

AN OBSERVER'S GUIDE TO VIEWING THE ECLIPSE

SOLAR SCIENCE

ALL-AMERICAN TOTAL SOLAR ECLIPSE

AUGUST 21, 2017

By Andrew Fraknoi and Dennis Schatz

On Monday, August 21, 2017, a total eclipse of the Sun will be visible in the continental United States for the first time in almost 40 years. A *total* eclipse is when the Sun is completely hidden by the Moon, the sky becomes dark, and the Sun's faint atmosphere (*corona*) becomes visible—looking like a beautiful halo (Figure 1). This total eclipse will *only* be visible on a narrow track stretching across the United States from Oregon to South Carolina. No other country will get to see the total eclipse this time.

The rest of the United States and other parts of North and Central America will see a *partial* eclipse, in which the Moon covers only a portion of the Sun. A partial eclipse is interesting, but nowhere near as awe-inspiring and memorable as a total eclipse. A partial eclipse is also dangerous to look at without something to protect your eyes from the Sun's damaging rays.

What Exactly Is a Total Eclipse of the Sun?

A total eclipse of the Sun occurs when the Moon gets between the Sun and the Earth and covers up the Sun. It just so happens that the Moon, as seen from Earth, and the Sun, as seen from Earth, are the same size in the sky. So if the two are exactly lined up, the Moon can hide the Sun from our sight. This allows us to see the Sun's corona,

FIGURE 1

During a total eclipse, the Sun is covered by the Moon, and the faint light of its corona becomes visible.



Source: Luc Viatour, Wikimedia Commons, CC BY-SA 3.0. https://en.wikipedia.org/wiki/File:Solar_eclipse_1999_4_NR.jpg

which appears as a beautiful ring of light around the edge of the dark Moon. The sky becomes so dark that the stars become visible, birds stop chirping because they think it is time to roost, and people have an eerie sense of it being night in the middle of the day. Many people feel that this is one of the most beautiful natural sights and worth seeing at least once in a lifetime.

Total eclipses of the Sun are only visible on a small part of the Earth's surface where the lineup of the Moon and Sun is exact and the Moon's shadow is darkest (Figure 2). If you are outside the zone of totality (which in 2017 will only be about 60–70 mi. wide), you will see just a partial eclipse. During a partial eclipse, part of the Sun is still visible, and the Sun is dangerous to look at. You will need protection for your eyes before you can look directly at the Sun—or you will need to project an image of the Sun (see instructions starting on p. 8).

How Long Will the Total Eclipse Last?

The exact cosmic lineup that forms a total eclipse lasts only a short time in any given location. The total phase in 2017 will last a maximum of 2 minutes 40 seconds in the center of the Moon's shadow.

(This is short for a typical total solar eclipse; some can last 7 minutes.) The exact time it lasts depends on your location in the shadow band. The closer you are to the central line of the eclipse shadow, the longer you will have to enjoy the spectacle.

Also, the sky must be clear to see the eclipse. If clouds hide the Sun, you will not see the eclipse at all—you'll miss all the fun. Selecting the spot to watch the eclipse also means researching the history of August weather in each location.

Where and When Can I See This Total Eclipse?

For those in the United States, the August 21 eclipse begins on a beach on the west coast of Oregon, and ends on a beach on the east coast of South Carolina, making a narrow diagonal track across the United States. It goes through portions of Oregon, Idaho, Wyoming, Nebraska, Kansas, Missouri, Illinois, Kentucky, Tennessee, Georgia, and South Carolina. Figure 3 shows the areas it will cross.

Note that the center line of the total eclipse really doesn't go through any of America's largest cities. It *will* be visible from Nashville and parts of the St. Louis and Kansas City metropolitan areas. But in

FIGURE 2

Diagram showing how the Moon blocks the Sun from Earth (not to scale)

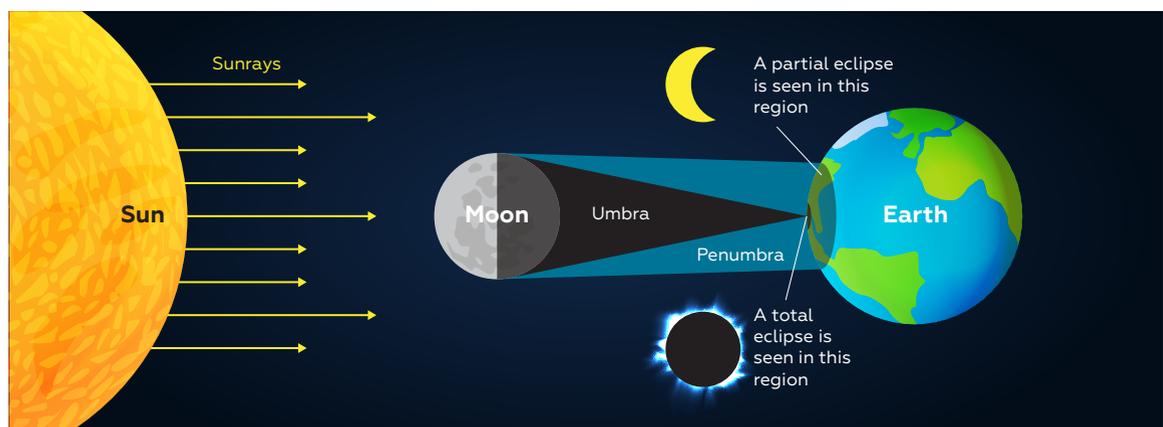


FIGURE 3**Map of the 2017 total eclipse path in the United States**

Source: Xavier Jubier; used with permission.

Los Angeles, the eclipse will only cover 62% of the Sun, in Chicago 87%, in New York City 72%, and in Miami 78%. See Table 1 (p. 4) for information regarding more cities.

Smaller towns that are well placed for total eclipse viewing include Salem, Oregon; St. Joseph, Missouri; Carbondale, Illinois; Hopkinsville, Kentucky; and Columbia, South Carolina. The websites at the end of this insert allow you to play with interactive maps and view lists of towns or parks where the total eclipse will be visible. But bear in mind that many of the best places to view the eclipse (meaning good weather predicted and long eclipse times) are likely to be sold out in terms of lodging and eclipse gatherings long before August 2017. If you want to travel to the total eclipse path, you need to plan ahead. Table 2 (p. 4) contains specific information about the Sun's height and the times for parts of the total eclipse in select cities.

The partial eclipse will be visible all over North America, weather permitting. Millions of people will see a big bite taken out of the Sun as the Moon gets in front of it. If you want to safely enjoy it, however, you must know how to protect your eyes.

What's the Best Location for Seeing the Total Eclipse?

There is no simple answer to this question. The ideal place to be is on the center line near a town or park where the weather is usually clear. The "wild card" is undoubtedly going to be the weather. One way to find the best places is to use some of the websites we recommend (or to search the web) to see where tourist groups and astronomer-led tours are going. They will most likely have done research about where weather prospects are likely to be the most favorable. Meteorologist Jay Anderson is the "guru" of eclipse

TABLE 1

Circumstances of the August 21, 2017 partial eclipse for the largest cities in the United States

(Note: None of the largest U.S. cities will see the total eclipse.)

City	Eclipse starts	Max eclipse	Eclipse ends	Fraction of Sun's diameter covered	Percentage of Sun's area covered
New York City	1:23 p.m.	2:45 p.m.	4:01 p.m.	0.77	71%
Los Angeles	9:06 a.m.	10:21 a.m.	11:45 a.m.	0.69	62%
Chicago	11:54 a.m.	1:20 p.m.	2:43 p.m.	0.89	87%
Houston	11:47 a.m.	1:17 p.m.	2:46 p.m.	0.73	67%
Philadelphia	1:21 p.m.	2:44 p.m.	4:01 p.m.	0.8	75%
Phoenix	9:14 a.m.	10:34 a.m.	12:00 p.m.	0.7	63%
San Antonio	11:41 a.m.	1:09 p.m.	2:38 p.m.	0.69	61%
San Diego	9:07 a.m.	10:23 a.m.	11:47 a.m.	0.66	58%
Dallas/Ft. Worth	11:40 a.m.	1:10 p.m.	2:39 p.m.	0.8	75%
San Francisco	9:01 a.m.	10:15 a.m.	11:37 a.m.	0.8	76%
Indianapolis	12:58 p.m.	2:25 p.m.	3:49 p.m.	0.93	91%
Washington, DC	1:18 p.m.	2:43 p.m.	4:02 p.m.	0.84	81%
Miami	1:27 p.m.	2:59 p.m.	4:21 p.m.	0.82	78%

TABLE 2

Eclipse information for selected cities where the eclipse will be total

City	Partial eclipse starts	Total eclipse starts	Total eclipse ends	Partial eclipse ends	Sun's altitude at totality
Salem, OR	9:05 a.m.	10:17 a.m.	10:19 a.m.	11:38 a.m.	40°
Casper, WY	10:22 a.m.	11:43 a.m.	11:45 a.m.	1:09 p.m.	54°
St. Joseph, MO	11:41 a.m.	1:06 p.m.	1:09 p.m.	2:34 p.m.	62°
Carbondale, IL	11:52 a.m.	1:20 p.m.	1:23 p.m.	2:48 p.m.	64°
Nashville, TN	11:58 a.m.	1:27 p.m.	1:29 p.m.	2:54 p.m.	64°
Columbia, SC	1:13 p.m.	2:42 p.m.	2:44 p.m.	4:06 p.m.	62°

weather, and many of the websites we recommend will carry his predictions. But, as you know from life experience, no one can predict the weather for sure. And if it turns out to be cloudy in a popular location, lots of people will try to move to get away from the clouds, perhaps creating traffic jams on small roads not designed for such crowds. So it will be important to be prepared and have a backup plan.

Are Eclipses of the Sun Dangerous to Watch?

The Sun's visible (and invisible) rays can cause serious damage to the sensitive tissues of the eyes, often without one being immediately aware of it! Normally, our common sense protects us from looking directly at the Sun for more than a second. But during an eclipse, astronomical enthusiasm can overwhelm common sense, and people can wind up staring at the Sun for too long. Make sure you have something with you to protect your eyes before the eclipse becomes total—or if you are only seeing the partial eclipse (see suggestions on the next couple pages).

The few minutes of total eclipse (when the Sun is completely covered) are safe, but any time that even a small piece of the bright Sun shows, your eyes are in danger. Astronomers will be working with many organizations and companies to help everyone observe the eclipse safely. Paper glasses with special filters made of protective material will be sold in a variety of places.

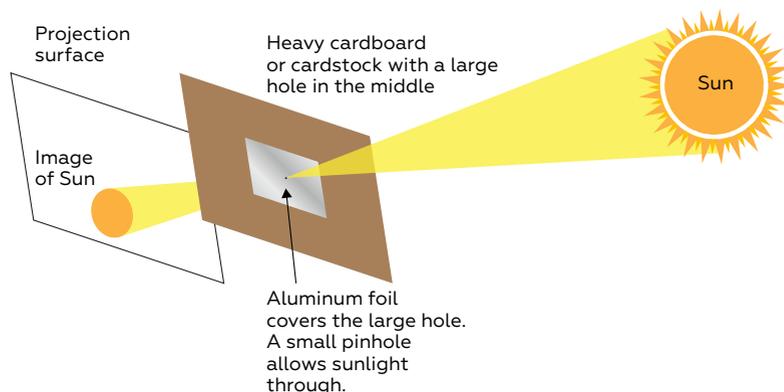
What Are Some Ways I Can Watch the Eclipse Safely When Part of the Sun Is Still Visible?

PINHOLE PROJECTORS TO INDIRECTLY VIEW THE SUN

If you don't have safe glasses, a good way to see the eclipse is to project an image of the partially

FIGURE 4

A pinhole projector made with two pieces of cardboard



eclipsed Sun. One easy method is to make a pinhole projector. Take two pieces of cardboard or thick paper. Put a pinhole in one (taking care to make a small, neat hole). Then, stand with your back to the Sun and let the Sun's light fall through the hole and onto the other sheet (Figure 4). You'll get a small but distinct image of the Sun. (A way to get a sharper pinhole is to cut a square out of the middle of one piece of cardboard, tape a sheet of aluminum foil over the hole, and put the pinhole in the foil instead of the cardboard.) The farther apart the two pieces of cardboard or paper, the larger the image of the Sun will be (but it will be a small image in any case).

You can also make such a pinhole projector inside a box, such as a cereal box or a tube or poster shipping box. Again, the image of the eclipsed sun on the box will be quite small, but it will be distinct.

You can find instructions for

- a cereal box viewer at http://hilaroad.com/camp/projects/eclipse_viewer/eclipse_viewer.html; and
- a UPS triangular shipping box viewer at www.exploratorium.edu/eclipse/how.html.



Safety note: You should definitely NOT look at the Sun through binoculars or a telescope, except during totality, because they concentrate the rays and make looking at the Sun *more* dangerous, not less. Only use such instruments to look directly at the Sun if you have a reliable solar filter specifically designed to fit them and know how to use it!

SUN FILTERS TO LOOK DIRECTLY AT THE SUN

To look at the Sun directly, except during the total phase of the eclipse, you need a good filter that can cut out not just its intense light but also its ultraviolet and infrared waves. Sunglasses and smoked glass are NOT OK! If you have access to welder's supplies (and not many people do), #14 arc-welder's glass is an excellent filter (but it has to be #14 and not a lower number). Alternatively, you can use special black or aluminized polymer filters or glasses available at many telescope stores or planetariums; but make sure you get them from a reliable source. Companies making and selling them in bulk include the following:

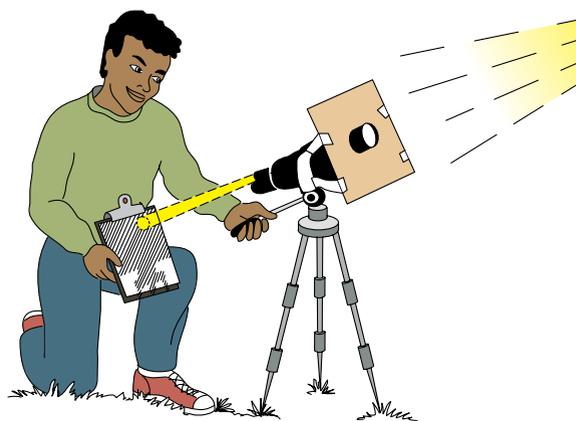
- Rainbow Symphony:
www.rainbowsymphony.com/eclipse-glasses.html
- American Paper Optics:
www.eclipseglasses.com
- Thousand Oaks Optical:
www.thousandoaksoptical.com/eclipse.html

PROJECTING AN IMAGE OF THE SUN THROUGH BINOCULARS

You can use one side of a pair of binoculars and a tripod to project a larger image of the eclipsed Sun. Before going outside, tape the lens cover to the opening of one side of the binoculars. If there is no lens cover, tape a piece of cardboard over the opening so no light can enter that side of the binoculars. Outside, extend the tripod to its full length and attach the binoculars securely to the tripod head. Then, cut a hole in the center of

FIGURE 5

Using binoculars to project an image of the Sun



Source: Schatz, D., and P. Allen. 2003. *Astro adventures II: An activity-based astronomy curriculum*. Seattle, WA: Pacific Science Center, p. 52.

the cardboard the same size as the binocular opening you did not cover. Slip the cardboard over the opening and tape it in place. See Figure 5 for how the setup should look when complete. Now point the large end of the binoculars toward the Sun and have someone else hold a white sheet or cardboard some distance away from the smaller end. Move things around until you see an image of the Sun on the paper or cardboard. Use the focus knob of the binoculars to make the image of the Sun sharper.

Do I Need a Telescope to See the Total Eclipse?

In a word, no. If you are in the right place in the zone of totality, and it's not cloudy, you are doing fine. Total eclipses are very democratic—they are

spectacular without any expensive equipment. Your eyes are all you need. In fact, by narrowing your view of the scene with a telescope, you miss the wonderful contrast between the glowing ring around the Sun and the darkening sky, which many people think is the best part. You could look at the total eclipse with a pair of binoculars to see the eclipsed Sun magnified, but only if they are right at hand. Don't miss the few minutes of the total eclipse scrambling around for equipment.

Advanced observers who want to photograph the eclipse will be using telescopes with special adapters for their cameras. But, especially if you are at your first eclipse, forget instruments, forget taking photos, and just relish the brief experience with all your senses.

What Do Experienced Eclipse Chasers Recommend for Those Who Are Seeing Their First Eclipse?

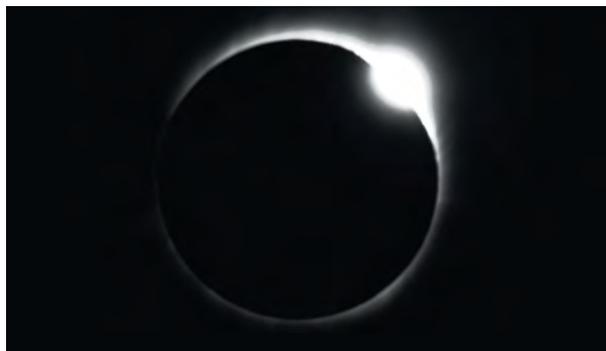
Some of their helpful hints include the following: Expect a big crowd and prepare for it. Everyone in your group should go to the bathroom just before leaving for viewing the eclipse. Bring drinks and snacks with you. Don't neglect the sunscreen, hats, and sunglasses if you are in an open area. For young kids, bring something to keep them occupied while waiting. For older people, bring a folding chair and a sun umbrella. (Remember sunglasses are for reducing glare; they don't have the protection to let you look directly at the Sun!)

What Should I Expect to Happen During a Total Eclipse?

As more and more of the Sun is covered by the Moon, shadows become sharper, temperatures (slowly) lower, and the sky grows darker. If you are viewing from high ground, you may be able to see the Moon's shadow on the land racing toward you (but that's not always easy to see).

FIGURE 6

The "diamond ring" effect during the total solar eclipse on July 22, 2009



Source: Lutfar Rahman Nirjhar, Wikimedia Common, CC BY-SA 3.0. https://commons.wikimedia.org/wiki/File:Diamond_Ring_of_22July,_2009.jpg

Just before the Moon completely covers the Sun, it will get significantly darker, and you may see "the diamond ring effect" (Figure 6). For a second, you see the faint ring of the Sun's last crescent of light and then the bright (diamond) flash of the last glimpse of the Sun. That flash is the light of the Sun glimpsed through a valley on the edge of the Moon.

Then, when the Sun is completely covered, the outer atmosphere (the Sun's corona) becomes visible as a faint flickering glow around the dark disk of the Moon. Sometimes, you can see red or pink *prominences*, small tongues of hot material jutting outwards. Also, take a moment to tear your eyes away from the Sun and glance around. The world is dark, but it's a darkness that is not quite like night and nothing like a cloudy day. (The sky near the Sun may look darker than the sky near the horizon.) You can frequently notice the absence of sound as wind dies down and living things seem to hold their breath.

You may see another diamond ring as the Sun emerges from behind the Moon, and then it's time to get protection in front of your eyes as a glowing sliver of the Sun becomes blindingly bright.

Why Is There Not an Eclipse Every Month, When the Moon in Its Orbit Reaches the Direction of the Sun?

The orbit of the Moon is tilted by about 5° from the orbit of the Earth around the Sun. This means that most months the Moon's position is either above or below the Sun's position when they are in the same part of the sky. But every six months or so, the two orbits cross, and then eclipses of the Sun and of the Moon happen. Total eclipses of the Sun are visible in only a narrow path along the Earth where the Moon's shadow is really dark. A century or more can pass before any given location on Earth sees a total solar eclipse again.

If I Miss This Eclipse, When Is the Next One Visible From the United States?

The next total solar eclipse to go through the continental United States will be on April 8, 2024. It will mostly go through a different set of states than the one in 2017.

Resources for Further Information

Eclipse maps for 2017 by Michael Zeiler: www.eclipse-maps.com/Eclipse-Maps/Gallery/Pages/Total_solar_eclipse_of_2017_August_21.html

Eclipse2017.org (by Dan McGlaun, an eclipse enthusiast): www.eclipse2017.org/eclipse2017_main.htm

Google map with solar eclipse path by Fred Espenak: <http://eclipses.gsfc.nasa.gov/SEmono/TSE2017/TSE2017.html>

How to Look at the Sun (*Sky and Telescope*): www.skyandtelescope.com/astronomy-news/observing-news/how-to-look-at-the-sun

Observing the Sun for Yourself (Stanford Solar Center): <http://solar-center.stanford.edu/observe>

Sky and Telescope's 2017 Eclipse Page with Jay Anderson's chart of best bets for good weather: www.skyandtelescope.com/astronomy-news/observing-news/americans-will-see-total-solar-eclipse-in-2017

The Great American Eclipse Site (by Michael Zeiler and Polly White): www.greatamericaneclipse.com

American Astronomical Society eclipse center: <http://eclipse.aas.org>

About the Authors

Andrew Fraknoi is the chair of the Astronomy Department at Foothill College near San Francisco, and the coauthor of a popular college textbook in astronomy. Asteroid 4859 has been named Asteroid Fraknoi in his honor.

(See: www.foothill.edu/ast)



Photo by Tucker Hiatt

Dennis Schatz was, for many years, the senior vice president of the Pacific Science Center in Seattle, and is the author of 23 science books for children. He was program director for science education at the National Science Foundation for four years.

(See: www.dennischatz.org)



Photo by the Association of Science-Technology Centers

About This Insert

This article is adapted from the book *Solar Science* by Dennis Schatz and Andrew Fraknoi, published by the National Science Teachers Association. The book includes activities and information about the Sun, its movements in the sky, its effects on Earth, and its eclipses (for use by teachers, after-school leaders, museum and planetarium educators, youth group leaders, etc.)



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