INTERNATIONAL JOURNAL
IHYA' 'ULUM AL-DIN

International Journal Ihya' 'Ulum al-Din
Vol 26, No 2 (2024): 197–216
DOI: https://doi.org/10.21580/ihya.26.2.23577

Exploring the New Moon during the Time of Prophet Muhammad Using Digistar 6 Planetarium

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Citation (APA):
Nurkhanif, M., Djamaluddin, T., Izzuddin, A., & Ahmad, M.R. (2024). Exploring the New Moon during the Time of Prophet Muhammad Using Digistar 6 Planetarium. *International Journal Ihya' 'Ulum al-Din*, 26(2), 197-216.

Submitted: 18 Oct 2024
Revised: 13 Nov 2024
Accepted: 18 Nov 2024
Published: 1 Dec 2024

Abstract: This article aims to present a digital visualization of the new moon (hilal) as a determinant of the beginning and end of Ramadan fasting, exploring the astronomical phenomenon of hilal visibility during the Prophet Muhammad's era using the Digistar 6 system in a planetarium. Several Islamic jurisprudence (fiqh) literatures discuss comparisons of fasting durations during the Prophet's time, ranging between 29 and 30 days. This study employs a qualitative research method based on library research, utilizing an astronomical approach and simulation observations in a planetarium. The data used include historical and astronomical data from the Prophet Muhammad's era, as well as related classical literature. The findings of the study include the integration of Digistar 6 technology with computational data to reconstruct the hilal phenomena of the Prophet's time. For instance, the elevation of the hilal marking the beginning of Syawal in 8 AH was observed at a minimum Moon Altitude of 02°06'22" above the horizon, with an elongation of 04°55'56" and an atmospheric clarity of 9.52%. The Prophet Muhammad observed Ramadan fasting nine times, with six instances involving 29 days of fasting and the remaining three involving 30 days, as determined through simulated physical imagery of the hilal.

Keywords: Digistar; New moon (hilal); Prophet Muhammad; Visualization

Abstrak: Artikel ini bertujuan untuk memaparkan visualisasi Bulan baru (*hilal*) sebagai penentu awal dan akhir puasa Ramadhan berbasis digital guna menelusuri fenomena astronomi yakni ketampakan *hilal* pada zaman Rasulullah SAW dengan menggunakan sistem Digistar 6 di planetarium. Disebutkan dalam beberapa literatur fiqih terkait perbandingan jumlah hari puasa zaman Nabi antara 29 dan 30 hari. Kajian ini merupakan riset kualitatif berbasis pada metode pustaka

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dengan menggunakan pendekatan astronomi serta simulasi observasi di planetarium. Data yang digunakan adalah data historis dan data Astronomis pada masa Rasulullah SAW serta literatur klasik yang berhubungan. Hasil dari penelitian antara lain, integrasi teknologi digistar 6 dengan data perhitungan dalam mengungkap *hilal* masa lalu di zaman Rasulullah Saw. Data ketinggian *hilal* awal Syawal terlihat dengan ketinggian *hilal* terendah di atas ufuk adalah 02°06'22" pada tahun 8 hijriyah dengan elongasi 04°55'56" serta kondisi atmosfer terkecil sebesar 9.52%. Jumlah berpuasa Ramadhan Zaman Rasulullah sebanyak Sembilan kali, diantaranya enam kali berpuasa sebanyak 29 hari dan sisanya (tiga kali) berpuasa dengan jumlah hari 30 hari berbasis pada citra fisis *hilal* simulative.

Kata Kunci: Digistar; Bulan Baru (Hilal); Rasulullah; Visualisasi

Introduction

The Hijri calendar, or Islamic lunar calendar, plays a central role in Islamic practices by marking important religious events and periods, such as Ramadan and Eid al-Fitr (Khusurur et al. 2024). The beginning of each month in this calendar is determined by the sighting of the new moon, or *hilal*, making accurate observation crucial for the proper performance of Islamic rituals (Mir and Banday 2023), (Ismail and Ghofur 2019). Historically, the sighting of the new moon has been essential in marking the beginning of Ramadan, the month of fasting and spiritual reflection. The traditional moon sighting practice, as established during the time of Prophet Muhammad (SAW), involved direct observation and heavily relied on visual confirmation and the testimony of witnesses (Tartory 2022).

During the time of Prophet Muhammad in Madinah, the method for determining the start of Ramadan was based on the practice of rukyatul *hilal*, or the naked-eye sighting of the moon. Prophet Muhammad instructed his followers to observe the *hilal* at the end of the month of Sha'ban. If the new moon was sighted, Ramadan would begin the following day (Amanah 2024). However, if the *hilal* was not sighted due to weather conditions or other factors, the month of Sha'ban would be completed to 30 days before announcing the start of Ramadan.

The duration of Ramadan fasting, alternating between 29 and 30 days, reflects the variability of the lunar calendar. While the exact number of times the Prophet fasted for either 29 or 30 days remains unclear, historical and religious texts provide insight into fasting practices during this holy month. The Prophet's fasting practices are documented in Hadith literature, though the specific number of times he fasted for 29 versus 30 days is not definitively recorded (Ahmed and Lykke 2014).

It is noted that the Prophet Muhammad fasted for 29 days more frequently than for 30 days, as mentioned in a Hadith narrated by Ibn Mas'ud (Al-Albani 2000).

ما صمت مع النبي صلى الله عليه وسلم تسعا وعشرين أكثر مما صمنا ثلاثين

"We fasted with the Prophet (SAW) for 29 days more frequently than fasting for 30 days."

According to Sulaiman Rasyid in his book *Fiqh Islam* and as-Sayyid Bakri in his work *I'anatut Thalibin* Volume II, it is stated that out of nine occasions, the Prophet (SAW) fasted for 30 days only once (Rasjid 2010), (Al-Bakry 1995). Moenawar Chalil, in his book *Nilai dan Hikmah Puasa*, mentions that Abu Dawud and at-Tirmidhi narrated that the Prophet (SAW) fasted nine times, and on one or two of those occasions, he fasted for 30 days. Similarly, Ibn Hajar in *Fathul Bari* Volume 8 also states that out of nine times, the Prophet fasted for 30 days on two occasions. An-Nawawi adds that fasting for 29 days could occur consecutively for up to four times (over four years) (Chalil 1982), (Ibnu Hajar 1379).

There are several applications, such as Stellarium and Sky Eye, used for simulating the *hilal*; however, they have not yet been able to display the *hilal*'s shape accurately (Sayehu 2017) . The Digistar 6 system, one of the tools used in planetariums, offers accurate 3D simulations of celestial objects that closely approximate their actual movement, both for past and future trajectories. With its digital technology, Digistar 6 provides high-quality visualizations in planetariums.

Advancements in digital technology offer new possibilities for understanding and visualizing astronomical phenomena. The Digistar 6 Planetarium, a state-of-the-art digital visualization tool, allows for high-resolution simulations of astronomical events, including the moon's phases. By using Digistar 6, researchers can reconstruct the appearance of the new moon as it was observed during the time of Prophet Muhammad, providing insights into historical moon sighting practices. This technology enables more accurate and detailed analysis of lunar visibility, enhancing our understanding of the challenges faced by early Muslims in determining the start of Ramadan.

Regarding the study of using Digistar 6 Planetarium, there are two previous studies focusing on celestial simulations. The *first* is a study by Irman Said Prasetyo et al., titled "Digistar 6-Based Planetarium as an Educational Media for Learning about the Sun Position Using a Horizontal Coordinate System." This article highlights the importance of understanding the position of celestial objects within a horizontal coordinate system, which is crucial in astronomy and astrophysics. The Digistar 6-based planetarium was shown to enhance students' understanding of the Sun's position by 32.89%, as indicated by the improvement in correct answers from pretest to posttest and a passing rate of 53.34% on the PAP version (Prastyo et al. 2022).

The *second* study is by Tolkah et al., titled "Digital *Hilal* Observation: Evaluating the Authenticity of *Hilal* Testimonials in Indonesia Using the Digistar-6 Planetarium System." This article examines the authenticity of *hilal* (new moon) sighting claims in Indonesia from 1962 to 2021. The study reveals inconsistencies in the application of minimum visibility criteria for the *hilal*, known as imkan al-rukyat. Approximately 45.5% of these claims are questioned due to insufficient elongation data and height data falling below the MABIMS criteria. The Digistar-6 Planetarium system was used to provide a 3D visualization of the *hilal* observation process (Tolkah, Nurkhanif, and Safiai 2024).

The focus of this study is to discuss the timing of fasting observed by Prophet Muhammad (SAW), specifically the duration of Ramadan during his time, from an astronomical perspective. This study integrates digital technology, specifically Digistar 6, to visualize the physical form of the *hilal* and comprehensively determine the number of fasting days during Ramadan in the time of the Prophet.

This study is a qualitative research project based on a literature review, employing an astronomical approach and observational simulations in a planetarium using Digistar 6 Planetarium. It includes gathering historical data related to the positions of the moon, the sun, and the moon's phases, as well as social aspects during the lifetime of Prophet Muhammad (SAW). The study also reviews classical literature related to these topics (Sugiyono 2014).

Results and Discussion

Ramadan Fasting in the Time of Prophet Muhammad (SAW) and Its Determination Method

Ramadan fasting is one of the Five Pillars of Islam, mandated for all Muslims. This obligation was first commanded in the second year of Hijrah, around 624 CE, and has since become a yearly practice observed by billions of Muslims worldwide. The establishment of Ramadan fasting during the time of Prophet Muhammad (SAW) holds profound significance, serving not only as an act of obedience to Allah SWT but also as a means to achieve piety and self-discipline.

Ramadan means "the month of intense heat" or "the month of scorching heat," reflecting the origin of the term from the Arabic word ramad, which refers to the intense heat or burning (Habnakah 1987). Before the time of Prophet Muhammad (SAW), the Arab community did not fully rely on the lunar calendar. Instead, every three years, they would add an extra month to align the calendar with seasonal changes. This mixed calendar system was known as the lunar-solar calendar or qamari-syamsiah calendar. (Thomas Djamaluddin 2010)

The scholars agree that the migration (hijrah) of Prophet Muhammad (SAW) to Madinah took place in the month of Rabi'ul Awwal of the first year of Hijrah. Imam al-Qasthalani, in his book Irsyad as-Sari li Syarh Shahih al-Bukhari, includes a chapter titled "The Obligation of Ramadan Fasting." He states: "The obligation of fasting in Ramadan was established in the month of Sha'ban of the second year of Hijrah" (Al-Qasthalany 2017).

Musa al-'Azimi states that the obligation of fasting during Ramadan was established in the month of Sha'ban of the second year of Hijrah, approximately one month after the qibla was shifted to the revered Ka'bah (Al-'Azami 2011). Other references indicate that the obligation of fasting was established on the night of the second day of the month of Sha'ban in the second year of Hijrah (Muhammad al-Baghdadi 1999).

Badruddin al-'Aini al-Hanafi, in his book Al-Binayah, states: "Fasting during the month of Ramadan was mandated in the second year of Hijrah, before the Battle of Badr. Some sources mention that this obligation was established in the month of Sha'ban of that year, leading to the Prophet Muhammad (SAW) fasting during nine Ramadans"(Al-'Aini 2000).

Imam an-Nawawi asy-Syafi'i, in his book Al-Majmu', states: "The Prophet Muhammad (SAW) fasted during Ramadan for nine years. This is because fasting was mandated in the month of Sha'ban of the second year of Hijrah, and the Prophet (SAW) passed away in the month of Rabi'ul Awwal of the eleventh year of Hijrah" (Al-Nawawi n.d.).

Al-'Allamah Al-Buhuti Al-Hanbali, in Syarh Muntaha al-Iradat, states: "The obligation of fasting during the month of Ramadan was established in the second year of Hijrah by consensus (ijma'). Therefore, the Prophet Muhammad (SAW) fasted during nine Ramadans by consensus" (Al-Buhuti 2021). According to As-Sayyid al-Bakri in I'anatut Talibin, the verse commanding fasting in Surah Al-Baqarah, verse 185, was revealed in the month of Sha'ban in the second year of Hijrah. Based on this, it can be concluded that Prophet Muhammad (SAW) began observing Ramadan fasting in the second year of Hijrah (Al-Bakry 1995).

Regarding the lunar months, particularly Sha'ban and Ramadan, they sometimes last for 29 days and sometimes for 30 days. This variability is due to the nature of the lunar calendar, which is based on the moon's phases (Khusurur et al. 2024). This variability has been explained by Prophet Muhammad (SAW):

إنا أمـة أمـية لا نكتب ولا نحسب الشهر هكذا وهكذا، يعنى مرة تسـعة وعشـرون ومرة ثلاثـون

"Indeed, we are an unlettered nation; we do not know how to write or calculate. The month is this way and that way: sometimes it is 29 days and other times it is 30 days (Al-Bukhari 1981)."

To determine whether the 30th day of Sha'ban is still part of Sha'ban or has entered Ramadan, and whether the 30th day of Ramadan is still part of Ramadan or has transitioned to Shawwal, it is crucial to ascertain the beginning and end of Ramadan. Prophet Muhammad (SAW) provided guidance on how to start and end Ramadan through his sayings. He instructed that the beginning of Ramadan is marked by sighting the hilal (new moon), and the end of Ramadan is determined in the same way, ensuring the accurate transition between months:

لا تصوموا حتى تروا الهلال ولا تفطروا حتى تروه فإن غم عليكم فاقدروا له

"Do not fast until you see the hilal, and do not break your fast until you see the hilal. If clouds obstruct your view, then complete the count of Sha'ban as thirty days (I. al-H. al-Q. al-N. A. al-H. Muslim 1995)."

On another occasion, the Prophet Muhammad (SAW) said:

صوموا لرؤيته وأفطروا لرؤيته فإن غبي عليكم فأكملوا عدة شعبان ثلاثين

"Fast when you see the hilal, and break your fast when you see it. If it is obscured from you, then complete the month of Sha'ban as thirty days (Al-Bukhari 1981)."

These two hadith provide guidance on determining the start and end of Ramadan based on the sighting of the hilal (new moon). The first hadith indicates that Muslims should neither begin fasting nor end it before sighting the hilal. If the sighting is obstructed by clouds or other weather conditions, then a count (be aware) should be used as an alternative.

The second hadith reinforces this principle, stating that fasting begins and ends upon sighting the hilal. If the hilal is not visible due to obstruction, Sha'ban should be completed as 30 days. Both hadiths emphasize the importance of moon sighting (rukyat hilal) as the primary method for determining the start and end of Ramadan, with astronomical calculations (hisab) serving as a backup when the hilal is not visible.

Social Conditions in Madinah When Ramadan Fasting Was Made Obligatory

It is important to remember that Madinah was a trade route from Syria and its surroundings to Mecca, so the dating system was already familiar to the inhabitants of Madinah before the arrival of Muhammad (SAW) (Lecker 2013). In Madinah, the calendar systems included the Jewish solar calendar, which focused on seasonal changes without considering daily variations, and the lunar calendar (Kamariah) inherited from their ancestors. The lunar calendar was particularly useful for the predominantly agrarian community in determining the start of months and recognizing dates by observing the phases of the moon (Ali Engineer 2000).

There is no precise information on when Prophet Muhammad (SAW) established the pure lunar calendar, replacing the lunar-solar calendar. However, it is highly likely that this transition occurred after the revelation of Surah At-Tawbah 36-37, which commands the elimination of the mixed calendar system and its replacement with the pure lunar calendar (Thomas Djamaluddin 2010).

With the lunar calendar system (Kamariah), it did not align with the seasons required by the inhabitants of Madinah. To reconcile the lunar calendar with the seasons, the solar calendar system was integrated with the existing lunar calendar system. This combined approach helped to synchronize the lunar months with the seasonal changes experienced by the people of Madinah (Syarif and Habibi 2024). As a result of this integration, a 13th month, known as Nasi', appeared every three years in the lunar calendar. This additional month was typically used for religious rituals and celebrations that were non-Islamic and often led people astray (Ali Engineer 2000). Therefore, Allah corrected this practice with His words:

إن عدة الشهور عند الله اثنا عشر شهرا فى كتاب الله يوم خلق السموت والأرض

"Indeed, the number of months with Allah is twelve in the Book of Allah from the day He created the heavens and the earth" (Surah At-Tawbah: 36)."

This was the first change made by Prophet Muhammad (SAW) to the existing calendar system in Arabia, particularly in Madinah, by eliminating the 13th month (Nasi'). Subsequently, in the second year of Hijrah, the verses about fasting were revealed (Surah Al-Baqarah 183 and 185), and the Prophet clarified the duration of lunar months, especially Ramadan, which could last either 29 or 30 days, through his saying:

إنا أمـة أمـية لا نكتب ولا نحسب الشهر هكذا وهكذا، يعنى مرة تسـعة وعشـرون ومرة ثلاثـون

The term "Ummah" in the hadith carries deep significance, symbolizing the shift from the tribal outlook prevalent among the Arab tribes at that time. The narrow social perspectives and restricted political life, shaped by tribal fanaticism and blood ties, began to slowly disintegrate. This was replaced by a more inclusive community where every member had equal rights and responsibilities (Al-Bukhari 1981).

Thus, Muhammad (SAW) established conditions that supported the formation of a unified society, namely the cohesive community of Madinah, without distinctions based on religion, tribal affiliations, or blood ties. Meanwhile, the phrase "Ummiyyah la naktubu wa la nahsubu," often translated as "an unlettered nation that cannot write or calculate," indicates that the Prophet did not differentiate between the educated and the uneducated (Farmzi 2021). Everyone was described as "unlettered" to avoid pride among the educated and feelings of inferiority among the less knowledgeable, thereby maintaining equality within the society.

Additionally, the hadith emphasizes that the duration of the month, especially Ramadan, can be either 29 or 30 days, contrasting with the practice at that time where Ramadan was always considered to be 30 days long. To determine whether Ramadan lasts for 29 or 30 days, Prophet Muhammad (SAW) provided guidance through his saying.

صوموا لرؤيته وأفطروا لرؤيته فإن غم عليكم فأكملوا عدة شعبان ثلاثين (Al-Bukhari 1981)

The hadith explains that the beginning and end of fasting are determined through the sighting of the hilal (rukyah). If the hilal is visible, then that night and the following day are considered the first day of the new month. However, if the hilal is not visible, that night and the following day are counted as the 30th day of the current month. This process is known as Istikmal. In another hadith, it is mentioned:

لا تصوموا حتى تروا الهلال ولا تفطروا ختى تروه فإن غم عليكم فاقدروا له

"Do not fast until you see the hilal, and do not break your fast until you see the hilal. If it is obscured from you, then estimate (complete the month as thirty days)(Muslim 1995)".

This hadith demonstrates the flexibility within Islamic law, where the inability to sight the hilal is not a barrier to properly observing fasting. Islam provides an alternative through estimation or calculation, prioritizing ease and accuracy in worship.

Based on the Prophet Muhammad's (SAW) narration, on the night of Friday to Saturday, the 29th of Sha'ban in the 2nd year of Hijrah, the companions attempted to sight the hilal after sunset but were unsuccessful. They reported this to the Prophet, who then declared that Sha'ban for that year would be completed as 30 days. Later, on the evening of Sunday, the 29th of Ramadan in the same year, the companions again attempted to sight the hilal and were successful. They reported their sighting to the Prophet, who then ordered that the fast be ended that night. Consequently, the Prophet and his companions fasted for 29 days of Ramadan that year (Ashshiddieqy 1971).

The Prophet used the method of hilal observation (rukyah) to determine the months of Ramadan, Shawwal, and Dhu al-Hijjah because it was a straightforward method for his companions. He did not find it necessary to provide examples or operational techniques first, as the companions were already accustomed to observing the moon phases to determine dates before he arrived in Madinah (Zufriani et al. 2023).

Through the observation of the hilal, the Prophet also indicated that the day begins at sunset, which was different from the previous practices in Arabia where the start of the day varied. Some began the day at sunrise, others from when the sun declined, and some from sunset.

The arrival of an A'rabi (a Bedouin Arab) before the Prophet exemplifies the unity of the community, where the Prophet did not distinguish between leaders and ordinary people. This hadith also teaches that the determination of the beginning or end of Ramadan is in the hands of the Prophet as the leader of the community, not just the Bedouin who sighted the hilal. Once the Prophet (SAW) made the determination, the entire community followed his decision.

Considering that the time of Prophet Muhammad (SAW) was the period of the Quran's revelation, the Prophet placed a high priority on focusing on the Quran. Therefore, he did not permit his companions to write anything other than the Quran, and naturally, writing and studying mathematical sciences (hisab) were even less encouraged by the Prophet.

لا تكتبوا عنى شيئا الا القران ومن كتب عنى غير القران فليمحه

"Do not write anything that you receive from me other than the Quran. Whoever writes anything other than the Quran from me should erase it" (Narrated by Muslim) (Muslim 1995).

It's well-known that before the advent of Islam, the Arab tribes, including those in Madinah, often experienced inter-tribal conflicts due to various interests. The persistent strife eventually led them to long for a peaceful and harmonious existence (N. Muslim 2023).

When the people grew weary of the ongoing conflicts, a bearer of peace named Muhammad arrived, bringing truth and tranquility. Consequently, Muhammad's arrival in Madinah was warmly welcomed, marked by the establishment of a peace and brotherhood agreement known as the "Constitution of Madinah." This event marked a crucial moment in fostering peace and coexistence among diverse communities. The "Constitution of Madinah" served as a foundational document outlining rights, duties, and principles for harmonious living, fostering a multicultural society. With this constitution, Muhammad (SAW) gained the opportunity to spread his message while reforming the local culture that was deemed inappropriate(Ghozali 2020).

With the command of fasting for Muslims, Prophet Muhammad (SAW) reformed the existing calendrical system in society. These reforms included establishing that a lunar year consists of 12 months, with no additional 13th month known as Nasi'. Each month, including Ramadan, could be 29 or 30 days long, depending on the sighting of the hilal (which was previously always assumed to be 30 days) (Stowasser 2014). The day begins after sunset, rather than at sunrise or the solar decline. The calendrical changes made by Muhammad (SAW) were well received by the society at the time for several reasons:

First, they understood that the calendrical changes made by Muhammad (SAW) were intended for the purposes of worship, while agricultural and planting needs could still be managed using the solar calendar (Zufriani et al. 2023). Second, the transition to a month based on the sighting of the hilal was not unfamiliar to them, as they were already accustomed to observing the phases of the moon to determine dates. Third, there was integration and solidarity between the Islamic and non-Islamic communities in their daily interactions (Abdurrahman 2021). Fourth, there was a shared awareness among both Muslims and non-Muslims that what Muhammad (SAW) brought was beneficial for communal life(Hasanah 2023).

Astronomical Calculation of Ramadan During Prophet Muhammad's Time

During the time of Prophet Muhammad (SAW), the start of Ramadan was determined simply and practically through the observation of the new moon (*hilal*). This method was suited to the conditions of the time, relying on direct and natural observation without advanced tools. The Hadiths of the Prophet also provide clear guidance on this, emphasizing the observation of *hilal* as a condition for starting and ending the fast.

However, over time and with advancements in science, the observation of *hilal* has faced many challenges, particularly regarding accuracy and consistency. Weather conditions, light pollution, and other factors often hinder the observation of the new moon. This has created a gap between the traditional methods used during the Prophet's time and the contemporary need for accuracy and efficiency in determining the start of Ramadan.

Table 1. Astronomical calculations for Ramadan and Shawwal during the Prophet's time

Hijry	*Month*	*Conjuction*		*Sunset*	*Moon Alt*	*Elongation*	*Day*
2	Ramadhan	Jum'at,24-02-624	11:03:19	18:27:51	02°25'48"	06°04'04"	29
	Syawal	Ahad, 25-03-624	23:13:22	18:39:34	08°10'44"	10°52'07"	
3	Ramadhan	Rabu, 13-02-625	00:41:25	18:22:37	08°21'40"	11°28'47"	29
	Syawal	Kamis,14-03-625	10:12:52	18:35:32	03°14'46"	06°44'01"	
4	Ramadhan	Ahad. 02-02-626	16:44:15	18:16:01	-00°41'11"	04°59'56"	29
	Syawal	Selasa,04-03-626	01:52:56	18:31:31	08°19'01"	10°49'04"	
5	Ramadan	Jum'at,23-01-627	06:36:07	18:09:12	03°48'59"	08°02'28"	30
	Syawal	Sabtu, 21-02-627	17:47:58	18:26:29	-01°10'30"	04°25'44"	
6	Ramadhan	Selasa, 12-01-628	14:11:02	18:01:12	-00°23'24"	05°17'37"	29
	Syawal	Kamis, 11-02-628	05:24:34	18:21:06	04°51'57"	07°34'48"	
7	Ramadhan	Sabtu, 31-12-628	14:55:18	17:53:19	-01°23'48"	05°01'45"	29
	Syawal	Senin, 30-01-629	09:43:01	18:14:15	02°09'38"	05°09'27"	
8	Ramadhan	Rabu, 20-12-629	14:35:51	17:46:26	-01°42'51"	04°54'12"	29
	Syawal	Jum'at, 19-01-630	09:10:45	18:06:36	02°06'22"	04°55'56"	
9	Ramadhan	Ahad, 09-12-630	20:04:29	17:41:26	-01°51'07"	04°42'12"	30
	Syawal	Selasa, 08-01-631	11:11:58	17:58:33	01°19'58"	04°04'07"	
10	Ramadhan	Jum'at, 29-11-631	08:25:35	17:39:11	01°05'32"	06°34'21"	30
	Syawal	Sabtu, 28-12-631	20:21:03	17:50:53	-03°40'03"	02°33'59"	

The urgency of astronomical calculations (hisab) has become increasingly clear in today's world. Although hisab was not widely practiced during the Prophet's time, advances in technology and astronomy now make it possible to estimate the position of the crescent moon (*hilal*) with high precision. Hisab offers a practical solution in situations where direct moon sighting (rukyat) is not feasible, providing certainty and ease in determining the start of Hijri months, including Ramadan.

This gap raises an important question about how modern Muslims can integrate the traditional rukyat (moon sighting) passed down from the Prophet's time with the accuracy of astronomical calculations (hisab). The discussion around integrating these two methods is not merely a matter of technical practice, but also about maintaining the alignment of Islamic law (sharia) with scientific advancements. This ensures that the determination of the start of Ramadan remains relevant and reliable in the context of modern life.

Here is the astronomical data, specifically the time of ijtima' (conjunction of the moon), the time of gurub (sunset), and irtifa' (the altitude of the hilal) for Madinah (Latitude = 24.4667° N, Longitude = 39.6° E) in the periods leading up to Ramadan and Shawwal from the 2nd to the 10th Hijri year.

Visualization of the Ramadan and Shawwal Hilal in the Prophet's Era

Visualization of the Ramadan and Shawwal *hilal* during the time of the Prophet can depict the sky conditions as seen by people in the Arabian Peninsula at that time. The *hilal* (thin crescent moon) marking the beginning of Ramadan and Shawwal would appear low on the western horizon after sunset. Due to minimal light pollution at that time, the *hilal* might have appeared clearer compared to modern observations. On those nights, the moonlight would be very faint, forming only a thin crescent, with the open desert surrounding Madinah or Makkah as the backdrop. The Prophet and his companions might have observed the *hilal* against a clear western horizon, with distant mountains and the sky transitioning from orange to blue as the sun set.

Visualization of the crescent moon, particularly in the context of Islamic tradition and the Prophet Muhammad, weaves together astronomy, cultural practices, and religious significance. The crescent moon marks the beginning of the Islamic lunar calendar, and its visibility has been a subject of scientific interest. Observing the *hilal* not only involves spiritual aspects but also requires scientific understanding of the moon's position relative to the sun and Earth. In the tradition of the Prophet, the start of the month was often determined through direct observation by witnesses, who would then report to local authorities. This illustrates a blend of simple science and deeply rooted social-religious structures. Over time, this method has evolved with modern technology such as telescopes and simulation software, although the fundamental principle remains the same: observing the *hilal* as an important marker in worship and the Muslim calendar. The visualization of the *hilal* also symbolizes the unity and togetherness of Muslims in celebrating sacred moments like Ramadan and Eid al-Fitr, where the appearance of the crescent moon marks the beginning of these significant events.

The Digistar 6 Planetarium System as a Visualization Tool for the New Moon

The term "planetarium" originates from modern Latin, combining "planeta," which means "planet," and "arium," which indicates a place for. This etymology reflects the role of a planetarium as a place for education and exploration of astronomy. A planetarium is a facility designed to simulate the night sky and provide educational experiences related to astronomy. It serves as a bridge between the public and scientific knowledge, enhancing understanding of celestial phenomena through immersive visual displays. Key elements of a planetarium include projectors, a dome, and a gallery of celestial objects (Sari and Wastuty 2022).

One of the projectors used in planetariums is the Digistar system. Digistar allows for precise star mapping, enabling a realistic representation of the night sky from different perspectives, not just from Earth (Moayyedian 2018). The Digistar system, developed by Evans & Sutherland and released in 1983, revolutionized planetarium technology by integrating computer graphics for accurate star projection and immersive educational experiences. This innovation allows users to explore celestial objects from various perspectives, enhancing astronomy education.

The development of Digistar, initiated by Stephen McAllister and Brent Watson, was significantly influenced by their backgrounds in astronomy and computer graphics. Their collaboration with Johnson Space Center in 1977 aimed to enhance astronaut training through advanced simulation technology. In the summer of 1977, McAllister developed a proof-of-concept software that facilitated the entry and display of data for 400 bright stars. This initiative marked a significant advancement in astronomical data visualization. McAllister's software was designed to automate the display of star data, improving data analysis efficiency. This aligns with advancements in automatic spectral line identification, where software compares the wavelengths of unknown stars with established databases to streamline the identification process. Steve and Brent initially saw the system's goal as celestial navigation training. Brent, who had recently worked at the Hansen Planetarium, consulted with his planetarium colleagues about their opinions on the potential of digital planetarium systems, leading Steve and Brent to focus the system on planetariums (Fajriani and Masturi 2023).

The primary goal of this planetarium system is to utilize computer graphics to overcome the limitations of traditional star ball technology, which could only display star maps from a terrestrial perspective. With computer graphics, stars can be visualized from a space perspective, including simulations of spaceflight. Additionally, planets and moons in the solar system can be accurately visualized at any time in history and from any viewpoint. The system uses original star location data from the Yale Bright Star Catalog, as well as random stars. (Palicki, 2014).

The Digistar 6 system offers advanced capabilities for visualizing crescent moon phases, especially in scientific contexts. The Digistar system has evolved over time with periodic enhancements and corrections. The Digistar system has 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 1. *Digistar 6 interface*

To understand the physical data of the crescent moon obtained from the simulation of crescent moon observation using the Digistar 6 Planetarium system, the author includes two sets of real crescent moon data for comparison. First, the physical data for the determination of the beginning of Dzulqa'dah 1444 Hijri, which fell on May 20, 2023. The observation was conducted at the Balai Ru'yat Ibnu Syatir Pondok Pesantren al-Islam Joresan Ponorogo, East Java, with the crescent moon's altitude at 6.2º and elongation at 9.75º. The observation was made using an automatic telescope, and the crescent moon image data was processed with Iris software, with 200 image frames taken.

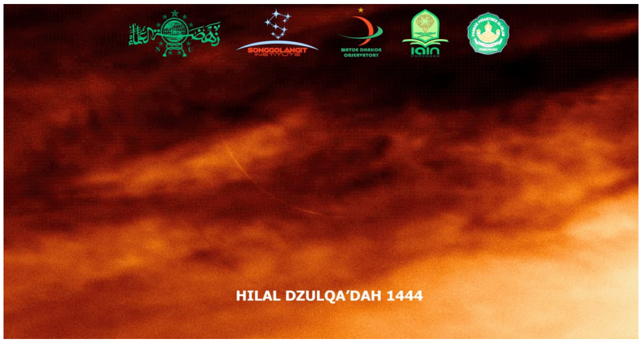

Figure 2. *Physical data of the real crescent moon for the beginning of Dzulqa'dah 1444 Hijri / 2023*

Then the author then compared the physical data of the real crescent moon with the simulation results from the Digistar 6 Planetarium system with similar parameters.

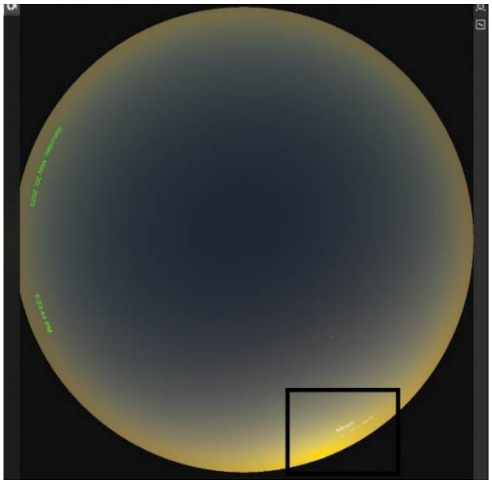

Figure 3. *Physical altitude of 6.2º and elongation of 9.75º in 2023 without Zoom processing*

Physical data of the crescent moon for the beginning of Dzulqa'dah 1444 Hijri without Zoom processing in the crescent moon observation simulation in the planetarium dome.

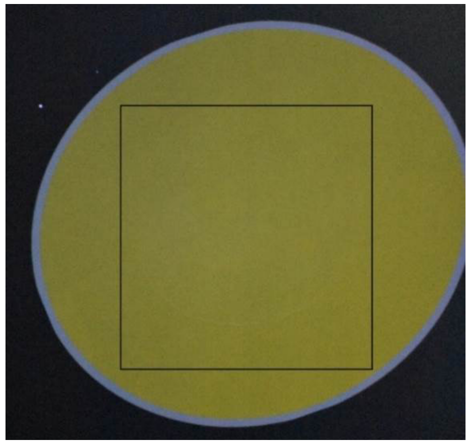

Figure 4. *Physical altitude of 6.2º and elongation of 9.75º in 2023 with Zoom processing*

The crescent moon appears clearly in the physical image after zooming and reducing atmospheric effects by 23.81%.

Physical data of the crescent moon for Ramadan and Shawwal in the Prophet's time

Visualizing the crescent moon during the time of the Prophet Muhammad aims to provide a realistic view of how crescent moon observations were conducted manually in the past. By using modern astronomical data and simulations through the Digistar 6 Planetarium system, it is possible to compare historical records and hadiths on crescent moon observations with actual sky conditions of that era. This helps verify the accuracy of traditional lunar observation methods and understand how modern scientific knowledge can complement our understanding of Islamic moon-sighting traditions. Additionally, this visualization serves as an effective educational tool for the public, particularly in understanding the significance of moon sighting for determining the start of Ramadan and Shawwal. It also helps draw conclusions about the differing scholarly opinions on the number of fasting days during the Prophet's lifetime.

First Ramadan Fasting during the Prophet's Time

On Friday, February 24, 624 CE, the first day of Ramadan began. The conjunction occurred at 11:03:19 local time on the same day. The crescent moon's altitude was 02°25'48" and elongation 06°04'04", with sunset at 18:27:51 local time. The first Ramadan during the Prophet Muhammad's time lasted 29 days. Calculations for the end of Ramadan in 2 AH indicate conjunction on Sunday, March 25, 624 CE, at 23:13:22 local time, with sunset at 18:39:34 local time. The crescent moon's altitude at the start of Shawwal in 2 AH was 08°10'44" with an elongation of 10°52'07". Given these values, the Shawwal crescent would be visible, confirming that Ramadan was not extended to 30 days. This conclusion is supported by physical observations of the Shawwal crescent in Medina with 50% atmospheric conditions.

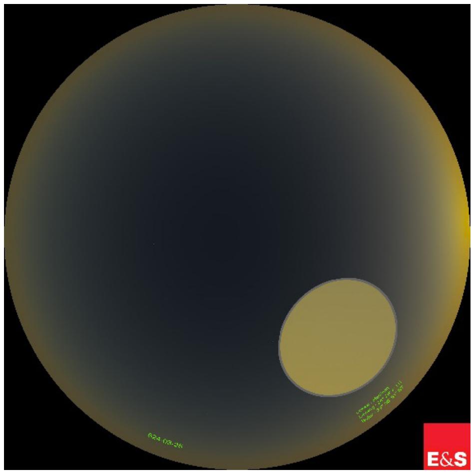

***Figure 5**. Physical data of the Shawwal 2 AH without Zoom*

***Figure 6**. Physical data of the Shawwal 2 AH with Zoom*

Second Ramadan Fasting during the Prophet's Time

The second Ramadan fasting during the Prophet Muhammad’s time began on Wednesday, February 13, 625 CE. The conjunction occurred at 00:41:25 local time that day. The crescent moon's altitude was 08°21'40" and elongation 11°28'47", with sunset at 18:22:37 local time. Ramadan lasted 29 days. For the end of Ramadan in 3 AH, the conjunction was on Thursday, March 14, 625 CE, at 10:12:52 local time, with sunset at 18:35:32. The Shawwal crescent had an altitude of 03°14'46" and elongation 06°44'01". The crescent was visible, confirming that Ramadan was not extended to 30 days. This conclusion is supported by the physical observation of the Shawwal crescent in Medina with 15.48% atmospheric conditions.

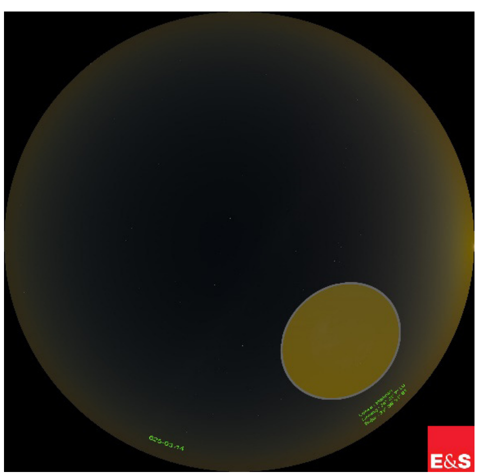

***Figure 7**. Physical data of the Shawwal 3 AH without Zoom*

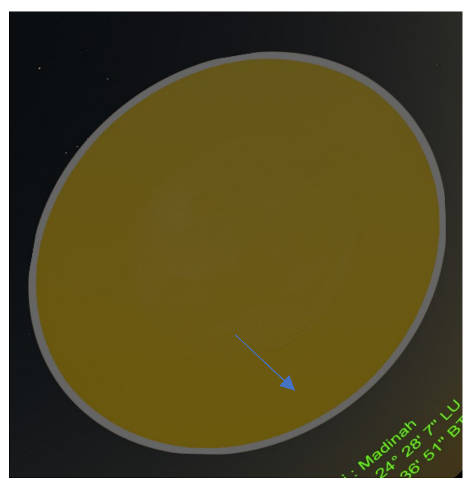

***Figure 8** Physical data of the Shawwal 3 AH with Zoom*

Third Ramadan Fasting during the Prophet's Time

The third Ramadan fasting during the Prophet Muhammad’s time began on Tuesday, February 4, 626 CE. The conjunction occurred two days prior at 16:44:15 local time. The crescent moon's altitude was -00°41'11" and elongation 04°59'56", with sunset at 18:16:01

local time. Ramadan lasted 29 days. For the end of Ramadan in 4 AH, the conjunction was on Tuesday, March 4, 626 CE, at 01:52:56 local time, with sunset at 18:31:31. The Shawwal crescent had an altitude of 08°19'01" and elongation 10°49'04". The crescent was visible, confirming that Ramadan was not extended to 30 days. This conclusion is supported by physical observations of the Shawwal crescent in Medina with 50% atmospheric conditions.

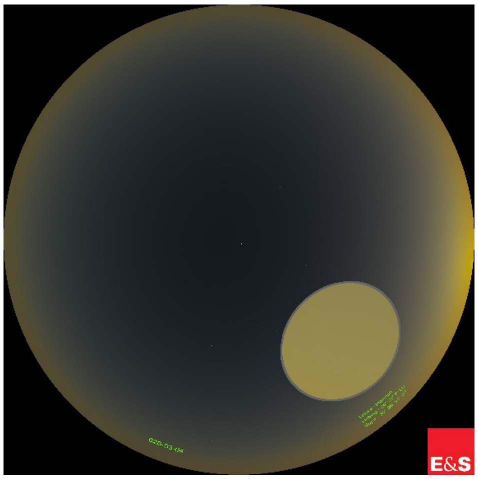

***Figure 9**. Physical data of the Shawwal 4 AH without Zoom*

***Figure10.** Physical data of the Shawwal 3 AH with Zoom*

Fourth Ramadan Fasting during the Prophet's Time

The fourth Ramadan fasting during the Prophet Muhammad's time began on Friday, January 23, 627 CE. The conjunction occurred on the same day at 06:36:07 local time. The crescent moon's altitude was 03°48'59" and elongation 08°02'28", with sunset at 18:09:12 local time. Ramadan lasted 30 days. For the end of Ramadan in 5 AH, the conjunction was on Saturday, February 21, 627 CE, at 17:47:58 local time, with sunset at 18:26:29. The Shawwal crescent had an altitude of -01°10'30" and elongation 04°25'44". Given these values, the Shawwal crescent was not visible, confirming that Ramadan was completed in 30 days. This conclusion is supported by physical observations of the Shawwal crescent in Medina.

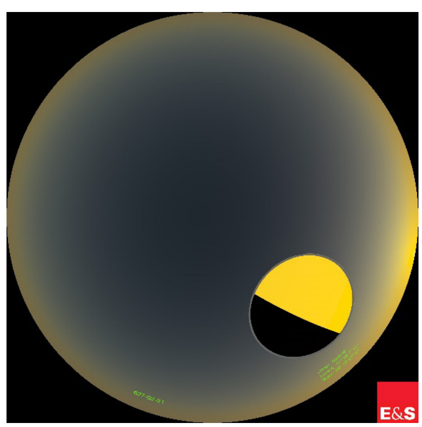

***Figure 11**. Physical data of the Shawwal 5 AH without Zoom*

Fifth Ramadan Fasting during the Prophet's Time

The fifth Ramadan fasting during the Prophet Muhammad's time began on Thursday, January 14, 628 CE. The conjunction occurred two days earlier at 14:11:02 local time. The crescent moon's altitude was -00°23'24" and elongation 05°17'37", with sunset at 18:01:12 local time. Ramadan lasted 29 days. For the end of Ramadan in 6 AH, the conjunction was on Thursday, February 11, 628 CE, at 05:24:34 local time, with sunset at 18:21:06. The Shawwal crescent had an altitude of 04°51'57" and elongation 07°34'48". The crescent was visible, confirming that Ramadan was not extended to 30 days. This conclusion is supported by physical observations of the Shawwal crescent in Medina with 14.29% atmospheric conditions.

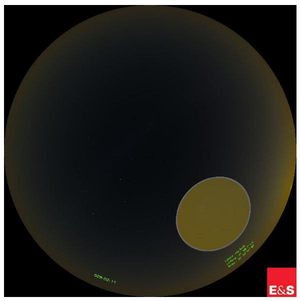

Figure 12. Physical data of the Shawwal 6 AH without Zoom

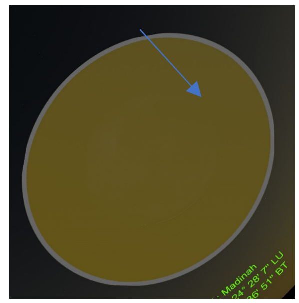

Figure 13. Physical data of the Shawwal 6 AH with Zoom

Sixth Ramadan Fasting during the Prophet's Time

The sixth Ramadan fasting during the Prophet Muhammad's time began on Thursday, January 2, 628 CE. The conjunction occurred two days earlier at 14:55:18 local time. The crescent moon's altitude was -01°23'48" and elongation 05°01'45", with sunset at 17:53:19 local time. Ramadan lasted 29 days. For the end of Ramadan in 7 AH, the conjunction was on Monday, January 30, 629 CE, at 09:43:01 local time, with sunset at 18:14:15. The Shawwal crescent had an altitude of 02°09'38" and elongation 05°09'27". The crescent was visible, confirming that Ramadan was not extended to 30 days. This conclusion is supported by physical observations of the Shawwal crescent in Medina with 10.71% atmospheric conditions.

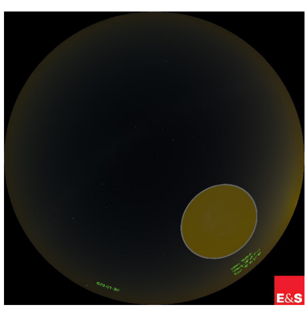

Figure 14 Physical data of the Shawwal 7 AH without Zoom

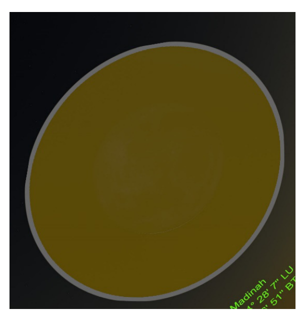

Figure 15. Physical data of the Shawwal 7 AH with Zoom

Seventh Ramadan Fasting during the Prophet's Time

The seventh Ramadan fasting during the Prophet Muhammad's time began on Friday, December 22, 629 CE. The conjunction occurred two days earlier at 14:35:51 local time. The crescent moon's altitude was -01°42'51" and elongation 04°54'12", with sunset at 17:46:26 local time. Ramadan lasted 29 days. For the end of Ramadan in 8 AH, the conjunction was on Friday, January 19, 630 CE, at 09:10:45 local time, with sunset at 18:06:36. The Shawwal crescent had an altitude of 02°06'22" and elongation 04°55'56". The crescent was visible, confirming that Ramadan was not extended to 30 days. This conclusion is supported by physical observations of the Shawwal crescent in Medina with 9.52% atmospheric conditions.

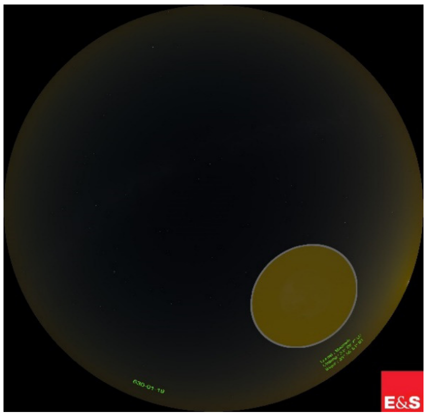

***Figure 16**. Physical data of the Shawwal 8 AH without Zoom*

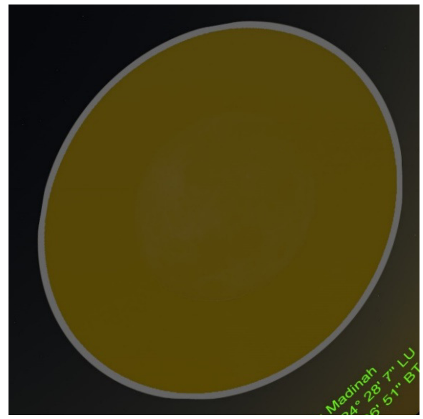

***Figure 17**. Physical data of the Shawwal 8 AH with Zoom*

Eighth Ramadan Fasting during the Prophet's Time

The eighth Ramadan fasting during the Prophet Muhammad's time began on Tuesday, December 9, 630 CE. The conjunction occurred two days earlier at 20:04:29 local time. The crescent moon's altitude was -01°51'07" and elongation 04°42'12", with sunset at 17:41:26 local time. Ramadan lasted 30 days. For the end of Ramadan in 9 AH, the conjunction was on Tuesday, January 8, 631 CE, at 11:11:58 local time, with sunset at 17:58:33. The Shawwal crescent had an altitude of 01°19'58" and elongation 04°04'07". Given these values, the Shawwal crescent was very difficult to see, confirming that Ramadan was extended to 30 days. This conclusion is supported by physical observations of the Shawwal crescent in Medina with 0% atmospheric conditions.

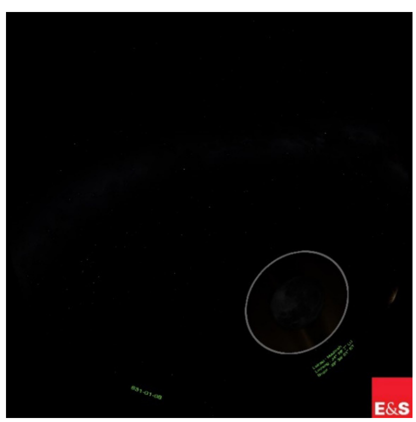

***Figure 18.** Physical data of the Shawwal 9 AH without Zoom*

Ninth Ramadan Fasting during the Prophet's Time

The ninth Ramadan fasting during the Prophet Muhammad's time began on Friday, January 31, 631 CE. The conjunction occurred two days earlier at 08:25:35 local time. The crescent moon's altitude was 01°05'32" and elongation 06°34'21", with sunset at 17:39:11 local time. Ramadan lasted 30 days. For the end of Ramadan in 10 AH, the conjunction was on Saturday, December 28, 631 CE, at 20:21:03 local time, with sunset at 17:50:53. The Shawwal crescent had an altitude of -03°40'03" and elongation 02°33'59". Given these values, the Shawwal crescent was not visible, confirming that Ramadan was extended to 30 days.

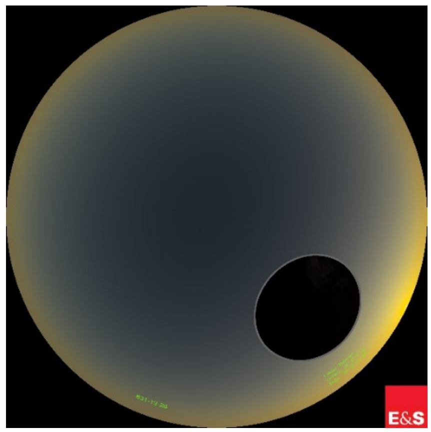

Figure 19. *Physical data of the Shawwal 10 AH without Zoom*

Conclusion

After simulating astronomical data using the Digistar 6 system to determine the physical appearance of the Shawwal crescent, it can be concluded that the Prophet Muhammad (SAW) observed Ramadan fasting 9 times. During this period, he completed 30 days of fasting in 3 years: the 5th, 9th, and 10th Hijri. This finding differs from what is stated in classical fiqh literature, which notes that the 30-day fast during the Prophet Muhammad's time occurred only twice, based on simulations using the Digistar 6 planetarium. Astronomical calculations for the beginning of the months, especially Ramadan and Shawwal from the years 2 to 10 AH, show that the lowest visible crescent elevation for Shawwal was 02°06'22" above the horizon in the year 8 AH, with an elongation of 04°55'56" and minimal atmospheric conditions at 9.52% visibility. The Digistar 6 planetarium system can serve as an educational tool for *hilal* (crescent moon) observation and help validate claims of *hilal* visibility by unaided observers. However, this study has limitations, as it does not include historical weather data from the Prophet Muhammad's time.

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