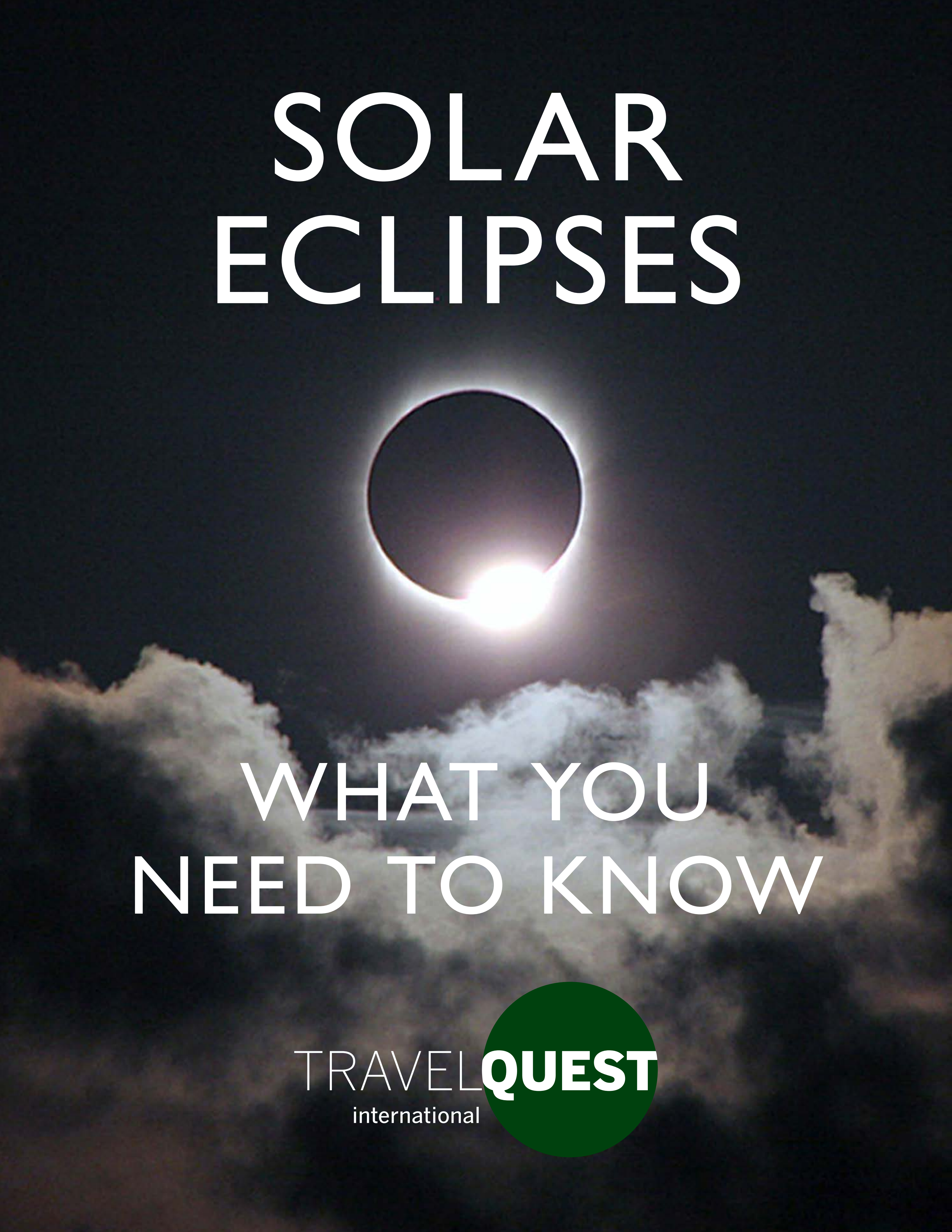
SOLAR ECLIPSES



WHAT YOU NEED TO KNOW

TRAVELQUEST
international

The eclipse sequence (from upper right to lower left) as seen from the M/V *Corinthian* off the west coast of Africa, November 3, 2013. [TQ/RICK FIENBERG]

YOUR TRAVELQUEST SOLAR ECLIPSE GUIDE

WELCOME, and thank you for joining us on our latest eclipse adventure. This two-part sourcebook is designed to help you get the most out of your eclipse-viewing experience. *Solar Eclipses: What You Need to Know* includes background information on solar eclipses, provides suggestions on what to watch for during the partial and total phases, and offers essential advice on how to safely view and photograph the eclipse. The companion PDF describes the specific details of the eclipse you'll soon be experiencing.

Advance preparation is the key to getting the most out of the eclipse — especially totality. We suggest that you familiarize yourself with this material before you travel, particularly if you plan to photograph the eclipse. The PDF design makes it convenient to load this sourcebook onto your tablet so you can bring it with you on the trip.

Bon Voyage!

THE TRAVELQUEST TEAM

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COVER: The third contact diamond ring lit up the clouds in spectacular fashion as seen from the m/s *Paul Gauguin* on July 21, 2009. [TQ/RICK FIENBERG]

ECLIPSE VIEWING SAFETY FIRST

All TravelQuest solar eclipse travelers are provided with special eclipse viewers that use safe, black polymer solar-filter material and are easy to wear. [TQ/RICK FIENBERG]

Everyone glances at the Sun now and then, and a quick look won't damage your eyes. In fact, if you do more than glance you'll start to squint, your eyes will begin to water and hurt, and you'll quickly turn away. That's your body's defense mechanism at work.

Trouble comes when you deliberately stare at the Sun. Why would you do that? To follow a solar eclipse, of course. But gazing at the Sun for a prolonged period without proper protection for your eyes may result in "eclipse blindness," a serious injury in which the eye's retina is damaged by solar radiation. Fortunately most victims of eclipse blindness recover their eyesight, but there are some who suffer permanent loss of a portion of their vision.

With one exception, it is never safe to look directly at the Sun without a solar filter. That exception is during totality, when the solar surface is completely blocked by the Moon. But totality is fleeting. Most of the time you'll be watching a partial eclipse during which filters are *always* required.

THE EYES HAVE IT

To view the progress of the eclipse without optical aid, use the special eclipse viewers provided to all TravelQuest travelers. Simply bend the arms inward at whichever of the scored lines makes them fit the best. If you wear prescription eyeglasses, you can adjust the eclipse viewers to fit over them. (If you are wearing sunglasses, take them off.)

Position the viewer in front of your eyes before looking up at the Sun — *be sure it completely covers your eyes.* You don't need to stare — the partial phases of the eclipse occur at a leisurely rate. So take a brief 5- to 10-second glance at the Sun. Then look away from the Sun and remove your eclipse viewers. If you do this every few minutes, you'll mentally create a time-lapse movie that reveals the progress of the eclipse.

So when do you not need solar filters? If you've never experienced totality before, wait until you hear the cries of "Diamond ring!" before removing the filters from your optical gear. You can watch the diamond ring / second contact without a filter (as long as you do not look through your optics), but be warned that your eyes will be dazzled and you'll likely miss the full extent of the corona during totality. Make sure your filters are back on at the third contact diamond ring (the end of totality).

PROTECT YOUR OPTICS

Your telescopes, binoculars, and cameras also need solar filters for two reasons: to protect them from solar rays, and to ensure you don't accidentally look at the Sun through an unfiltered instrument. In every case, *the solar filter must be attached to the front of your telescope, binoculars, or camera lens.* This ensures that the Sun's light and heat are kept out of the optics. Make sure the filter is attached securely so it won't pop off if your instrument is bumped.

If the filter is attached to the back end — the spot where you place your eye — sunlight concentrated by your optics will burn right though it. This is also why looking through unfiltered optics while wearing eclipse viewers is extremely dangerous and a recipe for serious eye damage.

There's a list of solar-filter suppliers in the companion PDF that describes the specific details of the upcoming eclipse. You'll encounter three types of filters: metal on glass (usually the most durable and expensive), aluminized polyester (frequently referred to as aluminized Mylar), and black polymer. Some render the Sun white, while others impart a yellow, orange, or blue tint. All are effective, so choose the type that best suits your preference and budget. There are some pre-made filters for binoculars and camera lenses, but you'll likely have to purchase solar-filter material and construct your own filter(s).

A solar eclipse is one of nature's finest spectacles. Simple precautions will ensure you can view it safely. ●

EYE SAFETY DURING SOLAR ECLIPSES

A TOTAL SOLAR ECLIPSE is probably the most spectacular astronomical event that most people will experience in their lifetime. There is a great deal of interest in eclipses, and thousands of eclipse chasers travel the world to observe and photograph them. But observing the Sun can be dangerous if you don't take the proper precautions.

SOLAR OBSERVING: CARE REQUIRED

The solar radiation that reaches Earth's surface ranges from ultraviolet (UV) to radio waves. While environmental exposure to UV radiation is known to contribute to the accelerated aging of the eye's outer layers and the development of cataracts, the concern regarding improper solar viewing during an eclipse is the occurrence of retinal burns or "eclipse blindness."

Exposure of the eye's retina to intense visible light causes damage to its light-sensitive rod and cone cells. The light triggers a series of chemical reactions within the cells, which damages their ability to respond to a visual stimulus and, in extreme cases, can destroy them. The result is a loss of visual function that may be either temporary or permanent, depending on the severity of the damage.

When a person looks repeatedly (or for a long time) at the Sun without proper protection for their eyes, this retinal damage may be accompanied by a thermal injury. The high level of visible and near-infrared radiation causes heating that literally cooks the exposed tissue. This thermal injury (photocoagulation) destroys the rods and cones, creating a small blind spot. The danger to vision is significant, because photic retinal injuries occur without any feeling of pain (there are no pain receptors in the retina), and the visual effects do not occur for at least several hours after the damage is done.

Just prior to totality it's not safe to view a thin solar crescent — even if it's partially obscured by clouds — without a solar filter. [TQ/RICK FIENBERG]

Interlaced fingers, multiple openings in a loosely woven straw hat, or a broad-leafed tree — low-tech ways to cast a pattern of solar crescents on the ground during the partial phases of an eclipse. [LYNN DONOGHUE]

Viewing the Sun through binoculars, a telescope, or other optical devices without proper protective filters can result in immediate thermal retinal injury. The only time that the Sun can be viewed safely without a filter is during totality, when the Moon completely covers the solar disk. *It is **never** safe to look at a partial or annular eclipse, or the partial phases of a total solar eclipse, without proper filters and techniques.*

Even when 99% of the Sun's surface is obscured during the partial phases of a solar eclipse, the remaining thin crescent is still intense enough to cause a retinal burn, even though overall illumination levels are comparable to twilight. Failure to use proper observing methods may result in permanent eye damage or severe visual loss. Unfortunately, it has been shown that most individuals who sustain eclipse-related eye injuries are children and young adults.

PROPER VIEWING TECHNIQUES

The same techniques for observing the Sun outside of eclipse can be used to view and photograph annular solar eclipses and the partly eclipsed Sun. The safest method is indirectly,

Three examples of safe solar viewing: wearing eclipse viewers (left), a homemade solar filter on a camera lens (center), and photography through a shade number 14 welder's glass (man at right in the background). [TQ/RICK FIENBERG]

by projection. Binoculars or a small telescope, mounted on a tripod, can be used to project a magnified image of the Sun onto a white card. But care must be taken to ensure that no one looks through the instrument. The main advantage of the projection method is that nobody is looking directly at the Sun, and many can simultaneously watch the partial phases.

The Sun can be viewed directly only when filters designed to protect the eyes are used. One widely available filter for safe solar viewing is shade number 14 welder's glass, which can be obtained from welding supply outlets. While fine for visual observing, welder's glass is a poor-quality filter for photography.

Baader AstroSolar Safety Film is a metal-coated resin sheet that can be used for both visual and photographic solar observations. This thin material has excellent optical quality and scatters very little light. The Baader material comes in two densities: one for visual use and a less-dense version optimized for photography. Unlike welder's glass, this Safety Film can be cut to fit any viewing device and doesn't break when dropped.

An alternative to the AstroSolar Safety Film is "black polymer." This material is stiffer than the Baader Safety Film and may be easier to work with if you're making a filter for your binoculars, telephoto lens, or telescope. Intended mainly for visual use, a black polymer filter gives an orange-colored image of the Sun (the Baader Safety Film produces a blue-white image). The eclipse shades provided to TravelQuest travelers use black polymer filter material.

Solar filters using an optically flat glass base coated with metallic layers are available from several manufacturers but are more expensive than Baader and black polymer filters. These glass filters are primarily for telescopes. You'll find a list of solar-filter suppliers in the companion PDF that describes the details of the upcoming eclipse.

DO NOT USE...

Just because the Sun looks dark doesn't mean the filter you're using is safe. Watching an eclipse using smoked glass was common 100 years ago — not any more. More recently, observers have used CDs, CD-ROMs, and DVDs as protective filters by covering the central openings and looking through the disk media. That's another bad idea — they're all made with very thin aluminum coatings, which is not safe.

Other *unsafe* filters include color and black-and-white film, film negatives with images on them (x-rays and snapshots), sunglasses (single or multiple pairs), photographic neutral density filters, and polarizing filters. Most transmit high levels of infrared radiation, which can cause a thermal retinal burn. The fact that the Sun appears dim, or that you feel no discomfort when looking at the Sun through the filter, is no guarantee that your eyes are safe.

Solar filters provided with inexpensive telescopes, usually designed to thread into an eyepiece, are dangerous. These glass filters can crack unexpectedly from overheating when the telescope is pointed at the Sun, and retinal damage can occur faster than you can move your eye from the eyepiece. Avoid unnecessary risks — do not use them.

OBSERVE WITH CARE

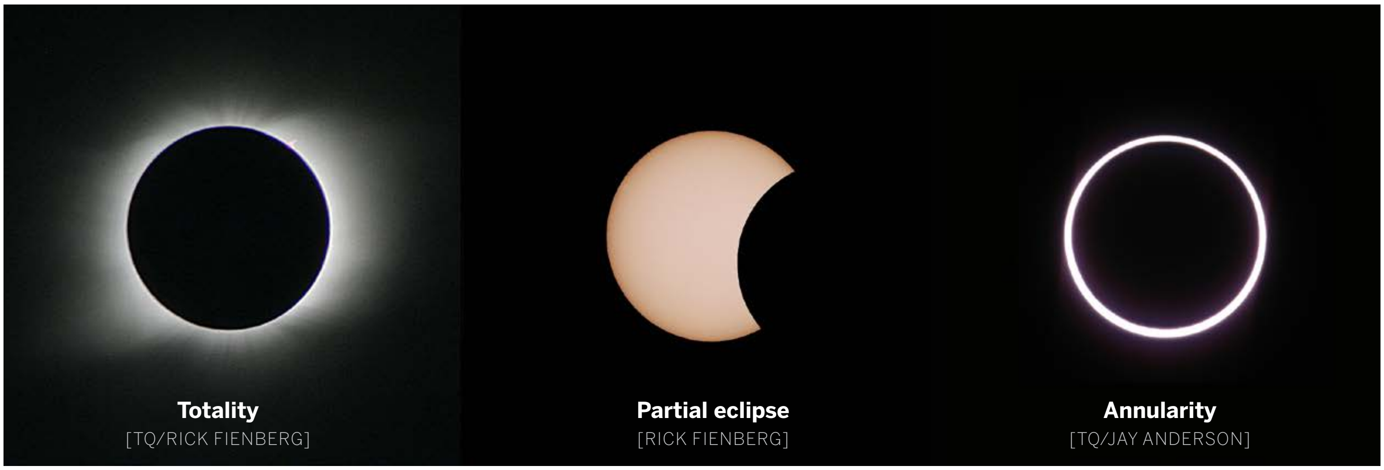
A final, critical note. Ensure the filter covering your camera, binoculars, or telescope, is securely fastened to the *front* end of your optics — the end closest to the Sun.

While it is definitely better to be safe than sorry, only a few simple precautions are required to safely observe and photograph the partial phases of a total solar eclipse (or all aspects of an annular eclipse). If you have any questions or concerns, please do not hesitate to raise them with your tour leaders. ●

Adapted from an original article by B. Ralph Chou, Professor Emeritus, Optometry and Vision Science, University of Waterloo (Canada).

Always remember that solar filters attach to the *front* or Sun-pointing side of your optics. [TQ/JAY ANDERSON]

ECLIPSE TERMINOLOGY



Totality [TQ/RICK FIENBERG] **Partial eclipse** [RICK FIENBERG] **Annularity** [TQ/JAY ANDERSON]

THE FOLLOWING are a number of terms used to describe various aspects of solar eclipses. You'll find many of them used throughout this sourcebook and hear others bandied about by your fellow eclipse travelers.

ANNULAR ECLIPSE. A solar eclipse where the apparent diameter of the Moon is too small to completely cover the Sun. At mideclipse, the Sun appears as a blindingly bright ring surrounding the Moon.

ANNULARITY. The maximum phase of an annular eclipse, when the Moon's entire disk is seen silhouetted against the Sun. Annularity occurs between second and third contact. It can last from a fraction of a second to a maximum of 12 minutes 30 seconds.

ANTUMBRA. The extension of the Moon's shadow beyond the umbra. Within the antumbra, the Sun appears larger than the Moon, which is visible in silhouette. An observer standing in the antumbra sees an annular eclipse.

BAILY'S BEADS. Caused by shafts of sunlight shining through deep valleys on the lunar limb (edge), they look like a series of brilliant beads popping on and off. They appear just prior to second contact and just after third. They're named after the English astronomer Francis Baily, who first described them during the annular eclipse of May 15, 1836.

CHROMOSPHERE. A thin, red-colored layer of solar atmosphere located just above the photosphere. It's briefly visible immediately after second contact and just prior to third.

CORONA. The Sun's upper atmosphere, visible as a pearly glow around the eclipsed Sun during totality. Its shape (sometimes elongated, sometimes round) is determined by the Sun's magnetic field and is linked to the sunspot cycle.

DIAMOND RING. A single Baily's Bead, shining like a brilliant diamond set into a pale ring created by the pearly white corona. It's the signal that totality is about to start (second contact) or has ended (third contact) — see the cover image.

DURATION. The time between second and third contact during a total or annular solar eclipse.

ECLIPSE MAGNITUDE. The fraction of the Sun's *diameter* covered by the Moon. It is a ratio of Sun/Moon diameters and should not be confused with eclipse obscuration (see below). So when the eclipse magnitude is 50% (50% of the Sun's diameter is covered), only 40% of the solar surface is obscured.

ECLIPSE OBSCURATION. The fraction of the Sun's *surface area* covered by the Moon. Do not confuse it with eclipse magnitude (see above). When 50% of the solar surface is obscured, the eclipse magnitude is roughly 60%.

FIRST CONTACT (C1). The moment when the Moon takes its first tiny nibble out of the solar disk — the beginning of the partial phase of an eclipse.

FOURTH (LAST) CONTACT (C4). The instant when the Moon no longer covers any part of the solar disk. This signals the conclusion of the partial phase of an eclipse.

HYBRID ECLIPSE. A solar eclipse that begins as an annular, becomes total for a brief time, and then reverts back to an annular before it ends. This is also known as an annular-total eclipse. On rare occasions, a hybrid eclipse may begin as an annular and end as a total, or vice versa.

NEW MOON. The lunar phase when the Moon is located in the same direction in the sky as the Sun. New Moon is the only lunar phase during which an eclipse of the Sun can occur. (See “When Worlds Align” on the next page for more details.)

PARTIAL ECLIPSE. A solar eclipse where the Moon covers only a portion of the Sun. A partial eclipse precedes and follows totality or annularity, but a partial can also occur by itself. A partial solar eclipse is visible over a wider swath of Earth than is totality or annularity.

PENUMBRA. The portion of the Moon’s shadow in which only part of the Sun is covered. An observer standing in the penumbra sees only a partial solar eclipse.

PHOTOSPHERE. The visible surface of the Sun, which consists of a gas layer at a temperature of roughly 5,500° Celsius.

PROMINENCE. Hot gas hanging just above the solar surface, usually appearing as a red-colored arc or filament hovering in the lower part of the corona. They are quickly covered by the Moon after second contact and revealed just prior to third.

SAROS. An eclipse cycle with a period of 6,585.32 days. When two eclipses are separated by a period of one Saros, the Sun, Earth, and Moon return to approximately the same relative geometry, and a nearly identical eclipse will occur (though the eclipse path will be shifted west by eight hours — one third of Earth’s rotation). On average, each Saros series lasts 12 or 13 centuries and contains about 70 eclipses.

SECOND CONTACT (C2). The instant when the total or annular phase of an eclipse begins. For a total eclipse, this is synonymous with the disappearance of the diamond ring.

SHADOW BANDS. Very faint, shimmering ripples of dark and light moving across the ground. These hard-to-see bands result from atmospheric “twinkling” of the thin solar crescent just before second contact and/or just after third contact. They’re best seen against a white background.

SUNSPOTS. Dark regions on the Sun where magnetic fields are bundled together and are so strong that the flow of hot, new gas from the Sun’s interior to the surface is inhibited. The spots appear dark because their temperature is about 1,000° Celsius cooler than the photosphere that surrounds them.

SUNSPOT CYCLE. The number of sunspots rises and falls in roughly an 11-year cycle. During sunspot minimum, the Sun’s corona appears elongated with streamers extending away from the solar equator; during sunspot maximum, the Sun’s corona appears more rounded and symmetrical.

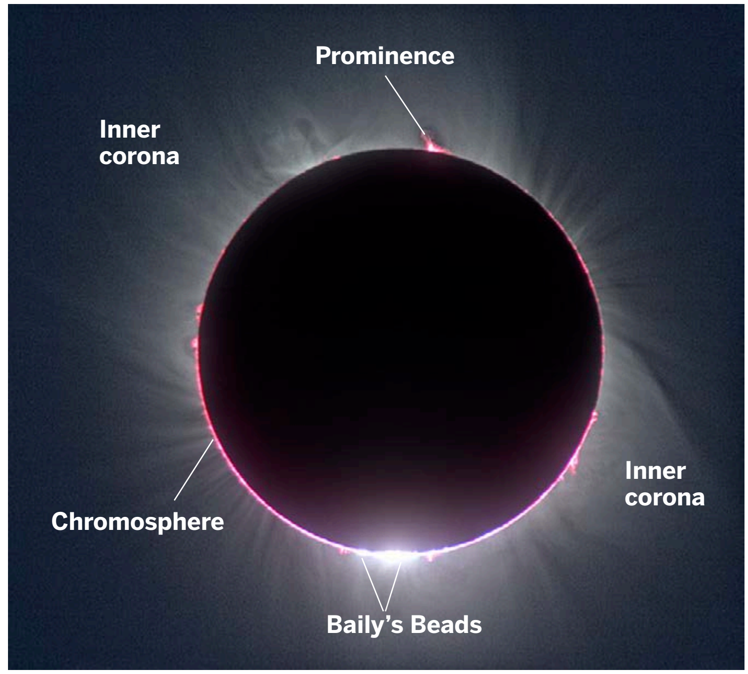


IMAGE © MILOSLAV DRUCKMÜLLER & PETER ANIOL.

THIRD CONTACT (C3). The instant when the total or annular phase of a solar eclipse ends. For a total eclipse, this is synonymous with the appearance of the diamond ring.

TOTAL ECLIPSE. A solar eclipse where the apparent diameter of the Moon is large enough to completely cover the Sun’s photosphere (even if only momentarily) and reveal the faint solar corona.

TOTALITY. The maximum phase of a total solar eclipse, during which the Moon’s disk completely covers the Sun. Totality occurs between second and third contact. It can last from a fraction of a second to a maximum of 7 minutes 31 seconds.

UMBRA. The darkest part of the Moon’s shadow. Within the umbra, the Moon appears larger than the Sun. An observer standing in the umbra sees a total solar eclipse.

UMBRAPHILE. A solar-eclipse aficionado; a person who will do almost anything, and travel almost anywhere, to see totality.

DID YOU KNOW?

- Annular eclipses outnumber total eclipses by a ratio of about 5 to 4.
- The maximum width of the path of totality is 167 miles (269 kilometers).

For more details about solar (and lunar) eclipses, go to eclipsewise.com.

WHEN WORLDS ALIGN

ECLIPSE \i klips´\ (n): the total or partial obscuring of one heavenly body by another. *(Merriam-Webster Online Dictionary)*

THERE'S NOTHING WRONG with the above definition of an eclipse, but it doesn't begin to convey the thrill and excitement that takes hold of eclipse chasers when the Moon encroaches upon the Sun.

What's more, a total solar eclipse is a rare event, at least in our corner of the cosmos. There are close to 200 confirmed moons orbiting the six planets in our solar system (Mercury and Venus lack moons). But in only one instance is there a moon that's the right size, at the right distance from its planet, to barely cover the brilliant solar disk and reveal the Sun's wispy corona. And that's our Moon, part of the Earth-Moon system.

The Sun's diameter is about 400 times that of the Moon. The Sun is also (on average) about 400 times farther away. This truly remarkable coincidence is what gives us total solar eclipses. If the Moon were slightly smaller or orbited a little farther away from Earth, it would never completely cover the solar disk. If the Moon were a little larger or orbited a bit closer to Earth, it would block much of the solar corona during totality, and eclipses wouldn't be quite as spectacular.

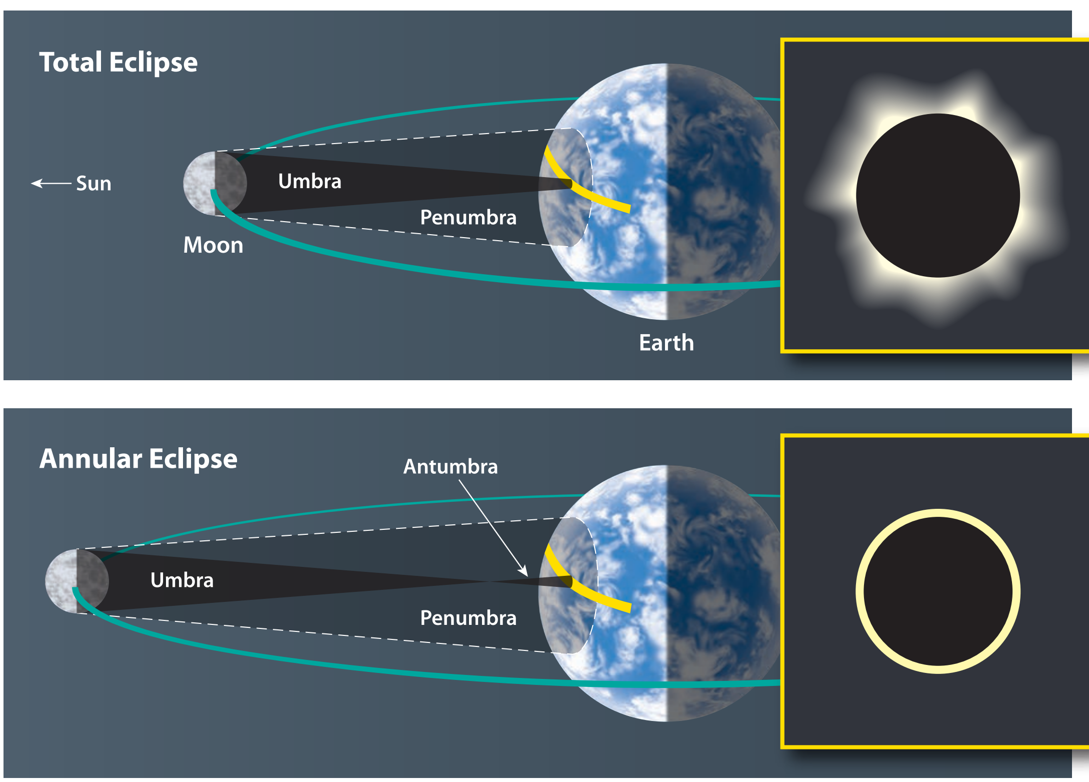
Of course the Moon doesn't totally eclipse the Sun every month — if it did, seeing totality wouldn't be as much of a thrill. And even when the lunar disk encroaches on the Sun, it doesn't always completely cover the solar disk. In fact, at new Moon — the only lunar phase when a solar eclipse can occur — the Moon usually misses the Sun altogether. Given all the variables, it's almost surprising that we see eclipses at all.

A CELESTIAL DANCE

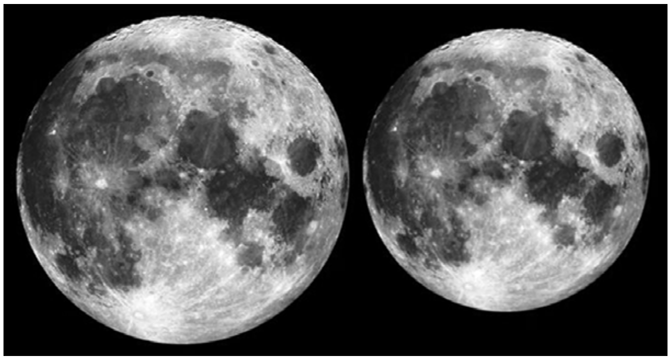
The Moon orbits Earth; both swing around the Sun. In a perfect universe, we'd see totality every month. But we don't, and here's why.

First, the apparent size of the Sun varies during the year because Earth's orbit is an ellipse, not a perfect circle. Our planet is closest to the Sun *(perihelion)* in early January and farthest *(aphelion)* in early July. So the Sun appears some 3% larger in January than in July (not that you'd notice), which means at times it's harder for the Moon to completely cover the Sun and create a total eclipse.

More dramatic is the change in the Moon's apparent diameter due to its elliptical orbit around Earth. When the Moon is closest to Earth *(perigee)*, its apparent diameter is 14% larger than when it's farthest *(apogee)*. When near perigee, the Moon can easily cover the entire solar disk and



A number of factors determine whether the Moon completely covers the Sun (a total solar eclipse) or doesn't (an annular eclipse).
[STEVEN SIMPSON X2]



The Moon revolves around Earth in an elliptical orbit. As a result, its apparent diameter is significantly larger when it is closest to Earth (perigee, left) than when it's farthest (apogee, right). [NASA]

create a total solar eclipse. But at apogee the Moon is too small to cover all of the Sun. At mideclipse a ring of sunlight *(annulus)* surrounds the lunar silhouette, resulting in an annular eclipse.

The variability in the apparent size of the Sun and Moon doesn't preclude a monthly solar eclipse. What does is the tilt of the Moon's orbit, which is 5° to the plane of Earth's orbit around the Sun or, equivalently, the Sun's apparent path around the sky as seen from Earth (the *ecliptic*). So, more often than not, the new Moon passes above or below the Sun, and the lunar shadow misses Earth completely.

But every 173.3 days, the new Moon passes through one of two crossover points *(nodes)* where the Moon's tilted orbit intersects the ecliptic. Here, at last, a solar eclipse is possible, though the Moon can pass through a node without the eclipse being total or annular — a partial eclipse occurs instead.

Does this limit eclipses to twice a year? Not quite, because the Moon doesn't have to move exactly through the middle of a node to cause an eclipse. It can be off by a little, which means it's possible to have two solar eclipses within 30 days of each other, though both will be partials.

The complications don't end there. Those nodes slowly shift *(precess)* westward, which means the months in which eclipses take place slowly change as the years pass. This also affects the type of eclipse that occurs: currently long annulars are more likely in January, long totals in July.

Finally, after 6,585 days (18 years, 11 days, 8 hours), the entire eclipse cycle repeats. This is known as the *Saros cycle*. When two eclipses are separated by a period of one Saros, the Sun, Earth, and Moon return to approximately the same relative geometry, and a nearly identical eclipse will occur (though the eclipse path will be shifted west by eight hours — one third of Earth's rotation). On average, each Saros series lasts 12 or 13 centuries and contains about 70 eclipses.

NOTHING LASTS FOREVER

The cosmic coincidence that gives us total solar eclipses isn't permanent. The Moon is ever so slowly moving away from our planet at rate of about 1.5 inches (3.8 centimeters) per year. As it recedes, its average apparent diameter shrinks. Eventually, the Moon will never be large enough to completely cover the Sun, and total eclipses will no longer be visible from Earth's surface.

And when might this sad prospect come to pass? The calculation is not precise — there are many unknowns such as whether the lunar retreat will continue at a constant rate and whether the solar diameter will remain stable over a long period of time. Still, some 1,000,000,000 (one billion) years from now, give or take a few hundred million years, the surface of Earth will experience its final total eclipse of the Sun. Annular eclipses will continue ad infinitum, though the percentage of the solar surface hidden by the Moon will gradually decrease.

So when you stand in the lunar shadow watching the Moon pass between Earth and the Sun, revel in the knowledge that you are witnessing one of the rarest events in the cosmos. ●

The Moon's shadow sweeps across Turkey in this view, from the International Space Station, of the March 29, 2006, total solar eclipse. Northern Cyprus is visible at the bottom of the image beneath the shadow. [NASA]

DID YOU KNOW?

- Minimum number of solar eclipses per year: 2 (2 partial or 1 partial and 1 annular or total).
- Maximum number of solar eclipses per year: 5 (4 partial and 1 annular or total).
- The Moon's shadow travels 1,100 miles per hour (1,770 kilometers per hour) at the equator and up to 5,000 mph (8,000 kph) near the poles.
- The average interval between solar eclipses for any spot on Earth is 375 years, but…
- An area within southeastern Missouri, southern Illinois, and western Kentucky will see two total eclipses within a span of less than seven years (August 21, 2017, and April 8, 2024).

DARKNESS IN DAYTIME
AN ECLIPSE-WATCHER'S GUIDE

"TOTALITY, no matter how long its duration, seems to last no more than eight seconds." This remark, by former *Sky & Telescope* editor Norm Sperling, succinctly describes the eclipse experience for many, particularly those encountering totality for the first time.

The following list is a guide of things to look for before, during, and after totality. In several cases, you'll be conflicted. For instance, you can't block the crescent and spot the corona before totality starts and simultaneously watch the approaching lunar shadow. But if you've never experienced totality, this list will help you know what to expect, and when.

FIRST CONTACT: THE ECLIPSE BEGINS. The Moon touches the Sun and takes its first tiny nibble out of the solar disk. First contact is initially visible through a telescope, then in binoculars, and finally with the unaided eye. *Regardless of how you view it, observing with a safe solar filter is an absolute must.*

THE VANISHING SUN. During the next hour or so, the Moon hides more and more of the Sun. It's a leisurely affair, so you have plenty of time to look around. As the eclipse progresses, can you detect any change in the color and quality of the sky, the clouds, nearby objects, and distant landscapes?

CHANGING LIGHT. Once more than half the Sun is covered, the light begins to fade, though imperceptibly at first. About 15 minutes prior to totality, the light becomes noticeably dimmer and starts to take on an odd or eerie "tint." Shadows become sharper and more detailed. Look away from the shrinking solar crescent — has there been a change in the color of the sky and clouds since the eclipse began?

ANIMAL AND HUMAN BEHAVIOR. As the sunlight dims, you may spot the local fauna acting in a peculiar manner. Many start to settle in as if night is falling. Notice the people around you — they're likely more animated than any local wildlife!

WEATHER. As totality nears, you may notice a perceptible drop in the temperature, and the wind may pick up or change direction.

DEEPENING DARKNESS. Look west a few minutes before totality. Can you see the oncoming umbral shadow? Clouds on the horizon will go dark as the Moon's shadow sweeps over them, making the approaching umbra more noticeable.

SHADOW BANDS. Very dim, undulating ripples of dark and light might appear, flowing across the ground or the side of a white building. These hard-to-see features are caused by atmospheric refraction of the thin solar crescent just prior to second contact and/or immediately after third contact.

EMERGING CORONA. Some 30 seconds before totality, cover the shrinking solar crescent with your outstretched thumb and remove your eclipse viewers. You'll likely spot the Sun's corona (its outer atmosphere) on the side opposite the crescent. But if you do this, you might miss the next two events!

BAILY'S BEADS. Just prior to totality, all that remains of the Sun are a few shafts of light shining through deep valleys on the lunar limb. The result is a few brilliant beads popping on, then off. If you're using optics to observe the beads, keep your solar filters on. If not, take the filters off.

DIAMOND RING. The lunar shadow envelops you. Only a single bead remains — it shines like a brilliant diamond set into a pale ring created by the pearly white corona surrounding the Moon's black silhouette. ***FILTERS OFF, EVERYONE!***

SECOND CONTACT: TOTALITY BEGINS! The last bead vanishes, the solar surface is hidden, and the Sun's ghostly, gossamer corona glows around the black lunar silhouette. Feel free to scream and yell in delight, or just stare in silent awe.

CHROMOSPHERE AND PROMINENCES. For a brief time after the start of totality, the Sun's chromosphere (lower atmosphere) remains visible along the solar limb (edge) still being covered by the Moon. This vivid arc of red vanishes quickly, so don't miss it. Depending on how active the Sun is, you may spot several streamers of red stretching up from the chromosphere into the corona. These are solar prominences, and they, too, soon disappear behind the encroaching lunar limb.

THE CORONA. Now's the time to explore the solar corona. Using just your eyes, take a few moments to carefully study the appearance of the corona near the Sun. Can you detect any color? Does the corona look smooth or mottled? Use averted vision (stare at the eclipsed Sun, but concentrate your attention on the corona streaming away from either side of the Sun) to determine how far east and west the faint, outer corona extends. Is it rounded or elongated? Now use binoculars or a telescope to check out detail within the corona. Look for loops and arcs that reveal solar magnetic fields, and compare the structure of the corona at the Sun's poles and equator (it's quite different).

PLANETS AND STARS. Brilliant Venus will likely be visible even before totality. Some of the other planets, and a few bright stars, might put in an appearance. But don't spend too much time looking for them — totality is fleeting!

SKY AND HORIZON. Sky darkness during totality varies from eclipse to eclipse. How dark it gets depends on the Moon's angular size, the presence or absence of clouds, and how close your site is to the centerline. Just outside the path of totality, the Sun is still shining, albeit dimly. This feeble light creates a beautiful 360° sunset glow around the horizon. Don't miss it.

EXPERIENCE TOTALITY. Beware of spending totality with your eye glued to your camera's viewfinder. Taking pictures is fine, but make sure you take time to appreciate what is truly a total sensory spectacle. If you're using a telescope to examine the stunning detail in the corona, pause for a few moments, look away, and absorb the surrounding vista.

TOTALITY'S FINALE. Yes, both the sky and the edge of the corona opposite where the Sun vanished really are a little brighter now. Fingers of red (prominences) slowly rise from behind the Moon's retreating limb. They are soon joined by an emerging arc of red light — the chromosphere. The end of totality is imminent.

THIRD CONTACT: DIAMOND RING. One blazingly bright bead of sunlight erupts into view. Totality is over. ***SOLAR FILTERS ON!*** The stages of the eclipse now repeat in reverse order.

BAILY'S BEADS. More rays of sunlight burst through lunar valleys and quickly combine to form a very thin crescent. The solar crescent rapidly expands, and the sky brightens quickly. If you want a few more seconds of corona viewing, block the emerging Sun with your thumb.

SHADOW BANDS. These dim ripples of dark and light may appear briefly while the solar crescent remains extremely thin.

RETREATING SHADOW. If you're not busy watching for shadow bands or squeezing in a few more seconds of corona viewing, quickly look away from the emerging Sun. Can you see totality's wave of darkness speeding rapidly into the east?

TEMPERATURE. The temperature will likely continue to cool slightly after totality concludes and begin to rise shortly thereafter. However, the change may be subtle and could be masked by a shift in wind speed and direction.

ANIMAL AND HUMAN BEHAVIOR. As the Sun emerges, so too will any wildlife that, as totality approached, decided something odd was happening and started to go to sleep. Meanwhile, your travel companions will be happily chatting among themselves, comparing images, and probably ignoring the returning solar disk.

THE RETURNING SUN. Just as it took a while for the Moon to cover the Sun, it will take an equally long interval for the Moon to move off the solar disk. (Actually, the time between third and fourth contact will *seem* much, much longer than between first and second contact!) But don't lose track of time — you'll want to witness the official end of the eclipse.

FOURTH CONTACT: THE ECLIPSE ENDS. The last tiny indentation on the Sun disappears, and the Moon no longer covers any part of the solar surface. The eclipse is officially over.

The key to not becoming overwhelmed by the sight of totality is to create a short list of what you really want to see and do, memorize it, and stick to it. Otherwise, you'll spend your time gaping at the hole in the sky and totality will fly by — in what will seem like eight seconds. ●

A caveat. *Some of the pre- and post-totality events described here will not be apparent if you are chasing the eclipse in an airplane or viewing it onboard a ship.*

WHAT IF IT'S CLOUDY?

I like to use the phrase "experience totality" rather than "see totality," because a total solar eclipse is the only celestial phenomenon I can think of that truly overwhelms the senses. Most astronomical observing involves straining to perceive something at the limit of visibility — a faint galaxy, a dim double-star companion, or a tiny festoon in Jupiter's clouds. A solar eclipse is the most extreme exception to this rule. You don't have to use averted vision, special filters, or other tricks to experience totality. You just have to put yourself in the right place at the right time and hope for clear skies. When the Moon's shadow arrives, it hits you over the head.

But what if we don't have clear skies? Other than on an eclipse flight, unwelcome clouds are always a possibility. Without doubt, the highlight of any solar eclipse is the gossamer corona, which is visible only if the sky is relatively clear and transparent. But many of the other phenomena described in the accompanying article can be experienced even if clouds cover the Sun. For example, it *will* get dark, the temperature *will* go down, any wildlife in the area *will* exhibit changes in behavior, and your fellow eclipse watchers *will* make sounds — though perhaps not happy ones.

You can take some comfort from remembering that even under perfectly clear skies, it's impossible for a single observer to take in everything that happens during a total solar eclipse. You can't look up in the sky at the last sliver of Sun at the same time you're looking down at the ground for shadow bands. You can't admire the pretty sunset colors around the horizon while you're examining coronal streamers in your telescope. So even in ideal conditions, you end up seeing some things that others miss, and missing some things that others see.

Obviously we hope to see the corona during the upcoming eclipse, and you can be sure that your tour leaders are doing everything possible to maximize the likelihood of success. No matter how the weather turns out, I'm confident you'll have a wonderful experience.

RICK FIENBERG, PhD, Trip Leader/Astronomer

IMAGING A TOTAL SOLAR ECLIPSE

THERE IS NOTHING quite like totality. So you'd really like nothing better than to show family and friends what the eclipsed Sun looks like. But capturing that perfect picture is challenging because totality is short, lighting conditions are tricky, and you don't get a second chance (at least not until the next eclipse, which is typically more than a year or two away). So preparation is the key.

When photographing an eclipse of the Sun, one rule is paramount: *Solar filters must always remain on cameras and telescopes during the partial phases.* Only during totality is it safe to remove them. (See the articles "Eclipse Viewing: Safety First" and "Eye Safety During Solar Eclipses" elsewhere in this sourcebook.) Filters should fit snugly over the *front* of all camera lenses and telescopes, but not so tight that they're difficult to remove quickly at the start of totality.

Here are three things to keep in mind while reading the next few pages. First, this article is intended mainly for digital-camera users; some comments won't apply if you're shooting with 35-mm film. Second, this article doesn't specifically address taking eclipse photos through a telescope, though some of the tips concerning telephoto lenses apply equally to telescopes. And third, you should practice prior to the eclipse by shooting the uneclipsed Sun (filters on, of course) at home before you embark on the tour.

SIZE MATTERS

If you simply want to shoot scenics and don't care about eclipse close-ups, then a point-and-shoot camera will work for you. If it has a decent zoom lens, some manual control, and image stabilization, you can take snapshots that record the progress of the partial phases, landscape scenes showing the dropping light level during the final minutes before totality, the 360° horizon glow visible during totality, and even totality itself. Before pointing your camera at the Sun at any time other than during totality, remember to put a filter over the camera lens (and over the viewfinder if the camera lacks through-the-lens viewing).

For close-up images of the eclipsed Sun, you'll need a digital single-lens-reflex (DSLR) camera with a telephoto lens. All focal lengths in this article are 35-mm equivalents. If you're not sure how to convert your lens's focal length to its 35-mm equivalent, check your owner's manual or the manufacturer's website.

A normal (50-mm) or wide-angle (35-mm to 17-mm fisheye) lens will take in the overall scene, but will not capture coronal detail because the eclipsed Sun's image size will

A composite image of totality, shot from Svalbard in 2015.
[IMAGES BY JUDY ANDERSON; COMPOSITION BY ALSON WONG.]

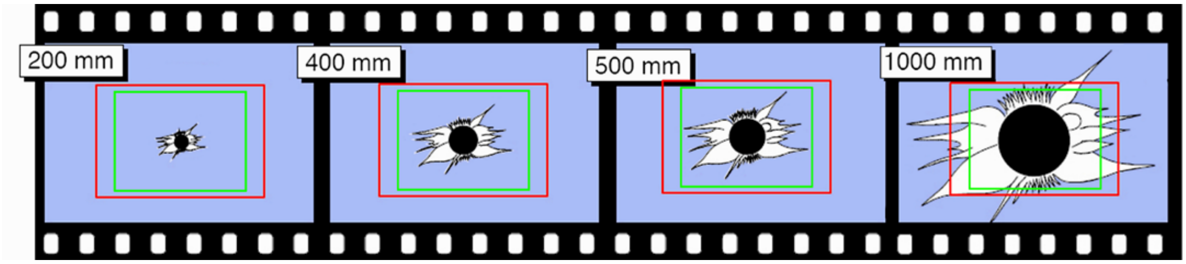
be tiny. To show a moderately large eclipsed Sun and outer corona, you need a lens with a focal length of at least 400 mm. For close-ups of Baily's Beads, the diamond ring, the chromosphere, prominences, and the inner corona, a 1200-mm telephoto (or larger) is recommended. (See the image-size diagram on the next page.)

EXPOSURE COUNTS

While you're shooting the Sun (pre-trip) to see how much of your camera's frame it will fill, also test exposures for the partial phases. Place your camera in manual mode, set the aperture, shoot a range of different exposures (using a solar filter, of course), and see which one produces the most pleasing results. You can then use that setting throughout most of the partial phases of the eclipse.

During the thin-crescent phases, you might want to increase the exposure by as much as one f-stop, since the solar limb (edge) is a little fainter than the center of the disk. If haze or clouds interfere on eclipse day, you may need to bracket by several f-stops (or switch to auto mode) to get a decent exposure.

Photographing totality is a different matter altogether and is something you can't practice beforehand (though you can shoot the full Moon as a brightness test, because it's about as bright as the Sun's inner corona). For specific suggestions on this topic, see "Shooting Totality" on the next page.



The eclipsed Sun's image size is shown for various telephoto lenses starting with a full-frame DSLR (or 35-mm film camera). The outside (red) rectangle indicates the equivalent field of view for Canon and Nikon DSLRs with APS-size chips; the inside (green) rectangle shows the field of view for most Olympus & Kodak DSLRs with their Four Thirds System. [ADAPTED FROM AN ILLUSTRATION INITIALLY PREPARED BY FRED ESPENAK.]

While you're testing exposures, also experiment with your camera's ISO setting. DSLRs often show no noise until the ISO is set above 400; point-and-shoot digitals aren't as good. Before the eclipse, make sure you preset your ISO rating; don't let your camera (via its "auto ISO" function) do it for you.

FOCUS IS CRITICAL

Don't leave the job of focusing to your camera's autofocus system. Manual focus is the way to go, and most telephoto lenses provide this option. As soon as you're set up at your eclipse-viewing site, attach the solar filter to the camera's lens, aim at the Sun, and focus. Take a couple of test shots to ensure the solar limb looks sharp.

Once the lens is focused, secure it by sticking a strip of masking tape to the lens's focus ring. If you're using a zoom lens, lock it to your preferred focal length with tape as well, since it can "self adjust" without warning — particularly if the camera and lens are pointed toward the vertical. At the same time, make sure your solar filter can be easily removed when totality strikes, without affecting the focus or the zoom.

KEEP IT STEADY

Even though you'll likely be shooting the partial phases at reasonably fast shutter speeds, there's nothing like a solid tripod to keep your optical system steady and ready for totality (when exposure times will be longer). The tripod is particularly important if you're using a camera with a long-focal-length lens, which may be heavy and unwieldy.

Quality does count. The left image was shot using an image-stabilized point-and-shoot camera with a 12x optical zoom; the right with a Canon 20Da DSLR camera and an 18- to 250-mm zoom lens racked all the way out to 250 mm. Both were hand held. While the size of the solar disk is about the same (both images are shown at the same scale), the DSLR shows its worth.
[*LEFT:* TQ/PAUL DEANS. *RIGHT:* TQ/RICK FIENBERG]

Many DSLRs or the lenses that attach to them possess image-stabilization (IS) systems. They're useful for normal or wide-angle photography, but image stabilization can help only so much when shooting the eclipsed Sun with a telephoto lens. The combination of IS and a tripod will ensure that your images are as sharp as possible. Two things image stabilization *will* do is let you use a lighter-weight tripod than you might otherwise and help reduce vibrations caused by a breeze.

SHOOTING TOTALITY

While the total phase of a solar eclipse always seems to pass quickly, there are sights and events within totality whose passage is even more fleeting. The diamond ring fades (or brightens) within seconds, and the red chromosphere and prominences aren't visible for much longer. The challenge of imaging totality is capturing these sights during their brief appearance. Fortunately, the corona is visible throughout totality, and just about any exposure will record some part of the Sun's pearly outer atmosphere.

But first — you won't get any pictures of totality if you don't remove the solar filter from your camera at second contact! If you forget, all you'll record is blackness.

Rapid changes occur during second and third contacts. At these times, you do *not* want to be fumbling with your camera's settings. Instead, decide in advance on the f-stop/shutter-speed combination you want for both contacts and set your camera accordingly before the onset of each diamond ring. One suggestion is to use a different shutter speed with the same f-stop (perhaps f/4) for each contact.

The Sun's atmosphere varies tremendously in brightness. The inner corona shines as bright as the full Moon; the outer corona is more than 100 times dimmer. Consequently, one exposure cannot capture the dynamic range of the corona.

That's why eclipse photographers shoot a sequence of exposures (using a fixed f-stop) that range from very fast to very slow. It's called *bracketing* and gives you the best chance of capturing all aspects of the solar atmosphere. At the fast end (1/1000 sec or less), only the innermost corona clinging to the solar limb appears. At the slow end (1 second or longer), the inner corona is burned out, but the faint tendrils of the outer corona show up nicely.

There is no single correct exposure for totality, so your best bet, at any f-stop (say, f/5.6 at ISO 100 or 200), is to shoot a sequence spanning the full range from the short exposure you used for the partial phases to the longest exposure you can manage without blurring (perhaps 1 second).

One thing you do *not* want to do is spend all of totality looking at the Sun through your camera's viewfinder and/or wasting time adjusting your camera's settings. So here's a sequence you might consider:

1) A minute or so before second contact, adjust your f-stop and shutter speed to be ready for second contact.

2) When everyone starts screaming "Diamond ring!" take the solar filter off your camera and start shooting. Keep firing until the brilliant diamond is gone, the corona emerges, and you're enveloped in the darkness of the Moon's shadow.

3) Next, have a quick look around — at the corona, the sky, the horizon, and your fellow eclipse chasers.

4) Now concentrate on shooting the corona. Run through your exposure sequence from fast to slow at a fixed f-stop.

5) Reset your camera so you're ready to shoot at third contact.

6) Now…look up and enjoy the show. The vast range of coronal brightness, the beautiful detail within the corona, and the delicate shading of the sky down to the colors on the horizon are something only your eye can take in. No matter how good your photographs, they won't do justice to the real thing. So make sure you take the time to see totality with your own eyes.

7) You'll have a little warning before the arrival of third contact. The edge of the corona opposite where the Sun vanished starts to brighten, red prominences may rise, and an arc of red light (the chromosphere) appears from behind the dark lunar limb. Third contact is imminent — so start shooting. When the diamond ring becomes too bright to look at, reattach the solar filter to your camera. Totality is over.

If you've never experienced totality before, and totality itself is short, don't attempt a complex photographic sequence. If you feel you must try to capture the event, execute items #1 and #2, then skip straight to #6. If you remember, start shooting again (#7) when you see third contact approaching.

ODDS AND ENDS

- Make sure your camera's flash is turned off. Flashes are an annoyance and, if nothing else, spoil the mood of the spectacle. If you use a point-and-shoot camera, and you're not sure if you can turn the flash off, put a piece of black tape over the flash for extra security.
- Most cameras have optical and digital zooms. Turn off the digital zoom; it's basically useless.

A digital shot of the beginning of totality on July 22, 2009, taken with a 200-mm lens. The photo provides a good sense of the coronal detail visible to the eye (perhaps augmented by binoculars). But to turn your images into something like this requires specialized image-processing software and hours of work at the computer. IMAGE © MILOSLAV DRUCKMÜLLER & PETER ANIOL.

- Shoot at the highest image-quality setting your camera supports.
- Use a remote control or cable release. This is probably an optional extra that didn't come with your camera, so pick up one (and test it) before you depart.
- Bring extra batteries. If the eclipse occurs late in the day, insert fresh batteries before the start of first contact. If you're using rechargeable batteries, charge them fully before you head to the eclipse-viewing site.
- Bring an extra memory card, insert it prior to the start of the eclipse, and then remove it (and lock it, if possible) after the eclipse has ended.

VIDEOGRAPHY

Today's digital camcorders offer excellent picture quality and reasonable sound, and most are quite compact — which makes them perfect for eclipse trips. There is much whooping and hollering when totality strikes, and it's always entertaining to watch and listen to the playback after the event.

The same still-photography "rules" apply to camcorder imagery, especially attaching a proper solar filter to your camcorder's lens if you're shooting the partial phases. Most camcorders have an optical zoom, so experiment before the eclipse to determine the optimum image size of the solar disk (ignore the digital-zoom option). During the partial phases, shoot three- to five-second clips of the Sun every four or five minutes to produce a time-lapse sequence that will compress the multi-hour event into minutes. You'll want to let the camcorder run during all of totality, but don't forget to take the solar filter off at second contact and to replace it at third.

If all you want is a scenic reminder of totality, your little point-and-shoot camera, or even your smart phone, will do. Here's the scene at mid-totality in Uganda (2013), taken with the camera in an iPhone 4S. While the corona is overexposed, the Moon's shadow is visible as the darkened region of high cloud centered on the Sun. [MONICA HILL]

Another option is to set your camcorder to record a wide-field view of your observing site. If you start recording 10 minutes before the onset of totality, you'll capture the changing light levels, the approaching or receding lunar shadow (depending on whether the camcorder is aimed west or east), the horizon glow at totality, and the reactions of everyone around you. Combined with the audio track, it'll likely be one of the most engrossing pieces of video you'll ever shoot.

During the past few years, pocket camcorders have become ubiquitous. They're found in everything from compact versions of regular camcorders to video-capable cell phones. While they're great for sharing videos over the Web or posting on blogs, the image quality and available features leave much to be desired when it comes to eclipse videography.

Another option is to use your DSLR to record high-quality video and audio. If you want to go this route, make sure you decide, *in advance,* whether you want to shoot stills or video, and then follow the appropriate tips given elsewhere. *Do not change your mind at the last minute!* Reconfiguring your camera with totality bearing down on you makes it likely you'll end up with no images or video at all.

BUT ALL I WANT IS A PICTURE!

What if you don't have big-time camera gear, or you just want to enjoy the eclipse…but still want a photographic memento of the event? Here's a little secret: Forget everything you just read! Well, maybe not everything (especially not the details about using solar filters), but a lot of it! Here's why.

Late-model cameras and lenses allow you to do things that weren't possible before and that render some of the tried-and-true traditional advice moot. For example, thanks to image stabilization, you can handhold a camera with a modest telephoto lens, even on a moving ship or aircraft, and achieve sharp images with exposures as slow as 1/15 second. And thanks to reasonably noise-free high-ISO performance, you can use ISO settings of 1600, 3200, or even higher. This means those 1/15 sec exposures can capture the middle to outer corona.

Thanks to sophisticated autofocus capabilities, you can even get away with no manual focus capability. Instead it's possible to autofocus on the eclipsed Sun using the arc where the Moon's silhouette is ringed by the bright corona. However, first you have to tell your camera to autofocus using only the center spot, not the whole array of spots.

Finally, if you do end up with a series of totality exposures, you can turn them into a thing of beauty even if they're not aligned. There's image-processing software that allows you to rotate/align individual frames to match and create seamlessly blended stacks of short, medium, and long exposures to achieve amazing results. The lovely image at the start of this article (page 12) is a composite of 13 shots with exposures ranging from 1/1600 to 1/13 second at ISO 640 and f/10.

FINAL THOUGHTS

A little preparation goes a long way. Always perform at least one dry run with all your gear before departing. This is critical because, depending on your destination, you might not be able to pick up forgotten equipment or replace gear that you discover doesn't work once you're on site.

However you decide to photograph the upcoming total solar eclipse, remember to actually look at the event. Don't spend all your time gazing at totality through your camera's viewfinder. No image, still or video, can compare with the experience of the real thing. ●

PACKING FOR ECLIPSE TRAVEL

IF YOU'RE OFF to see an eclipse and are bringing an assortment of cameras and telescopes, packing can be a challenge. If serious telescopic gear is going with you and you're flying, you already know that you have to check it, and you probably also know what you have to do to get it there safely.

But if you have a small portable telescope and/or a camera with a telephoto lens, you can (and should) carry it with you at all times. So here are a few tips for traveling with optics — whether to an eclipse or on any other excursion.

INSURANCE. Before you pack, insure your optics. No matter how careful you are, accidents happen. Replacing a small digital camera isn't expensive, but replacing a DSLR and telephoto lens is, and replacing a telescope gives new meaning to the word "pricey." Whatever you take, make sure it's covered.

CARRY ON. If you're flying to your destination, or if air travel is part of the trip, don't check optical gear unless it's absolutely unavoidable. With a large telescope, you have no choice, but small scopes and cameras should be part of your hand luggage. Keep in mind that airlines operating flights within a destination country often have lower size and weight limits for carry-on bags than do international flights. Therefore, pack your carry-on to the minimum size requirement.

PAD THE BAG. There's no need to be completely bereft of a change of underwear if your checked luggage (containing your clothes) is delayed or lost. Your gear-laden carry-on bag needs to be padded, so why not wrap your cameras and lenses in a few clothes? They'll cushion your optics and provide you with an emergency change of clothes if your checked bag is "misplaced" or "arrives missing."

REMEMBER: Extra clothes you can get anywhere. Replacements for damaged or forgotten optical gear are harder to come by.

TRIPOD. A large tripod for a large telescope is one item that can't be carried with you on the aircraft. Tripods for cameras are on the edge — some can be compacted enough to take as carry on, others can't. If you must check your tripod, have a contingency plan in case it doesn't arrive. Identify camera stores near your hotel in your arrival city. Or consider bringing along a tabletop or mini-tripod, or one of the odd-looking Gorillapods as a backup — it's better than nothing.

CRITICAL SPARES. Carry on critical items that might not be readily available at your destination. These include batteries for everything needing power, international power converters to charge your rechargeables, at least one spare memory card, and solar filters for your optics. Don't overlook important non-photographic items either. Prescription glasses and any medications should never be packed in checked luggage.

KEEP WATCH. Finally, never lose sight of your carry-on bag with all its optical gear. Even when transferring from airports to hotels, or moving by bus from one location to another, do not let that gear-laden case out of your sight — *ever.*

By keeping your bag with you at all times, you minimize the chances of theft or damage (or delays if your gear is in a checked bag that's lost). In many cases, optical equipment cannot be repaired or replaced at your destination; even a spare battery might be hard to find. ●

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