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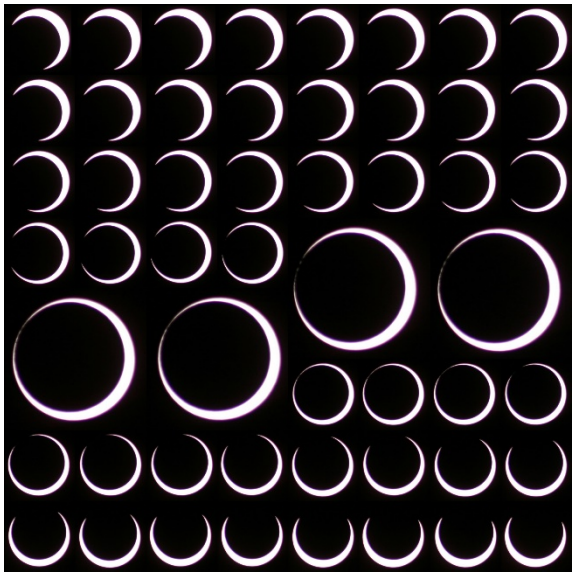
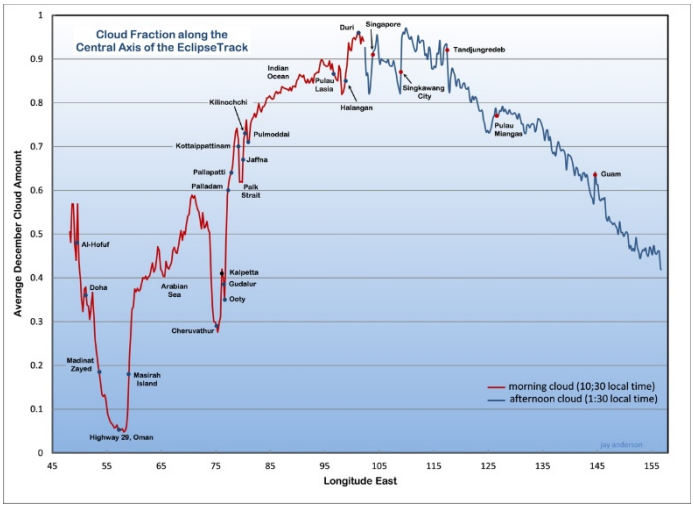
How to Photograph an Annular Solar Eclipse



Two Annular Eclipses will cross India within a period of 6 months. The first one is just a few days away on 26th December 2019. The antumbral path crosses southern India, in the states of Kerala, Karnataka and Tamil Nadu. Other than the ~125 kilometres wide path, the entire country will witness a partial eclipse.

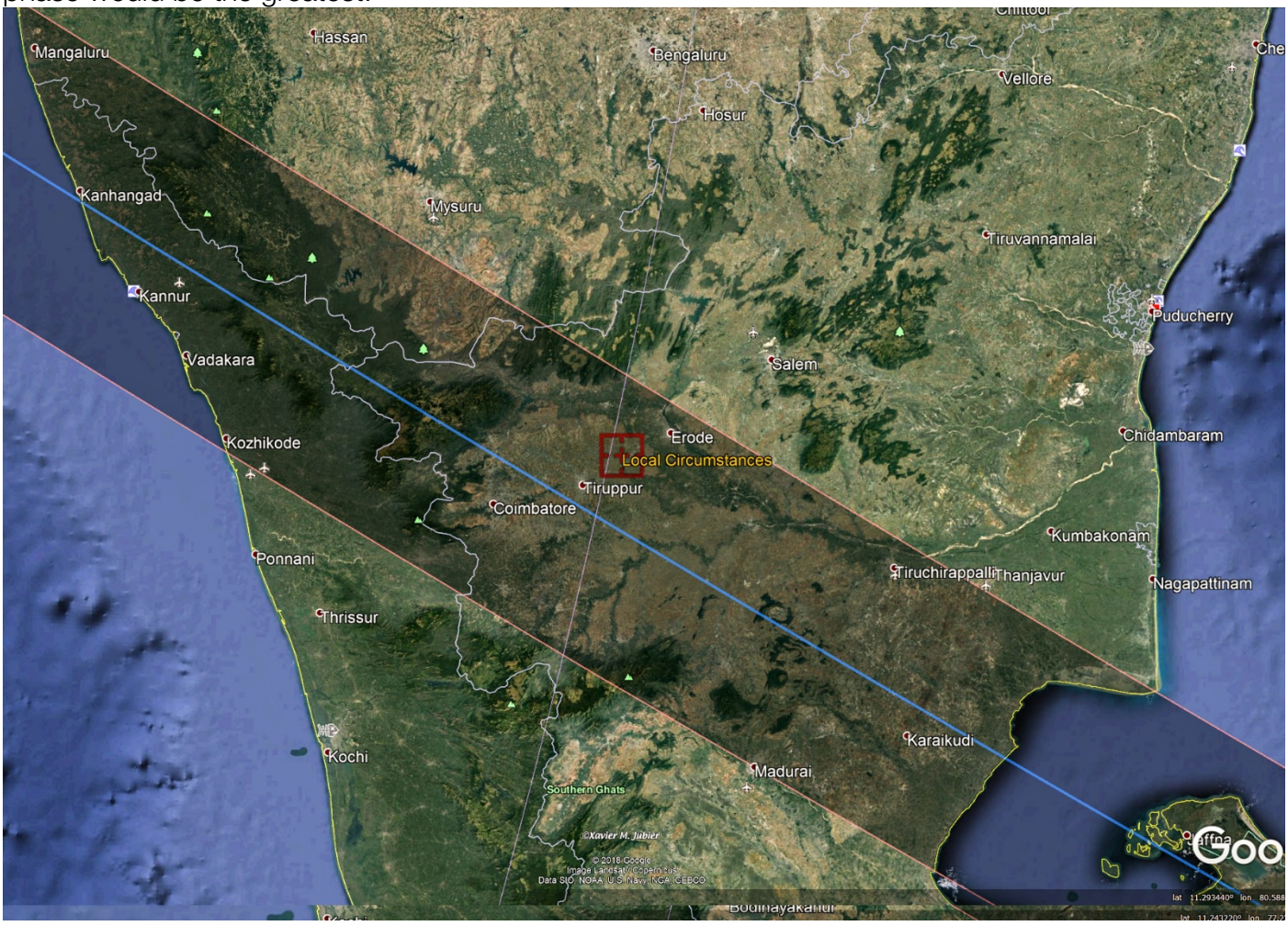
The second Annular eclipse is occurring on 21 June 2020. This time the path is crossing north India, in the states of Rajasthan, Haryana, Punjab, Uttar Pradesh and Uttarakhand. The point of the greatest eclipse lies in the Himalayas near Joshimath in Uttarakhand The width of the antumbral path is quite narrow ~20 kilometres. The entire country will witness a partial eclipse.

Location according to weather: One of the most important factor to choose a location is weather. The central part of a solar eclipse is a brief event. You need to ensure that clouds do not obscure the view at that important time. To choose a location ensuring clear sky, eclipse chasers around the work depend on a website maintained by a Canadian eclipse chaser Mr. Jay Anderson. You can peruse his website url – www.eclipseophile.com which will tell you the best cloud free conditions along the path of eclipse at the time of the eclipse. According to his cloud graph for 26th December 2019, the western



coast of India in Kerala has the best chance of cloud free eclipse, but much better weather conditions can be found in the desert of Saudi Arabia and Oman.

Location - On the edge or on the centreline?: If you choose a location right in the middle of the antumbral path, during the middle of the eclipse you will get to photograph a perfect annulus, i.e. the Moon would be perfectly centred around the Sun. At the centreline you will see a brief period of Baily's Beads at the time of second and third contacts. At the centreline the duration of annularity phase would be the greatest.



If you choose a location at the edge of the antumbral path, then the duration of annularity would be brief, but on the other hand you would get to see a fine display of Baily's Beads for a longer period. The display of Baily Beads would move along the circumference between the second and the third contact. The annular eclipse of 21 June 2020, although the duration is brief, there is expected a fine display of Baily's Beads all around the Moon, since the apparent size of Sun and Moon are similar.

If you are located somewhere in between the centreline and the edge of the antumbral path, then the Moon will cross the not exactly at the middle, but on the side. The solar ring would be thicker on one side, and thinner on the other side. If you are on the northern side of the path, the Moon will cross towards the southern side and vice versa.

Solar Filter: A solar filter is necessary to photograph an annular eclipse. The filter is necessary for the entire duration of the eclipse as the Sun will never get covered completely by the Moon. Photography of a Total Solar Eclipse is different. During the totality phase you need to remove the filter to capture the Corona and Diamond Ring. In the case of an Annular Solar Eclipse the filter needs to be attached to the front of the lens throughout the eclipse.

There are several types of solar filters available, some made of mylar produce a white sun, and others produce a yellow-orange sun. There are glass solar filters also available, which are costlier but provide clear and better resolution. Solar filters are available in two densities, the darker one is suitable for visual use and the lighter one is suitable for photographic use. The lighter solar filter, or you may call it brighter solar filter is more suitable as it provides more light and enables shorter exposures with the camera. The disk of the Sun is brighter in the centre and towards the edges it becomes darker. This effect is called 'Limb Darkening'. Since in an annular eclipse the centre is covered by the Moon and only the limb of the Sun (periphery) is visible, and since the limb is darker the exposures need to be longer. Here a brighter solar filter helps by reducing the exposure times.

You can purchase solar filters in size of 12 x 12 inch. You can cut the filter of appropriate size and build a solar filter using card board. A well establish method of making your own filter from sheets can be seen here - https://www.baader-planetarium.com/en/downloads/dl/file/id/338/product/3044/how_to_make_your_own_photo_solar_filter_for_cameras_and_telescopes.pdf

Make sure the filter is free of any pinhole, scratches or any other cut etc. from where the sunlight may leak inside.

Local Circumstances: You should be well aware of the times of all the events occurring in the solar eclipse from your location. The notable events are:

1st Contact – when the Moon and the Sun touch externally. 1st contact is never visible, but only a few seconds later the sun appears cut off slightly from the western side.
2nd Contact – when the Moon moves completely within the solar disk (in an annular eclipse).
Middle of Eclipse – when the Moon is completely in the middle of the solar disk (if you are situated on the centreline.
3rd Contact – when the Moon is tangent to the solar disk and is about to move out.
4th Contact – when the Moon completely leaves the Sun's disk.

Apart from the exact times of the contacts from your observing location, you should be aware of the direction and altitude above horizon at the time of each contacts.

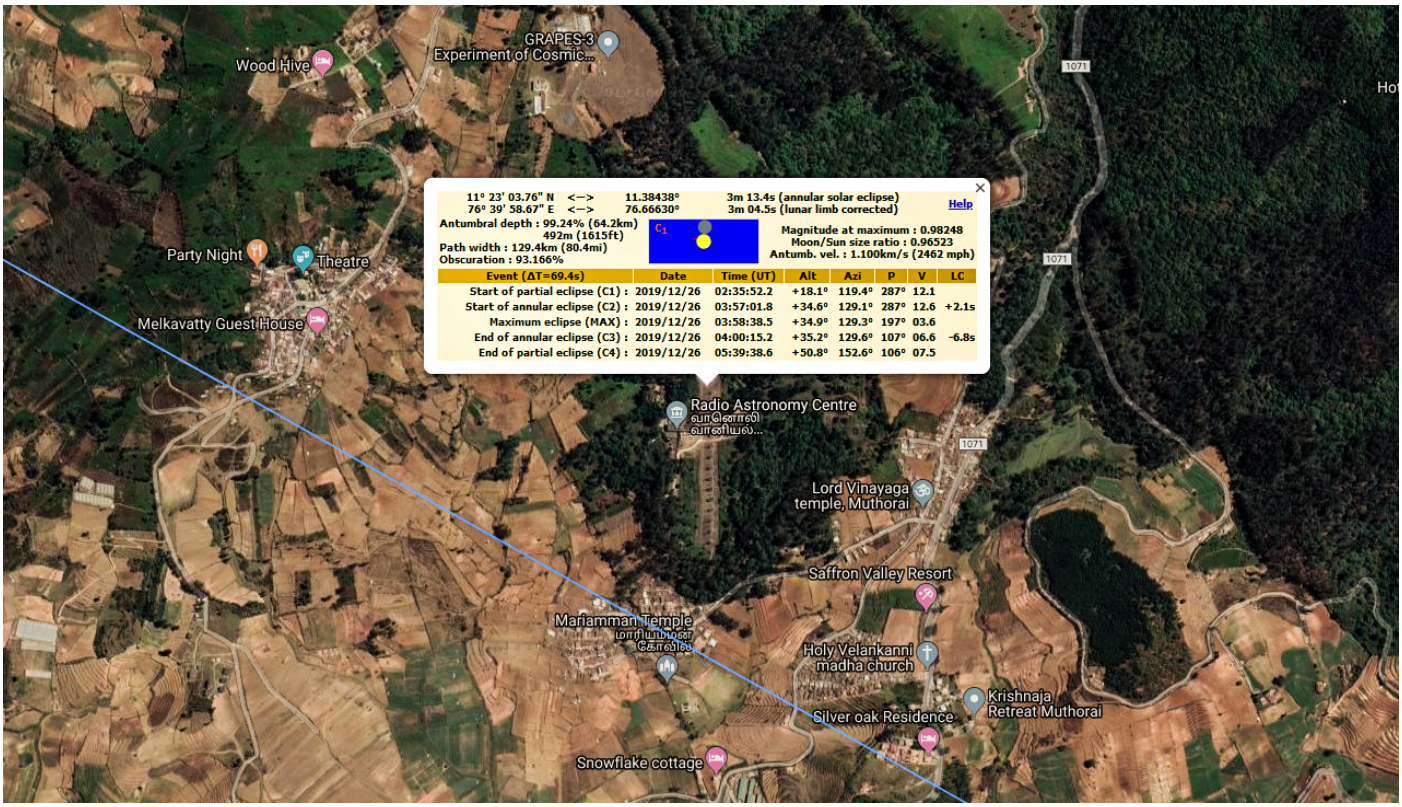
To find the Local Circumstances you could use Eclipse Chaser – Xavier Jubier's website - http://xjubier.free.fr/en/site_pages/solar_eclipses/ASE_2019_GoogleMapFull.html

Zoom in to find your exact location on this map. Click on the location to get the exact local circumstances.

The local circumstance will tell you accurately, the duration between each contacts. The most important is the duration between the second and the third contact, i.e. the duration of the annular portion.

From my location of Udhagamandalam, the duration of annularity on 26 December 2019, works out to be 3 minutes 13.4 seconds. The above website is quite accurate and it will also tell you if the duration is shortened because of any high lunar hill, for example at my site the actual duration of annular eclipse is 9 seconds less, because of presence of lunar hill. This is called 'Limb Corrected Value'.

You need to be ready in this short duration to shoot images in rapid succession and with bracketed exposures to get the correctly timed and correctly exposed image.



Focal Length: A shorter focal length lens will produce a smaller image of the Sun on your sensor and a longer focal length will produce a larger diameter of the Sun on the sensor. The formula to calculate the diameter of the Sun on sensor is –

Diameter of the Sun on Sensor = Focal length of the lens / 110

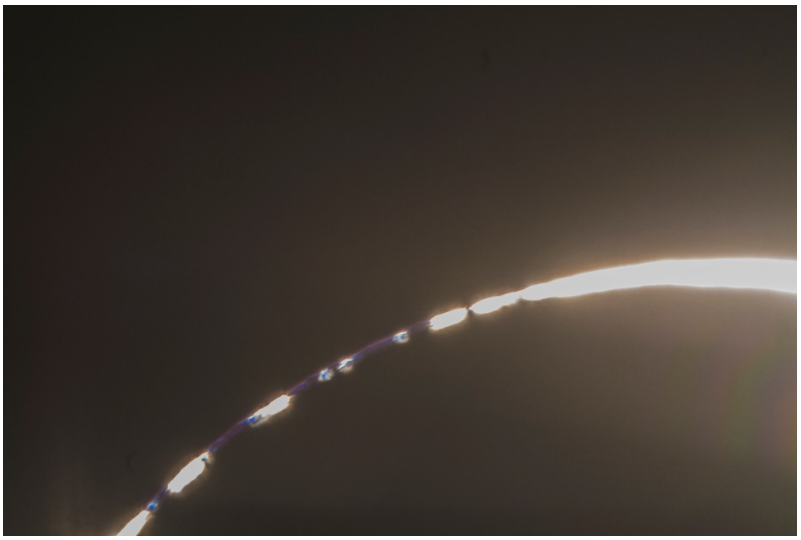
A 200 mm lens would produce an image which is 1.8 mm.

400 mm lens	Sun image size 3.63 mm
500 mm lens	Sun image size 4.55 mm
800 mm lens	Sun image size 7.27 mm
1000 mm lens	Sun image size 9.09 mm
1500 mm lens	Sun image size 13.63 mm
2000 mm lens	Sun image size 18.18

The smaller dimension of a usual crop sensor in DSLR cameras is approximately 14.8mm, in which case a 1500 mm lens image of the Sun would fit within the sensor but would be a tight fit, and you would need an accurate equatorial mount to track the Sun continuously.

This image is shot with a Crop sensor camera, using a 500mm focal length telescope. The image is uncropped.

In the image you can see Baily's Beads. This image was shot on 15 January 2010 at the northern edge of the antumbral path of the eclipse.



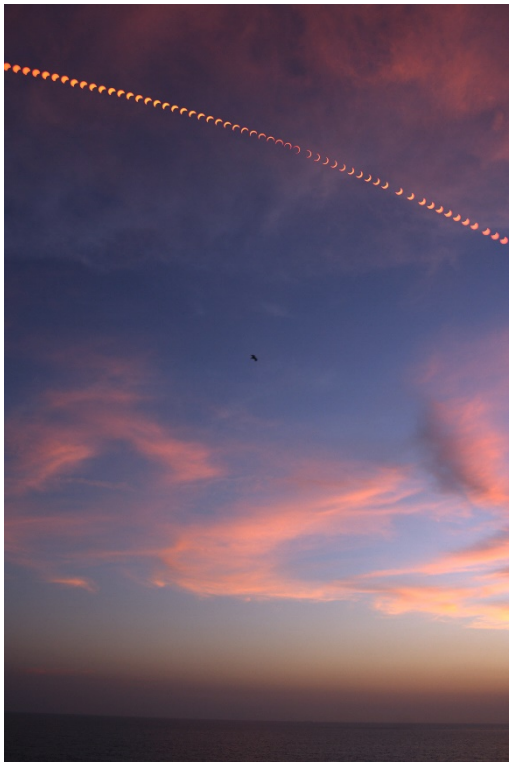
This image is shot with a Crop sensor camera, using a 4000mm focal length telescope. The image is uncropped.

Since the focal length is long, the entire Sun cannot fit in the field of view.

In the image you can see Baily's Beads. This image was shot on 15 January 2010 at the northern edge of the antumbral path of the eclipse.

Cell phones usually have a very small focal length, and a small sensor. The image of the sun is very small for the crescent and the annulus to be visible clearly. You could attach the cell phone behind the eyepiece of a binocular for a better image size. For this kind of photography (Afocal) to work, you need to put a solar filter in front of the binocular, and never behind the eyepiece of the binocular. Take care to completely cover the other lens of the binocular. You also need to attach the binocular to a tripod for stability.

Stability: As the focal length increases, the stability of the mount also needs to be increased. While a 200mm lens can be mounted on a sturdy tripod and the eclipse clicked, longer focal length lenses would require an equatorial mount. When the focal length increases to about a 1000mm then a very sturdy equatorial would be necessary to point the camera towards the Sun, without any vibrations as well as follow the Sun accurately, i.e. tracking.

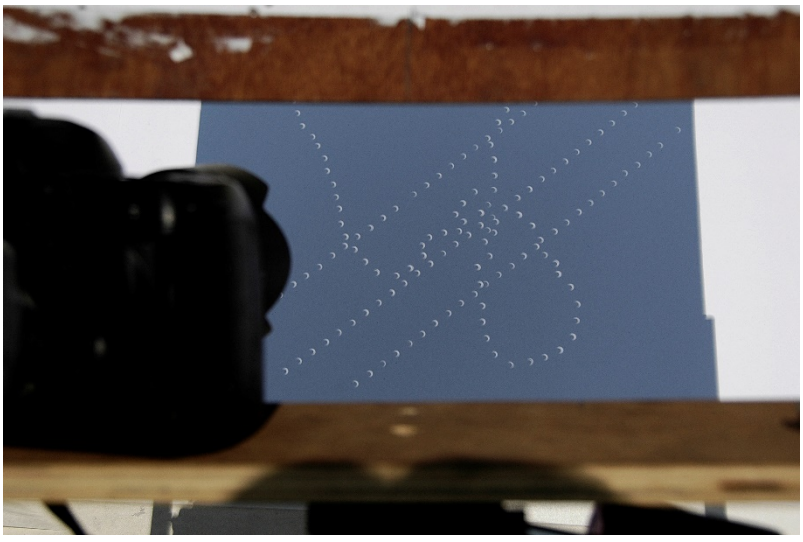


Composite image of the entire eclipse: A 24mm lens would produce an image of the sun which is 0.22 mm in diameter, very small, but the entire field of view of a 24mm lens would be large.

Using a crop sensor (22.2 x 14.8 mm) the field of view using a 24mm lens would be more than 50° on the larger side.

Using a full frame sensor (36 x 24 mm) the field of view using a 24mm lens would be 85°. Using such a wide angle lens you can frame the entire sequence of the eclipse in its wide field of view. Keep the camera stationary and tied down solid to a rigid structure and set up a periodic sequence of exposures. Later you can combine exposures shot at regular intervals to make one composite image of the entire eclipse

Pinhole eclipses, eclipses under the trees: Remember the pinhole camera? You can make pinholes in a cardboard or sheet of plywood and project eclipsed on a white sheet or on any other surface. As the eclipse progresses the shape of the image from these pinholes will change, first into crescents, then at the time of annular eclipse, into doughnuts, and then back again into crescents, but facing the opposite direction now. Look under the trees, there are eclipse shapes scattered all over, from the pin holes formed by the leaves in the trees. Look at the shadows, they are getting sharper and sharper as the eclipse progresses.



Photographing Baily's Beads: What are Baily's Beads? When the limb (periphery) of the Sun is being obscured by the Moon at the time of second and third contact, and the valleys and hills present on the lunar limb break the Sun into beads. There is good amount of preparation required before hand for capturing Baily's Beads.

To maximise the appearance as well as duration of Baily's Beads you need to position yourself correctly at the edge of the antumbral path. Such a calculation for location selection can be performed from Xavier Jubier's website – www.xjubier.free.fr He also has a full-fledged application which can be downloaded freely from his website and installed on an Apple computer to perform analysis of Baily's Beads from various location on the edge of path. Alternatively for location selection you could use the free software called 'Occult' – which primarily deals with lunar occultations but has an excellent routine for generating exact simulations of Baily's Beads from the particular locations. You can even export movies of simulations from Occult software.

The focal length required to photograph Baily's Beads should be large, maybe starting from 500mm and going up as far as 2000mm. If you are using an even larger focal length such as 4000mm, which can capture only a part of the Sun, in between the second and third contact you would need to slew the telescope appropriately to the correct position.

The duration of Baily's beads is very small, especially if you are observing from the centreline. You need to shoot rapidly at the correct time of their appearance. Xavier Jubier's software called Solar Eclipse Maestro works beautifully. It can control 4 cameras simultaneously, shoot exposures with

time reference to contact points. The contacts points, i.e. local circumstances are dynamically calculated according to the exact location that you are observing from. The best part about this software is that you can leave the camera and enjoy the visual observation of the eclipse.

Tracking the sun: If you are using an equatorial mount and following the Sun precisely, do not forget to change the tracking rate to 'Solar'. Usually the mounts are set to sidereal tracking rate, which means that the mount will track the star accurately, but the Sun has a different rate and it will drift in the camera field of view.

Exposure control, bracketing: The camera's inbuilt meter would be able to accurately gauge the correct exposure that is required, with the solar filter covering the front of the lens. So you can keep the camera metering to 'spot metering', select the centre spot and camera will calculate the exposure correctly. The problem begins when the Moon covers the Sun and the camera meter won't work anymore. In case you want to change the metering mode to evaluative or average, that won't work because the entire area is dark and only a ring of Sun remains. To give a correct exposure you need to experiment before the eclipse, typically one day before the eclipse, at the same time when the middle of eclipse is scheduled. Note the correct exposure and use manual mode of shooting and bracket all your exposures. Use 3 brackets or even better 5 brackets, of full stops on either side of the correct exposure. The bracketed exposures will also help you in case of clouds passing in front of the eclipse.

How to shoot sequential shots at regular intervals? Most current DSLR models these days have a inbuilt intervalometer to shoot exposures at regular intervals. More than the internal camera intervalometer I trust the external intervalometer much more. They are far more reliable. I also use 'Magic Lantern' for my specific Canon Cameras to automate my exposure sequences. Magic lantern also has the facility of programming the bracketing in any way that you want.

Photographing surroundings: During a Solar Eclipse keep your attention to the surroundings too apart from the Sun in the sky. There are a lot of changes happening around you too. Light is reducing, flora and fauna are behaving like twilight, and there is excitement among the eclipse watchers too.