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The Upcoming Total Solar Eclipse!

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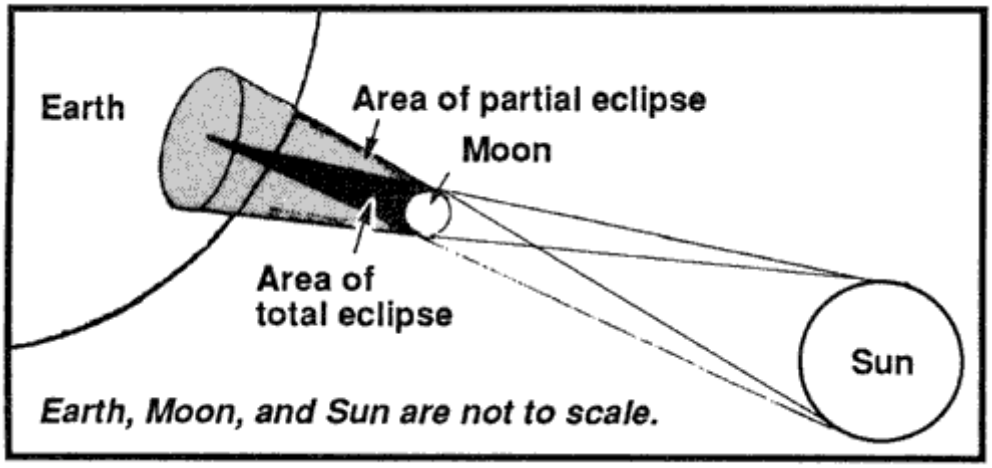
On 11 July 1991, people in certain parts of Hawaii, Mexico, and Central America will have a chance to see one of nature's most spectacular sights — a total eclipse of our Sun. And tens of millions of other people across the Americas will see a partial solar eclipse. This event is already being called the "eclipse of the decade,'' and for good reason! This is the first total eclipse since 1979 to cross any part of the North American continent, and, if you're in the right place, it will be one of the longest eclipses in this century.

What is a total eclipse of the Sun?

Eclipses are unique astronomical events, occurring when the Earth, Moon, and Sun are exactly aligned in space. A solar eclipse occurs when our Moon passes in front of the Sun, casting a shadow across a portion of the Earth's surface. From some vantage points on the Earth, the Moon will only seem to block a piece of the Sun, and the Moon's shadow will not be completely dark. This is called a *partial eclipse.* But when the alignment is just right, observers in a few lucky locations on the Earth will see the Moon appear to cover the entire disc of the Sun. The Moon's shadow will be completely black, and "darkness will come across the skies.'' This is called a *total eclipse.*

The size of the Moon's shadow that we see depends on the distances, and sizes, of both the Moon and the Sun. By the time the Moon's dark shadow reaches our planet during a total eclipse, it is only about 200-300 kilometers wide. As the Earth rotates on its axis, that dark shadow seems to sweep across our planet, creating a path of total darkness. Observers must be within that path, called the *path of totality,* at the right time, to see a total solar eclipse. Observers on either side of this path — almost 2,200 miles on either side — will see only the partial eclipse.



The shadow cast by our Moon 384,400 kilometers away would be similar in size to the shadow of a marble on a tennis ball 2 meters away. On this scale, the Sun would be a sphere 7 meters (23 feet) in diameter almost 750 meters away.

When do eclipses occur?

As the Moon orbits our planet, it sometimes comes between the Earth and Sun; sunlight falls on the side of the Moon not visible from Earth, and we say that the Moon is in its "new'' phase. Solar eclipses can only occur at the new Moon, but not every new Moon results in a solar eclipse. The Moon's monthly orbit around the Earth is tilted slightly, and it can pass as much as 5 degrees above or below a line between the Earth and Sun. In that case, the Moon's shadow will miss the Earth, and no eclipse will be seen. Thus, a solar eclipse is possible only when the Moon is exactly on that Earth-Sun line, and in the new phase.

Why is this eclipse so special?

Not every solar eclipse is a *total* eclipse! About 35 percent of the time, the Moon does not completely cover the Sun, and we see a partial eclipse. Since the Moon orbits the Earth on an elliptical path, and not along a perfect circle, its distance from the Earth varies. Occasionally, solar eclipses will occur when the Moon is at its farthest from Earth, and it will not completely cover the disc of the Sun. Instead, the Moon will appear to pass across the middle of the Sun, leaving a ring of bright sunlight around it. This is called an annular eclipse, and these occur about 37 percent of the time. So only 28 percent of all solar eclipses are total.

The July event is special for another reason, too. Because the path of totality for a total solar eclipse is so small, any particular place on Earth is treated to this special event on average only once in 360 years! And the path of the Moon's shadow for this eclipse is much more accessible to more people than any recent or near-future event. Mexico City lies directly in the path of totality, and, if the weather is clear, millions of people in that populated area could witness the eclipse.

And finally, this eclipse promises to last as long as seven minutes in some place — far longer than average. Indeed, the 1991 total solar eclipse will be the third longest eclipse since 1898, and the longest until the year 2132! Most eclipses last only three to four minutes. (The longest a total eclipse can last is approximately seven minutes, 40 seconds.)

What exactly happens during such an eclipse?

If you are lucky enough to be in the path of totality, you will see the Sun slowly covered by the Moon. This partial phase lasts up to an hour or more, depending on where and when you see the eclipse. During most of the partial phase, the dimming of sunlight is hardly noticeable; when seen through proper equipment, the Sun will appear to have a "bite'' taken out of it. Then, as the Moon slides totally in front of the Sun, the magic really begins! The sky will darken. The Moon's black disc will look almost like a hole in the sky, and peeking around the black disc should be a number of pinkish solar prominences, gigantic explosions of hot hydrogen gas that boil off from the Sun in spectacular arching shapes.

At the last instant before the Moon completely covers the Sun, observers may behold two fascinating sights. First, the last bit of sunlight streaming past the Moon might seem to break into "beads,'' (known as Bailey's Beads after the English astronomer Francis Bailey, who first described their appearance in 1836). Bailey's Beads arise from sunlight passing through lunar valleys in the Moon's uneven, cratered surface. The beads will last a few seconds, and wink out as the Moon glides further in front of the Sun. And finally, just as the last bead is visible, light from the Sun's outer atmosphere will start to be visible around the Moon, creating a glowing ring of light. This is called the "Diamond Ring Effect.''

The most dramatic part of the total eclipse is being able to see the Sun's *corona,* a ghostly aura streaming away from the Sun in all directions. Total eclipses are the only time most people ever get to see this delicately-hued layer of the Sun's outer atmosphere. Indeed, we on Earth are very lucky to live on the only planet in the solar system with a moon the right size and distance to just cover the Sun's disc, but not cover its corona as well. Our Moon is about 400 times smaller than the Sun, but it is also about 400 times closer, too, so it appears to be the same size in the sky.

The corona is the Sun's outermost atmospheric layer, with extremely hot gas (reaching temperatures near a million degrees) flowing off many millions of miles into space. The corona is usually outshone by the Sun's visible layer, called the *photosphere,* which is one million times brighter.

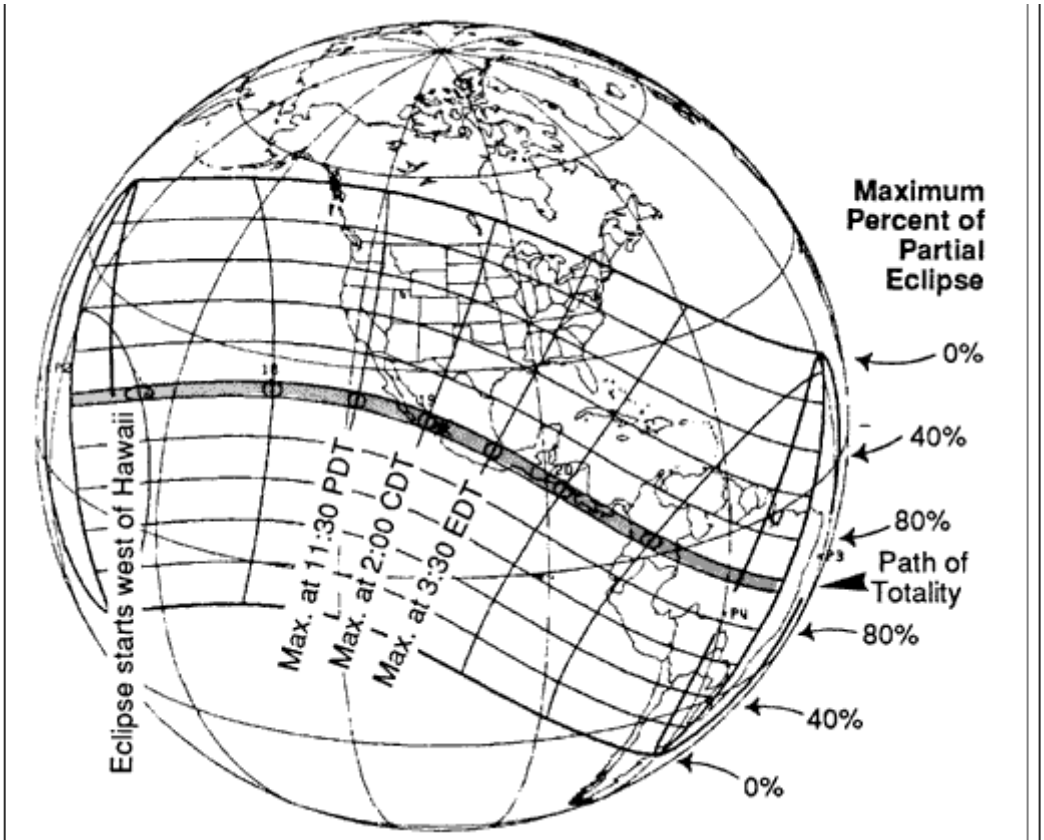
How dark will it get?

The darkness across the land in the path of totality during a total solar eclipse will be comparable to a night with a full moon, but slightly more eerie and wonderful. Many people have reported that some animals become quiet and even go to sleep, thinking that night has fallen!

The eclipse makes the daytime sky dark enough for stars and planets to be seen; during the 11 July event, Mercury, Venus, Mars, and Jupiter will all be visible in the darkened sky from the eastern Pacific Ocean and Mexico. And the bright stars of the constellations Gemini, Canis Major, Canis Minor, Orion, and Auriga should be visible, too! Away from the path of totality, the sky will not get significantly darker and the surrounding stars and planets will still be invisible.

Where and when will the *total* eclipse be visible?

On Thursday morning, 11 July 1991, the eclipse will start at sunrise roughly 12,00 miles to the west-southwest of Hawaii. The total phase of the eclipse starts at 7:30 a.m. over the main island of Hawaii, when the Sun is about 22 degrees high in the sky to the east-northeast. For the next 70 minutes, the Moon's shadow will glide across the Pacific Ocean, heading east-southeast towards Baja California. The path of totality crosses the Gulf of California a little before noon, local time, and arches to Guadalajara, Mazatlan, and Mexico City, before turning southeast to cross Central America, Columbia, and Brazil around sunset.



The path of totality crosses the Pacific Ocean, Mexico, and Central and northern South America. A partial eclipse will be visible north and south of these areas. (From F. Espenak, Predictions for the Total Solar Eclipse of 1991, NASA)

Where and when will the partial eclipse be visible?

Table 1 lists approximate local times for major cities across the U.S. and Canada, when the partial eclipse will start, when it reaches maximum coverage of the Sun's disc, what percentage of the Sun will be obscured, and when the eclipse ends. A more complete list of times for other locations can be found in Joe Rao's book, *Your Guide to the Great Solar Eclipse of 1991,* available from the ASP.

Aren't eclipses dangerous?

Ancient societies in China believed that solar eclipses were caused by a magical serpent that swallowed the Sun. During an eclipse, people would make a tremendous din, banging pots and pans, screaming and yelling, to frighten the serpent into releasing the Sun. Since the eclipses lasted only minutes, the people were always successful; the Sun always returned to the sky. Other stories from Native Americans and Western Europeans tell of the dread caused by eclipses, thought to indicate anger of the gods, plagues, death, and evil. But solar eclipses are not really dangerous, *as long as you take the proper precautions to observe them!*

Remember, it is the Sun, and *not* an eclipse, that can cause damage to the eye. People should never stare at the Sun, *at any time,* whether there is an eclipse or not. The Sun is very bright — more than 400,000 times brighter than the full Moon — and looking at it will cause pain. But it is not just this visible radiation that causes eye damage. The Sun also emits invisible ultraviolet and infrared radiation, and these rays can seriously burn the sensitive tissue of the retina, causing blindness. These rays cannot be usually felt until it is too late to save the eyesight.

If you are lucky enough to be in the path of totality, you *can* safely observe and photograph the Sun when it is totally eclipsed. No filters are necessary. The only danger comes from continuing to view the Sun when the total phase is over, and the bright limb comes back into view.

When is the next major solar eclipse going to pass over North America?

The next major total solar eclipse after 11 July 1991, visible over a large part of North America, will occur on 21 August 2017; the path of totality will stretch from British Columbia in the Northwest to the Carolinas in the Southeast, but the total phase will only last approximately two minutes, 40 seconds. Between 1991 and 2017, a number of partial and annular eclipses will also be visible. In May 1993, a slight partial eclipse will be visible in the Pacific Northwest and western Canada. Observers across the continental United States will have an excellent opportunity to see an annular eclipse on 10 May 1994, which promises to pass directly over a path running from Southern California to New York. And in February 1998, a partial eclipse will be visible from much of the Southeastern United States; the path of totality for that eclipse will pass over Columbia and Venezuela.

How can I observe the partial eclipse safely?

The safest way to observe the Sun, and watch the progress of the partial phase of the eclipse, is to not look directly at the Sun at all. Instead, project the Sun's image onto a piece of white paper, using a pinhole camera (see Activity #1) . Binoculars may also be used to project the Sun's image; they need to be supported on a tripod, one lens should be covered, and a sheet of white paper held behind the eyepiece. Focus the binoculars to achieve a sharp image. *Do not look directly at the Sun through the binoculars!* To observe the Sun safely before and during the partial phase of the eclipse, most of its light and its harmful ultraviolet and infrared rays must be filtered out. Safe filters include:

- Using two layers of fully exposed and developed black-and- white film (color film will *not* provide adequate protection).
- Using a special metal-coated piece of plastic, typically aluminized Mylar, certified for viewing the Sun. Double-sided coatings greatly reduce the possibility of filter defects. Two suppliers are:
    - Thousand Oaks Optical, Box 248098, Farmington, MI 48332-8098, 313-353-6825.
    - Roger Tuthill, Inc., Box 1086-A, Mountainside, NJ 07092, 800- 223-1063.
- Rectangular welder's glass, shade No. 14. Less dense shades (lower numbers) are not suitable for direct solar observation. Welder's glass will also produce a green-colored image.

Many filters that are sometimes recommended for observing the Sun are not safe for direct-eye viewing, including a piece of glass blackened by soot from a candle, sunglasses, photographic neutral-density filters, and solar filters that operate at the *eyepiece* of telescopes or binoculars. Eyepiece filters are especially dangerous; they are placed at the point where the Sun's light is most concentrated and magnified. They can crack or even explode.

Illustration caption

Table 1: Partial Eclipse Times

LOCATION	START	MAXIMUM	COVERAGE	END
Atlanta	2:30 p.m. EDT	3:31 p.m.	28%	4:29
Chicago	1:39 p.m. CDT	2:16 p.m.	13%	3:01
Dallas	12:56 p.m. CDT	2:11 p.m.	51%	3:23
Denver	11:44 a.m. MDT	12:50 p.m.	37%	1:56
Honolulu	6:31 a.m. HST	7:29 a.m.	96%	8:35
Los Angeles	10:12 a.m. PDT	11:28 a.m.	69%	12:47
Miami	2:41 p.m. EDT	3:49 p.m.	43%	4:51
Minneapolis	1:19 p.m. CDT	2:04 p.m.	11%	2:49
New York	3:09 p.m. EDT	3:34 p.m.	2%	3:59

San Francisco	10:11 a.m. PDT	11:20 a.m.	55%	12:33
Seattle	10:32 a.m. PDT	11:22 a.m.	20%	12:14
Washington, D.C.	2:55 p.m. EDT	3:33 p.m.	7%	4:10
Calgary	11:53 a.m. CDT	12:33 p.m.	9%	1:14
Toronto	2:57 p.m. EDT	3:24 p.m.	3%	3:50
Vancouver	10:36 a.m. PDT	11:22 a.m.	15%	12:09

COVERAGE is the fraction of the area of the Sun's disc covered at maximum.

Activity #1: Building a Projection Camera for Safe Eclipse Viewing

(adapted from Pacific Science Center, 200 Second Ave. N, Seattle, WA 98109)

Materials

- two five-gallon ice cream containers
- small square of aluminum foil
- tape
- white paper
- pin

Instructions

Cut a small 1-inch hole in one end of an ice cream container. Tape the piece of aluminum foil over the hole, and put a small pinhole in the foil. This will be where the sunlight will enter. Cut a larger viewing port far enough beneath the small hole to allow observation without blocking the Sun. Tape a piece of white paper at the bottom of the other container (this will be your viewing screen), and then tape the open ends of the two containers together.

Hold the projector so that the Sun is behind, and over your shoulder, so that the sunlight comes through the pinhole, and falls on the viewing screen at the opposite end. Do not look through the pinhole directly at the Sun.

Alternative 1

You can use a cardboard box instead of the containers, and put your head inside the box rather than cut a viewing port. Project the Sun's image through the pinhole onto white paper at the back of the box, and look away from the Sun to view the partial phase of the eclipse.

Alternative 2

Simply use two sheets of white cardboard, and put a small (1/16- inch) pinhole in one. Stand with your back to the Sun, and hold one sheet of cardboard in each hand. Project the Sun's image through the pinhole onto the second sheet, held about 2-4 feet away.

Alternative 3

A brighter and larger image can be obtained by punching a 1/4-inch hole in a piece of paper, covering a small flat mirror with the paper, and positioning the mirror in the sunlight to reflect the Sun's image onto a distant

wall (in a darkened room, if possible). Modeling clay works well to hold the mirror in place on a window sill. The image of the Sun will be 1 inch across for every 10 feet between the mirror and the wall.

Activity #2: Building a Safe Direct Solar Filter

(adapted from *Observe: Eclipses,* published in 1979 by the Astronomical League, and "Unsafe Solar Filters,'' by B. Ralph Chou, *Sky & Telescope,* August 1981)

Materials

- a roll of Kodak Pan-X black-and-white film
- two pieces of cardboard (about 8 inch square or larger)

Instructions

Open the roll of film, and unravel it completely for 30 seconds under a bright light. After exposing the film, *have it developed normally.* If you send it off for processing, include a note saying that the film is fully exposed, and to be used for solar observation; request it to be returned uncut.

Once the developed film is returned, cut it into pieces (about 2 inches by 2 inches will be fine). Cut a slightly smaller square opening in the middle of both pieces of cardboard. Tape *two* pieces of film together into a sandwich, and tape this over the opening in the cardboard. Position the second piece of cardboard over the first and tape them together.

The cardboard frame will act as a shade from the bright Sun, while you safely observe the partial phase of the eclipse through the film sandwich.

Note: One layer of black and white film is not safe — it reduces the amount of light hitting the retina, but does not eliminate the danger from observation during the partial phase of the eclipse. Two layers of film effectively reduce the incoming sunlight to a safe level. Black-and- white film is safe because it contains silver, which absorbs sunlight, including ultraviolet and infrared light. Color film does not contain silver, and is not safe. Undeveloped film is not safe.

For Further Reading

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