The Observation of Lunar Eclipses

by Helio C. Vital

Lunar eclipses are beautiful, interesting, and scientifically important events, which can be observed with very modest instruments and even by looking at the sun.The timing of two contacts, for example, can be carried out with small telescopes and allow us to calculate the radius of the Earth's shadow.For three decades, we have observed and investigated these events based on the analysis of tens of thousands of observations.As a result of this research, we reached a unique path worldwide in terms of empirical training on the predictability of total lunar eclipses, and since 2003, we have published our Portal de Eclipses Lunissolar (http://www.geocities.ws/lunissolar2003/) forecasts related to the contacts (limb and craters) and the brightness of the Moon, sometimes, even considering the influence of large vulcanic explosions.It also contributed to you so that, having a broader collection of observations, we could better understand the influence of the terrestrial atmosphere on the visual characteristics of the totally eclipsed Moon and, consequently, we could improve even more our forecasts.

Pre-Eclipse Activities

The meticulous planning of the activities to be carried out during a lunar eclipse is of fundamental importance for the guarantee of the quality of two observational data and must be carried out carefully.It is recommended to the observer that, in the days prior to the event:

(1) Use a planetary program to simulate the appearance of the sky during the eclipse, recording the apparent positions (height and azimuth) of the Moon.Isso will help in the choice of the observation site.Also check if there are obstacles on the horizon that could harm the observation of the eclipsed Moon.In the case of total eclipses, it is also necessary to select the main stars or bright planets (and their magnitudes), to be used to estimate the brightness of the Moon.

(2) Plan the activities to be carried out and the instruments to be used in your observations.Among the main activities, we suggest, in descending order of scientific importance: - Estimate the visual magnitude of the Moon and/or the Danjon Number during totality several times if possible, to determine the brightness curve of the fully eclipsed Moon; - Time the hours in which the edge of the shadow (or umbra, not the case) crosses the center of the main lunar craters (secondary contacts) and the lunar limb, starting or ending the partial and total phases of the eclipse (primary contacts); - Photograph, film or make sketches of the totally eclipsed Moon; - Register the hour of the first perception of the twilight;

(3) In the nights that precede the eclipse, the observer should familiarize himself with the craters (identification, location, characteristics) whose contacts he intends to time;

(4) Hours before the eclipse, the instruments to be used for the observation should be verified: watch, lantern, light, pencil, laptop, pencil and paper, camera (on tripod with

charged battery and, if possible, with an outstanding battery), telescope with a brighter eyepiece (30 to 70 times magnification) and binoculars (if possible, um 7x50).The lighting conditions of the environment must be tested to certify that they will be appropriate for consulting the map of the Moon or of the sky during the timings and estimates of brightness.

(5) Furthermore, the watches must be adjusted, using a source of hourly signals with an uncertainty of less than 1 second.It must also be true, or record the geographic coordinates (latitude, longitude and altitude) of the observation site.

Activities in Partial Phases

(1) Timing

(a) Identification of the edgeof the Umbra The timing of contacts is hampered by the diffuse and irregular appearance of the edge of the shade, so I recommend using the lowest telescopic magnification available, preferably 40 to 50 times.For this reason, we recommend that you choose to use the brightest eyepiece of your telescope.On the edge of the umbra, which essentially depends on the contrast, corresponds to the imaginary line, along which, the darkening of the eclipsed disk occurs more abruptly in the direction of the shadow's direction, or where the light gradient is maximum.It should not be confused with the end of the penumbra, where only a small fraction of the solar disk would remain visible to a hypothetical lunar observer (red and orange lines in Fig. 1).On the other hand, the edge of the umbra is not located inside the dark seashore, where the density of the shadow has stabilized at its maximum value (yellow line in Fig. 1).Therefore, it corresponds to an intermediate position, at the beginning of this footing (green line in Fig. 1).

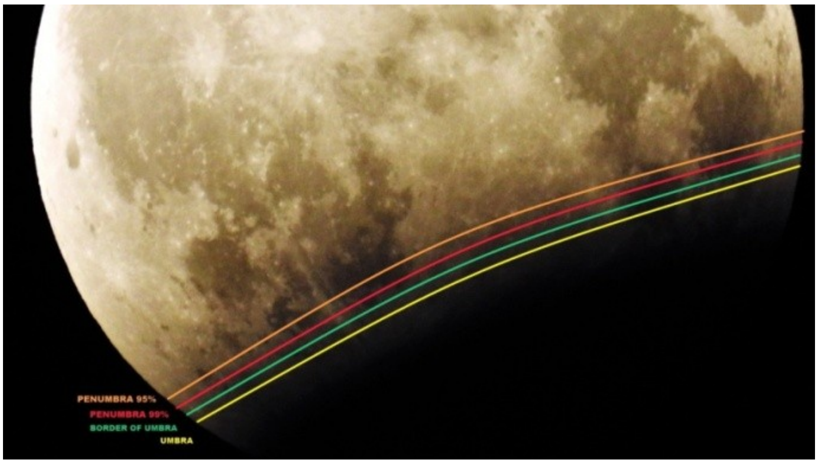

Figure 1 – Identification of the diffuse edge of the umbra

(b) Timings of Primary Contacts [U1 (beginning of partial eclipse), U2 (beginning of total eclipse), U3 (end of total eclipse) and U4 (end of partial eclipse)]

Although less accurate than crater contacts, limb contacts are also important and must be timed as well.Theoretically, each of them would correspond to a point on the lunar limb that undergoes a sudden variation in brightness, caused by internal or external tangency with the umbra.In the minutes that precede the end of a partial eclipse, for example, it is common to have the singular impression that the edge of the umbra is thinning and disappearing as it approaches the lunar limb.The observer must plan his observation, based on the contact times informed in Lunisolar (http://www.geocities.ws/lunisolar2003) for all lunar eclipsesobservable from Brazil.Also consider that differences in relation to predictions greater than 1 minute usually denote deficiencies or gross errors associated with timings.

(c) Timing of Secondary Contacts (contacts with the main craters)

On the nights before the eclipse, recognize the craters whose contacts you intend to time, trying to memorize their names, positions and features. We recommend that you use the map in Fig.2, published by Sinnott, editor of Sky&Tel Magazine.

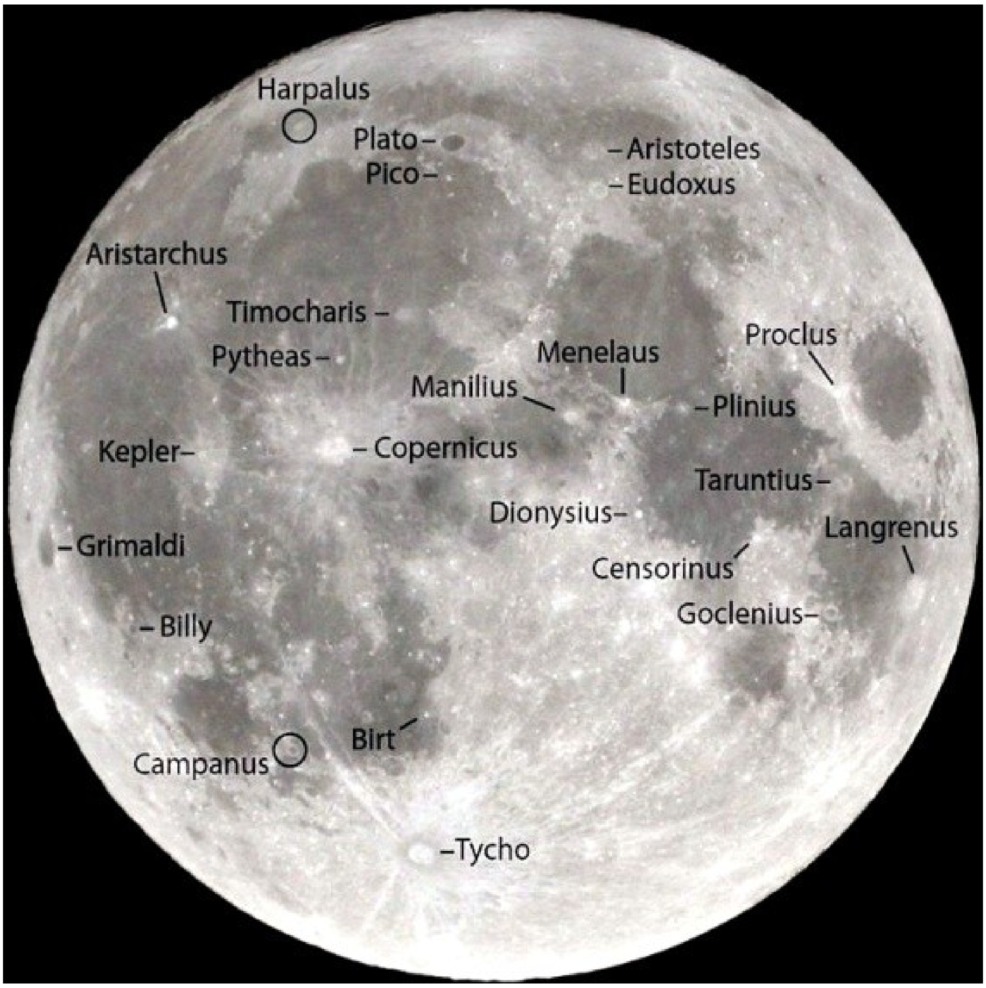

Figure 2 – Map of the Moon for Identification of Main Craters Courtesy: Roger Sinnott (Sky&Tel.)

You can choose a larger crater cluster of 15-25 craters if you are experienced in this activity, however we recommend a modest selection for beginners, 5-10 craters is preferred. In your planning, avoid choosing craters with contact times very close to each other, to avoid embarrassment at the time of observation, choosing those that you can identify more easily. Try to visualize the edge of the umbra in all its extension when it crosses the center of the crater, that is, at the instant of contact. If there is an opportunity, take the opportunity to check if you are "calibrated", comparing the instants you have already timed with the predictions, to verify the need for a fine adjustment in your way of identifying the edge of the umbra, before proceeding with the timing of the others. craters of your planning. In practice, many observers inadvertently adopt the red line instead of the green line. For each chosen crater, the time (hour, minute and second) in which the edge of the umbra crosses the center of the crater, either covering it (first partial phase, when immersions occur) or uncovering it (second phase partial, when emergences occur). Statistics show that the average uncertainty in times recorded by experienced observers is generally within ± (0.2 to 0.5) min.

(d) Photographic or Video Recordings of the Umbra's Passage through the Disk With your camera on a tripod and focusing at infinity, try to obtain photographic records (photos or videos) of the two partial phases.

(e) Partially Eclipsed Moon Brightness Estimates If you have time, try also to estimate the brightness evolution of the partially eclipsed Moon, using the brightest planets and stars in the comparison.Remember that the Moon's magnitude usually ranges from -9 to -3 in this phase.Thus, observed through an inverted 7x50 binocular, it should have magnitudes between -4 and +2.See more details below on the inverted binocular method.But be careful not to miss timings of the craters on your list, which at this stage are much more important.

Activities in the Total Phase

Determining the Moon's light curve during totality is arguably the most important scientific activity, given that eclipse brightness estimates are surprisingly rare.Some observational activities suggested for the totality, in descending order of scientific importance, are:

(1) Estimates of the Visual Magnitude of the Moon by the Inverted Binocular Method

The inverted binocular method, perfected by (Vital et al.), should be used to estimate the visual magnitude of the Moon during an eclipse.It consists of observing stars close to the eclipsed Moon with one of the eyes unarmed while the other view contemplates the Moon through the objective of one of the monoculars, instead of the eyepiece, trying to compare the brightness of the Moon with the brightness of the surrounding stars.Correction for loss of brightness is done later.For a 7x50 binocular, this loss usually corresponds to approximately 5.0 magnitudes.This means that if, in the middle of a total lunar eclipse, we notice that the Moon, observed through the wrong side of the binoculars, appears to have an intermediate brightness between a star of magnitude 2.0 and another of 2.6, being twice as close to the starbrighter, we can say that we estimate the magnitude of the Moon at: (2.0x2+2.6x1)/(2+1)-5.0=2.2-5.0= -2.8. This value would correspond to a moderately bright eclipse.Ideally, the exact value of this correction for the loss of brightness, which we know approaches 5 magnitudes for 7x50 binoculars, is determined experimentally.For example, Venus, Jupiter or the lunar crescent could be used in your determination.It is important to point out that the theoretical value of this correction, which is widely used by foreign observers, tends to significantly underestimate it, often causing the estimated brightness of the Moon in the middle of the eclipse to be overestimated by approximately half a magnitude.When choosing the comparison stars, remember to preferentially include reddish stars (closer to the color of the fully eclipsed Moon) and to exclude variable stars.If possible, perform several brightness estimates in order to construct the eclipse light curve.Also consider that the estimate of the lowest brightness of the Moon, which is usually observed in the minutes close to the center of totality, is the one of greatest scientific value.

(2) Visual Magnitude Estimates of the Moon by Defocusing

Another method to measure the brightness of the Moon, considering that it appears as a disk, in contrast to the punctual stars, is to blur it and try to compare it in magnitude with the neighboring stars, which will also be out of focus. For this, a diverging lens can be used. Another option, if you have myopia, would be to try a comparison without glasses.

(3) Estimates of Eclipse Brightness by the Danjon Method

Danjon created a scale related to the brightness of total lunar eclipses, described in Tab.1.

Table 1 - Eclipse Brightness Scale Created by Danjon

L (Danjon Number)	Appearance of the Moon
0	Very dark eclipse. Disk almost invisible to the naked eye.
1	Dark Eclipse. Gray or brown disk with details that are difficult to perceive
2	Dark red or rust-colored disk, darker in the center
3	Brick-colored disk with usually yellowish edge, lighter
4	Bright eclipse. Disk in orange or copper color and very light bluish edge

Try to avoid assigning extreme values (such as L=0 and L=4) to the Moon's disk, as in practice they rarely occur.Also consider that most inexperienced observers tend to underestimate L. We also recommend using decimal estimates.For example, let's assume that in the midst of totality, we come to the conclusion that 2/3 of the Moon's disk is brick-colored and 1/3 is reddish (darker), reminiscent of rust.It would then be reasonable that, based on Tab.1, our estimate for the Danjon Number would be: L = 2/3 x 3 + 1/3 x 2 = 2.7. In several eclipses, however, we noticed the need to segment (or section) the lunar disk into three areas of different brightness instead of two, as in the case illustrated in Fig.3.

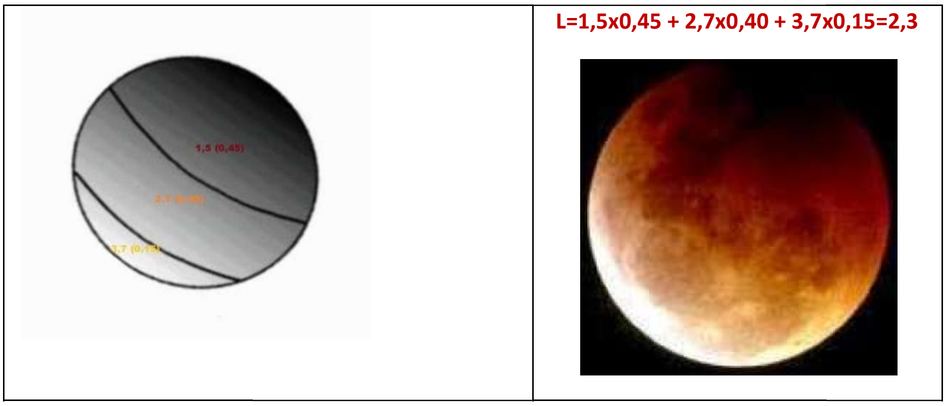

Figure 3 - Danjometry by Segmentation (Method created by the author)

The average value of L estimated can be easily correlated with the visual magnitude of the Moon by a correlation deduced by the author:
http:///www.geocities.ws/lunisolar2003.

(4) Photographic or Video Recordings of the Passage of the Umbra With your camera on a tripod, with the focus set to infinity and the flash off, try to obtain photographic records (photos or videos) of the total phase of the Moon, using different magnifications and including nearby stars and the horizon in the records, when possible.

(5) Sketches of Color and Gloss Distributions Draw the configurations presented by the lunar disk. All observational records must include times of observations. In addition, the coordinates of your site, atmospheric conditions (cloudiness, transparency and atmospheric stability) and the main characteristics of the instrument (aperture, focal length and magnification) must be included in your report. Always try to share your observations, making them accessible to those capable of publishing and/or analyzing them, not forgetting to send them to our eclipse portal (**lunisolar@gmail.com**).

Thank you very much for your attention and participation! Good luck with your observations!