Astronomy magazine

Your guide to preparing for the 2017 TOTAL SOLAR ECLIPSE

BEN COOPER

Observe from the center line

Rehearse for eclipse day

View the Sun safely

Decipher the eclipse pattern

Observe from the center line

An extra minute of totality is worth almost anything you have to do to get it.

by Michael E. Bakich

In all likelihood, the most important thing you'll read or hear about the August 21, 2017, eclipse is that you must get to the path of totality. It's true. As I like to say in my talks, the difference between viewing a partial eclipse and *experiencing* a total one is the difference between almost dying and dying — there's no comparison.

Once you've decided to adopt this sage advice, consider going one step further: Try your best to position yourself on the eclipse's center line. Any detailed map that shows the path of the 2017 total solar eclipse will have three curved lines on it. The two outer ones show the northern and southern limits of totality. Within their borders is where the Moon's umbra — its dark inner shadow — falls on Earth. And just like your art teacher told you in third grade: Stay inside the lines.

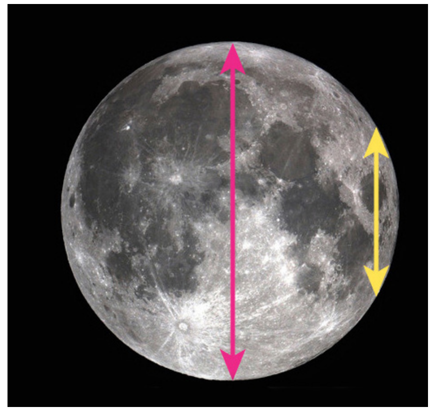
But it's the line midway between those two extremes that's most important. Astronomers call this the center line for obvious reasons. It's along this path that the central part of the Moon's shadow falls, and that's where you should try to be on eclipse day.

Here's why. Because the Moon is spherical, its shadow is round. During a total solar eclipse, the round shadow falls on Earth's surface. It's your choice where to stand under the shadow.

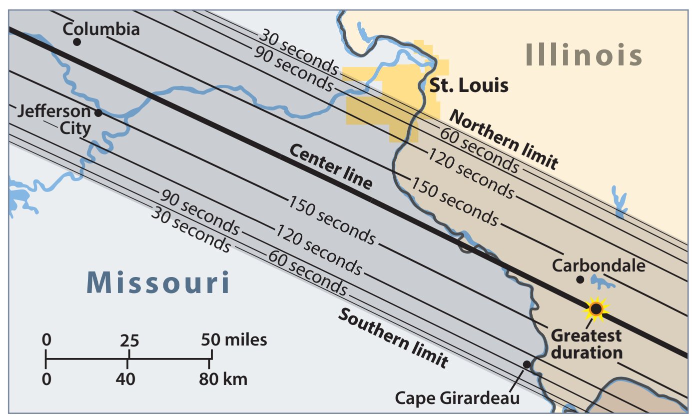
Imagine for a moment an image of the Moon with two lines drawn through it — one passes through the Moon's center, and the other is parallel to it but only half as long. We know the shadow cast by our satellite has the same shape as the Moon itself, so you'll enjoy a longer duration of totality if the shadow traces the longer line through your location than you will if it traces the shorter one. So, if the duration of totality on the center line you imagined is, say, two minutes, you might experience only one minute of totality along the other line.

If you take this example to the extreme, you could select a position on Earth that lies along the northern or southern limit of the path of totality. The duration of totality along the path's edges would be the briefest moment, much less than a second. And, in fact, some intrepid observers will position themselves at the umbral shadow's limit to record irregularities along the Moon's limb (its visible edge). These observations are possible because only a tiny percentage of the Sun's disk shines through lunar valleys or between mountains. It's important work, but it's a job for scientists. You, as a first-time eclipse viewer, want to maximize your time under the umbra.

So, get to the center line!



Why does being on the center line matter so much? From there, the shadow cast by the Moon delivers the maximum amount of totality possible (red arrow). Closer to the path of totality's edge, the shadow traces a much shorter arc (yellow arrow). JOHN CHUMACK

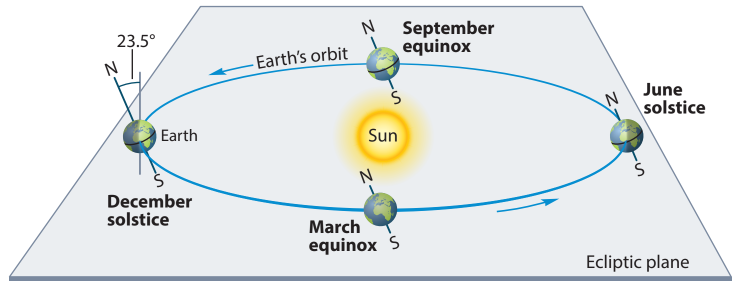


For the August 21, 2017, eclipse, the center line offers 2 minutes and 40 seconds of totality in southern Illinois. But as you move away from this line, your time under the umbral shadow shrinks noticeably. *ASTRONOMY*: ROEN KELLY

Michael E. Bakich *is a senior editor of* Astronomy *who will be conducting a huge free public eclipse watch at Rosecrans Memorial Airport in St. Joseph, Missouri, on August 21, 2017.*

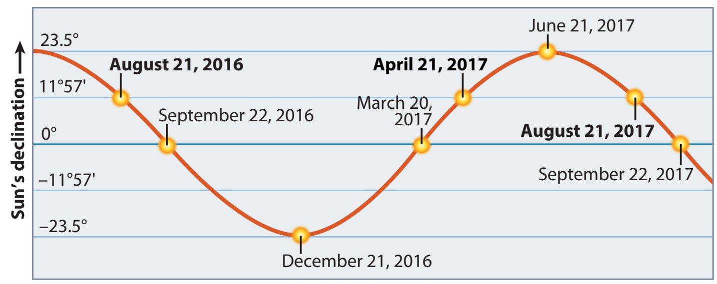
Rehearse for eclipse day

Here's how to do an actual run-through months before August 21, 2017. **by Michael E. Bakich**



Earth's axis tilts 23.5° to the pole of its orbital plane. That's why we have seasons, and it explains the Sun's changing declination during the year.

ALL ILLUSTRATIONS: *ASTRONOMY*: ROEN KELLY



The Sun sits at a declination of 11°57' on eclipse day, August 21, 2017. It will have the same declination — and thus will follow the same track across the sky — on August 21, 2016, and April 21, 2017.

As you read this, America's eclipse is a year away. But people are beginning to get nervous already. They ask questions, start making plans. The "hands-on" folks desire a bit more, however. They want to get out under the daytime sky and check out the circumstances themselves. If you're one of them, I have good news: There's a way to conduct an accurate rehearsal for the eclipse.

First, some background. Earth's axis tilts 23.5° to the pole of its orbit around the Sun. This orientation explains why we have seasons. When the northern tip of our planet's axis points toward the Sun, it's the Northern Hemisphere's summer. When the southern tip points sunward, the Northern Hemisphere experiences winter. Spring and autumn lie midway between these extremes. All seasons reverse in the Southern Hemisphere.

Because of the tilt, the Sun's maximum altitude at any location changes by 47° in the six-month span from June to December or December to June. On the June solstice (the Northern Hemisphere's first day of summer), the Sun stands as high in the sky at midday as it gets all year. Conversely, on the December solstice (winter's first day in the Northern Hemisphere), the Sun hangs lowest in the sky.

When astronomers give the Sun's position, they use two celestial coordinates: right ascension and declination. These values roughly correspond to longitude and latitude on Earth. The Sun's declination varies by 47° from most southerly (December solstice) to most northerly (June solstice). Except at those extremes, then, the Sun has the same declination twice each year.

At eclipse time on August 21, 2017, the Sun's declination will be approximately 11°57'. It probably goes without saying that in 2016, the date when the Sun's declination is closest to this value is also August 21. So, if you want to "practice" observing the Sun where it will be on eclipse day, head out August 21. Maybe you want to set up a filtered telescope. Maybe you want to take a few pictures. Or maybe you just want to check out a prospective observing site. How far away are any trees? Buildings? Whatever your reasons, you'll see how the Sun will perform on eclipse day.

Recall that there are two dates during the year when the Sun has the same declination. The other date in 2017 when our star's declination comes closest to 11°57' is April 21. The Sun's path through the sky that day will be the same as it will be on eclipse day. So, anything you want to try during the eclipse you can practice August 21, 2016, or April 21, 2017.

These dates are the closest approximations to what you'll see on eclipse day. The Sun will rise and set at the same times, and it will cross the meridian (the imaginary north-south line that passes directly overhead) at the same time. Here's something to consider, however: The Sun's declination doesn't change much from day to day. In fact, if you rehearse as many as three days before or after either date, you won't see any noticeable difference when August 21, 2017, rolls around.

View the Sun safely

Billions of people have experienced solar eclipses safely. Here's how. **by Michael E. Bakich**

ASTRONOMY: MICHAEL E. BAKICH

Eclipse glasses allow you to view the Sun in complete safety during the long stretches leading to totality and trailing afterward.

Observing the Sun can be dangerous. Solar radiation that reaches Earth's surface ranges from ultraviolet to radio waves, but only visible and near-infrared light concern us. If too much of this radiation reaches our light-sensitive retinas, "eclipse blindness" or retinal burns may occur.

Intense visible light damages rod and cone cells. The light triggers chemical reactions within the cells that damage their ability to respond to visual stimuli and, in extreme cases, can destroy them. Blindness — either temporary or permanent — results. When someone looks at the Sun without proper eye protection, a thermal injury also might happen. The high level of visible and near-infrared radiation heats the exposed tissue and literally cooks it. Man, that sounds nasty! This thermal injury destroys rods and cones, creating a blind spot. And what's worse is that retinal injuries occur without your knowing it — the retina has no pain receptors, and the bad effects don't appear immediately.

The only time you can view the Sun safely with the naked eye is during totality. Even during the late partial phases, when the Moon covers 99 percent of the Sun's visible surface, the slim solar crescent still packs enough of a punch to burn the retina. To avoid permanent eye damage, use the right observing methods.

The safest and least expensive technique is projection. Use a pinhole or a small opening to form an image of the Sun on a white card lined up with the Sun and the opening. Multiple openings in a hat or even between crossed fingers will cast a pattern of eclipsed Suns on a screen. This effect happens more naturally beneath trees within the eclipse path. The many "pinholes" formed by overlapping leaves create hundreds of solar images.

Another projection technique uses binoculars or a small telescope mounted on a tripod to project a magnified image of the Sun onto a white card. This method is great for showing to a group of observers, but make sure no one looks *through* the device.

To view the Sun directly, you need an approved solar filter. The ones that look like mirrors have atoms of aluminum deposited on plastic. Others (that look dark) use a thin piece of polycarbonate. Each drastically cuts both visible and near-infrared radiation to a safe level.

One filter many amateur astronomers have used for solar viewing is a #12 or #14 welder's glass, which produces a light-green image. But #14 is a dense filter, and welders seldom use it. So, although they aren't expensive, you may still have to special-order one of these.

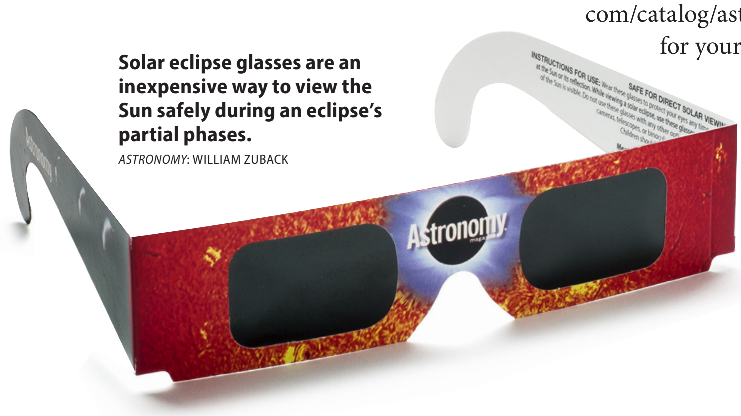
A much more available and even cheaper alternative is a product usually called "eclipse glasses." Several companies, and that includes *Astronomy* magazine, produce these cardboard glasses for safe solar observing. Visit www.myscienceshop.com/catalog/astronomy to buy some for yourself, family, and friends.

ASTRONOMY: MICHAEL E. BAKICH

An amateur astronomer uses a small telescope to project the Sun's image onto a white card. Such a setup allows viewing of an uneclipsed or partially eclipsed Sun.

10 WAYS **NOT** TO OBSERVE THE SUN

1 Space blankets or telescope covers
2 Black-and-white film that uses dyes instead of silver
3 Medical X-rays or any film with an image on it
4 Compact discs
5 Smoked glass
6 Sunglasses or multiple sunglasses
7 Color film
8 Neutral density filters
9 Polarizing filters
10 Any "solar" filter that screws into or fits over an eyepiece

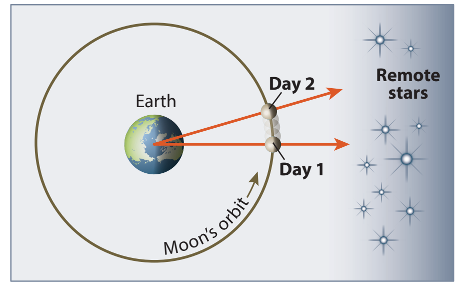


Solar eclipse glasses are an inexpensive way to view the Sun safely during an eclipse's partial phases.
ASTRONOMY: WILLIAM ZUBACK

Solar eclipse filters come in a variety of sizes, including ones that fit over binoculars or telescopes. *ASTRONOMY*: MICHAEL E. BAKICH

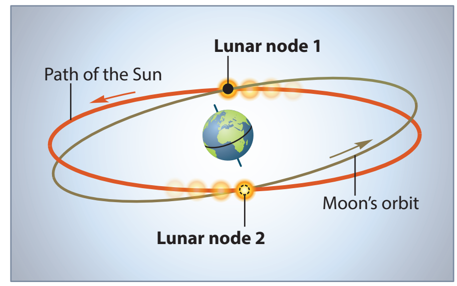
Decipher the eclipse pattern

Skywatchers have been accurately predicting eclipses for centuries. How do they do it? **by Michael E. Bakich**



On average, the Moon travels approximately 13° relative to the background stars each day. This rapid motion allows it to complete one circuit (a sidereal period) every 27.32166 days.

ALL ILLUSTRATIONS: *ASTRONOMY*: ROEN KELLY



The Moon's orbit around Earth intersects the apparent path of the Sun (which coincides with our planet's orbital plane) in two spots called "nodes." Our satellite returns to the same node (a draconitic period) every 27.21222 days.

You don't have to be an astronomer to know how eclipses happen: the Sun, the Moon, and Earth line up precisely. But you do have to know how these objects move to understand the pattern eclipses go through — one called the "saros." This is the time period after which nearly identical eclipses repeat.

The saros equals 6,585.3211 days. That's how long it takes for four periods related to the Moon to once again coincide. The first is the sidereal period — our satellite's orbital period with respect to the stars, 27.32166 days.

The second is the synodic period, 29.53059 days, the time it takes the Moon to go from any phase to the next occurrence of the same phase. Because we're talking about solar eclipses, we can simplify this to the time between successive New Moons — the phase at which such eclipses occur.

We don't experience a solar eclipse at every New Moon, however, because our satellite's orbit tilts with respect to Earth's orbit around the Sun. The Moon's orbit intersects Earth's twice each lunar month at points called nodes. That's the origin of our third period. A draconitic period is the time it takes the Moon to go from one node back to the same node, 27.21222 days.

Two successive eclipses in a saros have essentially the same duration because the Earth–Moon distance is nearly the same for each. If you guessed that this is because of the fourth period, you're catching on! The anomalistic period equals 27.55455 days. This is the time between two successive lunar perigees — our satellite's closest approach to Earth.

Now let's see how these periods relate. One saros — the next time all four of these lunar months align — equals 241 sidereal periods, which also equals 223 synodic periods, 242 draconitic periods, and 239 anomalistic periods. After one saros, therefore, the positions of the Sun, the Moon, and Earth will be nearly identical. It will be New Moon, our satellite will lie at the same node, and its distance to Earth will be the same.

And consider this: A saros is some 11 days longer than 18 years. In 11 days, Earth travels only 3 percent of its orbit, so its position with respect to the stars will be nearly the same, too. The second eclipse, however, will occur at a much different place on Earth.

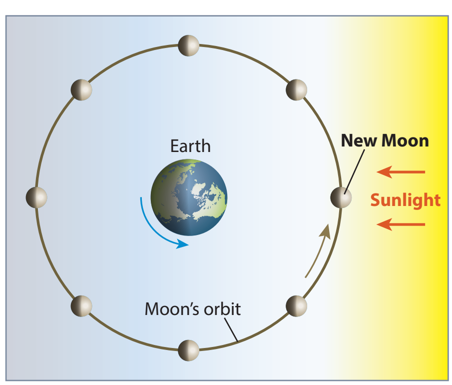
Here's why. The saros is not an integer. The extra 0.3211 day equals 7 hours 42 minutes and 23 seconds. So each successive eclipse in a saros happens this much later in the day, which means the region of visibility on Earth shifts 115.6° to the west.

Now it gets interesting. After three saros intervals — 54 years and 33 days — the region of visibility shifts 3 × 115.6°, or 346.8° — just 13.2° less than a full circle. Thus, the eclipse won't have only the same characteristics as one that occurred 54 years before, it will occur at roughly the same location and within an hour of the same time of day.

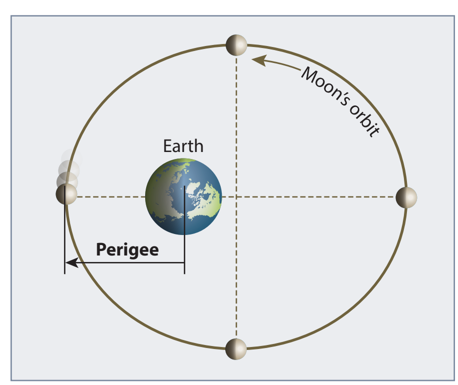
A saros series begins with partial eclipses visible at high latitudes in either the Northern or Southern Hemisphere. Next, a group of annular and then total eclipses appears over Earth's middle and equatorial latitudes. The series ends with more partial eclipses near the opposite pole from where the saros started.

About 238 solar eclipses occur each century. So, roughly 42 eclipses occur during a saros period of 18 years and thus, at any time, approximately 42 different saros series must be active.

The August 21, 2017, total eclipse belongs to saros 145. It's the 22nd eclipse in the series, which contains a total of 77. The first one was a partial eclipse January 4, 1639. The most recent one, a total eclipse, occurred across Europe and Asia on August 11, 1999. After 2017, the next one will happen September 2, 2035. And the last eclipse of saros 145 (a partial) will occur April 17, 3009.



It takes the Moon 2.2 days longer to orbit Earth relative to the Sun than it does relative to the stars. This interval between successive phases, a synodic period, lasts 29.53059 days.



The Moon's distance from Earth changes throughout the month. The time it takes to go from one perigee (closest approach) to the next (an anomalistic period) is 27.55455 days.