

Solar & Lunar Eclipses



A total solar eclipse is one of the most spectacular natural events to behold. Those who witness total solar eclipses consider themselves fortunate. They carry an indelible impression that is as much visual as it is emotional.

It is disheartening that most people never experience one of the greatest astronomical and sensory events on our Planet.

It is an incredible coincidence that the Sun and Moon appear the same size in the sky. It is even more amazing that our Moon gets the chance to perfectly eclipse the Sun. The odds of this coincidence are brought to light when we consider that our Moon is the only moon in our Solar System that perfectly eclipses the Sun. All the other moons of the Planets are either too large or too small in their orbits to eclipse the Sun in precisely the same manner as ours.

Although I have emphasized the glorious nature of the total solar eclipse, I don't want to undermine the beauty of a total lunar eclipse. But they are two different kinds of events. Total lunar eclipses are great "casual" events that allow one to comfortably sit and watch the coloration of the Moon gradually change as it moves through the Earth's shadow.

Overview of Solar and Lunar Eclipses

Both solar and lunar eclipses involve an alignment of the Earth, Moon and Sun. A solar eclipse is the blocking of the Sun by the Moon, either partially or totally. A lunar eclipse is the blocking of the Moon's light (from the Sun) by Earth's shadow.

Solar eclipses can occur only at the time of New Moon; lunar eclipses only at the time of Full Moon.

In order to see a total or annular solar eclipse, one must be on a narrow path that can stretch for a thousand miles or so on the Earth. Only those on the path will see the total or annular eclipse — those near it will see only a partial eclipse. On the other hand, lunar eclipses can be seen by almost everyone on the night side of the world.

Facing page. The bright "flare" at the top of this total solar eclipse picture is known as a "diamond-ring effect" and is produced by a minute vestige of the Sun's surface that pokes through the edge of the Moon. **Above.** Everyone gets to experience at least a few partial solar eclipses during their life.

Our
Moon is
the only
moon in
our Solar
System
that
perfectly
eclipses
the Sun.

Eclipses

Solar & Lunar Eclipses

Umbra and Penumbra Shadows

These are the names of the shadows responsible for all eclipses. The umbra is the innermost and darkest shadow. The penumbra is a secondary shadow around the umbra. You will see a solar eclipse if you are in the Moon's umbra or penumbra shadow. Lunar eclipses occur when the Moon passes into Earth's umbra or penumbra shadow.

Umbra and penumbra shadows are visible whenever it is sunny. If you look at the edge of an object's shadow, you will notice that it is fuzzy. This fuzzy edge is the penumbra and the main body of the shadow is the umbra.

Solar Eclipses

There are three types of solar eclipses: total, annular and partial. They are illustrated and explained below.



Total Solar Eclipse

Moon completely blocks Sun. The irregularly shaped halo around the Moon is the Sun's corona.



Annular Solar Eclipse

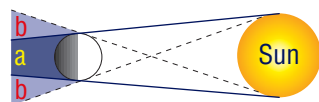
Moon moves completely in front of the Sun but does not cover the Sun.



Partial Solar Eclipse

Moon only partially blocks Sun. Those outside the path of a total or annular eclipse only see a partial eclipse.

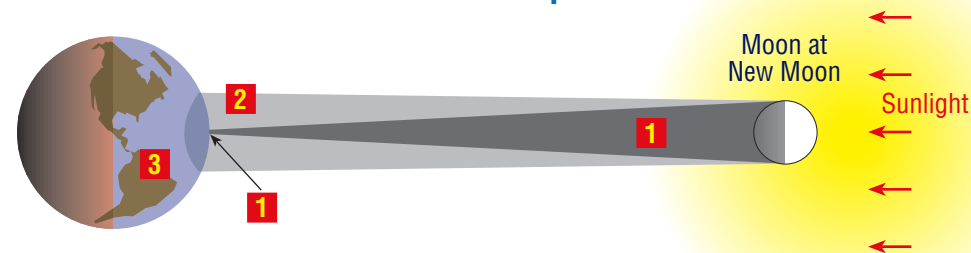
Why do annular eclipses occur? The Moon's orbit, like those of all orbiting bodies, is an ellipse; so the distance from the Moon to the Earth varies (see page 102). Annular eclipses occur when the Moon is farther away in its orbit than usual, making the apparent size of the Moon slightly smaller than the apparent size of the Sun. In these instances, the Moon is simply too small to totally block the Sun.



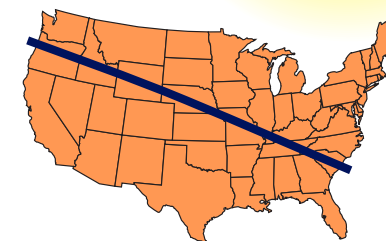
This exaggerated illustration depicts the formation of the umbra at (a) and the surrounding penumbra at (b). The geometry of these shadows is a result of the Sun's diameter.

Solar & Lunar Eclipses

Total Solar Eclipses

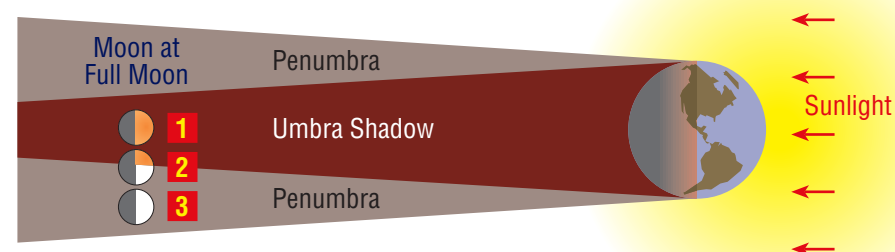


- 1 UMBRA.** The darkest part of the shadow where a total eclipse can *only* be seen. On Earth, the umbra can reach 170 miles (270 km) wide and travel one-third of the way around the world in a few hours.
- 2 PENUMBRA.** The secondary shadow where only a partial eclipse of the Sun will be seen. The penumbra is thousands of miles wide and straddles the path of the umbra on the Earth's surface.
- 3** Observers outside of the penumbra will not see the Sun eclipsed.



The **umbra path** for the total solar eclipse of August 21, 2017. The penumbra stretches for thousands of miles on both sides of the umbra.

Lunar Eclipses



- 1 TOTAL LUNAR ECLIPSES** occur when the Moon enters the Earth's umbra shadow. The Moon does not turn completely dark during a total lunar eclipse, instead, it turns a pretty red-orange color. A lunar eclipse is visible to almost half of the world.
- 2 PARTIAL LUNAR ECLIPSES** occur when only part of the Moon enters the Earth's umbra shadow. Partial lunar eclipses will show one edge of the Moon turning a slight orange color.
- 3 PENUMBRA LUNAR ECLIPSES** occur when the Moon only enters the Earth's penumbra shadow. Penumbral lunar eclipses may not be noticeable.

Solar & Lunar Eclipses

Observing Solar Eclipses

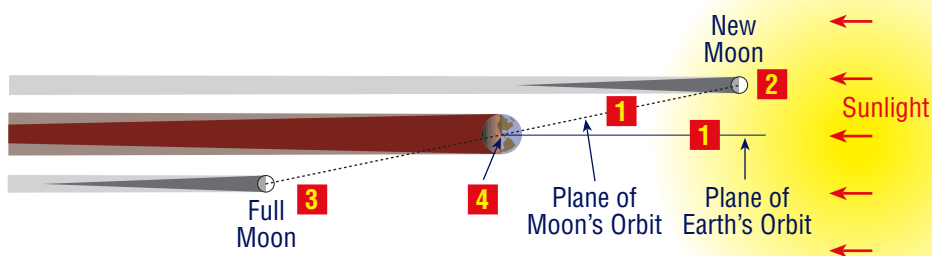
Lunar Eclipses

Lunar eclipses can be total, partial or penumbral, however, they do not share the characteristics of solar eclipses. Total lunar eclipses turn the Moon into a dark red-orange color instead of turning it completely black. The red-orange color is caused by sunlight refracted through the Earth's atmosphere. You see the same coloring at sunrise and sunset. Partial lunar eclipses may not be noticeable with the exception that an edge of the Moon may turn a little orange. Penumbral eclipses are usually not noticeable to the average observer.

Why Eclipses Do Not Happen Every Month

Solar and lunar eclipses do not happen every month because the Moon's orbit is tilted 5.1° to Earth's orbit, placing the Moon above or below the Sun or Earth's shadow at New Moon and Full Moon most of the time. The Moon must be positioned exactly at the point where its orbit crosses the Earth's orbit for an eclipse to occur. The Earth, Moon and Sun get perfectly aligned every 173 days, producing an eclipse somewhere on Earth.

Missed Eclipses



- 1** The Moon's orbit is tilted 5.1° to the Earth's orbit. This slight tilt is enough to place the shadows necessary for eclipses out of reach of the Earth or Moon.
- 2** The shadow of most **New Moons** falls either above or below the Earth.
- 3** At **Full Moon**, the Moon is usually above or below the Earth's shadow.
- 4** **Eclipses occur** when the Moon is either New or Full *and* the Moon crosses the plane of the Earth's orbit. This intersection happens every 173 days and this time interval is known as an eclipse season.

Frequency of Eclipses: The Saros

Up to two eclipses can occur during a 173-day eclipse season: one lunar and one solar. Anywhere from two to seven lunar and solar eclipses can therefore occur in a year. Eclipses also repeat themselves in 18 year cycles called Saros (actually 18 years, 11 days, 8 hours). So, all of the eclipses that happen in the year 2000 will repeat 18 years later in 2018. However, the 2018 eclipses will advance by 11 days and 8 hours, placing them one-third farther around the world than their previous locations. There are 42 Saros series running concurrently, providing us with an ongoing cycle of eclipses. The intensity of eclipses in a Saros (the ones that repeat every 18 years) waxes and wanes over time.

WARNING

Instant blindness or serious eye injury will result from looking at or near the Sun through telescopes, binoculars or cameras that are not properly equipped with solar filters.

OBSERVING SOLAR ECLIPSES

Safely Viewing an Eclipse. Safety of the eyes is of the utmost importance when viewing solar eclipses. Do not stare or even look directly at the Sun. Not only is this harmful to the eyes, but you cannot see the partially eclipsed Sun this way! I highly recommend using a solar or eclipse viewer/filter (like that pictured below). These inexpensive viewers are available at telescope shops, planetarium gift shops and from telescope dealers listed in the popular monthly astronomy magazines.

Eclipse viewers/filters like this are necessary for safely viewing the Sun during all solar eclipses. They can also be used to see large sunspots.



Observing Solar Eclipses

During a solar eclipse, the Moon's progress can be viewed with a telescope that is properly fitted with a solar filter. Please see page 222 on safely observing the Sun for more information.



The multitude of crescents in this picture are the eclipsed Sun, projected through pinholes formed from the interweaving of leaves on a tree.

There are novel ways to view the progress of solar eclipses. My favorite is using trees. If you look at a tree's shadow (the tree must have leaves) during a solar eclipse, you will notice that mixed in with the shadow are hundreds of crescent Suns. A tree with leaves creates a multitude of pinholes (like a pinhole camera) that project the outline of the Sun. Some trees work better than others.

Partial and Annular Eclipses. Partial eclipses can last for several hours. They are not noticeable unless a substantial portion of the Sun is covered by the Moon. Even with half of the Sun eclipsed, you may not notice any appreciable difference in sunlight.

To observe an annular solar eclipse, consult the local media, internet or popular monthly astronomy magazines for the location of the eclipse path. You cannot see the annular eclipse if you are not in its path. It will not get dark during an annular eclipse and the Moon will only be completely in front of the Sun for several minutes.

A solar or eclipse viewer/filter is needed to view the Sun during the entire partial and annular eclipse.

Total Solar Eclipse & Totality. Remember, to see a total solar eclipse, you must be on the eclipse path. Consult the local media, internet or popular monthly astronomy magazines for details and locations of the path.

A total solar eclipse will last for several hours and is treated as a partial eclipse until the time of totality, that is, when the Moon completely blocks the Sun's light. During the one to five

Observing Lunar Eclipses

minutes of totality, no solar filter is required. Everyone stands and stares in wonder. Many things happen during totality. The sky darkens a little (it does not get completely dark), and almost immediately, the white shimmering corona is seen surrounding the Moon. Around the Moon's edge, the thin red ring of the chromosphere may be visible along with prominences and flares protruding outward. If you look at the sky around the Moon, you will probably see a few stars and Planets (usually Venus and Mercury) and if you scan the whole sky, you will see the umbra shadow circling the sky and extending almost to the horizon. The sky near the horizon is still light but may have a red coloring like that at sunset. The entire scene is incredible. There is nothing like it! No camera can capture the experience of totality, and everyone is touched differently. People clap, cheer, cry and pray. I recommend that everyone experience a total solar eclipse!

OBSERVING LUNAR ECLIPSES

No special equipment or caution is necessary to view lunar eclipses but binoculars and telescopes can be used to enhance the event. Lunar eclipses are especially enjoyable when you can sit outside, talk with others and casually watch the event unfold.

For the most part, the Moon will turn a dark red-orange when it is completely in Earth's umbra shadow. Various hues of red and orange will slowly dance across the Moon's surface as it enters, passes through and exits the umbra. Since the umbra is considerably larger than the Moon, total lunar eclipses can last up to 3½ hours. If the Moon crosses the umbra dead center, it takes about an hour to completely enter the umbra. It will stay in the umbra for 1½ hours and finish as it started, taking an hour to leave.

2000–2050 Solar and Lunar Eclipse Tables for North America on Pages 230–234

The solar and lunar eclipse tables on the following pages summarize the location and time of these events. Since the intensity of the event and the exact time vary considerably depending on your viewing location, please consult your local media, the internet or the popular monthly astronomy magazines for details. Enjoy.

SOLAR Eclipses 2000 – 2031

Solar Eclipses in North America

Date of Solar Eclipse	Type of Solar Eclipse	Time of Day to View ¹	Locations ²
July 30, 2000	Partial	Around Sunset	<i>Alaska</i> , Western Canada, Northwest
December 25, 2000	Partial	Around Noon	<i>Midwest</i> , Continental US, Southern Canada
December 14, 2001	Partial	Early to Late Afternoon	<i>Hawaii</i> , Continental US
June 10, 2002	Partial	Late Afternoon	<i>West</i> , Midwest, Hawaii, Alaska, West Canada
May 30, 2003	Partial	Around Sunset	<i>Alaska</i>
April 8, 2005	Partial	Late Afternoon	<i>Florida</i> , South, Southwest
July 21, 2009	Partial	Around Sunset	<i>Hawaii</i>
May 20, 2012	Annular	Around Sunset	West , Hawaii, Alaska, Western Canada
May 9, 2013	Partial	Late Afternoon	<i>Hawaii</i>
October 23, 2014	Partial	Mid Afternoon	<i>West</i> , Midwest, Alaska, Western Canada
March 8, 2016	Partial	Around Sunset	<i>Hawaii</i> , Alaska
August 21, 2017	Total	Around Noon	Across the US! Hawaii, Canada & Alaska
June 10, 2021	Partial	Early Morning	<i>Northeast</i> , East
October 14, 2023	Annular	Late Morning	West , Continental US, Canada
April 8, 2024	Total	Around Noon	Midwest , Continental US, Canada, Hawaii
October 2, 2024	Partial	Early Morning	<i>Hawaii</i>
August 12, 2026	Partial	Early to Late Morning	<i>Alaska</i> to Northeast
January 26, 2028	Partial	Late Morning	<i>Florida</i> , South, East, Midwest
January 14, 2029	Partial	Around Noon	<i>Canada</i> , Continental US
June 11, 2029	Partial	Around Sunset	<i>Alaska</i> , Canada, Northwest
November 14, 2031	Partial	Mid Afternoon	<i>Hawaii</i> , Southwest, South, Florida

¹Check media sources for specific times for your location.

²First listed area is most favorable viewing location.

SOLAR Eclipses 2033 – 2051

Solar Eclipses in North America

Date of Solar Eclipse	Type of Solar Eclipse	Time of Day to View ¹	Locations ²
March 30, 2033	Total	Morning	Alaska , Canada, Hawaii, West, Midwest
September 1, 2035	Partial	Around Sunset	<i>Hawaii</i>
August 21, 2036	Partial	Morning	<i>Alaska</i>
January 5, 2038	Partial	Early Morning	<i>East</i> , Florida
July 2, 2038	Partial	Early Morning	<i>Florida</i> , Southeast, East
June 21, 2039	Annular	Early Morning	Alaska , Canada, Hawaii, West, Midwest
November 4, 2040	Partial	Around Noon	<i>East</i> , Continental US, Canada
October 24, 2041	Partial	Late Afternoon	<i>Hawaii</i>
April 19, 2042	Partial	Around Sunset	<i>Alaska</i> , Northwest Canada, Hawaii
April 9, 2043	Partial	Around Noon	<i>Alaska</i> , Western Canada, Hawaii, Northwest
August 22, 2044	Total	Around Sunset	Northwest , Alaska, Canada, Hawaii, West
February 16, 2045	Partial	Late Afternoon	<i>Hawaii</i>
August 12, 2045	Total	Around Noon	South to West , Hawaii, Canada, Alaska
February 5, 2046	Annular	Mid Afternoon	Hawaii , Alaska, West
June 11, 2048	Annular	Early Morning	Northern Midwest/Canada , East, South, Florida
May 31, 2049	Partial	Morning	<i>Florida</i>
November 14, 2050	Partial	Early Morning	<i>East Canada</i> , Northeast
April 10, 2051	Partial	Around Sunset	<i>Alaska</i> , Northwest Canada

¹Check media sources for specific times for your location.

²First listed area is most favorable viewing location.

LUNAR Eclipses 2000 – 2021

Lunar Eclipses in North America

Date of Lunar Eclipse	Type of Lunar Eclipse	Time of Day to View ¹	Locations
January 20, 2000	Total	Around Midnight	Hawaii, Alaska, Continental US, Canada
July 16, 2000	Total	Before Sunrise	Hawaii, West Coast
July 5, 2001	Partial	Before Sunrise	Hawaii
May 15, 2003	Total	Before Midnight	Continental US, Canada
November 8, 2003	Total	Early Evening	Continental US, Canada
October 27, 2004	Total	Evening	Continental US, Canada
October 17, 2005	Penumbra	Before Sunrise	Hawaii, Alaska, West
March 14, 2006	Penumbra	Early Evening	East Coast
March 3, 2007	Total	Early Evening	East Coast
August 28, 2007	Total	Before Sunrise	Continental US, Canada
February 20, 2008	Total	Around Midnight	Continental US, Canada
June 26, 2010	Partial	Before Sunrise	Hawaii, West
December 21, 2010	Total	After Midnight	Hawaii, Alaska, Continental US, Canada
December 10, 2011	Total	Before Sunrise	Hawaii, Alaska, West
June 4, 2012	Partial	Before Sunrise	Hawaii, West
November 28, 2012	Penumbra	Before Sunrise	Hawaii, Alaska
April 14, 2014	Total	Around Midnight	Hawaii, Alaska, Continental US, Canada
October 8, 2014	Total	Before Sunrise	Hawaii, Alaska, Continental US, Canada
April 4, 2015	Total	Before Sunrise	Hawaii, Alaska, West
September 27, 2015	Total	Evening	Continental US, Canada
February 10, 2017	Penumbra	Evening	Continental US, Canada
January 31, 2018	Total	Early Morning	Hawaii, Alaska, West
January 20, 2019	Total	Around Midnight	Hawaii, Alaska, Continental US, Canada
May 26, 2021	Partial	Before Sunrise	Hawaii, Alaska, West
November 19, 2021	Almost Total	Before Sunrise	Hawaii, Alaska, Continental US, Canada

¹Check media sources for specific times for your location.

LUNAR Eclipses 2022 – 2043

Lunar Eclipses in North America

Date of Lunar Eclipse	Type of Lunar Eclipse	Time of Day to View ¹	Locations
May 15, 2022	Total	Around Midnight	Continental US, Canada
November 8, 2022	Total	Before Sunrise	Hawaii, Alaska, Continental US, Canada
March 24, 2024	Penumbra	Around Midnight	Hawaii, Alaska, Continental US, Canada
March 13, 2025	Total	Around Midnight	Hawaii, Alaska, Continental US, Canada
March 3, 2026	Total	Before Sunrise	Hawaii, Alaska, West, Midwest, Canada
August 27, 2026	Partial	Around Midnight	Continental US, Canada
January 11, 2028	Penumbra	Around Midnight	Hawaii, Alaska, Continental US, Canada
December 31, 2028	Total	Early Evening	Hawaii, Alaska
June 25, 2029	Total	Before Midnight	Continental US, Canada
December 9, 2030	Penumbra	Early Evening	East
April 25, 2032	Total	Before Sunrise	Hawaii
October 8, 2033	Total	Before Sunrise	Hawaii, Alaska, Continental US, Canada
August 18, 2035	Penumbra	Early Evening	Midwest, East
August 6, 2036	Total	Evening	Continental US except West Coast
January 31, 2037	Total	Before Sunrise	Hawaii, Alaska, West
July 26, 2037	Partial	Evening	Continental US, Canada
November 30, 2039	Partial	Early Evening	Alaska
May 26, 2040	Total	Before Sunrise	Hawaii, Alaska, West Coast
May 15, 2041	Penumbra	Early Evening	East Coast
November 7, 2041	Penumbra	Around Midnight	Hawaii, Alaska, Continental US, Canada
April 5, 2042	Penumbra	Before Sunrise	Hawaii, Alaska
March 25, 2043	Total	Before Sunrise	Hawaii, Alaska
September 18, 2043	Total	Early Evening	Midwest, East

¹Check media sources for specific times for your location.

LUNAR Eclipses 2044 – 2051

Lunar Eclipses in North America

Date of Lunar Eclipse	Type of Lunar Eclipse	Time of Day to View ¹	Locations
September 7, 2044	Total	Before Sunrise	Hawaii, Alaska, West
July 17, 2046	Partial	Early Evening	East Coast
January 11, 2047	Total	Early Evening	Continental US, Canada, Alaska
July 7, 2047	Total	Before Sunrise	Hawaii, Alaska, West
December 31, 2047	Total	Around Midnight	Hawaii, Alaska, Continental US, Canada
June 25, 2048	Partial	Around Midnight	Midwest, East
December 19, 2048	Penumbra	Around Midnight	Hawaii, Alaska, Continental US, Canada
October 29, 2050	Total	Evening	Continental US, Canada, Alaska
April 25, 2051	Total	Early Evening	Continental US, Canada

¹Check media sources for specific times for your location.



Facing page. Beautiful shades of orange and brown dance across the Moon during total lunar eclipses.