



Integration of Ethnoscience and Physical Science Perspectives in Determining the Hijri Calendar in Kudus

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Abstract: This study explores the integration of ethnoscience and physics perspectives in determining the Hijri calendar in Kudus City, Central Java. Using a qualitative descriptive approach through observation, interviews, and document analysis, this research reveals that the Kudus community harmonizes scientific reasoning (*hisab*) with empirical and religious practices (*rukyat*) based on local wisdom. The findings show that the *hisab imkan rukyah haqiqi tahqiqi* method applied in the Menara Kudus Almanac represents an advanced traditional model that aligns with modern astronomical calculations involving the Moon's synodic cycle, celestial geometry, and atmospheric refraction. Scientifically, this study contributes to understanding how local ethnoscience can complement and contextualize formal knowledge of physics and astronomy. Practically, it provides insights for developing culture-based science education, particularly in astronomy learning, and offers empirical references for policy formulation on Hijri calendar standardization. However, the study is limited to the Kudus context, suggesting the need for comparative research across other Indonesian regions and further validation using digital simulation or optical instrumentation to enrich the integration between local wisdom and scientific astronomy.

Keywords: ethnoscience; hijri calendar; kudas tower almanac; physics

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INTRODUCTION

Astronomy is one of the oldest branches of science, influencing human life since ancient times. Before Islam, humans developed knowledge of astronomy through natural observations such as the movement of celestial bodies and weather changes for various purposes, including navigation, trade, and ritual calendars. In the Indonesian archipelago, astronomy also plays a significant role in people's lives, intertwined with history, anthropology, archaeology, and other aspects of life. Traditions such as agriculture, navigation, religious rituals, and calendar determination are heavily influenced by knowledge of astronomy (Butar-butur, 2021). The role of astronomy in determining the Hijri calendar is a crucial moment in Islamic history, as it helps determine the Hijri new year. The calendar is a system for recording important or historical events, such as the dates of religious celebrations, historical events, or relevant social activities. This calendar system allows humans to organize and plan their activities based on predetermined times (Fauzi, 2015). In Islamic civilization, astronomy played a crucial role in determining the Hijri calendar, which regulates important religious celebrations, including Ramadan, Eid al-Fitr, and the Islamic New Year.

The two main approaches used to determine the beginning of the Hijri month are *hisab* (astronomical calculations) and *rukyat* (direct observation of the crescent Moon). *Hisab* relies on mathematical and astronomical calculations using ephemeris data to precisely predict the Moon's position, while *rukyat* relies on empirical observations reflecting human experience, atmospheric conditions, and local traditions (Faid et al., 2025; Nasir et al., 2025). Both methods have advantages and disadvantages—*hisab* provides scientific predictability and accuracy, while *rukyat* embodies the religious and cultural dimensions of lunar observation. Therefore, integrating *hisab* and *rukyat* is crucial to achieving harmony between modern scientific reasoning and traditional religious practices (Majid, 2024).

In Indonesia, particularly in Kudus, Central Java, local practices in determining the Hijri calendar, exemplified by the Kudus Tower Almanac, demonstrate a rich blend of religious devotion and indigenous astronomical knowledge. This tradition reflects an ethnoscientific understanding that combines empirical celestial observation with inherited wisdom and religious interpretation. However, despite numerous local studies on calendar calculations, no research has specifically examined the integration of ethnoscience and physics in the context of the Hijri calendar in Kudus, despite the significant potential to enrich science education and preserve cultural heritage. An almanac, also known as a calendar, is a system for organizing time within a specific period. It contains information about the month, day, week, and year, as well as relevant events that occurred during those periods. Various forms of almanacs exist in different cultures and societies, each with its own unique calculation rules tailored to local needs and traditions. One of the most famous almanacs in

Indonesia is the Almanac Menara Kudus, a monumental work by a Muslim scholar named KH Turaichan.

The data used in calculating the beginning of the Hijri month, as stated in the Almanac of the Kudus Tower, comes from the *Maṭla' as-Sa'id* book. The calculation process is described in the book *al-Khulā shah al-Walyyah*, an important reference source in the Islamic calendar. These books provide guidelines and formulas for determining the Hijri month's beginning based on astronomical observations and calendar calculations. The Muslim community in Central Java, especially in the Kudus Community, pays close attention to the determination of the Hijri month's beginning as stated in the Almanac of the Kudus Tower. They consider this determination the main guide for the beginning of the new month in the Islamic calendar. However, there are sometimes differences in determining the beginning of Shawwal between the Almanac of the Kudus Tower and other authorities, such as the Government or other Islamic calendars. This can lead to differences in determining important dates in Islam, such as the start of Ramadan or Eid al-Fitr. These differences can spark debate and controversy within the community (Mujab, 2020; Mujab, 2010). Internationally, recent studies have emphasized modernizing lunar observations through digital and computational technologies. For example, Nasir et al. (2025) introduced the Circular Hough Transform method for detecting new crescent moons using digital imaging, while Marwadi (2021) and Khakzad (2022) examined Islamic calendar reform within a broader socio-religious context. This global perspective aligns with a growing movement toward integrating scientific inquiry with cultural and religious knowledge systems. Aikenhead and Ogawa (2007) and Suwandi et al. (2016) argue that integrating local knowledge (ethnoscience) with modern science enhances contextual understanding, promotes cultural inclusivity, and enriches students' scientific literacy.

Ethnoscience is an approach that integrates scientific knowledge with local wisdom and community culture. In the context of science learning, ethnoscience plays a crucial role in creating contextual and meaningful learning for students. According to Ismail et al. (2024), integrating ethnoscience into learning can improve conceptual understanding, critical thinking skills, and appreciation of local culture. In the context of determining the Hijri calendar, ethnoscience is relevant because the *hisab* and *rukyat* processes carried out by local communities are not only based on modern astronomical calculations but also on inherited knowledge passed down through generations. This traditional calendar system reflects collective knowledge based on the Islamic culture of the Indonesian archipelago, combining elements of celestial observation, local experience, and religious interpretation. By examining local practices of determining the beginning of the Hijri month through the lens of ethnoscience, we not only recognize the diversity of epistemologies in science but also appreciate the contribution of local cultures in shaping a holistic understanding of natural and religious phenomena. Therefore, this study explores how integrating ethnoscience perspectives and physics concepts in the context of the Hijri calendar can bridge the gap between traditional astronomy and modern science learning, particularly within the unique Indonesian cultural context. This research aims to provide an understanding of the determination of the Hijri calendar's beginning, the role of physics within the scope of astronomy, the Hijri calendar, and the integration of ethnoscience and physics approaches.

METHODS

This research uses a qualitative descriptive approach, with fieldwork and documentation methods, to explore the integration of ethnoscience and physics in determining the Hijri calendar in Kudus. The research was conducted in Kudus, specifically around the Menara Kudus Mosque and at the location where the Menara Kudus Almanac is compiled. This research was conducted in five main stages (Figure 1): Observation, Interviews, Documentation, Analysis, and Interpretation. This process ensured systematic data collection and analysis, enabling a comprehensive understanding of the integration of ethnoscience and physics within the local context of determining the Hijri calendar.

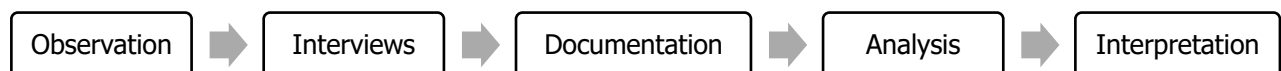


Figure 1. Research Process

Direct participant observation was conducted to understand community practices related to *hisab* and *rukyat*, including field visits during *rukyat* activities and observations of the almanac compilation process. Then, unstructured interviews were conducted with key informants to obtain detailed information about local astronomical traditions and the underlying physical and religious concepts. Supporting documents, such as the Menara Kudus Almanac, related manuscripts, and field notes, were collected and reviewed. Then, the collected data were analyzed using descriptive-qualitative analysis procedures, which include data reduction, data presentation, and conclusion drawing (Miles & Huberman, 1994). These findings are interpreted to uncover the meaning and implications of integrating the local ethnoscientific knowledge and physics concepts in the process of determining the Hijri calendar.

Informants were selected using a purposive sampling technique, based on their relevance to the research focus and depth of knowledge. A total of four informants were involved: one cleric and expert in the

science of astronomy involved in determining the beginning of the Hijri month, two almanacs responsible for the preparation and publication of the Kudus Almanac, and one community observer who participated in rukyat activities. Purposive criteria included (a) active participation in hisab or rukyat practices, (b) institutional or community recognition as practitioners or experts, and (c) willingness to share knowledge and documentation.

Data validity was ensured through source triangulation (comparing data from various informants) and technical triangulation (cross-checking observational data, interviews, and documentation). Additionally, member checking was conducted by returning interview summaries and interpretations to key informants to ensure their accuracy and credibility. As a qualitative study, this research is limited by its reliance solely on participants' subjective experiences and local practices, which may not be fully representative of other regions. The absence of quantitative data also limits the generalizability of the findings. However, this limitation is offset by the depth of the study's contextual understanding, which highlights local wisdom and scientific perspectives within the Kudus community.

RESULT AND DISCUSSION

The calendar is a necessity in human life because it serves as a regulator, a reminder, and a divider of time. In determining the Hijri calendar, this process involves not only scientific aspects such as physics (especially astronomy), but also local knowledge (ethnoscience) passed down from generation to generation, such as the rukyah and hisab methods. One of the main aspects in determining the Hijri calendar is the sighting of the first crescent Moon or hilal after *ijtima'* (conjunction), which in Islamic tradition is known as rukyatul hilal. Scientifically, the determination of the hilal is based on the criteria of *imkan ar-rukyah* (Figure 2), namely the possibility of seeing the hilal based on astronomical observations and calculations. These criteria include physical aspects such as the altitude of the hilal, the angular distance between the Moon and the Sun, and atmospheric refraction (Imron et al., 2015). In this context, physics plays a crucial role in objectively explaining the hilal phenomenon, including through concepts such as lunar synodic cycles, the motion of celestial bodies, and the geometric positions of the Moon relative to the Sun and Earth.

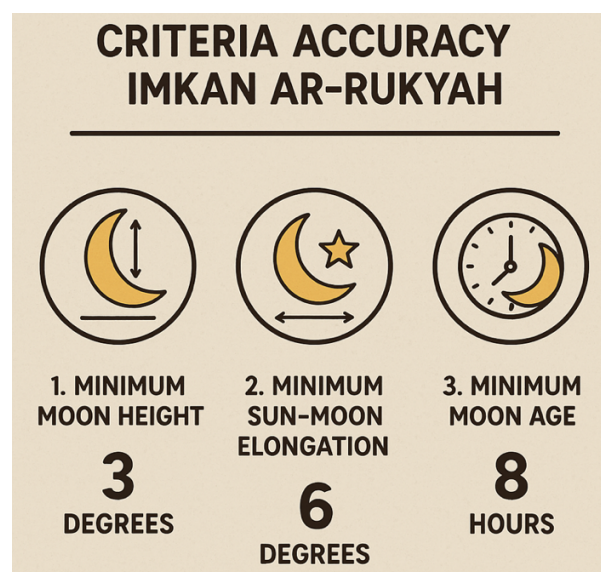


Figure 2. Criteria for the accuracy of *Imkan ar-rukyah*

Indonesia to date along with the MABIMS countries (Malaysia, Brunei Darussalam, Indonesia, and Singapore) (Figure 3), uses a minimum crescent moon sighting criteria of 2 degrees above the horizon, with an elongation of 3 degrees, and a minimum moon age of 8 hours after *ijtima'*, as guidelines for determining the beginning of the Hijri month (Ismail et al., 2024). Nevertheless, the observation process is still carried out monthly, indicating the importance of an empirical approach in local knowledge, in line with the principles of the scientific method in physics. The rukyah method is a form of ethnoscience application, specifically an attempt to observe the crescent directly with the naked eye or with optical instruments at sunset on the 29th of the month of Qomariah. Traditionally, people interpret the successful sighting of the crescent as a sign of the beginning of the month, and failure to see the crescent results in *istikmal*, which completes the month to 30 days (Khusurur, 2020). This view is based on the Prophet's hadith and shows how cultural practices and religious values are integrated into local science.

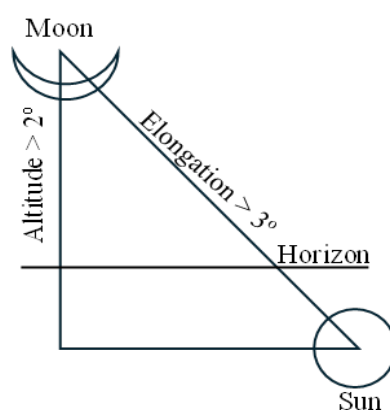


Figure 3. Geometrical parameters of Imkanur Rukyah criteria MABIMS

In contrast, the *hisab* (*rukayah bi al-'ilm*) method is a more mathematical and physics-based approach, using calculation formulas to determine the time of *ijtima'* and predict the position of the crescent Moon. In physics, *ijtima'* is known as a geocentric conjunction, which occurs when the Moon and Sun are at the same celestial longitude (Ar-Rofif, 2022). This period, which occurs every 29.531 days, is known as the lunar synodic cycle. This phenomenon forms the basis for determining the beginning of the month in the Hijri calendar.

The integration of *hisab* (physics) and *rukayah* (ethnoscience) reflects a collaboration between rational and empirical approaches, and local cultural practices that have existed for centuries. In astronomy, this integration poses a challenge because many find the topic difficult to understand due to the complexity of its formulas and concepts (Hamdani & Rojak, 2017). This integration creates a holistic understanding that determining the beginning of the month is not merely a scientific practice but also a form of local wisdom based on religious and social values. The existence of 29 days in the Hijri calendar also has scientific and cultural significance. From a physical perspective, this is a crucial point in determining whether the crescent Moon can be observed. From an ethnoscientific perspective, this is a decision-making moment involving the community, religious authorities, and traditions, all of which reflect local values in the scientific process. Thus, the integration of local knowledge and physics in determining the Hijri calendar can be understood as a representation of the dialogue between culture and science in responding to the practical and spiritual needs of Muslim society (Janah et al., 2019; Uzlifah, 2022).

In the context of physics, particularly astronomy, determining the beginning of the Hijri month using the *hisab* and *rukyat* methods can be scientifically explained by the principles of celestial body motion. The *hisab* method, as used in compiling the Menara Kudus Almanac, involves calculating the positions of the Moon and Sun based on astronomical data, including elongation, the crescent Moon's height, azimuth, and the Moon's age. This determination relies on Newton's laws of gravity and motion, as well as an understanding of elliptical orbits in the heliocentric system. Meanwhile, in the *rukyat* method, crescent observations can also be analyzed using physical optics, particularly light scattering (Rayleigh scattering), which affects the visibility of the crescent Moon at sunset.

The Hijri calendar begins at sunset and ends at sunset the next day. Based on this criterion, the crescent Moon will never be visible below the horizon on the 29th day, so that the beginning of the month or the continuation of the previous month can be determined with certainty. In the calendar system, a day is defined as one rotation of the Earth on its axis, which results in the apparent motion of the Sun over 24 hours. The fundamental difference between the Gregorian and Islamic calendars lies in the definition of the day's beginning. The Gregorian calendar begins the day at midnight (00:00), while the Islamic calendar begins the day when the Sun sets on the western horizon. The determination of time is also used to determine the direction of the Qibla, as stated in the Almanac of the Kudus Tower, where May 27 or 28 and July 15 or 16 are designated as *Yaumi Rashdul Qibla*, which is when the shadow of an object hit by sunlight points directly towards the Qibla (Budiwati, 2019). This is also done by the Ministry of Religious Affairs of the Republic of Indonesia, as shown in Figure 4.

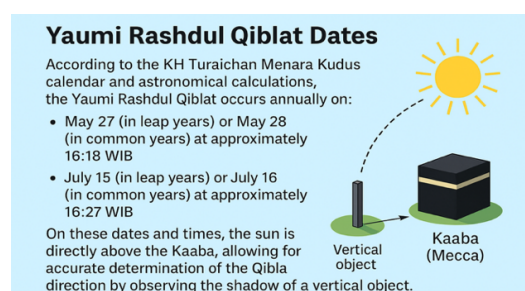


Figure 4. Determination of the Hijri calendar by the Ministry of Religion (2022)

KH. Turaichan Adjhuri, a prominent Islamic scholar and astronomer from Kudus, Central Java, was highly influential in determining the beginning of the Hijri month among the community, particularly in the Kudus region. He used the method of calculating the beginning of the lunar month in the Kudus Tower Almanac, which is classified as a form of *hisab haqiqi tahqiqi* and is considered more advanced than traditional *hisab* methods. This almanac is still widely used in Kudus due to its unique characteristics, model, and its applications in calculation. The data required for this method include the year, month, day, hour, and minute, as per the book *Al-Khulasah Al-Wafiyah*. The method used is *hisab qath'i*, which is a method of mathematical calculation that is precise and accurate, as well as the concept of *hisab imkan rukyah haqiqi tahqiqi*, which has high accuracy and is based on cumulative criteria, including *ijtima' qobla zawal*, a minimum height of 2 degrees, and a minimum age of 8 hours (Ilhami, 2023; Qomarani, 2019). In practice, *hisab imkan rukyah* is used to support rukyat (hilar observation), while *hisab qath'i* can be used independently to determine the beginning of the month.

The people of Kudus, particularly those surrounding the Kudus Tower, have a unique way of interpreting the crescent Moon. For them, the crescent Moon is not merely an astronomical marker for the beginning of the month, but also a spiritual symbol closely linked to preparations for worship. In oral tradition, religious leaders or elders of the mosque (*langgar*) have the moral authority to announce the crescent Moon's appearance to the community, which is usually greeted with religious activities such as communal prayers and recitations on the eve of the month's beginning. Furthermore, the practice of observing the crescent Moon is passed down through generations, both through informal teachings in Islamic boarding schools (*pesantren*) and from family to family. The *hisab* method used in the Kudus Tower Almanac serves as a concrete example of how local traditions and scientific approaches can harmoniously blend within Javanese Islamic culture. Although the terminology used differs, this *hisab* method aligns with the principles of modern physics. This demonstrates that local ethnoscience can achieve profound scientific understanding, even without modern equipment.

However, compared with other studies, our findings enrich the discourse in several ways. For instance, Faisal (2025) compares the *rukyah* and *hisab* methods across several regions in Indonesia and found that, in some cases, *hisab* predictions diverge from actual observations by more than 1 degree of altitude. This study's emphasis on the Kudus context, especially the use of the Menara Kudus Almanac and its specific criteria (*hisab imkan rukyah haqiqi tahqiqi*), fills a gap, as few works have focused in depth on community-level practice in a particular locale.

In contrast to research like "Moderate Way Implementing Rukyah and Hisab", which proposes a harmonization strategy between both methods (i.e., feedback loops) (Afifi & Abbas, 2022), our study shows how such harmonization is already embedded in local customs and traditions, rather than a mere theoretical proposal. Meanwhile, other critical works in hilal visibility science, such as the study on the correlation of hilal age and altitude by Ni'am et al. (2024), show that formulae used in classical texts (e.g., *Fath ar-Rauḥ*) often fail empirical calibration, especially in equatorial latitudes like Java (Ni'am et al., 2024). This underscores that the local model (Kudus Almanac) may provide an empirically grounded midpoint between strict classical formulae and pure *hisab* predictions. Thus, the Kudus case contributes a localized empirical model that can serve as a bridge between classical, observational, and modern astronomical approaches. It demonstrates that local knowledge and community practice can inform scientific discourse, not only by validating or critiquing formulae, but by offering a context-sensitive integration.

The people of Kudus interpret the crescent Moon sighting not only as an astronomical phenomenon marking the change of month in the Islamic calendar, but also as a spiritual symbol with religious and social dimensions. The crescent Moon is considered a sign of the beginning of important religious observances such as Ramadan, Eid al-Fitr, and Eid al-Adha, as well as a moment of transition celebrated with religious rituals. In practice, determining the month's start is often based on calculations inherited from KH. Turaichan Adjhuri, with the Almanac of the Menara Kudus, which some members of the Kudus community still use. This process is not only mathematical but also sacred because it is integrated with the community's spiritual values. In Kudus' local culture, particularly in the Menara Kudus area, the sighting of the new Moon is marked by communal prayers, religious studies, and the recitation of *sholawat* (prayer chants). Local religious figures, such as *kiai* (Islamic

scholars) or elders of Islamic boarding schools, play a central role in conveying the results of new moon observations to the community. Knowledge of the new Moon and the Islamic calendar is passed down through generations, both through informal education in Islamic boarding schools and through oral traditions within families. Parents who are proficient in astronomy or hisab (calculus) often teach their children how to read the calendar and understand natural signs, such as changes in the shape of the Moon, its position at sunset, or certain weather phenomena believed to be related to the beginning of a new month.

The existence of the Kudus Tower Almanac, compiled by KH. Turaichan Adjhuri reflects the integration of astronomical science and local cultural values. This almanac is not only considered a tool for calculating, but also a symbol of the cultural and spiritual identity of the Kudus community. Although there are sometimes discrepancies between local almanac calculations and official government determinations, the Kudus community maintains this tradition as part of its scientific and religious heritage. This shows that the Kudus Tower Almanac is not only an astronomical instrument, but also part of a social and religious system that binds the community through shared traditions. This practice strengthens local identity and becomes a concrete form of ethnoscience, where science, in this case astronomy and hisab, is experienced within the cultural and spiritual framework of the Kudus community (Admizal et al., 2023).

Advances in science and technology have enabled humans to observe and understand the universe's dynamics more accurately. For example, we now know that the Moon orbits the Earth, the Earth orbits the Sun, and the Sun orbits the center of the galaxy. This understanding aligns with the Quranic statement: "Everything revolves on its axis" (QS Yasin: 40), which indicates the regularity of the motion of celestial bodies in their orbits. Physics, particularly in astronomy, provides the scientific basis for understanding the rotation and revolution of celestial bodies. This demonstrates that observing celestial bodies is not only scientific but also has spiritual value and relevance in everyday life (Butar-Butar, 2020).

One concrete application of astronomy in Muslims' lives is determining worship times based on the Hijri calendar. This calendar is used to determine daily and annual worship times, such as prayer, Ramadan fasting, Hajj, and the holidays of Eid al-Fitr and Eid al-Adha (Putri, 2019). Knowledge of the Moon's phases is the main basis of this calendar system. Muslims use a lunar calendar (Hijri), based on the Moon's synodic cycle. Each year consists of 12 months, each with an average length of 29.53 days, for a total of approximately 354 days, approximately 11 days shorter than the 365-day Gregorian calendar (solar calendar) (Syarif, 2017). The Hijri calendar also plays a social and legal role in Muslim society, for example, by determining the forbidden months (during which war is prohibited), the time for zakat payments, and the implementation of other important contracts. In practice, determining the beginning of the Hijri month is done through two main methods: hisab (astronomical calculations) and rukyat (direct observation of the crescent Moon). The crescent Moon is the young crescent Moon visible after the conjunction phase (ijtima'). The rukyatul hilal activity is an important event held before Ramadan or Shawwal to confirm the beginning of the lunar month (Saputra, 2018). For example, the rukyatul hilal conducted in Indonesia in 2024 was used to determine the beginning of Ramadan and Shawwal, as shown in Figure 5.

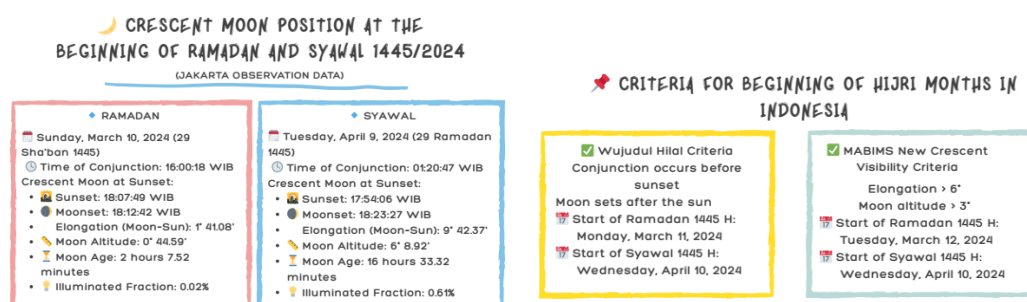


Figure 5. Example of determining the start of Ramadan and determining the start of Shawwal (the new Hijri year) in 2024 with Rukyatul Hilal.

In addition, the hisab system is also used by astronomers with a scientific and mathematical approach. One approach is hisab urfi, which uses calendar calculations based on the average lunar cycle and modern astronomical theory to determine the beginning of Ramadan and other months (Admizal et al., 2023). The integration of physics, specifically astronomy, with the religious needs of Muslims shows how science, technology, and religious values can work in harmony. Islam does not reject science but rather supports the exploration of knowledge that can improve the quality of human life, including through accurate and planned time management and worship. The integration of ethnoscience and physics can be seen in the study of determining the Hijri calendar. Ethnoscience reflects the local knowledge of communities, such as the Kudus community, which has a legacy of crescent moon observation traditions. Meanwhile, physics (particularly astronomy) provides explanations based on data and scientific instruments. A comparison of the two is shown in Table 1.

Table 1. Comparison of Ethnoscience and Physics Perspectives in Determining the Hijri Calendar

Aspect	Physics/Astronomy	Ethnoscience (Islamic Perspective)
Timing	The Gregorian calendar is based on the Sun's orbit, while a month lasts approximately 29–30 days. The 11-day difference each year causes a time lag in the lunar system.	The Islamic calendar is based on the lunar cycle (qamariyah). The Prophet Muhammad (peace be upon him) stated that a month consists of 29 or 30 days. The beginning of the month is determined by sighting the crescent Moon (rukyatul hilal).
The Beginning of the Hijri Month	A new moon is marked by the appearance of a crescent moon after conjunction. The average lunar cycle is 29 days, 12 hours, 44 minutes, and 2.8 seconds.	According to classical texts such as <i>al-Mathla' as-Sa'id</i> and <i>al-Khulāshah al-Wafiyyah</i> , determining the beginning of the month involves calculating the day, hour, and minute. Legacy calendars such as the Menara Kudus Almanac are used.
Rotation and Revolution	The Sun and Moon move according to the law of gravity with fixed orbits and periods.	QS. Ar-Rahman: 5 states that "The sun and the moon move according to their calculations," which are the basis for time and the calendar.
Characteristics of the Moon and the Sun	The Moon reflects sunlight and orbits the Earth.	QS. Yunus: 5 states that Allah made the Sunshine, and the Moon shine, with certain stages (<i>manzilah</i>).
Changes in Moon Phases	The Moon undergoes both sidereal (~27.3 days) and synodic (~29.5 days) revolutions. Synodic is used in the Islamic calendar.	QS. Al-Baqarah: 189 states that the crescent Moon is a marker of time and a marker of worship (including the Hajj).
Orbit	Each celestial body has a fixed orbit to prevent collisions.	QS. Yasin: 38–40 describes the orbits of the Sun and Moon, as well as the order of the universe.

The Kudus community's local knowledge of the crescent Moon is a form of ethnoscience that embodies cultural, religious, and social values. Meanwhile, modern astronomy explains the crescent moon phenomenon quantitatively and rationally. Table 2 summarizes the integration of these two approaches. Integration of ethnoscience and physics/astronomy not only enriches the body of knowledge but also serves as a foundation for contextual learning that respects local culture and global scientific knowledge. This collaboration can serve as an innovative approach to science education. Our study's contribution becomes clearer when contrasted with other works in the field. For example, the implementation of the MABIMS criteria in studies by Wahidi (2021) highlights that although the MABIMS guidelines are formalized, in practice their application is inconsistent—some regions emphasize rukyah, others rely more on hisab. By documenting how the Kudus community actually practices an integrated hisab–rukyah approach through the Kudus Almanac, this research provides empirical grounding for the theoretical critiques of criterion inconsistency. Similarly, the examination of disputes between Rukyatul Hilal and Hisab Hakiki in the Indonesian context underscores the need to harmonize these methods; our case study shows how such harmonization can manifest in a culturally embedded way (Koto et al., 2024).

Table 2. Integrative Framework of Kudus Ethnoscience and Physics/Astronomy

Component	Local Ethnoscience (Kudus)	Physics/Astronomy	Integration
Source of Knowledge	Oral tradition, legacy of scholars (KH. Turaichan), empirical observation	Telescope, astronomical calculations, simulation software	Both rely on sky observations, although with different approaches.
Hisab Method	Using the Kudus Tower Almanac and traditional calculations	Using modern astronomical algorithms and astronomical software	The same goal: determining the beginning of the Hijri month
Cultural Values	Spiritual, religious values, respect for figures	Objectivity, rationality, scientific certainty	Strengthening integrated learning of values and science
Study room	Violation, mosque, community forum	Formal classes, observatories, digital platforms	The potential for contextual and transdisciplinary learning
Objective	Determining worship times and strengthening cultural identity	Explaining celestial phenomena scientifically and accurately	Collaboration for a comprehensive and inclusive understanding

CONCLUSION

The results of this study demonstrate that determining the Hijri calendar in the Kudus community represents a successful integration between physics, particularly astronomy, and ethnoscience derived from local cultural traditions. Scientifically, this process involves applying principles of celestial mechanics, such as the lunar synodic cycle, the geometry of celestial positions, and atmospheric refraction, to determine the *imkan ar-rukyah* criteria. Ethnoscience, it reflects inherited empirical practices and religious values rooted in community-based observation of the crescent Moon (*rukyat al-hilal*). Together, these perspectives form a holistic model that bridges rational, empirical, and spiritual approaches to timekeeping in Islamic tradition. This study contributes scientifically by (a) providing an empirical model of how traditional hisab methods—such as the *hisab imkan rukyah haqiqi tahqiqi* used in the Menara Kudus Almanac—can align with modern astronomical theory, and (b) illustrating that local ethnoscience possesses epistemological value equivalent to formal scientific systems. It enriches the discourse on integrating culture-based knowledge into scientific frameworks, particularly in astronomy and science education. Practically, the findings imply that culture-based scientific practices can serve as an effective entry point for contextual and inclusive science learning. Teachers and curriculum designers may adopt the Kudus case as a model for ethnoscience-integrated physics education, allowing students to connect abstract astronomical concepts with familiar cultural contexts. Policymakers in religious affairs may use such localized models as supporting references for public calendar-setting policies, especially in regions where local traditions coexist with state or global astronomical standards. This study is limited by its qualitative scope and its focus on a single community, which may not fully represent the diversity of lunar calendar practices across Indonesia or other Muslim societies. The findings rely on descriptive interpretations rather than quantitative validation of astronomical parameters. Therefore, future research should conduct comparative studies across various regions—such as Gresik, Cirebon, and Aceh—to analyze variations in the integration of hisab-rukyat practices. Further exploration using digital simulations or optical instrumentation could also strengthen the scientific understanding of the *imkan ar-rukyah* phenomenon within ethnoscientific contexts.

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