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Annular Solar Eclipse in the Classical Islamic Astronomical Tradition

Jauharotul Maknunah Firman[1], Ahmad Syifaul Anam[2]
[1,2] Universitas Islam Negeri Walisongo Semarang, Indonesia
Email: unahfirman704@gmail.com, syifaulanam@walisongo.ac.id

Article Info	ABSTRACT
Article History Received 13-05-2025 Revision 16-07-2025 **Accepted 03-09-2025** **Keywords:** Classical Calculation Annular Solar Eclipse Scientific Integration	This study aims to analyze the limitations of the hisab method, as found in classical Islamic astronomy texts, in estimating the types of solar eclipses, particularly annular solar eclipses, and to offer an integrative approach with modern astronomical calculations. Although classical calculations have played a significant role in predicting celestial phenomena and determining prayer times, the methods employed do not account for key astronomical parameters, such as the apparent diameters and relative distances of the Sun and Moon from the Earth. As a result, it is unable to accurately distinguish between different types of solar eclipses. This research employs a descriptive qualitative method, combining a literature study with content analysis of classical Islamic astronomy texts and contemporary astronomical data and theories. This study concludes that classical astronomical calculations are insufficient for identifying annular solar eclipses, as they do not incorporate essential astronomical parameters. Integrating these traditional methods with modern astronomy is necessary to enhance the accuracy of eclipse predictions and reinforce the relevance of Islamic astronomy in the contemporary era.

I. Introduction

Islamic astronomy has played a significant role in Islamic civilization, particularly in determining the times of worship, such as prayer, fasting, and the beginning of the lunar month. One aspect of Islamic astronomy is calculating eclipses, a method used to estimate the timing of lunar and solar eclipses. The phenomenon of eclipses is not only studied scientifically but is also indirectly mentioned in the verses of the Qur'an. In the Qur'an, Allah says:

فَالِقُ الْاِصْبَاحِۚ وَجَعَلَ الَّيْلَ سَكَنًا وَّالشَّمْسَ وَالْقَمَرَ حُسْبَانًا ۗذٰلِكَ تَقْدِيْرُ الْعَزِيْزِ الْعَلِيْمِ

"*(He) who brings forth the morning and makes the night to rest, and (makes) the sun and the moon for reckoning. That is the decree of Allah, the Mighty, the All-Knowing*". (QS. Al-An'am: 96)

This verse indicates that celestial events, such as the movements of the Sun and the Moon, are among the signs of Allah's power and contain wisdom for humankind, including the phenomenon of eclipses. Furthermore, in an authentic hadith, the Prophet Muhammad (peace be upon him) said:

إنَّ الشَّمسَ والقَمَرَ لا يَنكسِفانِ لِمَوتِ أحدٍ من النَّاسِ، ولكنَّهما آيتانِ من آياتِ اللهِ؛ فإذا رَأيتُموهما فقُوموا فصَلُّوا

"*Indeed, the Sun and the Moon are two signs among the signs of Allah's greatness. They do not eclipse because of the death or life of anyone. So when you see them, pray and supplicate to Allah until they return to their normal state.*" (Hadith narrated by al-Bukhari No. 1041 and Muslim No. 901)

This hadith serves as the foundation for the eclipse prayer (ṣalāt al-kusūf/khusūf) and highlights the importance of studying this phenomenon as a form of tadabbur (contemplation) upon the signs of Allah. Historical records show that classical Islamic astronomers, such as Al-Battani, Al-Farghani, and Ibn Shatir, developed methods for hisab (astronomical calculation) to estimate the occurrence of eclipses in general. [1].

In the Indonesian local context, archipelagic scholars such as KH. Abdul Djalil Kudus, in his book Fathur Rouf al-Mannan, also developed eclipse calculation methods based on classical Islamic astronomy texts. These works are capable of predicting the timing of eclipses by using celestial geometric parameters, such as the positions of the Sun and the Moon relative to the Earth and their orbital nodes. However, these texts generally do not explicitly differentiate between types of eclipses, such as total, partial, or annular, due to limitations in observational instruments and the limited understanding of complex celestial mechanics at the time [2].

An annular eclipse occurs when the Moon is at apogee, its farthest point from the Earth, and its angular diameter appears smaller than that of the Sun. As a result, at the peak of the eclipse, the Moon's disk does not completely obscure the Sun, leaving a visible "ring of light" around it [3]. This type of eclipse is highly dependent on the apparent size difference between the Sun and the Moon, which varies according to their orbital positions and relative distances from the Earth.

Accurate calculations of annular solar eclipses require precise astronomical data, including variations in the elliptical orbits of the Moon and the Earth around the Sun, parallax values, and measurements of the actual distances between celestial bodies. Unfortunately, classical calculation methods lacked the instruments and mathematical models necessary to account for these variables. This limitation was primarily due to the observational technology available at the time and the absence of Kepler's Theory of elliptical orbits, which was only developed in Europe in the 17th century [4]. As a result, classical methods were unable to accurately distinguish between total and annular solar eclipses, although they could still predict the general timing of eclipse events.

Literature Review

Several previous studies present a diverse range of perspectives on solar eclipse calculation methods, encompassing both classical and modern approaches. Muhammad Farid Azmi, in his study of the book Al-Durru al-Anīq [5]. It demonstrates that the calculation method employed in the text is pretty accurate and even capable of classifying the type of eclipse that occurs. Meanwhile, Ismail, in his research on Hisab Urfi, found that this method is fast and practical, as it does not incorporate corrections for the Sun's position [6]. However, his study does not explain in detail how the Hisab Urfi method determines the type of eclipse. On the other hand, Siti Lailatul Mukarromah offers a modern approach, utilizing NASA's algorithm in solar eclipse calculations. Her research produces highly accurate results and is frequently used as a primary reference for determining both the timing and type of eclipse, making it a relevant benchmark for comparison with classical calculation methods [7].

Furthermore, Siti Anisah, in her research on the book Tadzkirat al-Ikhwan by KH. Ahmad Dahan As-Samarani, found that the text only reaches the stage of determining the possibility of an eclipse, without advancing to the classification of eclipse types [8]. Moh reported a similar finding. Faizal bin Jani and colleagues in their study on the contribution of the book Sullam al-Nayyirain. This text, like Fath al-Rauf al-Mannan, calculates only local eclipses in Indonesian regions with latitudes between -6° and -9°, without providing a broader discussion on eclipse classifications [9].

Meanwhile, Muazarotun Nafi'ah, in her research on the book Nūr al-Anwār by KH. Noor Ahmad Shidiq Saryani discovered that the mar'i climate-based calculation method was employed to identify the type of eclipse. However, the resulting classification remains limited to total, partial, and doubtful eclipses, without including the category of annular solar eclipses [10]. This review of the literature highlights the diversity of approaches to eclipse calculation, while also revealing a notable gap in the classical literature regarding the absence of a category for annular eclipses.

With the advancement of modern astronomy, high-precision astronomical data has become accessible through sophisticated software and databases such as the NASA Eclipse Catalog and the Skyfield Library. This study seeks to critically examine classical calculation methods using both historiographical and astronomical approaches, to assess the extent of their methodological and epistemological limitations, particularly those that contributed to the absence of an annular solar eclipse category. Thus, this research is not merely descriptive, but also analytical and constructive in redefining the position of classical astronomical calculations within the framework of contemporary Islamic science.

II. Method

This research employs a descriptive qualitative method, utilizing a literature study approach, to analyze the limitations of eclipse calculations found in classical Islamic astronomy texts, particularly those related to annular solar eclipses. Primary data is sourced from classical astronomical works, including Durul Aniq and Irsyadul Murid by KH. Ahmad Ghozali (Sampang), Risalah Zayn by Ibnu Yaqub al-Batawy (Jakarta), Nubala by Ali Mustofa (Kediri), Nurul Anwar by KH. Noor Ahmad S.S. (Jepara), Fath Rouf al-Mannan by KH. Abu Hamdan Abdul Djalil (Kudus), Sullam al-Nayyirain by Muhammad Mansur al-Batawy (Jakarta), and Tadzkirat al-Ikhwan by KH. Ahmad Dahan As-Samarani (Semarang). Secondary data is obtained from NASA's solar eclipse catalog and other scholarly literature discussing solar eclipse phenomena. The analysis utilizes content analysis and comparative methods to identify conceptual and methodological differences between classical Islamic astronomy and modern astronomy. Data validation is conducted through source triangulation, which involves comparing multiple references to ensure the accuracy and balance between scientific and Islamic scholarly perspectives.

III. Results and Discussion

Characteristics of an Annular Solar Eclipse

Etymologically, an eclipse is defined as an event in which another object obscures a light source. More broadly, it refers to the blocking or reduction in the visibility of a celestial body due to its passage into the shadow cast by another object [11]. In Arabic, the term for eclipse is kusūf or khusūf, both of which can refer to solar and lunar eclipses. However, more specifically, kusūf is commonly used to denote a solar eclipse (kusūf al-shams), while khusūf refers to a lunar eclipse (khusūf al-qamar) [12].

The term "eclipse" in English originates from the Greek word ekleipsis and the Latin word eclipsis. Among these linguistic origins, the Arabic terms are considered to more closely reflect the actual phenomena: kusūf means "covering," while khusūf means "entering." Thus, Kusūf al-Shams refers to an event in which the Moon partially or totally covers the Sun. It occurs during a conjunction (ijtimāʿ) of the Sun and Moon, where the cone of the Moon's shadow falls on the Earth's surface—an event known as a solar eclipse. Meanwhile, Khusūf al-Qamar describes an event in which the Moon enters the Earth's shadow. It takes place when the Earth is positioned between the Sun and the Moon, a configuration known as an opposition (istiqbāl), resulting in a lunar eclipse.

A solar eclipse occurs during the ijtimāʿ (conjunction) of the Sun and Moon, while a lunar eclipse occurs during istiqbāl (opposition) [13]. Although a solar eclipse happens during the new moon phase, not every new moon results in an eclipse. For a solar eclipse to be visible from a particular region on Earth, the alignment must be precise enough for the Moon's shadow to reach the Earth's surface. Depending on the apparent sizes and alignment of the Sun and Moon, the observable type of solar eclipse may vary. Solar eclipses are categorized into four types: total eclipses, partial eclipses, annular eclipses, and hybrid eclipses [14].

This section discusses annular solar eclipses explicitly, which are a unique type of solar eclipse. This condition occurs when the edge of the Moon (at the peak of the eclipse) only covers part of the Sun's disk, appearing as a glowing ring. This phenomenon occurs when the apparent diameter of the Moon, as seen from Earth, is smaller than that of the Sun. It is not due to the Moon physically shrinking, but rather because it is positioned at its farthest point from Earth, known as apogee, which makes it appear smaller in the sky and unable to cover the Sun's disk [3] completely.

Several factors contribute to the occurrence of an annular solar eclipse, including:

1. The Moon's distance from the Earth (apogee)

   The Moon follows an elliptical orbit around the Earth, resulting in variations in its distance. The closest point is called perigee, and the farthest point is apogee. When the eclipse occurs during apogee, the Moon appears smaller and cannot fully obscure the Sun, creating a visible ring of sunlight commonly known as the "ring of fire" [15].
2. Eclipse magnitude

   This refers to the ratio of the Moon's apparent diameter to that of the Sun at the time of the eclipse's peak. In an annular eclipse, this value is always less than 1 (typically ranging from 0.90 to 0.99), indicating that the Moon covers most but not all of the Sun, allowing a bright annular ring to remain visible around the Moon's silhouette [16].

Limitations of Classical Hisab in Accounting for Annular Eclipses

Classical hisab (astronomical calculation), as developed in the medieval Islamic scientific tradition by scholars such as Al-Khwarizmi, Al-Battani, and Ulugh Beg, primarily relied on circular orbit models and the assumption of uniform celestial motion to calculate the movements of the Moon and the Sun [17]. These models were influenced by the Ptolemaic geocentric system, which posited that the Moon orbits the Earth along a perfect circle at a constant speed.

However, in reality, the Moon's orbit is elliptical, as formulated in Kepler's First Law (the Law of Elliptical Orbits), and its velocity varies depending on its position in the orbit.

The Moon moves faster when it is near perigee (its closest point to Earth) and slower at apogee (its farthest point) [18]. This discrepancy between the classical model and actual celestial mechanics results in inaccuracies when determining the Moon's position and apparent diameter during eclipses. Consequently, classical hisab methods often fail to differentiate precisely between total and annular solar eclipses.

"*An even more powerful factor is the Moon's elliptical orbit around the Earth. When the Moon is at its average distance from the Earth or farther, its disk is too small to occult the Sun completely. In the midst of such an eclipse circle of brilliant sunlight surrounds the Moon, giving the event a ring like appearance; hence the name annular eclipse (from the Latin annulus, meaning ring).*" [16].

In an annular solar eclipse, the apparent diameters of the Sun and the Moon are the primary determining factors. The apparent diameter refers to the angular size of a celestial object as observed from Earth, which is directly influenced by the object's distance from the observer. When the Moon is farther from Earth in its elliptical orbit, its apparent diameter becomes smaller than that of the Sun, preventing it from fully covering the solar disk and resulting in a visible ring of sunlight around the Moon. Consequently, the accurate prediction of this eclipse type requires precise calculations involving both distance and angular measurement factors, which are not addressed in classical calculation methods.[19]

Classical calculation models that rely on circular orbits typically determine the apparent diameters of the Moon and the Sun using fixed or average values, without accounting for orbital eccentricity and real-time variations in distance. As a result, annular solar eclipses, which occur under conditions where slight differences in apparent diameters are crucial, cannot be accurately predicted using these classical methods. For instance, Al-Battani in his Kitab al-Zij was able to predict the timing and location of eclipses with notable accuracy. However, he was unable to distinguish between total and annular eclipses due to the limitations in calculating the apparent diameter [20]. While classical models are relatively reliable for estimating the general occurrence and timing of eclipses, they are inadequate for precisely determining the eclipse type, especially in the case of annular eclipses, which are highly sensitive to variations in apparent size.

Eclipse Determination Method in the Calculation of Classical Books

The classical calculation methods developed in the Islamic world between the 9th and 15th centuries CE, championed by scholars such as Al-Khwarizmi, Al-Battani, Al-Tusi, and Ulugh Beg [21]. These methods were rooted in manual observations, the use of geocentric models, and the assumption of circular orbits with uniform motion principles inherited from the Ptolemaic system. In the context of eclipse prediction, classical calculations relied on ephemeris tables (zij) that contained averaged positions of celestial bodies. However, these methods did not dynamically account for the apparent diameters of the Sun and Moon. Factors such as orbital eccentricity, atmospheric refraction, and parallax were either oversimplified or not incorporated at all. Consequently, although classical models were capable of predicting the general timing and approximate location of solar eclipses, they lacked the precision to determine the type of eclipse —whether total, annular, or partial — with accuracy [20]. The table below summarizes the eclipse prediction approaches found in selected classical Islamic astronomy texts.

Table 1. Table of Solar Eclipse Determination of Some Classical Books

No	Title of The Book	Author	Annular Eclipse	Eclipse Classification
1	Durul Aniq (Hakiki)	KH. Ahmad Ghozali (Sampang)	√	Based on classical zij and relatively accurate time estimation. The eclipse occurs based on the value of Hisshoh Al-'Ardl between 0˚ - 20˚, 160˚ - 200˚, 340˚ - 360˚. While the visible eclipse is based on the value of eclipse magnitude (G), m and S' with the following conditions [22]: - If G<0, then the eclipse is not visible - If G>0 and m>abs(S'), then Partial - If G>0 and m<abs(S'), then Annular
2	Irsyadul Murid (Hakiki)	KH. Ahmad Ghozali (Sampang)	√	Simplified model based on conjunction data. The possibility of an eclipse is based on the F value, which lies between 0˚ - 20˚, 160˚ - 200˚, 340˚ - 360˚. While the type of eclipse is determined from the value of the Corrected Maximum Lunar Latitude (U), with the following conditions [23] - If U < 0, then Total

				- If U > 0.0047, then Annular - If U is between 0 - 0.0047, then Total Annular
3	Risalah Zayn (Hakiki)	Ibnu Yaqub al-Batawy (Jakarta)	√	Basic calculation using average positions. Based on the shadow radius value, with the following conditions [24] : - Total = negative value - Annular = > 0.0047 - Hybrid = same conditions as total and annular combined - Partial = values between 1.5433+u and 0.9972 - No eclipse = < 1.5433+u
4	Nubala (Hakiki)	Ali Mustofa (Kediri)	√	Determination of the global eclipse type with the following conditions [25] : - If K<00° 59' 49.920'', then central eclipse - If K>00° 59' 49.920'', then eclipse - If K<(S + 00° 59' 49.920''), then non-central eclipse - If S<0, then Total - If S>0, then interpreted - If S>2.5405, then Partial - If S<2.5405, then Annular
5	Nurul Anwar (Hakiki)	KH. Noor Ahmad SS (Jepara)	X	The possibility of an eclipse is determined by summing the degrees in the eclipse table and matching it with the eclipse possibility table, considering the hour of ijtimak. The value lies between 0° and 20°, 159° and 190°, and 348° and 360°.[26] While the type of eclipse is based on the value of Ardlu Qomar Mar'I (C), with the following conditions [27] : - If C = 0, then Total - If C < 31 daqiqoh, then Partial - If C > 35 daqiqoh, then doubtful
6	Fath Rouf Al-Mannan (Taqribi)	KH. Abu Hamdan Abdul Djalil (Kudus)	X	Uses geometric positions of Sun and Moon based on classical ephemeris. If the value of hishshah al-‘ard falls within one of the four buruj—namely Aries (Hamal), Libra (Mīzān), Pisces (Hūt), or Virgo (Sunbulah)—then a specific condition applies: for Aries (0°) and Libra (6°), the value must be less than 6°, while for

				Pisces (11°) and Virgo (5°), the value must be greater than 24° [2].
7	Sullam Nayyirain (Taqribi)	Muhammad Mansur al-Batawiy (Jakarta)	X	Focuses on eclipse visibility in Indonesian latitudes (-6° to -9°). If the value of buruj haml and mizan is between 1° - 6° and if the value of buruj hut and sunbulah is between 24° - 30° [28].
8	Tadzkirat Al-Ikhwan (Taqribi)	KH. Ahmad Dahan As-Samarani (Semarang)	X	Calculates conjunction (ijtima') and eclipse visibility probability. Based on the value of hishshah al-ʻard, if it corresponds to the buruj Aries (Hamal), Libra (Mīzān), Pisces (Hūt), or Virgo (Sunbulah), and the degree value falls between 0°–6° or exceeds 24°, then specific eclipse-related conditions apply [29].
9	Buku "Pengantar Ilmu Falak"	M. Yusuf Harun	X	If the sum of the angular value of the Sun's motion and the value of the Sun's annual motion lies between the values 01° to 20°, 159° to 190°, and 348° to 360° [30].

The Taqribi method in classical Islamic astronomy provides approximate calculations based on simplified formulas, primarily aimed at determining the visibility and timing of celestial events such as eclipses. In contrast, the Hakiki method seeks greater precision by incorporating astronomical constants; however, it still depends on average values for the positions of celestial bodies. Despite these efforts, most classical texts do not account for critical astronomical variables such as the elliptical nature of orbits, real-time variations in the apparent diameters of the Sun and Moon, or the effects of parallax. As a result, these traditional methods are generally unable to identify or distinguish annular eclipses from other types explicitly.

The Integration of Classical Islamic Hisab and Modern Astronomical Calculations in the Context of Annular Solar Eclipses

Classical Islamic astronomy (hisab) has played a significant role in the Islamic tradition, particularly in determining times for worship and astronomical phenomena such as eclipses. Classical hisab is generally based on the geocentric model, with circular orbits and simplified parameters such as the positions of the Sun and Moon relative to the Earth and their nodes. It does not account for variations in distance and apparent size of celestial bodies [31]. As a result, classical hisab can predict the general timing and occurrence of eclipses. However, it lacks the precision to differentiate between types of solar eclipses, such as total, partial, and annular eclipses.

In contrast, modern astronomy has evolved significantly with the application of Kepler's laws, Newtonian gravitation, and highly accurate ephemeris data. In the context of annular solar eclipses, modern calculations can determine the apparent diameters of the Sun and Moon as well as their relative distances from Earth, which are crucial in predicting whether a particular solar eclipse will be total or annular [3]. An annular solar eclipse occurs when the Moon is at apogee, its farthest point from Earth, making it appear smaller than the Sun and thus unable to cover the Sun's entire disk. This results in a "ring of fire" effect, a feature that cannot be predicted using classical hisab methods alone.

Therefore, an integrated approach between classical hisab and modern astronomical data is necessary. This integration is not intended to negate the historical and methodological value of traditional Islamic astronomy but rather to enhance its precision and relevance in the contemporary scientific context. In practice, this means that classical hisab can still be used for the initial calculation (e.g., conjunction, elongation), but should be supplemented with modern astronomical tools, such as NASA's eclipse data, LAPAN's astronomical databases, or astronomy software like Stellarium and Occult, which take into account the physical parameters of celestial bodies.

This integration reflects the principle of taqābul baina al-maʻārif (the interconnection of knowledge), a concept that is increasingly relevant in contemporary Islamic scientific discourse. Thus, phenomena such as annular solar eclipses, which are beyond the detection capabilities of traditional hisab, can be explained and understood more accurately through scientific methods that remain aligned with Islamic values.

IV. Conclusion

This research demonstrates that although classical hisab science, as found in traditional Islamic astronomy literature, has made significant contributions to the prediction of celestial phenomena such as eclipses, it possesses fundamental limitations in accurately identifying the type of eclipse, particularly the annular solar eclipse. These limitations arise from the theoretical framework of classical hisab, which does not account for crucial parameters such as the apparent diameters of the Sun and Moon, as well as their relative distances from Earth.

In contrast, modern astronomy enables exact calculations of these factors, allowing for clear differentiation between total, partial, and annular eclipses. Consequently, a methodological integration between the classical heritage of Islamic astronomy and contemporary astronomical Theory and technology is essential. Such integration not only enriches the Islamic scientific tradition but also enhances the accuracy of astronomical predictions that carry significant implications for religious observances and socio-religious practices within the Muslim community. Thus, this integrative approach serves as both a scientific and spiritual response to contemporary challenges, paving the way for the development of Islamic astronomy science that harmoniously combines Islamic values with modern scientific discoveries.

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