The ENGLISH TELESCOPE *from* NEWTON *to* HERSCHEL

a SPECIAL EXHIBITION

16th OCTOBER 2008 - 22nd MARCH 2009

This exhibition is the Museum's contribution to the anniversary of the telescope. Our collection is strongest in the time between the working lives of two major figures in the history of astronomy, Isaac Newton and William Herschel, a period from the late seventeenth to the early nineteenth century.

There are other reasons for choosing this period. The English made important contributions to the instrument's development, including the invention and improvement of forms of reflecting telescope and the invention of the achromatic lens. These events are entwined with engaging human stories that reflect aspects of eighteenth-century life and society. So the exhibition is a series of episodes about more than the technical development of a scientific instrument.

In the surprising world of the eighteenth-century telescope, professors might work at grinding mirrors, instrument makers could write textbooks, a silk-weaver might challenge the authority of Newton, and a musician could use home-made instruments to change the very nature of astronomy.

BROAD SHEET

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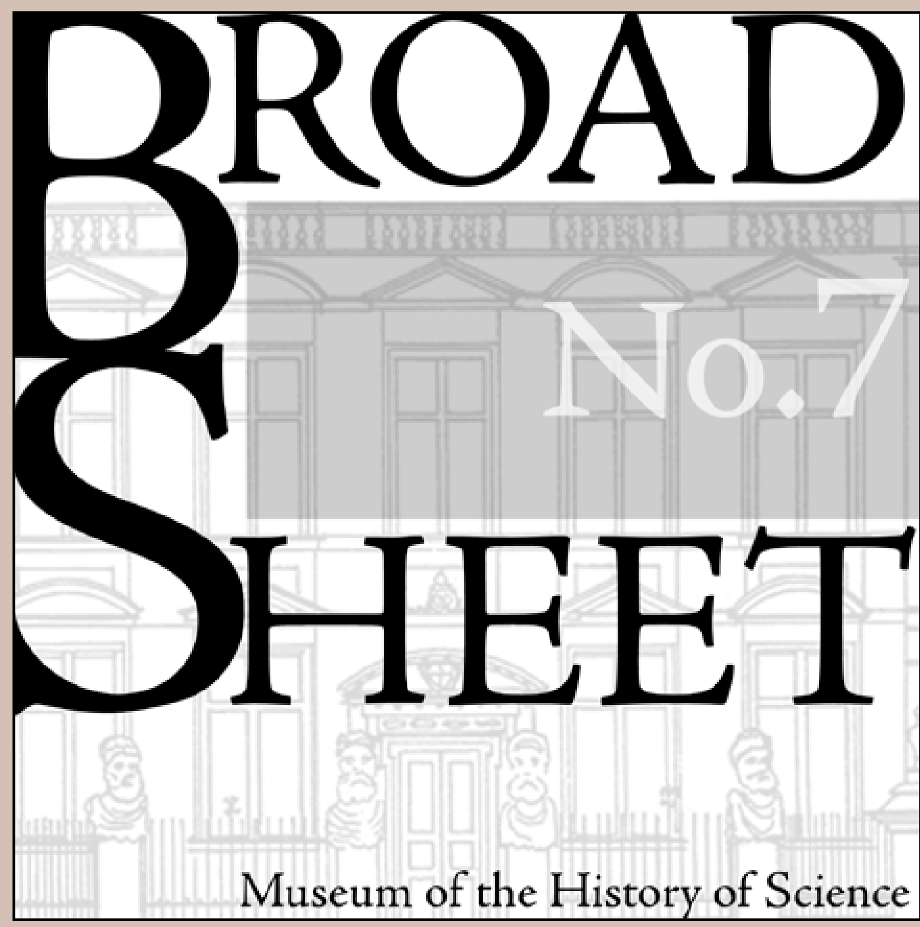

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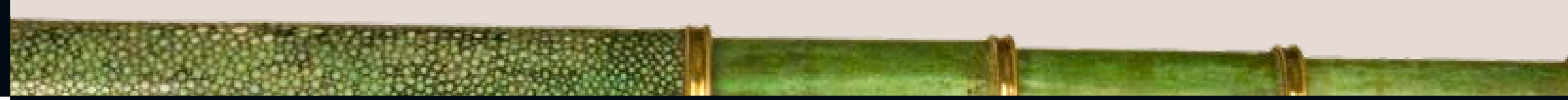
The Anniversary of the Telescope

In October 1608 a patent application was considered by the States General of the Netherlands from Hans Lipperhey of Middelburg, 'who claims to have a certain device by means of which all things at a very great distance can be seen as if they were nearby, by looking through glasses which he claims to be a new invention.' This reference, in a letter of introduction from the government of Zeeland dated 25 September 1608, is the first secure record we have of the existence of a telescope.

In May 1609 Galileo Galilei, a mathematician in Padua, Italy, heard of the invention by 'a certain Fleming' of 'a spyglass by means of which visible objects, though very distant from the eye of the observer, were distinctly seen as if nearby.' He began to work on improving the telescope, which was expected to have military applications on land and at sea.

At this stage there is no record of the telescope being considered of value for studying the heavens but in early August 1609, the English mathematician Thomas Harriot, who had been a student at Oxford, began making telescopic drawings of the moon. Though he knew nothing of Harriot's work, Galileo also turned his telescope to the night sky in the autumn and commenced a series of lunar observations on 30 November.

Four hundred years later, 2008-9 is being celebrated as the anniversary of the invention of the telescope and its application to astronomy. 2009 has been adopted by UNESCO as the International Year of Astronomy.



Refracting telescope by Will Longland, London, c.1695

Refracting telescope by John Yarwell, London, c.1685, with a detail showing his signature

Long and Short Telescopes

Galileo's observations of the heavens brought a rich harvest of discoveries and in the seventeenth century it was commonly thought that there was little left to find. One remaining problem was the puzzling appearances of the planet Saturn, solved by Christiaan Huygens's announcement of a ring structure in 1659.

Technical problems derived from two deficiencies in the lenses used at the time. 'Spherical aberration' refers to the fact that lenses whose surfaces are sections of spheres (the only sort that could be ground and polished by spectacle makers) do not bring all parallel rays of light to the same point, and so the image will be out of focus. 'Chromatic aberration' refers to the different behaviour of the different colours in light, such that, even with an optimally-shaped, non-spherical lens, rays of different colours will not return to create a sharp image after refraction.

It was found in practice that the only way to deal with these problems was to use an object-grass (the lens that first receives the light) with only a slight curvature. This meant that the deviation of the light would be slight and the telescope tube would have to be very long to allow room for an image to be formed. The best telescopes became very long and inconvenient to use.

According to Newton's account of the refraction or bending of light and its dispersion into the colours of the spectrum, the colours were not created by the process of refraction. The differently coloured rays were already present in the light, which was a mixture of these different rays, having different refractive properties. Refraction simply separated them out. Since lenses worked by refracting light, this dispersion into colours was unavoidable, so Newton concluded that a refracting telescope could never be perfected, so as to give a truly sharp image.

Newton proposed instead that telescopes should be made with mirrors. They worked by reflection, not refraction, so the dispersion of light into its different colours could be avoided: 'Seeing therefore the Improvement of Telescopes of given lengths by Refractions is desperate; I contrived heretofore a Perspective by Reflexion, using instead of an Object-glass a concave of Metal.'

It was important for the subsequent history of the telescope that in his book *Opticks*, Newton describes in detail how he ground and polished metal mirrors with his own hands. He also describes his attempts to improve silvered glass mirrors for telescopes.

When he introduces his arrangement of mirrors and lenses, in the construction that came to be called 'Newtonian', he describes its purpose as 'To shorten Telescopes'. The great length of good refractors had become a serious problem. Robert Hooke also had experimented with arrangements of lenses and mirrors to shorten telescopes and had published a number of designs.

Optical and Mechanical Gentlemen

In 1738 Robert Smith, Professor of Astronomy at the University of Cambridge, published his influential *Compleat System of Opticks*. Along with mathematics and theoretical optics, it offered a thorough account of all the practical aspects of making mirrors for telescopes. The list of subscribers includes many clergymen, lawyers, physicians and academics, as well as a number of well-known instrument makers.

Smith presents the mechanical work of making mirrors as a polite occupation, appropriate to the rational gentleman. The leading exponents, who make metal castings and grind and polish them by hand, are John Hadley, Vice-President of the Royal Society, James Bradley, Savilian Professor at Oxford, and Samuel Molyneux, a member of parliament and privy counsellor. Smith himself, a Professor in Cambridge, would shortly become Master of Trinity College and Vice-Chancellor of the University.

The precedent of Newton himself making mirrors for his telescopes and describing his practical methods in his *Opticks* was important for making this mechanical work popular among gentlemen. Such activities also became part of a growing passion for using reflecting telescopes in the popular study of astronomy within an increasingly fashionable interest in natural philosophy.

In both Newton's *Opticks* and Smith's *Opticks* there is discussion of the inclination and ability of the commercial makers to contribute to the development of these telescopes. The authors' comments are generally negative. Commercial opticians worked on glass lenses and it seemed doubtful whether their figuring and polishing skills could be transferred to metal mirrors, while at first the market for such telescopes must have seemed uncertain.

In fact there is more evidence of commercial experimentation than is generally acknowledged. While Newton made anonymous references to 'one of our London Artists' or to 'an Artificer at London', we know that makers such as Francis Hauksbee, John Rowley, Edward Scarlett and George Hearne were involved in early attempts to make reflectors.

Gregorian reflectors quickly became much more popular than Newtonian. In the arrangement due to the mathematician James Gregory light is received by a large (primary) concave mirror at the near end of the tube and reflected to a small (secondary) concave mirror at the far end from the observer, where it is reflected back to the primary, passing through a hole in the centre into the eyepiece. Hence the characteristic hole in the Gregorian primary mirror.

Detail of a presentation inscription on a Gregorian reflecting telescope by James Short, London, 1755

The eyepiece of a Gregorian reflecting telescope by Benjamin Martin, London, c.1770

Popular and Professional Astronomy

While gentlemen were encouraged by Robert Smith to grind and polish mirrors, more entrepreneurial promoters of popular natural philosophy sought to broaden their audience and their market. The common signal they adopted to announce that they offered a telescopic astronomy that would be entertaining as well as educational - and even devotional - was to describe it as suitable for ladies as well as gentlemen.

It was often the instrument makers who promoted such initiatives, through writing or publishing popular textbooks, giving or housing subscription lecture series with entertaining demonstrations, and devising instruments that were easy to use, appropriate to a domestic interior, and accommodated to a range of incomes.

James Ferguson published *An easy introduction to astronomy, for young gentlemen and ladies*, while Benjamin Martin offered *The young gentleman and lady's philosophy*. Experimental natural philosophy, with astronomy as a prominent component, became a fashionable pastime.

The Gregorian reflector was the ideal telescope for the amateur natural philosopher interested in the heavens. Mirrors could be made with much greater diameters than lenses. A telescope with a larger 'aperture' would collect more light and an observer could enjoy greater detail in the moon or Saturn, or wonder at the variety of nebulae or clusters of stars. That they had little potential for measurement was of no importance in this context. The Gregorian had the intuitive advantage over the Newtonian that the observer was looking towards the object of interest.

Gregorians are found in great numbers in the eighteenth century, signed by a great many London makers. It is far from certain, however, that many were the actual makers, as there was a great deal of sub-contracting to acquire parts, as well as retailing instruments in fact made by others.

One place where refracting telescopes are found in eighteenth-century astronomy is as telescopic sights on the measuring instruments used in observatories. After initial controversy over whether such sights really would improve accuracy, they became universally adopted in the great expansion of observatory work that characterised the period. Observatories were established across Europe by state and city governments, church authorities, scientific societies and wealthy individuals, and they were generally equipped with measuring instruments by London makers, such as John Bird, Jonathan Sisson, Jesse Ramsden or Edward Troughton.

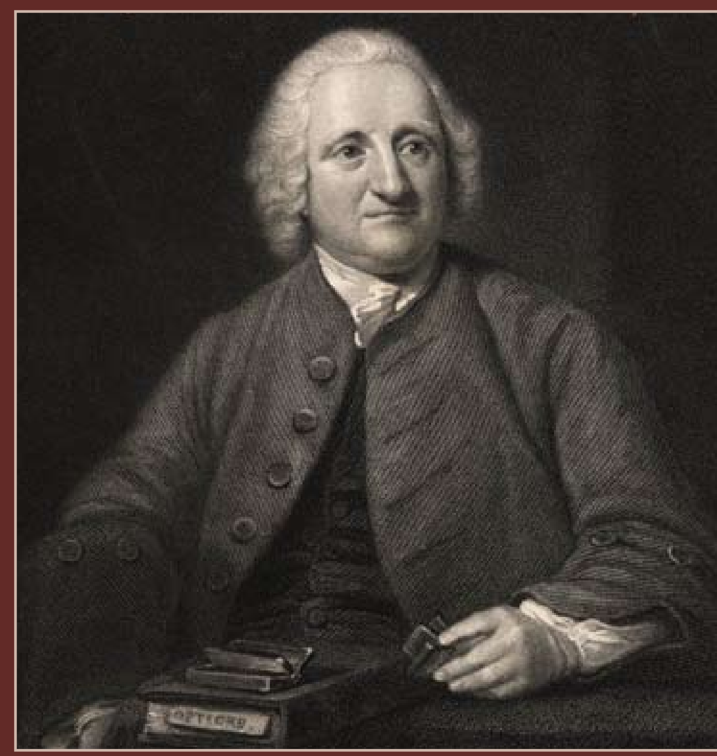
There was a clear distinction between the measuring activity in observatories, conducted by 'astronomers', and the qualitative observing open to anyone curious to view interesting objects in the night sky. The telescopic needs of the former were met by a refractor of relatively modest aperture, equipped as a sight, whereas a reflector suited the latter, since the larger aperture possible with a mirror was good for admiring detail in the solar system or wondering at fainter and farther objects, such as nebulae.

When the great cataloguer of nebula, William Herschel, detected an unknown planet while using a reflecting telescope to search for double stars, the famous astronomer Jérôme Lalande reported that this extraordinary and unprecedented feat had been achieved, not by an astronomer at all, but by a musician.

James Short and John Dollond

The fortunes of two telescope making enterprises dominate the middle decades of the eighteenth century. One was exclusively concerned with reflectors, the other with refractors. Both had direct connections with the technical legacy of Newton.

James Short was born in Edinburgh in 1710 and at the University there he came under the influence and patronage of the mathematician Colin MacLaurin, who was a friend and follower of Newton, and who encouraged Short's telescope making and promoted his reputation. Thanks to MacLaurin, Short was singled out for praise in Smith's *Opticks*. He made only reflecting telescopes.



A print of John Dolland, with prisms and Newton's *Opticks*

Portrait of James Short, oil on canvas, c.1758, attributed to Benjamin Wilson

John Dollond was a silk-weaver in a Huguenot family in Spitalfields, whose interest in practical optics led him to encourage his son Peter to become an optical instrument maker and eventually to join Peter in the partnership of 'J. Dollond and Son'. He came to challenge Newton's insistence that refracting telescopes inevitably produced blurred images with coloured fringes, and his portrait shows him holding Newton's *Opticks*, with a place marked, no doubt indicating the location of Newton's error.

James Short advertised himself as 'optician solely for reflecting telescopes'. In the world of instrument making it was very unusual to be so specialised but with so much prestige attached to making reflectors, Short's stipulation may have been an assertion of status as much as a business title. He himself probably made only the mirrors of his telescopes and not the tubes and stands.

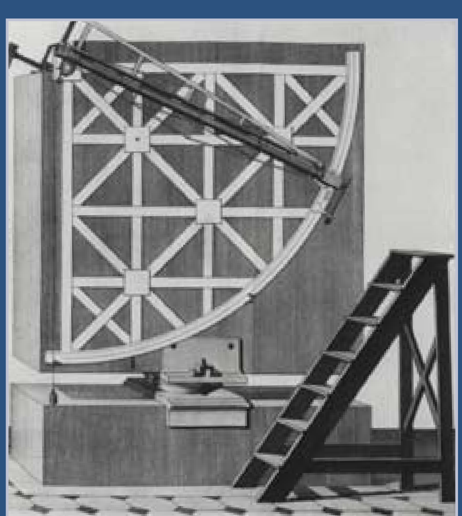
Short moved from Edinburgh to London in 1738 and his business was very successful: he made about 1370 telescopes and was worth some £20,000 at his death in 1768. He became a fellow of the Royal Society and was close to being appointed Astronomer Royal, believing he had been denied the appointment on account of his support for the chronometer maker John Harrison. The Museum has the largest collection of telescopes by James Short: nine are included in the exhibition, while a tenth - an example of the largest in Short's range - can be seen outside the entrance to the gallery.

John Dollond began his optical researches with complete confidence in Newton's conclusions but he came to doubt the reliability of the assumption that the dispersion of light (its separation into component colours) for a given degree of refraction or bending was the same for all types of glass. Dollond's subsequent experiments showed that this was not the case and that high-lead 'flint' glass had a significantly greater dispersive power than the more common optical 'crown' glass. This meant that by combining their effects light could be bent without being split into colours, and an 'achromatic' combination of two lenses could produce overall deviation without dispersion. Newton had been wrong.

Dollond explained his technique in a paper to the Royal Society in 1758 and was awarded the prestigious Copley Medal. In the same year he also took out a patent on his new lenses in partnership with the optical instrument maker Francis Watkins, who contributed his financial support. Dollond was elected a fellow of the Royal Society in May 1761 but died suddenly in November and his share in the patent passed to his son Peter.

Peter Dollond Against Allcomers

Refracting telescope by J. Dollond & Son, London, c.1760; a very rare example of a large telescope by the original Dollond partnership



A quadrant of 8ft radius by John Bird, 1753, with a telescopic sight

Hand-held Gregorian reflecting telescope by Benjamin Martin, London, c.1770

John Dollond's motives for patenting the achromatic lens are not entirely clear but his son Peter quickly set about exploiting the commercial advantage it gave him over other instrument makers.

Peter bought the share owned by his father's partner Francis Watkins in 1763 and in the same year took legal action against Watkins for infringement, and in the following year against the widow of the optician James Ayscough. Disgruntled and alarmed at this, 35 London opticians petitioned the Privy Council for the patent to be revoked on the grounds that the achromatic lens had been invented previously by someone else, an amateur optician called Chester Moor Hall, and had been widely sold before the patent application. The petition was not successful and Dollond continued with successful court actions against other makers to secure his position. In a judgement in Dollond's favour Lord Mansfield famously declared that it was 'not the person who locked up his invention in his scrutoire that ought to profit by such an invention, but he who brought it forth for the benefit of the public.'

One maker stood outside the fray for the time being: Jesse Ramsden married Peter Dollond's sister Sarah in 1766 and it is thought that he benefitted by his family connection to the patent holder, but after his separation from Sarah and the expiry of the patent, Ramsden too attacked Dollond – indeed he was probably the most effective critics of Dollond's position.

Peter, ever anxious to defend his father's reputation, in 1789 presented a paper on the subject to the Royal Society. It was read to a meeting but not published, whereupon Dollond himself arranged its publication. Ramsden responded with an account, also read before the Society, where he offered his personal experience of the matter and attributed the invention of the achromatic lens, not to his father-in-law John Dollond, but to Chester Moor Hall, who had been championed previously by the London opticians in their dispute with Peter.

The exhibition contains two key documents in the controversy: Peter Dollond's printed defence of his father and his draft response to Ramsden in manuscript. It was central to Peter's cause that his father had not simply been a jobbing optician, but a natural philosopher:

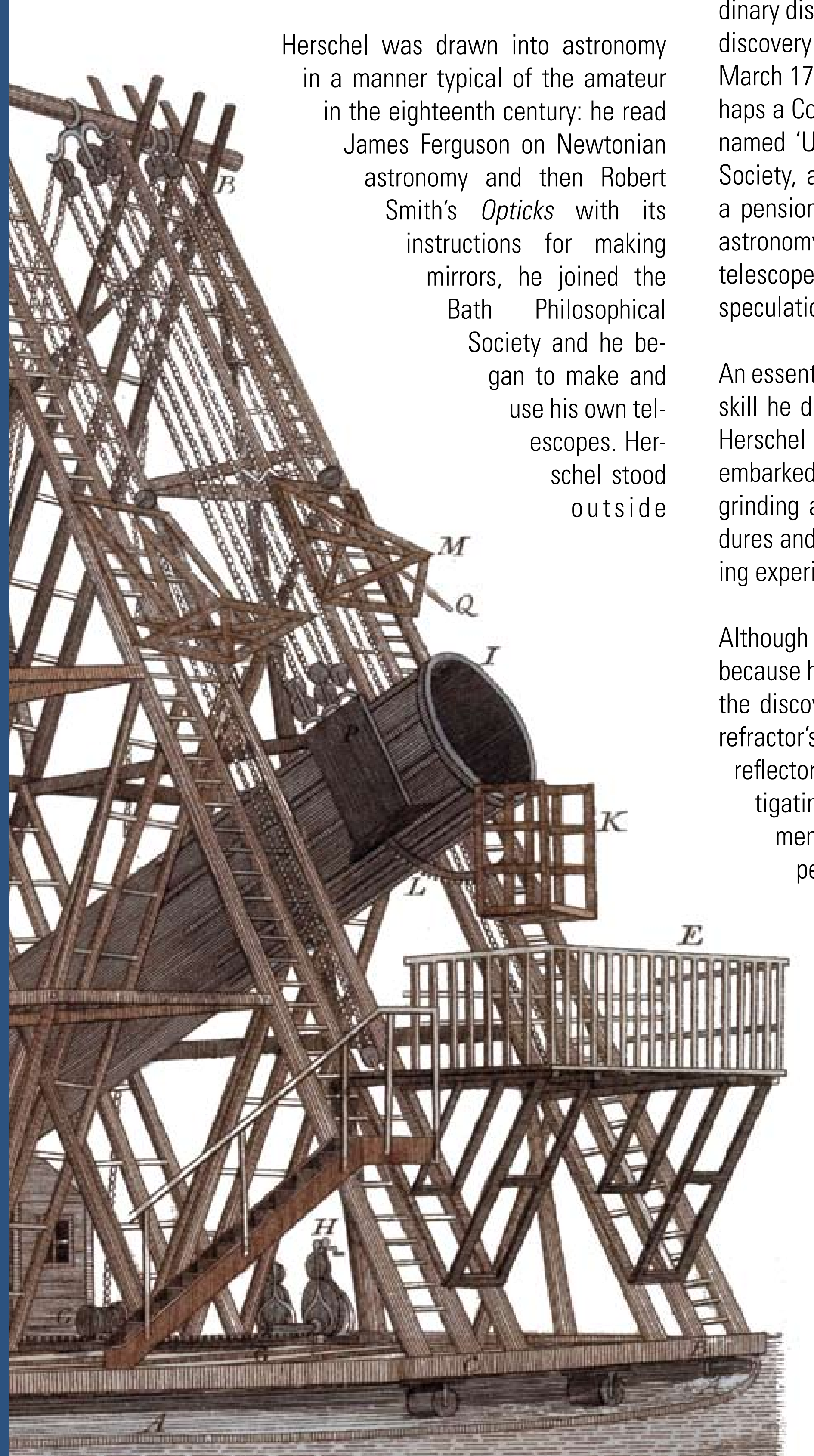
> In the beginning of the year 1757 Mr Dollond having tried the … 8th Expt. of the 2d part of the first book of Newton's *Opticks* and by that means having discovered the new principle which was that the dissipation of the different coloured rays was not in the same proportion to the mean refraction, in water as in glass ...

The key point was still Newton's error in the *Opticks*.

The Herschels and their Future

William Herschel came from Germany to England in 1757, driven by adverse fortune in the Seven Years War and seeking a living as a musician. He was successful as an organist, impresario, teacher and composer, and was appointed organist to the Octagon Chapel in Bath in 1766. Here he was joined by his sister Caroline, who was a talented singer.

Herschel was drawn into astronomy in a manner typical of the amateur in the eighteenth century: he read James Ferguson on Newtonian astronomy and then Robert Smith's *Opticks* with its instructions for making mirrors, he joined the Bath Philosophical Society and he began to make and use his own telescopes. Herschel stood outside the world of professional astronomers and his agenda was quite different from theirs. He quickly began to increase the size of his reflecting telescopes so as to enhance his view of the wonders he was discovering in the heavens.



Herschel might have remained an enthusiastic amateur and his ambitions for stellar astronomy ignored but for his extraordinary discovery of a planet in the solar system, the first such discovery in the entire history of written astronomy. On 13 March 1781 Herschel noted 'a curious Nebulous Star or perhaps a Comet'; this turned out to be the planet subsequently named 'Uranus'. Herschel was made a fellow of the Royal Society, awarded the Society's Copley Medal, and granted a pension by George III. He abandoned music for full-time astronomy. However outlandish his future plans for building telescopes, however imaginative and even embarrassing his speculations, he could not be ignored.

An essential ingredient in Herschel's success was the manual skill he developed for grinding and polishing metal mirrors. Herschel had begun polishing in 1773 but in March 1778 he embarked on a systematic series of experiments on casting, grinding and polishing, while carefully recording his procedures and results. Part of his manuscript record of his polishing experiments is in the exhibition.

Although the reflecting telescope was introduced by Newton because he believed that the refractor could not be improved, the discovery of Newton's mistake and the recovery of the refractor's fortunes in astronomy did not spell the end of the reflector. Herschel had mapped out a programme for investigating the universe at large in parallel with the instrumental ambitions that would make it possible. The prospect was a compelling one outside the more narrow agenda of professional astronomy and it survived Herschel into the nineteenth century and beyond.

Although it was an 'amateur' vision in the eighteenth century, Herschel had imagined giant reflectors looking deep into space and back in time, detecting unknown galaxies, discovering the physical arrangement of the entire universe and tracing its evolution over time. It was a vision that seemed deranged to some of his contemporaries and Herschel himself 'fit for Bedlam', but it closely resembles the programme of modern astronomy.

William Herschel's largest telescope, of 40ft focal length and a mirror of 4ft diameter. Image courtesy of the Royal Astronomical Society