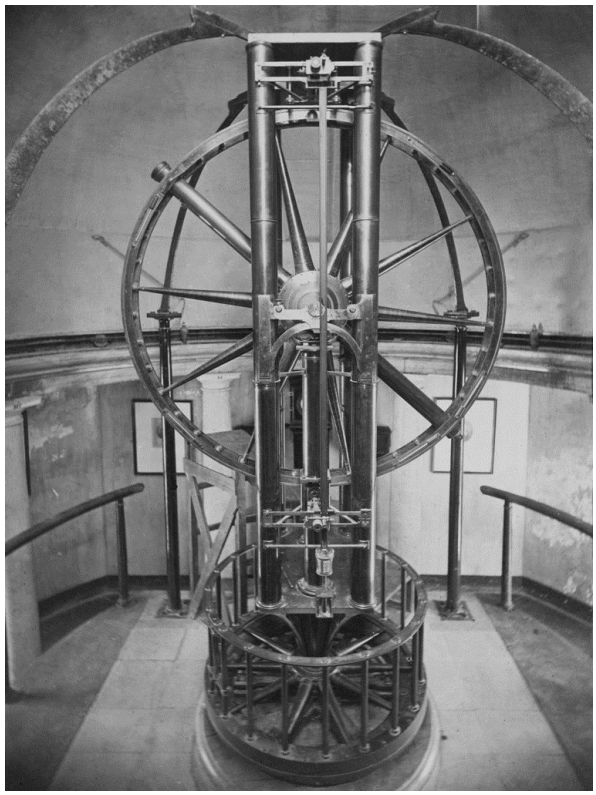


Fig.12 Ramsden's Palermo Circle in 1876
SSPL Image No. 10415856
Courtesy of the Science Museum, London

As well as the long delay in the completion of the instrument Sir George was put to endless trouble and expense in constructing the observatory, on top of a stair-tower and Library which he added to Shuckburgh Hall. In a letter to his friend John Lloyd (1749-1815), who had an observatory before 1783 at Hafodunes, Denbighshire and later at Wigfair, near St Asaph, Denbighshire, he describes the difficulties of dealing with Ramsden, of getting the dome and shutters made, and the great expense of the whole; he estimates the cost up to that date as £651.[44] Apparently the observatory roof, with its truncated cone dome, was designed by the same Mr Pope. This use of a dome is quite early; the first [hemispherical] dome listed by Donnelly was on the king's Kew Observatory at Richmond of 1769 and the next at the Dunsink observatory of 1785.[45] Mr Spaight suggests

that the first conical 'dome' used in Britain may have been designed by John Smeaton (1724-92) in 1753.[46]

The aperture of the instrument as delivered was 4.1-inch and the focal length 5-feet and 5-inches.[47] It had diaphragms hinged to the object glass end to stop the telescope down to half or a quarter of its aperture, perhaps for solar observing. The object glass is an achromatic doublet and the greatest magnification available was 400 times. The RA and Dec circles are 4-foot diameter, divided to 10 seconds of arc, reading to 1 second being by micrometers. Derek Jones points out that an equatorial mounting can be regarded as a form of analogue computer; Shuckburgh's RA circle actually measured the 'Hour Angle' which was subtracted from the Local Sidereal Time to give which is carried between two sets of three brass tubes of 3½-inch diameter and 5-feet and 10-inches long forming the Polar axis.[48] There are cross braces between the

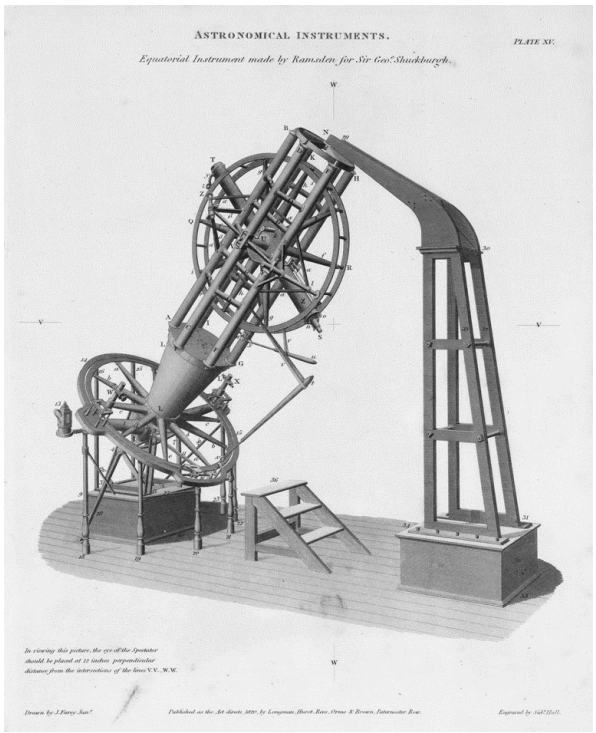


Fig.13 Engraving of Shuckburgh telescope
Rees, A., *The Cyclopædia…*(London, 1819)
SSPL Image No. 10418963
Courtesy of the Science Museum, London

tubes but no diagonal braces. The lower ends of these are joined to a large brass cone carrying the RA circle and itself resting on a conical footstep bearing of steel running in bell-metal. This alloy is also used for the frame joining the upper ends of the tubes and pivoted to the massive cast iron structure, towering 10 feet from the floor, which supports the upper end of the Polar axis; in its original setting this was further strengthened by two iron braces, at right angles, bolted through the walls of the telescope chamber. The rather fanciful looking balustrade round the bottom, with ten turned brass balusters reminiscent of a club fireplace, is actually, Sir George tells us, to protect the RA circle from damage from accidental knocks as people moved around the room. The position of the tube in RA and Dec was read off the two 4-foot diameter circles by micrometers each side of each circle (i.e. four in all), microscopes being provided to improve the accuracy of reading these.[49] The general impression is one of strength and solidity, but alas this was not borne out in practice.

The mounting has no driving clock – these were imagined by Hooke, but did not come into practical use on large instruments until the 1820s, the first one recorded being on Fraunhofer's great Dorpat 9½-inch Refractor of 1829.[50] However, Shuckburgh describes seeing, in the hands of 'President [Jean Baptiste Gaspard Bochart] de Saron' (1730-1794) at Paris, a small equatorial with what sounds like a clock drive in RA in 1775, and Mr William Russel FRS showed him a similar device, by Bird, in 1778.[51] The telescope was provided with a divided eyepiece micrometer by Ramsden and another micrometer by Dollond.[52] The eyepiece end has scales to read the angle from the vertical of the eyepiece wire – now called the parallactic angle, and a quadrant, still on the instrument, working with a spirit level from which the elevation of the tube could be read off thus giving the approximate altitude of the object directly.

Sir George wrote a lengthy and detailed account, with pardonable pride, of his splendid and expensive new instrument and its ancillary apparatus. This was read at the Royal Society on 21 March 1793 and subsequently published both in *Philosophical Transactions* and as a separate book.[53] The account includes a fine engraving of the whole instrument, which contrives to make it look a good deal bigger than it actually is, plus various detailed views. The text includes a detailed account of earlier uses of the equatorial principle in portable instruments harking back to Al-Tuzi and Apianus. The RAS Library copy of the pamphlet bears a presentation inscription from Sir George to George Medley Esq. and interestingly the Latin quotation from Manilius on the first page has been extensively altered by hand.

Considerable trouble was taken in the design of the room which held the telescope, and the vault which supported the heavy structure from the walls of the tower; attention to detail included the angling of

the handrail round the dome, needed for safety when clearing it of snow, to minimise the obstruction of the view of the telescope. The walls of the room can still be seen at the top of the tower at Shuckburgh Hall but alas there is no trace of the dome or any other technical details. The vault was made of bricks laid dry and grouted with gravel and hot lime, and left for two years to settle before being filled up with brick-work; Sir George states it was supporting a weight of nearly 30 tons. The 11-foot diameter dome was designed to be light but strong, made of iron rings carrying iron ribs, then layers of transversely laid thin deal planks, then thin copper, and white lead paint. The dome was definitely up by 1789, as described in the MS volume at Shuckburgh.

One of the design criteria employed was that the angular measurements of RA. and Dec. were made on graduated full circles rather than sectors of various angular extent, as used previously; Sir George devoted two pages of his *Account…* to describing the way in which these allowed greater precision in graduation, by permitting cross checking of the graduations in manufacture at 180 degrees across the circle, and also the checking of the instrument's internal accuracy by the astronomer himself.

The ancillary equipment included a very high precision spirit level for checking the levelling of the instrument – a problem which was just beginning to be understood in transit instruments – capable of being read to 1 second of arc. Allan Chapman describes this as 'probably the best level made in the eighteenth century'.[54] A cross section of the dome is also given showing it to be of truncated conical section with folding shutters to close the slit, like a transit instrument. A meridian mark was set up to enable the alignment of the tube to be readily checked and adjusted, at a distance of 2,970 feet south of the Observatory, 'surrounded by high pallisadoes, to protect it from the accidents of cattle, or curiosity' and unusually this was illuminated by an Argand patent lamp so that it would form an 'artificial star' by night, instead of only being usable in daylight.

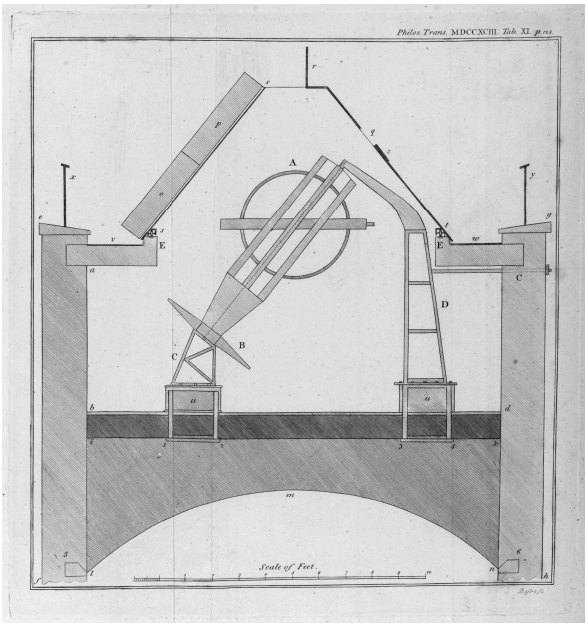


Fig.14 Engraving of the cross-section of the Shuckburgh Observatory tower
Shuckburgh 1793 (Ref.51)
Image No. D130704
Courtesy of the Science Museum, London

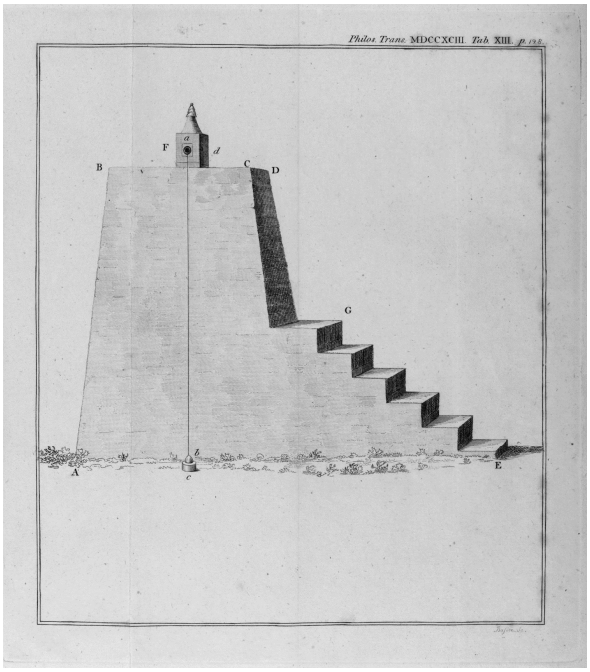


Fig.15 Engraving of the meridian marker for the original Shuckburgh Observatory
Shuckburgh 1793 (Ref.51)
Image No. D130708
Courtesy of the Science Museum, London

Sir George included the following high praise of Ramsden and his foreman: 'I think I am entitled to believe that the accuracy of these divisions under consideration is hardly to be equalled, and still less to be excelled, by that of any astronomical instrument in Europe; and from the unexampled diligence and care, with which the skilful artist Mr Matthew Berge, workman to Mr Ramsden, has executed them, I feel myself bound to bear this testimony to his merit'.

Ramsden pioneered a technique of circle division, fully described by Allan Chapman, which was initially kept secret between himself and Berge,

though later widely used.[55] This involved initially marking out the divisions with lightly punched dots, by use of the traditional beam compasses, followed by microscopical examination of the divisions and comparison with those on the opposite side of the scale. The dots were then corrected by being 'pulled over' as necessary with light taps of a hammer on a sharp pointed punch, in exactly the same way as a fitter may correct the position of a centre-popped hole before drilling. Precautions were also taken against distortions due to variations in temperature. Finally the dots were used as the centres for scribing lines to give a normal looking scale. The process must have been mind numbingly tedious – when Troughton tried the method he found it took about five months' work to graduate a full circle – and it produced scales which were actually quite rough looking, but, for their time, of consummate accuracy; it was claimed that the Shuckburgh instrument's circles showed a maximum error of half a second of arc. For 4-foot diameter circles this corresponds to a physical inaccuracy of 0.0015 mm. Further reduction in observing errors was achieved by averaging readings taken through two microscopes on each scale. It is most unfortunate that both circles of the Shuckburgh instrument were re-divided during the nineteenth century, denying us the chance to view this product of Berge's skill, for it was he that divided these circles. Doubtless the lengthy process of division contributed to the ten year gestation period of the instrument, commemorated in the engraved brass plate formerly mounted on the instrument.

After Sir George's death, in 1804, his son-in-law, the Hon. Cecil Jenkinson, later Lord Liverpool, donated the telescope to the Greenwich Observatory, which if Maskelyne's allegation is true was merely the righting of an older wrong. There was an intention in 1813-15 to remount the telescope as an equatorial on a new pier but the new mounting proved to be so unsteady that the telescope was never mounted on it. It was eventually re-erected, still on its original Equatorial mount, in a dome surmounting the East Building, in 1818.[56] This was a rather unfavourable position and Howse states that only two observations had been recorded as having been made with the instrument up to 1824. Thereafter it must have found regular use as the Dec circle was re-divided, in 1838, Berge's old divisions having worn away, and the same happened to the Hour (RA) circle which was re-divided by Simms in 1860.[57] One must assume that the instrument was moved at the time of the first re-division, as Howse also states that the East Building dome was then adapted for use with the new Sheepshanks 6.7-inch refractor in 1838. Where it resided from 1838, until its transfer to the Science Museum in 1929, is not yet clear.

There was much criticism of the instrument; Airy, viewing Ramsden's pioneering efforts with seventy years of hindsight, described it as 'a small indifferent telescope on a weak frame' and declined to spend any money on it, while the Revd. William Pearson, who incidentally held the living of South Kilworth, Leicestershire, only fifteen miles from Shuckburgh, from 1817 to 1847, in 1829 insinuated that the telescope had only been accepted at Greenwich because of the generosity of Sir George, which hardly squares with the story that it was originally ordered for the Royal Observatory![58] One might hypothesize, though there seems to be no definite evidence from a contemporary illustration, that this lack of rigidity would not have been helped if the iron braces which had been bolted through the walls at Shuckburgh, at 45 degrees each side of the plane of the mounting, were omitted when the instrument was re-erected at Greenwich, leaving the instrument at the mercy of flexure in the polar support and in the floor it was bolted to. The telescope remained at Greenwich until November 1929 and was then moved to the Science Museum, South Kensington, where it has been ever since, having been in store since 1988.[59]

The Shuckburgh Clock

In addition to the innovatory telescope described above, Sir George bequeathed to posterity an unusual clock. This was made by John Arnold & Son and instead of reading time, whether sidereal or mean, displays the sidereal time as converted to angle of RA, in degrees, minutes, and seconds of arc, on a similar principle to the original Tompion clocks supplied to Greenwich in 1691.[60] Sir George writes that this was 'a considerable convenience in observation, inasmuch as the equatorial circle and the clock, by these means, speak the same language'. Perhaps this should be seen as another stage in the process of facilitating observation, and particularly the reduction of observations, firstly by using an equatorial mounting reading positions directly in RA and Dec – or more likely north polar distance – and then by a clock reading angles directly. At all events the second idea does not seem to have caught on. Sir George describes in his observing book its arrival, accompanied by Mr Arnold, and its unpacking, setting up, and rating, on 19th-22nd October 1789; in 1795 he records that Arnold had to return because the clock had ceased to

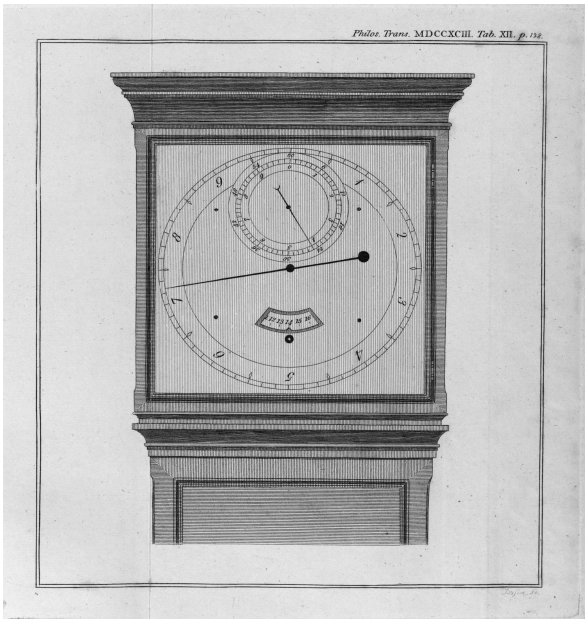


Fig.16 Engraving of dial face of the regulator clock from the Shuckburgh Observatory
Shuckburgh 1793 (Ref.51)
Image No. D130707
Courtesy of the Science Museum, London

run correctly, allegedly because of rusting of the pendulum crutch. It has a three-month going movement (Sir George claimed five months) and a 2/3rds second beating gridiron pendulum, 17.4-inch long; Shuckburgh notes that this unusual interval corresponded to 10 arc seconds of RA. He adds that it had been made in late 1787 and had been set up for testing in Somerset House, presumably in the Royal Society's rooms, for several months before transport to Shuckburgh; the maximum inaccuracy recorded was 3/10 second per day. It is now in the National Maritime Museum (NMM), known as 'Arnold No.1', having been presented to Greenwich at the same time as the telescope. It was transferred to the Science Museum with the Shuckburgh telescope but loaned back to the NMM in 1967.[61]

Sir Francis Shuckburgh (1789-1876)

This later member of the Shuckburgh clan, the 8th Baronet, Sir George's nephew, was elected as a Fellow of the Royal Society on 11 March 1824 but seems to have left little mark on scientific history except for a complaint recorded from Humphrey Davy that his proposal certificate did not include the statement usually required of scientific qualifications and achievements. He was, nonetheless, elected.[62] He is remembered in the family as an exponent of the characteristically Victorian arts of ornamental turning and ivory carving.

Isaac Fletcher and a redesign in Cumberland, the 'Fletcher' Development

A later 'variant' of the English Mounting was designed, and first built for a 9½-inch refracting telescope, of 12-foot focal length, by Mr Isaac Fletcher at the Tarn Bank Observatory, described as 'near Carlisle', but actually between Cockermouth and Workington, in the village of Greysouthen – pronounced Greysoon, still unimpeachably in England.[63] The key to this attribution was a description published nearly 40 years later of the Wanganui Observatory, New Zealand – apparently pronounced Wonganooey, to which Fletcher's telescope eventually migrated. Curiously this description does not specify that it is actually the same instrument; presumably the Wanganui committee were a little shy of admitting publicly that they had purchased a second hand telescope for their new Observatory![64] The instrument is still in existence at Wanganui, and the antipodean part of its history has recently been splendidly documented by Wayne Orchiston.[65] There it has made many contributions to double star astronomy and astronomical education. Among its equipment there is still a case of eyepieces

Fig.17 Photograph of the Fletcher telescope in its new and current site at Wanganui Observatory, New Zealand
Photograph courtesy Dr Wayne Orchiston.

labelled in Fletcher's own handwriting.[66] The description says the mounting was of the form designed by Fletcher, as many others had been.[67] This is an improved version of the 'cross axis' English mount, the principal change being that the Polar axis is most elegantly cast in iron in two opposing cones, with a cubical section in the centre through which the Dec axis passes. I refer to this here as the 'modified cross axis' or alternatively as the 'Fletcher' type.

The redesigning of the mount is described by Fletcher in a short paper to the RAS in 1865, though his instrument had been completed earlier, the telescope being supplied to him by Thomas Cooke in 1857.[68] The observatory completed by 1860 and W. S. Jacob later contributed a drawing of Jupiter made in March 1860 with the 9½-inch to the Society's collection of planetary drawings.[69] Among the disadvantages of the German mount Fletcher mentions the fact that the central pier gets in the way, and the need to reverse the instrument when the meridian is reached. With his successively larger telescopes he made many measurements of double stars. To anyone acquainted with engineering costs, it makes strange reading that the construction of the polar axis as a single casting was adopted, instead of a fabricated structure, on the grounds of economy. The pattern and core-making involved in casting a hollow polar axis in one piece, where the central cube was 17-inch on the side and

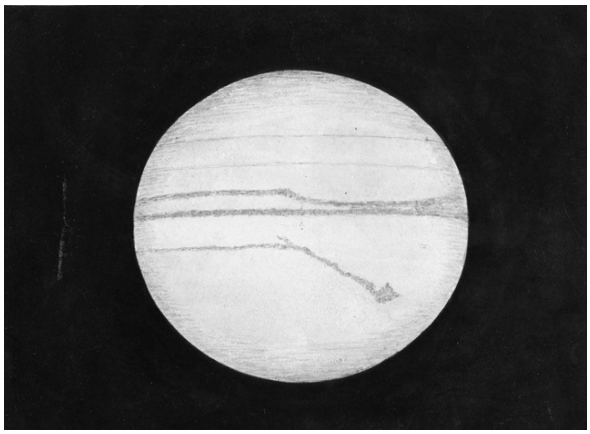


Fig.18 'Jupiter as seen at Tarn Bank in Mr Fletcher's equatorial (f = 147 in., ap = 9.5 in., power 250) 1860, March 12d. 7h. 40m.'
RAS ADD MS 18/31
Courtesy of the Royal Astronomical Society

the conical ends tapered from 16 to 8-inch diameter, and from ¾-inch to ⅜-inch in thickness, must have been of a very high order. Fletcher casually mentions that his brother Henry was involved as managing partner in the Lowca Engine Works, near Whitehaven, and doubtless this had an influence on the cost![70] The machining of the castings was evidently also of a high standard of accuracy; the weight of the moving parts of the instrument totalled 1.5 tons. The optics, tube and clock drive were made by Cooke at York. Fletcher mentions the use of powers up to 1000, and a Dawes solar eyepiece, a complicated contrivance with multiple lenses, diaphragms and coloured glasses mounted in three wheels. Fletcher also had a transit by Simms and a sidereal clock by Frodsham.

In an earlier paper to the RAS Fletcher gives quite a detailed description of his first telescope and the substantial building which enclosed it, with an octagonal base 18-foot high and 14-foot diameter, surmounted by a further 6½-foot round brick tower 11-foot 3-inch in diameter.[71] The telescope was by T. Cooke of York, 4¼-inch aperture and 6-foot focal length. It was originally on a portable German mount but was re-erected on a cross axis English one, with a polar axis of mahogany, which he describes as exactly like those of George Bishop (1785-1861), John Wrottesley (1798-1867) and Smyth. It was equipped with a driving clock, whose maker, is, alas, not specified, but which Fletcher says has a governor 'precisely similar to those used in steam-engines', i.e. probably the Watt type with balls.

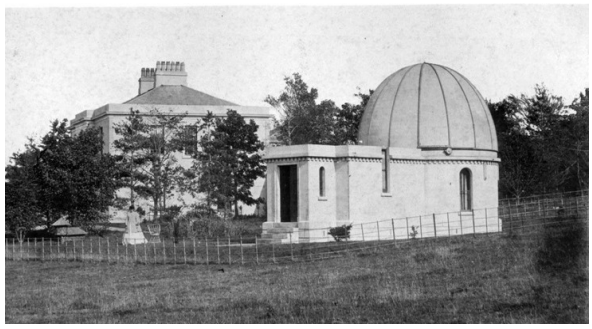


Fig.19 Photograph of Tarn Bank observatory
RGO Archives: Airy Papers (CUL MS. RGO6/148:32)
Courtesy of Cambridge University Library

Henry Fletcher evidently also had some interest in active astronomy, being elected a Fellow of the RAS in 1866, and in 1875 we find him writing to the Society requesting the loan of a 3 or 4-inch equatorially mounted telescope, though he later satisfied this requirement from other sources.[72]

Isaac Fletcher was born in 1827 and was evidently regarded as a 'local worthy' in Cumberland. Local genealogical works trace the family to Lancelot

Fletcher of Mockerlin, who died in 1698. Isaac was (Liberal) MP for Cockermouth from 1868 to 1879, and a JP for Cumberland.[73] He was also described as a prominent colliery owner and was Chairman for some years of the Cockermouth, Keswick and Penrith Railway Company. Isaac had two younger brothers, Henry Allason Fletcher (1834-1884), mentioned above, and William Fletcher (1831-1900), a Fellow of the Geological Society, who followed Isaac as MP for Cockermouth (1879-80) and was Chairman of Cumberland County Council 1889-92; his sister became Anne Harris. Isaac was elected a Fellow of the RAS on 11 May 1849 on the proposal of a brilliant list of sponsors, Charles May (of the Ipswich engineering firm Ransomes and May), Revd. W.R. Dawes, Revd. Richard Sheepshanks, Admiral W.H. Smyth, Dr John Lee, William Rutherford, John Couch Adams, Edward Riddle (another north-countryman) and Revd. Robert Main. Including the description of this telescope and its predecessor, of 4.2inch aperture, he contributed 16 papers to *Monthly Notices* on double stars and star positions, Saturn, and the Sun. He was regarded as significant enough to be featured in Poggendorff's *Biographisch-Literarisches Handwörterbuch*.[74]

Fletcher was evidently on good terms with Sir George Airy; as early as 1855 Fletcher was writing to him about the orbit of Jupiter; later correspondence from him in the Airy papers says little, alas, about the telescope and about actual observing, but extensive information is passed about the life of George Graham, resulting from the preparation of a biographical work on 'Cumberland Worthies'.[75] He also mentions the life of Revd William Pearson, another Cumbrian, of whose time as Treasurer of the RAS Airy comments that he 'put things in great confusion'. Airy's daughter, and on another occasion, his wife also, stayed at Tarn Bank. The RAS Archives contain 35 letters, most of them very routine; one, however, states that he is forwarding to the Society a small and rather battered altazimuth instrument which he had purchased as a memento at the sale of the effects of Sir Thomas Brisbane.[76] This instrument, described as 'Brisbane's Circle, of 2 foot diameter', was listed as RAS Instrument No 19, made by Troughton, but sadly was missing by 1876.[77] Another letter proffers help with the Society's Obituary of Admiral Smyth, with the approval of the family of the deceased.[78] The resulting notice, duly signed 'I.F.', is a masterpiece of friendship and humour.[79] Among his many interests he still found time to glory in the landscape of the Lake Counties; on 1 November 1874

Fig. 20 Portrait of Isaac Fletcher and his wife Esther outside the observatory, with 'Tarn Bank' in the background. Sent by Admiral W H Smyth to Airy with a note, dated 1865 May 31, 'I enclose a photograph of Fletcher's Observatory , in case you hav'n't got one….'. Although the figures are not labelled specifically there seems little doubt that they are Fletcher and his wife.
RGO Archives: Airy Papers
(CUL MS. RGO6/148:32)
Courtesy of Cambridge University Library

he writes that the day being indescribably magnificent we are on the point of starting for Watendlath.[80] Alas, no original observing material by Fletcher has come to light; the nearest found so far is W.S. Jacob's drawing of Jupiter already mentioned.

As well as his astronomical hobbies and industrial activities Fletcher was active in antiquarian studies, writing a history of Brigham Church, and he could be described as a primeval Industrial Archaeologist as another paper described the archaeology of the West Cumberland coal trade – indeed Marshall and Davis-Shiel suggest he may have been the first to apply the term 'Archaeology' to industry.[81] These articles appeared originally in the local archaeological journal and were later reprinted separately.[82] Brother Henry, reasonably enough for an ironmaster, extended this to the iron industry.[83] He was also a Fellow of the Geological Society and of the Society of Antiquaries. He served as President of the Cumberland Association for the Advancement of Literature and Science, to which he gave a Presidential Address on the Cum-

berland born watchmaker George Graham, and President of the Cockermouth Literary and Scientific Society, to which he lectured. Finally he became a Fellow of the Royal Society on 7 June 1855.[84] Like many nineteenth century industrialists he sought to add respectability to wealth by taking out a Grant of Arms in 1877.

To date, perhaps surprisingly for such a notable man, the only portrait located of Fletcher is the small photograph of him with Observatory and wife, in the RGO archives (fig.19); this can be compared with a small image of him in a group portrait of about 150 MPs in the House of Commons lobby, painted by Henry Barraud in 1872-3.[85]

Isaac Fletcher died tragically at the early age of 52, shooting himself in the head with a revolver in his rooms at Morley's Hotel, Charing Cross, London, on 3rd April 1879 – unusually, this fact was mentioned in his RAS obituary.[86] His death was evidently a great shock to Cumberland society, regret being expressed by figures from the Bishop of Carlisle downwards, and the newspaper accounts of his death, and of the inquest, fully reflect this. No obvious cause could be found and his brother William, with whom he was obviously on very close terms, suggested that it might have been caused by depression after an extended period of ill health, and perhaps exacerbated by the return of a lifelong tendency to epilepsy. The report also quotes a hint by William of Fletcher's character; 'He was an intellectual man, and took great pleasure in many scientific pursuits. He was a very genial man, and extremely fond of anecdote and humour, and although he was not quite what might be called a rich man,… his income … was more than sufficient for all his wants'. He had also used his wealth extensively for the benefit of local good causes. The verdict of the inquest jury was suicide while in a state of temporary insanity.[87]

The religious affiliations of the Fletcher family seem to have a certain ambiguity. Henry Allason Fletcher in his Will (written 1876) said he wished to be interred in the Quaker burying ground at Greysouthen, but he was actually buried at Moresby church, while Isaac was laid to rest in Brigham churchyard, local businesses closing for much of the day; some of those who proved the Wills 'affirmed' rather than swearing, and in an early letter from Isaac to Captain W.H. Smyth he uses the older 'Thee' and 'Thou' forms of address typical of North Country Quakers.[88]

In his Will, proved at Carlisle on 9 May 1879, Isaac Fletcher bequeathed 'Tarn Bank' to his executors (his brothers and brother-in-law), with a life interest to his wife Esther, the telescope and other moveable equipment being specifically left to Henry. His Will was proved on 22 August 1884 and makes no mention of the telescope so perhaps it had been sold by then. Alas, Isaac's Will does not bear an exact valuation, just 'under £30,000'; Henry's was more exact at £11,500 – about half a million pounds today.[89] The telescope arrived at Wanganui in 1903 and it is hoped that further research will reveal its locations in the meantime and detail its distinguished subsequent career in the measurement, particularly, of Southern variable stars. The Observatory building still exists in the grounds of 'Tarn Bank', a photograph of the exterior, but unfortunately not one of the telescopes *in situ*, being preserved in the RAS Archives, very likely the one mentioned as being sent to the Society with Mr Fletcher's description in 1865.[90] Both house and Observatory are Listed Buildings, Grade II. Wayne Orchiston has kindly supplied a photograph of the telescope in its present location.

Conclusion

Although flawed, both the type of construction and the excellent graduation of the Shuckburgh instrument mark important stages in the evolution of the equatorial telescope and the development of accurate measurement. The enthusiastic advocacy of its proud owner doubtless played a part in furthering its influence. Shuckburgh was an enthusiast, an early example of what Allan Chapman has described as the 'Grand Amateur' tradition. Fletcher, also a wealthy and enthusiastic amateur of wide interests, applied the advancing technology of the later Industrial Revolution to produce a modernised version of the configuration, evolving a type of telescope which was quite widely used for a further 70 years. The 'English Mounting' has long been superseded by computer controlled altazimuth mounted telescopes, but it played a significant part in two hundred years of astronomy. We should be glad both that the important Shuckburgh instrument is preserved as an early example of the genre (and it is to be hoped that it will one day be again placed on public display), and that the 'Cockermouth' telescope is still in active existence, albeit in a different hemisphere.

Acknowledgements

I must first acknowledge with gratitude the interest, hospitality, and encouragement of Sir Rupert Shuckburgh (13th Baronet) and of Messrs P.W. Lee

(Hon. Estate Archivist) and P. Vine, also of Shuckburgh; and also Mr B. Walker, of 'Tarn Bank'. I would most strongly emphasize that both Shuckburgh Hall and Tarn Bank remain private houses and are not open to the public.

I have also benefited from considerable assistance from the following gentlemen whose knowledge of the technology and history of telescopes is very extensive; Dr D.W. Dewhirst (Institute of Astronomy, Cambridge), Mr E.J. Hysom (Hytel Optics), Professor R.A. Jarrell, (York University, Canada), Dr D.H.P. Jones (IOA, ex RGO), the late Dr R. Learner (Imperial College), and Dr R. Willstrop (IOA).

Warm thanks are also due, for extensive assistance and encouragement with this paper, to the following, many of whom have been helpful far beyond the call of duty; Mr J. Betts (National Maritime Museum), Dr A. Chapman (Wadham College, Oxford), Miss B. Clark, Assistant County Archivist, Cumbria, Mr S. Ellison (House of Lords Record Office), Miss T. Fiske (National Portrait Gallery), Mr K. Johnson (Science Museum, London), Mr A.J. Kinder (British Astronomical Association), Mme F. Launay (Observatoire de Paris), Dr W. Orchiston (Carter Observatory, New Zealand), Miss H. Pattinson (Sotheby's), Mr A.J. Perkins, (RGO Archivist, Cambridge University Library), Mr M. Rigby, Miss M. Sampson (late Archivist, The Royal Society), Mrs Sharpe (Cockermouth Public Library), and Mr J.T. Spaight (Cornell University).

Author notes

Peter is unable to offer, as customary, the author's email address for correspondence. After his death in June 2012, his friend Françoise Launay of the Paris Observatory – biographer of astronomer Jules Janssen, recalled that the most advanced of Peter's unpublished work was a draft of this article, the subject of several lectures to astronomical societies. Peter's family retrieved the file from his computer, Françoise and *AA* Editor Kevin Johnson effected minimal polishing, and Kevin has resourced the illustrations – mostly chosen and used by Peter. The result is an article important to the history of astronomy. Learned, perceptive, written by a man at one with his subject, we hear Peter's voice – amusing and inevitably digressing to his antiquarian interests such as the Shuckburgh's funerary monuments, and a locomotive builder in note 69.

With the generous encouragement of his family and Françoise, the SHA is privileged to publish this article posthumously as a tribute to Peter's huge contribution to our discipline, a contribution detailed more explicitly in his full obituary in the SHA *Bulletin* – issue 23, forthcoming 2013.

Notes and Reference

1. Gingerich, Owen, 'What is an English Mounting?', *Sky &Telescope* (November 1967), 293-5.
2. Airy, George Biddell, *Account of the Northumberland Equatoreal and Dome, Attached to the Cambridge Observatory* (Cambridge University Press, 1844), p.3.
3. Howse, Derek, *Greenwich Observatory, Vol. 3: The buildings and instruments* (London: Taylor & Francis, 1975), pp.9, 75, 82, and 85-89.
4. Howse (1975), p.87.
5. Pearson, W.*, Introduction to Practical Astronomy*, vol.2 (London, author, 1829); King, Henry C., *The History of the Telescope* (London: Charles Griffin, 1955), p.232.
6. Hoskin, Michael. 'Astronomers at War', *Journal for the History of Astronomy*, 20 (1989), 175-212.
7. 'Report of the Council of the Society to the Tenth Annual General meeting, held this day [February 12, 1830]', *Monthly Notices of the Royal Astronomical Society,* 1 (1830), 151-168, p.153.
8. Herschel, J.F. William and South, James, 'Observations… Also a description of a Five-Feet Equatorial Instrument Employed in the Observations', *Philosophical Transactions of the Royal Society*, 114 (1824), 4-12 and plates.
9. I owe this delightful story to Dr Derek H.P. Jones, *pers. comm.*, 1999.
10. Airy (1844), 4-5.
11. Dewhirst, David W., *pers. Comm.*
12. Gingerich (1967) says it was Jonathan, but after Howse (1975), p. 81, the surviving fragment is signed Jeremiah; Jonathan Sisson died in 1747.
13. National Maritime Museum, Greenwich (Accession Number: PAF2940)
14. Chapman, Allan, *Dividing the Circle*, 2nd Edition (Chichester: Wiley/Praxis, 1995), 162-4 and plate 40.
15. Hooke, Robert, *Animadversions on the first part of the Machina Coelestis…* (London: John Martyn, 1674), plate 2, fig. 29.
16. Chapman (1995), 48-9 and plate 17.
17. Grant, R., *History of Physical Astronomy: from the Earliest Ages to the Middle of the Nineteenth Century* (London, 1852), 426-7
18. King (1955), 172; Ingallis, Albert G. (ed.), *Amateur Telescope Making* (1935), p.25.

19. Howard-Duff, I., 'George Bishop (1785-1861) and his South-Villa Observatory in S-Park', *Journal of the British Astronomical Association*, 96, No.1, Dec. (1985), p.20.
20. John Second Baron Wrottesley, 'Obituary', *Monthly Notices of the Royal Astronomical Society*, 28 (1868), 64-8
21. Jarrell, Richard A., *pers. comm.,* 1998.
22. Jarrell, Richard A., 'J. S. Plaskett and the Modern Large Reflecting Telescope', *Journal for the History of Astronomy*, 30 (1999), 359-390.
23. Sisson, George M., 'Grubb Parsons – from War to Peace', in Wall, Jasper V. (ed.), *Optics in Astronomy*, (Cambridge University Press, 1993), 267-281.
24. National Grid Reference, SP 497619.
25. Pevsner, Nikolaus, *Buildings of Warwickshire*, (Harmondsworth: Penguin Books, 1966), 438-9.
26. Anon, 'Upper Shuckburgh', *The National Gazetteer of Great Britain and Ireland* (1868), see GENUKI: UPPER SHUCKBURGH, Warwickshire (http://www.genuki.org.uk/big/eng/WAR/UpperShuckburgh/index.html) transcribed by Colin Hinson©
27. Jan Broadway, 'Shuckburgh, Sir Richard (1596–1656)', *Oxford Dictionary of National Biography*, Oxford University Press (2004) [http://www.oxforddnb.com/view/article/25478, accessed 30 Sept 2012]
28. Hickman, Douglas, *Warwickshire – A Shell Guide*, (London: Faber and Faber, 1979).
29. Sotheby's, London, Sale of 10 April 1991, Lot 85.
30. *The Record of the Royal Society* (4th edition, London, 1940), p.346.
31. Pevsner (1966).
32. CUL ADD MSS 4523–4234.
33. 'Charles Leeson Prince', obituary, *Monthly Notices of the Royal Astronomical Society*, 60 (1900), 321-4.
34. Some investigations about the life and work of the Benedictine monk Dom Nicolas Noël (1713-1783) have been made since this paper was written; see Launay, Françoise, 'Les instruments d'optique du père Noël', *l'Astronomie*, (December, 2007), 22-27.
35. Daumas, Maurice, *Scientific Instruments of the Seventeenth and Eighteenth Centuries and their Makers* (London: Portman Books, 1989), 170; unfortunately the illustration used by Daumas in fig. 90 is actually a smaller (8-French foot in length) telescope.
36. Vince, Samuel, *A Treatise on Practical Astronomy* (Cambridge, 1790), 152-169 and plate 6.
37. Meeus, Jean, 'Astronomical Tables of the Sun, Moon and Planets' (Willmann-Bell, Richmond VA, 1983)
38. Howse (1975), p.86.
39. Learner, Richard, *Astronomy Through the Telescope* (New York: Van Nostrand Reinhold, 1981), 68-9.
40. Howse (1975), 82 and 88.
41. Chapman (1995), p. 119; R. S. Archives, Letter 14/1/1781, MS GH. 120.
42. Currency conversion from Bank of England; 'Equivalent Contemporary Values of the Pound; a Historical Series, 1270 to 1998'
43. Lee, Peter W., (Hon. Archivist – Shuckburgh), *pers. comm.,* 1998
44. Spaight, John T., *pers. comm.,* 1998; Letter in National Library of Wales…… Lloyd was elected FRS in 1774.
45. Donnelly, Marian C., *A Short History of Observatories* (Eugene, Oregon: University of Oregon Books, 1973), 29-56.
46. Spaight, John T., *pers. comm*., 1998.
47. Howse, Derek, 'The Greenwich List of Observatories', *Journal for the History of Astronomy*, 17 (1986), A1-100, A81.
48. Jones, Derek, *pers. comm.,* formerly of the Royal Greenwich Observatory, Herstmonceux
49. Chapman's mention of six micrometers on each circle is based on a misreading of Shuckburgh's 'Account..'; Chapman, Allan*, Dividing the Circle: the development of critical angular measurement in astronomy* (Chichester: Ellis Horwood, 1990).
50. King (1955), p.184.
51. Shuckburgh, George, 'An Account of the Equatorial Instrument', *Philosophical Transactions of the Royal Society*, 83 (1793), p.74.
52. Howse (1975), p.87.
53. Shuckburgh (1793), 67-128, plates 9-14.
54. Chapman (1995), p.85.
55. Chapman (1995), 112-4.
56. Howse (1975), p.83 and figure 80.
57. Howse (1975), p.88.
58. Airy, George Biddell, Address to the Board of Visitors, Greenwich, 18 October 1858; Pearson, William, *An Introduction to Practical Astronomy* (London: privately published, 1829), vol.2, 518.
59. Science Museum, London (Accession Number 1929-979).
60. Howse (1975), 133, 136, 7 fig 124; date given there as about 1793.

61. With thanks to Mr Jonathan Betts for confirming this.
62. Hall, Marie B., *All Scientists Now; the Royal Society in the Nineteenth Century* (Cambridge University Press, 1984), p.24.
63. This description must have been for the benefit of ignorant southerners – it is 34 miles from Carlisle! (National Grid Reference: NY 074297).
64. RAS ADD MS 212, (newspaper article) 'Description of Wanganui Observatory, New Zealand', *New Zealand Graphic* 11th July 1903
65. Orchiston, Wayne, 'The English equatorial mounting and the history of the Fletcher Telescope', *Journal of Astronomical History and Heritage*, 4 (2001), 29-42.
66. Letter from A.T. Ward, Wanganui, to B. Walker, 1982; Orchiston 2001, op. cit. (ref.64)
67. RAS ADD MS 212, Reprint from the 'New Zealand Graphic', 11 July 1903, sent to RAS by F. J. Ward, 1903.
68. Chapman (1998), Chapter 5, note 109 on p.340.
69. Fletcher, Isaac, 'Description of an Equatoreal Mounting', *Monthly Notices of the Royal Astronomical Society,* 25, (1865), 241-3; drawing reference: RAS ADD MS 18/31.
70. This firm is usually known in railway circles as Fletcher, Jennings and Co, the title they bore from 1857 to 1884; two of their engines, much rebuilt, are still at work on the Tal-y-llyn Railway, in Merioneth. The works operated from 1840 to 1921; see Kyle, Ian, *Steam from Lowca: A History of the Rise and Fall of Locomotive Building at Lowca Foundry, 1840 – 1921*, (Whitehaven: Privately Published, 1974).
71. Fletcher, Isaac, 'Brief Description of a small Equatoreal and Dome at Tarn Bank, near Cockermouth', *Monthly Notices of the Royal Astronomical Society*, 10 (1850), 137-9.
72. RAS Correspondence, 1875 September 22.
73. Hudleston, C. Roy and Boumphrey, R.S., *Cumberland Families and Heraldry* (Cumberland and Westmorland Antiquarian and Archaeological Society, 1978), 118.
74. Poggendorff, Johann C, *Biographisch-Literarisches Handwörterbuch* (Leipzig, J.A Barth, 1898), vol. 1, p. 452.
75. RGO 6/383/133-179.
76. RAS Correspondence, 3 August 1864.
77. Howse, H. Derek, 'The Royal Astronomical Society Instrument Collection: 1827-1985', *Quarterly Journal of the Royal Astronomical Society*, 27 (1986), 212-236.
78. RAS Correspondence, 27 October 1865.
79. Obituary: Admiral William Henry Smyth, *Monthly Notices of the Royal Astronomical Society*, 26 (1866), 121-129.
80. RGO 6/383/151.
81. Marshall, John D. and Davies-Shiel, Michael, *Industrial Archaeology of the Lake Counties* (Newton Abbot: David & Charles, 1969), p.15.
82. Fletcher, Isaac, 'The Archaeology of the West Cumberland Coal Trade' and 'Brigham Church', *Transactions of the Cumberland and Westmorland Antiquarian and Archaeological Society*, respectively Old Series 3 (1877), 266-313, and Old Series 4 (1878), 149-177; also published as separate booklets in 1878 and 1879.
83. Fletcher, Henry A., 'The Archaeology of the West Cumberland', *Transactions of the Cumberland and Westmorland Antiquarian and Archaeological Society*, Old Series 5 (1881), 5-21.
84. The Record of the Royal Society (4th ed., 1940), p.475.
85. Walker, Richard J. B., *A Catalogue of Paintings, Drawings, Engravings and Sculpture in the Palace of Westminster* (Property Services Agency Library Service, 1988).
86. Obituary: Isaac Fletcher, *Monthly Notices of the Royal Astronomical Society*, 40 (1880), 194.
87. *The Carlisle Journal*, Tuesday 8 April, 1879.
88. RAS Correspondence, 1853 (copy).
89. Bank of England, op. cit. (ref. 42)
90. RAS ADD MS 93 No. 27

Jesse Ramsden: the craftsman who believed that big was beautiful

Anita McConnell
Department of History & Philosophy of Science,
University of Cambridge

Ramsden was renowned for the design, craftsmanship and accuracy of his larger instruments, and for his workforce of up to fifty people, unusual in the scientific instrument workshops of his day. The workshop also produced a variety of lesser instruments. Following in the footsteps of Jonathan Sisson and John Bird, he built up an enduring reputation for design and precision of manufacture. Ramsden's own business archive does not survive, but correspondence with his various customers and letters between third parties illuminate his working life. These documents also reveal that there were several major astronomical instruments for which he accepted commissions but failed to deliver.

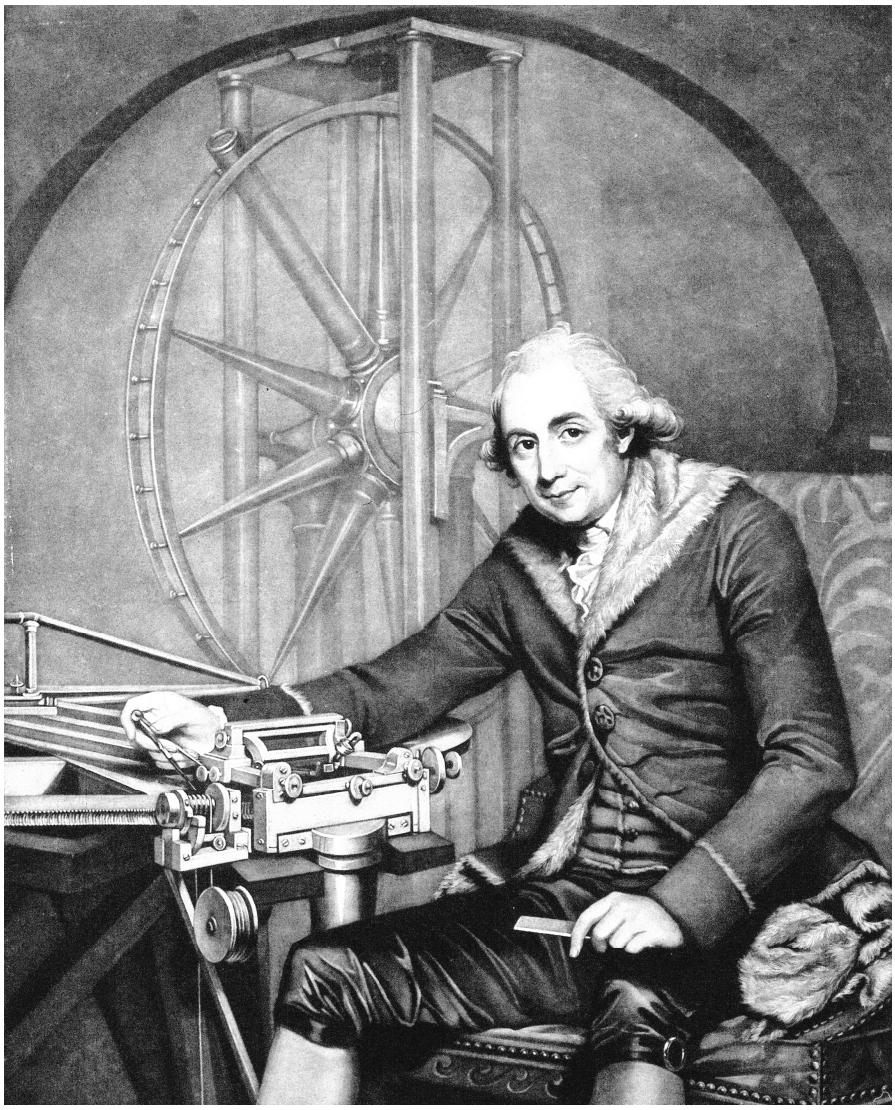


Fig.1. Jesse Ramsden, seated by his dividing engine. Mezzotint by John Jones, 1791, from the portrait by Robert Home which now hangs in the Royal Society's house
Author's photograph

Somewhere between London's numerous self-employed subcontractors and makers of small items, and the major mechanical engineers such as James Watt (1736–1819) of the Soho Works at Birmingham and Bryan Donkin senior (1768–1855) of Bermondsey, are men like Jesse Ramsden (1731–1800), who thought and built big. Building big calls for spacious premises, because – obviously – one cannot build a large brass instrument in the garret of a building with narrow access and limited floor loading. Ramsden's big instruments were not just those for astronomy; he thought big across the range. Their construction was not a one-man-and-a-boy job; manoeuvring the sections around, onto the lathe, and then assembling the parts, may need a block-and-tackle, with the muscle power of several strong men. It must also be remembered that although Ramsden was rewarded for his design and manufacture of the dividing engine, which made possible the rapid and accurate division of arcs and circles, his engine tables could only carry instruments up to about 12 inches in radius. In Ramsden's workshop all instruments above this size were hand-divided.

In their search for greater accuracy, astronomers increased the overall size of their instruments so that with the aid of micrometer, measurements down to two seconds of arc could be read off on the graduated arc. Before Ramsden entered into business, James Bradley (1692–1762), the third Astronomer Royal had demonstrated the value of observations made with large instruments from the best makers – George Graham (1673–1751), Jonathan Sisson (c.1690–1747) and John Bird (1709–1776). Bradley, a remarkably productive man, both before and during his years at Greenwich, was responsible for the discovery of the nutation of the earth's axis in 1728 and in the following year, the aberration of light. He calculated the speed of light and, by failing to find evidence of stellar parallax, showed that the stars were far more distant than generally supposed.

Any person or institution commissioning a big instrument needs enough money to pay for it, not just for the instrument, but its packing cases and, if destined for Europe, its insurance and shipping across to the continent, and its road transport thereafter, before summoning another large and competent team to hoist it into position and set it up. Between the commissioning and the delivery many months or years might intervene, during which the craftsman had only the 50% deposit with which to purchase the materials. He had to find a way of getting a cash flow to pay his rent and taxes, and his workmen meanwhile. Unlike the lesser craftsmen, he needed a bank account.

Some years ago I wrote an article in *The London Journal* with the title of 'From craft workshop to big business', in which I identified some of the handicaps from which Ramsden's contemporaries suffered.[1] John Bird's house near the Strand was unsuitable for making large mural quadrants and we do not known where these were constructed; however we do know that he moved from the Strand to a new house in St Marylebone, and rented an additional ground-floor workshop before he could construct the instruments for Oxford Observatory. The Troughtons were seriously obstructed by the narrow passage leading from their Peterborough Court workshops into Fleet Street. They got round this by getting Bryan Donkin to cast their larger pieces for astronomical instruments, making the optical parts in Peterborough Court and taking these to Donkin's Thames-side factory at Bermondsey to assemble the instrument. As for the Dollonds (in business from 1752) and Edward Nairne FRS (1726–1806), whose speciality lay in geophysical and electrical apparatus, we know only where their shops were located, on public thoroughfares. The Dollonds restricted themselves to telescopes, their speciality being in shaping lenses, while Nairne, later Nairne & Blunt did not make large pieces.

Many astronomical instruments can be manufactured in a range of sizes. One of the simplest is the sextant, basically a two-dimensional instrument which in its smallest form, for surveying and navigation, can be hand-held. When enlarged, as sextant or, more usually as a quadrant, it has to be put on a stand. Transits may also be made small and portable for field astronomy. But within the observatory, quadrants and transits may be made larger and sturdier, and can be fixed to a wall or between piers for stability. Questions arise as to the source of the necessary fine quality plate or rolled brass. It was also in demand by clockmakers, but in smaller quantities. Some brass was manufactured in Bristol, where copper and calamine (zinc ore) and coal for smelting were all accessible nearby, and in Cheshire, using copper from the Parys mine on Anglesey. There is also mention of 'Hollands brass', which had been shipped from Holland but which was manufactured further east, near Aachen.[2]

Mural quadrants

With heavy apparatus, brass cannot bear the weight of the turning parts. Here steel must be employed. Unfortunately we do not have any documents identifying Ramsden's supplier of his steel – the actual composition of such metals was poorly understood at the time, and it is possible that Ramsden

was advised by his friends in the Society of Engineers and thereafter bought from them or from their suppliers. Much the same goes for the mural quadrant, and for the free-standing circle where the base pivot must carry an even greater weight. The weight of the frames of such mighty pieces can be reduced without losing strength by constructing the sections of angle-brass, or by employing the tapered hollow cone. Ramsden was not the first to appreciate the utility of this structure and he made good use it for other large apparatus, as we shall see.

With mural quadrants we are definitely in the realm of big instruments. The rationale behind their increasing size was to expand the scale and thereby get a more precise measurement. The dividing engine had no place in dividing large arcs. This was a long and tedious operation, and part of the delay in quadrant manufacture arose because hand-dividing could only be done in good day-light and at an even temperature. Any oil lamp brought close enough to illuminate the arc would very soon warm that segment causing uneven expansion of the metal.

Mural quadrants had a long history. The earlier ones had brass arches fastened to thin iron frames, and look rather spindly. An iron-framed quadrant by Jonathan Sisson was installed at Greenwich Observatory but had fallen into disrepair by 1742 when James Bradley arrived as the new Astronomer Royal. The first all-brass mural quadrant is in the observatory at Bologna. It has a radius of five feet and was made by Jonathan Sisson in 1739, bearing a signed and dated lens by James Mann.[3] An eight-foot radius quadrant, its arc slightly exceeding 45º, was made by his son Jeremiah Sisson, in 1770, for King George's Kew Observatory, and hangs in the Science Museum. John Bird (1709–1776), like Ramsden, a north-countryman by birth, was considerably older than Ramsden and had been working in London since about 1740. He made quadrants for Greenwich in 1750, for Pierre-Charles Le Monnier's private observatory in Paris, and for St Petersburg Academy Observatory in 1752, for the Academy of Sciences Observatory at Stockholm in 1753, Göttingen in 1755, and Cadiz in 1758. His two illustrated texts , first on *The method of dividing astronomical instruments* (1767) and the second *The method of construction of mural quadrants, exemplified by a description of the brass mural quadrant at the Royal Observatory at Greenwich* (1768), were composed at the instigation of the Board of Longitude and published at their expense. Bird received £500 each for these books, compensation for the time he had spent preparing them.[4] Their publication stimulated the demand for mural quadrants at home and abroad, besides inspiring

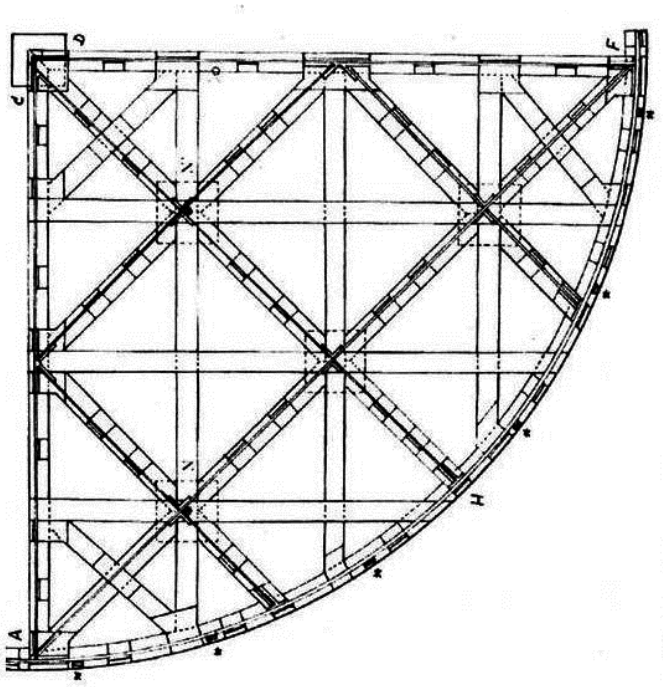


Fig. 2 Bird's diagram of the structure of his quadrant
The method of construction of mural quadrants ... (1768)
By the author

Jeremiah Sisson and Ramsden. Bird went on to deliver two instruments for Oxford University Observatory, in 1772 and one for Mannheim in 1775.

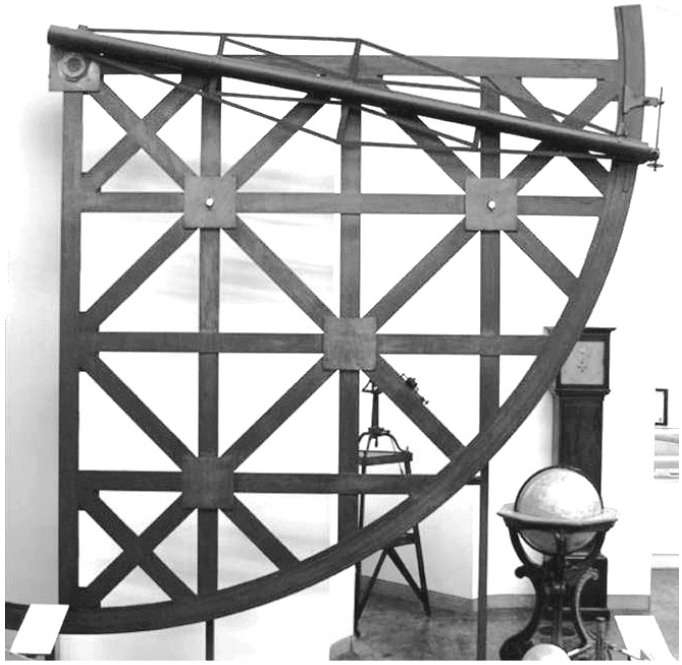


Fig. 3 Bird's mural quadrant for Mannheim Observatory, with Dollond optics, 1775
Courtesy of Landesmuseum für Technik & Arbeit, Mannheim

You may well ask how Bird managed to construct these large items if, as I had claimed, he was handicapped by a lack of suitable premises and the appropriate workforce. He was also constrained by his

illnesses: he suffered from the painful affliction of gravel in the kidney. The answer is that we do not know; we have no Bird business archives beyond a brief run of payments-out from Coutts' bank for the last ten years of his life, plus what can be gleaned from his customers and visitors – notably Lalande in 1763 and Bernoulli in 1769 – and between third parties. [5]

However, we return to Ramsden, whose abilities to construct large apparatus within his own workshop and under his immediate supervision brought visiting foreign astronomers to his door. During the 1770s, the Jesuits who had been in charge of many of Europe's universities and their observatories, fell into papal disfavour and were ejected from their posts. This came about at a time when the individual states and principalities were seeking to map their regions and their borders. The first stage of cartography is to know where you are on the surface of the globe – latitude and longitude, and these call for an astronomical observatory with instruments capable of determining this point. Astronomers were great travellers and clearly enjoyed visiting other observatories to compare apparatus and results. The European astron-

omers enjoyed only a brief summer, their world being greatly disrupted, first by the French Revolution, then over a wider region by Napoleon, whose idea of collecting instruments was simply to repatriate the best examples to France where many have ended up in the Conservatoire des Arts et Métiers.

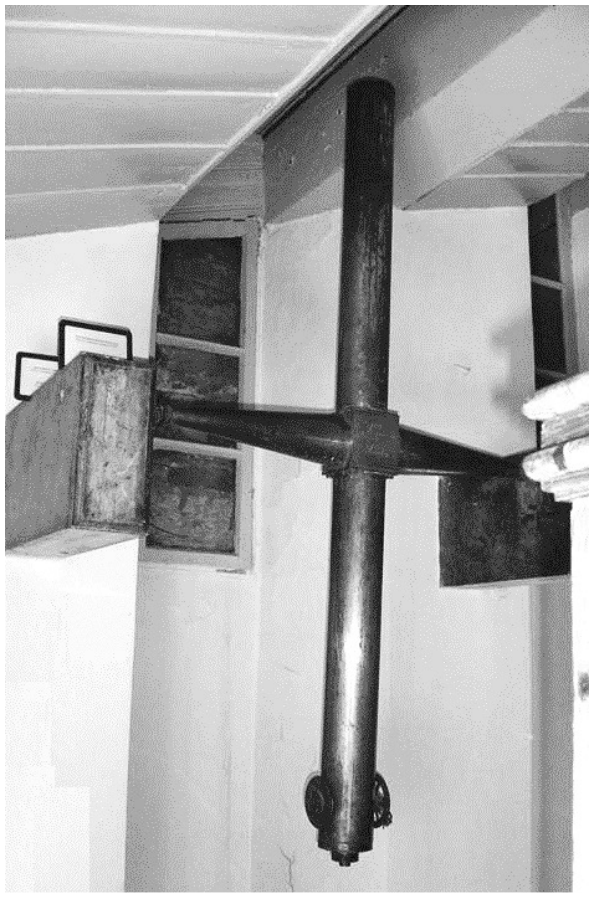


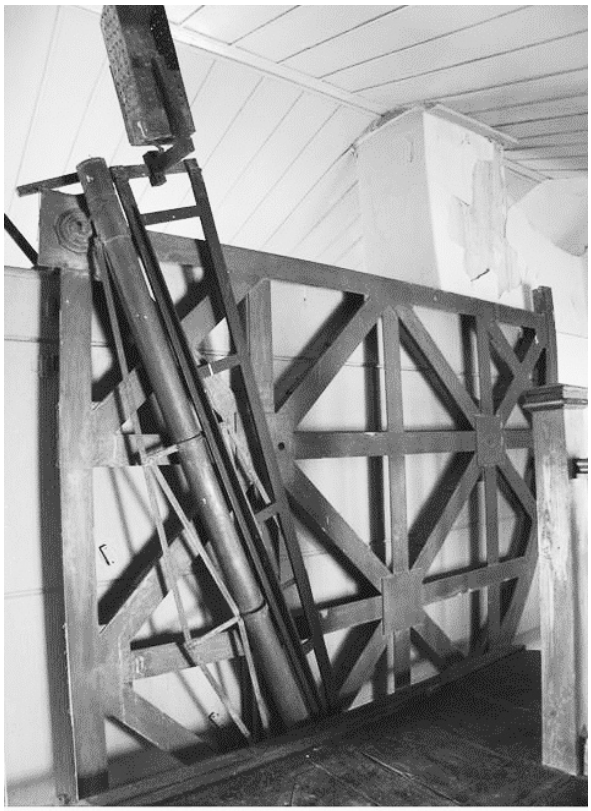
Fig. 4 (left) Vilnius Observatory, constructed in 1771 for the Ramsden instruments. (right) Ramsden transit instrument, 1771, in its original position at Vilnius Observatory
Photographs by Romualdas Svierdrys and author

The Vilnius transit and mural quadrant

Ramsden's first large instrument was a transit telescope, made in 1771 when he was still at premises in the Haymarket. It was sent to the ancient university of Vilnius, then part of the Polish kingdom. A new observatory building was erected to house Ramsden's instruments. During Soviet rule the university library was shipped to Moscow, but the apparatus never fell victim to Soviet scrap dealers. Now, with Lithuania independent and the university library returned, the observatory has been restored to its former elegance.

It is possible that this order came via Peter Dollond who made the lenses, for at this time Ramsden and Sarah Dollond, married in 1766, were still together. They parted before 1784, dates which have implications for the lenses in Ramsden's later telescopes. There followed a 3-foot refracting telescope, again with Dollond lenses, and in 1776 a mural quadrant. Slight corrosion of the brass has

revealed the method of jointing by dove-tails the segments of the arch.



Ramsden's Piccadilly premises

By this time Ramsden had taken the short step to Piccadilly, adjacent to St James' churchyard, where he first took a house (No. 199) with yard and rear workshop, then leased the adjacent former carriage works. This structure consisted of three-story workshops surrounding an open central yard, with a broad passage to Piccadilly which ran beneath the upper stories of No. 196 which he acquired later. Houses on either side of the passage provided a dwelling for his foreman Matthew Berge (c.1753–1819) and some other workmen and in his final years Ramsden had begun to have them rebuilt. Customers were received at Ramsden's shop in the house next to the churchyard, where Ramsden himself lived.

We are fortunate that these premises were on Crown land and therefore Ramsden's negotiations for leases, permissions to rebuild, and so forth were negotiated with the Crown Estate Surveyors, and have survived in the National Archives.[6] In 1830 this site was exchanged for Crown land adjacent to Charing Cross, belonging to the Governors of Bethlem Hospital, where the government intended to make improvements. An isometric drawing of the great workshop, dated 1781, with some earlier Ramsden documents, are now held in the Bethlem Royal Hospital Archives, Beckenham. After Ramsden's death the building of Regent Street and Piccadilly Circus caused a renumbering, with No. 199 becoming 196 and 196 becoming 193.

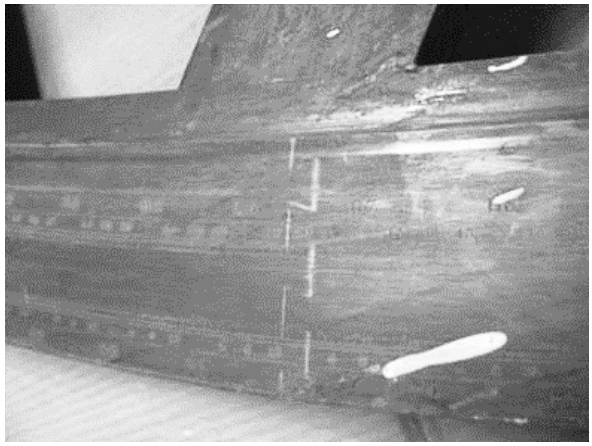


Fig. 5 (left) Upper portion of Ramsden's mural quadrant at Vilnius. A walkway constructed across the quadrant prevents a photograph of the entire instrument. (top) Detail showing the dovetailing construction of the quadrant arch
Photograph courtesy of Romualdas Svierdrys

The advantage of a capacious workshop and a skilled workforce meant that Ramsden could oversee the manufacture of new types of instruments and make adjustments during their construction. Visitors were surprised at the size of Ramsden's workforce, unusual in the instruments trade, though common enough in manufacturing industries outside London. Some fifty people, including British and foreign apprentices and journeymen, foremen, shop men, and general labourers, have been noted. Thirty-five can be identified, by name and nationality, showing that they came from many parts of Europe and some went on to fame and fortune in their own countries.

Ramsden himself was not always on the premises, having other meetings in or beyond London. His supervisor and leading craftsman was Matthew Berge, whose skills were widely admired and who broadly inherited the business.

The Padua mural quadrant

Padua, the ancient secular university of the Venetian Republic, took delivery of an 8-foot quadrant with micrometer in 1778. The tower of the university, located in the city centre and without views of the horizon, was not suitable as an observatory, so the tower of an old castle, built in 1242 was converted. Its situation alongside a small canal leading from Venice, allowed building materials, and later the quadrant, to be brought by boat. Giuseppe Toaldo, a

Fig. 6 Padua, the old observatory
Author's photograph

forward-thinking astronomer listed the instruments needed. John Bird was Toaldo's first choice but he declined the order, being fully occupied with the Oxford quadrants. Pisani, the Venetian Resident in London, conveyed the order to Ramsden in October 1775, along with 200 guineas as down-payment, for its completion in 12 months. Three years later, when the quadrant was finished in November 1778, Maskelyne inspected it and reassured Pisani's successor as to its accuracy. There was no delay over its shipment and it arrived at Padua in 1779. Ramsden wanted to send one of his assistants to direct its erection but this was refused on grounds of cost, as was the recruitment of Giuseppe Megele, the craftsman who had erected a quadrant by Canivet at Brera Observatory in Milan, and a local workman was employed to direct the numerous masons, carpenters and painters who dealt with its mounting.[7] The astronomer Giovanni Santini, who arrived at Padua Observatory in 1806, declared the mural quadrant to be the most perfect instrument made by the celebrated craftsman Ramsden. His observations focussed on establishing the orbits of the minor planets. In 1837, however, Santini began observing with a meridian circle by Starke of Vienna. The Padua quadrant has been restored and is on display in the tower, now refurbished as an Observatory Museum.

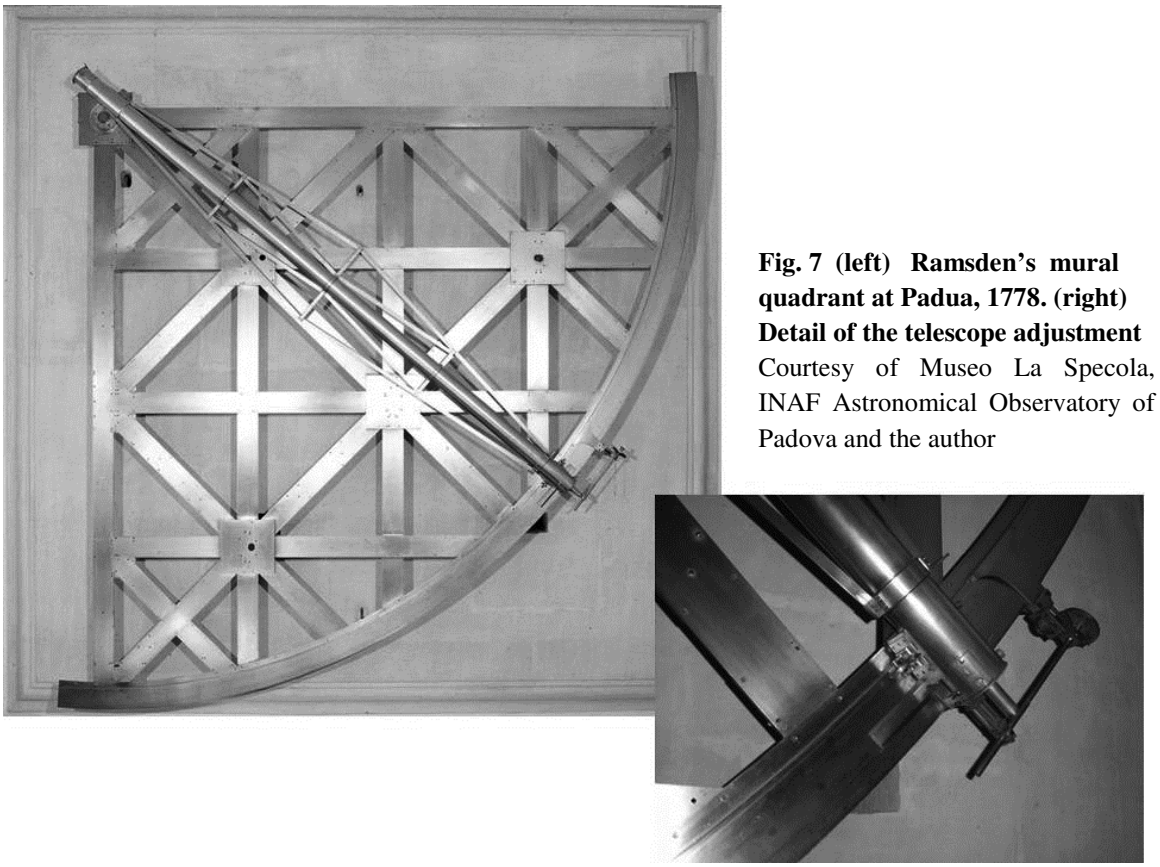


Fig. 7 (left) Ramsden's mural quadrant at Padua, 1778. (right) Detail of the telescope adjustment
Courtesy of Museo La Specola, INAF Astronomical Observatory of Padova and the author

The Duke of Marlborough's quadrant

The next quadrant was destined for the observatory of George Spencer (1739–1817), the very rich fourth Duke of Marlborough at Blenheim. Delivered in the 1780s, the quadrant was secured to pillars so that it could be rotated to face north or south.[8] Ramsden's quadrant had to be returned for adjustment and the Duke summoned him to Blenheim on several occasions, a journey which took him away from his workshop for several days at a time. During the 1790s, when the Duke's measurements were seen to vary from those on Bird's quadrants at Oxford, there were more complaints. Ramsden prepared a device to align it, comprising a plumb- line and cross-wire, supported on a wooden frame and not touching the quadrant, the results convincing Oxford's astronomer, Thomas Hornsby, and the Duke that the errors lay on the arch of Bird's quadrant.[9] We have enthusiastic praise from the many foreign visitors, though apparently none were permitted to look through the telescope. No drawing of the Duke's observatory or of this quadrant has been found.

The Brera mural quadrant

The dimensions of a mural quadrant were limited by its transport and the observatory building for which it was intended, in this case Brera Observatory, located in the old palace of Brera in Milan, then part of Austrian Lombardy. In 1786 a five (French) foot radius quadrant by Canivet had been purchased but within a few years it was found to be hopelessly inadequate. With the ejection of the Jesuits, Barnaba Oriani went to London to procure a replacement, and visited the Duke of Marlborough's Observatory. Inspired, he ordered from Ramsden a mural quadrant 8 feet in radius in 1786. Its delivery was held up for many months waiting for a ship which had hatches large enough to admit its massive packing case. The cost of shipping was increased because of the requirement that nothing should be loaded on top of the quadrant's crate. We know that a wooden device similar to that at Blenheim was included as that item appears on the invoice. It was finally shipped to Genoa in December 1790. From there its crates must have been hauled along the old Roman Via Postumia, a broad highway with easy gradients, over a summit at 772 metres, across the River Po, and eventually to Milan. The quadrant remained in use till about 1840. Sited in the centre of Milan, the building soon became unsuitable as a working observatory. The observatory now houses an astronomical museum. Sadly, Ramsden's quadrant has been stripped of its optics; only the frame remains, and is not on display.

The Palermo circle

The Jesuits were expelled from Sicily in 1767. It was left to the Bourbon government of the Kingdom of Naples to rebuild the teaching system and to create in 1779 a Royal Academy. The mathematician Giuseppe Piazzi was appointed as Professor of Astronomy, and wishing to learn how to make observations and what apparatus he should buy, spent two years in Paris and London. He arrived in London in 1787 and on a visit to Greenwich noted the limitations of Bird's quadrant. Persuaded by Ramsden, he became convinced by Ramsden that a circular instrument would give him the accuracy he was looking for. Ramsden had in fact been considering the advantage of full circles over quadrants since at least 1781.[10] He argued that a circle of three foot radius could replace a quadrant of four foot radius; the construction of the circumference would be more stable and maintain its form better than a quadrant frame; it would take a six-foot telescope, with a vernier at each end to allow the most precise subdivision, moving about its centre. The circle could be divided with greater ease and accuracy, and by being able to reverse the telescope, any errors of division would be revealed.

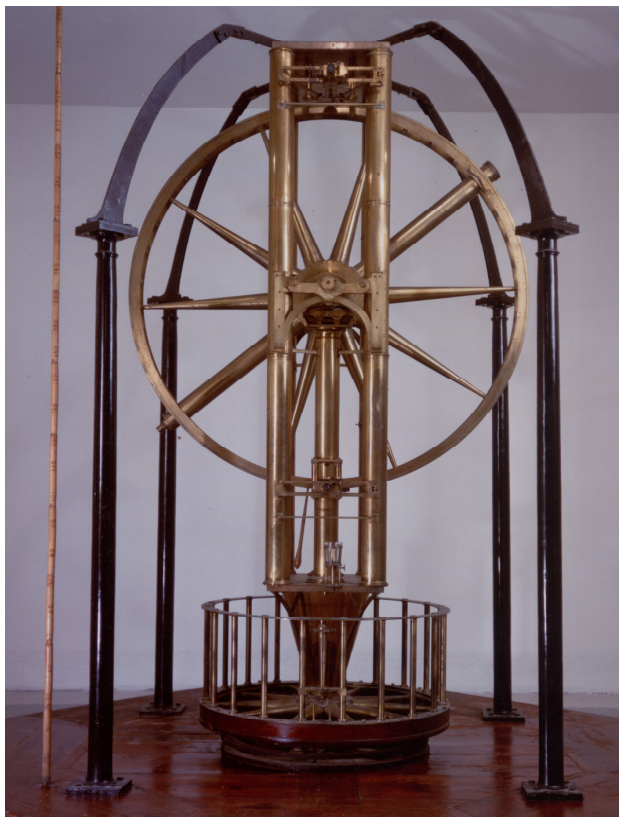


Fig. 8 Ramsden's circle at Palermo, 1789. Photograph after restoration while out of its confined space in the observatory
Courtesy of INAF-Osservatorio Astronomico di Palermo

So Piazzi was persuaded. But he had arrived at a very busy time for Ramsden: besides the Brera quadrant, Ramsden was making an eight-foot circle for Francesco Caetani, Duke of Sermoneta for the observatory established in the grounds of his palace in Rome. This is something of a mystery piece and my attempts to follow the story through have been defeated, as so many other people were, by Napoleon. The Caetani family still flourishes in Rome, but its archives are discontinuous. It seems likely that the order was cancelled and that parts of the Caetani instrument were incorporated in the Palermo circle, since with Ramsden being urged on by Piazzi, calling frequently at the workshop, it was constructed with remarkable speed, and during a time when Ramsden had several large items under construction. It was finished by August 1789, shipped to Naples, and arrived in September that year.

The Palermo circle is a visually outstanding piece of precision engineering. Over nine feet high under its revolving roof, (also designed by Ramsden) and now restored to its former brilliance, its position under the dome means that only favoured visitors can get a good look at it in situ. Although Piazzi was very proud of his new toy, the Astronomer Royal John Pond was critical of its overall design and performance and Piazzi himself suffered from some of its defects. However, its unusual shape and his observation of the first minor planet, Ceres, brought fame both to Piazzi and to Palermo Observatory.

Ramsden's circle remained in use until 1855. In 1854 the observatory acquired a meridian circle by Pistor & Martins of Berlin and in 1859 an equatorial telescope by Merz of Munich.

Other large instruments: the Shuckburgh equatorial

While a flow of lesser instruments were being produced in the workshop by Ramsden's large workforce, supervised by his able foreman Matthew Berge, other large items were taking shape. Sir George Shuckburgh FRS (1751–1804), the wealthy owner of an observatory at Shuckburgh Hall, in the Midlands, commissioned from Ramsden a giant equatorial telescope for positional astronomy which would combine the properties of a transit with a meridional quadrant. By offering 500 guineas, Shuckburgh capped the price of £500 which Greenwich had offered for an equatorial sector and for which, in 1778, Ramsden had received a £200 advance. He may have begun work on the Greenwich sector, but seems to have abandoned it and probably incorporated parts of the sector in the Shuckburgh mounting. The Greenwich Visitors summoned Ramsden to their meetings and on another occasion they themselves trooped along to Piccadilly to call on him, where they were shown what he claimed to be 'parts' of this sector. But in 1783 they eventually accepted that they were not going to receive satisfaction. He was by then engaged on constructing apparatus for William Roy's Greenwich to Paris triangulation and the Greenwich Visitors may have given way to that more important royal commission

Ordered in 1781, the equatorial was delivered ten years later. Sir George wrote a long laudatory description in *Philosophical Transactions*.[11] We also learn that this colossus had been carried by canal barge from the Thames to Lower Shuckburgh Wharf. Unusually, Sir George devoted several pages to a description of the observatory dome, designed by George Pope, another of Ramsden's foremen. Like so many oversize, dual-purpose instruments, the telescope was never entirely satisfactory. Sir George's heir offered it to the Radcliffe Observatory who declined it. He then donated it to Greenwich Observatory where it was set up and used. Berge had been commended for the fine division of its circles which was probably why with repeated cleaning they had become invisible. The circles were re-divided in 1838 and 1860. In 1929 the equatorial suffered the ultimate fate of being transferred to the Science Museum. It now languishes in store.

The circles that Ramsden never made…

The Florence circle

In 1778, after Ramsden had decided that astronomical circles were better than quadrants Felice Fontana, the energetic curator of a new museum and observatory being planned in Florence by Duke Pietro Leopoldo of Tuscany, arrived in London. He called on Ramsden, who encouraged him to provision the observatory with the finest instruments. The list Ramsden wrote for Fontana included two eight-foot quadrants, or alternatively a complete twelve-foot diameter circle.[12] The list was sent back to Italy and there, as you might expect, matters rested. It is not clear if a formal commission was prepared. In 1782 Jeremiah Sisson delivered a zenith sector and a transit, but nothing arrived from Ramsden. In 1792 it was decided to build the circle at Florence. But this shows why astronomers came to London for their purchases, for there were many practical difficulties: who could construct such a novel apparatus without models, where could such a massive piece be assembled, and how, when finished, it could be carried into the observatory. The great circle was never built.

The Gotha circle

The Seeberg Observatory at Gotha, built by 1789 in the territory of another very rich Duke, Duke Ernst II von Sachsen-Gotha-Altenburg, was to be somewhat over-equipped, with an eight-foot astronomical circle and two mural quadrants. Alas, the Duke and his Hungarian astronomer, Franz Xaver von Zach, spent the next few years waiting for their circle, their tempers heated up by a growing awareness that Piazzi's circle had been delivered during this time, and by the Duke's suspicion that another great circle was under construction. He did not know that this was Ramsden's geodetic theodolite, which we shall come to in a moment. This long story has come to light in the correspondence between the Duke and Count Hans Moritz von Brühl, Saxon minister in London, who had his own well-equipped observatory near Harefield, a village then in Middlesex.[13] The transit and other lesser instruments did arrive, but despite von Brühl's repeated visits to Ramsden's workshop, where he probably suffered the usual brush-off by being shown a piece of instrument claimed to be part of the Duke's circle, it became obvious that Ramsden was seriously ill; when he died, the Duke turned to Edward Troughton for a 3½-foot circle.

The Dunsink circle

However, fixed circles did come to replace quadrants. For in 1784 Henry Ussher came to London to purchase from Ramsden the best possible instruments for the new Dunsink Observatory, just outside Dublin. Among these was a transit instrument, delivered in 1785, for which Ramsden devised a new method of levelling, avoiding the need for a spirit level or plumb-line attached to the transit. Microscopes focussed through holes in the telescope tube, on an image of the plumb-line which hung independent of the instrument; this became known as 'Ramsden's ghost'.[14]

The circle went through many delays, trials and tribulations before being delivered in 1808, long after Ramsden's death. So what went wrong? It is suggested that Ramsden and Ussher fell out; Ussher died in 1790, at which time Ramsden dusted off the cobwebs from the ten-foot circle only to find that London's sulphurous air had corroded the thin metal at the ends of its hollow conical arms. He took six inches from each arm and waited to see if the thicker metal was stable. It was not, and he took off another six inches, reducing the diameter to eight feet. Ill health and finally death overtook him. The circle was finished by Berge and according to John Brinkley (1763–1835), then astronomer at Dunsink, proved satisfactory. It had become obsolete long before the Observatory ceased to function in 1937; the instruments were neglected until 1947 when Hermann Brück was appointed as director. He modernised the Observatory and placed the circle in the Library as a decorative feature. It remained there until the building suffered a disastrous fire in 1977, when it was put in an outside store to await restoration. Thieves stole it in 1981 for the scrap value of its brass.

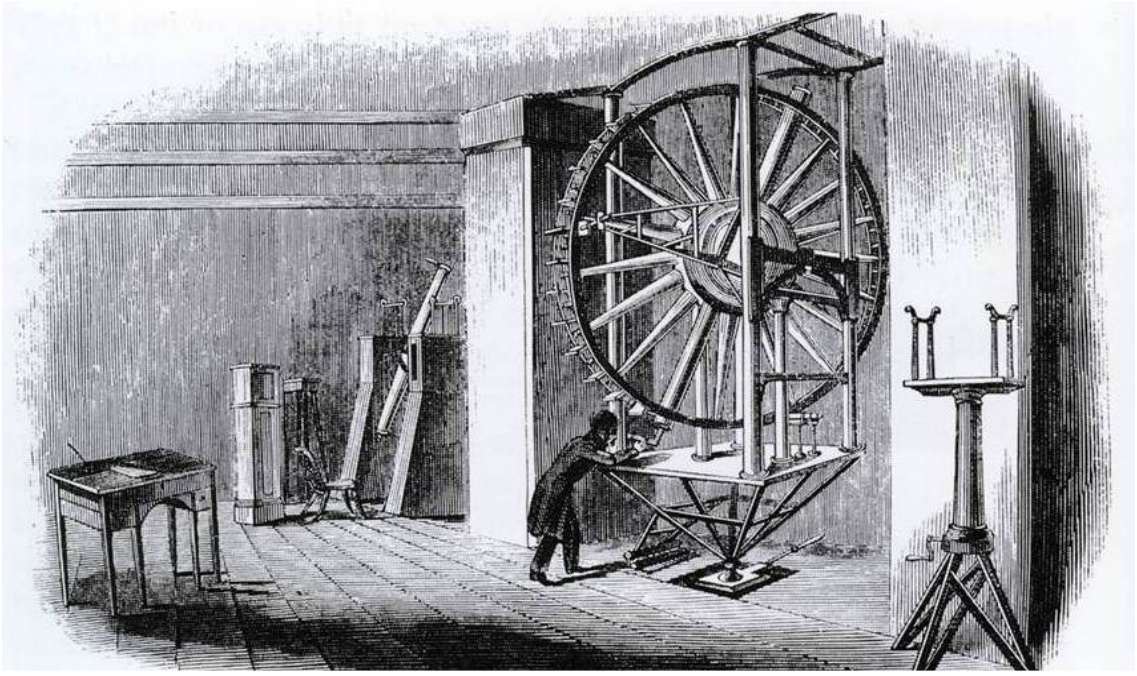


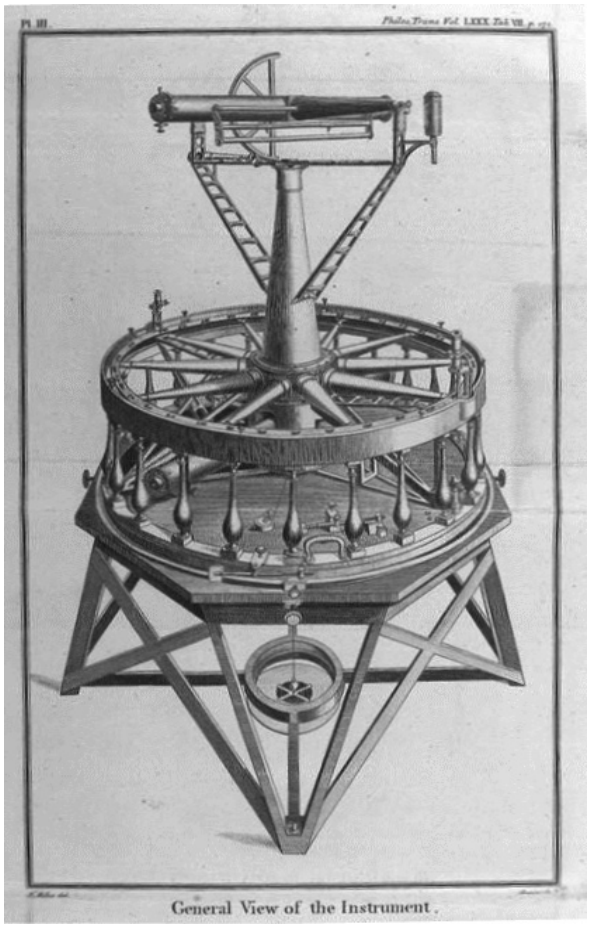
Fig. 9 Ramsden's circle for Dunsink Observatory. Ordered as a ten-foot circle in 1787; delivered by Berge as an eight-foot circle in 1808
Taylor, W.B.S., *History of the University of Dublin* (London, 1845)
Courtesy of the author

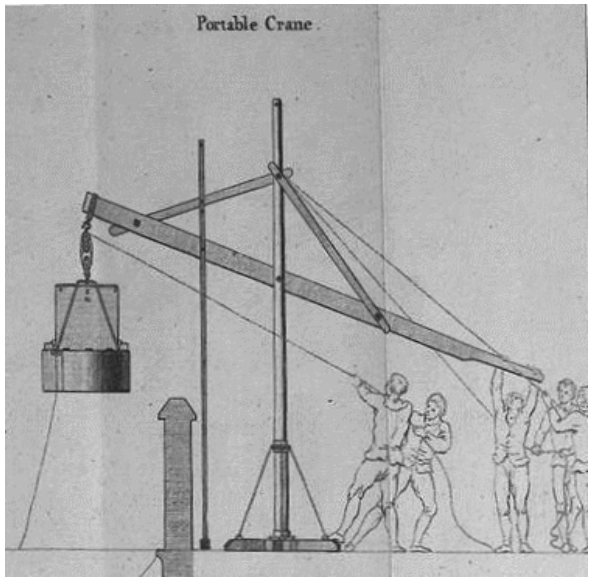
Instruments for the Paris Observatory

What would have been Ramsden's final circle was ordered in 1788 by Cassini IV for the Paris Observatory. Cassini also wanted a fancy piece of engineering and proposed a mural quadrant of 8 feet radius, mounted out from the wall so as to rotate, like that of Le Monnier. He then proposed that Ramsden should replace the counterweight with the complete circle. Ramsden objected to this arrangement as the circle would stand directly over its axis and needed no counterweight, but Cassini did not understand what was involved. These items and a transit were all to be delivered within about two years. A down payment was made in 1789, but subsequent bribery had no effect. Ramsden was rather busy on other matters, and probably had no wish to consign a valuable instrument into the turmoil of the French Revolution. Cassini retired from the Observatory in 1793 without having seen even his transit, which was constructed by Berge and reached Paris in 1803.

The Great Theodolite

The advantage of the circle was very much in Ramsden's mind in 1784 when the British and French governments agreed on a project to link the observatories of Greenwich and Paris by triangulation in order to establish their exact difference in longitude. William Roy (1726–1790) of the Royal Engineers worked out a survey plan and Ramsden was asked to construct suitable instruments and apparatus. Roy's plan envisaged a 2½-foot quadrant as the principal instrument but when he consulted with Ramsden they agreed that the angles should be taken by a circular instrument, three feet in diameter, effectively a giant theodolite. The baseline and other preliminaries were accomplished, all with apparatus specially constructed by Ramsden. The circle was eagerly awaited … and awaited. Three years passed, a workshop accident, Ramsden's illnesses, and surely the many other demands on his time, all delayed matters, but in the summer of 1787 Roy took the circle into the field. A special waggon was constructed to transport the 200-pound theodolite on its journeys, and a team of skilled men were needed to hoist it onto its specially-constructed scaffolds, including one to position the theodolite directly over the Greenwich transit, and on various church towers. During the summers and autumns of 1787 and 1788 the triangulation was successfully achieved, the results being published in 1790, after Roy's death. But while the theodolite was under construction, the French instrument maker Etienne Lenoir developed Jean-Charles de Borda's design for a geodetic repeating circle only one foot





Heave ho!

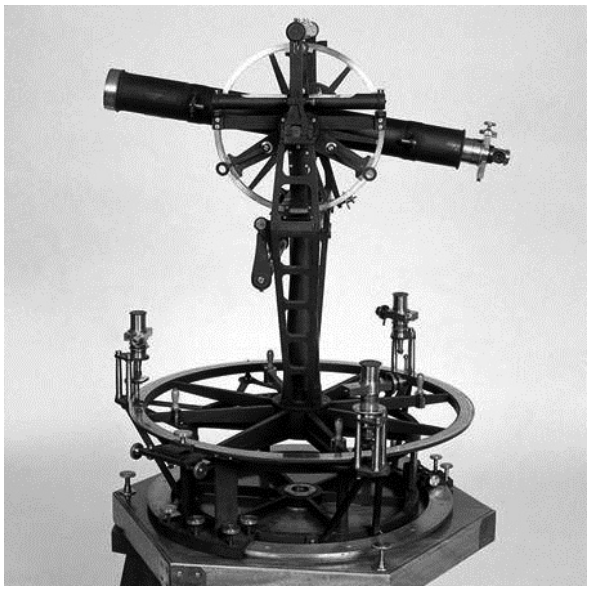
Fig.10 (left) Ramsden's geodetic theodolite, sketched by Thomas Milne. (top) Hoisting the great instrument in its case
Philosophical Transactions 75 (1785), Plates VII and XI.
Courtesy of the Royal Society of London

Fig. 11 Borda's repeating circle (20-inch Dia.), by Etienne Lenoir, Paris, 1784-88
Courtesy of INAF-Osservatorio Astronomico di Palermo

in diameter. The individual readings were less accurate than single readings on Ramsden's circle, but the repeating principal yielded the same result. The Borda circle was of course far easier to transport and raise up onto towers and scaffolds. It was immediately adopted, both in France, and soon in Britain where Edward Troughton and other instrument makers copied and improved it.

Encouraged by Roy, the East India Company ordered another great theodolite for the Trigonometrical Survey of India, then rejected it because the incorporation of Ramsden's improvements had increased the contract price. In the event, the EIC procured their large instrument from William Cary. The Ramsden theodolite was purchased for the new Ordnance Survey, which thus had two identical instruments with which to set out the primary triangulation of the British mainland, and later that of Ireland. In 1792 Ramsden was ordered to construct a smaller theodolite, 18 inches in diameter. Delivered in 1795, it was employed on the second-order triangulation. This instrument survives in the present Ordnance Survey Heritage Collection.

During the re-measurement of the distance between Paris and Greenwich, in 1821-23, William Cary was asked to fit four additional microscopes to Ramsden's instrument. This arrangement, plus one of the original microscopes, divided the circle into five parts, allowing measurements to be made on different parts of the circle without having to change zero and,



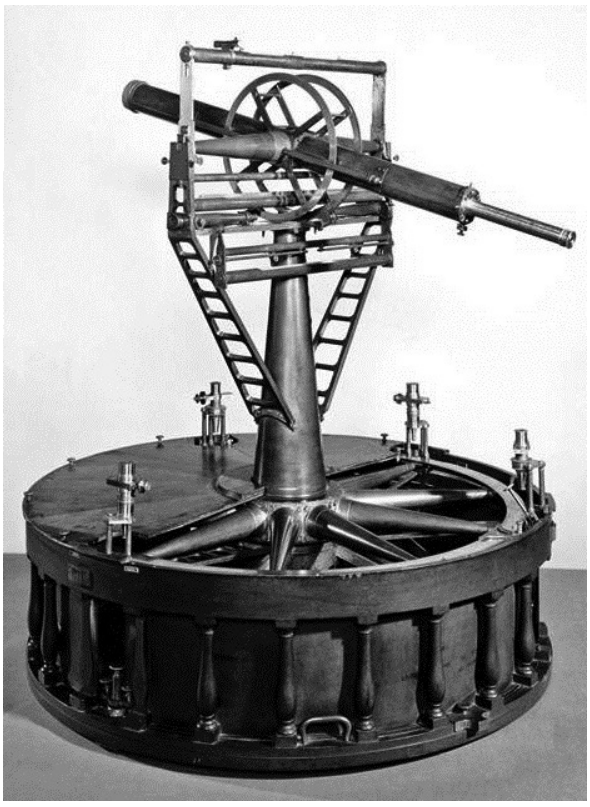


Fig. 12 (top) Ramsden's geodetic theodolite, 1791, for the Ordnance Survey, as later modified (left) Ramsden's 18-inch theodolite, 1795, for the Ordnance Survey
Courtesy of the Science Museum, London and Ordnance Survey Historical Collection

by averaging the results, brought it closer to the repeating principle

Ramsden's original theodolite was stored in the Ordnance Survey's Southampton headquarters and was destroyed by German bombing in 1940. The second (Ordnance Survey) theodolite has survived and is in the Science Museum.

Another great theodolite, plus a transit telescope were ordered from Ramsden in 1792. The theodolite was intended for a survey of the Swiss canton of Berne, presumably without anyone thinking how it could be hauled up mountains rather higher than those tackled by the Ordnance Survey. It was not delivered until 1797, when the first Napoleonic war was hampering British exports to the continent.[15]

The Long-beam Precision Balance

The last big piece to come from Ramsden's workshop was a precision hydrostatical balance, paid for in 1788 by Sir Joseph Banks. The desideratum was absolute sensitivity extending to very small mass differences, and the balance beam had to be as light as possible without flexing under high loads. Such beams were usually frames, but Ramsden adopted the internally-braced cone, his favourite device for combining lightness with rigidity. The Government, through the Royal Society, wished experiments to be made to see if Excise Office methods of rating spirits were acceptable and could be imposed on the trade without argument. These experiments were undertaken during the 1790s by the chemist Sir Charles Blagden (1748–1820). After Banks' death his widow donated the balance to the Royal Society and it was used by the President, William Hyde Wollaston, in 1824. The balance had lost its pans before being conveyed to the Science Museum in 1900.

Conclusions

Throughout his working life, from 1763 when he first established his own premises in the Strand until 1800, Ramsden's workshops delivered a variety of lesser instruments, the greater number being refracting and reflecting telescopes, sextants, portable quadrants, levels, and barometers. His instruments went on most major British and European expeditions. Some of his European journeymen returned to their homelands and advertised their years with Ramsden to attest to their competence. It is difficult to imagine what Ramsden would have been asked to manufacture had he continued in good health for another decade. For by then Georg Friedrich Reichenbach (1772–1826), who had constructed his own dividing engine in 1796, had devised the meridian circle, which combined the mural circle and transit into a free-standing apparatus. It rapidly came into use in Europe, while the mural

Fig. 13 Ramsden's long-beam precision balance, 1788
Courtesy of the Science Museum London & Royal Society of London

circle continued to be preferred in Britain. In France, Henri-Prudence Gambey (1787–1847) was able to divide by machine a 2-metre circle for Paris Observatory. But the day of Big is Beautiful was coming to an end, along with the primacy of the London workshops. In the nineteenth century astronomical observatory apparatus was diminishing in size, with no loss of accuracy. The association of Reichenbach with other instrument makers and especially with the optical glassmaker Josef von Fraunhofer (1787–1826) meant that German craft in brass and glass would rule in many of the world's observatories.

Acknowledgements

My thanks to Roger Hutchins for his advice on improving this text, and to Ileana Chinnici for permitting use of images from the Palermo Observatory.

Notes and References

1. *London Journal*, 19/1 (1994), 36-53.
2. Day, J., *Bristol Brass: The History of the Industry* (Newton Abbot: David and Charles, 1973)
3. Baiada, A., Bònoli, F. & Braccesi, A., *Museo della Specola*, (Bologna, Bologna University Press, 1995), 108-110.
4. Howse, D. *Nevil Maskelyne: The Seaman's Astronomer*. (Cambridge UK, Cambridge University Press, 1989), 105-6.
5. Lalande, J. J., 'Journal d'un voyage en Angleterre en 1763', *Studies on Voltaire and the eighteenth century*, No.184. (1980); Bernoulli, J., Lettre quatrième, 64; lettre septième, 111; lettre huitième, 115-125; lettre neuvième, 126. *Lettres Astronomiques* (Berlin, 1771)
6. TNA, MSS CRES 2/729 and 730 (un-foliated long bundles)
7. Lorenzoni, G. (Favaro, A. ed.), *I primordii dell'Osservatorio Astronomica di Padova,* (Venezia: 1922).
8. This structure was perhaps inspired by the 8-foot quadrant by Bird, delivered in 1774, for which Pierre Charles Le Monnier had constructed a rotatable section of wall.
9. Chinnici, I. and Randazzo, D., 'Tracing Ramsden's plumb-line level', *Journal of the History of Astronomy*, 42/2 (2011), 161-176.
10. Bickerton, D. and Sigrist, R., *Marc-August Pictet (1752-1825): Correspondence sci-ences et techniques: tome III: Les cor-respondants britanniques*. (Geneva: Slatkine, 2000), 204-10.
11. G. Shuckburgh, 'An account of the equatorial instrument' *Philosophical Transactions* 83 (1793), 67-128 & plate. This account was also published as a separate monograph.
12. Ramsden, J., 'The most perfect instruments for a complete astronomical observatory'. Florence: Archivio di Stato di Firenze, Ms Misc. Finanze 438, 14pp within a large unfoliated bundle. Reproduced in McConnell, A., *Jesse Ramsden (1735-1800): London's leading scientific instrument maker,* (Aldershot: Ashgate, 2007), 307-312.
13. National Archives of Scotland, GD 157, 3-33.
14. H. Ussher, 'An account of the new method of illuminating the wires, and regulating the position of the transit instrument.' *Trans. Royal Irish Academy*, 2 (1788), 13-26.
15. The later adventurous life of this theodolite is related in McConnell (2007), 216-8.

The Author

Anita McConnell was for 24 years a curator at London's Science Museum. She then worked free-lance for several years before being recruited as a Research Editor on the Oxford Dictionary of National Biography.

The 1769 Transit of Venus Observatory in Lewes, Delaware

James E. Morrison

Member – The North American Sundial Society

Geoffrey Thurston

Member – British Astronomical Association, The British Sundial Society & The North American Sundial Society

The highest priority astronomical problem of the eighteenth century was to determine the distance from the Earth to the Sun, from which the scale of the entire solar system could be calculated. The most promising method of solving this problem was based on precise measurements of the rare event of a transit of Venus across the Sun's disc.

The American Philosophical Society of Philadelphia embarked on an extensive transit observation programme for the 1769 transit with observatories at Statehouse Square – now named Independence Square – in Philadelphia, David Rittenhouse's farm in Norriton, Pennsylvania and a temporary site in Lewes, Delaware.

The Lewes team had a very short time to establish an observatory capable of observing the transit, to determine the observatory's geographic coordinates and to document their transit observation. The methods they used to determine the observatory's coordinates are examined in detail and the probable location of the observation site is deduced.

Background

The Holy Grail of astronomy in the seventeenth to nineteenth centuries was to determine the size of the solar system and grasp the scope of interstellar space. The relative sizes of the planetary orbits were well defined as ratios at that time, but not in units of distance; miles or other measurement. If the distance from the Earth to the Sun, the so-called *Astronomical Unit* (AU), were known, then the sizes of the orbits of all the planets could be calculated and the scale of the solar system defined. Actually, the distance from the Earth to the Sun does not have to be measured. Finding the distance between any two planets, or the distance of any planet from the Sun allows the distances between all to be calculated as the relative distances from the Sun for all of the planets were known.

A *transit* is when a planet, Mercury or Venus, passes in front of the Sun's disc as seen from the Earth. In 1677, a young Edmond Halley (1656-1742), who became the second Astronomer Royal and was the discoverer of the famous Halley's Comet, conceived a method of determining the distance between Venus and the Earth by measuring the

duration of a transit at locations widely separated in latitude. Knowing the distance to Venus allowed the size of the AU to be calculated. He refined the details for 40 years and finally submitted it to the Royal Society in 1716.[1] Theoretically, Halley's method can be used with either Mercury or Venus, but Venus is the only practical option due to its larger size and proximity to the Earth, which offers the largest angle to be measured.

Planet	AU
Mercury	0.39
Venus	0.72
Earth	1.00
Mars	1.52
Jupiter	5.20
Saturn	9.52

The only time to make the measurements is during a transit of Venus. This rare astronomical event occurs only every 121.5 years or 105.5 years, usually followed by a second transit eight years later. Transits of Venus were observed in 1639, 1761, 1769, 1874, 1882, 2004 and June, 2012. The next transits of Venus are not until 2117 and 2125.

The key events to be observed are the instant Venus's disc touches the Sun's disc on entry (first contact), when Venus is fully inside the Sun's disc (second contact), the instant the edge of Venus touches the Sun's disc on exit (third contact) and when Venus completely exits the Sun's disc (fourth contact) (Fig. 1). Halley's method requires timing the entire transit and relies on observations taken at sites widely separated in latitude. A second method developed by Joseph-Nicolas Delisle, requires the exact time of either ingress or egress from sites widely separated in longitude.[2] The objective of both methods is to determine the difference in the position of Venus on the solar disc as seen from geographical locations as far apart as possible. The measurements for two observation sites are combined to determine the size of the Earth as seen from the Sun; the *Solar Parallax*. Calculating the AU is very simple once the solar parallax has been determined.

Both methods work, but both have problems. The requirement to time the entire transit for Halley's method restricts the observation site to a relatively small area of the globe, but needing only the time duration of the transit frees the observers from having to coordinate their local times. Delisle's method requires the time of either ingress or egress, not the entire transit. However, the accuracy of the result depends on precise knowledge of the longitudes of the observing sites, which was very imprecise in the eighteenth century.

The apparent size of the Sun as seen from Earth is about 31arc-minutes. Venus at transit, at about 1arc-minute, is small but can actually be seen with the naked eye if a dense filter is used to block the Sun's glare. The parallax angle to be measured is very small; 8.794 arc-seconds, which is about the size of a one pence coin, viewed from half a mile away. Small errors in the parallax angle give errors of hundreds of thousands of miles in the AU. It was essential that the transit observations be as accurate as possible in both the time of the event and the location of the observations.

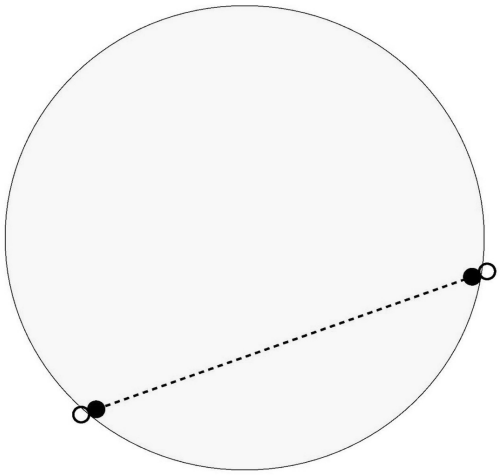


Fig. 1 Observing the Transit
By the authors

The first Venus transit observed by anyone was on November 24, 1639 (Old Style), by Jeremiah Horrocks, from Much Hoole, a village north of Liverpool, England and by William Crabtree of Lower Broughton, Salford, near Manchester observing under Horrocks's tutelage.[3] The next transit, and the first transit of Venus to be widely observed, was in 1761, and observation of the transit was a worldwide undertaking. Britain, France and other countries sent expeditions to remote locations, where some of them were quite successful but others endured terrible hardship and disappointment. The 1761 transit was barely observable from North America being visible only in Newfoundland as it ended before the sunrise further west.[4] The only reported observation from this western location was by Prof. John Winthrop (1714/15-1779) of Harvard College who journeyed to St Johns by sea.

Observing the 1769 transit became high priority, as there would not be another opportunity until 1874.

The June 3, 1769 transit was not ideal for Eastern North America as it would end after sunset, but the predicted time of its beginning, near 2 pm, local time provided the opportunity to observe most of the transit and measure the instants when Venus first touches and is totally within the Sun's disc.[5] The Astronomer Royal, Reverend Dr. Nevil Maskelyne, distributed a 50 page manual with detailed practical instructions on how to establish an observatory and use it to observe the transit.

The driving force behind the efforts to observe the transit in North America was the American Philosophical Society in Philadelphia, which was a fully-functioning organization by 1768. Within the Society, David Rittenhouse, the most accomplished American astronomer of his time, led efforts to establish observation sites in Statehouse Square in Philadelphia and at his home in Norriton, Pennsylvania (PA), about 20 miles northwest of Philadelphia. Significant effort was exerted to define the coordinates of and equip the sites, but there was one problem: If it were cloudy at one site, it would probably also be cloudy at the other. It was decided to sponsor an observing site at a more remote, but accessible, location in an effort to provide some redundancy.[6]

The reason for selecting Lewes is not recorded, but reasonable inferences can be made. Realistically, there was little development away from Philadelphia, and Lewes was one of the very few inhabited areas within a reasonable travel time. Being located on Delaware Bay made it much easier to reach as water transportation was faster and easier than attempting to negotiate the available roads. In addition, Lewes was somewhat in the public eye at that time because a lighthouse, only the sixth in North America, went into operation there in the spring of 1769. The intent was to set up the observatory at the lighthouse, which was situated near the Atlantic coast, just south of Cape Henlopen and due east of Lewes. A secondary objective was to determine the coordinates of the new lighthouse as an aid to mariners.

A brief geographic history of Delaware

Delaware is the forty-ninth largest state in the United States of America (motto: 'Small Wonder'), and yet was the first to ratify its Constitution.

Delaware's geographic history is closely tied to Pennsylvania. When William Penn was granted a large province in North America in 1681, he was concerned that it could become land-locked if a rival or enemy closed Delaware Bay to traffic from Pennsylvania. He petitioned King Charles II for an addition to his holdings along the western shore of Delaware Bay, which was granted. Three counties were already loosely defined and all he had to do was to establish a legislative foundation and exert his control. For example, before Pennsylvania was chartered, the three counties were named New Castle, St. Jones and Deal. He immediately changed St. Jones County to Kent County and Deal County to Sussex Country. He also instituted law enforcement and legislative functions. For all practical purposes, the Delaware counties are the same now as they were in 1681.

The creation of Pennsylvania resulted in a long conflict between that province and Maryland. Maryland had been chartered in 1632, but its boundaries were not precisely defined. The key points in the grant description were that the northern border of Maryland was 'beneath' 40 degrees north latitude and east to the Delaware River, but with an important proviso; Maryland's grant did not include any land that had been previously settled.

Dutch, Swedes and Finns had already established a toe-hold along Delaware Bay with the largest settlements at New Castle (New Amstel to the Dutch) and what became Lewes. Hence, this land could not be part of Maryland. In 1681, a grant for the land within a 12 mile radius of New Castle was given to Penn. The land along Delaware Bay south of the New Castle circle to Cape Henlopen was leased to Pennsylvania. This action added three counties to the three near Philadelphia defined by Penn.

A more complicated situation was created with Maryland's northern border with Pennsylvania. The 12-mile radius from New Castle formed the southern limit of Pennsylvania, which was south of the 40 degree latitude Maryland claimed. Hence, there was a meaningful strip of land claimed by both colonies.

In addition, the western border of the three lower counties was not defined, which created even more confusion. After decades of petitions and counter-petitions by the Penn and Calvert families, the case was finally taken up by the Court of Chancery for a final, binding settlement. The case went on for another 15 years until Lord Hardwicke's resolution in 1749. The terms of the final settlement were similar, and identical in the essential stipulations, to the terms they had been arguing about for 90 years:

- The southern border of Pennsylvania's three lower colonies is defined by an East/West line, called The Transpeninsular Line, beginning 139 perches east of a stone marker at Fenwick Island and proceeding west to Chesapeake Bay. The south-west corner of Sussex County is located half the

length of the line from either end; the Mid-Point. The *Transpeninsular Line* was surveyed in 1750-51 by two surveyors from Pennsylvania and two from Maryland. It was resurveyed and the marker locations confirmed and reset as necessary in 1974.

- The northern border is defined by a circle of 12 mile radius with its centre at the New Castle Courthouse.
- The western border is defined by a line from the Mid-Point to the point where the line is tangent to the circle described above; the *Tangent Line*. The Tangent line is at an angle of 3° 35.2 arc-minutes west of north and is about 82 miles long. It was surveyed by Mason and Dixon in 1763.

There is an additional detail in the northwest corner that is not relevant to this outline. What we now call the state of Delaware was the 'Lower Three Counties' of Pennsylvania in 1769. For all practical purposes, Delaware became a separate entity in 1704, but was still officially part of Pennsylvania until statehood in 1787. Delaware was represented as a separate colony in the First Continental Congress in 1774. For simplicity, we refer to this area as 'Delaware' in this discussion.

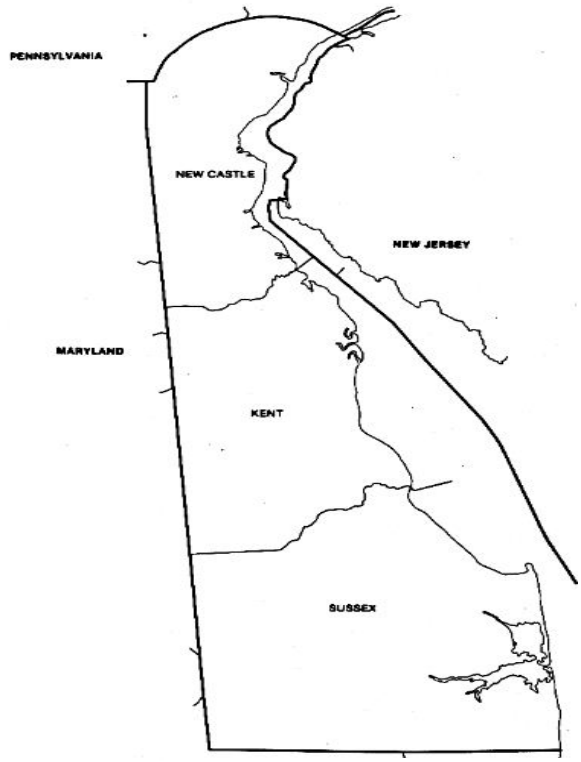


Fig. 2 The borders of the three counties of Delaware
By the authors.

The Mission

The overall mission was to establish a temporary observatory in Lewes capable of observing the transit accurately and to observe the transit and document all relevant details of the site and the observations. Knowing the exact geographical coordinates of the observation site was critical. The methods used to derive the AU depend on multiple observations of the transit elements from widely separated locations and the times are meaningful only if the coordinates of the observing sites are accurate. In particular, for the 1769 transit the observing site's longitude must be accurately known.

The Team

The men who would set up the observatory and observe the transit were chosen for their technical skills, independence, reliability and meticulous attention to detail.

Owen Biddle (1737- 10th March, 1799) was the clear leader of the expedition. He had worked as a clock and watch maker, but later became a successful import/export merchant. He was widely respected and was elected the first curator of the American Philosophical Society. He was known as a man who, if given a job to do, he did it quickly, quietly and without fanfare. Biddle was a Quaker, described by his daughter Anne as '…a man of quick feelings and nervous temperament'.[7]

Joel Bailey (1732 – 24th October 24, 1797), from Chester County, PA was, perhaps, one of the best surveyors in America. He could be counted on to make, modify, improve or repair any piece of surveying instrument and he was fully capable of taking on any surveying job, no matter the scale. He worked with Charles Mason (1728-1786) and Jeremiah Dixon (1733-1779) on the survey of the West Line defining Pennsylvania's southern border and commonly called *The Mason-Dixon Line.*[8] He also made the precision levels used to measure the length of a degree of latitude and worked personally on the measurements with Mason and Dixon. Bailey was Mason and Dixon's 'right-hand-man' and worked on every aspect of this critical survey.[9]

Little is known about Richard Thomas other than he was a competent surveyor who was engaged from time to time to do precision surveys for the Philosophical Society or the government. He was not an official team member, but paid his own way on this expedition, just to participate.

The Place

The team arrived in Lewes on Friday, 26th May, 1769. The sailing distance from Philadelphia, down the Delaware River and through Delaware Bay is a little over 100 miles, depending on the exact course taken. If they left Philadelphia at first light, around 4:30 am local time, and averaged about 8 mph, they would have arrived in the late afternoon. Sunset on 26th May was at about 7:30 pm, which left them some time to evaluate their situation. It is possible they made the trip over two days. There is no hint that any of the transit team had ever been to Lewes before, although Bailey was familiar with the area as the Mason/Dixon team had stayed in Dover and Bailey had travelled all of western Delaware.

The original intention was to assemble their observatory near the newly-activated Cape Henlopen lighthouse. The lighthouse was located on the aptly named Great Dune, which was less than ¼ mile inland from the Atlantic and somewhat elevated over the nearby terrain. Their first order of business was to inspect the site. The lighthouse was about three miles from the centre of Lewes, using the road that was cut to provide access during construction. They grasped the reality of Middle Atlantic coastal weather immediately; constant wind and blowing sand. Clearly, this was not a place to set up delicate instruments requiring a steady mount.

Later that same day, they made arrangements to rent a house about ¼ miles southwest of Lewes on South Street, now known as Savannah Road.[10] Biddle described the house as in a 'retired state', but made no comment about it otherwise except that the door faced south. We can infer that the house was unoccupied, but adequate for their needs. The property provided an unobstructed view of the sky to the south, which was the most important factor.

Fig. 3 Cape Henlopen Lighthouse
By courtesy of the Lewes Historical Society

Weather became an issue the next day, with clouds and frequent rain. Based on their descriptions over the next few days, we can infer that their weather was the result of a low pressure system which also affected the Philadelphia and Norriton sites.[11]

The Observatory

The report of the transit observations was very simple; the geographic coordinates of the observing site and the times of first and second contact. The temporary observatory had to be capable of allowing precise measurements of the beginning of the transit and recording the times to the second.

Times were to be reported as *apparent time.*[12] That is, the time defined by the hour angle of the true sun. Setting a clock to show apparent (local) time requires the clock to be set exactly to noon when the Sun crosses the local meridian, or is due south. This, in turn, requires a lengthy process of precise observations of the Sun and selected stars to establish the rate of the clock. The method advocated by the Astronomer Royal for this purpose involves timing when the Sun or star passes through a specific but arbitrary altitude above the horizon both before and after crossing the meridian using an equal altitude instrument with two horizontal crosshairs and a means to lock the telescope in place. The meridian is midway between the two equal altitude crossings and thus, the mid-time of the observations defines the time of meridian transit of the celestial body.

They set up their instruments the next day, 27th May, and began the process of setting their clock to the exact local time by observing the Sun during the day and bright stars at night with their equal altitude instrument. The other critical element was the exact geographic coordinates of the observing site, which required performing a demanding survey. This topic is treated in detail below.

Their Equipment

They did not list all of the equipment they brought with them to Lewes, but we know it included three telescopes and mounts, a telescopic theodolite and an equal-altitude instrument. The telescope used by Biddle was a 3-inch Gregorian reflector made in London, possibly by James Short and purchased by Thomas Penn as a gift to the Philadelphia Library Company. The telescope's maker is not documented, but the instrument was sent to Short in London for repair, indicating that he probably made it.[13] Biddle made an equatorial mount for it and modified the rack work which enabled him to track the Sun easily. Bailey used

an achromatic refracting telescope of longer focal length, made by the Dollonds. This instrument did not have a mount and they improvised a ball-and-socket attached to a post as recommended by the Astronomer Royal. A clock to time the transit was required and theirs was very probably a full-size clock with a metre long pendulum beating seconds. The clock was attached to a sturdy post just outside the house. They made or brought smoked glass solar filters.

Fig. 4 Surveying theodolite by Benjamin Cole and chain with a set of drawing instruments
By courtesy Jeffrey Lock, Colonial Instruments

They had basic surveying gear, including the theodolite mentioned above, at least one 66-foot iron surveying chain and necessary posts, hammers, axes and other items that constituted a surveyor's kit in those days, plus their personal effects.

The Survey

One of the crucial elements of the transit measurements was exact knowledge of the latitude and longitude of the place where the observations were made. There was not enough time for them to determine their location astronomically, so they had to measure the site's geographical coordinates relative to an existing point of known latitude and longitude, which could be supplied by the Transpeninsular Line.

The Transpeninsular Line was defined by stone markers and mileposts and was intended to follow the parallel of latitude west from the easternmost marker at Fenwick Island, across the peninsula to Chesapeake Bay. The legal start of the line is not marked as it is off shore, 139 perches east of the Fenwick Island marker. A perch is a distance measure of 16.5 feet, one-quarter chain, also called a rod. The line was marked by stone markers at the 5, 10, 20 and 25 mile points and also at the Mid- Point, 34 miles and 309 perches from the start of the line. The original

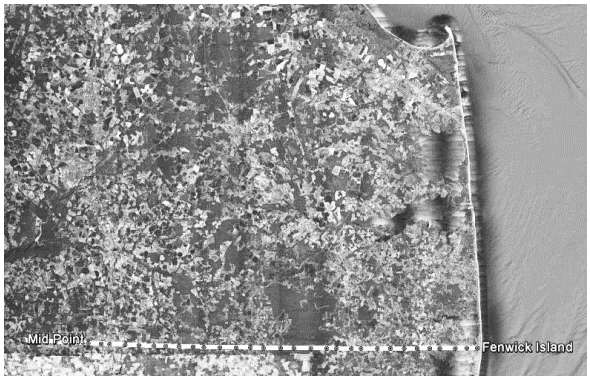


Fig. 5 The Transpeninsular Line
By the authors generated using Google Earth.

surveyors were instructed to set posts each mile, but there is no evidence this was actually done. The markers are cut from native stone with the Calvert family arms carved on the south side and the Penn arms on the north side. The dots on the line in Fig. 5 accurately represent the current markers. The boundary was resurveyed by the National Geodetic Survey in 1974, and all monuments that were lost or had been moved were replaced and mileposts were installed about each mile.[14]

The most important point on the Transpeninsular Line is the Mid-Point Marker, defining the centre of the Delmarva Peninsula and the southwest corner of Delaware. The latitude of this marker was painstakingly measured by Mason and Dixon in 1767 as 38° 27′ 34″ N using astronomical observations.

Fig. 6 Fenwick Island Marker
Photograph taken by the author J E Morrison.

Bailey and Biddle assumed all of the markers on the line were on this precise latitude.[15] Their intent was to measure the distance from the observatory to a point on the Transpeninsular Line to determine the observatory's geographic coordinates. The modern latitude of the Mid-Point marker using the NAD83 (91) model for the shape of the Earth is 38° 27′ 36″.29213.

Owen Biddle wrote,

> The four following days continued cloudy, with frequent rains. But that we might not be idle in the meantime, and have it in our power to ascertain our latitude and longitude, in case we should be disappointed of celestial observations for that purpose; Joel Bailey and Richard Thomas, went to take the courses and distances from our observatory, to the provincial west line, which was run from Fenwick's Island to the *middle point* of the peninsula; so that our observatory might thereby be connected to Messrs. Mason and Dixon's meridian line.[16]

This statement seems a bit disingenuous. They had brought all of the equipment needed to perform the survey and clearly intended to use it. David Rittenhouse strongly implies they planned the survey from the beginning.[17] On the other hand, the surveying equipment may have been brought as a precaution against bad weather (which happened), with the intention of using it only as a backup. However, they could have just as easily done nothing and waited for good weather to make the necessary astronomical observations to pinpoint their location. Even then, it would have taken weeks and required sophisticated instruments to perform all of the astronomical observations required.

Biddle's statement that Bailey and Thomas did the survey very likely understates the magnitude of the operation. Their mission was to determine the distance of the observatory north and east of a point on the Transpeninsular Line, which required an open traverse of over 20 miles, much of it through undeveloped land, and they had less than four days to complete it and get back to Lewes.

An open traverse is a line-of-sight surveying technique using a series of connected line segments to measure the distance between two points. The distance between the start and end points is calculated from the field data using simple trigonometry. The sequence of steps is outlined as follows:

1. The starting point for each line segment is marked by a stake. The measuring instrument, a telescopic theodolite in this case, is mounted on a tripod and placed exactly over the stake using a plumb-bob for precise positioning. The instrument is levelled and usually pointed directly north or south using a compass built into the instrument.
2. A direction is chosen and a man is sent in that direction with a rod. He takes the rod to a point that is in the approximate direction desired and the man at the instrument and the man with the rod communicate with hand signals until a good place is found. The angle is recorded. The 66-foot long chain is dragged in the required direction taking care that the chain is flat over its entire length. The instrument man directs his chain men to the exact line and a stake is driven to mark the end of the chain and the number of chains is recorded.
3. This is repeated until the chain reaches the rod and any partial chains are recorded or the end point of the segment is moved until it is an even number of chains.
4. The instrument is packed and taken to the rod position and the process repeated.

This was done 120 times for a total of 2148 chains before the traverse was complete.

Clearly, two men could not do this alone. Biddle had been advanced £20 for expenses, which was a considerable amount of money for the time. They probably hired a wagon and driver to carry the equipment and extra gear needed for camping out on the way. They would also have hired two or three burley young men to drag the chain, drive stakes and cut limbs and trees that were in the way. There were surely some hangers-on attracted by the novelty of the undertaking who probably helped when needed. Experienced chain-men were available in Delaware from the Mason and Dixon survey, but there is no mention they were used. The crew was at least eight or nine men for the full traverse, with others involved to help cross creeks and the Indian River. There were probably other men on horseback who could scout the best route. Mason and Dixon's crew was generally 35-40 men and included two wagons, eight horses, cooks, stewards, tent keepers, chain men and labour-ers. Their main instrument was transported in a wagon, on a featherbed.[18]

Biddle did note that they stuck to established roads as much as possible, as it would have taken too long and been too expensive to try to clear a direct route through the woods. Colonial roads were quite different from modern roads. They were generally quite wide, up to 200 feet, as a safety measure and to accommodate the driving of livestock. Unlike modern roads, there was often no defined roadbed.

It is clear that Bailey was aware of the location of the marker stones on the Transpeninsular Line and that he headed for the settlement now known as Selbyville, near the 10 mile marker stone. His traverse terminates at a point which he describes as being on the Transpeninsular Line at a distance of 9 miles 86 perches from the stone in Fenwick Island. We can infer he determined this by measuring 234 perches east from the 10 mile marker to his intersection point near the current milepost 9.

Fig. 7 Mason and Dixon setting out their line
By courtesy of the Mason and Dixon Line Preservation Partnership.

By calculating the accumulated distances travelled in southerly and westerly directions and applying them to his termination point, Bailey was able to establish how far the observatory was located east and north of the Mid-Point.

Fig. 8 shows Bailey's route derived from the raw traverse data. It is not perfectly valid to plot Bailey's route on Google Earth as published because there are differences in the mapped coordinates of the route points between the spherical model used by Bailey and the ellipsoidal model used by Google Earth. That said, there is still value in seeing the shape of the route and deductions can be made that lead to better understanding of the actual route taken.

Mason and Dixon did not need the longitude of the Mid-Point to complete their work and this critical element was unknown. In May, 1770, nearly a year after the transit, The American Philosophical Society commissioned Biddle and Bailey to conduct a further survey to establish the Mid-Point's longitude. The added survey was from the New Castle Court House to the observatory in State House Square, Philadelphia, to determine the longitude of the courthouse. The New Castle Court House was already connected to the Mid-Point through the Tangent Line, and the latitude and longitude of the State House

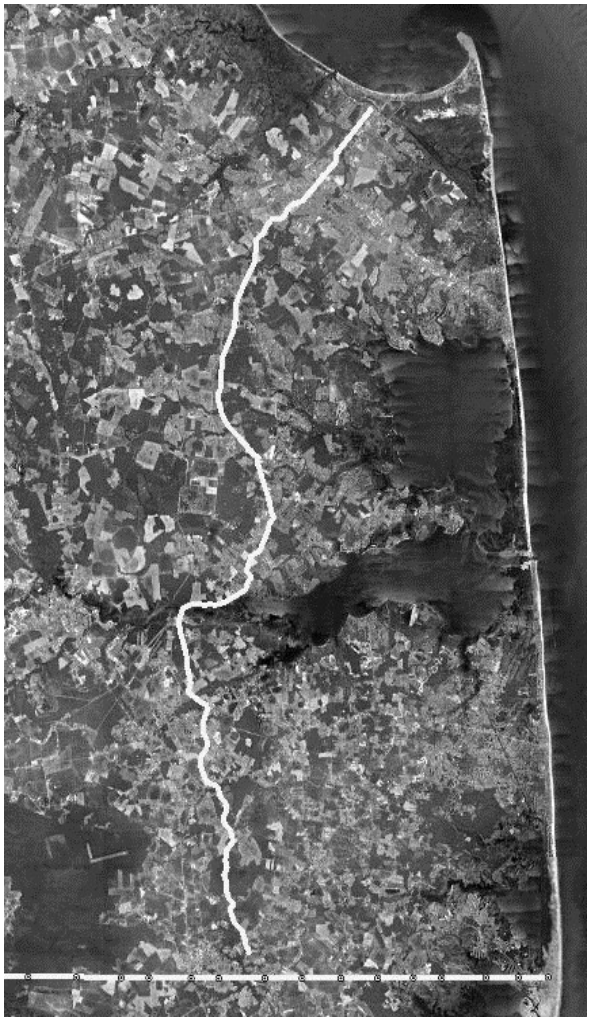


Fig. 8 Bailey's Route
By the authors generated using Google Earth.

Observatory had been determined with a survey from Rittenhouse's observatory conducted shortly after the transit. Thus, the final piece of the puzzle, the longitude of the Mid-Point, was supplied by this additional traverse.

Once this traverse was completed, Biddle and Bailey were able to declare that the Lewes observatory was located at 38° 46′ 38″.3 North and 75° 8′ 30″ West.[19]

These values would place the observatory near the intersection of Pilottown Road and Shipcarpenter's Street in current day Lewes, using modern mapping methods. Although this position was adequate for measurements of the transit of Venus, it is unlikely, for a number of reasons, that this is the precise location of the observatory. For example, Biddle mentioned that the observatory was on South Street (now Savannah Road) and about ¼ mile from the town. Their derived coordinates do not meet either of these criteria. So where was the Lewes observatory?

Site Latitude

When Bailey's traverse ended he was not at the latitude he assumed. Mason and Dixon's astronomical latitude of the Mid-Point was 38° 27′ 34″ N, and Bailey's assumed latitude for the entire line. Note the route shown in Fig. 8 ends at this latitude, short of the Transpeninsular Line. However, the Transpeninsular Line is not a true parallel of latitude and the latitude of both milepost 9 and marker 10 is actually 38° 27′ 04″.4 N which is 29″.6 (2995 feet.) less than the latitude assumed for the Mid-Point and the entire line. The difference in the reference latitude changes the site latitude to 38° 46′ 8″.3 N. This adjustment places the observatory position much closer to South St., as described by Biddle.

Site Longitude

The derived longitude was based on the results of four separate surveys (Fig. 9):

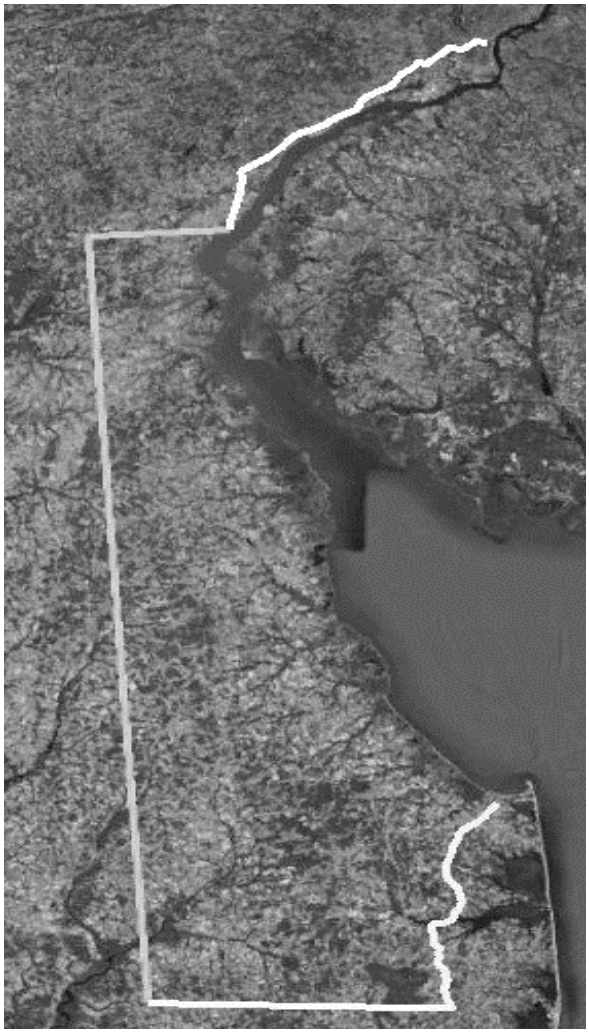


Fig. 9 Connected Traverses

By the authors generated using Google Earth.

1. The Mason and Dixon survey of Delaware's western border is a line, called the Tangent Line, from the mid-point of the Transpeninsular Line to the point where the line is tangent to a circle of 12 mile radius centred at the New Castle Courthouse. This survey establishes the difference in longitude of the Mid-Point to the New Castle Courthouse.[20]
2. The coordinates of the observatory in Philadelphia were determined by a carefully conducted traverse from David Rittenhouse's farm in Norriton to the Statehouse in July, 1769.[21] Rittenhouse had made observations over several months to measure his exact location and his results were trusted. Thus, the Statehouse observatory coordinates would include any error in Rittenhouse's measurements.
3. The survey from the New Castle Courthouse to Philadelphia was used to determine the court-house's longitude, which was then used to derive the longitude of the mid-point.

Joel Bailey's traverse measured the distance of the Lewes observatory meridian east of the mid-point.

Any errors in any of these surveys will be reflected in the final value of the longitude of the Lewes observatory.

The assumed position for the State House observatory in Philadelphia was 75° 8′ 45″ W, from the Rittenhouse survey. There are no extant remains of the State House observatory and its exact location is still not precisely known. We do know the longitude of the Philadelphia observatory was within a second or two of 75° 9′ 0″ W in modern coordinates. An analysis of the published field data using modern coordinates for the key points places the Lewes observatory at 75° 8′ 42″.7 W, which is quite close to Savannah Road.

Potential Errors

The best observatory coordinates that can be derived from the source data are: 38° 46′ 8″.3 N, 75° 8′ 42″.7 W. There are a number of factors that could have influenced the accuracy of the recorded traverse sets leading to placing the observatory incorrectly.

Bailey was a skilled surveyor who was well practiced in the painstaking methods employed by Mason and Dixon, and he could be relied upon to work to the highest accuracy within the time, weather and instrument constraints to which he was subject. However, even he would not have claimed that his results were free of all errors and it is worth considering the origin of the most likely sources of such errors:

- The magnetic declination used by Bailey might not be accurate. It is very hard to read a small compass to the accuracy needed. The variation measured by

Bailey in Lewes was 3° 55′.[22] Bailey also did the survey from the New Castle Court-house in Delaware to Independence Hall in Philadelphia, presumably with the same theodolite, and reports the magnetic declination as 3° 15′ W.[23] This value actually fits the data better. Changing compass needles also affects accuracy.

- All bearings are reported to 5 minutes of arc, indicating his theodolite had a vernier scale with 5 arc-min. resolution. It is unlikely reliable readings were possible to this level of precision with his equipment and differences would accumulate over the entire survey.
- Almost all distances are recorded in full perches. It is, of course, possible that the surveyors tried to execute their instrument sets in full perches, but this would be very hard to do accurately without changing the observed bearings. The skill and experience of the chain men would have been a factor in this regard.
- Bailey's model of the earth was a spherical one in which the degree of latitude was 68.896 miles long rather than the more accurate ellipsoid in current use in which a degree of latitude in Delaware is 68.977 miles. The differences are not great, but they do affect the accuracy of the overall results.
- It is also possible, even likely, that some of the published field data has typographical errors or incorrect values were printed due to setting type from handwritten source material. Several lines in the data are obviously incorrect, such as transposing digits (45 instead of 54, for example), or incorrectly declaring a direction (W instead of E).
- We cannot rule out computational errors. Bailey probably reduced his data using tables of logarithms, probably to seven places. It is very easy to make mistakes when performing such tedious calculations and the table may have had slight errors.
- It must be noted that it was raining for most of the time during the survey. It is hard to keep an accurate field journal in good weather and it is plausible that some of the recorded values were smudged and rendered difficult to read. The poor weather could have been a factor in many aspects of performing the traverse.

Route Analysis

The coordinates derived above would appear to support a likely location for the Lewes observatory. However, it is prudent to validate the result as there are so many possible errors in the raw field data.

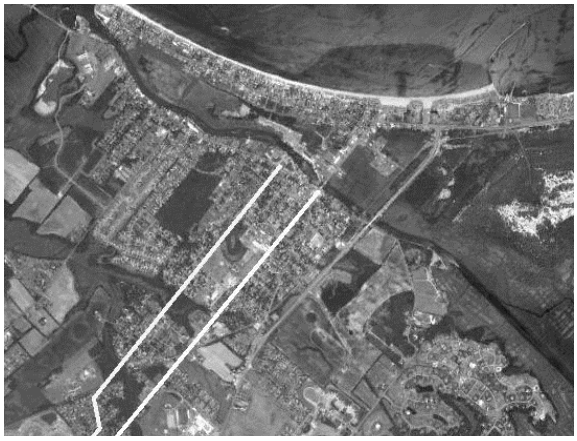


Fig. 10 Start of Traverse from Bailey's Data
By the authors generated using Google Earth.

There is a striking visual clue when the route defined from the raw data is plotted on a Google Earth map (Fig. 10). The first leg of the route is exactly parallel to Savannah Road (South Street), but displaced to the north and west, indicating the starting point of the displayed route should be shifted to match the roads. We are able to identify and adjust for some of the errors by comparing the shape of the traverse with the clearly corresponding shape of roads and traces of former roads.

Fig. 11 Route Bias Adjustments
By the authors generated using Google Earth.

For example, the labelled section of the route shown in Fig. 11 is drawn from Bailey's data. The solid route follows the roads in this area. The two segments can be made to overlap nearly perfectly without changing Bailey's data by applying bias adjustments that apply to the entire traverse. We found through trial-and-error that, if all of Bailey's distance measurements are

increased by 1.5% and each course were increased by 1° 18′, the resulting route matches the roads in this area very closely. These adjustments are justified by the inherent difficulty of making precise measurements with their instruments and considering the weather.

We do not need to match the whole traverse to locate the observatory. We need only establish the position of the first leg to identify the starting point, and this is made easier because we know that the first course was straight down Savannah Road. The adjusted traverse provides an excellent match to the first nine miles and, thereby, allows us to identify Bailey's starting point with confidence

No detailed maps of the 1769 road system in Sussex County exist, but it was found that maps from D. G. Beer's Atlas of 1868 match the modern roads very closely. Fig. 12 shows how closely the adjusted route follows the roads at the start of the traverse. Figs. 13 and 14 show the route taken in southern Sussex County.

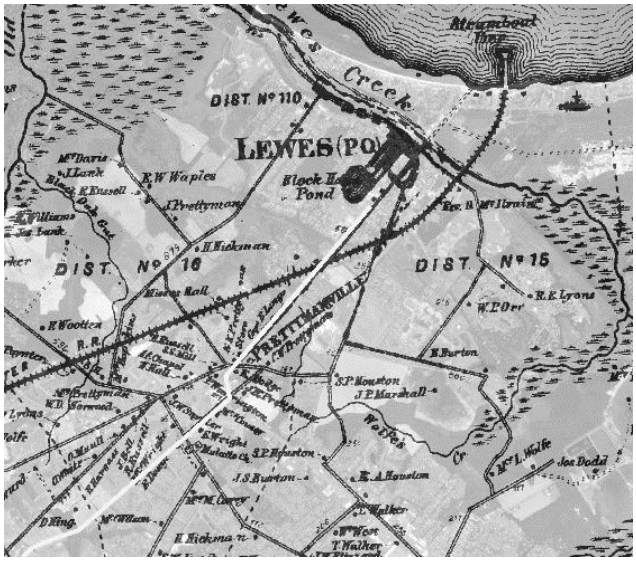
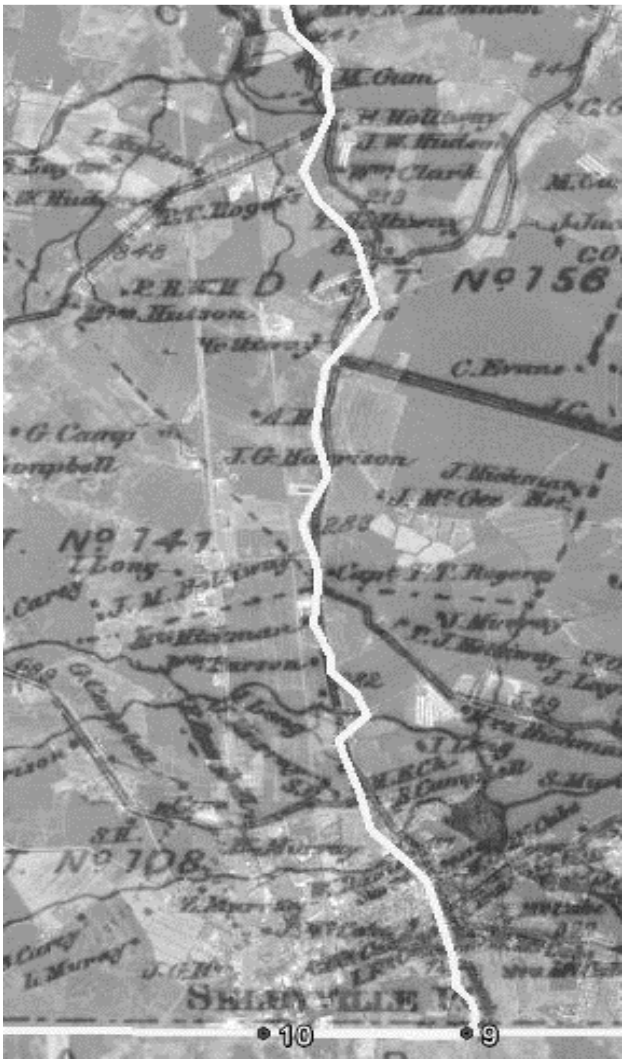


Fig. 12 Beginning of Route
By the authors generated using Google Earth and *D.G. Beers Atlas* of 1868 supplied by the Delaware Department of Transportation, Mapping Division.



Figs. 13 & 14 Route near Dagsboro and ending in Selbyville
By the authors generated using Google Earth and *Beers Atlas of 1868* supplied by the Delaware Department of Transportation, Mapping Division.

The Location of the Temporary Observatory

The conclusion on the most likely location of the temporary observatory is based on Bailey's traverse data recreated in WGS84 coordinates and corrected by comparison with the road patterns visible on Google Earth. These corrections comprise small adjustments to the whole traverse to eliminate apparent biases in course and distance and one adjustment of 6° to one leg to match an obvious line feature. The adjusted route provides a significantly better match to the road patterns and suggests a very credible route for the traverse.

Fig. 15 Observatory Site
By the authors generated using Google Earth.

Fig. 16 Complete Traverse
By the authors generated using Google Earth.

We conclude the most probable location for the Lewes Transit Observatory of 1769, is near **38° 46′ 12″.3 North** and **75° 8′ 38″.1 West**. The site was within the boundaries of what is now Bethel Methodist Cemetery, which is on land originally intended for use as a Quaker cemetery, but was apparently never used for that purpose. It is about 0.2 miles southwest of 4th Street and is on South Street (Savannah Road), thus meeting all of the qualitative criteria mentioned by Biddle. Coincidently, this site is the highest point in Lewes.

The most probable site location is shown in Fig.15. The circle is about 1 arc-second in radius (≅ 100 feet), for scale. We are confident the Lewes Venus Transit Expedition observatory was within the circle. The complete traverse as reconstructed is shown in Fig. 16.

Astronomical observations at Lewes Observatory

The requirements of the astronomical activity at Lewes were threefold. Firstly, optical instruments were required which made the precise timing of the contacts discernible to the observers. Secondly, timepieces set to apparent (local) time were needed to record the timing of the contacts. Finally, instruments capable of determining latitude and longitude were desirable to validate any ground surveys used to locate the observatory.

The transit of Venus across the sun is visible to the human eye provided a filter is used to reduce the light intensity from the sun's disc. However, the planetary disc has an apparent size of less than one arc-minute at inferior conjunction and thus the timing of exterior and interior contacts is difficult to achieve with precision. The task becomes more practicable if a telescope is used to provide an enlarged image of the planet and that part of the sun's limb around the point of contact. A filter was still required and was generally created by smoking clear glass over a candle flame. The filter was then interposed between the eyepiece and the observer.[24]

Biddle made his observation of the transit using a reflecting telescope with a magnification of 150 times, which was of Gregorian type with a focal length of two feet.[25] He claimed that it was in 'exceeding good order at the time and defined the limb of the Sun, and spots on its disc, very nicely'. He had mounted it on a

Fig. 17 Gregorian Reflector made by James Short of London, 1755
SSPL Image No. 10324543
By courtesy of the Science Museum, London.

polar axis and had contrived a fine adjustment in right ascension to keep the planet within the field of view.

Bailey used a refracting telescope of about four and a half feet length which had been manufactured in London by the Dollonds using their recently patented achromatic doublet as the objective. This doublet lens used elements made from crown and flint glass and

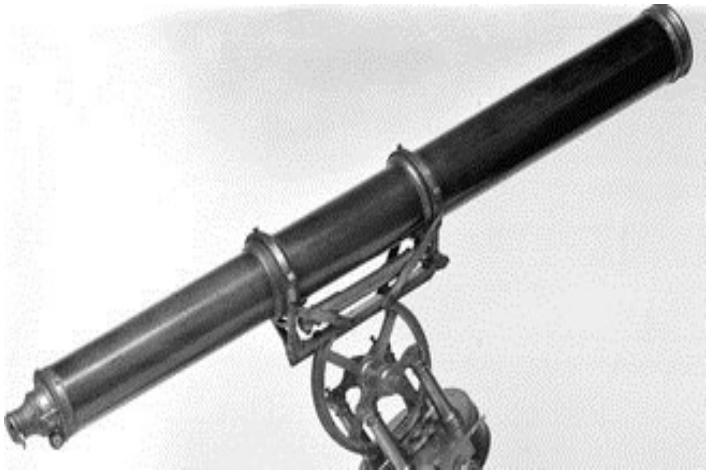


Fig. 18 Dollond achromatic telescope fitted on an equatorial mounting and used by Dr Lind to observe the 1769 transit of Venus in Scotland
SSPL Image No. 10196616
By courtesy of the Science Museum, London

was designed to minimise the chromatic aberration inherent in a refracting telescope. Chromatic aberration results in each colour being brought to focus at a slightly different distance from the objective lens and in particular generates a coloured fringe around the limbs of sun and planets. Such a fringe would obviously impede the determination of the moment of contact and would be clearly undesirable in transit observations. It is clear that Biddle regarded this instrument as inferior to his reflecting telescope and so we might infer that the chromatic aberration was still troublesome despite Dollond's innovative objective lens. Bailey was also disadvantaged because this telescope was mounted using a ball and socket joint with no recorded means of compensating smoothly for the rotation of the earth.[26] Biddle recorded that he set

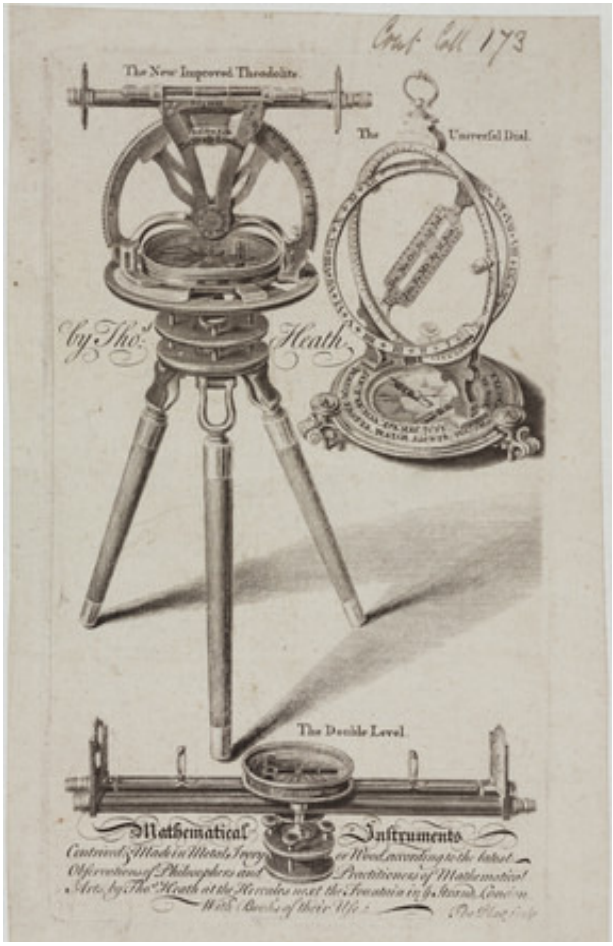


Fig. 19 Theodolite and Surveying Level by Thomas Heath, London, eighteenth century
SSPL Image No. 10422653
By courtesy of the Science Museum, London

the clock using a theodolite to record equal altitudes of the Sun and stars. He described this theodolite as follows;

> It was a theodolite, with telescopic sights, in which there were cross hairs; it had a spirit level to adjust the plane of the instrument horizontally; and also one applied to the telescope parallel with its axis, and at right angles to the other spirit level. By means of these two levels and adjusting screws, we found we could adjust it very nearly, the instrument being a very good one of its kind.[27]

The basic requirements for an equal-altitude instrument are to have a telescope which can be adjusted and then fixed in altitude and which can then be rotated about a vertical axis to observe a body as it passes through that fixed altitude on each side of the meridian.

The Astronomer Royal published instructions and advice to those observing the transit in The Nautical Almanac and Astronomical Ephemeris for the Year 1769 and he gave particularly detailed instructions therein for the equal altitude method.[28] The Nautical Almanac was first published by Nevil Maskelyne for the year 1767 and contained daily data on solar and lunar positions. It can be assumed from the regular flow of correspondence between the Astronomer Royal and the American Philosophical Society that Biddle would have had access to the 1769 edition of the almanac and the relevant ephemeris data before embarking for Lewes, even if he were not carrying a copy with him.

The method of use for obtaining equal altitudes may be summarised as follows:

1. Mount the instrument on a substantial wooden pier firmly fixed in the ground.
2. Level the instrument by means of the spirit levels and adjusting screws.
3. Select a suitable body for observation to the east of the meridian and note the altitude and the time by clock when the body crosses each horizontal wire in the telescope eyepiece.
4. Repeat the observation with the telescope set to the same altitude when the body crosses the corresponding wire in the opposite direction to the west of the meridian and note the time by the clock.
5. The mean of these times for a star gives the time by the clock when the star transits the meridian and, provided that the right ascension of the star is known, the apparent sidereal time can be determined.
6. The same procedure also works for the sun but in this case a correction has to be applied to account for the changing declination of the sun between observations. The correction can be calculated by means of a table appended to the Nautical Almanac so that the apparent solar time can be determined.

A theodolite is also equipped with a graduated, horizontal azimuth circle which can be used to determine the instrumental azimuth of the body at the fixed altitude east and west of the meridian. The true meridian then lies midway between these azimuths. The meridian may be more accurately determined by calculating the local time of transit for a given body and then clamping the azimuth circle at the time of transit with the vertical wire of the telescope bisecting the body. A meridian mark may then be made on the ground by swinging the telescope down to the horizon and marking a distant point which falls beneath the vertical wire.

Biddle's observations were hampered by prolonged bad weather but he was able to make sufficient observations to enable him to rate his timepiece and set it to local apparent time. He recorded that he set up his observatory on 1769 May 27 and set his clock by taking equal altitudes of the sun and then of some fixed stars in the evening. Unfortunately, the next four days were cloudy so observations were not possible. On June 02 the weather cleared and more equal altitudes of the sun were taken. On June 03, the day of the transit, the weather was fine with calm air and not a cloud in view, so further equal altitudes of the sun were taken before and after the time of the transit. It appears that Biddle had ample observational data to enable him to determine accurate apparent times for the external and internal contacts from his timepiece.[29]

According to Bailey, his survey compass was calibrated with reference to their meridian line which indicates that Biddle had also made observations as described above to establish a meridian mark on the ground.[30]

We do not know the exact nature of Biddle's astronomical instruments but his own account indicated that he was prepared to determine both latitude and longitude by celestial observation. The zenith distance of the sun or a star of known declination in transit would have provided a measure of the latitude of his observatory but it is unlikely that his theodolite would have been able to measure zenith distance with better than one arc-minute accuracy and the derived latitude would therefore have been defined only to within one nautical mile.

The Nautical Almanac for 1769 included predictions for the eclipses of Jupiter's innermost moon, Io so that the local timings of these events could be compared to observations made at Greenwich. The difference in local time of the observations would then correspond to the observatory's difference in longitude from Greenwich. However, the table seems to indicate that during Biddle's time in Lewes there were no eclipse events simultaneously visible from Lewes and Greenwich. Thus, it is not surprising that he was unable to establish his longitude by astronomical observation.

Results from the observations

The transit observation itself, on June 3, went perfectly. The weather was crystal clear, without a cloud in the sky, and the transit team documented the required times.

The results of the observation reported by Biddle in apparent time were:

Owen Biddle's external contact:	2 hr.11 min.53 sec.
Owen Biddle's internal contact:	2 hr.29 min.53 sec.
Joel Bailey's external contact:	Lost by accident
Joel Bailey's internal contact:	2 hr.29 min.53 sec.[31]

This information, together with the precise location of the observatory, would contribute to a determination of the size of the solar system and provided the justification for the expedition.

Simon Newcomb was rather complimentary about the Lewes observations. Biddle had taught two boys to chant the seconds so the person logging the events would hear the notice of the event and the spoken second at the same time.[32] By contrast, Rittenhouse had not made adequate provisions for exact time recording for all three observers and Newcomb did not use Rittenhouse's observations as the times were suspect, although he did use the other two. Newcomb's decision is understandable as Rittenhouse fainted at the instant the transit started, probably due to being over-excited about the event to which he had devoted so much.

The solar parallax derived by Dr William Smith using Biddle's external contact and those recorded at several European observatories was 8″.862.[33]

Observational times were submitted by 171 professional and amateur astronomers. The published values of the solar parallax were derived from combining many reports and no single site dominated the analysis. Later astronomers considered only observations that met some technical criteria relating to how the observations defined the instant of ingress and egress, and the specific observations were not always listed. Encke combined many observations in 1824, probably including the Lewes results, to arrive at a value of 8″.571 ± 0.037″ for the solar parallax, which resulted in a value of 95,370,000 miles for the AU, a value that was used for many years. The uncertainty in this parallax value amounted to about half a million miles in the AU.

Great effort to refine the values was mounted for the 1874 and 1882 transits, including the use of photography, but the results were still not satisfactory and measuring the solar parallax in this way was abandoned. It proved too difficult to get sufficiently precise ingress and egress times for Venus on the Sun's disc. The modern value for the Constant of Parallax is 8″.794143, which gives a value of 92,955,807 miles (149,597,871 km) for the mean Astronomical Unit.[34] There were, however, many side benefits of the transit expeditions around the world and the exact coordinates of many remote locations were measured, along with detailed observations of eclipses, transits of Mercury and measurement of magnetic declination and gravity. In the case of Lewes, the survey also established the coordinates of the Cape Henlopen lighthouse. The modern value for the AU was found by radar ranging of Venus and Mercury and by telemetry measurements from interplanetary spacecraft.

Epilogue

Owen Biddle was prominent in the American Philosophical Society. He was elected curator (1770), secretary (1773) and councillor (1782), and delivered the annual oration in 1781.[35] He was a Quaker, but was active in a non-combatant role in the Revolutionary War, serving primarily as Deputy Commissioner of Forage, under his brother, Clement and with Thomas Paine, author of *Common Sense*, as his clerk. In this role, he was responsible for finding, buying and distributing food, animal feed and raw materials, a thankless and frustrating job considering colonial finances. After the war, he was disowned by the Quakers, along with about a hundred others, for his participation in the war. He was instrumental in the formation of a new 'Free Quaker' community. The war and its aftermath were not kind to Biddle. Three ships in which he had invested were captured during the war and he was forced to dissolve most of his property to avoid bankruptcy. He was not active in the American

Philosophical Society after 1782. He worked as an apothecary merchant in Philadelphia.[36] His later years were spent in the Community of Friends, where he was active in establishing a boarding school in Chester County. He had seven children.

Joel Bailey continued work as a surveyor. His role in the transit apparently impressed the membership and he was elected to the American Philosophical Society in 1770.

Although the objective of the expedition was to collect the required data for the Venus transit, the long term impact was much greater. The observers established the geographical coordinates of several important places with good accuracy. The study and discipline required to equip and use the transit observatories and to collect and process the transit data was the first venture of the colonies into world-class astronomy and their experiences were invaluable in building a foundation for American science.

Conclusion

This paper has described the extraordinary efforts made to observe and accurately time the transit of Venus in 1769 from a temporary observatory in Lewes and to determine the geographical location of that observatory. The data relating to the location of the observatory has been analysed and a probable precise location has been determined.

Acknowledgments

The authors wish to thank:

Mike DiPaolo, Executive Director of the Lewes Historical Society, George Kent, of the Delaware Department of Transportation, Mapping Division, William ('Sandy') Schenck of the Delaware Geologic Survey. This project could not have been accomplished without their generosity.

References & Notes

1. Halleio, Edm., 'Methodus Singularis Qua Solis Parallaxis Sive Distantia a Terra, ope Veneris intra Solem Conspiciendoe, Tuto Determinari Poterit', *Philosophical Transactions of the Royal Society*, 29 (1714-16), 454-464.
2. Ball, Robert, *A treatise on Spherical Astronomy* (Cambridge, 1908), 312-322.
3. Chapman, Allan, 'Jeremiah Horrocks, The Transit of Venus, and the 'New Astronomy' in Early Seventeenth-Century England', *Quarterly Journal of the Royal Astronomical Society*, 31 (1990), p. 333.
4. Winthrop, John, 'Observation of the Transit of Venus, June 6, 1761, at St. John's, Newfound-Land: By John Winthrop, Professor of Mathematicks and Philosophy at Cambridge, New England' *Philosophical Transactions of the Royal Society*, 54 (1764), 279–283
5. Rittenhouse, David, 'Calculations and Projections of the Transit of Venus', *Transactions of the American Philosophical Society*, 1 (1771, revised 1789), p. 4.
6. Danson, Edwin, *Drawing the Line*, (Wiley, 2001), p. 194.
7. Biddle, Henry D., 'Owen Biddle', *The Pennsylvania Magazine of History and Biography*, 16 (1892), p. 300.
8. Mason, Charles, 'Mason & Dixon's Line', *Original Journal of the Commissioners* (1763), 331-332.
9. Danson (2001), p. 85.
10. Biddle, Owen. 'An account of the Transit of Venus over the Sun's Disk as observed near Cape Henlopen', *Transactions of the American Philosophical Society*, 1 (1771, revised 1789), p. 84.; Biddle, Owen, 'Observations of the Transit of Venus over the Sun, June 3, 1769; made by Mr. Owen Biddle and Mr. Joel Bayley, at Lewestown, in Pennsylvania. Communicated by Benjamin Franklin, LL.D., F.R.S.' *Philosophical Transactions of the Royal Society*, 59 (1769), p. 414.
11. Biddle (1769), p. 415.
12. Maskelyne, Nevil, 'Instructions relative to the observation of the ensuing transit of the planet Venus Over the Sun's disk On the 3rd of June 1769', *The Nautical Almanac And Astronomical Ephemeris, for the Year 1769.*
13. Wolf, Edwin, *At the instance of Benjamin Franklin: a brief history of the Library Company of Philadelphia, 1731-1976*, (Library Co. of Philadelphia, 1976).
14. Meade, Buford K., *Report on Surveys of Delaware/Maryland Boundaries* (U.S. Department of Commerce, National Ocean Survey, 1982), 7-8.
15. Biddle (1771, revised 1789), p. 85.
16. Biddle (1771, revised 1789), p. 84.
17. Smith, William, 'An account of the Transit of Venus over the Sun's Disk as observed at Norriton', *Transactions of the American Philosophical Society*, 1 (1771, revised 1789), p. 11.
18. Mason, Charles, *Mason & Dixon's Line Original Journal of the Commissioners 1763*, p. 70.

19. Biddle (1771, revised 1789), 88-91.
20. Mason, C. & Dixon, J., 'Observations for Determining the Length of a Degree of Latitude in the Provinces of Maryland and Pennsylvania, in North America', *Philosophical Transactions of the Royal Society*, 58 (1768).
21. Smith, William, 'Account of the terrestrial measurement of the difference of longitude and latitude, between the observatories of Norriton and Philadelphia', *Transactions of the American Philosophical Society*, 1 (1771, revised 1789), 114-120.
22. Biddle (1771, revised 1789), p. 86.
23. Biddle (1771, revised 1789), p. 87.
24. Maskelyne, Nevil, Instructions relative to the observation of the ensuing transit of the planet Venus Over the Sun's disk On the 3rd of June 1769, *The Nautical Almanac And Astronomical Ephemeris, for the Year 1769.*
25. Smith (1771, revised 1789) p. 11.
26. Biddle (1771, revised 1789), 89-90.
27. Biddle (1769), p. 415.
28. Maskelyne (1769).
29. Biddle (1771, revised 1789), p. 84.
30. Biddle (1771, revised 1789), p. 86.
31. Biddle (1771, revised 1789), p. 90.
32. Newcomb, Simon, 'Discussion of observations of the transits of Venus 1761 and 1769', *Astronomical Papers prepared for the use of the American Ephemeris and Nautical Almanac, Bureau of the Navy* (1890), p. 387.
33. Smith, William. The Sun's Parallax deduced from a comparison of the NORRITON and some other American observations of the transit of Venus, 1769; with the GREENWICH and other European observations of the same., *Transactions of the American Philosophical Society*, (Volume I, 1771 revised 1789) Page 176.
34. At the 28th General Assembly of the International Astronomical Union, Beijing, 2012, it was resolved that the astronomical unit be redefined as 149597870700m exactly and the symbol 'au' be adopted. (IAU Division 1, resolution B2)
35. Biddle (1892), *passim*.
36. Bell, Whitfield Jenks, *Patriot-Improvers: Biographical sketches of members of The American Philosophical Society, Volume One, 1743-1768*, (American Philosophical Society, Philadelphia, 1997), p. 302.

The Authors

James E. Morrison is retired from a 40 year career in computers, including 30 years with IBM. He is the author of *The Astrolabe*, a complete treatise on the history, design and uses of all types of astrolabes and related instruments. He has a bachelor's degree in Physics from Oklahoma State University and a Masters Degree in Systems Engineering from Southern Methodist University. He lives in the United States at Rehoboth Beach, Delaware.

Geoffrey Thurston served as a General Duties Officer in the Royal Air Force for 26 years. He then managed a research and development programme for high-altitude, long-endurance unmanned aircraft. He is now retired and devotes most clear nights to the observation of asteroids. He has an MA in mathematics from Oxford University.

Neptune: towards understanding how Adams's upbringing enabled him to predict, then miss the discovery of the century

Brian Sheen, FRAS
brian.sheen@virgin.net

Roseland Observatory

The story of John Couch Adams the great Cornish astronomer of the nineteenth century is well known and this paper will not revisit old ground. However, many questions remain unanswered and in this paper I propose to indicate some of them as section headings, and seek to address them. In this way Adams's early life is examined, and its effect on his academic life during the time of the Neptune discovery. The row that followed discovery is high-lighted together with the equally contentious issue of the new planet's name. Although it is usually believed that Adams graciously accepted the failure of the Cambridge University Observatory to find his planet, examination of his later work which is often highly critical of French astronomers sheds a different light on that theory.

Fig. 1 Lidcott Farm the Adams family home
By courtesy of Richard Sleep

John Couch Adams was born in 1819 in an isolated farmhouse at Laneast, north Cornwall, as the eldest of a large family

To what extent did the nature of Adams's childhood influence his demeanour at Cambridge?

This part of Cornwall is very quiet even today, and people visit it for that very quality, the hustle and bustle of city life is a world away. Hence people deal with one another in a supportive and non-confrontational way. If asked a question you give your response and that is the end of the matter. His father was a tenant farmer and his landlord lived at the imposing Palladian 'Tregeare House', just a mile from the Adams farm, and was one of the largest estates in the county

The landlord was John King Rennall Lethbridge who proved and he turned out to be very supportive. When Adams won one of Cambridge University's most prestigious awards as 1st Smith's Prizeman the

Fig. 2 Tregeare House Adams Landlord's House
By courtesy of Pat and Anthony Winter
Winter C.W.R., *In Sundry Places:…*(1999),

news reached Lethbridge at Launceston, he rode his horse home and on entering the yard took off his hat and shouted 'Adams for ever'. This was an apparent conversion from his earlier view that 'scarce resources should not be spent on college bills and that education was getting more prevalent and was not well paid'.[1]

> After Lethbridge's death it was said of him:
> Besides these services to his neighbours and his County, he conferred an obligation on the Nation and on Science, by the judicious and kind protection which he offered to the illustrious Astronomer John Couch Adams, at that critical period of his early life, when the career of a greatly talented boy maybe determined by the direction and encouragement he receives. The father of Adams was a moorland tenant of Mr Lethbridge with a very large family, and when the extraordinary abilities of the son attracted attention in his remote and limited sphere, the judgement, encouragement and patronage of the landlord were most usefully exerted on his behalf.[2]

This final sentence relates to the Manganese Mine found on the Adams farm and which funded to a large extent John's university education. The right of a tenant to farm the surface of the land does not extend to the right to extract minerals from below ground. The mineral rights belong to the 'lord of the manor' and so of course do the profits from the sale of the minerals.

This was also the time when the children's hymn 'All things bright and beautiful' contained the lines 'the rich man in his castle the poor man at the gate God made then high and lowly and ordered their estate' and described the situation in Cornwall. So Adams went to Cambridge with great respect for his 'elders and betters'. This verse is in the original 1848 version; it has long since been removed from hymn books.

Where did Adams get his brains from?

It was evident from an early age that Adams had an intellect that was far beyond the normal. Of course all the modern ways of monitoring ability and universal education were still in the future. The truth is that he was not alone, his siblings were all to do great thing or at least the boys were. A lack of schooling meant that the girls in the family were not able to demonstrate their ability. However, they were able to pass the genes on to their children and it is a matter of record that many of the Adams extended family went on to be high achievers. The best clue comes from the fact that Adams's mother Tabitha Knill Grylls inherited from her Aunt Grace Couch a small estate of some 100 acres which was only a short distance from Adams's birthplace. The estate included a library which contained some books on astronomy originally owned by Grace's husband, John Couch. Eighteenth century books became Adams's early companions. It was certainly unusual to be able to read such volumes in those days, and it is evident that from this line the interest in astronomy stems, and indeed his ability to put it to good use.[3]

Did Adams high ability stem from the fact that he had a special brain condition?

Adams arrived at Cambridge University as a poor sizar and yet he was marked out as a student of exceptional ability, especially as a mathematician. There should be little surprise therefore to find that a student who could score twice the mark of the runner up should demonstrate quirks and differences from the normal person. These quirks, often single instances, have been assembled to suggest that he had a mild form of Asperger's syndrome. It is a suggestion that finds little support amongst the historians of astronomy at Cambridge today. However, one of the problems he would have encountered would be that of initially understanding and being understood by his fellow students, the Cornish dialect being very different from that spoken in England.

Although Adams was focused and single minded in the pursuit of the 'disturbing planet', he also found time for a wide range of pursuits. He was a good singer and Cornish wrestler, and each year he picked up the prize as the best in class for Greek Testament studies. He was also very fit; it being recorded that on one occasion he walked from Cambridge to London via Greenwich.[4]

There is no doubt that Adams did have self-confidence and the evidence is that he was looking for a problem that would test his skills. In George Biddell

Airy's 1832 report on, *The progress of astronomy*, he found what he was looking for in the final paragraph:

> In the preceding suggestions I have endeavoured to fix on definite points for the attention of astronomers. I need not mention that there are other subjects (the theory of Uranus, for instance,) in which the existence of difficulties is known, but in which we have clue to their explanation.[5]

When Adams arrived in Cambridge Airy was already Director of the Royal Observatory at Greenwich. It impacted on the young Adams when he found Airy's report in a Cambridge second hand book shop in 1841. His noted comment was:

> …formed a design at the beginning of this week, of investigating as soon as possible, after taking my degree, the irregularities in the motion of Uranus which are yet unaccounted for in order to find whether they may be attributed to the action of an undiscovered planet beyond it; and if possible then to determine approximately the elements of its orbit etc., which would probably lead to its discovery.[6]

The details of the search have been examined many times over the years. However one or two points remain unresolved.

Why did Adams not reply to
Airy's Radius Vector Question?

After completing his first calculations, Adams left a brief note of them at the Royal Observatory, Greenwich. Airy, later accused of neglecting a young man, actually wrote to him asking for clarification of what to Airy was a key issue – how was Adams tackling the 'radius vector' element of the calculation. It was long alleged that Adams was neglectful, even discourteous in failing to reply, thus terminating any correspondence.

However, a part written letter was discovered in the Cornwall Records Office in 2004 by Dr Craig Waff. A clue to the reasons behind Adams failure to reply may be gleaned from this letter to Airy that was started, but never finished – something important seems to have prevented the letter from being finished. The draft reads:

> Sir, I must apologise for having called at the observatory the other day at so unreasonable an hour, the reason was that I had only arrived in town that morning & it was necessary for me to be in Cambridge the same day, so that I had no other opportunity. The paper I then left contained merely a statement of the results of my calculation; I will now, if you will allow me, trouble you with a short sketch of the method used in obtaining them. My attention was first directed to the anomalies in the motion of Uranus by reading, some time since, your valuable Report on Astronomy. If the action of known planets really proved insufficient to account for the perturbations of Uranus, it appeared to me that by far the most probable hypothesis which could be formed for that purpose, would be that of the existence of an undiscovered planet beyond. If this were the case, I conceived it might be possible to find from an examination of the observed perturbations, the approximate position of the new planet, so as to assist Astronomers in discovering it. The solution of this problem, however, would be deeply impracticable at present, without making some assumption as to the mean distance. Fortunately, Bode's law supplies us with a value which, at any rate has a claim to be first tried. Accordingly, using the differences between Observations, and the Tables given in Bouvard's Equations of condition as far as they extend, and subsequently those supplied by the Cambridge and Greenwich Observatories, together with those in the various numbers of the Astron. Nachrichten, I obtained values of the mass and position of the assumed planet, so as to satisfy all the observations very nearly. The series however, not being sufficiently continuous at one or two points, Professor Challis had the kindness to request you to communicate the results of a few of the Greenwich observations to supply the deficiency. For your kindness in sending the whole of the Greenwich observations of Uranus, I beg you will accept my warmest thanks. On receiving them, I determined to make them the base of a new investigation taking into account several quantities which I had previously neglected. The later observations used were the same as before…[7]

It is clear from a study of the available Adams records that a significant number of documents dating from the pre-discovery period have vanished – it is known that they were removed by the Adams family. We know that Adams had requested that no biography be written until after his death. The letter above is one that escaped the purge.

The standard explanation of Adams's failure to reply is that he considered the question trivial, which indeed it is if you accept the universality of the law of gravity extending right through the solar system and beyond. Adams certainly did, but Airy had clear reservations which he later communicated to Challis on Dec 21st 1846 by letter after the planet's discovery and succinctly expressed in the following terms:

> There is no *a' priori* reason for thinking that a hypothesis which will explain the error of longitude will *also* explain the error of radius vector. If

the numbers for theoretical radius vector had been discordant with the observed numbers of radius vector then *the theory would have been false*, not from any error of Adams but from a failure in the law of gravitation. On this question therefore turned the continuance or fall of the law of gravitation.[8]

Maybe the reason that Adams did not complete his letter was the thought that if senior astronomers like Eugene Bouvard and Thomas Hussey had tried to commend to Airy the theory of an exterior planet, and had been rebuffed by Airy, did he, Adams, really stand a chance?

Another possible explanation of Adams holding back his letter until he did further calculations was to satisfy himself regarding the resonance problem**.** It is clear that Adams's work, using successively revised calculations using modified elements, was placing the disturbing planet closer and closer to resonance with Uranus. This in turn would produce perturbations on a much grander scale than the evidence revealed. Airy would then have dismissed Adams work without further consideration. The fact is that the planets are in resonance, but the mid-eighteenth century happened to be a quiescent period in the cycle![9]

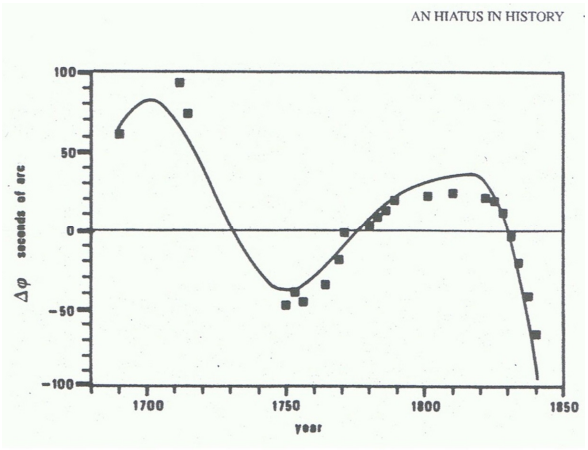


Fig. 3 From 'Perturbations of Uranus by Neptune: a Modern Perspective'
C.C Lai Lam & K. Young *American Journal of Physics*, **58**, No.10 (Oct. 1990) 946-953
By courtesy of Professor K Young

The evidence for this awareness by Adams is found in a letter which – a reprint of which can be found in Lionville's Journal de mathematics, 1876 – where he dealt with Professor Pierce's, 16th March 1847, objection to his calculations, where Adams states 'the period of Neptune itself is almost exactly double that of Uranus, and this gives rise to some very considerable reciprocal perturbations of a character quite different to those which would be caused by our hypothetical planets'.[10] The fact that Adams's later orbits included considerable eccentricity indicates that he was already fully aware of the effects of two planets in resonance. We need to bear in mind that perturbation analysis before the availability of modern computers was very difficult, and involved long calculations of sines and cosines plus secular terms, for which Adams was trying in turn different values for different key elements. Trying to find the position of an unknown body of unknown mass and distance from the Sun only from its observed effect upon another was a challenge that most of those familiar with celestial mechanics shrank from tackling. This is a situation that pertains even to this day.[11]

Was Adams's work used by Challis?

As soon as Airy read that Le Verrier in Paris was close to finding the position of the supposed perturbing planet, and realising Adams work was closely parallel, Airy who had no suitable refractor at Greenwich, urged James Challis the Director of the Cambridge Observatory to use the powerful Northumberland Refractor to urgently search for the new planet.

It is often stated that Challis diligently applied himself to his interpretation of Airy's instructions as being to repeatedly comb an area of the ecliptic 30 degrees by 10 – a huge area, strewn with stars – by noting the position of every star down to the 11th magnitude and to see which, if any, had moved since the previous scan. It has been alleged that Adams's contribution at this stage was nil. This is not so, since in fact a study of Challis's Reports shows that he made constant reference to Adams's calculations.[12] In reality the preliminary report by Le Verrier of his own work which resulted in very similar results to the figures that Adams had privately given only to Airy and Challis gave Challis confidence in his search.

The disturbing planet eventually named Neptune is now known to be of magnitude 8, so why was the much fainter level and therefore much larger number of 'stars' chosen? The brightness of a solar system object in the sky depends on its physical size, its distance from the Earth and its albedo i.e. the percentage of incident light reflected. As an ice giant Neptune is large, it also has a high albedo when compared with a rocky planet. As a body beyond Uranus it would be moving much more slowly than any other planet or main belt asteroid, it might even be stationary when observed for the first time. Hence there is no doubt that the method employed by Challis would have eventually turned up the planet. It is also true that the Cambridge Observatory was overworked so that Challis undertook the whole search himself

and that every short cut to secure early success should have been employed.

Why did Challis take so long to find the planet?

Fundamentally, although acknowledging the principle, he and Airy lacked the conviction that it would be possible to locate an unseen object from its effect on a nearby planet. This explains the large search area and the perceived need for re-examination of that area. Another problem is that the stars were very closely packed especially those between magnitudes eight and eleven in that part of the sky. Also Challis was older than many other full time observers and had laboured long and hard on difficult observing projects before. On this search he did not check each day the previous night's observations, but waited until he had the results for a much larger area. Had he done so much heartache would have been prevented?

What of the Cup of tea story?

One story appears to highlight these problems. Towards the end of September 1846 Challis was discussing the problem with the Rev William Towler Kingsley (1815–1916), Tutor of Sidney Sussex College over dinner in Cambridge. In those days dinner at college was taken at 4.00pm, Challis related that he had seen a 'star' that appeared to show a disk. Under pressure from Kingsley, not an astronomer, he agreed to examine it under a higher power. On their return to the Observatory the sky was clear; however they were prevented from going to the scope by James Challis's wife insisting that they should fortify themselves with a cup of tea. By they time they reached the Dome the sky had clouded over and the last opportunity for independent discovery was lost.[13] News reached England a day or so later of the visual discovery in Berlin. Of course the perception is that the 'star' would have been easy to observe as soon as the pair started work.

However, it is more likely that it was only dusk while tea was being taken and that the cloud appeared as the temperature dropped, a common enough occurrence in England – it is all in the timing. Furthermore, it would have been as late as 8.30 pm before observing could start. Astronomical Twilight ended then, and the position of the 'star' would clear the horizon to an acceptable amount, which is some 15 degrees – there was no Summer Time in those days.

However the exact date is open to question, Challis's own report gives a first reference to a disk on September 29th, both from a comment from Le Verrier and also in his own log of observations. News of the discovery reached England from the continent on the 1st October, so the only realistic date for the tea incident seems to be the 30th when according to the log no observations were made.

Conspiracy theory – did Airy give any help to the French?

The success of Le Verrier in Paris, who had started after Adams, and the swift discovery at his instigation by the Berlin astronomers, gave rise to thoughts that Airy had given Le Verrier some underhand assistance. Certainly members of Adams family thought so, however examination of the facts do not support these ideas.[14] Airy was a Cambridge man through and through; he designed and built the Northumberland Telescope, the best in Europe for the purpose. Also he kept the pressure on Challis to find the disturbing planet, passing on positional information about Uranus throughout the summer of 1846. There is now no doubt that every effort was made to ensure a Cambridge success. Tragically, events conspired to thwart that ambition.

Why did Le Verrier and Arago not employ the telescopes of the Paris Observatory to ensure the glory was all theirs?

Although it is not easy to establish which instruments were available and in use at the time of the search, recent work indicates that none were larger than 15-cm, inadequate for the task. In addition, the Observatory was based in the city and the atmosphere was laden with soot reducing the effectiveness of those modest instruments. It was in fact the parlous state of French observational astronomy that caused the astronomers there to concentrate on mathematical analysis at that time.[15]

Why was Galle able to find Neptune so easily?

The pivotal fact is that Le Verrier's letter to Johann Gottfried Galle asking him to use the Berlin Observatory's 24.4cm (9¾-inch) Fraunhofer refractor to search for the planet at a specified position arrived on September 23rd, Director Johann F. Encke's, birthday. A long anticipated birthday party meant that the observatory would be available without Encke's supervision, and the opportunity was taken by the young and enthusiastic astronomers, Galle and Heinrich d'Arrest! In addition there was a clear moonless night. Crucially, the latest star maps produced by Berlin and covering the relevant area, but not yet distributed to other observatories, were available, the telescope was of excellent quality, and at 4.8cm (2-inch) smaller than the 11.5-inch (29.2cm) Northumberland telescope in Cambridge there were less faint stars to check!

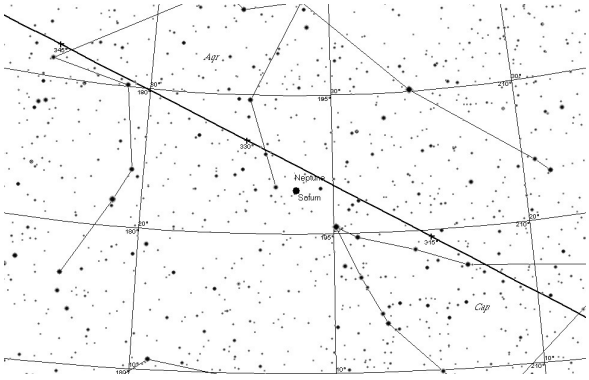


Fig. 4 Chart of the discovery area showing stars down to the 8th Magnitude prepared By the author using Sky Map Pro©

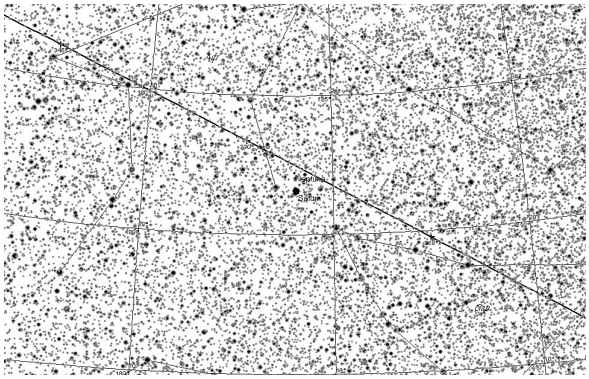


Fig. 5 Chart of the discovery area showing stars down to the 11th Magnitude prepared By the author using Sky Map Pro©

Hence the discovery took only an hour or so, although of course the 'new star' needed to be checked, how fast was it moving in its orbit, was it a main belt asteroid just one of a number of magnitude eight bodies still to be discovered in 1846. Or was it in fact a blue star. By the following night all these doubts had been removed, it was very close to the position indicated in Le Verrier's letter and showed a barely measurable disk.

The correspondence relevant to the discovery went as follows: John Russell Hind (Director at the Regent's Park Observatory) to Challis, Sept 16, 1846.

> Sir, I have received a letter this morning from M. Herve Faye of the Paris Observatory on the subject of Le Verrier's planet, which I think may be of some service in the search. I mentioned to him a few days since that I had heard you were employed in observing stars with a view to its discovery and that I was similarly occupied. I will give the extract of M. Faye letter, So far I am not successful in this search, our instruments do not appear to me to be powerful enough for it.[16]

This letter indicates that following Le Verrier's preliminary notice of his work and indication of an approximate area, published in Paris, a very few of those with potentially adequate refractors were actively searching and communicating as usual, although it seems that neither principal was aware of this.

Le Verrier seems only to have sought help from Berlin and wrote to Galle Sept 18th 1846.

> Dr J. G. Galle, You see sir I have demonstrated that we cannot understand the observations of Uranus without introducing the effect of a hitherto unknown planet. What is remarkable there is only one position in the ecliptic that this perturbing planet can be located. Here are the elements of the orbit that I assigned to this star.
>
> The current position of the star shows that we are now, and we will be still, for several more months favourably positioned for its discovery. Moreover from its high mass it can be concluded that its apparent diameter is more than 3 second of arc.[17]

The actual elements were those presented to the Academie des Sciences on Aug 31st 1846 It was entitled 'Sur la planete qui produit les anomalies observees dans le mouvement d'Uranus. – Determination de sa mass, de son orbite et da sa position actuelle.

Semi-major axis	36.154 AU
Sidereal period	217.387 years
Eccentricity	0.10761
Longitude of perihelion	284° 45'
Mean longitude, Jan. 1, 1847	318° 47'
Mass	1/9300
True heliocentric longitude, Jan. 1, 1847	326° 32'
Distance from the Sun	33.06 AU[18]

> Galle to Le Verrier, Berlin, Sept 25th 1846.
>
> The planet you reported the position of really exists. The same day that I received your letter, I found a star of the 8th magnitude, which was not included in the excellent star map Hora XXI – designed by Dr. Bremmiker – as part of a collection of celestial maps published by The Royal Academy of Berlin.[18]

Professor Heinrich C. Schumacher (director of the Hamburg Observatory) wrote to Le Verrier, Altona Sept 28th 1846. 'I must send you my heartfelt and most sincere congratulations on your brilliant discovery. This is the noblest triumph of theory that I know of'.[19]

The Map problem

It has often been stated that the Cambridge University held a perfectly good map of the search area. This is

likely to be Karl Harding's map, known to be inaccurate and only recording stars down to the 8th magnitude, not the 11th as required by the Airy/Challis search plan, and therefore was not adopted by Challis as the basis for his search.

Sir John Herschel's contribution

Sir John, one of the finest astronomers of the day, summarised the relative positions of the Adams and Le Verrier predictions for the planet in the best of the contemporary reviews. He gives the following details for 23rd September 1846.

> The geocentric longitude determined by Dr Galle from this observation was 325 deg. 53 mins. which converted into heliocentric, gives 326 deg. 52 mins., differing 0 deg. 52 min from M. Leverrier's place, 2 deg. 27 mins. from that of Mr Adams and only 47 mins. from the mean of the two calculations.[20]

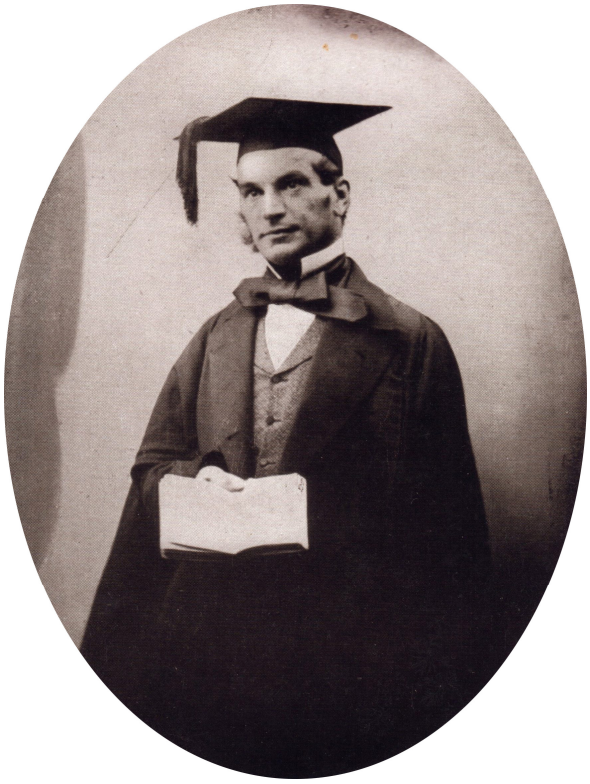


Fig. 6 Photograph of John Couch Adams
By courtesy of the Royal Astronomical Society
From 'John Couch Adams, the discovery of Neptune' by W.M. Smart. No 11 *Occasional Notes of the Royal Astronomical Society* August 1947.

Why was the row between the French and the British so bitter and long lasting?

Shortly after the announcement of the discovery, Airy supported by several Cambridge men in key positions, asserted the priority of Adams's work and this was swiftly interpreted by the press as a claim to co-discovery. A huge international row ensued. Both sides claimed that they had found the new planet first. Adams and Le Verrier were each unaware of the activity of the other. There was far more vitriol than the situation justified, most of it fuelled by the French press. There are explanations for this. First, it was only thirty years since the battle of Waterloo when the British and Prussians (Berliners) had combined forces to defeat the French. Second, there was a need to divert the French Public's attention from the sad and sorry state of the Paris Observatory. Attack is the best form of defence. D.F.J. Arago, director of the Paris Observatory, became involved but it seems that the vitriolic 'quotes' from his speeches that appeared in the *Le National* newspaper in fact came from its Editor. 'Airy has it on record that Arago moved the expulsion of the *Le National* editor from a special board meeting called to discuss this issue soon after the article was published, but that his motion was rejected'.[21]

The naming of the New Planet

This too was controversial. The account that follows is by Sir Henry Holland FRS, (1788–1873), royal physician and traveller, who describes a letter from Le Verrier that set the scene for another turbulent period in the discovery saga

> That which most strongly clings to my memory is an evening I passed with Encke and Galle in the Observatory at Berlin, some 10 or 12 days after the discovery of the planet Neptune on this very spot; and when every night's observations of its motions had an especial value in denoting the elements of its orbit. I had casually heard of the discovery in Bremen, and lost no time in hurrying on to Berlin. The night in question was one of floating clouds gradually growing into cumuli; and hour after hour passed away without sight of the planet which had just come to our knowledge by so wonderful a method of predictive research. Frustrated in this main point, it was some compensation to stay and converse with Encke in his own observatory, one signalized by so many discoveries, the stillness and darkness of the place broken only be the solemn ticking of the astronomical clock, which, as the unfailing interpreter of the celestial times and motions, has a sort of living existence to the astronomer. Among other things discussed while thus sitting to together in a sort of tremulous impatience, was the name to be given to the new planet. Encke told me that he had thought of Vulcan, but deemed it right to remit the choice to Le Verrier, then supposed

the sole indicator of the planet and its place in the heavens; adding that he expected Le Verrier's answer by the first post. Not an hour had elapsed before a knock at the door of the observatory announced the letter expected. Encke read it aloud; and, coming to the passage where Le Verrier proposed the name of 'Neptune', exclaimed, 'so lass den Namen Neptune sein' it was a midnight scene not easily forgotten. A royal baptism with its long array of titles would ill compare with this simple name of the remote and solitary planet thus wonderfully discovered. There is no place, indeed, where the grandeur and wild ambitions of the world are so thoroughly rebuked and dwarfed into littleness, as in the astronomical observatory. As a practical illustration of this remark, I would add that my own knowledge of astronomers – those who have worked themselves with the telescope – has shown them to be generally men of tranquil temperament, and less disturbed than others by worldly affairs, or by the quarrels incident even to scientific research. I may mention as instances occurring to me at the moment, the two Herschels, Encke, Bessel, Piazzi and Bond. Other examples might readily be supplied.[22]

However, only a few days after writing that letter, Le Verrier had a volte-face and suggested that the preferred name should be Le Verrier. Sir Harold Spencer-Jones later described the situation well:

On 1 October, Le Verrier wrote to Airy informing him of the discovery of the planet. He mentioned that the Bureau des Longitudes had adopted the name Neptune, the figure a trident, and that the name Janus, which had also been suggested, would have the inconvenience of making it appear that the planet was the last in the solar system, which there was no reason to believe.

Nevertheless Arago announced to the French Academy on 5 October that 'Le Verrier had delegated to him the right of naming the planet and that he had decided, in the exercise of this right to call it Le Verrier. 'I pledge myself', he said, never to call the new planet by any other name than Le Verrier's Planet".[23] Many astronomers were against naming the planet Le Verrier – Airy was their spokesman.

Airy to Le Verrier 12.01.47:

I intended my paper, (Airy's full report to the RAS meeting of the 13th November 1846) as a history of all that I know bearing upon this wonderful discovery, and I wish that you or some person well acquainted with what has been done in France would write your portion of the history.

I very much wish that you would pay a visit to England. It would gratify me very much to have the pleasure of receiving you in my house. I am sure you would find that in England, not only among men of accurate science but also among the people generally, there is no national feeling adverse to the respect due to you; which is not incompatible with the assertion of some claims in favour of Mr Adams. Since your book arrived, I have conversed on it with only two competent judges of its merit, Sir John Herschel and Sir J.W. Lubbock; and they regard it with the most unbounded admiration.

Will you now permit me to mention a subject of utmost delicacy, which I mention now in the most private way only because I am confident that, if it is not now mentioned privately, it will soon be mentioned publicly, I mean the name of the planet. From my conversation with the lovers of astronomy in England and from my correspondence with astronomers in Germany, I find that the name assigned by M. Arago is not well received. They think in the next place that the character of the name is at variance with that of all the planets. They think in the next place that M. Arago as your delegate could do only what you could do, and that you would not have given the name which M Arago has given. They are all desirous of receiving a mythological name selected by you. In these feelings I do myself share. It was believed, at first that you approved of the name Neptune and on that supposition we have used the name Neptune when it was necessary to give a name. Now if it was understood that you still approved of the Neptune (or Oceanus as some of my English mythologists suggested – or any other of the same class), I am sure that all England and Germany would adopt it at once, I am not sure that they will adopt the name that M. Arago has given.[24]

Le Verrier to Airy, Jan 29 1847:

Sir and dear colleague,

I have carefully studied the previous note that you have presented to the Society of Astronomy. Thank you for the terms in which you talked about my work and that your last letter contains kind remarks, relating to this subject. You are, sir, among a small number of astronomers who are familiar with celestial mechanics. After I had given my memoirs I was convinced I would find the planet and I said to myself, rather naively, that I would call it Planet of Le Verrier, similar to Halley's comet, Encke's comet etc., that's all. When the planet was found it was proposed by the Bureau of Longitudes to call it Neptune. I was a big part of the Bureau at that time, but did not

have charge of it. By writing to various astronomers I told then the decision the Bureaux had made, but without adding blame or approval.25

Harold Spencer Jones adds:

At a later date, when relations between Arago and Le Verrier had become strained, the true story was told by Arago. It appears that Arago had at first agreed to the name Neptune, but Le Verrier had implored him, in order to serve him as a friend and as a countryman to adopt the name Le Verrier. Arago had in the end agreed, but on condition that Uranus should always be called Planet Herschel, a name which Arago had frequently used.

The greatest of men are liable to human weaknesses and failings; Le Verrier was described by his friends as a mauvais coucheur, an uncomfortable bedfellow, by the general consensus of astronomers the name Neptune was adopted for the new planet; the name Le Verrier did not long survive.

This statement by Le Verrier was not correct. The minutes of the Bureau des Longitudes show that the Bureau had not considered assigning a name by 1 October, when Le Verrier had written not only to Airy but also to various other astronomers in Germany and Russia informing them that the Bureau des Longitudes, 'had adopted the name Neptune, the figure a trident'. The Bureau neither assigned the name Neptune nor subsequently withdrew it. The minutes of the Bureau des Longitudes show that Le Verrier's statements were repudiated by the Bureau at a subsequent meeting. It seems that the name Neptune was Le Verrier's own choice in the first instance but that he soon decided that he would like the planets to be named Le Verrier. There is no explanation of his reasons for stating that the name Neptune had been assigned by the Bureau des Longitudes; it was, in fact outside the competence of the Bureau to assign a name to a newly discovered planet[26]

Was Adams disappointed about the failure to secure Neptune for Britain?

Although he never showed to friends in Cambridge his regrets that after so much work he should lose the race to discovery, his family were left in no doubt that it affected him greatly**.**[27] Adams great personal difficulty was in his readiness to publish his work. He had failed to meet with Airy in the early days, and had failed to get any paper read or published prior to discovery.

His full paper was presented at the RAS meeting 13th Nov 1846, following accounts by Airy and Challis. It was included as a supplement to the 1851 Nautical Almanac which was published in January 1847.

In addition to the Appendix in the Nautical Almanac it was also published as a standalone preprint. As a preface or 'Advertisement' to this preprint it is written;-

This paper was communicated by the Author to the Royal Astronomical Society, and was read to that body, at their ordinary meeting, on November 13, 1846. The press of the Society being engaged on an extensive paper, on the longitude of Valentia, by the Astronomer Royal, and it being deemed of national importance that Mr ADAMS's Paper should be submitted to the world without loss of time, application was made to Capt. W.H.SMYTH R.N., President, and to the Rev. R. Sheepshanks, Secretary, of the Society who with their usual promptitude and zeal, granted permission for the immediate printing and publishing of the Paper by the NAUTICAL ALMANAC OFFICE; and it is under these circumstances that the investigations of Mr. Adams first appear as an as an extract from the Appendix to the NAUTICAL ALMANAC for 1851.

Nautical Almanac Office, W.S.STRATFORD,
3,Verulam Buildings, Superintendent of the
Gray's Inn, London. Nautical Almanac
December 31, 1846'

Prior to this there were only Adam's private 1841 Memorandum that started his quest followed by the October 1845 memo to Airy and the Sept 1846 memo also to Airy. He failed to get his paper read on the 15th Sept at the British Association meeting.

His Nautical Almanac memoir was described by Spencer Jones in the following terms:

It was a masterpiece, it showed a thorough grasp of the problem: a mathematical maturity which was remarkable in one so young. Hansen, a top authority on lunar theory, stated that Adams's investigation showed more mathematical genius than Le Verrier's. Airy himself said On the whole I think Adams's mathematical investigation superior to M. Le Verrier's. However both are so admirable that it is difficult to say.[28]

In truth Adam's work was not wasted. Using only the observations taken at Cambridge he was able to calculate the true orbit of Neptune. William Lassell who owned a large reflector was requested to search for any satellites. Triton was spotted almost immediately, and from the derived information the mass of Neptune was calculated.

Much of the evidence of Adams's disappointment is contained in his scientific papers. He spent a great deal of his time demolishing the work of the French

astronomers. Regarding Bouvard's tables of Saturn we read: 'I was immediately struck with the magnitude of the tabular errors in heliocentric latitude'.[29] Challis does not escape either: 'I am able to prove that the principal conclusions of Professor Challis are erroneous', these comments refer to a paper about the Moon's orbit.[30] Even Airy does not escape unscathed.[31] Of Le Verrier on the other hand, he said: 'I have great pleasure in being allowed to express the great satisfaction in doing honour to the eminent astronomer whose labours have added so greatly to our knowledge of the solar system'. This was on the occasion of the presentation of the RAS Gold Medal to Le Verrier in 1876, 'For his work on the four great planets Jupiter, Saturn, Uranus and Neptune'.[32]

Adams had to wait a long time however to deliver the *coup de grace* when at the 1884 Meridian Conference in Washington he was able to secure the Greenwich meridian as the Prime Meridian of the world in the face of a determined bid by the French in favour of the Paris meridian.[33]

Today we recognised that both Adams (1st) and Le Verrier (2nd) predicted the position of Neptune with sufficient accuracy to allow a successful search to be undertaken. Galle working with d'Arrest discovered Neptune by knowing what they were looking at, after a short search. Hence the terms co-predictors and co-discoverers are used. Adams's brilliance as a young post-graduate was finally revealed to his peers by the publication of his work on Neptune in 1847. However his enduring reputation is based upon his later work on lunar and planetary theories. Director of the Cambridge University Observatory from 1861 to 1892, his work on the most difficult problem, the 'Three body problem or Lunar Theory' made him the foremost European mathematician of his generation, and for it he was awarded the RAS gold medal in 1866.

Conclusion

Such was the furore over Britain losing the discovery of Neptune, and so persistent the attempts to hold Airy responsible, that to his great credit Airy drew together every scrap of evidence available into a single file, now known as the Neptune File. The ROG library was hidden underground during the Second World War until 1955. Olin Eggen, chief assistant, took the Neptune File circa 1965, prior to departure for Australia and later to South America, Eggen died in Chile in 1999. This file together with many other texts were recovered by Adam Perkins soon after. On recovery it was catalogued in 1999 and given the RGO Archives title, 'Papers relating to Neptune and the minor planets and requests for information', and the Cambridge University Library's class mark MS RGO 6/96A. Since that date Scholars have discovered relevant primary material in a number of sources. No pre - 1999 account could claim to be definitive. This paper has sought to review in a balanced way some of the new evidence that bears upon particular aspects of the Neptune controversy, and in particular upon Adams's enigmatic character. However, every time the end of the story seems to be in sight more facts are uncovered. The French side of the story has been written up finally in James Lequeux book, *Le Verrier: Savant magnifique et deteste* (Parc d'Activite de Courtaboeuf: EDP Sciences, 2009). The English translation is James Lequeux; *Le Verrier: magnificent and detested astronomer*, edited and with an introduction by William Sheehan, translated by Bernard Sheehan (New York: Springer 2013). This text, about to be published at the time of writing, lies outside the scope of the current work. There remains a great deal of information gleaned from many sources about Adams time in Cornwall which remains to be written up. The saga is pretty dramatic at times and this is deserving of a film which is Maarten Roos's ultimate objective. For a brief introduction see *Searching for Neptune* www.vimeo.com/26332551.

In addition, although a lot of good work is now in the public domain much of it lies in rare texts and journals which are difficult to find. Over the years there has been much talk of achieving a more complete biography of Adams, or a definitive review of the Neptune discovery timeline. However, such is the complexity of the history that it is unlikely that such a text by an individual author would be acceptable to other experts. Perhaps the way forward is to gather together all the well founded papers and articles into one volume, similar in fact to Adams's *Collected Scientific Papers*. The ultimate aim of this paper is to stimulate thinking about the relevance of Adams's Cornish upbringing, and to stimulate discussion that will result in a good video and book. For me this is not the end of the story, not even the beginning of the end, merely the end of the beginning.

Acknowledgements

The paper would have been impossible to prepare without the considerable help and assistance of an informal group of 'Neptunians' and other specialists including the late Dr Craig Waff, Dr William Sheehan, Dr Robert Smith, Dr Roger Hutchins, the late Peter Hingley, Mark Hurn, Dr Allan Chapman, Dr Maarten Roos, Dr Ken Young and Anisley Cocks, researcher Cornish Mining World Heritage Site Office. Also, the 2012 cohort of Work Experience students.

The author

Brian is the director of Roseland Observatory in Cornwall which exists in principle to encourage people from all walks of life to appreciate the environment about us in the way that suits them best. He serves on the RAS Education Committee and is the SHA's co-ordinator for Cornwall within the Society's county survey project.

Notes and References

1. Harrison, H. M., *Voyager in Time and Space* (The Book Guild, Lewes, Sussex., 1994) p. 19.
2. Winter C.W.R., *In Sundry Places: The story of the Tregeare Estate* (For-Get-Me-Not Books, Chippenham, Wiltshire, 1999), p. 129.
3. Adams W.G.., *The Scientific papers of John Couch Adams,* vol. 1 (Cambridge University Press, 1896), p. xv.
4. Smart W.M., *John Couch Adams and the discovery of Neptune*, Occasional notes of the Royal Astronomical Society, No 11 (1947), 12-14.
5. Airy, G.B., 'The progress of astronomy during the present century', *British Association for the Advancement of Science* (1832), 125-89.
6. Adams W.G., (1896), p. lv.
7. Unfinished draft letter, Adams to Airy dated 13.11.1845. Cornwall Record Office: Adams family papers AM p. 330.
8. Adams, W.G.., (1896), p. xxx.
9. Adams, W.G.., (1896), p. xxxi.
10. Adams, W.G.., (1896), 63-64.
11. Roy, A.E. and Clarke, D., *Astronomy principles and practice* (Adam Hilger Ltd., 1997), 150-154.
12. Adams, W.G., (1896) xlix-liv and 47-53.
13. Smart, W.M., (1947), p. 31 and 32.
14. Harrison H.M. (1994). P. 24 and 25.
15. Hutchins. R. *British University Observatories 1772–1939* (Ashgate Publishing Ltd., Aldershot 2008), 242-246.
16. Letter filed in date order, in RGO 6/96A, ROG Archive, Cambridge University Library.
17. The letter in French is cited in MNRAS (1911), Vol. 71, p. 278.
18. The letter in French is copied and filed in dated order RGO 6/96A.
19. The letter in French is copied and filed in date order in RGO 6/96A.
20. Herschel, J.F.W., *Outlines of Astronomy* (Longmans, Green and Co., London, 1869) p. 540.
21. Letter Airy to C. Wentworth Dilke ROC 13.01. 1847. ROG 6/94A ROG Archive, Cambridge University Library.
22. Chambers, G.F., *Astronomy for General Readers* (Whittaker & Co., 1905) 105-106.
23. Spencer-Jones, H., *John Couch Adams and the discovery of Neptune* (Cambridge University Press, 1947), p. 39.
24. Letter Airy to Le Verrier 12.01. 1847. RGO 6/96A, ROG Archive, Cambridge University Library
25. Le Verrier to Airy. 29.01.1847. RGOMcA. 33:17. ROG Archive Cambridge University Library.
26. Spencer-Jones, H., (1947), p. 41 and 42.
27. Harrison, H.M., (1994), p. 20 and 25.
28. Spencer-Jones, H., (1947) p. 37.
29. Adams, W.G., (1896), p. 87 and 88.
30. Adams, W.G., (1896), p. 129.
31. Adams, W.G., (1896), 205-219.
32. Adams, W.G., (1896), p. 355.
33. Harrison, H.M., (1994), 186-207.

Publishing in the Journal

A principal aim of the Society is to encourage both members and others to research any aspect of the history of astronomy across the century history in England, Ireland, Scotland and Wales or elsewhere when it impinges upon the former. It also supports researchers, whatever their experience, to share their enquiries and results in the Society's publications, thereby preserving their work for posterity. We are happy at any stage to discuss your topic via email, and put you in touch with one of our editorial team who will be able to assist you in shaping it for publication.

In the first instance please contact me (kevin.liam.johnson@gmail.com). There is easy opportunity to publish your shorter or less formal material in the SHA Bulletin (for which please contact Clive Davenhall; please see Objectives page of this journal).

Independent Reviewers of Papers

An important principle is that papers published in *The Antiquarian Astronomer* are to be of a standard that will be recognised as giving the research and the Society lasting credibility. To fulfil this principle, each paper is peer-reviewed by one or more Reviewers, in addition to the usual scrutiny by the Editorial Team. Reviewers are selected for their knowledge of the subject of the paper, able to provide helpful feedback to the author and to the editor. The Editor and authors acknowledge with thanks the advice and support offered by the independent reviewers for papers published in this Issue 5.

Guidelines for Authors

The latest version can be found on our website (www.shastro.org.uk) under Publications or can be supplied upon request by the Editor.

Errata

The Antiquarian Astronomer Issue 5, February 2011
'Charles Frederick Butterworth (1870–1946): The man with stars in his eyes' by Gary Kewin reference 43, p.13

The editor is grateful for being notified by Kevin Kilburn of the omission of the detail that BAA and SPA variable star observer Tony Markham, former Assistant Director of the SPA Variable Star section is also one of only four UK observers who have made in excess of 100,000 visual magnitude estimates and in 2009 received the BAA Stevenson Award for this achievement.

The Antiquarian Astronomer Issue 6, January 2012

The editor is grateful for being notified by the author of errors in the captions for pages 80 and 82.
Figure 10 on page 80 should read:

Fig. 9 The Bowditch comet seeker, circa 1890. Compare with Fig. 13.
Harvard University Archives, UAV 630.271 (E4722).

Figure 12 on page 82 should read:

Fig. 11 Ring micrometer.
Godfray, H., *A Treatise on Astronomy* (Cambridge and London: MacMillan and Co., 1866), p.293.

The Antiquarian Astronomer

Journal of the Society for the History of Astronomy

Society for the History of Astronomy

SHA Council* & Officers

Honorary President	Dr Allan Chapman	
Honorary Vice-Presidents	Dr Michael Hoskin	
Chairman	Madeline Cox FRAS*	madeline.cox@gmail.com
Vice-Chairman	Gilbert E. Satterthwaite FRAS*	gesatterthwaite@btinternet.com
General Secretary	Stuart Williams*	secretary@shastro.org.uk
Treasurer	Roger Hutchins FRAS*	roger.hutchins@btinternet.com
The Antiquarian Astronomer		
Editor	Kevin Johnson FRAS*	kevin.liam.johnson@gmail.com
Assistant Editor	Kevin Kelvin FRAS*	kevinkilburn@sky.com
Bulletin and E-News		
Editor	Clive Davenhall	newsletter@shastro.org.uk
Layout Editor	Peter Grego	petermoon1@yahoo.co.uk
Membership Secretary	Bob Bower	robert@rbower.orangehome.co.uk
Membership Records Officer	Tony Kinder FRAS	Anthony_kinder@hotmail.com
Publicity Secretary	Mike Leggett FRAS	leggett189@btinternet.com
SHA Survey Co-ordinator	Roger Jones*	ziksby@gmail.com
Librarian	Madeline Cox FRAS	library@shastro.org.uk
Archivist	Mark Hurn FRAS	archive@shastro.org.uk
Website Manager	Stuart Williams	webmaster@shastro.org.uk

http://www.shastro.org.uk

Antiquarian Astronomer

Journal of the Society for the History of Astronomy

Contents of Issue 7, March 2013

ISSN 1740-3677