THE 1769 TRANSIT OF VENUS

The day was June 3, 1769. Venus was between the Earth and the Sun, a situation that is called a "transit of Venus". When that happens, Venus is visible as a small dark spot in front of the sun. With a telescope, you can project the sun's image on a screen (it's too bright to look at directly), and hopefully you can note the exact moment when Venus appears as a dark spot at the edge of the sun, and the exact spot later on when it appears to leave the other edge of the sun. Before it lines up with the edge of the sun, and after it lines up with the other edge, you can't see it because its dark side is towards the Earth.

FIGURE 1. A photograph taken during the transit of Venus in 2012

Depending where you are on the Earth, the moment when Venus first appears at the edge of the sun should occur at slightly different times, because the line between the edge of the sun and Venus can only hit Earth along a (curved) line. By knowing the distances and angles between two observation points, then, we can work out how far away Venus is.

In 1769, nobody still believed that the Earth was the center of the universe. Even though there was still no direct observational evidence of the Earth's motion, the beauty of Newton's law of universal gravitation and his derivation of Kepler's three laws about the motions of the planets from his law of gravitation had convinced all scientists that

the planets move around the sun in ellipses. Kepler's third law connects the size of their orbits with the length of their "year" (the time it takes them to go around the sun). Thus, the whole structure of the solar system was known except for the actual size of it! If one distance could be measured (say the distance from Earth to Venus, or Earth to Mars, or to any one planet) then all the other distances in the solar system could be calculated. But measuring any one distance had turned out to be too difficult, so far.

Newton's work had been done in the late 1600s, and it had enabled those who understood it to calculate and predict the motions of the planets. The transits of Venus are fairly rare (because the orbit of Venus is slightly tilted to the plane of Earth's orbit, so you have to wait until the two planets line up close to the line of intersection of the planes of their orbits). Transits of Venus occur in pairs, about one pair per century. The Royal Astronomer of England, Edmond Halley (whom you may know as the discoverer of Halley's comet) wrote a paper in 1716, predicting the transits of Venus on June 6, 1761, and June 3, 1769, and urging the observation of those transits to establish the scale of the solar system. He pointed out that if those opportunities were missed, the next chance wouldn't occur until December 9, 1874. He was 59 when he wrote that paper in 1716, so he knew that he wouldn't be alive to observe those transits: he was writing to a future generation.

In 1769, the astronomers didn't drop the ball. The story is told on p.64 of [1], and that source is closely followed here. Observers from eight nations were in England, Baja California, Noray, Peru, Hudson Bay, the Cape of Good Hope, Siberia, and the East Indies. Nevil Maskelyne, Astronomer Royal in 1769, was at the peak of the mountain on St. Helena, the island off Africa where Napoleon was exiled. Halley had tried to observe the transit of Mercury there in 1677, when he was only nineteen. Captain James Cook, in has famous voyage across the Pacific in the *Endeavor*, had dropped astronomer Charles Green in Tahiti. French astronomer Guillame Le Gentil had tried to go to India to observe the 1761 transit, but he didn't manage it, because the French settlement at Pondicherry, where he planned to observe, fell to the British in a battle. Not wishing to miss the 1769 transit, he decided to stay in India–but on the fateful day, June 3, a cloud bank blocked his view. He returned to France, but found that he had been declared dead, his assets had been distributed, and his post as astronomer was filled by someone else! Charles Mason and Jeremiah Dixon, famous for the Maxon-Dixon line in Pennsylvania, were in South Africa to observe the transit of Venus. Not everyone had bad luck: 150 observations of the transit were made. When these results were analyzed, the "astronomical unit" (distance from Earth to Sun) was found to be about 91 million miles. (Today's value is 93 million.) The results were somewhat disappointing in their accuracy, as it proved difficult to judge the precise moment when Venus's silhouette entered the solar disk, due to atmospheric turbulence and optical distortions. But with 150 measurements, something could be said, and at last people knew this size of the solar system, for the first time in history.

There were transits of Venus in 2004 and 2012. You can search the web for images; one is at the top of this page. It's also worth mentioning that Cassini, director of the Royal Observatory in Paris, had tried to observe the parallax of Mars, by observing the position of Mars from Paris and (with the help of an assistant) from an island off the coast of South America at the same time. He thought he had succeeded, but others were not convinced; it

was a difficult observation and only two people were involved. He got the value 89 million miles for the astronomical unit, so perhaps he wasn't as far off as some people thought. Because he was the director of the Royal Observatory, his value carried a certain authority, but in a sign of the progress of science, authority alone was no longer enough.

References

[1] Hirschfeld, Alan W., *Parallax: The Race to Measure the Cosmos*, Holt Publishers, New York, 2002.