How to see the 2024 Total Solar Eclipse

A practical guide for the first-time eclipse watcher

by Brian Ventrudo & Manish Panjwani
of AgenaAstro.com

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First Edition

Front cover photo of the eclipsed Sun courtesy of Luc Viatour/Wikipedia Commons. Cover product photos courtesy of Thousand Oaks Optical, Baader Planetarium, and Lunt Solar Systems.

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About This Book

This guide by Agena Astro explains everything you need to know to see the total solar eclipse of April 8, 2024, even if you've never observed a solar eclipse before, and even if you don't know anything about astronomy.

Unlike other eclipse guides, this book does not overwhelm you with the science and history of solar eclipses, or with complicated explanations about advanced eclipse photography. Instead, it's a guide for the casual or beginning eclipse watcher who wants to understand a little about this amazing event and who wants to choose and use inexpensive and easy-to-use solar filters and other basic tools to safely see it.

In the first chapter of this guide, you learn why eclipses happen and how they work.

The second chapter takes you through the particulars of the April 2024 eclipse, including timing, location, weather prospects, and links and descriptions of useful maps and tools.

The third chapter, perhaps the most important chapter in the book, gives you essential safety tips for observing a solar eclipse with or without a telescope.

Chapters 4 through 7 guide you through the essential tools of observing an eclipse including simple solar eclipse glasses, solar viewing cards, dedicated solar binoculars and telescopes, and solar filters to outfit 'regular' astronomy telescopes, binoculars, and camera lenses. You also get a few tips about how to take a snapshot of the eclipse with a smartphone or camera.

This guide is self-contained, but it also includes links to useful information, maps, and videos to help you learn more about solar eclipses. To open these links, you will need to read this book on a device with internet access.

There are also many links in this book to maps, guides, and other useful tools for safely observing partial and total solar eclipses. You can choose to acquire some of these tools if you feel they will enhance your experience of safely enjoying this solar eclipse.

An important word of advice: if you plan to purchase equipment for observing the April 2024 eclipse, consider doing so as soon as possible. There will almost certainly be shortages of products as the eclipse nears.

Preface – Experiencing a Total Solar Eclipse

On April 8, 2024, a total solar eclipse will pass in a narrow band over Mexico, the continental United States, and southeastern Canada. Millions of people live within a day's drive of the narrow path of this eclipse, so it may be one of the most watched astronomical events in history.

A total solar eclipse is one of the most awesome and spectacular events in all of nature, which is why you should see one for yourself at least once in your life. If you can make your way to the narrow path of the 2024 total solar eclipse, you will see—for a brief span of up to four minutes and twenty-eight seconds —the Moon slide across the face of the Sun. During these minutes, your surroundings will grow dark, birds and animals will go silent, and the sky will fill with bright stars. The brilliant face of the Sun will be replaced by a black disk, and around this disk you will see a band of glowing red gas in the Sun's outer atmosphere and the ethereal silver-white streamers of the solar corona, the outer reaches of the Sun that are always there but which are usually overwhelmed by the Sun's bright light.

Even experienced amateur and professional astronomers are awestruck by the sight of a total solar eclipse. The astronomy writer Timothy Ferris, for example, in his book *Seeing in the Dark*, describes his view of the total solar eclipse of March 2, 1970 in North Carolina:

"Suddenly the sky collapsed into darkness and a dozen bright stars appeared. In their midst hung an awful, black ball, rimmed in ruby red and surrounded by the doomsday glow of the gray corona. No photograph can do justice to this appalling sight: The dynamic range from bright to dark is too great, and the colors are literally unearthly."

For the April 8, 2024 eclipse, the 'path of totality', where you can see the total solar eclipse, runs in a long but narrow 120-mile-wide band from western Mexico at the city of Mazatlán through Texas and up through Ohio and western New York and into Ontario, Québec, New Brunswick, Prince Edward Island, and Newfoundland. Large cities such as Dallas, Indianapolis, Cleveland, Buffalo, and Montréal are on the path of totality, and many others are nearby. You must be somewhere in this narrow band to see the total solar eclipse. But outside this band, essentially anywhere in North America, you can see—with a safe solar filter—a partial solar eclipse where the Moon slides across the face of the Sun but does not cover it completely. It's still an impressive sight that shows you first hand the clockwork motion of the solar system.

If you've never seen a total solar eclipse before, this will be the opportunity of a lifetime.

- Brian Ventrudo and Manish Panjwani
  January 2024

Chapter 1 – How Solar Eclipses Work

The Basics

It's a remarkable coincidence, but the Sun, which has a diameter 400 times greater than our Moon, is almost exactly 400 times farther away. That means, when the alignment is right and the Moon passes directly between the Earth and Sun, the Moon almost exactly covers the visible part of the Sun's surface for a few minutes and leaves only the eerie glow of the Sun's outer corona visible to Earthly observers over a long but very narrow path across the Earth's surface. This is a *total solar eclipse*.

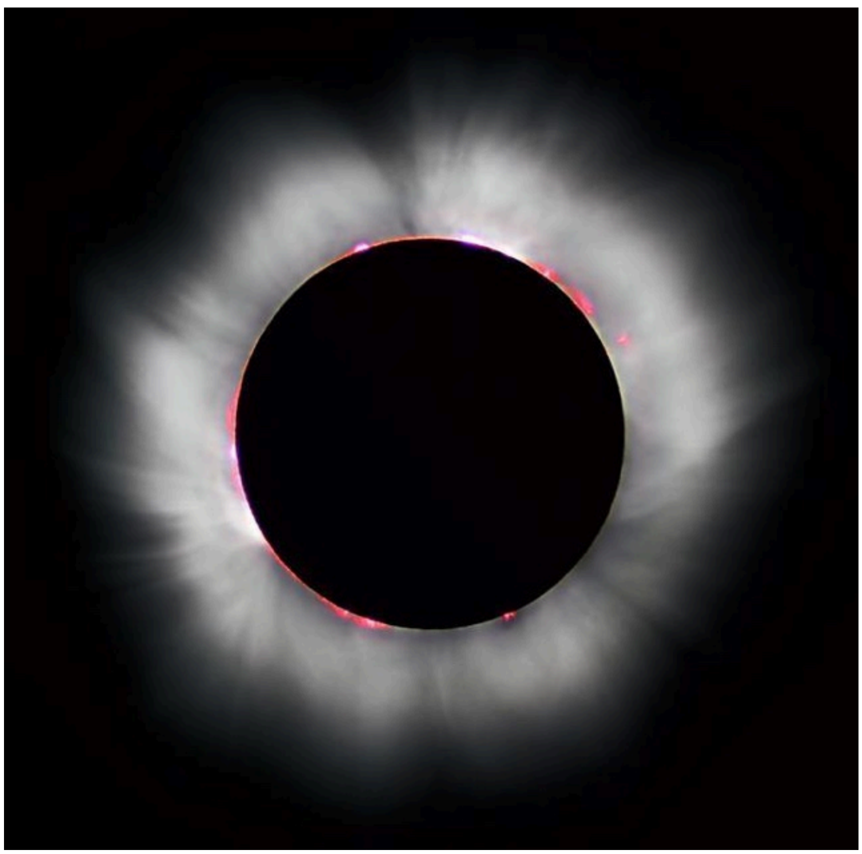


Figure 1-1: A total solar eclipse occurs as the Moon completely covers the bright face of the Sun, and reveals the reddish chromosphere and white streamers from the solar corona. Credit: Luc Viatour/Wikipedia Commons.

Solar eclipses are a common event somewhere on Earth every year, and they occur twice a year, on average. However, a total solar eclipse is rare at any particular place on Earth. It takes many hundreds of years—on average—for a total solar eclipse to revisit a particular location. Nor does the Moon's shadow necessarily cast itself in convenient locations during a total solar eclipse. These events can occur in populated areas, but are more likely to occur across oceans, arctic regions, or in the middle of a desert simply because these regions cover more of the Earth than densely populated urban areas. That's why the total solar eclipse of April 8, 2024 is particularly remarkable: it will take place over a densely-populated continent with a good road system that makes it easy for millions of people to see the event.

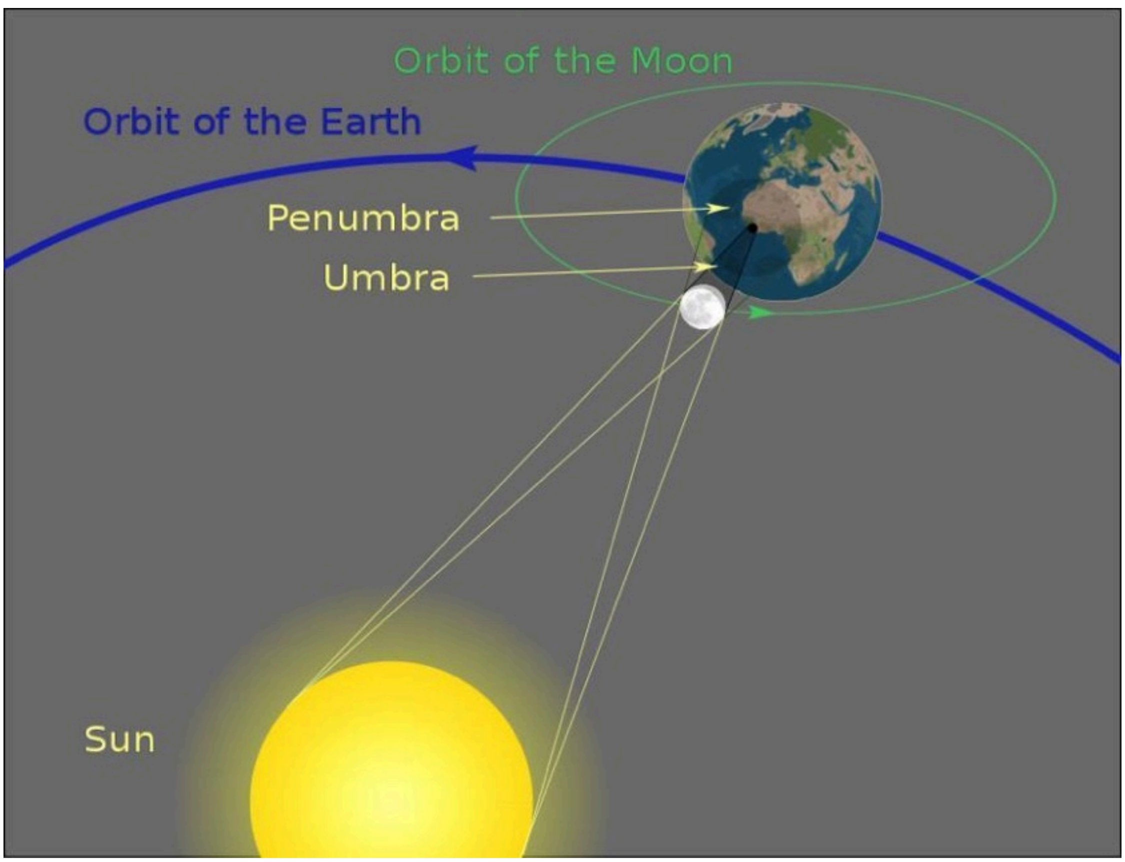


Figure 1-2: The geometry of a solar eclipse showing the umbra and penumbra shadows cast onto the surface of the Earth. Image credit: Wikipedia Commons.

During a solar eclipse, as the Moon passes between the Sun and Earth over the course of an hour or two, it casts two types of shadows. The umbra is the narrow dark shadow cast by the Moon, while the penumbra is a fainter outer shadow. During an eclipse, both shadows travel along the surface of the Earth at more than 1,000 miles an hour as the Moon moves along in its orbit, and these shadows move west-to-east across thousands of miles of the Earth's surface. The path of the umbra is only about 120 miles wide at most, roughly, and within its path an observer can see the full total solar eclipse during which the Moon blocks the bright face of the Sun. This is the *path of totality*. **You MUST be in this path to see the total solar eclipse.** Along the centerline of this path, you will see between two and seven minutes of totality, depending on the Earth-Moon-Sun alignment during a particular eclipse. Off the centerline, but still within the narrow path of the umbra, the duration of totality decreases.

The penumbra is much wider than the umbra and spans many thousands of miles on either side of the path of totality. Within this shadow, an observer sees a *partial solar eclipse* in which the Sun's face is only partially covered by the Moon. More of the Sun's face appears covered for observers closer to the path of the umbra.

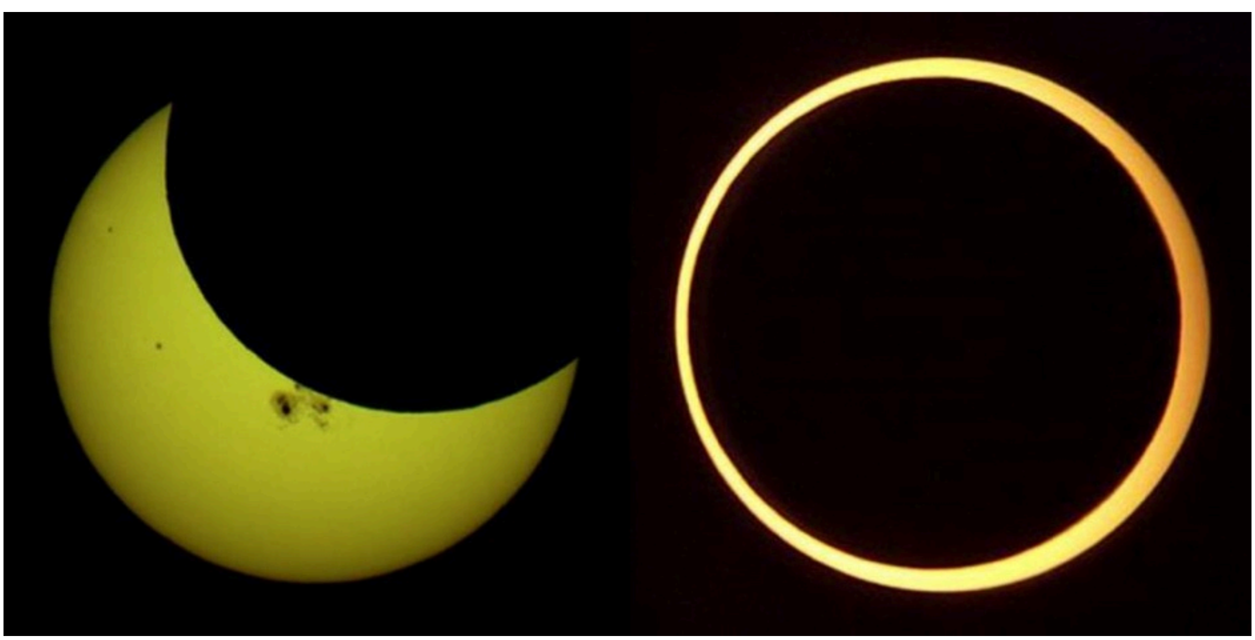


Figure 1-3: A partial solar eclipse (left) and an annular solar eclipse (right). Credit: Wikipedia Commons.

Not all solar eclipses are total. If the Earth, Moon, and Sun are not perfectly aligned but are still aligned to within their angular diameters, the Moon does not completely cover the face of the Sun and does not cast an umbra onto the Earth, only a penumbra. Observers along the path of the penumbra will see a *partial solar eclipse*, but no one will see a total eclipse in this case.

Or if the Moon passes directly between the Earth and Sun when it's near the most distant point in its monthly elliptical orbit around Earth, when its apparent diameter is slightly too small to completely cover the Sun, a thin ring of the Sun's light is still visible around the Moon's dark disk. This is an *annular solar eclipse*. An annular solar eclipse falls across the United States on October 14, 2023 on a path from Oregon to Texas.

A total solar eclipse is by far the most spectacular of the three main types of solar eclipses, and the eclipse of April 8, 2024 will be of this type.

There's more to solar eclipses, of course, and if you want to learn a little more about how they work, the Appendix at the end of this book is a good place to start.

Chapter 2 - The Solar Eclipse of April 8, 2024

Overview

Scientifically, the total solar eclipse of April 8, 2024 is not expected to be more important than any other total solar eclipse. But it will be the first total solar eclipse across the continental United States since the coast-to-coast 'Great American Eclipse' of August 21st, 2017, the first in Mexico since July 11, 1991, and the first across southern Canada since February 26, 1979. This eclipse will be the last total solar eclipse visible across the continental U.S. until August 12, 2045, the last visible in southern Canada until August 23, 2044, and the last across Mexico until March 30, 2052.

Because of its location in a populous continent, where hundreds of millions of people live within a day's drive of the path of totality, this will be one of the most watched astronomical events in history. The 'Great North American Eclipse', as some call it, will give many sky watchers their best chance to see one of the most awesome spectacles in nature without the need to travel to a remote international location.

When and Where to See the April 2024 Eclipse

The path of totality of the eclipse—the narrow band where the total solar eclipse will be visible—passes a narrow band across three countries, including:

- The states of Sinaloa, Durango, and Coahuila in Mexico
- Texas, Arkansas, Missouri, Illinois, Kentucky, Indiana, Ohio, New York, Connecticut, and Maine in the U.S.A.
- Southern Ontario and Quebec, central New Brunswick, western Prince Edward Island, the northern tip of Cape Breton in Nova Scotia, and eastern Newfoundland

The penumbra, where a partial solar eclipse will be visible, passes across the rest of the United States (except for Alaska), all of Canada, Mexico, and Central America, and northern South America.

Even along the path of totality, the solar eclipse begins with a partial eclipse as the Moon begins to pass in front of the Sun. It covers an increasing part of the Sun's visible disk and, after about an hour and twenty minutes, roughly, the Moon completely covers the solar disk, marking the beginning of totality. For this eclipse, along the centerline of the path, totality lasts between three and four minutes, approximately. After totality, part of the Sun's disk is exposed and a partial eclipse continues for just over an hour until the last part of the Moon appears to exit the solar disk and the eclipse ends.

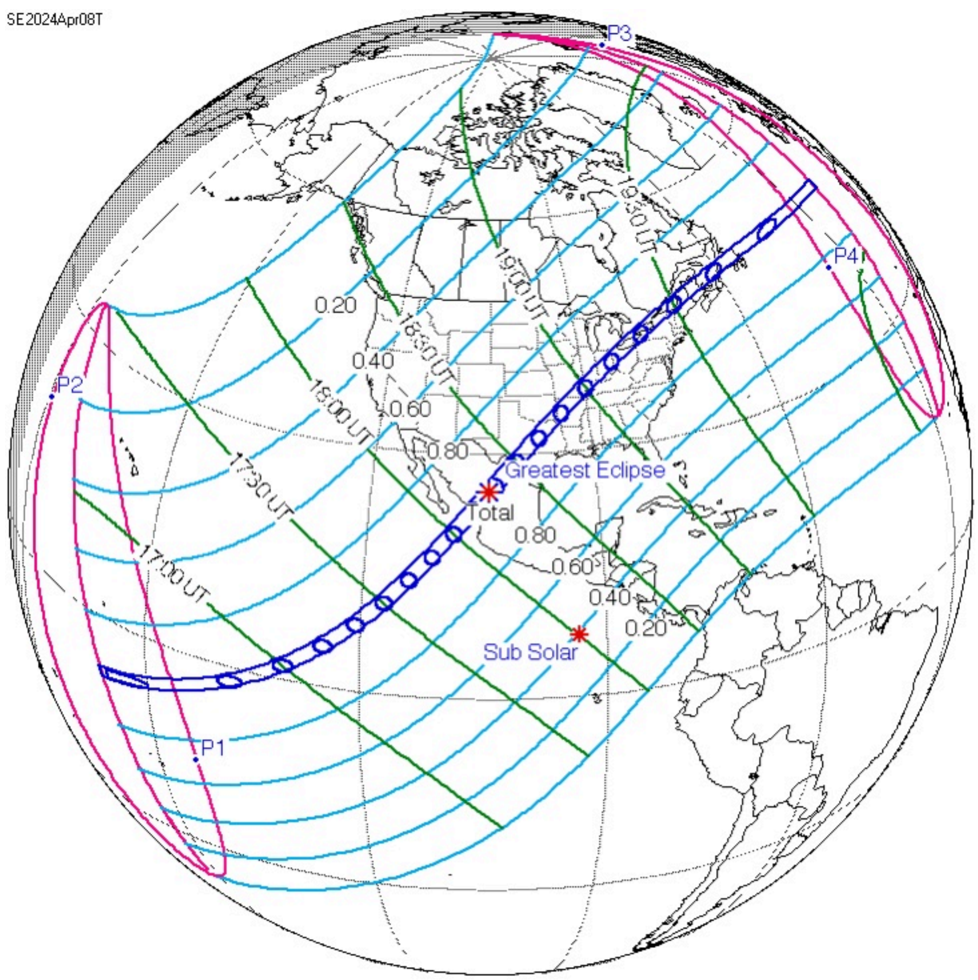


Figure 2-1: A map showing the narrow path of the umbra (in dark blue) where the total solar eclipse is visible, and the very wide path of the penumbra (in the grid of green and cyan), where a partial solar eclipse is visible to some degree during the eclipse of April 8, 2024. Image credit: NASA.

The total eclipse will also pass over cities and large towns in the U.S. including Dallas, Waco and Austin (barely), Little Rock, Indianapolis, Terre Haute, Dayton, Toledo, Cleveland, Erie (PA), Buffalo, Syracuse, and Plattsburgh (NY). In Canada, the totality falls over Hamilton, Kingston, and Niagara Falls in Ontario, Montreal (barely) and Sherbrooke in Quebec, Fredericton in New Brunswick, Tignish and Summerside in P.E.I. and Gander in Newfoundland.

The eclipse occurs on April 8, 2024 in the late morning and into the afternoon, local time, across the United States. It begins as the Moon's shadow begins to fall on the south Pacific Ocean east of Bora Bora in French Polynesia at 15:42 UT (Universal Time) in the early morning local time. The shadow makes landfall as the eclipse gets started at 16:51 UT or 10:51 a.m. MDT near Mazatlán on the west coast of Mexico (it does not reach totality until 12:07 p.m. MDT at Mazatlán).

The Moon's shadow then speeds northeast over Mexico into the continental United States before moving into Canada. The total eclipse continues into the Atlantic Ocean towards, but not reaching, the Azores and ends at 20:53 UT, a little over five hours after it began.

Nazas, Mexico experiences the longest duration of totality of 4 minutes and 28 seconds. But along the centerline of the path, totality lasts between about three and four minutes depending on the location. The table below lists the approximate local times of the beginning and end of the partial and total phases of the eclipse for several cities along the path.

City	Duration of Totality	Partial Eclipse Begins	Total Eclipse Begins	Partial Eclipse Ends
Mazatlan, Sinaloa	4m 14s	10:51 am MDT	12:07 pm MDT	1:32 pm MDT
Nazas, Durango	4m 27s	11:58 am CDT	1:15 pm CDT	2:39 pm CDT
Dallas, TX	3m 47s	12:23 pm CDT	1:40 pm CDT	3:02 pm CDT
Carbondale, IL	4m 08s	12:42 pm CDT	1:59 pm CDT	3:18 pm CDT
Indianapolis, IN	3m 46s	1:50 pm EDT	3:06 pm EDT	4:23 pm EDT
Buffalo, NY	3m 45s	2:04 pm EDT	3:18 pm EDT	4:32 pm EDT
Hamilton, ON	1m 45s	2:03 pm EDT	3:18 pm EDT	4:31 pm EDT
Sherbrooke, QC	3m 23s	2:15 pm EDT	3:29 pm EDT	4:38 pm EDT
Fredericton, NB	2m 16s	3:23 pm ADT	4:34 pm ADT	5:41 pm EDT
Bonavista, NL	2m 51s	4:03 pm NDT	5:13 pm NDT	6:17 pm NDT

Note: UT is 'Universal Time', a standardized time used by astronomers. It is essentially equivalent to 'Greenwich Mean Time'. To convert Universal Time to your own time zone on a specific day, you can use the conversion tool at this link: http://www.worldtimeserver.com/convert_time_in_UTC.aspx

Figure 2-2, provided courtesy of GreatAmericanEclipse.com, shows the path of the April 8, 2024 eclipse across North America. To see the brief total solar eclipse along the path of totality, timing is essential: you must be on the path of totality at the right time. There are hundreds of towns and cities across the long and narrow path, too many to list in this book. This eclipse-specific link from GreatAmericaEclipse.com gives a table of the duration of the total eclipse in many cities along the eclipse path and includes more detailed maps for the parts of North America along the eclipse path:

https://www.greatamericaneclipse.com/april-8-2024

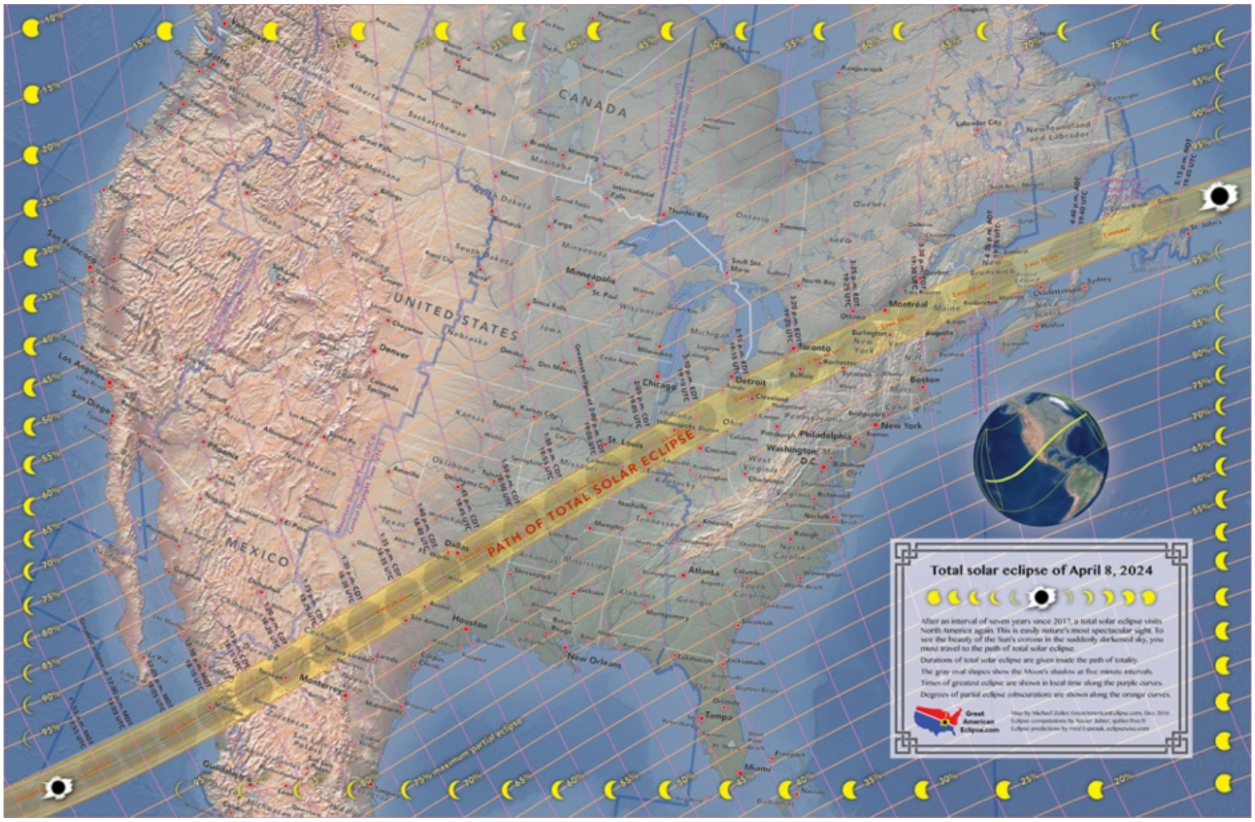


Figure 2-2: The yellow band shows the path of totality across the United States for the total solar eclipse April 8, 2024. Off the path of totality, all of Mexico, Central America, Canada, and the U.S. (except for Alaska) will see a partial eclipse in which part of the Sun's face is covered by the Moon at maximum eclipse. Credit: GreatAmericanEclipse.com.

Weather Prospects for the Eclipse

Astronomers can calculate the timing and position of a solar eclipse down to the second and the yard, but calculating the weather at any particular position is a much more challenging proposition. It's frustrating to travel for hundreds of miles (or more) to see a solar eclipse only to get clouded out. Even on a mostly sunny day, a patch of cumulus clouds can float across the Sun at just the wrong time. But predictions based on historical weather patterns during early April along the path of totality suggest some locations offer a better chance of clear weather than others. The weather in much of North America is changeable and unsettled at this time of year.

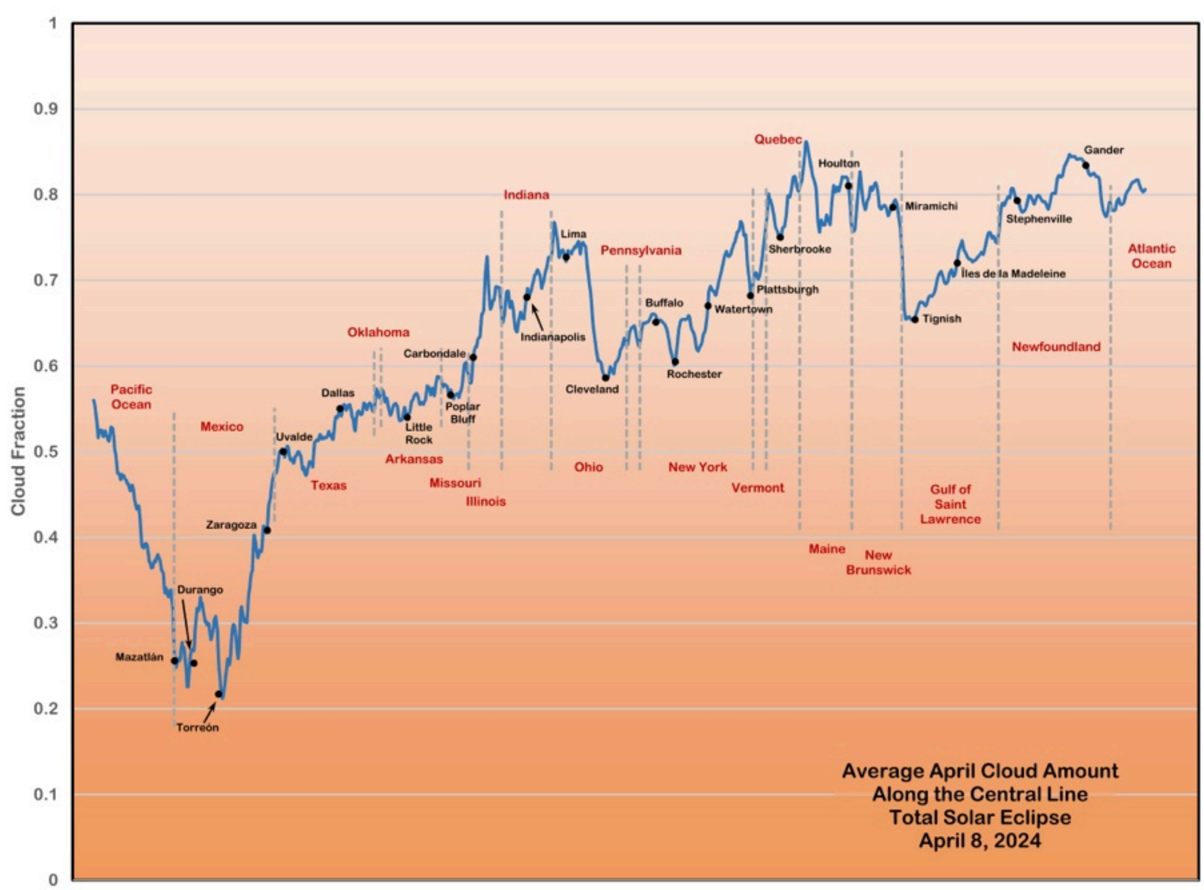


Figure 2-3: Average daytime cloud cover in April along the path of totality. The best weather prospects in Mexico and Texas. The least promising prospects are in Québec, Maine, and Newfoundland. Credit: Jay Anderson at [Eclipsophile.com.](Eclipsophile.com)

Figure 2-3 shows the statistical chances of morning and afternoon clouds along the path of totality from coast to coast in terms of fractional cloud cover in the month of April. Mexico offers the best chances of clear skies during this eclipse, especially in Mazatlán, Durango, and Torreón where the fractional cloud cover, historically, is less than 30% on April 8. This part of the path also offers the longest span of totality on the centerline of more than four minutes. By contrast, all of the U.S. and Canada have a chance of 50% or more of cloud cover. Texas and Arkansas are the most promising places, historically, while the chances of clear sky diminish almost uniformly moving north and east.

Wherever you go, if you can, stay mobile so you can evade cloud cover on the day of the eclipse. Locations with access to highways offer that option. Trying to observe the eclipse from rural areas or parks may make it harder to get on the move at the last minute. Since the eclipse occurs in early spring, you may want to make sure you're prepared for sudden changes in weather and for snow and freezing rain.

For far more detailed discussion of weather prospects along the eclipse path, look at Jay Anderson's excellent website at this link:

https://eclipsophile.com/2024tse/

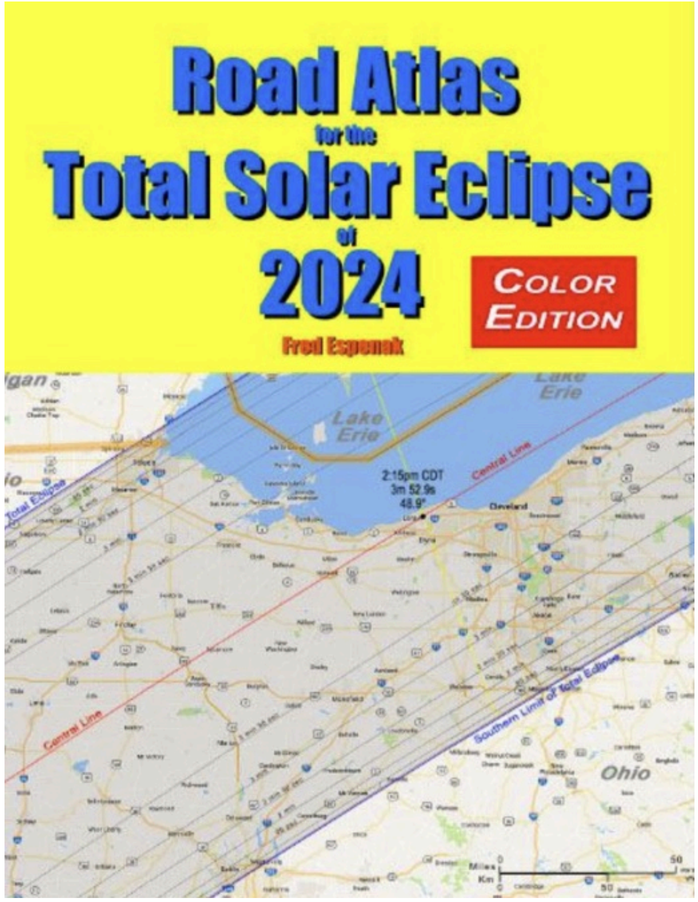


Figure 2-5: "The Road Atlas for the Total Solar Eclipse of 224" by Fred Espenak.

Useful Tools and Links

Road Atlas for the Total Solar Eclipse of 2024. The retired NASA scientist and eclipse expert Fred Espenak has created a detailed road atlas to help you find the best places to drive to and see the 2024 eclipse. This atlas, considered by many to be the most authoritative of its kind, contains a comprehensive series of 26 full color maps of the path of totality across Mexico, the United States, and Canada. It shows both major and minor roads, towns and cities, rivers, lakes, parks, national forests, wilderness areas and mountain ranges. The path of totality on each map is depicted as a lightly shaded region with the northern and southern limits clearly identified. The total eclipse can only be seen inside this path. The closer one gets to the central line of the path, the longer the total eclipse lasts.

Armed with the "Road Atlas" and the latest weather forecasts, you will be ready to chase totality no matter where it takes you along the eclipse path. A road atlas may seem like an anachronism, but it will be helpful for those who don’t have GPS or map apps on their phone, or for those who do not have cellphone service in remote locations.

The *Road Atlas for the Total Solar Eclipse of 2024* is available in color at the links below:

Color Edition:
http://agenaastro.com/road-atlas-total-solar-eclipse-2017-color-espenak.html

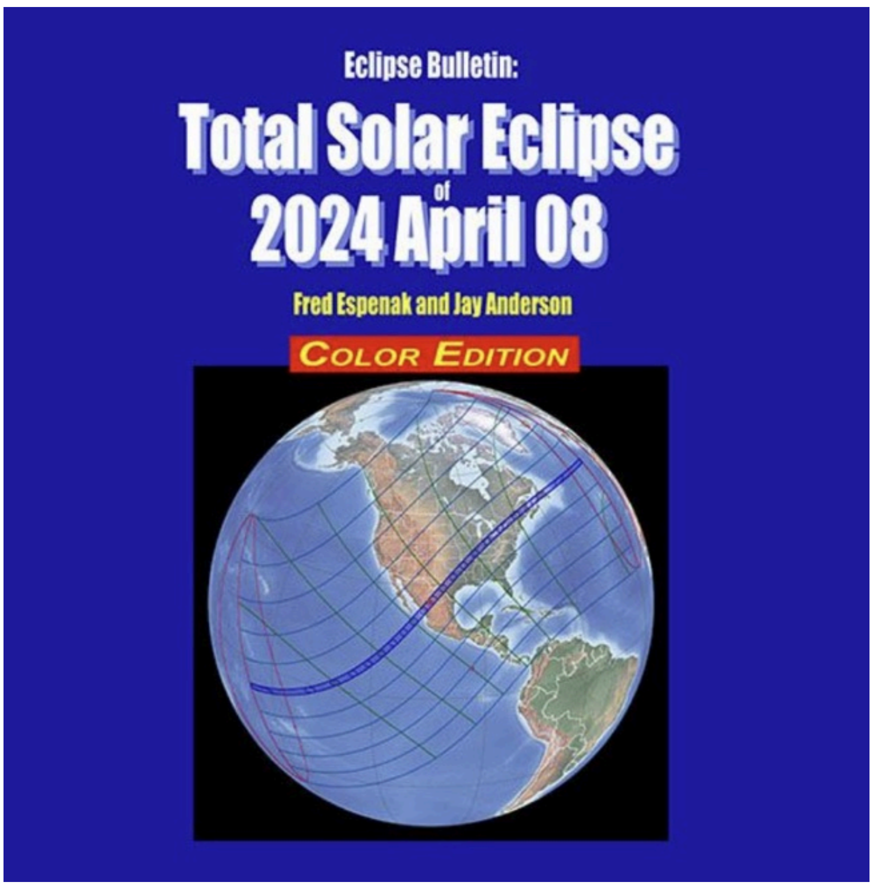


Figure 2-6: “Eclipse Bulletin: Total Solar Eclipse of 2024 April 8” by Fred Espenak and Jay Anderson.

Eclipse Bulletin: Total Solar Eclipse of 2024 April 8. The eclipse expert Fred Espenak and his colleague Jay Anderson have created the highly detailed and authoritative *Eclipse Bulletin* packed with every conceivable detail about the April 8, 2024 solar eclipse. The exact details about the path of the Moon's shadow can be found in a series of tables containing geographic coordinates, times, altitudes, and physical dimensions. A set of high resolution maps plot the total eclipse path across the USA. They show hundreds of cities and towns in the path, the location of major roads and highways, and the duration of totality with distance from the central line. *Eclipse Bulletin: Total Solar Eclipse of 2024 April 8* is also available in color at the links below:

Color Edition:
https://agenaastro.com/eclipse-bulletin-total-solar-eclipse-of-2024-april-08-color-edition-by-espenak-and-anderson.html

The Complete Guide to the 2024 North American Eclipse

Fred Espenak along with American Paper Optics also offers a 36-page guide to the April 8, 2024 solar eclipse that comes with two pairs of solar eclipse glasses along with helpful hints for safely viewing the eclipse:

https://agenaastro.com/get-eclipsed-the-complete-guide-to-the-2024-north-american-eclipse-by-espenak-with-2-solar-eclipse-glasses.html

Chapter 3 – Eye Safety and the Five Phases of a Total Solar Eclipse

The dangers of watching a total solar eclipse are real, but they are often overstated in the media. To understand when (and if) it's safe to look at a solar eclipse without a proper solar filter, it helps to understand how a solar eclipse unfolds.

A total solar eclipse has five stages. In only one stage—the brief stage of totality when the Moon completely covers the brightest part of the Sun for a few minutes—is it safe to observe the Sun without a solar filter over your eyes or over the objective lenses of your camera, telescope, or binoculars. **Aside from the brief few minutes of totality, you MUST use a safe solar filter to observe the eclipse.**

If you look at the eclipse or try to photograph it outside of the brief time of totality when the Moon completely covers the brightest part of the Sun, then **permanent damage to your eyes or equipment may result.**

And remember—to experience totality, you must be on the narrow path of the total eclipse. **Outside of this path, you will only see a partial eclipse and you must use proper solar filters at all times when you look towards the Sun.**

In the first stage of the eclipse, called *first contact*, the leading limb of the Moon becomes visible across the Sun's disk. It looks like the Sun has a bite or a notch taken out of it. Over time, the Moon continues to cover more of the Sun, and if about 70% or more of the Sun is covered during an eclipse, you may notice a slight change in the lighting of the surrounding landscape. But the Sun is still far too bright to look towards without a safe solar filter.

Finally, for observers on the narrow path of totality, the Moon will almost completely cover the Sun. Just a few rays of light will shine through valleys or gaps between mountains on the limb of the Moon. This will appear as a string of bright points along the Moon's edge. These are called 'Baily's Beads'. At last, a single point of light will remain, giving rise to the 'Diamond Ring' effect. Even at this point, the few sun rays peeking through are still too bright to take in without a solar filter. At the second stage of the eclipse, called *second contact,* as the trailing limb of the Moon covers the Sun, the last bead of light will slowly grow fainter as the Moon completely covers the Sun like a lens cap. The sky and surrounding landscape will grow dark, birds and animals will grow quiet, and the air will cool noticeably. This is the beginning of totality, and at this point you can remove the solar filters from your eyes or telescope to see the awesome spectacle of the red chromosphere and icy white corona surrounding the black Moon.

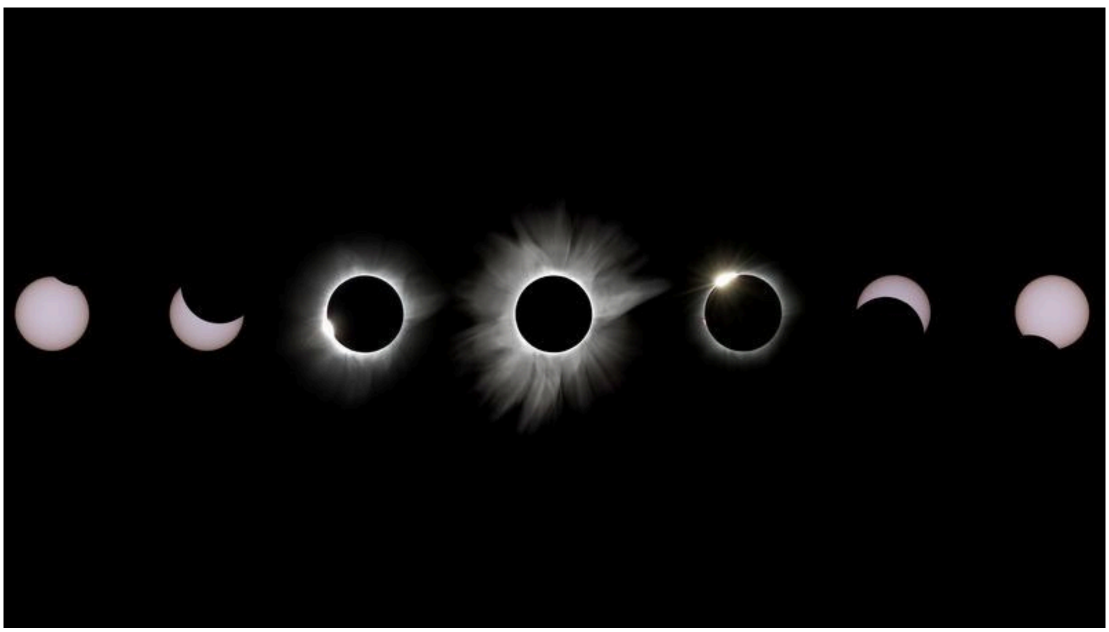


Figure 3-1: The stages of a total solar eclipse. At left, the Moon first begins to encroach on the Sun's disk, then progresses further (second from left). Just before it completely covers the Sun, one or more brilliant rays of light may emerge through a lunar valley. At center, when the Moon completely covers the eclipse, the total solar eclipse begins and lasts for a few minutes. This is the only time it is safe to look at the Sun without a solar filter. In the three images at right, the Moon begins to recede from the Sun's face. Credit: Justin Ng - justinngphoto.com.

The video at the link below shows you an extraordinary close-up of a solar eclipse in 2012. Note the Diamond Ring effect at the beginning of the total eclipse at second contact, and the reemergence of the Diamond Ring along with Baily's Beads at the end.

https://vimeo.com/55189777

When the Moon maximally covers the solar disk, we reach the third stage of a total solar eclipse, the instant of maximum eclipse. Then the Moon moves further so that the trailing limb exposes the Sun and the Diamond Ring and Baily's Beads reappear. This is *third contact* (and the fourth stage of the eclipse) and the point at which the total eclipse ends. **You must look away from the spectacle at this point**, however beautiful you may find it. Put on your solar eclipse glasses or solar filter and continue watching the partial phase of the eclipse over the next 90 minutes or so. Finally, at the fifth stage of the eclipse, the Moon's trailing edge will pass across the Sun—this is *fourth contact*—and the Sun's disk will appear whole again.

Figure 3-2: A combination of images show the progress of a partial solar eclipse as seen from southern California in 2012. From this location, a total eclipse did not occur during this event. At all times during a partial solar eclipse, a safe solar filter is essential to prevent eye damage. Credit: Wikipedia Commons/Author Jimnista.

For the April 8, 2024 eclipse, the span of time from second contact to third contact—the total eclipse or the period of totality—lasts at most four minutes and twenty-eight seconds, or more typically about four minutes depending on your location along the path of totality. If you are off the centerline of the path of totality, it will last for a shorter time. If you are outside the path of totality altogether, you will only see a partial eclipse of the Sun and you will need eye protection for the entire event.

Now that you understand the workings of solar eclipses, it’s time to learn about the tools you need to see one safely. The next chapters guide you through selecting solar filters, solar telescopes, and other tools essential for observing the 2024 total solar eclipse.

Chapter 4 – Seeing the Solar Eclipse without a Telescope

Overview

If you're on the path of totality for the April 8, 2024 eclipse, you need no special equipment to observe the brief phase of totality when the Moon covers the brightest part of the Sun. As explained in Chapter 3, this brief time, which will last no more than four minutes and twenty-eight seconds for this eclipse, is the only time when you can turn your unprotected eye towards the Sun. But without some sort of solar filter, **you must look away from the Sun before and after totality**.

However, most people want to observe the eclipse during the time when the Moon only partially covers the Sun. The anticipation of the impending total eclipse is exciting, and it's fun to watch the Moon slowly slide across an increasing fraction of the Sun's visible face. To observe the partial phase of the solar eclipse, you need some form of safe solar filter over your eyes or telescope. In this chapter, you'll learn about the options for safely observing the eclipse—and the Sun generally—with very simple and inexpensive tools.

Essential Safety Tips

First, an important word about safety. Solar observing is the most potentially hazardous activity for amateur astronomers and casual sky watchers in an otherwise fairly safe pastime. Looking at the Sun just with your naked eye is dangerous enough. But looking at the Sun through a telescope or binoculars without a proper solar filter is **a sure way of going blind in less time than it takes to blink**. Astronomy equipment manufacturers have developed a number of filter technologies that allow for safe solar viewing. To make sure you don't make a dangerous mistake when trying to observe the Sun or a solar eclipse (other than the brief period of a total solar eclipse), **here are some things you should NEVER do**:

- Never look at the Sun directly with your unaided eyes without a safe solar filter, even through thick haze, for any length of time.

- Never look at the Sun through a telescope, even your finder scope, without a proper solar filter. Although you may at first feel no pain when you look at the unfiltered Sun because your retina has no nerve endings, you will be permanently blinded almost instantly if you look at the Sun through any size telescope.
- Never leave a telescope unattended outside in the daylight, especially around children, unless caps or solar filters are securely placed over the main objective and the finder objective. At the sight of a telescope, the curious and uninformed just might try a little solar observing, either accidentally or deliberately. You should treat a telescope in daylight like a loaded gun.
- Never use a solar filter designed to thread into the eyepiece of an otherwise unfiltered telescope. These filters are often supplied with cheap "department store" telescopes. All the light from the Sun is focused through the telescope onto these little filters which eventually crack or melt and allow concentrated sunlight to suddenly hit your eye. A proper solar filter removes most of the light and heat from the Sun before it enters the telescope at the objective lens or mirror.
- Never use as a solar filter smoked glass, sunglasses, layers of photographic film, photographic filters, sheets of Mylar from a camping blanket, Pop-Tart wrappers, or the bottom of a beer bottle (!) to observe the Sun. None of these will protect you sufficiently.

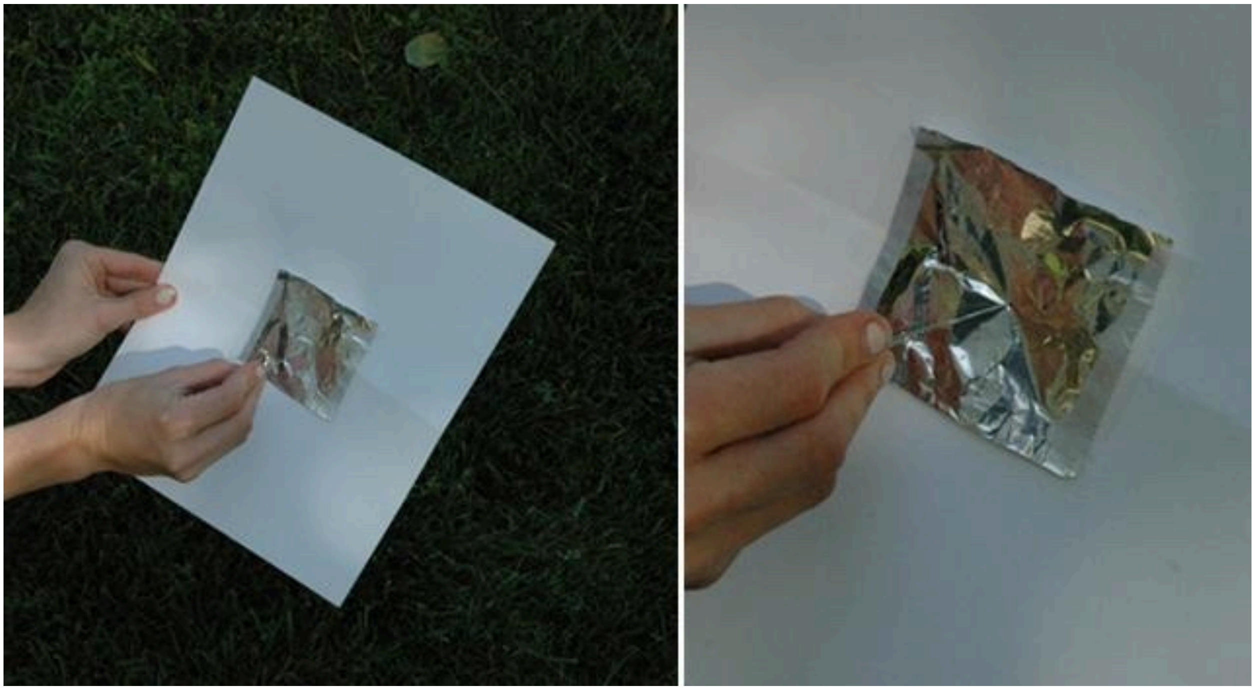


Figure 4-1: Making a pinhole camera to project an image of the Sun. Using aluminum foil taped over a hole in a piece of paper allows for a smaller and more uniform pin hole. Credit: NASA.

Solar Projection

The simplest technique of all to observe the Sun without a telescope is to use a pinhole camera. Just poke a tiny hole in a piece of cardboard or a thick piece of paper, aim the pinhole at the Sun, and project the image onto a second piece of paper at least a couple of feet away. Or to make a smaller, more precise pinhole, use a piece of aluminum foil taped over a hole in a piece of paper (see Figure 4-1). This approach gives a small and faint image of the Sun, but it’s good enough to reveal the progress of a partial solar eclipse. Sometimes during a partial eclipse, you can even see multiple images of the eclipsed Sun cast onto the ground by the pinhole gaps between leaves on a tree.

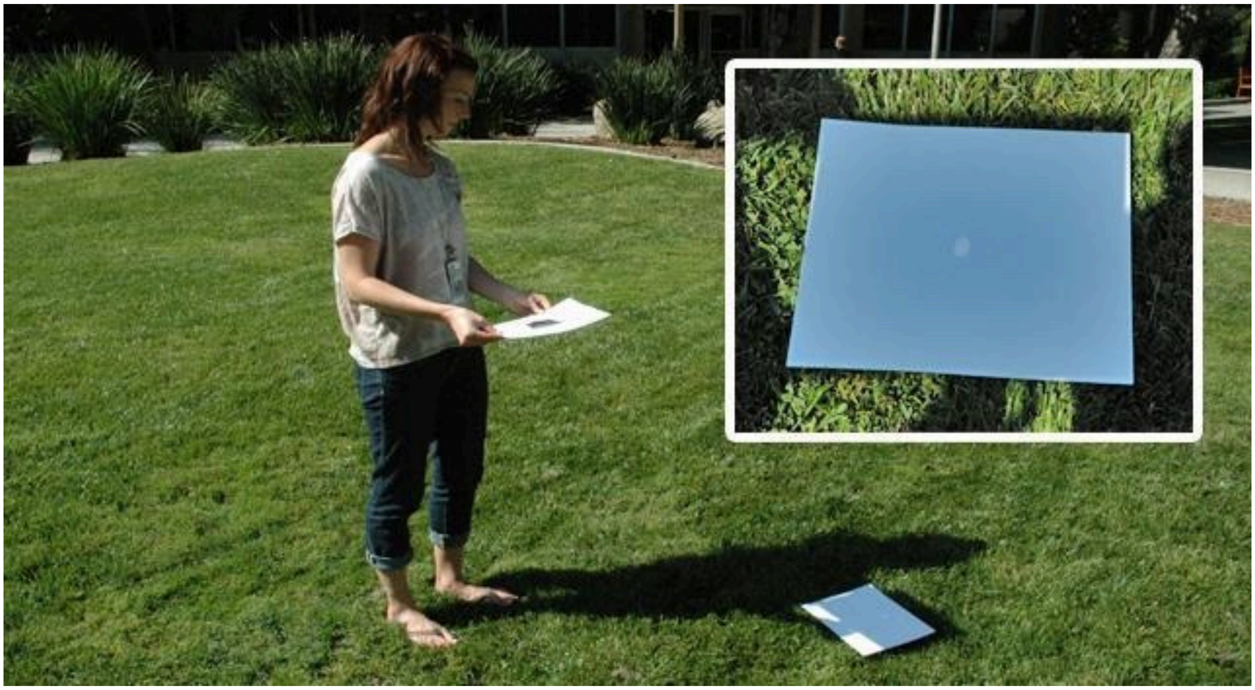


Figure 4-2: Projecting the image of the Sun through a pinhole is a simple and inexpensive way to watch the progress of a solar eclipse. Credit: NASA.

Solar Eclipse Glasses and Solar Viewing Cards

Solar viewing cards (Figures 4-3 and 4-4) and eclipse glasses (Figures 4-5 and 4-6) are the next steps up from a pinhole camera. These simple and inexpensive devices are safe solar filters packaged for naked-eye observation of the Sun and solar eclipses. **However, DO NOT use eclipse glasses with an otherwise unfiltered telescope to see the Sun**. These simple filters cost only a few dollars and they use a special plastic solar film to reduce the intensity of the Sun's visible light by a factor of 100,000 or more to a safe level. They also reduce dangerous infrared (IR) light and ultraviolet (UV) light as well as the heat from the Sun.

The solar film in eclipse glasses and viewing cards pass so little light that you can't see anything else through them other than the bright disk of the Sun. So to see the brief phase of totality, when the Moon completely covers the Sun, you will need to remove these glasses to see the action. When you see the Sun begin to poke out from behind the Moon, look away and put your glasses back on before you look at the eclipse again.

Before using a pair of eclipse glasses or a solar viewer, make sure they are in good condition. Hold them up to a lightbulb or to the sky away from the Sun and look for tiny pinholes or tears in the plastic filter. If you can see any light, discard them and grab a new pair.

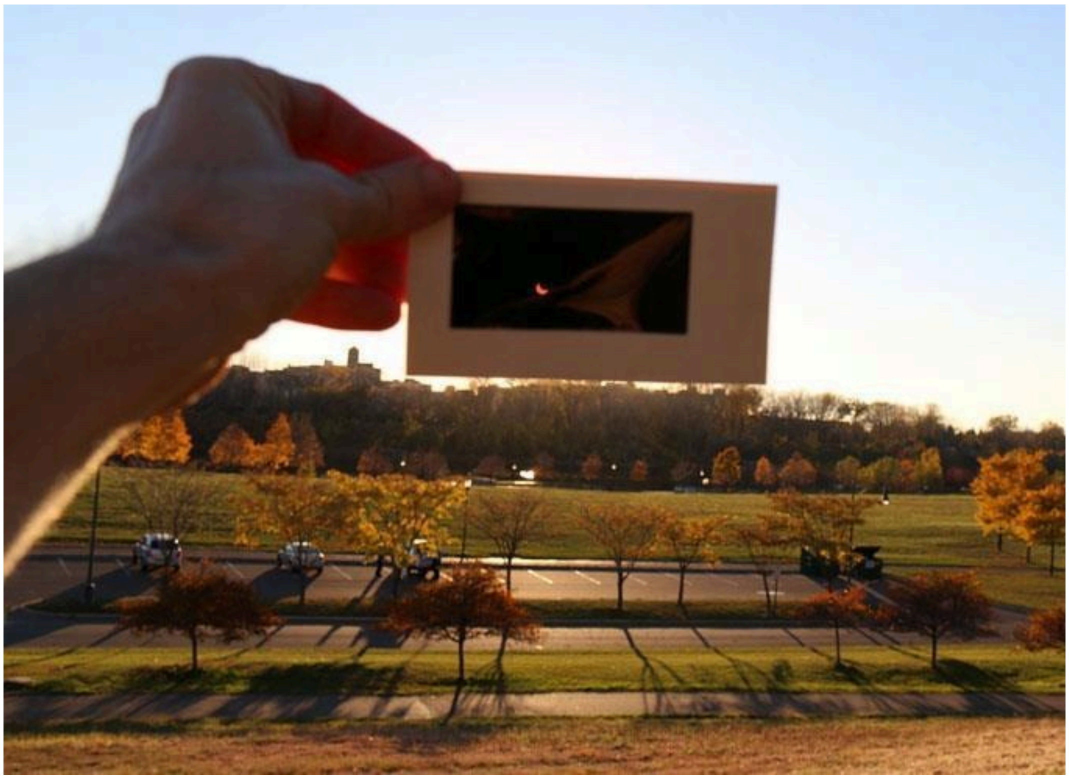


Figure 4-3: The image of a partially eclipsed Sun through a solar viewing card held at arm's length. Image credit: Tom Ruen/Wikipedia Commons.

Eclipse glasses or solar cards are available in larger volume packs so they can be handed out to participants in at group events during solar eclipses.

SAFETY NOTE: Solar eclipse glasses and viewers and welder's glass are for use in viewing the Sun with your otherwise unaided eyes only. **Do NOT use these devices to view the Sun through an otherwise unfiltered telescope or binoculars**. The concentrated image of the Sun can quickly damage and burn through solar film and glass and result in permanent eye damage.

Figure 4-4: A solar eclipse viewing card

You may hear of other options that will filter the Sun's light, options such as plastic CDs or DVDs, photographic film, dark sunglasses, metallic candy wrappers or thermal blankets, or the bottom of dark beer bottles. As mentioned earlier, **none of these are safe!** Even if they reduce the visible light sufficiently, they will not block dangerous UV and IR light from the Sun to a safe level. **Do not use them!**

Figure 4-5: A young eclipse watcher wearing a pair of eclipse glasses. Credit: Ken Lund/Flickr under the Creative Commons License.

Useful Tools and Links

How to make a pinhole camera. NASA's step-by-step guide to making a pinhole camera with simple material to observe the Sun and solar eclipses.

https://www.jpl.nasa.gov/edu/learn/project/how-to-make-a-pinhole-camera/

Solar Viewing Cards. Simple, inexpensive, and robust, solar viewing cards are one of the easiest and safest ways to observe the Sun and a solar eclipse. **Do NOT use these to look at the Sun through a telescope or binoculars.** They are for use with your unaided eyes only.

https://agenaastro.com/solar-astronomy/solar-eclipse-glasses-and-viewers.html

Figure 4-6: A pair of solar eclipse glasses.

Solar Eclipse Glasses. Eclipse glasses stay on your head and make it easy to observe the Sun during a solar eclipse. Like solar viewers, they're made with a safe plastic solar film that reduces the Sun's light and heat to a safe intensity. Do NOT use these with otherwise unfiltered telescopes or binoculars.

Agena Astro has approved and safe solar viewing glasses from leading brands such as Celestron, Meade, and Thousand Oaks Optical in packs ranging from one piece to 50 pieces (with higher per-piece discounts in larger packs). See what's available at the link below:

https://agenaastro.com/solar-astronomy/solar-eclipse-glasses-and-viewers.html

Celestron Solar Eclipse Viewing and Imaging Kits.

Celestron Solar Eclipse Kit #1. For families and small groups, Celestron packaged four sets of eclipse shades (glasses) and a short guide into an EclipSMART eclipse kit:

http://agenaastro.com/celestron-eclipsmart-solar-shades-observing-kit-44405.html

Celestron Solar Eclipse Kit #2. Celestron also has a kit with a 2x magnifying solar viewer to help you get a closer view of the Sun, along with a short guide.

http://agenaastro.com/celestron-eclipsmart-power-viewers-sun-eclipse-observing-kit-44006.html

Celestron Solar Eclipse Kit #3. The deluxe 8-piece Celestron solar eclipse kit includes four pairs of solar observing shades, a pair of solar eclipse glasses, a handheld photographic filter, a guide, and a double-sided map.

http://agenaastro.com/celestron-eclipsmart-ultra-8-piece-sun-observing-imaging-kit-44414.html

Figure 4-7: The Celestron 8-piece EclipSMART solar observing kit.

Chapter 5 – Solar Filters for Binoculars, Telescopes, and Cameras

Overview of Solar Filters

Observing a solar eclipse with plastic eclipse glasses or a solar viewing card is a pleasurable and exciting experience. But many observers want to get a closer look at the progress of the eclipse towards totality. For that, you will need some sort of optical aid, either binoculars or a telescope, with safe solar filters that greatly reduce the light and heat from the Sun. Such instruments also offer you the chance to examine, up close, the fascinating features on the Sun during an eclipse or on any clear day.

If you already have binoculars, a telescope or spotting scope, or a camera, can you use them to observe the solar eclipse? The answer is 'yes', but only if you safely outfit them with a solar filter. In this chapter, you learn about outfitting your optics with white-light solar filters so you can safely observe the 2024 solar eclipse before and after totality. These removable filters fit over the front of a scope, binoculars, or even a camera lens to prevent too much light from entering the optics. They also have the advantage that you can take them off during the brief moments of totality when it's safe to look at the eclipse. You can also use these solar filters to examine and explore the ever-changing visible face of the Sun on any clear day.

White light is simply the full spectrum of light we can see with our eyes. The actual color of the Sun rendered by a specific white light solar filter may be white, yellow, orange, or yellow-orange in color, but these are all called "white light" views of the Sun.

White-light solar filters come in three main varieties: glass filters, mylar filters, and a specialized AstroSolar film manufactured by Baader. These filters, once safely mounted over the entrance to your telescope or camera, are all you need to safely observe the Sun with a telescope. You can use your regular eyepieces with your telescope to observe the Sun with these front-mounted solar filters. No other accessories are required.

Figure 5-1: An image of the Sun taken with a white-light glass solar filter. Credit: Wikipedia Commons.

Seeing the Sun and Solar Eclipses in White Light

The white light we see from the Sun is generated inside the Sun by energetic nuclear reactions, and it takes the light many years to make its way out of the dense depths of the Sun's interior. When it does, it passes through a thin, transparent, and hot outer layer of the Sun called the *photosphere*. When we see the visible white light from the Sun, we are seeing the Sun's photosphere.

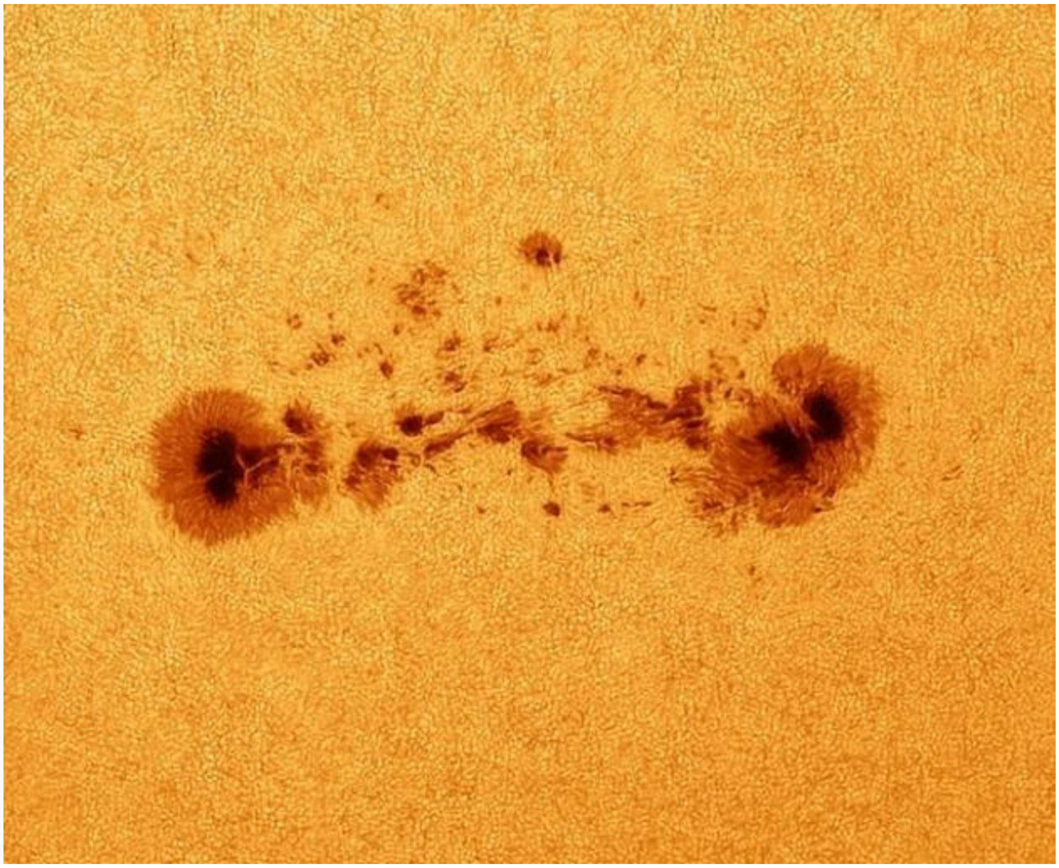


Figure 5-2: A highly magnified image of a sunspot group showing solar granulation. This is not a typical image that's accessible visually with a small telescope, but it shows what is accessible to more advanced solar observers. Credit: Sergio Castillo.

Fortunately, the Sun's photosphere has many interesting formations you can look for when you're watching a solar eclipse, or at any other time when the Sun is visible. These formations include:

Sunspots. These well-named features appear as dark spots on the face of the Sun. Sunspots are large storms of intense magnetic activity caused by twisting tubes of magnetism deep within the Sun. These tubes wind through the innards of the Sun and pop out into the surface from time to time. When they do, they cool the gas of the Sun's photosphere somewhat, which is why these areas appear slightly darker than their surroundings. They are not always visible, but when they are, larger sunspots can be seen in a pair of solar binoculars or a small solar telescope.

Solar Granulation. In a pair of solar eclipse glasses, the Sun appears smooth. But with some magnification in a telescope, you will see that the Sun's face appears 'grainy'. These grains, or *solar granules* as they are properly called, are convection cells in the outer layers of the Sun, much like bubbles in a pot of soup. Each of these bubbles is a thousand miles across and churns up hot gasses from the lower reaches of the Sun. The gas cools, then falls down again into the lower regions of the photosphere.

Faculae are bright areas in the Sun's photosphere. They are also caused by magnetic activity, but the magnetic field is concentrated in much smaller bundles than in sunspots. Faculae are hotter than the surrounding photosphere, which is why they appear brighter. They are usually best seen near the darker limb, or edge, of the solar disk.

Limb Darkening. The farther down you can see into the Sun's photosphere, the hotter the gas and the brighter it appears. But as you look along the limb of the Sun, you get a glancing view through the outer layers of the photosphere where the gas is cooler and darker. This effect is known as limb darkening. It's obvious even in a small telescope with a white-light solar filter.

Figure 5-3: The effect of limb darkening at the edge of the visible disk of the Sun.

Glass Solar Filters

Glass solar filters are a great choice for budget solar observing with a telescope. These filters use flat polished glass coated with nickel and chromium to attenuate the Sun’s light to 1/1000 of 1% of full intensity. The glass filter is mounted in a holder that can be fixed to the entrance to a telescope tube. Glass solar filters give good white-light views of the Sun at low to moderate magnification, and give the Sun's image a pleasing orange-yellow tint (see Figure 5-4).

Spectrum Telescope, Thousand Oaks, and Orion are the main manufacturers of glass solar filters. Their cost depends on the aperture of the filter. One size does NOT fit all: you must order a glass solar filter that’s mounted in a cell designed to fit your particular telescope, camera lens, or pair of binoculars.

Figure 5-4: A glass solar filter that mounts over the objective lens of a telescope. Credit: Spectrum Telescope.

Thin Film Solar Filters

Mylar Solar Filters

Mylar solar filters can be even more economical than glass filters. They give the Sun an odd blue tint, which some observers don't like, but this tint can be removed by using a #23A red color Wratten filter at the eyepiece. Mylar solar filters are specifically designed for solar observing. They are not the same as low-grade Mylar sheets used for thermal blankets and packaging, which are NOT recommended for solar observing or for making do-it-yourself solar filters. Mylar filters are generally considered to be an inferior choice for a solar filter.

Figure 5-5: An objective-mounted solar filter made with Baader AstroSolar film. Credit: Baader Planetarium.

Solar Polymer Film Filters

Some vendors such as Baader Planetarium and Thousand Oaks have engineered a specialty metalized polymer film that acts as an excellent solar filter. Baader's product is known as AstroSolar film, while Thousand Oaks calls their film Solarlite.

Solar filters made with these polymer films are durable and they give a natural white image of the Sun with just a slight tint of blue (in the case of Baader AstroSolar film) and yellow-orange (in the case of Solarlite). These filters result in very good white-light solar images at high magnification, generally much better than what's available with a glass solar filter. Film filters are mounted in mechanical cells without added stress to help maintain high-image quality over a wide range of operating temperature. Don't be surprised to see wrinkles in these thin-film filters when they are mounted in a cell. The wrinkling does not affect image quality.

Like glass filters, solar film filters can fit a wide range of telescope apertures, and they are also available for binoculars, spotting scopes, and camera lenses as well. A link to an online solar filter selector tool at the end of this chapter will help you choose a mounted solar filter for your telescope, camera, or binoculars.

Want to make your own solar filter? You can, and this is often the most economical approach. You can purchase small sheets of Baader AstroSolar or Thousand Oaks Solarlite film to make your own solar filter. Agena Astro offers pieces of these solar films in sizes from 1.5" to 12" square. The film comes with instructions to make your own simple cell to hold the film over your telescope.

Figure 5-6: A Baader Astrosolar film filter mounted in a cell on a small spotting scope. Credit: Baader Planetarium.

Figure 5-7: A pair of Baader AstroSolar film white-light filters mounted on binoculars. Credit: Baader Planetarium.

SAFETY NOTE: Make sure you double check to make sure your glass or film solar filter and its mounting cell are securely fixed to the front of your telescope tube before you aim at the Sun. Make sure you get a filter that fits the tube of your scope or binoculars. One size does not fit all. Most vendors have the filters mounted in cells to match the most common apertures of telescopes available on the market.

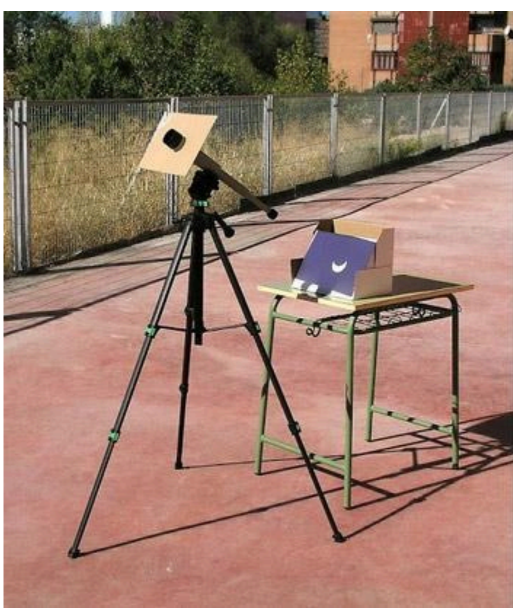
An Alternative to Solar Filters - Solar Projection with a Telescope

If you don’t have a solar filter available for your binoculars or telescope, you can project the image of the Sun from a small unfiltered telescope onto a white screen. The projection method dates back nearly to the invention of the telescope itself. In its simplest form, the technique simply involves holding a thick piece of paper or cardboard a foot or two behind the eyepiece of a telescope when the scope is aimed at the Sun and brought to focus. The image from the eyepiece projects onto the paper screen. The greater the distance from the eyepiece to the screen, the larger the image. That's all there is to it.

Because the telescope is unfiltered when using the projection method and the Sun's full intensity falls into the optics, this method is **best suited for small refractors of less than 3" to 4" aperture**. Larger telescopes collect too much light and heat which may result in damage to the eyepiece.

To get a projected view on the screen with good contrast, place a small diaphragm made of cardboard over the top or bottom of the telescope tube to block unwanted sunlight from falling onto the imaging screen. No other special equipment is required for this method, though some vendors sell a white screen and a mechanical holder that fixes on the back of the telescope or focuser to hold the screen in place.

SAFETY NOTE: When using the projection technique with telescopes or binoculars, remember the full intensity of the Sun is coming out of the eyepiece. So make sure no one, especially a small child, walks up and looks through it. For the same reason, it's also good practice to cover the finder scope of a telescope during a solar observing session.



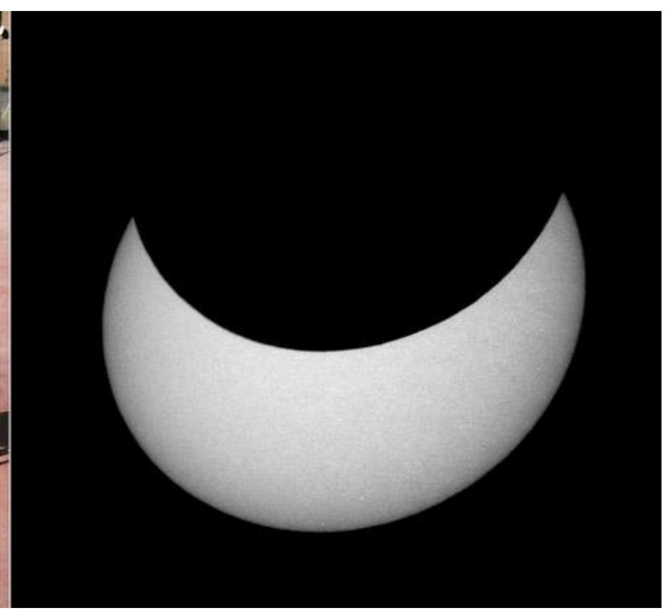


Fig. 5-8: Projecting the Sun's image during a partial solar eclipse onto a screen with a small unfiltered telescope. Credit: Luis Fernández García/Creative Commons License.

You can also use a pair of binoculars mounted on a tripod—with a cap placed over one of the two objective lenses—to project the image of the Sun onto a screen. However, with binoculars, it's best to observe the Sun for only a few minutes at a time because the Sun's heat can damage the adhesive used to hold the glass prisms in place inside the sealed optical tube of the binoculars. With magnification of 7x to 10x, binoculars show much more on the Sun's disk than the unaided eye with a pair of eclipse glasses.

The projection method is also well suited for showing the Sun's disk and the progress of a solar eclipse to larger groups of observers, especially during partial solar eclipses.

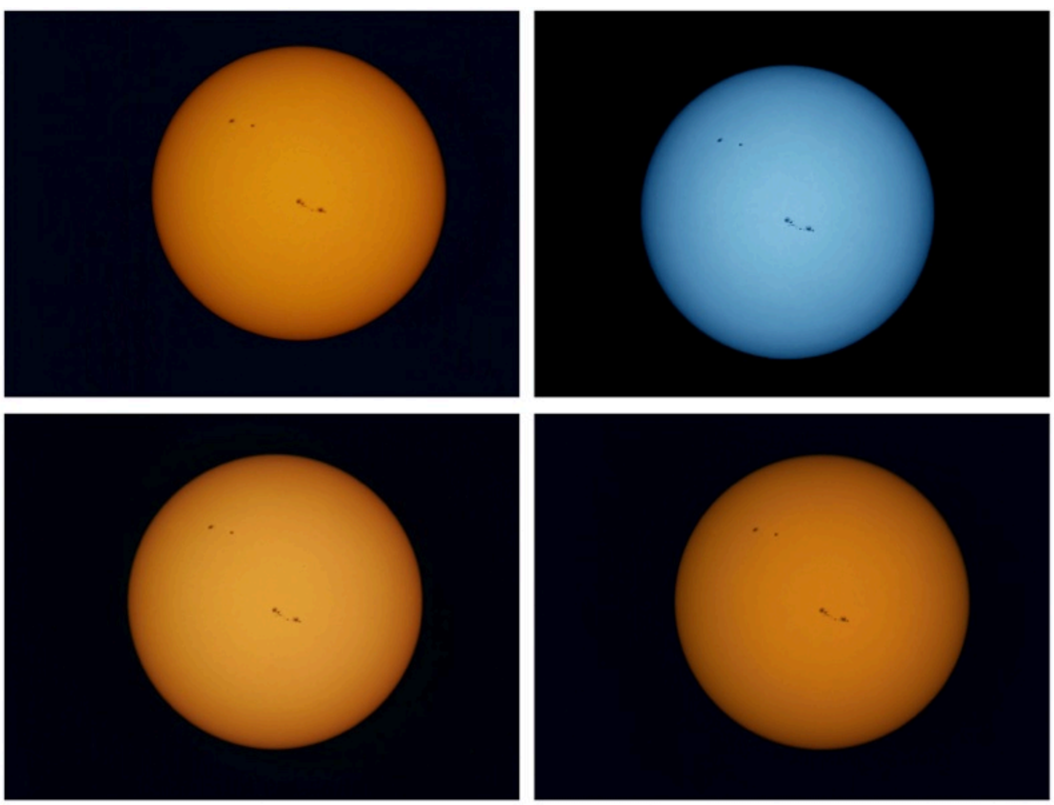


Figure 5-9: Four images of the Sun taken with a camera through a small telescope and various solar filters. Clockwise, from upper left, the images are taken with a

Spectrum Telescope glass solar filter, Baader AstroSolar film filter, Spectrum Telescope solar film filter, and Thousand Oaks solar film filter. Credit: Sergio Castillo/Agena Astro.

Useful Links and Tools

White Light Mounted Solar Filters (for Telescopes, Binoculars, and Spotting Scopes). Agena Astro offers perhaps the widest range of film or glass white light solar filters available anywhere. They carry filters from Baader Planetarium, Celestron, Meade, Spectrum Telescopes, Thousand Oaks Optical, and others. Filters are available to fit virtually any size telescope and budget.

http://agenaastro.com/solar-astronomy/white-light-solar-filters/white-light-solar-filters-for-telescopes.html

Baader AstroSolar and Thousand Oaks Solarlite Film Filters Solar (Film Sheets). Making your own solar filter costs a fraction of buying a commercially mounted filter and it's an easy and exciting craft project. If you are interested in making your own solar viewers and filters with solar film, you can find a square piece of film of the right size for your application at this link: http://agenaastro.com/solar-astronomy/white-light-solar-filters/solar-film-sheets.html

Thread-On Camera Filters: Thin film solar filters are available mounted in a screw-on cell for camera and camera lenses from Spectrum Telescopes and Thousand Oaks Optical:

http://agenaastro.com/solar-astronomy/white-light-solar-filters/camera-solar-filters.html

Chapter 6 – Dedicated Solar Binoculars and Telescopes

Overview

In the last chapter, you learned about solar filters that let you turn nearly any telescope or pair of binoculars into a safe instrument for observing the Sun during a solar eclipse. In this chapter, you'll learn about dedicated solar telescopes and binoculars with built-in solar filters that offer a great deal of safety and convenience, especially for new and casual solar eclipse observers. These instruments can also be used to observe features on the entire visible face of the Sun on any clear day.

Figure 6-1: Sunspots visible on the Sun through a telescope during a partial solar eclipse. Credit: Justin Dolske/Flickr under the Creative Commons License.

White Light Solar Telescopes and Binoculars

White-light solar telescopes and binoculars come with an integrated white-light solar filter over the objective lens or mirror. This is a big advantage, especially for casual observing or for beginners, because the observer does not need to carry around an extra solar filter or remember to safely mount it to the telescope before a solar observing session. Also, the filter can't be accidentally removed during a session, so these telescopes can be inherently safer when used correctly. There is one drawback to these scopes. Since you can't remove the solar filter, you can't observe the brief period of totality with these telescopes or binoculars because, during these brief minutes, the totally eclipsed Sun is too faint to be visible through the solar filter. But these telescopes are excellent for watching the partial phase of a solar eclipse or for general solar observation. They are usually designed for a modest magnification of less than 25-50x, which is far more than binoculars. This results in more detail of the progress of the eclipse itself as well as better views of sunspots and other features.

Figure 6-2: The Celestron EclipSMART solar telescope with an integrated white-light solar filter. Note the solar filter is inside the telescope and not visible in this photo. Credit: Celestron.

For even more convenient observing, although with lower magnification, a pair of dedicated solar binoculars are also useful tools for eclipse observers. Like solar telescopes, these binoculars have polished glass solar filters mounted over the objectives. They have objective lenses of 25mm to 50mm, enough to provide better resolution than a pair of eclipse glasses, and a magnification of 10x or 12x. That’s less than a telescope, but the lower magnification makes it easier to get a steady image when hand-holding these optics. As with the telescopes, you don’t need to carry around the solar filters for the binoculars as separate parts, and the filters can’t be removed accidentally. Nor, however, can they be removed to observe the Sun during the brief time of the total solar eclipse.

Figure 6-3: A pair Celestron solar binoculars are for dedicated solar observing. They are available in 10x25, 10x42, and 12x50 versions.

Useful Links – White Light Solar Telescopes and Binoculars

Celestron EclipSMART Solar Telescope. A compact 50mm telescope with integrated solar filter comes with an eyepiece that gives a magnification of 18x, a solar finder to help you aim the telescope at the Sun, and a tripod for mounting.

http://agenaastro.com/celestron-eclipsmart-travel-scope-50-22060.html

Celestron EclipSMART Solar Binoculars. Intended for handheld use and travel, these dedicated solar binoculars with integrated polished glass solar filters are available in a 10x25 configuration larger 10x42 and 12x50 configurations for improved resolution of solar features.

http://agenaastro.com/solar-astronomy/white-light-solar-filters/solar-viewing-binoculars/shopby/celestron_eclipsmart.html

Seestar S50 All-In-One Smart Telescope. A smart telescope that comes

https://agenaastro.com/seestar-s50-all-in-one-telescope-by-zwo.html

Seeing the Sun and Solar Eclipses in H-Alpha

The most striking views and images of the Sun are obtained with filters that pass only a tiny fraction of light that's blasted out by glowing hydrogen gas. This light, which shines with a deep red-orange color, comes from the Sun's chromosphere, a narrow layer of gas above the photosphere.

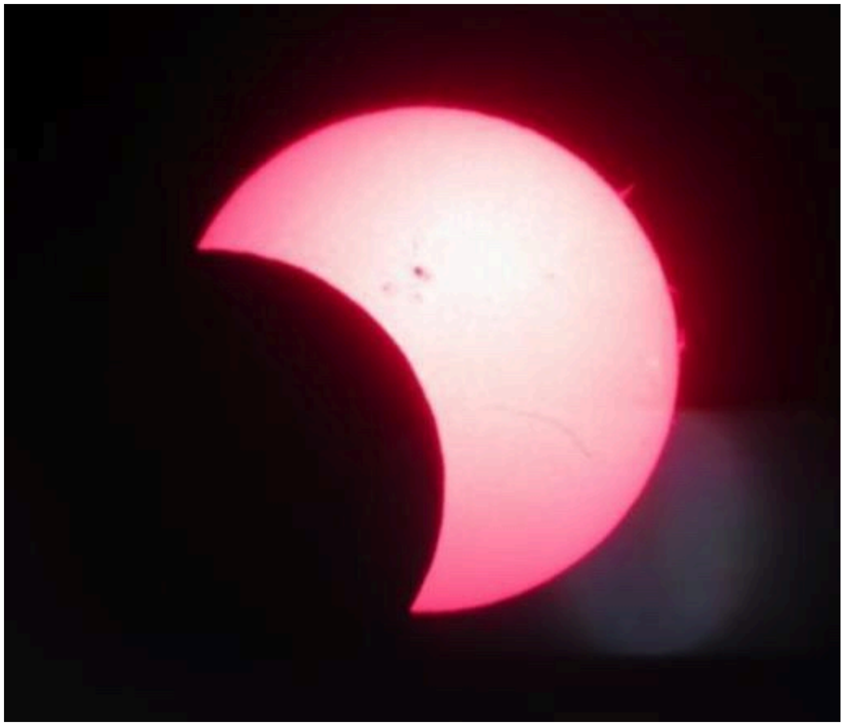


Figure 6-4: A partial solar eclipse on October 23, 2014 taken with a smartphone held at the eyepiece of an H-alpha solar telescope. Prominences are visible at the right limb of the Sun, and a long solar filament is seen below center. A large sunspot group is visible above and to the left of the centerline of the Sun. Credit: Brian Ventrudo.

To see this red light, astronomers use a special **Hydrogen-Alpha** solar filter. These filters give views of stunning solar features that are not visible with white light solar filters. These features include dramatic *solar prominences*, which are dense clouds of gas and charged particles suspended above the photosphere of the Sun by magnetic field loops. Prominences are sometimes visible along the limb of the Sun's disk, and if you see them during a solar eclipse (see Figure 6-4), they are even more dramatic.

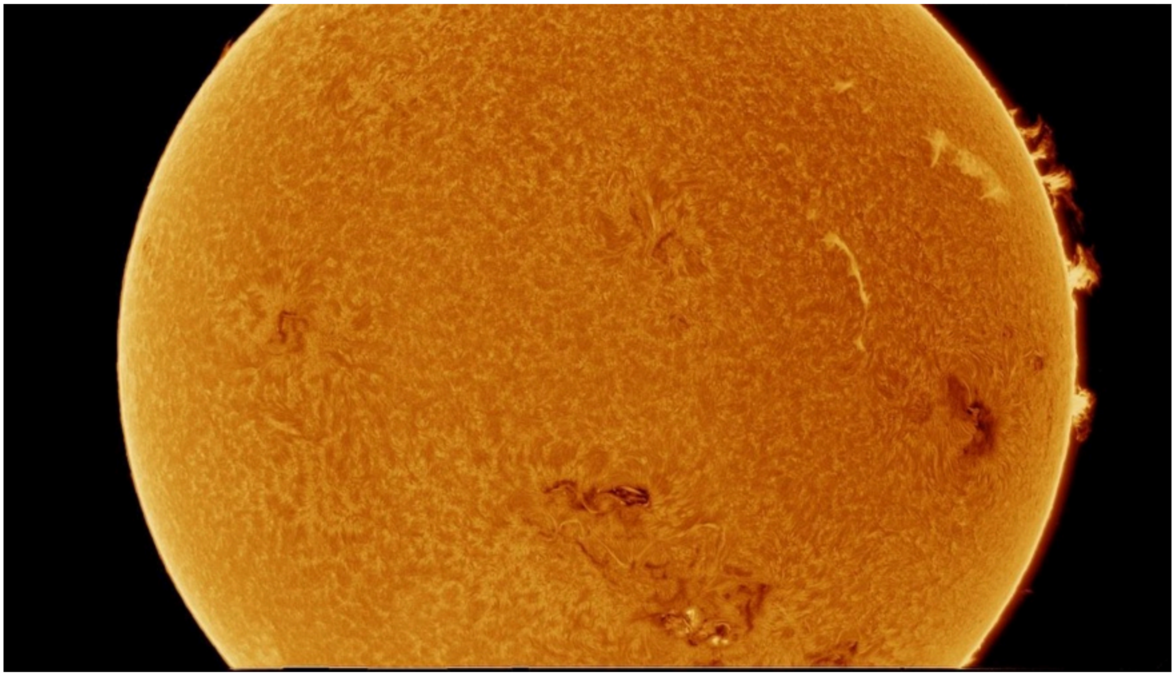


Figure 6-5: An image of the partial solar disk taken with a 60mm Lunt H-alpha solar telescope. Image credit: Brian Ventrudo.

If you see a prominence in the central part of the Sun rising up towards the Earth, it's called a *filament*. Filaments appear as dark rope-like structures etched into the face of the Sun. If sunspots are present, you might also see *plages*. These are bright patches visible around a sunspot. Sunspots themselves are not as conspicuous in this deep-red part of the solar spectrum because, with H-alpha filters, you see higher up in the chromosphere rather than into the photosphere where sunspots take root.

Figure 6-6: The Coronado Personal Solar Telescope (P.S.T.) has an integrated H-alpha solar filter and a 40mm objective lens. This scope is small and light enough to be mounted on a good photo tripod. Credit: Meade Instruments/Coronado.

H-Alpha Solar Telescopes

To see any of these features—prominences, filaments, and plages—during a solar eclipse, or at any time, you must use an H-alpha solar filter or a complete H-alpha solar telescope. The filters themselves can be used on many standard astronomy telescopes, but they are recommended only for experienced amateur astronomers.

For beginning solar observers or those looking for the most dramatic possible view of the Sun during a solar eclipse without much fuss, a small dedicated H-alpha solar telescope offers an easier turn-key solution. These refractor telescopes have everything you need to see the ruby-red disk of the Sun in H-alpha including a lens, eyepiece, tube, H-alpha solar filter, and a so-called blocking diagonal to keep the Sun’s light at a safe intensity.

While H-alpha solar filters and telescopes are more expensive than many options for solar observing, these little scopes are well worth the investment if you want to get the most dynamic views of the Sun during a solar eclipse. These scopes are primarily made by Coronado and Lunt Solar Systems. The Personal Solar Telescope (P.S.T.) by Coronado has an objective lens of 40 mm and a filter passband of <1 Angstrom. This is good enough for views of major prominences and other such features in the Sun's chromosphere. There is also a version of the Coronado PST with a double-stacked filter with an overall bandpass of <0.5 Angstrom for even more dramatic views of the Sun's chromosphere. Lunt also has a dedicated solar telescope with a 40mm aperture and <0.75 Angstrom passband.

Both Lunt and Coronado also have H-alpha solar telescopes with larger apertures and more sophisticated filters.

Figure 6-7: The Lunt Solar Systems LS50THa solar telescope. Credit: Lunt Solar Systems.

H-alpha solar telescopes from Coronado and Lunt also come with tuning mechanisms to slightly alter the H-alpha filter to give you better views of some features depending on their speed towards or away from Earth. These small scopes must also be mounted on photographic tripods or on standard telescope mounts to provide steady views.

Useful Links – H-Alpha Solar Telescopes

Coronado Personal Solar Telescope (P.S.T.) This standard model shows large prominences and filaments and is ideal for starting out in H-alpha solar observing during eclipses or on any clear day.

http://agenaastro.com/coronado-40mm-pst-personal-solar-telescope.html

Coronado Personal Solar Telescope (P.S.T.) – Double-Stack Filter. With an extra filter stage to narrow down the light from the Sun's chromosphere, this scope gives very sharp views of solar features in the Sun's chromosphere.

http://agenaastro.com/coronado-40mm-0-5-pst-personal-solar-telescope.html

Lunt Solar Systems 40mm f/10 Solar Telescope and LS50THa Solar Telescope. With a slightly larger aperture than the Coronado P.S.T. telescopes, these self-contained solar scopes are also an excellent option for H-alpha eclipse observation and for day-to-day solar observing.

http://agenaastro.com/solar-astronomy/solar-viewing-telescopes/hydrogen-alpha-solar-telescopes/shopby/lunt_solar_systems.html?price=-1000

Several other larger aperture H-alpha solar telescopes are available from Coronado and Lunt. While they are expensive, they offer excellent views of the solar disk during the eclipse or on any clear day:

https://agenaastro.com/solar-astronomy/solar-viewing-telescopes/hydrogen-alpha-solar-telescopes.html

Chapter 7 – Taking Images of the Solar Eclipse

When it comes to trying to take an image during the brief few minutes of totality, many expert photographers and amateur astronomers have one suggestion: don't. You only have, at most, about 240 seconds during the April 2024 total solar eclipse to enjoy one of the most spectacular events you will ever see. You don't want to spend time fiddling with your camera during this fleeting opportunity. This will surely be the most photographed eclipse of all time, so if it's your first total eclipse, just enjoy the show and you can see plenty of images taken by expert photographers afterwards.

Figure 7-1: A cropped image of a total solar eclipse taken with a DSLR with a 55mm focal-length lens, ISO1600, f/4, and 1/15s shutter speed. Image credit: Romeo Durscher/NASA Goddard.

However, if you wish to try your hand at imaging, this chapter has a few tips and ideas to get you started taking simple images with a camera and lens or at the eyepiece of a telescope with a safe solar filter. However, since it's not a topic for beginners, the techniques of taking images of the Sun through the telescope, using the telescope as the camera lens, will not be covered here!

General Tips for Imaging a Solar Eclipse

- Taking an image of a solar eclipse during the partial phase involves the same consideration as imaging the Sun in general. You **MUST use a solar filter over your camera lens or over the objective lens of your telescope or binoculars.** If the Sun is too bright to look at with your eyes without a solar filter, it's too bright to image without a solar filter.
- As with visual observation, once the eclipse reaches totality and becomes safe enough to see with your eyes, you can—and must—remove the solar filter from your camera. Otherwise, your camera will not see anything. Once totality ends, if you wish to image the subsequent partial eclipse, **you must replace the filter.**
- Do not use a flash. It will not help with an image of the eclipse and it's distracting to those around you.
- Don't trust autofocus to work correctly during totality. Focus on the Sun manually through a solar filter before totality, then turn off autofocus before totality begins.
- Practice focusing and taking images during the partial phase of the eclipse before totality begins, or practice weeks in advance on the full Moon.
- Make a checklist of all the equipment you need for the eclipse, especially if you are traveling. Also make a checklist of the steps required to take an image of the eclipse, including the tips in this chapter.
- Use a tripod to get a steadier image. And use a timed or remote shutter release to avoid camera shake.

Eclipse Imaging with a Smartphone or Camera

If you just want to take a snapshot of the solar eclipse with your smartphone, point-and-shoot, or DSLR, there are a few things to keep in mind (along with the important tips in the previous section). Remember… during the brief time of the total solar eclipse, you do NOT need a solar filter to take an image. However, during the much longer partial solar eclipse before and after totality, you MUST use a solar filter over your camera lens.

Visually, the Sun and Moon appear quite small, just about half the width of your little finger held at arm's length. So unless you have a long zoom lens with a focal length of at least 300mm (35mm equivalent), then your image of the Sun before, during, and after the brief few minutes of the total eclipse will appear quite tiny, and you may be disappointed with the results. The best you can hope for with even a basic 55mm lens and a DSLR camera is shown in Figure 7-1, for example.

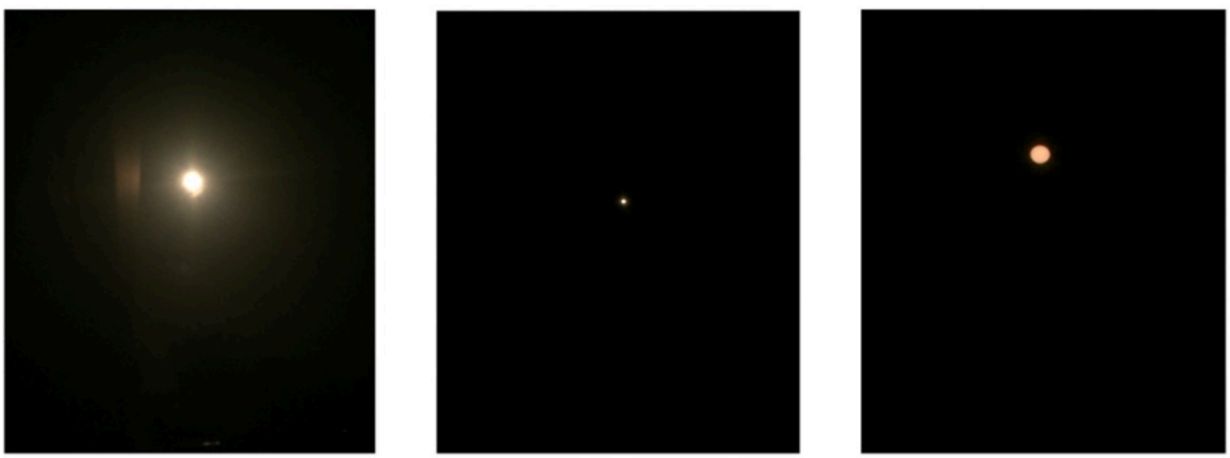


Figure 7-2: Images of the Sun taken with a smartphone camera with a piece of polymer solar film held over the lens. The image at left, taken with the camera's widest field of view, shows the Sun as small and overexposed. The image in the middle, also with the widest field of view, was taken with an app that allows for manual setting of the camera exposure time. The image at right was taken with the same app, but with the camera zoom at maximum. This is as large an image of the Sun that is possible with this smartphone camera. Credit: Sergio Castillo/Agena Astro.

This will be the first total solar eclipse in America where virtually everyone owns a smartphone with a built-in digital camera. Tens of millions of casual viewers will attempt to shoot the eclipse—either directly by pointing their smartphone at the Sun (NOT RECOMMENDED), by placing the phone behind a solar viewer or glasses or a telescope's eyepiece, or by using dedicated smartphone solar filters and mounts. While these snapshots may be adequate as personal keepsakes of the event, the significant limitations of smartphone cameras mean these images will almost always be of poor quality for the following reasons (see Figure 7-2):

- The focal length of smartphone lenses is very small. As a result, the solar disk will be tiny! Even when you zoom in, it will be much too small to give a pleasing image.
- You cannot control exposure times with most smartphone cameras, so images of the Sun, even through a solar filter, will be overexposed. Apps are available to help you manually control your camera's settings to control exposure duration, and they will help, but again, the small image scale may not make it worth the purchase price of the app.
- Hand-holding a camera is bound to result in a blurry image due to camera shake. So it's important to mount your smartphone on a tripod for better results.

Some third-party vendors offer clip-on zoom lenses for smartphones that give larger images sizes, but again, they are often insufficient to capture the relatively small solar disk.

If you don't have a long zoom lens for your smartphone, point-and-shoot, or DSLR, you can try snapping an image of the surrounding landscape during the total eclipse, or of people silhouetted against the darkened sky, or even a short video of the sounds of the crowd during totality. Or you can snap an image of the partial solar eclipse through a solar eclipse card or eclipse glasses along with the surrounding landscape (see, for example), Figure 4-3.

And if you have a good zoom lens for your DSLR camera or a point-and-shoot camera with a long zoom, you must use a safe solar filter to protect your camera and eyes during the partial phase of the solar eclipse. You can use filters made of thin solar film, as mentioned in the last chapter, which will fit over many camera lenses. Or you can select solar film mounted in screw-on cells that thread into the end of camera lenses like a standard camera filter (see Figure 7-4). These filters are made by Thousand Oaks and Spectrum Telescopes. To find the right diameter of these filters to match your camera lens, consult your camera's manual or the manufacturer's specifications.

Figure 7-3: A Thousand Oaks thread-on camera filter (left) made with SolarLite polymer film. The filter mounted on a DSLR lens (right). Credit: Agena Astro

As for camera settings, during the brief phase of totality, the Sun's corona appears about as bright at the full Moon. So you can set your camera accordingly for shutter speed, aperture, and ISO. Try ISO 200-400, aperture of f/4 to f/5.6, and a shutter speed from 1/10s to 1/1000s over multiple images. During the much longer phases of the partial solar eclipse, before and after totality, these settings are also a good starting point when your camera has a solar filter in front of its lens.

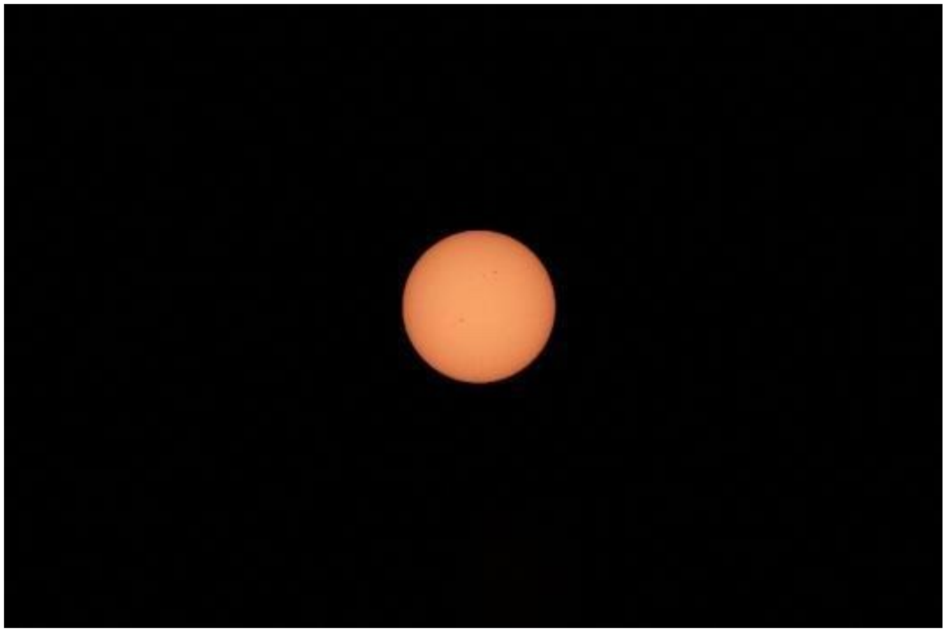


Figure 7-4: An uncropped image of the Sun with a DSLR camera with APS-C sensor and a 400mm lens (which is a 640mm equivalent to a full-frame DSLR camera). Credit: Sergio Castillo/Agena Astro.

Afocal Solar Imaging

While wide-angle camera landscape shots during the totality are easiest, there is one straightforward way to capture a close-up view of the eclipse through the eyepiece of a telescope: *afocal imaging*.

Figure 7-5: A smartphone holder from Celestron that enables imaging directly through the eyepiece of a telescope.

To do afocal imaging, you adjust the focuser of a telescope to achieve a good visual solar image in your eyepiece, then simply hold your smartphone or camera up to the eyepiece, adjust the camera focus to get a sharp image in the viewfinder or on the screen, and take the picture. You can hold the camera by hand, but to get the best results, invest in a mechanical holder that secures the smartphone or camera to the focuser of the telescope to keep the camera in place and stationary as the image is taken. Heavier point and shoot cameras or DSLRs with a lens can be placed on a camera tripod and moved close to the eyepiece of the telescope. If possible, use a timer or remote shutter release to take the image with the camera or phone without having to touch it. As with any sort of imaging through a telescope, a solid mount helps with getting a sharp image. Because camera shutter times are fairly fast for solar afocal imaging, a tracking mount is not critical.

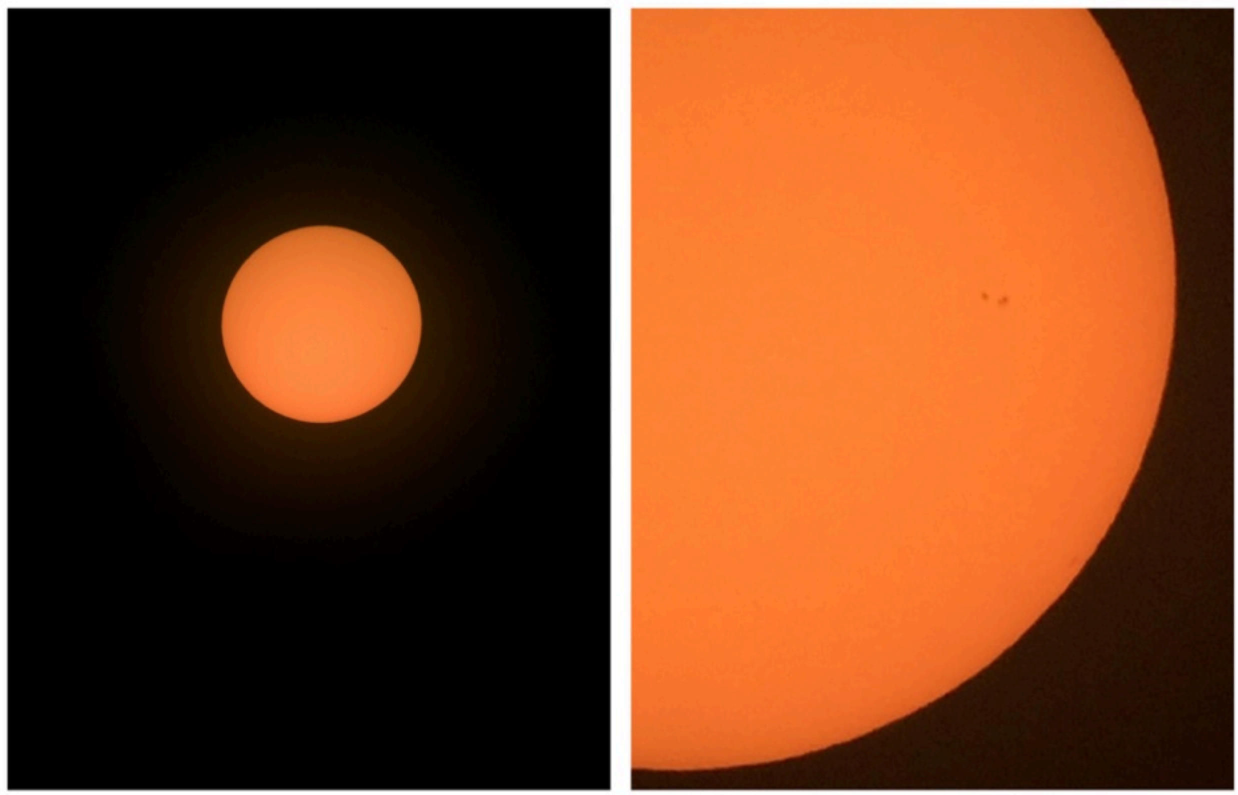


Figure 7-6: Uncropped afocal images of the Sun taken with a smartphone held with a holder/bracket at an eyepiece with focal length of 18.2mm and a telescope with 80mm objective lens and focal length of 480mm. A polymer solar filter was used over the objective lens of the telescope. The image on the left was taken with the smartphone camera set to lowest zoom setting. The image on the right was taken with the smartphone camera set to highest zoom setting. The camera automatically set the exposure. Credit: Sergio Castillo/Agena Astro.

With afocal solar imaging, you can adjust the camera's optical or digital zoom to get close-ups of the image produced by the eyepiece (see Figure 7-6). You can also switch eyepieces in the telescope to change the magnification and field of view.

Once again, a warning: do not try afocal solar eclipse imaging with a telescope without using a proper solar filter **over the objective lens or mirror of the telescope**. It's dangerous to handle an unfiltered telescope when pointing it towards the Sun, and you may damage your eyes inadvertently. You will surely damage the sensor of your smartphone or camera if it's exposed to unfiltered and highly intense and tightly focused light from a telescope.

As for camera settings for afocal imaging, use ISO 200 or 400 and set the widest possible aperture (i.e., the lowest f-stop number such as f/2.8 or f/4). Try a range of exposure times. Since even the filtered Sun is quite bright, start with something in the range of 1/30s to 1/500s. Shorter exposures capture more detail of sunspots and other features on the face of the Sun in white light.

Useful Links

Solar Filters for Cameras. Agena Astro has a wide selection of white light solar filters for camera lenses for shooting images of the partial solar eclipse before and after totality. See the link below:

http://agenaastro.com/solar-astronomy/white-light-solar-filters/camera-solar-filters.html

How to Photograph the Solar Eclipse. The noted astrophotographer and eclipse watcher Alan Dyer has useful tips for beginners and experienced photographers who are new to solar eclipses in this video:

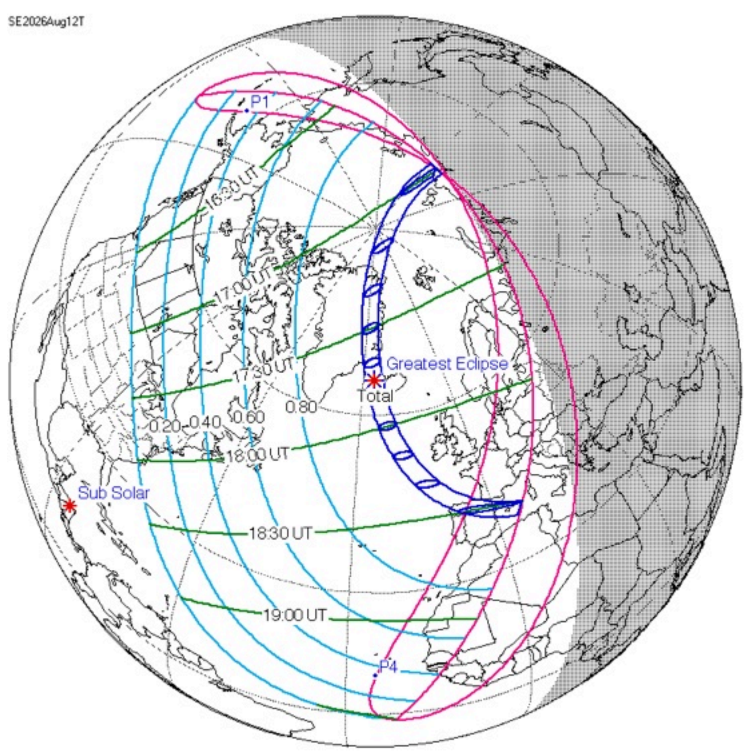
https://youtu.be/D-K2YCLtaEU?si=e0Z-NBKShW93x5Dk

Epilogue – The Next Solar Eclipse

This guide has taken you through everything you need to know to see the total solar eclipse of April 8, 2024. You learned why eclipses happen and how they work. You learned when and where to see the eclipse. And you found some essential tips and suggestions about how to safely see the eclipse with a wide range of tools from a simple solar viewer or pair of eclipse glasses, to white-light solar filters for your telescope or camera, to complete solar telescopes with H-alpha solar filters that give the most dramatic views of the Sun.

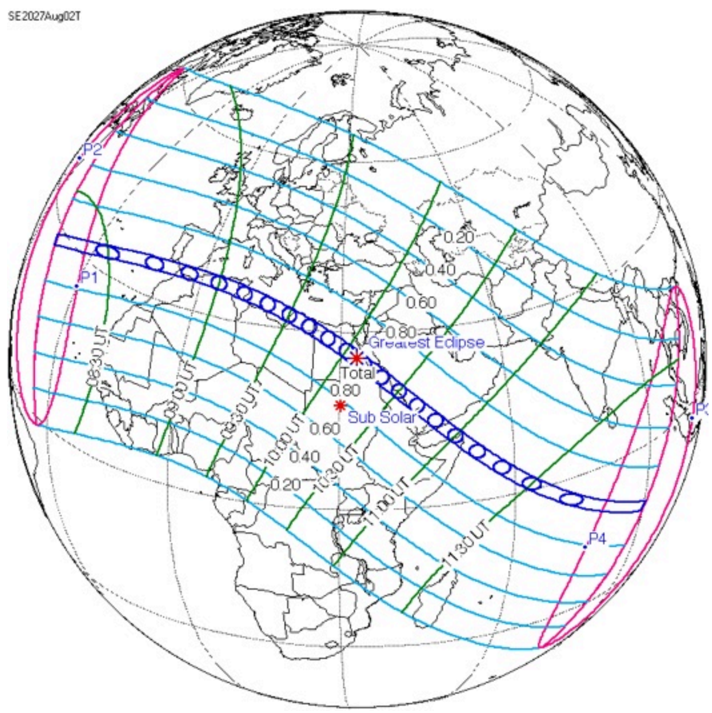
Now it's up to you to make your way to the narrow path of totality!

Once you see this eclipse, you may develop an interest in seeing another. There are solar eclipses of some kind every year, but they are not always total eclipses and they are not always in a convenient place to get to. Here's a brief summary of upcoming total solar eclipses over the next several years:



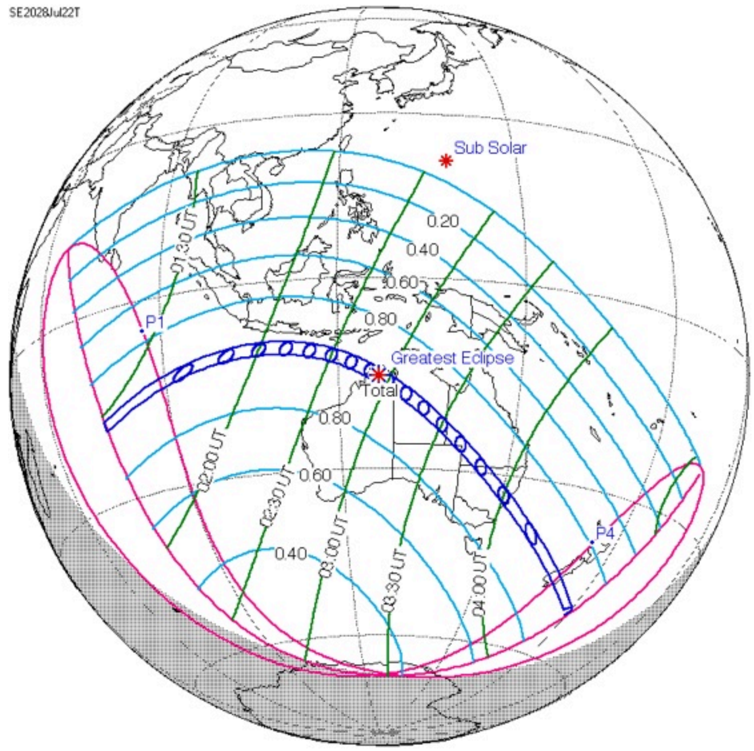
The path of the solar eclipse August 12, 2026 northern Spain, Iceland, and Greenland. Image credit: NASA.

August 12, 2026 – This event will be visible in a narrow band across northern Spain including the cities of Valencia, Zaragoza, Palma, and Bilbao, the north Atlantic, Iceland, and Greenland. The eclipse will last as long as two minutes and eighteen seconds near Iceland. Learn more about this eclipse [at this link](#).



The path of the solar eclipse August 2, 2027 southern Spain, Gibraltar, north Africa, and the Arabian peninsula. Image credit: NASA.

August 2, 2027 – This eclipse passes across southern Spain, Gibraltar, North Africa, and the Arabian peninsula. The maximum duration of totality will be six minutes and twenty-three seconds over Egypt. [See the path at this link](#).



The path of the solar eclipse of July 22, 2028 over Australia and New Zealand. Image credit: NASA.

July 22, 2028. This total solar eclipse passes diagonally from the northwest to southeast across Australia, including the city of Sydney, and into New Zealand where it passes over Queenstown and Dunedin. See the path at this link.

Start planning now!

Appendix - A Deeper Look at Solar Eclipses

Solar eclipses don't happen at random. They are a consequence of the layout and mechanics of the Earth, Moon, and Sun. In this section, you'll learn a little of the inner workings of a solar eclipse so you can understand their cycles and occurrences. You don't need to understand this information to see the total eclipse in 2024, or any other eclipse, but as with all knowledge, it will make your experience and contemplation of a solar eclipse more enjoyable.

The Earth orbits around the Sun once a year in a more or less flat plane in space. The Earth is in that plane of course, and from our point of view this plane is defined by a circle traced around the sky. We call this circle the *ecliptic*, and the Sun is always somewhere on that circle and appears to move around the circle during the year as the Earth moves around the Sun. The band of the ecliptic passes through twelve constellations which we call the *zodiac*.

As the Earth makes its way around the Sun once a year, the Moon moves around the Earth and completes its cycle of phases from New Moon to New Moon every 29.53 days, a period known as a *lunation* (or if you want to get fancy, it's also called a *synodic month*). But the plane of the Moon's orbit is tilted by 5^o relative to the plane of the Earth's orbit, so the Moon does not exactly follow the ecliptic. It spends half its time above and half its time below the ecliptic each month. But twice a month, the Moon's path crosses the ecliptic at the point where these two circles around the sky intersect. Astronomers call these crossing point *nodes*. The ascending node is the point at which the Moon moves north across the ecliptic; the descending node is the point where the Sun moves south across the ecliptic (see image below).

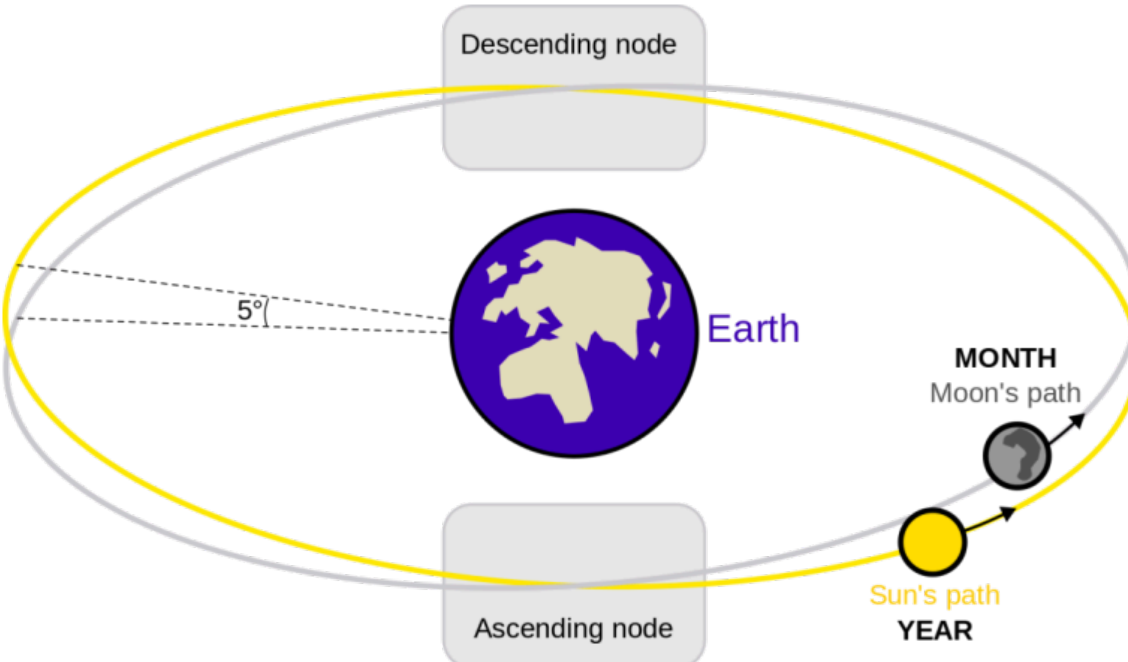


Figure A-1: The Moon's orbit is tilted by 5° relative to the plane of the Earth's orbit around the Sun. When the planes of the orbits intersect—at the ascending and descending nodes, a solar and lunar eclipse can occur. Image credit: Wikipedia Commons.

Because of the 5° tilt of the Moon's orbit relative to the path of the Sun, the Moon does not pass directly in front of the Sun each month at New Moon to cause a solar eclipse, nor does the Earth pass between the Sun and Moon each month at Full Moon to cause a lunar eclipse. An eclipse will occur only when the Moon crosses a node at Full Moon when the Sun is directly opposite the Moon in the sky, or at New Moon when the Sun and Moon overlap at the same node.

If the Moon and Sun were tiny points of light, they would have to lie exactly on the nodes for an eclipse to occur. But they are not points of light. They appear as disks about 0.5° across, so eclipses can occur when New Moon and Full Moon occur close to a node, but not necessary when they are exactly at a node. It turns out eclipses can occur during a 34-day period that occurs twice each year when the Full and New Moons are close enough to a node to at least partially line up with the Earth and Sun. These are called *eclipse seasons*. If a Full Moon happens during an eclipse season, there will be a total or partial lunar eclipse. If a New

Moon happens during an eclipse season, there will be a total, annular, or partial solar eclipse. And since it takes just 14.5 days for the Moon to move from New Moon to Full Moon, if there's a solar eclipse at New Moon, there will be a lunar eclipse at Full Moon about two weeks before or after the solar eclipse. Also, a solar eclipse is joined by a second solar eclipse approximately six months later (or more precisely, six lunation periods of 29.5 days). It's the same for a lunar eclipse.

Let's consider an example. The solar eclipse of April 8, 2024 is preceded by a partial (penumbral) lunar eclipse on March 24-25, 2024. It's also followed about 6 months later by an annular solar eclipse visible across the south Pacific and extreme southern South America on October 2, 2024. Depending on the timing of the eclipse seasons during a calendar year, there can be as many as seven eclipses in a year (both lunar and solar) and as few as four eclipses during a year (both lunar and solar).

If you talk with eclipse experts, you may hear them talk about the Saros Cycle and which 'Saros' a particular eclipse belongs to. The Saros Cycle was discovered by ancient Chaldean astronomers more than 3,000 years ago. They used it to understand and predict lunar eclipses, but it applies to solar eclipses as well and it helps us understand how the geometry that produces a particular eclipse repeats itself over time. A solar eclipse, for example, happens at New Moon which happens every 29.53 days. It happens during an eclipse season which happens, on average, every 173.3 days. And it happens when the Moon is nearest to the Earth in its orbit, which happens every 27.3 days. These three factors repeat themselves, it turns out, every 6,585.3 days or 18 years, 11 days, and 8 hours. Pick any solar eclipse, wait for this period of time, and the same eclipse will happen at the same node, same time of year, and with the Sun and Moon in the same part of the sky. This is the Saros Cycle.

Two consecutive eclipses in a Saros Cycle do not happen at the same place on Earth, however. That's because of the extra 8 hours in each cycle during which the Earth makes 1/3 of a rotation westward. For example, the April 8, 2024 eclipse is part of the Saros Cycle #139 (or simply Saros 139). It occurs across North America. The next eclipse in Saros 139 occurs exactly 18 years, 11 days, and 8 hours later on

April 19-20, 2042, but it will be visible over the Philippines, Indonesia, and the eastern Pacific.

Solar eclipses that take place near the Moon's ascending node have odd Saros numbers, and eclipses that occur near the descending node have even Saros numbers.

Every three consecutive eclipses in the same Saros cycle happen back at the same longitude on Earth. That's because the Earth will have made a complete turn: the 8 hour delay in each cycle, for three cycles, adds up to 24 hours. But 33 extra days will have passed after these three cycles, 11 days for each cycle, which means the Sun will be a little higher or lower in the sky depending on the season in which it occurs, and the Moon's shadow will be a little higher or lower depending on whether the eclipse happens at an ascending or descending node. The upshot is that the eclipses of a particular Saros cycle begin far north or south near one of the Earth's poles, repeat every 18 years, 11 days, and 8 hours in narrow curved paths around the planet, cross the equator, then head towards the opposite pole. After that, the Saros cycle ends as the Moon's shadow no longer passes anywhere across the Earth during these particular alignments. Most Saros cycles have 71 or 72 eclipses, though some have more or less. The alignments of the Earth, Moon, and Sun described by Saros 139, for example, began on May 17, 1501 with an eclipse in the far northern hemisphere. They end on July 3, 2763 with an eclipse in the far southern hemisphere.

The image below shows the location of the path of four consecutive eclipses from Saros 139 starting with the April 8, 2024 eclipse. Notice that after three Saros cycles, the eclipse happens at almost the same longitude but at a more southerly latitude. The eclipse of April 8, 2024 will repeat at the same longitude but further south, from Mexico through the southeastern United States on May 11, 2078.

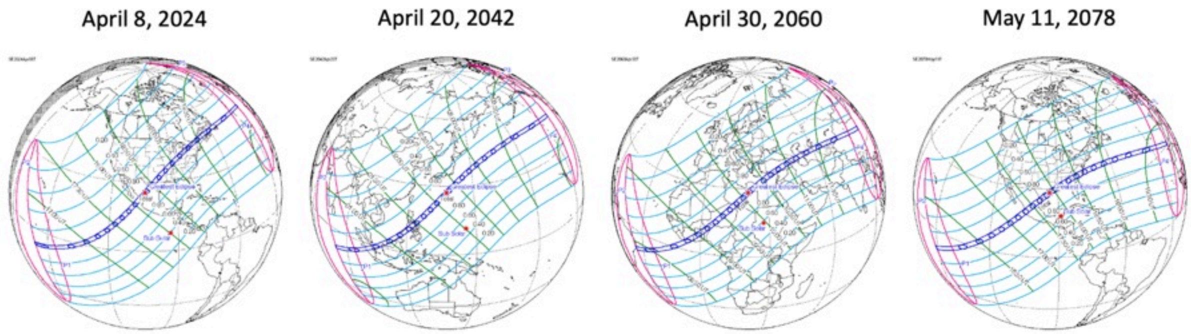


Figure A-2: The path of four consecutive eclipses from Saros 139. This image shows the displacement of the same eclipse path westward until it ends up nearly back at the same longitude, but slightly southward. Image credit: NASA/Agena Astro.

As mentioned at the beginning of this appendix, you don't need to understand the Saros cycles and the intricacies of the Moon's motion across the sky to enjoy an eclipse. But it does help you appreciate the consequences of the geometry and clockwork motion of the solar system in action.

About the Authors

Brian Ventrudo is a writer, scientist, and astronomy educator. He received his first telescope at the age of 5 and completed his first university course in astronomy at the age of 12, eventually receiving a Master's degree in the subject. He also holds a Ph.D. in engineering physics from McMaster University. During a twenty-year scientific career, he developed laser systems to detect molecules found in interstellar space and planetary atmospheres, and leveraged his expertise to create laser technology for optical communications networks. Since 2008, Brian has taught astronomy to tens of thousands of stargazers through his websites OneMinuteAstronomer.com and CosmicPursuits.com.

Manish Panjwani has been an active amateur astronomer since before Halley's Comet last visited our neighborhood. A former wireless communications consulting engineer and management consultant to various Fortune 500 companies, Manish started Agena Astro in 2003. Since then, Agena has become one of the leading online retailers of telescopes and astronomical accessories worldwide. Besides observing from his heavily light-polluted backyard in Los Angeles, Manish enjoys conducting astronomy outreach programs in local schools. Manish also holds a Master's degree in Electrical Engineering from Virginia Tech and an MBA from the Kellogg School of Management at Northwestern University.

About Agena Astro

Whether you are an absolute beginner with a passing interest in the upcoming eclipse, an enthusiastic amateur astronomer, or an advanced expert in astronomy, Agena Astro has everything you need to get ready for the Total Solar Eclipse of August 2024.

Founded in 2003 and based in the greater Los Angeles area, Agena Astro is one of the largest and most trusted online astronomy stores in the world. With over 5,000 products in stock, Agena has telescopes, binoculars, eyepieces, imaging cameras, and astronomy accessories, including many hard-to-find items you won't see anywhere else. Agena carries products from the leading brands you know and trust:

- Celestron
- Meade
- Coronado
- Lunt Solar Systems
- Tele Vue
- Baader Planetarium
- Thousand Oaks Optical
- Explore Scientific
- Blue Fireball
- GSO
- Askar/Sharpstar
- Spectrum Telescopes
- Sky-Watcher
- William Optics
- ZWO Astronomical Cameras
- And many more…