Lesson Plan

The 2017 Total Solar Eclipse

Time Required
Approximately
60 minutes

Vocabulary
Solar Eclipse
Umbra
Penumbra
Corona

SkyGuide Lesson

Teachable Moments -> The 2017 Total Solar Eclipse

Guiding Question

Why, where, and how do I safely view the 2017 total solar eclipse?

Key Concepts

- A solar eclipse is caused by the Moon blocking the light of the Sun and casting a small shadow on the Earth.
- There will be a total solar eclipse visible in the contiguous United States on August 21, 2017.

Standards Connection

NGSS

Disciplinary Core Idea: Earth's Place in the Universe and Crosscutting Concepts—Patterns Scale, Portion, and Quantity; and Systems and System Models.

Grades 5 – 12
Space Systems

Grades 9 – 12
Space Systems

NSES

General
• Abilities necessary to do scientific inquiry
• Understanding about science and technology
Science as a human endeavor
• Motions and forces

Grades 6 – 8
Earth in the solar system

Grades 9 – 12
Origin and evolution of the Earth system

Introducing the Lesson

Eclipses are special events. Strictly speaking, an eclipse occurs when one celestial body prevents the Sun's light from illuminating another. Lunar eclipses occur when the Moon passes through the shadow cast by the Earth, rendering the Moon darker for a few hours. Earth's shadow is always there. It's why satellites can pop into view at night, or vanish while you're watching them glide overhead. We can only see them while sunlight can reach them. Astronomers can observe eclipses elsewhere, too. The four large moons of Jupiter frequently cast their shadows on the giant planet, or on one another.

When the Moon is between the Sun and the Earth, the Moon's shadow falls in a circular shadow on the Earth. Lucky observers inside that shadow see a total solar eclipse. By a cosmic coincidence, the Sun is both 400 times larger than the Moon, and also 400 times farther away, making the two celestial objects the same size in the sky. For this reason, we get to observe some special solar phenomena during totality. Because the Moon is constantly sliding along its orbit, the shadow races across the Earth's surface following a predictable narrow track. That's why eclipse enthusiasts can plan their expeditions years in advance. Observers within a limited distance along either side of the track will see the Moon cover only a portion of the Sun in a partial solar eclipse.

Eclipses are caused by our Moon as it makes its monthly trip around the Earth, but due to the nature of the Moon's orbit, they don't happen every month, and each one is visible only from specific locations on the Earth. In this article, we'll look at what causes solar and lunar eclipses, point out some online resources, provide some details about the total solar eclipse occurring across the Continental USA on August 21, 2017 some others you may wish to travel to see.

The Earth's orbit carries it around the Sun once a year – in 365.24 days to be exact. In the meantime, every 27 days, 7 hours, and 43 minutes, the Moon completes a single orbit around the Earth. This is where we get the term "month" from, and these two reliable and regular orbits are the bases for our calendars.

As viewed from the Earth's surface, the Moon moves are from west to east with respect to the distant background stars. In fact, over the course of an evening, it's easy to observe the Moon traveling eastward compared to stars located near it in the sky. At the same time, due to the Earth's rotation toward the east, the entire sky, including the Moon, appears to shift westward.

At one point in the Moon's monthly orbit, it passes between the Earth and the Sun. The moment when the Moon moves from west of the Earth-Sun line, to the east of it, is the definition of New Moon. Within hours on either side of the moment of New Moon, we can't see the Moon due to the nearby Sun's glare and, in any case, the half of the Moon facing the Sun is fully lit, while the half facing us is dark. Roughly two weeks later, the Moon has travelled half of its orbit to place the Earth between it and the Sun. This time, when the Earth crosses the straight line between Sun and Moon, a Full Moon occurs. At that moment, the entire side of the Moon facing Earth is illuminated by sunlight, and the Full Moon rises just as the Sun sets at our backs.

If the Sun, Earth, and Moon were all orbiting in the same plane (imagine a model of them on a tabletop), every New Moon would temporarily block the Sun and cast its circular shadow on the Earth. At every Full Moon, the Earth would hide the Sun from the Moon as it passed through our shadow for a few hours, producing a Total Lunar Eclipse. So why do these events seem to be so rare?

The main reason eclipses occur rarely, and are visible from different locations on Earth, is because the Moon's orbit is tilted, or inclined, by about 5° from the Earth's orbital plane. While the bodies in the Solar System orbit the Sun in roughly the same plane, each body's orbit is tilted by a small angle that carries it sometimes above and sometimes below the Solar System's "tabletop", like the rising and falling horses on a rotating carousel.

On infrequent, but predictable occasions, the moments of New Moon and Full Moon occur when the Moon is situated at the place where its orbit and the Earth's orbit intersect, also known as a node. This is the geometry that creates eclipses. The Earth has a much larger diameter than the Moon, so an eclipse can still occur when the Moon is slightly below or above the node. That is why each eclipse is visible from a particular latitude on the Earth. When the Moon is near a node, it is either climbing slightly or descending slightly as it orbits. The effect of this is to add a slant to the eclipse track on the Earth. The Earth's constant rotation during the eclipse serves to lengthen the eclipse track. That's why the tracks of totality change in both latitude and longitude.

Lunar and Solar eclipses occur in matched pairs. Once the Moon's orbital nodes synchronize with the New or Full phase and produce an eclipse, it will usually generate the other type of eclipse two weeks later, but it won't be visible at the same location.

The elliptical orbits of the Earth and Moon around the Sun cause the geometry of the three bodies to slowly evolve over time, another reason why eclipse dates and tracks shift around. It turns out that every 6,585.3 days (18 years 11 days 8 hours), the orbits closely repeat their alignments and a series of eclipses repeats. This cycle is called a Saros. Two eclipses separated in time by one or more saros' will occur with similar geometries, but the extra 8 hours means that the Earth will have rotated one-third of a day, shifting the track location westward.

Solar Eclipses

For an unknown, but fortunate reason, the size of the Sun's disk and the Moon's disk observed from Earth are almost exactly the same, even though the Sun is about 400 times larger! If this were not so, we would not be treated to the splendor of a Total Solar Eclipse.

During a Total Solar Eclipse, the Moon's round shadow sweeps across the Earth, completely blocking the Sun for observers along the track of the shadow for only a few minutes. The best eclipses have 250 km wide tracks and many minutes of totality. Along both sides of the track, observers see only part of the Sun obscured – the farther from the path of totality, the less of a "bite" is taken out of the Sun. This is called a Partial Solar Eclipse. Because the Moon's orbit is elliptical, it is brought closest (perigee) and farthest (apogee) from the Earth during every orbit, making the Moon subtend a slightly larger and smaller angle in the sky respectively. When the Moon is near apogee during a Total Solar Eclipse, it is too small to completely cover the Sun's disk, and we observe an Annular Solar Eclipse. By the way, a solar eclipse is actually not an eclipse, but an occultation – when one body passes in front of, and obscures, the other. Astronomers use the term "contact" to describe the progress of an eclipse or occultation. First contact is said to occur when the leading edge of each of the two disks (either the body's physical edge or the Earth's shadow's edge) first touch. Only after this occurs, will one see the "bite" in the edge of the Sun or Moon. Fourth (or last) contact occurs at the end of the encounter, at the moment when the two disks separate, i.e., the "bite" disappears.

If one disk is smaller than the other, such as the Moon's smaller disk compared to the Earth's large round shadow, then two more contacts can occur. Second contact occurs as soon as one disk is entirely within the other, and third contact occurs just as the smaller disk ceases to be fully enclosed. For Lunar Eclipses, there are contacts for the Penumbra and the Umbra, and these are designated P1 through P4 and U1 through U4. Total Solar Eclipses don't really have second and third contacts, but Annular Eclipses and planetary transits of the Sun do.

Observing solar Eclipses

It is NEVER safe to look at a Solar Eclipse without eye protection, with one exception. Observers during the few minutes of totality may turn their gaze upon the Moon-obscured Sun and see the glorious corona and red solar prominences that rise from the Sun's photosphere. Outside of totality, part of the Sun's disk is exposed, and any amount of unprotected viewing is harmful to your eyes. Sunglasses are NOT enough to protect your eyes. They may make the sunlight dim enough to seem comfortable, but they do not filter out the harmful invisible ultraviolet (UV) and infrared (IR) radiation that damages eye tissue.
Safe methods of observing solar eclipses include special eclipse glasses (commonly inserted into astronomy magazines published prior to major eclipses), #14 or darker welder's glass, pinhole projection setups, and special telescope filters. NEVER pass unfiltered sunlight through a telescope or binoculars. Damage to vision will be instantaneous, the equipment will likely suffer damage, and there is risk of fire, too. Safe solar filtering systems are available through most astronomy retailers.

Total Solar Eclipse of August 21, 2017

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. Basically, northern South America and all of Central and North America will be treated to at least part of the eclipse.

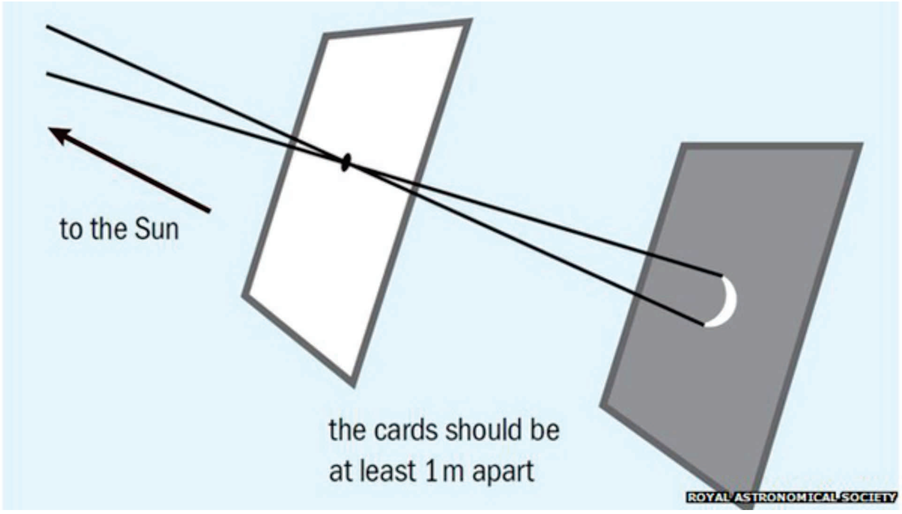
The time of totality, and the height of the Sun in the sky, depends on your longitude. The western states and provinces will see maximum eclipse around 10:18 am local time, and the Sun will be nicely positioned 40 degrees above the eastern horizon. In central Missouri, maximum eclipse occurs at 1:14 pm local time, with the Sun 63 degrees above the southern horizon. The eastern seaboard will see totality around 2:48 pm local time, with the Sun 61 degrees above the southwest horizon. In each case, first contact occurs about 90 minutes earlier and last contact takes place 90 minutes later. Astronomy magazines, newspapers, and websites will publish the precise timings for your city.

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.

While a partial eclipse shape can be seen through thin cloud, clear skies are extremely important for enjoying totality during a solar eclipse. Be sure to check your local forecast the days and hours ahead, and be prepared to drive east or west along the track of totality to reach clear skies. Ensure that you don't veer too far south or north.

Extension Activities

Activity: Have your students construct a pinhole camera to safely project and view the Sun .



Vocabulary Link

Solar Eclipse: An eclipse of the sun by the moon that occurs when the moon passes in front of the sun. Solar eclipses can be partial, total, or annular. Only the few people in the narrow path of totality see a solar eclipse as total.

Umbra: The area traced on a planet during an eclipse where the eclipsed light source is completely blocked. Observers in the umbral shadow of a solar eclipse, for instance, see a total eclipse. See also penumbra.

Penumbra: The area traced on a planet during an eclipse where only a portion of the eclipsed light source is blocked. Observers in the penumbral shadow of a solar eclipse, for instance, see only a partial eclipse. See also umbra.

Corona: The uppermost level of a star's atmosphere. In the sun, the corona is characterized by low densities and high temperatures greater than one million degrees Celsius (two million degrees Fahrenheit).

Evidence of Learning

Upon completion of this lesson, you should have evidence that students can:

- Explain what a total solar eclipse is.
- Understand the geometry that results in a total solar eclipse.
- Recognize the difference between a solar and lunar eclipse.

Additional Resources

SkyGuide->**Student Exercises-**>Unit A-> A5: Eclipses