Chapter 7 - Eclipses

Updated 10 July 2006

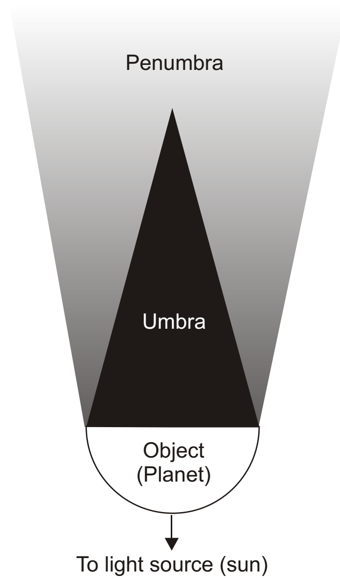

Figure 7.1 The umbra and the penumbra are the two regions of any object's shadow.

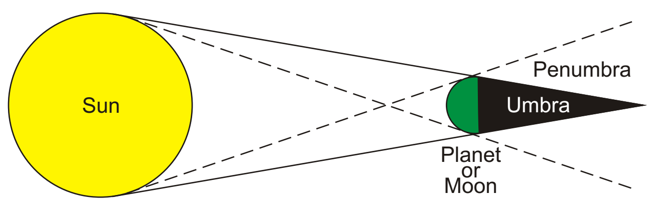

Figure 7.2 The structure of shadows is caused by the extant size of the Sun. If the Sun were point-sized the penumbra would not exist – there would only be umbra. Redraw this figure a few times, each time using a smaller solar disk. Watch what happens to the lines outlining the penumbra and umbra regions as the disk gets smaller. In your final redraw, use a point-sized Sun.

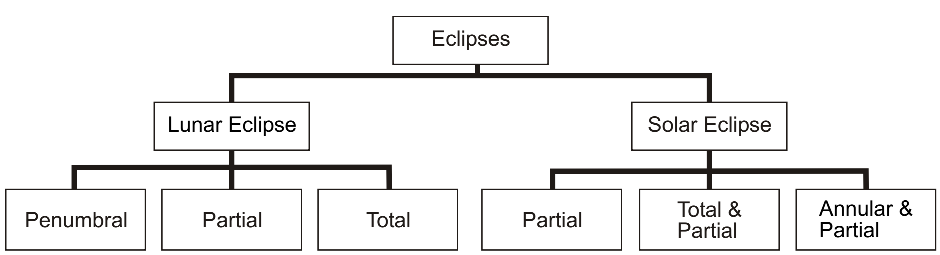

Figure 7.3 This is a flow chart showing the relationship between the different types of eclipses.

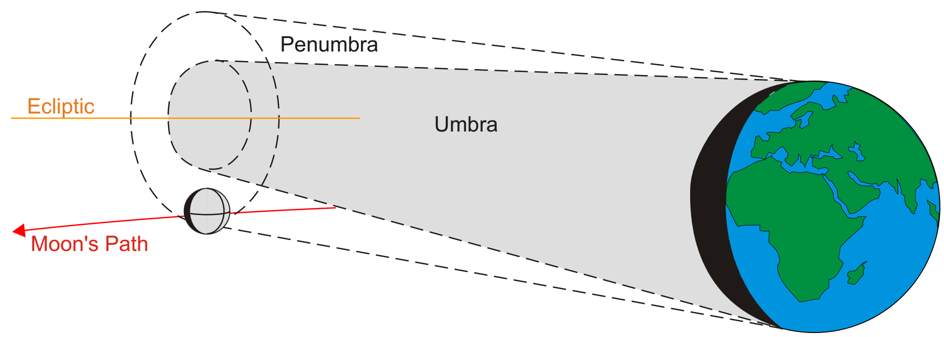

Figure 7.4 During a penumbral lunar eclipse the Moon moves through only the penumbral portion of the Earth’s shadow. Any change in the appearance of the Moon is barely noticeable.

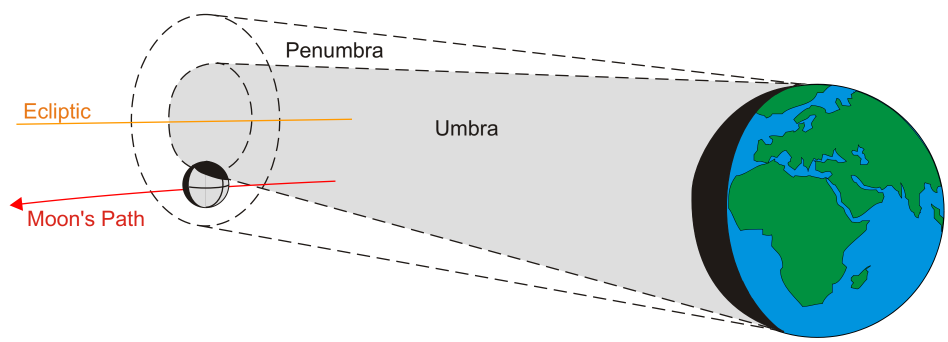

Figure 7.5 During a partial lunar eclipse part of the Moon moves through the umbra portion of the Earth’s shadow. One can easily see the Earth’s curved shadow move across the Moon’s face.

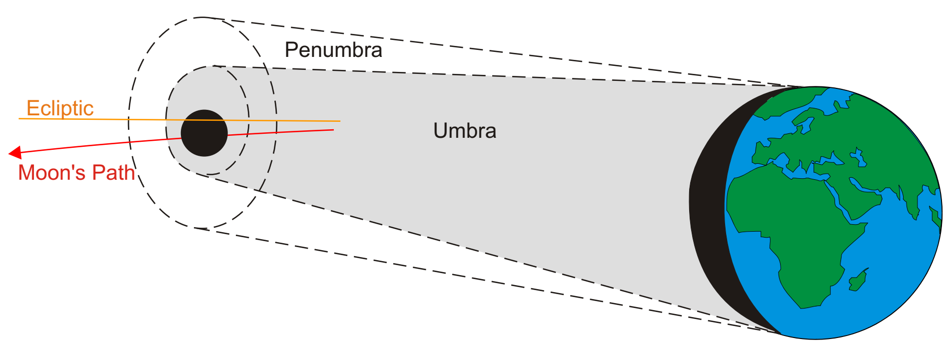

Figure 7.6 During a total lunar eclipse the entire Moon moves through the umbra portion of the Earth’s shadow. During totality the Moon turns a coppery-red color.

Figure 7.7 The Moon passes through the Earth's umbra showing the curvature of the Earth's shadow on its face while implying the size of the umbra at the distance to the Moon. This is a collage of photos from the total lunar eclipse of 28 October 2004. (Photos courtesy of Kevin S. Jung.)

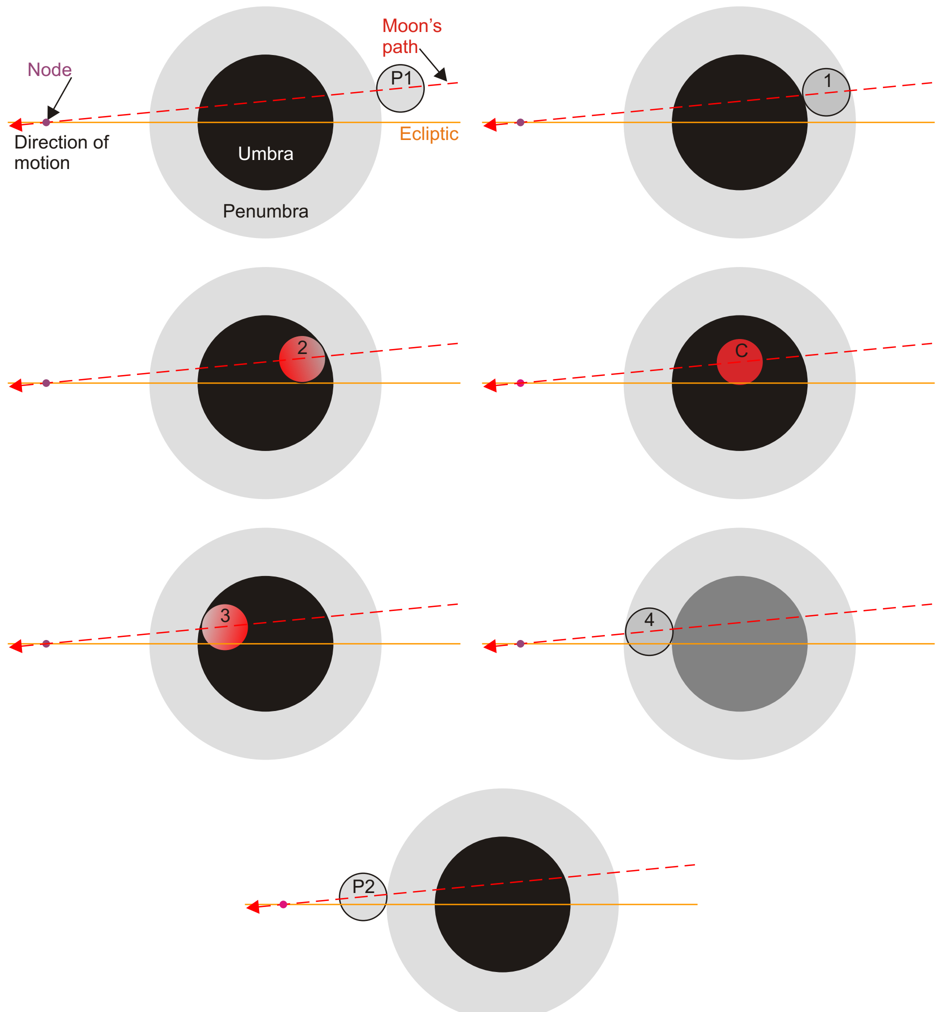

Figure 7.8 As the Moon moves through the Earth's shadow during a total lunar eclipse it passes through stages. An eclipse is described by the timings of these stages in Universal Time. Eclipse duration, from U1 to U4, may be as long as four hours. For the total lunar eclipse of 28 October 2004, the timings (UT) were: P1 = 00:05, U1 = 01:05, U2 = 02:23, C = 03:04, U3 = 03:44, U4 = 04:53, P4 = 06:02.

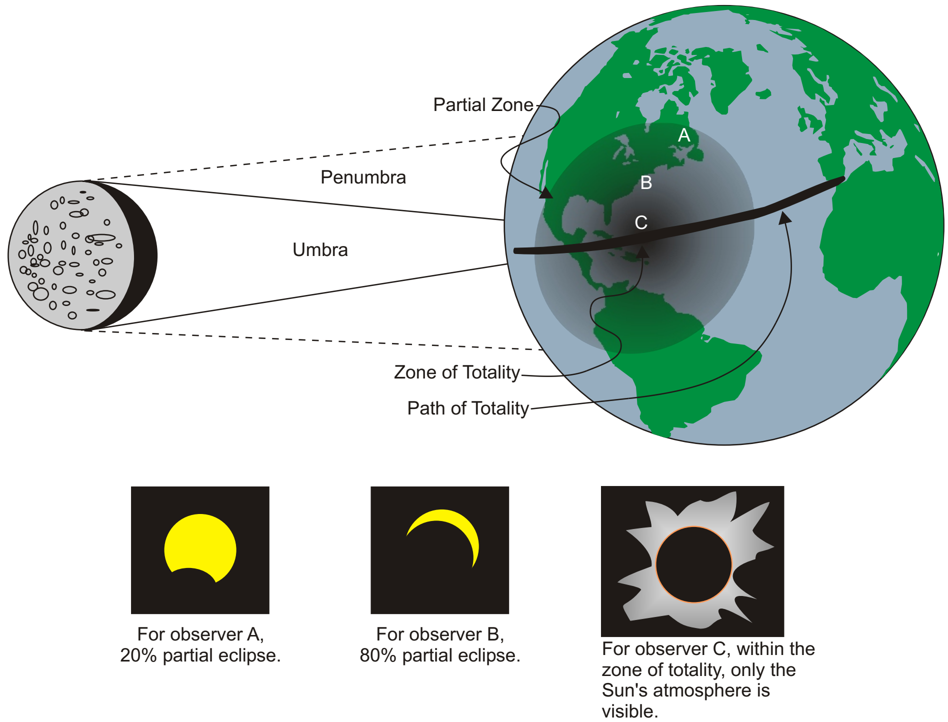

Figure 7.9 When then Moon passes in front of the Sun, which can occur when the Sun and the Moon reach the same node at the same time, we see a solar eclipse. Those who are standing in the path of totality see a total solar eclipse and those in the partial zone (in the Moon's penumbra) see a partial solar eclipse. While the penumbral zone can be over 6000 km (3700 mi) across, some people are so far from the path of totality that they do not see an eclipse at all. This is a result of geocentric parallax.

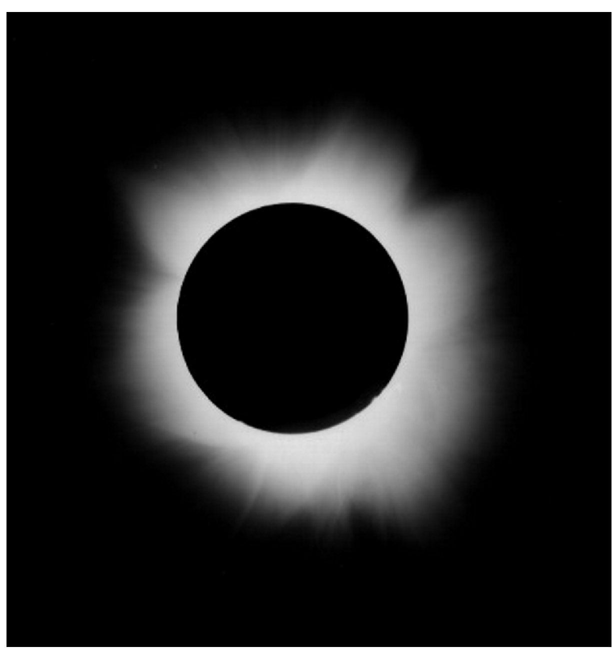

Figure 7.10 The total solar eclipse of 8 June 1937. (Courtesy of the United States Naval Observatory library.)

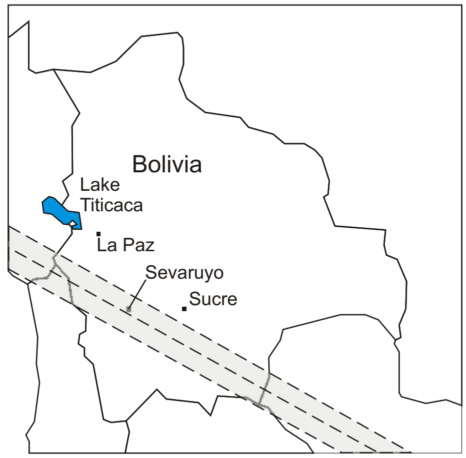

Figure 7.11 The path of totality for the 4 November 1994 eclipse passed through Sevaruyo, Bolivia at about 09:00 local time. This small town was near the center line of the path.

Figure 7.12 The path of totality for the 4 November 1994 total solar eclipse, passing through South America.

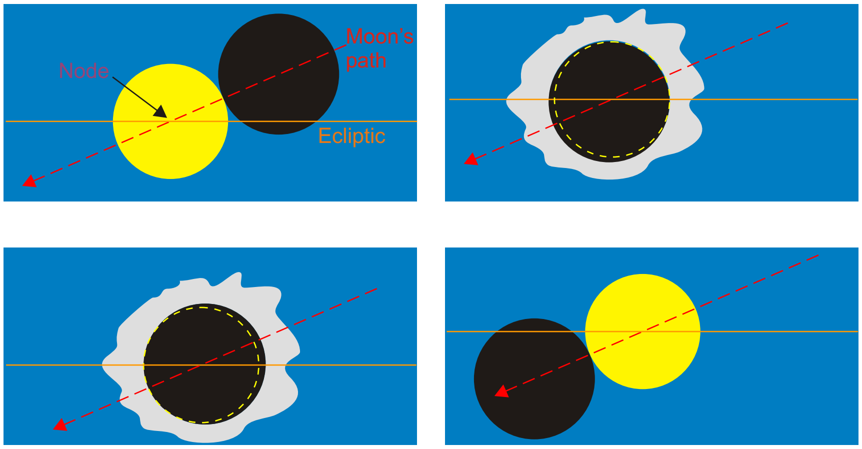

Figure 7.13 The contacts, or stages, of a total solar eclipse. First contact (upper left) occurs when the eastern limb of the Moon touches the western limb of the Sun, signaling the beginning of the eclipse. Second contact (upper right) is the beginning of totality. Third contact (lower left) is the end of totality. Fourth contact (lower right) is the end of the eclipse.

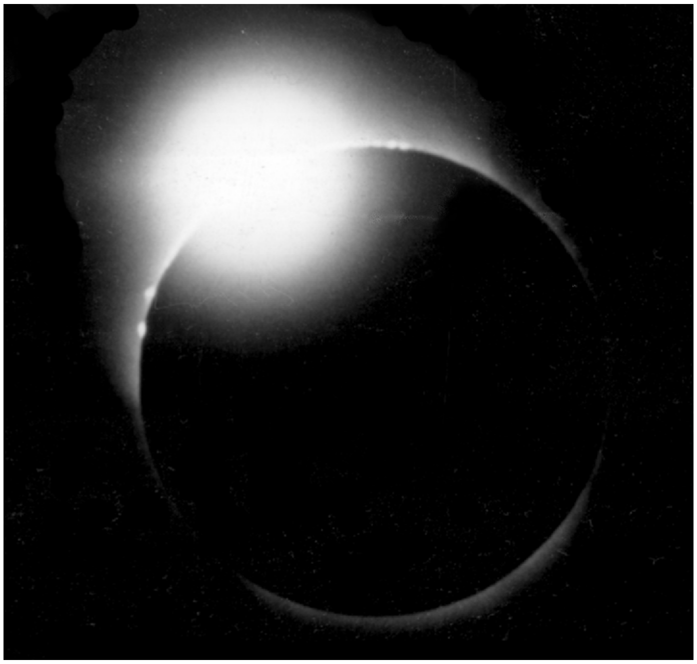

Figure 7.14 The diamond ring effect, photographed at Sevaruyo, Bolivia on 4 November, 1994. (Photo courtesy of Herbert DeVries.)

Figure 7.15 Two photos of the full Moon showing its apparent size at perigee (closest to Earth, left) and apogee (farthest from Earth, right) points in its elliptical orbit. When a solar eclipse occurs with the Moon near apogee, it is not large enough to cover the disk of the Sun and an annular eclipse occurs.

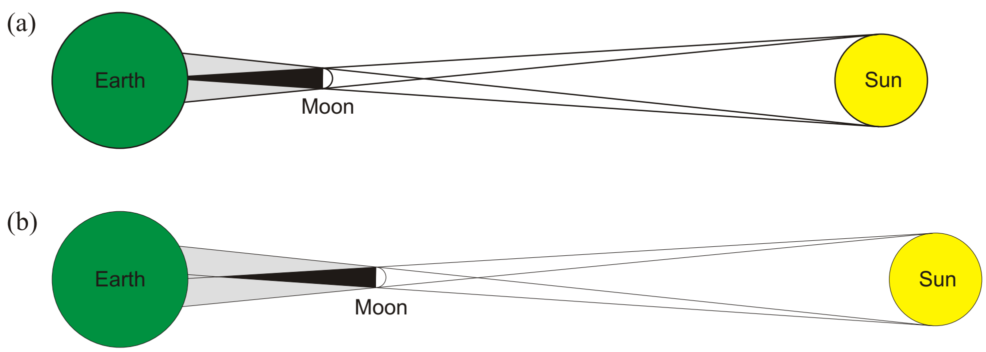

Figure 7.16 The difference between a total solar eclipse and an annular solar eclipse is caused by the elliptical orbits of the Moon and Earth. If the eclipse occurs while the Moon is in the farther region of its orbit (around apogee) the Moon's umbra is not long enough to reach the surface of the Earth. (a) During a total solar eclipse, the Moon's shadow can reach the Earth's surface. (b) During an annular eclipse, the Moon is too far from the Earth and its shadow can not reach the Earth's surface.

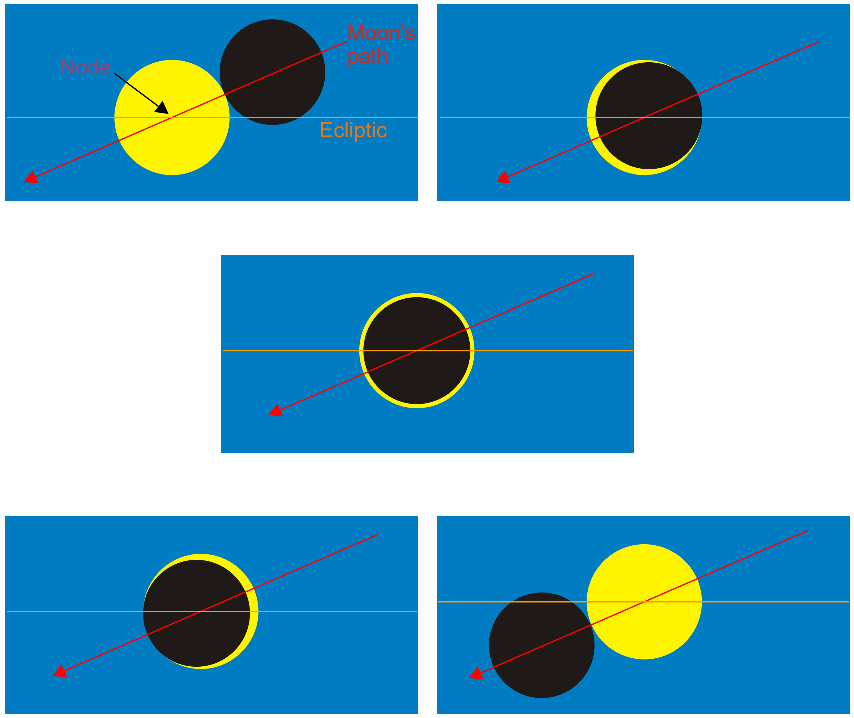

Figure 7.17 The contacts, or stages, of an annular solar eclipse. First contact (upper left) is the same as for a total eclipse. Second contact (upper right) is the beginning of annularity. Center contact (center) is maximum annularity where the ring is symmetrical. Third contact (lower left) is the end of annularity and fourth contact (lower right) is the end of the eclipse.

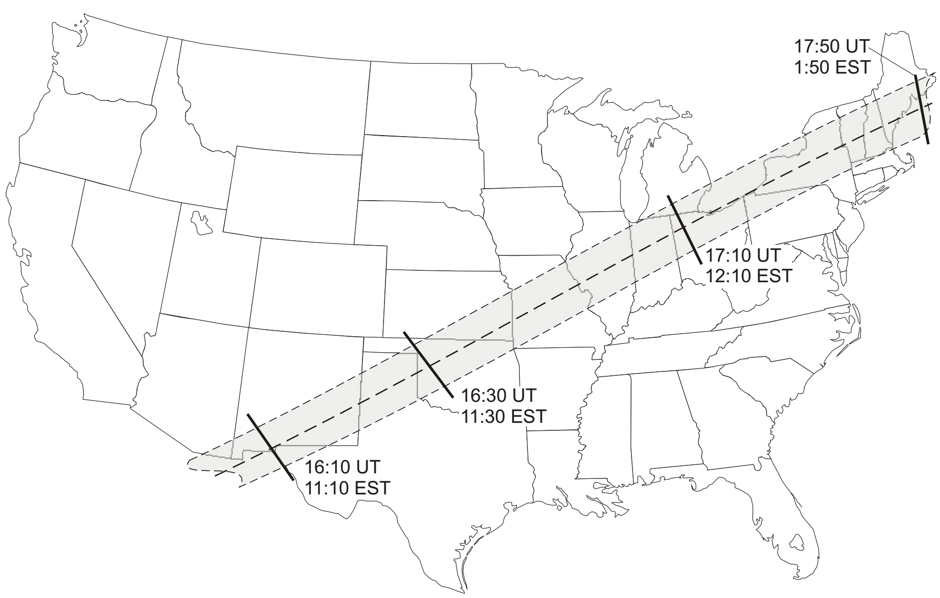

Figure 7.18 The path of annularity for the 10 May 1994 solar eclipse passed through the United States. Anyone standing in this path saw the annular eclipse and anyone outside it, in the path of the penumbra, saw a partial solar eclipse. Those outside the path of the penumbra saw no eclipse.

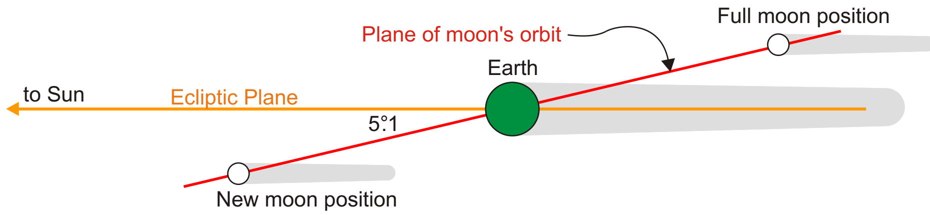

Figure 7.19 The Moon’s orbital plane is inclined by 5°.1 to the ecliptic plane. At the Moon’s distance from the Earth, this small angle is enough to allow the Moon to miss the Earth’s shadow. This is a “side view” of a non-eclipse season arrangement as shown in figure 7.22 at position A or C.

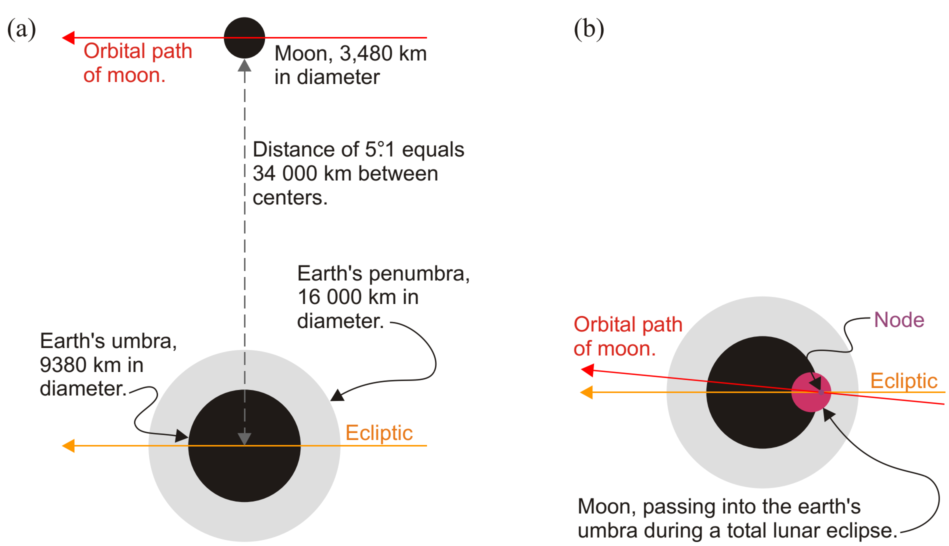

Figure 7.20 The Moon crosses the ecliptic – at a node – twice each month. A lunar eclipse occurs if the Moon and the Earth’s shadow are near the same node at the same time. (a) When it is not an eclipse season, the Moon can miss the Earth's umbra by as much as 16 000 km. (Drawn to scale.) (b) A lunar eclipse may occur only during an eclipse season, when the Moon and the Earth's shadow cross a node simultaneously. (Drawn to scale.)

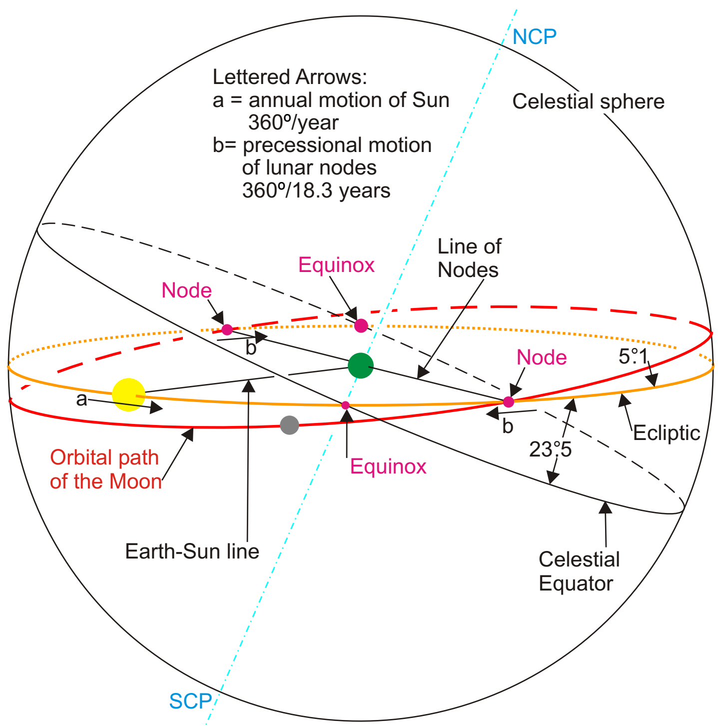

Figure 7.21 The orbit of the Moon on the celestial sphere lies close to the ecliptic. The nodes are the points where the Moon's orbit crosses the ecliptic, one on each side of the celestial sphere. The line of nodes is drawn between these two points, passing through the Earth. As the Sun moves along the ecliptic and it passes through a lunar node, the Earth-Sun line then matches the line of nodes, creating an eclipse season. If the Moon is at a node at the same time we see either a lunar eclipse or a solar eclipse.

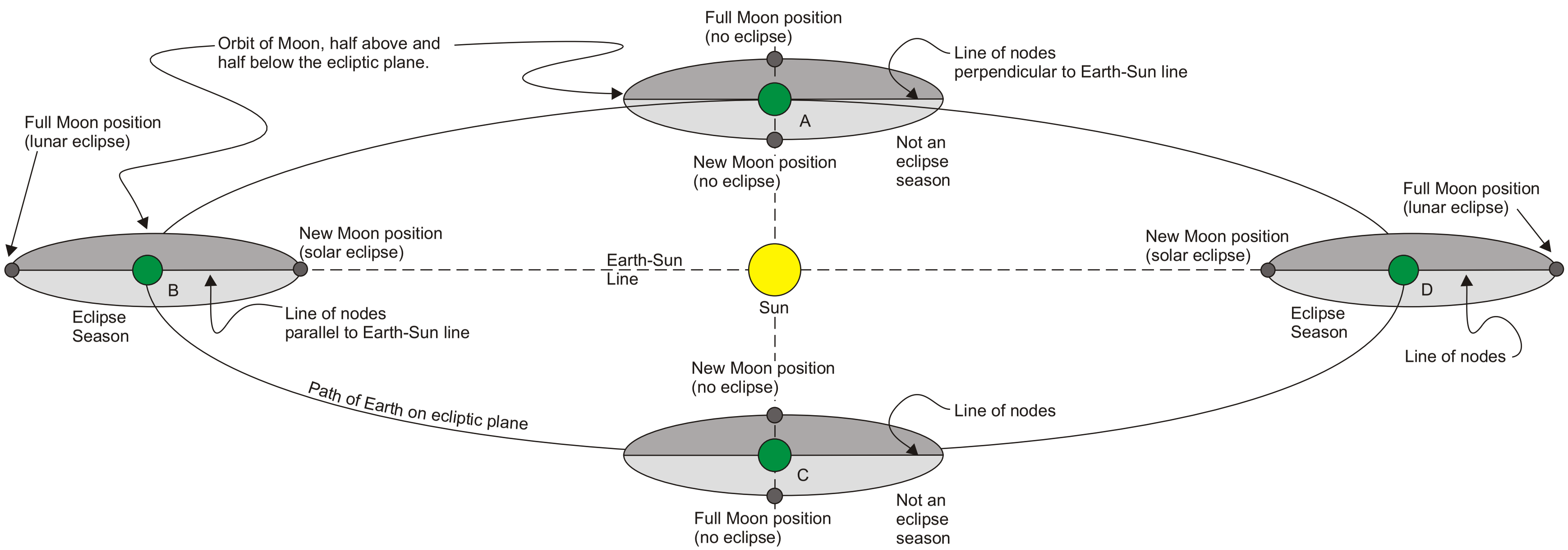

Figure 7.22 An eclipse season occurs when the Moon's line of nodes points toward the Sun. This occurs twice each year, as shown here at positions B and D. Compare this drawing at A with figure 7.20a – the full Moon is above the ecliptic plane and the Earth's shadow. At position C, which also is not an eclipse season, the full Moon is below the ecliptic plane and the Earth's shadow. When the Earth-Moon system has moved along its solar orbital path to a position in an eclipse season (positions B and D), the situation is like that shown in figure 7.20b – a lunar eclipse will occur. The discussion is the same for the new Moon positions and solar eclipses. Eclipses can only happen during an eclipse season. Compare this figure with figures 7.23 and 7.24.

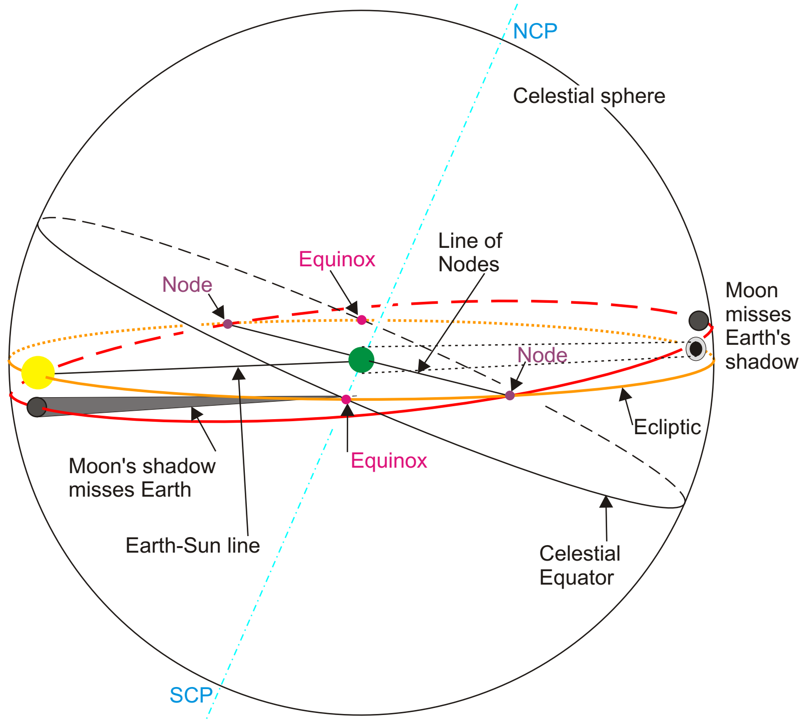

Figure 7.23 When the Earth-Sun line is not near the line of nodes – the Sun is not near a node – there can be no eclipses. The Moon's shadow passes below (or above if on the other side of the sphere) the Earth and the Moon passes above (or below) the Earth's shadow. The circles representing the Sun, Moon, Earth and Earth's shadow are not drawn to any scale. Compare this figure with figures 7.22 and 7.24.

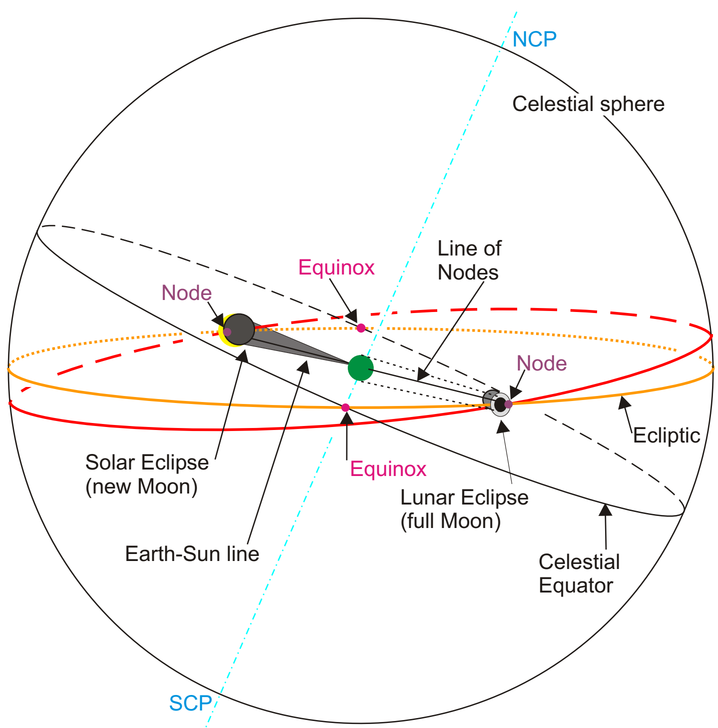

Figure 7.24 When the Earth-Sun line is near the line of nodes – the Sun is near a node – then eclipses are "in season." There will be a solar eclipse and possibly a lunar eclipse. The circles representing the Sun, Moon, Earth and Earth's shadow are not drawn to any scale. Compare this figure with figures 7.22 and 7.23.

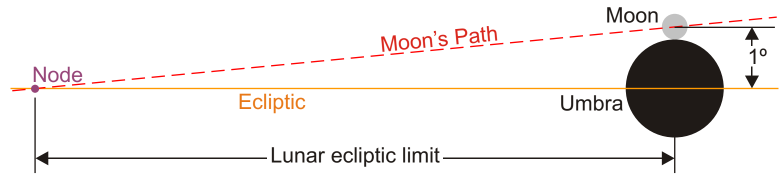

Figure 7.25 The lunar ecliptic limit determines the farthest distance from the node for which a lunar eclipse may occur. The major lunar ecliptic limit is twice this distance, because the eclipse may occur on either side of the node.

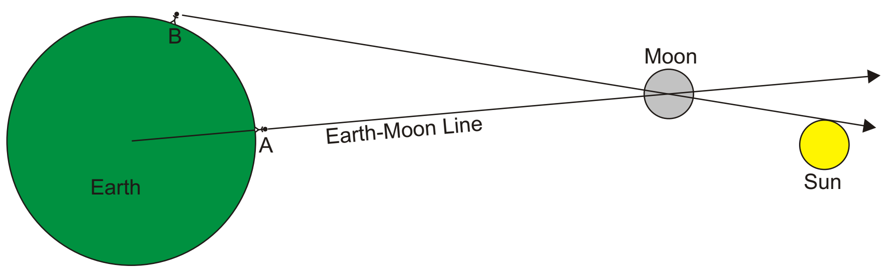

Figure 7.26 Geocentric parallax is the result of an observer being located on the surface of the Earth instead of at the center. It creates an apparent misalignment of the Moon and the Sun which may lead to a solar eclipse for observer B, but not for observer A, who is closer to the true Earth-Moon center line.

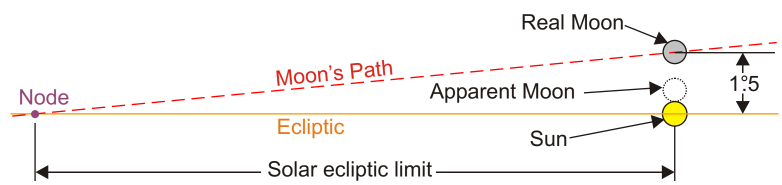

Figure 7.27 The solar ecliptic limit determines the farthest distance from the node for which a solar eclipse may occur. The limit is increased over its true length by geocentric parallax. The major solar ecliptic limit is twice this distance, because the eclipse may occur on either side of the node.