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The Limitation of Optical Equipment in New Crescent Moon Visibility: Insight from 27 Years of Observation Data in Sarawak, Malaysia

(Had Peralatan Optik dalam Kenampakan Anak Bulan: Pemerhatian daripada Data Cerapan 27 Tahun di Sarawak, Malaysia)

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ABSTRACT

New Crescent Moon visibility has been extensively studied throughout history due to its undeniable importance in determining the Islamic calendar. Previous visibility models have relied on linear statistical theory, which does not fully account for the circular nature of the variables involved such as atmospheric turbulence, light pollution and limitations of optical equipment. In order to address this matter, this study proposed a new visibility using the limitation of New Crescent Moon sighting via an optical equipment. Data were categorized into two visibility categories, namely: visible to the theodolite and potentially requiring telescopes based on the night visibility that has been captured. The categorization is determined based on the residual local data observations collected in Sarawak, spanning from 1997 to 2023. The proposed limitation was applied by 31 positive data from 167 observations which results indicate that the visibility based on moon ages and altitude of the moon features parameter. This study suggested that the limitation of sighting the New Crescent Moon using an optical equipment range between 11 and 13 h of moon age with a moon altitude of 5° and 6°. These new criteria have a significant positive impact on enhancing the likelihood of observing the New Crescent Moon and improving the accuracy of the Islamic calendar especially in Sarawak.

Keywords: Correlation; limitation; New Crescent Moon; observation equipment; Sarawak

ABSTRAK

Kajian kenampakan Anak Bulan sangat penting dalam menentukan tarikh dalam kalendar Islam. Sebelum ini, parameter kenampakan Anak Bulan banyak bergantung pada teori statistik linear yang tidak mengambil kira faktor luaran seperti keadaan atmosfera, pencemaran cahaya dan keterbatasan peralatan optik. Oleh itu, kajian ini meneliti had kenampakan Anak Bulan dengan memberi tumpuan kepada keterbatasan peralatan optik dalam cerapan Anak Bulan. Data dikategorikan kepada dua jenis kenampakan iaitu boleh dilihat dengan theodolit dan boleh kelihatan menggunakan bantuan teleskop berdasarkan kenampakan. Pengelasan ini berdasarkan data cerapan yang dilakukan di Sarawak digumpulkan dari tahun 1997 hingga 2023. Limitasi yang dicadangkan menggunakan 31 data positif daripada 167 data cerapan bagi menentukan hubungan antara umur Anak Bulan dan altitudnya ketika kenampakan berlaku mengunakan peralatan. Hasil kajian menunjukkan bahawa Anak Bulan boleh dikesan menggunakan peralatan optik apabila usianya berada dalam julat 11 jam hingga 13 jam dan berada pada altitud 5 darjah dan 6 darjah. Penemuan ini memberikan sumbangan penting dalam meningkatkan ketepatan penentuan awal bulan Islam, terutamanya di Sarawak.

Kata kunci: Anak Bulan; korelasi; limitasi; peralatan cerapan; Sarawak

INTRODUCTION

The development of equipment is one of the characteristics in scientific activities, especially in the transition into the Industry Revolution 4.0, including the field of Islamic Astronomy. Due to supporting human needs in this course, observation technology continues to rapidly integrate in an effort to understand the layout of universe's movement (Bruin 1977). This is also a factor when astronomy is included in the branch of science especially applying the material activities such as the use of optical equipment observation and theoretical activities (Ahmad Hariz et al. 2025). This aligns with recent efforts to refine moon visibility criteria, such as using modelling criteria to more accurately classify visibility levels either using unaided eye, optical aid or not visible based on parameter like moon age and moon altitude. The significance of this study provides value to the science of astronomy, which requires research to form criteria using optical equipment and identifying the level of limitation based on the equipment used when observing the New Crescent Moon for the purpose of Islamic calendar (Baharrudin 2002). In the past, the criteria were based on a different parameter that measured when observing for the New Crescent Moon sighting (Muhamad Syazwan et al. 2024).

Determining the visibility of the New Crescent Moon is a piece of wisdom that help predict the beginning of the Hijri calendar month. Therefore, astronomers have carefully examined the definition of a New Crescent Moon. It refers to the phase of the moon after conjunction Earth-Moon-Sun on the west horizon that appears on the first night until the third night. For new crescent moon visibility, both geocentric and topocentric calculations are used, with topocentric calculations being more accurate for local observations (M.S., M.S.A. & M.H. 2023). The key parameters are moon age (time since conjunction) and altitude at sunset, along with elongation (angular distance from the sun) and other factors like crescent width. Topocentric calculations account for the observer's specific location on Earth, providing a more precise view of the crescent's position and visibility compared to geocentric calculations which use the Earth's center just like show in Figure 1. The geocentric and topocentric perspectives offer different viewpoints when discussing the visibility of the New Crescent Moon. Geocentric calculations consider the moon's position relative to the Earth's center, while topocentric calculations account for the observer's specific location on Earth. This difference is crucial because the moon's apparent position and visibility can vary slightly depending on the observer's latitude and longitude, making topocentric calculations more accurate for predicting local sightings.

Ilyas (1994), an early modern astronomer, believes that the term 'New Crescent Moon' or in Islam refer as *hilal* that is the moon observed on the first night it appears, until the third night. After that, the new moon will move to full crescent moon phase. In New Crescent Moon phase, from a physical perspective, it is in very small sized that make it very hard to be seen and close to the position of the sunset (Fotheringham 1910).

In addition, the criteria are primarily based on the data related to the New Crescent Moon observed at the beginning of each Hijri calendar month. The variables subjected to measurement normally elongation, moon's altitude, sun's altitude, arc of vision, crescent moon width, lag time from sunset to moonset and crescent moon's age after conjunction. Selection of these parameters for the criteria are predominantly at achieving the minimal contrast required between the moon's brightness and the sky's illumination including another factor like parallax, reflection, light pollution and the weather pattern (Ahmad Hariz et al. 2024b). In essence, this study considered specific parameters with their definition as shown in Table 1 to ensure either the New Crescent Moon is sufficient to pronounced enough for the New Crescent Moon to be sighted using the moon's altitude and moon age based on the first visibility.

Various criteria developed in Malaysia limits the visibility of the New Crescent Moon using the naked eye method (Ahmad Hariz et al. 2024a). Malaysia, one of country members in MABIMS (Malaysia, Brunei, Indonesia and Singapore), which in 2021 these countries had reached a consensus on the adoption new criteria call *Imkanur Rukyah* for determining the beginning of a new month in their calendars based on the Figure 2. These criteria include ensuring that the moon's altitude at sunset being at a minimum of three degrees and the elongation between the moon and the sun to be at least 6.4 degrees (Nasir et al. 2024).

Hence, this study aimed to investigate inquiries related to the limitation of optical equipment used for observing the moon for theodolite and telescope. The specific focus was observation data provided by the Department of Mufti Sarawak. These sites in Sarawak are among the 29 locations designated for moonsighting activities in Malaysia. Therefore, this study discussed the limitations encountered when sighting the New Crescent Moon in Sarawak using their optical observation equipment. Then, the results will form a new criterion and be able to identify the optical equipment's limitations in determining the beginning of the New Crescent Moon especially in Sarawak.

METHODS

This study carried out New Crescent Moon sighting activities at all Sarawak observatories as shown in Figure 3, namely Stesen Hilal Teluk Bandung, Kuching (1° 45' 11" N, 110° 18' 53" E), Pusat Falak Bintulu (3° 12' 48" N, 113° 02' 56" E) and Pusat Falak Miri (04° 18′ 59″ N, 113° 57′ 27″ E). Historically, these sites were the first locations used for sighting the New Crescent Moon in Sarawak since establish of the Department of Mufti Sarawak around 1997.

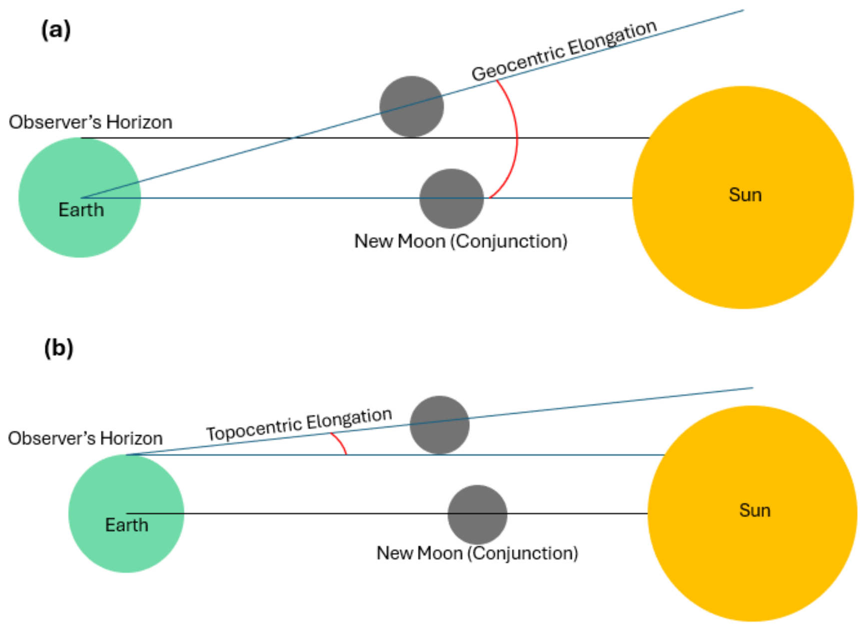

FIGURE 1. Global view of the variable's parameter after a conjunction Sun-Moon-Earth in perspective (a) geocentric and (b) topocentric

TABLE 1. Definition of moon altitude and moon age parameters

Parameter	Definition
Moon altitude	The angular height of the moon above the horizon, measured in degrees. It influences the visibility of the crescent moon and is affected by atmospheric conditions. This month's altitude parameter is usually used together with the sun's descent angle and the sun's zenith distance to obtain elongation
Moon age	The period of time from the occurrence of the Sun-Moon-Earth conjunction until the time of moonset or will also create the lag time parameter between sunset and moonset. Typically measured in hours or days. It indicates the moon's phase progression and affects its visibility

The observations were initially conducted only for three Hijri calendar months (29th of Syaaban, Ramadan and Zulkaedah), each year to determine the start of the Islamic month until 2013. Starting in 2004, observations were conducted using theodolite operated by surveyors and the New Crescent Moon sighting committee to validate the visibility of the New Crescent Moon if it is sighted (Bahagian Falak 2022). This study used various equipment and methods during the observations such as the naked eyes, theodolite and telescopes (Roslan et al. 2017). The images were then recorded using a Digital Single-Lens Reflex (DLSR) and Charge-Coupled Device (CCD) as shown in Figures 4 and 5.

Interviews were conducted to clarify related questions and obtain additional information. An interview is a method used for obtaining oral information through a face-to-face conversation process. This method aims to obtain information directly from several people involved in the field of observation and astronomy in Malaysia especially Sarawak.

Since the Department of Mufti Sarawak was established in 1997, assigned observers have relied solely on the naked eye to observe the New Crescent Moon. This method continued until 2004, when optical equipment was introduced to assist with observations. In general, the human eye has a diameter of approximately 4 mm and a width of 12.5 mm, hence, the amount of light that enters the eye is extremely limited (Fatoohi, Stephenson & Al-Dargazelli 1998). In contrast, the magnifying power of a telescope significantly enhances observation capabilities. A telescope with an 8-inch focal length is capable of capturing approximately 900 times more light compared to the unaided human eye. In contrast, a large-aperture telescope equipped with a 5-meter primary mirror can

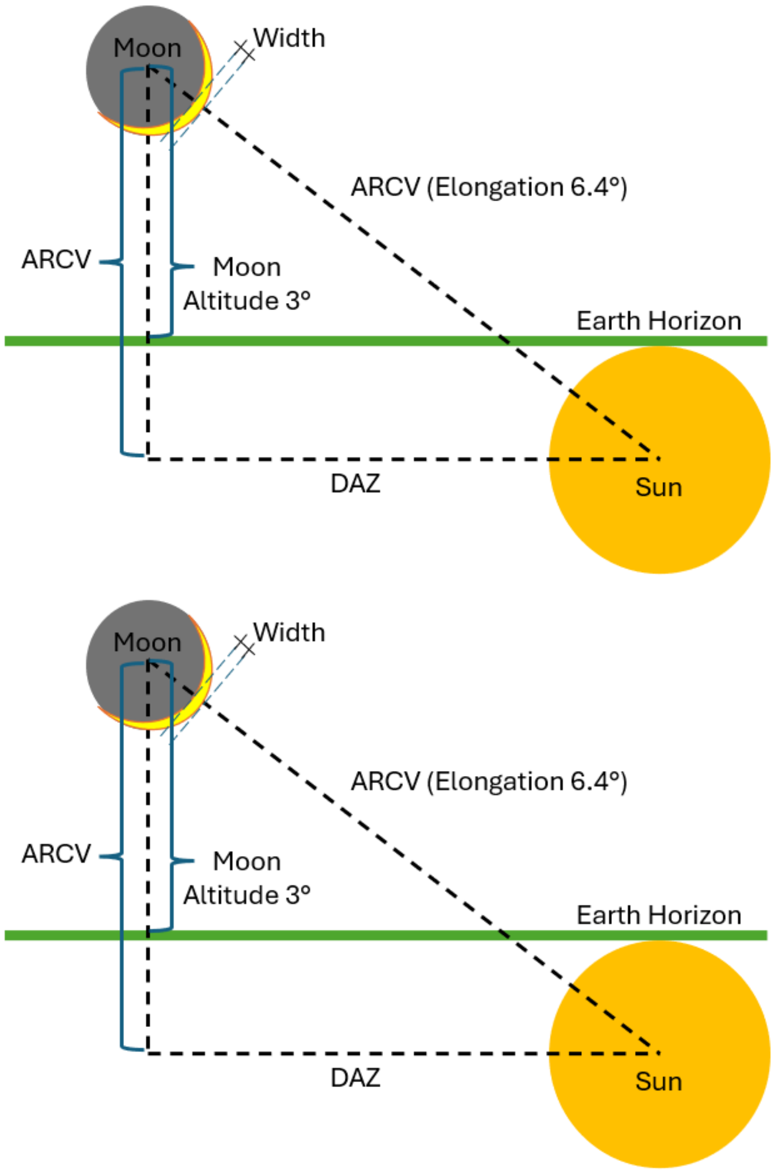

FIGURE 2. MABIMS criterion for determining the sighting of New Crescent Moon (Illustration from Nurul Kausar et al. 2014)

FIGURE 3. Moon sighting observation sites in Sarawak

gather nearly one million times the amount of light detectable by the human visual system. This substantial increase in light-gathering capacity significantly enhances the telescope's ability to observe faint celestial objects.

This study adopted the q-test when developing New Crescent Moon visibility criteria according to the limitations of the equipment by following the Yallop (1997) equation. The statistical q-test methods to evaluate crescent moon visibility as introduced by Yallop relative to the observable moon altitude and the age of the moon. These techniques enable a statistical estimation of the chance's crescent being viewed amidst different weather conditions and observational parameters.

Yallop's q-test for crescent visibility, the equation depends illuminated crescent and the background sky structures over it, defined using the following equation:

$$q = \frac{ARCV - \widehat{ARCV}}{10}$$

where ARCV denotes the actual contrast of the crescent moon as opposed to the theoretical threshold contrast for visibility and 10 is an observational normalization constant. Increasing q-values are associated with greater visibility of the crescent as shown in Table 2, where Yallop's model visibility has been ranked.

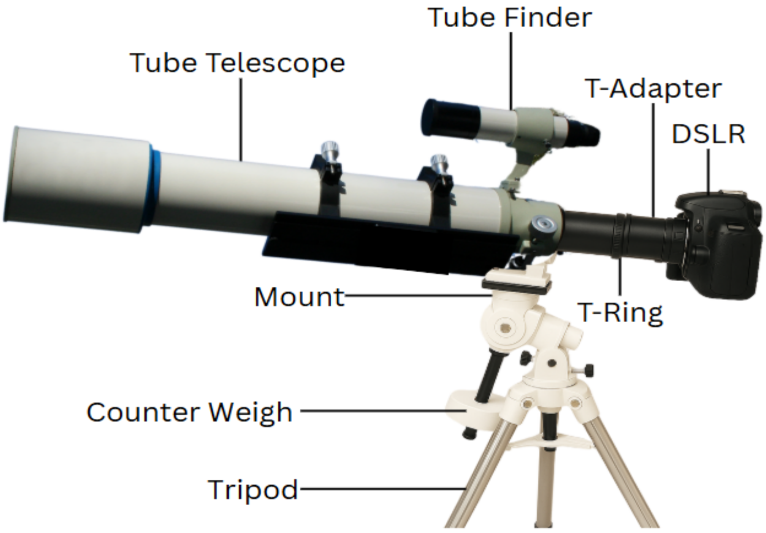

FIGURE 4. Equipment setup for moon sighting activity using telescope attach DSLR

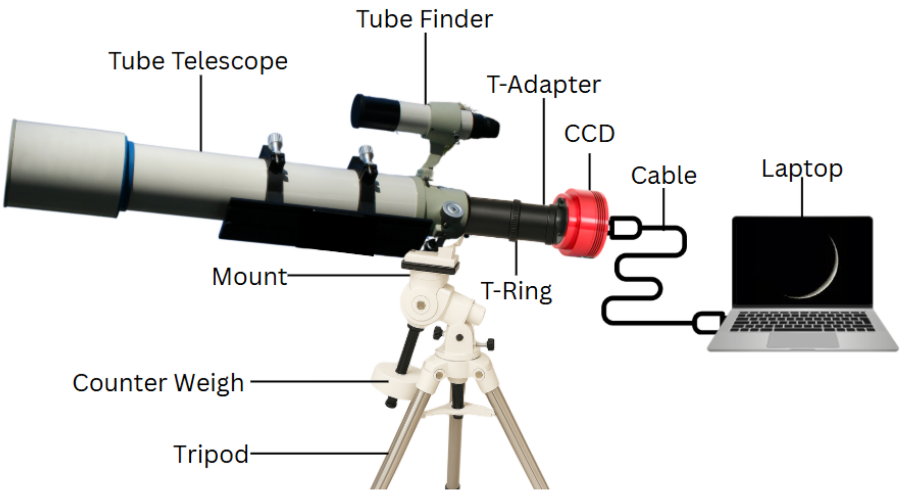

FIGURE 5. Equipment setup for moon sighting activity using telescope attach CCD

The q-test for moon altitude estimates whether the moon is high enough above the horizon to be possibly seen. This is formulated as:

$$q = \frac{(h - h_0)}{\sigma_h}$$

where h means the observed moon altitude in degrees; h_0 denotes the minimum threshold altitude for crescent visibility which is based on past works set at 5.0°, and σh is the standard deviation in measurements of altitudes which is assumed to be 1.0°. A q-value greater than 0 indicates that the moon is high enough to be seen, while a negative figure means that it is beneath the altitude limit and surrounding space.

The q-test for the moon has achieved a suitable age for a human to view it is called the moon age parameter. The formula is expressed as:

$$q = \frac{(A - A_0)}{\sigma_A}$$

where A refers to the observed moon age in hours after conjunction; A_0 is the fixed low value in the threshold moon age for uncloaked visibility which is empirically determined to be 15 h and σA is moon age measurement's standard deviation which is usually in the range of 1.5 to 2.0 h. A q-value greater than zero means that based on normal contour conditions the moon is old enough to be viewed, whereas negative value means the moon too young to be observable.

These q-tests are measuring to refine the prediction accuracy of New Crescent Moon visibility. Contrast visibility is primarily assessed by Yallop's model, who along with altitude and moon age-based q tests, focuses on the moon's position and age vertically in the sky accounting for the time of year. The integration of these methods forms a comprehensive structure for analysis of conditions for crescent sighting under varied weather conditions and for observational conditions.

For this study, the dataset included recordings of New Crescent Moon sightings using theodolites and telescopes. The main parameters obtained for each observation include moon altitude (degrees, arcminutes) which indicates the height of the moon above the horizon at the time of the observation, and moon age (hours, minutes), which indicates the time elapsed since conjunction (Maunder 1911). Q-test thresholds were determined by first converting moon age from hours and minutes to decimal hours, while moon altitude was converted from degrees and arcminutes into decimal degrees (McNally 1983). The q-test values were calculated using the lowest moon age and altitude for both theodolites and telescopes. These computed q-values were then compared with Yallop's empirical threshold to ascertain the visibility conditions.

This study also applied the same q-test on 31 data and found that the q-test values are higher than Yallop's threshold with a positive crescent sighting using an optical equipment is to be 12 h 59 min of moon age with a moon altitude of 05°44'08".

RESULTS AND DISCUSSION

New Crescent Moon activities continue to be the focus of the Islamic Affairs Officer in the Sarawak Mufti Department. They conduct observations every month at each observatory in Sarawak and the results help determine the beginning of the Hijri calendar based on the *Imkanur Rukyah* Criteria. Therefore, data on the New Crescent Moon's visibility from 1997 to 2023 kept by the Department of Mufti Sarawak were collected and analysed for the documentation of this study.

Practically, there is a slim chance for the naked eye to sight a New Crescent Moon. Therefore, observing the New Crescent Moon requires optical equipment, such as the theodolite and telescope that can support the naked eye (Nasir et al. 2025). This equipment has their limitations when determining the New Crescent Moon's visibility depending on the type of equipment and parameters used (Schaefer 1996). The Department of Mufti Sarawak provided datasets spanning from 1997 to August 2023 in which the study collected 167 data points over a period of 27 years, out of which 31 were considered observable as positive data. Remaining data was inaccessible due to obstructions from climate change disaster like haze, ever-changing weather patterns and minimal values for the qualitative indicators to be measured.

According to Table 3, there are 10 data observation records using theodolite as an optical observation equipment for sighting the New Crescent Moon at the Department of Mufti Sarawak. There are three recorded sightings of the New Crescent Moon on the first night of Hijri calendar and seven recorded sighting on the 30th night of the Hijri calendar. The highest recorded moon age for a New Crescent Moon observed using the theodolite was in October 2020 (Rabiul Awal 1442), at 40 h 14 min with an altitude 16°23'39". In contrast, the lowest recorded moon age was in March 2018 (Rajab 1439), at 22 h 08 min at 06°20'46". Based on this data, the New Crescent Moon will be visible, when using the theodolite as an observation equipment, only if the minimum moon age is 25 h or more, or if the moon's altitude is at least eight degrees and above. Given this limitation, when evaluated using the q-test and data in table above, there could be eight successful observations using the theodolite, provided there are no weather related obstacles or other interfering factors.

According to Table 4, there are 21 recording of New Crescent Moon sighting using telescope equipments conducted at the Department of Mufti Sarawak. Six sighting were recorded on the 29th night of the Hijri calendar and 12 sighting on 30th night of the Hijri calendar. The highest recorded moon age for a New Crescent Moon observed

TABLE 2. The q-test types by Yallop (1997)

Types	q-test value	Justification
A	q>+0.216q	Easily visible to the unaided eye
B	−0.014<q<+0.216	Visible under certain atmospheric conditions
C	−0.160<q<−0.014	May need optical aid to find the thin crescent before it is visible to the unaided eye
D	−0.232<q<−0.160	Can only be seen with binoculars or a telescope
E	−0.293<q<−0.232	Below the normal limit for detection with a telescope

using a telescope was in September 2022 (Rabiul Awal 1444), at 36 h and 52 min with an altitude at 12°46'29". This observation was conducted using the Skywatcher Esprit 80MM ED. In contrast, the lowest recorded moon age was in November 2021 (Rabiul Akhir 1443), at 12 h 59 min with an altitude 05°44'08". This observation was conducted using the Skywatcher Evostar 120ED. Based on this observation and an average evaluation using the q-test, the New Crescent Moon will be visible using a telescope only if minimum moon age is 20 h or more, or if the moon's altitude is at least eight degrees and above. Based on this q-test, which used the data in table above for evaluation, there cloud be 16 successful observations using the telescope, provided there are no weather related obstacles and other interfering factors. This proposed limitation was based on data acquired from the Department of Mufti Sarawak. Therefore, in order to obtain equipment limitation based on the New Crescent Moon parameter and establish criteria for the visibility based on optical equipment, further research needs to be conducted (Zulkeflee et al. 2022).

The Q-Q plots for altitude and moon age provide crucial insights into their impact on the visibility of the New Crescent Moon, directly correlating with the study on the limitations of optical equipment for New Crescent Moon observation in Sarawak. The Q-Q plot for altitude indicates a strong linear relationship, suggesting that altitude values generally conform to normal distribution expectations. However, higher than normal values suggest certain atmospheric conditions may be present that can obstruct New Crescent Moon observation. Mathematically, it is assumed that higher altitudes improve conditions because atmospheric extinction and scattering is less. But local influences like humidity and temperature changes pose observational concerns. In the case of the tropical areas of Sarawak, persistent cloud cover and elevated moisture levels within the atmosphere at some heights can diminish contrast of the moon against the sky, making it harder to see, regardless of being at higher vantage points. The Q-Q plot relating to moon age also has a linear relation, providing evidence that age of moon data conforms to expectation. Nevertheless, deviations for older ages of the moon suggest variability concerning how successful observations are around the minimum visibility threshold. Hence, the Q-Q plots in Figure 6 deepen the insights generated in 27 years of positive observational records in Sarawak, asserting that while altitude and moon age potentially effect by environmental factors and the brightness of the sky pose additional constraints. Enhancing the New Crescent Moon detection accuracy and precision requires optimizing monitoring approaches like placing equipment, skill of observer and weather observation as an external factor in moon sighting activities.

The methods proposed by Yallop in 1997 (the q-test) is one of the most accepted practices to estimate the visibility of the New Crescent Moon. The q-test is applied to the observational data from theodolites and telescopes to study their minimum detection thresholds. Implementing Yallop's q-test formula, the computed values for theodolites were 1.33 and telescopes 0.73. Yallop's classification suggests that a q-value equal to or greater than 0.216 signifies the crescent moon is easily visible. From the results, it can be concluded that for theodolites, the computed q-value is 1.33 which supports that the crescent moon is visible as it is above the threshold. For telescopes, the q-value ascertained in the previous step is 0.73 which also corroborates visibility but is closer to the threshold value. This means that both theodolites and telescopes fulfil the visibility criterion which suggests that these instruments are adequate for crescent moon detection. Theodolites have a visibility requirement of 6.33° of the moon's altitude due to stronger q-value visibility. In the case of the telescopes, with their higher sensitivity, the required altitude is less 5.73°. This indicates that telescopes provide an advantage in observing the New Crescent Moon at lower altitudes and earlier phases. The q-values also being positive means both results would verify the proposed minimum criteria of 13 h of the moon age and 5.7° for telescopes, and around 22 h of moon age and 6.3° altitude for theodolites. The findings in Figure 7 show the role of optical equipment in improving observation procedures and the precision of the Islamic lunar calendar.

The Q-test is often implemented to forecast the visibility of the New Crescent Moon, although its accuracy is inconsistent in different studies. Yallop (1997) proposed the q-test based on a polynomial regression model with a cutoff of 0.216, whereby positive values denote visibility and lower values indicate the crescent is too faint to be detected. This model is conveniently used for crescent moon sighting predictions.

TABLE 3. Sightings of the new crescent moon using equipment theodolite

No.	Year & Month including site location	Night visibility	Equipment	Moon altitude on the first sighting	Moon age
1	January 2016 Rabiul Akhir 1437 (Pusat Falak Bintulu)	1	Topcon Total Station	10°32'18"	34 h 13 min
2	April 2017 Syaaban 1438 (Pusat Falak Bintulu)	30	Topcon Total Station	08°42'27"	23 h 11 min
3	July 2017 Zulkaedah 1438 (Teluk Bandung Kuching)	30	Topcon Total Station	11°39'10"	25 h 59 min
4	March 2018 Rejab 1439 (Pusat Falak Miri)	30	Topcon Total Station	06°20'46"	22 h 08 min
5	December 2018 Rabiul Akhir 1439 (Pusat Falak Miri)	30	Topcon Total Station	05°56'16"	27 h 46 min
6	January 2019 Jamadil Awal 1440 (Pusat Falak Bintulu)	1	Topcon Total Station	09°40'57"	33 h 58 min
7	October 2020 Rabiul Awal 1442 (Pusat Falak Bintulu)	1	Topcon Total Station	16°23'39"	40 h 14 min
8	February 2022 Rejab 1443 (Teluk Bandung Kuching)	30	Total Station Sokkia	10°30'10"	29 h 56 min
9	May 2022 Zulkaedah 1443 (Teluk Bandung Kuching)	30	Total Station Sokkia	01°49'47"	23 h 38 min
10	September 2022 *Rabiul Awal 1444* (Teluk Bandung Kuching)	30	Total Station Sokkia	10°51'32"	37 h 00 min

Sources: Jabatan Mufti Sarawak 2021

TABLE 4. Sightings of the new crescent moon using telescope equipment

No.	Year & month in Hijri &Gregorian	Night visibility	Equipment	Moon altitude on the first sighting	Moon age
1	April 2019 / Syaaban 1440 (Pusat Falak Bintulu)	30	GSO 6 Inci	10°32'18"	26 h 36 min
2	Julai 2020 / Zulhijjah 1441 (Teluk Bandung)	29	Sky-Rover Triplet APO 80MM F/6 Telescope	08°42'27"	17 h 32 min

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3	Julai 2020 / Zulhijjah 1441 (Teluk Bandung Kuching)	29	Skywatcher Espirit 80ED Super APO Triplet	11°39’10”	17 h 38 min
4	Julai 2020 / Zulhijjah 1441 (Teluk Bandung Kuching)	29	GSO 6 Inci	06°20’46”	17 h 39 min
5	Mac 2021 / Syaban 1442 (Teluk Bandung Kuching)	30	Skywatcher Espirit 80ED Super APO Triplet	10°52’15”	24 h 52 min
6	Ogos 2021 / Muharram 1443 (Teluk Bandung Kuching)	30	Skywatcher Espirit 80MM ED Triplet Refractor	09°56’25”	21 h 20 min
7	Oktober 2021 / Rabiul Awal 1443 (Pusat Falak Miri)	30	Skywatcher Espirit 80MM ED Triplet Refractor	11°12’43”	23 h 29 min
8	November 2021 / Rabiul Akhir 1443 (Pusat Falak Miri)	29	Skywatcher Evostar 120ED	05°44’08”	12 h 59 min
9	Febuari 2022 / Rejab 1443 (Pusat Falak Miri)	30	Skywatcher ED Triplet 120MM	13°49’13”	29 h 23 min
10	April 2022 / Ramadan 1443 (Pusat Falak Miri)	30	GSO 8 Inch	03°23’30”	28 h 59 min
11	May 2022 / Zulkaedah 1443 (Pusat Falak Miri)	30	Skywatcher Evostar 120ED	04°18’22”	23 h 38 min
12	May 2022 / Zulkaedah 1443 (Pusat Falak Bintulu)	30	GSO 6 Inci	02°33’18”	23 h 38 min
13	May 2022 / Muharam 1444 (Teluk Bandung Kuching)	29	Skywatcher Espirit 80MM ED	02°04’51”	17 h 21 min
14	Augt 2022 / Safar 1444 (Pusat Falak Miri)	30	Skywatcher Evostar 120ED	06°15’21”	26 h 37 min
15	Sept 2022 / Rabiul Awal 1444 (Teluk Bandung Kuching)	30	Skywatcher Espirit 80MM ED	12°46’29”	36 h 52 min
16	Sept 2022 / Rabiul Awal 1444 (Pusat Falak Miri)	30	Skywatcher Evostar 120ED	09°32’35”	36 h 48 min

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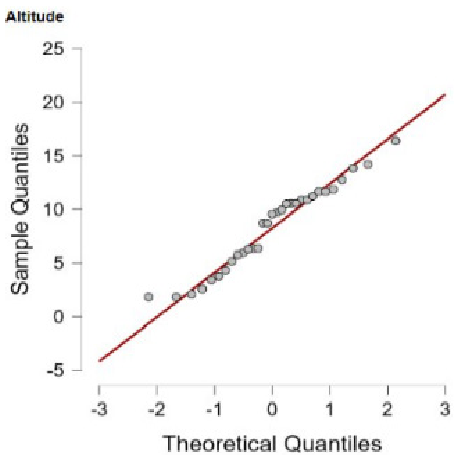
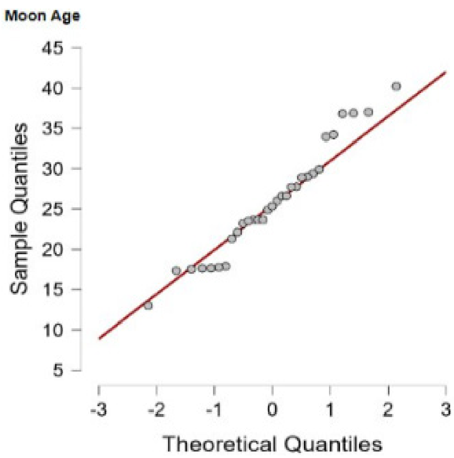
17	Feb 2023/ Syaaban 1444 (Pusat Falak Miri)	30	Ritchey–Chretien 6”	11°51’33”	27 h 44 min
18	Feb 2023/ Syaaban 1444 (Teluk Bandung)	30	Skywatcher BK1025 AZGT	14°11’03”	28 h 54 min
19	Mar 2023 / Ramadhan 1444 (Teluk Bandung)	29	Skywatcher Espirit 80MM ED	01°49’28”	17 h 53 min
20	Mar 2023 / Ramadhan 1444 (Pusat Falak Miri)	29	Ritchey–Chretien 6”	03°43’55”	17 h 45 min
21	Aug 2023 / Safar 1445 (Pusat Falak Miri)	30	Ritchey–Chretien 6”	05°08’13”	25 h 20 min

Sources: Jabatan Mufti Sarawak 2021

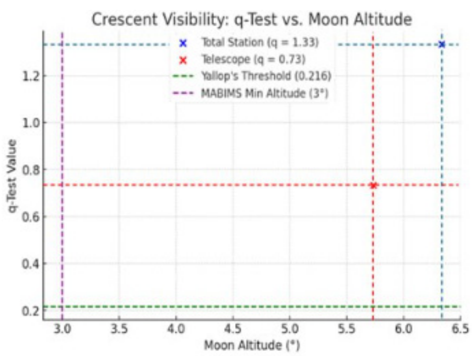


(a)

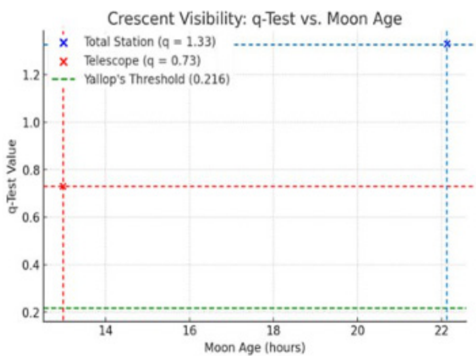


(b)

FIGURE 6. Q-Q plots for (a) altitude and (b) moon age



(a)



(b)

FIGURE 7. Comparison of q-test values with moon altitude and moon age for crescent visibility assessment. (a) q-test vs. moon altitude (b) q-test vs. moon age

At Baitul Hilal Teluk Kemang, a q-test study was conducted on 254 observations and the results showed instances of crescent moon visibility even when q-test values were less than Yallop's threshold. The lowest recorded q-value for a successful sighting was -0.347 which shows that Yallop's criteria could be questionable under some circumstances. This suggests the Q-test, at times, is overestimating the conditions needed for crescent moon visibility (Nazhatulshima et al. 2022).

Based on Table 5, Sarawak 27-year study applied the q-test for theodolites and telescopes. The resulting q-value was 1.33 with theodolites as opposed to 0.73 with telescopes. Both values were above Yallop's limit of 0.216. This reinforces the notion that optical instruments work well for detecting crescent moons although theodolites had a higher requirement for moon altitude than telescopes (6.33° vs. 5.73°). The results illustrate the way different optical instruments can affect crescent visibility measurements.

The global studies of the Teluk Kemang region demonstrated that several moons were spotted with relatively low q-values, whereas the Sarawak study verified that optical equipment unconditionally identifies the crescent above Yallop's threshold (Nazhatulshima et al. 2022). Factors such as sky brightness and the atmosphere also impact results, indicating that models of visibility should account for regional specifics and the limits of equipment used. Those developing methods based on Table 5 to sight crescent moons as a final product should adjust guidelines precisely towards enhancing dependability and precision for determining visibility of New Crescent Moon.

On another side, Figure 8 demonstrates the successful observations made in the Gregorian months. The data suggests that April has the highest visibility, with notable frequencies observed in July and October, whereas February, May and August have lower visibility. This behaviour can be associated with Sarawak's tropical equatorial climate, where climatic phenomena largely influence the weather conditions that determine the possibility of viewing the night sky.

This explains the lack of visibility throughout January, February and early March with marginal improvement towards April during the tail end of the monsoon. The Southwest Monsoon, from May to September is generally dry, experiencing significantly less rainy days which improves the visibility for astronomical observations. However, local phenomena like haze during summer months from bushfires or convective storms in the evening can hinder visibility in certain months. The data showcases this with dips in visibility during May and August but higher visibility during July and October, likely due to clearer skies in the transition months. Alongside, December also shows moderate visibility which aligns with previously stated observations where most sky observations in this month were recorded on 30th of Hijri months, presumably due to strategic timing aligned with moon sightings.

Figures 8 and 9 further highlights observatory conditions as good sky conditions with 48% of observations falling under relatively good conditions, 50% under moderate and only 2% being categorized as poor. The very minimal percentage of poster visibility suggests that extreme whether phenomena such as rampant cloud cover and long periods of storms seldom coincide with observation attempts or excessive data collection during the night. The evaluation verifies that weather conditions in Sarawak considerably affect the visibility of astronomical phenomena. Optimal periods for observations occur in the transition months of April, July and October, as these months have lower cloud cover and dryer atmospheric conditions. On the other hand, the visibility range is limited during monsoon months and haze-affected months like February, May and August. These trends aid in the planning of future astronomical events by guaranteeing the best conditions to observe the skies, which can be strategically scheduled for maximum visibility.

When the Sarawak State Mufti Office was upgraded to the status of the Sarawak State Mufti Department in 2014, the state government began allocating a dedicated budget for upgrading observation equipment at the three observatories, which have been officially gazetted as Hilal Station in Sarawak. Hence, the selection of a telescope as an organizational asset is crucial for achieving the department's objectives. Several key observational activities must be considered before purchasing a telescope, such as planetary observation, solar observation, moon observation and deep space object observation. It is essential for personnel to ensure that the selected telescope align with these observational requirements by thoroughly analysing its specifications. Below are some important telescope specifications that should be considered:

Aperture

Aperture is the size of the opening at the front of the telescope. This specification is very important because the aperture's function is to gather light. The larger the aperture's size, the clearer a celestial object will be. Usually, a small telescope has an aperture of 3 to 4 inches, which is suitable for observing the surface of the moon and planets with high magnitude values such as Venus, Jupiter and Saturn. Large telescopes that are 8 inches and above could collect more light and are suitable for observing night objects, such as galaxies and nebulae.

Focal length

Focal length is the distance between the objective lens and the point where the light is focused. Focal length enlarges the image of an object and is very suitable for observing small objects such as planets. Hence, if the planet Jupiter is observed using a 900 mm focal length, the planet would be seen as a very small object, but if a 3000 mm focal length telescope is used, the image of the planet would be large. However, it must be remembered that the larger the focal length, the darker an object. Therefore, it is important to choose a large aperture.

TABLE 5. Key findings and differences in Q-test results

Study	Dataset	Lowest Q-test value for visibility	Key findings
Q-test visibility (Yallop 1997)	Global observational data	0.216 (visibility threshold)	Q-test model to classify crescent visibility, widely used in moon sighting predictions
Circular Regression Model Study (Nazhatulshima et al. 2020)	254 observations at Baitul Hilal Teluk Kemang	-0.347	Found that the crescent moon was sometimes visible even below Yallop's threshold, suggesting that the Q-test is not always a strict predictor of visibility
Sarawak 27 Year Study	167 observations, 31 confirmed sightings	0.73 (telescope), 1.33 (theodolite)	Optical equipment consistently detects the crescent moon above Yallop's threshold, with theodolites requiring a higher moon altitude (6.33°) than telescopes (5.73°)

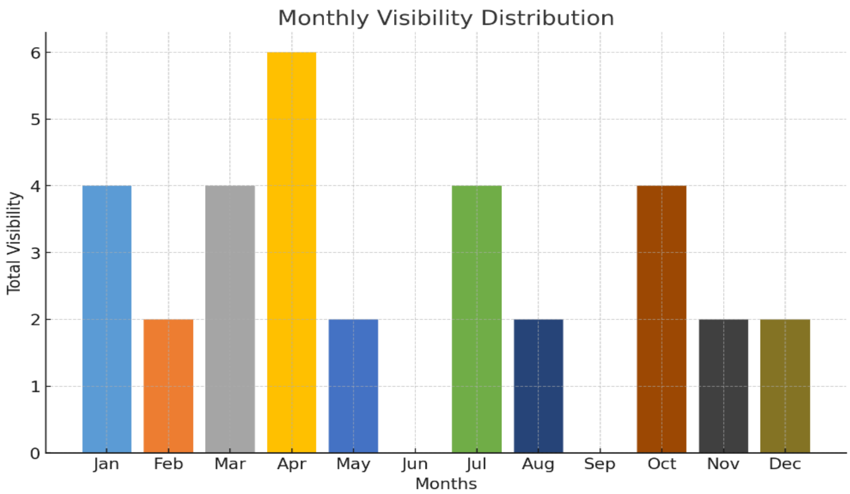


FIGURE 8. Monthly distribution of crescent visibility observations

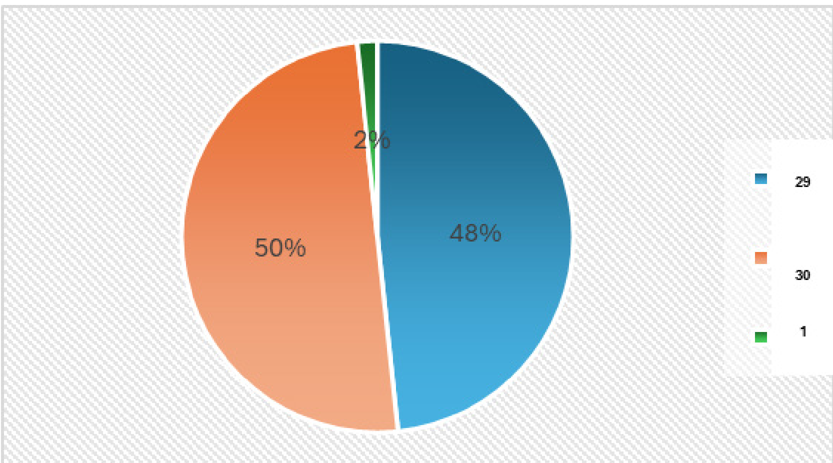


FIGURE 9. Distribution of night observation categories

Focal ratio

Focal ratio, which refers to the relationship between aperture and focal length is an important specification if a telescope is chosen for astrophotography purposes. The observer will get the focal ratio value by dividing the focal length by the aperture. For example, a telescope that has a focal length of 900 mm and an aperture of 90 mm when divided by 900/90, will provide a value of f/10. A telescope can determine whether the slewing value is at a fast level, moderate level or a slow level based on the focal ratio. The fast level typically starts with f/5 and below, the medium level is f/6-f/10 and the slow level is f/10 and above. A focal ratio with a high level of slewing is very suitable for observing deep sky objects because the exposure time of the camera will be shorter.

CONCLUSIONS

This study proposed new criteria for New Crescent Moon sighting based on observations conducted using optical equipment, particularly telescopes, to enhance the accuracy of determining the beginning of the Hijri month in Malaysia. The recommended criteria, based on meticulous data collection spanning from 1997 to August 2023, suggest that the New Crescent Moon can be sighted when it reaches a moon age of 12 h 59 min and attains a moon altitude of 05°44'08". These refined criteria offer an alternative approach for Sarawak's authorities to consider when developing the Islamic calendar and significantly contributing to the field of astronomy. These criteria account for factors, such as a clear western horizon by employing optical equipment such as telescopes, which provide greater precision and sensitivity compared to traditional naked-eye observations, thereby improving the reliability and accuracy of New Crescent Moon sightings (Roslan et al. 2018). The findings of this study may contribute analytical discussions and comparative evaluations related to the development of visibility parameters for the New Crescent Moon. In Malaysia, the currently applied criterion is *Imkanur Rukyah*, which specifies a minimum moon altitude of 3 degrees and an elongation of 6.4 degrees after sunset. This standard replaces the earlier criterion, which required a minimum altitude of 2° and an elongation of 3° or a minimum moon age of 8 h after conjunction. The results presented may support the refinement and validation of criterion thresholds. Future studies should focus on, extensive global data collection to address the limitations of New Crescent Moon sighting using telescopic methods. In conclusion, the proposed criteria, informed by observations conducted using optical devices, like telescopes, present a valuable alternative for enhancing the accuracy and reliability of determining the beginning of the Hijri month, which would eventually advance astronomical practices in Malaysia and beyond.

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