31-4 The Speed of Light

Prior to the seventeenth century the speed of light was thought by many to be infinite, and an effort to measure the speed of light was made by Galileo. He and a partner stood on hilltops about three kilometers apart, each with a lantern and a shutter to cover it. Galileo proposed to measure the time it took for light to travel back and forth between the experimenters. First, one would uncover his lantern, and when the other saw the light, he would uncover his. The time between the first partner's uncovering his lantern and his seeing the light from the other lantern would be the time it took for light to travel back and forth between the experimenters. Though this method is sound in principle, the speed of light is so great that the time interval to be measured is much smaller than fluctuations in human response time, so Galileo was unable to obtain a value for the speed of light.

The first indication of the true magnitude of the speed of light came from astronomical observations of the period of Io, one of the moons of Jupiter. This period is determined by measuring the time between eclipses of Io behind Jupiter. The eclipse period is about 42.5 h, but measurements made when the earth is moving away from Jupiter along path *ABC* in Figure 31-11 give a greater time for this period than do measurements made when the earth is moving toward Jupiter along path *CDA* in the figure. Since these measurements differ from the average value by only about 15 s, the discrepancies were difficult to measure accurately. In 1675, the astronomer Ole Römer attributed these discrepancies to the fact that the speed of light is finite, and that during the 42.5 h between eclipses of Jupiter's moon, the distance between the earth and Jupiter changes, making the path for the light longer or shorter. Römer devised the following method for measuring the cumulative effect of these discrepancies. Jupiter is moving much more slowly than the earth, so we can neglect its motion. When the earth is at point *A*, nearest to Jupiter, the distance between the earth and Jupiter is changing negligibly. The period of Io's eclipse is measured, providing the time between the beginnings of successive eclipses. Based on this measurement, the number of occultations during 6 months is computed, and the time when an eclipse should begin a half-year later when the earth is at point *C* is predicted. When the earth is actually at point *C*, the observed beginning of the eclipse is about 16.6 min later than predicted. This is the time it takes light to travel a distance equal to the diameter of the earth's orbit. This calculation neglects the distance traveled by Jupiter toward the earth. However, because the orbital speed of Jupiter is so much slower than that of the earth, the distance Jupiter moves toward (or away from) the earth during the 6 months is much less than the diameter of the earth's orbit.

EXERCISE Calculate (*a*) the distance traveled by the earth between successive eclipses of Io and (*b*) the speed of light, given that the time between successive eclipses is 15 s longer than average when the earth is moving directly away from Jupiter. (*Answer* (*a*) 4.59×10^6 km (*b*) 3.06×10^8 m/s)

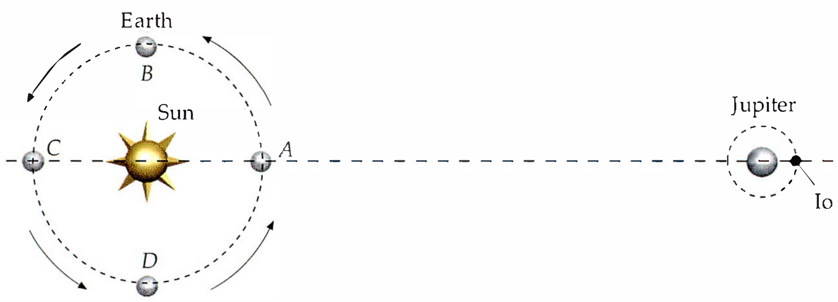

FIGURE 31-11 Römer's method of measuring the speed of light. The time between eclipses of Jupiter's moon Io appears to be greater when the earth is moving along path *ABC* than when the earth is moving along path *CDA*. The difference is due to the time it takes light to travel the distance traveled by the earth along the line of sight during one period of Io. (The distance traveled by Jupiter in one earth year is negligible.)