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Empowering Astronomical Exploration: Advancement of New Moon Observation Devices in Sarawak, Malaysia

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Abstract

Understanding the motion of celestial objects is essential for space exploration. Observing the new crescent Moon requires advanced technological devices due to the moon's position in the atmosphere and the refraction of sunlight on the horizon. Nowadays, theodolite and telescope applications are commonly used for new crescent moon sightings because they offer superior visibility compared to the naked eye. In Sarawak, the Falak Section holds the authority to observe the new crescent Moon to determine the beginning of the Hijree month. Thus, this study aims to examine the development of devices to observe the new moon crescent in the Sarawak Mufti Department. Qualitative methods are employed, involving the perspectives of astronomers and data on new crescent Moon observations using the observation devices in the Falak Section. From 1997 onwards, the Sarawak Mufti Department had three theodolites and seven telescopes specifically for new crescent moon observations. Additionally, there are 22 recorded data of new crescent Moon sightings using these devices. These findings indicate a direct correlation between the observation devices and the potential visibility of the new crescent Moon in Sarawak. This study will benefit the Sarawak Mufti Department in evaluating suitable devices for new crescent Moon observations, whether acquiring new devices or selecting devices for new crescent moon observations.

Keywords: New crescent Moon, Devices, Sarawak Mufti Department, Correlation, Potential Visibility, Falak

1. Introduction

The Muslim, Hindu, and Hebrew calendars rely on the lunar system, but most lunar calendars have moved away from the traditional practice of visually observing the new crescent Moon each month in favour of using calculation methods. Although several countries like Saudi Arabia, Malaysia, Pakistan, Indonesia, and Singapore, continue to observe the traditional method of marking the start of a calendar month by relying on Moon observations [1][2]. Starting in 2021, the nations belonging to Malaysia, Brunei, Indonesia, and Singapore (MABIMS) reached a consensus to adopt new criteria for determining the beginning of a new month in their calendars, which are 3° for altitude and 6.4° for the new crescent Moon elongation. These criteria include ensuring that the moon's altitude at sunset is a minimum of 3° and that the elongation between the moon and the sun is at least 6.4°.

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With advancements in technology, astronomers have adapted their observation methods, transitioning toward the use of astronomical imaging facilitated by digital cameras attached to telescopes. This technique aids in capturing and preserving images of the emerging crescent Moon. However, the visibility of the new crescent Moon within these images has posed challenges because of its minimal contrast against the sky, making detection difficult. [3][4]. Consequently, the captured images lack the clarity necessary to serve as conclusive evidence of their visibility. This study introduces a solution by proposing the application of Contrast Limited Adaptive Histogram Equalization (CLAHE) to enhance the image's contrast. Following this, the bilateral filter is employed to reduce noise, and ultimately, the Maximally Stable Extremal Regions (MSER) detector is used to identify and delineate the region containing the new crescent moon in the image [5][6].

For amateur or professional astronomers, skill in the use of equipment is crucial. Without the right equipment and the skills to use it, the goal of observation will fail. Observation equipment is a tool used for observation in astronomy, including calculation activities and practical exercises. There are several differences in observation equipment, especially in its use, where equipment is manually operated with the help of the hand, such as *in the Gawang Anak Bulan* and Sine Quadrants. *Gawang Anak Bulan* is a traditional equipment that is widely used in Malaysia and Indonesia. This equipment is easy to use and precise enough to localize the position of the crescent Moon. It is made from thread with dimensions of 20 cm and 2 mm thickness. This equipment would be positioned to provide a clear view of the horizon, where the new crescent Moon is expected, with the observer aligning the window to frame the desired sky segment. Through this window, the observer waits for the crescent to appear after sunset, minimizing visual distractions and focusing on the sighting. In comparison, there is also the use of automatic equipment with a combination of manual and digital operation, such as theodolite and telescope. In operating the equipment used, whether it is modern or traditional, the user must know the basic concepts and specifications of the equipment. Modern observational equipment consists mainly of optical types. There is also traditional equipment that is not of the optical type.

Most observational activities in Malaysia now use high-tech telescopes equipped with computerized control and analysis systems. This allows insight analysis to be conducted more effectively[7][8][9]. In addition, telescope technology has improved with the advancement of radio and infrared telescopes [10]. This sophistication allows astronomers to study electromagnetic waves, radio, infrared, ultraviolet, x-rays, gamma, and other cosmic waves. Therefore, it is different from Sarawak, which has a different development of equipment in terms of time and inclusion as an ownership asset compared to other states in Malaysia. Hence, the scope of this study is confined to investigating inquiries related to advancements in optical instruments used for moon observation, including telescopes and theodolites. The specific focus will be on the Sarawak Mufti Department and the KUSZA Observatory, both situated within the campus of Universiti Sultan Zainal Abidin (UniSZA) in Peninsular Malaysia. Importantly, these sites are among the 29 designated locations for moonlighting activities in Malaysia.

2. Theodolite

Theodolite is a small telescope used in angle measurement work [11]. Theodolite is a standard tool for measuring the horizon and elevation angles between observation points. Although various types of theodolites exist today, they all have the same working principle. The difference may only exist in the method for determining the angle reading. The point is that more modern theodolites will have many facilities to make survey work more accurate. If a person has expertise in operating any type of theodolite, he will not face any problem when

using another type of theodolite[12]. In general, complete theodolite equipment for observation should include a theodolite tripod, insulating glass, lighting set, and solar filter. Therefore, in general, there is some progress in Theodolite equipment in the Sarawak Mufti Department.

3. Development of Theodolite Tool for Total Station Technology

Rapid developments in Electronic Distance Measurement (EDM) equipment allow surveyors or amateur astronomers to measure distances, especially long distances, more easily and with higher accuracy. Total Station is a type of theodolite that can measure angles and distances together. The Total Station is a combination of electronic theodolite and EDM [13]. In general, the theodolite or total station is an essential tool for Islamic Affairs Officers in every mufti department in Malaysia because it helps them check the direction of the Qibla and observe the new crescent Moon activity [14]. These activities are part of the scope of the jurisdiction of the Falak Section for a mufti department. The following table 1 is the development of the theodolite, including the year of asset ownership in the Mufti Department of Sarawak.

Table 1: Development of the theodolite including the year of asset ownership in the Mufti Department of Sarawak[15][16].

Theodolite	Year	Advantage
Theodolite NE-20S	2004	- Easy to carry - Double A battery
Topcon Total Station ES-103	2014	- Has a prism, solar filter, and rechargeable battery - Type of Total Station without a Reflector
Sokkia Total Station CX 103	2015 and 2016	- Enlargement: 30 times - Accuracy Angle: 3" - Main Objective Size: 45 mm

Figure 1: Sokkia Total Station CX 103 During the Observation of the new crescent Moon of *Zulkaedah* 1443[15][16].

4. Telescope

The telescope works by changing the angle of incidence on the eye so that the collection of light increases and the image formed is larger. When a telescope is used to look at an object, the angle of incidence falls on the main objective of the telescope. The light that passes

through this main objective will be focused on the prime image knot, and the eyepiece will refract the light parallel to the eye. In addition, the telescope is an optical equipment that requires high handling skills to ensure that the purpose of observation is successfully achieved, especially in observing the moon[12]. The larger the telescope's diameter, the lighter can be collected. Therefore, for the observation activities of the new crescent Moon at the Sarawak Mufti Department, Table 2 below provides the development of the telescopes that have been used.

Figure 2: Sky Rover ULT 80 ED Telescope with HEQ5 Mount[15][16].

Table 2: Telescopes used in Sarawak State Department [15][16].

Telescopes and their Types	Years	Advantage
Telescope Celestron LX200 12" (Maskuto Cassergrain Reflection Optics – Catadioptric)	2011	- High GPS accuracy - *Database-autostar, 145,000 names of celestial objects* - focus Zero Image Shift Microfocusing
Telescope Sky Rover ULT 80 ED Glass Triplet (Refractive Optics)	2015	- Observation of deep-space objects - Artificial telescopes - Sharper image focusing - Saves time processing quality images
Telescope GSO 6″ & GSO 8″ (Newtonian Reflection Optics)	2018	- Observation of deep-space objects - Coma Reducer mirror that sharpens the image of the observatory and ultrawide objects - Mounted with the AZ-EQ5 GT
LUNT Solar System Telescope (Refractive Optics)	2018	- Remarkable Observation of the Sun - Build-in Alpha Hydrogen Module - A lightweight telescope
Sky-Watcher StarTravel 102 mm (Refractive Optics)	2018	- Having an optical tube allows viewing images like craters of the moon - Observation of deep-space objects
Telescope Skywatcher Esprit 80 ED	2018	- Observation of deep-space objects - A doublet field flattener was used to minimize the effect of aberrations.

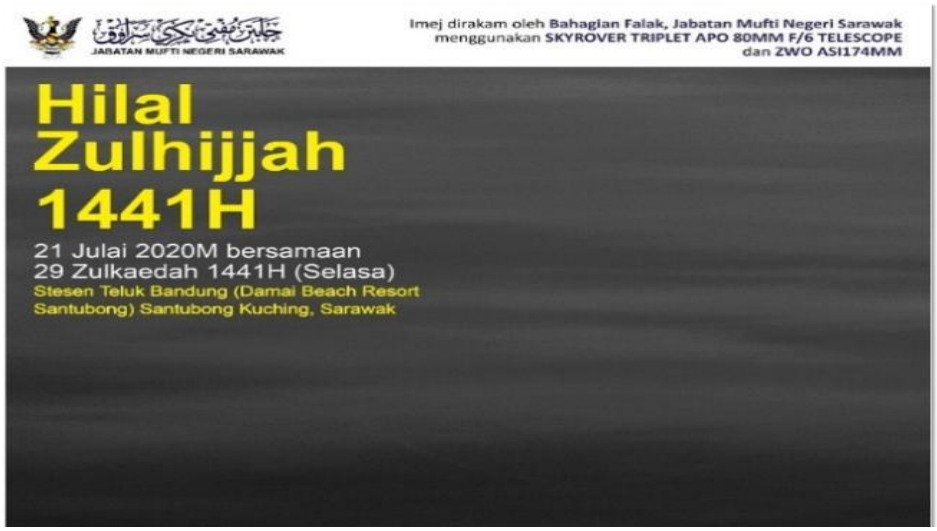

Figure 3: New crescent moon image captured using Sky Rover ULT 80 ED Telescope
Source: Sarawak Mufti Department[15][16].

5. Sarawak Mufti Department of Auxiliary Equipment

5.1 Smartphone Camera

Among the cameras used before 2016 was the observer's smartphone camera because a dedicated camera for observing the moon had not yet been supplied. A Smartphone Camera is an image recording device that uses a mobile phone capable of capturing images and often recording video using one or more built-in digital cameras. Most Smartphone Cameras are smaller and more compact than Digital Single Lens Reflex (DSLR) Cameras or Compact Cameras. Many types of Smartphone Cameras are often used nowadays, but differences are based on specific focal length values that determine the difference between each type of Smartphone Camera.

5.2 Canon EOS 70D

Canon EOS 70D camera, which is the first Digital single lens reflex (DSLR) type camera, was supplied in 2016 after two years when the Sarawak Mufti Department changed from the Sarawak State Mufti Office status. This camera is supplied with a Double Charge Device (Charge Couple Device, CCD), which can detect dim objects such as the moon with low brightness. Usually, the Sarawak Islamic Affairs Officers combine this Canon EOS 70D using a telescope using a T-Mount or T-Ring.

5.2.1 Camera Mechanism in the Moon Observation Activity

To obtain a good image in the observation activity of the new crescent moon, the camera mechanism should be balanced between aperture, shutter speed, and International Organization for Standardization (ISO). ISO is simply a camera setting that will brighten or darken a photo. If one of these mechanisms is lacking or excessive, the image of the new crescent moon is not good and even makes it invisible. Based on the age of the new crescent moon, which is under 24 hours, the aperture should be at a moderate setting. The shutter speed should be low and under 1 s. Due to the dark sky and limited light of the moon, the ISO should be high, usually between 3200 and 6000 ISO.

5.2.2 Dual Charge Devices

In addition, in 2019, a Charge Coupled Device (CCD) was used to image the observation activity of the moon at the Sarawak Mufti Department. CCDs can astronomically be imaged in low light intensities at 10-4 levels above the sky background. CCD imaging is highly dependent on the alignment accuracy of the telescope and mounting system. The fixture must

be adjusted to track and slew accurately. Every element in the telescope system must be optimized to obtain the best possible image. Table 3 shows that among the CCDs used.

Table 3: CCD Mufti Department when observing a new crescent Moon[15][16].

Brand	CCD type	Existence of a Fan	Pixels
ZWO ASI 120 MC	Colour	None	1280 x 960 (1.2 MP)
ZWO ASI 183 MM	Monochrome	Yes	5496 x 3672 (20MP)
ZWO ASI 174 MM	Monochrome	Yes	1936 x 1216 (2.3 MP)

6. Observation Equipment with Records of Moon Sightings in Sarawak

From 1997, no records or information on the sighting of the new crescent Moon were obtained from the Sarawak Mufti Department when only using the naked eye. However, in 2016, after a year of using the Topcon Total Station ES-103 equipment for moon observation activities, the first moon sighting was recorded at Tanjung Batu Bintulu with a moon age of 34 h and 13 min. The following year, the number of new crescent Moon records increased from one in 2016 to two in 2017 using the same Total Station equipment. This amount of data remained constant in 2018, when the Topcon Total Station ES-103 equipment recorded two sightings of the new crescent Moon. This shows that after becoming more adept at using specific equipment, the practice of the equipment is improving for observing the new crescent moon's activities.

In 2018, GSO 6″ and GSO 8″ telescopes produced in Taiwan, which are reflecting optical telescopes based on the Newtonian design, were supplied to the Sarawak Mufti Department to observe the new crescent Moon. The result of the inclusion of this telescope asset, after a year of being used for observation activities, finally there is a record of the sighting of the moon using the GSO 6″ Telescope in April 2019 at the same time as Syaaban 1440 at Tanjung Batu Hilal Station, Bintulu with a moon age of 26 h 36 min where the image was taken using a Canon 70D DSLR camera. Combining these two tools helps observers obtain images of the new crescent Moon more easily. In 2019, there is also a record of the appearance of the new crescent Moon using Topcon Total Station ES-103 with a moon age of 26 h and 36 min.

Base on the Figure 4 bellow of the record of new crescent Moon sighting in Sarawak, on the 2020, the observation day 29 Zulkaedah 1441, the record of the sighting of the moon with a lunar age of 17 h 38 min was created at Teluk Bandung Hilal Station, Kuching when the Sky Rover ULT 80 ED Telescope was able to track the moon well combined with the ZWO ASI 174MM, which was supplied in 2019. This shows that imaging using ZWO is very helpful for observers in observing the moon. The second appearance of the Zulhijjah Moon is also visible when the observer can direct the Skywatcher Esprit 80 ED Telescope and the GSO 6" Telescope to the position of the moon well, where these two telescopes are assisted by Canon DSLR camera equipment. This proves the importance of combining imaging equipment with a telescope to obtain a record of the moon's appearance. In the same year, there was a record of the sighting of the Early Rabiul Moon using the new Total Station Sokkia with a moon age of 40 h and 14 min.

In 2021, the new crescent Moon's sighting record continued to increase to four due to the use of telescopes compared to previous years, when only two data points of the new crescent Moon could be seen using Theodolite equipment. This occurs because the telescope has a better field of vision than the theodolite. The first data for 2021 occurred in March, corresponding to the month of Syaaban 1442 Hijree, where the age of the moon is 24 h 52

min with an altitude of 10°52'15" using the Sky-Watcher Espirit 80ED Super APO Triplet Telescope. The second data in March corresponds to the month of Muharram 1443 Hijree, where the age of the moon is 21 h 20 min with an altitude of 9°56'25" using the Sky-Watcher Espirit 80ED Super APO Triplet Telescope. The third data is in October, corresponding to the month of Rabiul Akhir 1443 Hijree, where the age of the month is 23 h 29 min with an altitude of 11°12'43" and uses the Sky-Watcher Espirit 80ED Super APO Triplet Telescope. The last data for the year 2021 is in the month of Rabiul Akhir 1443 Hijree, corresponding to November, where the age of the month is 12 h 59 min, the record of the appearance of the youngest moon in Sarawak. The moon's height at the time of its first appearance was 5°44'08" at azimuth 252° 20'54" using Sky-Watcher Evostar 120ED, where images were taken using ZWO ASI 174MM.

Until September 2022, six records of the new crescent moon have been seen in Sarawak, and the complete sighting data for 2022 may be more than that for 2021 because the progress of observation equipment can increase the sighting record of the new crescent moon. The three moon sighting data for February, April, and May 2022 were obtained using telescope equipment during observation, but there are also three records using theodolite equipment that were used on the same day of observation, namely for February and May. Meanwhile, from 2023 until August that year, only three moon sightings were recorded by the Sarawak Mufti Department. The report for this year is slightly lower than the report from the previous year due to weather conditions such as rainy and cloudy on the horizon. There are also changes in the equipment, such as the newest equipment that was used, which is RC GSO 6", which could have an impact on the visibility of the new crescent moon in that year. In addition, no data were recorded so far using the theodolite in that year. Figure 4 shows 22 recorded data on the new crescent Moon since the introduction of new equipment for moon sighting in the Sarawak Mufti Department.

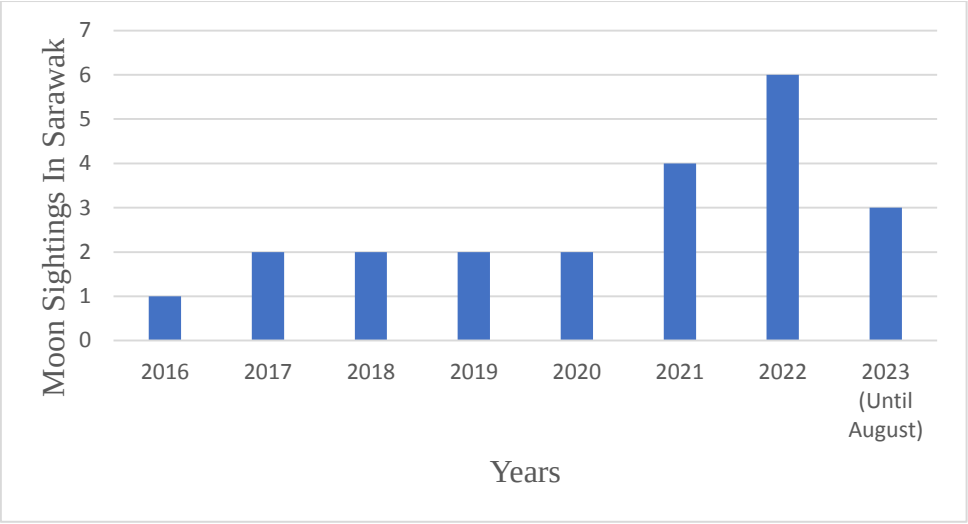

Figure 4: Record of new crescent Moon Sighting in Sarawak

7. Conclusion

Advances in observational technology, particularly in Sarawak, have significantly increased the accuracy and rate of new crescent Moon sightings. The integration of advanced equipment such as the Topcon Total Station ES-103 and various telescopes has resulted in a significant increase in recorded moon sightings. These data highlight the vital role that combining imaging devices and telescopic equipment plays in improving observation results.

Notably, the year 2021 marked a major change, with more sightings with telescopes compared with theodolites, highlighting the superior ability of telescopes to sight. This development demonstrates the transformative impact of technological advancements on traditional observation methods that allow for more precise and frequent observations.

However, the number of sightings recorded in 2023 has decreased, which is important to note given that the data covers only August. This decrease can be attributed to meteorological factors, with bad weather and environmental variables playing a significant role. Furthermore, this decrease may reflect the impact of limited data collection within the timeframe, emphasizing the importance of comprehensive annual records for analyzing trends.

Regardless of these technological advancements, environmental challenges such as inclement weather continue to pose significant obstacles. These external factors highlight the ongoing need for advances in both equipment and techniques to mitigate their effects. The advancement of observational methods has not only increased the capability for more reliable and frequent moon observations but also established a standard for the necessary equipment and operational skills at the Sarawak Mufti Department. This evolution is critical for maintaining the precision of the Islamic lunar calendar and strengthens the department's critical role in confirming the beginning of each Hijree month. As a result, advances in optical technology are more than just technical enhancements; they are an important component of cultural and religious values, which assists the Sarawak Mufti Department in fulfilling its duties with increased effectiveness and precision.

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