2017 Total Solar Eclipse

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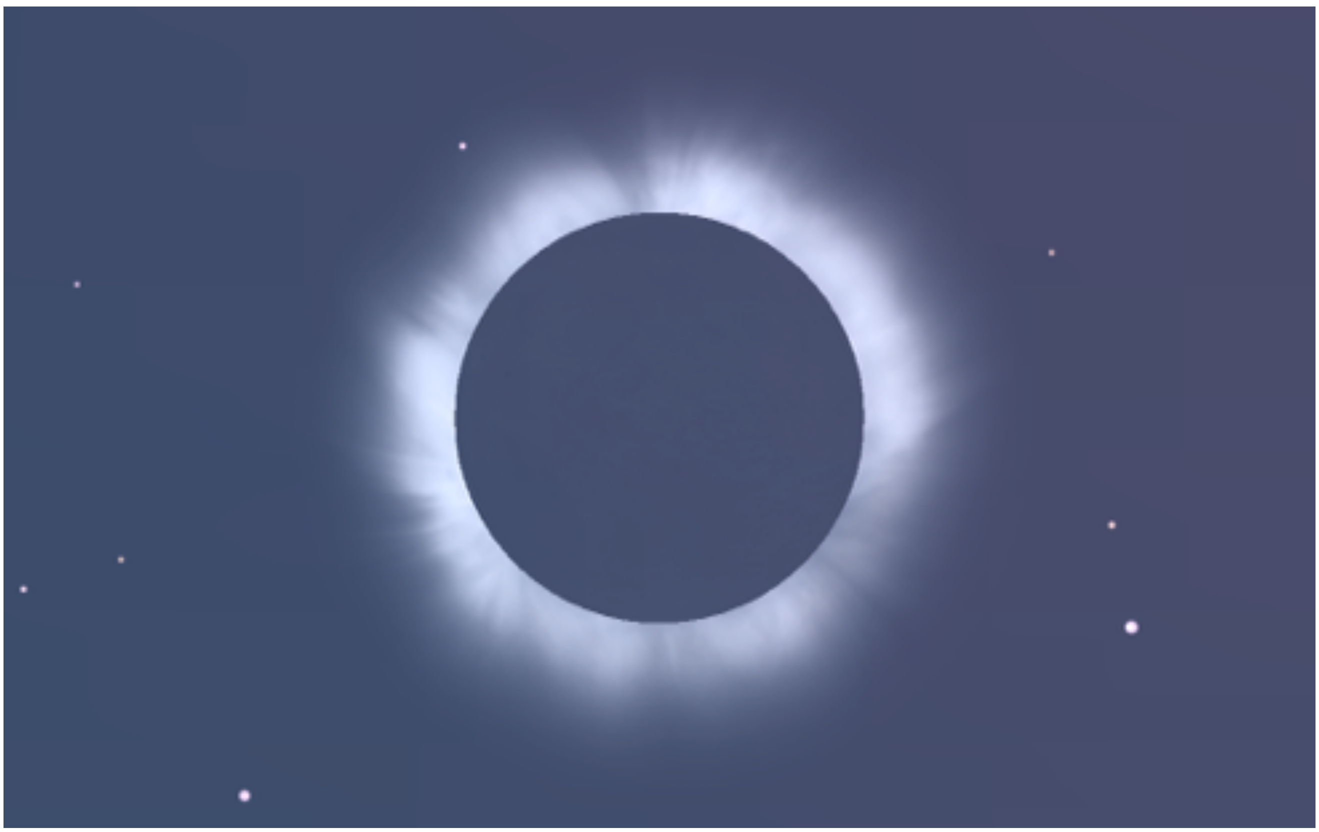

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Introduction

On August 21, 2017, a Total Solar Eclipse will occur along a track running across the Continental USA from Salem, Oregon to Charleston, South Carolina. At most points along the track, totality will last more than two minutes, peaking at 2 minutes, 41.6 seconds just east of St. Louis, Missouri. Observers south and north of the track will see only a partial eclipse, the degree varying depending on the distance north or south.

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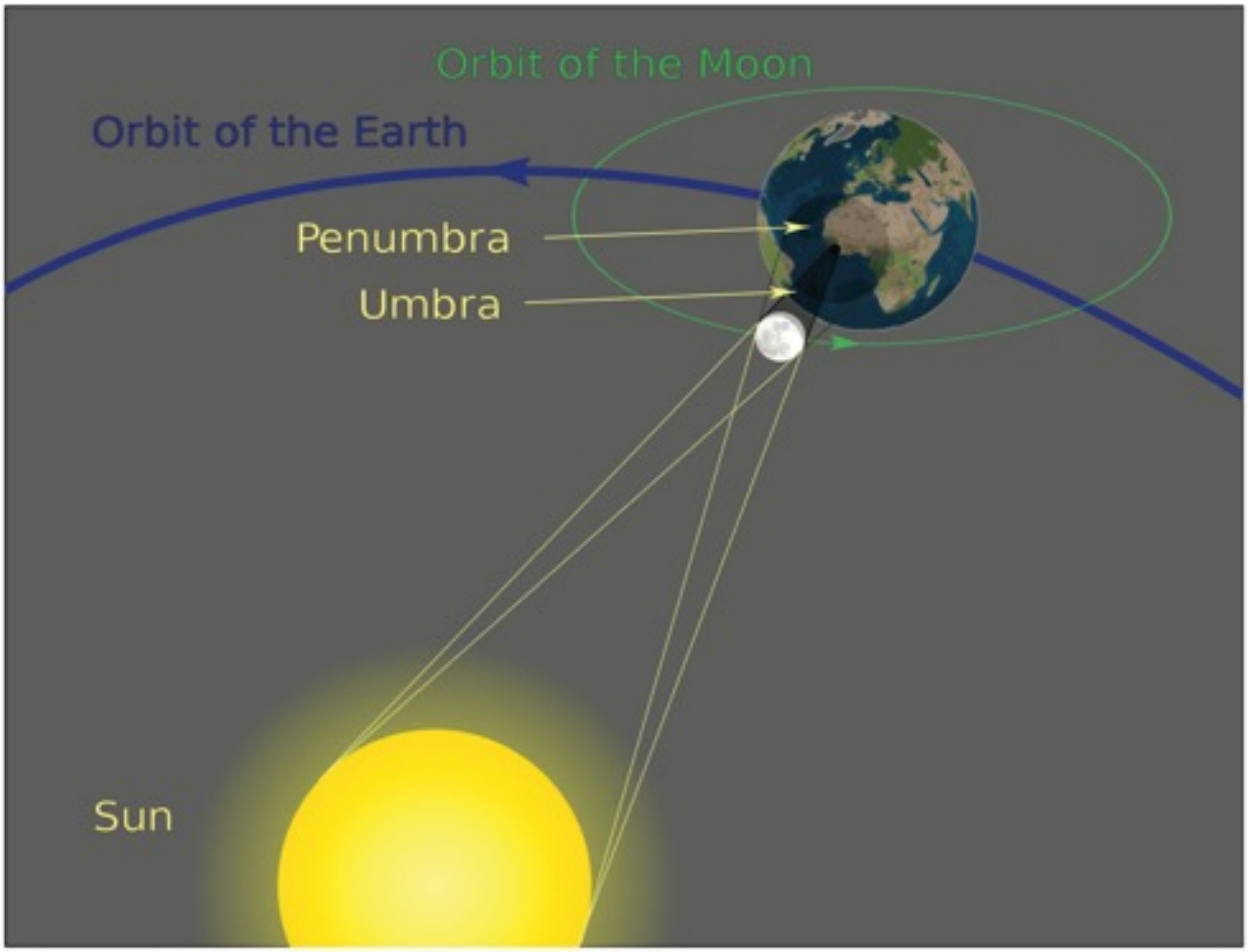
2017 Total Solar Eclipse

What is a Solar Eclipse

The Moon will cast a dark shadow on the Earth when it passes directly between the Sun and the Earth. This blocking of the Sun's light produces a phenomenon known as a solar eclipse. The image below shows a total solar eclipse as seen from Sampit, Indonesia on March 9, 2016. During a total solar eclipse the Moon completely covers the Sun's disk. The March 9, 2016 solar eclipse was the most recent total solar eclipse.

This illustration shows a total solar eclipse as seen from Sampit, Indonesia on March 9, 2016. Image credit: Starry Night Software.

The dark, inner part of the shadow cast by the Moon on the Earth is known as the umbra. A person standing within the umbra will experience a total solar eclipse. The path of the umbra will slowly track eastward as the Earth rotates. This dark path that the umbra sweeps out as it travels over the surface of the Earth is known as the path of totality. Everyone standing within the path of totality will experience a total solar eclipse, a complete blocking of the Sun's disk by the Moon. The outer part of the Moon's shadow, where only some of the Sun's light is blocked is known as the penumbra. Observers on the Earth in the penumbra shadow will see a partial solar eclipse.



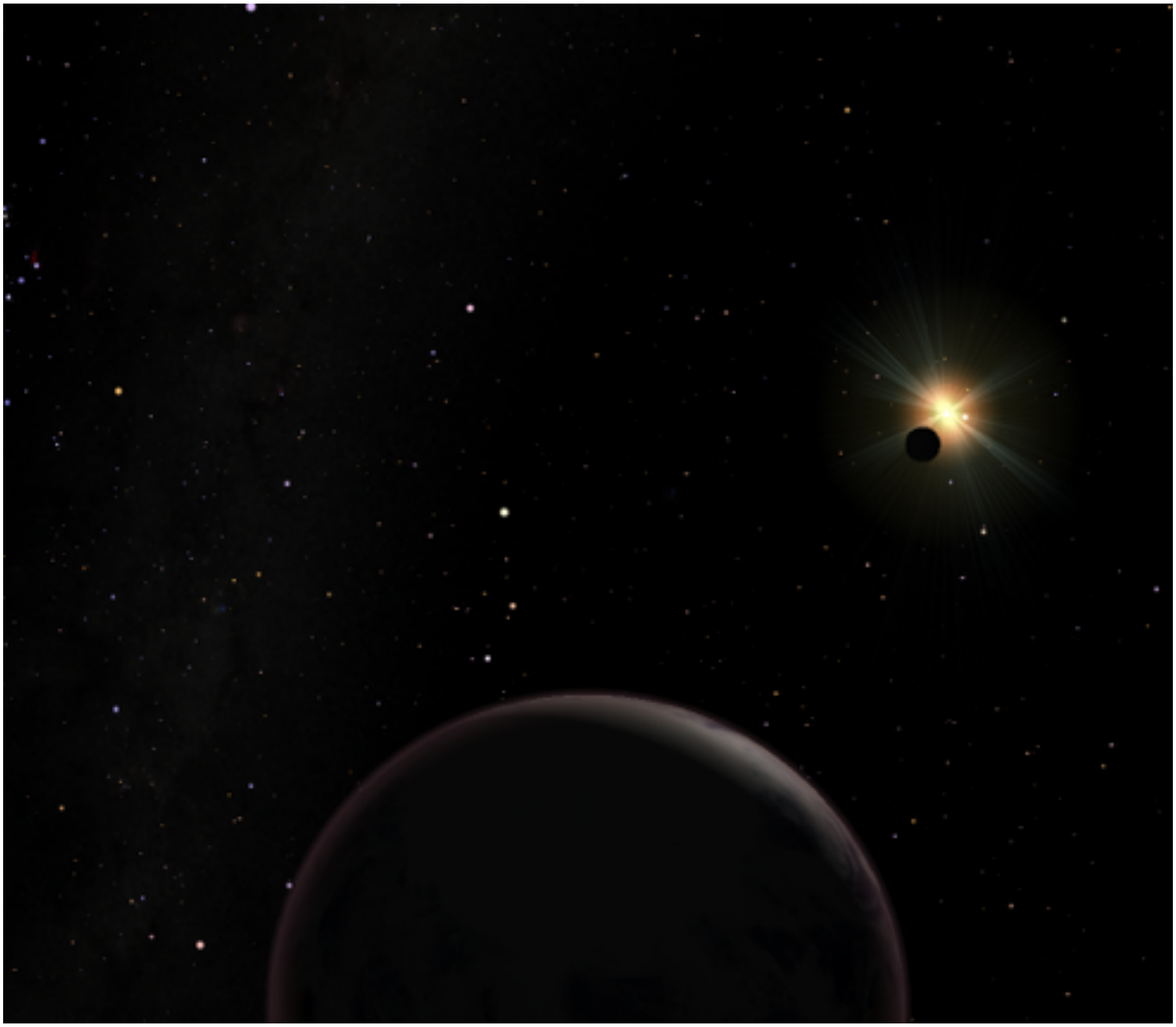
A diagram illustrating the formation of the umbra and penumbra..

One unique phenomenon that occurs at the beginning and end of a total solar eclipse is known as Bailey's beads. Bailey's beads refers to small slivers of sunlight, or beads, that are still visible around the Moon during a total solar eclipse. These "beads" are the result of light filtering through the irregular surface of the Moon as a result of topographical features like mountains, craters, and valleys. Another unique view, known as the diamond ring effect, is seen when only one bead is visible. Bailey's beads are named in honor of Francis Bailey (1174 – 1844) who provided an explanation for these small slivers of light in 1836.

A view of Bailey's beads and a montage of the actual total solar eclipse over Indonesia including two examples of the diamond ring effect (images 3 and 5).

The recent total solar eclipse of March 9, 2016 spent most of its time over water, with only a small part of the path of totality covering land in Indonesia. The next total solar eclipse on August 21, 2017 will, however, be quite different.

The Total Solar Eclipse of 2017



The next alignment of the Earth, the Moon, and the Sun that will produce a total solar eclipse will occur on August 21, 2017. The image above shows this particular geometric alignment. Totality will begin over the Pacific Ocean at 16:48:32 (UT) and will end over the Atlantic Ocean at 20:01:35.

Unlike the recent solar eclipse of March 9, 2016, the path of totality for the 2017 solar eclipse will spend a great deal of time over land. The upcoming total solar eclipse will also be quite unique since the land part of the path of totality will be located entirely within the contiguous

United States. The land part of the path of totality will start in Oregon on the Pacific coast at 17:15:58 UT. The path of totality will then follow a curved band through the continental U.S. until the land part of totality ends at the South Carolina coast on the Atlantic Ocean at 18:49:01 UT. The last time an eclipse was visible from both American coasts was June 8, 1918.

Locations outside the path of totality will see a partial eclipse at the same time that Charleston experiences a total solar eclipse. Miami, for example, is about 900 km (559 miles) south of Charleston. At the same time that totality occurs in Charleston, Miami in Florida will experience a partial eclipse with approximately 78.3% of the Sun's disk covered by the Moon.

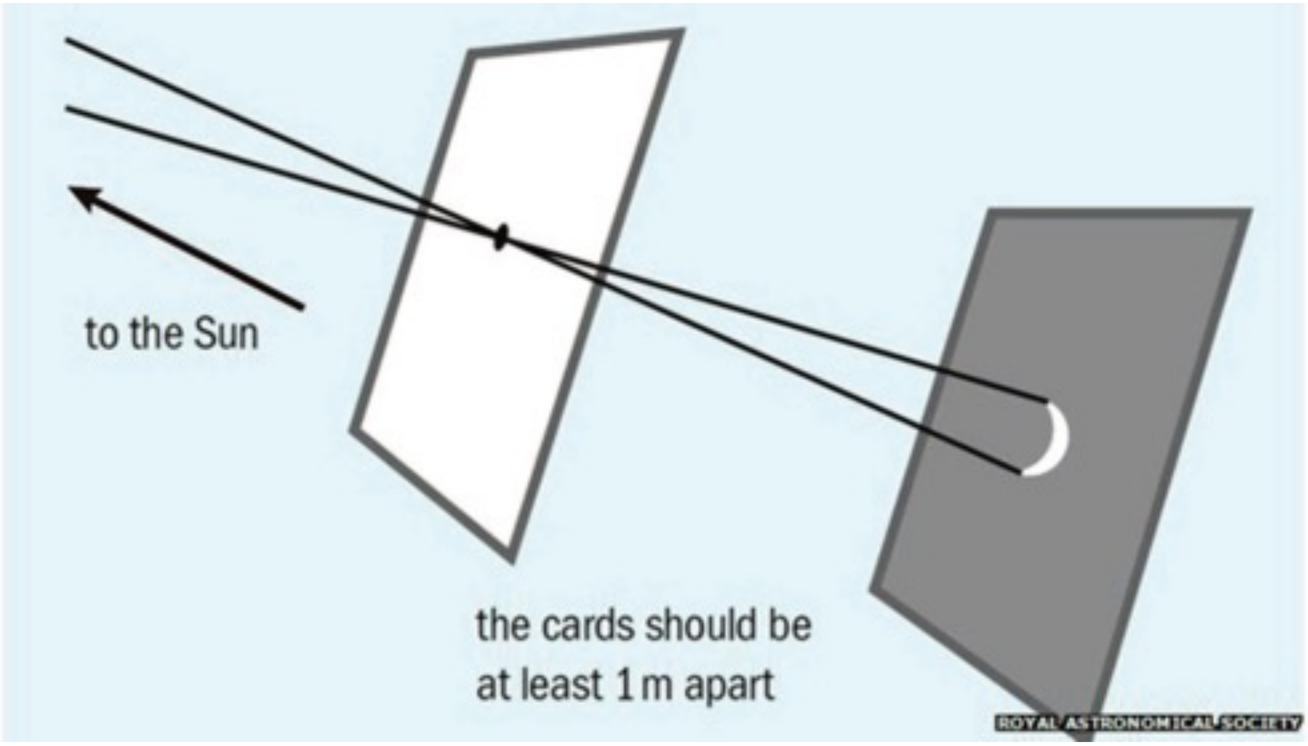
Safely Watching the Eclipse

The Sun is so bright that looking at it for even a few seconds can result in damage to the eyes or even blindness. As a general rule, **NEVER** look at the Sun either directly with unaided eyes or through binoculars or a telescope. Since the retina is not sensitive to pain, damage to the eyes can occur without the observer even being aware of it.

Although the Sun's intensity is reduced during a solar eclipse, it is still dangerous to look directly at the Sun. One safe way to observe the solar eclipse is the through the use of eclipse glasses that possess special solar filters that block out the harmful rays of the Sun. It is important to note that sunglasses, even expensive ones, are NOT appropriate for solar eclipse viewing as they will not sufficiently reduce the harmful rays of the Sun and prevent eye damage from occurring.

One of the safest ways to observe a solar eclipse is through the method of pinhole projection. This method projects an image of the Sun thorough a pinhole on an upper card to a second viewing card behind the first pinhole card. Make sure that your back is to Sun when viewing the projected image on the second card; this reduces any chance that you may inadvertently look at the Sun during this process of pinhole projection. What you have really produced with these two cards is a very simple pinhole camera.

Another way to safely observe the eclipse will be to attend solar eclipse viewing events that many local astronomy clubs and Science centres will be setting up right across North America. These events will provide opportunities for safe viewing of the eclipse.



Observers directly in the path of totality will actually have a small window of opportunity to directly observe the solar eclipse. During the brief period of totality it is safe to look directly at the obscured Sun; the Sun will be as bright as a full Moon during totality. Note that safe viewing is ONLY available for observers directly in the path of totality and **ONLY** during the brief period that totality actually occurs. The view to the right in the main panel shows how the total eclipse will look like from Casper, Wyoming; totality starts at 17:42:42.5 UT and will last for 2 minutes and 26 seconds. Direct viewing in Casper, Wyoming is only safe during this extremely short time interval.

Totality brings additional observing opportunities, but you'll need to work quickly. The naked eye star Regulus, in Leo the Lion, will be sitting less than one degree (about a finger's width) to the upper left of the eclipsed Sun. Reddish Mars, though slightly dimmer at magnitude 1.77, will be 8 degrees (just under a fist diameter) to the right of the eclipse. Looking farther along the same line, very bright Venus will be located 34 degrees to the lower right (west) of the eclipse. Look 51 degrees in the opposite direction for bright Jupiter. For a challenge, you can hunt for Mercury, at visual magnitude 4.2, sitting only 10 degrees to the left of the eclipse.

Solar Eclipses in History

King Henry's Eclipse, 1133

On August 2, 1133 CE a total solar eclipse occurred in England. A contemporary account stated that "the day darkened over all lands; and the Sun became as it were a three-night-old Moon, and the stars about it at mid-day. Men were greatly wonder-stricken and were affrighted, and said that a great thing should come thereafter." King Henry I of England (1068 – 1135), the son of William the Conqueror, did die after the eclipse, although his death occurred four years later in 1135 CE as a result of food poisoning from eating too many lampreys (i.e. eels). Despite the four year interval between the eclipse and Henry's death, the passing of King Henry I was widely believed to have been foretold by the eclipse and only served to reinforce the then common belief that eclipses were bad omens for monarchs.

Halley's Eclipse, 1715

The total solar eclipse of 1715 CE is historically significant because English astronomer and physicist Edmund Halley (1656 – 1742) produced the first map for an eclipse event that showed the predicted path of the umbra on the ground. A careful examination of Halley's map shows that the eclipse is dated to occur on April 22, 1715. This, however, is the old Julian calendar date; England only adopted the "new" Gregorian calendar in 1752. The proper date for Halley's eclipse using the modern calendar is thus actually May 3, 1715.

Nat Turner's Eclipse, 1831

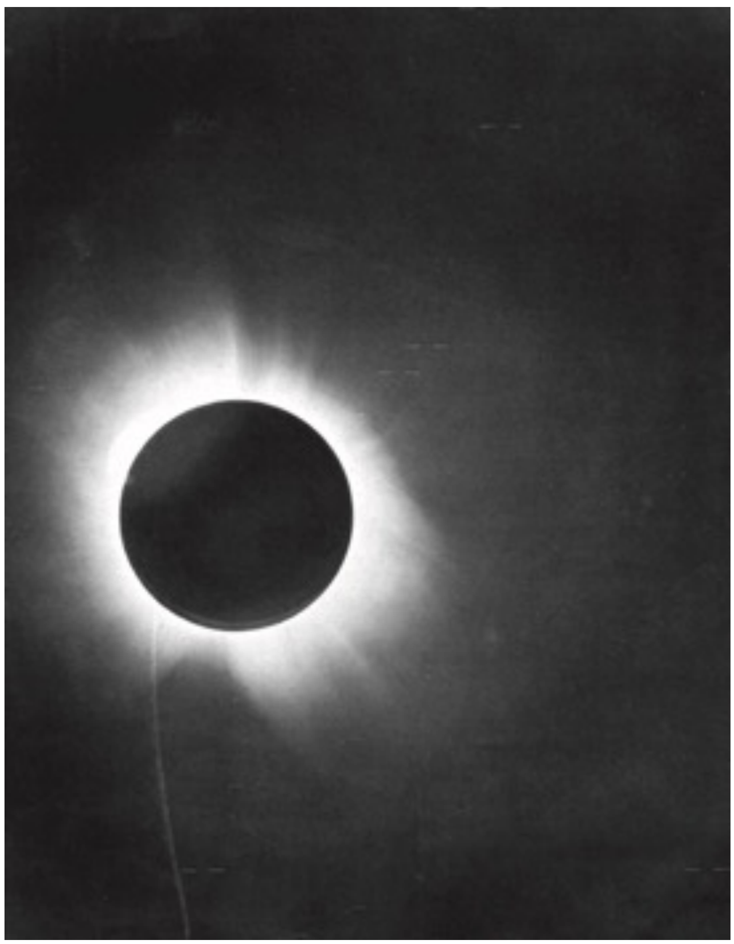
Discovery of Nat Turner.

Nat Turner (1800 – 1831) was an African American slave who led a slave revolt in Virginia in 1831. Turner believed that he could hear divine voices and see prophetic visions. He stated that "I had a vision ... I saw white and black spirits engaged in battle, and the sun was darkened." A solar eclipse occurred on Feb. 12, 1831 CE which Turner interpreted as a message from God urging him to begin planning for a slave insurrection; Turner eventually began his slave revolt on August 21. Although the revolt was quelled after two days, Turner himself evaded capture for an additional two months before eventually being caught. Turner was hanged on November 11. The recent 2016 film The Birth of a Nation recounted the story of Nat Turner's slave revolt.

(**Note:** *Turner's eclipse was not a total solar eclipse in which the Moon completely covers the Sun's disk. Turner's eclipse was instead an annular eclipse in which the Moon is too far away from the Earth to completely cover the Sun's disk. A bright ring is still visible around the Sun at maximum coverage during an annular eclipse. Approximately 96% of the Sun was obscured during the annular eclipse that Nat Turner observed on Feb. 21, 1831.*)

Einstein's Eclipse, 1919

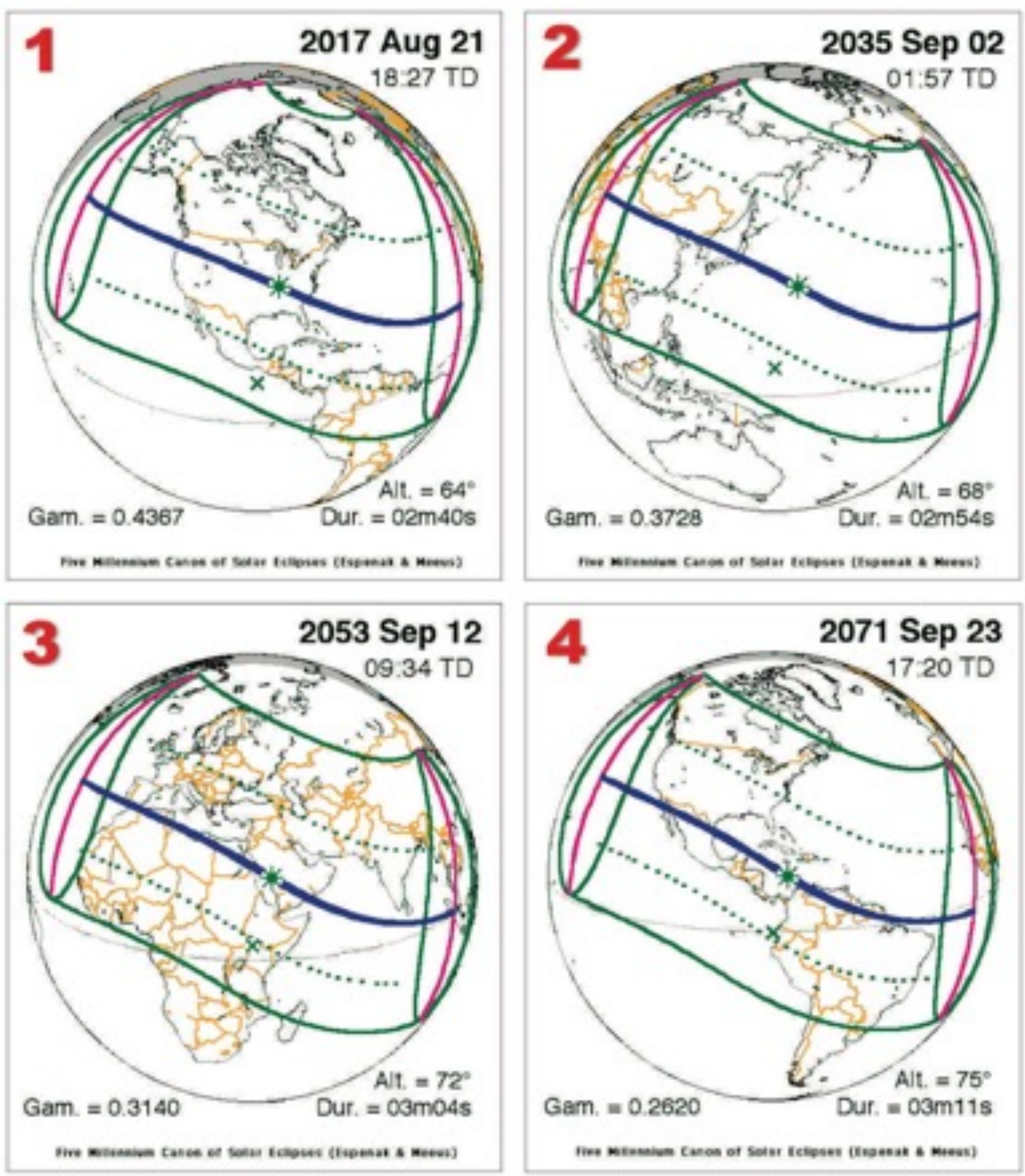
The total solar eclipse of May 29, 1919 CE is important in Science history because it provided the first experimental test of Albert Einstein's general theory of relativity. Einstein's theory had predicted that the very fabric of space would be warped by the presence of large massive bodies like the Sun. This warping would cause light to travel in a curved path near a massive body instead of in a straight line. This prediction was test by Sir Arthur Eddington (1882 – 1944), an English physicist, during the May 29 total solar eclipse. Eddington observed in an expedition to the island of Principe off the coast of West Africa that light from the Hyades star cluster was indeed warped by the eclipsed Sun in complete accord with Einstein's theory.



One of Eddington's actual plates of the 1919 eclipse that helped to confirm Einstein's theory of general relativity.

The Saros Cycle

Solar eclipses are produced as a result of a particular alignment of the Earth, the Moon, and the Sun. The alignment responsible for the August 21, 2017 eclipse can be seen in the main panel to the right. The same relative geometry that will result in the August 21, 2017 eclipse will not occur again until 223 synodic months have passed. A synodic month is the time taken for the Moon to complete one complete cycle of its phases (i.e. the time taken to go from a new Moon back again to a new Moon). This time period between successive eclipses, 223 synodic months, is known as the Saros cycle. A time period of 223 synodic months is also equal to 6,585.3 days or 18 years, 11 days and 8 hours. This means that the next geometric alignment similar to August 21, 2017 will not occur again until Sept. 2, 2035.



Note that the 2035 solar eclipse is not centered over North America, but is instead centered over the Pacific Ocean. The reason for this is that the Saros period is not equal to a whole number of days, but instead has an extra time displacement of 8 hours or 1/3 of a day. This means that the Earth will have completed an extra 1/3 of a rotation (i.e. 1200) before the eclipse occurs. A total of 3 Saros periods (i.e. 3 x 1/3 = 1) are, therefore, required before a solar eclipse will return to the same geographic region. The next solar eclipse to take place in the same geographic region as the Aug. 21, 2017 solar eclipse will, therefore, occur on Sept. 23, 2071.

Note that the Sept. 23, 2071 solar eclipse will have shifted south in location from the similar Aug. 21, 2017 solar eclipse. The reason for this is that the length of the Saros cycle is 18 years and 11 1/3 days; the extra 11 1/3 days in the Saros cycle means that each succeeding eclipse will now occur later in the year than previous eclipses. The shifting locations of the Earth and the Moon in their orbits in this extra time interval accounts for the change in the exact eclipse path location.

Solar Eclipse Math

Calculating the Speed of the Lunar Shadow on the Earth

1 Average Speed in the West: The total solar eclipse starts at Madras, Oregon at 17:19:37.9 UT. The total eclipse will start 741 km further east at Idaho Falls, Idaho at 17:32:59.6 UT. Calculate the average speed of the Moon's shadow in the western U.S. as it travels between Madras and Idaho Falls.

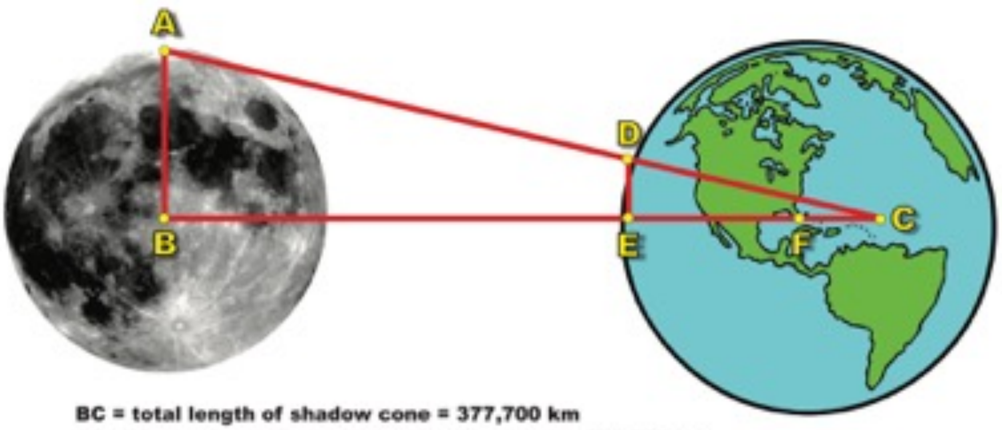
2 Average Speed in the East: The total solar eclipse starts at Nashville, Tennessee at 18:27:29.2 UT. The total eclipse will start 578 km further east at Columbia, South Carolina at 18:41:49.6 UT. Calculate the average speed of the Moon's shadow in the eastern U.S. as it travels between Nashville and Columbia.

3 You should notice that the average speeds are not the same. Why should the average speed of the lunar shadow vary as the umbra travels from the west coast to the east coast of the U.S.?

Answers: 1) Total travel time between Madras and Idaho Falls = 13:21.7 min = 13.362 min ≈0.223 h. Average speed = (total distance) / (total time) = 741 km / 0.223 h ≈ 3,320 km/h. The average speed of the Moon's shadow in the west is approximately 3,320 km/h (i.e. 2,060 mph). **2)** Average speed = (total distance) / (total time) = 578 km / 0.239 h ≈ 2,420 km/h. The average speed of the Moon's shadow in the east is approximately 2,420 km/h (i.e. 1,500 mph). **3)** The speed of the umbra is connected to the Earth's orbital motion. The umbra would be at its slowest near the equator because the Earth's speed of rotation is fastest there. Increasing latitude leads to an increase in the umbra's speed as the Earth's speed of rotation gradually decreases. The August 21, 2017 eclipse shadow gradually travels south as the umbra travels from the west coast to the east coast of the U.S.; this results in a gradual decrease in the umbra's speed.

Calculating the Radius of the Lunar Shadow on the Earth

The diagram below represents the Moon-Earth geometry during the August 21, 2017 solar eclipse. Notice that the geometric length of the shadow cone, BC, actually extends well beneath the Earth's surface, even going past the centre point of the Earth located at point F. The intersection of this shadow cone at the Earth's surface, DE, represents the radius of the umbra on the Earth's surface.



Use the information contained in the diagram above to calculate the diameter of the umbra on the Earth's surface.

Answer: ΔABC and ΔDEC are similar triangles (angle-angle similarity). We can, therefore, write:

AB/BC = DE/EC or DE = ((AB)(EC))/BC

EC = (BC- BF) + EF

= (377,700 km - 372,027 km) + 6,378 km

= 5,673 km + 6,378 km

= 12,051 km

Substituting this value for EC into our original equation will allow us to determine DE, the radius of the umbra.

DE = (AB)(EC) / BC

= (1,737 km)(12,051 km) / (377,700 km)

≈ 55.42 km

This gives a diameter for the umbra of approximately 110.8 km (i.e. diameter equals two times the radius). (NOTE: This method only provides an approximation of the umbra diameter, yet it is, nonetheless, still quite accurate. More detailed calculations predict that the actual umbra diameter near Carbondale, Illinois at the midpoint of the 2017 solar eclipse will be 115 km; this is quite close to our approximation of 110.8 km)