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Digital Hilal Observation: Evaluating the Authenticity of Hilal Testimonials in Indonesia Using the Digistar-6 Planetarium System

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Abstract

This article aims to provide supporting data to test the authenticity of testimonial claims of sighting the hilal (new moon) that have been received and decided by the Ministry of Religious Affairs of the Republic of Indonesia (RI) from 1962-2021 during the isbat session for the determination of the beginning of the months of Ramadan, Shawwal, and Dhu al-Hijjah. Building upon the results of the author's previous research that revealed inconsistencies in the application of the minimum visibility criteria for the hilal known as imkan al-rukyat by the Ministry of Religious Affairs Indonesia. Approximately 45.5% of the hilal testimonial claims found in the Minister of Religious Affairs' decisions are doubted for their authenticity due to various reasons, including the absence of elongation data and the presence of hilal altitude data below the Ministers of Religious Affairs of Brunei Darussalam, Indonesia, Malaysia, and Singapore (MABIMS) criteria. To substantiate the old data, this article employs the Digistar-6 planetarium system to provide a scientifically accurate 3D visualization of the hilal observation process through a full-dome planetarium. Using a qualitative descriptive approach, this article examines all the testimonial claims data after classifying them based on the application of the imkan al-rukyat theory in MABIMS in Indonesia. The findings show several key points: First, there is no elongation data available in all of these decisions. Second, there is a variation in the use of astronomical calculations for hilal data, especially before the implementation of MABIMS criteria. Third, there is astronomical data on hilal claims post the implementation of MABIMS criteria that are accepted with altitudes below 2°. Fourth, the tendency is that the hilal can be seen with optical aids during hilal altitudes above 3° and elongations exceeding 6°.

Keywords: *Islamic Astronomy, Hilal Testimonials, MABIMS Criteria, Ministry of Religious Affairs Decisions, Digistar-6 Planetarium.*

INTRODUCTION

Most Muslims rely on the sighting of the hilal (new moon) as a marker for the beginning of the Islamic lunar months, particularly for religious matters such as the start of Ramadan, Shawwal, and Dhu al-Hijjah. One way to ascertain the presence of the *hilal* is through *rukyat al-hilal* (observation), which is an effort to spot the first crescent moon in the western sky shortly after sunset (Azhari, 2007). Of course, the *rukyat al-hilal* in question should be in accordance with Shariah standards and scientific criteria (Muklas, 2009). Despite the challenges of moon observation, many individuals strive to do so to determine the start of Islamic months and establish significant dates such as the beginning of Ramadan or Eid al-Fitr. Various organizations and institutions also conduct organized moon observations to ensure accuracy in determining these dates. In some countries, especially those with a Muslim-majority population like Indonesia, the Ministry of Religious Affairs often holds a Hilal Sighting Confirmation Session. This session is a meeting or forum convened to determine the start of the Hijri lunar month based on moon observation (Nurkhanif et al., 2022).

The Hilal Sighting Confirmation Session is an effort to reach consensus and agreement on the national level for determining the beginning of the Hijri month so that Muslims can collectively celebrate important events. However, it should be noted that the approaches and methods used in these sessions can vary between different countries (Rohmah, 2018). During these sessions, astronomers, religious scholars, and representatives from the Ministry of Religious Affairs of Indonesia or related institutions gather to discuss reports of *hilal* sightings conducted in various regions. They deliberate on moon observation information such as visibility of the *hilal*, weather conditions, and the validity of the received reports. After the discussion, the session reaches a decision on whether the *hilal* has been sighted or not. This decision is then officially announced by the Ministry of Religious

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Affairs of Indonesia or the relevant authorities. The determination of the start of the month is crucial for establishing significant dates in the Islamic calendar, such as the beginning of Ramadan, Eid al-Fitr, and others.

The Ministry of Religious Affairs of Indonesia records and archives the results of the Hilal Sighting Confirmation Session based on the reports of *rukyat al-hilal* deemed acceptable at all observation points. A summary of the session results is compiled in both hard and soft copies, underscoring the importance of documentation and data storage concerning the determination of the beginning of the Hijri month in Indonesia. The Minister of Religious Affairs' decisions regarding the start of Ramadan, Shawwal, and Dhu al-Hijjah from 1962-2011 are then printed by the Ministry of Religious Affairs in the form of books and distributed to all Ministry of Religious Affairs offices of Indonesia, making access and reference easier for employees and the public regarding the determination of important dates in the Islamic calendar. In the digital era, the Ministry of Religious Affairs in Indonesia has adapted by uploading the decisions from 1962 to the present on the official Ministry of Religious Affairs website. This enables the public and relevant parties to easily access and refer to the latest decisions regarding the determination of the beginning of the Hijri month. These steps demonstrate transparency and the Ministry of Religious Affairs' efforts to provide accessible information to the public while facilitating consistency in determining important dates in the Islamic calendar across Indonesia.

Upon examination, it appears that there are indications of inconsistencies within the Ministry of Religious Affairs of Indonesia, as stated in the content of the decisions, particularly regarding the consistent application of the conditions under which the *hilal* can be seen, in accordance with the criteria of *imkan al-rukyat* that are still agreed upon and applied in Indonesia. Additionally, previous research by the author has found many accepted *hilal* testimonies documented in the decisions whose authenticity is questionable, accounting for 45.5% of all *hilal* confirmations from 1962-2021 (Nurkhanif et al., 2022). Nearly 90% of this 45.5% lack physical evidence of the *hilal* (Nurkhanif et al., 2022). However, the hypothesis from these research findings is limited to the reevaluation of astronomical *hilal* data and does not yet present physical data on the shape of the *hilal*.

There are several applications that can be used to determine the physical appearance of the *hilal* from the results of moon observation simulations, such as Stellarium and Sky Eye (Sayehu, 2017). However, these applications are not capable of displaying the physical shape of the *hilal* that closely resembles the actual *hilal* during observation. To the best of the author's knowledge, there is the Digistar-6 system, which is the main system used in planetariums as an application to display celestial objects in a manner that closely replicates their natural patterns and movements, both for tracking historical and future celestial movement (E&S, n.d.). Three-dimensional simulations of celestial objects can be viewed using one or more projectors in a planetarium, utilizing a round, sky-dome theater. The positions of celestial objects can be accurately displayed at any given time thanks to this software. With this digital technology, Digistar-6 is one of the planetarium programs capable of providing high-quality visualizations. Therefore, the author intends to use this tool to provide data on the physical appearance of the *hilal* as seen and accepted by the Ministry of Religious Affairs of Indonesia, as recorded in the KMAs for the determination of the beginning of Ramadan, Shawwal, and Dhu al-Hijjah from 1962-2021.

LITERATURE REVIEW

Research related to *rukyat al-hilal* or observations of the *hilal* has been extensively conducted, with approximately 310 scientific journals addressing this topic. However, only two studies have specifically examined the decisions of the Ministry of Religious Affairs of Indonesia resulting from the Hilal Sighting Confirmation Session for the determination of the beginning of Ramadan, Shawwal, and Dhu al-Hijjah. First, a study conducted by Djamaluddin (2001) titled 'Re-evaluation of Hilaal Visibility in Indonesia'. The focus of this research was to analyze documents of *hilal* sightings from 1962-1997, which had legal legitimacy due to the swearing-in of observers who claimed to have seen the *hilal*. The research findings were used to formulate criteria for *hilal* visibility in Indonesia. Second, a study conducted by Muhammad Nurkhanif et al. (2022) titled 'The Integration Between Syar'i and Astronomy to Determine the Beginning of Hijri Calendar: An Applied Study of Moon Elongation to Prove the Hilal Testimony'. This research focus was to examine the decisions of the Ministry of Religious Affairs of Indonesia from 1962-2021 regarding the determination of the beginning of Ramadan, Shawwal, and Dhu al-Hijjah by recalculating all hilal claim data, with a specific focus on determining elongation. By understanding the elongation values, it was possible to classify the types of *hilal* confirmations made by the Ministry of Religious Affairs of Indonesia. 45.5%

of all *hilal* claims received fell into the category of *isbat maslahiy* (Ministry of Religious Affairs' decisions based solely on fiqh aspects considering benefits).

In addition, there are several research related with Digistar-6 plantarium system such as Chastenay (2016) titled 'From Geocentrism to Allocentrism: Teaching the Phases of the Moon in a Digital Full-Dome Planetarium'. This article mentioned that a digital planetarium can be used to teach moon phases to children aged 12 to 14. To fully understand moon phases, one must imagine the moon as a round object (as seen from space), orbiting the Earth while illuminated by the Sun, and reconcile this perspective with geocentric views. Digital planetariums allow learners to have both allocentric and geocentric views of moon phases. Based on qualitative data collected before, during, and after the planetarium session, it was demonstrated that five out of six participants had a better understanding of moon phases after the planetarium session.

A study conducted by Chun Yu et al. (2017) titled 'Learning About the Scale of the Solar System Using Digital Planetarium Visualizations'. They studied the use of digital planetariums to teach distance and relative size in an introductory undergraduate astronomy class. The results of their research showed visible benefits for students who visited the planetarium as a powerful tool for visualizing scales spanning several orders of magnitude. The advantages also indicated the usefulness of broader visualization approaches for physics class simulations.

A study conducted by Tanaka et al. (2019) titled 'Relationship between Faithfulness and Preference of Stars in a Planetarium'. In this research, they investigated the relationship between faithfulness and preferences in star fields in a planetarium through psychometric experiments with 47 observers. The experimental results indicated that there were perceptual differences between male and female observers in their preference for faithful star reproductions. Male observers preferred faithful star reproductions, while female observers favored brighter star reproductions over faithful ones.

A study conducted by Kovalenko (2019) titled 'Astronomy: Learning Theories Applicable for Education in Planetarium Environment'. This research concluded that in an educational activity, there are important theories to be taught to learners, such as environmental science, neuroscience, left and right brain, community of practice, control theory, social learning theory, Vygotsky and social cognition, learning styles, Piaget's theory, constructivism, brain-based learning, multiple intelligences theory. All these learning theories are briefly explained. All the mentioned learning theories may be relevant to some extent, especially in astronomy education in a planetarium environment. For example, the theory of Multiple Intelligences can be effectively tested when teaching in a Planetarium and is worthy of further research. Astronomy learning through a planetarium medium using a Multiple Intelligences approach is worth offering to audiences with varying levels of intelligence (Safiai et al., 2020; Safiai et al., 2021).

A study conducted by Spathopoulos (2020) titled 'Using Freeware Planetarium Software to Simulate the Astronomical Measurements of Ancient Greeks." In this research, it is mentioned that ancient Greek astronomers devised clever methods to determine the size and distance of the Earth, Moon, and Sun. In the modern era, the advent of planetarium software allows educators to reproduce these pioneering measurements in the classroom. This article presents some activities based on observations and experiments conducted over 2000 years ago. By using freeware planetarium software, students are introduced to significant milestones in the history of astronomy in an immersive and interactive manner. From the above literature review, it can be observed that there has been no study specifically addressing the use of the Digistar-6 planetarium system for the purpose of simulating *hilal* observations, which is the focus of this article.

METHODOLOGY

This research employs a qualitative research approach with a descriptive method (Sugiyono, 2014). The data analysis method used in this research is the Miles and Huberman model (Sugiyono, 2014), which is pursued through three steps:

Data reduction: This step involves meticulously detailing the collected data. As mentioned earlier, the research object in this article is the decisions of the Minister of Religious Affairs of Indonesia resulting from the Hilal Sighting Confirmation Session) for the determination of the beginning of Ramadan, Shawwal, and Dhu al-Hijjah from 1962-2021, totaling 146 decisions (Muhammad Nurkhanif et al., 2022). Subsequently, several data have been selected regarding the claims of *hilal* sightings that were accepted and used as the basis for determining the beginning of the Hijri calendar. There were 56 such claims of *hilal* sightings. Out of these 56 data points, this article classified them into two phases: the *hilal* determination phase before and after the implementation of MABIMS criteria.

Data presentation: Data is presented in various forms such as tables, graphs, or pictograms. After sorting the data, the author recalculated the astronomical data for the 56 claims of *hilal* sightings to determine the *hilal's* altitude and elongation angle. These recalculated data served as the basis for testing their validity and accuracy as the basis for determining the beginning of the Hijri calendar claimed by observers. It should be noted that in the author's previous research, it was found that 45.5% of all the data consisted of claims of *hilal* sightings accepted based on the sworn statements of observers who claimed to have seen the *hilal* without supporting physical data.

Conclusion or verification: The third step involved using the Digistar-6 planetarium system tool to find physical data regarding the *hilal* by simulating the movements of the sun and moon during sunset, known as the *rukyat al-hilal* simulation. The process begins by configuring the desired location according to the location data where the hilal was sighted by Ministry of Religious Affairs of Indonesia. Next, the moon's position is placed on the western horizon at sunset with atmospheric conditions at 100% full. The visualization of the *rukyat al-hilal* is simulated on the planetarium dome to make it appear as if the *hilal* is being observed in real-time. Once the moon's and sun's positions align with the calculation data, the next step is to turn on the 'on-camera' feature. This feature is a physical projection of the *hilal* through a simulative telescope, which is then displayed by zooming in until the *hilal* is visible if the conditions for *hilal* visibility, including altitude and elongation angle according to the concept of *imkan al-rukyah*, are met.

It should be noted that the simulation of *hilal* observation using the Digistar-6 planetarium system neglects factors that typically arise during image capture through any CCD camera. The process involved in the simulation of *hilal* observation only corrects for atmospheric conditions that can be adjusted according to the atmospheric conditions at sunset. Atmospheric thickness can be minimized until the *hilal* becomes visible. If, even after reducing the atmosphere, the *hilal* is not visible, it is unlikely to be seen during real *hilal* observation at a particular location. This is because, in addition to the atmosphere, there are other factors such as air pollution, cloud pollution, and local light pollution. These factors affect the success or failure of seeing the *hilal*. If the results of the simulation of *hilal* observation using the Digistar-6 planetarium system successfully show the physical appearance of the *hilal*, it does not necessarily guarantee that the *hilal* will be visible during real *hilal* observation at a specific location. This means that if the simulation of *hilal* observation using the Digistar-6 planetarium system yields the result of the *hilal* being invisible, it will be very difficult, if not impossible, for the *hilal* to be seen during real observation.

Figure 1. *Interface Digistar 6 menu setting atmosphere*

This article mentioned that in the practical implementation of the MABIMS criteria mentioned above, observers tend to overlook certain aspects, notably the moon-sun distance (elongation angle), which seems to receive less attention compared to the *hilal's* altitude. As previously noted by the author in earlier research, astronomical data, specifically elongation data, is missing in the Minister of Religious Affairs' decisions (KMA) regarding the determination of the beginning of the months of Ramadan, Shawwal, and Dhu al-Hijjah (Muhammad Nurkhanif et al., 2022). For example, in one case, why the *hilal* is not visible even though its altitude is over 2 degrees may be attributed to the contrast between the faint light of the *hilal* and the still relatively twilight. This contrast is influenced not only by the *hilal's* altitude above the horizon but also its distance from the sun. Furthermore, considerations such as the timing of *ijtimak* (conjunction), the azimuth difference, and the *hilal's* position suggest that the *hilal* may already be visible at sunset, but the likelihood is very low. Based on the above circumstances, to ascertain the validity of *hilal* claims in the Minister of Religious Affairs' decisions for the years 1962-2021, it is necessary to obtain comprehensive and complete astronomical data. This can be achieved by processing astronomical data through a *hilal* simulation model using the Digistar-6 planetarium system.

RESULT AND DISCUSSION

Hilal Sighting and MABIMS Criteria

This matter relies on a jurisprudential foundation when providing the boundaries of when the *hilal* can be seen astronomically at sunset during the process of *rukyat al-hilal* (Khazin, 2004; al-Isfahani, 2008). Because worship times are local in nature, determining them based on the appearance of the *hilal* is the easiest method (Djamaluddin, 2005; Maskufa, 2009). The absolute requirement for the validity of a *hilal* marking the beginning of a month in the Islamic calendar is that the Moon must be above the horizon just after sunset. However, if the distance between the sun and the moon is too close, even though the sun has set, its brightness may still be too strong, making the *hilal* impossible to see clearly (Putri, 2012). In such cases, a minimum requirement for the distance between the sun and the moon, known as elongation, is established (Azhari, 2008). Odeh states that at least two of these parameters mentioned above should be used together to obtain accurate results (Odeh, 2004). Odeh's view is already applied in the criteria of *imkan al-rukyat* MABIMS, which include three parameters such as hilal altitude, elongation, and moon age.

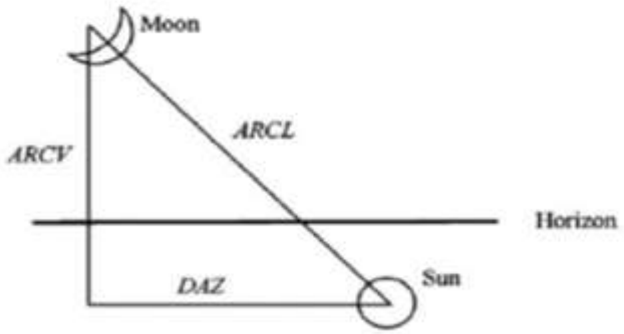

Figure 2. Basic Geometry of *Hilal* Visibility

Theoretically, the visibility conditions of the *hilal* are established to assist in determining and identifying the observed object accurately and correctly. Ideally, these conditions should be applied in a balanced manner. Siddiq, (2009) mentioned that the parameters of *hilal* visibility commonly used by observers in the field are closely related to important aspects such as the moon's age, moon's altitude, elongation, arc of vision (ARCV), delta azimuth and relative azimuth (DAZ), and crescent width (Sabiq, 2022). Furthermore, various astronomy experts have their own methods that are not far from these parameters. In 1989, the initiation of *imkan al-rukyah* began to be used by the Ministry of Religious Affairs of the Republic of Indonesia and MABIMS as one of the efforts to achieve a common understanding of the various methods for determining the beginning of the Hijri calendar in Indonesia and the Southeast Asian region.

The criteria of MABIMS are one of the *imkan al-rukyat* theories agreed upon by the four countries, namely Brunei Darussalam, Indonesia, Malaysia, and Singapore, with the minimum criteria being a moon's altitude of 2 degrees, elongation of 3 degrees, and/or moon's age of 8 hours (Majlis Ulama Islam Singapura, 2014). However, based on the results of national-level meetings on August 14-15, 2015M / 29-30 Syawwal 1436H in Jakarta, a meeting of astronomy experts on August 21, 2015M / 6 Dhu al-Qaadah 1436H in Jakarta, a regional-level meeting (MABIMS) on August 2-4, 2016 M / 27 Syawwal to 1 Dhu al-Qaadah 1437H in Malaysia, and an international seminar on November 28-30, 2017, in Jakarta, the LAPAN criteria were proposed to become global criteria called Neo-MABIMS criteria by converting the altitude difference to altitude. Thus, the proposed criteria became a moon's altitude of 3º and a geocentric elongation of 6.4° (Sabda, 2019).

In order to accept the testimony and sightings of the observers, conditions must be met by scholars (Hasan, 2005), such as: first, being just according to the elements of justice set by the scholars. Second, the integrity of their sight, skill, debating practice, and repetition, such that one observation is sufficient at a given moment (Jam et al., 2018). Third, being free from psychological factors that could prepare an object to become a crescent moon, known as visual hallucination. Fourth, the sighting must be after the birth of the crescent moon and must last for some time after sunset so that it can be seen. Fifth, there should be no clouds or other obstructions that divert the view, considering the observer's location and altitude, as the location where the crescent moon appears on the horizon may vary (Royyani et al., 2021). Al-Subky (1329) adds that judges must verify witnesses with many factors, such as the justice of the witness, the control of the witness, the witness's condition, and what might be the purpose of the testimony. Witnesses who can obstruct the acceptance of testimony.

Digistar-6 Planetarium System

In linguistic terms, the word 'planetarium' is derived from modern Latin, combining 'planeta' (planet) and 'arium' (place for). It can be singularly referred to as 'planetarium' or plurally as 'planetariums' or 'planetaria'. A planetarium is a facility used to observe simulations of celestial objects. Its essential components include a projector, a dome, and a celestial object gallery (Dictionary, n.d.). Digistar is a planetarium projector and computer-based content system that was first designed by Evans & Sutherland and released in 1983. Initially, this technology focused on presenting accurate and high-quality star displays, including showing stars from perspectives other than Earth's surface, simulating journeys through the stars, and accurately representing the night sky (E&S, n.d.). Digistar was conceived by Stephen McAllister and Brent Watson, both amateur astronomers and longtime computer graphics engineers. In 1977, E&S consulted with the Johnson Space Center on a spaceflight training simulator for astronauts. McAllister wrote a proof-of-concept software for this consultation, including data for 400 bright stars and software to display them. Steve and Brent initially saw the system's goal as a celestial navigation training tool. Brent, who had recently worked at the Hansen planetarium, asked his fellow planetarium workers for their opinions on the potential of a digital planetarium system, and both Steve and Brent shifted their focus to planetariums. The primary goal of the planetarium system was to use computer graphics to overcome the limitations of traditional star ball technology, which only allowed flat star displays from the Earth's surface perspective. With computer graphics, stars could be displayed from space perspectives, including simulating spaceflight views. Similarly, planets and moons within the solar system could be accurately displayed at any point in history from any perspective. The system used the real star locations from the Yale Bright Star Catalog, as well as random stars (Palicki, 2014). The Digistar system has evolved over time with periodic enhancements and corrections (E&S, n.d.). The Digistar system has had several versions, including Digistar (1983), Digistar II (1995), Digistar 3 (2002), Digistar 4 (2010), Digistar 5 (2012), Digistar 6 (2016), and Digistar 7 (2021).

Figure 3. *Digistar 6 interface*

Recalculation of the Claims of Hilal Sighting

The recalculations of the claims regarding the sighting of the *hilal* amounted to 56 data points from the Ministry of Religious Affairs of Indonesia from 1962 to 2021 for the determination of the beginning of Ramadan, Shawwal, and Dhu al-Hijjah. This was done using the Accurate Hijri Calculator 2.2.1 software developed by Abdurro'uf, Ph.D., an alumnus of the Department of Physics at Brawijaya University. The purpose of these recalculations was to determine the astronomical data of the *hilal's* altitude and elongation. The Accurate Hijri Calculator (AHC) is software that can be used as a tool for calculating the beginning of the hijri lunar months, including those related to the religious rituals of the Islamic community, such as Ramadan, Shawwal, Dhu al-Hijjah, and other hijri months. In its development, this software is based on astronomical algorithms, which have been verified by comparing their calculations with the sighting data from the Ministry of Religious Affairs of Indonesia, USNO software, and Accurate Time 5.3.4 software. Additionally, AHC accommodates various criteria for hijri dating used in Indonesia and internationally, making it a useful tool for those following specific dating criteria.

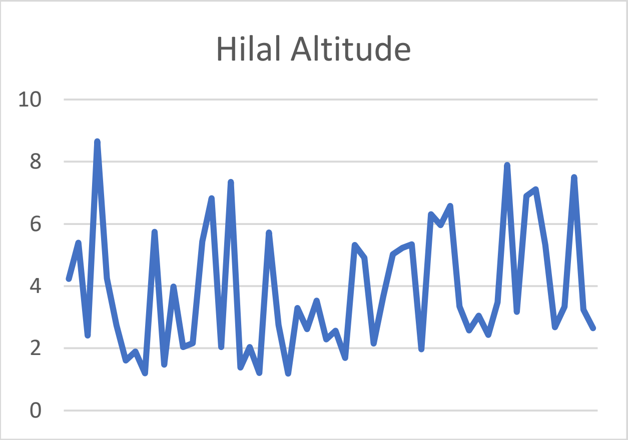

Figure 4. Crescent Altitude Data from 1962-2021

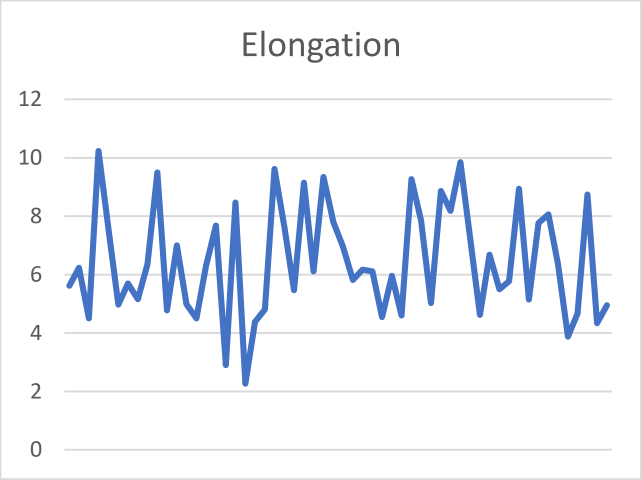

Figure 5. Elongation Data from 1962-2021

Physical Crescent Before Implementation of Imkan MABIMS

From the entire dataset, if the author bases it on the year of the old implementation of Imkan al-ru'yah MABIMS, there are 30 data claims of the crescent visibility from 1962 to 1997 because the old Imkan al-ru'yah MABIMS was applied in 1998 (Directorate General of Islamic Community Guidance, 2011).

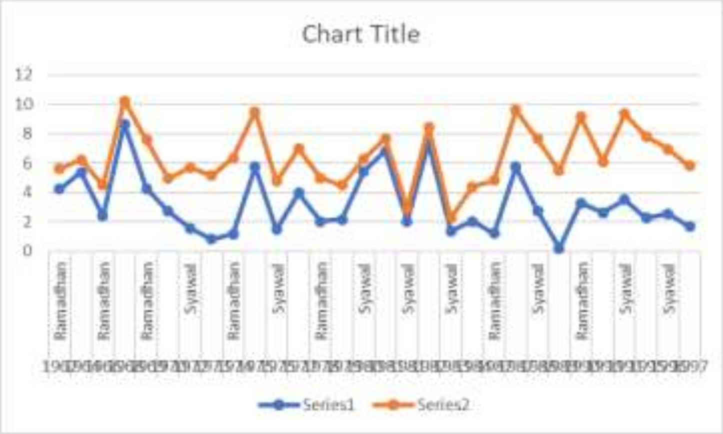

Figure 6. Data of Crescent Visibility from 1962-1997

From these 30 data points, there are 8 astronomical data points with a crescent's altitude of less than 2º. The lowest crescent altitude was recorded in 1973 CE, coinciding with the beginning of Ramadan in 1409 Hijri, observed at Masjid Klender, East Jakarta, with a crescent altitude of 0.2001º and elongation data of 5.468º. The highest crescent altitude data was obtained in 1972 CE, coinciding with the beginning of Shawwal in 1392 Hijri, observed at Ancol, North Jakarta, with a crescent altitude of 1.592º and elongation data of 5.692º. Furthermore, from 1962-1997, there are 29 astronomical data points with crescent altitudes greater than 2º. The highest astronomical data point was recorded during the determination of the beginning of Shawwal in 1388 Hijri, which corresponds to the year 1968, observed at Pelabuhan Ratu, with a crescent altitude of 8.659º and elongation data of 10.323º. The smallest astronomical data point was recorded during the determination of the beginning of Shawwal in 1401 Hijri, which corresponds to the year 1981, observed at Pelabuhan Ratu, with a crescent altitude of 2.037º and elongation data of 2.9006º. From this data, the author then simulated both sets of data (crescent altitudes < and > 2º) to determine the physical characteristics of the crescent using the Digistar 6 planetarium system.

Figure 7. Data of Crescent Altitude < 2 degrees at KMA RI from 1962-1997

The author selected a sample of the highest crescent altitude data from those 8 data points, which, as a whole, were still below 2 degrees. This data corresponds to the claim of crescent visibility during the determination of the beginning of Shawwal in 1392 Hijri, which occurred on November 6, 1972, with a crescent altitude of 1.592 degrees and an elongation data of 5.692 degrees. The data also includes the solar azimuth value of 253.7276 degrees, lunar azimuth value of 248.5713 degrees, and the time of conjunction at 8:21:14 local time in Ancol, North Jakarta.

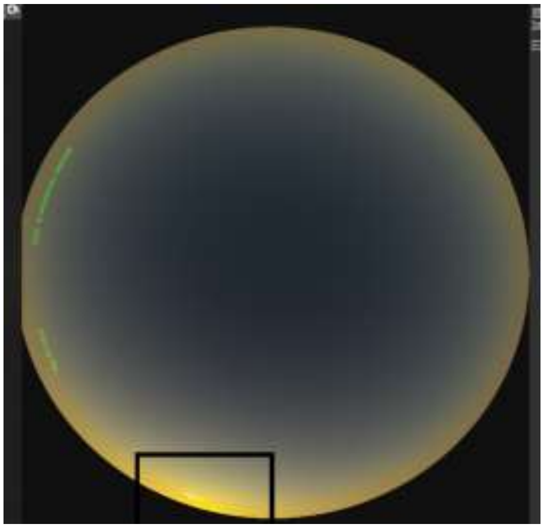

Figure 8. Crescent Physics 1.592º, Elongation 5.692º at KMA RI 1972 without Zoom

The image of the crescent physics data above represents the claim of crescent visibility through the simulation of the Digistar 6 planetarium system during the determination of the beginning of Shawwal in 1392 Hijri, which occurred in 1972 with the observation location in Tanjung Priuk, North Jakarta. This physical data was obtained without the zooming process, and the crescent's position is indicated by the black marker at the time of sunset within the planetarium dome's circle.

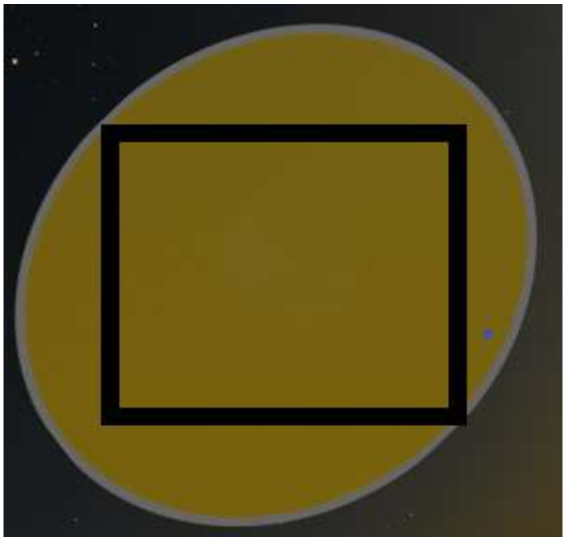

Figure 9. Crescent Physics 1.592º, Elongation 5.692º at KMA RI 1972 with Zoom Process on Telescope Camera

After zooming in on the crescent using the telescope camera feature and reducing atmospheric intensity to 15.48%, the crescent is not visible with a height of 1.592º and elongation data of 5.692º. Therefore, it can be said that the credibility of this crescent claim is questionable if there is no real physical evidence of the crescent, especially if the claim is made without optical aids. Furthermore, the author presents crescent physics data from 1962 to 1997, which includes data with crescent heights greater than 2 degrees. In this context, the author provides a comparison of crescent data above 2 degrees, crescents at 3 degrees, and the highest crescents above 7 degrees.

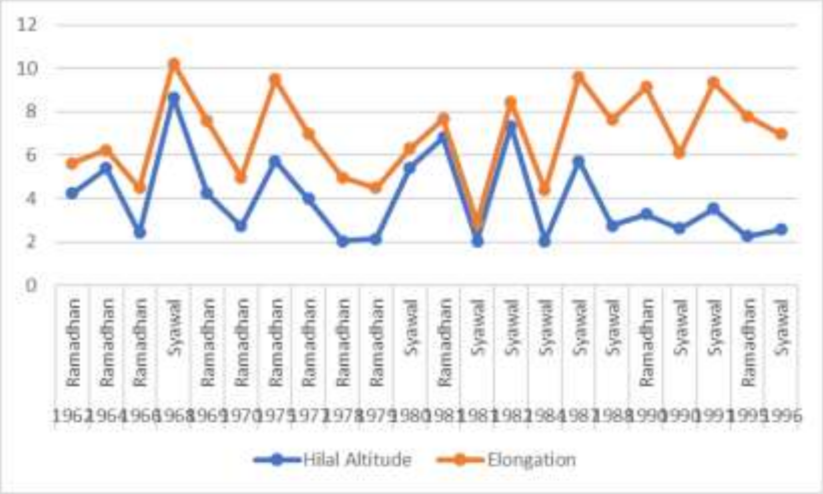

Figure 10. Crescent Data > 2 Degrees in KMA RI 1962-1997

The highest data is from the crescent testimony claim in the year 1968 for determining the beginning of Shawwal 1388 hijriah. This claim comes from one of the crescent observation locations in Pelabuhan Ratu, with astronomical data of a crescent height of 8.659º, elongation of 10.323º, Sun azimuth of 246.258º, Moon azimuth of 242.6058º, and conjunction time on December 20th at 1:18:35 local time.

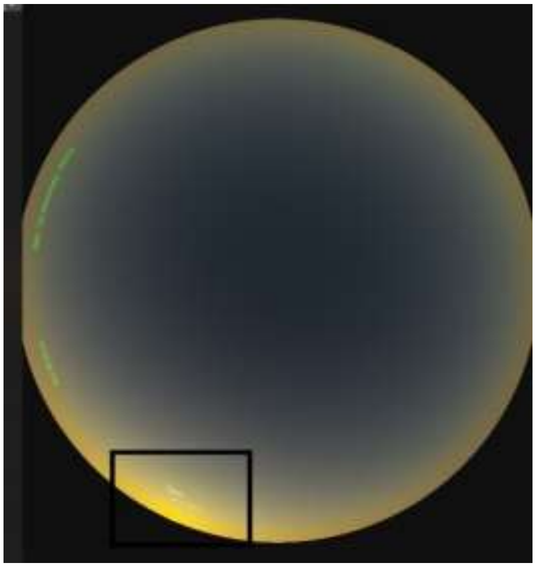

Figure 11. Crescent Physics 8.659º, Elongation 10.323º in KMA RI 1968 without Zoom Process

The image of the crescent's physical data above was obtained without the zoom process, and the crescent's position is indicated by the black marker at the time of sunset within the planetarium dome circle for the determination of the beginning of Shawwal 1388 hijriah, which coincides with the year 1968, with the astronomical data mentioned above.

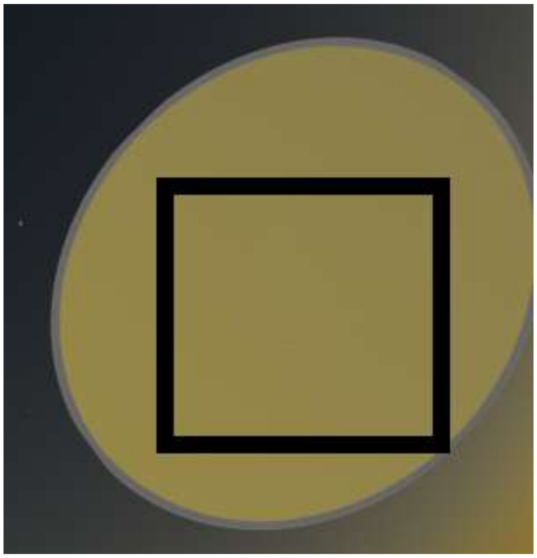

Figure 12. Crescent Physics 8.659º, Elongation 10.323º in KMA RI 1968with Zoom Process

After zooming in on the crescent using the telescope camera feature and reducing atmospheric intensity to 46.43%, the crescent becomes visible. However, it may still be somewhat challenging to see the crescent during crescent observation without optical aids such as telescopes and other optical devices. Next, the lowest astronomical data for the crescent above 2 degrees was during the determination of the beginning of Shawwal 1401 hijriah, which coincided with the year 1981, with the observation location in Pelabuhan Ratu. The crescent's height was 2.037º, the elongation was 2.9006º, the azimuth of the Sun was 288.2697º, the azimuth of the Moon was 288.6835º, and the conjunction occurred on July 31 at 10:51:58 local time.

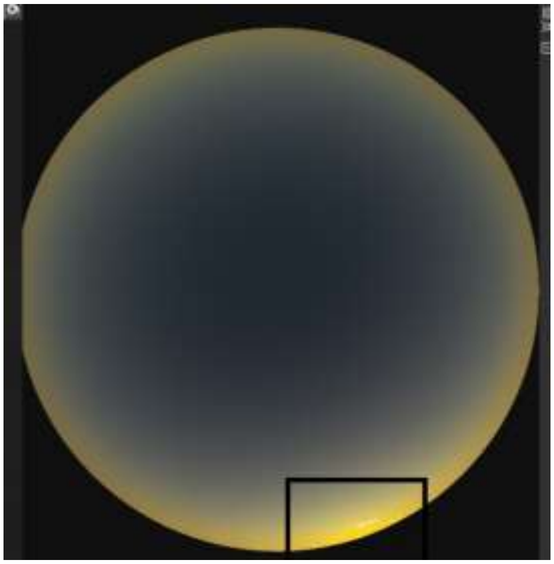

Figure 13. Crescent Physics 2.037º, Elongation 2.9006º in KMA RI 1981without Zoom Process

The image of the crescent physics above was obtained without any zooming process. The position of the crescent at the beginning of Shawwal 1401 hijriah, which coincided with the year 1981, is marked by the black marker when the Sun sets within the planetarium dome's circle.

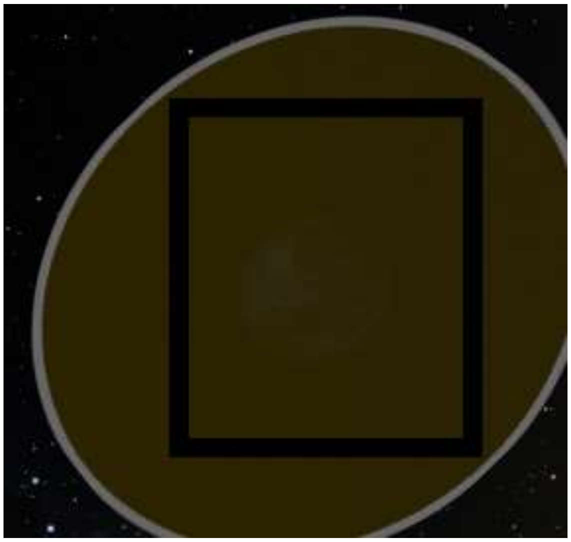

Figure 14. Crescent Physics 2.037º, Elongation 2.9006º in KMA RI 1981 with Zoom Process

After zooming in on the crescent using the telescope camera feature and reducing atmospheric intensity to 2.38%, the crescent is very difficult to see with a height of 2.037º and an elongation of 2.9006º. Under these conditions, it would be extremely challenging to spot the crescent without optical aids such as a telescope or other devices. Therefore, the credibility of this crescent claim can be doubted without real physical evidence. For comparison, the author tested a crescent testimony claim with a height of 3 degrees and an elongation greater than 6.4 degrees. This data is from the observation at the beginning of Ramadan 1397 hijriah, which occurred on August 15, 1977, in Cakung, East Jakarta, with a crescent height of 3.9119º, an elongation of 7.0087º, azimuth of the Sun 284.0083º, azimuth of the Moon 278.8508º, and the conjunction occurring at 4:31:05 local time.

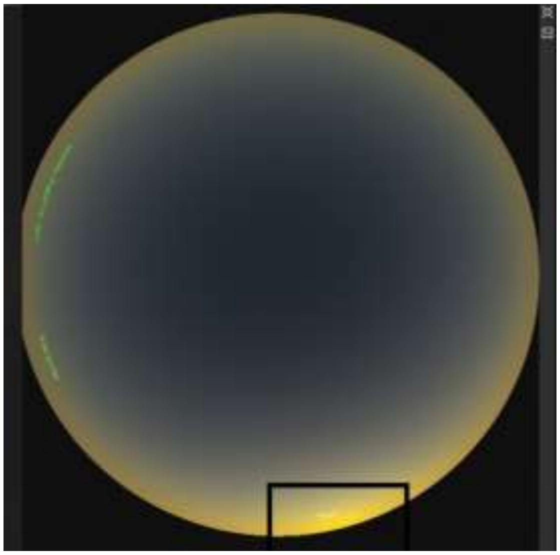

Figure 15. Crescent Physics 3.9119°, Elongation 7.0087° in KMA RI 1977without Zoom Process

The image of the crescent physics data above was obtained without any zooming process. The position of the crescent at the beginning of Ramadan 1397 hijriah, which occurred in 1977, is indicated by the black marker at the time of sunset in the planetarium dome circle.

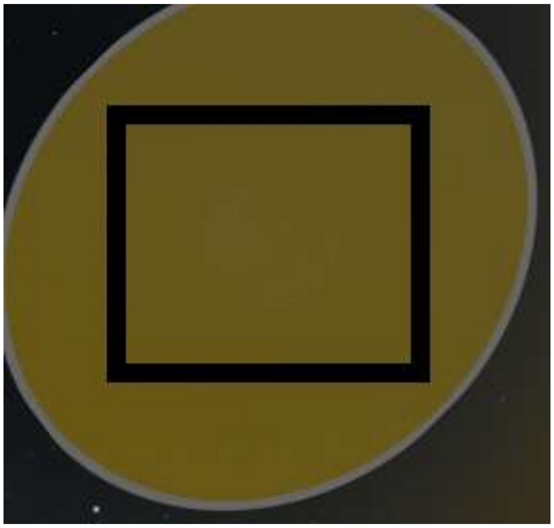

Figure 16. Crescent Physics 3.9119°, Elongation 7.0087° in KMA RI 1977without Zoom Process

After zooming the crescent using the telescope camera feature and reducing atmospheric intensity to 15.48%, the crescent is slightly difficult to see with a height of 3.9119° and an elongation of 7.0087°, even with the assistance of optical instruments. This crescent will be very difficult to see without the use of a telescope and a CCD camera for photographing the physical crescent. In fact, crescent observation will be even more challenging if there are other hindering factors such as cloud pollution, local horizon humidity, and so on. Therefore, claims of successful crescent sighting with crescent data below 6 degrees and elongation of 9.75 degrees without optical aids will fall into the category of not being easy. In this research, the author obtained two claims of crescent testimonies that the crescent should not have been visible because its condition was still below the horizon. These two crescent claims are, first, the crescent claim data in determining the beginning of Ramadan in 1930 hijriah, which coincided with 1970. In the decision of the Minister of Religious Affairs (KMA) RI, there is astronomical calculation data that mentions the crescent's height reaching 2° 47', whereas the results of the recalculation show that the crescent's height is still below the horizon at around -0° 46'58" and elongation of 4° 59'. Second, the crescent claim data in determining the beginning of Shawwal in 1393 hijriah, which coincided with 1973. In the decision of the Minister of Religious Affairs (KMA) RI, there is astronomical calculation data that mentions the crescent's height reaching 3º 45', whereas the results of the recalculation show that the crescent's height is about 0º 50'13" and elongation of 5º 9' 37".

Crescent Physics After the Implementation of MABIMS Imkan

After the author tested the crescent physics data found in KMA RI before the application of the old MABIMS imkan (2,3,8), the author then tested the crescent physics data found in KMA RI after the application of the old MABIMS imkan since 1998 until now. However, the author only focused on testing the crescent physics data until 2021, which is the last year of the old MABIMS imkan application towards the implementation of the new MABIMS imkan (3, 6.4) in 2022 as decided by the Minister of Religious Affairs of Indonesia. There are 26 crescent testimony claim data that have been received and decided by the Ministry of Religious Affairs of Indonesia as the basis for determining the beginning of Ramadan, Shawwal, and Dzulhijjah (Directorate General of Islamic Community Guidance, 2011).

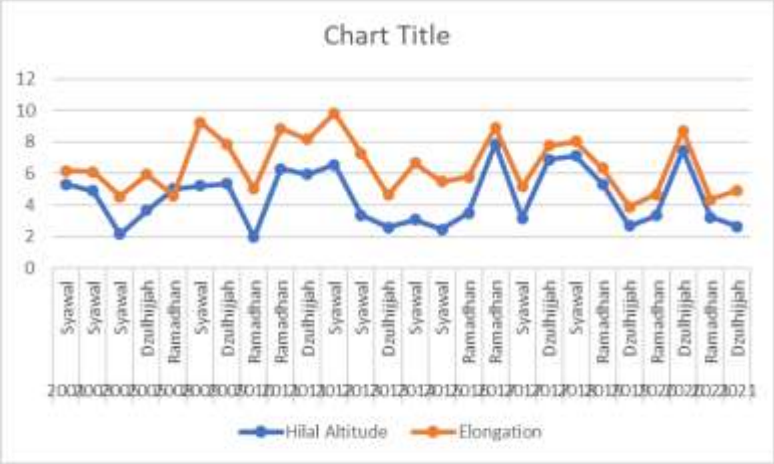

Figure 17. Data Crescent Testimony Claims in KMA RI 1998-2021

Of those 26 crescent testimonies claim data mentioned above, there is one claim with the crescent's height still below the old MABIMS imkan. This claim was made during the determination of the beginning of Ramadan in 1431 hijriah, which coincided with the year 2010, in various crescent observation locations in East Java, including Gresik, Surabaya, and Probolinggo, as well as in the DKI (Special Capital Region of Jakarta) and Bengkulu regions. The astronomical data for the crescent's height was approximately 1º 57'59" and elongation 4º 48'11" for the DKI region, crescent height 1º 58'39" and elongation 5º 13'37" for the Bengkulu region, and crescent height 1º 48'18" and elongation 4º 50'10" for the East Java region.

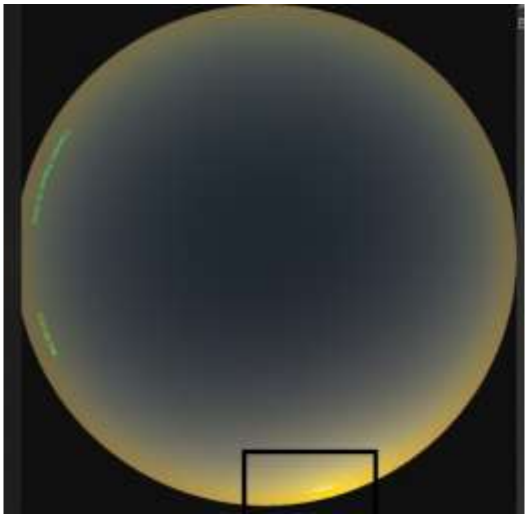

Figure 18. Physical Characteristics of the Hilal 1.8051º, Elongation 4.8361º on KMA RI 2010 without Zoom Process

The image of the physical data above was obtained without any zoom process. The position of the hilal at the beginning of Ramadan 1431 Hijriah, corresponding to the year 2010, is indicated by the black marker at the time of sunset within the planetarium dome circle.

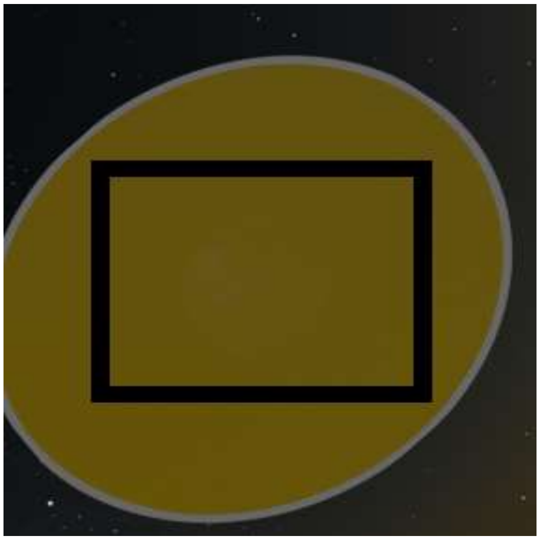

Figure 19. Physical Characteristics of the Hilal 1.8051º, Elongation 4.8361º on KMA RI 2010 with Zoom Process

After zooming in on the hilal using the telescope camera feature and reducing atmospheric intensity to 2.38%, the hilal remains very difficult to see with a height of 1.8051º, an elongation of 4.8361º, an azimuth of 285.5441º for the Sun, and an azimuth of 281.4915º for the Moon. Under these conditions, it would be extremely challenging to observe the hilal without optical aids such as a telescope and other optical devices. Therefore, the authenticity of this hilal claim can be questioned without real physical evidence. In addition to the physical hilal data above, there are also claims of hilal sightings with heights >2º, totaling 5 data points. From these 5 data points, the author selected the highest hilal claim >2º but still < 3º, which is the claim of the hilal sighting at the beginning of Dzulhijjah 1434 Hijriah, corresponding to the year 2013, with astronomical data of a hilal height of 2.0857º and an elongation of 4.3964º, observed in Kolaka, Southeast Sulawesi.

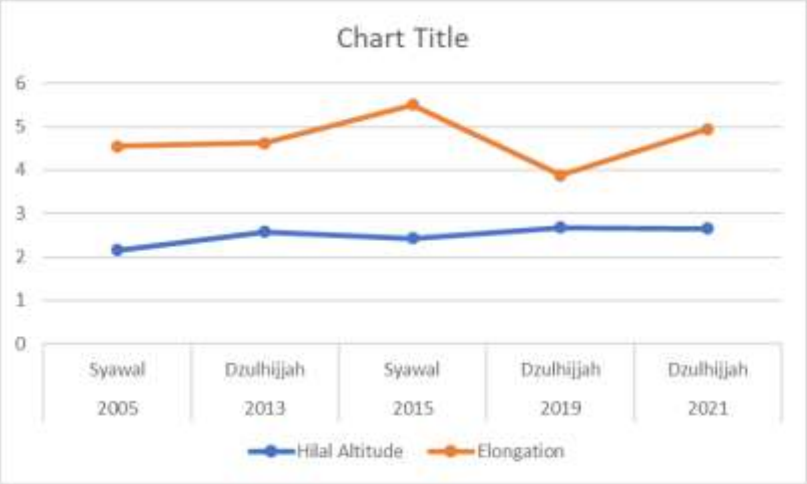

Figure 20. Data hilal > 2 degrees, < 3 degrees in KMA RI 1998-2021

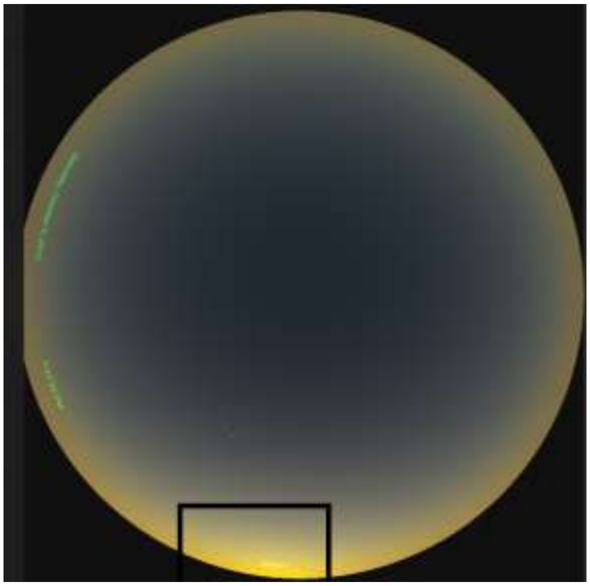

Figure 21. Physical data of the crescent moon with 2.0857º height and 4.3964º elongation in KMA RI 2013 without the Zoom process

The image of the physical data above was obtained without the Zoom process. The position of the crescent moon at the beginning of Dzulhijjah 1434 hijriyah, which coincided with the year 2013, is marked in black at the time of sunset within the planetarium dome circle.

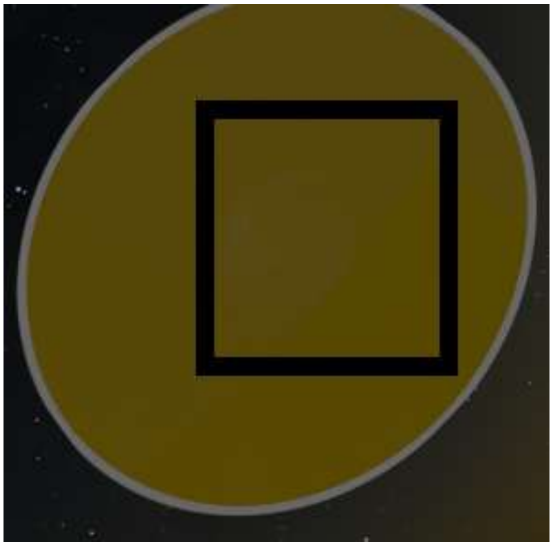

Figure 22. Physical data of the crescent moon with 2.0857º height and 4.3964º elongation in KMA RI 2013 with the Zoom process

After zooming in on the crescent moon using the telescope camera feature and reducing atmospheric intensity to 9.25%, it is challenging to see the crescent moon with a height of 2.0857º and an elongation of 4.3964º (meeting the minimum requirement of the old MABIMS). The azimuth of the Sun is 265.06º, and the azimuth of the Moon is 261.7732º. Under these conditions, it becomes very difficult to observe the crescent moon without optical aids such as a telescope and other devices. Therefore, the claim regarding the sighting of the crescent moon can be doubted in the absence of real physical evidence. Furthermore, there are 20 testimonial crescent moon sighting data with heights greater than 3º from 1998 to 2021. The author selected a sample of crescent moon sighting data with the highest crescent moon height, specifically, the data regarding the sighting of the crescent moon at the beginning of Ramadan 1438 hijriyah, which coincided with the year 2017 in the observation location of Kupang, East Nusa Tenggara. The astronomical data includes a crescent moon height of 7.5387º and an elongation of 8.5151º, with a Sun azimuth of 291.3833º and a Moon azimuth of 289.8329º.

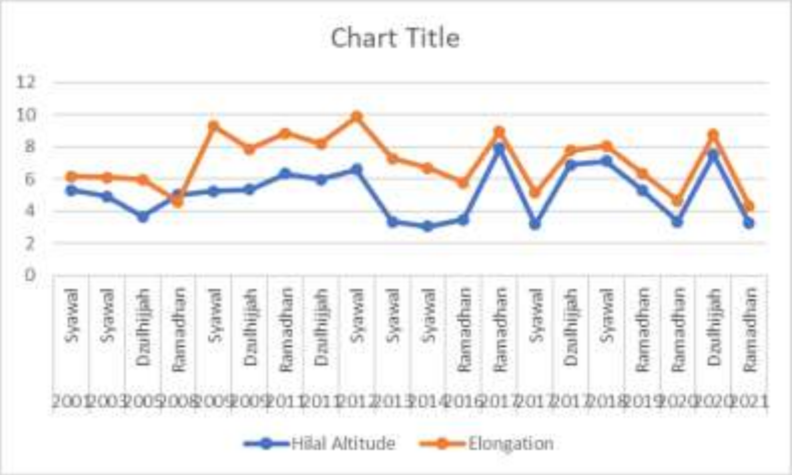

Figure 23. Physical data of the crescent moon with 7.5387º height and 8.5151º elongation in KMA RI 2017 without the Zoom process

The image of the physical data above was obtained without the zoom process. The position of the crescent moon at the beginning of Ramadan 1438 hijriyah, coinciding with the year 2017, is marked by the black marker at the time of the sunset within the planetarium dome's circle.

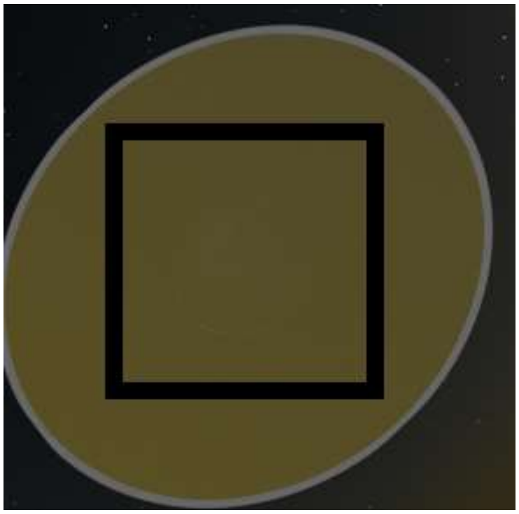

Figure 24. Physical data of the crescent moon with a height of 7.5387º and an elongation of 8.5151º in KMA R2017 with the Zoom process

After zooming the physical data using the telescope camera feature and reducing atmospheric intensity to 14.29%, the crescent moon can be seen clearly with the naked eye or with optical aids, with a height of 7.5387º and an elongation of 8.5151º. This condition would make it slightly difficult to observe the crescent moon with just the naked eye, especially if there are other disturbances such as cloud or local light pollution. In addition to the above-mentioned sample data, there is also a data claim of witnessing the crescent moon that has reached the lowest limit of the new MABIM visibility (3, 6.4). This claim data of witnessing the crescent moon occurred during the determination of Shawwal 1435 hijriyah, coinciding with the year 2014, with data showing a height of 3.053º and an elongation of 6.6814º, located at the observation site of Bukit Condrodipo Gresik.

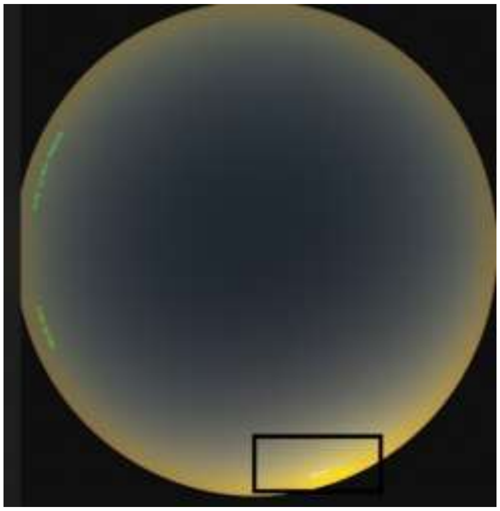

Figure 25. Physical data of the crescent moon with a height of 3.053º and an elongation of 6.6814º in KMA RI 2014 without the Zoom process

The image of the physical data above was obtained without the zooming process. The position of the crescent moon at the beginning of Shawwal 1435 hijriyah, coinciding with the year 2014, is indicated by the black marker at the time of sunset within the planetarium dome's circle.

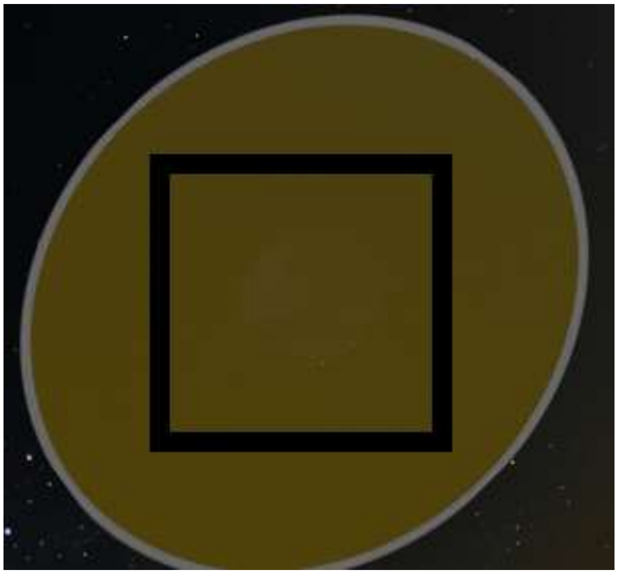

Figure 26. Physical data of the crescent moon with a height of 3.053º and an elongation of 6.6814º in KMA RI 2014 with the Zoom process

After zooming in on the crescent moon using the telescope's camera feature and reducing atmospheric intensity to 8.33%, the crescent moon can be observed with a height of 3.053º and an elongation of 6.6814º, with the Sun's azimuth at 289.2203º and the Moon's azimuth at 283.786º. Under these conditions, it would be very difficult to see the crescent moon without optical aids such as a telescope, and the authenticity of the claim regarding the crescent moon may be doubted if there is no physical evidence.

Comparison of Simulated Crescent Moon Physical Data with Real Crescent Moon Physical Data

In order to understand better the physical data of the crescent moon obtained from simulated observations using the Digistar 6 planetarium system, the author provides two sets of real crescent moon physical data for comparison. First, the physical data of the crescent moon at the beginning of the month of Dhu al-Qi'dah 1444 hijriyah, corresponding to May 20, 2023. The observation took place at the Ru'yat Ibnu Syatir Observatory at the Al-Islam Joresan Islamic Boarding School in Ponorogo, East Java, with a crescent moon height of 6.2º and an elongation of 9.75º. The observation process involved using an automatic telescope and image data processing with Iris software, involving a total of 200 image frames.

Figure 27. Real physical data of the crescent moon at the beginning of the month of Dhu al-Qi'dah 1444 Hijr

The author then compared the real physical data of the crescent moon with the results of the simulated observations using the Digistar 6 planetarium system with a similar setup.

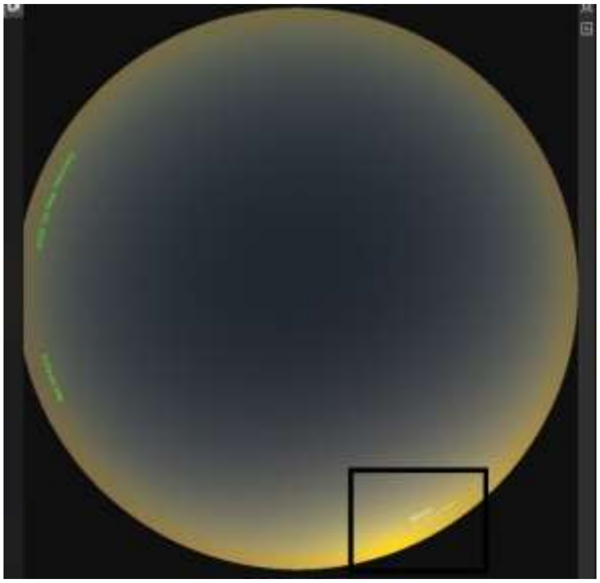

Figure 28. Physical data of 6.2º and elongation of 9.75º in 2023 without Zoom

Physical data of the crescent moon at the beginning of the month of Dhu al-Qi'dah 1444 Hijriyah in 2023 without the zoom process in the simulated moon observation at the planetarium dome.

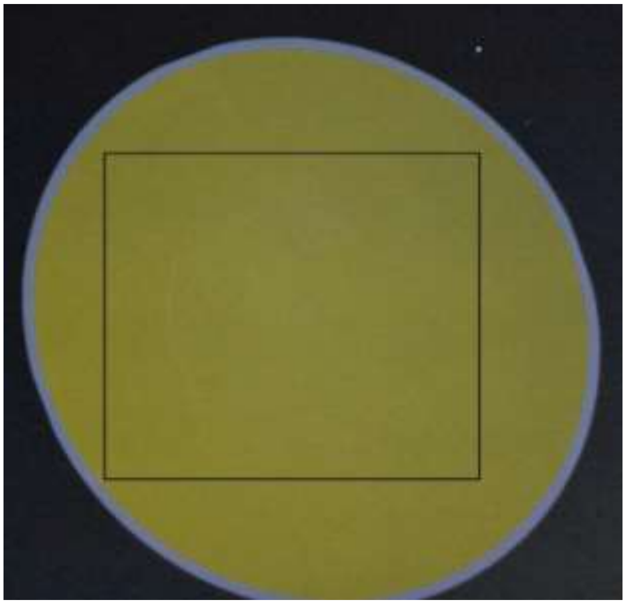

Figure 29. Physical data of 6.2º and elongation 9.75º in 2023 with zoom

The hilal is clearly visible in the physical image of the hilal after the zoom process, reducing the atmospheric influence by 23.81%. The two physical data of the hilal in determining the beginning of the month of Ramadan 1436 hijriyah, which falls on June 17, 2015. The observation location is at the Ru'yat Hall Cndrodipo Gresik East Java with a hilal altitude of 9.287º and elongation of 10.4051º. The observation process uses an automatic William telescope and the imaging of the hilal uses a NIKON D3100 camera.

Figure 30. Physical data of the crescent moon at the beginning of the month of Ramadan 1436 Hijriyah / 2015

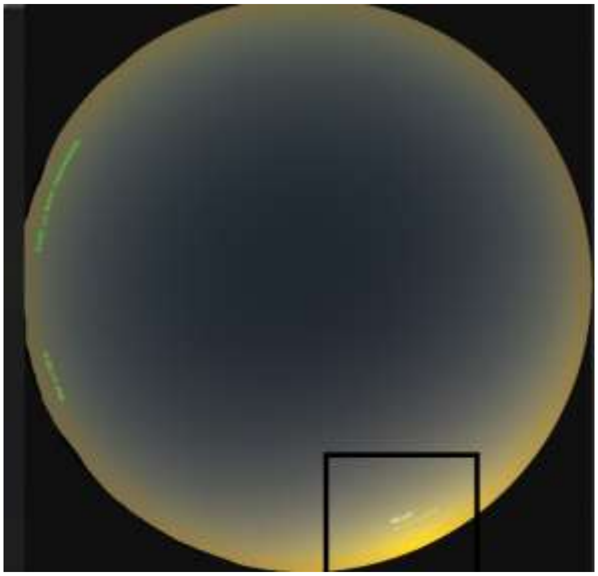

Figure 31. Physical data of the crescent moon with 9.287° altitude and 10.4051° elongation in 2015 without the zoom process.

Figure 32. Physical data of the crescent moon with 9.287° altitude and 10.4051° elongation in 2015 with the zoom process.

CONCLUSION

Based on the presentation of physical data of the crescent moon from the testimonial claims of the moon sightings found in the Minister of Religious Affairs of Indonesia's decisions for determining the beginning of Ramadan, Shawwal, and Dhu al-Hijjah from 1962 to 2021, it can be concluded that the simulation of moon observation using the Digistar-6 planetarium system can be used as one of the means to reevaluate old data regarding the claims of moon sightings that lack physical evidence during the moon observation. Claims of moon sightings are susceptible to being unverifiable due to various factors such as the core factors of celestial objects, including the data on moon altitude and elongation, which are insufficient for the moon to be visible. In addition to these core factors, there are other important factors such as atmospheric pollution at the moon observation locations, local light pollution, weather conditions, and other factors that can hinder the observer's ability to see the moon. All 56 claims of moon sightings found in the decisions of the Minister of Religious Affairs of Indonesia have highly varied astronomical data, which the author presents in the table below:

Table 1. Hilal's altitude and elongation

1	**Hilal Altitude <2 degr**	**9**	**Min Elongation**	**2.266**	**Max Elongation**	**5.814**
2	Hilal Altitude >2 degree	15	Min Elongation	2.898	Max Elongation	7.795
3	Hilal Altitude >3 degree	10	Min Elongation	7.795	Max Elongation	9.35
4	Hilal Altitude >4 degree	24	Min Elongation	4.602	Max Elongation	10.232
	Total	56				

Inconsistencies in all the astronomical data found in the decisions of the Minister of Religious Affairs of Indonesia include, Firstly, there is no data on elongation in all these decisions. Secondly, there is variation in the use of methods for calculating astronomical moon data, especially before the implementation of the MABIMS theory. Thirdly, there is astronomical data of post-implementation claims of MABIMS with altitudes below 2 degrees that have been accepted. Based on these three conclusions, all claims of moon sightings below 3 degrees and elongation below 6 degrees are very difficult and even impossible to verify the visibility of the moon, especially without the use of optical aids such as telescopes during the moon observation process. As a continuation of research related to the importance of the Digistar-6 planetarium system, the author plans to conduct research on the effectiveness and prospects of the new MABIMS theory, which has been implemented in countries such as Malaysia, Brunei Darussalam, Singapore, and especially Indonesia, where its applicability was decided by the Minister of Religious Affairs of Indonesia in 2022.

Acknowledgments

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