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Application of Scientific Approach to Determine Lunar Crescent's Visibility

[1]Mohd Saiful Anwar Mohd Nawawi, [2]Mohd Zambri Zainuddin,
[2]Nazhatulshima Ahmad, [1]Mohammaddin Abdul Niri, [1]Saadan Man,
[1]Raihana Abdul Wahab, [1]Khadijah Ismail and [1]Nurul Huda Ahmad Zaki

[1]Department of Fiqh and Usul,
Academy of Islamic Studies, University of Malaya, 50603 Kuala Lumpur, Malaysia
[2]Department of Physics, Faculty of Science, University of Malaya, 50603 Kuala Lumpur, Malaysia

Abstract: The visibility of lunar crescent has been explained in Islamic Law (*fiqh*) by previous scholars. Until today, the explanations which were nuance in qualitative sense are still provide vacuum and need to be studied critically with different method particularly in quantitative approach. Therefore, this paper will present the application of scientific approach using sky illumination measurement to explain lunar crescent's visibility. The approach combines computational and observational technique will help *fiqh* in explaining the phenomenon explicitly and strengthen it with empirical descriptions. The sky illumination measurement was performed using a light meter in Teluk Kemang, Malaysia from 2007 until 2009. The authors employed the observational data to obtain the estimate values of sky illumination for the day which lunar crescent was seen from 1972 until 2009. The analyses of the values then were correlated with relative altitude and sun depression angle. The authors found that the range of sky illumination for lunar crescent to be seen is 2.95-92.80 lux. For the highest sky illumination value (92.80 lux), relative altitude should be $\geq 5^0$ and the depression angle should be $\geq 0.5^0$.

Key words: Sky brightness · Lunar crescent · Illumination · Depression angle and relative altitude · *Hilal*

INTRODUCTION

The existence of the crescent moon is a vital astronomical phenomenon to human being as well as for Muslim. The observation of lunar crescent for Muslim is important to determine the beginning of Islamic month particularly for the fasting month namely Ramadhan. There are various Hadis (the prophetic tradition) reported by Muslim and Bukhari through different chain of authoritative narrators regarding to the crescent visibility. The Prophet Muhammad (p.b.u.h) had said:

Fast when you see it (crescent) and break the fast when you see it (crescent). Nevertheless, if it obscured from you then complete *Sha'ban* to thirty [1].

The above authentic Hadith is an explanation on how to determine the crescent moon. In this Hadith, the Prophet has instructed his companion to determine a new month by using the naked-eye method. Using the above Hadith, some jurists from different school of law consisted from *Hanafiah, Malikiah, Hanabilah* and *Shafi'iah* were against the use of calculation made by astronomers to determine a new month. They claim the Prophet has provided the simple method of determining the early crescent without the need to refer the astronomer's calculation [2].

Instead, there is an Hadith of the Prophet which can be referred as the justification for the use of calculation in determining moon crescent visibility.

Do not fast until you see the crescent and do not end your fast until you see it, but if it was obscured from you then calculate it [1].

In this Hadith, the Prophet has said "*faqdirulah*" which means "calculate it". The Prophet Muhammad told to look for the early crescent in determining the new lunar

Corresponding Author: Mohd Saiful Anwar Mohd Nawawi, Department of Fiqh and Usul,
Academy of Islamic Studies, University of Malaya, 50603 Kuala Lumpur, Malaysia.
Tel: +603-70676011, Fax: +603-70676141.

month, but if it was obscured by the clouds thenit has tobe calculated. Therefore, this Hadith becomes the premise by some jurists in advocating the use of calculationmade by astronomers [3].

From views of *fuqaha'*, they accept observation totally as a mechanism and method to determine the lunar crescent visibility but some of the *fuqaha'* reject the calculation because of the following factors:

Firstly, in the lifetime of the Prophet, Islam arrived for the convenience of its Muslimcommunity, notto create burden on its Muslimcommunity. Hence, observation is the suitable method to use in that timeas only some of them knew about calculation [4]. Observation is the easiest and appropriate method to the people during that time according to their ability. If Prophet asked them to use another method, it may trouble them. Now, there is another method, which is more accurate and less discrepant in determining the starting of a month. There are experts in astronomy, geology and physics in this era. Scientists have done research of it. Using the accurate calculation to determine the new month in a year is *Qiyas al-awla* [5]. The Hadith has stated the appropriate method which is observation and at the same time do not reject calculation which is comprehensive in achieving the objective. This method brings unity in *shi'ar* and *'ibadah* of the Muslim community [4]. In addition, without astronomers who have expertise and tools in determining the beginning the lunar month accurately, crescent visibility observation is the only method for the early Muslim community. This was the reason for the prophet's directive for observing the crescent moon and without the reason it will lift up the directive. Hence, due to a legal maxims (*al-qa'idah al- fiqhiyyah*), the rule is dependent of its efficient reason (*'illah*) and when reason is absence, the rule is not applicable anymore. Therefore, it is a cause effect between reason and the rule [6]. Today, the development in astrometry, the improvement of computing tool and the instrumentation of astronomy have made astronomical calculations an effective method in fulfilling the Islamic requirements.

Secondly, in Islamic sciences, as in Greek and Latin astronomy where *astrologia* and *astronomia* were often used interchangeable, there is no clear distinction between the words signifying astronomy and astrology; the term *nujum* can mean one as well as the other. In the glorious days of Islamic schools, astrologers were often confused with astronomers. Astronomers and astrologers were deemed as the same because the astronomers practiced astrology. For example, al-Biruni (973-1048 C.E) excels as much as in astronomy and astrology. Although many modern scholars try to discount his astrological studies, there is no doubt that soon after his death he became well known in Muslim world as the perfect master in astrology as well as astronomy, which were usually combined under one discipline in Islam. The astronomical and astrological works of al-Biruni are so numerous that until today they have not yet been fully studied [7]. Al-Biruni is also the author of a comprehensive manual on astrology that he wrote at the instigation of his patroness although astronomy was in his heart [8]. Only around the thirteenth century that astronomy was fully distinct from astrology [7].

Thirdly, calculations made by Islamic calendar practitioners, inaccurately referred to as astronomers, produced results which were different by two or three days. For example, "A" produced a calculation and his result showed 29 days only in *Sha'ban* whereas "B" also did a calculation but his result showed 30 days in *Sha'ban*. Their calculations cannot be accounted in the lunar visibility determination, because in mathematics any methods used must bear equal results.

Fourthly, almost all of the *fuqaha'* reject the calculations because they rely on this Hadith, "We are illiterate community that does not write or calculate; month is this much and this much" [8].However, illiteracy in the community is not encouraged and the Prophet has tried to help them since the battle of *Badr* to the extent that the captives who knew reading and writing but were unable to pay ransom were allowed freedom after teaching ten children to read and write [9].

Therefore, wide varieties of criteria have been proposed to predict the visibility of crescent moon. Different criteria have been developed and adopted to be appropriate with the requirements of Islamic law. Each result explains the suitable parameter to predict the visibility of moon's crescent. Modern studies on astronomical field specifically on the subject were contributed by Fotheringham [10], Maunder [11], Danjon [12], Bruin [13], Schaefer [14], McNally [15], Ilyas (1984) [16] and Odeh [18]. Each of them has made criteria to find minimum condition for lunar crescent to be visible by different approaches.

Every approach consists either on empirical or theoretical methods. The empirical method is based on analyzing the collection of observational data. The criterion then formulated regarded on the analysis to be implemented as the best parameter used in the observation. On the other hand, the theoretical method is conducted considering the various factors affecting crescent visibility to be designed as descriptive mathematical model [17].

The sky illumination condition is measured during the day of the moon crescent expected to be visible. Regarding on the previous study, which has resulted different criteria, this work is trying to propose the range of illumination to observe the moon's crescent. If the observation is made to soon after sunset then the twilight sky may be too bright to pick out the faint lunar crescent. Just after the sunset, the reading of sky illumination on llight meter still high due the brightness of the sky. Then, the sun move downward below horizon and making the solar depression angle. The larger the depression angle, the higher the probality to see the lunar crescent. This is due to sky begins turning darker and darker. The larger relative altitude, the chances to see the lunar crescent will be higher. If the distance of the sun and the moon is nearer, the brightness of the sun will cover the moon light which causing difficulties in crecent's visibility. Threshold relative altitude proposed was 12° for Fotheringham[10], 11° for Maunder [11] and 10. 5° for Ilyas [19].

MATERIALS AND METHODS

The sky illumination observation using a light meter was performed at Teluk Kemang Negeri Sembilan (101° 51' E, 2° 26' N). These works were carried out from 2007 until 2009. Teluk Kemang was chosen according to the appropriate azimuth angle for the crescent to be visible. The Light Meter was directed at angle which crescent's moon expected to be visible.

Table 1: Sky illumination recorded on 7 April 2008

Local Time (Hour:Minute)	Elapsed Time after Sunset (Minute)	Sky Illumination (lux)
7:10 PM	-10	700
7:12 PM	-8	570
7:14 PM	-6	400
7:16 PM	-4	270
7:18 PM	-2	140
7:20 PM	0	110
7:22 PM	2	80
7:24 PM	4	54.1
7:26 PM	6	34.6
7:28 PM	8	22.6
7:30 PM	10	18.6
7:32 PM	12	10.4
7:34 PM	14	5.8
7:36 PM	16	3.6
7:38 PM	18	2.3
7:40 PM	20	0.9
7:42 PM	22	0.6
7:44 PM	24	0.3

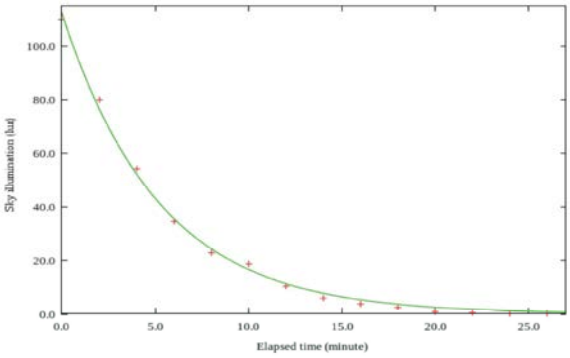

Fig. 1: Sky illumination vs. Elapsed time on 7 April 2008

The observations were carried out before and after sunset depending on moon and sun positions. The measurement was taken several times with aid of synchronized timer. We have chosen the data on 7 April 2008 as the reference (Table 1) to estimate the sky illumination value for positive reported data in the literature from 1972-2009.

The elapsed time for the data, negative values were recorded before sunset and the positive values after sunset. Other parameter namely sun altitude, moon altitude, moon age, relative altitude etc. which taken from Moon Calculator 6.0 program were scrutinized. Then, a graph was plotted:

RESULTS AND DISCUSSION

Figure 2 depicts the relative altitude and sun altitude versus sky illumination for the lunar crescent's was seen from 1972 until 2009. In general, the sky illumination will give higher reading as the sun move higher above the horizon. This is due to the brightness of the sky during the daytime. When the sun sets and elapsed time increasing, the value on sky illumination is decreasing. Percentage of crescent visibility is higher when the sky illumination is low because the sky becomes darker. From the hypothesis, it is known that the lower the sun altitude or the sun depression angle, the sky illumination would give a lower reading as the sky illumination is greatly affected by the sun light. Hence, the larger the depression angle, the darker the sky will be. There were 13 out of 23 crescents moon data that had been seen with the sun depression angle recorded at -3° or more and with the value of 4.33-13.67 lux. Therefore, the darker the sky is, the easier for crescent moon to be seen. However, there are 8 data which sun's altitude at 0° to -1° with high sky illumination of 52.24 – 92.80 lux, where the crescent moon reported to be sighted. In other words, even the sky is bright, crescent moon could be seen.

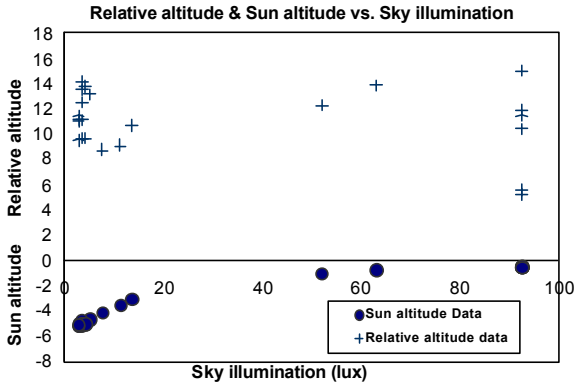

Fig. 2: Relative altitude and Sun altitude vs. Sky illumination

This could happen if elongation of the moon is large enough so that moon's altitude is much higher during sunset.

Relative altitude is the separation distance between the sun and the moon. The higher relative altitude gives the higher probability for visibility of crescent moon. This is due to the position of the moon that is high above the horizon at sunsets. So does the sky illumination. From the figure 2, we could had identified that the relative altitude of 15 out of 23 visible crescents moon data, showed as high as 8.755° up to 14.133° with sky illumination 2.95 to 13.67 lux. The crescent moon at this condition needs the sky to be appropriately dark before it can be seen.

There are also data showing the young crescent was seen at higher sky illumination and larger relative altitude. 6 data was recorded with maximum sky illumination of 92.80 lux fitted for relative altitude in the range 5-15 degree. Furthermore, there are 2 more data with rather high sky illumination and large relative altitude. The visibility of crescent moon occurred with sky illumination at 63.27 lux and 52.24 lux with relative altitude 13.805° and 12.254° respectively. This occurrence could happen even with brighter sky and high relative altitude. The maximum point of sky illumination recorded when crescent was seen is 92.80 lux. For sun altitude higher than -0.5° degree, there is still no crescent observed in the recorded data. This shows clearly that the crescent of the moon should be observed after sunset. The maximum of sky illumination for the sighted crescent is considered to be 92.80 lux, a minute of elapsed time after sunset with 0.5° of sun depression angle and ≥5° of relative altitude. In addition, the potential range value for sky illumination for crescent being seen is between 2.95-92.80 lux.

CONCLUSION

This research attempted to show the dimension of scientific approach in explaining the visibility of lunar crescent which had been discussed widely in *fiqh*. The scientific approach combines the method of calculating and observing the crescent moon. If only the observation is being done, it may be questioned, as for example the scattering of the sunlight between clouds might create a form of light in the shape of crescent. If the calculation only is applied, it looks like we do not support the verdict from Islamic law. Hence, the best way is to combine both methods which can fulfill Islamic law and scientific considerations.

From the results of this study, the authors found that the range of sky illumination for lunar crescent to be seen is 2.95 -92.80 lux which correspond to $11.056^0 - 5.563^0$ relative altitude respectively. The highest sky illumination value (92.80 lux) corresponds to relative altitude between the moon and the sun should be $\geq 5^0$ and the depression angle of the sun should be $\geq 0.5^0$.

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