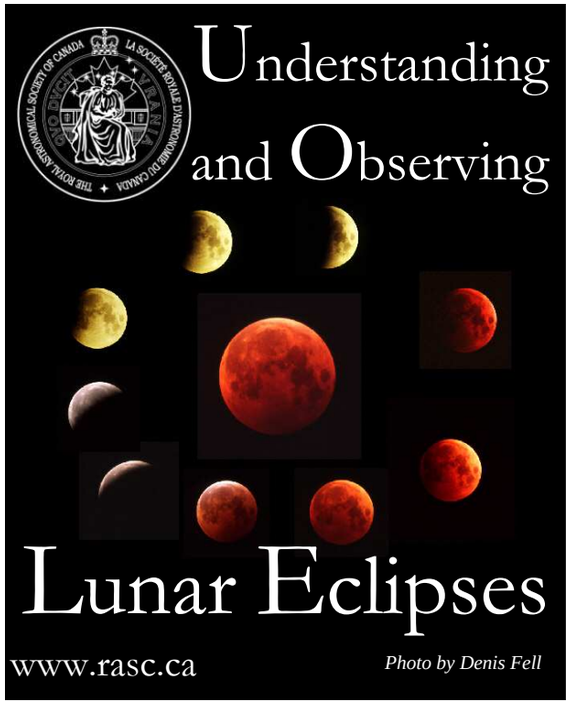


A lunar eclipse is an interplay between celestial motions, and the reflection, refraction and scattering of sunlight. Total lunar eclipses are beautiful events, and can be simply enjoyed for their own sake, or, whether with the unaided eye, binoculars, or a small telescope, are opportunities to do some basic science. Large telescopes confer no great advantage in viewing lunar eclipses.

Lunar Phases and Motions

Normally, the Moon shines by reflecting unaltered sunlight. A common misconception is that lunar *phases* are somehow caused by the shadow of the Earth falling onto the Moon. In reality, since the Moon is in orbit around the Earth, the Moon's phases are the result of our changing viewing angle of the Moon as it orbits the Earth once every 29.5 days.

Lunar Eclipses

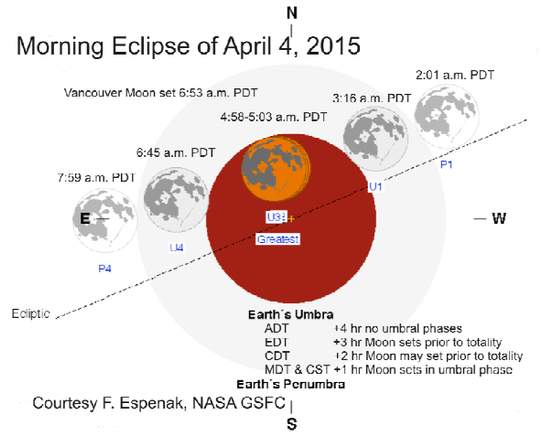
There *is* a time that the Earth's shadow can change the Moon's appearance, and that is during a lunar eclipse. Lunar eclipses can only occur with a Full Moon, though not all Full Moons need be associated with eclipses. Because of the tilt of the Moon's orbit with respect to the Earth's orbit, most Full Moons pass above or below the Earth's shadow. When the two orbital paths intersect, as they do twice a year, there is a chance for eclipses, both lunar and solar, provided the Moon is in the correct phase at the time (full for lunar and new for solar). The key factor for eclipses is that the three bodies, Sun, Earth and Moon are in a straight line.

A lunar eclipse is visible at exactly the same time all across the night time side of Earth, though local times differ because of time zones.

The Earth is much larger than the Moon, at 12756 km versus 3475 km across, so the diameter of the Earth's shadow is several times the Moon's diameter. The Moon's motion across the starry background amounts to about 1/2 degree, or its apparent diameter, per hour.

Because the Sun is not a point source, shadows cast in sunlight do not have sharp edges. The Earth's shadow thus consists of two parts: the dark central part, where the Sun's light is completely blocked by the Earth, called the umbra (about 9000 km across); and the outer lighter part where only part of the Sun's light is obscured, called the penumbra (about 16000 km across).

Depending on the path of the Moon through the Earth's shadow, four types of eclipses may occur; partial penumbral, penumbral, partial umbral, and total umbral.



Penumbral Eclipses

When a full Moon passes through the Earth's shadow, but not through the Earth's dark umbral shadow, a penumbral eclipse takes place. There are also penumbral phases of umbral lunar eclipses.

Partial penumbral eclipses are essentially impossible to see. Unless the moon's edge passes within about 1100 km of the umbra, the unaided eye is unlikely to detect any dimming. Penumbral shading becomes darker the closer to the umbra. Don't confuse variations in the reflectivity of lunar surface features with darkness differences in the penumbral shadow. While not as noticeable as umbral colours, the deeper penumbra can show a range of dusky brown or yellowish–brown colours.

Partial Umbral Eclipse

Partial umbral lunar eclipses occur when the Moon enters the Earth's umbral shadow, but not centrally enough to become completely immersed. To the uninitiated, a partial umbral eclipse can bear superficial resemblance to lunar crescent phases, but instead of weeks to change phase, the eclipse passes in hours.

Although not every partial umbral eclipse lead to a total umbral eclipse, every total umbral eclipse has partial phases.

First contact is when the Earth's umbra first touches the Moon's celestial eastern (lunar western) or leading limb and *fourth contact* occurs when the umbra departs the moon's celestial western (lunar eastern) or trailing limb. Second and third contacts only happen in total umbral eclipses and are discussed later. After fourth contact with the umbra, the reddish shading of the penumbra will gradually leave the Moon until it is imperceptible at fourth contact.

Total Umbral Eclipse

At second contact, the moon completes its journey into the umbra. For as long as 104 minutes (but usually shorter) the moon will be completely shielded from the sun's direct rays.

During totality, the full moon's usual brightness may drop by a factor from 10,000 to 1,000,000 times, but its brightness does not drop to zero. If the Earth had no atmosphere, the Moon would be completely black during a total umbral

eclipse. Instead, the Moon can take on a range of colours from dark brown and red to bright orange and yellow. The exact appearance of the eclipsed Moon is influenced by weather activity along the Earth's terminator: if it is mainly cloudy, most of the Sun's rays will be blocked and the eclipse will be relatively colourless and dark; if clear, the light reaching the Moon will be tinged with sunsets, leading to an orange or red colour.

To reach the Moon, sunlight must first pass deep through the Earth's atmosphere which scatters out most of the blue-coloured light and bends or refracts a small portion the remainder. So, the Moon is red for the same reason the sky is blue! If you were standing on the Moon during a total lunar eclipse, you would see the Earth completely eclipse the Sun. As well, you'd see a bright red ring around the Earth representing all the sunrises and sunsets happening simultaneously around the world.

Observing Lunar Eclipses

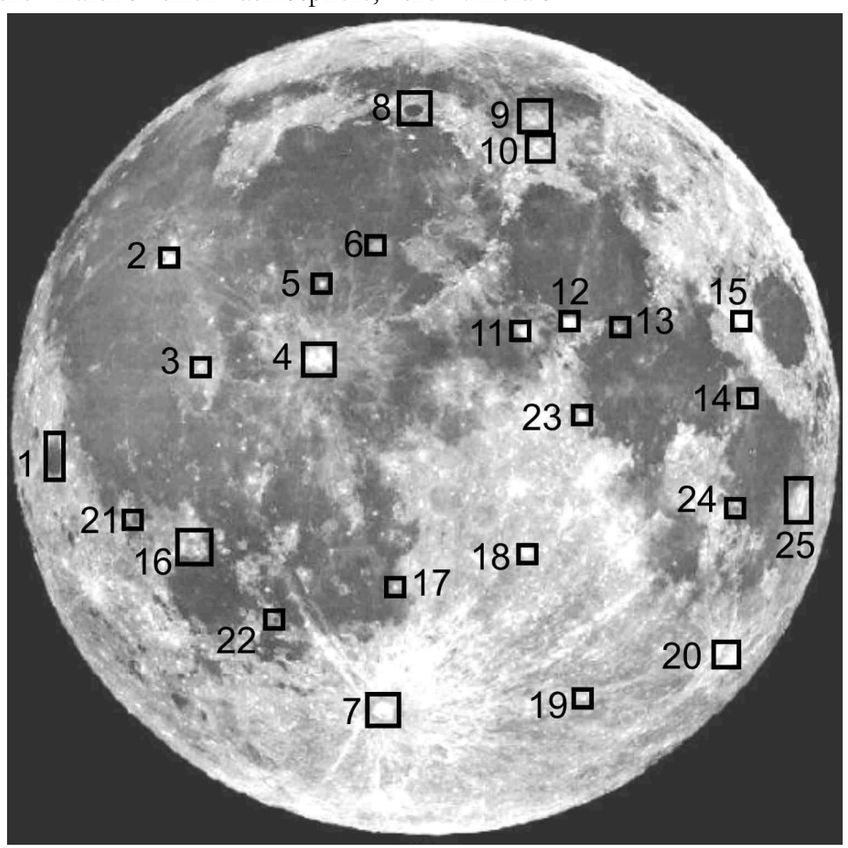
Unlike solar eclipses, lunar eclipses are completely safe to watch with no specialized equipment or protective filters. There are at least two kinds of observations which can be made which are of scientific value during a lunar eclipse. One is to estimate the colour and darkness of the eclipse at its greatest extent using French astronomer, André–Louis Danjon's (1890–1967) scale. This estimate is best done either the unaided eye or with low power binoculars.

The Danjon Luminosity Scale	
0	Very dark eclipse. Moon almost invisible, especially at mid–totality.
1	Dark eclipse, gray or brownish in coloration. Details distinguishable only with difficulty.
2	Deep red or rust–colored eclipse. Very dark central shadow, while outer edge of shadow is relatively bright.
3	Brick–red eclipse. Umbral shadow usually has a bright or yellow rim.
4	Very bright copper–red or orange eclipse. Umbral shadow has a bluish, very bright rim.

Another is to estimate, to the nearest tenth of a minute, the time when the umbra's edge enters and leaves the Moon's surface (first through fourth contacts), as well as the times when it obscures various craters. Such timings provide information about the size and shape of the Earth's shadow in this particular eclipse. Due to the Earth's thick atmosphere, the umbra's diameter and shape are variable and is typically larger by approximately two percent than the simple geometry would predict. Use an ordinary watch synchronized with a time signal or an accurate computer clock.

Use a low magnification, so that the edge of the umbra is a well defined line. The other important consideration is that most or the entire Moon fit into your field of view at one time. A simple map, like the one in this brochure, is actually easier to use at full Moon than a larger, more detailed map or atlas.

Craters for Lunar Eclipse Timing



1. Grimaldi,
2. Aristarchus
3. Kepler
4. Copernicus
5. Pytheas
6. Timocharis
7. Tycho
8. Plato
9. Aristoteles
10. Eudoxus
11. Manilius
12. Menelaus
13. Plinius
14. Taruntius
15. Proclus
16. Gassendi
17. Birt
18. Abulfeda E
19. Nicolai A
20. Stevinus A
21. Billy
22. Campanus
23. Dionysius
24. Goclenius
25. Langrenus

Top row: just after first contact to second contact. Bottom row: Third contact to just before fourth contact. Photo by Denis Fell

More information on the topics covered in this brochure is available in the *Observer's Handbook*, which is included with membership in the Royal Astronomical Society of Canada.

Find out more

To learn more about the Royal Astronomical Society of Canada, or membership in the Society, contact your local Centre or the Society's National Office:

Website:
www.rasc.ca

E-mail:
Nationaloffice@rasc.ca

Telephone:
Phone: (416) 924-7973
Fax: (416) 924-2911

Mailing Address:
The Royal Astronomical Society of Canada
203 - 4920 Dundas St W
Toronto ON M9A 1B7