Biographical Encyclopedia of Astronomers

Horrocks, [Horrox] Jeremiah

Born Toxteth Park near Liverpool, England, circa 1619

Died Toxteth Park near Liverpool, England, 3 January 1641

In addition to being the first person to accurately predict and observe a transit of the planet Venus, Jeremiah Horrocks also discovered the inequalities in the motions of Jupiter and Saturn, and improved upon Johannes Kepler's lunar theory to such an extent that it could not be further improved upon for over a century. It is believed that when Sir Isaac Newton stated he had stood on the shoulders of giants, he had Horrocks in mind

Very little is known about Horrocks's early years. His family was of modest origin; his father, William Horrocks, was a farmer, while his mother, Mary Aspinwall, was the daughter of a well-established family in Toxteth Park. After an early education by local tutors, Horrocks enrolled at Emmanuel College, Cambridge, before reaching the age of 14. As a sizar, he earned his tuition fees and living expenses by serving as the servant of a wealthier student. Horrocks devoured classical literature, often reading Latin authors to become more familiar with the language. He was unable, however, to pursue formal studies in the subjects that most interested him, namely, mathematics and astronomy. Thus, after three years at Cambridge, Horrocks left without attaining a degree. It was not uncommon for students with limited means to leave, as the university required additional cash payments to qualify for a degree. Horrocks felt he had learned all that was of interest to him in Cambridge and returned to Toxteth Park In the summer of 1639, he accepted employment with the most prominent family in the village of Hoole, possibly as a tutor. Horrocks returned to Toxteth Park after about a year in Hoole. In the 19th century, it became common to refer to Horrocks as a clergyman, but available evidence argues against his ever having been ordained.

The study of astronomy preoccupied Horrocks after he left Cambridge. Using an astronomical radius he made for himself, Horrocks found that actual planetary positions were substantially different from what could be projected based on Philip von Lansbergen's *Tabulae Motuum*. That conclusion was also drawn by William Crabtree, with whom Horrocks became acquainted through a mutual friend, John Wallis, whom Horrocks met at Cambridge. Crabtree introduced Horrocks to the *Tabulae Rudolphinae* and other works of Kepler Although they never met—Horrocks died the day before their first meeting was planned—Horrocks and Crabtree became very close friends through their correspondence. Their observations indicated the superiority of Kepler's tables compared to Lansbergen's, but they still found Kepler to be in error. The two young astronomers agreed that their work would thereafter be based strictly on their own observations and not on tables prepared by someone else. Horrocks undertook to correct Kepler's Rudolphine Tables of the motions of the Sun, Moon, and the planets.

One of Horrocks's early projects in this effort was to measure the apparent diameter of the Sun on a regular basis throughout the year. His observations were accurate enough to show that the

apparent solar diameter varied exactly as would be expected if the Earth's orbit was an ellipse with the Sun at one focus. On the basis of these observations, Horrocks developed a more accurate theory of the apparent annual motion of the Sun than those of all his predecessors. Horrocks also attempted to extend this methodology to the apparent diameters of the planets and the Moon, but his results were compromised by the nature of his measuring devices

Detailed observation of the planets also proved rewarding for Horrocks, as he detected the apparent acceleration of Jupiter in its orbit and the apparent deceleration of Saturn in its orbit as one passed the other. He suspected that these values might be subject to periodic changes, and had he lived long enough, he would no doubt have confirmed that hypothesis. It is apparent from these results that Horrocks was a very careful observer, producing valuable results despite the rather crude nature of the astronomical radius as a measuring device

Nothing demonstrates Horrocks's skillful integration of observation and theory better than his prediction and observation of the 1639 transit of Venus. Kepler had predicted transits of both Mercury and Venus for the year 1631. The predicted transit of Mercury, observed by Pierre Gassendi at Paris, provided the earliest observational confirmation for Kepler's methodology and is often cited as a turning point in the acceptance of Copernican cosmology. The 1631 transit of Venus was not observed, as it began after sunset in Europe. However, Lansbergen had also predicted a Venus transit for 1639. Although Horrocks placed more faith in Kepler, the possibility of a second transit piqued his curiosity. Horrocks examined Lansbergen's tables and determined that Lansbergen was indeed correct: A transit would occur around 3:00 p.m. On December 4, 1639, using the Rudolphine Tables, Horrocks was able to understand why Kepler predicted that the second transit would pass below the visible disk of the Sun. However, with Horrocks's revised and more accurate version of Kepler's table, it was clear that Venus would transit the southern face of the Sun, though well below the position predicted by Lansberg. Horrocks did not have absolute faith in his own calculations, so he began his observations on December 3. His observations were made following the procedure used by Gassendi: A small telescope projected an image of the Sun onto a white surface in a darkened room. Venus was not detected on December 3. On December 8, a Sunday, Horrocks watched the Sun from sunrise until 9:00 a.m., from 10:00 a.m. until noon, and from 1:00 p.m. until 3:00 p.m., his predetermined time of transit. He was called away at that time, but when he returned at 3:15 and adjusted his telescope, Hor-rocks was overjoyed to see a sharp, round, black disk on the projected face of the Sun. Venus had entered the disk of the Sun, and the transit had already proceeded to second contact. Horrocks watched the transit for about 35 minutes until the Sun set

During this time, he observed Venus move the distance of about two planetary diameters across the Sun's face. From his observations, Horrocks calculated the diameter of Venus to be about 1/30 the diameter of the Sun. Based on his extensive measurements of the Sun's apparent diameter, the resulting apparent diameter of Venus was 76 ± 4", much smaller than the traditional value of 180". Moreover, on the basis of this observation, Horrocks proposed a value for the horizontal solar parallax of only 14", substantially lower than any previous value, for example, Tycho Brahe's 180", Kepler's 59", or Johannes Hevel's 40". (The last figure was published a generation after Horrocks.)

Horrocks's discovery of the possible transit of Venus only a month before it was predicted to occur left him little time to alert the broader scientific community, but it seems likely that he also had too little confidence in the accuracy of his methods to do so. He wrote to his brother in Manchester and to Crabtree, both of whom he believed might enjoy the experience of observing the transit. His brother was clouded out; so the only person who would confirm Horrocks's observation was Crabtree. Although the Sun was obscured by clouds for most of the transit period, it appeared suddenly at 3:35, and Crabtree was able to prepare a sketch that confirmed Horrocks's smaller figure for the apparent diameter of Venus

Horrocks's description of his observation of the transit of Venus, his analysis of his results, and their significance were drafted as *Venus in Sole Visus* before his death. The manuscript was eventually transmitted to Danzig by Christiaan Huygens and was published posthumously in 1662 by Hevel as the first chapter of the latter's self-published book on the transit of Mercury, titled *Mercuris in Sole Visus*.

Horrocks's other substantial achievement was in his development of a new lunar theory, which he discussed in letters to Crabtree and William Gascoigne. Horrocks's major discovery was that the line of apsides for the lunar orbit oscillates periodically and the orbital eccentricity varies over time. His ability to account for these effects produced a lunar theory that was superior to that of Kepler. John Flamsteed showed that Horrocks's lunar theory reduced errors to only 2' compared to 15' errors in the best of previous theories Newton learned of Horrocks's theory when he received a copy of Horrocks's Opera Post-huma in 1672. Although Newton attempted to improve the theory, he was unsuccessful. It was not until Tobias Mayer published his initial lunar theory in 1753 that any improvement over Horrocks's theory was achieved. Substantial improvement of lunar theory would have to wait until the introduction of perturbation theory and the substitution of Leibnizian calculus for conventional geometry by Leonhard Euler, Pierre de Laplace, and Joseph Lagrange.

Francine Jackson

Selected References

Applebaum, Wilbur (1972). "Horrocks, Jeremiah." In *Dictionary of Scientific Biography*, edited by Charles Coulston Gillispie. Vol. 6, pp. 514-516. New York: Charles Scribner's Sons

Bennett, J. A. (1984). "Seventeenth-Century English Astronomers." *Journal for the History of Astronomy* 15:54-56.

Chapman, Allan (1982). *Three North Country Astronomers*. Manchester: Neil Richardson. (See also J. A. Bennett's review of this work.)

—— (1990). "Jeremiah Horrocks, the Transit of Venus, and the 'New Astronomy' in Early Seventeenth-Century England." *Quarterly Journal of the Royal Astronomical Society* 31: 333-357.

Gaythorpe, Sidney B. (1954). "Horrocks's Observations of the Transit of Venus 1639 November 24 (O. S.) II. On the Probable Site from Which the Observations Were Made." *Journal of the British Astronomical Association* 64:309-315

Grant, Robert (1863). "The Glasgow Observatory." *Astronomical Register* 1, no. 6: 420-428.

Horrocks, Jeremiah (1662). *Venus In Solis visa. In Mercuris in Solis visas Gedani*, by Johannes Hevelius. Danzig.

—— (1673-1678). *Opera posthuma*, edited by John Wallis. London.

Taton, René and Curtis Wilson, (eds.) (1989). *Planetary Astronomy from the Renaissance to the Rise of Astrophysics,* Part A: *Tycho Brahe to Newton. Vol. 2A of The General History of Astronomy*. Cambridge: Cambridge University Press.

Whatton, Rev. Arundell Blount (1859). *Memoirs of the Life and Labours of Rev. Jeremiah Horrox.* London: Werther, Macintosh and Hunt

Wilson, Curtis (1987). "On the Origin of Horrocks's Lunar Theory.*" Journal for the History of Astronomy* 18: 77-94.