

# The Transit of Venus

## Measuring the Distance to the Sun

Based on the article at <http://brightstartutors.com/blog/2012/04/26/the-transit-of-venus/>, where additional details and the math may be found.

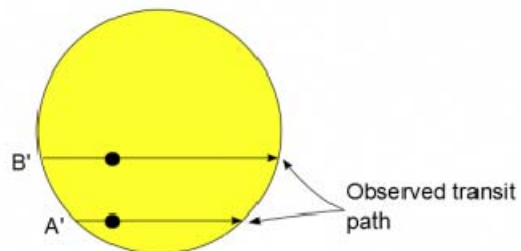
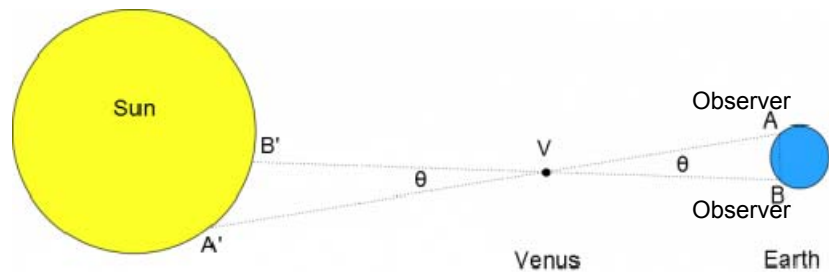
On June 5, 2012, people from many countries will be able to see a rare transit of Venus. This just means that Venus will be between the Earth and Sun, so that Venus will appear as a small dot on the Sun's surface.

Scientists studied the Venus transits in the eighteenth century in order to calculate the distance to the Sun, and to the other planets in our solar system. This was one of the most important scientific questions of the age, because only the *relative* distance of each planet from the Sun was known.

In 1716, the English astronomer Edmund Halley described a method for using a Venus transit to measure the solar system. Observers on two different locations on the Earth would see Venus appear to travel across the front of the Sun along two different paths (A' and B'), and could measure the angle between the two locations ( $\theta$  in the diagram below). Using the distance between the observers, and the angle to Venus, trigonometry can determine the distance to Venus.

Almost a hundred years earlier, Kepler's third law enabled astronomers to calculate the relative distance to the planets using each planet's orbital period. Since astronomers already knew that the Sun-Venus distance was 0.72 times the Sun-Earth distance, knowing the distance to Venus would make it fairly easy to calculate the distance to the Sun.

Unfortunately, it's not that easy in practice—the angle  $\theta$  was very small—too small to accurately measure at the time. Halley anticipated this problem and proposed that, instead of measuring Venus' position on the Sun directly, each observer would *time* the duration of the transit. For all observers, Venus appeared to drift across the Sun's disk at the same rate. However, because some observers would see Venus cutting across a longer path on the Sun, their times would be longer than others. These times might differ by only a few minutes out of the several hour duration of the transit, but each transit time can be measured with an accuracy of a



few seconds.

Britain, Austria, and France each launched expeditions to collect data by observing and timing the transits from several locations throughout the world. In all, 250 observers were dispatched to over 100 locations, including Lt. James Cook's famous voyage around the world that stopped in Tahiti to observe the transit. The transit expeditions were a success: when the data were calculated, the computed Earth-Sun distance ranged from 146,000,000 km to 151,000,000, within 2.6% of the correct value of 149,597,900 km. One source of error was limb darkening: when Venus is near the edge of the Sun--the critical moment for transit timing--the black of space seems to reach in and touch the planet. This makes it very difficult to say precisely when a transit begins or ends. Captain Cook's expedition stopped in Tahiti to make observations and his measurements disagreed with those of ship's astronomer Charles Green, who observed the transit beside Cook, by as much as 42 seconds.

Measuring the distance to the Sun was a major step in our efforts to measure the universe. Within a few decades, astronomers used parallax to find the distance to nearby stars. They accomplished this by measuring the stars parallax: sighting on a star with a telescope, then repeating the sighting six months later, when the Earth was on the opposite side of the Sun, and the angle to the star was slightly different. Because the base of the huge triangle formed was just twice the Earth-Sun distance, knowing this distance was necessary to find the stellar distances.