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Young Moon Visibility Criterion Based on Crescent Illumination and Sky Brightness Contrast Model

[1]*Ahmed Kamil Ahmed and* [2]*Abdul Halim Abdul Aziz*

[1]School of Physics, Universiti Sains Malaysia, 11800 USM Pulau Pinang, Malaysia
[2]Department of Astronomy and Space, College of Science, University of Baghdad, Baghdad, Iraq

Abstract: The aim of this research is to present a new criterion for earliest crescent visibility based on the brightness difference between the young crescent and its background sky at sunset. In this work, 141 and 52 of lunar crescent observations from Malaysia and Iran respectively has been studied and analyzed. The data collected consisted of visible and non-visible observation data (naked eye and optically aided). The results indicated that the Moon's percentage illumination (or Moon's phase) must be $\geq$ 0.52 % $\pm$ 0.10 % and 0.39 % $\pm$ 0.10 % for Malaysia and Iran respectively. The average sky brightness during sunset measured was 6.80 $\pm$ 1.13 magnitude/arcsecond^2.

Key words: Moon Visibility · Crescent Illumination · Sky Brightness

INTRODUCTION

After conjunction, the first lunar crescent visible to the eye is called Hilal. The crescent sighting is used to determine the beginning of new Islamic month [1]. There are two approaches to determine the first visibility of lunar crescent, empirical and theoretical. The empirical approach is based on the selected observed parameters such as the Moon's age, altitude or elongation, etc. to create a visibility criterion. The theoretical approach relies on known physics to derive mathematical visibility models [2].

The problem here is to predict, from astronomical conditions, whether a new Moon can be sighted at a given location. Much effort has been put by the astronomers to match predictions with observations. Contrary to common belief, young crescent visibility has been difficult to predict accurately despite great strides being made in positional astronomy and related sciences. We hope this work will provide some insights into this issue and offer a scientific solution to a religious issue.

Atmospheric factors such as turbulence in the air, humidity, dust and pollution also contribute to visibility of the new Moon. This is especially true when the crescent is low across the sky, near the horizon, as it always is at the start with the lunar month. In addition, these effects vary from one position to another and from one evening to the next [3]. The physiological variations of the observers' eyesight also contribute to variability of the results. However, it is a requirement that the crescent must eventually reach the human eye, whether aided or unaided.

The contrast in the context of the first lunar crescent visibility is defined as the ratio of two components, the luminance of the lunar crescent and the brightness of the sky [4]. In particular, the first astrophysical model that studied the earliest visibility of new lunar crescent was due to Bruin [5], in which the crescent brightness and that the twilight sky has taken into consideration [6]. The contrast between the Moon's brightness and the background sky is determined and compared to the minimum brightness that the naked human eye (or the telescope) can see. This results in a prediction model for sighting the young crescent on any specific night from any specific location [7].

The most complete model has been proposed by Schaefer [8] as well as Doggett and Schaefer [9]. This model calculates the quantity of (Rs) according to the formula: Rs = log [Rcalc/Rmin(vis)], which represent the logarithmic ratio between the actual brightness of the Moon to the required brightness of the Moon for

Corresponding Author: Ahmed Kamil Ahmed, School of Physics,
Universiti Sains Malaysia, 11800 USM Pulau Pinang, Malaysia.

sighting. Atmospheric, geographic and physiological factors affect the quantity Rmin(vis). The quantity of (Rs) is a measure of the probability of crescent sighting under the given observing conditions. Sultan [10] tried to develop a new method for predicting first crescent sighting based on the twilight brightness and light intensity coming from the thin lunar crescent reaching the eye, encroaching upon the limits of human eye perception. Qureshi [7] exhibited work on the minimum magnitude and twilight sky brightness with the different crescent widths. The elevation above sea level, the local temperature and relative humidity have been taken into account based on the algorithm by Schaefer [11]. Moon's magnitude and brightness have been compared with the sky brightness to develop the minimum visibility curves. From these quantities, an empirical criterion was derived. The criterion is based on the more than 450 observational data by Odeh [12]. This study has suggested new visibility ranges and best time for crescent sighting. Mohd Nawawi *et al*. [13] approached by using sky illumination measurement (light meter) to explain the lunar crescent visibility. The sky illumination measurements were performed in Teluk Kemang, Malaysia from 2007 until 2009. They found the range of sky illumination for visible lunar crescent was 2.95 to 92.80 lux. In addition, the relative altitude must be 5° at the solar depression angle of 0.5°. Finally, ÖZLEM [14] proposed the indigenous criterion that used the two reliable parameters, altitude and crescent width and made it possible to forecast the visibility for any phase of the Moon, not just limited to crescents.

In this research, we determine the value of sky twilight brightness and correlate with the Moon's illumination. We present a new criterion for earliest crescent visibility based on the brightness difference between the young crescent and its background sky during sunset.

Observational Data: Two detectors have used in this study namely the human eye and the Sky Quality Meter (SQM-LU). The stimulus is of course light and both represent logarithmic changes. A Unihedron Sky Quality Meter, designed by Doug Welch and Anthony Tekatch, was used. The SQM used light-to-frequency silicon photodiode; the light sensor (TSL237) provides the microcontroller with brightness reading that has been temperature compensated and calibrated. The sensor is covered with an HOYA CM-500 filter to block near-infrared light. The general block diagram of SQM-LU is shown in Figure 1.

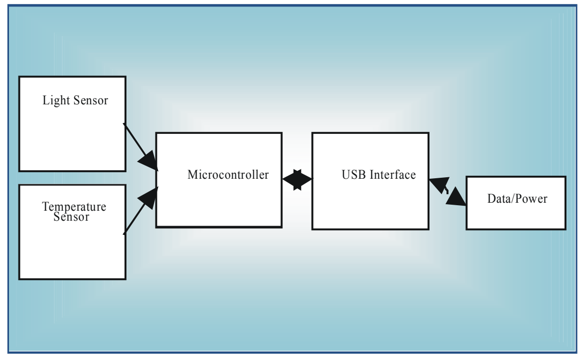

Fig. 1: Illustrates the basic elements of SQM-LU

Fig. 2: Sky Quality Meter; model LU (front and back of unit)

SQM measures the brightness of the night sky in unit of magnitudes per square arc second. The response band has been chosen for spectral purposes and gives magnitudes closely corresponding to those seen by a light-adapted human eye. The magnitude per arc second scale is logarithmic. Therefore, large changes in sky brightness correspond to relatively small numerical changes. Figure 2 depicts the unit of Sky Quality Meter.

The observations of western sky brightness have performed between September 2012 and January 2013 intermittently [14]. The Sheikh Tahir Observatory has been chosen for data collecting in accordance of photometric moonless nights. It's situated in Pantai Acheh, Pulau Pinang, Malaysia. The geographical coordinates of latitude is 5° 25' North and longitude is 100° 12' East as well as the altitude is 40 m above sea-level. The SQM is fixing at altitude about 5° above the

horizon facing an obstruction free open sea in the western sky. Special all-round hood has placed in front of the detector for averting unwanted stray light coming from the sides. Data has been collected every five minutes for approximately two hours covering the period of sunset to the onset of astronomical twilight. Positions of the Moon and Sun have determined using the XEphem based routines. The SQM has been calibrated using an NIST standard lamp in an integrating sphere radiometer and retain a precision of 10 %.

Calculation of Moon's Illumination and Crescent's Width: The key factor in the earliest crescent visibility is the Moon's elongation, also referred as the Arc of Light (ARCL). In terms of (ARCL) the Moon's phase (or illumination) is given by [15]:

$$\text{Illumination} = (1 - \text{Cos (ARCL)}) / 2 \quad (1)$$

Alternatively, the illuminated crescent width (W) may be used as follows [16]:

$$W = D \times \text{Sin}^2 ((\text{ARCL}) / 2) \quad (2)$$

where: (D) is the lunar diameter.

RESULTS AND DISCUSSION

Sky Brightness: The sky photometry has been carried out from September 2012 to January 2013 intermittently. Table 1 tabulates the dates. Data on 16 October 2012 has not been used as the sky totally covered with cloud and raining.

Figure 3 shows the averaged measured light curve of evening sky from sunset to astronomical twilight, fitted with a polynomial fit (R^2 value = 0.9889) as follows:

$$Y_o = -6\times10^{-7} X_o^6 - 5\times10^{-5} X_o^5 - 0.0011 X_o^4 - 0.0017 X_o^3 + 0.1141 X_o^2 - 0.4177 X_o + 6.3734 \quad (3)$$

Visibility Criterion: We studied 141 and 52 of young crescent observations from various locations and observers in Malaysia (JAKIM archive) and Iran [17] respectively. The data included successful (visible) and unsuccessful (non-visible) observations (optically aided and naked eye). The results have been displayed in Figure 4, based on topocentric positions, at the time of local sunset. It shows the relationship between the Moon's phase (%) and the simulated sky brightness (magnitude/arcsecond^2) obtained from Figure 3 for both Malaysia and Iran (visible and non-visible) as shown:

Table 1: Observation dates for sky brightness measurements at Sheikh Tahir Observatory

Date	Duration	Weather
14 September 2012	Approximately 2 hours	Cloudy
15 September 2012	Approximately 2 hours	Cloudy
16 September 2012	Approximately 1.75 hours	Partly Cloudy
14 October 2012	Approximately 2 hours	Mostly Cloudy
16 October 2012	Approximately 2 hours	Cloudy and Rainy
11 January 2013	Approximately 1.8 hours	Mostly Cloudy
12 January 2013	Approximately 1.7 hours	Partly Cloudy
13 January 2013	Approximately 1.7 hours	Mostly Cloudy

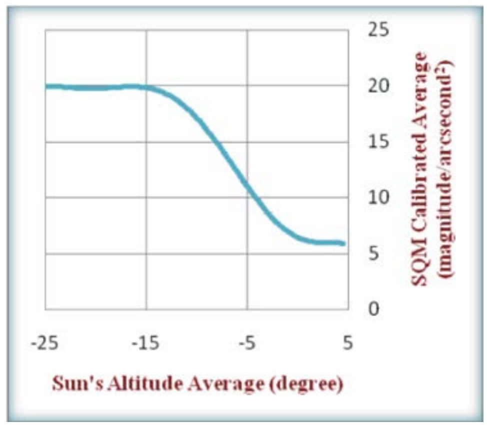

Fig. 3: Show the relationship between averaged SQM calibrated outputs versus the Sun's altitude

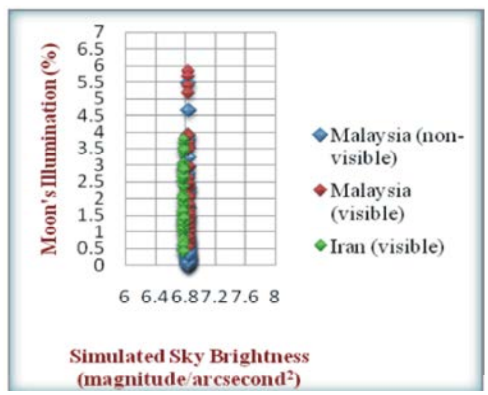

Fig. 4: Shows the relationship between Moon's illumination versus simulated sky brightness, at the time of local sunset for Malaysia and Iran data

DISCUSSION

We take that Moon's illumination is the key factor that contributing to young crescent visibility. We choose the time of sunset as the standard reference frame to assess a new Moon's visibility by taking its illumination (i.e. brightness contrast) against the background sky. The background sky brightness will be an observational constant since it is always at the time of sunset.

From Figure 4, the threshold visible observations for Malaysia were at 0.52 % illumination while for Iran, it was at 0.39 %. The average of sky brightness was 6.8 magnitude/arcsecond^2 for both Malaysia and Iran. It is noted that non-visible observations for Malaysia showed as occur in a range of illuminations from 0 % to 5.45 %. This means that the threshold values for visibilities are also the minimum recorded during the observation. Non-visibility at threshold values can be a result of many variable factors that is hard to take into account when formulating a general criterion such as clouds at the horizon (much of Malaysia's observations is hindered by such clouds), aerosol content of the atmosphere at the observing site, instruments used and not least the eyes of the observers themselves. Between the two results, we regard 0.39 % illumination as the lowest observed condition during sunset while the Malaysian value of 0.52 % illumination represents a value suited for the Malaysian more humid, warm and cloudy equatorial weather conditions.

CONCLUSION

We found two empirical values for contrast based youngest crescent Moon visibility criteria, one based on Malaysian data and the other on Iranian data. For crescent visibility the Moon's percentage illumination (or Moon's phase) must be $\geq$ 0.52 % ± 0.10 % and 0.39 % ± 0.10 % for Malaysia and Iran respectively. The average sky brightness during sunset found to be 6.80 ± 1.13 magnitude/arcsecond^2. Based on our study, we conclude the 0.39 % illumination is the minimum criterion for young crescent visibility, while 0.52 % illumination is suited for more humid and warmer equatorial regions.

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REFERENCES

1. Raharto, M., E.P. Arumaningtyas and N. Sopwan, 2010. Theoretical Contrast for Hilal Visibility Prediction at Pelabuhan Ratu. AIP Conf. Proc., 1325: 105-108.
2. Fatoohi, L., J. Stephenson, F.R. and S.S. Al-Dargazelli, 1999. The Babylonian First Visibility of the Lunar Crescent: Data and Criterion. JHA, xxx, 51-72.
3. Guessoum, N., 2010. New Moon on the Horizon: An Astronomer's Guide to Solving the Start of Ramadan [Online]. Available from World Wide Web: http://www.nature.com/nmiddleeast/2010/100809/.
4. Hoffman, R.E., 2003. Observing the New Moon. Mon. Not. R. Astron. Sco., 340: 1039-1051.
5. Bruin, F., 1977. The First Visibility of the Lunar Crescent. Vistas in Astronomy, 21: 331-358.
6. Kumari, B.P, S.H. Kulkarni Jadhav, D.B. Londhe, A.L. and H.K. Trimbake, 2008. Exploring Atmospheric Aerosols by Twilight Photometry, Journal of Atmospheric and Oceanic Technol., 25: 1600-1607.
7. Qureshi, M.S., 2010. A New Crescent for Earliest Visibility of New Lunar Crescent. Sindh Univ. Res. Jour. Sci. Ser., 42(1): 1-16.
8. Schaefer, B.E., 1987. An Algorithm for Predicting the Visibility of the Lunar Crescent. Proceedings of the Lunar Conference, International of the Institute of Islamic Thought, Herndon, Virginia, United States, 11: 1-12.
9. Doggett, L.E. and B.E. Schaefer, 1994. Lunar Crescent Visibility. Icarus, 107: 388-403.
10. Sultan, A.H., 2003. Hijri Calendar & Lunar Visibility: Physical Approach. 3rd Islamic Astronomical Conference (Applications Astronomical in Islamic Shari'a), October 20th - 22nd, Amman, Jordan.
11. Schaefer, B.E., 1988. Visibility of the Lunar Crescent. Quarterly Journal of the Royal Astronomical Society, 29: 511-523.
12. Odeh, M.S., 2004. New Criterion for Lunar Crescent Visibility. Experimental Astronomy, 18: 39-64.
13. Mohd Nawawi, M.S.A., M.Z. Zainuddin, N. Ahmad, M. Abdul Niri, S. Man, R. Abdul Wahab, K. Ismail and N.H.A. Zaki, 2012. Application of Scientific Approach to Determine Lunar Crescent's Visibility. Middle-East Journal of Scientific Res., 12(1): 96-100.
14. ÖZLEM, A., 2014. A Simplified Crescent Visibility Criterion [Online]. Available from World Wide Web: http://www.icoproject.org/pdf/ozlem_2014.pdf.
15. Qureshi, M.S., 2005. Computational Astronomy and the Earliest Visibility of Lunar Crescent. University of Karachi, Pakistan, pp: 1-20.
16. Ilyas, M., 1997. Astronomy of Islamic Calendar. Kuala Lumpur: A.S. Noordeen.
17. Hasanzadeh, A., 2012. Study of Danjon Limit in Moon Crescent Sighting. Astrophys Space Sci., 339: 211-221.