Convergence or Coincidence: Ancient Measurements of the Sun and Moon—How Far?

If two experiments measure the same phenomena from two different viewpoints and both get the same result (within, of course, experimental error) it stands to reason they are converging toward the correct answer. Why would anyone think otherwise? This chapter discusses the modern convergence of several measurements of the speed of light and compares this case with the ancient converging measurements of the relative distances of the moon and sun from Earth. The former was a real convergence. The latter was a coincidence. Could scientists at either time have known which is which?

2.1. The Speed of Light

Enter a dark room. Light a candle and the room seems instantaneously bright, dispelling the darkness. But is it instantaneous? One thing we can conclude from observation: the light is not evenly distributed over the room because it is brighter or more concentrated closer to the candle. This means that the light’s intensity decreases with recession (the distance, $D$) from the source; that there is a mathematical law for this was first worked out by the German mathematician-astronomer Johannes Kepler in the 17th century. He showed that the intensity ($I$) of light obeys an inverse-square law (that is, $I \propto 1/D^2$). This seemed to imply that light is not instantaneous—for, if it were, the room would be uniformly lit. But can it be proven that the speed of light is finite?

The question about the possible instantaneous speed of light was debated over the ages, at least since the ancient Greeks. Little changed on this matter in the Middle Ages and Renaissance. Kepler’s Italian contemporary, Galileo, tried to test it. Placing himself and an assistant on two distant hilltops at night with lanterns, he thought that by opening one’s lantern when seeing the other’s flash would result in a visible delay if the speed were finite. But the experiment was inconclusive: there was no time lag, which meant either that light moves instantaneously or the speed is too fast to measure by this experiment. In his last book, Two New Sciences (1638), Galileo wrote: “If not instantaneous, light is very swift.”
Galileo, nevertheless, with his discovery of the moons of Jupiter in January 1610, bequeathed another method of measuring the speed of light. A study of the motions of the moons revealed that when Jupiter’s moons passed behind the planet, the measured intervals of time were different at different times of the year, which corresponded to Jupiter being at different distances from Earth. Over three decades after Galileo died, the Danish astronomer Olaf Rømer concluded that this difference seemed to point to a time lag in the light from the moons reaching Earth—the sort of thing Galileo was looking for if the speed is finite. The Dutch scientist Christiaan Huygens used Rømer’s data to calculate a value for the speed of light. The details of the experiment are not of concern here, only the result: the value was 124,000 miles/sec, which is extremely fast. This was the first empirical evidence that the speed of light is finite. The only question was the accuracy of this value.

In the early 18th century the Englishman James Bradley measured the speed of light from a different point of view, based on his discovery of what he called the aberration of light. He realized that in looking at stars through a telescope he had to adjust the angle of the sighting to take into account the motion of Earth; this was analogous to tilting an umbrella when walking through rain in order to keep dry. Again the details of the experiment are not of interest, only the value for the speed of light, which was 186,233 miles/sec. Since both his and Huygens’s values were within the same broad range, these two measurements were assumed to be “correct” in that the speed of light was indeed finite and that the task at hand was to measure it to closer and closer accuracy. This conviction was based on the fact that both numbers were arrived at by entirely different means, so it was reasonable to assume that these scientists were in fact measuring the same thing in different ways—that is, it was case of the convergence of data. Both measurements had been astronomical, and it is not surprising that the first measurements would be so, given the extreme speed of light.

In the next century the certainty in convergence was reinforced by some “tabletop” experiments. In mid–19th century the Frenchman H.L. Fizeau performed a laboratory experiment on light using a rotating cogwheel and got 194,000 miles/sec. Later the American Albert Michelson used a revolving mirror and, performing the experiment on several occasions, obtained an average value of 186,281 miles/sec.

Today the value is 186,290 miles/sec (299,790 km/sec). There is no doubt that in these cases of measuring the speed of light by different means, there was a convergence around and toward the correct value. As well, the speed of light is the fastest propagation of anything that we know of. In Galileo’s experiment, the hills were only about a mile apart: no wonder his experiment was inconclusive!

This story of the measurement of the speed of light is by way of prefacing the account of a similar convergence of measurement made in ancient astronomy. This was a measurement of the relative distances of the sun and moon from Earth. To tell this tale I need to sketch some background information about everyday naked-eye astronomy and the ancient model of the universe.