SkyNews Astronomical events for Indian observers

Special Eclipse Issue

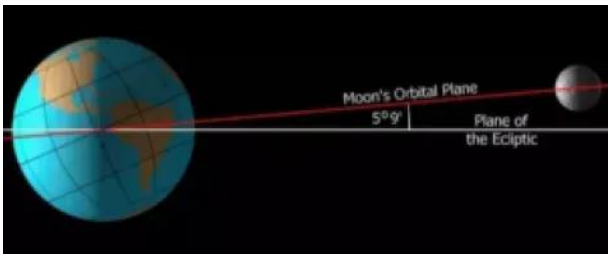
ECLIPSES

An eclipse takes place when the Sun, the Moon and the Earth are in a straight line. If the Earth comes between the Sun and Moon, its shadow falls on the Moon and the eclipse is known as a lunar eclipse. A solar eclipse takes place when the Moon comes between the Earth and Sun, casting its shadow on certain parts of the Earth. In these regions, the Sun is seen partially or completely hidden behind the Moon.

Hence by definition, a solar eclipse takes place during new moon (*amavasya*,अमावस्या) and a lunar eclipse takes place during full moon (*Purnima*,पौर्णिमा).

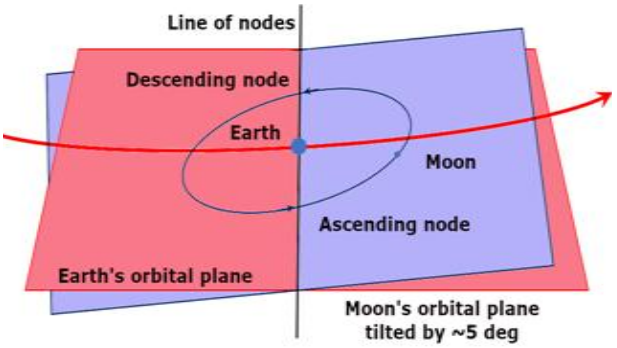
Why is it that we do not see an eclipse during every new moon or full moon?

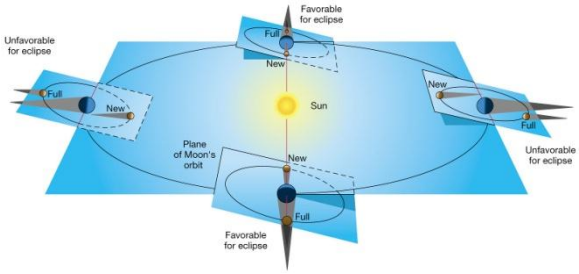
The reason is that an eclipse will only take place if the three heavenly objects are in a straight line. It so happens that the Moon's orbital plane, which is the plane in which the Moon orbits the Earth, is tilted to the orbital plane of the Earth, also called the plane of the ecliptic, by about 5 degrees. Hence during most full and new moons the three objects are not perfectly aligned. On the rare occasions when they are aligned, the eclipse takes place.



Angle formed by the orbital planes of the Moon and the Earth. The figure is not to scale. Image courtesy of Dr. John McCarthy. https://www.totalidad.com.ar/en/con-que-frecuencia-ocurren-los-eclipses-eng/

The line joining the point of intersection of the two planes to the Sun is called the 'line of nodes'. An eclipse can take place only if the Moon is less than 5 degrees away from the line of nodes. The point at which the Moon crosses the plane of the Earth from below is called the 'ascending node'; the point at which it crosses the same from above is called the 'descending node'. In Indian astronomy, the ascending node is *Rahu* and the descending node is *Ketu*.





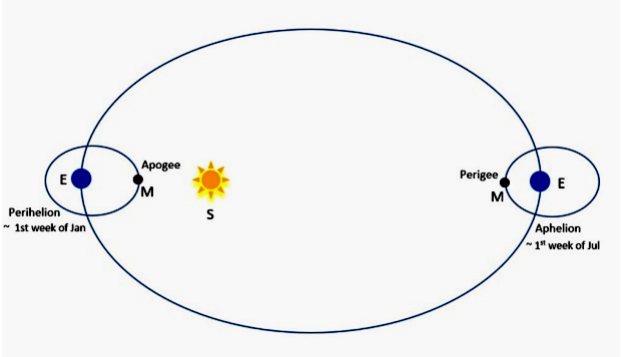
Source: https://www.explainxkcd.com/wiki/images/3/30/Eclipse_Diagram.jpg

Solar eclipses:

During a solar eclipse the Moon comes between the Earth and Sun; consequently its shadow falls on the Earth. But the diameter of the Moon is just about one fourth that of the Earth. Hence the shadow covers a limited portion of the Earth's surface, spanning just a few hundred kilometres. Thus a solar eclipse is seen over a very narrow belt on the ground. Contrast this with a lunar eclipse, where the entire Moon gets covered by the Earth's shadow during totality. Thus a lunar eclipse can be seen from every point on the ground where the Moon is visible.

However, the relative distances are such that the apparent diameters of the Sun and Moon are nearly the same when seen from the Earth. Hence for those who are fortunate to be in the belt of totality of a solar eclipse, the few tens of seconds of totality present a glorious sight where the entire Sun hides behind the Moon, giving us a rare glimpse of its corona or outermost atmosphere. There are other phenomena such as Bailey's Beads and the diamond ring that offer a visual treat to the watcher as the Moon, with its mountains and valleys, inches its way across the Sun.

Now consider a situation where the Moon is close to apogee (its farthest distance from the Earth); its apparent size will be a little less than on other days. And if the Earth is close to perihelion (its closest distance to the Sun), then the Sun will have a larger apparent size. If a solar eclipse occurs during such a time, the Moon, with its smaller apparent size, will not cover the Sun entirely. What we will see at the peak of the eclipse is the major part of the Sun's disc blocked out, surrounded by a circle of light, often called a 'ring of fire'. This is an 'annular solar eclipse' or an 'annular eclipse' ('annulus' means ring, hence the term).



The next solar eclipse:

The next solar eclipse that will be visible over India will be an annular eclipse on **26 December 2019**.

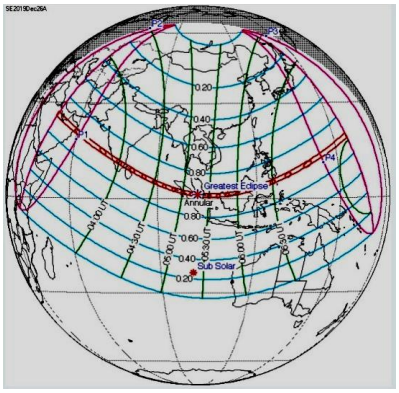
The 'ring of fire' will be visible over parts of the Middle East, India, Sri Lanka, Malaysia, Indonesia, the Northern Mariana Islands and Guam. Over India, the path of annularity will traverse parts of South India, over Kozhikode and Coimbatore.

Over **Mumbai**, 84.2% of the Sun will be covered by the Moon. Please see the table giving the timings of the partial phase of the annular solar eclipse at various places.

How to watch a solar eclipse safely:

There are a lot of myths, fears and superstitions associated with eclipses. They are believed to be harbingers of doom, leaving in their wake misfortune and trouble. This is so ingrained in our ethos that some people, even with a background in science, choose to play safe and stay at home during the eclipse. They end up missing one of the most magnificent sights a person can witness in her or his lifetime.

A solar eclipse can be observed without any harm if due precautions are taken.



The path of the annular eclipse of 26 December 2019. Map derived from https://en.wikipedia.org/wiki/Solar_eclipse_of_December_26,_2019#/media/File:SE2019Dec26A.png

It is strongly advised that one should never look at the Sun directly. Light enters the human eye through the pupil; it then passes through the lens and is focussed on the retina. From the retina, the image of the object is transmitted to the brain. The pupil is surrounded by the iris which expands and contracts depending on the level of light, thus regulating the amount of light that enters the eye through the pupil. This does not happen instantaneously; there is a time lag between contraction or expansion of the iris in high or low light respectively. That is why we experience momentary 'blindness' when we move from a dark to a bright area; we have to wait till the iris contracts sufficiently to let in the right amount of light.

Normally if we try to look at the Sun directly for more than a few seconds, the contracting iris will cause us to close our eyes or look away, thus acting as a natural shield. Though we can ignore the contraction and force ourselves to stare at the Sun, we are not inclined to do so because there is no interesting feature on the Sun's surface that can be seen with the naked eye. But during an eclipse we see progressive change happening on the Sun. Hence at such a time we tend to look at the Sun for longer durations. Added to this is the fact that as the light gets diminished as the eclipse progresses, the contraction of the iris gets proportionately reduced. These factors combine to let the Sun's light enter the eye in larger-than-usual concentrations, making the retina susceptible to permanent damage.

Whenever a part of our body is exposed to excessive heat or radiation, the sensation of burning is conveyed to our brain by pain receptors. The natural reaction is immediately to withdraw from such exposure. But the retina of the human eye does not have any pain receptors. Hence one does not feel the sense of

burning or pain on looking at the Sun directly. The awareness comes when it is too late, when the person is afflicted with partial or sometimes even total blindness.

It is therefore prudent to play safe and avoid letting the light from the Sun fall directly on the retina. Kindly note that once the retina is damaged, no amount of medical intervention can reverse the condition.

It is unsafe to see a partial or annular eclipse with the naked eye even if 99% of the Sun is covered by the Moon. The few seconds of totality are the only time when the eclipse can be seen directly with the naked eye.

There are three basic ways to observe the progress of a solar eclipse safely:

a) By applying the principle of pinhole projection of the Sun's image
b) Projecting the Sun's image through a plane mirror.
c) Looking at the Sun through a 'safe' filter (▲**caution: ordinary fashion goggles will not be adequate!**)

Let us examine each of these methods:

a) Pinhole imaging:

A small hole on the roof acts like a pinhole camera and gives a reasonably sharp image of the Sun on the floor or on a wall. You only have to look for such a place in your house.

Alternatively, you can create a set up for such a projection by taking a cardboard or a plastic tube of approximately 5 cm diameter and about 1.5 meters long. Close one end of the tube with a thick sheet of paper and pierce a small hole in the centre. Place a piece of butter paper or tracing paper at the other end. Point the pinhole end towards the Sun, and observe its image on the tracing paper. Shade the tube from extraneous sunlight on all sides. The image of the Sun will be clear and safe.

b) Imaging with mirrors:

A small plane mirror, pocket sized or slightly larger, can be used to project an image of the Sun by reflection, on a plain wall 10 to 30 metres away. A large image of the Sun is formed, and the further away the wall, the sharper the image. This is a very suitable method for showing the eclipse to a large number of people.

Alternatively, a screen can be mounted on a telescope or a binocular about half a meter away from the eyepiece. A large, sharp image will be formed, which can be visible to many people at the same time. (▲▲**caution: make sure that nobody looks through the telescope or binocular at the Sun. This is much more dangerous than looking at the Sun with the naked eye.**)

c) Looking directly through a safe filter:

The simplest way of observing the eclipse is to use specially prepared and certified solar eclipse goggles (▲**caution: normal sunglasses are not effective and are not advised.**)

Solar filters that are specially designed to protect the eyes are available. Most of them have a thin layer of chromium or aluminium deposited on the surface so as to reduce the amount of radiation passing through. A safe solar filter transmits less than 0.003% of visible light and less than 0.5% of near-infrared radiation.

A **welding glass** of shade no. 13 or 14 may be used to observe the Sun without the help of any instrument. Glasses of lighter tint or shade may not be completely safe.

Sometimes **exposed** x-ray film can be used as a filter, but it is safe only if it has been fully exposed to light and developed to its maximum density, that is 'blackness-intensity'. The metallic silver on the film acts as a protective layer. The newer films may have dye instead of silver and are unsafe.

Colour film, black & white film without silver, used photographic or x-ray films, smoked glass, sunglasses (both single and multiple), neutral density filters used in photography, polarising filters, floppy disks, CDs and DVDs **are unsafe**. Many of these are transparent to infrared radiation, and can result in thermal retinal burn.

When observing the eclipse through a telescope, **it is important to use a filter that cuts off the light before it enters**

the objective rather than a filter over the eyepiece. This is because the filter over the objective allows only a small amount of light to enter the telescope. All the light entering a telescope gets concentrated at the focus. If sunlight is allowed to enter the telescope without being cut down at the objective, the powerful concentration of this light at the focus will damage the eyepiece and the filter that is over it. **This is very dangerous. Damage will most certainly be caused to the eye or any instrument that is over the eyepiece and there is no corrective measure for this.** If you are not experienced in using this kind of setup, please avoid this method.

A spectacle that should not be missed:

We have underscored the importance of taking due precautions when observing a solar eclipse. In the run-up to the event, the media tend to advise over-caution. Although such messages are issued with the best intentions, they can have a negative repercussion. It has been seen during earlier eclipses that busy metropolitan roads remain deserted as people forcibly shut themselves indoors since they are too scared to expose themselves to the sky.

Such negative warnings may also backfire. Those who heed such warnings later find that they could have enjoyed the eclipse like so many others; they then tend to become sceptical and dismiss the good advice of genuine, authoritative figures in any matter, such as the harm brought by smoking, chewing tobacco or taking drugs.

Totality: the only phase that can be seen with the naked eye:

As we have seen before, during a total solar eclipse the Sun will be totally eclipsed for a brief period along a narrow band along the ground. This is the long-awaited period when we can watch the solar corona with the naked eye. There are some other phenomena that can be observed with the naked eye:

Multiple crescents: When we are under a tree, we see a number of images of the Sun on the ground. These are formed because the gaps between the leaves act as pinholes, forming multiple images of the Sun. During the partial phase of the eclipse, these images take the form of crescents, giving a very interesting effect. This effect is best seen under trees having large leaves. Selection of an appropriate observation site is important to observe the approaching shadow. Select a high place with a clear view in the north-east direction, preferably right up to the horizon. Just before totality, the shadow of the moon is seen rushing towards us from this direction. This is an overwhelming experience.

Shadow bands: Spread out a large, white sheet on flat, open ground. Just before totality, light and dark bands can be seen on the sheet. These are 'shadow bands' of light and shadow. As the Moon advances over the Sun's disc, the latter gets reduced to a slit in the few moments before totality. Just as stars, which are point sources of light, twinkle in the night sky due to the turbulence in the Earth's atmosphere, the light from this tiny slit keeps shifting its position, shimmering on the white sheet and giving the appearance of thousands of snakes slithering on the ground.

Myths that need to be demolished:

a) Myth: There are dangerous types of radiation such as cosmic and gamma rays that are emitted during a solar eclipse and therefore it is better to play safe and stay indoors and avoid exposure to the eclipse.

   Fact: The radiation present during the eclipse is nothing but the normal sunlight in which we move around every day. There is nothing else either in the form of dangerous radiation or germs, bacteria, viruses or pathogens that is generated during a solar eclipse

b) Myth: The reflection of the Sun being eclipsed can be observed in a shallow basin containing water, with the naked eye. The justification is that the image is sufficiently cooled in the water so that it does not harm the eye.

   Fact: This is **not** safe. The image of the Sun is reflected from the upper surface of the water which has high reflectivity. Not enough radiation is absorbed to make it safe for observation without a proper filter.

c) Myth: The eclipse is especially harmful for pregnant women and they should avoid being exposed to it, and also avoid the use of any equipment or appliance, or else the foetus may be deformed at birth.

Fact: The eclipse will cause no harm whatsoever to a pregnant woman or to the foetus. There are many examples of pregnant women who have used various types of equipment to enjoy the sight of an eclipse, with no harm being caused to them or to their unborn babies. Such babies have been born completely normal and have lived long, happy, healthy lives.

d) Myth: You can see the eclipse through a glass plate blackened with soot or lamp black.

Fact: **Please do not do that.** The human eye is sensitive to the infrared radiation that penetrates through the soot. The latter prevents the pupil from contracting and so the retina of the eye actually receives more infrared radiation than normal.

Photographing solar eclipses:

Not too long ago, photography was done on film which was then removed from the camera and sent for developing and printing. Nowadays it has become extremely easy to take photographs using digital cameras or in-built cameras in mobile handsets.

Photographing a solar eclipse can be trivial on the one hand, and an extremely complex exercise on the other, depending on the available resources and the personal choice of the photographer.

A solar eclipse, as we have seen, occurs when the Moon comes between the Earth and Sun and the three objects are aligned in a straight line. Based on the angular diameters of the Moon and the Sun, which in turn are dependent on the distances of these objects from the Earth, we may witness either a total solar eclipse or an annular solar eclipse.

In a total solar eclipse, the Moon completely blocks the disc of the Sun, resulting in a few moments of darkness and a magnificent visual treat in the sky above.

Photographing an annular solar eclipse requires the same technique and requirements as photographing the partial phase of a solar eclipse. One needs a good filter on the camera to cut down the light entering the camera so as not to burn the camera chip.

The coolness and presence of mind of the photographer are vital elements in the success of eclipse photography. Sudden decisions may have to be made in the span of a few seconds, since each eclipse brings unexpected and unknown challenges. Let us look at one success story during the annular eclipse of 15 January 2010. Fourteen year-old Dhruv was excited as he planned to photograph the entire eclipse with his simple Nikon E3700 digital camera. He couldn't wait to capture the ring of fire, and had his camera ready, equipped with the right filter.

But the clouds played spoil sport. The entire sky was overcast, and nothing was visible. As the eclipse neared its peak, he got the idea to

A perfect circle. Fourteen year old Dhruv received the Young Astrophotographer of the Year award by the Royal Observatory, Greenwich for this picture. Judge Rebekah Higgitt said of the photo: "I loved how the perfect geometry of the eclipsed Sun contrasts with the chaotic shapes of the clouds. By using the clouds as a filter, Paranjpye has been able to reproduce wonderful, contrasting colours."

remove the filter from his camera. He photographed the overcast sky where he knew the Sun was, directly without a filter. The result he got was amazing, and he was conferred with the Young Astrophotographer of the Year award by the Royal Observatory, Greenwich. So with good presence of mind, even a simple point-and-shoot camera can deliver wonders.

The technique and requirements for photographing a total solar eclipse are very different. We shall not get into details here, but in short, the camera filter is to be removed only during totality and quickly put back after the total phase is over.

Saros cycle of eclipses:

'Saros' means repetition. The ancient Babylonians discovered a saros cycle of repetition of eclipses. During the second millennium BC, the Babylonian astronomers had started keeping records of the positions of the Moon and planets. And by the fourth century BC, there was enough data accumulated for them to observe repeated cycles of lunar eclipses. They found that lunar eclipses have a

cycle of 18 years. This knowledge enabled them to predict lunar eclipses.

Solar eclipses were different. Unlike a lunar eclipse, a solar eclipse is visible only over a narrow geographical region. It does not last long; and it is insignificant unless more than 50% of the Sun is covered by the Moon. Hence the periodicity of solar eclipses was not completely established at that time.

Place	Begins	Alt^{o}	Maximum	Alt^{o}	%	Ends	Alt^{o}
Agartala	08:34	27	10:01	39	50.8	11:40	43
Aizawl	08:38	29	10:05	40	48.9	11:44	43
Amaravati (AP)	08:10	19	09:35	35	79.8	11:17	48
Bengaluru	08:06	18	09:30	35	92.9	11:11	50
Bhopal	08:11	14	09:29	28	67.6	11:03	40
Bhubaneshwar	08:20	23	09:46	37	64.0	11:29	46
Chandigarh	08:20	11	09:31	22	51.3	10:54	32
Chennai	08:09	21	09:35	38	89.0	11:19	52
Daman	08:09	10	09:22	25	80.6	10:54	39
Dehradun	08:21	12	09:33	23	50.7	10:57	33
Delhi	08:17	12	09:31	24	55.3	10:57	34
Gandhinagar	08:06	9	09:22	23	73.9	10:52	37
Guwahati	08:40	27	10:03	37	44.7	11:36	41
Hyderabad	08:08	17	09:31	33	80.4	11:10	46
Imphal	08:43	30	10:09	39	45.5	11:45	41
Jaipur	08:13	11	09:28	24	61.1	10:56	35
Japal Rangpur	08:08	17	09:31	33	80.8	11:11	47
Kanyakumari	08:08	21	09:31	38	91.0	11:14	55
Kohima	08:45	29	10:10	39	43.5	11:44	41
Kolkata	08:27	25	09:53	38	56.0	11:33	44
Leh	08:27	10	09:35	20	43.2	10:53	29
Lucknow	08:20	16	09:37	28	54.9	11:07	38
Mt. Abu	08:08	9	09:23	22	70.3	10:51	35
Mumbai	08:04	11	09:22	26	84.2	10:55	41
Naini Tal	08:21	13	09:35	25	51.2	11:01	35
Nanded	08:08	15	09:29	30	77.6	11:06	44
Panaji	08:04	13	09:23	29	91.7	10:59	45
Patna	08:26	20	09:45	32	50.6	11:17	40
Pune	08:05	12	09:23	27	83.9	10:58	42
Raipur	08:14	19	09:37	33	66.9	11:15	44
Ranchi	08:22	21	09:45	35	57.5	11:23	43
Shimla	08:21	11	09:32	22	50.0	10:55	32
Srinagar	08:23	8	09:31	18	46.5	10:48	28
Trivandrum	08:07	20	09:30	37	91.3	11:11	54
Udaipur	08:08	9	09:24	23	69.2	10:53	36

Timings of partial phase of the ASE. All timings are in Indian Standard Time, nearest to a minute.

Where to get safe eclipse goggles: Kutuhal Science Activities Pvt. Ltd. have come up with safe eclipse viewers conforming to the transmission requirements of ISO 12312:2-2015. Please visit www.kutuhal.co.in or email kutuhal@gmail.com. You may also visit the website of the Public Outreach & Education Committee of the Astronomical Society of India <here>

These pages are contributed by: Arvind Paranjpye (paranjpye.arvind@gmail.com)(http://arvindparanjpye.blogspot.com/) and Anjanee Rao (rao.anjanee@gmail.com)