Part 1

TRANSITS OF VENUS: HISTORY, RESULTS AND LEGACY

https://doi.org/10.1017/S1743921305001225 Published online by Cambridge University Press

John Butler and Allan Chapman view the start of the transit of Venus,
8 June 2004

https://doi.org/10.1017/S1743921305001225 Published online by Cambridge University Press

Transits of Venus: New Views of the Solar System and Galaxy
Proceedings IAU Colloquium No. 196, 2004
D.W. Kurtz, ed.
© 2004 International Astronomical Union
doi:10.1017/S1743921305001225

Jeremiah Horrocks, William Crabtree, and the Lancashire observations of the transit of Venus of 1639

Allan Chapman

Modern History Faculty, Wadham College, Oxford University, Oxford OX1 3BD, UK

Abstract. When Jeremiah Horrocks correctly predicted, and with his friend William Crabtree observed, the Venus transit of 24 November 1639, these two men became more than the first astronomers in history to witness a rare celestial phenomenon. For Horrocks's and Crabtree's achievement constituted in may ways the first major astronomical discovery to be made in Renaissance England. It is also clear from their writings, moreover, that the two men, working in the isolation of rural Lancashire and well away from London or the universities, were fully conversant with contemporary discoveries made in continental Europe by Tycho Brahe, Galileo, Kepler, Gassendi, and others. In many ways, therefore, their work begs more questions than can easily be answered, such as why the rural North-West produced not only Horrocks and Crabtree, but other contemporary astronomers such as the Lancastrians Charles Towneley, Jeremy Shakerley, and their Yorkshire friend William Gascoigne. Yet in addition to whatever regional circumstances might have been present, and how easy it might have been for an educated rural Lancastrian to be fully informed about what astronomers in Paris, Prague, or Florence were doing, what cannot be denied is the outstanding originality of their wider achievement. For Jeremiah Horrocks in particular was a physical scientist of genius. His correct determination of the elliptical shape of the lunar orbit by 1638 when he was about 20 and his wider work on planetary dynamics place him amongst the most creative researchers of the seventeenth century. Central to Horrocks's and Crabtree's achievement was Crabtree's realisation by 1636 that contemporary published astronomical tables were unreliable, and that if one wanted to do serious work in understanding the heavens, then one had to observe and measure them for oneself, and learn to draw original conclusions.

Standing in the early dawn light, at the University of Central Lancashire's Alston Observatory at Longridge, Preston, as the Sun rose on 8 June 2004, was a moving experience. For as it broke through the low cloud on that hot and sultry summer morning, we all saw the Sun as no human being for the last 120 years had seen it: with a distinct semi-circular bite taken out of its lower left limb (or upper right, as seen through a telescope). Venus, indeed, had begun to transit at 6.24 a.m. B.S.T., but first contact could not be observed, and not until 'Cythera', as the ancients called her, was already indenting the solar limb about 6.30, could we see with our own eyes that the 2004 transit of Venus was actually happening. Second contact, at which point Venus makes her first appearance as a distinct disk on the solar surface, was witnessed at 6.44 a.m., and after that we set about the leisurely process of watching the planet making its stately way across the Sun. Then after a hearty breakfast at the Hall, the IAU party was taken by bus to the Lancashire village of Much Hoole, 8 miles south-west of Preston, to observe Venus as she gently slid off the face of the Sun around lunch time.

Of course, all the astronomers at Alston Hall had state-of-the-art equipment. High-resolution catadioptric and reflecting telescopes, mylar and other filters, binoculars, and the great Wilfred Hall equatorial refractor, the 15-inch object-glass of which could produce a projected image of Venus that was as big as a tennis ball, were all freely available

https://doi.org/10.1017/S1743921305001225 Published online by Cambridge University Press

on site, thanks to the University. Very importantly, we were not only able to predict the elements of the transit with great accuracy, but also to know in advance how big the Venusian image would appear on the solar disk, and how fast it would move. For these last crucial nuggets of information we really had two men to thank. They were Jeremiah Horrocks and William Crabtree, who between them had successfully computed and observed the first recorded transit of Venus on 24 November 1639 (4 December New Style), and had told us what to expect. What brought the IAU to Preston and the North-West to observe and celebrate the 2004 transit was the fact that Horrocks and Crabtree were local lads, and subsequent British scientists came to recognise them as the founding fathers of research astronomy in these islands.

And just as astronomers had gathered in Alston Hall and Much Hoole, so some 30 members of the Salford Astronomical Society had brought telescopes to various parts of the city of Salford, largely under the organisation of Ken Irvine, Director of the Salford Observatory, where they both observed the transit scientifically and demonstrated it to the public. For it had been in Salford that Crabtree had observed the 1639 transit.

By the time of the 1639 Venus transit, what we might think of as 'modern' astronomy was already advancing rapidly. But within the science several major debates were taking place, not only about the structure of the heavens themselves, but also about mankind's capacity to unravel that structure. The classical philosophy of the Greeks, for instance, had been concerned with defining the nature of the absolute and eternal truths, such as those of geometry, and had largely worked on the assumption that the way to get at truth itself was through disciplined intellectual deduction, based upon precise axioms. Sense knowledge was mistrusted, largely because the senses could, on a certain level, be so capricious. For simple human perceptions could vary across a very wide spectrum, giving rise to endless opinion and debate about what exactly was seen by a given individual, whereas the intellectual truths of deductive geometry and mathematics seemed to be beyond dispute. Indeed, this perceptual problem lay at the heart of the scientific revolution, for much of the new data that were pouring out not only of astronomy, but also of the sciences of geography and anatomy, were sensory and not deductive in character. For who could have deduced the existence of the American continent from first principles laid down by Strabo, Ptolemy, and the other classical geographers; and how could William Harvey in 1628 have discovered the circulation of the blood in living creatures from a careful reading of Hippocrates and Galen? In fact, all of these discoveries were the products of new physical, exploratory, and experimental researches that led human experience into hitherto uncharted territories of understanding. For it seemed that if one could discipline the human senses by means of the right procedures and techniques – such as the use of specially designed instruments which enhanced human perception, and a system of public peer review whereby results could be verified across a community of observers – then one really could discover those new continents of knowledge of which the visionary philosopher Sir Francis Bacon had written.

Where the new scientific approach of that period which we call the European Renaissance differed from that of the classical and medieval worlds lay not just in its recognition of the true value of sense-knowledge, but in the way in which it developed that knowledge within a method that embodied an investigative or forensic attitude to nature. For as Bacon had recognised, and begun to explore in *The Advancement of Learning* (1605) and *Novum Organon* ('The New Method', 1620), the experimental method of science was capable of opening up and researching new fields of natural knowledge that had been closed to traditional understanding. For whereas classical and medieval science had been what might be called curatorial in its approach, passing on a given body of facts and interpretations, such as the geometry of Euclid and the deductive physics of Aristotle,

https://doi.org/10.1017/S1743921305001225 Published online by Cambridge University Press

the experimental method aimed to break into pastures new and go beyond the systems of the ancient philosophers. And in many ways, this is why the great geographical discoveries of Columbus and Magellan had exerted such a profoundly imaginative effect on Renaissance scientific thinking: because these continental discoveries were not only sensory in character, but also subject to independent verification by other navigators. It had not been for nothing that the allegorical title page of Bacon's *Novum Organon* had depicted a modern three-masted ship sailing out through those very Pillars of Hercules which the ancients believed marked the westernmost boundaries of human knowledge, to make new discoveries in that great ocean of wonders that lay beyond.

And in the same way that one could think of an explorer's ship as a scientific instrument that facilitated the discovery of natural truths which could never have been revealed without it, so this new forensic, experimental approach to nature quickly gave rise to new instruments that took us to and opened up hitherto unknown realms of nature. Those unprecedentedly accurate angle-measuring instruments devised by Tycho Brahe between 1572 and 1598, for instance, were contrived with the expectation of providing firm physical proof, either for or against the geocentric cosmology of Copernicus; and though failing in this original intention because the required accuracies were beyond the manufacturing capacities of the age, they nonetheless generated a vast new harvest of astronomical facts which were to provide the foundation for the researches of Kepler, Gassendi, Horrocks, Crabtree, and Gascoigne.

But it was the telescope, first used for scientific purposes by Galileo in 1609, which became arguably the most momentous scientific instrument of the Renaissance. For the telescope fundamentally changed mankind's understanding of the universe, showing the Moon to be a world possessing distinct topographical features, the planets to be rotating spheres and not mere points of light, and the stars to be countless in number and receding ever dimmer into a seeming infinity. By the mid-1630s, when Horrocks, Crabtree, and Gascoigne were beginning to make their own highly original contributions, continental European astronomy was firmly established as the fastest advancing and the most intellectually provocative of all the sciences. What seemed to give astronomy such intellectual authority was its susceptibility to instrumental quantification. For whilst medicine and the life sciences, in spite of major discoveries in anatomy, were still incapable of curing most illnesses, and chemists, because of their fundamentally incorrect understanding of the nature of matter, were unable to explain chemical change in a coherent fashion, astronomy seemed to go from strength to strength. Much of that development hinged upon the fact that, unlike medicine and chemistry, astronomy was not a comparative or qualitative science, but a quantitative, exact one. For the new Tychonic measuring instruments and post-Galilean telescopes made it possible to measure angles to an increasing level of precision, and thereby establish physical standards based upon the division of the 360° circle, to make astronomy a truly predictive science. Conversely, medicine, botany, chemistry, mineralogy, and meteorology still lacked any distinct criteria which rendered them amenable to precise quantification, so that they were left thrashing around in a myriad of discrete observed empirical facts that lacked any kind of coherent interpretative or predictive structure.

It would be wrong, however, to see astronomy's progress between 1570 and 1635 as simple, uncomplicated, and based upon self-evident hard facts. There were still big issues, both intellectual and technical, that awaited resolution, some of which are still with us today. One might say that three especial problems were felt to be in need of solution by the astronomers of the early seventeenth century. The first of these was to establish the truth or falsehood of the Copernican heliocentric theory. The second was to ascertain the size, or perhaps the infinity, of the universe. And the third was to understand the

https://doi.org/10.1017/S1743921305001225 Published online by Cambridge University Press

nature of the force which made the planets move through space with such unchanging regularity. For once Tycho Brahe's new star and cometary observations between 1572 and 1588 had seriously undermined the credibility of the ancient crystalline spheres, the question remained as to how planets and comets moved through a seeming void with no apparent means of support or impulse. Did they move under the action of some form of magnetism or unspecified occult force, or were their periods and velocities somehow governed by their individual ponderousness and distances from each other?

While none of these questions could be adequately answered even by 1650, it is important to bear in mind that they assumed a vital importance in the creative scientific imaginations of Horrocks, Crabtree, and Gascoigne; as their surviving writings so clearly testify, these three North-country astronomers wrestled with them mightily in that creative dynamic developing between practical observation and theory out of which all original science springs. Without any doubt, they were the first Englishmen to work consistently with true originality towards this end.

Why was work of this originality brought to life in a thinly-populated strip of northern England lying between Liverpool to the west, Leeds to the east, Preston in the north and Salford in the south? And how, one might well ask, did Jeremiah Horrocks, working perhaps as a teacher and Bible Clerk in Toxteth, Liverpool, and Much Hoole; William Crabtree, a Salford cloth dealer; and William Gascoigne, the son of a minor county gentleman of Middleton, Leeds, obtain the resources to actively advance the great intellectual movement going on in continental Europe? For in Europe, the great new discoveries in astronomy and the other sciences came out of rich cities, royal courts, universities or ecclesiastical chapters – of great centres of patronage in Florence, Paris, Copenhagen, and elsewhere. Why creative English astronomy took root in relatively remote and rural Lancashire and west Yorkshire is hard to tell, though it did initiate what would, in many ways, be something of an enduring tradition in British science: for more than a couple of centuries to come, and well into the nineteenth century, it was indeed the inspired, informed 'Grand Amateurs', often of modest yet independent circumstances, who were to form the intellectual cutting edge of British science, and who addressed themselves to the most profound questions of the age.

While Horrocks, Crabtree, and Gascoigne may have lived in a geographically remote part of Britain, as far as metropolitan or direct continental influences were concerned, one must not forget that each of these men had received a sound education: two of them had attended university, and all had enough spare cash and access to those lines of communication necessary to obtain copies of the works of Tycho, Kepler, Galileo, Descartes, Gassendi, Lansberg, and several other contemporary scientific researchers. For the names and ideas of these and other men are regularly mentioned and evaluated in the surviving correspondence of the North-country astronomers.

As Peter Aughton has recently shown, from surviving wills of the Horrocks and Aspinwall families, and from Oxford and Cambridge University registers, several of Jeremiah Horrocks's relatives had preceded him to university. For while the Horrockses and Aspinwalls (on his mother's side) were successful watch-makers and yeomen farmers active in the Toxteth area, they clearly valued education, making sure that clever sons went at least to grammar school, and often to university. While I have not been able to trace William Gascoigne's name in any registers, he nonetheless claimed in one of his surviving letters to have been at Oxford. William Crabtree made no university claims, it is true, but he is said to have attended the 'Manchester School', which was probably a grammar school attached to the Collegiate Church (which became Manchester Cathedral in 1847). This means, therefore, that all three men would have been Latin literate – the key to the world of learning in the early seventeenth century – and Chetham's College

https://doi.org/10.1017/S1743921305001225 Published online by Cambridge University Press

Library (in the School founded by Humfrey Chetham in 1653, and still standing to the immediate north of Manchester Cathedral) later acquired one of William Gascoigne's notebooks, in which he had made several juvenile attempts to correctly spell his name in Latin! Without the Latin tongue, indeed, the works of Tycho, Kepler, Gassendi and others would have been closed to them.

Through his work in the textile trade, William Crabtree is also likely to have had connections in London, and the Crabtree and Horrocks correspondence contains references to Samuel Foster, Professor of Geometry at Gresham College, London. Samuel Foster, indeed, was one of the men whom Crabtree, no doubt at Horrocks's request, appears to have alerted to the impending transit of Venus in 1639, though Foster does not seem to have made a successful observation.

Yet while the scientific brilliance and originality of Horrocks and his friends in the north is beyond doubt, it would be entirely wrong to think of them as the only English people interested in modern astronomy in that age. Indeed, Thomas Harriot, the mathematical friend of Sir Walter Raleigh and the 'Wizard' Earl of Northumberland, was a convinced Copernican, as had been Thomas Digges a generation before in the 1570s. Harriot, moreover, was already using a newly-imported 'Dutch spyglass' to observe sunspots through the thick winter mists of the Thames valley as early as 8 December 1610, which was several months ahead of Galileo's 'official' discovery of the spots in 1611; though neither Harriot nor his Welsh friend Sir William Lower ever published their results, so that their original work only saw the wider light of day after 1833 when some of Harriot's surviving manuscripts were printed in Stephen P. Rigaud, 'Account of Harriot's Astronomical Papers', and followed by more detailed researches by twentieth-century Harriot scholars. And in addition, there were Samuel Foster's predecessors at Gresham College, London, which after its foundation in 1597 had produced a succession of illustrious Professors of Astronomy and Geometry: men such as Henry Briggs, Henry Gellibrand, and Edmund Gunter. In 1619, moreover, Sir Henry Savile endowed Oxford University with two scientific chairs, once again in Astronomy and Geometry; and if Gascoigne had in fact studied at Oxford, as he later claimed, it is likely that he could have attended the lectures of John Bainbridge, who was Savilian Professor of Astronomy throughout the 1620s and 1630s, and was probably the first man to publicly lecture on Galileo and Kepler in Oxford. Likewise, Gascoigne may have heard the lectures of Henry Briggs, who left Gresham College to become Oxford's first Savilian Professor of Geometry up to his death in 1631. Both Bainbridge and Briggs were convinced Copernicans.

How, therefore, can one claim such outstanding originality for Horrocks, Crabtree, and Gascoigne, if England already enjoyed not only this richness in mathematicians and astronomers, but also a flourishing London-based trade in mathematical instrument-making, as men like Humfrey Cole and Elias Allen manufactured large numbers of accurate quadrants, dials, and precision computational scales?

I would argue that what made the North-country astronomers so important was their attitude to research and the seeking out and testing of new astronomical knowledge, for the London and Oxford professors, in so many ways, had different areas of interest from the northern group. Indeed, their own especial interest in experimental research tended more to the study of geomagnetism than to planetary astronomy; while another long-term interest of the London and Oxford professors lay in the improvement of computational techniques – such as the development of logarithms, which had been pioneered by Henry Briggs – for the wider mathematical community. Yet when it came to astronomy itself, they still seemed happy to work within the wider ground rules laid down by Tycho Brahe, Kepler, and others, and to use printed volumes of planetary tables (often deriving from Tycho's original observations) as a way of calculating their celestial triangles.

https://doi.org/10.1017/S1743921305001225 Published online by Cambridge University Press

None of these London or Oxford astronomers, therefore, seem to have been active, night-by-night practical observers of the heavens – and here lies the crunch. For if one simply uses a cross-staff, quadrant, or similar angle-measuring instrument to check occasional planetary angles against the standard tables, then one is more likely to be able to explain away errors on scale mis-graduation and similar grounds than if one is experiencing the mounting nightly frustration of finding such a proliferation of errors as to make one declare the tables false or useless, as William Crabtree and Jeremiah Horrocks declared the tables of Philip Lansberg to be by 1636!

Another important factor in assessing an astronomer's originality was how he used his telescope. Did he see the telescope as a way of merely confirming Galileo's discoveries, or did he want to devise new usages in order to extract a bit more research mileage out of the simple optical systems of the 1630s? For it is clear that, by the 1630s, telescope technology had hit an *impasse*, as object glasses and magnifications had not improved much since about 1615, and would not do so significantly till the new optical innovations of Giuseppi Campani and Eustachio Divini and the Huygens brothers in the 1650s. So considering the very limited capacity of contemporary telescopes, how might a skilled observer use his instrument to give him that extra mileage? By using it, perhaps, to watch the dark edge of the Moon snuff out the individual stars of the Pleiades and thence draw the conclusion that the stars were but points of light and not disks – as Horrocks and Crabtree did on the night of 19 March 1637 [*Op. Post.* 151]; by contriving to turn it into an angle-measuring micrometer (as Gascoigne did, as will be shown presently); or else by using it to observe the transit of Venus!

For these were some of the areas in which Horrocks and his friends displayed such astonishing scientific creativity in the late 1630s. To them, indeed, astronomy had ceased to be the essentially passive science of error correction, and became in their hands a more aggressive, forensic intellectual discipline that aimed to go beyond what the past had laid down, and work by a self-conscious process of inquisition. While the great figures of modern astronomy, such as Galileo, Kepler, and Gassendi, had discovered stunning new facts, and while Gassendi's published observations show that he was constantly putting Tycho to the test, it was in many respects the North-country astronomers who came to think of astronomy from an 'experimental' perspective. One wonders, indeed, whether these men were familiar, if only by repute, with the above-mentioned writings of Sir Francis Bacon, whose emphasis upon taking nothing in nature on trust, and on using 'experiment' as a tool whereby one might inquire forever deeper into the structures of the natural world, seemed so clearly reflected in what was going on in Preston, Salford, and Leeds.

There is nothing to suggest that, up to about 1640, Horrocks and his circle were using instruments that were innately superior to those being used in London, Oxford, or in the great cities of continental Europe. Even the best telescopes at this period rarely had effective object glasses of more than 1.5 inches in diameter, and a clear magnification of 40 or 50 times would have been doing very well for that time. And while one might have made guesses at very small angles, such as those displayed between the stars of the Pleiades, by comparing such angles to the known $30'$ of the lunar diameter, it was not possible to use the telescope as a direct measuring, as opposed to a viewing, instrument. In fact, the only way in which one could make measurements through a telescope before 1640 was by using the telescope to project an image of the Sun, as a preliminary to ascertaining the relative positions of objects upon its surface, as Galileo, Father Christopher Scheiner, and others did with sunspots, Gassendi and Quietanus did with the Mercury transit of 1631, and Horrocks and Crabtree did with the Venus transit in 1639.

https://doi.org/10.1017/S1743921305001225 Published online by Cambridge University Press

To measure larger angles around the sky, one used one or more instruments of a type that had been familiar to European astronomers for centuries. These could include the 90° graduated quadrant, for reading vertical angles. Or if one wanted to measure the horizontal (or 'Right Ascension') angles between, let us say, the Moon and a bright star, then one used a version of the 'Astronomical Radius' or 'Baculus'. Astronomical Radii were 'T'-shaped configurations, often made in wood, where the short end of the 'T' was graduated with a tangent scale against which the observer could measure his angles when the Radius was held up to his eye, in the manner of a crossbow. By the 1630s, indeed, European astronomical literature was rich in the details of how one might design and make a 'Radius' and a quadrant, and there is no reason to believe that the probably home-made angle-measuring instruments of Horrocks and Crabtree were any better than those described by their older Parisian contemporary, Pierre Gassendi, with whose published works they were clearly familiar. I would suggest that what made the northern astronomers so significant is the manner in which they used them.

Having become disillusioned with the reliability of contemporary astronomical tables by 1636, William Crabtree and then Jeremiah Horrocks took it upon themselves to measure celestial angles on a nightly basis after the manner of Tycho Brahe. The primary objects of concern were the Moon, Sun, and planets as they moved around the ecliptic against the background of the Zodiac stars, and their movements with relation to each other. As a consequence, Jeremiah Horrocks in particular began to draw some remarkable conclusions from the emerging data. For one thing, over a given period of time Saturn seemed to be slowing down while Jupiter was speeding up, in a way which was quite inexplicable in terms of existing planetary theory, but seemed to suggest that the planets exerted some kind of attraction upon each other. But more immediately significant was the behaviour or the Moon.

The dynamics of the lunar orbit around the Earth, and its relation to the Sun, had long been acknowledged as one of the most baffling in astronomy. That the Moon did not rotate around the Earth in a simple circular orbit, but in an eccentric circle, had been known for centuries, and aspects of 'transit' or eclipse phenomena had long been the indicator. Why, for instance, were some total eclipses of the Sun – when the Moon transits the solar disk – annular, while others were not? Could it be that the Earth-Moon distance varied in accordance with a complex cycle? And why did eclipses of the Moon, when the Earth, Moon, and Sun were on a straight axial line, come in such complex varieties? For instance, the terrestrial shadow could be bronze, black, or blood-red in colour, and cover the whole or only part of the lunar disk. Of course, Hipparchus back in the second century BC had developed his famous 'Diagram' of the shadows projected within the Earth, Moon, and Sun system, and had even used them to compute a remarkably accurate proportionate distance of the Moon from the Earth in terms of Earth radii; yet the dynamical astronomy of the Moon was still replete with unanswered questions.

By 1638 Jeremiah Horrocks, who had a detailed familiarity with the celestial mechanics of the 'Hipparchian Diagram', had come to an analytical understanding of the Earth-Moon system that was substantially in advance of anything that had been achieved by any preceding or contemporary astronomer. It was based, moreover, on his own and Crabtree's original observations, and went on to beg wider questions in planetary dynamics, such as the nature of the force that moved astronomical bodies around their centres of rotation. For by 1638, Horrocks had come to realise that the Moon moved around the Earth not in an eccentric circle – where the lunar orbit itself was a perfect circle, but where the Earth did not occupy the geometrical centre of that circle – but in an ellipse. In this respect, he became the first astronomer to go beyond Kepler's work on

https://doi.org/10.1017/S1743921305001225 Published online by Cambridge University Press

the elliptical orbit of Mars around the Sun, to demonstrate that another astronomical body in the solar system also moved in an elliptical orbit, with one of the foci of the lunar orbit within the Earth. Once such a realisation had been made, and the eccentric circle model abandoned, several long-standing anomalies about the lunar orbit became amenable to explanation.

Yet Horrocks had not merely realised that the lunar orbit around the Earth fitted neatly with a Keplerian ellipse, but he went on to draw an even more profound dynamical conclusion: namely, that the long axis of this ellipse – or apside line – itself possessed an independent rotation in space over a period of time. In short, the whole Earth-Moon system was rotating around a point in space, while the dynamics of the system seemed to relate the whole to the constantly changing position of the Sun. Horrocks's own interest in the tides further related to this problem, as variations in the Earth's tidal patterns seemed to be governed by close and further approaches by the Moon, and also by the Sun. Indeed, the complex dynamical relationship between the Earth, Moon, and Sun, and the moving elliptical planes operating within this system, which Jeremiah Horrocks had been the first astronomer to describe coherently, would later become immortalised as Sir Isaac Newton's 'three bodies problem', and would play a major role in the development of the theory of Universal Gravitation. And Newton would acknowledge his fellow-Cantabrigian in *Principia* (1687).

Horrocks's realisation of the ellipticity of the lunar orbit, and of the apsidal precession of that orbit, was very much the product of meticulous observation and independent analysis. By 1637 or so, one can see Horrocks looking for further cross-checks whereby to test his overall ideas, and this becomes particularly manifest in his concern with seasonal and systematic variations in the diameter of the Sun and Moon. Did the Moon's (and Sun's) diameter over a given period vary in accordance with predictions derived from elliptical orbital criteria? Of course, it had been known from classical times that the lunar and solar diameters were around $30'$, or $0\overset{\circ}{.}5$. What Horrocks needed, however, were very slight yet crucial variations around this figure to an accuracy of a few arc seconds.

There were two ways of attempting to obtain these values. The first, which had even been known to medieval astronomers, was to make a pinhole projection of the Sun into a darkened room. By measuring the exact projection distance between the pinhole and the solar image falling on a screen, along with the precise diameter of that solar image, one could obtain the angular diameter as a tangent function. Indeed, as early as 1636, Horrocks and Crabtree were monitoring changes in the solar diameter by means of this projection technique, and finding that on 12 December 1636 [*Op. Post.* 140], for example, with a pinhole aperture of 5 units, at a projection distance of 4100 units, the solar diameter was $42\frac{1}{2}$ units, or $31'\,26''$. (Seventeenth-century astronomers generally worked in geometrically-related proportions rather than specific units of measure, but if Horrocks's 5-unit projection aperture was around one-twenty-fourth of an inch across – '*quarum uncia nostra Anglica habet 24*' – then the projection distance would have been about 14 ft 3 inches, and the solar diameter about $1\frac{3}{4}$ inches.) A brilliant full Moon diameter could also be measured by the same technique. Horrocks was fully familiar with the projection method, though its main defect lay in the inevitable slight fuzziness which a pinhole image produced, leading to an inevitable margin of error when trying to work to a critical level of accuracy. In the Latin translation of Horrocks's letter to Crabtree which John Wallis produced in 1673, this pinhole technique was referred to as the 'Foramen' or aperture method.

The second method was really a refinement of the Astronomical Radius mentioned above. Horrocks referred to it as his instrument '*filis ferries*', or with two iron needles

https://doi.org/10.1017/S1743921305001225 Published online by Cambridge University Press

or fine pointers, on 4 January 1637 [*Op. Post.* 255]. A pair of metal pointers, needles, or stretched wires (? *filum*) would be mounted vertically and parallel to each other in the end of a long rod, with only a small part of an inch between them. Horrocks would view the Sun or Moon between these needles, and then gradually move them up or down the rod on a slider or transom until he reached a point where the angle subtended between the needles as viewed from the end of the rod was exactly the same as the angular diameter of the body under observation, in so far as it now filled the opening between the needles precisely. By knowing in advance the exact distance between the needles, in relationship to the feet, inches, and fractions or other units of proportion down the rod at which he had needed to place his eye to make the body fill the space, he could compute the precise angular diameter of the Sun or Moon. On 9 December 1636 [*Op. Post.* 252], he used such a pair of '*stylis ferries*', mounted on his 11-foot-long Astronomical Radius, to obtain a value of between 34′ and 35′ for the solar diameter. Then, a month later, on 4 January 1637 [*Op. Post.* 255], he used the same 11-foot Radius and '*filis ferries*' configuration to measure the angle subtended between Jupiter and Venus.

Even so, these were still naked-eye methods, for in 1637 neither Horrocks nor any other astronomer in Europe had yet devised a reliable way of measuring angular distances through the telescope. That fundamental invention was to be made in the late 1630s when William Gascoigne happened to make a lucky discovery. For Gascoigne, who was a keen inventor, had noticed that a spider had spun a thread through a Keplerian optical arrangement with which he was working. As luck would have it, the spider's web fell exactly at the combined focal points of the objective and eye glasses, so that when looking through the optical arrangement, Gascoigne saw the web bright and sharp within the field of view. Gascoigne quickly grasped the optical physics involved and started to use these reticules as marker points in the field of what was probably the first telescopic sextant. This sextant was five feet in radius, and modelled on the sextant of Tycho Brahe (though Tycho's sextant was only a naked-eye instrument), and was capable of measuring the distance between astronomical bodies – such as the angle between the Moon and a fixed star – to an unprecedented degree of accuracy.

Then, in addition to the telescopic sextant which reputedly measured down to $0\overset{\circ}{.}001$ against an engraved 60° scale, Gascoigne had the brilliant idea of putting two vertical marker points into the same telescopic field. Each marker point could be controlled by a fine pitched screw so that he could adjust them, be they marker points, two stretched threads, needles, or knife-edges, until they precisely enclosed the Sun, Moon, planetary bodies, or cluster of stars. Once they were enclosed, Gascoigne could use the known pitches of the screws to measure the size of the prime-focus image falling within the telescope to a very tiny fraction of an inch, and, knowing the focal length of the lens producing that image, calculate the angular size of the object to a hitherto unattainable degree of accuracy.

Indeed, Gascoigne's telescopic sights and micrometer were the ideal instruments for testing Horrocks's theories about elliptical orbits, and for establishing the exact angular diameter of the Moon at key stages in its orbit as the apsidal line turned around the Earth with relation to the Sun. The telescopic sight could monitor the Moon's nightly motion against the fixed stars to a level of accuracy impossible for any previous astronomer – and thereby make it feasible to establish precise variations of the Moon's velocity in different parts of its orbit – while the micrometer enabled the observer to correlate regular changes in the Moon's observed diameter to specific parts of its orbit. In short, Gascoigne's telescopic sights and micrometer became key instruments in establishing the elliptical, Keplerian orbit of the Moon, first realised by Horrocks from less accurate observations made about three years previously. The whole sequence of events, moreover, exemplifies

https://doi.org/10.1017/S1743921305001225 Published online by Cambridge University Press

that perceived relationship between theory, invention, observation, and refinement of data, which so characterised the working methods of Jeremiah Horrocks and his friends.

As soon as Gascoigne's inventions had been seen by Crabtree, probably on a visit to Yorkshire in the late summer or early autumn of 1640, their significance was immediately recognised. Writing to Gascoigne from Salford on 30 October 1640, Crabtree asked how he might obtain such instruments for himself, and, no doubt, for Horrocks: 'Could I purchase it with Travel, or procure it with Gold, I would not be without a Telescope for observing small Angles in the Heavens [the micrometer]; nor want the Use of your other Device of a Glass in a Cane [tube] upon the moveable Ruler of your Sextant [telescopic sight].' Observation of the changing lunar diameter with relation to orbital position, moreover, was clearly high on both men's intellectual agenda, for as Crabtree lamented in the same letter, 'I lost the little Paper, wherein I noted the Moon's Diameter, which we observed when I was with you: I pray you send it to me' [*Phil. Trans.* 1717, p. 607]. What is more, by the time of his writing this letter to Gascoigne, Crabtree was also making arrangements for a visit to Wigan, Lancashire, 'where much Brass is cast', to see if he could 'procure such an one cast', meaning, one presumes, a frame or small precision components for a sextant similar to Gascoigne's which Crabtree himself could complete and to which he could add telescopic sights.

Sadly, it is unlikely that Jeremiah Horrocks had time to use Gascoigne's telescopic sights and micrometer, if duplicates of Gascoigne's originals were only becoming available in Lancashire in the late autumn or winter of 1640, for Horrocks died suddenly on 3 January 1641. Horrocks's sudden death, moreover, was rendered all the more poignant by the excited expectation which he himself entertained of Gascoigne's instruments being used to independently substantiate his own discoveries, especially those of the lunar orbit; for as Crabtree wrote to Gascoigne on 28 December 1640, 'My Friend Mr Horrox professeth, that little Touch which I gave him, hath ravished his mind quite from itself, and left him in an Exstasie between Admiration and Amazement. I beseech you, Sir, slack not your Intentions for the Perfection of your begun Wonders.' [*Phil. Trans.* 1717, p. 608].

It is clear from surviving correspondence, however, that Crabtree and Gascoigne did try to use the new instruments to provide observational substantiation for Horrocks's work, for in a letter to Crabtree, dated Christmas Eve 1641, Gascoigne declares 'Mr Horrox his Theory of the Moon I shall be shortly furnished to try' [*Phil. Trans.* 1717, p. 605], while William Derham, who edited these letters for the *Philosophical Transactions* of the Royal Society in 1717, adds [p. 609] 'Then ... follows an Account of the Agreement of Mr Horroxs Theory of the Moon with Mr Gascoigne's Observations.' Maddeningly from our point of view, however, Derham fails to print these crucial sections of the correspondence: a correspondence which, while surviving in at least ten detailed letters in 1717, has subsequently vanished, so that all we have are the selections which Derham edited for the Royal Society.

Yet other fragments of what was clearly a very substantial correspondence between Crabtree and Gascoigne had entered the possession of the Revd John Flamsteed, for not only did Flamsteed see Horrocks, Crabtree, and Gascoigne as the founding fathers of British research astronomy, and the intellectual heirs of Galileo and Kepler, but he began his massive three folio volume *Historia Coelestis Britannica* (1725) by printing five pages of their surviving letters and observations, made between 1638 and 1643. Of the highest significance in our understanding of the three North-country astronomers, moreover, is a set of nearly 80 observations of the lunar diameter, made by Gascoigne with his micrometer, between January 1641 and December 1642, and printed by Flamsteed in his *Historia*. What is immediately clear from these micrometer observations is that they

https://doi.org/10.1017/S1743921305001225 Published online by Cambridge University Press

record orbital variations in the lunar diameter that have a precision which transcends all the previous results obtained by pinhole or iron stylus methods. For the gradual, often nightly, changes are expressed in arc *seconds*, and display clear flow patterns of diameter change over the course of individual lunations.

As a way of trying to make an objective assessment of the quality of these lunar diameter observations, I was delighted when some years ago astronomers at the Royal Greenwich Observatory (RGO), Herstmonceaux – an organisation subsequently destroyed by a short-sighted government – agreed to run Gascoigne's historical observations through their computer. When they had back-calculated the position of the Moon to those dates and times upon which Gascoigne made his observations, I was astonished at how good these early observations were. In addition, the former RGO was kind enough to run a set of Gascoigne's planetary diameter measurements through their computer as well, though as one might expect, Gascoigne's micrometric observations of the diameters of Jupiter, Mars, and Venus displayed wider margins of error, as these objects are so small when observed from the Earth, especially in the low-powered and aberrated telescopes of the early seventeenth century. Yet they were in a different league of accuracy when compared with previous planetary diameter measures made by European astronomers using needles and holes in conjunction with the naked eye. For example, Gascoigne's measurement of the apparent angular diameter of Jupiter for the night of 25 August 1640 was 51″, whereas the correct value calculated by the RGO for that date was 41″ [Chapman 1990, p. 43].

If results of this quality were being obtained by the infant micrometer of 1640, one can fully appreciate Horrocks's, Crabtree's, and Gascoigne's exhilaration at the prospect of providing physical substantiation for Horrocks's Lunar Theory. And while poor Horrocks died just as Gascoigne's micrometric observations were getting into their regular stride, at least Crabtree and Gascoigne – who both died in the summer of 1644 – lived long enough both to see Horrocks vindicated, and to know that they had pushed astronomy beyond what Kepler had achieved, as well as having gained insights into nature disclosed to no other men.

To understand Horrocks, Crabtree, and the transit of Venus of 1639, and to place their observation of that event into its proper historical and technical context, I believe that it has been necessary to take the somewhat circuitous route that we have followed so far. For Horrocks and Crabtree were not simply lucky amateurs who saw something that all the European professionals had missed, but were men working within a very clear research agenda of their own, who were acutely aware of the strengths and weaknesses of contemporary European astronomy, and who had developed their own very ingenious working methods.

Of course, the transit of Venus was very much of a type in many respects with the researches outlined above, in so far as both its observation and interpretation were rooted in the study of planetary dynamics, the passing of bodies in front of bodies, and the measurement of precise angles. It was also part and parcel of Horrocks's and Crabtree's wider agenda of showing the tabular calculation school of astronomy to be wrong, for while the *Prutenic Tables* of Erasmus Rheinhold and the *Tables* of Lansberg could perhaps have predicted a transit, those predictions would not have fallen on the correct day, while the tables of Largomontanus put the Venus conjunction position too far south for the planet to have passed across the Sun in any case.

It is likely that this confusion found amongst the tables, combined with Horrocks's own established experience as a planetary position observer, led him to the conclusion by 26 October 1639 [*Op. Post.*, p. 331] – on which date he wrote to Crabtree to alert him – that Venus would pass across the Sun's disk on 24 November. Horrocks seems, in

https://doi.org/10.1017/S1743921305001225 Published online by Cambridge University Press

addition to Crabtree, to have asked his brother Jonas, then living in Toxteth, to keep watch as well, which leaves us to conclude that Jeremiah was not the only astronomical Horrocks and possessor of a telescope, though Jonas Horrocks saw nothing. Crabtree also appears to have passed on notification of the event to Samuel Foster, Gresham Professor of Astronomy in London; though as in the case of Jonas, Horrocks subsequently cites no actual observation by Foster. Yet one man who would have been ideally suited to make the transit observation, and to whom no reference is made either in surviving correspondence or in Horrocks's subsequent treatise *Venus in sole visa*, is William Gascoigne. One is therefore left to assume that in October 1639 Gascoigne had not yet made the acquaintance of Crabtree, in spite of the fact that detailed astronomical observations by Gascoigne survive from 10 December 1638 (published by Flamsteed, *H.C.B.*, p. 1), suggesting that Gascoigne was already a well-equipped and experienced astronomer by that date. William Derham, however, in the Crabtree to Gascoigne letter dated 7 August 1640 which he published in *Philosophical Transactions* in 1711, was of the opinion that this letter was the first communication which passed between the two men, though the superscription 'To his Loving Friend Mr William Gascoigne, at his Father's House in or near Leeds in Yorkshire' and references to prior astronomical communications suggest that the two men had already come to know each other quite well by August 1640. Indeed, it is possible that they had known each other since the winter of 1639-40, for Flamsteed mentions a letter '*Ex alia Gascoignii ad Crabtraeum*' dated 22 March 1640 [*H.C.B.*, p. 3]; but as it is cited in a context of observations made in October and December 1640, one wonders whether this was a typographical error for 22 March 1640/41, falling as this date did immediately prior to the then legal New Year of Lady Day, 25 March. (On another occasion Flamsteed cites a Crabtree letter describing a lunar eclipse dated 18 March 1640/41: *H.C.B.*, p. 1.) On the other hand, Crabtree's description of himself as '*de facie ignotus*' ['though my face is unknown to you'] would imply that the two men had not yet met. But either way, it would be interesting to know who introduced Crabtree to Gascoigne.

One likely agent of introduction between the two men were the brothers Charles and Christopher Towneley, of Towneley Hall, Burnley. For the Towneleys, like Gascoigne, were intellectually-inclined Roman Catholic gentry living some 20 miles apart across the Lancashire and Yorkshire Pennines. What is more, William Crabtree was clearly on good terms with 'Mr Townley' already by this time, mentioning him twice in the August 1640 letter, and hoping in the near future to bring him, along with 'my Friend and second Self Mr Jeremiah Horrox, being near Preston ... to see Yorkshire, and you'. Firm friendships, therefore, already seem to have been in place by the summer of 1640.

The long letter which Crabtree sent to Gascoigne on 7 August 1640 – it took up 10 pages when printed in the *Philosophical Transactions* in 1711 – was concerned with solar observations, and Crabtree's agreement with Galileo that sunspots were actually on the solar surface, as opposed to being little planetoids in orbit around the Sun, as Gassendi was arguing. Yet in addition to sunspots, Crabtree's letter to Gascoigne discusses two other topics, both on the same theme of seeing dark objects in silhouette upon the solar disk, and of trying to make measurements of them. One of these was the details of a recent solar eclipse, where Crabtree promised to send not only his own observations, made at Broughton, Salford, along with those of Jeremiah Horrocks made at Much Hoole 'between Liverpool and Preston', but also 'Mr Foster's at London' [*Phil. Trans.* 1711, p. 288]; Mr Foster seems to have been the Gresham College Professor.

The other solar-related topic in the 7 August 1640 letter is the 24 November 1639 transit of Venus. From Crabtree's wording, it is clear that Gascoigne had not seen the transit for himself – which is confirmed by the absence of Gascoigne's name in Horrocks's

https://doi.org/10.1017/S1743921305001225 Published online by Cambridge University Press

subsequent *Venus in sole visa* – although a prior discussion had clearly taken place between Crabtree and Gascoigne about the angular diameter of the transiting Venus on the Sun's disk, for it is mentioned in the 7 August letter. Crabtree describes his own partial clouding-out in Salford, though he did have time for at least one good observation. His friend Horrocks at Much Hoole, however, had been more fortunate, having seen Venus 'clearly from the time of its coming onto the Sun till the Sun's setting'. However, both Crabtree's and Horrocks's observations had been in close agreement as far as the main features of the transit were concerned, such as the small angular size of Venus when seen on the Sun's disk, and the Venusian orbital details extracted from the observation.

Central to Crabtree's and Horrocks's concern with the transit of Venus, however, had been Kepler's prediction of impending Venus and Mercury transits across the Sun's disk in 1631, in *Admonitio ad Astronomos* (1630). No one had been able to observe the Venus transit of 6 December 1631, because it occurred after sunset in most European locations. But as we say above, the Mercury transit, on 7 November 1631, had been successfully observed by Pierre Gassendi in Paris, who had drawn some significant facts from the event. The most important of these was the surprisingly small angular size of Mercury as it passed across the Sun: a mere 20″, indeed, as against the several arc minutes traditionally ascribed to it by astronomers looking at Mercury as it shone in the evening or morning sky. Secondly, by being able to see Mercury on the disk of the Sun, one could fix the planet's position in the sky to a much higher level of accuracy than before, for the daily position of the Sun in the ecliptic was known more precisely than that of any other 'planetary' or wandering body. And from Mercury's position at a particular time on a given day with relation to the Sun's centre, it would be possible to apply precise corrections to the theoretical knowledge of Mercury's orbit. The technique which Gassendi had employed to observe the 1631 Mercury transit was that of telescopic projection on to a white screen – basically the same method as that used by Galileo in 1612, and which had been pretty well perfected by Christopher Scheiner for making a daily sunspot record and described and illustrated by him in *Rosa Ursina* (1626-1630).

By the late 1630s, Horrocks and Crabtree were familiar both with Kepler's Mercury and Venus transit predictions for 1631, and with Gassendi's observation. It is also likely that it was Gassendi's surprising discovery of Mercury's smallness when seen in transit which aroused Horrocks's suspicion that Venus might also subtend a much smaller angular diameter than the several arc minutes traditionally ascribed to it, and made him especially keen to observe the event when he realised that a transit would occur on 24 November 1639. And as we saw above, Horrocks came to the conclusion that a transit would occur on that day from disagreements about the exact day and time of Venus's inferior conjunction as displayed in the major astronomical tables, for it is at inferior conjunction, of course, that Venus passes between the Earth and the Sun. Kepler had been of the opinion that after the 1631 transit the Earth, Venus, and solar straight-line inferior conjunction would not re-align for another 130 years. But from his awareness of the errors of the tables, his own observations of the motions of Venus, and by that peculiar genius which made him one of the most brilliant planetary dynamicists who has ever lived, Jeremiah Horrocks came to grasp by mid-October 1639 that Kepler had been mistaken, and that Venus would once again cross the Sun on 24 November.

At the time of the transit, Horrocks was living in the Lancashire village of Much Hoole, some 8 miles south-west of Preston. Legend has it that he was curate at the parish church of St. Michael, at which the Revd Robert Fogg was Rector, but there are no contemporary references to his clerical status, and even Wallis, Flamsteed, and Derham, all of whom were Anglican clergymen, and who were to be such active publishers of his scientific importance over the next eighty years, never speak of Horrocks as an ordained colleague.

https://doi.org/10.1017/S1743921305001225 Published online by Cambridge University Press

Most important of all in this respect, Jeremiah Horrocks, who seems to have been no more than 21 or 22 years old at most in 1639, was simply too young to have been ordained deacon, for the minimum age for an Anglican deacon, both in 1639 and today, is 23, and for a priest, 24. It is more likely that Horrocks was working as a schoolmaster or a private tutor in Much Hoole – perhaps in the employ of the Stones family of Carr House, who were not only local landowners but also merchants trading with London and Amsterdam – and assisting in church as a Bible Clerk on Sundays. For in this capacity, where he would have read the Psalms, Collects, and Old Testament Lessons, he would have gained invaluable experience for a future career as a clergyman. And every evidence is that Horrocks, who was a deeply devout Cambridge graduate, would have presented himself for ordination when he reached the right age.

Though Horrocks's calculations led him to believe that Venus would cross the Sun on Sunday 24 November 1639, he decided, just to be on the safe side, to keep watch on Saturday 23rd. After all, the standard tables did put inferior conjunction on the Saturday. And to make the observation, he used a technique similar to that used by Gassendi in 1631. A small refracting telescope was used to project an image of the Sun on to a six-inch-diameter circle drawn on to a sheet of white paper. The circle had been carefully divided into 360°, so that it would be possible to establish the coordinates of the transit with great accuracy [Horrox, *Venus*, p. 121]. Although Horrocks does not say so, one presumes that the telescope and projection screen must have been connected to each other by a wooden bar or shaft, to maintain a line of collimation.

The day of the transit was overcast, and while Horrocks mentions the 'higher' duties which occupied his time for parts of the day, and gave rise to the story that he was the parish curate, he nonetheless enjoyed sufficient snatches of leisure to keep an eye open for any breaks in the clouds. But not until 3.15 in the afternoon, and with less than 40 minutes to sunset, did Horrocks see Venus just entered upon the solar disk (ingress had probably occurred at 2.49 p.m.), at $62^\circ\,30'$ from the top limb, seen as a telescopic reversal. He then managed to secure two more sightings, at 3.35 and 3.45 p.m., before he lost the Sun on the horizon. William Crabtree in Salford seems to have enjoyed the same short late-afternoon break in the clouds, later telling Gascoigne that 'The Clouds depriv'd me of part of the Observation', though his and Horrocks's 'Observations agreed, both in the Time and Diameter [of Venus], most precisely' [*Phil. Trans.* 1711, p. 288].

The central concern to both Horrocks and Crabtree was the apparent angular diameter of Venus. No doubt on the basis of Gassendi's Mercury diameter measurement in 1631, Horrocks confidently informed Crabtree on 26 October 1639 [*Op. Post.*, p. 331] that he expected the Venusian diameter to be about $1'$. On the day of the transit, Horrocks found that the planet actually subtended $1'\,12''$, or $1'\,16''$ at most (after applying corrections), and not the $7'$ supposedly attributed to it by Kepler or the $11'$ of Lansberg [p. 331], while Crabtree independently measured Venus's diameter to $1'\,3''$ [Horrox, *Venus*, pp. 131, 187]. Both figures were obtained by each man marking the size of Venus on his projection screen, and calculating it as a fraction of the known apparent solar diameter for the day. What is more, Crabtree and Horrocks independently found the planet Venus to be perfectly round and jet black in colour: clearly a totally opaque body, and not self-luminescent as certain ancient philosophers had believed the planets to be.

Though William Crabtree does not seem to have obtained more than a single observation of Venus in transit because of clouds, Jeremiah Horrocks obtained three. From these three Venus positions, he was able to calculate the planet's velocity, making it possible to work out when the transit would have started and ended. It was also possible, from the angle at which it passed across the Sun, to calculate the node (the point at which the orbit of Venus intersects the ecliptic) and other characteristics of the orbit to a new

https://doi.org/10.1017/S1743921305001225 Published online by Cambridge University Press

level of accuracy, and thereby substantially improve our understanding of the theory of the planet's motion.

The 20″ apparent diameter of Mercury observed by Gassendi and the 1′ 16″ corrected diameter of the transiting Venus led Horrocks to derive a new value for the horizontal solar parallax of 14″, which was very much smaller than the values ascribed to it by classical and modern astronomers. Yet impressive as Horrocks's figure was, one must not forget that he came to it via a line of celestial geometrical reasoning which we now know to have been false. For influenced as he was by Kepler's harmonic and geometrical reasoning, Horrocks had concluded that, when viewed from the Sun, both Mercury and Venus would subtend angular diameters of 28″ [Horrox, *Venus*, p. 208]. Knowing that the Earth was around 8000 miles in diameter (and presumably larger than the inner planets), he thought that it too would subtend 28″ when viewed from the Sun. Believing as he did that the planets (with the exception of Mars, which presented such a tiny visible expanse when viewed through the telescope) became physically larger and moved more slowly in orbits of increasing radii as their distance from the Sun increased, one comes to understand why Jeremiah Horrocks was so concerned with obtaining accurate measurements for the angular diameters of the planets: if Mercury, Venus, and Earth subtended 28″ when seen from the Sun, did Mars, Jupiter, and Saturn do likewise? Knowing the distance of the Sun was a key component in this exercise, as it would enable the astronomer to supply some physical dimensions to the proportions predicated by Keplerian theory. Saturn, for instance, thought to be right at the edge of the solar system in the seventeenth century, seemed to be especially large when viewed with simple telescopes at that time, for the ring system was often mistaken for planetary bulk. And as the line connecting the centre of the Sun to the centre of a planet bisects this 28″ diameter, thereby creating a pair of right-angled triangles across the Earth's equatorial diameter, Horrocks considered that the solar parallax must be 14″.

Erroneous in its fundamental cosmological assumptions as Horrocks's value for the solar parallax was, its very smallness with regard to all previous parallax values had the immediate effect of making the solar system seem incredibly large, with an Astronomical Unit of 15 000 Earth radii, or 59 600 000 miles. With Tycho Brahe's solar parallax value, however, the Sun was only about 4 600 000 miles away, while Kepler's 59″ parallax would still have put it at only around 10 000 000 miles. In this respect, therefore, Jeremiah Horrocks is not without significance as a cosmologist, and as an early proponent of cosmological vastness based not on philosophical speculation so much as upon (albeit misinterpreted) telescopic observations and measurements.

It must be fully understood, however, that there was no way in which Horrocks could have measured, or even thought of measuring, the solar parallax directly from the 24 November 1639 transit, as eighteenth- and nineteenth-century astronomers attempted to do from later transits. For the measurements taken in 1761, 1769, 1874, and 1882 came from a variety of observing stations scattered around the globe, as astronomers laid out great base lines across the Earth's surface. For to measure the solar parallax from trigonometrical observations of Venus on the Sun's disk, one needs at least two widely-spaced observing stations.

Looking back in hindsight, one can see how the 1639 transit formed a natural apotheosis to the short and staggeringly brilliant astronomical career of Jeremiah Horrocks. While he did follow-up work on the post-transit Venus positions, as the planet moved to eastern elongations as a morning star, and was, according to Crabtree (7 August) clearly fascinated by the news of Gascoigne's instruments, this would turn out to be his last great piece of research. Mercifully, he had sufficient time to write up his and Crabtree's findings into *Venus in sole visa*, and then he died suddenly on 3 January 1641. We do

https://doi.org/10.1017/S1743921305001225 Published online by Cambridge University Press

not know what he died of, at the age of 22 or 23, and sadly, our only surviving record of his death comes from the manuscript obituary penned by Crabtree himself:

> 'Mr Jeremiah Horrox's Letters to me in the years 1638, 1639, 1640, up to the day of his death very suddenly on the morning of the 3rd January [1641]; the day before he had arranged to come to me. Thus God puts an end to all worldly affairs. I have lost alas my most dear Horrox. Hinc illae lachrimae [thence those tears]. Irreparable loss!' [*Op. Post.*, p. 338; English, Whatton, Memoir, p. 58]

And if Horrocks was planning a journey from Toxteth (having returned to the family home from Much Hoole sometime in the summer or autumn of 1640), then one might assume that he was not suffering from a long-term disease. Perhaps he died in an accident, or from a sudden virulent winter infection. We simply do not know.

Judging from the letters printed by Flamsteed, it is clear that Crabtree and Gascoigne continued to correspond until 1642. But this correspondence seems to have ended with the onset of the Civil Wars in August 1642, for Gascoigne received a commission as Providore for Yorkshire in the army of King Charles I. There is no record of Crabtree having served in any army, though as the Salford and Manchester areas were supportive of Parliament, the two astronomical friends could have found themselves on different sides in the great conflict. Yet Crabtree, Gascoigne, and their mutual friend Charles Towneley senior all died within a month of each other: Towneley and Gascoigne falling in the Battle of Marston Moor, fought on 2 July 1644, and Crabtree making his will on 19 July, and being buried within the precincts of the Manchester Collegiate Church on 1 August 1644, close to where he had received his education. We have no information as to the cause of Crabtree's death.

After the deaths of Horrocks, Crabtree, and Gascoigne, various people tried to collect together and preserve their manuscripts, though it was the Pendle Forest, Lancashire, astronomer Jeremy Shakerley who first acknowledged Horrocks's achievement in print, in three books, which he published between 1649 and 1653. Then Christopher Towneley, Charles's younger brother, who survived the battle of Marston Moor and lived on until 1674, certainly obtained a body of the manuscripts, along with the 'carkasse' of Gascoigne's sextant, and these were studied by the young John Flamsteed after 1672. Flamsteed, deeply Protestant Anglican clergyman that he was, became a friend and long-standing correspondent of the Roman Catholic Richard Towneley, Charles's son and heir to the Towneley estates in Lancashire, while Richard Towneley himself was an active scientist, leaving a large collection of books, manuscripts, and scientific instruments in his will in 1706. Other bodies of manuscripts found their way to London, where Sir Jonas Moore (who as a young man in Lancashire had been part of the Towneley circle, and as a knighted Royalist in the 1660s was an early Fellow of the Royal Society and the patron of John Flamsteed) assisted in bringing them to the attention of Oxbridge and Metropolitan scientists. The early Royal Society resolved to see these national treasures published, and though an unspecified number were destroyed in the Great Fire of 1666 – in the hands of Nathaniel Brooks the printer – sufficient remained for John Wallis to edit into the *Opera Posthuma* of Jeremiah Horrox (*sic*) in 1673.

But it was Horrocks's account of the 1639 Venus transit which not only immortalised him and his friend Crabtree, but was also the only complete major work that he left at his death in January 1641. This manuscript was certainly copied by others over the next few years: by John Worthington of Manchester, perhaps, Horrocks's Emmanuel College student contemporary, who could well have introduced Horrocks to Crabtree in 1635 or 1636, when Jeremiah was staying over in Manchester on the last leg of his journey back to Liverpool from Cambridge, and who was clearly interested in his deceased friend's

https://doi.org/10.1017/S1743921305001225 Published online by Cambridge University Press

achievements. Worthington rose up to be a Head of House and a dignitary of Cambridge University in later life, and tried to find a publisher for '*Venus in Sole Visa*'. Samuel Hartlib, the expatriate German scholar living in England, is said to have obtained two manuscript copies of '*Venus*', one of which was studied by a member of the Mercator dynasty of Flemish cartographers and scientists. Then in April and May 1661, as the original Fellowship of the Royal Society was forming, the great Dutch astronomer Christiaan Huygens, who was elected a Fellow of the Society in 1663, was in London. Huygens was certainly interested in Horrocks, and also acquired a copy of the '*Venus*' manuscript from Sir Robert Moray, who in turn had got it from Sir Paul Neile. Via Huygens, the manuscript, or yet another copy of it, was passed on to his Polish friend Johannes Hevelius in Dantzig, and when Hevelius published his own account of the Mercury transit of 1661, he issued it in conjunction with a printing of Horrocks's Venus transit manuscript. Thus, in 1662, Horrocks's *Venus in Sole Visa* at last saw the light of day in an elegantly-printed volume under the imprimatur of one of Europe's most illustrious astronomers. Published in this way, it is hardly surprising that the work of Horrocks and Crabtree came to be blazoned across learned Europe. In the wake of this prestigious publication, the Royal Society's issuing of *Opera Posthuma* (in which Horrocks's and Crabtree's letters were translated into Latin for a clearly targeted international readership), and the publishing of fragments of the Crabtree-Gascoigne correspondence by Derham and then Flamsteed in the early eighteenth century, it is clear that the work of the North-country astronomers had entered into the full consciousness of the European scientific movement. Newton sang the praises of Horrocks in *Principia* (1687), while they were accorded recognition on a variety of levels: as original proponents of practical observation, as celestial mechanists of genius, and as inventors of crucial new scientific instruments, such as the telescopic sight and the micrometer.

By the nineteenth century, Horrocks and Crabtree in particular came to be seen as iconic figures by British astronomers. To Sir John Herschel, for instance, Horrocks was 'the pride and boast of British astronomy'. He was commemorated – at long last – in Much Hoole parish church, and in Westminster Abbey in 1874, while artists such as Eyre-Crowe, Ford Maddox Brown, and W. R. Lavender immortalised Horrocks and Crabtree at those short, critical moments when Venus briefly revealed herself in transit, in magnificent oil paintings. It is true that here Horrocks and Crabtree, of whose authentic appearances we know nothing whatsoever, were draped in the garb of the Victorian romantic imagination: both men are thin and emaciated, and Crabtree, who was 29 years of age in 1639, looks like a manic 70-year-old with an incongruously young wife and small children, while Horrocks has become a gaunt puritan! Their early deaths also excited the romantic imagination of Victorian scientific hagiographers: was not Gascoigne a dashing Cavalier, tragically meeting his death in battle at the age of 32, and could not Horrocks easily be seen as an intense genius, nervous and deeply devout; a starving curate, probably consumptive, whose frail hold on life finally snapped in his early twenties? It was not for nothing that in 1959 W. F. Bushell styled him 'The Keats of English Astronomy'. Yet in reality we know nothing about these men's appearance, physical build, health, or – with the exception of Gascoigne – cause of death. One can only assume that they enjoyed a considerable physical robustness, considering the amount of stunning achievement they packed into such short lives, at the same time as earning their living.

Yet historical *reality* never ceases to be full of surprises. Ten or twelve years ago, no one could have predicted that major Horrocks documents would emerge out of their hiding-place of centuries, and present themselves in the saleroom. Yet this is precisely what happened in the spring of 1995, when Mark Westwood, a scholar and academic book dealer of Hay-on-Wye and himself an Emmanuel College graduate, was commissioned by

https://doi.org/10.1017/S1743921305001225 Published online by Cambridge University Press

an undisclosed vendor to sell what was probably Jeremiah Horrocks's own handwritten Latin manuscript of '*Venus in Sole Visa*'. Both Mr Westwood and I agreed that the handwriting was very similar to that of Horrocks himself, while the leather boards into which a subsequent owner had bound it also contained, probably in a scribal hand, a fair copy of '*Venus*', along with the manuscript of Horrocks's '*Praeludium Astronomicum*'. Mercifully, when these manuscripts came up for auction later in 1995, it was possible for Cambridge University Library to purchase them, so that they will be curated in perpetuity by the academic institution in which Horrocks first acquired his extra-curricular fascination with modern astronomy.

Then equally remarkably, in November 2004, Horrocks's manuscript '*Observationes Astronomiae ...*' for the years 1635 to 1637 suddenly came up for sale at Sotheby's as part of a larger collection of historical astronomical documents. This valuable manuscript, written over 36 leaves and almost certainly in Horrocks's own hand, shows that he was observing as early as June 1635, which may have been around the time that he met Crabtree. It also contains his original observations of Jupiter and Saturn for 1636, which were to be so significant in his emerging ideas of planetary attraction, as well as other important investigations. And as all of this work was being done at the Horrocks family home at Toxteth, Liverpool, between Jeremiah's return from Cambridge and his departure for Much Hoole in 1639, it represents the earliest major scientific research to have been undertaken in and adjusted to the geographical position of Liverpool, and therefore has enormous cultural significance for the North-West of England.

Unlike the '*Venus in Sole Visa*' manuscript, I was unable to examine or even see this '*Observationes*' manuscript, and can only speak of it from the details contained in the published Sotheby's catalogue, and from what my friend Alan Bowden of National Museums on Merseyside, Liverpool, could tell me from his own brief inspection. For sadly, the saleroom bidding for the manuscript escalated beyond the sums which had been pledged for Merseyside Museums, and it was knocked down to another purchaser. Attempts are currently in hand, January 2005, to prevent the manuscript from leaving Great Britain if any request for an export licence is made, or at the very least, of having its contents computer-scanned and made available to the international scholarly community.

Yet as we have seen above, Jeremiah Horrocks had no geometrical method, beyond his mistaken idea that the planets subtended 28″ diameters as viewed from the Sun, by which one could measure the solar parallax from the three brief views of Venus in transit that he obtained in November 1639, so Horrocks's and Crabtree's observations played no enduring part in establishing that vital astronomical quantity. Indeed, another 38 years would elapse before an astronomer realised how the Sun's parallax might truly be measured from an inner planet transit. And that realisation was to be made by the young Edmond Halley when, on 7 November 1677, he observed a transit of Mercury from the island of St Helena in the south Atlantic. It occurred to Halley, a geometer of genius, who curiously enough was in 1677 about the same age that Horrocks had been in 1639, that if astronomers in Europe were observing Mercury's passage across the Sun at the same time as he was in St Helena, then they would see it on a slightly different part of the Sun's surface. London or Paris and St Helena are around 56° apart on the Earth's surface, and after establishing exact trigonometrical base lines between observing stations (using Jupiter's satellites to determine longitudes and accurate telescopic quadrants to fix latitudes), it should be possible to use a transit of Mercury to obtain the solar parallax by triangulations and timings. This would be accomplished by the astronomer using a good telescope to observe the ingress and egress of the transiting planet, while timing the duration of passage with an accurate regulator clock. For observers stationed at two different latitudes on the Earth would indeed see Mercury enter and leave the Sun from

https://doi.org/10.1017/S1743921305001225 Published online by Cambridge University Press

slightly different parts of the limb, and describe lines of slightly different lengths upon it. If these differences of both position and time could be measured with sufficient accuracy, Halley argued, then the distance of Mercury, and by extrapolation of the Sun, could be extracted from them.

But Mercury turned out to be too small and fast-moving for practical measurement by this method, which led Halley to realise that Venus transits, with a larger planetary body and longer transit time, would be much more suitable. The only problem was that no individual around in 1677 was likely to witness the next Venus transit in 1761. Yet this did not prevent Halley from paying considerable attention to the celestial mechanics of a forthcoming Venus transit which he knew that he would never see, and over the next few decades and into the early eighteenth century, he published several papers which developed his method of observation. As 1761 drew closer other astronomers, learned societies, and governments began to make plans for 1761 and 1769. Joseph-Nicholas Delisle in France refined the data, published a *Mappemonde* of where in the world the whole or parts of the 1761 Venus transit would be seen, and improved Halley's originally-suggested observing technique. Delisle also drew attention to the fact that in 1753 Mercury would transit the Sun's disk, and that this event could act as something of a training ground for the Venus transits of 1761 and 1769. The eighteenth-century transits, moreover, assumed a new intellectual importance in the wake of Newton's Laws of Motion, for if the Astronomical Unit could at last be established with accuracy, then not only could the proportions of the solar system be ascribed definitive physical values, but gravitation theory could be further perfected.

Other scholars and historians of astronomy, however, will go on in the present volume to discuss the problems, adventures, and achievements of the observers of the 1761, 1769, 1874, and 1882 transits. It is hard to imagine that anyone, no matter where they were in the world, could have observed the Venus transit of 8 June 2004 without a sense of wonder and of great occasion. And those who had gathered at Broughton Spout, Salford, within a stone's throw from where William Crabtree had lived, or those, including the IAU Colloquium 196 Conference Party, who, after witnessing the start of the transit at Alston Hall, then assembled in the gardens of Carr House and St Michael's churchyard, Much Hoole, where Horrocks had lived in 1639, to watch its latter stages, could not have failed to appreciate the historical significance of time, place, and event. For it was from Salford and Much Hoole that, 364 years before, a profoundly far-reaching observation had been made by two English amateurs. It would subsequently blazon their names before the *savants* of Europe, and inaugurate for English research astronomy an enduring reputation for originality and excellence.

Acknowledgements

I wish to thank Dr Robert van Gent for his information, and for directing me to sources regarding the passage of Horrocks's manuscript of '*Venus in Sole Visa*' from London to Hevelius, via Christiaan Huygens in Holland. I also wish to thank Carl Barry and Lilian Fletcher of Salford for access to their genealogical researches into the Crabtree family, and also Kenneth Irvine, Director of the Salford Astronomical Society Observatory. Among them, these three have produced credible evidence to suggest that a house still standing in Broughton Spout, Salford, is likely to have been the one where Crabtree lived and from which he observed the 1639 transit.

https://doi.org/10.1017/S1743921305001225 Published online by Cambridge University Press

References

Abbreviations

Op. Post. – see Horrocks, *Opera Posthuma*
H.C.B. – see Flamsteed, *Historia Coelestis Britannica*
Phil. Trans. – see *Philosophical Transactions*

Primary sources: letters and publications

Jeremiah Horrox [Horrocks], *Jeremiae Horrocci Liverpoliensis Angli ex Palinatu Lancastriae Opera Posthuma* (London, 1673), for the letters of Jeremiah Horrocks and William Crabtree.

J. Horrocks, *Venus in Sole Pariter Visa Anno 1639*, published in Latin by Johannes Hevelius, as an addition to his *Mercurius in Sole Visa Gedani* (Dantzig, 1662).

J. Horrocks, *Venus in Transit Across the Sun*, English translation of *Venus in Sole Visa*, by Arundel Blount Whatton, and appended to 'A Memoir of his [Horrocks's] Life and Labours' (London, 1859).

J. Horrocks: known manuscripts:

'*Venus in Sole Visa*'; '*Venus in Sole Visa*'; '*Jeremiae Horroxj Praeludium second Astronomicum Liber primus De motu Solis*': three original manuscripts (two of 'Venus') bound into the same set of leather boards, and acquired at auction by Cambridge University Library, 1995.

'*Venus in Sole Visa*', acquired by the Royal Observatory, Greenwich, Library, 1838. RGO 76/1.

'*Venus in Sole Visa*', also in the Royal Observatory collection, RGO 68/C.

'Philosophical Exercises', RGO 68/B.

'*Explicatio brevis et perspicua Diagrammatis Hpparchi*', RGO 68/D.

Other MSS in RGO 68/E.

'Astronomical observations and notes for the years 1635-1638'. Autograph manuscript in eighteenth-century vellum-backed paper boards. Sold in auction at Sotheby's, London, 4 November 2004, to an unspecified vendor. Nothing currently known beyond details in Sotheby's sale catalogue.

John Flamsteed, *Historia Coelestis Britannica*, 3 vols. (London, 1725). Vol. I, pp. 1-5, for Crabtree-Gascoigne correspondence and observations, 1638-1643.
J. Flamsteed, *The 'Preface' to John Flamsteed, 'Historia Coelestis Britannica', or British Catalogue of the Heavens, 1725*, edited and introduced by A. Chapman, based on a translation by Alison Dione Johnson (National Maritime Museum Monograph No. 52, 1982).

William Crabtree, Letter to William Gascoigne on sunspots and solar observations, 7 August 1640, ed. William Derham, *Philosophical Transactions* 27 (1711), 279-90.

William Crabtree and William Gascoigne, selections from correspondence 1640-1, ed. William Derham, *Philosophical Transactions* 30 (1717), 604-10.

William Gascoigne to William Oughtred, undated letter but probably written in February 1641: Stephen J. Rigaud, *Correspondence of Scientific Men of the Seventeenth Century*, 1 (Oxford, 1841), 35-9. Also Gascoigne to Oughtred, 2 December 1640, Rigaud, *Correspondence* 1, 33-4. [Rigaud also reproduces letters by Flamsteed, John Collins, and others about Horrocks, Crabtree, and Gascoigne from the 1660s and 1670s.]

Edward Shereburne, *The Sphere of Marcus Manilius* (1675): see supplement 'Catalogue of famous astronomers' for early biographies of Horrocks, Crabtree & co.

J. Crossley, 'The Diary and Correspondence of Dr John Worthington', 3 vols. (Chetham's Society Publications, 13, 36, 114 (Manchester, 1847-1886).

Jeremy Shakerley Anatomy of "*Urania Practica*" (London, 1649).

Jeremy Shakerley *Synopsis Compendiana* (London, 1651).

Jeremy Shakerley *Tabulae Britannicae* (London, 1653).

Richard Towneley, 'A description of an instrument for dividing a foot into many thousand parts', *Philosophical Transactions*, 1667, 541.

https://doi.org/10.1017/S1743921305001225 Published online by Cambridge University Press

Secondary sources

Peter Aughton, *The Transit of Venus. The Brief, Brilliant Life of Jeremiah Horrocks, Father of British Astronomy* (Weidenfeld and Nicolson, Windrus Press, London, 2004).

E. Axon, 'The Broughton Estate plans', *Transactions of the Lancashire and Cheshire Antiquarian Society*, 1905. Estate plan of 1637 drawn by William Crabtree.

John E. Bailey, 'The writings of Jeremiah Horrox and William Crabtree ... reprinted with additions', in the *Palatine Notebook*, Dec. 1882 and Jan. 1883 (1883).

Francis Baily, *An Account of the Revd. John Flamsteed* (1835).

Carl Barry and Lilian Fletcher, 'William Crabtree of Broughton. A hunt for his domicile' (Salford, 2004). A computer text of genealogical and topographical researches. Copy generously presented to A. Chapman, December 2004. Copy also on deposit in the Central Library, Peel Park, Salford.

W. F. Bushell, 'Jeremiah Horrocks, the Keats of English Astronomy', *Mathematical Gazette* 43, 343 (February 1959) 1–16; reprinted in the North West Astronomy Series by the Liverpool Astronomical Society, 1992

A. Chapman, 'Jeremiah Horrocks, the Transit of Venus, and the "New Astronomy" in early seventeenth-century England', *Quarterly Journal of the Royal Astronomical Society* 31 (1990), 333-57. Reprinted in Chapman, *Astronomical Instruments and their Users: Tycho Brahe to William Lassell* (Variorum, Ashgate Collected Studies, Aldershot, 1996).

A. Chapman, *Three North-Country Astronomers* (Manchester, 1982).

A. Chapman, *William Crabtree 1610-1644. Manchester's First Mathematician* (Manchester Statistical Society, 1995).

A. Chapman, 'The Astronomical Work of Thomas Harriot', *Quarterly Journal of the Royal Astronomical Society* 36 (1995), 97-107.

A. Chapman, 'Reconstructing the angle-measuring instruments of Pierre Gassendi', in *Learning, Language, and Invention: Essays presented to Francis Maddison*, edd. W. D. Hackman and A. J. Turner (Variorum, Aldershot, 1994). Reprinted in Chapman, *Astronomical Instruments and their Users.*

A. Chapman, *Dividing the Circle. The Development of Critical Angular Measurement in Astronomy, 1500-1850* (Praxis-Wiley, Chichester, 1990, 1995).

Chetham Society, *Miscellanies*, vol. 63, for Crabtree family.

Betty M. Davis, 'The astronomical work of Jeremiah Horrox', University of London M.Sc. thesis (1967).

Sidney B. Gaythorpe, 'A Galilean telescope made about 1640 by William Gascoigne ... ', *Journal of the British Astronomical Association*, June 1929, 238-41.

S. B. Gaythorpe, 'Horrocks' observations of the Transit of Venus, 1639', *Journal of the British Astronomical Association*, Dec. 1936, 60-8; July 1954, 309-15.

S. B Gaythorpe, 'Jeremiah Horrocks: Date of Birth, Parentage, and Family Associations', *Transactions of the Historical Society of Lancashire and Cheshire* 106 (1954), 23-33.

S. B. Gaythorpe, 'Horrocks' Observations and Contemporary Ephemerides', *Journal of the British Astronomical Association* 47 (1937), 156-7.

David W. Hughes, 'Horrocks's bogus law', *Astronomy and Geophysics* vol. 46, Feb. 2005, 114-16.

David W. Hughes, 'Why did other European astronomers not see the Transit of Venus', these proceedings.

John Roche, 'The Radius Astronomicus in England', *Annals of Science* 8 (1977), 102-12.

John W. Shirley (ed.), *Thomas Harriot, Renaissance Scientist* (O.U.P., 1974).

F. J. M. Stratton, 'Jeremiah Horrox and the Transit of Venus', *Occasional Notes of the Royal Astronomical Society* 7 (1939).

G. H. Turnbull, 'Samuel Hartlib's Influence on the Early Royal Society', *Notes and Records of the Royal Society* 10 (1953), 101-30.

Charles Webster, 'Richard Towneley (1629-1707). The Towneley group and seventeenth-century science', *Transactions of the Lancashire and Cheshire Historical Society* 18 (1966).

https://doi.org/10.1017/S1743921305001225 Published online by Cambridge University Press

Discussion

Jesus de Alba Martinez: Do you think that the curriculum information of Horrocks includes astronomy as a kind of Quadrivian curriculum?

Allan Chapman: Yes, that's perfectly right. Certainly when you'd been to Cambridge, or Oxford, or any other major European University at that period, or even in the Grammar School, you would have studied the Quadrivian, including astronomy, geometry and simple calculation. This would have given you a basic familiarity with the laws of proportion, such as would have been taught in the ancient Roman schools, and which came to be enshrined in the curricula of Europe's medieval Universities. Horrocks would have picked up quite a lot of information about the classical universe, especially of Ptolemy (probably including Johannes Sacrobosco's *De Sphaera Mundi*, c. 1240) as part of the Quadrivian. In Cambridge, however, there would probably have been no formal teaching of the *new* astronomy. Indeed, Horrocks pretty well tells us that he was taught no new astronomy in Cambridge! Therefore, you are quite correct, Sir, for like Kepler, like Gassendi, like all astronomers in Europe, Horrocks would have had a Quadrivian training.

David Sellers: The well-known translation of the "*Venus in Sole Visa*" by Whatton describes Venus as coming into the image that was projected by Horrocks from the top right and that description has been fatefully reproduced in the Ford Madox Brown painting at Manchester Town Hall and the paintings by Lavender and Eyre Crowe of Horrocks observing, but is it not the case that a Galilean telescope would have inverted the image, but not reversed it, and that would actually mean that the stained-glass window at Hoole Church, although fanciful, is nevertheless the right way round?

Allan Chapman: You're absolutely right there, Sir, it was! We don't know exactly whether he was using a Galilean or a Keplerian. I suspect a Galilean although a few years later Gascoigne in Leeds is certainly observing with a Keplerian. I suspect the telescope he would have bought for half a crown would have been a general telescope for looking at horse-riding and things of this sort, which of course would have given you the right-way-up image, so I suspect he was working with a Galilean, although there's no proof; he doesn't say it.

David Hughes: I love the first painting [by JW Lavender]. What was special about 1903? Why did he happen to paint it then?

Allan Chapman: I don't know why. It's quite remarkable – between 1879, I think, when the Manchester corporation commissioned the Ford Madox Brown, till 1903, with the 1891 Eyre Crowe which was shown at the Royal Academy, there seems to have been a sort of burst of some fascination in Jeremiah and his friends. I suppose one could say too that the great interest in the area of Much Hoole, and the Reverend Robert Brickel, the windows, the sundial ... I think it probably had something to do with a sense of England's glory, England's greatness, and of course the movement of naturalistic history painting. What you do have in British art in the late 19th century is a looking for great scenes to paint, such as, let's say, "The Death of General Gordon at Khartoum", and "Captain Cook's discovery of Australasia". This becomes a sort of tradition in English art in the late 19th century; very naturalistic, photographic in its accuracy. I suspect our friends Horrocks and Crabtree fell into that tradition as great Englishmen.

https://doi.org/10.1017/S1743921305001225 Published online by Cambridge University Press

David Hughes: Is it true that the Ford Madox Brown painting was exhibited with the other two paintings at Southport in 1903 for the British Association for the Advancement of Science?

Allan Chapman: I don't know, David.

David Hughes: I think the three were exhibited together at that time and it was certainly at Southport, but there are very few details about it. I thought you might know.

Allan Chapman: I didn't know that, so I'll see if I can confirm it, because, although they couldn't take one from the Manchester Town Hall wall, there was a canvas one in the Manchester art gallery; so yes, it would have been very easy to put them all together in Southport.

Robert van Gent: You mentioned this problem of how the manuscript came into various hands through Christiaan Huygens. It was in 1661 he got a copy of the manuscript. He knew he wanted to publish about it, so he just simply passed on Horrocks' notes.

Allan Chapman: Do you know that for certain?

Robert van Gent: Yes, you can find details in the correspondence.

Allan Chapman: Is there correspondence on it?

Robert van Gent: Yes, there is correspondence. I can give you details.

Allan Chapman: Thank you. I do appreciate that. I did suspect that because John Evelyn mentions being at an early gathering of the Royal Society in 1661 where King Charles II was present. They looked at the Moon and he mentions Monsieur Huygens being present. So, Huygens was clearly in England.

Robert van Gent: He was also saying that there would be a Mercury transit, so he was going to watch the transit.

Allan Chapman: This is what historical research is all about: Material comes out, and I thank you for that.

Jamie Matthews: Is there any evidence of scepticism amongst the rational community when these results came out? After all, they couldn't be verified, since it was a once in a lifetime event. And how soon was it that any of the predictions that arose from Horrocks' and Crabtree's observations could be verified?

Allan Chapman: Well, of course they wouldn't have been able to see another transit till 1761. Yet nobody denied or doubted the truth of Horrocks' and Crabtree's claims for, after all, the major tables did predict an inferior conjunction of Venus for 23 or 24 November 1639, and all placed that conjunction very close to the solar disk, so there was no reason to doubt the authenticity of the observation. When Christiaan Huygens obtained a manuscript copy of Horrocks' 'Venus' in 1661, he regarded it as a work of great significance, and Huygens was instrumental in securing its publication by Johannes Hevelius in Dantzig soon afterwards. Now, had Horrocks, or one of his posthumous English admirers, been able to secure a publication from some printer in Paternoster Row

https://doi.org/10.1017/S1743921305001225 Published online by Cambridge University Press

in London, it could have come years before Hevelius' edition in 1662. It is also clear by the 1660s the early Royal Society Fellows were viewing Horrocks' as a figure of truly international standing, and Horrocks' Emmanuel College contemporary, the Reverend John Wallis, F.R.S (now Savilian Professor of Geometry at Oxford) took on the task of editing Horrocks' and Crabtree's surviving correspondence for international publication in 1672–3.

Nick Kollerstrom: In the Ford Madox Brown picture you have the image just projected up onto a wall, and you said that Horrocks and Crabtree wouldn't have used this method – there would've been some sort of bar connecting the telescope with the screen. Would you like to comment on it?

Allan Chapman: You're absolutely right, Nick: You couldn't have madde a reliable observation without both the telescope and the projection screen being fixed to a common axis – such as a wooden bar. With such an arrangement, one could gently nudge the whole optical system to make it track the sun. Over the years I have tried to replicate the observing techniques of Horrocks and his contemporaries. I have made cross-staffs, tried to measure solar and lunar diameters with holes – or "foramen" – devices, and made solar projection systems to view sunspots. And I can assure you, you cannot keep a solar image within a circle drawn on a piece of paper, unless that paper, and the telescope, are all part of one optical axis. So I feel that Ford Madox Brown was wrong when he showed Crabtree observing by simply *aiming* the solar image across the room.

Steve Dick: Would Horrocks have know of John Wilkins, Bishop John Wilkins, 1638 "The Discovery of a World in the Moon"?

Allan Chapman: He could have done. Wilkins is also one of my own great heroes, not to mention that he was Warden of my college. Horrocks could have read Wilkins' "Discovery", but he never mentions it. Yet surprisingly, on his circa 1635 list of astronomers works he knew, there are no Englishmen, and the only English scientific writer whom Horrocks subsequently mentioned, if my memory serves me right, was the navigation book author Edward Wright. In 1638, moreover, Wilkins was only 24, and not much older than Horrocks himself. So I am afraid that there is no record of Horrocks being acquainted with Wilkins' work.

Steve Dick: Why would Horrocks not have told everybody else to look for the transit?

Allan Chapman: Well he did! He told not only Crabtree, but also wrote to his brother in Liverpool, and got probably Crabtree to write to Samuel Foster in London, which of course he mentioned, "Can you tell Mr Foster?" Which tends to indicate that Crabtree had a London correspondence with Gresham College which I'd love to know more about. Clearly Foster and Crabtree knew each other. But there simply was only a month before the event. Horrocks was not in a position to send this to printing presses, and there were no international journals in those days, so he depended on letters to friends and I think he's very lucky, considering communication delays, that Crabtree was able to secure a co-observation.

https://doi.org/10.1017/S1743921305001225 Published online by Cambridge University Press