



The Venus Transit 2004

... **Extended InfoSheet F1**

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History of transit observing

1. First predictions and the transits of 1631 and 1639

The prediction of transits of Venus and Mercury across the Sun requires a good knowledge of the orbital movements of the inner planets. This was possible from the beginning of the XVIIth century thanks to the work of Johannes Kepler (1571-1630) and to the publication in 1627 of the Rudolphine Tables, so named by Kepler in homage to his former patron, Rodolph II of Hapsburg (1552-1612), emperor of Germany. Kepler predicted a transit of Mercury on 7 November 1631 and a transit of Venus on 7 December 1631, both of which he did not live long enough to see. He also found that the transits of Venus occur about every 120 years.

The transit of Mercury on 7 November 1631 was observed in Paris by the astronomer Pierre Gassendi (1592-1655): *"Le rusé Mercure voulait passer sans être aperçu, il était entré plutôt qu'on ne s'y attendait, mais il n'a pu s'échapper sans être découvert, je l'ai trouvé et je l'ai vu; ce qui n'était arrivé à personne avant moi, le 7 novembre 1631, le matin"* ([Note 1](#)).

This transit was also observed by three other people: Remus Quietanus in Rouffach (Upper-Rhine, Alsace), Father Cysatus in Innsbruck (Tyrol) and an anonymous Jesuit in Ingolstadt (Bavaria). The transit of Venus was not observed because of inaccuracies in the Rudolphine tables. The transit was to occur on 6-7 December 1631 when it was night-time in Europe; actually the end of the transit would have been visible from Central Europe.

The English youth Jeremiah Horrocks (1619-1641) predicted an impending transit of Venus for Sunday, 4 December 1639 at 3 o'clock of the afternoon (24 November 1639 by the Julian calendar); this prediction disagreed with the 120-year period found by Kepler. He observed the transit from his village of Hoole (near Preston) by projecting the image of the Sun on a graduated sheet of paper and so carried out the first measurement of a transit of Venus. Actually, he could not observe the entire phenomenon, having to interrupt his observations to attend to his religious obligations.

Using his observations, Horrocks calculated the position of the node of Venus' orbit; he estimated that the apparent diameter of Venus was not more than a minute of arc and that the value of the solar parallax was not greater than 14", corresponding to a Sun-Earth distance of about 14,700 Earth radii (94 million kilometres). His *Venus in sole visa*, in which he describes his observation, was published by J. Hevelius in 1662. Other parts of his work on Venus were published by John Wallis in 1672.

The transit was also observed by Horrocks' friend William Crabtree (1610-1644) in Manchester. Crabtree was so amazed by the observation that he failed to make any measurement...



William Crabtree observing the transit of Venus on 4 December 1639
 Painting by Eyre Crowe - Walker Art Gallery, Liverpool

Kepler's third law allows the size of the solar system to be estimated, apart from a scale factor. Knowing only the separation between two planets or between a planet and the Sun is enough to calculate all the other distances. The solar parallax is the angle subtended at the Sun by the Earth's radius so knowing the parallax is equivalent to knowing the Sun-Earth distance.

The measurements and calculations carried out in antiquity grossly underestimated the actual value of this distance. The following table shows the various values:

| Authors | Value of the Sun-Earth distance | Value of the parallax | Sun-Earth Distance in km |
|----------------------|--------------------------------------------------------------------------|-----------------------|--------------------------|
| Anaximander | ~54 terrestrial radii | ~1.06° | ~344,000 |
| Eudoxus | 9 times the Earth-Moon distance | - | ~3,450,000 |
| Aristarchus of Samos | 18 to 20 times the Earth-Moon distance, i.e. about 360 terrestrial radii | ~9.5' | ~7,300,000 |
| Hipparchus | 2,490 terrestrial radii | ~1.4' | ~15,860,000 |
| Posidonius | 13,090 terrestrial radii | ~15.8" | ~83,380,000 |
| Ptolemy | 1,210 terrestrial radii | ~2.8' | ~7,708,000 |
| Copernicus | 1,500 terrestrial radii | ~2.4' | ~9,555,000 |
| Kepler | - | < 1' | < 21,790,000 |
| J. D. Cassini | - | 9.5" | 137,600,000 |
| Flamsteed | - | 10" | 130,715,000 |
| Picard | - | 20" | 65,357,000 |

The last three values were calculated using measurements of the parallax of Mars at the time of its opposition in September 1672.

The transits of Venus and Mercury

In 1677, on the island of St. Helena, Edmond Halley (1656-1742) observed the transit of Mercury which took place on November 7. He then thought of a method to determine the solar parallax and hence the Sun-Earth distance. It excluded the transits of Mercury, because Mercury's parallax is too small and its transits are more difficult to observe. His method is based on comparing the times of transit of Venus measured from several sites located at different latitudes. The difference between the observed transit times leads to the parallax of Venus and then to the parallax of the Sun.

Halley had to leave to his successors the task of carrying out the observations and of applying his method to the predicted transits of 1761 and 1769. His predictions and recommendations were published in the Philosophical Transactions of the Royal Society in 1691, 1694 and 1716. Halley's method consisted of

measuring the time elapsed between the first and the last interior contact of Venus with the solar disk from at least two sites having the greatest possible difference in latitude.

For that, it is often necessary to travel very far and to carry out preliminary observations at the sites in order to determine accurately their geographical coordinates: latitude for deducing the parallax of the planet and longitude for synchronizing the observations. Using this method, Halley hoped to determine the solar parallax to an accuracy of one part in 500 if the observation of the contacts was made with a precision of two seconds of time.

The French astronomer Joseph-Nicolas Delisle (1688-1768) proposed, in 1722, another method related to the observation of a single phase of a transit (first or last interior contact); this method increased the number of possible observing sites by adding all the places where only one phase was observable. However, it required a very good knowledge of the longitudes of the observing sites and that was difficult to obtain in the middle of the XVIIIth century.

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Note 1: "Cunning Mercury wanted to cross without being seen, it came sooner than anyone had expected but it could not escape being discovered, I found it and I saw it; it happened to nobody before me on 7 November 1631 in the morning"

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