New approach on study of new young crescent (Hilal) visibility and new month of Hijri calendar

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Abstract. We present a preliminary result on criteria of a young moon crescent visibility and the beginning of new month in Hijri calendar. We present our study of all possibility of moon’s astronomical position at sun-set time in one diagram. The altitude of the moon vs the elongation between the moon and the sun, and the azimuth differences between the sun and the moon plotted over the diagram. The purpose of constructing the diagram is to see easily all used/proposed criteria of the beginning of the Hijri’ month on a single diagram, then the position of the new young crescent of the moon on the diagram can be analysed easily, whether it is included in criteria of young moon crescent (hilal) visibility or excluded. Some cases of Hijri calendar of 2017 – 2018 in Indonesia are examined and provided in this paper.

1. Introduction

Hijri calendar is a lunar calendar, historically it is not directly form in a system which is recognized and widely used as general calendar. The need of Hijri calendar began when the first fasting month started. In the era of prophet Muhammad in Madinah the first lunar crescent visibility was used the beginning of the Ramadhan, if it found hilal after sunset then the beginning of the new Hijri month started, if it is not found hilal then the previous month should be maximized to 30 days and the new month will start the day after hilal observation (started from the sun set time or the beginning of Maghreb time). During this prophet Muhammad era, the element of Hijri calendar has been arising, but not implemented yet.

The tabulation method is introduced during a period of al Khulafa ar Rasyidun in Madinah from 11 H/632 AD ─ 40 H/661 AD; the second Khulafah is Umar ibn Khattab, and he governs for 10 years 6 months in the period of 13 H/634 AD ─ 32 H/644 AD. The earliest Islamic Calendar system or Hijri Calendar using tabulation methods developed during Khulafah Umar bin Khatthhab (17 H or 639 CE), the calendar is called Hisab Urfi.

There are two ways to construct Islamic calendar, through tabulation and recently through direct calculation and using a criterion of the first visibility of the moon.
During Khulafah Umar bin Khaththab, the idea to construct Hijri calendar using tabulation approach was implemented. The proposed calendar is mainly for administration and for some Moslem can be used as guide the beginning and the end of Ramadhan, the pilgrim or Hajji.

Basically the Hijri calendar is a lunar calendar. The beginning of new month will be around the visibility of new young crescent using naked eye, as soon as after conjunction. Usually conjunction between the moon and the sun, a moment that the moon and the sun at the same the ecliptic longitude will guide the date of observation of the first new young crescent. One year consist of 12 months, it sequences of the name from the first month up to the last month of the year respectively as follows: Muharram, Safar, Rabi’ul awal, Rabi’ul akhir, Jumadal Ula, Jamadal Akhirah, Rajab, Sya’ban, Ramadhan, Syawal, Dzulqadah and Dzulhijjah. Each month consists of minimum of 29 days and maximum of 30 days.

The structure of Urfi’s calendar, the number of days in each month alternately between 30 days and 29 days, the first month (Muharram) consist of 30 days, the second month (Safar) consist of 29 days, the third month (Rabi’ul Awal) consist of 30 days … etc. The number of days of each month fixed 29 days or 30 days except for Dzulhijjah in Urfi calendar. Except Dzulhijjah consists of 29 days if the year is basit then Dzulhijjah consists of 30 days if the year is kabisat. The kabisat’s year determine by 30-year rule, the first rule is each 30 years will compose 11 years with 355 days (kabisat year) and 19 years with 354 days (basit year). The beginning of Hijri calendar, 1 Muharram 1 H, corresponds to 15 or 16 of July 622. If the fraction of the division of Hijri year divided by 30, $S = \text{Frac} \left( \frac{H}{30} \right) \times 30$, and the results is $S = 2, 5, 7, 10, 13, 15, 18, 21, 24, 26$ and 29 then $H$ is kabisat year.

The Urfi calendar is good for lunar calendar, but there are some critics, the beginning of new month does not correspond to the young lunar crescent visibility soon after conjunction. A new Hijri lunar calendar, called Hisab Hakiki, each new month should correspond to hilal visibility. It is hard to match between young lunar visibility and the beginning of new month, without understand the movement of the moon and criteria of young crescent visibility.

Naturally it is hard to unify a lunar crescent visibility. When the conjunction happened in the summer and winter solstices, then the hilal cannot be seen by some people in the northern or southern hemisphere [1], and when the conjunction happened in the summer and winter solstices, the lunar crescent visibility will be more than 24 hours after conjunction, the crescent visibility during the day time, the sky is extremely very bright [2]. The different sky brightness between aphelion and perihelion passage of the earth. When the earth in the position of perihelion passage (in January), the distance from the earth to the sun will 5 million km closer compared to the distance from the earth to the sun when the earth in the position of aphelion passage (in July) [3]. The cloudiness in January will be more compared in July. The variation of sky brightness and cloudiness a long of the year will also make variation on hilal visibility [4].

Based on the nature we make a new approach on hilal visibility criteria as well as a simple criterion for Hijri Calendar.

2. Methods
We constructed a diagram between altitude of the moon and the elongation between the moon and the sun for one place, Pelabuhan Ratu, all data are calculated data during 622 M – 3000 M using Jeans Meeus Algorithm [5]. The calculated astronomical position of “hilal” are not contaminated by variation of brightness and quality of weather. All variation of brightness and quality of weather will effect on hilal visibility, then the observational data will be an empirical data which developed a criterion of hilal visibility. All proposed criteria from Ilyas [1,6,7] and Indonesia Government (the altitude above 2 degree) put on the diagram.

From the data in the diagram we will analyze each zone and learn about several beginning of Ramadhan, Syawal and Dzulhijjah.
3. Result and Discussion

3.1. Diagram Altitude - Elongation

We construct a diagram between altitude and elongation of the moon as well as the azimuth then the dot is generated moon from calculation between 622 M and 3000 M. Position of the moon at the sun set time at Pelabuhan Ratu (West Java, Indonesia) are plotted. All empirically data obtained by previous study put on the diagram.

Comparing data (Figure 1) of all hilal with condition positive (above horizon) between 0 – 24 hours with azimuth theoretical plot. The left side is a line with equation \( y = x + 1.05 \). The spread of data is due to the age of the moon from the conjunction. Hilal Ramadhan 1438 H (red dot), conjunction on 26 May 2017, 02:44 wib, age: 15.02 hours, elongation 9.73 degree, altitude of the moon at sunset time 8.2 degree, azimuth different 1.92 degree, time lag: 40 minutes. The first Ramadhan 1438 H is 27 May 2017.

Comparing data (Figure 2) of all hilal with condition positive (above horizon) between 0 – 24 hours with azimuth theoretical plot. The left side is a line with equation \( y = x + 1.05 \). The spread of data is due to the age of the moon from the conjunction. Hilal Syawal 1438 H (red dot), conjunction on June, 24, 2017, 09:41 wib, age: 8.28 hours, elongation 5.72 degree, altitude of the moon at sunset time 3.7 degree, azimuth different 3.26 degree, time lag: 20 minutes. The beginning of Syawal 1438H June 25, 2017.

Comparing data (Figure 3) of all hilal with condition positive (above horizon) between 0 – 24 hours with azimuth theoretical plot. The left side is a line with equation \( y = x + 1.05 \). The spread of data is due to the age of the moon from the conjunction. Hilal Dzulhijjah 1438 H (red dot), conjunction on August, 22, 2017, 01:30 wib, age: 16.43 hours, elongation: 8.95 degree, altitude of the moon at sunset time 7.1 degree, azimuth different 0.82 degree, time lag: 34 minutes. The beginning of Dzulhijjah 1438H is August 23, 2017. Idul Adha 1438 H is September 1, 2017.

Comparing data (Figure 4) of all hilal with condition positive (above horizon) between 0 – 24 hours with azimuth theoretical plot. The left side is a line with equation \( y = x + 1.05 \). The spread of data is due to the age of the moon from the conjunction. Hilal Ramadhan 1439 H (red dot out of the diagram), conjunction on May 15, 2018 at 18:48 wib, age: -1.03 hours, elongation: 4.1 degree, altitude of the moon at sunset time -0.6 degree, azimuth different 4.72 degree, time lag: 2 minutes. The beginning of Ramadhan 1439 H is May 17, 2018.

Comparing data (Figure 5) of all hilal with condition positive (above horizon) between 0 – 24 hours with azimuth theoretical plot. The left side is a line with equation \( y = x + 1.05 \). The spread of data is due to the age of the moon from the conjunction. Hilal Syawal 1439 H (red dot), conjunction on June 14, 2018 at 02:43 wib, age: 15.07 hours, elongation: 9.1 degree, altitude of the moon at sunset time 7.4 degree, azimuth different 1.33 degree, time lag: 37 minutes. The beginning of Syawal 1439 H is June, 15, 2018.
Figure 1. Diagram Altitude – Elongation (A-E) for Ramadhan 1438 H, the line Azimuth from 2 to 10

The position of hilal (red dot) on the diagram A-E for Ramadhan 1438 H shows that agreement of all criteria will produce the same day of Ramadhan 1438 H.

Figure 2. Diagram Altitude – Elongation for Syawal 1438 H, the line Azimuth from 2 to 10, Pelabuhan Ratu

The position of hilal (red dot) on the diagram A-E for Syawal 1438 H shows that agreement of all, the same day of Syawal 1438 H.
Figure 3. Diagram Altitude – Elongation for Dzulhijjah 1438 H, the line Azimuth from 2 to 10, Pelabuhan Ratu

Figure 4. Diagram Altitude – Elongation for Ramadhan 1439 H, the line Azimuth from 2 to 10, Pelabuhan Ratu
Figure 5. Diagram Altitude – Elongation for Syawal 1439 H, the line Azimuth from 2 to 10, Pelabuhan Ratu

Figure 6. Diagram Altitude – Elongation for Dzulhijjah 1439 H, the line Azimuth from 2 to 10, Pelabuhan Ratu

Comparing data (Figure 7) of all hilal with condition positive (above horizon) between 0 – 24 hours with azimuth theoretical plot. The left side is a line with equation $y = x + 1.05$. The spread of data is due to the age of the moon from the conjunction. Hilal Dzulhijjah 1439 H (red dot out of the diagram),
conjunction on August 11, 2018 at 16:58 wib, age: 0.97 hours, elongation: 1.4 degree, altitude of the moon at sunset time -0.8 degree, azimuth different 1.12 degree, time lag: 1 minutes. The beginning of Dzulhijjah1439 H is August 13, 2018. Hari Idul Adha 1439 H is August 22, 2018.

Figure 1 to 6 are examples of hilal position on the diagram Altitude – Elongation and then direction to decide the beginning of Ramadhan, Syawal and Dzulhijjah. The position of “red dot” on the diagram will show the date will be unique for all or some differences. Ramadhan 1438 H and 1439 H when the sun in the extreme in northern hemisphere, the longest fasting Ramadhan. Typical hilal on the diagram provided on Figure 7.

3.2. Hilal at Summer Solstice
It is interesting to see how the hilal distributed on the diagram Altitude – Elongation when the sun position in the extreme of northern hemispheres (declination of the sun above 27 degree) at summer solstice. The data show that the hilal tend to have larger elongation.

![Figure 7: Diagram Altitude – Elongation when the sun position in the extreme of northern hemispheres (declination of the sun above 27 degree) at summer solstice, the line Azimuth from 2 to 10 degree, at Pelabuhan Ratu](image)

If global nature of hilal visibility will be included into consideration of criteria, then we will choose to observed young crescent in the day time, which needs telescopes and instrumentations to observe the crescent visibility in the day time. Several young crescent in the day time, they conclude that the arc of light for the young crescent will be around 4.5 degree or 6 degree [8].

In figure 1 – 6, shows diagram when the sunset and sunrise phenomena can be observed easily. So the picture represents arc of light as function of altitude and azimuth. It becomes very simple, arc of light as unique criteria, because the hilal of summer or winter solstices will be observed during the day time.

The arc of light criteria may not change the previous conclusions on the beginning of Hijri calendar as indicated in Figure 1 through Figure 6.

4. Conclusion
A new approach on Study of New Young Crescent (Hilal) Visibility and New Month of Hijri has been provided in Figure 1 through Figure 6. We propose a unique criterion for Hijri lunar calendar, using arc of light and one value, for example 6 or 6.4, depend our consideration on lunar visibility on equatorial and subtropical observation. Unification of Hijri calendar is still going on, our proposed criteria can be
used for the unification of Islamic calendar ideally to cover several condition of lunar visibility and all placed around the world. The dynamic of the phenomena will need agreements widely among Moslem around the world. Understanding several phenomena on hilal visibility globally needs more study of several cases from the basic diagram.

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