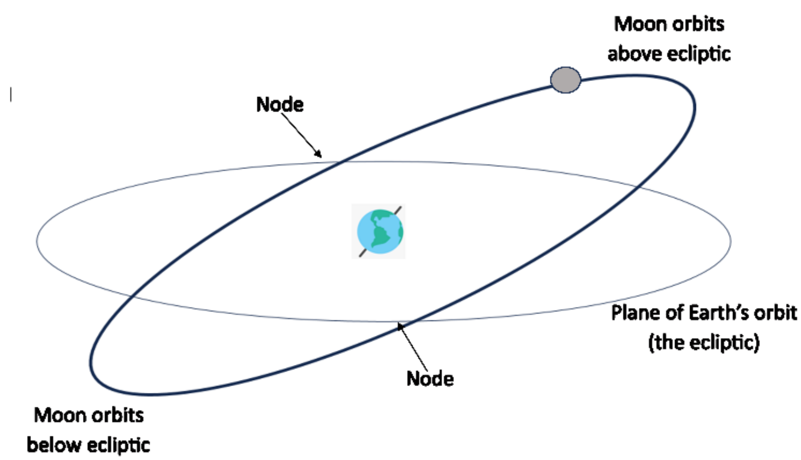
One Good Target

With Some Other Sights Worth Seeing
While You're in the Neighborhood

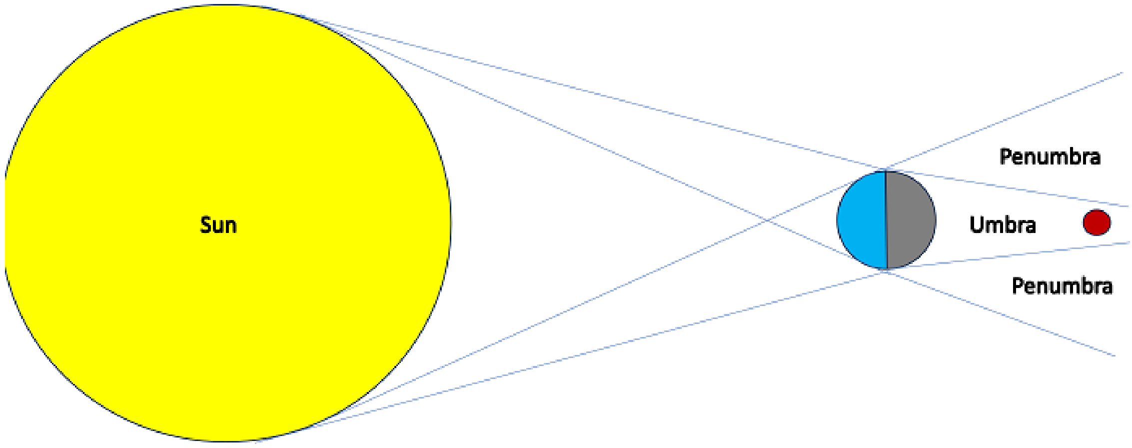
March
The Eclipsed Moon

Although it lacks the emotional impact of its solar cousin, a total eclipse of the Moon is well worth observing in its own right. While a solar eclipse is also an *occultation,* because our view of the Sun is physically blocked by the Moon, a lunar eclipse is not: in a lunar eclipse, it is not a solid object, but rather *Earth's shadow* that obscures the Moon. Also unlike a total solar eclipse, which can be seen only along the narrow path traced out by the Moon's shadow racing across the surface of the Earth, a lunar eclipse can be seen from anywhere on Earth's night side, although the geometry of a lunar eclipse prevents us from seeing one in daylight.

In order for a lunar eclipse to occur, Earth must lie directly between the Sun and the Moon, since that is the only arrangement in which the Sun can cast Earth's shadow onto the Moon. Since that is also the arrangement that exists when the Moon is full, it follows that an eclipse can occur only at full Moon. At most full Moons, the Moon passes either above or below Earth's shadow, due to the fact that the Moon's orbit is tilted 5.15° in relation to Earth's orbit. An eclipse results only if the full Moon occurs near one of the two *nodes* where the Moon's orbit crosses the plane of Earth's orbit.



As the Moon enters an eclipse, it encounters two distinct and very different Earth shadows. The first is called the *penumbra,* and is not much of a shadow at all: it's almost impossible to detect any change in the Moon's appearance until roughly 70% of the lunar disk lies within the penumbral shadow. Even then, the difference can be very slight and subtle, like comparing dried paint with a satin finish to the same color paint with a flat finish.

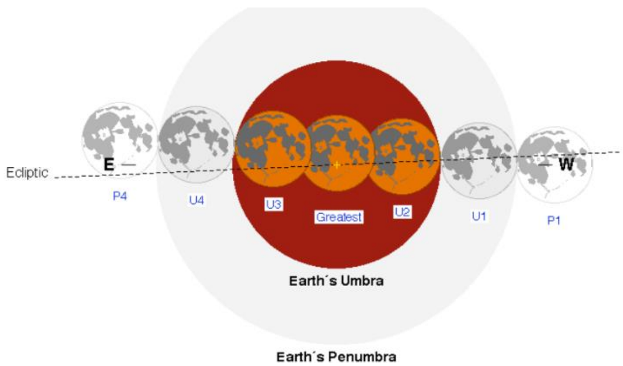


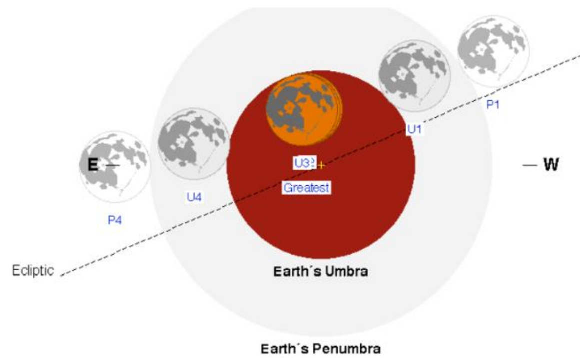
The inner, darker shadow is called the *umbra*, and its characteristic red color is why we sometimes refer to the eclipsed Moon as a *Blood Moon*. There's an interesting reason for the umbra's red hue. When sunlight enters Earth's atmosphere, it bounces off molecules of oxygen and nitrogen, which are much smaller than the light's wavelength. This process, known as *Rayleigh scattering,* affects light at the blue end of the spectrum to a much greater extent than light at the red end. This effect is most pronounced when the Sun is near the horizon and its light therefore passes through a thicker-than-usual mass of atmosphere before reaching our eyes: the unscattered red light passes straight through, giving us our red sunsets and sunrises, while the scattered light gives us our blue sky above the sunset. The photo on the left below, taken from the International Space Station in May 2010, illustrates what happens *(credit: NASA* – the white stripe above the sunset is a cloud layer).

As the diagram above indicates, the light at the outer edges of the umbra has passed through Earth's *terminator* – the line separating night and day, which is where all of our sunrises and sunsets occur. Some of that light refracts into the umbra, bringing with it the red coloration that results from Rayleigh scattering. When roughly 75% of its disk it is within the umbra, the Moon begins to take on that reddish color– a color that literally reflects back to our eyes all of the sunrises and sunsets occurring anywhere on Earth at that moment. That's why the eclipsed Moon's color during any given eclipse is affected by the condition of Earth's atmosphere: the size, type, and quantity of suspended particles, the presence or absence of clouds, and other atmospheric factors influence the color and brightness of the light refracted into the umbra, and thus the color and brightness of the eclipsed Moon. The Moon can also show us a slightly different color display for 5-10 minutes just before totality, and again for 5-10 minutes just after it, when the umbra's red color is accompanied by a blue-purple band that reflects the color of our upper atmosphere, where the ozone layer absorbs much of the red light, producing a colorful image known as *the Japanese lantern effect* as shown in the photo on the right below *(credit: Wikimedia /photographer Larry Johnson, New Braunfels TX).*

If the full Moon lies directly on a node, we will see a *total lunar eclipse* as the Moon is completely engulfed by the umbra. If it is near a node but not directly on it, we will see a *partial eclipse* if the Moon skirts the edge of the umbra, or possibly only a nearly-undetectable *penumbral eclipse* if the Moon passes through the penumbra without touching the umbra. If the Moon's center passes directly over the center of the umbra – which is called a *central eclipse* – the eclipse will be darker than if the Moon crosses the umbra off-center. In that case, the limb of the Moon closer to the edge of the umbra will be noticeably brighter than the more deeply-immersed limb.

The length of the eclipse also depends on whether the Moon passes through the center of the umbra, in which case it will spend a maximum of 1 hour 47 minutes in totality. If it crosses the umbra off-center, totality will not last as long. NASA's *Lunar Eclipse Page* (excerpts below) will show you how central a given eclipse will be, as well as whether it can be seen from your location, timings of each phase, and much other useful information.





The *contact points* used in timing and describing lunar eclipses are similar to those used for eclipses of the Sun:

P1 = Moon's leading edge first contacts the penumbra [penumbral eclipse begins]
U1 = Moon's leading edge first contacts the umbra [partial eclipse begins]
U2 = Moon's trailing edge contacts the umbra [totality begins]
GE = Greatest Eclipse, when the Moon is most deeply immersed in the umbra
U3 = Moon's leading edge exits the umbra [totality ends]
U4 = Moon's trailing edge exits the umbra [partial eclipse ends]
P4 = Moon's trailing edge exits the penumbra [penumbral eclipse ends]

Lunar eclipses are classified using *the Danjon scale*, created in 1921 by French astronomer André Danjon:

L0 = an extremely dark eclipse, nearly black: the Moon is almost invisible at mid-totality.
L1 = a dark eclipse, grey or brown in color: the Moon's surface details can be seen only with difficulty.
L2 = a deep red or rust-colored center, with slightly brighter reddish edges.
L3 = the center of the Moon is brick-red, surrounded by a brighter yellowish rim.
L4 = a very light eclipse, with little change in the visibility of details:
copper or orange colored at the center, with a brighter bluish edge.

The *Danjon value* changes at different times during an eclipse, and different parts of the Moon can display different Danjon values simultaneously, depending on the Moon's position within the umbra.

A lunar eclipse also presents opportunities for amateur observers to participate in citizen science. One way is to record *crater timings* – the exact times when specific craters enter and leave the umbral shadow. This information is useful in calculating the umbra's precise size and shape: because the umbra includes the shadow of Earth's atmosphere, it's always a little larger than calculations based only on the size and shape of the planet would suggest, but the discrepancy varies paradoxically and inconsistently from one eclipse to the next, for reasons that are not fully understood but presumably relate to atmospheric conditions. To provide meaningful crater timing data, you'll need a telescope with an aperture between 60mm and 8 inches with a low or medium power eyepiece, a good Moon map to be sure you identify the craters correctly, and an accurate timepiece – preferably a self-setting radio controlled watch (available from sources including Casio and Citizen) that synchronizes itself to radio time signals.

For most craters, record the time (to the nearest 0.1 minute) when the umbral shadow crosses the visual center of the crater; but for very large craters, report the time when the shadow first touches the crater's edge and the time when it reaches the opposite edge – the midpoint will be the crater crossing time. Report your timings to Roger Sinnott (senior contributing editor at *Sky & Telescope* magazine) by email to roger.sinnott@verizon.net for compilation and analysis.

For any specific eclipse, you can find estimated timings for selected craters on the *Sky & Telescope* website and other online sources, as well as in the Royal Astronomical Society of Canada's annual *Observer's Handbook*, helpfully presented in the order in which they will be covered (and later uncovered) by the umbra. The estimated timings are presented in UTC (Coordinated Universal Time); you will have to convert them to your local time. RASC and *S&T* usually list a couple dozen timing craters, which often include:

Aristarchus	Copernicus	Kepler	Plinius
Aristoteles	Dionysius	Langrenus	Proclus
Autolycus	Endymion	Manilius	Pytheas
Billy	Eudoxus	Menelaus	Riccioli
Birt	Goclenius	Messier	Taruntius
Campanus	Grimaldi	Pico Mons	Timocharis
Censorinus	Harpalus	Plato	Tycho

Magnitude estimates are another way for amateur observers to engage in citizen science during a lunar eclipse. While the Danjon scale is the most common way to describe the brightness of the Moon in eclipse, it's not a very objective measurement. Brazilian physicist Helio de Carvalho Vital spearheaded an effort to enlist amateur observers to gather magnitude estimates during totality as a more objective means of gauging the eclipsed Moon's brightness, which is useful in understanding the volume of aerosols such as smoke, volcanic ash, and other materials suspended in the upper atmosphere.

To estimate the Moon's magnitude, you'll need a pair of binoculars, but you'll want to use them backwards: point the eyepiece end at the Moon, then look into the large lenses at the front. You'll see an image of the Moon that is much smaller than the naked eye view, making its brightness easier to compare with the brightness of nearby stars. You should gauge the stars' brightness naked eye, without using binoculars or any other visual aid. You probably won't find one nearby that's exactly the same brightness as your tiny Moon, but try to find one that's a little brighter, and one that's a little dimmer. Identify those stars, check their magnitudes, and interpolate between them to estimate the magnitude of the Moon as seen in your reversed binos, then subtract a correction factor that depends on the binoculars' magnification power: subtract 4.5 for 8x glasses, 4.2 for 7x, and 3.9 for 6x. For example, if the Moon in reversed 7x50 binos seems a little fainter than a nearby mag 3.1 star and a little brighter than a mag 3.9 star, you might interpolate the Moon's magnitude as 3.5, then subtract the 7x conversion factor to produce an estimated magnitude of -0.7 for the Moon at that moment.

Make estimates at different points as the Moon passes through the umbra. You can report your results to Roger Sinnott at the same email address as is used for crater timings. Magnitude reports should include the time to the nearest minute, the identity and magnitudes of your comparison stars, the power of the binoculars you used, and your lunar magnitude estimates before and after subtraction of the magnification factor.

The beginning of lunar totality, Jan. 20, 2019 (credit: author)

So what should you do during a lunar eclipse? First, see how soon you can discern a change in the Moon's appearance after it enters the penumbra. Once it enters the umbra, track the gentle curve of Earth's shadow as it creeps across the Moon's face (and later as it slowly retreats) – and tip your hat to Aristotle, who pointed to that gentle curve 2400 years ago as proof that the Earth is round. How sharp is the shadow's edge, and how abruptly does its darkness fall off? Do any of the Moon's surface features show through it? You can watch the shadow naked-eye, or use firmly-mounted binoculars or a telescope to get a better view. You won't need much aperture for this job – even the smallest telescope will do it – but it's important to keep the magnification low: you want to be able to see the entire disk of the Moon in order to appreciate the Earth's curved edge. Notice how the Moon somehow looks more three-dimensional now than it did before the eclipse began. Watch the Moon turn red as it becomes more fully submerged in the umbra, reflecting all of Earth's sunrises and sunsets simultaneously in a single image. How much of the Moon's surface detail can you see now? Greatest eclipse is a good time to estimate the Moon's Danjon value, and to check for variations on different parts of the Moon's surface. Especially if you're out in the country, take a few minutes to look beyond the Moon and notice how many faint stars, previously washed out by the full Moon's brightness, begin to creep into visibility as the eclipse transforms the moonlit sky into the darker sky of a moonless night. See if you can spot that change happening on the ground, as the scene around you slowly darkens with the extinction of the bright moonglow. Did you see the Japanese lantern effect as totality began? If not, look for it again as totality ends. If the Moon is still in the umbra at sunrise or sunset, you might be able to spot a rare *selenelion,* which occurs when an image of the not-quite-risen or already-set Sun or Moon appears above the horizon as a result of *refraction*, allowing you to see both the Sun and the eclipsed Moon on opposite horizons simultaneously – a view that would be geometrically impossible without the magic of refraction: because Earth sits directly between the two bodies, they cannot both be above the horizon at the same time. But most of all, allow yourself to experience the wonder and beauty of this event, which will be over sooner than you expect – and then look forward to the next one. Like their solar cousins, lunar eclipses are few and far between, so don't miss them when you have the chance.

Rick Gering / March 2026