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To the Heavens in Rural Lancashire: Jeremiah Horrocks and His Circle, and the Foundation of British Astronomical Research

Allan Chapman

In continental Europe, the astronomical revolution of the Renaissance was the product of great urban centres and powerful patrons who backed and promoted the work of figures such as Galileo and Kepler. In the British Isles, however, things were very different. Queen Elizabeth I and the succeeding Stuart kings were relatively hard up, by European standards, whereas England in particular had one of the richest and most powerful middle classes in the world. This chapter describes how it was from these people that Britain's own astronomical revolution was born.

Astronomical research and the scientific revolution in sixteenth- and seventeenth-century Europe

The scientific revolution in continental Europe was, in so many ways, the product of institutions. The 40-year analysis of astronomical tables, and their errors, which led Nicholas Copernicus to propose in 1543 that the earth moved around the sun, was accomplished through the time and resources made available to him from the revenues of the Polish Cathedral where he was a Canon. Tycho Brahe's re-observation of the northern heavens between 1572 and 1598, which released a flood of new data into the scientific community, was performed on the strength of generous official grants from the Danish government; while both Galileo and Johannes Kepler, in addition to holding university professorships, benefited from the support of powerful monarchs. Galileo, after rising to fame in 1610, became a scientific courtier to the Medici family in his native Tuscany;

while Kepler inherited Tycho's last appointment – though not his lavish revenues – as mathematician to the Holy Roman Emperor.

All of these men, and a good number besides, had come to wrestle with one of the most intractable intellectual problems of the Renaissance: why did the planets not move as the astronomical tables said that they should? Why was it that, when one took the historic observations and tables of the Greeks such as Hipparchus and Ptolemy, of medieval Europeans such as John de Sacrobosco, or of fourteenth-century Arabs like Ulugh Beigh they all failed to predict the motions of the heavens with accuracy? Of course, all these astronomers took it as axiomatic that the sun, moon, planets, and stars rotated around an earth that was fixed in the centre of the universe, and believed that one could explain the apparent speeding up and slowing down of certain planets, such as Mars, by making adjustments to the geometrical models which they believed could be used to account for the complex motion of the heavens.

Yet the idea that the earth actually moved around the sun, and that the earth and planets might well move in elliptical and not circular orbits, was one of the most profound realisations about the world in which we live ever to have been made by the human mind. Its imaginative power was immense, for the notion that the earth might be spinning in space flew in the face of reason and common sense, for how did we avoid being flung into space? On the other hand, these seemingly absurd ideas did make it much easier to model the movements of the planets, so that observed astronomical phenomena agreed with geocentric mathematical predictions.

And of course, what had played a fundamental role in gathering this fresh evidence was a radically new concept of the power of sense-knowledge. Did this include no more than what our five natural senses revealed to us, or did it also encompass the new and very precise data revealed to us by the telescope and recently invented precision angle-measuring instruments which raised our age-old senses to a more refined level of perception? Indeed, in 1665, Robert Hooke was to refer to these instruments as 'artificial Organs', in so far as they presented to the human senses an abundance of new information of which mankind had been ignorant since the dawn of time.

By 1630, therefore, the nature of the heavens, the possibility of the sun being at the centre of the solar system, and the interpretation of the new telescopic discoveries, such as Galileo's discovery of the moons of Jupiter or the spots on the sun, were being discussed across learned Europe. And needless to say, they were being debated in the British Isles as well, as people read the works of Galileo and Kepler, and bought telescopes – often made in Holland or Paris – with which to look at the planets for themselves. Yet so far the British response to these great continental discoveries was generally the conservative one of admiration, wonder, and gradual acceptance. For even by the 1630s no Englishman (except the reclusive, unpublished and now deceased Thomas Harriot) had made major independent discoveries in the New Astronomy, whether in London, Oxford, Cambridge, or at the artistically cultured court of King Charles I. On the other hand, one might suggest that at the same time as the Italian Renaissance was giving expression to the genius of Galileo and England was witnessing the flourishing of Shakespeare, so England was on the verge of making another of its contributions to Renaissance civilisation, by taking the European astronomical discoveries where Kepler and Galileo had left off, to take them yet further. For in so many ways England's great legacy to the Renaissance lay in her sciences.

Amateur astronomers in north-western England

While it is true that in the early seventeenth century Henry Briggs and Henry Gellibrand at Gresham College, London, were making major experimental advances in our understanding of the nature of terrestrial magnetism (in the wake of William Gilbert's *De Magnete* of 1600), the next advances in astronomy, after those of Galileo, Kepler, and Pierre Gassendi, were unfolding in the most unexpected of places: rural Lancashire, and across the Pennines in West Yorkshire – a part of England, moreover, which was thinly populated, relatively poor, and lacking in major educational resources. One of the very last places, indeed, where one might have expected to find a group of men who were actively wrestling with the great continental discoveries, and making advances beyond them. For what had been done in Florence, Prague and Paris was being examined and further developed in Salford, Liverpool, and villages such as Much Hoole near Preston, and Middleton just outside Leeds.

Why the English astronomical Renaissance should have sprung up in this north-western environment is not easy to explain. There were no especial lines of patronage in the region that were fundamentally different from what one might have expected to find in Norfolk or Devonshire, let alone what could have been possible in London, Oxford, and Cambridge. After all, there were intellectually inclined county squires, small merchants, and clergy spread across the country, though their interests tended more to literature or the arts, rather than to science. Nor did the region possess any particular local attributes which may have led to the cultivation of astronomy in a serious way. Yes, it is true that Liverpool was a port, but in 1630 it was still very much of a regional port serving the Irish Sea and the coasting trade, and would not necessarily have been stimulated by the astronomical needs of global navigation. In that respect, London, Bristol or Plymouth would have provided more fertile astronomical soil. Quite simply, there is no obvious set of social or economic circumstances that can be invoked to explain why the European Astronomical Renaissance took root in rural Lancashire and West Yorkshire, beyond the contingent presence of a small group of individuals who happened to be interested in the subject.

The most intellectually significant of these individuals was Jeremiah Horrocks (1618/19 to 1641), the son of a Toxteth, Liverpool, yeoman farmer with family connections to the local watch-making trade. Horrocks's brother Jonas also had astronomical interests, and probably owned a telescope, though we know nothing of Jonas beyond a few passing remarks by Jeremiah. Then there was William Crabtree (1610–44), a clothier, or cloth-dealer, of Salford, who was already established as a serious astronomer by 1636, and was a formative influence on the young Horrocks. And there was also William Gascoigne (1612–44), who seems to have been descended from a Catholic landed family at Middleton near Leeds, and to have received part of his education at Oxford.

Very clearly, these three north-country astronomers had each received a good general education. Horrocks and Gascoigne had attended university (Horrocks had matriculated at Emmanuel College, Cambridge, where he resided between 1632 and 1636), though neither had taken degrees. William Crabtree had attended the 'Manchester School', which would probably have been a grammar school attached to the Collegiate Church (now Manchester Cathedral). Yet while none of these men would have encountered the New Astronomy of the European Renaissance on a formal curricular basis at school or university, all three would have received a good grounding in Latin, the language of learning in the early seventeenth century, and hence would have had access to the writings of Tycho Brahe, Galileo, Kepler, Gassendi, and the other European discoverers. We know that they did have access to the works of these men for the simple reason that they mention them in their surviving correspondence, along with the works of lesser figures such as Philip Lansberg, Ismael Bouilleau, and others. Crabtree especially seems to have owned a decent library of both contemporary and historical astronomy, having no doubt acquired these works through his contacts in the textile trade, which in those days operated through London and Flanders. We also know that Crabtree had some sort of correspondence with Samuel Foster, Professor of Astronomy at Gresham College, London, for he mentions him by name in a letter to Gascoigne.

Yet these three figures, Horrocks, Crabtree, and Gascoigne, very clearly had correspondence with and connections to a wider diaspora of learning in the region and did not operate in isolation. Their active and sustained correspondence for instance fed into and advanced their individual researches making them to some extent a connected endeavour and acted as one sounding board for their discoveries and applications. They were part of a wider circle rather than individuals in isolation. Common to them all, for instance, were the brothers Charles (Snr) and Christopher Towneley, of Towneley Hall near Burnley, Lancashire, and to a lesser extent the Sherburnes of Stonyhurst. Both the Towneleys and the Sherburnes were old Roman Catholic gentry families, largely frozen out of public life because of their faith, yet still forces to be reckoned with and generous patrons of learning in their native Lancashire. It is almost certain, moreover, that they were connected with the Gascoignes, a family of the same social rank and Catholic faith, living just a few miles to the east on the Yorkshire side of the Pennines. We also know that men from both the Towneley and Gascoigne families died in the Royalist cause in the great Civil War battle fought on relatively nearby Marston Moor, Yorkshire, on 2 July 1644. The Towneleys in particular were active in science, both as practitioners and patrons, through at least two generations. In the early 1660s, for instance, the Halifax, Yorkshire, physician Dr Henry Power was conducting barometric experiments at the top and bottom of Pendle Hill, Lancashire, with Charles Towneley, along with investigations into the 'fiery' and other 'damps' found in coal mines and other deep pits in the vicinity. Richard Towneley, son of Charles Towneley (Snr) and nephew of Christopher, then became in his generation a friend and correspondent of the Revd John Flamsteed, the first Astronomer Royal, in the 1670s, and when Richard Towneley drew up his will in 1706, he specifically mentioned the value of the scientific instruments that he owned. It had been Richard Towneley who not only came to acquire some of the surviving instruments and papers of Horrocks, Crabtree, and Gascoigne, but who also made them available for the young Flamsteed to study when he visited Towneley Hall in 1672, and who played a part in passing on their achievements to the Royal Society and on to the wider realm of learning.

The achievements of Horrocks and his circle

So what did Horrocks, Crabtree, and Gascoigne do that was so original? They were certainly not the first English Copernicans, nor were they the first to read the works of Galileo and Kepler; while Thomas Harriot and Sir William Lower had probably discovered sunspots as early as

December 1610, which was some months before Galileo, though they did not seem to fully grasp their significance, and failed to publish their findings. The real significance of Horrocks and his circle lay in their attitude towards the nature of new knowledge, and the emphasis which they placed upon original observations made with modern instruments (as opposed to a relatively uncritical acceptance of the achievements of the past), added to which they were confident that they, and fellow 'moderns', belonged to a new epoch in the history of astronomical discovery – an epoch, indeed, in which mankind would break free from the shackles of ancient authority, which they believed had bound astronomical knowledge since the days of the ancient Greeks. This new trust in instrument-derived sense-knowledge is clearly manifested in Horrocks's and Crabtree's correspondence after 1636, where they express disillusionment with the errors present in the standard published tables – Horrocks had an especial animus against the *Tabulae Motuum* of Philip Lansberg – and in their constant concern with observing, measuring, and recording. It is also displayed in William Gascoigne's invention, around 1639, of that historically portentous instrument, the telescopic eyepiece micrometer, whereby very tiny angles could be measured to a critical level of accuracy through the telescope.

But most of all, Horrocks's, Crabtree's, and Gascoigne's scientific confidence derived from the telescope itself. For did not Galileo's 'perspective cylinder' of 1610 show that the telescopic universe was a very different place from the universe seen solely by the naked eye? For to the naked eye, the planets were but moving stars, whereas through the telescope, they appeared to be spheres and worlds in their own right. Jupiter, moreover, even had four hitherto unknown satellites going around him, thereby nonplussing those conservative astronomers who said that the earth was the only point of rotation in the universe, because it was at the centre. What is more, Venus showed phases, which strongly suggested that it turned around the sun and not the earth; while even the sun itself, far from being serene and changeless as the ancients had taught, was revealed by the telescope to rotate on its axis every 28 days, and was sometimes blotted with sunspots. And perhaps most of all, it was the moon which most undermined classical astronomical authority, for through the telescope, the lunar surface showed a complex geography of craters, 'seas', bays, and mountains, that reminded one of maps of the earth's surface. Was the moon a world like our own, with 'Selenite' (from the Greek moon goddess Selene) inhabitants?

Now Horrocks, Crabtree, and Gascoigne invented none of these ideas. They had simply spilled across Europe after Galileo's monumental

Siderius Nuncius ('Starry Messenger') of 1610, in which he had announced his first telescopic discoveries, and which had made him famous across learned Europe. But what these Galilean discoveries did was to make people realise that if they could build yet more powerful telescopes and even more delicate measuring instruments, then they might discover yet more celestial wonders. This sense of new possibilities suffuses the correspondence of Crabtree and Horrocks during the late 1630s, and in one letter of 7 August 1640, Crabtree describes his own telescopic observation of some recent sunspots, and uses them as evidence of the fact that the sun possesses an independent axial rotation.

Then in addition to the telescopic discoveries, the new celestial mechanics of Johannes Kepler had a profound influence upon the northern astronomers, and from a surviving list of 31 astronomical books which Jeremiah Horrocks knew in 1635, no less than four titles were works by Kepler. Crabtree, moreover, seems to have owned an even larger astronomical library.

Kepler's significance lay in his announcement in 1608 that the planet Mars, instead of moving in a circular orbit, as had been thought to be the case since time immemorial, actually moved in an ellipse. Then in 1619, Kepler amplified his original discovery by describing an exact mathematical ratio in accordance with which Mars and by extension the other planets sped up and slowed down as they orbited. And of course, it was around the sun that Kepler argued the planets orbited, and not the earth. And what this new Keplerian celestial mechanics did was provide astronomy with its first exact mathematical laws. For in Kepler's eyes, the planets did not move because they were attached to great transparent spheres which rotated about the earth, as the ancients had concluded, but rather moved in empty space, under the control of some invisible yet mathematically exact force which he believed emanated from the sun. Later astronomers would call this force gravity. But what is of crucial importance in the present context is that Jeremiah Horrocks was the first scientist in Britain and in Europe to take the concept of orbital ellipticity and develop it further.

From a series of meticulous observations and measurements, Horrocks had come to conclude by 1638 that the moon also moved around the earth in an elliptical orbit, of which the earth occupied one of the geometrical foci. This breakthrough enabled him to begin to make sense of the very complex orbit which the moon describes around the earth as part of its 28 day and longer orbital cycles when its changing position is measured against the positions of the fixed stars. This changing earth–moon distance, moreover, predicated that the angular diameter subtended by the moon, as observed from the earth, must vary across the lunar cycles, and if one could measure these changing angular sizes accurately, one could check the theory by means of something like an experimental test.

This is one reason why the telescope eyepiece micrometer which William Gascoigne invented around 1640 was to become so crucial, for in its capacity to measure celestial angles to within a few arc-seconds, it enabled one to apply stringent tests to a theory. For as the north-country astronomers came intuitively to understand, scientific knowledge was to be most effectively advanced when new discoveries enabled the framing of new hypotheses, and where in turn, these hypotheses had to pass the acid test of scrupulous physical investigation and proof if they were to stand firm. It was not for nothing, therefore, that when Crabtree saw Gascoigne's early micrometer in 1640 he wanted one for Horrocks and himself, and asked Gascoigne 'Could I purchase it with Travel, or procure it for Gold?'

Horrocks's work on the moon's motion, and his theory of how it moved in an elliptical orbit, would itself have been a spectacular work of genius by any standards; but then, from his analyses of the orbital data, Horrocks drew a further conclusion, namely, that the long axis – or apside line – through the lunar orbital ellipse does not remain in one place with reference to a given point in the starry background, but actually rotates back upon itself, or precesses, as the earth–moon–sun position constantly changes in space. These lunar orbital dynamics discovered by Horrocks would later prove invaluable to Sir Isaac Newton when he developed his theory of Universal Gravitation, half a century later.

At the heart of Crabtree's, Horrocks's, and Gascoigne's work was a great deal of practical, hands-on observation of the heavens, especially of the sun, moon, and planets as they moved amongst the stars of the zodiac. And whilst these men used the basic geometry of the zodiac, with its 12 signs each encompassing 30° of sky, it should be emphasised that they displayed no sign of interest in astrology or astrological prediction. Indeed, in some of their letters and surviving writings they pour contempt upon astrology. Yet on the other hand, they saw no reason why the immemorial zodiac divisions should not be used to monitor the physical motions of the planets, quite apart from their occult connotations.

Measuring the exact distance of the sun, moon, and planets from each other, and from the First Point of Aries (Spring Equinox) was crucial for these northern astronomers, because that was the way in which they uncovered the errors in the standard astronomical tables, and went on to draw original conclusions about the planetary motions. And for this, they used a variety of probably home-made mathematical instruments whereby they could read degrees and minutes of arc in the sky. Both Horrocks and Crabtree owned several types of 'Astronomical Radii' and at least one quadrant for measuring lateral and vertical angles in the sky, while in addition Crabtree seems to have timed observations with a clock. With these instruments, they were able to construct new tables for the motions of the planets that were more accurate than the published ones. Indeed, Horrocks's and Crabtree's letters are full of these observations, measurements, and comparisons with the standard published tables, and it is clear that they were consciously trying to obtain regular results that were more accurate and more reliable than those tables.

We do not know whether William Gascoigne's invention of the micrometer was spurred on by what Crabtree and Horrocks were doing in Lancashire, or whether the micrometer was the product of his own wrestlings with the same problems as they were dealing with. Yet what is beyond doubt is that the micrometer was one of the watershed inventions in the history of optical and mechanical technology. It came from the astronomer's need to be able to measure very small angles through the telescope, such as the varying angular diameters of the sun and the moon at different seasons of the year, to see if the variations conformed to predicted Keplerian criteria, or else to note the positions of the planets from dim stars in the starry background. For while the telescope had been around as a scientific instrument since 1609, it had so far proved impossible for astronomers to devise a way whereby a pair of marker points – like the crosshairs in a modern rifle sight – could be inserted into the telescope's field of view to enable the observer to measure the relative positions of objects in that field. But Gascoigne made that crucial optical discovery – where to place a marker to make it stand out in a telescope field – at his father's house near Leeds in 1640, and then went on to develop it further. He next had the bright idea of inserting two marker points into the same field, and controlling each with a delicate screw so that an astronomer looking at the moon, let us say, could carefully adjust one screw-controlled marker point to one side of the moon, and the other to the other side. Once this had been achieved, the astronomer could use his knowledge of the optical geometry of his telescope to calculate the angle subtended between the two marker points to a critical level of accuracy.

And by 1640–41, Gascoigne was using his micrometer to monitor the changing seasonal diameters of the moon, in accordance with the Keplerian theory of elliptical orbits mentioned above. Quite simply, an instrument which would come to be recognised as of prodigious scientific importance had been thought out, built, and used to elucidate the most abstruse scientific puzzles of the age by a young country gentleman living in an obscure Yorkshire manor house. It is hardly surprising that when Gascoigne's friends Crabtree and Horrocks heard of the device, they also wanted micrometers to give a new level of precision to their own telescopic observations. Yet it would not be until the 1660s that Gascoigne's instrument came to be known to the wider world, in consequence of the chaos of civil war which descended upon Britain in 1642.

It was in 1639, however, that Jeremiah Horrocks made the discovery which would immortalise both himself and Crabtree. Now while Kepler, in his own study of planetary dynamics, had correctly predicted that the planet Venus would pass across the sun's disk in 1631, no one had observed this because it happened after sunset for European observers. Kepler had said that another Venus transit would not occur until 1761, but in October 1639 Horrocks, now working in some ecclesiastical capacity (though still too young to be a priest) in the village of Much Hoole, near Preston, Lancashire, calculated that on 24 November 1639 Venus would once again transit the sun. He told Crabtree and other astronomical friends, but only he and Crabtree saw the event on that cloudy late November day. Horrocks had found that the celebrated Kepler had made an error in the orbital theory of Venus; he corrected that error, and, along with Crabtree, became the first person on the face of the earth to witness a Venus transit. Horrocks then wrote a short Latin treatise describing his and Crabtree's work, in which he reminded his intended readers of the importance of not simply following others, but of relying on one's instruments and observations if one wanted to make original discoveries and to advance scientific knowledge. He also used his *Venus in Sole Visa* ('Venus in transit across the sun') as a manifesto for his Copernicanism, as he drew unambiguously sun-centred solar system evidences from the transit observation.

Only five other Venus transits occurred after 1639, falling in 1761, 1769, 1874, 1882, and, most recently, on 8 June 2004. Another will occur in 2012, but after that, we must wait until 2117.

These three astronomers all died young, Horrocks and Crabtree of natural causes in 1641 and 1644 respectively, while Gascoigne fell at Marston Moor in 1644. After their deaths Richard and Christopher Towneley began to collect what survived of Horrocks's, Crabtree's, and Gascoigne's books, manuscripts, and instruments. What is clear, however, is that these three men's work inspired others in the vicinity. Jeremy Shakerley, a Lancashire client of the Towneleys, was deeply influenced by 'Our worthy Country-man, Master Jeremy Horrox', and became the first writer to mention Horrocks's name in print, in his books published between 1649 and 1653. Then there was Nathan Pighells, and the young Sir Jonas Moore. It was Moore, indeed, who would take the work of this Lancashire circle to London, and after 1660, into the ranks of the newly established Royal Society, which august body would, in 1672, publish Crabtree's and Horrocks's surviving correspondence, rightly deeming it the beginning of a critical, observational and experimental tradition of British science.

Yet a clear indication of the perceived international importance of the work of Horrocks and his friends can be seen in the fact that Horrocks's *Venus in Sole Visa* was first published in Dantzig, Poland, in 1662. It seems that in the early Royal Society, a manuscript copy of the *Venus* treatise came into the hands of the illustrious Dutch astronomer Christiaan Huygens, when he was on a visit to London. Somehow a copy passed from Huygens to Hevelius in Dantzig, and Hevelius published it at his own expense in 1662. And as Huygens and Hevelius were two of the most illustrious astronomers in Europe at that time, one gets some measure of how the work of the northern astronomers was coming to be perceived by the international world of learning.

Conclusion

As was indicated at the outset, there is no easy or obvious explanation why the great European astronomical Renaissance should have taken root in what was then the remote and relatively backward north-west of England in the 1630s. But that is simply what happened. What is more, the researches and personal friendships that sprang up between Horrocks, Crabtree, Gascoigne, Towneley, and others begs more historical questions than can be easily answered. These questions, moreover, encompass such topics as the way in which books and ideas spread across Europe, the precise nature of the motivations which drove these men, and the relationship between their astronomy and their wider beliefs.

Particularly fascinating in this latter context were their religious beliefs, for in addition to the fact that they were sincere and devout Christians, their friendships cut across denominational lines, for Horrocks and Crabtree were Protestant Anglicans, while Gascoigne and the Towneleys were from Recusant old Roman Catholic families: ancient gentry families which had simply refused to acknowledge King Henry VIII's Protestant Reformation. Indeed, there were a good many of these old Recusant Catholic families in Lancashire, and in some cases they paid a heavy price for their faith: crippling Recusancy Fines to the Protestant government, severe punishment if Roman Catholic priests were found to be visiting their houses, and exclusion from the public life of their class, for Recusants could not generally serve as magistrates, regular military officers, or Members of Parliament. Perhaps one reason why the Towneleys, Gascoignes, and Sherburnes developed such conspicuous scientific and wider cultural interests is because these were subjects from which English Catholic intellectuals were not excluded by law. Yet to find Recusants on such amiable terms with their intellectual Protestant neighbours forces us to revise some of the hoary myths not only about Catholics and Protestants in the seventeenth century, but also about the wider relationship that existed between science and religion. For what all of these men saw in science, in addition to its technical fascination was an avenue for the deepening of their Christian faith as they explored the intricate wonders of God's Creation. For as the devout Protestant Johannes Kepler put it, scientific discovery was but 'thinking God's thoughts after Him'. This view would also have been concurred with by Galileo who, in spite of his brush with the Inquisition for teaching the Copernican theory as a fact when he could not prove the same, lived and died a devout Roman Catholic, as would the Jesuit astronomers in the Collegio Romano. Indeed, to attempt to make historical sense of the seventeenth-century scientific revolution without recognising the powerful inspiration exerted by the Christian faith upon Catholics and Protestants alike would be like some future historian trying to understand the history of twentieth-century Russia while ignoring the impact of Marxism.

Yet what is hard to explain in social and historical terms is why it was in rural Lancashire that the European astronomical revolution first took root. And that rooting and flourishing was acknowledged not only by Christopher Towneley and Sir Jonas Moore, who lived long enough to see the British establish a powerful metropolitan base in the Royal Society, but when the Revd John Flamsteed's *magnum opus*, the *Historia Coelestis Britannica* ('British Account of the Heavens') was brought out in three thick folio volumes in 1725, he commenced this, the first great star catalogue of the Royal Observatory, Greenwich, with five pages of hitherto unpublished observations and correspondence that had passed between Crabtree and Gascoigne between 1638 and 1643. For to Flamsteed, these north-country amateur astronomers, supported by their own financial resources rather than by institutions, laid the foundation stone upon which subsequent British astronomical research was built.

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