Jeremiah Horrocks | Encyclopedia.com

(*b*. Lancashire, England, 1618; *d*. Toxteth Park, England, 13 January 1641)

astronomy.

The precise date and place of Horrocks' birth are not known and the record of other biographical details is a meager one; there is good evidence, however, that his father may have been James Horrocks, a watchmaker, and his mother the former Mary Aspinwall. He grew up in Toxteth Park, then a small village about three miles from Liverpool. From 1632 to 1635 he attended Emmanuel College, Cambridge, working as a sizar for his maintenance, but he left without taking a degree. He taught himself astronomy and familiarized himself with the chief astronomical works of antiquity and of his own time.

Shortly after leaving Cambridge he befriended William Crabtree. a clothier or merchant of Broughton, near Manchester. Crabtree had studied astronomy for several years and the two young and enthusiastic friends carried on an extensive correspondence on astronomical matters that continued until Horrocks' death. Beginning in June 1639, Horrocks lived for about a year in Hoole, a village a few miles north of Liverpool, and then returned to Toxteth Park. He died suddenly, the day before an intended visit to Crabtree.

In his extraordinary and short-lived career Horrocks turned his attention to almost every aspect of astronomy. He was an assiduous and careful observer, always anxious to extend the limits of precision and to seek out and eliminate sources of possible observational error. One of his aims was to carry on the work of Tycho, but by utilizing the new opportunities available in the age of the telescope. He redetermined the astronomical constants for several planets, imaginatively investigated the problem of the scale of the solar system, improved the theory of lunar motion, began a detailed study of the tides, and theorized about the forces responsible for the motions of the planets.

As a theorist, Horrocks, although he was not in possession of the principle of inertia, represents a transition between the physical astronomy of Kepler and the fertile period 1660–1680 associated with the names of Borelli, Hooke, Halley, and Newton. His writings remained unpublished in his lifetime and the extent of his influence on his successors has yet to be explored.

In 1635 Horrocks began to compute ephemerides from Philip van Lansberge's *Tabulae motuum coelestium perpetuae* (1632). Comparing the results of his calculations with his own and Crabtree's observations, he concluded that Lansberge's tables were not only inadequate but also based on a false planetary theory. Upon Crabtree's advice he began to use Kepler's *Tabulae Rudolphinae* (1627) and soon became convinced that the tables were superior to all others and the only ones founded on valid principles. He devoted the next few years to correcting their errors and improving their accuracy.

Having some misgivings about Kepler's physical theories, Horrocks turned to the study of Kepler's works and soon became an ardent disciple. He accepted Kepler's doctrines of elliptical planetary orbits, with the sun situated in the orbital planes, and of the constant inclination of these orbits to the ecliptic. Horrocks affirmed that he had carefully and repeatedly tested Kepler's rule of the proportionality between the squares of the planetary periods and the cubes of their mean distances, and that he had found it to be absolutely true. With Kepler, he held that a planet moves more rapidly at perihelion than at aphelion and he believed planetary velocity to decrease proportionally with increasing distance from the sun. There is no mention in his surviving works of Kepler's law of areas.

Horrocks also accepted Kepler's viewpoint on the unity of celestial and terrestrial physics and his program for the creation of a celestial dynamics. He tentatively put forward a dynamical model of his own, however, which he felt eliminated some of the worst features of his master's. He started with Kepler's hypothesis that the sun moves the planets both by its rotation and by the emission of a quasi-magnetic attractive force, which becomes weaker with distance and attracts the planets as well as acting as a series of lever-arms pushing them along. The specific shape of the planetary orbit is the result of a dynamic equilibrium between a lateral (pushing) and a central force. Horrocks repudiated Kepler's idea that each planet has opposite sides "friendly" and "unfriendly" to the sun which cause it to be alternately attracted and repelled in different parts of its orbit and thus to move in an ellipse.

Possibly influenced by his reading of Galileo's *Dialogue Concerning the Two Chief World Systems*, Horrocks linked his celestial dynamics to the principles of falling bodies on earth and illustrated his conception by analogy with a pendulum. The planets may be seen as having a tendency to fall toward the sun or to oscillate about it freely, as the pendulum bob does about its mean position. But "Ye suns conversion doth turn the planet out of this line framing its motion into a circular, but the former desire of ye planet to move in a streight line hinders the full conquest of ye Sun, and forces it into an Ellipticke figure" (Manuscripts, Notebook B, fols. 16–17).

An analogy with a conical pendulum further illustrated his point. Horrocks pointed out that if a ball suspended by a string is withdrawn from its position at rest beneath the point of suspension, and given a tangential impulse, the ball will follow an elliptical path and its major axis will rotate in the direction of revolution—exactly as does the line of apsides of the lunar orbit. He further supposed a slight breeze blowing in the direction of the major axis, to support the analogy that the center of motion is in the focus of an ellipse rather than its center. According to Horrocks, therefore, and in contradistinction to Kepler, the planets tend always to be attracted to the sun and never to be repelled by it.

Horrock's conception of gravitation and his theory of comets also differed somewhat from Kepler's. He hinted that the planets exert an attractive force on each other as well as on the sun; it is only because the sun is so massive compared to the other bodies in the solar system that it cannot be pulled from its place at the center. Originally, Horrocks proposed that comets are projected from the sun and tend to follow rectilinear paths. Like a stone thrown upward, they eventually reach a point of zero velocity and then return with accelerated motion; but since they are all the while influenced by the rotating force from the sun, they are thereby deflected into more or less circular paths. Horrocks later surmised that cometary orbits were elliptical.

In mathematical planetary astronomy, he carefully redetermined the apparent diameters of several celestial bodies, examined afresh the manner of calculating their parallaxes, and obtained improved elements for several orbits. For the horizontal solar parallax, Horrocks proposed a figure of 14″ which he arrived at by an ingenious and novel line of reasoning spiced with a dash of metaphysical speculation. It was a value not to be improved on for many years and vastly superior to Tycho's 3′ and Kepler's 59″ and even to Hevelius' 40″, a generation after Horrocks. He therefore obtained a figure for the radius of the earth's orbit of "at least... 15,000 semidiameters of the earth," or about 60,000,000 miles (*Transit of Venus Across the Sun*, p. 151) He reduced Kepler's estimate of the solar eccentricity, and subtracted 1' from the roots of the sun's mean motion. Having discovered the irregularities in the motions of Jupiter and Saturn, he suggested specific corrections in the *Rudolphine Tables* for their mean longitudes and velocities, and he may have suspected that the increase in Jupiter's velocity and the decrease in Saturn's over a long span of time were periodic.

His program of correcting Kepler's tables led to Horrocks' prediction of a transit of Venus, and he became the first astronomer to observe one. Consulting the tables of Lansberge, and afterward those of Reinhold, Longomontanus, and Kepler, he learned that there would be a conjunction of Venus and the sun some time in early December 1639. The four tables differed from each other in this estimate, however, by as much as two days. Horrocks discovered a small constant error in Kepler's tables which displaced Venus about 8' too much to the south, whereas Lansberge's erroneously elevated its latitude by a still greater amount. Correcting Kepler's error, Horrocks found that Venus would transit the lower part of the sun's disk on 4 December and wrote to Crabtree urging that they both make careful observations upon the expected date of conjunction.

Horrocks used a method of observation proposed for eclipses by Kepler and adapted to the telescope by Gassendi for the latter's observation of the transit of Mercury of 1631. The sun's light was admitted through a telescope into a darkened room so that the sun's disk was reproduced on a white screen to a diameter of almost six inches; the screen was divided along the solar circumference by degrees and along the solar diameter into 120 parts. Crabtree, observing near Manchester, saw the transit for only a few minutes and failed to record the data precisely, but his general observations proved to be in agreement with those made by his friend. Horrocks was more successful, and his analysis of his observations enabled him to correct earlier data for the planet.

Other astronomers had determined the apparent diameter of Venus as upwards of 3′, but Horrocks found it to be 1′ 16″ ± 4″, quite close to the modern value. The transit observation also enabled him to redetermine the constants for Venus' orbit, yielding better figures for its radius, eccentricity, inclination to the ecliptic, and position of the nodes. As a result, he was also able to correct the figures for the rate of Venus' motion; he determined it to be slower by 18′ over 100 years than Kepler's tables showed.

His contributions to lunar theory, to which he turned his earnest attention in 1637, were among his most important. Following Kepler, he had as the physical cornerstone of his lunar theory the assumptions that the lunar orbit is elliptical and that many of the moon's inequalities are caused by the perturbative influence of the sun. In observation, he followed the practice initiated by Tycho of studying the moon in all its phases and not merely in the syzygies. Consequently, he was able to make improvements in the constants for several lunar inequalities, but his precepts were not reduced to tabular form until after his death. His most significant achievement in lunar theory was to account for the second inequality of longitude (evection, discovered in antiquity) by an unequal motion of the apsides and a variation in eccentricity. Depending on the moon's distance from the sun, he added to the mean position of the apogee or subtracted from it up to 12° and altered the eccentricity within a range just over 20 percent about its mean value.

Horrocks' lunar theory was first published in 1672. Tables constructed by Flamsteed were included in the edition of the following year. From observations made in 1672 and 1673, Flamsteed concluded that they were better than any then in print and Newton later proposed corrections which further improved their accuracy. Tables based on Horrocks' lunar theory continued in use up to the middle of the eighteenth century, when they were superseded by Mayer's.

Horrocks' papers remained with his family but a short time. Part of them were destroyed in the course of the English civil war, part were taken by a brother to Ireland and never seen thereafter, and still another portion was destroyed in the Great Fire of 1666. The remainder passed into the hands of an antiquary, who also managed to obtain letters by Horrocks from the Crabtree family. From the late 1650's until their eventual publication, Horrocks' manuscripts were widely circulated. The first part to be printed was his treatise on the transit, *Venus in sole visa*, which was published by Hevelius in 1662. The newly founded Royal Society assumed responsibility for publication of most of the remainder as *Opera posthuma* in 1672–1673.

BIBLIOGRAPHY

I. Original Works. Horrocks' surviving manuscripts are kept with Flamsteed's papers, vols. LXVIII and LXXVI, at the Royal Greenwich Observatory, Herstmonceux, Sussex. They are also available on film at the Public Record Office, London, and are briefly described in Francis Baily, *An Account of the Reud. John Flamsteed, the First Astronomer-Royal* (London, 1835), p. lxxiii. Horrocks' copy of Lansberge's *Tabulae perpetuae* with his corrections and marginalia is in Trinity College Library, Cambridge.

The principal published source for Horrocks' writings is his *Opera posthuma* (in some copies having the variant title *Opuscula astronomica*), John Wallis, ed. (London, 1672–1673; 1678), the text of which represents a conflation by Wallis of several treatises on the same subjects. Wallis also abridged Horrocks' letters to Crabtree and translated them into Latin. There is one important difference among the various editions. In that of 1672, the lunar theory was related in a letter of Horrocks to Crabtree dated 20 December 1638 (pp. 465 ff.) In all subsequent editions, this letter was replaced by Flamsteed's description of a letter from Crabtree to Gascoigne, 21 July 1642, explaining Horrocks' lunar theory. The *Venus in sole visa* was published with *Johannis Hevelii Mercurius in sole visus Gedani* (Danzig, 1662), pp. 111–145, from a version earlier than at least one of the texts now at Herstmonceux, together with notes by Hevelius. It has been published as *The Transit of Venus Across the Sun*, Arundell B. Whatton, trans. (London, 1859; 1868).

II. Secondary Literature. See Stephen P. and Stephen J. Rigaud, *Correspondence of Scientific Men of the Seventeenth Century* (Oxford, 1841), *passim*, especially the letters of Wallis and Flamsteed on Horrocks and Crabtree. The best recent work on Horrocks has been done by Sidney B. Gaythorpe in the following articles: "Horrocks's Observations and Contemporary Ephemerides," in *Journal of the British Astronomical Association*, **47** (1937), 156–157; "Horrocks's Observations of the Transit of Venus 1639 November 24 (O.S.)," *ibid*., **47** (1936), 60–68, and **64** (1954), 309–315; "Jeremiah Horrocks and his 'New Theory of the Moon,'" *ibid*., **67** (1957), 134–144; "Jeremiah Horrocks: Date of Birth, Parentage and Family Associations," in *Transactions of the Historic Society of Lancashire and Cheshire*, **106** (1954), 23–33; "On Horrocks's Treatment of the Evection and the Equation of the Centre...," in *Monthly Notices of the Royal Astronomical Society*, **85** (1925), 858–865. See also Betty M. Davis, *The Astronomical Work of Jeremiah Horrox*, University of London M. Sc. thesis (1967), and H. C. Plummer, "Jeremiah Horrocks and his Opera Posthuma," in *Notes and Records of the Royal Society of London*, **3** (1940), 39–52.

Among the still useful older accounts are John E. Bailey, *The Writings of Jeremiah Horrox and William Crabtree... Reprinted, with Additions, etc. from the* Palatine Notebook *of Dec. 1882, and Jan. 1883* (Manchester, 1883); Francis Baily, *Supplement to the Account of the Revd. John Flamsteed* (London, 1837), pp. 680–93; Jean Baptiste J. Delambre, *Histoire de L'astronomie moderne*, II (Paris, 1821), 495–514; Robert Grant, *History of Physical Astronomy from the Earliest Ages to the Middle of the Nineteenth Century* (London, 1852 [?]), pp. 420–428, 545; and Arundell B. Whatton, "Memoir of Jeremiah Horrox," the introduction to his translation *The Transit of Venus Across the Sun*, cited above, pp. 1–107.

Wilbur Applebaum