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“FOR THE GOOD OF ASTRONOMY”: THE MANUFACTURE, SALE, AND DISTANT USE OF WILLIAM HERSCHEL’S TELESCOPES

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According to an entry following that for 29 October 1783 in his autobiographical memorandums, it was at the behest of King George III that William Herschel began to sell reflecting telescopes. “The goodness of my telescopes being generally known”, Herschel wrote,

I was desired by the King to get some made for those who wished to have them. Getting the woodwork done by his Majesty’s cabinetmaker, I fitted up five 10 feet telescopes for the King, and very soon found a great demand for 7 feet reflectors. This business, in the end, not only proved very lucrative, but also enabled me to make expensive experiments for polishing mirrors by machinery.¹

The King placed his order within weeks of Herschel’s acceptance of a pension that would allow him to dedicate himself to astronomy, his only duty being to reside near Windsor Castle and be available to show his instruments to royal visitors when so requested. George was to present a 10ft reflector as a gift to the fourth Duke of Marlborough (Figure 1), to the Count de Brühl, and to the University of Göttingen in his native Hanover, while a fourth went to his own observatory at Kew. According to his polishing log, Herschel cast the mirrors between October 1783 and February 1784.² For his efforts, Herschel received £787, nearly four times his annual pension of £200.³

While much scholarly attention has focused on the telescopes with which Herschel observed,⁴ very little has been written on the manufacture, marketing, and distant use of his ‘commercial’ instruments,⁵ and much of what exists in print is woefully inaccurate (itself an indication of the low estimation of the business). Herschel’s venture into the market place has been a matter of embarrassment and discomfort for his many biographers. “This was telescope-selling,” James Sime harrumphed, “not star-observing. It cost time and trouble, that might have been devoted to better purpose”.⁶ In Sime’s view, an activity so patently commercial as selling telescopes was beneath the dignity of the astronomer, no matter what the dividends:

An arrangement so unwise, from the shopkeeping look it wore, should not have been proposed or sanctioned. It was a source of profit to the astronomer; but it did not differ from allowing Herschel to set up a factory for the manufacture and sale of telescopes with the Royal arms over the door, and “By Appointment Royal Astronomer to the King” painted underneath.⁷

Other biographers have shared Sime’s distaste. “Herschel did not come into the world to drive a lucrative trade”, Anges Clerk opined. “It was undertaken, not for

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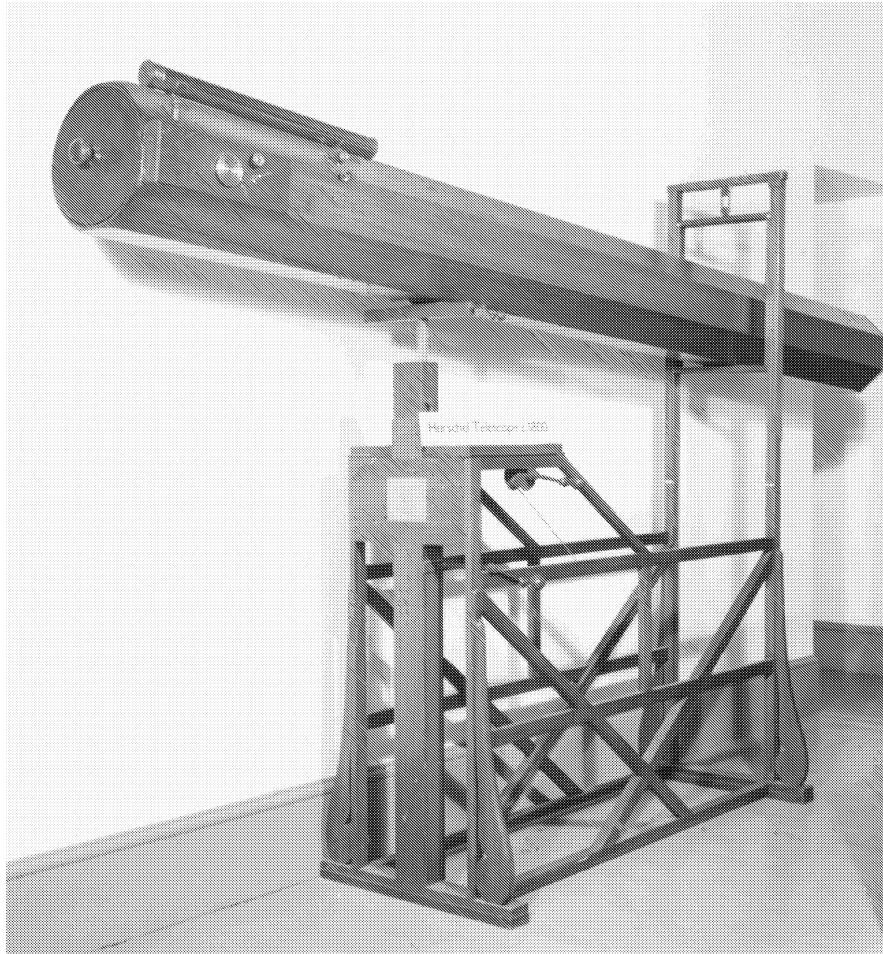


FIG. 1. The 10ft reflector presented by King George to the fourth Duke of Marlborough, and now in the Whipple Museum of the History of Science, Cambridge University.

itself, but for what was to come of it; yet there was danger lest the end should be indefinitely postponed in the endeavour to secure the means.”⁸ Angus Armitage summed it up: “It may seem a matter of regret that the great astronomer’s time and energy should have been taxed in this manner, to so little purpose.”⁹

The prevailing view of the business — as one undertaken reluctantly, and under financial duress — owes much to the unflattering manner in which Caroline Herschel described the venture.¹⁰ After cataloguing the expenses incurred by relocating to Datchet in 1782, travelling back and forth between Bath, Windsor, and London,

and improving the 20-foot telescope, Caroline suggests that her brother was forced to ply the telescope trade for want of being adequately provided for by the King. “It seemed as if it was supposed”, she wrote,

enough had been done to enable my Brother to leave his profession [music] that he might have time to make and sell Telescopes, and the King ordered four 10 feet himself and many 7 f besides had been bespoke. Much time had already been expended on polishing the mirrors for the same. But all this was only retarding the work of a 30 or 40 f Instrument which was the chief object to obtain as soon as possible. For he was then on the wrong side of 45 and felt the injustice he would be doing to himself and to the cause of Astronomy by giving up his time to making telescopes for other observers.¹¹

If Herschel plied the telescope trade (Caroline and other writers maintain), then he did so merely to supplement his income and to help pay for the construction of the 40ft telescope. Furthermore, they suggest that as a commercial undertaking, the business had little or nothing to do with Herschel’s more important astronomical endeavours. But Caroline’s account of the business, and by extension, all those that have come to rely upon it, need to be weighed against other surviving documents. This paper will therefore reconstruct when the telescopes were made, what observers did with them, and why Herschel built them. By making telescopes for other observers, it will be argued, he helped not only fund his experiments to automate the grinding of mirrors, but also to ensure the diffusion and acceptance of his observations.

1. *The Business of Astronomy*

Drawing upon Caroline’s account, Herschel’s biographers have assumed that the bulk of the telescope commissions were undertaken between 1782, when he was named court astronomer at Windsor, and 1785, when he received funds to build the 40ft reflector. In his *History of the telescope*, for example, King asserts that the majority of the telescopes Herschel sold were “constructed during his three years at Datchet”.¹² According to Caroline, it was only through the timely intercession of William Watson, Jr, who played a part in securing Herschel £2000 from the King towards the cost of the 40ft in the summer of 1785, that Herschel was saved from such “unproductive” toil:

[Dr Watson] saw my Brothers difficulties and expressed great dissatisfaction. And on his return to Bath he met among the Visitors there several belonging to the Court..., to whom he gave his opinion concerning his Friend and his situation very freely. In consequence of which soon after my Brother had through S^r J. Banks the promiss that 2000 pounds would be granted for enabling him to make him self an Instrument.¹³

The four-volume manuscript, “Experiments on the construction of specula”, in which Herschel recorded all the work of casting, grinding, and polishing specula, is at odds with Caroline’s account. Had he been hard at work making telescopes for

others during his years at Datchet, one might reasonably expect to find some record of the activity in what were essentially his 'lab notebooks'. And yet, between June 1781 and July 1785, Herschel made only twenty-four entries.¹⁴ These entries record work on his own 20ft mirrors, the five mirrors he cast for the King, and a few mirrors he made or repolished gratuit for friends and neighbours.¹⁵ He had spent his first year at Datchet (August 1782 to October 1783) designing and building the 20ft with which he was to do his greatest work as an observer, and experience in the use of the instrument with its wholly novel mounting called for a succession of improvements that evidently preoccupied him. For example, in 'sweeps' for nebulae the telescope was directed to the south and the sky allowed to drift slowly past while Herschel kept watch for any nebula that came into view. To increase the area of sky covered in a sweep, a workman was employed to raise and lower the telescope over a range of 2° . In 1784 Herschel devised a mechanism to warn the workman when he had reached the upper or lower limit and should reverse his winding of the handle, but it was not entirely satisfactory, and in 1785 an improved mechanism was introduced.¹⁶ Such improvements were central to his programme of observations and took precedence over any outside activities.

And so it was that although Herschel received a couple of requests for telescopes before 1785, it was only at the beginning of that year — when it still seemed he might have to fund the 40ft himself — that he took the decision to make telescopes for private sale and so entered the telescope trade. His friend Magellan wrote to Johann Bode on 21 January 1785:

He promised me that he would produce under his supervision (merely to support the work of astronomy and not for his own interest) this sort of telescope of his own invention, which may be ordered for European observatories through me, and also that he will finish the mirrors with his own hands. A telescope of 7 foot focal length with all of the accessories of eyepieces and micrometer costs about 200 Guineas. They are very light and the mounting can be moved by a single person. The 10ft telescope, of which he's making four for the King now, requires an expenditure about 600 Guineas, and one of 20 feet, with all the needed movements included, costs 2500 to 3000 Guineas. I ask you to make this news of astronomical science known.¹⁷

Over the course of the next thirty years, Herschel sold upwards of 80 reflecting telescopes or mirrors (compared, for example, with the 1,370 Gregorian reflectors made by James Short¹⁸), and this earned him more than £15,000.¹⁹ The majority of these telescopes, most of which were 7ft or 10ft in focal length with mirrors of six inches and nine inches respectively, were made between 1785 and 1801. In the twilight of his life, Herschel made a list of instruments he had made for others, but unfortunately did not record when the instruments were sold.²⁰ Examination of Herschel's correspondence and polishing logs, however, shows that Herschel sold about fifteen reflectors between 1785 and 1788, twenty-two more between 1789 and 1794,

fifteen between 1795 and 1801, two in 1805, and seven between 1811 and 1814. Twenty-five telescopes and mirrors, mentioned in Herschel’s list of telescopes sold, cannot be dated, but were undoubtedly undertaken after 1785.²¹

Aside from Schroeter’s request for a mirror in 1783, there is only one inquiry in Herschel’s correspondence, prior to 1785, as to whether he would make telescopes for other observers. When the German astronomer Christian Mayer wrote to Herschel in 1782 asking whether he would make telescopes for sale, Herschel replied:

I made telescopes only to indulge the very great love I had for astronomical observations, therefore it will at present not be possible to furnish you with such a one; but I believe in a short time I shall give the model of my instruments and the method of making the Specula to some optician, and if that is found practicable, I suppose one of my 7 feet Telescopes might be made for about 50 Guineas; but I fear opticians will hardly bestow that excessive care and attention which are necessary to form a truly parabolic Speculum of a considerable diameter.²²

Herschel’s plan to contract with an optician never materialized. As Caroline noted in 1783, when her brother “had an opportunity of looking about for Mathematical workmen Obicians and Foundries &c.”, he found that “all what was done in Town seldom answered expectation”.²³

By the summer of 1785, however, Herschel found the right craftsman for the job: his brother Alexander.²⁴ He also drafted his sister Caroline to help out with the enterprise. Just as she had been trained as a singer and music copyist when it suited her brother, so too was she trained to lend a hand in the workshops when his interests turned to telescope making. “I became in time as useful a member of the workshop as a boy might be to his master in the first year of his apprenticeship”, she wrote.²⁵ Caroline often performed the more menial tasks, such as cleaning the brass work for 7ft and 10ft telescopes, though she was also entrusted with the rough grinding and finishing of some 7ft and plain mirrors.²⁶ As Herschel’s amanuensis, Caroline was later kept busy copying the directions for the assembly and use of the many telescopes despatched from Slough.

Herschel’s foray into the commercial telescope market thus began in earnest in the summer of 1785, just as construction on the 40ft reflector was about to get under way. Some of his workmen evidently did double duty, making parts for 7ft and 10ft telescopes. Writing from Datchet in July 1785, William told his brother that

I have bought a complete set of tools for working in Brass; erected a small forge; have a Brass workman; the Cabinet maker is employed; the Joiner at work; the Smith forging away, so that I hope to get some instruments finished pretty fast. My Brass Man (as we call him) is a stupid fellow, but knows a good deal of the business. When you come he shall be your journey-Man.²⁷

How long, and in what capacity the various artisans worked for Herschel is unclear. What is clear is that Herschel did not always craft every piece of every telescope he sold. For example, the King’s cabinet maker made the mahogany stands for the five

10ft telescopes purchased by George III (hence the reduced price for the instruments), and continued to make telescope stands for Herschel until at least 1801, as evidenced by a letter of that year, in which Herschel inquired as to whether or not “the tube and two stands are finished”.²⁸ Even optical parts were sometimes made by others. As Herschel confided to the instrument maker Tiberius Cavallo, who had ordered a 7ft instrument, “the eyepieces would have been done before now, if the work had only fallen to the share of my workmen; but I had the pattern to prepare to send to Tom to be cast, the tube to be drawn, the glasses to be made, etc.... As soon as I have them my men can begin to set them which will take about 10 or 12 days”.²⁹

As nearly all of the telescopes were sold after the King had (if grudgingly) provided further funding for the 40ft telescope together with a generous allowance for its upkeep, Herschel did not need to finance its construction by selling telescopes.³⁰ Moreover, his marriage to the wealthy widow Mary Pitt in 1788 largely freed him from pecuniary concerns.³¹ And yet, the business was just taking off at a time when the Herschel household found itself in comfortable circumstances. While the financial rewards of the business (perhaps as high as £20,000) were probably a factor in his decision to make telescopes for other observers, the potential return was by no means the only consideration. Throughout the 1780s, astronomers and opticians expressed scepticism about Herschel’s instruments and magnifying powers, his observing techniques, and his observations. In a letter of 1785, for example, Cassini IV confided to Herschel that “many fear that your telescope is subject to optical illusions”.³² Herschel’s telescope business needs to be examined in the context of such challenges.

2. “*For the Good of Astronomy*”

Herschel’s “On the parallax of the fixed stars” and his “Catalogue of double stars”, read before the Royal Society in December 1781 and January 1782,³³ respectively, were greeted with some scepticism, owing in large measure to the unprecedented magnifications Herschel reported using. Watson wrote to Herschel explaining that

few are inclined to give you credit for your assertions. What, say your opposers, Opticians think it no small matter, if they sell a telescope [that] will magnify 60 or 100 times, and here comes one who pretends to have made some, which will magnify above 6,000 times — is this credible? So that by what I can learn, the trade as well as astronomers oppose your pretensions.³⁴

Among those who challenged his claims were the instrument makers Edward Nairne³⁵ and Jesse Ramsden,³⁶ who questioned the ability of anyone to see anything with the magnifications Herschel employed, and astronomers like Alexander Aubert³⁷ and Nevil Maskelyne,³⁸ who suspected that he had made an egregious error in measuring the power of his oculars.³⁹ Watson consoled Herschel that “your facts will be verified”, but cautioned that “in the meantime, it will be necessary for you to take such measures as may as much as possible counteract the effects of this opposition”.⁴⁰

He further advised his friend to “get some scientific persons to observe with your instruments and by the testimony of others authenticate your facts; particularly as to seeing the stars without aberration, as well as seeing any one of them magnified 6,000 times”.⁴¹

Herschel set out to blunt the criticisms of his foes, and to enlist the support of leading astronomers and instrument makers. He wrote to Aubert, his friend and a wealthy astronomy enthusiast who maintained one of the best-equipped private observatories of the day. “I find by my very excellent friend Dr. Watson”, he said,

that my observations will stand much in need of the protection of some kind gentleman well known in the astronomical line, who may give credit to them by his own observations; Give me leave to beg of you (for the love of Astronomy’s sake) to lend your assistance, that such facts as I have pointed out may not be discredited merely because they are uncommon.⁴²

Herschel enclosed a set of star charts, with the location of his double stars marked in red ink, “to try your telescopes upon”. Maskelyne, Astronomer Royal, and the Rev. Thomas Hornsby, the Savilian professor of astronomy at Oxford, also received copies of the charts. “Several of the facts I have reported being uncommon,” he explained to Hornsby, “[they] stand a fair chance of being discredited till they are verified by some well known astronomer”.⁴³ Cavallo found Herschel’s approach amusing. He confided to his friend Dr James Lind that “by calling me to witness the stars, [Herschel] inverts the common order of things; for I always heard, that the stars were called upon in every age to witness human affairs, but never that men were requested to witness the duplicity of the stars”.⁴⁴

Although Aubert eventually, with some coaching from Herschel, managed to resolve many of the double stars, and promised to help “convince the world that although your discoveries are wonderful, they are not imaginary”,⁴⁵ other observers encountered greater difficulties. After repeated attempts to resolve some of the fainter doubles, an exasperated Maskelyne wrote to Herschel that his double stars “must make every astronomer tremble for his telescopes, lest they should not enable him to see what you describe”.⁴⁶ When other astronomers failed to resolve the objects he reported, Herschel was careful to fault their instruments, rather than their competence as observers.⁴⁷ In reply to a letter from the German astronomer Johann Bode, Herschel wrote that “I believe that your Dollond will give you a perfect view of some of the double stars with a magnification of 300, but there are some that demand more and that you will never be able to see with such an instrument”.⁴⁸ Christian Mayer, who had been one of the first to study and catalogue double stars, was similarly unable to duplicate many of Herschel’s observations. “You will find that I account for the difference in our observations on some stars”, Herschel explained, “from the difference of our instruments. The power of your mural Quadrant I suppose to be about 70 or, at least not exceeding 100. Mine begins at 227 and goes on to 1,2,3,4,5,6 thousand”.⁴⁹

In his “Second catalogue of double stars”, published in *Philosophical transactions*

in 1784,⁵⁰ Herschel claimed that other observers would not be able to reproduce many of his observations, particularly those belonging to his ‘first class’ of double stars. “As these are some of the finest, most minute, and most delicate objects of vision I have ever beheld”, he wrote, one ought “not condemn his instrument or his eye if he should not be successful in distinguishing them”.⁵¹ He assumed that, on the basis of those stars that they could resolve, other astronomers would “be inclined to give some credit” to those they could not. Herschel sought to make recognition of faint doubles the benchmark of how much light an instrument gathers, and doubles with a small angular separation the test of the ‘distinctness’ of the image.⁵² But since the ‘doubleness’ of Herschel’s double stars was itself a matter of controversy, the success or failure in resolving them had to be determined through negotiation.⁵³ Were his telescopes, as Cassini’s colleagues suspected, “sujet à des illusions optiques”?⁵⁴ Eighteenth-century telescopes were, after all, subject to a host of defects. A spurious internal reflection had led James Short to argue that Venus had a small moon that exactly mirrored the planet’s phases.⁵⁵

Faced with such challenges, Herschel stressed the limitations of the refractor, and the superior light-gathering power of his reflectors. In his 1786 “Catalogue of one thousand new nebulae and clusters of stars”, for example, Herschel wrote that “some of the nebulae which I have called very bright, and very large, may only be just perceivable, as very faint small patches, in many of our best common telescopes”.⁵⁶ No astronomer wanted to be stuck with a ‘common telescope’, and when Herschel announced in 1785 that he would make telescopes for those who wished to have them, he found an eager market — one that he had done much to create. Typical of the requests he received was that of the Italian astronomer Giuseppe Piazzi, who asked Herschel to make him a 7ft reflector. “I want to establish an observatory that might contribute to the progress of astronomy”, he explained. “It would be a pity, if I were restricted to see only the sky visible to ordinary telescopes.”⁵⁷ A few years later, the Milanese astronomer Barnaba Oriani begged Herschel to make him a telescope “pour le bien d’astronomie”.

Several astronomers have had the good fortune to obtain from you, Monsieur, excellent seven foot telescopes, the astronomers of Milan, who for a long time have read in the *Philosophical transactions* of the astonishing discoveries that you have made in the heavens, desire to see with one of these telescopes a small part of the marvels, that you have so well described in your memoirs. I must beg you, Monsieur, to make us one of these instruments.⁵⁸

Herschel’s biographers give the impression that nearly all of the telescopes he made for others languished unused in the drawing rooms of wealthy dilettantes. Clerke, for example, complained that “not an observation worth mentioning was made with any of the numerous instruments sent out from Datchet or Slough, save only those acquired by Schroeter or Pond. The rest either rusted idly, or were employed ineffectually...”⁵⁹ Yet many of the telescopes found their way into the major observatories of the day. Herschel (see the Appendices) made telescopes for such prominent astronomers as

Nevil Maskelyne and John Pond at the Royal Greenwich Observatory, James Hamilton at Armagh, Abraham Robertson at the Radcliffe Observatory, Robert Blair at Edinburgh, Alexander Daune at Aberdeen Observatory, and Patrick Wilson at Glasgow University’s observatory. On the Continent, Johann Schroeter at Lilienthal, Johann Bode at the Berlin Academy of Sciences, Baron von Zach at Seeberg Observatory, Karl Seyffer at Göttingen, Piazzi at the Palermo Observatory, and Oriani at the Brera College Observatory acquired telescopes from Herschel, as did the royal observatories at Madrid (Figure 2), Hesse-Darmstadt and St Petersburg.

A number of amateur astronomers purchased telescopes from Herschel. These included the Saxon ambassador to England, the Count de Brühl, who built a private observatory at his villa in Harefield. He was a patron of the clockmaker Thomas Mudge, and of the Baron von Zach, who later headed the Seeberg Observatory in Sax Gotha. The King presented one of the five 10ft reflectors to de Brühl, who later purchased a 7ft as well. John Lloyd, FRS, a long-time correspondent of Aubert’s (and visitor to Slough), built a large and well furnished observatory on his estate at Hafvordanos in Wales, which he later equipped with a Herschel reflector.⁶⁰ Aubert acquired three telescopes from Herschel and used them at his observatory at Loampit Hill and later at his observatory at Highbury.⁶¹ Aubert lived down the street from Captain Joseph Huddart, FRS, a retired naval officer who purchased a Herschel telescope, which he erected in his backyard observatory at Highbury Terrace.⁶² Many other British amateurs (such as William Hodgson and James Ferguson) and instrument makers (such as George Edwards and Edward Nairne) acquired telescopes from Herschel and erected them in private observatories.⁶³

On the Continent, amateurs like Baron Friedrich von Hahn purchased a 7ft reflector from Herschel, and two mirrors, of 12 and 18 inches in diameter, which he mounted himself at his observatory in Remplin.⁶⁴ The Count de Gessler, a minister in the Königlich Preussischer Geheimer Finanzrath in Berlin, acquired a 7ft reflector from Herschel around 1790, when he relocated to Dresden.⁶⁵ There he befriended Johann Gottfried Köhler, ‘Inspektor’ of the Mathematical Salon in Dresden, who purchased a mirror from Herschel and mounted it in a tube and frame.⁶⁶ Other German purchasers included a Mr Pangh of Duren (in 1787), a Mr Vogel in Danzig (date unknown), and a Mr Haussman (in 1811).

Herschel hoped that others would use the reflectors to verify his observations.⁶⁷ What the many recipients actually did with them can be gleaned from Herschel’s correspondence. Bode, Schroeter and Pond all turned their reflectors towards the double stars of his catalogues. Edwards reported seeing “ Σ Bootes & several other Double stars in great perfection”, as did Hodgson, who wrote that he was “gradually looking at the double stars you have pointed out”.⁶⁸ William Giningham, an assistant at Armagh Observatory, reported that he and Dr Hamilton had used the 10ft Herschel reflector to repeat Herschel’s observations on Jupiter’s rotational period. While he praised the “excellent reflector”, Giningham confessed, “I sometimes wish it provided with a rough right ascension and declin. arch as the difficulty of finding Clusters, nebulae &c without it is extreme to young astronomers”.⁶⁹ Andrew Ure of

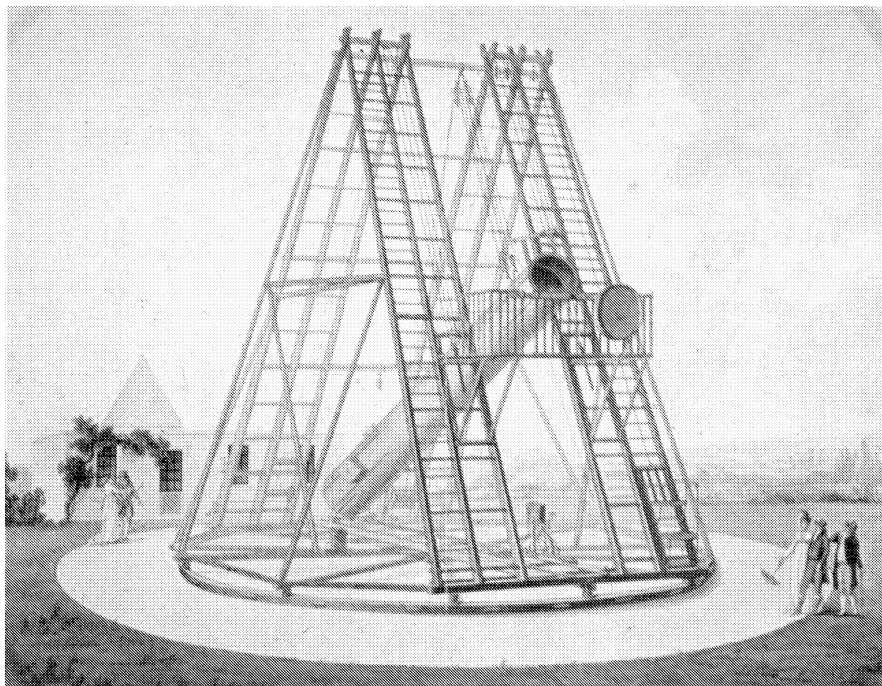


FIG. 2. The 25ft reflector that Herschel made for the King of Spain. The most successful of his large instruments, it was erected in Madrid in 1804, only for the mounting to be destroyed by Napoleonic troops in 1808. From a watercolour supplied with the telescope, courtesy of Madrid Observatory.

Glasgow Observatory (and later author of *The philosophy of manufactures*⁷⁰) commented obscurely that “the noble instruments of your fabrication which we possess have enabled me to see ... the perfect correspondence between your delineations and the phenomena of nature”.⁷¹

The many letters that were sent from Datchet and Slough, filled with references to faint nebulae, lunar volcanoes, and other discoveries, fired the imaginations of the readers of *Astronomisches Jahrbuch*. As von Hahn confided to Herschel, “the love of astronomy is starting to spread in Germany. What is more, your great discoveries have contributed to this”.⁷² German observers purchased telescopes and mirrors from Herschel in large numbers to observe these celestial objects. Schroeter was the most active of these, referring to his 4ft or 7ft Herschel reflectors in dozens of publications and letters to colleagues.⁷³ With these instruments, along with a *Herschelische Lampenmikrometer*, he observed black spots on the surface of Jupiter, hunted for Algol’s hidden *Sternchen*, or companion star, studied the *Lichtpunkte* on the Moon, which Herschel had described as erupting volcanoes, and measured Venus’s rotational

period. After observing the crater Aristarchus, the reported site of one of Herschel’s lunar volcanoes, Schroeter concluded that it was unexceptional.⁷⁴ Bode examined the *Lichtpunkte* in a lengthy article. “It is of course true, that when the Moon stands in the morning sky and it is night on the western half, the terminator moves closer to Aristarchus; by itself, what does the darkened Moon’s burning volcanoes have to do with this arc? And is its fire supposed to appear less bright, whether that region lies closer to or further from the rising and setting of the Sun?” Bode wondered how fiery eruptions could occur on the Moon, since it has “no atmosphere”.⁷⁵

Göttingen’s 10ft reflector, which Herschel delivered in person in 1786, was employed by two generations of observers at the university. After looking at the Moon through the instrument, Georg Christoph Lichtenberg enthused about the instrument, saying that “the Herschel telescope, with which the King has equipped our observatory, is the most perfect work of this art, that I have seen in my life...”.⁷⁶ Professor Karl Seyffer used the reflector to time lunar occultations of stars between January and March 1794.⁷⁷ Karl Ludwig Harding, professor of astronomy at Göttingen, discovered the comets 1813 II, 1824 II and 1832 II with this instrument.⁷⁸ At Seeberger Observatory, Baron von Zach used the 7ft Herschel reflector between 1790 and 1795 to time transits of Jupiter’s moons, examine lunar craters, and observe Saturn’s satellites.⁷⁹ He also timed transits of Jupiter’s moons in 1797 and 1798 and occultations of stars by the Moon in 1798 and 1799.⁸⁰

Baron von Hahn, who maintained a large astronomical library and observatory on his estate at Remplin, published several papers on planetary nebulae, the planets, and the Sun, which he observed with his 7ft and a 20ft Herschel reflector.⁸¹ In 1800, he discovered the faint central star of M57 — a star that had eluded Herschel’s keen eye.⁸² Finally, J. G. Köhler in Dresden, who purchased a mirror from Herschel, published observations of Jupiter made with the completed instrument in 1792.⁸³ Together with his friend the Count de Gessler, who also owned a reflector by Herschel, in May 1799 he observed the transit of Mercury across the Sun’s disk using Köhler’s reflector at the Mathematical Salon in Dresden.⁸⁴

3. *Herschel as Mechanic, Improver and Entrepreneur*

In 1792, with the 40ft completed and his telescope-making business established, Herschel decided to take a holiday. From May to August, he toured the leading manufactories of England with his friend, the Polish General Komarzewski. The two had corresponded for years.⁸⁵ The companions set off for Birmingham, where they dined with James Watt, Samuel Galton, James Keir, and William Withering — all members of the Lunar Society.⁸⁶ On 6 June they toured the Soho Iron works.⁸⁷ Herschel watched as “iron made from pigs [was made] into malleable Iron by putting it into the finery — (they call it a finery; it should be refinery perhaps) and by stirring and melting a good while with coke it coagulates into lumps”.⁸⁸ While in Birmingham, the travellers marvelled at pressing engines, a reverbatory air furnace, and a machine for boring cylinders. In mid-June, they headed northward, passing the famous iron

bridge at Colebrook Dale, visiting a cotton mill in Manchester, and touring a glass works. Along the way, Herschel made dozens of sketches in his journal, of bellows, ratchet wheels, cranks, pistons, boilers, condensers, gears, levers, furnaces, and steam engines. After touring various manufactories in Glasgow, they finished the northern leg of the trip in Edinburgh, where they examined machines for scouring, carding, and spinning wool.

If scholars have thus far paid little attention to Herschel's telescope-making enterprise, then part of the reason lies in their view of the astronomer as a gentleman cosmologist and observer, and not as, for example, a successful entrepreneur and mechanic. Typically, artisans made and sold instruments; gentlemen purchased and used them. This social divide helps to explain why Herschel's mechanical and optical work is often treated as a qualitatively different sort of enterprise from that of contemporary instrument makers like Edward Nairne, Jesse Ramsden, or Peter Dollond. Since Herschel did not advertise his telescopes (though one could argue that Herschel's praise of his own instruments in *Philosophical transactions* constituted advertising), nor open a shop on Fleet Street, historians have concluded that Herschel had little in common with the commercial world of instrument makers. Herschel was, after all, astronomer to the King, a recipient of royal patronage, and a member of the Royal Society, a body to which few instrument makers were admitted.

But as his factory tour suggests, Herschel was fascinated by machinery and shared the Enlightenment's enthusiasm for improvement.⁸⁹ In this respect, he was typical of a growing coterie of improver types in the Lunar Society of Birmingham and the Royal Society. While Herschel's circle of friends included scientific luminaries, he also rubbed shoulders with leading entrepreneurs, engineers and businessmen, such as James Watt and Matthew Boulton, both of whom were astronomer enthusiasts.⁹⁰ Watt was sufficiently impressed with Herschel's mechanical ingenuity that he would call upon him as an expert witness in the case of *Watt v. Bull* in 1793. The celebrated engineer John Smeaton, whose ingenious design of the Eddystone lighthouse won him wide acclaim, was an occasional visitor at Slough as well as being a close friend of Alexander Aubert; he was also an astronomy enthusiast and applied his engineering knowledge to designing observatories for Matthew Raper, John Lloyd, and Aubert.⁹¹ Aubert, in addition to being an avid astronomer, headed the London Assurance Company and the Committee for the Improvement of Ramsgate Harbour. Joseph Huddart, an acquaintance through the Royal Society and occasional visitor at Slough, invented a machine for winding cordage that distributed the strain upon the yarn equally throughout the cable; the former East India Company captain set up a manufactory in Maryport and retired to Highbury Terrace, where he constructed a small observatory and undertook various astronomical projects.⁹² Finally, Sir Joseph Banks, Herschel's patron and the President of the Royal Society, sought to strengthen British commercial self-sufficiency by linking science with the purposes of empire.⁹³ Herschel was thus no stranger to the world of patents, machinery, and improvement.⁹⁴

Throughout the 1780s, Herschel sought, as he confided to Lalande, "to improve

the telescope, and to reduce the art of making them, to a certainty”.⁹⁵ After finding his telescopes superior to those of Aubert and Maskelyne, he boasted to Caroline, “Let me but at it again! I will make such telescopes, and see such things...”.⁹⁶ Herschel’s experiments to polish mirrors by machine began in January 1789. No doubt the arduous task of grinding and polishing the massive 48-inch mirror, and the need to supply mirrors for the many 7ft and 10ft telescopes orders that poured in, played a role in Herschel’s desire to mechanize this aspect of telescope construction. Between January and April 1789, Herschel designed and built machines for polishing 7ft, 20ft, and 40ft mirrors.⁹⁷ The work proceeded quickly. As Herschel noted,

It will be supposed that the invention of a polishing apparatus would require a number of trials, but my long experience polishing mirrors by hand was here of great importance, for I had only to invent the method of giving that motion to a mirror which I already knew it ought to have, and when I failed it was because the machine did not do what I intended it should do, and the cause of the failure generally pointed out the remedy.⁹⁸

The polishing machines helped Herschel keep pace with telescope orders. By 1794, when the Empress of Russia inquired as to the prices and sizes of telescopes Herschel sold, he could reply that he had “machines prepared to make telescopes of nine sizes”.⁹⁹ Herschel’s efforts to reduce the grinding and polishing of specula to a certainty survives in the polishing machines he created, and the mirrors produced by their operation. But the planned treatise on polishing mirrors never materialized, much to the later consternation of Lord Rosse.

4. *Conclusions*

Herschel did not sell telescopes during the financially lean years at Datchet, as Herschel’s many biographers have assumed. Caroline’s suggestion that her brother made telescopes simply to make ends meet, or to finance the 40ft instrument, needs to be reevaluated in light of the fact that nearly all the instruments were made after the great telescope was financed and under construction. The sale of telescopes did help defray the costs of experiments to mechanize the grinding of mirrors, as Herschel claimed, but they also paid another dividend. By making telescopes for other observers, Herschel enabled them to reproduce many of his observations on double stars and nebulae. In this respect, Herschel’s efforts mirror those of Galileo, who distributed his telescopes to other astronomers that they might verify his discoveries.

TABLE 1. List of dated Herschel reflectors and mirrors made for other observers.

Year	Item	Purchaser	Dreyer ¹	Maurer ²
1781	7ft mirror ³	John B. Bryant (<i>fl.</i> 1779–92), member of Bath Phil. Soc.	no	no
1781	Gregorian mirror repolished, 18 June 1781 ⁴	Thomas Parsons (1744– 1813), member of the Bath Phil. Soc.	no	no
1783	Optics for 4ft reflector ⁵	Johann Hieronymus Schröter (1745–1816), Chief Magistrate of Lilienthal	no	C–8
1784	9½-inch mirror repolished ⁶	Alexander Aubert, FRS (1730–1805), Governor, London Assurance Company	no	no
1785	Five 10ft reflectors, ordered Oct. 1783, completed by 1786 ⁷	King George III	five: £787.10s	B–4 B–5 B–22 B–24
1786	7ft reflector ordered (completed 1788) ⁸	Duke of Saxe Gotha	no	no
1786	2 mirrors, eyepieces, focuser, and other parts for 7ft reflector ⁹	Johann Hieronymus Schröter	£65	C–7
1787	Optics for 7ft reflector ¹⁰	J. P. Pangh of Duren	£31.10s	no
1787	7ft reflector ordered (delivered 1790) ¹¹	Graf von Gessler, minister in the Königlich Preussischer Geheimer Finanzrath, Berlin	£105.8s	no
1787	7ft reflector delivered ¹²	Tiberius Cavallo, FRS (1749–1809)	no	no
1788	7ft reflector ¹³	Dr Robert Blair (1748– 1828), from 1785 Prof. of Practical Astronomy, Edinburgh Univ.	£71	B–10
1788	7ft reflector delivered ¹⁴	Dr Nevil Maskelyne, FRS (1732–1811), Astronomer Royal	£105	B–16
1788	Optics for 7ft reflector ordered (delivered autumn 1790) ¹⁵	Stockholm Observatory	£31.10s	C–4
1788	7ft reflector ordered ¹⁶	Princess Daskow (1744– 1810)	£168	no
1789	One of two 7ft reflectors ¹⁷	Duke of Tuscany	£105	B–7
1789	7ft reflector delivered ¹⁸	L'Abbé Fabarel, of Dijon, France	£105	no
1789	Optics for 7ft reflector ¹⁹	Johann Gottfried Koehler (1745–1801), Inspector, Dresden Mathematical Salon	no	no
1789	7ft reflector ²⁰	Abbé Fontana	£105	no (maybe B–32?)
1790	7ft reflector delivered (Dec.) ²¹	Giuseppe Piazzi (1746– 1826), director, Palermo Obs.	£105	B–13
1790	Optics for 7ft reflector ²²	Count Knühl	£31.10s	no
1790	7ft reflector ²³	Mr Newenham	£105	no

Table 1 continued]

1790	7ft reflector ²⁴	Mr Henry of Dublin	no	no
1790	7ft reflector ordered (delivered 1792) ²⁵	Dr Martinus van Marum (1750–1837), experimenter at Teyler’s Museum, Haarlem	£105	B–14
1790	7ft reflector shipped to Spain ²⁶	Spanish Ambassador	£117.12s	B–29
1791	Large 7ft reflector delivered ²⁷	Baron Friedrich von Hahn (1742–1805), per financial agent O. Daclin	no	B–26
1791	7ft reflector or mirror ordered (delivered 1793) ²⁸	George Gottlieb Schmidt (1768–1837)	no	
1792	7ft reflector ordered (delivered 1793) ²⁹	Barnaba Oriani (1752–1832), director, Milan Obs.	£105	B–8
1792	12-inch mirror for 20ft reflector, and two eyepieces, ordered (delivered c. 1794) ³⁰	Baron von Hahn of Mecklenberg	no	C–2
1792	10ft reflector ³¹	Dr Patrick Wilson (1743–1811), Prof. of Practical Astronomy, Glasgow Univ.	£80	B–9
1793	10ft reflector ordered (delivered Sept. 1795) ³²	Dr James Archibald Hamilton (1747–1815), director, Armagh Obs.	£210	B–23
1793	Optics for 7ft reflector ³³	Ludwig X	£63	C–3
1793	7ft reflector ³⁴	Count de Brühl (1736–1809)	£105	maybe B–19
1793	10ft reflector ordered (delivered 1794) ³⁵	George Edwards, instrument maker	£210	no
1794	10ft reflector ordered (delivered 1796) ³⁶	Empress Catherine II of Russia (1719–96), possibly gift from George III	£210	B–25
1794	7ft reflector ordered (it arrived Lisbon, Dec. 1796) ³⁷	John Pond, FRS (1767–1836), Astronomer Royal from 1811	£31.10s	
1794	7ft reflector ³⁸	Sir John Francis Acton (1736–1811)	no	yes
1796	25ft and large 7ft ordered (both shipped 1802) ³⁹	King of Spain	£3150	B–1 B–28
1796	7ft reflector delivered, autumn 1796 ⁴⁰	John Lloyd, FRS (1750–1815), lawyer	£105	no
1797	7ft reflector delivered ⁴¹	William Larkins (<i>fl.</i> 1760–1800), Accountant-General, East India Company	no	no
1798	18 $\frac{3}{4}$ -inch mirror for 20ft reflector ordered ⁴²	Baron Friedrich von Hahn (1742–1805)	no	C–1
1799	7ft reflector (for Walmer Castle, to give early warning of a French invasion) delivered ⁴³	William Pitt (1757–1806), Prime Minister 1783–1801	£105	no
1799	7ft reflector delivered ⁴⁴	William Hodgson, FRS (d. 1824)	no	no

Table 1 continued]

1799	7ft reflector delivered ⁴⁵	Mr (Robert?) Carrington	no	no
1800	7ft reflector delivered ⁴⁶	Bertheau	no	no
1800	7ft reflector ⁴⁷	no name given	no	no
1800	20ft ordered, delivered 1806 ⁴⁸	St Petersburg Academy	?	B–20
1801	7ft reflector ⁴⁹	Capt. Joseph Huddart, FRS (1741–1816)	£106.1s	no
1801	7ft reflector delivered ⁵⁰	Mr Ferguson	no	no
1801	7ft reflector ⁵¹	Dr Alexander Dauneay, Aberdeen	£105	
1801	7ft mirror ⁵²	José de Mendoza y Rios (1763–1816)	gratis	no
1805	7ft reflector ⁵³	General Kritoff	£105	no
a. 1805	7ft reflector ⁵⁴	Mr Sligo, Princes's Street, Edinburgh	no	no
1811	7ft reflector or mirror ⁵⁵	Mr Hausemann (possibly John Michael Haussmann, Inspector General of Mines, Cassel)	no	no
1811	14ft reflector ⁵⁶	Glasgow	£400	B–21
1812	Repolished 10ft mirror ⁵⁷	Glasgow Univ.	no	no
1812	10ft reflector ⁵⁸	Oxford Univ.	£315	B–6
1813	10ft reflector ⁵⁹	Greenwich Obs.	£315	
1814	“Large” 10ft and 7ft reflectors, received 1816 ⁶⁰	Lucian Bonapart I (1775– 1840), brother of Napoleon I	£2310	B–2

Notes to Table 1]

1. Herschel's list of “telescopes made to order and the prices paid for them”, printed in J. L. E. Dreyer, *The scientific papers of Sir William Herschel* (2 vols, London, 1912), i, pp. l–li. Herschel is specific that the list is partly from memory “and cannot be supposed to contain a complete account of them”.
2. Andreas Maurer, “A compendium of all known William Herschel telescopes”, *Journal of the Antique Telescope Society*, no. 14 (1998), 4–15.
3. RAS MS Herschel W.5/12.1–4, Expt 1/251, 9 June 1781. [In subsequent citations of this form the MS number is understood.]
4. Expt 1/252, 18 June 1781.
5. Letters from J. H. Schroeter, RAS Herschel MS W.1/13.S.14, 31 July 1783, and S.20, 12 Sept. 1783 [citations below of the form S.20 have “RAS Herschel MS W/1/13.” understood]; Henry C. King, *The history of the telescope* (High Wycombe, 1955; reprint edn, New York, 1979), 135.
6. Expt 1/266, n.d. [1784].
7. Expts 1/269, 30 April, and 1/275, 21 July 1785. The destination of the fifth instrument is unknown; it is not in Windsor Castle, as one might have suspected.
8. Letter from de Brühl, B.138, 7 June 1786; to Rev. Mr Warde, 6 Jan. 1788 [all letters from Herschel are in RAS Herschel MS W.1/1, where the items are in chronological order].
9. King, *op. cit.* (ref. 5), 135.
10. Letter from J. P. Pangh, P.4, 15 Dec. 1787.
11. Letters to J. E. Bode, 12 Sept. 1787; from de Brühl, B.144, 7 June 1788; from de Brühl, B.145, 20 Mar. 1789.

12. Letter to T. Cavallo, 17 Dec. 1787. Herschel says the packing crates are ready. The telescope is not recorded in Cavallo's estate sale, *Sotheby & Co. Catalogues of sales: A guide to the microfilm collection 1734–1850* (3 vols, Ann Arbor, 1973), 3 June 1811.
13. Letter from R. Blair, B.100, 20 June 1788.
14. Letter from N. Maskelyne, M.35, 10 June 1788.
15. G. Pipping, *The chamber of physics: Instruments in the history of sciences collections of the Royal Swedish Academy of Sciences, Stockholm*, 2nd edn (Stockholm, 1991), 100–1.
16. “A 7ft telescope of any sort, for the Princess of Daskow may be ready in 3 months after it is ordered”, letter to Rev. Mr Warde at the British Museum with list of telescope prices, 6 Jan. 1788.
17. Letter from J. Planta, P.46, 9 Oct. 1788.
18. Letters from Fabarel, F.1, 18 May, and F.2, 17 Sept. 1789.
19. Letter from de Brühl, B.145, 20 Mar. 1789. An avid astronomer, Koehler published numerous observations in Zach's *Monatliche Correspondenz*, Bode's *Astronomisches Jahrbuch* [hereafter *AJB*], and in the *Philosophical transactions*.
20. Letters from J. Planta, P.55, n.d; to Planta, 10 Aug. 1789.
21. Letter from G. Piazzi, P.15, 10 June 1790. Piazzi, famous for his discovery of the first asteroid on 1 Jan. 1801, had been summoned in 1780 by the Prince of Caramanico to fill the chair of higher mathematics at the Academy of Palermo. Towards the end of the 1780s, he went to England to obtain instruments for a new observatory. He purchased a fine 5ft vertical circle from Ramsden, which was installed in the observatory in the Santa Ninfa tower of the royal palace of Palermo. Caroline tell us that when visiting the Herschels, “poor Piazzi did not go home without getting broken cheenes [shins] by falling over the rack-barr”, *Caroline Herschel's autobiographies*, ed. by Michael Hoskin (Cambridge, 2003), 77.
22. Letter from de Brühl, B.150, 12 Aug. 1790.
23. Letter from W. Walker, W.2, 22 July 1790.
24. Letter from W. Walker, W.2, 22 July 1790.
25. Letter from Martinus van Marum, M.10, June 1792. Frederic Guillaume Fries, who was employed by van Marum in 1790–91, assisted at observations made with this telescope on 29 Dec. 1790, and on 11 April 1791, and was paid for four and five hours of work, respectively (R. J. Forbes (ed.), *Martinus van Marum: Life and work* (Haarlem, 1969), vol2, 291–2).
26. Manuel López Arroyo, *El gran telescopio de W. Herschel* (Madrid, 1978).
27. Letter from O. Daclin, D.1, 1 May 1791; returned for refiguring, Expt 3/40, 16 May 1794.
28. Letters from G. G. Schmidt, S.9, 26 Nov. 1791, and S.11, 16 Mar. 1793.
29. Letter from B. Oriani, O.4, 30 Apr. 1792.
30. Letter from F. von Hahn, H.1, 5 Mar. 1792.
31. Expt 4/329, 15 July 1812: “This mirror belongs to a 10ft telescope presented by my late friend Dr. Wilson to the college of the University of Glasgow. I made it for him in 1792.” After his retirement in 1799, Wilson moved to London, and he and Herschel met regularly to discuss scientific questions.
32. Letters from J. A. Hamilton, H.11, 17 Nov. 1793, H.12, 27 Nov. 1793, and H.14, 2 Sept. 1795. Expt 3/80, 8 Aug. 1794.
33. *Georg Christoph Lichtenberg 1742–1799* [exhibition catalogue] (Carl Hauser Verlag, 1992), 133, Fig. 191.
34. Letter from de Brühl, B.153, 25 Nov. 1793. Erected in his observatory at Harefield.
35. Letters from George Edwards, E.3, 10 Feb. 1793, and E.4, 27 Aug. 1794; expt 3/74, July 1794.
36. Expt 3/52, 10 June 1794.
37. Letters from John Pond, P.56, 7 Aug. 1795, and P.57, 29 Dec. 1796.
38. John Francis, who maintained a private observatory, S. Carlo alle Mortelle Observatory, in Naples, purchased a 7ft reflector from Herschel around 1794. In 1795, Herr Cassella, Königl. Astronomen in Neapel, wrote: “Der Minister Acton lies sich vor einigen Jahren ein vortreffliches 7 fussigen

Notes to Table 1 continued]

- Teleskop von Dr. Herschel aus London kommen." *AJB*, 1799, 244.
39. Letter of José Mendoza, M.92, 16 Jan. 1796, and expt 3/590, 21 July 1801. See James A. Bennett, "'On the power of penetrating into space': The telescopes of William Herschel", *Journal for the history of astronomy*, vii (1976), 75–108.
 40. Expt 3/325, 9 Aug. 1796. Letter from J. Lloyd, L.59, 14 Aug. 1796. For payment, see National Maritime Museum, HRS 1, Household accounts 1795–1825, entry for 7 June 1796. Telescope listed in *Bibliotheca Llwydiana: A catalogue of the entire library and philosophical apparatus, the late property of John Lloyd, Esq. L.L.D.*, 15 Jan. 1816 (National Library of Wales).
 41. RAS MSS Herschel W.1/1.8.15, Herschel to Caroline, 21 Aug. 1797. He possessed a private observatory at Blackheath.
 42. Letter from F. von Hahn, H.5, 10 Oct. 1798; expt 3/564, 23 Oct. 1799.
 43. Letter from Charles Burney, B.179, 22 Sept. 1799. On this unique telescope, designed for installation in Walmer Castle overlooking the Dover Straights and to give early warning of a French invasion, see Michael Hoskin, *The Herschel partnership* (Cambridge, 2003), 100–1. Unfortunately no trace of it can now be found.
 44. Letter from W. Hodgson, H.21, 1 Oct. 1799. Telescope listed in *Sotheby & Co. Catalogues of sales* (ref. 12 above), 28 Feb. 1824. Hodgson maintained an observatory at his house in Hertfordshire.
 45. Letter from Carrington, C.4, 19 Sept. 1799. Carrington paid the balance on a telescope he had evidently received.
 46. Letter from Soltau, S.64, 17 Oct. 1800, asking Herschel to get Mr Bertheau's telescope ready for shipping.
 47. Letter from Robert Tangate, T.1, 8 Nov. 1800: "I have an order for one of your small size telescopes to go abroad."
 48. Letter from Nicholas Fuss, F.8, 16 Oct. 1800. Herschel polished the mirror in July 1805, expt 4/53, and it arrived the following year. See V. L. Tchenakal, "W. Herschel's mirror telescopes in Russia" [in Russian], *Istoriko-astronomicheskie issledovaniya*, iv (1958), 253–340, p. 329. Maurer gives the date as 1803, but this appears to be an error.
 49. Letters from Joseph Huddart, H.31, 12 Oct., and H.32, 15 Dec. 1801.
 50. Letter from Bertie Greatehead, G.19, 6 Nov. 1801, giving directions on where to deliver the telescope.
 51. Letter from Alexander Dauney, D.8, 24 March 1801.
 52. Expt 3/597, 31 Oct. 1801.
 53. Expt 4/56, July 1805.
 54. Scottish Records Office, RH4/21/45, David Brewster to James Veitch, 9 Dec. 1805: "I saw a few days ago, one of Dr. Herschel's seven feet Telescopes. It is a fine instrument, & the machinery which produces the verticle & horizontal motions are wonderfully simple & excellent. It had a variety of powers from 50 to 2000; the diameter of the speculum was 6 inches, with a few specks on its surface. The instrument belongs to a Mr. Sligo in Princess Street, & cost £105." I owe this reference to Alison Morrison-Lowe.
 55. Expt 4/258, July 1811.
 56. Brian Warner, "The William Herschel 14-foot telescope", *Monthly notices of the Astronomical Society of South Africa, Cape Town*, xlv (1987), 158–63.
 57. The mirror was bequeathed to the University by Dr Wilson. Andrew Ure has Herschel repolish it, U.1, 26 Apr. 1812.
 58. Letter to Abraham Robertson, 2 July 1812.
 59. Letter from John Pond, P.58, undated. See H. D. Howse, *Greenwich Observatory*, iii: *The building and instruments* (London, 1975), 117.
 60. Letter to Alexis Boyer, RAS MS Herschel W.1/4.8, 27 May 1816, says the telescope is ready.

TABLE 2. List of undated Herschel reflectors and mirrors made for other observers.

Year	Item	Purchaser	Dreyer	Maurer
a. June 1782	7ft reflector ¹	Dr William Watson, Jr, FRS (1744–1824), physician	gratis	B–11
1785–95?	6ft reflector ²	John Russell III (1745– 1806), painter	no	no
a. 1790	7ft reflector ³	Mr Trudaine, through Magellan	£107.2s	no
a. 1790	7ft reflector ⁴	Duke of Richmond	£117.12s	
a. 1794	10ft reflector	Sir Francis Drake (d. 1794)	£210	no
c. 1800	10ft reflector	Emperor Franz I (1768– 1835) of Austria	£210	B–3
c. 1800	7ft reflector ⁵	John Robison, LL.D. (1739–1805), lecturer in chemistry, Glasgow Univ.	no	
Unknown	7ft reflector ⁶	Alexander Aubert	no	no
Unknown	6ft reflector, mirror polished by Herschel ⁷	Alexander Aubert	no	no
Unknown	7ft reflector	Johann Elert Bode (1747–1826), director, Berlin Obs.	£105	no
Unknown	7ft reflector	Mr Dunn	£105	no
Unknown	7ft reflector	Capt. Thomas Thetin	£105	no
Unknown	7ft reflector	Edward Nairne FRS (1726– 1806), electrician	£105	no
Unknown	Optics for 7ft reflector	Count Hoseihl (?)	£31.10s	no
Unknown	Optics for 6ft reflector	Mr Shard (or Sharp?)	£31.10s	no
Unknown	7ft reflector	Mr Vögel	£105	no
Unknown	10ft reflector	Mr Brahm or Brehm	£210	no
Unknown	10ft reflector	London Society	£210	no
Unknown	7ft reflector	Chevalier Fortequerri	£105	no
Unknown	7ft reflector	Dr Belcher	£105	no
Unknown	Optics for 7ft reflector	Dr Dinvidee	£26.5s	no
Unknown	Optics for 7ft reflector	Mr Trimmer	£31.10s	no
Unknown	7ft reflector	Mr Deane	£157.10s	no
Unknown	7ft reflector	To China, possibly when Dr James Lind went there in 1788	£105	no
Unknown	7ft reflector	Col. Martin	£105	no

1. W.16, June 1782, where Watson mentions he has viewed the Moon. The instrument is preserved in the Science Museum, London. On 2 May 1782 Herschel wrote to John Edwards concerning his recipe for speculum metal, telling him of “a tryal that was made upon that composition by D^r Watson, who having just nearly finished a 7ft Newtonian Reflector, wanted small Specula casting”. As we know from Expt 1/257, 11 March 1783, that Herschel then repolished a mirror he had earlier made for Watson, Herschel’s letter to Edwards must refer to a 7ft he himself was constructing (but without revealing his willingness to make reflectors for friends), in which case the instrument can be dated to May 1782.

2. See *Sphaera: The newsletter of the Museum of the History of Science* (Oxford, autumn 1995). Russell’s

Notes to Table 2 continued]

- detailed book of lunar sketches begins in 1785. Since he painted Herschel's portrait in 1794, perhaps he received the telescope around that date.
3. Seymour L. Chapin, "'In a mirror brightly': French attempts to build reflecting telescopes using platinum", *Journal for the history of astronomy*, iii (1972), 87–104, p. 89.
 4. Mirror repolished in 1790.
 5. In a letter to James Veitch dated 16 Feb. 1800, David Brewster claimed that Robison got a 7ft reflector from Herschel around 1800 (Scottish Records Office, RH4/21/24).
 6. According to the catalogue of the Aubert sale (*Sotheby & Co. Catalogues of sales: A guide to the microfilm collection 1734–1850* (3 vols, Ann Arbor, 1973): "A catalogue of the very valuable and extensive collection of astronomical and mathematical instruments of the late Alexander Aubert, esq of Highbury House, Islington July 21, 1806", Lot 317, Aubert had a "7ft Newtonian telescope, by Herschel, with a divided achromatic object glass micrometer, 8-inch and half-diameter, by Dollond". Dollond purchased the instrument at auction for £76.
 7. "A 6ft reflecting telescope, with a speculum lately polished by Herschel", *ibid.*, Lot 316.

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REFERENCES

1. RAS MS Herschel W.7/8.
2. RAS MS Herschel W.5/12.1, expt 264. Entry 264 reads: "His Majesty requiring me to make some 10 feet telescopes, I cast several mirrors for them in a small furnace erected in my house, they were 9 inches in diameter, or about 8,8 of polished surface when finished. I ground and polished five of them at different times." The entry is undated, but as entry 266 is dated 10 March 1784, Herschel must have started on the project in late 1783 or early 1784. A second entry in April 1785 suggests that Herschel was still at work on the telescopes.
3. For an account of the circumstances leading to Herschel's pension, see Simon Schaffer, "Uranus and the establishment of Herschel's astronomy", *Journal for the history of astronomy*, xii (1981), 11–26. The King took his time paying the bill. Herschel wrote to Mr Gieswell on 26 Feb. 1791: "I beg you will be so obliging as to mention to the King, when you find a convenient opportunity, that the 5th ten-feet telescope which I have made for his Majesty has been ready a great while, and that I fear it is not safe in the place where I am obliged to keep it, so that I wish for his Majesty's orders where to deliver it. At the same time I beg the favor of you to tell me whether I shall send the bill for these five telescopes to you to give to the King, or whether you know where it would please his Majesty that I should send it. The King knows very well that astronomers and experimental philosophers are always poor, and, as the liberal patron of Arts and Sciences, I make no doubt, will not suffer them to be in want." Letter 656, in vol. i of *The later correspondence of George III*, ed. by A. Aspinall (Cambridge, 1962).
4. Especially James A. Bennett, "'On the power of penetrating into space': The telescopes of William Herschel", *Journal for the history of astronomy*, vii (1976), 75–108.
5. A major contribution is however Andreas Maurer's "A compendium of all known William Herschel telescopes", *Journal of the Antique Telescope Society*, no. 14 (1998), 4–15. Maurer set out to document the "fate and whereabouts" of Herschel telescopes that have survived, wholly or in

part, or for which substantial documentation exists. In what follows we cast our net more widely, attempting to include all those instruments mentioned (however briefly) in the records.

6. James Sime, *William Herschel and his work* (New York, 1900), 122.
7. *Ibid.*, 104.
8. Agnes Clerk, *The Herschels and modern astronomy* (New York, 1895), 33. So too in his 1919 biography, Macpherson wrote that “the work of making telescopes for other observers, though lucrative, was in many respects a waste of time. Herschel had long contemplated the construction of a very large telescope, but this was impossible so long as his spare time was given to the manufacture of smaller instruments, the great majority of which passed into the possession of royal or aristocratic dabblers in astronomy and were practically mere ornaments”. Hector Macpherson, *Herschel* (London, 1919), 31.
9. Angus Armitage, *William Herschel* (London, 1962), 27.
10. On Caroline Herschel, see Michael Hoskin, *The Herschel partnership, as viewed by Caroline* (Cambridge, 2003; hereafter *Partnership*), and *Caroline Herschel's autobiographies*, ed. by Michael Hoskin (Cambridge, 2003; hereafter *Autobiographies*).
11. *Autobiographies*, 78–79.
12. Henry C. King, *The history of the telescope* (High Wycombe, 1955; reprint edn, New York, 1979), 127. Richard Lerner similarly concluded that Herschel “made about fifty telescopes in the period between 1782 and 1785” (*Astronomy through the telescope* (New York, 1981), 60). J. B. Sidgwick, though less precise about the number of telescopes produced, believed that much of the work was done at Datchet. “The rising pressure of astronomical work at Datchet was balanced by no corresponding relaxation in the workshop.... [Herschel] began to receive requests for his telescopes in ever-increasing numbers, and the manufacture of reflectors for private sale ... soon developed into a thriving concern” (*William Herschel: Explorer of the heavens* (London, 1953), 102).
13. *Autobiographies*, 79. On the funding of the 40ft, see Michael Hoskin, “Herschel’s 40ft reflector: Funding and functions”, *Journal for the history of astronomy*, xxxiv (2003), 1–32.
14. By way of comparison, Herschel made 531 entries in the polishing logs between 2 Dec. 1790 and 16 Dec. 1793.
15. Between 1782 and 1785 Herschel made a mirror for Schroeter’s 4ft telescope and a mirror for Thomas Parsons (entry 251). He repolished a Gregorian mirror for John B. Bryant (entry 252), a 9-inch mirror for Alexander Aubert (entry 266), and the mirror of a 7ft reflector that he had made for his ally William Watson (entry 257).
16. See Michael Hoskin, “Alexander Herschel: The forgotten partner”, *Journal for the history of astronomy*, xxxv (2004), in press.
17. Published in *Astronomisches Jahrbuch* for 1788, 161–4.
18. For a description of James Short’s business, see Harriet Wynter and Anthony Turner, *Scientific instruments* (New York, 1975), 199.
19. J. L. E. Dreyer, *The scientific papers of Sir William Herschel* (2 vols, London, 1912; hereafter Dreyer), i, p. li transcribes Herschel’s own list of instruments and the prices he had charged, which total £14,743.
20. Harry Ransom Humanities Research Center, University of Texas at Austin, Herschel Family Papers, manuscript M1114 (n.d.). The list is reprinted in Dreyer, pp. i–li. At the bottom of his list, Herschel wrote: “the above list of persons for whom telescopes were made, is partly put down from memory and cannot be supposed to contain a complete account of them.” Indeed, Herschel forget to note the sale of telescopes or mirrors to Tiberius Cavallo (1787), Inspektor Kohler (1789), Mr Henry of Dublin (1790), J. J. Schmidt (1791), Baron Hahn (1794), Mr Larkin (1797), Mr Carrington (1799), William Hodgson (1799), Baron Hahn (1800), M. Bertheau (1800), Gen. Kritoff (1805), and Mr Hausemann (1811).
21. See Tables 1 and 2 for a complete list of all of the telescopes mentioned in Herschel’s correspondence and polishing logs. Two of the undated instruments were definitely made before 1790: a 7ft for the Duke of Richmond which he asked Herschel to repair in 1790, and a 7ft for Mr Trudaine.

- Trudaine's telescope is mentioned in Seymour L. Chapin, "'In a mirror brightly': French attempts to build reflecting telescopes using platinum", *Journal for the history of astronomy*, iii (1972), 87–104, p. 89.
22. RAS MS Herschel W.1/1 [entries in chronological order], Herschel to Mayer, 8 Oct. 1782.
 23. *Autobiographies*, 73.
 24. John Tracy Spaight, "Alexander Herschel as telescope maker", *Journal for the history of astronomy*, xxxiv (2003), 95–96; Hoskin, "Alexander Herschel" (ref. 16).
 25. *Autobiographies*, 55.
 26. *Autobiographies*, 78.
 27. William Herschel to Alexander, 10 March 1785, RAS MS Herschel W.1/9.3. A journeyman was a workman who had completed his apprenticeship.
 28. In a letter of 25 Aug. 1801, Herschel wrote "let William when he goes to Windsor call on Taylor the cabinet maker, to inquire if the tube and two stands are finished", letter to Caroline, RAS MS Herschel W.1/8.
 29. RAS MS Herschel W.1/1, Herschel to Cavallo, 17 Dec. 1787.
 30. The Royal Archives, Windsor Castle, RA GEO/6650: "Received from his Majesty by the hands of Mr. Gieswell Dec. 12, 1785 the sum of £200 and on Feb 18, 1786 the sum of £300, in all five hundred pounds, advanced on account, for an instrument now making for his majesty's encouragement, Feb. 18, 1786." Other payments were made in July and Nov. 1787, Feb., April and July 1788, and June 1789.
 31. For Mary's increasing affluence see *Partnership*, 92, 95–96.
 32. "Beaucoup peuroient que votre telescope etoit sujet a des illusions optiques", Jean-Dominique de Cassini to Herschel, 15 Feb. 1785, RAS Herschel MS W.1/13.C.6.
 33. William Herschel, "On the parallax of the fixed stars", *Philosophical transactions*, lxxvii (1782), 82–111, and "Catalogue of double stars", *ibid.*, 112–52.
 34. William Watson to Herschel, 25 Dec. 1781, RAS MS Herschel W.1/13.W.13.
 35. "Even Nairne doubted of your power", Watson to Herschel, 18 Dec. 1781, RAS MS Herschel W.1/13.W.12.
 36. Ramsden objected that at a power of 6450, a celestial object would take "less than a second in passing thro' the center of your field of view". Watson to Herschel, 11 Jan. 1782, RAS MS Herschel W.1/13.W.14. Herschel responded in his letter to Watson of 13 Jan., RAS MS Herschel W.1/1.
 37. "Aubert could not help being suspicious of some mistake", Watson to Herschel, 18 Dec. 1781, RAS MS Herschel W.1/13.W.12. Herschel sent Aubert sky charts with double stars marked in red ink, and begged him to verify that the stars were indeed double, Herschel to Aubert, 9 Jan. 1782, RAS MS Herschel W.1/1, see C. A. Lubbock, *The Herschel chronicle* (Cambridge, 1933), 102–3.
 38. "Dr Maskelyne told me yesterday after the Society was over, that tho' he did not in the least doubt your veracity, he could not help thinking that you was mistaken as to your high powers", Watson to Herschel, 11 Jan. 1782, RAS MS Herschel W.1/13.W.14.
 39. The German astronomer Johann Schroeter later expressed another concern, confiding to Herschel that "I can not comprehend how such an instrument [a 7ft reflector], with a magnification of 1000 times, can still give sufficient light, to see your double stars", Schroeter to Herschel, 31 July 1783, RAS MS Herschel W.1/13.S.14.
 40. RAS MS Herschel W.1/13.W.13, Watson to Herschel, 25 Dec. 1781.
 41. RAS MS Herschel W.1/13.W.15, Watson to Herschel, 4 Jan. 1782. The difficulties Herschel encountered are recounted in Simon Schaffer, "Herschel in Bedlam: Natural history and stellar astronomy", *The British journal for the history of science*, xiii (1980), 211–39.
 42. RAS MS Herschel W.1/1, Herschel to Aubert, 9 Jan. 1782.
 43. RAS MS Herschel W.1/1, Herschel to Hornsby, 1 Feb. 1782.
 44. British Library ADD MS 22,897, Cavallo to Lind, 27 Dec. 1782.
 45. RAS MS Herschel W.1/13.A.8, Aubert to Herschel, 22 Jan. 1782.

46. RAS MS Herschel W.1/13.M.16, Maskelyne to Herschel, 5 Feb. 1782. Even when he acquired a 7ft reflector from Herschel in 1791, he still experienced difficulties: “I have made use of the late fine weather to try what I could see with the 7 feet reflector, which you furnished the observatory with. I have seen Σ Bootes very well with it, but can make nothing of η Corona Borealis, with the power ... which I reckon to be 350. With the next which I take to be 500 I can see nothing but a confused blaze.... I have also looked at Saturn with this telescope, which it shews very well, but have never seen more than two satellites with it.” Maskelyne to Herschel, 15 Sept. 1791, RAS MS Herschel W.1/13.M.49.
47. On faulting instruments or assistants rather than valued colleagues, see Steve Shapin, *A social history of truth* (Chicago, 1994), chap. 5, “Epistemological decorum: The practical management of factual testimony”.
48. RAS MS Herschel W.1/1, Herschel to Bode, 18 May 1784. “Je crois que votre Dollond vous donnera une tres par faite avec un aggrandissement de 300 pour les etoiles doubles; mais il y en a qui en demandent plus & que vous ne verrez jamais avec un tel instrument.” In other words, a good telescope was one that could resolve Herschel’s double stars! See also RAS MS Herschel W.1/13.S.14, Schroeter to Herschel, 31 July 1783.
49. RAS MS Herschel W.1/1, Herschel to Mayer, 8 Oct. 1782.
50. William Herschel, “Catalogue of double stars”, *Philosophical transactions*, lxxv (1785), 40–126.
51. RAS MS Herschel W.1/1, Herschel to Lalande, 23 May 1783.
52. King, *History of the telescope* (ref. 12), 160: “Astronomers wished to see Sir William Herschel’s double stars for themselves and they began to assess the performance of their telescopes by the ease with which they resolved these objects.” King notes this put pressure on Dollond and others.
53. Which could lead to “the Experimenter’s Regress” problem described by Harry Collins, *Changing order: Replication and induction in scientific practice*, 2nd edn (Chicago, 1991). Many French astronomers had trouble verifying Herschel’s double star observations. On Mechain’s difficulties, see Schaffer, “Uranus and the establishment of Herschel’s astronomy” (ref. 3), 21.
54. Jean-Dominique de Cassini to Herschel, 15 Feb. 1785, RAS MS Herschel W.1/13.C.6.
55. According to a pamphlet in a cardboard box stored in 1998 on a shelf next to reference desk in the library of the History and Philosophy of Science Department at Cambridge University.
56. William Herschel, “Catalogue of one thousand new nebulae and clusters of stars”, *Philosophical transactions*, lxxvi (1786), 457–99, p. 467.
57. “Ici [Palermo] je vais etablier un Observatoire qui peut-etre contribuera aux progress de l’astronomie. Ce serai donc un dommage, que je fus restraints a ne voir le Ciel, qu’a vu les telescopes ordinaires.” Piazzi to Herschel, 5 Aug. 1790, RAS MS Herschel W.1/13.P.16.
58. RAS MS Herschel W.1/13.O.4, Oriani to Herschel, 30 April 1792.
59. Agnes C. Clerke, *The Herschels and modern astronomy* (London, 1895), 34.
60. National Library of Wales, Wygfair manuscript 12418D, Shuckburgh to Lloyd, 5 Oct. 1778. John Lloyd’s instruments and observatory are described in *Bibliotheca Lywydiana*, “A Catalogue of the Entire Library ... and Philosophical Apparatus, the Late Property of John Lloyd, esq.”.
61. See *Sotheby & Co. Catalogues of sales: A guide to the microfilm collection 1734–1850*, Reel 19, 21 July 1806.
62. The reflector is mentioned *ibid.*, Reel 36, 20 Aug. 1823.
63. In “Conceptual problems with the use of the terms amateur and professional for the 18th century”, a paper given at the meeting of the History of Science Society in 1999, I argued that the terms ‘amateur’ and ‘professional’ were not mutually defining until the nineteenth century, that many of the nuances that would later accrue to these terms do not map onto eighteenth-century experience, and finally that the terms do much to obscure the wide diffusion of expertise between those who worked at Greenwich (for example), and those who worked in private observatories.
64. On von Hahn’s observatory, see *Astronomisches Jahrbuch* (hereafter *AJB*), 1797, 240–4. On the 12-inch mirror, he noted: “Ich habe die Politur dieses Spiegels aussert schön gefinden; sein Oberfläche gleicher einem reinen Wasser ohne Faber.”

65. Scottish National Archives, Papers of Count de Brühl, GD 157/3385/2, Letter from Comte de Knuht to de Brühl, 2 Jan. 1790: "Depuis votre depart de Dresden nous avons recue un ministre de Prusse. Mon le Comte de Gesler! qui est grand connoisseur! et amateur! de l'astronomie et d'autre sciences. Je regrets beaucoup qu'avant mon depart de Dresden son Telescope de Herschel grand 7 pied! n'estoit pas encore arrivé."
66. See *Allgemeine Deutsche Biographie*, 444, and J. C. Poggendorff, *Biog.-litt. Handwörterbuch zur Geschichte der exacten Wissenschaften*, i, 1290.
67. William Kitchener noted Herschel's desire to have his observations verified: "Dr. Herschel has expressed a wish, (that as they are some of the finest, most minute, and most delicate objects of vision he ever beheld,) to hear his observations have been verified by other persons, and offers the following caution, as to the adjustment of the focus of our telescopes, and advises those who wish to examine the closest of these curious double stars ..." (*A companion to the telescope*, 2nd edn (London, 1811), 10).
68. RAS MS Herschel W.1/13.E.4, Edwards to Herschel, 27 August 1794, and H.22, Hodgson to Herschel, 2 August 1805. William Hodgson's reflector is listed in his estate sale: *Sotheby & Co. Catalogues* (ref. 61), Reel 37, 28 Feb. 1824.
69. RAS MS Herschel W.1/13.G.11, Gimingham to Herschel, 9 Nov. 1796.
70. Andrew Ure, *The philosophy of manufactures* (London, 1835).
71. RAS MS Herschel W.1/13.U.1, Ure to Herschel, 12 April 1812.
72. "Die Briefe Friedrich v. Hahns an William Herschel, 1792–1800", Archenhold-Sternwarte Berlin-Treptow, Sonderdruck no. 36, ed. by Dietmar Fürst and Jürgen Hamel (Berlin-Treptow, 1990), Letter 6, Hahn to Herschel, 10 Oct. 1798. "Die Liebe zur astronomie beginnt sich in Deutschland auszubreiten. Dazu haben vor allem Ihre großen Entdeckungen beigetragen."
73. See *Georg Christoph Lichtenberg: Briefwechsel*, ed. by U. Joost and A. Schöne, iii (Munich, 1983), Letter 2000, Schroeter to Lichtenberg, 8 January 1792. For references to Schroeter's observations with the 7ft Herschel reflector cited in the *Astronomisches Jahrbuch (AJB)*, see *AJB*, 1787, 253–4; *AJB*, 1789, 150–4; *AJB*, 1790, 194–205; *AJB*, 1791, 216–20; *AJB*, 1791, 201–3; *AJB*, 1792, 150; *AJB*, 1792, 176–90; *AJB*, 1793, 202; *AJB*, 1794, 124–6; *AJB*, 1795, 206–19; *AJB*, 1796, 158–60; *AJB*, 1799, 153–4; *AJB*, 1800, 166–75; *AJB*, 1801, 193–201.
74. "... selbst die Krater hatten keinen Glanz", in "Ueber den Mondfleck Aristarchus", *AJB*, 1791, 201–3.
75. "Ueber die von verschiedenen Astronomen in der dunkeln Seite des Mondes bemerkten Lichtpunkte", *AJB*, 1792, 112–27.
76. *Lichtenberg: Briefwechsel*, iii (ref. 73), Letter 1638, Lichtenberg to Samuel Thomas Sömmerring, 9 Nov. 1788.
77. "Beobachtungen von Fixsternenbedeckungen, zu Göttingen angestellte", *AJB*, 1797, 223–4.
78. W. Olbers, Letter of 7 August 1824, *Astronomische Nachrichten*, no. 63 (1824), cols. 241–2, cited by Andreas Maurer in a preliminary and unpublished version of his "Compendium" (ref. 5).
79. *AJB*, 1792, 111; *AJB*, 1794, 170; *AJB*, 1795, 248–50; *AJB*, 1799, 131–5.
80. *AJB*, 1802, 211–16.
81. *AJB*, 1790, 227–32; *AJB*, 1793, 249; *AJB*, 1794, 241–6; *AJB*, 1795, 226–32; *AJB*, 1797, 155–8; *AJB*, 1802, 204–10; *AJB*, 1803, 106–7; *AJB*, 1804, 195–7; *AJB*, 1805, 97; and *AJB*, 1806, 215–19.
82. Using the 20ft telescope. See *AJB*, 1803, 106–7, and Robert Burnham, *Burnham's celestial handbook* (New York, 1978), ii, 1164.
83. *AJB*, 1790, 147; *AJB*, 1794, 202–13; *AJB*, 1796, 176–7.
84. *AJB*, 1802, 211–16.
85. RAS MS Herschel W.1/13.K.7–29.
86. Robert E. Schofield, *The Lunar Society of Birmingham: A social history of provincial science & industry in 18th century England* (Oxford, 1963).
87. Schofield commented, "The Soho Works early became a place to be visited, one of the wonders of 'modern' England", *op. cit.*, 27.

88. “Copies of diaries kept by WH on various tours, 1791–1817”, RAS MS Herschel W.7/15, p. 5.
89. Richard Sorrenson, “George Graham, visible technician”, *The British journal for the history of science*, xxxii (1999), 203–23. Sorrenson contends that the ‘invisible technicians’ of the seventeenth-century Royal Society gave way to the increasingly visible and respected technicians of the eighteenth century.
90. On the Enlightenment interest in ‘improvement’, see Lorraine Daston, “Afterward: The ethos of Enlightenment”, in William Clark, Jan Golinski, and Simon Schaffer (eds), *The sciences in enlightened Europe* (Chicago, 1999), 495–504, p. 496. See also Larry Stewart, “A meaning for machines: Modernity, utility, and the eighteenth-century British public”, *Journal of modern history*, lxx (1998), 259–94.
91. Schofield describes an exchange of letters between Small and Watt. On 31 January 1770, for example, Watt wrote to Small: “I propose when you and I meet to spend some of our leisure time on trying some experiments &c on glass for Dollonds.” In a letter of 19 October 1771, Small wrote to Watt: “I have been by the way endeavoring to cheapen & improve telescopes, but I have not due leisure.” Schofield, *op. cit.* (ref. 86), 105–6.
92. Smeaton’s interest in astronomy and the engineering drawings he prepared for these observatories will be the subject of a later article. For a guide to the engineering drawings, see *A catalogue of the civil and mechanical engineering designs 1741–1792 of John Smeaton, F.R.S., preserved in the library of the Royal Society* (London, 1950). The plans for the observatories are in vol. iv, folios 21–27.
93. Huddart was elected F.R.S in 1791. He sent observations on eclipses of Jupiter’s moons observed at Bombay, 25 March 1780 to Maskelyne (RGO4/187 misc. corresp.).
94. John Gascoigne, *Science in the service of Empire: Joseph Banks, the British state, and the uses of science in the Age of Revolution* (Cambridge, 1998).
95. The picture of Herschel as abstract theorist, untouched by worldly concerns, obscures his ties with business and engineering circles – ties that grew stronger in the next generation of British astronomers. On the commercially-oriented men who founded the Royal Astronomical Society, whom Ashworth labelled “business astronomers”, see William J. Ashworth, “The calculating eye: Baily, Herschel, Babbage, and the business of astronomy”, *The British journal for the history of science*, xxvii (1994), 409–41.
96. RAS MS Herschel W.1/1, Herschel to Lalande, 23 May 1783.
97. Lubbock, *The Herschel chronicle* (ref. 37), 116.
98. Bennett, *op. cit.* (ref. 4), 89.
99. RAS MS Herschel W.5/14.1, f.18. Quoted in Bennett, *op. cit.* (ref. 4), 91.
100. RAS MS Herschel W.1/1, Herschel to Shairp at St Petersburg, 9 March 1794.