A special issue of Prime Focus by the Kalamazoo Astronomical Society

Great North American ECLIPSE

Get Ready for April 8, 2024!

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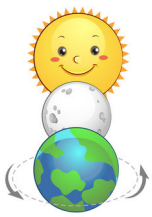


Observations by Richard S. Bell

Welcome to this special eclipse-themed issue of *Prime Focus*! This is, without a doubt, the largest issue of *Prime Focus* ever published. I can also promise this will be the biggest issue of the newsletter I will ever do! It was an immense chore to assemble, so I hope you enjoy it and that it inspires you or increases your excitement to travel to the path of totality on April 8th. Please share this issue with anyone interested in seeing the solar eclipse.

This issue is for the months of March and April. The Community Eclipse Presentations I'm doing as part of the Eclipse Series reach their peak in March. I'll be traveling to libraries across west Michigan nearly every day of the week. I also want to have plenty of time to make my own personal preparations for Eclipse Day. So, yes, this will be the last issue until the end of April.

The KAS will be going on hiatus in April. Absolutely no club our outreach activities are planned. The eclipse is early in the month, but many members will use the eclipse as an excuse to take a vacation. We will also need time to relax and decompress. Some of us may also be depressed if the weather doesn't cooperate! We do have four excellent activities in March, though. "Mr. Eclipse" Fred Espenak will present *Experiencing Totality: The Great Eclipse of 2024* (via Zoom) on March 1st. I hope all local members join us at the Kalamazoo Area Math & Science Center. We will give away two copies of *Field Guide to the 2023 and 2024 Solar Eclipses* by Michael Zeiler and Michael Bakich right after the main talk. After the break, Gordon Telepun will discuss the popular Solar Eclipse Timer app he developed (more about that in an article on page 40).

The *Intro. to Amateur Astronomy* lecture series concludes on March 9th. Attendance for the first two installments was down compared to 2021 and 2022, which isn't surprising, but Parts 3 and 4 have been comparable to past online versions of the series. Don't get me wrong, this installment far outstrips any in-person version we've done in the past. I look forward to getting another 200 or so Certificates of Completion ready for mailing.

Our only observing activity of the month is the Messier Marathon on March 9th. That will be held at Richland Township Park. The official start time is 7pm, but you are welcome to arrive earlier or later. There's no gate to worry about, like we do at the Nature Center. In fact, if I post a cancellation and it turns out to be clear (as was the case for the February Freeze Out), you can still head out. Even if you don't want to participate in the marathon, you can simply enjoy a little observing and comradery with KAS members. This will also be an opportunity to test out your equipment before the eclipse!

The Eclipse Series concludes on March 15th with an Astrophotography SIG meeting. Our special guest will be Alan Friedman, an artist and incredibly skilled solar imager. Seriously, his images are just phenomenal. Even if you have no interest in astrophotography, you'll enjoy his solar images.

And that's it! No other activities until May 3rd. If you do travel to the path of totality on April 8th, please do the KAS a favor: document your experience. We will be asking members to share their eclipse adventures at the May and June meetings. I wish everyone clear skies on April 8th. This is it!

February Meeting Minutes

The Kalamazoo Astronomical Society's general meeting and sixth installment of the Eclipse Series was brought to order on Friday, February 2nd, at 7:05 pm EST by President Richard Bell. Exactly 93 members and guests were in attendance at the Kalamazoo Area Math & Science Center (KAMSC), while at least another 164 joined us virtually on Zoom.

Our very special guest speaker, who traveled from Santa Fe, New Mexico, to join us in person, was Michael Zeiler. Mr. Zeiler is a geographer, cartographer, author, and creator of the very popular *Great American Eclipse* website. He is also an avid eclipse chaser, so his maps charting the paths of eclipses have become highly regarded. The title of his presentation was *A Tour of the April 8, 2024, Total Solar Eclipse*.

Mr. Zeiler is a retired professional cartographer who worked for the leading provider of geographic information systems (GIS) software. He traveled to see his first total solar eclipse in 1991. In 2009, while writing his book, *Modeling Our World*, he realized there was a need for eclipse maps of high precision and good cartographic quality.

After creating his first eclipse map for the total solar eclipse in July 2009, he launched eclipse-maps.com in 2010 to showcase new and historic eclipse maps. Recognizing the widespread public interest in the August 2017 eclipse, he launched the *Great American Eclipse* website on August 21, 2014.

Mr. Zeiler explained that eclipse maps with unprecedented details are now possible because of high-resolution laser-altimeter data of the Moon from the Japanese Kaguya probe and NASA's Lunar Reconnaissance Orbiter. This led to the first lunar-limb-corrected eclipse maps.

Mr. Zeiler played an animation he created of the Moon's shadow moving across North America. It simulates the view from a spacecraft 125 miles high, chasing the shadow. It highlights the time of totality, duration of totality, speed of the Moon's shadow, and the width of the path of totality.

The first-ever eclipse map was made by the German mathematician, astronomer, and philosopher Erhard Weigel in 1654. Mr. Zeiler asked why we even need eclipse maps since they're only good for a few hours on one day. After the event is over, they're only good as a souvenir. He said that eclipse maps are treasure maps. They are your guide to the most beautiful celestial sight you will ever see, and eclipses are such special events that it's worth making a map only good for a few hours.

The first eclipse map for one visible in the Americas (with the path going through Mexico) was created in 1727. The purpose of the maps was more to determine longitude than a guide to seeing the eclipse itself. The first eclipse map for one visible from the United States didn't come along until 1834.

Mr. Zeiler then took us on a unique and detailed tour of the April 8, 2024, total solar eclipse. The first map showed a color-coded view of the length of totality along the path. Totality is longest in Mexico and Texas. One of his most popular maps, which garnered lots of laughter from the audience, is shown on page 5. It drives home the fact that people should make every effort to travel to the path of totality.

An animated GIF made with Fred Espenak, titled *The Moon's Shadow* on his 2024 eclipse overview page, was shared. Mr. Zeiler then played a video of the Moon's shadow racing along the path of totality in the United States. From the video, it was clear how round the shadow is in Texas, and becomes it more elongated the further along the path it gets.

Mr. Zeiler then shared a series of maps for each state along the path. The first was a Midwest Regional Map. Mr. Zeiler noted that most sources state there are 13 states in totality's path, but there are actually 15. Tiny portions of Tennessee and Michigan are within the path. They each only receive about one minute of totality, though.

Maps from *Field Guide to the 2023 and 2024 Solar Eclipses*, written by Mr. Zeiler and Michael Bakich (retired senior editor from *Astronomy* magazine), were then shared. (Two copies of the field guide were donated to the KAS, and they will be given away at the March General Meeting.) In addition to the beautiful and detailed maps, it includes extensive commentary on each region along the path.

Some of the more unique eclipse maps that Mr. Zeiler created were then shared. There are five NASA crewed spacecraft on display in museums along the 2024 eclipse path! These include the Apollo 7 capsule at the Frontiers of Science Museum in Dallas, the Gemini 3 capsule at the Grissom Memorial in Mitchell, Indiana, the Apollo 15 capsule at the USAF Museum in Dayton, Ohio, the Gemini 8 capsule at the Neil Armstrong Air & Space Museum in Wapakoneta, Ohio, and Skylab 3 at the Great Lakes Science Museum in Cleveland.

The next map showed the calculated curves of dimmed sunshine levels (called eclipse obscuration). If you are along one of the curves on the map, then at the moment of local greatest eclipse, you will experience the simulated sunshine received by a planet or dwarf planet. The curve for Saturn, for example, runs along the outside edge of totality. Kalamazoo, with nearly 96% obscuration, is along the line for Jupiter.

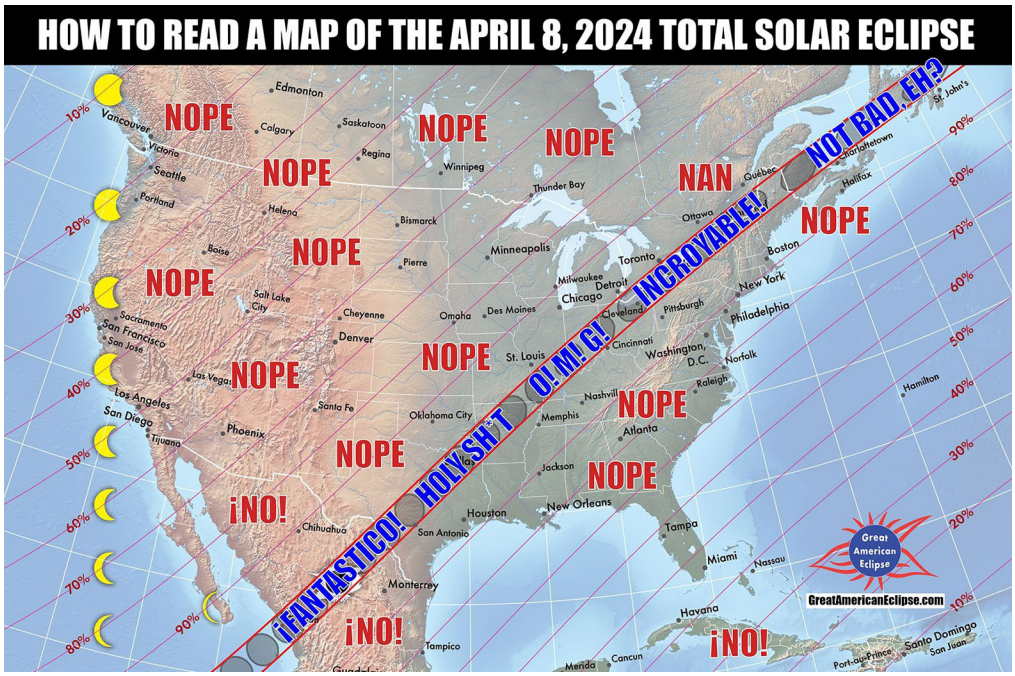
Do you want to view the eclipse from a place along the path with an eclipse-related name? Well, Mr. Zeiler has a map for that as well! One spot near the centerline of the path is the unincorporated community of Corona, Missouri. Luna Pier, Michigan, is right on the edge of totality. The "hitting the nail on the head" award goes to Eclipse Island in Newfoundland!

Another map showed national parks and mountain peaks inside the eclipse path. There are 18 parks either within or very close to the path. Aside from viewing the eclipse from a location with a lot of natural beauty, many of the parks may be located under dark skies. Eclipses can only occur during New Moon, of course, so it's also an opportunity to do some fine stargazing.

Several planetariums are also within the path of totality. Many of them will likely be holding special events on April 8th. Mr. Zeiler also assembled a map stadiums and speedways within the path. Saluki Stadium in Carbondale, Illinois, held an event in 2017, and they'll be doing it again in 2024.

Many zoos are also within the path of totality. This could be an interesting opportunity to see how wildlife behaves during totality.

All of the maps mentioned above can be viewed in an article Mr. Zeiler wrote for *Sky & Telescope's* website.



The next section of the presentation was about the national impact of the 2024 eclipse. All of the maps mentioned here are shown on the *Great American Eclipse* website (scroll down to the part labeled "The Impact of the Eclipse").

The first map was a prediction of the number of visitors to each state along the eclipse path. Mr. Zeiler made two assumptions. First, people will make the shortest drive to the centerline from their homes. Second, people close to the path would be more willing to travel into it.

Predicted to have the best chance of clear skies on April 8th, Texas ranked number one. The high-end prediction estimates 720,000 visitors, with a low-end estimate of 180,000. New Hampshire ranked the lowest, with only 600 to 2,500 visitors on Eclipse Day.

Using census demographic data, Mr. Zeiler calculated that 31,625,000 people already live within the path of totality, or about 10% of the U.S. population. Over half of the population lives within 250 miles of the eclipse path. Conclusion: It's not unreasonable for anyone to drive to the path of totality!

Eclipse phenomena was the next section of the presentation. Mr. Zeiler first described the Saros cycle, the interval in which a solar eclipse repeats. The eclipse on April 8th is part of Saros Series 139. It has a repeating cycle of 18 years, 11 days, 8 hours, with 71 events. The series started with a partial solar eclipse on May 17, 1501, and ends with a partial eclipse on July 3, 2763. The duration of totality is increasing with each eclipse in the series and will peak with member 39 at 7 minutes and 29.22 seconds on July 16, 2186. That is less than two seconds of the maximum length of totality possible.

Mr. Zeiler then shared a complex graphic with all the solar eclipses of the 21st century organized by Saros cycle.

At the start of his presentation, Mr. Zeiler promised a "world premiere" of a new form of eclipse that, up until this point, only he and his wife knew about. He finally shared it with us, and it was worth the wait. Mr. Zeiler shared the first-ever maps to predict the locations within the eclipse path where a double-diamond ring effect could be seen. There are 15 maps in all, and they were released online on February 22nd.

The last section of the presentation was on future eclipses. Maps from this portion of Mr. Zeiler's talk were from his book *Atlas of Solar Eclipses: 2020 to 2045,* also co-written with Michael Bakich. He said it took a year of his life to complete.

A map of the gap between eclipses for each state was shown (see it in the S&T article linked earlier). The last eclipse seen in Michigan was on June 30, 1954, and the next, excluding the 2024 eclipse, will be on September 14, 2099. Arizona has the longest gap. The last total eclipse in that state was in 1806. The next won't be until 2205.

Mr. Zeiler concluded his wonderful presentation with a preview of the next two total solar eclipses. The eclipse on

Lucky winners Jennifer Wilke, Molly Williams, Beatrice Richter, Penelope Richter, and Heather Harrison.

August 12, 2026, traces out a path over five countries: Russia, Greenland, Iceland, a tiny tip of Portugal, and Spain. Maximum duration is 2 minutes and 18 seconds. Mr. Zeiler plans to rent a big house in Spain and view it with his whole family.

The path of the total solar eclipse on August 2, 2027, touches a dozen countries: Morocco, Spain, Algeria, Tunisia, Libya, Egypt, Sudan, Saudi Arabia, Yemen, Somaliland, and Somalia. Maximum duration is a whopping 6 minutes and 32 seconds. Mr. Zeiler has plans to view it from Luxor, Egypt.

The next total solar eclipse to occur on American soil is in Alaska and takes place on March 30, 2033. Totality for that eclipse has a maximum duration of 2 minutes and 37 seconds. For the 48 contiguous states, the next eclipse is on August 23, 2044. It begins in Greenland, passes through western Canada, and ends in North Dakota. Maximum duration is 2 minutes and 4 minutes.

The next big American eclipse is on August 12, 2045. Like the 2017 eclipse, it goes from coast to coast. This time, the Moon's umbral shadow traces out a path from northern California to central Florida. Maximum duration is 6 minutes and 6 seconds.

While taking questions, Mr. Zeiler showed a video of the scenery around him and the changing sky brightness during the eclipse on July 2, 2019, from Elqui Valley, Chile.

Immediately following the talk, we held another random number drawing for several prizes. The first was a copy of *2024 Night Sky Almanac* by Nicole Mortillaro. The lucky winner was our own Molly Williams!

The next two prizes were donated by Michael Zeiler. The first was a 22" x 34" copy of the 2024 total solar eclipse map. The winner was guest Beatrice Richter. A 26" x 24" Midwest Regional Map went to Girts Lorencis.

The last three prizes were donated by Duane & Marjorie Gregg, KAS members from Ennis, Montana. The first, a "See the Stars" bag (using artwork by November guest speaker Tyler Nordgren), went to Heather Harrison. A "Space Shuttle Atlantis" bag was won by Penelope Richter. The final prize was a homemade astronomy-themed blanket and quilt. The lucky winner was Jennifer Wilke.

Snacks for our break period were supplied by Mike Sinclair. Mike Dupuis offered to bring snacks to the March meeting.

The first item in Richard's President's Report was an update about membership renewal. A hard copy letter will be mailed to those who still have not renewed their KAS membership. Elapsed members will be purged from the roster on March 2nd.

Mike Dupuis, Jacky Powell, and Jack Price all volunteered at STEM Night at Paramount Charter Academy on January 24th. Upcoming volunteer opportunities include a STEM event at St. Michael Lutheran Church on February 16th and Family Science Night at Hastings Public Library on February 21st. (Our hands-on activity at all these events was the Pinhole Eclipse Viewer seen on page 11.)

Help is needed preparing an Eclipse Shades order for three schools: Galesburg-Augusta, Tekonsha, and KAMSC (702 pairs in all). We plan to meet at Sunnyside Church on Sunday, February 4th, at 4:00 pm.

Richard again asked for members planning to view the 2024 eclipse from Chalk Bluff River Resort and Park in Uvalde, Texas, to contact him. He plans to schedule a Zoom meeting to arrange an activity or two.

Finally, he encouraged all members planning to travel to the path of totality to document their experiences and share them at either the May or June general meetings and in future issues of *Prime Focus*.

The only observing report was from Joe Comiskey. He recently viewed the Straight Wall (Rupes Recta) on the Moon.

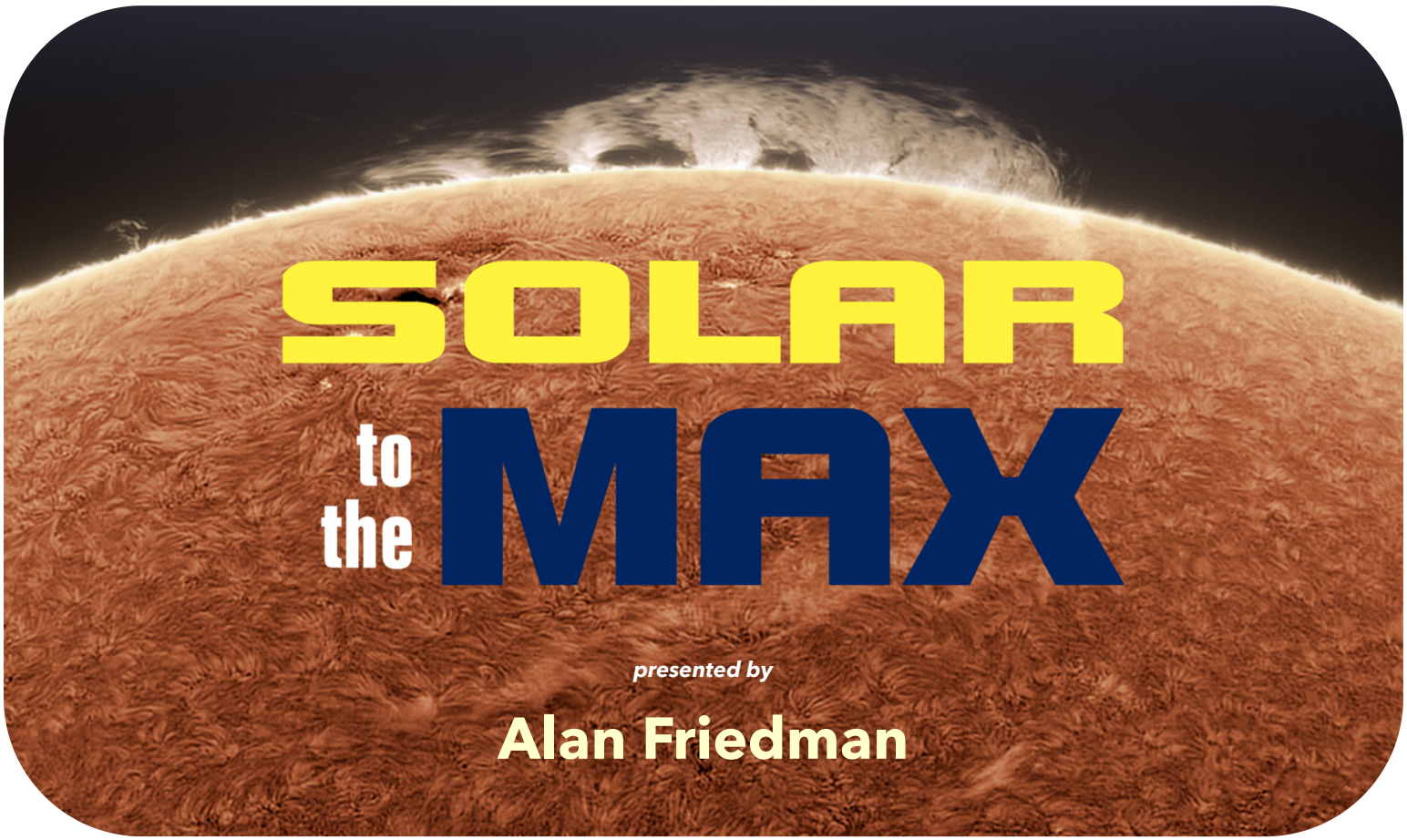
In astronomical news, the final flight of the Mars helicopter, Ingenuity, was on January 18th. One or more of its rotor blades sustained damage during landing. It had 72 successful flights.

The Hubble Space Telescope detected water vapor in the atmosphere of GJ 9827d, an exoplanet approximately twice Earth's diameter. The exoplanet is as hot as Venus at roughly 425° C (797° F) and it was discovered by the Kepler Space Telescope in 2017. It orbits a red dwarf star every 6.2 days and is 97 light-years away in the constellation Pisces.

Richard then summarized all the activities we have scheduled during the month of February and encouraged everyone to join us for the March meeting.

The meeting concluded at about 9:16 pm. Several board members took Mr. Zeiler to dinner at University Roadhouse after the meeting.

The featured talk can be viewed in its entirety on our YouTube Channel.



The Sun is a unique and rewarding subject for the astrophotographer. It can be studied in different wavelengths, imaged from almost any location and can be presented in different ways to portray our star in a unique and compelling light. The Sun is now well along on its journey to maximum activity (predicted in 2025) with a total eclipse visible from North America in April 2024. Now is the perfect time to hone our solar imaging skills for the opportunities to come. This talk will discuss technical and creative considerations in solar imaging with the goal of exercising those solar "muscles" and preparing for the increase in activity that lies just around the corner.

— About the Speaker —

Alan Friedman is an artist and astrophotographer who records our neighborhood star from his backyard in Buffalo, NY. He is a four time recipient of the Astronomy Photographer of the Year awards hosted by the Royal Observatory and his solar portraits have been featured in the exhibition of the same name at the National Maritime Museum in Greenwich, England. His photography has been the subject of books, lectures, a TEDx talk and featured on NASA's popular website Astronomy Picture of the Day (APOD). Alan's work has been exhibited nationally, including a collaborative show Fire and Ice and a solo show Into the Light which was mounted at the Palm Court Gallery, Orange County, CA in conjunction with the Solar Decathlon. By day, Alan is president and CEO of Great Arrow Graphics, a greeting card publisher. He is a research associate at the Buffalo Museum of Science and a member of the Buffalo Astronomical Association.

Friday, March 15th @ 8:00 pm

Held Exclusively on Zoom • Click to Register

Introduction to Amateur Astronomy

The five-part lecture series that will help you become a star-hopping skymaster concludes this month! Participants that attend ALL FIVE parts and sign-in as instructed will receive a Certificate of Completion. Please register if you haven't done so already. Here is the final topic:

Part 5 — March 9th:

The Art of Astrophotography

Astrophotography is the art of photographing the night sky. Over the past two decades that art has undergone a revolution as digital cameras have overtaken their film counterparts. In some ways this has made the field more technical, but in many ways shooting the sky is easier than ever! We'll start with the basics like using a stationary photographic tripod and work our way up to imaging with sophisticated CCD or CMOS cameras. Constellation patterns, the Milky Way, the night-to-night motion of the planets, bright comets, northern lights, and perhaps a meteor all await you.

Time: **1:00 pm - 3:00 pm**

Location: **Online via Zoom**

Visit the *Introduction to Amateur Astronomy* web page for more information on the entire series.

KAS Eclipse Hands-On Activities

Included with this special issue of *Prime Focus* are two hands-on activities the whole family can do together ahead of the total solar eclipse on April 8th. Please feel free to share them with educators as well. They are free for anyone to use. No permission is required.

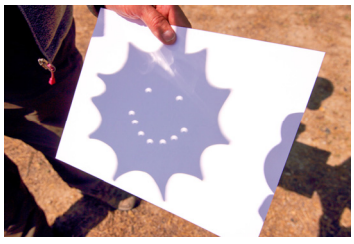
The first is a Solar Eclipse Flipbook. First created in 2017, it has been updated for the 2024 eclipse. It works best when printed on 65# cardstock paper. A heavy-duty stapler is also required.

The flipbook shows how the total solar eclipse on April 8th will appear from Wapakoneta, Ohio, because that is the town nearest to Kalamazoo that is along the centerline of totality. A bonus reason is that it is the home town of Neil Armstrong, the first man to set foot on the Moon!

Cut out the individual frames of the flipbook along the black lines only. For best results, stagger each frame a bit so it is easier to flip through each segment. Experiment before you staple it together. Hold the flipbook in your left hand and flip from the top through the pages. The eclipse lasts about two and a half hours, and each page of the Solar Eclipse Flipbook jumps ahead by 10 minutes. Notice how quickly totality passes. It is a brief phase of the eclipse, but very spectacular!

The second activity is an Eclipse Pinhole Projector. Pinhole projection is a safe and fun way to view any solar eclipse. When the Sun becomes about a 50% crescent shape, shadows on the ground become much sharper. Anything that can cast a shadow, allowing small amounts of sunlight to peer through, will create projections of the crescent Sun.

The Pinhole Viewer works best when printed on 100# or heavier cardstock paper. Cut out the eclipse design on page 11. Use a hole punch to spell out a name, message (i.e., 2024 Eclipse), or a fun design. The diameter of the punch shouldn't be more than 3 millimeters, or about ⅛". A pin can also be used, but widen the holes a bit with a sharp pencil. A craft stick or tongue depressor can be glued on with a glue stick or permanent double-sided tape. This acts as the viewer's handle.



To use the viewer, hold it parallel to the ground over an open, smooth surface like a sidewalk. Another way is to project the Sun onto a plain sheet of light-colored paper or cardboard. Position the viewer so that it projects a clear, distinct image of the Sun, and you are ready to view the eclipse safely.

Total Solar Eclipse

as seen from Wapakoneta, Ohio

on April 8, 2024

01 - 1:54 pm EDT

02 - 2:04 pm EDT

03 - 2:14 pm EDT

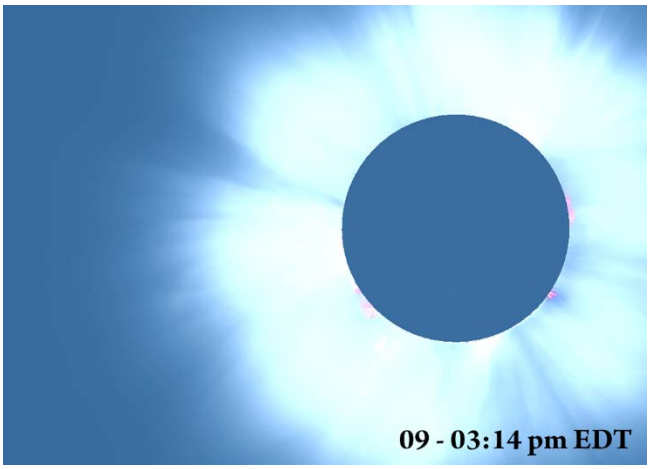
04 - 2:24 pm EDT

05 - 2:34 pm EDT

06 - 2:44 pm EDT

07 - 2:54 pm EDT

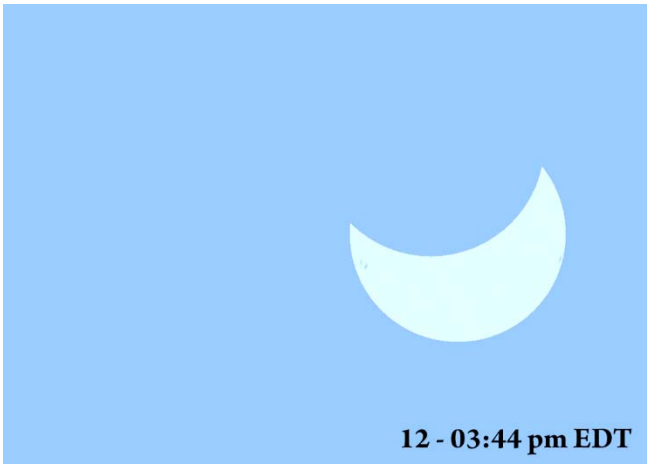
08 - 03:04 pm EDT



09 - 03:14 pm EDT

10 - 03:24 pm EDT

11 - 03:34 pm EDT



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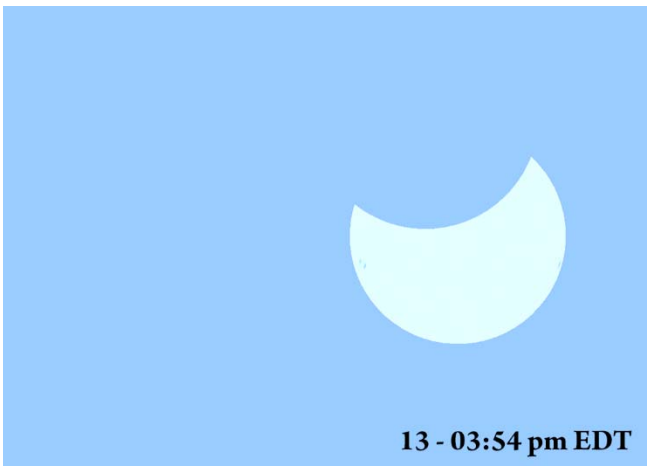
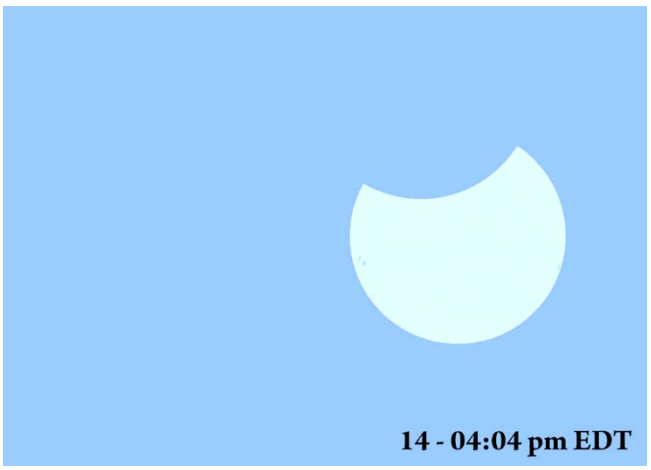
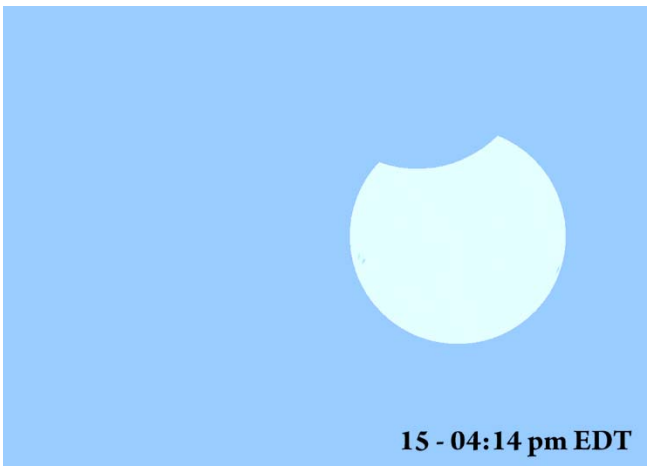


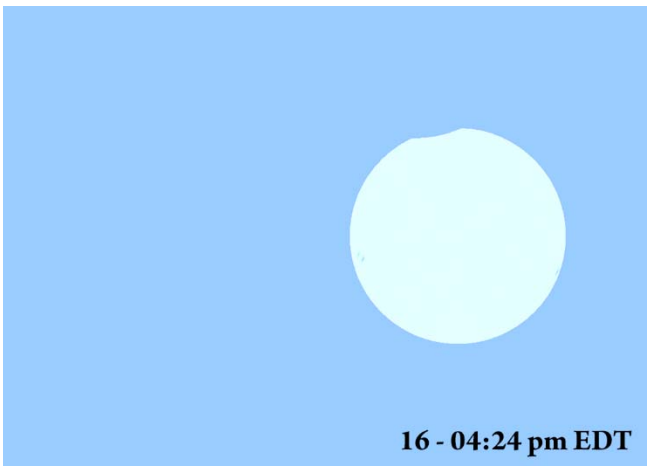
13 - 03:54 pm EDT



14 - 04:04 pm EDT



15 - 04:14 pm EDT



16 - 04:24 pm EDT

Kalamazoo Astronomical Society's

ECLIPSE

Pinhole Viewer

Here We Go Again!

Nearly seven years have passed since the *Great American Eclipse* of 2017. Members of the KAS were up and down the path of totality, and many of them shared their experiences in the October and November 2017 issues of *Prime Focus*. That was a special day, and I often look back on it with fond memories. However, much of the past seven years have been difficult, and, thanks to the pandemic, many people are weary of the word "corona." Well, I say it's *our* word, and we're taking it back!

That's because on Monday, April 8, 2024, the Moon will once again cast its ethereal shadow on our planet, tracing out a 115-mile-wide, 9,190-mile-long path. People within that shadow will get to experience the grandest phenomenon in all of nature, a total solar eclipse, and see the glorious solar *corona*.

Approximately 4,400 miles of that path cross the North American continent from Mexico, through the United States, and Canada. Everyone in the continental United States will be able to enjoy a partial solar eclipse, but don't settle for even a 99% eclipse. You want to experience a 100% total solar eclipse!

The path of the totality crosses through 13 states, including Texas, Oklahoma, Arkansas, Missouri, Illinois, Kentucky, Indiana, Ohio, Pennsylvania, New York, Vermont, New Hampshire, and Maine. The path also grazes small parts of Tennessee and Michigan. About 50 square miles of Monroe County, Michigan, will get to experience around 1 minute totality. So, if you absolutely cannot leave Michigan (maybe you're on parole or something), you can still enjoy a total eclipse. This is, technically, the first total solar eclipse visible from Michigan since June 30, 1954.

Eclipse for the Ages

Total solar eclipses are always greatly anticipated astronomical events, and interest in the 2024 *Great North American Eclipse* will be heightened by several factors.

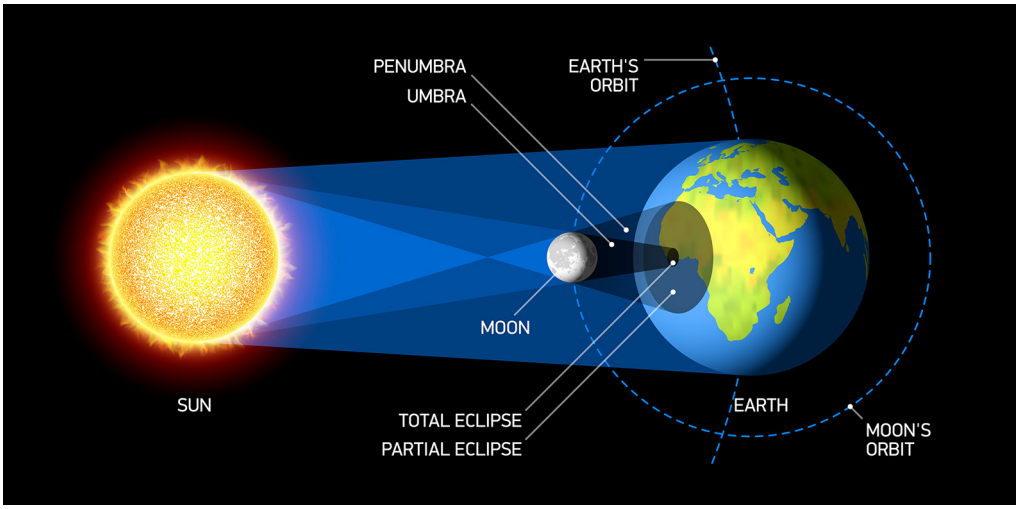
For starters, public awareness of the forthcoming eclipse is greatly enhanced by the recent memory of the 2017 eclipse. The biggest thing the 2024 eclipse has going for it is that its maximum duration of totality is nearly double that of the 2017 eclipse. Nazas, Mexico, will enjoy 4 minutes and 28.13 seconds of totality. Compare that to the 2 minutes and 41.6 seconds Carbondale, Illinois, received in 2017.

Even though the 2017 eclipse traveled from coast to coast, the only major cities partially or fully in the path were Kansas City, St. Louis, and Nashville. This time around, the path sweeps over nearly 32 million people in the U.S. and millions more in Mexico and Canada. Major metropolitan areas partially or fully in the path include Mazatlán, Torreon, San Antonio, Dallas, Indianapolis, Cleveland, and Montreal. Millions more are within a few-hour drive of major population centers in the eastern U.S. and southeastern Canada. Assuming the weather is unusually clear on April 8th, this could easily be the most-viewed eclipse in history.

The second significant factor of this eclipse is that it occurs close to solar maximum. The key to understanding the solar cycle is differential rotation. The Sun, not being a solid body, rotates faster at the equator than at the poles. All stars are essentially big balls of plasma, a very hot, electrically charged gas, so they have copious amounts of magnetic activity. Thanks to differential rotation, these magnetic fields get more and more twisted over time. This leads to increased solar activity like sunspots,

prominences, solar flares, and coronal mass ejections. The 2017 eclipse took place near solar minimum, and the next solar maximum is predicted to occur in 2025. We've already seen plenty of increased solar activity over the past year, and this will continue beyond April 8th.

Solar maximum will also affect the appearance of the corona. We saw three magnificent streamers during the 2017 eclipse. This time, the corona will be full with multiple streamers in all directions. I can't wait!



Configuration of a total solar eclipse. Astronomers refer to a three body alignment such as this as a syzygy.

Solar Eclipse Mechanics

Solar eclipses happen because of the most amazing coincidence in the solar system. The Sun is approximately 400 times the Moon's diameter (880,000 miles ÷ 2,200 miles = 400×), but the Moon is approximately 400 times closer on average (93,000,000 miles ÷ 239,000 miles = 389×).

Therefore, purely by coincidence, the Sun and the Moon appear to have about the same angular diameter in the sky! Obviously, the Moon's angular width must be a bit bigger than the Sun for totality to last almost 4½ minutes. That will indeed be the case on April 8th. The Moon's angular diameter will be 33′ 13″, while the Sun's apparent span will be 31′ 56″.

This happenstance cannot be found anywhere else in the solar system. Mercury and Venus have no natural satellites, so solar eclipses are not possible from either world. The two moons of Mars, Phobos and Deimos, orbit relatively close to the Martian surface, but their angular diameters are still insufficient to completely obscure the Sun. Moons of the outer planets, such as Jupiter and Saturn, appear far larger than the Sun does from those distant worlds. They cover up the Sun's disk and then some (plus, there's no place to stand on a gas giant)!

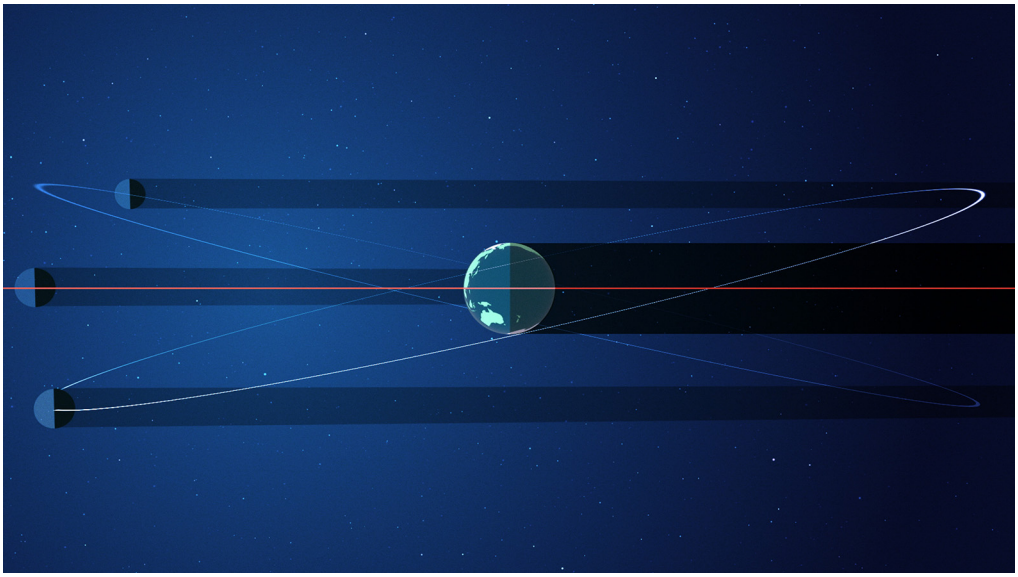
Quite simply, total solar eclipses happen when the Sun, Moon, and Earth are in a nearly perfect straight line and in that order. In astronomy, we refer to this as a syzygy.

When the Moon is between the Sun and Earth, its phase is new. As a result, no direct sunlight can reflect off our nearest celestial neighbor's surface onto Earth. Therefore, I tend to refer to New Moon as "No Moon" because it's invisible to us. Notice from your monthly calendar that we experience a New Moon at least once a month (29.53 days to be exact), so why don't people get to witness at least one solar eclipse a month?

The Moon's orbit is tilted by 5° with respect to the plane of Earth's orbit, the *ecliptic*. Solar eclipses can only take place when the Sun and Moon both meet at or near a *node*, one of two points in space where their paths appear to cross. Since the Moon and Sun don't appear as points of light and happen to be about the same size in the sky, they don't have to line up perfectly for an eclipse to take place.

On average, eclipses occur every 18 months somewhere around the world. For a period of about 34 days, the Sun and Moon both pass close enough to a node for an eclipse to happen. This period is referred to as an *eclipse season*, a time when eclipses are likely to happen. The previous total solar eclipse took place on April 19, 2023, and the next one after 2024 will happen on August 12, 2026.

When Sun, Moon, and Earth align and sunlight strikes the Moon, it casts a shadow that falls onto our planet. Every shadow has two distinct parts. The inner, darker shadow, where no direct sunlight shines, is called the *umbra*. The outer shadow, where some sunlight still shines, is referred to as the *penumbra*. Lucky observers within the umbra will experience the full grandeur of a total solar eclipse. Those within the penum-



The Moon's orbit is tilted 5° with respect to the ecliptic, the plane of Earth's orbit around the Sun. This is why we don't experience a total solar eclipse every month. Most times, the Moon's shadow passes above or below Earth's orbital plane. We only enjoy total eclipses when the New Moon crosses the ecliptic.




Indirect methods of viewing a solar eclipse include (from left to right) the classic pinhole projection box, a Pringles can, an ordinary household colander, and trees.

bra will only witness a partial solar eclipse.

The two types of eclipses may seem similar, but they're very different experiences. Think about it this way: a partial solar eclipse is like driving a Fiat, while a total solar eclipse is like driving a Ferrari. You're behind the wheel in both cases, but driving a Ferrari is a much more exhilarating experience!

Eclipse Safety

Most observing pursuits, like viewing the planets, stars, meteors, or aurora on a clear night, pose no threat to your vision. This is not the case with solar eclipses, since the Sun is involved.

As you know full well, staring at the Sun for just a couple of seconds is downright painful, and prolonged viewing without taking proper precautions can cause permanent damage to your vision. Fortunately, it's very simple to protect yourself and enjoy eclipses without fear of damaging your vision. There are two basic methods to safely observe the Sun: the indirect and direct methods.

The absolute safest way to enjoy a solar eclipse is by not looking at the Sun at all! This is the indirect method. You can use everyday materials found around the house to project an image of a solar eclipse. When the Sun is reduced to a narrow crescent, shadows become sharper. As a result, anything that casts a shadow while letting small amounts of sunlight through will create images of the eclipse.

A classic indirect viewing method is using a Pinhole Projector Box. I made one of these to safely view a partial solar eclipse in 1984. Any ordinary rectangular box will do. Place a bright white sheet on the inside of the box, and cut out a small square or rectangular hole on the opposite end. Tape some aluminum foil over the hole you just cut out, and then use a pin to poke a hole in the center of the aluminum foil. When the eclipse begins, turn your back to the Sun but let its light filter through the hole. An image of the Sun will be projected onto your white sheet of paper. You can safely view the eclipse, but never look at the Sun directly!

If you have no desire to stick your head in a box during the eclipse, then you can use anything with holes in it. A colander will work just fine and create multiple crescent suns. Nature even provides a means to view an eclipse! The numerous small gaps between the leaves of trees and even holes in the leaves themselves act as small pinhole projectors.

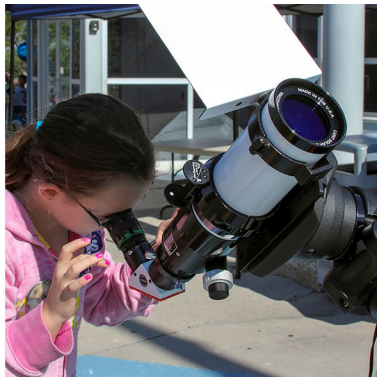
The drawback of the pinhole projection method is that you typically don't get a very large, sharp image. You could also use a pair of binoculars or a telescope for safe viewing without the use of a proper solar filter. This method is referred to as solar projection.

Unfiltered binoculars or a telescope are aimed at the Sun, and the resulting image is projected onto a screen mounted near the eyepiece. This provides a larger image of the eclipsed sun, and several people can view it at the same time.

However, be sure that no passers-by, especially children, are allowed near the eyepiece of an unfiltered telescope. Viewing through an unfiltered telescope would cause excruciating pain and likely cause permanent damage to one's eyes.

A safer way to do solar projection with a telescope is to construct a Sun Funnel. A telescope eyepiece, clamped onto the narrow end of a trimmed funnel, projects an image of the Sun onto a rear projection screen mounted at the funnel's wide end. The eyepiece is safely inside the funnel, so no youngsters can peer through the telescope. (See the article on page 43 for more information



Direct methods of viewing a solar eclipse include (from left to right) Eclipse Shades, binocular solar filters, telescope solar filters, and hydrogen-alpha filter.

on constructing a Sun Funnel.)

The most satisfying method to view the eclipse is the direct method. This means you look directly at the Sun, but with proper projection.

Eclipse Shades are the easiest, cheapest, and most satisfying way to directly observe the Sun during a solar eclipse. The lenses are made of a "black polymer" or silvery Mylar-like material that blocks 100% of ultraviolet (UV) and infrared light (IR), plus 99.999% of the Sun's visible light. The black polymer shades give an orange view of the Sun, while the Mylar shades make the Sun appear bluish-white.

If Eclipse Shades are unavailable, a #14 or darker (higher number) welding glass is also suitable for solar viewing. These welding glasses also block UV and IR light and transmit only a tiny fraction of the Sun's visible light. Typical welding glass will make the Sun appear green.

Some people like to get a close-up look at the action! Nowadays, numerous optics manufacturers produce solar filters made to fit on the ends of telescopes and binoculars. These filters reduce the sunlight to safe levels before it enters the observing instrument. Always take care that solar filters are securely fastened so that they cannot accidentally fall off during viewing.

There are some binoculars available that are intended to only look at the Sun. This reduces the slight risk of a filter becoming damaged while in use, but these highly specialized binoculars will serve no other purpose than viewing the Sun.

Viewing the eclipse through a properly filtered telescope can be quite a thrill. The jagged edge of the Moon will stand out in stark contrast to the Sun's smooth surface. If you're lucky, maybe you'll even see sunspots obscured by the Moon!

Eclipse Success Tips

Eclipse chasers spend months, if not years, planning every detail of their journey into the Moon's shadow. At this point, you only have weeks (at best) to plan for the *Great North American Eclipse*, so let's hit the highlights.

Hotels inside the path of totality have been booked solidly for well over a year. On the remote chance that some are still available, expect to pay many times the usual daily rate. Your best bet, if you absolutely must stay in a hotel, is to do so outside the eclipse path and then drive into the path before sunrise on Eclipse Day.

Camping is a much better option at this point. If regular campsites are booked near your desired eclipse viewing site, then check the website of the nearest town. Many towns along the eclipse path will likely make special campsites available during the eclipse. After all, they want you to spend money in their area!

Be sure to arrive at or near the central eclipse path about 2 days early. The *Great North American Eclipse* may trigger the largest mass migration of people in history! Therefore, roads leading to the eclipse path may (or probably will) be clogged with traffic jams. That's why it's best to arrive at or be as close to the eclipse path as you can.

Fortunately, the eclipse does occur on Monday. Spend the weekend hiking, biking, swimming, or visiting local attractions. Many towns along the eclipse path are hosting a variety of activities to keep you entertained before Monday's epic eclipse.

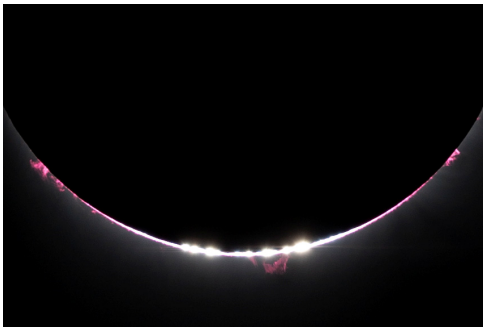
Once you arrive at or near your viewing site, don't waste time checking the news or social media websites. Keep an eye on the weather forecasts! While I regularly checked the latest forecasts in 2017, I was never too concerned about the weather. This is NOT the case for early April. If past satellite images from April 8th are any indication, a lot of people are going to be disappointed. I hope I'm wrong.

In the days leading up to the eclipse, watch the hourly forecasts on websites like Weather Underground religiously. Switch to visible satellite images from sites like Ventusky or Windy in the hours leading up to the eclipse. Continue to reevaluate the weather at your preferred observing location 24, 12, and 6 hours before totality.

If the need does arise to travel to an alternate location, then be sure to have a GPS (like the one in your smartphone) and eclipse path maps handy. You don't want to inadvertently travel outside the path and only observe a partial solar eclipse. Michael Zeiler, a professional cartographer, has gorgeous eclipse maps on his *Great American Eclipse* website.

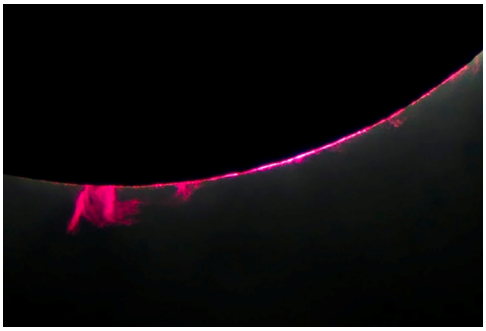
What to Look for on Eclipse Day

Event times along the eclipse path vary by location. See the table of eclipse times for American cities along the path on page 16. Event times for your exact



Baily's Beads

Diamond Ring Effect



Prominences

location can be found on Xavier Jubier's Google Eclipse Map Page. Just click anywhere inside or outside the path, and it will give you all the pertinent times of the eclipse's stages.

Let's say circumstances keep you in Kalamazoo. Here's what you can expect to see: The partial solar eclipse begins at 1:54 pm EDT. It may take a few minutes to spot the Moon beginning to take a bite out of the Sun. More and more of the Sun will disappear behind the dark moon until maximum eclipse at 3:10 pm. Try to take at least a 15-minute break from work around this time, if possible. At this point, about 96% of the Sun's face will be obscured by the Moon. The sky will become noticeably darker, and you may even feel a drop in temperature. As mentioned earlier, don't forget to look under a shade tree for pinhole images of the crescent sun (assuming there are leaves on the trees in early April). It will be the highlight of the eclipse from Kalamazoo. The partial eclipse will then end at 4:24 pm.

Everything discussed above can be viewed from anywhere along the eclipse path, but the Moon keeps obscuring more and more of the Sun.

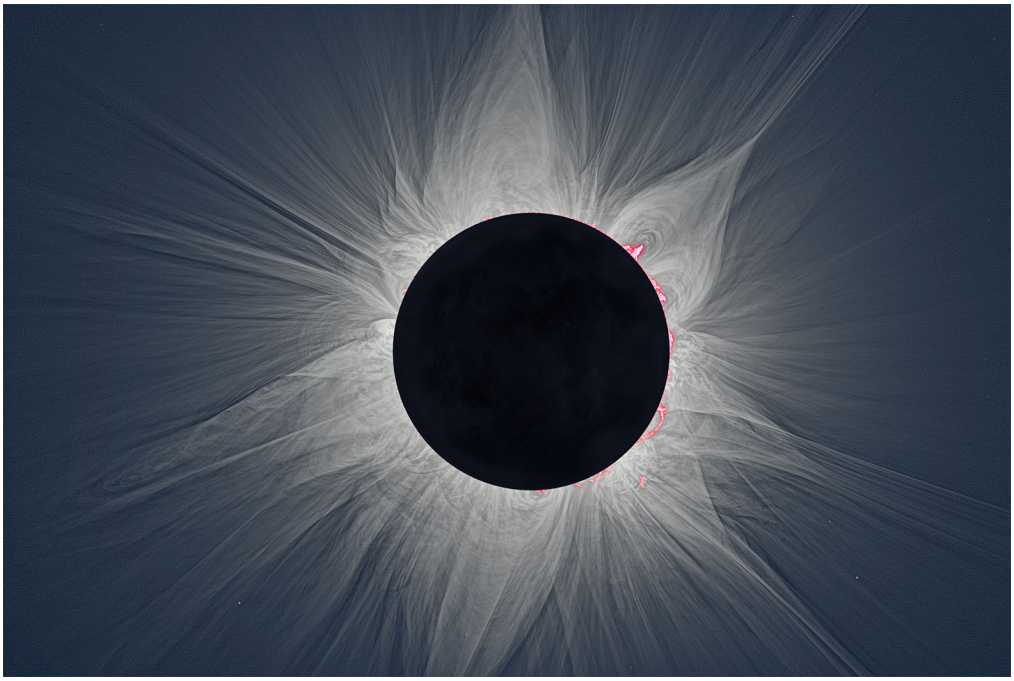
About a minute before and after totality, when the Sun appears as the narrowest of crescents, look for the most elusive feature of a total solar eclipse: shadow bands. The same atmospheric conditions that cause a star's light to twinkle at night can cause sunlight reduced to a narrow slit to ripple across a surface. It is easier to see if you throw a white sheet on the ground.

Not every eclipse produces shadow bands; it depends on local atmospheric conditions around the time of totality. Even if they do occur, most miss them because their gaze is fixed on the even greater show about to begin overhead. It is best to look for them just after totality anyway.

Just a few seconds before and after totality, beads of light appear along the limb of the Moon's rugged surface. These lights are called Baily's beads after British astronomer Francis Baily (1774 - 1844) who described them so eloquently during an annular eclipse on May 15, 1836. They occur because the edge of the Moon is not smooth but jagged with mountain peaks and valleys.

On the brink of totality, Baily's beads flicker out one by one until the most brilliant bead remains. This glint of light or brightening on the Moon's edge creates the dazzling "diamond ring" effect - the solar jewel. This final sparkling event signals the arrival of the Moon's shadow. Remove your Eclipse

Location	First Contact (Partial Begins)	Second Contact (Totality Begins)	Maximum	Third Contact (Totality Ends)	Fourth Contact (Partial Ends)
Dallas, TX	12:23 p.m. CDT	1:40 p.m. CDT	1:42 p.m. CDT	1:44 p.m. CDT	3:02 p.m. CDT
Idabel, OK	12:28 p.m. CDT	1:45 p.m. CDT	1:47 p.m. CDT	1:49 p.m. CDT	3:06 p.m. CDT
Little Rock, AR	12:33 p.m. CDT	1:51 p.m. CDT	1:52 p.m. CDT	1:54 p.m. CDT	3:11 p.m. CDT
Poplar Bluff, MO	12:39 p.m. CDT	1:56 p.m. CDT	1:56 p.m. CDT	2:00 p.m. CDT	3:15 p.m. CDT
Paducah, KY	12:42 p.m. CDT	2:00 p.m. CDT	2:01 p.m. CDT	2:02 p.m. CDT	3:18 p.m. CDT
Evansville, IN	12:45 p.m. CDT	2:02 p.m. CDT	2:04 p.m. CDT	2:05 p.m. CDT	3:20 p.m. CDT
Cleveland, OH	1:59 p.m. EDT	3:13 p.m. EDT	3:15 p.m. EDT	3:17 p.m. EDT	4:29 p.m. EDT
Erie, PA	2:02 p.m. EDT	3:16 p.m. EDT	3:18 p.m. EDT	3:20 p.m. EDT	4:30 p.m. EDT
Buffalo, NY	2:04 p.m. EDT	3:18 p.m. EDT	3:20 p.m. EDT	3:22 p.m. EDT	4:32 p.m. EDT
Burlington, VT	2:14 p.m. EDT	3:26 p.m. EDT	3:27 p.m. EDT	3:29 p.m. EDT	4:37 p.m. EDT
Lancaster, NH	2:16 p.m. EDT	3:27 p.m. EDT	3:29 p.m. EDT	3:30 p.m. EDT	4:38 p.m. EDT
Caribou, ME	2:22 p.m. EDT	3:32 p.m. EDT	3:33 p.m. EDT	3:34 p.m. EDT	4:40 p.m. EDT



This image shows the spectacular solar corona on display during the April 2023 eclipse from Exmouth, Australia. It is a composition of 77 eclipse images with exposures ranging from 1/125 to 1 second. It shows more detail than can be seen with the unaided eye, but the corona on April 8th should have a similar structure. Credit: Pavel Štarha, Shadia Habbal, Miloslav Druckmüller

Shades once Baily's beads become visible. It will heighten the drama of the diamond-ring effect and won't cause any damage to your eyesight, since they will disappear fairly quickly. However, once Baily's beads reappear after the second diamond ring, quickly put the shades back on.

When the brilliant disk of the Sun is obscured, there is a good chance of seeing prominences erupting from the Sun's surface, often in a loop configuration. Usually these red, cloud-like appendages of hydrogen that arch above the surface are tiny, but if the Sun is in an especially active phase, they can be spectacular, reaching a maximum height of nearly one-third the diameter of the Sun itself.

Odds are you'll need binoculars or a telescope to spot prominences during totality. Hopefully, the approaching solar maximum will increase our odds of viewing large prominences peeking out from behind the lunar limb. And yes, totality is perfectly safe to view with unfiltered binoculars or a telescope. Just be conscious of when the Sun will reappear!

Just as the diamond-ring effect ends, a halo of light around the Sun comes into view - the corona (the Latin word for "crown"). The corona is a tenuous layer of gas surrounding the Sun at a temperature of ~3,000,000° F. It always surrounds the Sun, but is a million times fainter than the Sun's surface. Therefore, it can only be seen with the unaided eye during totality. It is the grandest sight of a total solar eclipse.

Think of it like this: Imagine you can only see the Grand Canyon for a few minutes every 18 months! That's the situation we're in with totality. The corona is a thing of astounding beauty and, by definition, quite alien. There's nothing else like it in nature.

As totality approaches, see if you can spot the Moon's incoming shadow, the umbra itself. It glides along the surface of Earth at an average speed of approximately 1,900 miles per hour!

During totality, the sky will take on a dark blue hue. Mercury will be the planet closest to the Sun, about 7° to the northeast. The innermost planet will have a magnitude of 4.3, so you would need binoculars to spot it. At magnitude -3.9, Venus can be easily spotted 15° to the northeast. You shouldn't have any trouble locating it about 15 minutes before totality. Jupiter lies just under 30° east-northeast of the Sun.

Periodic comet 12P/Pons-Brooks will be 6° west-northwest of Jupiter or 25° east-northeast of the Sun. Unless there's an unexpected outburst, you will need binoculars to spot it. Frankly, you should view totality as sacred and not take your gaze away from the corona for more than a second or two.

Songbirds may mistake totality for nightfall and go silent, thinking it's time to roost. Owls might begin to hoot, and other nocturnal animals may appear. Wildlife will grow momentarily confused when the Sun quickly reasserts itself. This may be difficult to hear and observe if there are hundreds or perhaps thousands of screaming and crying people around you.

The temperature can drop as much as 25° F as the Moon blocks more and more of the Sun's heat. You may need to have a jacket ready before totality! As you can see, total solar eclipses are a fully immersive event. Not only can you see it, but you can also hear it around you and feel it on your skin. It is the most surreal experience you will ever have.

Beyond 2024

The first question you'll ask yourself when the eclipse is over is: When is the next one? As stated earlier, the next total solar eclipse takes place on August 12, 2026. It'll be visible along a path from Russia, Greenland, Iceland, a tiny tip of Portugal, and Spain. Maximum duration of totality is 2 minutes and 18 seconds.

The next total solar eclipse visible from the continental United States won't be until August 23, 2044. The curved path of that eclipse begins in Greenland, passes through western Canada, and ends in North Dakota. Maximum duration is 2 minutes and 4 seconds.

Another eclipse goes from coast to coast in the United States again, this time from California to Florida, on August 12, 2045. Maximum duration for that eclipse is a whopping 6 minutes and 6 seconds!

Twenty years is a long time to wait for those of us who can't afford to go globetrotting. Therefore, the *Great North American Eclipse* on April 8, 2024, is the best one to occur for years to come. Find a way to get to totality; you won't regret it.

Richard Bell is a lifetime member and the current president of the Kalamazoo Astronomical Society.

The First Time

How Chasing Solar Eclipses Opened Me Up to the Awe of Living

by **Dr. Kate Russo**

It is 11 August 1999 and I am gazing up at the Sun, my eyes protected by a flimsy cardboard solar filter. I am completely unprepared for what is to come. In a few moments, my life will turn upside down as I experience my first total solar eclipse.

I am in the path of the Moon's shadow – the path of totality – that is to sweep in a narrow band across much of continental Europe. My partner and I are in a crowd of 10,000 people congregating along a French beachfront promenade. We hear a multitude of languages as we prepare our patisseries and wine. Through our solar filters, we watch the Moon slowly move in front of the Sun. I know what is to happen – a perfect alignment of Sun, Moon, Earth. And me.

A sense of unease suddenly washes over me. Something is wrong.

Looking around, I notice the oddness of the light. It is as if we are on a stage and the Sun is a spotlight that's dimming. The color of the world is draining. My senses widen; I notice the cooling of the air on my skin. I shudder. Dread and terror crawl through my body. This isn't how the world should be! I no longer understand what is happening. The hair on the back of my neck stands up. I shiver again with goosebumps.

I look around for several minutes with creeping unease. The spotlight above continues to fade. Then, without warning, nature goes haywire in a way that I struggle to comprehend. I let out an involuntary noise as the Moon's central shadow rushes in with an ominous presence. Suddenly, an eerie darkness envelops us. There is absence of day, the spotlight is gone. Where moments ago the Sun shone, there is now nothingness. We are in totality. My logical brain screams at me: Where is the Sun? We need the Sun!

Around me there are screams, then a hushed silence. My mouth remains agog, solar filters clenched uselessly in my fist. I stare at the black Sun – now an unfathomable black hole in the dark sky. I cannot believe what I see: cannot comprehend the disappearance of our life force. This surely is the end of the world! Another wave of terror passes over me.

As my eyes adapt in the darkness, a halo of ethereal light appears around the eclipsed Sun. A somersault of emotions now replace the terror – excitement, euphoria, amazement and wonder. The world is not ending! Instead, we are witnessing our Universe. A profound awe washes over me in a way I have never felt before. How could such immense, sublime beauty be possible? I notice a deep sensation in my chest, buried within, like a swelling, a knowing.

We are in the Moon's shadow and the world is holding its breath. The full meaning is finally revealed. This darkness is the shadow of our closest celestial body, our beloved Moon. We are in the Moon's shadow! I have viewed the Moon thousands of times, but never before have I connected or understood it in this way. I am experiencing the three-dimensionality of our Universe – and it is vast. My mind expands with understanding, and with this comes another epiphany. The totally eclipsed Sun is like a portal, allowing me to fully experience our reality.

Time unravels and unites past, present and future – condensing my existence into this one moment. I am disoriented in place and person. I am here in another lifetime, thousands of years ago, facing the same wonder and terror. I am my primitive ancestors, and also my future selves. Yet I am also present and alive in this moment. How is this possible? It makes no sense, yet this revealed wisdom of unity seems the key to understanding life.

My prior-held understandings of the world seem so

Dr. Kate Russo was giddy with excitement just after seeing her 5th total solar eclipse in Turkey on March 29, 2006. Credit: Geordie McRobert

limited. Instead, I gain a deeper perspective, a life-changing shift in knowing. I understand that I am part of something so much greater than I could have ever imagined. I am connected to our Universe; to life itself. I am connected to humanity – to those immediately around me, and beyond. I understand I am but one person, a small speck of humanity in this vast Universe. I am insignificant, yet powerful in communion. I am humbled and in awe in a way I've never before felt, but I understand now. This experience is what makes us human, and unites us. That swelling sensation in my chest returns. I have an embodied appreciation and gratitude for everything.

I am in this altered state forever, in this strange inbetween shadowland. But somehow the spell breaks and I return to our time-bound Earth. I am aware again of the crowd around me, and the recommencement of time. I sense totality will soon be over.

The crowd screams in unison as the Moon's central shadow sweeps rapidly over and away. The Sun's blinding light returns, bathing everything in warmth and color again. Our life force is back! This fills me with relief, yet an incredible longing to return to where I was, when I was there. I remember to breathe again. I hug my partner, unable to speak, my throat tight with emotion. I turn to take in the world around me. Birds return to the skies. People are hugging, I see their tears. The total eclipse is over. The world did not end. Life as we know it, and always knew it, continues, with every second. Yet I am no longer the same.

What just happened? Totality is an awe-inspiring natural event, surpassing our imagination of what is possible. It triggers an 'altered state' in which we are no longer time-bound. Fully immersed in the moment, our egos dissolve.

At a physical level, the experience heightens our senses, and our skin tightens with goosebumps. This triggers a feeling in our core that the American psychologist Dacher Keltner in *Born to Be Good* (2009) explains as the vagus nerve (which connects the brain and key bodily organs) responding to calm us down. Totality is an example of what the German philosopher Martin Heidegger in *Being and Time* (1927) described as 'ecstasy': moments of eerie darkness triggering our primal fear, which turns to wonder and awe, allowing deep insights into what it means to be human.

The American existential psychologist Kirk Schneider argues that some people will be averse to these experiences: as long as they prize efficiency and a 'quick fix' approach to living, they will be awe-resistant – guarded against the chance of transformation. Like him, I believe that, by opening up to awe, we can find meaning in suffering and live a deeper, fuller life. This requires an unconditional acceptance of the experience of being present, and an understanding that we can, and should, just be.

On that day in August 1999, unwittingly, I became an eclipse chaser. I am now part of a swelling movement, a community of chasers – gathering along the path of totality every 18 months or so. We stand united in awe and wonder as the Moon's shadow plunges us into an uncanny darkness again. We have found what binds us together, and understand our connection. Eclipse chasing is more than a hobby or mere Instagrammable event. It is a way of life, an understanding, a state of being. I am an eclipse chaser.

Totality is the perfect metaphor for life – it is intense, terrifying, awe-inspiring, beautiful, fleeting, and then it is over. Let's chase these moments that inspire and connect us. Open yourself up to awe, and find meaning in moments that are there for the taking. Make your every second count.

Kate Russo is a clinical psychologist. She is the author of Total Addiction *(2012) and* Being in the Shadow *(2017). After living in Belfast, Northern Ireland, for over 20 years, she has recently returned home to her native tropical North Queensland, Australia, where she works in private practice.*

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From Stonehenge to Saros

Has any naturally occurring event kept humanity as preoccupied as eclipses? Many eons ago, some very tenacious civilizations devoted centuries of industry to understanding the cycles of the Sun and Moon and predicting the arrival of eclipses. Built by a Neolithic culture over a period of about 1,500 years, Stonehenge may be the world's first eclipse clock, constructed not with metal gears but with tons of rock hauled from quarries more than 150 miles away.

During the first millennium C.E., Mayan astronomers relentlessly tracked Venus across the heavens in the belief that it was responsible for eclipses. In doing so, they ended up discovering how many days passed between eclipses.

Meanwhile, in Mesopotamia, the Chaldeans had long since rejected the Greek idea of celestial objects moving in perfect circles when, through tireless observation, they realized that something else was happening. In the process, they discovered the long-sought secret to predicting eclipses.

As these stories demonstrate, sometimes persistence pays off.

2800 B.C.E.
The builders of Stonehenge created the world's first eclipse computer.

Built nearly 5,000 years ago from some 250 tons of sandstone and bluestone on Salisbury Plain in south-central England, Stonehenge is a marvel of prehistoric engineering. It consists of a circular embankment, 360 feet in diameter, dug into the chalk plateau. Upon its completion, Stonehenge consisted of a circle of 30 linked archways made of sandstone, or sarsen, surrounding a horseshoe-shaped arrangement of five much larger bluestone trilithons—structures consisting of two vertical stones supporting a third horizontal stone laid on top—that faced northeast. The purpose behind these stones, many of which have fallen or been removed, has been a mystery for centuries. The people who created Stonehenge had no written language and left no record of why they built the structure. Yet all signs point to the site as a massive astronomical calendar and eclipse computer.

If that's correct, then Stonehenge demonstrates the great importance this culture placed on tracking celestial events. The people who built Stonehenge had no work animals, no wheeled carts, and no metal tools. They dug holes in the ground using deer antlers. The sandstones that form the circle of 30 linked archways came from a quarry 25 miles north of the site. The larger bluestones of the inner horseshoe traveled a much greater distance: Geologists determined in 2011 that they were taken from an outcrop in Wales, 160 miles away, and dragged to the site on logs.

Stonehenge was clearly a huge undertaking, one that required extreme labor and the focused energies of a culture over many centuries. The site was constructed in phases over a period of at least 1,500 years, beginning with the circular embankment, which dates to around 3100 B.C.E It's believed Stonehenge was originally a spot for midwinter and midsummer festivals, as well as

a burial ground. Inside the embankment is a circle of 56 pits, each roughly three feet in diameter and two feet deep. Called Aubrey holes after John Aubrey, who first identified them in the 17th century, they once contained the remains of 63 men, women, and children. By about 100 years later, Stonehenge featured a timber structure and was functioning as an enclosed cremation cemetery.

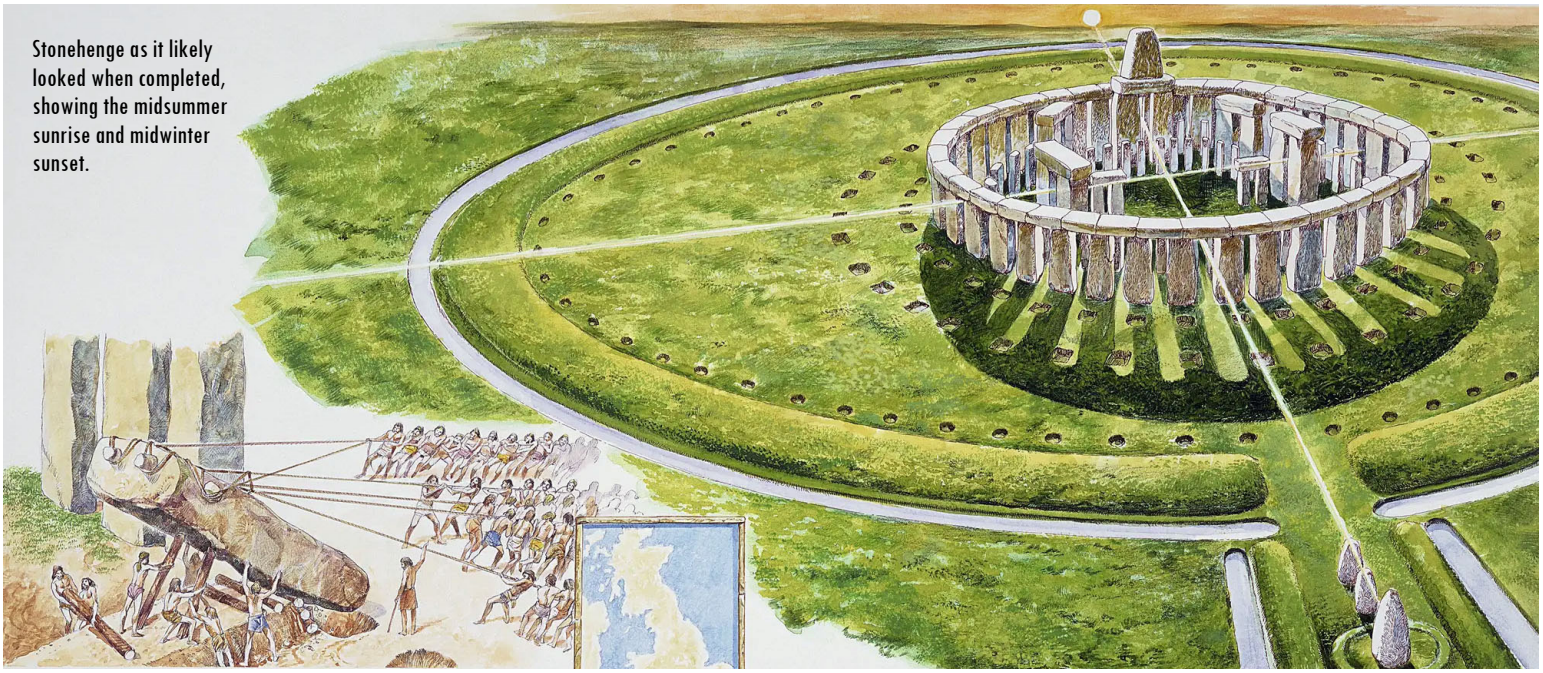
It was around 2800 B.C.E. that the site began to take shape as we know it today, evolving over the next roughly 1,000 years to become a crude but highly accurate astronomical observatory.

Imagine yourself back 4,500 years ago, on a June morning before sunrise, standing at the center of Stonehenge amid the trilithons. From here, facing northeast, you would have a line of sight through one of the 30 archways to a pointed Heel Stone, a 35-ton upright rock some 245 feet away. It's believed that a companion Heel Stone once sat to its left. Peering at the space between the two stones, you would have seen the Sun rise on that first day of summer, when it's at its furthest point north of the equator and daytime is longer than at any time of the year.

But the builders of Stonehenge weren't interested in only the Sun's activity. The 30 surrounding sarsen archways appear to have been a form of lunar calendar. The time between two Full Moons is 29.5 days. Not coincidentally, 29 of the Stonehenge archways are the same width—only one is half as wide as the others. Ringing the archways are two circles of 29 and 30 holes each; together, they average out to 29.5. It's believed that the people of Stonehenge might have used the archways together with the holes to keep track of solar and lunar eclipses. By placing two rocks in holes opposite one another—to represent the ecliptic nodes—and regularly moving two other stones that represent the Sun and Moon from hole to hole, they could predict a celestial conjunction: a lunar eclipse would occur when the stones fell on opposite node stones, and a solar eclipse would take place when they met on the same node stone.

Researchers believe that the builders of Stonehenge could predict eclipses by observing the Sun's rays through the structure's circular rings.

Whether this information would have been used to help with planting crops, for religious ceremonies, or to divine the future, no one knows. The puzzle of Stonehenge has taken decades to piece together, and much is still being learned. Until recently, it was thought that perhaps Stonehenge had never been completed—that its missing stones were never there to begin with. Then, during the dry summer of 2014, the stewards



Stonehenge as it likely looked when completed, showing the midsummer sunrise and midwinter sunset.

The windows of the Maya's Caracol observatory aligned with the of Venus.

who look after the monument didn't have a watering hose long enough to reach beyond the inner stone circle. As summer went on and the grass became parched, unsightly brown spots began to appear on the ground in the spaces between the stones. They were soon identified as the places where the missing rocks once stood. Years later, the ground still bears the marks of the tons of stone that stood there. These ghosts of Stonehenge confirm that the Neolithic stones once formed a full circle, shedding a little more light on what is probably ancient England's greatest achievement.

1000 C.E.
The Maya discovered the exact number of days between eclipses.

Like the builders of Stonehenge, the Maya of pre-Columbian Mesoamerica were obsessed with astronomy. One of their central concerns was accurately predicting when eclipses would occur.

During their Classic era, from roughly 200 to 1000 C.E., the Maya kept impressively detailed astronomical records and did so without the aid of telescopes. Using nothing more than their eyes and crossed sticks as sighting devices, they recorded movements of the Sun, Moon, stars, and planets that were among the most accurate of the time and, in some instances, more on point than determinations made by astronomers in Africa, Europe, and Asia.

They calculated the synodic month—the period of the Moon's phases—more accurately than the Greek astronomer Ptolemy, a feat that required their understanding of how Earth and the Sun affect when the Moon is seen and how much of it is visible.

Likewise, the Maya calculated the solar year—the time it takes for the Sun to return to its position in the sky following a full cycle of seasons—and did so more precisely than the Spanish had by the time they arrived and conquered the Maya in the 16th century, destroying most of their culture and records in the process.

Why were the Maya's calculations so accurate? Fear probably had a lot to do with it. Mayan sky watching had nothing to do with crop planting or scientific curiosity; it was solely for the purpose of divining the future. The Classic era was a time of great upheaval for the Maya, and they believed that by understanding past cycles of time, they could predict future events. Accepting that the fate of your civilization might depend on some seemingly minor astronomical phenomenon would be a strong motivation for meticulous observation and record-keeping.

What few records remain of the Maya reveal that they studied not just the Sun, Moon, and stars but also the planets Jupiter, Mars, Mercury, and, of particular importance, Venus. Many Mayan buildings were constructed to align with Venus, and sightlines through the windows of the Caracol, an observatory at the ancient site of Chichén ltzá, align with the northernmost and southernmost

points of the planet's path. The rising of Venus as the morning star represented the rebirth of the Maya Hero Twins, figures in an ancient myth that represent the duality of all things, including life and death, male and female, sky and earth, day and night, and Sun and Moon.

Venus was also associated with warfare, and the first sighting of the planet in the eastern dawn sky following a long period of absence—an event known as its heliacal rising—was a sign to be on the alert for a major upheaval. Mayan leaders often launched their military campaigns to coincide with the heliacal rise of Venus.

Not surprisingly, given their obsession with the heavens, the Maya were aware that eclipses had seasons. In the Dresden Codex, one of the few books to survive the destruction of the Maya civilization by the Spanish, many entries include the figures 148 and 177—the exact number of days between lunar eclipses.

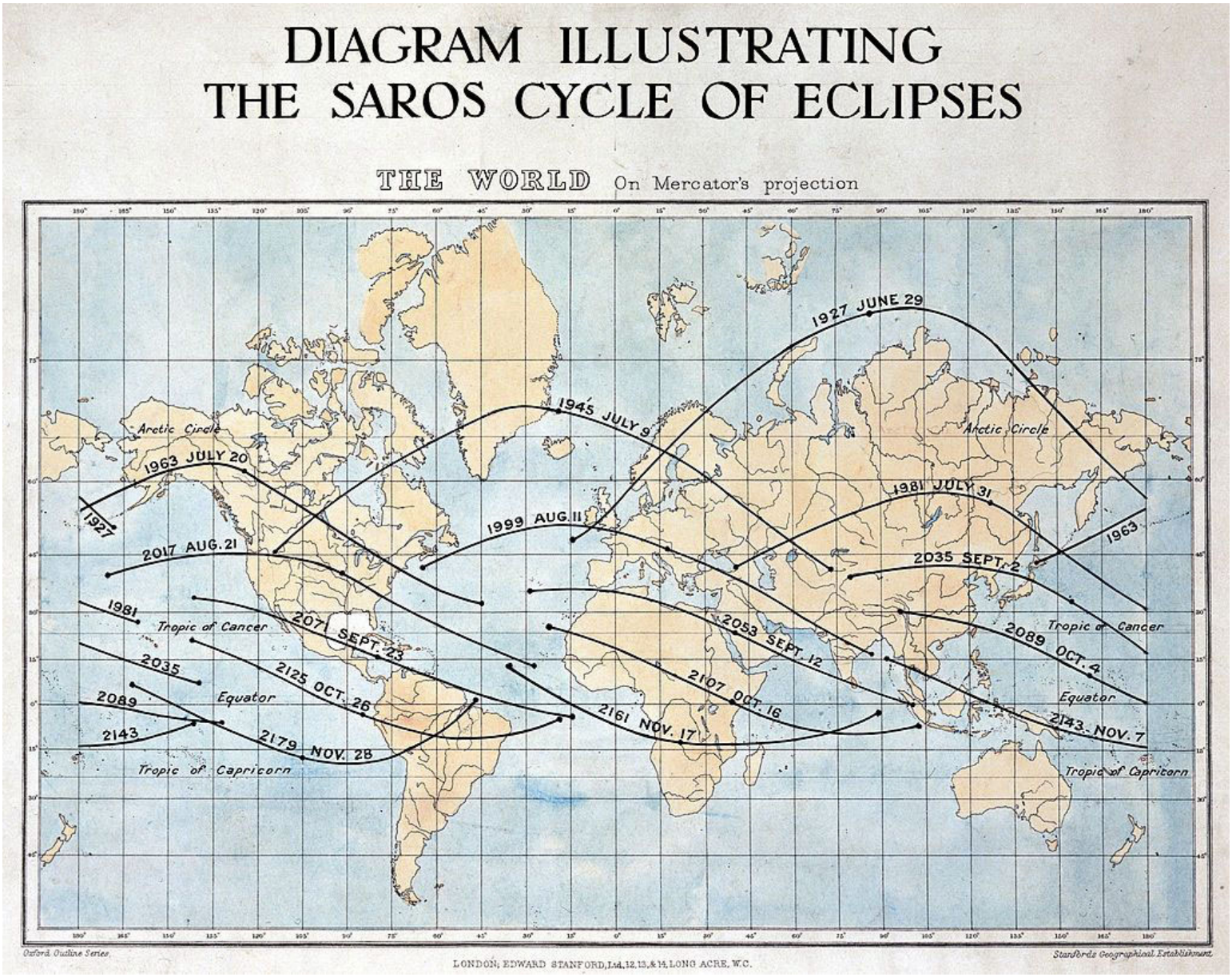
In the Codex, eclipses are illustrated with a black-and-white figure—the Sun and Moon—being eaten by a serpent. Once again, this is Venus working her treachery, assisted by a swarm of celestial bodies that fly like insects through the heavens to help entrap the Sun and wreak darkness and destruction upon Earth. Though the reasoning is primitive, the analysis behind the numbers was anything but.

300 B.C.E.
The Babylonians discover the eclipse-predicting saros cycle.

Babylonia is at the cradle of Western astronomy. The Sumerians were the first urban society in southern Mesopotamia (modern-day southern Iraq), residing there from about 6500 B.C.E to 1940 B.C.E., and our modern astronomy bears the strong influence of Sumerian astronomy. Using their base-60 numerical system, the Sumerians divided up circles and times into units of 60. They are the reason we divide a circle into 360 degrees and hours and minutes into 60 units.

The Babylonians were the first to notice that astronomical activity was periodic, and they applied math to help them predict when celestial events would recur. They calculated the length of the days of a solar year and recorded 21 years of the rising of Venus, a hercu-

Entries in the Maya Dresden Codex, a page of which is shown here, include the exact number of days between lunar eclipses: 148 and 177.



The Chaldeans are thought to be the first people to have identified the cyclical nature of eclipses, known as the saros cycle.

lean effort that demonstrated that planetary movements were consistent and could be plotted with accuracy.

The frequency and quality of astronomical observations increased in the eighth century B.C.E under the Chaldeans, a social class of astrologers and astronomers in southern Mesopotamia. Unlike the Greeks, who believed the planets moved in circles and rotated with uniform motion, the Chaldeans were strictly empirical. They didn't use geometry and had no interest in how the universe began—cosmology—or speculation about its design.

Among the Chaldeans' greatest contributions were their discovery of eclipse cycles and the saros cycle. From the eighth to the first century B.C.E., they kept almost daily astronomical records of the Moon and the planets as they were positioned relative to the stars. By the seventh century B.C.E., their records included data about weather as well as political events, the economy, and anything else that might eventually demonstrate a pattern relevant to the positions of celestial bodies.

From these centuries of record-keeping, a pattern did eventually emerge: the saros cycle. The Chaldeans recognized that lunar eclipses are separated by six lunar months and occasionally by five, with a lunar month being the time between Full Moons, or about 29.5 days.

They further saw that eclipses occurred every 223 synodic months, approximately 6585.3211 days, or 18 years, 11 days, and eight hours. Although the Chaldeans recognized the saros cycles' application to lunar eclipses, they work for solar eclipses as well. (The earliest reference to the saros is found in fragments of records made by Berosus, a Chaldean priest and historian who lived around 260 B.C.E.)

That we know any of this is due to the importance that the Greeks placed on astronomy. When Babylon fell to Alexander the Great in 331 B.C.E., he had the astronomical texts translated. There is evidence that third-century B.C.E. Babylonian priests may have taught their astronomy to Greeks, which, fortunately, ensured its transmission through the ages.

25 Tips to Plan for the 2024 Eclipse

by Michael Bakich

Follow these 25 common sense tips, and you'll be ready to rock for the April 2024 eclipse.

1. Take Eclipse Day off — now!

April 8, 2024, may turn out to be a very popular vacation-day request. If you're considering checking out the eclipse, be sure to get that vacation request in now and mark it on your calendar.

2. Make a weekend out of it

Eclipse Day in 2024 is a Monday. Lots of related activities in cities that will experience totality during the 2024 total solar eclipse will occur on Saturday and Sunday. Find out what they are, where they're being held, and which you want to attend, and make a mini-vacation out of the eclipse. Events like cruises to exotic locations will allow you to experience the full social impact of the eclipse.

3. Attend an event

You'll enjoy the eclipse more if you hook up with like-minded people. If you don't see any special goings-on a few months before April 8th, call your local astronomy club, planetarium, or science center. Anyone you talk to is sure to know about eclipse activities.

4. Get involved

If your interests include celestial events and public service, consider volunteering with a group putting on an eclipse event. You'll learn a lot and make some new friends in the process.

5. Watch the weather

Meteorologists study a chaotic system. Nobody now can tell you with certainty the weather a specific location will experience on eclipse day. And don't get too tied up in the predictions of cloud cover you'll see for that date. Many don't distinguish between "few" (one-eighth to two-eighths of the sky covered), "scattered" (three-eighths to four-eighths), or "broken" (five-eighths to seven-eighths) clouds and overcast. Also, many of the "predictive" websites use satellite data, which detects much more cloudiness than human observers. In both cases, you need to dig deeper.

6. Stay flexible on eclipse day

Unless you are certain April 8th will be clear, don't do anything that would be hard to undo in a short time. For example, let's say you're taking a motor home to a certain city. You connect it to power, hook up the sewage hose, extend the awnings, set up chairs, start the grill, and more. But if it's cloudy six hours, three hours, or even one hour before the eclipse starts, you're going to want to move to a different location. Think of the time you would have saved if you had waited to set up. Also, the earlier you make your decision to move, the better. Just imagine what the traffic might be like on eclipse day.

7. Don't plan anything funky

Totality during the 2024 total solar eclipse will be the shortest four and a half minutes of your life. All your attention should be on the Sun. Anything else is a waste. And be considerate of those around you; please, no music.

Related: 20 great places to see the total solar eclipse

8. Pee before things get going

Yes, this statement could be phrased more politely, but you needed to read it. And follow it. This tip, above and beyond any other on this list, could be the most important one for you. Don't wait until 10 minutes before totality to start searching for a bathroom. Too much is happening then. Make a preemptive strike 45 minutes prior.

9. Notice it getting cooler?

A basic smartphone or a point-and-shoot camera that takes video will let you record the temperature drop. Here's a suggestion: Point your camera at a digital thermometer and a watch, both of which you previously attached to a white piece of cardboard or foam board. Start recording video 15 or so minutes before totality and keep shooting until 15 minutes after. The results may surprise you.

10. Watch for the Moon's shadow

If your viewing location is at a high elevation, or even at the top of a good-sized hill, you may see the Moon's shadow approaching. This sighting isn't easy because as the shadow crosses Indianapolis, for example, it is moving at 1,992 mph (3,206 km/h), or more than 2½ times the speed of sound. Another way to spot the shadow is as it covers thin cirrus clouds, if any are above your site. Again, you'll be surprised how fast the shadow moves.

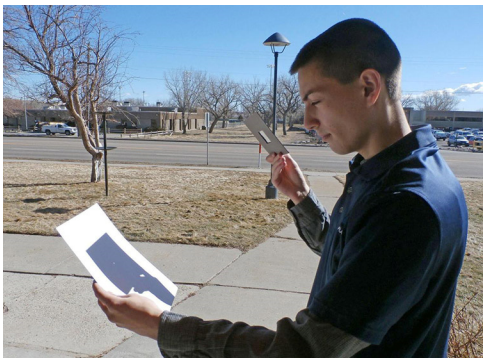
11. View the 360° sunset

During totality, take just a few seconds to tear your eyes away from the sky and scan the horizon. You'll see sunset colors all around you because, in effect, those locations are where sunset (or sunrise) are happening.

12. Get a filter in advance

Cardboard "eclipse" glasses with lenses of optical Mylar cost about $2. Such a device — it's not a toy — will let you safely look directly at the Sun. It filters out most of the light, all of the dangerous infrared (heat) and ultraviolet radiation, which tans our skin. Buy one well in advance, and you can look at the Sun anytime. Sometimes you can see a sunspot or two. That's cool because to be visible to our eyes, such a spot has to be larger than Earth.

Another safe solar filter is a #14 welder's glass, which also will cost you $2. Wanna look cool at the eclipse? Buy goggles that will hold the welder's glass. I've even seen people wearing whole helmets. Either those or goggles serves one purpose — you won't need to hold the filter, so you can't drop it.



13. No filter? You can still watch

Except during totality, we never look at the Sun. But what if you've forgotten a filter? You can still watch by making a pinhole camera. It can be as simple as two pieces of paper with a tiny hole in one of them. (Try to make the hole as round as you can, perhaps with a pin or a sharp pencil.) Line up the two pieces with the Sun so the one with the hole is closest to it. The pinhole will produce a tiny image, which you'll want to have land on the other piece of paper. Moving the two pieces farther apart will enlarge the Sun's image but will also lessen its brightness. Work out a good compromise.

14. Bring a chair

In all likelihood, you'll be at your viewing site several hours before the eclipse starts. You don't really want to stand that whole time, do you?

15. Don't forget the sunscreen

Even though the eclipse happens in early April, you'll be standing around or sitting outside for hours. You may want to bring an umbrella for some welcome shade, especially if you're viewing the event from the Southwest. And if you see someone who has forgotten sunscreen, please be a peach and share.

16. Take lots of pictures

Before and after totality, be sure to record your viewing site and the people who you shared the total solar eclipse with.

17. The time will zoom by

In the August 1980 issue of *Astronomy* magazine, author Norm Sperling contributed a "Forum" titled "Sperling's 8-

second Law" in which he tries to convey how quickly totality seems to pass. I'll just quote the beginning here.

Everyone who sees a total solar eclipse remembers it forever. It overwhelms the senses, and the soul as well — the curdling doom of the onrushing umbra, the otherworldly pink prominences, and the ethereal pearly corona. And incredibly soon, totality terminates.

Then it hits you: 'It was supposed to last a few minutes — but that couldn't have been true. It only seemed to last eight seconds!'

18. Bring snacks and drinks

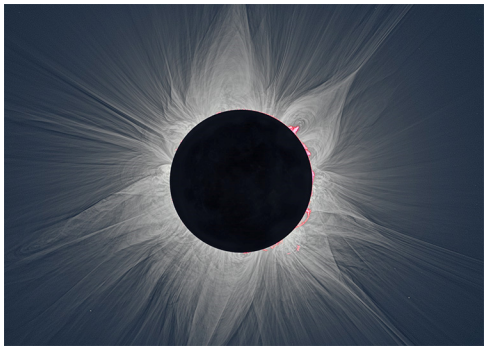
You're probably going to get hungry waiting for the eclipse to start. Unless you set up next to a convenience store, consider bringing something to eat and drink.

19. Not many people you meet will have seen totality

If you're planning an event or even a family gathering related to the eclipse, consider this: Statistically, only a few percent of the people you encounter will have experienced darkness at noon. You will be the expert. A telescope equipped with an approved solar filter will help Sun-watchers get the most from the eclipse.

20. Invite someone with a solar telescope

In the event you're thinking of hosting a private get-together, make sure someone in attendance brings a telescope with a solar filter. While it's true that you don't need a scope to view the eclipse, having one there will generate quite a bit of buzz. And you (or the telescope's owner) can point out and describe sunspots, irregularities along the Moon's edge, and more.



21. Experience totality alone

The 2024 total solar eclipse plus the events leading up to it will combine to be a fabulous social affair. Totality itself, however, is a time that you might want to mentally shed your surroundings and focus solely on the sublime celestial dance above you. You'll have plenty of time for conversations afterward. A get-together with family and friends after the eclipse will help you unwind a bit and hear what others experienced.

22. Schedule an after-eclipse party or meal

Once the eclipse winds down, you'll be on an emotional high for hours, and so will everyone else. There's no better time to get together with family and friends and just chat. Or, take a secondary position and just listen to others talking about what they've just experienced. Fun!

23. Record your memories

Sometime shortly after the eclipse, when the event is still fresh in your mind, take some time to write, voice-record, or make a video of your memories, thoughts, and impressions. A decade from now, such a chronicle will help you relive this fantastic event. Have friends join in, too. Stick a video camera in their faces and capture 30 seconds from each of them. You'll smile each time you watch it.

#24. Don't be in a rush afterward

Traffic, or the new term I have for what we all will experience on eclipse day — gridlock — will be horrendous after the event at some locations. And the sooner you try to leave, the worse it will be. Relax. Let the part of the eclipse between third and fourth contacts play out. Many people will view this portion as "what we saw before totality, but in reverse." For this section, however, all the tension will be gone.

25. *Don't photograph the eclipse!*

This tip — specifically directed at first-time eclipse viewers — may sound strange because it's coming to you from the former photo editor of the best-selling astronomy magazine on Earth. But I've preached this point to thousands of people who I've led to far-flung corners of our planet to stand under the Moon's shadow. True, few of them have thanked me afterward. But I can tell you of upwards of a hundred people who have told me with trembling voices, "I wish I'd followed your advice. I spent so much time trying to center the image and get the right exposures that I hardly looked at the eclipse at all." How sad is that?

And here's another point: No picture will capture what your eyes will reveal. Trust me, I've seen them all. Only the top 1% of the top 1% of photographers have ever come close. And — no offense meant — but you, with your point-and-shoot pocket camera, off-the-shelf DSLR, or cutting-edge smartphone, are not one of them.

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The Great 2024 ECLIPSE

PREPARE NOW FOR THE TOTAL SOLAR ECLIPSE THAT WILL SWEEP ACROSS MEXICO, THE U.S., AND CANADA ON APRIL 8, 2024.

Written by experts in eclipses and eclipse-chasing, *The Great 2024 Eclipse* — a 60-page, fully illustrated guide — is packed with essential how-to material for anyone preparing to witness the total solar eclipse.

On sale now on leading newsstands across the U.S. and Canada. Or order on shopatsky.com or by calling 800-253-0245. (*S&T* subscribers get $2 off cover price of $11.99.)

How to Shoot SOLAR ECLIPSE Images & Videos

Most experienced eclipse chasers recommend that first-timers—especially those attending their first total solar eclipse—just watch the spectacle and not try to capture it in images or video. There's so much to see with your eyes, and you'll be able to view countless other people's pictures and movies online afterward anyway. But now that so many people carry smartphones with built-in cameras almost everywhere they go, it's inevitable that most first-time eclipse-watchers will want to record something of their experience for later viewing. In this article, we provide the essential information every eclipse photographer needs to get the best possible results.

When shooting still images or video of a total solar eclipse, one rule is paramount: special-purpose solar filters must always remain on cameras and telescopes during the partial phases. Only during totality is it safe to remove them (see our Eye Safety section). Filters should fit snugly over the front of all camera lenses and telescopes, but not so tightly that they're difficult to remove quickly at the start of totality.

Here are four things to keep in mind while reading this article:

1. The suggestions offered here are intended mainly for users of digital single-lens reflex and mirrorless cameras (DSLRs and DSLMs); we also offer some tips on shooting with smartphone cameras. Some of the comments on this page won't apply if you're shooting with film or recording on tape.
2. Comments about shooting totality apply only if you're within the path of the Moon's umbra. On April 8, 2024, the path of totality is only about 115 miles wide but stretches from Mexico to Texas to Maine to eastern Canada. Outside either path, you'll have only a partial eclipse.
3. This article doesn't specifically address taking eclipse photos through a telescope, though some of the tips concerning telephoto lenses apply equally to telescopes. See the links at the end if you plan to shoot through a telescope, which is really not something you should try unless you have prior experience.
4. You should practice before the April 8, 2024, total eclipse by shooting the uneclipsed Sun (with solar filters over the front of your optics, of course) in the days or weeks leading up to the eclipse.

Size Matters

If you simply want to shoot scenics and don't care about eclipse close-ups, then a smartphone or point-and-shoot camera will suffice. If it has a decent zoom lens, some manual control, and perhaps image stabilization, you can take snapshots that record the progress of the partial phases through a solar filter, landscape scenes showing the dropping light level during the final minutes before totality, the 360° horizon glow visible during totality, and even totality itself.

Before pointing your camera at the Sun at any time other than during totality, remember to put a special-purpose solar filter over the camera lens (and over the viewfinder if the camera lacks through-the-lens viewing).

Several new products are available to facilitate shooting solar eclipses with smartphone cameras; see the "Solar Filters for Smartphones" section of our Suppliers of Safe Solar Filters & Viewers page.

For close-up images of the eclipsed Sun, you'll need a digital single-lens reflex (DSLR) or mirrorless (DSLM)

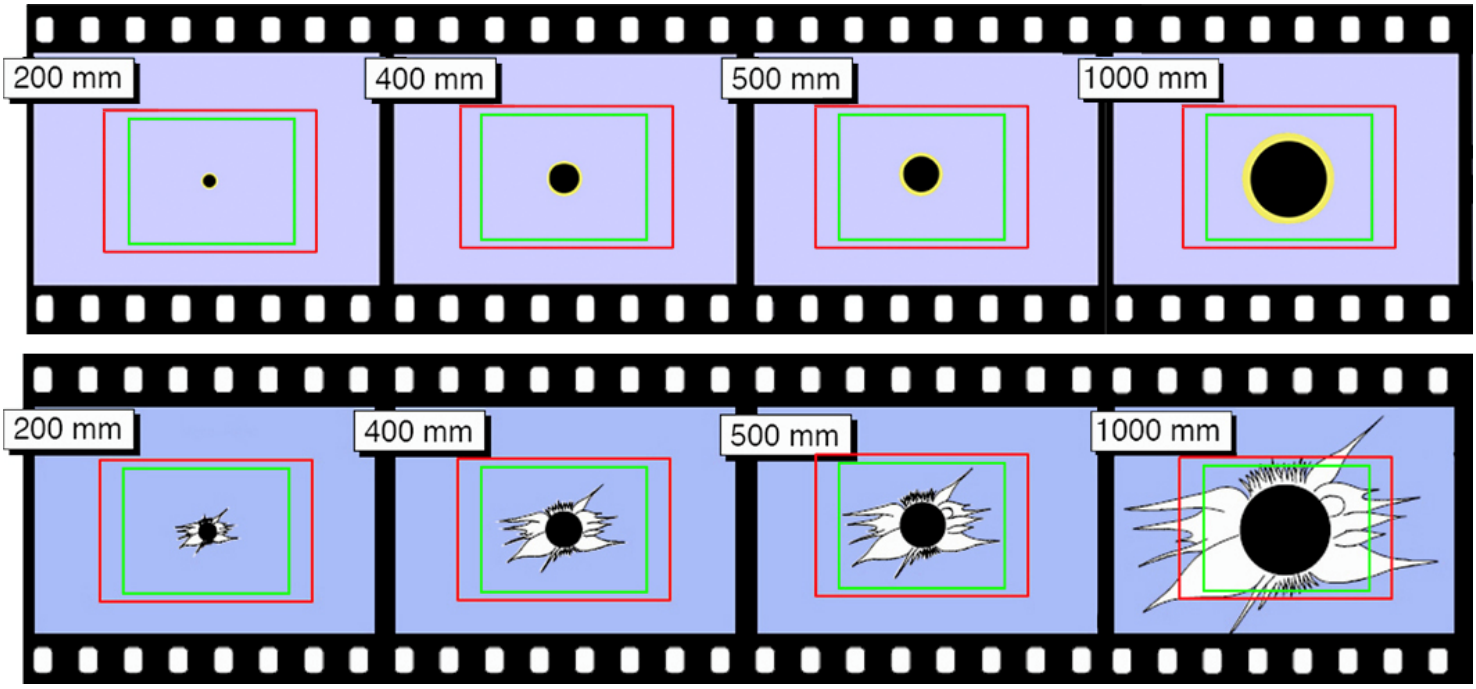
interchangeable-lens camera with a telephoto lens or a point-and-shoot camera with a high-power zoom lens.

A normal (50-mm) or wide-angle (35-mm to 10-mm fisheye) lens will take in the overall scene but will not capture coronal detail during totality because the eclipsed Sun's image will be tiny. To get a moderately large solar image, you need a lens with a focal length of at least 300 mm. (All focal lengths in this article are 35-mm equivalents; if you're not sure how to convert your lens's focal length to its 35-mm equivalent, check your owner's manual or the manufacturer's website.) For close-ups of Baily's Beads, and of the diamond rings, the chromosphere, prominences, and the corona, a 1,000-mm telephoto (or longer) is recommended. That's the realm of telescopes; again, we don't cover that kind of imaging here, as it's recommended only for those with experience.

mously with radial distance from the Sun. So, while one exposure may work for the partial phases, you'll need a wide range of different exposures to capture all the phenomena of totality.

During the transitions between the partial phases and totality at second and third contact, the scene in the sky changes rapidly. You'll already be worried about getting your solar filter off and back on at the right moments, so you don't also want to worry about changing your ISO, aperture (f-stop), and exposure times. It's better to use one ISO and one f-stop throughout the entire eclipse and vary only the shutter speed.

When testing your exposure settings, try higher ISO numbers and larger apertures (smaller f/numbers), because totality is much fainter. Late-model digital cameras often show no noise until the ISO is set above 400; point-and-



The eclipsed Sun's image size is shown for various telephoto lenses with a full-frame DSLR or DSLM (or 35-mm film camera), with an annular eclipse at top and a total eclipse at bottom. The outside (red) rectangle indicates the equivalent field of view for DSLRs/DSLMs with APS-size sensors; the inside (green) rectangle shows the field of view for digital cameras that use Four Thirds System chips. An easy way to check the size of the Sun's image is to take test shots (with a solar filter in place) before the day of the eclipse. Note that you'll shoot all phases of an annular eclipse through a solar filter, so the background sky will appear black, not light blue as shown here. Adapted from an illustration initially prepared by Fred Espenak.

Software developer Xavier Jubier has posted his Shutter Speed Calculator for Solar Eclipses online. Among other features, it illustrates the image size of the Sun for various combinations of camera model, sensor size, and focal length.

Exposure Counts

While you're practicing shooting the Sun to see how much of your camera's frame it will fill, try testing for exposure too.

The Sun's brightness changes by orders of magnitude between the partial phases (when you'll shoot through a solar filter) and totality (when you'll shoot without a filter). Moreover, the brightness of the solar corona varies enor-

shoot models generally aren't as good. Experiment with ISO settings of 400, 800, and perhaps even 1600 to figure out which setting produces the best images of the full Sun when combined with apertures of f/5.6 or f/4 and the shortest exposure times your camera can deliver. On eclipse day, you'll use your fastest shutter speeds during the partial phases and a wide range of shutter speeds during totality.

The Sun's surface brightness remains constant throughout most of the partial phases of the eclipse, so no exposure compensation is necessary. During the thin-crescent phases shortly before and after totality, you might want to increase the exposure time by a factor of 1.5 or even 2 (equivalent to one f-stop), since the solar limb (edge) is noticeably fainter than the center of the disk. If haze or clouds interfere on

Recommended Exposures for Imaging a Total Solar Eclipse

SUN - Full Disk or Partial Eclipse
Through Full Aperture Solar Filter

f/	50	100	200	400	800
2.8	1/2000	1/4000	-	-	-
4	1/1000	1/2000	1/4000	-	-
5.6	1/500	1/1000	1/2000	1/4000	-
8	1/250	1/500	1/1000	1/2000	1/4000
11	1/125	1/250	1/500	1/1000	1/2000
16	1/60	1/125	1/250	1/500	1/1000
22	1/30	1/60	1/125	1/250	1/500
32	1/15	1/30	1/60	1/125	1/250

SUN - Total Eclipse: Prominences
No Filter

f/	50	100	200	400	800
2.8	1/4000	-	-	-	-
4	1/2000	1/4000	-	-	-
5.6	1/1000	1/2000	1/4000	-	-
8	1/500	1/1000	1/2000	1/4000	-
11	1/250	1/500	1/1000	1/2000	1/4000
16	1/125	1/250	1/500	1/1000	1/2000
22	1/60	1/125	1/250	1/500	1/1000
32	1/30	1/60	1/125	1/250	1/500

SUN - Total Eclipse: Inner Corona (3° field)
No Filter

f/	50	100	200	400	800
2.8	1/250	1/500	1/1000	1/2000	1/4000
4	1/125	1/250	1/500	1/1000	1/2000
5.6	1/60	1/125	1/250	1/500	1/1000
8	1/30	1/60	1/125	1/250	1/500
11	1/15	1/30	1/60	1/125	1/250
16	1/8	1/15	1/30	1/60	1/125
22	1/4	1/8	1/15	1/30	1/60
32	1/2	1/4	1/8	1/15	1/30

SUN - Total Eclipse: Outer Corona (10° field)
No Filter

f/	50	100	200	400	800
2.8	1/4	1/8	1/15	1/30	1/60
4	1/2	1/4	1/8	1/15	1/30
5.6	1 sec	1/2	1/4	1/8	1/15
8	2 sec	1 sec	1/2	1/4	1/8
11	4 sec	2 sec	1 sec	1/2	1/4
16	8 sec	4 sec	2 sec	1 sec	1/2
22	15 sec	8 sec	4 sec	2 sec	1 sec
32	30 sec	15 sec	8 sec	4 sec	2 sec

These exposure tables are given as guidelines only. The brightness of prominences and the corona can vary considerably. You should bracket your exposures to be safe.

eclipse day, you may need to bracket by a full f-stop or more (or switch to automatic mode) to get decent results.

To capture the faint outer corona, you'll want to push your exposures as long as possible. The maximum practical exposure depends on whether your camera is hand-held (and if so, whether it has image stabilization), attached to a fixed tripod, or tracking the sky on a motorized mount to compensate for Earth's rotation.

On eclipse day, make sure you preset your ISO rating and f-stop; don't let your camera (via its "auto ISO" function) do it for you. For any combination of f-stop, ISO number, altitude of the Sun in the sky, and elevation of the observer above sea level, Xavier Jubier's Shutter Speed Calculator for Solar Eclipses suggests an exposure time for each phase of the eclipse. Fred "Mr. Eclipse" Espenak's Solar Eclipse Exposure Guide does the same in a simple tabular format. Don't rely exclusively on tools like these; use them as a starting point. As noted above, test your setup on the uneclipsed Sun well in advance, and on eclipse day, bracket your exposures.

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

Focus Is Critical

Don't leave the job of focusing to your camera's autofocus system. Manual focus is the way to go, and most telephoto

Notice that the telephoto lens in the image above has tape on it. This is to ensure that both the focus and zoom settings stay in place and don't slip when you least expect it - like during totality! Make sure the camera and lens are on a steady tripod as well. You can even weigh it down, as is being done here.

lenses provide this option. As soon as you're set up at your eclipse-viewing location, attach the solar filter to the camera's lens, aim at the Sun, and focus. When sunspots are visible, as is likely to be the case in 2024 since the Sun is near "solar maximum" (its cyclical peak of magnetic activity), focus on the spots; otherwise, focus on the solar limb. Take a couple of test shots to ensure that the images look sharp.

Once the lens is focused, secure it by sticking a strip of masking tape to the lens's focus ring. If you're using a zoom lens, lock it to your preferred focal length with tape as well, since it can "self-adjust" without warning, particularly if the lens is pointed high in the sky. Make sure your solar filter can be easily removed when totality begins and restored when totality ends, without affecting the focus or the zoom.

Keep It Steady

Even though you'll likely be shooting the partial phases of the eclipse at reasonably fast shutter speeds, there's nothing like a solid tripod to keep your optical system steady. This is especially true for a total solar eclipse, when you'll be shooting longer exposures during totality. The tripod is particularly important if you're using a camera with a long-focal-length telephoto lens, which may be heavy and unwieldy.

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

Some image-stabilization systems get confused when a camera is mounted on a tripod, causing the image to jerk around. As we keep repeating, test your equipment before eclipse day to make sure you know which features improve your results, which features are best avoided, and how to enable the former and disable the latter.

Shooting Totality

Obviously, this section applies only if you're in the path of totality for a total solar eclipse. To find out whether your home or any other specific location lies within this path on April 8, 2024, see Xavier Jubier's Google Map, which supports zooming in to street level.

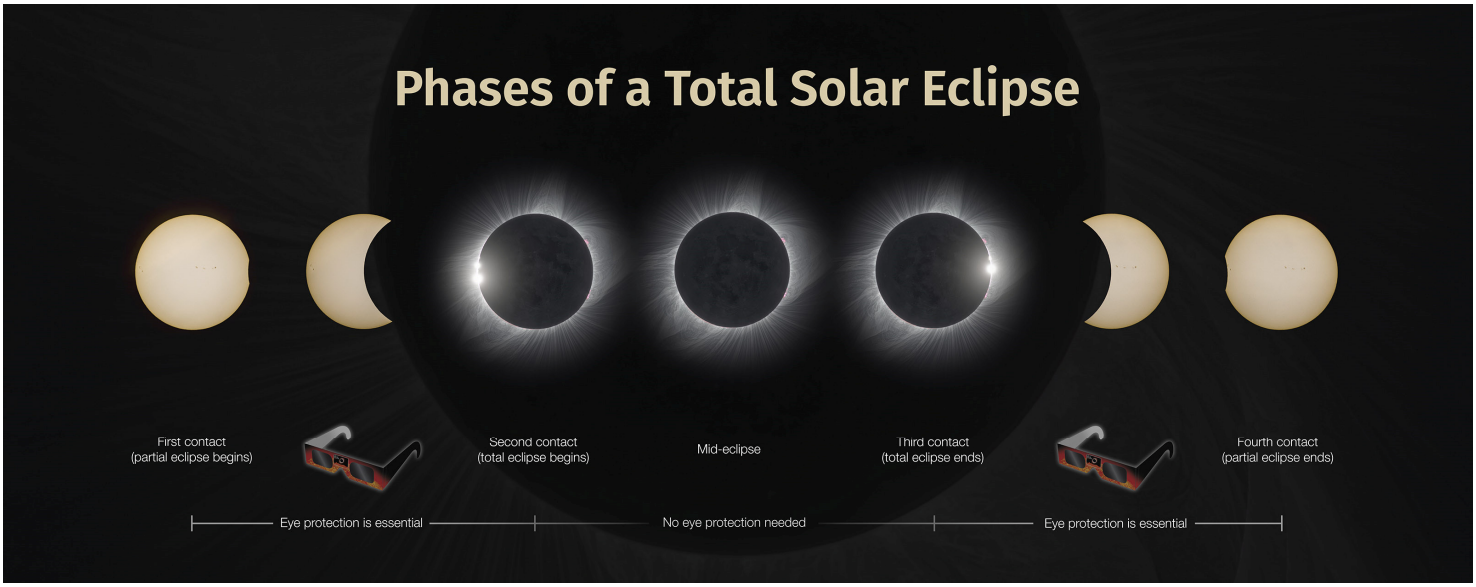
If you don't already live or work within the path of totality, we strongly recommend that you travel there if you can, especially if you've never experienced totality before (and because the next total solar eclipse to sweep across North America doesn't occur until 2045). As described elsewhere on this site, the difference between a total solar eclipse and a partial or annular eclipse is quite literally the difference between night and day! (See our 2-minute video explainer if you're still unsure whether to make the effort to get into the path of totality.)

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

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

Rapid changes occur during second and third contacts, the beginning and end of totality, respectively. At these times, you don't want to be fumbling with your camera's settings. Instead, decide in advance on the ISO/f-stop/shutter-speed combination you want for both contacts and

Solar filters for camera lenses and telescopes should be secure but quick and easy to remove before totality. You don't want to inadvertently move the camera or change the focus or zoom settings.



set your camera accordingly before the onset of each diamond ring. Even better, as noted above, use the same ISO and f-stop settings throughout the eclipse so that you only need to vary the shutter speed to capture different phenomena.

The Sun's atmosphere varies tremendously in brightness. The inner corona shines as brightly as the full Moon; the outer corona is less than 100th as bright (in other words, it's quite dim). One exposure cannot capture this wide, dynamic range. That's why eclipse photographers shoot a sequence of exposures (using a fixed ISO and f-stop) that range from very short ones to very long ones. This gives you the best chance of capturing all aspects of the magnificent solar corona.

At the short end (1/1,000 second or less), only the innermost corona clinging to the solar limb appears. At the long end (1/10 second or longer if you can hold sufficiently steady), the inner corona is burned out, but the faint tendrils of the outer corona show up nicely. There is no single correct exposure for totality, so your best bet, at any f-stop, is to shoot a sequence spanning the full range from the short exposure you used for the partial phases to the longest exposure you can manage without blurring (perhaps a few tenths of a second).

A digital shot of the beginning of totality on July 22, 2009, taken with a 200-mm lens. The photo - a composite of short, medium, and long exposures - provides a good sense of the coronal detail visible to the eye (perhaps augmented by binoculars). But to turn your images into something like this requires specialized image-processing software and hours of work at the computer. Credit: Miloslav Druckmüller, Peter Aniol

If you do manage to capture a series of totality exposures, you can turn them into a thing of beauty using a computer. There's image-processing software that allows you to rotate and align individual frames to match and create seamlessly blended stacks of short, medium, and long exposures to achieve amazing results.

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

1. A minute or so before second contact, adjust your f-stop and shutter speed to be ready for second contact.
2. When everyone starts screaming "diamond ring!" take the solar filter off your camera and start shooting. Keep firing until the brilliant diamond is gone, the corona emerges, and you're enveloped in the darkness of the Moon's shadow.
3. Next, have a quick look around — at the corona, the sky, the horizon, and your fellow eclipse observers.
4. Now concentrate on shooting the corona. Run through your exposure sequence from short to long at a fixed f-stop.
5. Reset your camera so you're ready to shoot at third contact.
6. Now…look up and enjoy the show! The vast range of coronal brightness, the beautiful detail within the corona, and the delicate shading of the sky down to the colors on the horizon are things only your eye can take in. No matter how good your photographs are, they won't do justice to the real thing. So, make sure you take the time to see totality with your own eyes.

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

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

- Use a remote control or cable release to avoid "camera shake." This is probably an optional extra that didn't come with your camera, so pick up one (and test it) before eclipse day.
- Bring extra batteries and insert fresh ones before first contact (that is, before the beginning of the partial eclipse). If you're using rechargeable batteries, charge them fully before the eclipse begins, and have a spare set, also fully charged, that you can insert shortly before annularity or totality.
- Bring an extra empty, formatted memory card, insert it prior to the start of the eclipse, and then remove it (and lock it, if possible) after the eclipse has ended.

This scenic view of La Silla Observatory was taken during the July 2019 eclipse. It is a 1/3-second exposure taken with a Sony mirrorless camera (set at ISO 100) and a 24mm, f/4 lens. Point-and-shoot cameras or even smartphones are capable of taking similar shots.

Odds and Ends

- Make sure your camera's flash is turned off. Flashes are an annoyance and, if nothing else, spoil the mood of the spectacle. If you use a point-and-shoot camera and you're not sure you can turn the flash off, put a piece of black tape over the flash for extra security.
- Most cameras have optical and digital zooms. Turn off the digital zoom; it's basically useless.
- Shoot at the highest image-quality setting your camera supports (RAW if possible).
- If you're in the path of totality for a total solar eclipse, bring a flashlight, preferably one that shines with red light. It can get dark enough during totality that you won't be able to see your camera settings without one!

Videography

Today's DSLRs, DSLMs, and smartphone cameras offer excellent video quality and reasonable sound — there's no longer any need to bring a dedicated video camera. During a total solar eclipse, there is much whooping and hollering when totality strikes, and it's always entertaining to watch

The Solar Snap kit from American Paper Optics has everything you need to easily photograph an eclipse with a smartphone. Download the provided app, attach the solar filter and you are ready to capture the eclipse!

and listen to the playback after the event. Indeed, many eclipse veterans will tell you that the best part of any total solar eclipse video is the audio!

The same rules that apply to still photography apply to video imagery, especially the one about keeping a proper solar filter attached to your camera if you're shooting closeups of the Sun. Before the eclipse, use the zoom function to determine the optimum image size of the solar disk (ignore any digital-zoom option), and shoot a short bit of test footage just to make sure your settings are good.

During the partial phases, shoot three- to five-second clips of the Sun every four or five minutes to produce a time-lapse sequence that will compress the multi-hour event into minutes. This is best done with your camera mounted on a tripod. Depending on the image size of the solar disk, you may want to let the video run continuously from just before second contact to just after third to capture Baily's Beads popping on and off and to show the Moon moving across the solar face in real time (keeping in mind that all this will take several minutes). Remember to take the solar filter off at second contact and to replace it at third.

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

If you want to share images and videos on social media or post them on blogs, shooting with a smartphone camera is fine. But if you're concerned about image quality, a DSLR or DSLM is the way to go. If you're using one, you should determine in advance if you want to shoot stills or video, particularly if you plan to capture Baily's Beads. While the overall eclipse is a leisurely affair, the beads are a rapidly changing event. Decide a few minutes before second and/or third contacts how you want to image them. Do not change your mind at the last minute! Reconfiguring your camera with totality bearing down on you means you could well end up with no images or video at all.

Want to see some examples? There are vast numbers of solar eclipse videos on YouTube and Vimeo.

Keeping It Simple

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

Late-model cameras and lenses allow you to do things that weren't possible before, rendering some of the tried-and-true traditional advice moot. For example, thanks to image stabilization, you can hand-hold a camera with a modest telephoto lens and achieve sharp images without a tripod. And thanks to reasonably noise-free high-ISO performance, you can use ISO settings of 1600, 3200, or even higher for faster shutter speeds. During a total solar eclipse, you might be able to capture the middle to outer corona with exposures as short as 1/15 second!

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

And then there's your smartphone. The cameras on the latest models can produce better results than dedicated point-and-shoot cameras did just a few years ago. New products such as Solar Snap and its included app for your smartphone make easy work of sizing the solar image, focusing, and adjusting the exposure. In addition, you can buy auxiliary lenses that strap on to your phone to enable high-magnification telephoto or superwide-angle shots, adapters that let you connect your smartphone camera to a telescope eyepiece, and apps that give you control over shutter speed, aperture (f-stop), and sensitivity (ISO rating). And, of course, smartphones can capture not only still im-

ages but also video and audio.

Remember to place a solar filter over your phone's camera lens if you plan to snap pictures of the partially or annularly eclipsed Sun, or over the front of your telescope if you plan to shoot the partial phases or any phase of an annular eclipse with your phone attached to the eyepiece.

The main challenge with using smartphone cameras for astronomical photography is that they tend to overexpose bright objects (e.g., the Moon or the inner solar corona) and have trouble focusing on dim objects (e.g., almost everything else in the sky). Zooming in to make the subject bigger often helps. If your smartphone camera has an HDR (high dynamic range) feature, turn it on and hold your phone very steady — use a tripod if possible. In HDR mode, your phone's camera will automatically take several images in rapid succession with different exposures; with any luck, one of them will be pretty good, or you can combine several to get a composite that's reasonably well exposed across the entire frame.

Patricia Reiff, science lead at the Rice Space Institute and a veteran eclipse chaser, offers the following recommendation for would-be smartphone eclipse photographers: Choose video mode — not still-image mode — and prop your camera (or use a tripod) so that it faces northwest toward your observing group. Record video (and audio) from a minute or two before totality begins to a minute or two after it ends. During a total eclipse, if you're lucky, you'll capture one of its most dramatic effects: the Moon's dark shadow racing toward you and washing over you at more than 1,000 miles per hour. Once that happens, look up, and WHAM! There's the totally eclipsed Sun! Recording the visual and voice reactions of your friends and family throughout totality is priceless. Other eclipse-watchers will take better pictures of the eclipse, but they won't capture your reaction!

Final Thoughts

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

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

More Articles About Solar-Eclipse Imaging & Video

- *Smartphone Photography of the Eclipse*
  (Sten Odenwald, Goddard Space Flight Center)
- *How to Photograph a Solar Eclipse*
  (Fred Espenak, MrEclipse.com; includes table of ISO settings, f-stops, and exposures)
- *Photographing the Eclipse! You Really Want to Do It?*
  (Dan McGlaun, Eclipse2024.org)
- *Photographing Solar Eclipses*
  (Bill Kramer, Eclipse-Chasers.com)
- *Tips for Photographing a Total Solar Eclipse*
  (Edwin Aguirre & Imelda Joson, *Sky & Telescope*)

Here's a handy online tool to help you choose your camera settings:

- Shutter Speed Calculator for Solar Eclipses
  (Xavier Jubier)

Here are some of the most remarkable images ever captured of total solar eclipses:

- Eclipse Photography Home Page
  (Miloslav Druckmüller)

Our Books & Articles page includes links to several extensive treatments of eclipse imaging:

- Books on Eclipse Imaging & Video

Our Apps & Software page includes links to programs that can automate your eclipse imaging:

- Camera Control for Automated Eclipse Imaging

Be sure to check out Alan Dyer's two-part presentation held as part of the KAS Eclipse Series:

- *Part One: How to Photograph the Eclipse*
- *Part Two: How to Process Eclipse Images*

This article was adapted from the original version that appears on the American Astronomical Society's website. It has been edited to remove references to the October 2023 annular eclipse. Used with permission.

Eclipse Photography Checklist

by Fred Espenak

Preparation Checklist
(weeks or months before eclipse)

- ❒ Set up all your equipment for testing
  - Make checklist of all necessary equipment
    - Camera, lens, solar filter, tripod, batteries, memory cards, cables, etc.
  - Include any tools you will need
  - For video camera or computer, how long do batteries last?
  - If planning bursts with a DSLR, how may shots before buffer is full?

- ❒ For maximum stability, set tripod as low as practical
  - Do not extend center column
  - Hang weight (water bottle, bag of rocks, etc.) from center of tripod or tape to legs

- ❒ Practice aiming, framing and tracking the Sun with your camera
  - If using equatorial mount, learn how to polar align in daytime
    - Use compass for NORTH & angle finder for LATITUDE.
  - If NOT using equatorial mount, practice tracking Sun
    - (How long does it take the Sun to drift out of your field of view?)
  - Note: Sun moves across the sky at the rate of 1 diameter every 2 minutes

- ❒ Make sure you can remove the solar filter quickly without moving Sun out of field
  - Solar filter must be secure enough that wind won't blow it off
  - Practice removing filter smoothly

- ❒ Prepare brief *Eclipse Day* notes
  - Use clipboard or index cards
  - List eclipse contact times for quick reference
  - Eclipse Day checklist
  - Any other notes you need at your fingertips

- ❒ Carefully pack up all your equipment
  - Set up all your equipment one last time
  - How long does it take to set up?
  - Consult checklist to make sure you have everything
  - Use poly tarp to lay out equipment before packing for eclipse
  - Don't remove anything once you've packed

Eclipse Day Checklist

- ❒ Carefully set up all your equipment (~1 hour before 1st contact)
  - For equatorial mount, perform a daytime polar alignment
    - Verify that mount is tracking well
  - Include any tools you will need

- ❒ Camera check
  - Put in a fresh (charged) battery
  - Put in fresh memory card (≥ 16 GB)
  - Set image quality to RAW or RAW+JPEG (use best quality JPEG if no RAW)

- ❒ Use GPS to synchronize time on devices
  - Wristwatches, cameras, computers, etc.

- ❒ For mobile phones and other "simple" cameras
  - **DO NOT USE FLASH!**
  - Disable flash via camera settings
  - Place opaque tape or cardboard over flash

- ❒ Set camera/lens to MANUAL focus (if possible)
  - Autofocus does not work well
    - Crescent Sun too bright
    - Twilight landscape too dark
  - Focus manually on crescent Sun or landscape (before totality begins)

- ❒ Secure lens focus, zoom and aperture.
  - Fix with piece of masking tape (or gaffer tape)

- ❒ Stabilize Tripod against vibration and wind
  - ○ Keep tripod as low as possible (don't use center column)
  - ○ Hang weight from tripod (water bottle, sand bag, rocks, etc.)
  - ○ Use vehicle as wind shield

- ❒ For Automation Photographers
  - ○ Verify GPS connection or manually sync correct time
  - ○ Verify camera connection to PC or intervalometer
  - ○ Trigger camera shutter to confirm

Eclipse Day Timeline

- ❒ 15 minutes before 2nd Contact (Totality begins)
  - ○ Check battery and memory card (replace if needed)
  - ○ Check/Adjust focus (tape down to secure)

- ❒ 10 minutes before 2nd Contact
  - ○ Look at pinhole crescents (under trees, or use hands)
  - ○ Begin looking WEST for sky darkening

- ❒ 5 minutes before 2nd Contact
  - ○ Check camera focus and pointing
  - ○ Look for Planets (Venus 15° southwest of Sun)
  - ○ Look SOUTHWEST for approaching shadow

- ❒ 1 minute before 2nd Contact
  - ○ Check camera focus and pointing
  - ○ Look for shadow bands

- ❒ 30 seconds before 2nd Contact
  - ○ Remove solar filter (carefully)

- ❒ 10 seconds before 2nd Contact
  - ○ Begin burst sequence of Diamond Ring effect (~1 second or less between frames)
  - ○ DO NOT LOOK through camera until TOTALITY begins (this applies to optical viewfinders of DSLRs)

- ❒ 2nd Contact – TOTALITY BEGINS!
  - ○ Center Sun in viewfinder
  - ○ Begin Exposure Sequences (~1/500 down to ~1 second)

- ❒ During TOTALITY
  - ○ Shoot Exposure Sequences 3 times or more
  - ○ DO NOT try to change memory card, battery or lens
  - ○ TAKE TIME to LOOK at the eclipse! (coronal structure, prominences, twilight sky, planets, etc.)

- ❒ 10 seconds before 3rd Contact (TOTALITY Ends)
  - ○ Alarm warning for 3rd Contact (wrist watch, computer, etc.)

- ❒ 5 seconds before 3rd Contact (TOTALITY Ends)
  - ○ Begin burst sequence to capture: chromosphere, Baily's beads, and diamond ring
  - ○ ~1/1000 @ 1 frame per second (or faster)
  - ○ Shoot until 10 seconds after 3rd Contact

- ❒ 15 seconds after 3rd Contact (End of Totality)
  - ○ Replace solar filter
  - ○ Look for shadow bands
  - ○ Watch Moon's shadow recede to the NORTHEAST

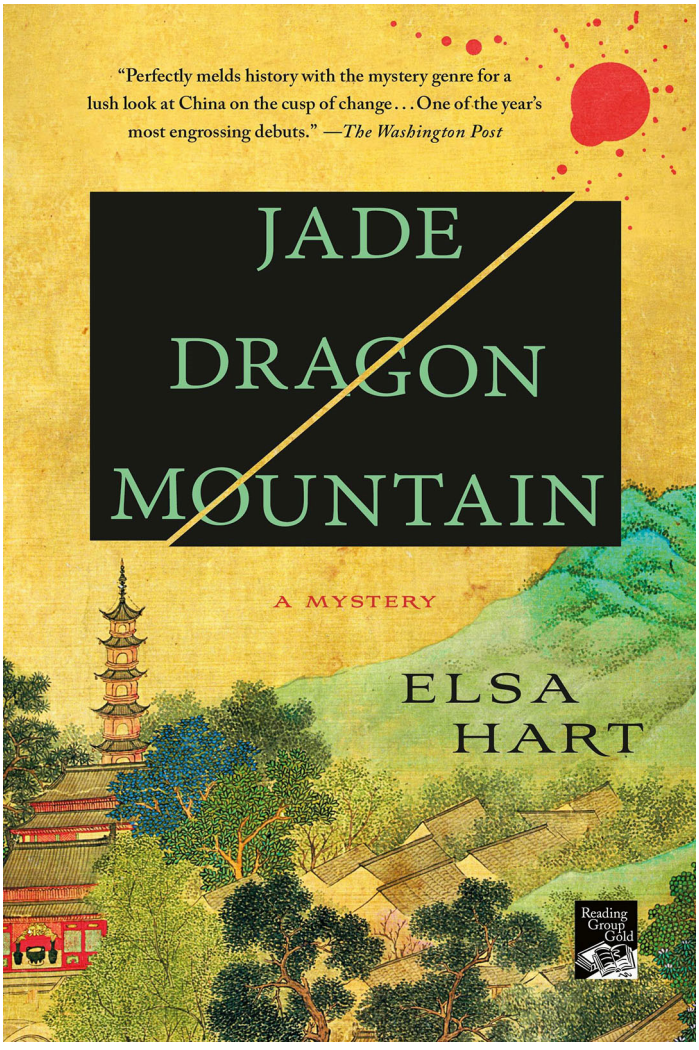
- ❒ 5 minutes after Totality
  - ○ Lock memory card of eclipse photos
  - ○ Label memory card and store in safe place (make backup after eclipse ends ASAP)
  - ○ Begin plans for trip to next Total Solar Eclipse!

Used with permission.

Two Eclipse Mysteries and a Musical

by **Karen Woodworth**

Although I enjoy reading good non-fiction works about eclipses, I'm also interested in reading fiction that uses an eclipse in its plot. I've recently read two good mysteries that might interest you. The first is *Jade Dragon Mountain* by Elsa Hart. It's the opening book of a trilogy of mysteries centering around Li Du, a former imperial librarian who is now in exile. The story is set in 1708 in Dayan, the last Chinese town before the Tibetan border. Although Li Du plans just to pass through the town on his way to Tibet, his cousin, the magistrate, requests his help in solving the murder of a Jesuit astronomer. The plot hinges on a solar eclipse that is scheduled to happen in less than a week. (According to EclipseWise, the date of the eclipse was September 14, 1708.) This is a cerebral historical mystery without gore. There are many characters to keep track of, but you can find a character list at Book Companion.



The second mystery I've been reading is a historical mystery set in the twentieth century. *Death in the Stars* is the ninth book in the Kate Shackleton mystery series by Frances Brody, but it's the first book in the series that I've read. The story begins in the days before the total solar eclipse of June 29, 1907, in England. Detective Kate Shackleton accompanies a singer and a comedian to see the eclipse with the Astronomer Royal. It's an early morning eclipse, and the comedian is missing when the eclipse is over. He's discovered unconscious and taken to the local hospital, where he dies. The mystery deepens from there. This book can be read as a stand-alone mystery without reading the other books in the series. It reminds me a bit of the Miss Fisher mysteries by Kerry Greenwood.

A book that you may have already read is being turned into a musical! Author David Baron, composer/lyricist/librettist Michael John LaChiusa, and director Bill Rauch are collaborating on the Broadway musical *American Eclipse*, based on Baron's book of the same name that tells three stories of the total solar eclipse of July 29, 1878. They'll be at Baylor University in Waco, Texas, on April 7th for a concert performance of songs from the musical that includes a conversation about the creation of the work. A new edition of the book has been released, and a book club kit PDF is available on the *American Eclipse* website.

Helping People Time a Total Solar Eclipse

by **Gordon Telepun**

I went to my first total solar eclipse on June 21, 2002, in Zambia, Africa. At that time, YouTube did not exist, and minimal eclipse preparation information was available online. Eclipse observers and photographers relied on Fred Espenak's book *Totality* and the NASA Eclipse Bulletin, also authored by Fred.

Fred inspired me, and I was determined to succeed in photographing my first eclipse. I practiced and practiced my photography routine and thought I was ready. However, I was utterly ill-prepared for the intensity of witnessing the minutes before 2nd contact and the wonder of standing in the umbra where time seems to fly by! The magnificence of the event is fantastic and should be enjoyed, but it can become a distraction if you are a new eclipse photographer.

At my first eclipse, I was about 20 seconds late starting my imaging going into C2 and about 10 seconds late coming out of C3. I realized at my first eclipse that you can't time an eclipse with your watch, and photographers needed help! So after that eclipse, I developed the first "talking eclipse timer" that spoke out loud, counting down to the contact times. It ran on Windows Pocket PC, but the contact times were entered manually because the "person digital assistant" devices of the time did not have geolocation. The contact times were extrapolated from the NASA Bulletins, and this introduced a few seconds of error, but the app worked great!

In 2017, I took advantage of the computing power of mobile devices and re-developed the app to include geolocation, automatic calculation of the contact times, more announcements, reminders about removing and replacing glasses, an eclipse practice video, and partial phase image clock times. The app allowed users to be "talked" through the entire eclipse.

In 2024, the app has more announcements, a built-in tutorial, and device sound check tests. Being inspired by Fred again, there is a new feature called Photographer's Mode. When this mode is enabled, all announcements are about eclipse timing, with additional timing announcements during totality. The only other statements are about removing solar filters, max eclipse, and replacing solar filters.

The Solar Eclipse Timer app is an excellent tool for eclipse observers and photographers!

Dr. Gordon Telepun is a board-certified plastic surgeon in private practice in Decatur, AL who became passionate about total solar eclipses after witnessing his first one in Zambia, Africa, in 2002.

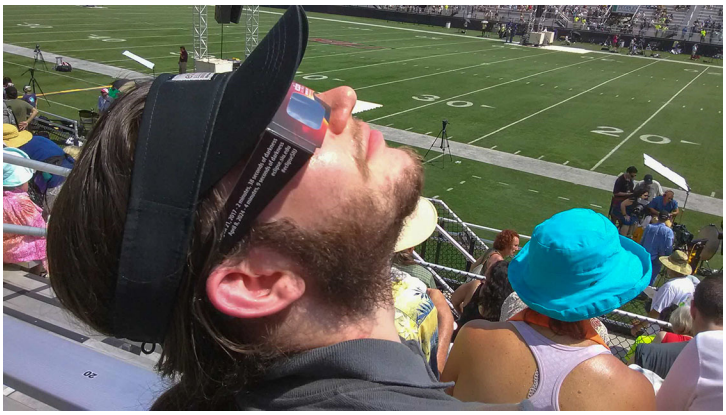
Eclipse Shades, Mini-SunOculars, and SunOculars

A Comparison

by **Karen Woodworth**

Because I'm at a point in my life where it's difficult for me to stay awake at night for dark sky observing, I decided to try solar observing. I began with Lunt mini-SunOculars, and because I enjoy them, I got a pair of full-size Lunt SunOculars as well. This article is a comparison of the two with reference to Eclipse Shades, since those were used by so many people in 2017. You will only be able to see the Sun with any of these viewing instruments; they cannot be used for any other type of viewing.

Eclipse Shades provide no magnification and no adjustments for vision: therefore, they must be worn with glasses or contact lenses if you're nearsighted like I am. Both the mini-SunOculars and the SunOculars can focus each eye individually, so I find that it works well to use them without my glasses. (I tried using them with my contact lenses but couldn't focus as well.) The focus mechanisms are different between the two instruments. The eyepieces on the mini-SunOculars adjust the focus by turning clockwise or counterclockwise. You can adjust the space between your eyes for the best fit on your face simply by moving the barrels farther apart or closer. The space between your eyes can be adjusted on the full-size SunOculars in the same manner. To focus the left lens on the SunOculars, you close your right eye and turn the knob in the middle. Once your left lens is in focus, you open your right eye, close your left eye, and turn the ring on the base of the right eyepiece clockwise or counterclockwise to focus. The SunOcular eyecups can be made deeper or shallower by turning them.



Eclipse shades are an affordable way to safely view the Sun during a solar eclipse, but provide no magnification to check on daily solar activity (and should **NEVER** be used with binoculars or telescopes). Here, Arthur Woodworth views the August 21, 2017, solar eclipse from Saluki Stadium in Carbondale, Illinois.

Karen observes our local star with her Lunt Solar Systems 8×32 SunOculars, dedicated binoculars that permit safe observation of sunspot activity, eclipses, and planetary transits.

The eclipse shades show you the Sun in an orange-yellow color. No sunspots will be visible due to the lack of magnification (unless they're *really* big). The mini-SunOculars show you the Sun in the same orange-yellow color. I perceive the Sun as being about twice as big in the mini-SunOculars as in the eclipse shades; their specifications are 6×30, so in reality, their magnification is greater. (If you're not familiar with binocular measurements, the first number refers to magnification, and the second number refers to the aperture or diameter of the lenses in millimeters.) Large sunspots will be visible as small black dots. On the solar image from spaceweather.com accompanying this article, I was able to see only sunspot 3234. The full-size SunOculars show the Sun as white, but it is a comfortable image. (When the Sun is lower in the sky right after sunrise or before sunset, the color will be orange-yellow.) I perceive the Sun as being about twice as big with the SunOcu-

Lunt 8×32 SunOculars

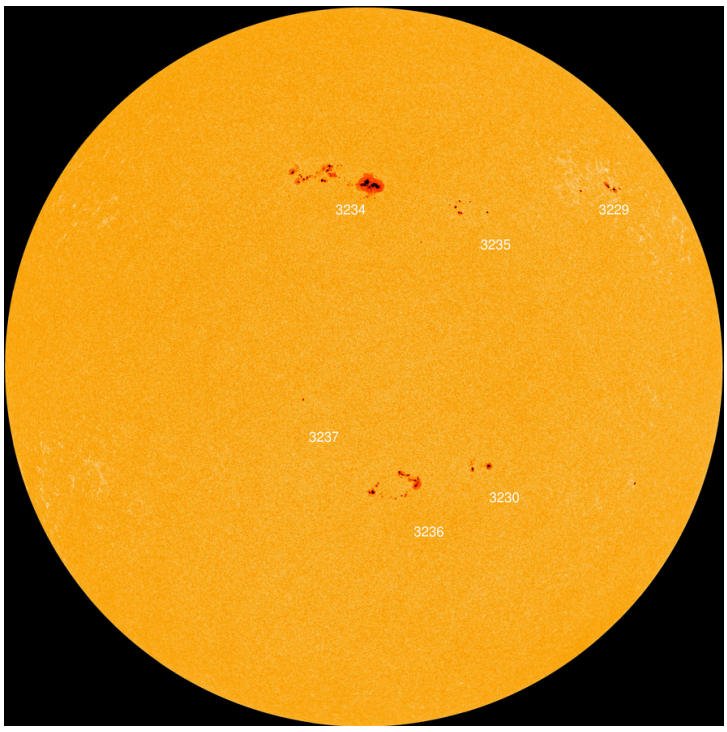
Prism Type:	Roof
Magnification:	8×
Aperture:	32mm
Eye Relief:	13.6mm
Eyecups:	Adjustable
Focus Type:	Center
Weight:	18 oz.
Price:	$129.00

Lunt 6×30 Mini-SunOculars

Prism Type:	None
Magnification:	6×
Aperture:	30mm
Eye Relief:	~9.0mm
Eyecups:	Fixed
Focus Type:	Ind. Eyepiece
Weight:	<10 oz.
Price:	$24.95

lars as it was with the mini-SunOculars, or around four times as big as with the eclipse shades. The full-size SunOculars specifications are 8×32. Sunspots still show up as black dots, but they're a little bigger. Along with sunspot 3234, I was able to see two others, probably 3236 and 3230.

Is it difficult to find the Sun? It can be at first. The best method is to orient your body toward the Sun, put your head down, move the SunOculars to cover your eyes, then raise your head until you see the Sun. You may need to turn your head left or right a little. The same method will work for the mini-SunOculars, but it takes a little bit longer to find the Sun with them since the viewing field is smaller. If you stand in the same place to observe at the same time each day, you should get quicker at finding the Sun.



The Sun, as seen with the Helioseismic Magnetic Imager (HMI) aboard the Solar Dynamics Observatory, on February 26, 2023. Karen was only able to observe sunspot group 3234 with the mini SunOculars.

The mini-SunOculars come in red, yellow, or blue with a list price of $24.95 on luntsolarsystems.com. The full-size SunOculars come in black, red, yellow, or blue with a list price of $129.00. I chose red, the "danger" color, for both my SunOculars and mini-SunOculars. The SunOculars come with a strap, removable rubber lens covers, a removable rubber eyepiece cover, a carrying case with a strap, a cleaning cloth, and an instruction booklet. The mini-SunOculars have a string to wear around your neck and nothing else. I keep mine in a gift box.

Whenever I have the chance to observe the Sun, I tend to use both the mini-SunOculars and the full-size ones together, switching back and forth between the smaller orange and larger white views. I polled my family on their preferences. My husband, Klay, liked the orange-yellow color of the minis but found the full-size SunOculars easier to use. My son Arthur preferred the full-size SunOculars because he found the image to be brighter and the focusing to be more intuitive.

Any of these options will work to see solar eclipses; the eclipse will be biggest in the full-size SunOculars, but it may be white instead of orange-yellow. If you want to observe sunspots, you'll get the best view through a solar telescope or with solar filters for your telescope. However, I like the ease of picking up the SunOculars for a quick peek at the Sun in the middle of the day.

My thanks to Richard S. Bell for recommending space-weather.com as a source for sunspot identification and for helping me to clarify the meaning of white light viewing (the type of viewing done by both sizes of SunOculars).

Karen Woodworth (and family) have been members of the Kalamazoo Astronomical Society since 2010. She currently volunteers as the club librarian.

Build a Sun Funnel

by **Richard S. Bell**

The biggest party of the year will take place on April 8, 2024! Millions of people will travel to the path of totality to experience the total solar eclipse. Totality is the main event, no question, but the partial phases of the eclipse are also enjoyable to observe. After all, you're watching the clockwork motion of the solar system in action.

Families and entire towns will host eclipse parties and festivals. Viewing the partial stages of the eclipse through a properly filtered telescope is enjoyable, but there's only room for one person at a time. Solar projection is the way to go with large groups of people.

Standard solar projection could be problematic if small kids are around. They may try to look through the telescope, which could be very dangerous. A safer way to do solar projection is to build a Sun Funnel!

The Sun Funnel was adapted from an existing design for a 2003 Great Lakes Planetarium Association Conference workshop by Chuck Bueter and Gene Zajac. The rear-projection screen, a key ingredient, is an idea borrowed from Bruce Hegerberg's Sun Gun. Those of you who have been in the KAS for a while know I built one of these when the *Sky & Telescope* article first came out in June 1999.

The Sun Funnel is much more portable, far cheaper, and super easy to make. It took me about 20 minutes to put it all together.

Both Don Stilwell and I built Sun Funnels for the Transit of Venus in 2012. Hundreds of people at Warren Dunes State Park were able to safely view the transit and even snap some souvenir pictures!

A refractor works best with the Sun Funnel. Heat from the Sun could damage the secondary mirror holder of your Newtonian reflector or Schmidt-Cassegrain telescope. If you do use a Newtonian, then stop down its aperture to 1 or 2 inches.

Most of the required materials are readily available. The first is a FloTool Funnel (#05034). They are available at AutoZone for only $5.29 (plus tax). You'll also need a large (2.5" × 5.5") and small (13/16" × 1.5") hose clamp. The total cost of the hose clamps at the local hardware store for me was $3.58.

Da-Lite Da-Tex rear projection screen material is available online from AV Outlet. They sell an 8" × 8" piece of material (the minimum sized piece required) for $16.38 plus shipping.

Begin constructing your Sun Funnel by cutting the little flat tab off the wide end of the funnel with a hacksaw. Sand off the rough edges with some course sandpaper.

Now use the hacksaw to cut 7 inches off the narrow end of the funnel and discard this piece. It's okay if your cut is slightly titled. You should have about 10 inches of the funnel left. Stand the funnel on its wide end and cut straight down the middle of the new narrow opening, making your cut about 1 to 2 inches deep. The narrow end of the funnel will now have two semicircles of plastic rather than a solid circle. This gives you some flexibility when inserting an eyepiece later.

Sand all cut surfaces with some sandpaper. You'll also want to use the sandpaper to remove the sharp little piece of plastic protruding from the side, about halfway down the length of the funnel.

The eyepiece you use for projecting the Sun's image depends on the focal length of the telescope you use. Just use this equation to figure it out:

$$FL_{eyepiece}\ (mm) \approx FL_{telescope}\ (mm) \div 43$$

Make sure the eyepiece doesn't have any plastic parts. I tried using a low-quality Huygens eyepiece I had lying around, but it melted a little bit! Be sure to remove any rubber eyecup or grip your eyepiece might have.

Insert the eyepiece into the narrow end of the funnel and use the small hose clamp to secure it in place. Use the large hose clamp to attach the rear projection screen. Continuously pull down the screen material as you tighten the hose clamp, so the screen has no wrinkles. The finished product should look like the image shown to your left.

For more detailed instructions (with step-by-step images), be sure to see the PDF article on NASA's Eclipse website.

The Sun Funnel can be used beyond the eclipse for group viewing of sunspots or transits of Mercury. Some people are very leery about viewing the Sun through a telescope. The Sun Funnel eliminates the need to worry.

CONSTANT COMPANIONS

Circumpolar Constellations, Part II

by **Kat Troche**

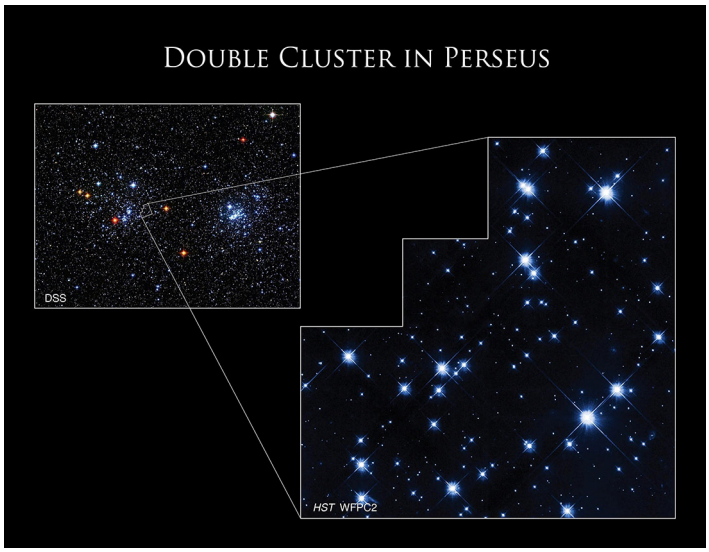
As the seasons shift from Winter to Spring, heralding in the promise of warmer weather here in the northern hemisphere, our circumpolar constellations remain the same. Depending on your latitude, you will be able to see up to nine circumpolar constellations. This month, we'll focus on: **Lynx, Camelopardalis, and Perseus**. The objects within these constellations can all be spotted with a pair of binoculars or a small to medium-sized telescope, depending on your Bortle scale – the darkness of your night skies.

In the appearance of left to right: constellations Perseus, Camelopardalis, and Lynx in the night sky. Also featured: Cassiopeia as a guide constellation, and Capella as a guide star. Credit: Stellarium Web.

Double Stars: The area that comprises the constellation Lynx is famous for its multiple star systems, all of which can be separated with a telescope under dark skies. Some of the notable stars in Lynx are the following:

- **12 Lyncis** – a triple star that can be resolved with a medium-sized telescope.
- **10 Ursae Majoris** – a double star that was once a part of Ursa Major.
- **38 Lyncis** – a double star that is described as blue-white and lilac.

Kemble's Cascade: This asterism located in Camelopardalis, has over 20 stars, ranging in visible magnitude (brightness) and temperature. The stars give the appearance of flowing in a straight line leading to the Jolly Roger Cluster (NGC 1502). On the opposite side of this constellation, you find the asterism **Kemble's Kite**. All three objects can be spotted with a pair of binoculars or a telescope and require moderate dark skies.



A ground-based image from the Digitized Sky Survey (DSS) in the upper left shows Caldwell 14, the Double Cluster in Perseus, with an outline of the region imaged by Hubble's Wide Field and Planetary Camera 2 (WFPC2).

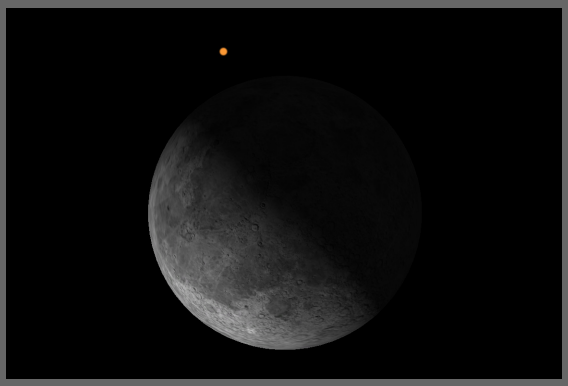
Ground-based image: Digitized Sky Survey (DSS); Hubble image: NASA, ESA, and S. Casertano (Space Telescope Science Institute); Processing: Gladys Kober (NASA/Catholic University of America)

Double Cluster: The constellation Perseus contains the beautiful Double Cluster, two open star clusters (NGC 869 and 884) approximately 7,500 light-years from Earth. This object can be spotted with a small telescope or binoculars and is photographed by amateur and professional photographers alike. It can even be seen with the naked eye in very dark skies. Also in Perseus lies **Algol, the Demon Star**. Algol is a triple-star system that contains an eclipsing binary, meaning two of its three stars constantly orbit each other. Because of this orbit, you can watch the brightness dim every two days, 20 hours, 49 minutes – for 10-hour periods at a time. For a visual representation of this, revisit NASA's What's Up: November 2019.

From constellations you can see all year to a once in a lifetime event! Up next, find out how you can partner with NASA volunteers for the April 8, 2024, total solar eclipse with our upcoming mid-month article on the Night Sky Network page through NASA's website!

Highlights of the March Sky

3rd AM: Antares is a mere 17" above the northern tip of the Moon when they rise in the south-east after 2am EST. The Moon occults the star for parts of the southern U.S., but only grazes the red-orange supergiant star from southwest Michigan. The distance between them increases as they rise higher in the sky. They will be less than 2° apart when the Sun rises at 7:13 am.



3rd Last Quarter Moon at 10:23 am EST

10th New Moon at 5:00 am EDT

13th DUSK: A waxing crescent Moon is about 3° to the upper right of Jupiter.

14th PM: The Moon, two days before first quarter and lurking in Taurus, is about 1½° below the Pleiades.

17th First Quarter Moon at 12:11 am EDT

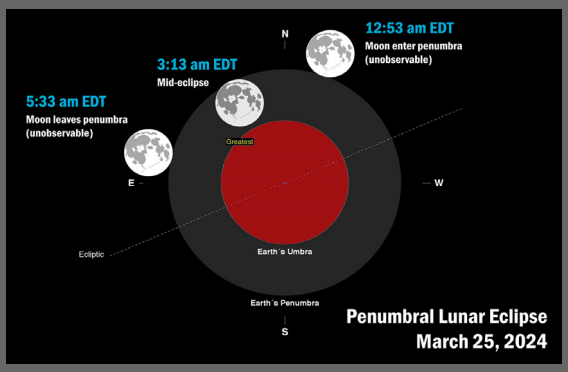
18th DUSK: A waxing gibbous Moon is less than 3° to the lower right of Pollux in Gemini.

19th Spring begins in the Northern Hemisphere at the equinox, 11:06 pm EDT.

21st PM: The waxing Moon gleams 3½° above Regulus, the heart of Leo the Lion.

25th Full Moon at 3:00 am EDT

AM: A deep penumbral lunar eclipse begins at 12:53 am EDT. Mid-eclipse occurs at 3:13 am, when 96% of the Moon's disk will reside within the penumbra, Earth's outer shadow. The Moon's southern hemisphere should appear noticeably darkened. The eclipse concludes at 5:33 am.



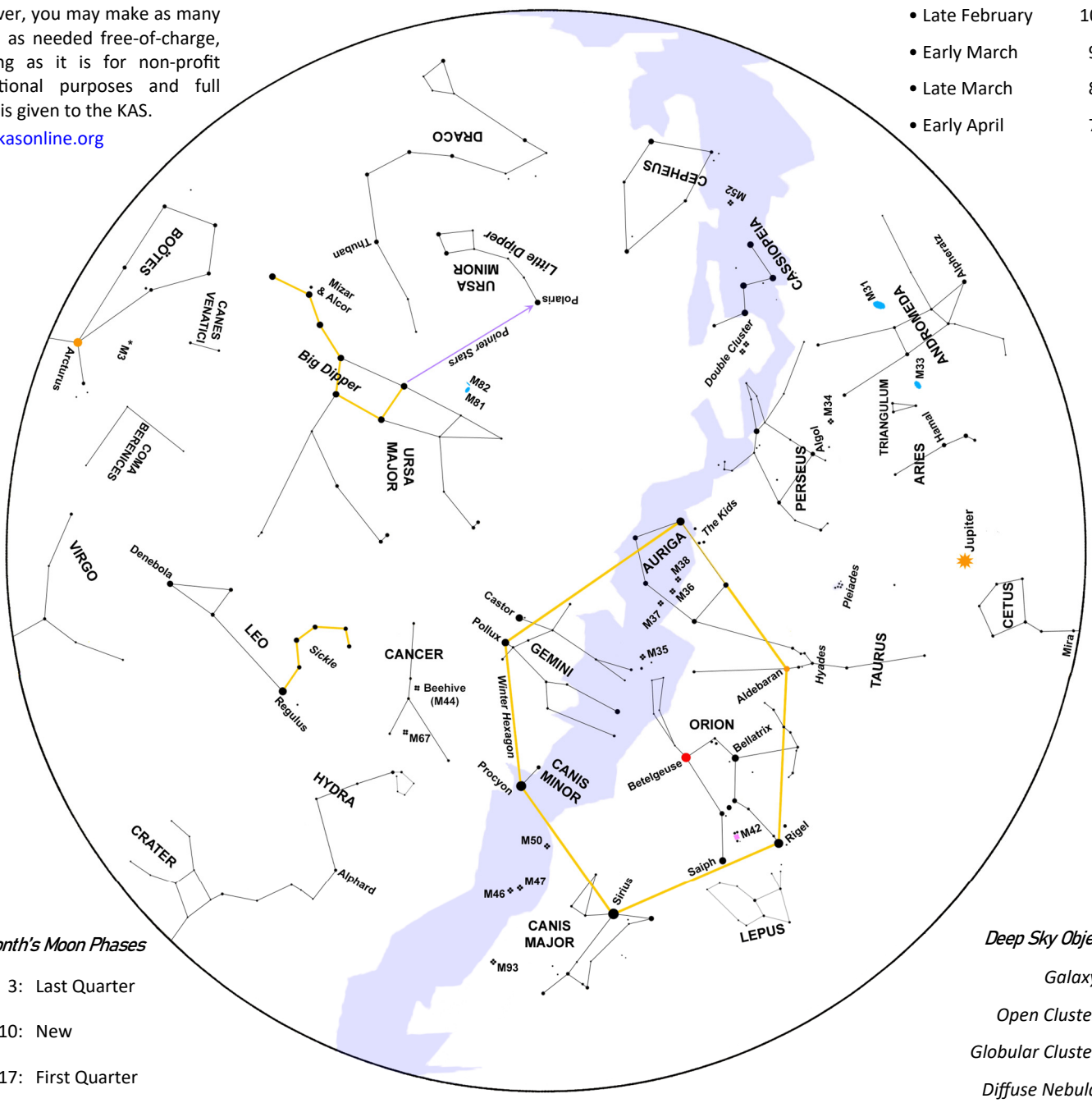
26th PM: The Moon will be about 3° to the lower left of Spica when they rise above the east-southeastern horizon at about 10:00 pm.

30th AM: A waning gibbous Moon leads Antares by about 4° as they rise above the southeastern horizon.

March Night Sky

This map represents the sky at the following local standard times:

- Late February 10 pm
- Early March 9 pm
- Late March 8 pm
- Early April 7 pm



This Month's Moon Phases

- 3: Last Quarter
- 10: New
- 17: First Quarter
- 25: Full

Deep Sky Object Key

- *Galaxy*
- *Open Cluster*
- *Globular Cluster*
- *Diffuse Nebula*
- *Planetary Nebula*

Antares, the red-orange supergiant star that represents the heart of Scorpius, will only be 17″ above the Moon when they rise together in the southeast on the morning of March 3rd. Binoculars may be needed to spot the star. Watch the Moon pull away from Antares until sunrise.

A waxing crescent Moon will be 3° to the upper right of Jupiter at dusk on March 13th. On the following evening, March 14th, the crescent Moon gleams about 1½° below the Pleiades. Binoculars will add to the enjoyment of both events.

A penumbral lunar eclipse will be observable from west Michigan during the early morning hours of March 25th. During mid-eclipse, at 3:13 am EDT, you will notice an obvious darkening on the southern half of the Moon's. About 96% of the Moon's disk will reside in Earth's penumbra. This eclipse is related to the total solar eclipse visible from the United States on April 8th.

The Moon, one day past full, and Spica will be about 3° apart on the evening of March 26th. We come full circle on the morning of March 30th. The Moon leads Antares by 4° when they rise in the southeast.

Highlights of the April Sky

Fred Espenak

1st Last Quarter Moon at 11:15 pm EDT

6th DAWN: Look toward the east-southeast horizon before sunrise and watch a waning crescent Moon, Mars, and Saturn rise. Mars leads the trio about 4½° to the Moon's upper right. Saturn will be about 2° above the Moon. Venus compliments the trio 16½° to the east.

8th New Moon at 2:21 pm EDT

A **TOTAL SOLAR ECLIPSE** will cross North America along a 120-mile-wide, 4,400-mile-long path from Mexico, the United States (from Texas to Maine), and Canada. See the special article on page 12 to learn more.

10th DAWN: Mars and Saturn will only be ½° apart when they rise above the east-southeastern horizon.

DUSK: A waxing crescent Moon will be about 4° to the upper right of Jupiter.

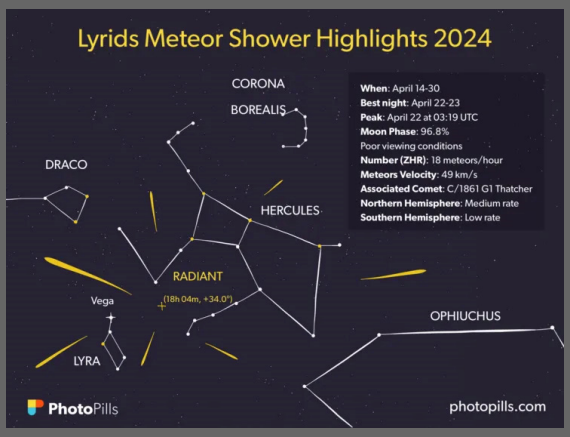
11th PM: The crescent Moon hangs about 6° to the upper left of the Pleiades.

14th The Moon forms a triangle with Gemini's two brightest stars, Castor and Pollux. The Moon will be around 6° below Pollux.

15th First Quarter Moon at 3:13 pm EDT.

18th PM: A waxing gibbous Moon trails Regulus, the brightest star in Leo, by 6°.

22nd AM: The Lyrid meteor shower is predicted to peak at 3:30 am EDT, but is severely hampered by the Moon. The maximum zenithal hourly rate is 18 meteors per hour.



22nd PM: The Moon is about ½° to the upper left of Spica in Virgo.

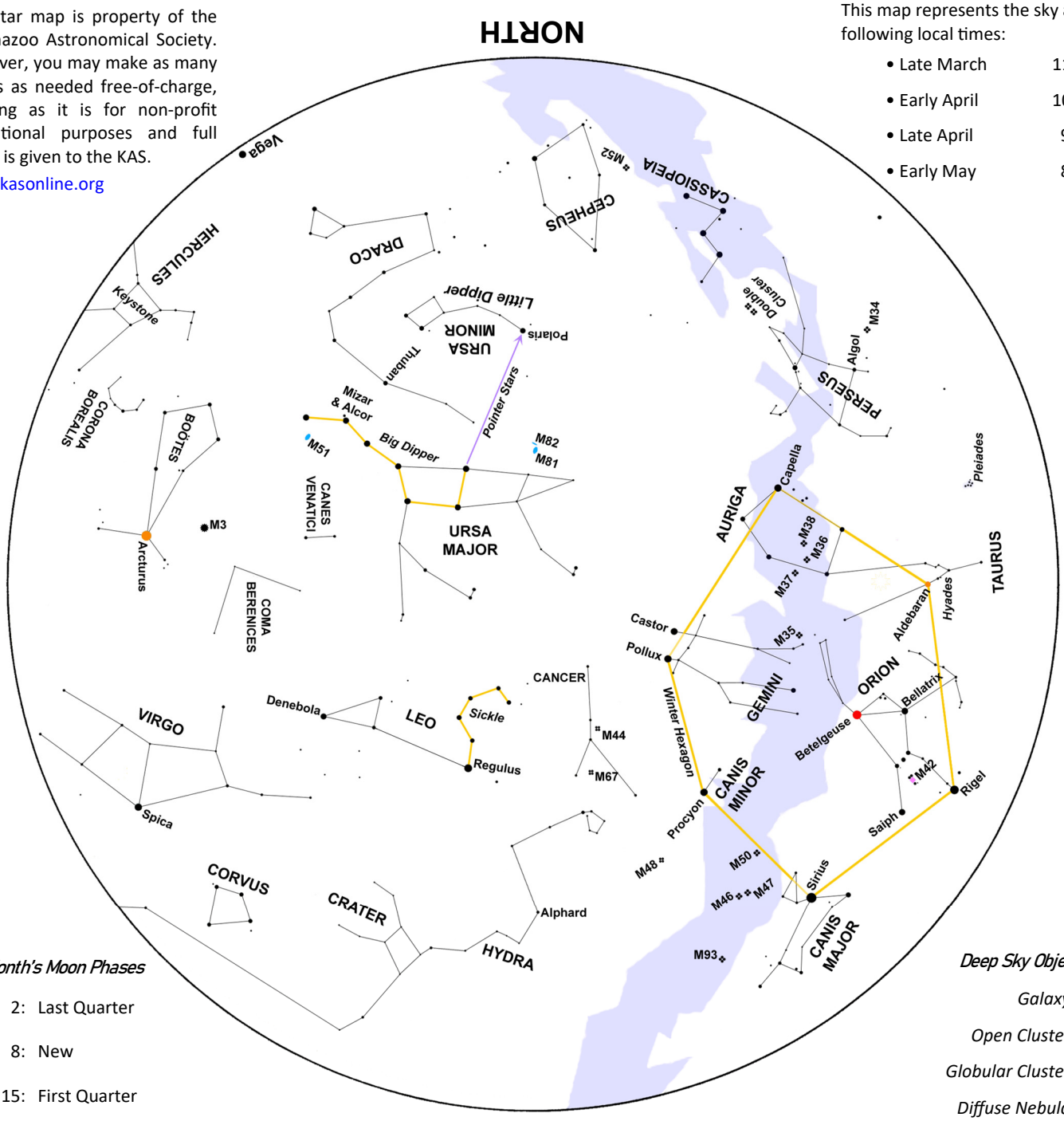
23rd Full Moon at 7:49 pm EDT

27th AM: A waning gibbous Moon is about 5° to the lower left of Antares, the heart of Scorpius, the Scorpion.

April Night Sky

This map represents the sky at the following local times:

- Late March 11 pm
- Early April 10 pm
- Late April 9 pm
- Early May 8 pm



This Month's Moon Phases

- 2: Last Quarter
- 8: New
- 15: First Quarter
- 23: Full

Deep Sky Object Key

- *Galaxy*
- *Open Cluster*
- *Globular Cluster*
- *Diffuse Nebula*
- *Planetary Nebula*

April's biggest sky highlight is, without a doubt, the total solar eclipse visible along a 115-mile-wide, 4,400-mile-long path in the United States from Texas to Maine.

You must be within this narrow path to see phenomena such as Baily's beads, the diamond-ring effect, and the stunning solar corona. The exact times of totality along the eclipse path vary, so please refer to the numerous online resources, such as NASA's 2024 solar eclipse website.

Southwest Michigan will only experience an ~96% partial eclipse. First contact occurs at 1:54 pm EDT, with maximum coverage at 3:10 pm. When the Sun appears as a narrow crescent, the sky will be slightly darker, the air will feel a bit cooler, and shadows become sharper. Look under a shade tree and see if you can spot crescent suns all over the ground. The eclipse ends at 4:24 pm.

Proper projection must be utilized during the entire duration of the eclipse. Use #14 welder's glass or a pair of Eclipse Shades. Only totality is safe to view with the unaided eye. The next eclipse won't happen in the 48 contiguous states until 2044.

ECLIPSE SERIES

EXPERIENCING TOTALITY

The Great Eclipse of 2024

presented via Zoom by

"Mr. Eclipse"
Fred Espenak

BONUS DEMONSTRATION!

Gordon Telepun will show us the ins and outs of his popular SOLAR ECLIPSE TIMER app after the main presentation.

7pm | FRIDAY, MARCH 1ST

Kalamazoo Area Math & Science Center
600 West Vine St., Suite 400

Also held on Zoom | Scan to Register