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Parameters for an Independent Islamic Hijri Calendar: A Historical and Astronomical Approach

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Abstract. A calendar should function not only as a system for tracking time but also as a framework for astronomical calculation. An ideal, independent calendar enables the calculation of celestial positions—such as those of the sun, moon, and stars—directly from its own chronology. This stands in contrast to the current methodology for the Islamic Hijri calendar, which relies on external astronomical data to determine its dates. This paper explores the essential parameters required to develop an independent Islamic Hijri calendar that is both scientifically robust and religiously authentic. By synthesizing historical practices, astronomical principles, and modern advances in calendar science, this research proposes a set of foundational criteria for an independent and self-sufficient Islamic calendar system.

Keywords: Independent Islamic Hijri Calendar, Wada Date, Arafah Mean Time, Nasii' prohibition, Farewell Pilgram

1. Introduction

A calendar is a system for organizing days into weeks, months, and years for social, religious, commercial, or administrative purposes. It is structured to reflect astronomical cycles, such as the movement of the sun or moon. The Islamic calendar, in particular, is a lunar system, as affirmed in the Qur'an:

- *He is the One Who made the sun a radiant source and the moon a reflected light, with precisely ordained phases, so that you may know the number of years and calculation ˹of time˺. Allah did not create all this except for a purpose. He makes the signs clear for people of knowledge. (QS 10:5).*

- *Indeed, the number of months ordained by Allah is twelve—in Allah's Record1 since the day He created the heavens and the earth—of which four are sacred. That is the Right Way. So do not wrong one another during these months. And fight the polytheists together as they fight together against you. And know that Allah is with those mindful ˹of Him˺.* (QS 9:36)

- *They ask you ˹O Prophet˺ about the phases of the moon. Say, "They are a means for people to determine time and pilgrimage."* (QS 2:189).

The Quran informs us that the year consists of twelve months, and that the lunar mansions (manazil) mark the moon's positions in the sky, which can be used to track the time (counting year). Following the Hadith of the Prophet Muhammad ﷺ, the beginning of each Hijri month is determined by the physical sighting of the new crescent moon (hilal). When a sighting is confirmed, that night marks the beginning of a new month. If the moon is not sighted, the new month is delayed by one day. This practice often leads to variations in calendar dates across different regions. Furthermore, it has also led to the development of various models for predicting crescent visibility and alternative calendar concepts based on these visibility models.

As a lunar calendar, the Hijri calendar has months that are either 29 or 30 days long. This variability is both theologically and scientifically justified, as it aligns with the Prophetic hadith stating the possible lengths of the Hijri months (Sahih al-Bukhari, 5302) and with the average lunar synodic cycle of 29.53 days. Therefore, an ideal calendar is one whose cycle closely mirrors natural astronomical cycles, particularly the lunar cycle. The synodic period—the time it takes for the moon to return to the same phase as observed from Earth—averages about 29.53 days. This means that for a calendar to align with the true lunar rhythm, the distribution of month lengths should reflect this average: approximately 47% of months should be 29 days long, while about 53% should be 30 days long. Such a structure ensures that the calendar remains in harmony with the actual phases of the moon, providing both scientific accuracy and consistency with natural phenomena.

Unfortunately, to this day, all Hijri calendar systems rely on the Gregorian calendar for their computation. This dependency, and the lack of a unified global system, has prompted calls for the development of an independent Islamic calendar based on objective, scientific parameters. An independent calendar is defined as a system that can be constructed and operated without relying on data from other calendrical systems. It uses its own astronomical reference points to arrange dates and can, in turn, be used to calculate celestial positions. The Gregorian calendar is a prime example of an independent calendar, as it is constructed directly based on the solar cycle and can be used for astronomical calculations.

This paper investigates the parameters required to establish such an independent Islamic Hijri Calendar, aiming to balance religious tradition, historical facts, and scientific accuracy.

The Historical and Astronomical Epoch. Our investigation identifies the Farewell Pilgrimage in 10 AH as the pivotal moment for this new calendar's epoch. This is also in line with the suggestion of a conventional Islamic calendar by Rashid and Moklof (2017), which used the Farewell Pilgrimage as the basis for its model. The prohibition of *Nasii'* (intercalation) during this event marked the definitive transition from a lunisolar to a purely lunar calendar system. On that occasion, the Prophet Muhammad ﷺ declared that

"Time has come back to its original state which it had when Allah created the Heavens and the Earth; the year is twelve months, four of which are sacred. Three of them are in succession; Dhul-Qa'da, Dhul-Hijja and Al-Muharram, and (the fourth being) Rajab Mudar (named after the tribe of Mudar as they used to respect this month) which stands between Jumad (ath-thani) and Sha'ban." (Sahih al-Bukhari, 4662). This declaration provides a theological mandate to base the calendar on perpetual astronomical cycles. Interestingly, there were specific astronomical phenomena at that time that can be related to the phrase, "Time has come back.", i.e:

1. **The Equinoctial Conjunction:** The conjunction (ijtimāʿ) on 29 Dhu al-Ḥijjah 10 AH occurred with both the Sun and the Moon positioned near the vernal equinox, a primary astronomical reference point. Although an equinoctial conjunction follows the 235-synodic-month Metonic Cycle, calculations show that the recurrence of a conjunction for a specific Hijri month near the vernal equinox follows a cycle of approximately 33.5 years.
2. **The Annular Solar Eclipse:** An annular solar eclipse occurred at the end of Shawwāl 10 AH. Since solar eclipses follow the Saros cycle of approximately 235 synodic months (~19 years), this event can also serve as a significant marker of a celestial cycle. This solar eclipse is also known as the "Muhammad's Eclipse" because its occurrence coincided with the death of Ibrahim, the son of Prophet Muhammad ﷺ (Haikal, 2021).

Together, these events provide perpetual and objective astronomical cycles upon which an independent calendar can be constructed. This paper will detail the parameters derived from this historical and astronomical context.

2. The Foundational Parameters: Epoch, Meridian, and Lunation

2.1. The Wada Date (WD): The Historical Epoch

The location, day, date, and time of the Sermon at Arafah are recorded with precision in both historical and astronomical sources: it was delivered after the sun passed the meridian (local noon) at Mount Arafah on Friday, 9 Dhu al-Hijjah, 10 AH. Therefore, we propose the Day of Arafah at 12:00 (**Arafah Mean Noon**) from the Prophet Muhammad's ﷺ Farewell Pilgrimage as the epoch, or starting point, for the Islamic calendar calculation. We designate this as the first "Wada Date" (**WD = 1**).

The Wada Date (WD) denotes the cumulative day count, starting from this epoch at noon on 9 Dhu al-Hijjah, 10 AH at Mount Arafah. This approach diverges from the Hijri Day Number proposed by Ilyas (1991), primarily due to the historical uncertainties surrounding the date of 1 Muharram 1 AH and its lack of connection to a pivotal prophetic event. In fact, the Prophet's Hijrah did not occur on 1 Muharram 1 AH, but rather took place from the end of Safar to 12 Rabiʻul Awwal 1 AH emphasizing that the conventional start of the Islamic calendar does not coincide with the actual date of this seminal event. Although we acknowledge Ilyas's (1991) suggestion to use a location within Saudi Arabia as a reference point, we recommend a site of greater historical and prophetic importance: Mount Arafah, situated in Saudi Arabia. In this model, the WD functions similarly to the Julian Day (JD) in

Gregorian calendar calculations, serving as a continuous count of days from a fixed astronomical and historical reference.
Further details and discussion regarding the Wada Date (WD) will be addressed in a separate section to provide a clearer understanding of its derivation and application within the calendar system.

2.2. The Arafah Meridian and Arafah Mean Time (AMT): The Spatial Reference

The Arafah Meridian, defined by the longitude of Mount Arafah where the Prophet Muhammad ﷺ delivered his Farewell Sermon, holds significant potential as the prime meridian for the Islamic calendar. Designating this meridian as the reference point provides the Islamic calendar with a unique and historically rooted anchor, distinct from the Greenwich Meridian used in the Gregorian system. This approach not only aligns the calendar with a moment of profound religious importance but also establishes a consistent geographical basis for determining the start of days, months, and years. Establishing the Arafah Meridian as the prime meridian thus underscores the independence and authenticity of the Islamic calendrical system, reinforcing its legitimacy in both scientific and spiritual dimensions.

The establishment of an Islamic geographical coordinate system, which designates Arafah as the prime meridian in place of the conventional Greenwich reference, has a direct impact on determining the global Islamic date change line. By anchoring the calendar to the Arafah meridian, the International Date Line for the Islamic calendar is redefined as its antipodal meridian. This antipodal meridian passes almost entirely over the open Pacific Ocean, clipping only a few significant land areas, such as a sparsely populated region of Alaska and the Tuamotu Archipelago in French Polynesia.

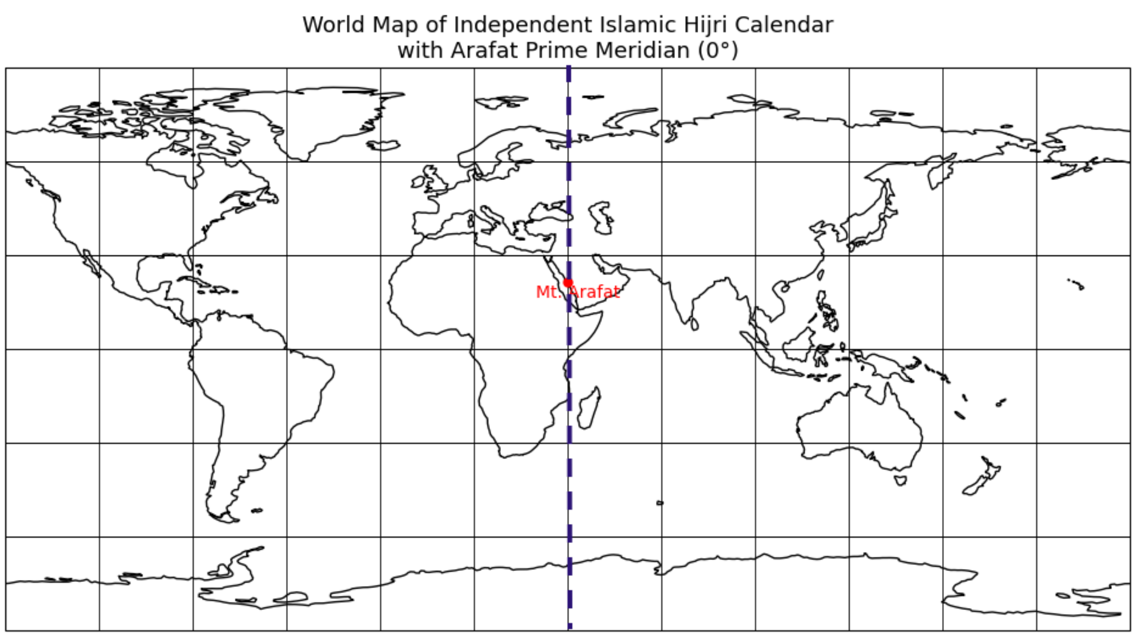

Fig1. The accompanying figure visually illustrates the concept of the Arafah Prime Meridian and its pivotal role in redefining the Hijri International Date Line. In the diagram, Mount Arafah is marked as the central meridian (0°), serving as the anchor for all calendrical calculations in the proposed Independent Islamic Hijri Calendar system.

Figure 1 illustrates this new configuration. The figure highlights how the antipodal meridian functions as the new Hijri International Date Line, demonstrating a unified approach for determining the start of days and months throughout the Muslim world. It shows that this line predominantly traverses the open Pacific Ocean, ensuring that the transition of Islamic days occurs in a manner distinct from the conventional Greenwich-based system. Additionally, the figure displays the geographic distribution of landmasses relative to the new date line, indicating minimal disruption to populated regions. By putting the prime meridian on Arafah, the figure emphasizes both the spiritual significance and the practical implications of this system for global Islamic timekeeping.

Building upon the significance of this meridian, the concept of Arafah Mean Time (AMT) emerges as a standardized temporal reference derived from it. Adopting AMT allows the Islamic calendar system to establish a uniform timekeeping standard intrinsically linked to a location of paramount religious and historical importance. This approach provides a coherent alternative to Greenwich Mean Time while reinforcing the distinctiveness of the Islamic calendrical framework. Using AMT ensures that all key astronomical events—such as the *ijtima‘* (conjunction) and the determination of the new month—are calculated relative to the same meridian, thereby enhancing the calendar's consistency and unity for the global Muslim community. In this way, Arafah Mean Time functions both as a symbol of Islamic identity and a practical tool for precisely regulating religious observances.
The establishment of an Islamic geographical coordinate system, which designates Arafah as the prime meridian in place of the conventional Greenwich reference, has a direct impact on determining the global Islamic date change line. By anchoring the calendar to the Arafah meridian, the International Date Line for the Islamic calendar is redefined as its antipodal meridian. This antipodal meridian passes almost entirely over the open Pacific Ocean, clipping only a few significant land areas, such as a sparsely populated region of Alaska and the Tuamotu Archipelago in French Polynesia.

This adjustment ensures that each Islamic day begins consistently worldwide according to this spiritually significant reference point, resulting in date transitions that differ from those of the Greenwich-based system.

2.3. The Islamic Lunation Number (ILN)
In the model proposed here, the Islamic Lunation Number (ILN) is defined as a lunation corresponding to the new moon (conjunction) within the Hijri month, standardized to occur on the 29th day of that month, and counted from the conjunction time after the Wada‘ Hajj (the Farewell Pilgrimage of the Prophet ﷺ) designated as **ILN 1**. This contrasts with the proposal of Ilyas (1991), who calculated the ILN starting from 1 Muharram 1 AH. Our departure from Ilyas's baseline is not merely due to the historical uncertainty surrounding the date of 1 Muharram 1 AH, but also because that date holds no direct connection to prophetic history and lacks the support of a definitive astronomical phenomenon.

Conversely, the chosen epoch is supported by clear astronomical phenomena. The conjunction on 29 Dhu al-Hijjah 10 AH was the first to occur after the sun passed the vernal equinox, providing a significant astronomical anchor. Interestingly, this event also represents the last Dhul-Hijjah conjunction while the sun occupied the northern hemisphere (positive declination). The following year, during Dhul-Hijjah of 11H, the conjunction had already shifted to the southern hemisphere (negative declination). As the vernal equinox serves as a key reference for many calendars, we have a strong astronomical reason to set this lunation as the first lunation of the independent Islamic Hijri calendar system. With this definition, it can also be stated that the first (1^{st}) lunation marked the beginning of the new era, corresponding to the first (1^{st}) date of the first (1^{st}) month in the 11^{th} year, which can be abbreviated as 1.1.11 (Muharram 1^{st} 11H).

The Islamic Lunation Number (q) can be represented by the following mathematical formula:

$$q = month + 1 + 12 * (year - 11) \qquad (1)$$

Table 1: Correlation between Hijri Months, Years, and The Islamic Lunation (q)

Month	Hijri Year	The Islamic Lunation (q)
12	10	1
1	11	2
2	120	1,311
3	250	2,872
4	500	5,873
5	1,000	11,874
6	1,100	13,075
7	1,210	14,396
8	1,310	15,597
9	1,420	16,918
10	1,430	17,039
11	1,450	17,280
12	1,500	17,881

3. Criterion 29: The Operational Rule for Monthly Structure

3.1. Rationale and Definition

The 29th day of the Hijri month holds particular significance as a reference point for the *ijtima'*(conjunction), the precise moment when the sun and moon share the same ecliptic longitude. Traditionally, the occurrence of the *ijtima'* near the end of the lunar month is crucial for determining the commencement of the following month. By systematically defining the day on which the conjunction occurs as the 29th—a principle we term **Criterion 29**—the calendar establishes a consistent and objective basis.

This "Criterion 29" was first conceptualized by Setyanto in 2002 (Setyanto, 2008) and later proposed as a new method for constructing the Hijri calendar (Setyanto & Hamdani, 2015).

It was further advocated as the foundation for a unified international Hijri calendar under the title "Independent Calendar as the Basis for the Unity of the International Hijri Calendar" (Setyanto & Hamdani, 2017). However, at that time, the methodology for building such an independent calendar was incomplete because it required a calculation concept wholly separate from existing systems.

This criterion 29 aligns perfectly with the command for lunar sighting (*rukyat hilal*) on the 29th day, as the new crescent only becomes visible after the *ijtima'* has occurred. Furthermore, this definition inherently precludes observing the crescent moon before it is astronomically feasible (i.e., before conjunction). The rationale for the 29th Criterion is based on the Islamic day beginning at sunset. Consequently, conjunction occurring any time on the 29th day guarantees the presence of the hilal above the horizon, thus establishing a coherent relationship between calculations and observations.

3.2. The Counting Rule

According to Criterion 29, the day of the *Ijtima'* is systematically defined as the 29th of each hijri month. The first day of the month is then determined by counting backward from this fixed point: the 28th , 27th , and so on, down to the 1st.

This establishes a predictable pattern:

- If the 29th day of a given month (for example, Ramadhan) falls on a particular weekday (for instance, Sunday), then the 1st day of that same month will also fall on the same weekday, Sunday. This alignment results from the method of counting days backward from the fixed point of the conjunction.
- The determination of whether the month in question (M1/Ramadhan) consists of 29 or 30 days depends on the weekday on which the conjunction for the following month (M2/Syawal) occurs. Specifically, the 29th day of the next month will fall on either the next sequential weekday (d+1, which would be Monday) or the one after (d+2, Tuesday).
    - If the 29th day of month M2 (Syawal) falls on d+1 (Monday), this signifies that month M1(Ramadhan) had a total of 29 days.
    - If the 29th day of month M2 (Syawal) falls on d+2 (Tuesday), this indicates that month M1 (Ramadhan) was 30 days long, and therefore, the 30th day of M1 fell on Monday.

To illustrate the viability of the system, we have documented the Start Days of Months for years 10H and 11H in accordance with Criterion 29 as outlined below:

Table 2: Start Days and Lunation Numbers of Months in the Hijri Year 10

No.	Month	Lunation	1st Day	29th Day	30th Day
1	Muharram	-11	Tuesday	Tuesday	Wednesday
2	Safar	-9	Thursday	Thursday	-
3	Rabiul I	-8	Friday	Friday	-
4	Rabiul II	-7	Saturday	Saturday	Sunday

5	Jumadil I	-6	Monday	Monday	-
6	Jumadil II	-5	Tuesday	Tuesday	Wednesday
7	Rajab	-4	Thursday	Thursday	-
8	Sya'ban	-3	Friday	Friday	Saturday
9	Ramadhan	-2	Sunday	Sunday	-
10	Syawal	-1	Monday	Monday	Tuesday
11	Dzulqodah	0	Wednesday	Wednesday	-
12	Dzulhijjah	1	Thursday	Thursday	Friday

Table 3: Start Days and Lunation Numbers of Months in the Hijri Year 11

No.	Month	Lunation	1st Day	29th Day	30th Day
1	Muharram	2	Saturday	Saturday	Sunday
2	Safar	3	Monday	Monday	-
3	Rabiul I	4	Tuesday	Tuesday	Wednesday
4	Rabiul II	5	Thursday	Thursday	-
5	Jumadil I	6	Friday	Friday	Saturday
6	Jumadil II	7	Sunday	Sunday	-
7	Rajab	8	Monday	Monday	Tuesday
8	Sya'ban	9	Wednesday	Wednesday	-
9	Ramadhan	10	Thursday	Thursday	Friday
10	Syawal	11	Saturday	Saturday	-
11	Dzulqodah	12	Sunday	Sunday	Monday
12	Dzulhijjah	13	Tuesday	Tuesday	-

3.3. The WADA DATE : The Astronomical Calculation

The current method for calculating *ijtima'* (lunar conjunction) relies on the Gregorian calendar and Greenwich Mean Time. The key objective is to transition this calculation to the proposed Islamic framework of Criterion 29, using the Wada Date (WD) and Arafah Mean Time. This will create a truly independent Islamic calendar system. The crucial next step is to adapt existing astronomical formulae to run on this new framework. The following formulae can be used to find a WD for any given date of hijri calendar. Let WD_{dmy} be the Wada Date for a given Hijri date with day (*d*), month (m) and year (y)

$$WD_{dmy} = WD_{29} - 29 + dmy \qquad (2)$$

$$WD_{29my} = \lfloor a + \beta q + cA^2 + dA^3 + eA^4 \rfloor \qquad (3)$$

where;

$WD_{29my} = WD\ of\ 29th\ day\ of\ a\ given\ hijri\ month\ (m)\ and\ year(y)$

$q = Islamic\ Lunation\ Number = month + 1 + 12 * (year - 11)$

$A = Abad\ (Hijri\ Century) = \frac{q}{1200}\text{a} = -8.26434186776169$
$\beta = 29.5305853725391$
$c = 1.51873906110916 \times 10^{-4}$
$d = 1.73464455373051 \times 10^{-7}$
$\text{e} = 6.46814445693685 \times 10^{-10}$

These constants a, β, c, d and e are derived from translating the Moon phases equation (eq.47.1) in Astronomical Algorithm (Meeus, 1998), which is based on the Gregorian calendar and the Julian Date concept. The original equation uses a moon conjunction epoch of January 6th 2000 which corresponded to Ramadhan 29th 1420H. Applying Criterion 29 yield :

$$q = 16918$$

$$A = Abad\ (Hijri\ Century) = \frac{16918}{1200} = 14.098333$$

Assuming a linear correlation *(T=* $oA + p$) between parameters and constants of the moon phases in JDE and WDE, we relate the JDE parameters (k,T) to the corresponding WDE parameters (q,A). These correlated parameters are then substituted into the JDE equation to derive the WDE Equation. The same procedure is applied to the other equations related to the Moon phases.

Just remember: case for the WD of the 30th, if WD_{30my} is equal to $WD_{30(m+1)y}$, then there is no 30th of the month. It is important to note that some core corrections remain necessary, particularly with regard to planetary arguments. For this work, we have already translated the 14 equations of planetary arguments—originally formulated for the Gregorian calendar—to be compatible with Criterion 29. A more detailed discussion regarding the methodology of this translation presented in a separated paper.

4. The Crescent Visibility Assessment in the Independent Islamic Calendar

Currently, the crescent visibility is a fundamental aspect in Islamic calendar. To assess the crescent visibility in this independent Islamic calendar, we analyzed 1620 months from 10 AH to 135 AH. For each 29th day, the geocentric lunar elongation was computed at sunset at Arafah. The dataset yielded a minimum elongation of 0.22°, a maximum of 14.87°, and an average of 7.23°. The resulting elongation values were then categorized based on the length of the observed month: 29-day months (blue) and 30-day months (orange). From the dataset of 1,620 months, 860 months (53.08 %) consisted of 30 days and 760 months (46.92%) consisted of 29 days. This distribution aligns with the natural lunar cycle that serves as the basis of the lunar calendar—the synodic period, which averages 29.530588 days. For calendar design, this implies that to approximate the true average lunar month length, approximately 53.08% of months should be 30 days and 46.92% should be 29 days.

Therefore, the Criterion 29 used in constructing the Independent Islamic Hijri Calendar (IHC) accurately synchronizes the calendar with the underlying astronomical phenomenon.

Figure 2 presents the distribution of these elongation values over the study period. Distinct patterns are evident and may be summarized as follows:

1. **Boundary for 29-Day Months:** The elongation for 29-day months spans from 4.66° to 14.87°. The lower limit of 4.66° represents the minimum value at which a 29-day month is observed. All months with elongations below this value resulted in a 30-day month.
2. **Boundary for 30-Day Months:** The elongation for 30-day months spans from 0.22° to 9.53°. The upper limit of 9.53° represents the maximum value at which a 30-day month is observed. All months with elongations above this value resulted in a 29-day month.
3. **Imkan Rukyat Region:** The elongation range from 4.65° to 9.53° defines a transition zone where the length of the ensuing month is not determined solely by elongation. We can call this region the "imkan rukyat" region. This area encompasses all study results on the visibility of the hilal. Interestingly, the region has an average elongation of 6.80°, which is lower than the average elongation for the entire dataset.

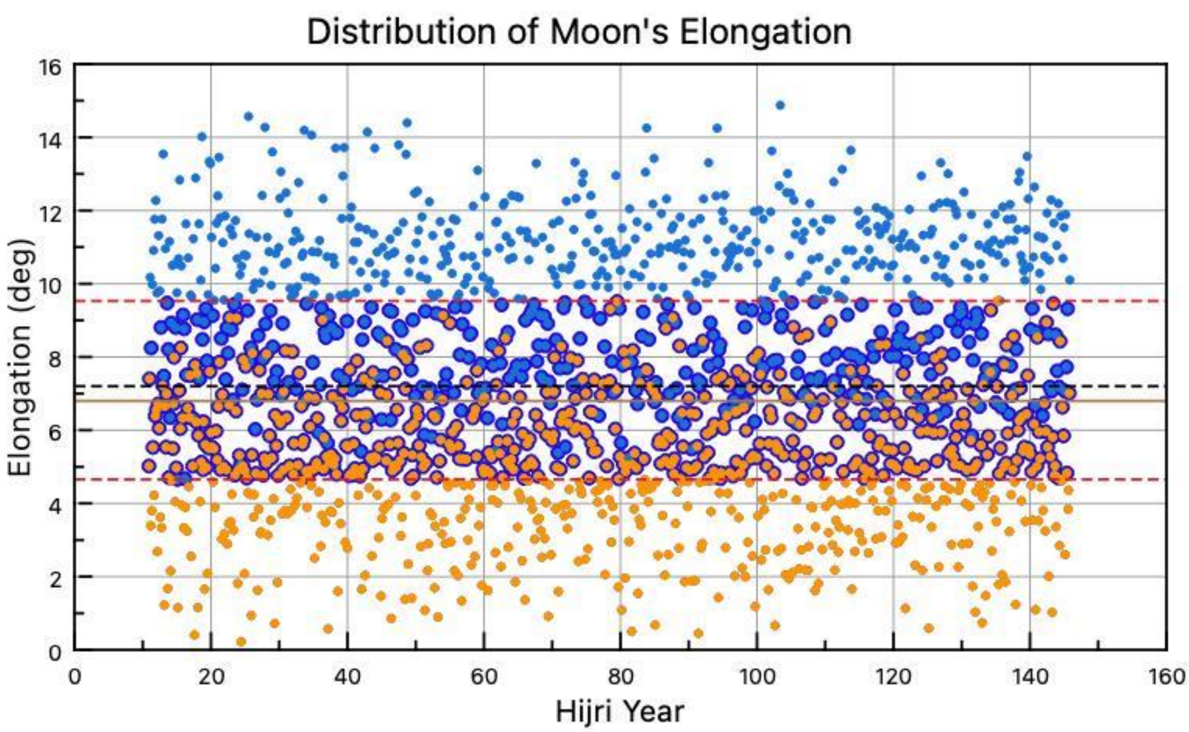

Figure 2 shows the Moon's elongation values over 1620 lunar months in the Independent Islamic Calendar, measured on day 29 of each month from 10H to 135H. Blue dots mark 29-day months; orange dots mark 30-day months. The minimum for 29-day months is 4.66°, and the maximum for 30-day months is 9.53°. The "imkan rukyat" zone between these values reflects months that may be 29 or 30 days, with an average elongation of 6.8°. This visual highlights the statistical basis for crescent visibility in the calendar.

5. Conclusion: A Synthesized System for Independence

The implementation of this system promises a unified, predictable, and truly independent Islamic Hijri calendar for the global Muslim community. This synthesis fulfils the objective of creating a calendar that is not only derived from its own chronology but is also capable of internal astronomical calculation, achieving a true balance between faith and science. The foundation of this system is Criterion 29, which offers profound simplicity. By fixing the conjunction as the 29th day of every month, it establishes an intuitive and unchanging anchor. This elegantly simple rule for determining the month's length—based on the weekday of the following conjunction—makes the calendar easily understandable and predictable for everyone, while remaining firmly grounded in astronomy.

This mechanism is structured within a self-contained reference frame defined by key parameters: the Wada Date (WD) as the historical epoch, the Arafah Meridian and Arafah Mean Time (AMT) as the spatial and temporal reference, and the Islamic Lunation Number (ILN) as the cycle count. Crucially, the adoption of the Islamic Prime Meridian at Arafah enables the calendar's universal application. By establishing a single, globally recognized longitudinal reference, it synchronizes calendrical events across diverse regions, ensuring key dates are uniformly calculated and fostering unity by eliminating discrepancies. Rooted in a moment of profound religious significance, aligned with unambiguous historical facts, and anchored in perpetual astronomical cycles, this framework delivers a calendar that is both intellectually robust and spiritually resonant.

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