A SELECTIVE LITERATURE REVIEW OF YOUNG MOON CRESCENT VISIBILITY STUDIES

By:
Baharrudin Zainal
KUSZA Observatory
Sultan Zainal Abidin Religious College
21300 K. Terengganu, MALAYSIA.
email: baharzai@kusza.edu.my
bayamas@hotmail.com

1. Introduction

Young moon sighting have long been ritual work done by ancient societies to determine calendar dates. With a little knowledge of the celestial motions, the ancient astronomers sighted the young moon crescent at the end of every month. Using the simple method for the length of the month, they started the new month if the moon had been sighted (the month has 29 days) or delayed for one more day (to 30 th. days) if the moon was not sighted. In conjunction with the development of the 'knowledge in science', the ancient astronomer started to predict the posibilities of the young moon crescent visibility.

2. Ancient And Islamic Medieval Age Studies

Based on long time experiences, Babylonia astronomers used the age of the moon and time difference between sunset and moonset as a simple criterion of first lunar crescent visibility. According to Ilyas (1984), the criterion used during the Babylonian era contains the fact that the age of the moon must be more than 24 hours from conjuction of the sun and the moon to the local sunset time, and the moon must be above the horizon 48 minutes after sunset. The ancient astronomers had the ability to relate the value of the lag time with the angular diferences between sun and moon, which was always mentioned as, $a_s \geq 12°$. According to Bruin (1977), these quantities were also used by Hindu astronomers in 500 A.D, but they added an important element, that the width of the lunar crescent influenced the visibility.

In the Islamic medieval age, Babylonian and Hindu sources still dominated the young moon visibility criterion, but the Islamic astronomers started to develop computational methods including the apparent angular separation of the sun and the moon (a_s), the difference in time between sunset and moonset and the lunar apparent velocity of the moon. According to King (1983), Muslim astronomer some like al-Farazi, Yaqub bin Tariq, al-Khawarizmi and al-Naziri, who follow the Hindu basis on the time lag between sunset and moonset. On al-Khawarizmi's work of the lunar visibility (9 th. century), he used the same quantities of angular separation and was followed by many Islamic astronomers. From the table summarized by Ilyas (1984), it shows that Al-Battani, Abdul Rahman Al-Sufi, Al-Biruni and Ghiyath Al-Din Al-Kashani used the same quantities, $a_s \geq 12°$.

A famous Islamic astronomer in the 8th. century, Ya'qub Ibn Tariq proposed two joint conditions regarding arc of separation between moon and sun (s), and arc of light (L), as

$$s \geq 12° \quad \text{and } L \geq 0;45^{dgt} \text{ , or}$$

$$s \geq 10° \quad \text{and } L \geq 1^{dgt}$$

Notes: $1^{dgt} = 15°$ arc of light, when full moon $= 12^{dgt}$

(King, 1993)

Two centuries later, a great Egyptian astronomer, Ibn Yunus did more detailed work on lunar crescent visibility. Ibn Yunus identified some of the problems, including the solution of the apparent distance between the sun and the moon, which determines the width of the crescent, the lag time between sunset and moonset and the moon distance from the earth. After these problems had been solved, the lunar visibility for the month can be predicted . Ibn Yunus 's theory on lunar visibility can be summarized as follows,

$$\text{time lag} \geq 12° \text{ (or 48 minutes)}$$

$$\text{moon velocity} \geq 13°/\text{day}$$

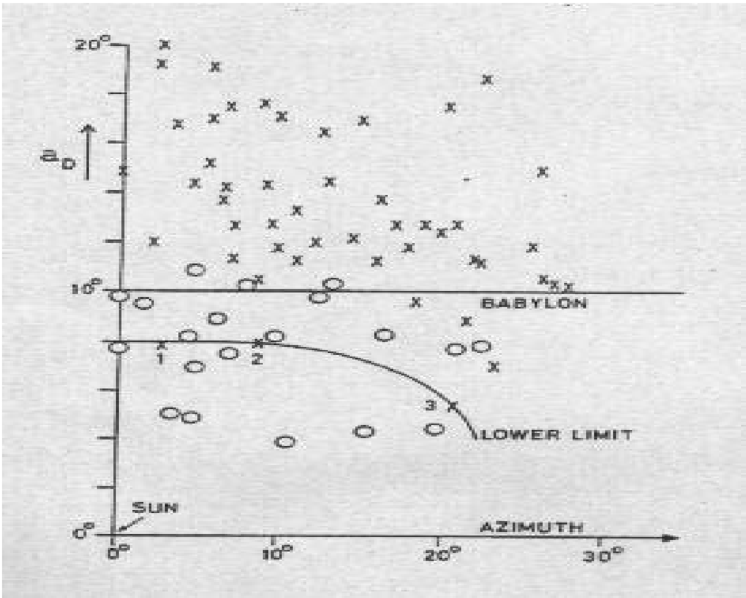
$$2/3^{dgt} \leq \text{units of light} \leq 1^{dgt}$$

Ibn Yunus also mentioned that the limit of visibility depends on the moon position (either at apogee or perigee), because this will change the apparent diameter of the lunar crescent.

As a conclusion, the ancient and Islamic medieval age studies of lunar visibility show a good correlation between observational and empirical theory. This later on contributed to modern studies when Bruin (1977) and Ilyas (1984) verified that the qualities of both of the studies were good.

3. Modern Studies And Their Findings

Modern studies of the lunar visibility have been done by Schmidth at Athens using 72 samples of young moon data which he collected for nearly 20 years (1859 - 1867). The sets of the data collections were later on used by Fotheringham (1910) to develop altitude-azimuth separation criterion to determined the lunar visibility. For every set of Schmidth data, including the positive observations (successful) and negative observations (unsuccessful), Fotheringham distributed them as moon altitute during sunset as a function of the azimuth separation. He then plotted a curve which separated the positive and negative observations. Using the curve, it is possible to evaluate if the young moon crescent can be visible or not . Since Fotheringham's data is based on Schmidth's observations, there is no effect on the place of the observer (latitude and longitude). Maunder (1911) worked on Fotheringham's model and added a few more observation data and considered that some of the negative data by Schmidth are wrongly taken, and must be considered as a successful observational data. After doing modifications to the Fotheringham's model, the curve move downward and became known as the Fotheringham - Maunder criterion, which was an important development in empirical method of the lunar visibility studies. According to Ilyas (1997) this important finding could not totally be realized and widely used for calendrical purposes or lunar visibility studies until the 1970's.



(Source: Bruin, 1977)

Figure 1 : Fotheringham curve of visibility and modifications by Maunder

The studies of lunar visibility saw an improvement when Bruin (1977), developed the theoritical method which considered the western sky brightness, the brightness of the moon surface, width of the lunar crescent (*w*), solar depression and contrast for the unaided human eye . In order to established physical criterion of lunar visibility, Bruin formed a curve of moon altitute and solar depression, (h + s) as a function of solar depression (s). This was combined together with a few set of the lunar crescent width and Bruin lunar visibility curve are useful to see some correlations in young moon characteristic. Ilyas (1981, 1984, 1988) used Bruin lunar visibility curve in order to established and improved a few matters in the young moon crescent visibility studies.

Bruin (1977) proposed the practical value for the width on the earliest visibility is $w > 0.5$. However, after this was reduced by Ilyas (1981), with a minimum limit of $w = 0.25'$ and using Bruin criterion of the altitude separation, Ilyas finally found that, the value of a_L matched with the Maunder minimum visibility of moon-sun separation.

In order to implement the visibility parameter into global use, Ilyas (1984), developed the model altitude of the moon as a function of the arc of light. Using a value of moon-sun separation at 6°, Ilyas extend the curve for the large arc of light value, making it very useful at high latitudes. This model, created a more updated and broadened theoretical form.

After Ilyas's reformation on the Bruin criterion, the next step was to expand Fotheringham - Maunder (1911) criterion to make it useful for high latitudes. Using inverted and extrapolation from Bruin value of large a_L , Ilyas (1988), extent Fotheringham - Maunder curve to a much larger of azimuth separation . Hence, this two form Ilyas (1984 & 1988) become composite criterion theoretical and observational which an important finding in modern studies of young moon crescent visibility.

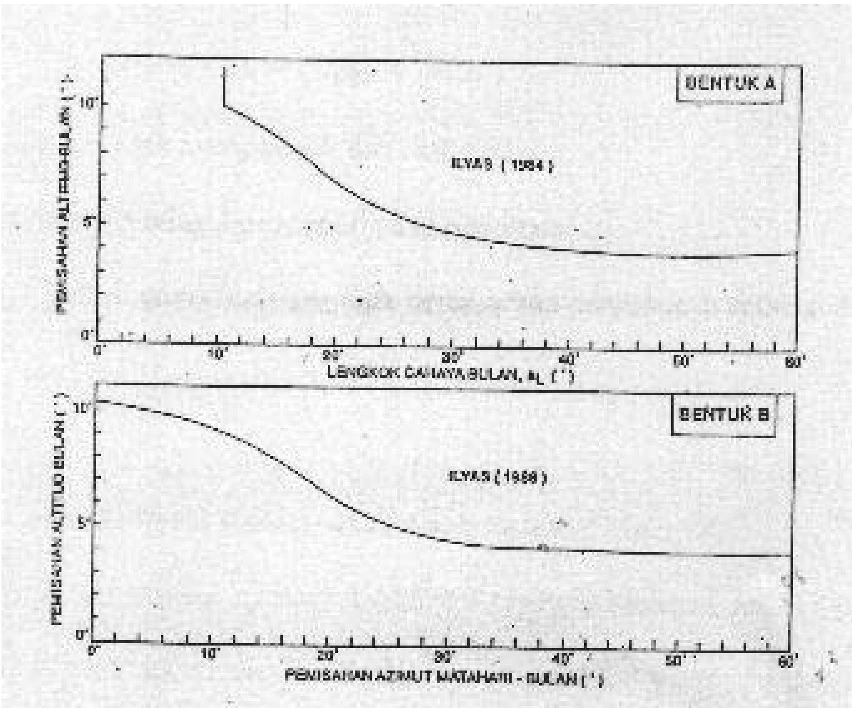


Figure 2: The composite criterion by Ilyas (1984 & 1988)

On the physical approach done by Danjon (1932), he measured the correlation between the sun and the moon elongation with the illimunation of the lunar crescent. Using 75 sets of the observational young moon formation, Danjon found out that the length of the lunar crescent became shortened as the moon closer to the sun. Danjon deduced the magnitude of the lunar crescent shortening in form of the deficiency arc as a function of elongation (Ilyas, 1983). Danjon found that the light from young moon cannot directly reflect if the angle of the elongation is smaller than 7°, or in other word the young moon crescent have no capability to reflect the light. If less than the lowest limit, the moon illimunation will dissappear and the crescent cannot be sighted. This value was later on called the 'Danjon limit'. Danjon proposed the modelling of the lunar crescent length as a function of the sun-moon angle. He deduced that when the moon was less than 7° from the sun, the arc length of the crescent would be 0°. The validity of the Danjon model of the length of lunar crescent has been recognized by Schaefer (1991), by his moonwatch campaign, but not matching from Ilyas (1983) results on re-examination of the Danjon limit. On Ilyas studies to re-examine the Danjon limit, he found out that the limit value is simply an extrapolation by Danjon, and the limit must be upward to 10.5°. On his detailed explaination, Ilyas added that the Danjon limit is only a general guide for the young moon's earliest visibility, and cannot be used as a criterion for the calendrical visibility prediction. This comment refers to the resolution on Islamic Countries Calendrical Conference, Istanbul (1978), which adopted a simple criterion for elongation and sun - moon separation. Ilyas (1984) justified this as 'underestimate value' especially on predicted data in the tropical region. On the other hand, Mc Nally (1983), proposed the hypothesis of the effect of atmospheric turbulance (seeing) on the young moon crescent. According to the hypothesis, seeing causes the crescent to be invisible where the cusp is narrower than the size of the seeing disk (Schaefer,1991). Using some experiments tested by himself and by Blackwell (1946), Schaefer (1991) finally concluded that the effects of the seeing on the width of the cusp are irrelavant to the length of the lunar crescent.

Other quantities which are still considered to justify the young moon crescent visibility consist the moon age and the lag time between sunset and moonset. Eventhough, these two quantities have been used since ancient times, there are a few interesting facts which have been discovered by recent reseachers. Ilyas (1984) found that the age of the moon varies according to latitude and this phenomenom be used to determine the 'point' at which the moon will achieve the same age at local sunset which was useful in developing the concept of the Lunar Date Line. Moon age always refers to the time of conjunction between sun and moon to the local sunset. But on Malaysia visibility parameters, the age of the moon are referred to the time from conjunction to moonset, for the reason that the moon still has the possibility to be visible long before she set. Even if the moon age can show us the possibility of the young moon crescent visibility, there is some confusion over when the average of the moon age has been taken as a fix and single parameter for calendrical purposes.

Hence, the other parameter widely used to justify the possibility of the young moon crescent visibilty is the time lag between sunset and moonset. As mentioned, this rule has been used by Babylonians, Hindus and Muslims when the time lag was more than 48 minutes ($a_s \geq 12°$), Ilyas (1984) recoqnized that the criterion are meaningfull and usefull at the lower latitudes. For general use, Ilyas studied the seasonal variability of the time lag and summarized it for certain latitudes. It is generally known that both moon age and the time lag cannot be used as a main quantity to predict the visibility of the young moon crescent since there are seasonal and latitude changes. Furthermore, these quantities can be closely related to arc of light and sun-moon separations.

As in many scientific studies, there is usually a conflict between the theoretical and observational. Although Bruin proposed a useful theoretical work, Schaefer (1987), claimed that many of Bruin's assumptions were incorrect, especially regarding the twillight sky brightness, lunar surface brightness and physiological data for lunar vision. Meanwhile, Schaefer adopted Bruin's and Ilyas's criterion of visibility, he added some new parameters such as visual extinction coefficient and atmospheric clarity.

In recent development of young moon crescent visibility studies, some attempt has been made to improve the prediction models. These can be summarised as follows:

- B.D Yallop who proposed the 'best time' for the first visibility
- Khalid Shaukat who proposed the 'topocentric altitude' and 'width of crescent' criterion.
- Ahmad Monzur using his MoonCalc, predicted world-wide sighting results. These results can be verified against actual sighting.

4. The Present Challenges

Using the observational approach, the present challenges in studies of the young moon crescent visibility are:

(i) To establish the minimum guide of the visibility according to the local circumstances an experience. This will contribute to improve the width of the uncertainty zone of the Lunar Date Line.

(ii) To re-examine the length of the lunar crescent, from Danjon’s model (1932) with more data collections and confirm the effects of the atmospheric turbulance to the young moon crescent width from the Mc Nally (1983) hypothesis.

(iii) To scrutinize the effect of the local atmospheric conditions for the visibility characteristic.

(iv) To identified the suitable visibility parameter which can be applied to the local calendrical purposes.

REFERENCES

Bruin, F. (1977). The First Visibility of the Lunar Crescent. *Vistas in Astronomy*, Vol. 21, ms. 331 - 351.

Ilyas, M. (1981). Lowest Limit Of The *w* In The New Moon's First Visibility Criterion Of Bruin And It's Comparison With The Maunder Criterion. *Q. Jl. R. Ast. Soc*. 1981 Vol. 22 ms 154 -159.

Ilyas, M. (1983). The Danjon Limit Of Lunar Visibility: A Re- examination. *Jl. R Ast. Soc. Can* . 1983. Vol 77, no. 4. ms. 214 - 219.

Ilyas, M. (1984). *A Modern Guide To Astronomical Calculations of Islamic Calendar, Times & Qibla*. Kuala Lumpur: Berita Publishing.

Ilyas, M. (1988). Limiting Altitude Separation In The New Moon's First Visibility Criterion. *Astron. Astrophys*. 1988 Vol. 206, ms 133 - 135.

King, David.A. (1993). Ibn Yunus On Lunar Crescent Visibility. In David A.King *Astronomy In The Service Of Islam*. *Journal For The History Of Astronomy. Science History Pub. Ltd. 1988*. Vermont: Variorum Reprints .

McNally, D. (1983). The Length of The Lunar Crescent. *Q. Jl. R. Ast. Soc*. 1983, Vol 24, ms 417 - 429.

Schaefer, B.E. (1987). An Algorithm For Predicting The Visibility Of the Lunar Crescent. *Proceedings Of The Lunar Conference, International Of The Institute Of Islamic Thought*, Herndon, Virginia, 5 - 6 June 1987. ms 11:1-12.

Schaefer, B.E. (1988). Visibility of the Lunar Crescent. *Q. Jl. R Ast. Soc.* 1988 Vol 29, ms 511-523.

Schaefer, B.E. (1991). Length of the Lunar Crescent. *Q. Jl. R Ast. Soc.* 1991 Vol 32 ms 265-277.

Schaefer, B.E, Ahmad, I.A, Dogget, L. (1993). Records For Young Moon Sightings. *Q. Jl. R Ast. Soc.* 1993 Vol 34, ms 53 - 56.