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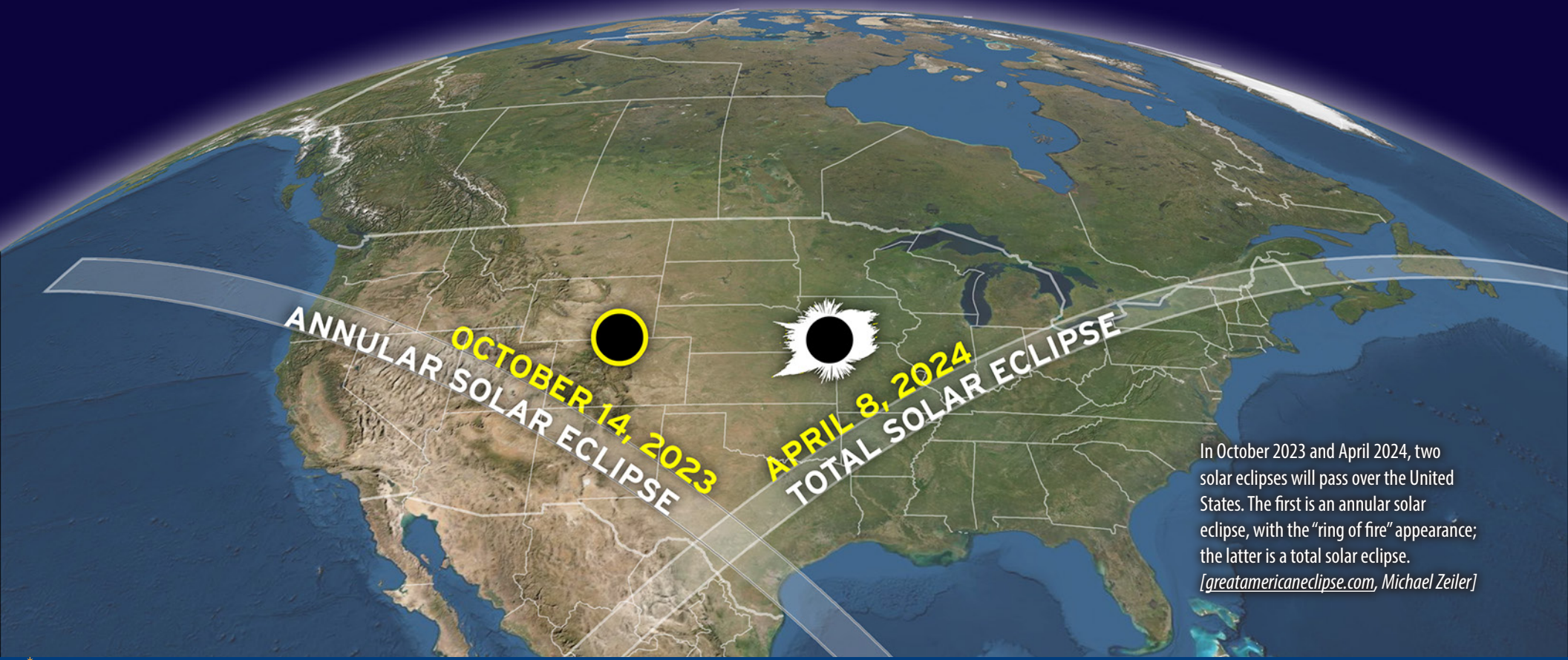
The Sun, Moon, and You

This guide will help you prepare yourself, students, friends, and neighbors — and provide tips on running events — for the October 2023 and April 2024 solar eclipses.

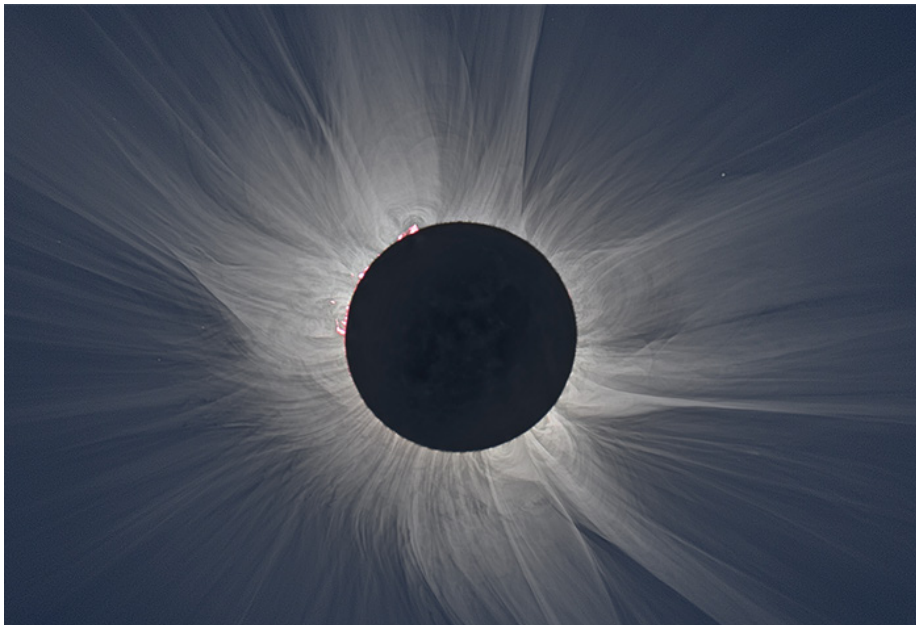
By Douglas Duncan



In October 2023 and April 2024, two solar eclipses will pass over the United States. The first is an annular solar eclipse, with the "ring of fire" appearance; the latter is a total solar eclipse. *[greatamericaneclipse.com, Michael Zeiler]*

Can you name a science event that will engage 100 million people? I can: a total eclipse of the Sun. A NASA and University of Michigan survey found that over 100 million people saw the 2017 Great American Eclipse, either in person or online. In 2023 and 2024, two solar eclipses will be visible throughout the United States, and we have a great opportunity to enable students and others to enjoy a rare spectacle.

This article is to help you prepare yourself, students, friends, and neighbors for the upcoming eclipses. It debunks some of the most common misconceptions about eclipses that I have seen during the 12 eclipses I've experienced. It also explains how you can fund raise and financially sustain such events, or even profit for your school or organization, as my university has done. By providing safe eclipse-watching glasses, information and guidance about how to watch



A total solar eclipse is an awe-inspiring and memorable sight. *[S. Habbal, M. Druckmüller and P. Aniol]*

The author viewed his first eclipse March 7, 1970, at a small village near Miahuatlán, near Oaxaca, Mexico. *[Douglas Duncan]*

an eclipse, and how to take pictures with a phone, you'll greatly improve people's eclipse-viewing experience.

My first solar eclipse was on March 7, 1970, at a small village near Miahuatlán, near Oaxaca, Mexico. Two friends and I drove for five days from Pasadena, California, in a Volkswagen Beetle. The total eclipse lasted 3 minutes and 20 seconds, but it seemed *much* faster. I brought a telescope and camera, and my plan was to take just a few pictures and then watch totality. I taped a countdown, with my voice saying, "Three minutes left, two minutes 50 seconds left…" and so on, so that I would not have to waste time looking at my watch in the dark. By the time I noticed the recording, it was saying, "60 seconds left…!" After totality, I looked at my camera and found that I had taken 20 photos! The time flew by. So, I warn you — the total

part of an eclipse is so dramatic that you are likely to lose track of time, which is short and precious. Plan beforehand what you intend to do during those short minutes, and don't plan too much.

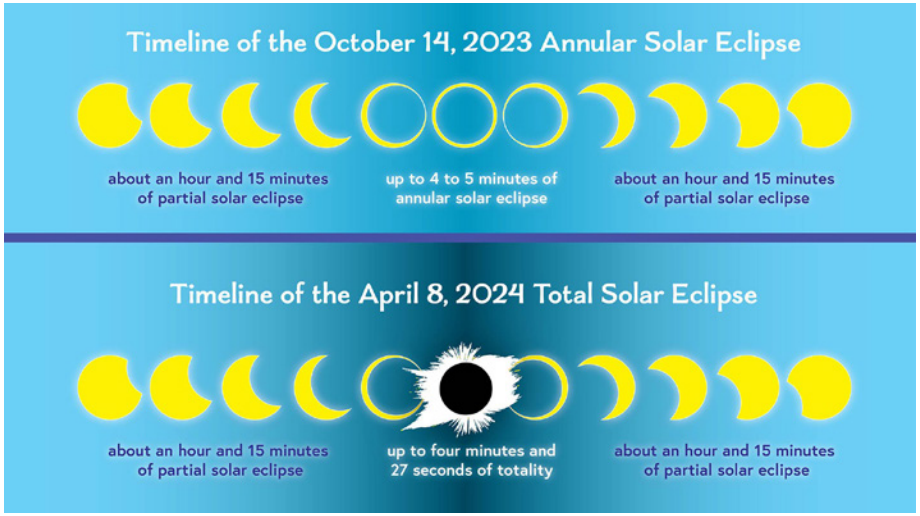
The sight of a total eclipse was so beautiful and profound that I continued chasing them all over the world. I lead groups of people to see eclipses, and many of them get "hooked" and become eclipse chasers.

I also experience great frustration at every eclipse. I see so many people realize at the last minute that there is something spectacular to see but, being unprepared, miss it. They hadn't planned ahead and bought eclipse-watching glasses, and without them, they couldn't view the partial phase safely. If you help people prepare — for example, if you run a school or community event — you will receive much thanks. Plus, there's a bonus if you prepare this event well with enough supplies: You can make thousands of dollars profit. Because many people don't realize that an eclipse is coming until the news blitz that always happens just a few days before, *you* can be the one who prepares in advance, in ways outlined below. As an example, for a partial eclipse in 2012, we prepared and opened our football stadium, and 10,000 people attended!

90% partial eclipse ≠ total eclipse

Far more people see a partial eclipse than a total eclipse because you need to be in just the right place to see the Sun totally covered by the Moon, whereas an entire continent can see a partial eclipse. Only people inside the grey path labelled "Total Solar Eclipse" in the map at the start of this article will see a total eclipse.

It is nearly impossible to convey how spectacular a total eclipse of the Sun is to someone who hasn't seen one. Maybe you have seen a partial solar eclipse, and you think that if you've seen most of the Sun covered by Moon, then you've seen most of what a total eclipse offers. Wrong. Entirely wrong! The Sun is enormously bright,



This graphic shows how much time each partial and total phase of the next two solar eclipses lasts. [greatamericaneclipse.com, Michael Zeiler]

so bright in fact that only 1 percent of our star is as bright as 4,000 Full Moons. That is why even a 99 percent partial eclipse misses the spectacular effects one sees during a total eclipse — the remaining sunlight is too strong. That is why it is worth travelling to where an eclipse is total if you possibly can.

If you can't travel to the total eclipse, watch the partial one. The *entire* continental U.S. will see at least part of the Sun covered by the Moon on October 14, 2023, and again on April 8, 2024 — a view that special eye wear can let you see. It is a strange and interesting sight to see the Moon take a dark "bite" out of the Sun.

Safety matters

People often ask if there is dangerous radiation when there's an eclipse, and the answer is, there's sunlight! Sunlight *is* radiation, and it is dangerous if not observed properly. Eclipse day is just like any other day. You may have seen a lens focus sunlight and burn paper. If

your eye lens focusses sunlight, it can burn your retina. So, you **must protect your eyes** to look at the Sun.

Two American companies, American Paper Optics and Rainbow Symphony, have produced tens of millions of inexpensive glasses for looking at our star. These have been used safely at many eclipses for decades. It is important to order these well in advance of either eclipse, because at the last minute, the factories get overwhelmed with orders. An important warning: It is common for cheap glasses from China to flood eBay and other markets before an eclipse. Never trust glasses not produced by reputable vendors to protect your eyes. I once helped destroy 100,000 substandard glasses from China that falsely claimed to have passed the International (ISO) quality standard allowing only a specific amount of radiation through the filters.

You MUST Protect Your Eyes to Look at the Sun

The Sun appears more than a billion times brighter than the brightest stars and 400,000 times brighter than the Full Moon. Your eye can handle the enormous differences between day and night because it has a logarithmic response, so that what appears to be a brightness ratio of 1, 2, 3, 4, 5… is actually 2, 4, 8, 16, 32 … in terms of energy output. Even a thin solar crescent exposing 1 percent of the Sun is bright enough to prevent you from seeing the solar corona and prominences. That same amount of light could have detrimental effects on your unaided eyes. Special eclipse-watching glasses are 1,000 times darker than sunglasses. The frames are made of cardboard, and their film lenses have been certified to pass only safe amounts of visible, infrared, and ultraviolet light.

Use only certified glasses to look at the Sun — even during the partial phase of an eclipse. *[ASP]*

You can use binoculars to project an image of the eclipse's partial phase onto paper. *[Douglas Duncan]*

If you have a small group, you may project an image of the Sun using binoculars. As this video shows, you don't look at the Sun; instead, you turn binoculars into a projector. When I do this, I always deputize one other person to be sure no one grabs the binoculars, because I tend to get very wrapped up in answering questions when I have a group.

Another way to view an eclipse is by photographing it. But that's not as easy as it sounds. At previous eclipses, I've noticed that many people were trying to take photos of the Sun with their phone. They often failed, because phone cameras are programmed to take photos of people, not of a white ball against a light-blue background. Also, sunlight can damage your phone camera just as it would damage your eye if you didn't use a filter.

For that reason — shameless plug coming — I spent 2021 developing a filter and app that make it easy to take pictures of the Sun with your phone camera. "Solar Snap" comes with glasses for you,

Dr. Douglas Duncan's Solar Eclipse Suggestions

The author, pictured here using eye protection to view the partial portion of the August 2017 solar eclipse, organized a viewing event in Wyoming. *[Douglas Duncan]*

- If a total eclipse passes within a day's drive of where you are, try to go see it! You will remember it vividly for the rest of your life. A partial eclipse of any percentage — even more than 95 percent — is very interesting but it is not *nearly* as spectacular as a total eclipse.
- If this is your first total eclipse, do not attempt to photograph totality. Good eclipse photography is difficult, and the short duration of totality (mere minutes) passes unbelievably quickly. You'll be able to find great shots of totality on the web after the event.
- Use binoculars **only during totality**, when the Moon completely covers the Sun. The view of prominences and the Sun's corona is unbelievably beautiful in binoculars. Before the diamond ring marks the reappearance of the Sun, you must stop looking through the binoculars or else the focused light could damage your retinas.
- You will not see many stars during a total eclipse because in doesn't get fully dark, but you can still see bright stars and planets. Look around you for the circular sunrise along the horizon.
- If you have a "countdown" that you start to play at the beginning of totality, it can be helpful. You do not want to waste precious time trying to look at your watch in the dark. There is now an app to help you. If you make a countdown recording, insert reminders to look for planets, look at the horizon glow sunset, warn about the approaching end of totality, and so on. Totality goes by very, very fast, and there is no "replay!"

The author developed Solar Snap to enable more people to take photos of the Sun with their smartphones. Inset: Through the Solar Snap phone application, the author captured the crescent Sun. *[American Paper Optics, Douglas Duncan]*

phone filters that are made of the same filter material as the glasses, and a free mobile application optimized for taking Sun photos. It also has two Velcro© dots to attach the filter to your phone. I tested Solar Snap at a partial eclipse in 2021, with the results seen here, and then 100 people beta-tested it. Solar Snap can be ordered here. A portion of every purchase will go to support the ASP.

What you see at a total eclipse

A total eclipse and a partial eclipse start out the same. The Moon slowly creeps in front of the Sun, taking more than an hour to do so. Use safe eclipse-watching glasses to follow the progress. During this partial eclipse, if you are near any trees that let light filter through their

leaves to the ground, you will see hundreds of little "crescent Suns" on the ground. Each one is an image of the Moon covering part of the Sun. A colander, a woven blanket, or even a small hole punched in a piece of paper will also project an image onto what's below.

When the visible disk of the Sun becomes a sliver, the pace of the eclipse seems to accelerate. Perhaps 20 minutes before *totality*, the term used for the time during which the Moon completely covers the Sun, the temperature around you starts to drop. Shadows become sharp-edged because the source of light is getting smaller. Colors appear more saturated.

When only a tiny bit of the Sun remains, the darkening seems to accelerate even more. You may see bright planets such as Venus or

Each hole between leaves acts as a pinhole camera, letting an image of an eclipsed crescent Sun through. *[L. Arthurs]*

As the Moon blocks most of the Sun's light, you'll notice the landscape colors changing and shimmering. You may even notice what looks like sunset across the horizon. The *Mercury* editor captured this photograph of the Atacama Desert during a solar eclipse in 2019. *[Liz Kruesi]*

Jupiter, as you would at dusk. (Know beforehand what planets will be in the sky and where.) The Moon's shadow is rushing toward you at about a half-mile per second. If you are at a place where there are mountains or clouds in the distance and you face west, you can see the mountains or clouds go dark as the lunar shadow envelops them perhaps 10 to 15 seconds before totality reaches you. It is eerie!

Stranger still is that the entire color palette of the landscape seems to shimmer with a silvery hue. I often feel as if I'm in a science fiction movie, or a dream.

Then, suddenly, totality hits. You see the long silver streamers of the Sun's outer atmosphere, its corona, stretch across the sky,

The "diamond ring effect" occurs during the final moments of totality, as the Sun starts to peek through lunar valleys. *[NASA/Rami Daud, Alcyon Technical Services]*

making patterns shaped by the Sun's magnetic field. You see the pink flames of prominences at the Sun's edge. The Moon makes an incredibly black "hole" in the center of the picture. It is usually too dark to see a watch or the dials on a camera, but it's not like night — only the very brightest stars and planets are visible. I always view totality with a good pair of binoculars. This gives a wonderful view, and I recommend it strongly. Of course, you can use unfiltered binoculars during only the *total* part of the eclipse — otherwise you would damage your eyes! Plan beforehand to know exactly how long totality will last in your location, and maybe make a recorded countdown like I did at my first eclipse.

During totality, take time to look around. If there are animals, they may do strange things. In a Bolivian eclipse, llamas surrounded us. We didn't notice the llamas at all before totality; no one saw where they came from. They came down a trail towards us, then just milled around! In the 1999 Galapagos eclipse, dozens of whales and dolphins surfaced right next to our small ship, stayed for totality, and then swam away. We never saw them again.

Also, look into the distance. The Moon's shadow during the 2024 eclipse will be roughly 100 miles in diameter. That means if you are in the middle of the path of totality, 50 miles away the ground and sky are still in sunlight. If you have a clear horizon, you can see a 360° sunset!

No video can capture a total eclipse the way your eyes can. Totality seen in person is something you will never forget. But the audio can give you an idea of how people react. They scream and cheer. My home page has videos of animals at eclipses, a totality video edited for use on radio and TV, and an unedited video that shows how college students reacted to this celestial event that looks like the end of the world. They say much more than, "Holy cow!" (It is R-rated for language.)

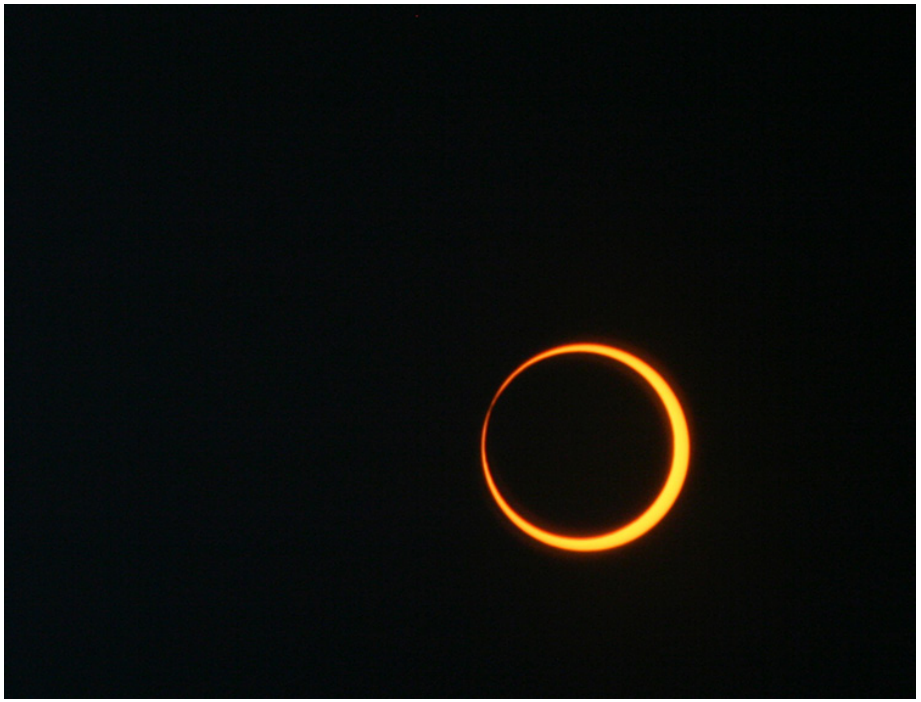
I do not recommend trying to photograph a total eclipse unless you have professional equipment mounted with a motor to track the Sun. Totality is brief, and it is easy to miss the spectacle while fiddling with equipment. Professional photographers will take awesome photos like the one at the right and share them. If you want to take pictures with your phone, Solar Snap makes it easy to image the partial eclipse, and there's no pressure because it happens slowly. But, the total eclipse is very different, short, and hard to photograph.

The "Solar Snap" app has an automatic feature that will take photos every minute without you pushing the button each time. If you put your phone on a tripod, you can press that button and the phone will take photos of the partial eclipse with the filter on. As the Sun slowly moves across the sky, you will have to re-aim — expect to do that every 15 minutes. During totality, you can take the filter off

the phone, press the "Totality" button, and the phone will take photos by itself, leaving you to watch and experience the eclipse. If you decide to do this practice weeks in advance on the not-eclipsed Sun.

The view during an annular eclipse

While much of the attention in the next few years is on the total eclipse of April 8, 2024, skywatchers in the U.S. will also experience a different type of solar eclipse: an annular eclipse. The orbit of the Moon around Earth isn't round, but is instead about 5 percent elliptical. That means the Moon can appear 5 percent larger or smaller in the sky. (When it is slightly bigger at Full Moon, we have the much-over-hyped "super Moon" terminology.) On October 14, 2023, the Moon will eclipse the Sun, but because of specific orbital geometry on that day, it will appear smaller than average and will not produce a total eclipse. Instead, there will be what is called an *Annular* or "Ring of Fire" eclipse. Maximum eclipse will look like this telephoto image. Because some of the Sun is always visible, you must protect your eyes during an entire annular eclipse. You never remove protective glasses or other solar filter.



One can see why an annular solar eclipse has the nickname "ring of fire." This image captured totality during the May 20, 2012, annular eclipse. *[NASA/Bill Dunford]*

Run an eclipse-watching event

I encourage anyone who reads this article to prepare your neighborhood for eclipse watching — whether in the path of totality or not. Plan an event in a park or schoolyard. Talk with local newspapers and radio and television stations. Local papers especially are short on reporters and good stories. Provide information and offer to write a draft story. Impress on them how rare solar eclipses are. Tell them that *mis*information and rumors circulate at every eclipse, and they can help people safely enjoy a great spectacle. Explain that there is no strange, dangerous radiation that appears only during an eclipse. It is the same Sun and the same solar radiation (sunlight) pre-, during-, and post-eclipse. The only danger comes from trying to watch an eclipse without protecting your eyes.

If you are at a middle or high school, talk to your principal now. (I have not worked with elementary age students at eclipses, so I can't recommend school events for students that young.) You can talk to service clubs such as Kiwanis, Rotary International, and others. Ask if they would provide financial assistance so you can supply eclipse-watching glasses and correct information to schools and schoolchildren in your town. Ask them to help publicize your event. Also talk to Boy and Girl Scout Troops. And do this well in advance!

If you're organizing a large event, think about the logistics: bathrooms, parking, food services, a public address system, etc.

Guidelines for Running an Eclipse-Watching Event

- Prepare well in advance. A year ahead is not too soon.
- Find a venue with parking, bathrooms, water, shade, and possibly food.
- Enlist groups such as Kiwanis, Rotary, and the Boy and Girl Scouts to help distribute information and to fund and distribute safe eclipse-watching glasses and Solar Snap.
- Work with local media — newspapers, radio, and TV — to highlight how wonderful a total eclipse is to see. Accentuate the positive. Publicize safe eclipse-watching.
- Try to get local stores to sell (and advertise) safe eclipse-watching glasses and Solar Snap. Tell them that the glasses can be printed with ads or coupons on them. This is also a great fund raiser for your local science center or planetarium.
- Let me know via email how it goes.

Our 2012 partial eclipse event drew 10,000 people. Who will help you handle a large crowd? If we had spent one minute per person providing each with eclipse-watching glasses and a brief explanation, it would have taken 166 hours to deal with all those people! We used the ticket windows in the stadium to distribute glasses. A local hardware store sold eclipse glasses for more than a week prior, which lessened the crowding.

The hardware store made $20,000 profit in one week on eclipse glasses, and I still find the humor in the observations of the store staff as they were overrun by people wanting the glasses. As one of the staff said, "In my 37 years, I can't think of any product that created this much excitement." People called, lined up, and bought them for friends. Legitimate eclipse glasses at wholesale cost about 75 cents or less. They typically sell at market value for $2 — and that difference can finance eclipse events and make money. (Solar Snap is also available wholesale.) We worked with non-profit groups that raise money for schools. One such group donated money for us to purchase 20,000 more glasses and give them free to students throughout the city of Boulder.

Approach hardware shops or other local stores that many people patronize. It is difficult to explain what a big event the eclipse will be, and most stores will never have sold eclipse-watching glasses. Have them watch the video interview with Boulder Colorado hardware store employees. This video is very persuasive and explains how the store had to set purchase limits because of the rush for these glasses. If they ordered well in advance, glasses can have school or store logos or advertising printed on them, and a discount coupon for purchases.

During the 2012 partial solar eclipse, the author helped organize an event on the University of Colorado, Boulder, campus, which drew 10,000 people. *[Casey Cass, Univ. of Colorado]*

Other materials to help you prepare

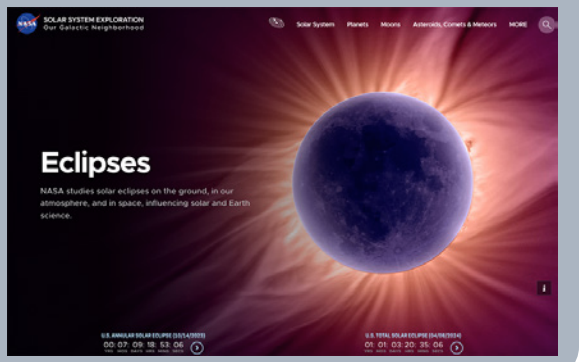
My Fiske Planetarium team has received funding from NASA to make short videos about the upcoming eclipses. These are available for free at the Fiske eclipse website. We are planning four short videos: Watching a Partial Eclipse, Watching a Total Eclipse, What Causes Eclipses, and Advice for Principals and Administrators for the 2023 and 2024 solar eclipses. You may also know that Coursera offers hundreds of free college courses online. I created a course, "The Sun and the 2017 Eclipse." Taking it will prepare you to answer questions you might get about our star and solar eclipses.

The public has a great appetite for cool science when it is well presented, and nothing is more dramatic than a total eclipse.

Seeing a total solar eclipse is a truly awe-inspiring sight. The *Mercury* editor captured this image of the July 2, 2019, eclipse, during totality from La Silla Observatory in Chile. *[Liz Kruesi]*

Additional Online Materials

- American Paper Optics: eclipse glasses; if you're an educator, click here for a discount.
- Eclipse Weather: an excellent site for long-range and eclipse-day forecasts along the path of totality.
- Fiske Planetarium Eclipse
- NASA Solar Eclipse
- Rainbow Symphony: eclipse glasses and viewers; if you're an educator, use code *LoveTeachers* for a discount.
- Solar Snap
- The Great American Eclipse: excellent eclipse maps and information.



Unfortunately, not all media outlets, editors, and producers know this, so it can be a challenge to get on radio and TV. Please use all the videos and materials in this article, as well as the resources listed below, and help make the 2024 total eclipse the most-watched one in U.S. history. ✪

DOUGLAS DUNCAN is a retired faculty member in the Department of Astrophysical & Planetary Sciences of the University of Colorado and also a popularizer of astronomy. From 2002-2018 he directed the Fiske Planetarium. From 1997-2002 he did science commentary on the Chicago Public Radio station WBEZ, and he has appeared on television programs such as the History Channel and BBC Horizon. In April 2024, he will be leading an eclipse-watching group to "Totality over Texas."