Sun – Part 3 - distance calculation 1


Christiaan Huygens

In the 3rd century BCE, the Greek polymath Eratosthenes calculated Earth's circumference via comparison of the Sun's declination between places of known distance apart. Knowledge of Earth's radius created a baseline to determine greater distances. A century later, Hipparchus worked out the Earth-Moon distance indirectly, but accurately, from the geometry of lunar eclipses.

Aristarchus then used Hiapprchus's calculations to determine the sizes of Moon and Sun, and distance to the Sun. When the Moon is seen from Earth to be exactly half illuminated (at first and last quarter), there is a right angle between Earth, Moon and Sun, with the Moon at the right angle. From this, Aristarchus, using geometry, was able to measure the angular distance in the sky between Sun and Moon, add it to the known Earth-Moon distance, and calculate the Earth-Sun distance. However, a small inaccuracy in assumption of Sun-Moon-Earth angle led to a calculated result equivalent to only 8 million kilometres, which was known to be much too small.

In the 1st century CE, Ptolemy estimated Sun-Earth distance as 1,210 times Earth's radius, approx 7.71 million km, but it was, again, far too small. At best, the earlier calculations were best estimates. It was not until 1653 that the Dutch physicist Christiaan Huygens first accurately measured the distance to the Sun. He used the phases of Venus to find the angles in a Venus-Sun-Earth triangle. He knew that actual Venusian phase depended on the angle it made with Sun as seen from Earth. When Venus appears half lit, Earth, the Sun and Venus form a right angle.

If any two internal angles and the length of one side of a triangle are known, the length of another side can be calculated. Huygens knew the Sun-Venus-Earth angle (from the phases), and could directly measure the Sun-Earth-Venus angle. He also needed the Venus-Earth distance to be able to use trigonometry to obtain the Earth-Sun distance. Huygens knew that if you measure the apparent size of an object, and know its true size, the distance to that object can be calculated. He thought he knew Venus's size, but from unscientific techniques like numerology and mysticism. However, through pure luck, he correctly thought that Venus and Earth were similar sizes. Using this assumption, he was able to determine the distance of Venus from Earth and, knowing that distance, plus the angles made by the triangle, he calculated the distance to the Sun.

Huygens was the first to scientifically calculate almost the correct value of the Sun-Earth distance. However, because his method involved some guesswork and was not completely scientifically grounded, he usually does not get the credit. This tends to go to Giovanni Cassini and Jean Richter. In 1672, using a completely different method from Huygens, one with no lucky element to produce the correct result, the two French astronomers

accurately determined the distance of Mars from Earth. They were then able to use the same method to refine the then accepted dimensions of the solar system, including the distance of the Sun from Earth.

Sources: Ridpath, I (Ed) (2012) Oxford dictionary of astronomy 2nd ed rev, www.en.wikipedia.org