L A P O R A N
PENELITIAN

Analysis of accuracy of the beginning of hijriah months reckoning of ad-Dur al-Aniq book in 20 years

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Abstrak. Dalam khazanah perkembangan ilmu falak dan metode hisab di Indonesia, dikenal beberapa kitab falak klasik dengan metode beragam. Mulai dari kitab Sulam an-Nayyirain, Syamsul Hilal, Durus al-Falakiyyah, Nurul Anwar dan lain sebagainya. Salah satu yang menarik untuk dikaji ialah kitab Ad-Dur al-Aniq karya KH. Ahmad Ghozali Muhammad Fathullah, ahli falak yang berasal dari Madura yang dinyatakan sebagai kitab falak modern dengan metode hisab tahqiq bi at-tadqiq. Metode hisab tahqiq bi at-tadqiq ini adalah yang paling akurat karena memiliki proses yang panjang dan banyak interpolasi di dalamnya. Hisab awal bulan Hijriah dalam kitab ini melalui 4 tahapan utama yakni penghitungan ijtimak, waktu magrib, posisi matahari dan bulan saat magrib serta kesimpulan hisab. Pada tiap tahapannya juga terdiri dari beberapa kali proses penghitungan dan ta'dil. Melalui proses perhitungannya, dapat dibuktikan bahwa metode perhitungan dalam kitab ad-Dur al-Aniq termasuk kategori metode tahqiqi bi at-tadqiq dengan algoritma yang sangat panjang dan beberapa koreksi yang banyak sehingga mendapatkan hasil yang sangat akurat. Adapun teori dan sistem perhitungan didasarkan pada rumus astronomi modern (teori spherical trigonometri) dan menggunakan scientific calculator atau computer sebagai alat hitung. Setelah dilakukan perbandingan hasil perhitungan dengan menggunakan algoritma Jean Meeus dan SKYCAL NASA, hasilnya, rata-rata selisih perhitungan antara ketiganya tidak lebih dari 2 menit.

Katakunci: Akurasi, hisab, Durr al-Aniq, tahqiq bi at-tadqiq

Abstract. In the treasures of the development of astronomy and the method of reckoning in Indonesia, there are several classical Islamic astronomy (falak) books with various methods such as the book Sulam an-Nayyirain, Syamsul Hilal, Durus al-Falakiyyah, Nurul Anwar, and so on. One of the interesting things to study is the book Ad-Dur al-Aniq by KH. Ahmad Ghozali Muhammad Fathullah, an expert in astronomy who came from Madura, the book which is declared as a modern Islamic astronomy book with the method of reckoning tahqiq bi at-tadqiq. This method of reckoning tahqiq bi at-tadqiq is the most accurate because it has a long process and there are many interpolations. The calculation of reckoning for the beginning of the Hijri month in this book goes through 4 main stages, namely the calculation of ijtima, the time of sunset, the position of the sun, and the moon at sunset, and the conclusion of the reckoning. At each stage, it also consists of several counting processes and ta'dil. Through the calculation process, it can be proven that the calculation method in the book ad-Dur al-Aniq is included in the category of the tahqiqi bi at-tadqiq method with a very long algorithm and several corrections so that it gets very accurate results. The theory and

calculation system are based on modern astronomical formulas (spherical trigonometric theory) and use a scientific calculator or computer as a calculation tool. After comparing the calculation results using the Jean Meeus algorithm and NASA SKYCAL, the result is that the average difference between the three calculations is no more than 2 minutes.

Keywords: Accuracy, reckoning, durr al-Aniq , tahqiq bi at-tadqiq

BAB I
PENDAHULUAN

The study of Islamic astronomy both in Indonesia and in other countries, in the modern world, has developed in a more dynamic direction. The use of modern theories accompanied by changes in assumptions has made the Islamic astronomy developing in Indonesia as dynamic as the development of science.

Based on this, one of the branches of fiqh is Islamic astronomy which has a scope related to knowledge of the times of worship and the direction of the Qibla. The method used is known as the reckoning method. Some of the reckoning methods formulated by the scholars of falak include urfi reckoning and tahqiqi reckoning. 2 Each of these methods has various wrong possibilities.

In the treasures of the development of Islamic astronomy and the method of reckoning in Indonesia, there are several classical Islamic astronomy (falak) books with various methods such as the book Sulam an-Nayyirain, Syamsul Hilal, Durus al-Falakiyyah, Nurul Anwar, and so on. Some of the literature seems to be an indicator that astronomy and the method of hisab have developed in such a way and have their fans, especially in Indonesia. Even in the modern era, some of the reckoning methods written in the falak books have been applied in software so that they are easier to learn.

Along with the development of astronomy in Indonesia, until now, more and more astronomers have emerged from various regions. One of the interesting people to study is KH. Ahmad Ghozali Muhammad Fathullah, an Islamic astronomy expert from Madura who has produced many works such as Islamic boarding school style books, both in the field of Islamic astronomy and others. KH. Ahmad Ghozali, who studied with Sheikh Yasin Al-Fadani in Mecca, is also the caretaker of the Al Mubarak Islamic Boarding School in Lanbulan, Madura. What is quite surprising, as a Kiai with a pure Islamic boarding school background, was able to produce phenomenal works such as the book Ad-Dur alAniq which he declared as a modern falak book with the method of reckoning tahqiq bi at-tadqiq. This book is included in the new falak book because its writing was just completed in 2011.3 The content of this book revolves around the problem of the new moon and eclipses using the tahqiq bi at-tadqiq method. This method is the most accurate because it has a long process and manyinterpolations 4 The results of the calculations are under reality. The inconsistency with reality in the calculations is only about one to two minutes. 5 This article, in particular, will analyze the accuracy of the early reckoning of the month of AdDur al-Aniq using the Jean Meeus algorithm and the SKYCAL program (Sky Events Calendar) on the official NASA website as two algorithms used to calculate the position of celestial bodies and the quality level of accuracy has been recognized by the world with errors only in the range of seconds.

A. A brief biography of KH. Ahmad Ghozali

KH. Ahmad Ghozali is a native Madurese son who was born on January 7, 1962 AD in a village called Lanbulan, Baturasang village, Tambelang district, Sampang district, East Java. His father named KH. Muhammad Fathullah and his mother Hj. Zainad Khoiruddin. KH. Muhammad Fathullah was the founder of the Al-Mubarok Lanbulan Islamic boarding school in 1952.

KH. Ahmad Ghazali tends to deepen his religious knowledge since he was a child. His formal education was only completed in grade 3 elementary school because he preferred to continue his religious education at his father's own Islamic boarding school. KH. Ahmad Ghozali also studied with his two brothers, KH. Kurdish Muhammad (late) and KH. Barizi Muhammad. In 1977, KH. Ghozali studied at KH. Maimun Zubaer in Rembang during the month of Ramadan. This was done every consecutive year for 3 years until 1980. Besides, he also studied at KH. Hasan Iraqi (late) in the city of Sampang, every Tuesday and Saturday, in 1981 AD. After completing his education in his cottage, under the care of his father, he continued his studies at Makkah al-Mukarromah for about 15 years. Precisely at the As-Shulatiyah Islamic Boarding School for seven years. There he studied with scholars whose scientific authority was recognized. These scholars are Shaykh Isma'il Ustman Zain al-Yamany al-Makky, Shaykh Abdullah al-Lahjy, Shaykh Yasin bin Isa al-Fadany, and other scholars.

KH. Ahmad Ghozali's expertise in the field of Islamic astronomy was obtained from the results of learning through many Kiai and teachers, from Sheikh Mukhtaruddin al-Fimbany al-Makky to other teachers such as KH. Abd Nashir Syuja'i (late), KH. Kamil Hayyan (late), KH. Hasan Basri (late), KH. Zubair Abd Karim (late).9 KH. Ghozali is also active in the Nahdlatul Ulama Religious Social Institution for the East Java Region, namely as Deputy Chairperson of Syuriyah Nahdlatul Ulama in Sampang Regency, Chairperson ofSyuriah Nahdlatul Ulama in Tambelang District, Advisor for the Falakiyyah Nahdlatul Ulama Institute of East Java, BHR Member of East Java and also a member of Hisab Rukyah at the Ministry of Religious Affairs of Indonesia. He was a very productive person in writing books. Several books were not only oriented towards Islamic astronomy, but also other fields of science such as hadith, hadith science, fiqh, and science of inheritance. Several books in the field of Islamic astronomy, namely the At-Taqyidah al-Jaliyah, Bugyah ar-Rafîq, Irsyād alMurīd, Ad-Dur al-Aniq, and other books.

B. Classification of hisab in the book of ad-Dur al-Aniq

Ad-Dur al-Aniq is classified as a modern Falak book because its writing was completed in 2011 by KH. Ahmad Ghazali. Some of the Islamic astronomical books by KH. Ahmad Ghazali has been recognized for his quality by various groups, ranging from Falak activists in Islamic boarding schools to academics. The two books before Ad-Dur al-Aniq, namely the books of Irsyad al-Murid and Tsamrat al-Fikr, besides being studied and researched by Islamic boarding schools and academics, are also being used as official literature by Lajnah Falakiyah Nahdlatul Ulama at the central and

branch offices. By the Hisab Rukyat Agency of the Ministry of Religious Affairs Indonesia, the method to determine the beginning of the Hijri month in the two books is also being applied to determine the beginning of Ramadan, Syawal, and Zulhijjah. 11 Contemporary scholars of reckoning classify modern reckoning methods into three models. 12 Besides having different methods, the three of them also have different levels of accuracy in the calculation results. The three methods are:

1. The Reckoning Method of Tahqiqi bi at-Taqrib This method has the lowest level of accuracy among the three methods. The results of the calculations are a bit far from reality.
2. The Reckoning Method of Tahqiqi bi at-Tahqiq13 This method has a level of accuracy above the tahqiqi bi at-taqrib method. The results of the calculations are somewhat close to reality.
3. The Reckoning Method of Tahqiqi bi at-tadqiq This method is the most accurate because it has a long process and a lot of interpolation in it. The results of the calculations are under reality.

The odds of not matching reality in the calculations were only about one to two minutes. The Ad-Dur al-Aniq according to KH. Ahmad Ghazali uses the Tahqiqi bi at-tadqiq reckoning method with a very high level of accuracy. The contents of the book Ad-Dur al-Aniq include reckoning the beginning of the Hijri month and reckoning the eclipse of the moon and the sun. The calculation of the reckoning method in this book is based on the astronomical data of the city of Sampang Madura with a South Latitude of -07° 12 'and an East Longitude of 113° 15' and a height of 5 meters and Time Zone 7.

C. Criteria for determining the beginning of the hijri month

According to Islamic astronomers, there are several different criteria for determining the start of the Hijri month. Some of these criteria have been described in the book Ad-Dur al-Aniq, namely:

1. Criteria of Ijtima' Time Ijtima' or conjunction is when the sun and moon are at the same astronomical longitude. 16 The Islamic astronomers who adhere to the criteria of ijtima are divided into three groups:
    a. A group of people who believe that if there is ijtima before Fajr, even if it is only for one minute, then that day there will also be a new moon. The country that uses this criterion is Libya.
    b. A group of people who believe that if Ijtima occurs before midnight even if it's only one minute, then the next is a new moon. The country that follows this criterion is Kuwait.
    c. Those who believe that if Ijtimak occurs before the sun sets, then the next day is a new moon.
2. Criteria for Sunset. This criterion occurs when the moon is not visible after sunset on the 29th of the Hijri month, and ijtimak occurs before the sun sets, then the next day is the new moon. One of these criteria has been adopted by the State of Saudi Arabia since 1419 AH. However, especially in the months of Ramadan, Shawwal and

Zulhijah must be accompanied by rukyat in syar'i. In the previous period, the State of Saudi Arabia only adopted the rukyat hilal system.

3. Criteria for the Wujud al-Hilal This criterion believes that if the new moon is above the horizon after sunset, while before sunset there has been an ijtimak, then the next day is a new moon, even though the new moon cannot be seen. This criterion is shared by some Indonesian Muslims. Organizations that adhere to the Mazhab of criteria for the Wujud al-Hilal include Muhammadiyah and Persis.
4. Criteria for Imkan Ru'yah This criterion requires the possibility of being able to see the moon to enter the new month. Adherents to this criterion are also divided into 3 groups:
    a. The group that sticks to imkan rukyah only and applies it to all Hijri months. Since 2002, the Indonesian Islamic Unity Organization (PERSIS) has used the criteria of imkan rukyat until now. 18
    b. Groups that carry out rukyat imkan accompanied by the implementation of rukyat hilal in all Hijri months. In this case, the NU community organizations are consistent in implementing the criteria of imkan rukyat by implementing rukyat in all Hijri months. 19
    c. Groups that carry out rukyat imkan accompanied by the implementation of rukyat hilal only during the months of Ramadan, Syawal, and Zulhijah. This opinion was carried out by the Ministry of Religious Affairs of the Republic of Indonesia.

This criterion is widely adopted by Indonesian Muslims. Besides, groups of Muslims who believe in the criteria for determining the beginning of the Hijri month with imkan rukyat have different categories:

a. Category of Month age. Namely, when the distance between ijtima and the setting of the sun afterward is more than 12 hours. If that happens, then rukyat hilal is possible.
b. Category of mukts al-qamar. This category requires that there is a distance between the setting of the sun and the moon for more than 30-40 minutes. If that happens, then rukyat hilal is possible. 20
c. Category of Danjon. Namely, when the azimuth difference between the sun and the moon is more than 7 degrees. If that happens, then rukyat hilal is possible. 21
d. Category of Istanbul Congress. Namely when the angle difference between the sun and the moon is more than 8 degrees and the altitude of the hilal is at least 5 degrees. If that happens, then rukyat hilal is possible.
e. Category of MABIMS. Namely, the criteria agreed upon by the Religious Affairs Ministers of Brunei, Indonesia, Malaysia, and Singapore (MABIMS). This category requires that the altitude of the new moon is not less than 2 degrees and the elongation is not less than 3 degrees and the age of the moon is not less than 8 hours.

BAB II
METODE PENELITIAN

A. Method of reciting early hijri month in ad-Dur al-Aniq

As the name implies, Ad-Dur al-Aniq presents23 the deepening of astronomical calculations by going through several ta'dil or interpolation processes to produce calculations with a high degree of accuracy. Broadly speaking, the reckoning at the beginning of the month of this book goes through 4 main stages, namely the calculation of ijtima, the time of sunset, the position of the sun and the moon at sunset, and the conclusion of the reckoning. Each stage also consists of several counting processes and ta'dil. Here are the details of the reckoning of the beginning of the month contained in Ad-Dur al-Aniq:

1. Calculating Ijtima' To find out the beginning of the Hijri month, the first calculation of the occurrence of ijtima or conjunctions is done. The calculation of ijtima requires data including the harakat year of majmu'ah, mabsuthah year, and syahr (month). For example, how to calculate the beginning of the month of Ramadan 1442 AH. using the method of reckoning the tahqiqi bi at-tahqiq for the Jakarta headquarters. Several stages that must be passed include:
    a. In the first stage, the majmu'ah year is predetermined first, which is 1440 H, the remaining 2 is the mabsuthah year. As for the month, look for the perfect month data, namely the month of Sha'ban. Filling in the column Al-Alamah (A), Khisshah al-ardh (F), al-Khasshah (M ') and al-Markaz (M) can be searched on the schedule on pages 157 to 158. If all the data has been filled in to answer sheet, then the data is added up as in the following worksheet:

Table 1
Years of Majmu'ah, Mabsuthah and Syahr

السنة الهجرية		(A) العلامة	حصة العرض (F)	(M') الخاصة	(M) المركز
مجموعة	1440	2458371,664	45,5986	45,2696	245,8869
مبسوطة	2	708,7341	16,0922	259,606	338,5285
شهر	SYA'BAN	236,2447	245,3641	206,5353	232,8428
Amount		2459316,643	307,0549	151,4109	97,2582

    b. For the sum of Khisshah al-ardh (F), al-Khasshah (M ') and al-Markaz (M), if the sum is greater than 360 then it is reduced by 360.
    c. The next step is ta'dil. In this stage, ta'dil (T) is performed 8 times, then added up. To find the required data ta'dil on pages 159-162. Globally ta'dil uses the formula T = A - (A - B) x C. Before looking for ta'dil, you are required to find the Dalil 1 to 8 first with the initial stage of the sum of data modal. Each of the Dalils has its formula.

1) Dalil I is M.
2) Dalil II is 2 x M
3) Dalil III is M'
4) Dalil IV is 2 x M'
5) Dalil V is M + M'
6) Dalil VI is M – M'
7) Dalil VII is 2 x F
8) Dalil VIII is 2 x F – M'

The next step is to search the data for ta'dil on pages 159-162 of the Dalils that have been obtained. For example, ta'dil I is taken from a Dalil I with data on page 159. From the Dalil, data for A is taken so that the result is 0.1721. While B is 0.1717. while C is the decimal number of the Dalil. Furthermore, the ta'dil formula is used so that it produces 0.1720 data. Likewise, for the next ta'dilta'dil. The following is a search for ta'dil in the answer sheet:

Table 2
Table of Ta'dil

***Dalil* Formula**	***Dalil***	**A**	**B**	**C**	***Ta'dil***
Dalil I (M)	97,2582	0,1721	0,1717	0,2582	0,1720 T1
Dalil II (2xM)	194,5164	-0,0005	-0,0005	0,5164	-0,0005 T2
Dalil III (M')	151,4109	-0,1972	-0,1910	0,4109	-0,1947 T3
Dalil IV (2xM')	302,8218	-0,0137	-0,0135	0,8218	-0,0135 T4
Dalil V (M+M')	248,6691	0,0047	0,0048	0,6691	0,0048 T5
Dalil VI (M-M')	305,8473	0,0061	0,0060	0,8473	0,0060 T6
Dalil VII (2xF)	254,1098	-0,0100	-0,0100	0,1098	-0,0100 T7
Dalil VIII (2xF-M')	102,6989	0,0010	0,0010	0,6989	0,0010 T8
				T = Amount T1 to T8	**-0,0349**

d. The next step is to look for Al-Alamah Mu'adalah (AM). Al-Alamah Mu'adalah is the sum of Al-Alamah, Ta'dil and 0.5 (half a day) so that the result is 2459317,108. AM is used to find out ijtima in the Miladi calendar.
e. Al-Alamah Mu'adalah (AM) is used to convert the time of ijtimak to the miladi calendar. First, look for WI ET with decimal data, from AM data multiplied by 24. Then look for WIUT using WIET - DT (Delta T) data. Next, look for WIWD (Ijtima' hours) using WIUT + Time Zone (TZ). The time zone for the Jakarta area is 7 hours. So, the data found for WIWD = 9.5669 or 9:34:01 o'clock.
f. The next step is to find the day with AM data (only the numbers before the comma). For the record, if the WIWD result is more than 24, then for charging B, AM is constant without being reduced. Conversely, if it is less than 24, then AM is reduced by 1. Meanwhile, C is the AM data that is searched in the sanah majmu'ah data from the Julian calendar on page 163. Then the remainder of BC is to be filled in column D as the capital for searching for sanah mabsutah on the same page. The remaining days from D-E are for miladi month data and the last remainder is the date of the ijtima.

For day and market data, AM data (numbers before commas) are used. In contrast to B, if WIWD is more than 24, then R is AM + 1. If it is less, then AM is constant. Search for days using the formula (R + 2) / 7. Only digits after the comma are used to make Hr1 data. Looking for the day of the occurrence of Ijtima with Hr1 x 7 so that you find the rounding result is 2.While the market is using the formula (R + 1) / 5. only the decimal numbers are used to be Psr1 data. Looking for the market for the occurrence of Ijtimak with Psr1 x 5 so the result is 3.

g. So it can be concluded, the occurrence of ijtima early Ramadan 1442 H. will occur on Monday, 12 April 2021 at 09:34:01. The conversion table to the Gregorian calendar is as follows:

Table 3

Search for Ijtima' Day

تعديل العلامة	تحويل التاريخ اليولياني إلى الميلادي		وقت الإجتماع		
0,1720 T1	AM	2459317,108	Day	Monday Pon	2
-0,0005 T2	WI-ET	2,5870	Date	12	
-0,1947 T3	WI-UT	2,5669	Month	April	4
-0,0135 T4	WI-WD	9,5669	Year	2021	
0,0048 T5	B	2459316,000	Hour	9,5669	09:34:01
0,0060 T6	C	2451544			
-0,0100 T7	D	7772	2000	Ijtima' Code	2021,367302
0,0010 T8	E	7670		Year Code	20210412
-T = 0,0349	G	102	21	Delta T	72,30830253
	H	90	April		
	K	12			

2. Calculating Magrib Time

The search for Maghrib time is determined using data from the majmu'ah year, mabsuthah, month, and day. The data used is Khasshah as-Syamsi (m) from previously mentioned and taken on pages 167-169. All m add up to one. In searching Maghrib time, data for latitude and longitude of the place, as well as the height of the place are also needed. If the place of rukyat is the city of Jakarta, then LS = 06˚10'00 "and BT = 106˚49'00" with an altitude of 10 m. The difference in longitude between the city of Sampang and Jakarta in hours is 0.4289. Then, the data is used to find the semi-diameter (sd), Dip (low ufuq)24 , sun height (h), declination (δ), equation of time (e), and ghurub time as shown in the worksheet table below:

Table 4

Search for Magrib Time after Ijtima'

التاريخ	خاصة الشمس	الغروب الوسطي			
الهجري	M	Latitude	-6,166667	sd	0,266462727
1440	**246,405**	Longitude	106,81667	Dip	0,092760145
2	**337,805**	SL/NL	S	h	-0,934223
8	**204,0193**	WL/EL	T	δ	8,931802778
29	**28,5824**	Longitude of Harakat	113,25	e	-0,010786
Amount	96,8117	Difference in Longitude	0,4289	Ghurub	18,00933352

3. From the above calculations, it can be concluded that the ghurub syams or Maghrib time after ijtimak of the early Ramadan 1442 H. in Jakarta, occurred on Monday Pon, 12 April 2021 at 18:00:34 istiwa'
4. Calculating the position of the sun and moon at magrib After knowing the time of ijtima and time of Maghrib, the final step is to know the position and state of the sun and moon by using the reckoning method of tahqiqi bit-tadqiq. This final step is divided into several important stages, as follow:
    a. Search for the harakat of the Sun and Moon at the Longitude Point with Majmu'ah Years, mabsuthah years, months, days, hours, minutes, and seconds. The data on the sun and moon's harakat are available on pages 166 - 171. All these data are then added up to get the total harakat of the Sun and Moon at the longitude point of Sampang. Then look for the harakat of the Sun and Moon at the difference between Sampang longitude and place longitude. If the search location is located west of Sampang, it is added. Conversely, if in the East, it is subtracted.
    b. Search for Thul asy-Syams with 9 ta'dil. Dalil I uses data from Khasshah asSyams (m), while Dalil II uses 2 x m data. The results of ta'dil are added with wasath as-Syams (S).

Table 5
Thul asy-Syams

طول الشمس					
***Dalil* Formula**	***Dalil***	**A**	**B**	**C**	***Ta'dil***
Dalil I (M)	97,5689	1,9003	1,8960	0,5689	1,89785 S1
Dalil II (2xM)	195,1378	-0,0052	-0,0055	0,1378	-0,00524 S2
				Thulus Syamsi (S') = S + S1 + S2	**22,76461**

c. Calculating the declination of the Sun and Mathla' Mustaqim Syams. With a note, if Thul asy-Syams is between 0-90 then am without adding anything. If thul asy-Syams is between 90-270, then am is added 180. And if thul asySyams is between 270-360, then am is added 360 1) The sun's declination (dm) = sin-1 (sin S' x sin O) = 8,85307445 2) Mathla' Mustaqim Syams (am) = tan-1 (tan S' x cos O) = 21,05747322

d. Calculating the distance between the earth-sun with 2 ta'dil. Dalil I with m, Dalil II with 2 x m. The results of the ta'dil are summed by the true geocentric distance unit. True geocentric distance is the average unit ofdistance between the earth and the sun,25 which is 1,00014. The results are as in the following worksheet:

Table 6
Earth-Sun Distance Calculation

البعد بين مركز الأرض ومركزالشمس (R)					
***Dalil* Formula**	***Dalil***	**A**	**B**	**C**	***Ta'dil***
Dalil I (m)	97,5689	0,0020	0,0023	0,5689	0,00220 R1
Dalil II (2xm)	195,1378	0,00014	0,0001	0,1378	0,00014 R2
				(R) = R1 + R2 + 1,00014	**1,00248**

e. Calculating several points includes: 1) Nisfu qotris syams (sd)= 0° 15' 59,63" / R= 0,265904999 2) Equation of time (e) = (S - am) /15 = -0,01236488 3) Inkhifadlul ufuq (Dip) = (1,76/60) x √ TT (10)= 0,092760145 4) Irtifa' syams (hm) = -(sd + 34,5/60 + Dip) = -0,9337 5) Sun Time Angle (GM) = cos -1 (- tan ϕ x tan dm + sin hm /cos ϕ/cos dm) = 89,9862 6) Ghurub of Sun wasthi (GRM) = GM / 15 + 12 – e = 18,01144179 7) Ghurub of Sun (WD) = GRM + ((TZ x 15) - λ) / 15 = 17,89033068 8) Azimuth of Sun(azm) = tan -1(-sin ϕ /tan GM + cos ϕ x tan dm /sin GM) = 278,8041047

f. Search for Thul al-Qamar (Mo) with 9 ta'dil. Ta'dil thul al-qamar data can be found on pages 175–183. The ta'dil formula and the results are in the following worksheet:

Table 7
The calculation of Ta'dil Thul al-Qamar

تعديل طول القمر (Mo)					
***Dalil* Formula**	***Dalil***	**A**	**B**	**C**	***Ta'dil***
Dalil I (A)	155,4837	2,6578	2,5579	0,4837	2,6095 M1
Dalil II (2 x D - A)	212,0915	-0,6751	-0,6939	0,0915	-0,6768 M2
Dalil III (2 x D)	7,5752	0,0802	0,0916	0,5752	0,0868 M3
Dalil (2 X A)	310,9674	-0,1636	-0,1612	0,9674	-0,1613 M4
Dalil V (m)	97,5689	-0,1837	-0,1833	0,5689	-0,1835 M5
Dalil VI (2 x N)	262,3386	0,1132	0,1135	0,3386	0,1133 M6
Therom VII (2xD-2xA)	56,6078	0,0487	0,0493	0,6078	0,0491 M7
Therom VIII (2xD-m-A)	114,5226	0,0521	0,0517	0,5226	0,0519 M8
Therom IX (2xD+A	163,0589	0,0156	0,0147	0,0589	0,0155 M9
Thulul Qomar (Mo) = M + M1 to M9					**26,56407 Mo**

g. Search for 'Ardh al-Qamar with 4 ta'dil on pages 182–183. The ta'dil formula and the results are in the following worksheet:

Tabel 8

The Calculation of 'Ardh al-Qamar

عرض القمر (B)					
***Dalil* Formula**	***Dalil***	**A**	**B**	**C**	***Ta'dil***
Dalil I (N)	311,1693	-3,8703	-3,8110	0,1693	-3,8603 B1
Dalil II (A+N)	106,6530	0,2697	0,2683	0,6530	0,2688 B2
Dalil III (A-N)	204,3144	-0,1129	-0,1174	0,3144	-0,1143 B3
Dalil IV (2xD-N)	56,4059	0,1436	0,1453	0,4059	0,1443 B4
'Ardh al-Qamar (B) = Amount B1 to B4					**-3,56149948**

h. Calculating the declination of the month (dc) and Mathla' Mustaqim Qamar (ac). Especially for Mathla' Mustaqim Qamar, if thul al-qamar is between 0-180 then the ac result is unchanged. And if thul al-qamar is between 180-360, then ac = 360 - ac. 1) Moon Declanation (dc) = sin -1 (sin B x cos O + cos B x sin O x sin Mo) = 6,922510423 2) Mathla' mustaqim qomar / Ascensiorekta Bulan (ac) = cos -1 (cos Mo x cos B x cos dc) = 25,93863971

i. Earth-Moon distance calculation with 4 ta'dil. The ta'dil formula and the results are in the following worksheet:

Table 9

The Distance Calculation of Earth-Moon

بعد القمر (r)					
***Dalil* Formula**	***Dalil***	**A**	**B**	**C**	***Ta'dil***
Dalil I (A)	155,4837	18946,6860	19097,9921	0,4837	19019,8728 r1
Dalil II (2xD-A)	212,0915	3137,0240	3102,3355	0,0915	3133,8500 r2
Dalil III (2xD)	7,5752	-2933,9347	-2927,2007	0,5752	-2930,0613 r3
Dalil IV (2xA)	310,9674	-366,3407	-373,9044	0,9674	-373,6578 r4
Bu'dul Qomar (r) = 385000,56 + r1 to r4					**403850,564 r**

j. Calculating a few points at the end, among others:

Table 10

Calculating a few points and formulas and the results

SEARCH	**FORMULA**	**RESULT**	
		Decimal	**Degree**
Ikhtilaf al-mandhar[26] *Qamar Ufuqi* (Hp)	$\sin^{-1}(6378{,}14 / r)$	0,904928034	0° 54' 18"
Nisfu Qatr a-Qamar/ Semidiameter of	0,272476 x Hp	0,246571171	00° 14' 48"

Moon (sdc)			
Zawiyah Zmn Qm/ Angle Time of Moon (GC)	(ST – ac + λ)	85,06932696	85° 04' 10"
Irtifa' Qamar Geocentric (hc)	sin $^{-1}$(sin ϕ x sin dc + cos ϕ x cos dc x cos GC)	4,122142012	04° 07' 20"
Samt al-Qamar/ azimuth of Moon (azc)	tan $^{-1}$(-sin ϕ / tan GC + cos ϕ x tan dc /sin GC)	277,4308527	277° 25' 51"
Farq as-Samti/ Difference of Azimut[27] (z)	Azc – Azm	1,373251947	01° 22' 24"
Inkisar Syu'a / *Refraction* (Ref)	0,0167 /tan (hc + 7,31/(hc+4,4))	0,19165594	00° 11' 30"
Ikhtilaf al-Mandhar (P)	Hp x cos hc	0,902587056	00° 54' 09"
Irtifa' Qamar Toposentric (hc')	hc – P +Ref + Dip – sdc	3,219554955	03° 13' 10"
Zawiyah Istithalah (d)	cos $^{-1}$(cos (Mo – S') x cos B)	5,205914521	05° 12' 21"
Nur al-Hilal (i)	180 – d- 0,1468 x((1-0,0549 x sin A)	174,7810741	174° 46' 52"
Nur al-Hilal (nh)	with *ta'dil nh*	0.2075 %	
Mukts al-Hilal (mh) taqribi	hc x 4'	0.59456687	00:16:29
Farq al-Irtifa'[28] (Y)	hc – hm	9.87023234	05° 03' 21"
Bu'du Zawiyah[29] Mt-HI (C)	cos $^{-1}$(cos z x coz Y)	10.0604233	05° 14' 19"

k. Calculating Nur al-Hilal (nh) in Percent with ta'dil Nur al-Hilal on page 186.

Table 11

The Calculation of Nur al-Hilal

نور الهلال (nh)					
***Dalil* Formula**	***Dalil***	**A**	**B**	**C**	***Ta'dil***
Dalil (i)	174,7811	0,2700	0,1900	0,7811	0,207514074

5. Calculating the Conclusion

   The final stage in determining the beginning of the month by using the reckoning method of tahqiq bi at-tadqiq in the book ad-Dur al-Aniq is to conclude. From the many counting processes, it can be concluded that the early reckoning of Ramadan 1442 H. is as follows:

   a. Ijtimak end of the month : Sya'ban 1442 H./the Beginning of Ramadan 1442 H.
   b. Fall on Monday, 12 April 2021
   c. At: 09:34:01 Western Indonesian Time
   d. Geocentric hilal height: 04° 07' 20"
   e. Topocentric hilal height: 03° 13' 10"
   f. Azimuth of hilal : 277° 25' 51"
   g. Elongation : 05° 12' 21"
   h. Nur- al-Hilal: 0.208%
   i. Sunset: 17:53:25 WIB
   j. Azimuth of sun : 278° 48' 15"
   k. Position of the moon form the sun : 01° 22' 24" South Hilal of the sun
   l. Length of the moon above the horizon (taqribi) : 00:16:29

B. Comparison of accuracy with Jean Meeus algorithm and SKYCAL (Sky Events Calendar)

One of the early reckonings of the month in the study of Islamic astronomy is by calculating the time of the occurrence of ijtima or conjunction of the moon and sun. To obtain certainty about the accuracy of the results of the reckoning at the beginning of the month of the ad-Dur al-Aniq book, it is necessary to compare the results of the calculation of the ijtimak book of ad-Dur al-Aniq with the Jean Meeus algorithm and NASA's SKYCAL (Sky Events Calendar)30 which has been tested for accuracy at the world. The comparison between the three things is to display the results of the calculation of ijtima at the beginning of the month of Ramadan in the next 20 years from 1442 AH. to 1461 AH. The details of the calculation results are shown in the following table:

Table 12

Difference in Ijtimak Hisab ad-Durr al-Aniq and Jean Meeus Algorithm

No.	Year	Month	Day, Date/LT		Ijtimak *ad-Durr al-Aniq*		Algorithm of Jean Meeus		Difference
			Day	Date	UT	Jakarta	UT	Jakarta	
1	1442	8	Monday	12/04/21	02:34:01	09:34:01	02:30:44	09:30:44	00:03:17
2	1443	8	Friday	01/04/22	06:28:11	13:28:11	06:24:15	13:24:15	00:03:56
3	1444	8	Wednesday	22/03/23	17:26:25	00:26:25	17:23:01	00:23:01	00:03:24

4	1445	8	Sunday	10/03/24	09:00:50	16:00:50	09:00:18	16:00:18	00:00:32
5	1446	8	Friday	28/02/25	00:45:14	07:45:14	00:44:38	07:44:38	00:00:36
6	1447	8	Tuesday	17/02/26	12:02:02	19:02:02	12:01:07	19:01:07	00:00:55
7	1448	8	Saturday	06/02/27	15:54:20	22:54:20	15:56:02	22:56:02	- 00:01:42
8	1449	8	Wednesday	26/01/28	15:14:19	22:14:19	15:12:26	22:12:26	00:01:53
9	1450	8	Monday	15/01/29	17:26:02	00:26:02	17:24:23	00:24:23	00:01:39
10	1451	8	Friday	04/01/30	02:50:29	09:50:29	02:49:24	09:49:24	00:01:05
11	1452	8	Wednesday	25/12/30	17:33:29	00:33:29	17:32:02	00:32:02	00:01:27
12	1453	8	Sunday	14/12/31	09:05:33	16:05:33	09:05:39	16:05:39	- 00:00:06
13	1454	8	Friday	03/12/32	20:52:08	03:52:08	20:52:51	03:52:51	- 00:00:43
14	1455	8	Tuesday	22/11/33	01:36:54	08:36:54	01:39:10	08:39:10	- 00:02:16
15	1456	8	Saturday	11/11/34	01:15:40	08:15:40	01:16:10	08:16:10	- 00:00:30
16	1457	8	Wednesday	31/10/35	02:56:19	09:56:19	02:58:34	09:58:34	- 00:02:15
17	1458	8	Sunday	19/10/36	11:46:49	18:46:49	11:49:49	18:49:49	- 00:03:00
18	1459	8	Friday	09/10/37	02:33:44	09:33:44	02:34:14	09:34:14	- 00:00:30
19	1460	8	Wednesday	29/09/38	18:54:55	01:54:55	18:57:15	01:57:15	- 00:02:20
20	1461	8	Sunday	18/09/39	08:20:27	15:20:27	08:22:48	15:22:48	- 00:02:21

Based on this table, it can be seen that the smallest difference from the calculation of ijtima between the book ad-Dur al-Aniq and the Jean Meeus algorithm occurred at the beginning of Ramadan in 1453 H. with a difference of only 6 seconds. Meanwhile, the largest difference occurred at the beginning of Ramadan in 1443 with a total difference of 3 minutes 56 seconds. If the average value of the difference between the results of the calculation of ijtima is drawn between the book ad-Dur al-Aniq and the Jean Meeus algorithm, the result is 1 minute 43 seconds. From this average value, it can be concluded that the calculation of ijtima based on the book ad-Dur al-Aniq is very close to an accurate value because the results of the calculation of Jean Meeus' algorithm only have an error value of 2.5 seconds.

In the next comparison, the author compares the results of the calculation of the book ijtimak ad-Dur al-Aniq with the calculation of celestial bodies in the NASA SKYCAL (Sky Events Calendar) program which can be accessed online on the official NASA website. The object of the calculation is still the same, namely the beginning of the month of Ramadan in the next 20 years from 1442 H. to 1461 H. Here are the results:

Table 13

Comparison of Hisab Ijtimak ad-Dur al-Aniq with NASA SKYCAL

No.	Year	Month	Day Date/LT		Ijtimak Durr al-Aniq		SKYCAL NASA		Difference
			Day	Date	UT	Jakarta	UT	Jakarta	
1	1442	8	Monday	12/04/21	02:34:01	09:34:01	02:31:00	09:31:00	00:03:01
2	1443	8	Friday	01/04/22	06:28:11	13:28:11	06:24:00	13:24:00	00:04:11
3	1444	8	Wednesday	22/03/23	17:26:25	00:26:25	17:23:00	00:23:00	00:03:25
4	1445	8	Sunday	10/03/24	09:00:50	16:00:50	09:00:00	16:00:00	00:00:50
5	1446	8	Friday	28/02/25	00:45:14	07:45:14	00:45:00	07:45:00	00:00:14

6	1447	8	Tuesday	17/02/26	12:02:02	19:02:02	12:01:00	19:01:00	00:01:02
7	1448	8	Saturday	06/02/27	15:54:20	22:54:20	15:56:00	22:56:00	- 00:01:40
8	1449	8	Wednesday	26/01/28	15:14:19	22:14:19	15:12:00	22:12:00	00:02:19
9	1450	8	Monday	15/01/29	17:26:02	00:26:02	17:24:00	00:24:00	00:02:02
10	1451	8	Friday	04/01/30	02:50:29	09:50:29	02:49:00	09:49:00	00:01:29
11	1452	8	Wednesday	25/12/30	17:33:29	00:33:29	17:32:00	00:32:00	00:01:29
12	1453	8	Sunday	14/12/31	09:05:33	16:05:33	09:05:00	16:05:00	00:00:33
13	1454	8	Friday	03/12/32	20:52:08	03:52:08	20:53:00	03:53:00	- 00:00:52
14	1455	8	Tuesday	22/11/33	01:36:54	08:36:54	01:39:00	08:39:00	- 00:02:06
15	1456	8	Saturday	11/11/34	01:15:40	08:15:40	01:16:00	08:16:00	- 00:00:20
16	1457	8	Wednesday	31/10/35	02:56:19	09:56:19	02:59:00	09:59:00	- 00:02:41
17	1458	8	Sunday	19/10/36	11:46:49	18:46:49	11:50:00	18:50:00	- 00:03:11
18	1459	8	Friday	09/10/37	02:33:44	09:33:44	02:34:00	09:34:00	- 00:00:16
19	1460	8	Wednesday	29/09/38	18:54:55	01:54:55	18:57:00	01:57:00	00:02:05
20	1461	8	Sunday	18/09/39	08:20:27	15:20:27	08:23:00	15:23:00	00:02:33

Based on the table 13, it can be seen that the smallest difference in the calculation of ijtima in the book ad-Dur al-Aniq with NASA's SKYCAL (Sky Events Calendar) program occurred at the beginning of Ramadan in 1459 H. with a difference of only 16 seconds. While the largest difference occurred at the beginning of Ramadan in 1444 H. with a total difference of 3 minutes 25 seconds. If you take the average value of the difference between the results of the calculation of ijtima in the book ad-Dur al-Aniq with NASA's SKYCAL (Sky Events Calendar) the result is 1 minute 49 seconds. From this average value, it can be concluded that the calculation of ijtima in the book ad-Dur al-Aniq is very close to an accurate value.

BAB IV
PENUTUP

Based on some of the explanations and analyzes above, it can be proven that the calculation method in the book ad-Dur al-Aniq is included in the category of the intrinsic method bi a-tadqiq, which is a calculation with a very long algorithm and several corrections so that it gets very accurate results. The theory and calculation system are based on modern astronomical formulas (spherical trigonometric theory) using a scientific calculator or computer as a calculation tool.

This book also has one feature, which is that it can be used to count years at any time. Besides, the results of the calculation of haqiqi bi at-tadqiq method of adDur al-Aniq book can be compared for accuracy with the results of the Jeen Meeus algorithm calculation or NASA calculations with an average difference of not more than 2 minutes.

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