# Solar eclipse: tools and ideas for observation

Science, Astronomy

## Experience a Solar Eclipse

You don’t witness an eclipse…you EXPERIENCE it!

You can literally feel the ominous shadow of the moon before it arrives. The temperature drops. The wind picks up speed. The sunlight slowly dims, bathing your surroundings in an eerie twilight that produces colors with shades rarely seen in the natural world. Then it is time. Moments before totality a wall of darkness comes speeding towards you at up to 5, 000 miles per hour—this is the shadow of the moon. You feel alive. You feel in awe. You feel anxiety. Then—totality! Where the sun once stood, there is a black disk, outlined by the soft pearly-white glow of the corona, about the brightness of a full moon. Small but vibrant reddish features stand at the eastern rim of the moon’s disk, contrasting vividly with the white of the corona and the black of the of moon’s disk. These are prominences, giant clouds of hot gas in the sun’s lower atmosphere. After what seems like a brief moment, the moon continues on its journey and the shadow races away, marking the end of totality. It is then you ask, “ When is the next one?”

Participating in a total solar eclipse is as addictive and insatiable as eating that first potato chip. It’s no wonder thousands of people from all over the world converge every year or two on a tiny strip of land no larger than 1% of the Earth’s surface to experience this awesome phenomena.

The next total solar eclipse will occur on March 20, 2015. It will be the last one visible in Europe until the eclipse of August 12, 2026. To add scientific value to your viewing experience it on that day, why not try to perform these projects that will enhance your observing skills and enjoyment of this spectacular event.

## Environmental Changes

Observing project: Observe and log any changes you see in your environment and in the behaviors of wildlife in the 15 minutes on either side of totality.

There are significant changes in weather during eclipses. As the amount of sunlight is reduced, the temperature begins to fall. This results in corresponding changes in the barometric pressure, wind speed and direction, dew point and humidity. These changes can sometimes result in unexpected fog or dew. As the sun dwindles to a smaller and smaller crescent, the surrounding landscape very gradually takes on a late-afternoon appearance in the final minutes before totality. The changing colors of the landscape and clouds can be quite striking as well with yellows and oranges most often seen. Animals are very perceptive to changes in their environment. Livestock, wild birds, squirrels, insects and even domesticated pets will behave in interesting ways. Some animals, accustomed to feeding schedules, dictated by dawn and dusk, exhibit changes in eating habits. Roosters crow on cue as twilight comes and goes, while mosquitoes may go on a feeding frenzy. Fish are reportedly more willing to bite around totality. Note the changes you observe in your surroundings.

Photography Project: As a side project, take a photograph of a light-colored surface, such as a bed sheet, sandy ground, the side of a house, a street or a piece of white cardboard. Projected on them will be the leaf-formed pinhole camera images of crescent suns. Still or video available-light photographic sequences at fixed aperture and shutter speed, would be useful in determining where these images are first and last visible on each side of totality. Photography of diminishing light effects may be attempted, especially with low-light video cameras. Also, don’t neglect photographic studies of wildlife behaviors and photo documentation of chart recordings from weather instruments.

## The Lunar Shadow and Sky Darkness

Observing Project: Observe and record features of the lunar shadow and sky darkness in response to the following questions:

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- How many seconds before totality was the shadow seen?
- In what direction did the shadow become visible?
- How did its darkness, appearance and color compare with the surrounding unshadowed sky?
- How would you describe its very rapid motion and changing appearance, color and shape?
- In what directions did you have time to look during as well as immediately before and after totality?
- How would you describe the appearance and color of the sky in each of these directions as totality progressed?

When and how did the shadow disappear?

Describe how the light changed as the eclipse progressed (include any times as accurately as possible).

What stars and planets were you able to identify?

How soon before totality did stars and planets become visible?

How long after the end of totality did stars and planets disappear?

What kind of weather conditions existed during the eclipse (include the fraction of sky obscured by clouds and the direction of clouds, types of clouds, cloud coloration, sky coloration haze, etc.)?

Did you detect any color on the disk of the moon during totality?

How did the darkness and color of the moon compare to the sky a few degrees away from the eclipsed sun?

As the moment of totality approaches, the shadow of the moon sweeps out of the west to immerse observers along its path. Once the shadow's leading edge has swept over your site, the sky darkens significantly. Observers who have adapted their vision with dark goggles prior to the onset of totality have reported bright stars and planets becoming visible more than a minute before the thin solar crescent is obscured. In the 1970's William H. Glenn of York College of the City University of New York developed the above questionnaire which still provides one of the best set of guidelines for lunar shadow and sky darkness observations.

Observers should also estimate the degree of sky darkness using such criteria as the readability of newspaper headlines, ordinary newsprint, the hour or second hand of wrist watch or some similar method. Measurements made with photoelectric cells or photographic light meters would be of even greater value. As an aid in locating the brightest stars and planets during totality, consult sky charts in advance and note their location in relation to the sun, as well as magnitude which can serve as another indicator of sky darkness.

Photography project: Photograph the lunar shadow and sky darkness in relation to the above questions.

A DSLR camera equipped with a fish-eye lens is an advantage in capturing the lunar shadow. Mount your camera on a level tripod, point it at the zenith and orient it with respect to the compass points. Each frame should capture the entire sky from horizon to horizon, showing the sunrise-sunset effect and darkness as the shadow advances. With the compass points penned onto each photo, it is a simple matter to determine the azimuth of the approaching and receding shadow and to relate any sunrise and sunset effect noticed to an accurate position on the horizon. The exact time of each exposure can be determined later if a tape recorder is used to simultaneously record the triggering of the camera shutter and radio time signals. Video cameras with wide-field lenses or attachments produce impressive results as well, but should be adjusted for full manual operation to prevent them from automatically correcting for the diminishing light adjusting exposure times or f/-stops or both throughout the eclipse.

## The Diamond Ring and Baily’s Beads

Observing project: Calculate the position angles of the diamond ring and Baily’s beads, which are measured by north through east around the moon’s limb.

This may be accomplished either by direct observation with appropriate filters or by eyepiece projection onto a screen. In either case, care must be taken to insure proper orientation of the sun’s image with respect to the compass points. The best approach is to use either an illuminated eyepiece reticle marked off in degrees or a similar scale drawn on the projection screen. Proper orientation of the reticle or screen may be accomplished by carefully monitoring of the westward solar drift during the partial phases. The last, faint beads visible around second contact and the first ones visible around third contact have the greatest scientific value and should be carefully timed and measured.

Shortly before second contact, the opposing horns of the slender crescent sun begin to converge on one another. At the same time, the tenuous solar atmosphere becomes visible against the darkening sky, shining out around the end of the moon where the sun has already been covered. The combination of this “ ring” of light and the single brilliant “ diamond” of sunlight where the horns are converging creates a most striking appearance —the diamond ring. The effect last for a very short time. Soon, the horns of the solar crescent close completely, and the diamond begins to break up, to be replaced by an array of brilliant beads of sunlight caused by the sun shining through valleys and depressions on the moon’s leading limb.

Baily's beads also quickly succumb to the encroaching moon, winking out one or two at a time until totality is fulfilled. The disappearance of the last bead marks the moment of second contact and the beginning of totality. Totality ends with third contact when the beads reappear at the trailing limb. Shortly thereafter, another diamond ring appears and quickly absorbs the beads as the crescent sun diverge once more.

Photography project: The diamond ring and Baily's beads should be photographed without the dense solar filters used for visual observing. Yet, they are still partial eclipse phenomena and should be considered hazardous to your eyesight. The safest approach is to center the camera on the sun during the last seconds of the partial phases while the solar filter is still attached. When the horns of the crescent converge to form the diamond, remove the solar filter and begin exposures without looking through the viewfinder again. You will want to bracket them somewhat in order to capture the full range. But keep in mind that if you're shooting around f/11 at 1/250th second or its equivalent, you will not want to shoot totality at these settings. Remember to adjust your exposure settings accordingly once the beads are gone and totality begins (and again at the end of totality when you are shooting the beads and ring again).

Video photography may be attempted with camcorders in the automatic exposure mode and the solar filter removed for satisfactory results, but many photographers will prefer to set exposure parameters manually here too. Vary the f/stop through a pre-determined range to accent beads of varying intensities. Unlike still and motion picture cameras, most camcorders have viewfinders which are miniature television monitors and present no danger to the eyesight since you at not looking at the sun itself.

**Flash Spectrum**

Observing project: Observe the sun’s emission spectrum at the very beginning of totality and just after the last bit of the photosphere has been covered by the Moon. For a period of several to perhaps ten seconds the chromosphere is visible as a red arch. Describe this phenomenon in your log.

Photography project: Using either a DSLR or video camera, record the sun’s emission spectrum at the very beginning of totality and just after the last bit of the photosphere has been covered by the Moon.

**Contacts**

Observing project: Accurately time the moon’s contacts with the solar limb.

This may be carried out by pinhole projection, eyepiece projections with binoculars or telescopes or direct viewing through safe solar filters with naked-eye, binoculars, or telescopes. For accurate timing, many observers tape record their voice comments over short wave radio time signals. First contact is the instant when the moon’s limb is initially seen encroaching on the solar disk. This the most difficult contact to time since you must anticipate where the moon will first appear against the sun’s limb. Fourth contact, when the moon leaves the sun, is easier to time, since the observer can anticipate the event with greater certainty. Second contact marks the beginning of totality. It is when the moon’s leading edge completely covers the sun’s disk. Third contact occurs when the moon’s trailing edge leaves the sun’s disk and exposes the sun’s photosphere once more. The best method to time these events depends on the contact being timed. Eyepiece projection onto a white screen offers the best method for timing second contact, since the photosphere projects prominently while the chromosphere does not. Third contact is best timed by the reappearance of Baily's beads. The first bead's appearance stands out in stark contrast to the dimmer phenomena of totality and presents little difficulty for eyepiece projection or direct viewing methods.

Photography project: Still and video sequences around the time of second and third contacts can pinpoint the times of these events when taken in conjunction with a tape recorded time signal; video cameras are especially advantageous here. Frequent and accurately timed exposures around first and fourth contact make impressive sequences allowing contact timings to be extrapolated. High-quality camcorder video with radio time-signals on the audio track can be reduced later to yield precise contact timing.

## Corona

Observing project: Observe and record changes in the corona, including its shape and extent, intensity variations and streamers as detailed below.

As totality arrives, the pearly-white solar atmosphere flashes into view surrounding the new moon's darkened disk. This is the corona, extending millions of kilometers into space and shining with the intensity of the full moon. The inner or K-corona, composed largely of electrons, displays a continuous backdrop for viewing prominences. The outer dust or F-corona extends for several solar diameters. It varies in shape from eclipse to eclipse, but is generally irregular and features spectacular radial streamers. The sun's corona varies from a generally uniform and circular appearance around times of sunspot maximum to a highly irregular one near sunspot minimum. Observing the corona should focus on its shape and extent, intensity variations and streamers.

Shape and Extent—During the eclipse, measure the shape and extent of the corona using a hand-held reticle etched with bull's eye, linear scales and azimuth circles. Orient the azimuth circle's to the zero degree position with the sun's North Pole. The corona's extent may then be called out and tape recorded in terms of solar radii at chosen-position angle intervals. The tape recording can be later transcribed into your written log. Inexpensive reticles can be obtained from engineering and surveying supply houses.

Intensity Variations—The corona does not exhibit the same brightness intensity throughout. Subtle differences occur both radially and circumferentially as a result of variations in the density of the coronal gases. Use the reticle to measure the position angle and extent of the uneven texture of the corona's brightness employing a five-step linear scale, where 0 is the darkest and 5 is the most brilliant part of the corona. This can be tape recorded during the event and later transcribed into your log.

Streamers—These long finger-like strands near the equator and fan-shaped appendages near the poles align themselves with the sun's magnetic field. They also vary significantly in number, structure and distribution throughout a sunspot cycle. Estimate their number and describe their shapes, position angle and extent.

In lieu of a written description in your log, observers with minimal artistic skill can try their hand at sketching the corona using a technique known as " mapping." This requires you to draw a circle representing the sun in the center of a sheet of graph paper and shade the surrounding squares in during to totality to match the shape and extent of the corona. Intensity variations in the corona may be shown by using the above five-step scale to outline changes within the squares on their graph paper in a " paint by numbers" approach. The squares can also be used to drawn in the more spectacular streamers.

Photography project: With any diffuse object like the corona, its appearance is a function of the exposure time and f/ stop. Shorter exposures will capture greater structural detail in the inner corona, enhancing the streamers, while failing to capture the impressive extent of the outer corona. Longer exposures do capture the outer corona, while washing out the other details. Software programs can be used to combine individual exposures to create composite images which capture the best of both extremes. Video photography should be attempted with automatic focus and exposure features disengaged, since they provide highly unreliable under low lighting conditions. Experiment in advance with the full moon, and settle on a range of f/stops and focal lengths which show detail on lunar surface features. This should provide an adequate mid-range for coronal photography with most camcorders.

## Prominences

Observing project: Using an eyepiece reticle with linear scales and azimuth circles, measure the position angle of prominences as well as their relative height. In addition, identify the types of prominences that ring the sun during totality using the following chart (editorial note: needs to be supplied).

Prominences visible during totality may be relatively quiescent, persisting for many weeks without significant change, or they may be violently active, erupting outward as far as three million kilometers from the sun's surface. The more active prominences will exhibit changes from minute to minute.

Single Arch—This is one of the most common shapes of a prominence, representing charged solar material flowing up from the solar atmosphere and down again following local magnetic field lines.

Double Arch—Much rarer than a single arch, this has two arches that are connected to each other via a center stream of material.

Broken Arch—Likely to be an evolutionary stage of a single arch, a broken arch features gaps in the stream of material where the plasma density is either too low to be detected, or the material has been blown away or disrupted by solar wind streams.

Unconnected Arch—This is where one end of the arch has not reconnected to the solar surface. This is also likely to be an evolutionary stage of the single arch, where the material is still travelling down the magnetic field lines to the surface.

Straight Pillar—This appears as an eruption vertically up from the solar surface, and is quite common. It could also be an arch seen edge-on.

Curved Pillar—This is simply a pillar that is bent out of shape by magnetic or other forces, and could also be the early stages of an arch seen at an angle.

Inclined Pillar—This is where the material at the base of the eruption and throughout the prominence is at a significant angle to the surface.

Mound—This is also a fairly common type of prominence, and is seen as a relatively but fairly low eruption. It has a width equal to or greater than its height.

Hedgerow—This is a grouping of many smaller prominences that are likely to have come from the same source of activity.

Pyramid—This common type is like a combination of a pillar and a mound, typically featuring a wide base that converges to a fairly sharp point.

Broken Pyramid—This is a pyramid that has some damage in the form of holes in the plasma stream, or whole sections of plasma that have broken off. It is also likely to be an evolutionary stage of a regular pyramid.

Fork—This is two prominences, typically of pyramid or pillar form that are very close together. The width between them is usually less than the base width of the thinnest prominence.

Detached—Here the material has lifted off the surface entirely, and appears to be completely disconnected from the surface. It is possible that some low density interconnecting material is there, but is not detectable with the observer’s equipment.

Anomalous—As is to be expected with any classification system, there are prominences that have no discernable shape or features than can place them in a distinct category. Due to the random and very complicated nature of solar surface eruptions and magnetic fields, these kinds of prominences are relatively common.

Photography Project: One recommended setting that works well for capturing prominences is f/8 at 1/250. However, it is wise to bracket exposures somewhat to capture the varied structure exhibited by the prominences.

## Shadow Bands

Observing project: Observe and record information on the presence (or absence) and behaviors of shadow bands along with relevant meteorological data. This includes measurements of the width and separation of the bands, their direction and speed of movement as well as their duration and timing of any changes. Please note that the direction of motion of the bands may or may not parallel their length. Measurements should be taken at 30-second intervals.

For a few minutes on either side of totality, alert observers may notice bands of undulating shadows racing across the ground, the sides of buildings or across other light-colored surfaces. Attempts to explain this phenomenon have focused upon the atmospheric rather than the astronomical sciences, for the bands do not reliably appear or exhibit similar behaviors at each eclipse, even when eclipses have similar geometric circumstances. When they do appear, shadow bands vary considerably in both width and separation, but range most frequently between 0. 75 and 2 inches in width and are separated from one another by 2 to 10 inches. Their direction of motion across the ground seems to depend upon where an observer is located along the eclipse path. Their velocities vary most often between 5 to 10 feet per second.

Photographic project: Dim lighting, poor contrast and rapid movement make still photography difficult at best. Low-light camcorders offer a significant advantage and can be centered on the viewing screen to capture the motions of the bands for later playback and data reduction.

There's only one last thing left to do. Enjoy the eclipse!!