بسم الله الرحمن الرحيم

In the Name of Allah, the Most Beneficent, the Most Merciful

Astronomical Calculation as a Foundation to Unify International Muslim Calendar: A Science Perspective[1]

Dr. Tono Saksono[2]
(tsaksono@gmail.com)

Introduction

Issues on method for determining the beginning of lunar month in connection with Muslim law has created controversy in Indonesia. The controversy occurs especially when one has to follow the methodology: by *moon sighting* (rukyat) or by means of astronomical and mathematical calculation (hisab). Indonesian Muslims have long been experiencing the split between the proponents of astronomical calculation on the one end, and moon sighting on the other. Fortunately though, the split has not created any disharmony in our religious affairs nor in our daily social lives in spite of the fact that this has been going on for almost fifty years. The controversy has, however, taken up a lot of energy with all the pros and cons. Furthermore, this has created frustration among the majority of Muslims when they have to decide as to what method they have to follow. For a member of an organization that is the proponent of any madzhab (school of thought), they normally have either emotional as well as cultural ties to follow whatever decision taken by the organization. However, for those who have no any cultural connection with any madzhab, the decision is difficult indeed.

The same problems with brother Muslim in the United States

The similar controversy apparently comes to the spotlight recently to brother Muslim in the United States when on August 13, 2006, *the Islamic Society of North America (ISNA)* decided to use the astronomical calculation to replace the *moon sighting* method in marking the beginning of Ramadan and other sacred Muslim months. Such a decision has created protest from Muslim scholars from all over the world despite the fact that ISNA has been practicing the moon sighting methods for tens of years to come up with a conclusion that Muslims in North America need to have a more reliable Muslim calendar with which they will be able to propose days off for Muslim employees who need to perform Eid prayers. With moon sighting as the only means to mark the beginning of a lunar month, ISNA had

---

[1] Presented at the International Symposium: *Towards the Unified International Muslim Calendar,* Sahid Hotel, 4-6 September 2007, Jakarta. This paper reflects the summary of a research work conducted by the Center for Islamic Studies, Indonesia. The work itself is in the process of printing entitled: *Mengkompromikan Rukyat & Hisab.*

[2] Director, the Center for Islamic Studies, Indonesia.

found it difficult to negotiate with the American government and the business community alike to propose a day off for Muslim employees to perform Eid-ul-Fitr or Eid-ul Adha prayer because of its high degree of uncertainty. With a more reliable calendar developed through mathematical and astronomical calculation, ISNA will be able to propose days off for Muslims employees well in advance, at least one year earlier because the technique is able to mark the sacred days with highest degree of accuracy.

Many Muslim scholars, however, do not really appreciate the fact that ISNA'a fatwa (decree) actually takes effect after as long as thirteen years involved in scientific research starting when it joined the *Committee for Crescent Observation* (CFCO[3]) in 1994. During the period of time, ISNA undertook a comprehensive moon sighting practice and research by sending hundreds of volunteers (hilal observers) every month to places that are ideal for moon sighting practice all over the United States and Canada, and come up with a conclusion that moon sighting is completely unreliable for determining the Muslim calendar in a modern society where all business transaction and government committment have been bound by time contraints dan deadline.

Islamic Laws for Ramadan

The foremost legal ground for saum (fasts) during Ramadan is revealed by Allah SWT in:

شَهْرُ رَمَضَانَ الَّذِيَ أُنزِلَ فِيهِ الْقُرْآنُ هُدًى لِّلنَّاسِ وَبَيِّنَاتٍ مِّنَ الْهُدَى وَالْفُرْقَانِ فَمَن شَهِدَ مِنكُمُ الشَّهْرَ فَلْيَصُمْهُ وَمَن كَانَ مَرِيضاً أَوْ عَلَى سَفَرٍ فَعِدَّةٌ مِّنْ أَيَّامٍ أُخَرَ يُرِيدُ اللّهُ بِكُمُ الْيُسْرَ وَلاَ يُرِيدُ بِكُمُ الْعُسْرَ وَلِتُكْمِلُواْ الْعِدَّةَ وَلِتُكَبِّرُواْ اللّهَ عَلَى مَا هَدَاكُمْ وَلَعَلَّكُمْ تَشْكُرُونَ

Ramadan is the (month) in which was sent down the Qur'an, a guidance for mankind, also clear (proofs) for guidance and judgment (between right and wrong). So every one of you who is present (at his home) during that month, he must observe saum (fasts), and whoever is ill, or on a journey, the prescribed period (should be made up) from other days. Allah intends ease for you; He does not want to make things difficult for you. (He wants you) to complete the prescribed period, and to glorify Him in that He has guided you; so that you may be grateful to Him. (HQ, Al-Baqara: 185)

The above verse only reveals the broad idea of the prescribed fasting during the month of Ramadan, without detailing as to when the Muslims have to start the saum. The detail is however revealed in the next verse of the same chapter:

أُحِلَّ لَكُمْ لَيْلَةَ الصِّيَامِ الرَّفَثُ إِلَى نِسَآئِكُمْ هُنَّ لِبَاسٌ لَّكُمْ وَأَنتُمْ لِبَاسٌ لَّهُنَّ عَلِمَ اللّهُ أَنَّكُمْ كُنتُمْ تَخْتَانُونَ أَنفُسَكُمْ فَتَابَ عَلَيْكُمْ وَعَفَا عَنكُمْ فَالآنَ بَاشِرُوهُنَّ وَابْتَغُواْ مَا كَتَبَ اللّهُ لَكُمْ وَكُلُواْ وَاشْرَبُواْ حَتَّى يَتَبَيَّنَ لَكُمُ الْخَيْطُ الأَبْيَضُ مِنَ الْخَيْطِ الأَسْوَدِ مِنَ الْفَجْرِ ثُمَّ أَتِمُّواْ الصِّيَامَ إِلَى اللَّيْلِ وَلاَ تُبَاشِرُوهُنَّ وَأَنتُمْ عَاكِفُونَ فِي الْمَسَاجِدِ تِلْكَ حُدُودُ اللّهِ فَلاَ تَقْرَبُوهَا كَذَلِكَ يُبَيِّنُ اللّهُ آيَاتِهِ لِلنَّاسِ لَعَلَّهُمْ يَتَّقُونَ

It is made lawful to you to go unto your wives on the night of the fast. They are apparel for you and you are the same for them. Allah is aware that you were deceiving yourselves in this respect and He has turned in mercy toward you and

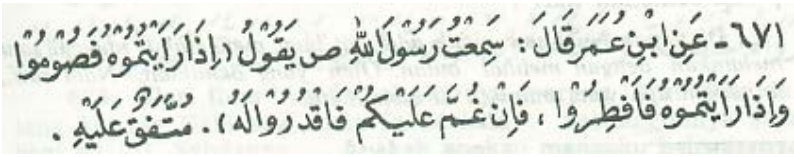
[3] Prominent ulemas, Muslim scientists (Astronomy, Mathematics, Computing), and trained hilal observers are involved at CFCO (see Reydan)

forgave you. So now be in contact with them and seek what Allah has ordained for you, and eat and drink until the white thread becomes distinct to you from the black thread of the dawn, then complete the fast till night, and have no contact with them while you are in your devotion in the mosques. These are the limits imposed by Allah, so approach them not. Thus does Allah make clear His ayah for men that they may guard (against evil) (HQ, Al-Baqara: 187).

In the debate on the dispute of astronomical calculation method versus moon sighting, many Muslim brothers and sisters always referred to prophetic sayings (hadith) which too, give the details as to when to start and to end the holy Ramadan, they are quoted:

لاَ تَصُومُوا حَتَّى تَرَوُا الْهِلاَلَ ، وَلاَ تُفْطِرُوا حَتَّى تَرَوْهُ.

Do not fast till you see the new moon, and do not break fast till you see it" (Saheeh Muslim)


٦٧١ - عَنِ ابْنِ عُمَرَ قَالَ : سَمِعْتُ رَسُولَ اللهِ ص يَقُولُ (إِذَا رَأَيْتُمُوهُ فَصُومُوا
وَإِذَا رَأَيْتُمُوهُ فَأَفْطِرُوا ، فَإِنْ غُمَّ عَلَيْكُمْ فَاقْدُرُوا لَهُ) . مُتَّفَقٌ عَلَيْهِ .

Ibnu Umar (ra), reported Allah's Messenger (pbuh) as saying: "When you see it[4] then you must observe saum, and when you see it, then break your fast; but if it is overcast, then calculate for it. (Saheeh Muslim)

Obviously, Allah uses different words when expressing the *meeting* of His ummah with the month of Ramadan (شَهِدَ) and when He ordered the Messenger (pbuh) to give the details of the timing to start and to end the saum by using words *tara* (تَرَو) and *raaytum* (رَأَيْتُمْ) upon the sighting of hilal (crescent) at the sunset. Another word of similar importance in the quoted hadith is *faqduru* that has the same root as word *qaddara* (قَدَّرَ) which simply means *to calculate, to measure,* or *to decide*. The dispute arises in interpreting whether or not we have to sight the hilal physically.

The proponents of moon-sighting firmly believe that the words *tara* (تَرَو) and *raaytum* (رَأَيْتُمْ) in the above-quoted hadiths are something to do with the act of seeing the hilal physically. Some Muslim scholars even decline any use of modern instrument (such as binoculars, telescope and so forth) in lieu of direct eye sighting, claiming that this is the message from Allah for those who live in the remote area for whom such technology is unreachable[5]. However, we immediately sense inconsistency in this matter. If being universal really matters irrespective of human achievement in science and technology, we then have to stick with Allah's guidance upon the commencement of saum in the above verse: *until the white thread becomes distinct to you from the black thread of the dawn.* Apparently, we are now using modern instrument (clock, wristwatch and so forth) as a representation of advanced *mathematical calculation* and the advent of human technological achievements.

In the mean time, the proponents of mathematical and astronomical calculation (hisab) believe that the act of seeing in the above hadiths is not necessarily physically as with the

[4] Hilal
[5] See Memon (reference 5)

advent of modern astronomy, the position of any celestial body can accurately be calculated and monitored at any time from anywhere in the globe. In so doing, the words *tara* (تَرَو) and *raaytum* (رَأَيْتُمْ) simply mean to calculate it or *to see it by means of knowledge*, and hence the word *qaddara* (قَدَّرَ) emphasizes the option of mathematical calculation.

Statistics of word ro'a in the Qur'an

We firmly believe that there is no Muslim who will contest that our sources of Islamic Laws are four listed in order:

1. The Holy Qur'an.
2. The Sunnah, which comprises the words, deeds, and acknowledgments of the Prophet Muhammad (pbuh), as transmitted through reliable sources;
3. The Ijmaa' of ummah (consensus of the legal Muslim scholars);
4. Qiyas (analogical reasoning as an effort to extract an opinion based on Islamic Law in the absence of definitive proofs).

Differences are something that we are not capable of avoiding to exist in our worldly life. They have always existed from the beginning of the creation of humankind and will continue to exist until the last day. What we have to avoid is these differences from creating fracture within the brotherhood of Islam. We firmly believe that every difference has a solution and the solution for Islamic differences is found in none other than the Qur'an and the practices of His final Messenger, Muhammad (pbuh). We have to remember that Allah has instructed:

يَا أَيُّهَا الَّذِينَ آمَنُواْ أَطِيعُواْ اللّهَ وَأَطِيعُواْ الرَّسُولَ وَأُوْلِي الأَمْرِ مِنكُمْ فَإِن تَنَازَعْتُمْ فِي شَيْءٍ فَرُدُّوهُ إِلَى اللّهِ وَالرَّسُولِ إِن كُنتُمْ تُؤْمِنُونَ بِاللّهِ وَالْيَوْمِ الآخِرِ ذَلِكَ خَيْرٌ وَأَحْسَنُ تَأْوِيلاً

O you who believe! obey Allah and obey the Messenger and those in authority from among you. If you dispute over anything, then refer it to Allah and the Messenger, if you believe in Allah and the last day. This is better and very good in the end. (HQ, An-Nisa: 59)

If we refer to the hadith to mark the beginning of holy month of Ramadan we quoted before, we immediately recognize the *key words* in these two hadiths and many more of the same spirit. They are: *tarawu al-hilalu*, *tarauhu*, *raaytumuhu* and also *faqduru lahu*. Let us, as instructed by Allah in His holy verse quoted above, refer to the holy Qur'an and analyze these words.

The word *ro'a*, although originally means *to see visually*[6] (ru'yatul bil fi'l), apparently appears more frequently with the meaning of *seeing with cognition*[7] (ru'yatul bil 'ilm) in the holy Qur'an. The word changes according to its context to become *tara* (تَرَ – *you see* or *you*

[6] *Visual: adj. of gained by seeing* - Longman Dictionary of Contemporary English, 1991, p. 1176.

[7] *Cognition: the act or experience of knowing, including consciousness of things and judgment about them* – Longman Dictionary of Contemporary English, 1991, p. 189.

relize/understand), or *nara* (نَرَى – *we see* or *we realize/understand*) or *yara* (يَرَى – *he/she sees* or *he/she realizes/understands*). This word and its derivatives apparently appear in 187 verses of the holy Qur'an, out of which there are 143 verses (78%) the word (and its derivatives) carries the meaning of *cognitive seeing* (ru'yatul bil 'ilm)[8]. Only the remaining 41 verses (22%) carry the original meaning of *seeing visually* (ru'yatul bil fi'l). Should we be interested in the number of chapters instead, then *ru'ytaul bil 'ilm* is contained in 61 chapters (68%), whilst *ru'yatul bil fi'l* is contained in 29 chapters (32%). From this proportion alone, we immediately sense the clear message from the Omniscient Allah SWT that He actually wants us to make use of our intellectual capacity as human rather than just our capability of *seeing*. Table-1 and Table-2 respectively show verses that contain the word *ro'a* when it means *seeing visually* and *cognitive seeing*. Moreover, a great deal of verses to contain word *ro'a* in Table-2 carries the meaning of seeing the unseen (ghaib). There is no doubt that this kind of *act of seeing* is of highest level as it is related to faith, and cannot be included into seeing physically[9].

#	Chapter #	Chapter Name	Verse
1	2	Al-Baqara	55, 144
2	3	Ali-Imran	13, 143
3	7	Al-Araf	27, 143, 146
4	8	Al-Anfal	48
5	9	At-Taubah	26, 40
6	10	Yunus	54
7	12	Yusuf	4, 31
8	13	Ar-Rad	2
9	19	Maryam	26
10	20	Taha	107
11	24	An-Noor	40
12	25	Al-Furqan	40
13	26	Ash-Shuara	61, 218
14	27	An-Naml	40
15	31	Luqman	10
16	33	Al-Ahzab	9
17	37	As-Saaffat	55
18	46	Al-Ahqaf	24
19	53	An-Najm	11, 13
20	54	Al-Qamar	2
21	63	Al-Munafiqoon	4, 5
22	68	Al-Qalam	26
23	69	Al-Haaqqa	8
24	76	Al-Insan	19, 20
25	81	At-Takwir	23
26	83	Al-Mutaffifin	32
27	90	Al-Balad	7
28	102	At-Takathur	6, 7
29	107	Al-Maun	6

Table 1: Verses to contain the word ro'a when it means *ru'yatul bil fi'l*

#	Chapter #	Chapter Name	Verse
1	2	Al-Baqara	165, 243, 246, 258
2	3	Ali-Imran	23
3	4	An-Nisa	44, 49, 51, 60, 61, 77
4	5	Al-Maeda	83
5	6	Al-Anaam	6, 25, 27, 30, 40, 46, 47, 68, 93
6	7	Al-Araf	148
7	8	Al-Anfal	50
8	9	At-Taubah	126
9	10	Yunus	50, 59, 88, 97
32	35	Fatir	8, 27, 40
33	36	Ya-Seen	31, 71, 77
34	37	Saaffat	14, 102
35	39	Az-Zumar	21, 38, 58, 60
36	40	Ghafir	69, 84, 85
37	41	Fussilat	15, 39, 52
38	42	Ash-Shura	44
39	45	Al-Jathia	23
40	46	Al-Ahqaf	4, 10, 33, 35

[8] This paper does not intend to claim that the inventory is complete. It might have missed some verses unintentionally, but it is believed that it will not change the proportion significantly let alone dramatically.

[9] In the Day of Resurrection, the way we *see* is believed to be different from what we do now – Wallahu 'Alam.

10	11	Hud	28, 63, 88
11	12	Yusuf	35, 59
12	13	Ar-Rad	41
13	14	Ibrahim	19, 24, 28
14	16	An-Nahl	48, 79
15	17	Al-Isra	62, 99
16	18	Al-Kahfi	63
17	19	Maryam	75, 77, 83
18	20	Taha	89, 92
19	21	Al-Anbiya	30, 44
20	22	Al-Hajj	2, 18, 63, 65
21	24	An-Noor	41, 43
22	25	Al-Furqan	22, 41, 42, 43, 45
23	26	Ash-Shuara	7, 75, 201, 205, 225
24	27	An-Naml	86
25	28	Al-Qasas	71, 72,
26	29	Al-Ankabut	19, 67
27	30	Ar-Room	37
28	31	Luqman	20, 29, 31
29	32	As-Sajda	12, 27
30	33	Al-Ahzab	19
31	34	Saba	9, 31, 33, 51
41	47	Muhammad	20
42	48	Al-Fath	29
43	52	At-Tur	44
44	53	An-Najm	19, 33, 35
45	56	Al-Waqia	58, 63, 68, 71
46	57	Al-Hadid	12
47	58	Al-Mujadila	7, 8, 14
48	59	Al-Hashr	11, 21
49	62	Al-Jumua	11
50	67	Al-Mulk	3, 19, 27, 28, 30
51	70	Al-Maarij	6
52	71	Nooh	15
53	72	Al-Jinn	24
54	76	Al-Insan	13
55	79	An-Naziat	36, 46
56	89	Al-Fajr	6
57	96	Al-Alaq	7, 9, 11, 13, 14
58	99	Al-Zalzala	7, 8
59	105	Al-Fil	1
60	107	Al-Maun	1
61	110	An-Nasr	2

Table 2: Verses to contain the word ro'a when it means *ru'yatul bil 'ilm*

Let's take a look at the process of seeing which will start with a bundle of light coming from a light source (the sun or flash light) that fall unto an object that is further reflected into the lens in our eyes. The process of seeing actually happens in stages. A bundle of rays called photons move from the object into the eyes through a lens that is located in the front part of the eyes. These incoming rays are further gathered to form an image that is smaller in size and was imaged upside down within the eyes' retina. This bundle of rays are further sent to the brain as electrical pulse through neurons and continue to reach the so called the center of vision in the back part of our brain. As such, the process of seeing actually takes effect in this tiny center of vision that is located in an isolated part of the brain. This is a light proof part of the brain that is completely dark with not a single ray of light can reach therein, similar to back part of our old optical camera. The colorfulness of flowers and the beauty of panorama we encounter in our worldly life are therefore just electrical pulses that reach our center of vision. The brain will then execute even more important step what we call a mental or psychological process by interpreting the form, position, orientation, size, color, and texture of the object, and then matching it with virtually countless images that are already stored in the human's memory. This is called a cognitive process that constitutes the most important part of the process of seeing. If one loses his/her sight when he has reached adult age, he/she can still perceive the colorfulness of the worldly life around him because his/her brain is still working perfectly. However, if one damages his/her brain, he/she will not be able to transform an imaged picture in his retina into a meaningful message.

Sharia to support calculation

Allah has instructed us to make use of our utmost intellectual capacity to think deeply about all signs in His ayah (essentially the whole universe He has created for humankind):

هُوَ الَّذِي جَعَلَ الشَّمْسَ ضِيَاءً وَالْقَمَرَ نُوراً وَقَدَّرَهُ مَنَازِلَ لِتَعْلَمُواْ عَدَدَ السِّنِينَ وَالْحِسَابَ مَا خَلَقَ اللّهُ ذَلِكَ إِلاَّ بِالْحَقِّ يُفَصِّلُ الآيَاتِ لِقَوْمٍ يَعْلَمُونَ

It is He Who made the sun a shining thing and the moon as a light and measured out its (their) stages, that you might know the number of years and the reckoning (of time). Allah did not create this but in truth. He explains the Ayah (lessons, revelations) in detail for people who have knowledge. (HQ, Yunus: 5).

The above verse embraces all two key words we are disputing blatantly so far. It simply says that the hilal's position may be calculated, and this is in compliance with Allah's command so that we know the reckoning of time. Of paramount importance is that Allah wants us to make use of our utmost intellectual capacity as human beings. These two words are *waqaddarahu* (وَقَدَّرَهُ) that simply means *and measured out* (this is exactly the same word as that is used in the above quoted hadith), and *hisab* (الْحِسَابَ) that simply means *the reckoning* (*of time*). Further than that, these two words are enhanced within the same verse to show that Allah explains His ayah (signs, proofs, revelation, guidance, etc) for *people who have knowledge* (لِقَوْمٍ يَعْلَمُونَ). It is very obvious, the above verse is trying to say that Allah loves His servants who have knowledge, those who think deeply to know the number of years and the reckoning of time with the help of whatever exists in the whole universe that has been created for us so that we keep learning how Great He is. Subhan Allahu . . . Allahu Akbar. Isn't it really showing how Allah has put us in a very honorable position? So why should we keep disputing every time whilst we are ignoring Allah's command to think, contemplate and analyze the greatness of Allah through whatever exist in the whole universe He has created for us? Therefore, *seeing* is not supposed to be just *physically*, but *think deeply and thoroughly*.

Human error in moon sighting

In statistics we learned what we consider as errors that comprises of *gross*, *systematic*, and *random errors*. Human error is prone to end up with gross error (blunder) whose magnitude is unpredictable. In any decision making system, such error should be avoided whatever it costs! Such error may come from wrong reading the number 25 instead of 52, for example. Or someone reads 500 grams when the scale reads only 50 grams. This type of error is typical human error especially when he/she is under strong psychological pressure and very strict time constraint. This is what happens to many crescent observers (hilal observers). Their psychological burden is huge as they have to shoulder spiritual consequences within very limited time of only 15-60 minutes as the hilal soon sets to follow the sun[10]. Binary type of decision (on or off, black or white, right or wrong, visible or invisible) always reserves full of serious error of this kind. If we are consistent in seeking the pleasures of Allah, why should we then so obvious in risking our faith to something that is very prone

[10] Hilal altitude of 12° will give the moon-observer approximately 48 minutes before it sets in the western horizon.

to gross error like this? In the mean time, the classical problems with moon sighting are as follows:

- Weather and atmospheric condition of the Earth (cloud, fog, haze, pollution, etc);
- Crescent altitudes. ISNA conculdes that the crescent altitude must be in the order of 12 degress in order to be visible;
- Distance between the Moon and the Sun (if it is too close, the twilight is still too bright so that it is practically almost impossible to see the crescent);
- Quality of observer's eyes;
- Quality of optical instrument;
- Psychological condition of the observer (within time contraint of 15-60 minutes!);
- Cost;
- Above all, it is a very subjective matter because all ummahs have to rely only on a few people (ie. hilal observers) without being able to access the transparency of the process of seeing.

In Indonesia, we have data that a crescent observer trainee has to be trained for teens of years to end up with wrong decision when he interpreted a gloomy slit between clouds as crescent. Other trainee who has been practicing moon sighting for decades, end up with joy of seeing hilal but it was up side down?[11] These are very typical human errors that end up with blunder and we have to avoid it, whatever the price is. In the calculation method, blunders insha Allah can be avoided by applying double check calculation. To some extents, systematic error can be eliminated within the calculation system that will be too technical to be discussed in this paper. What remains is random error that cannot be removed however versatile our computation system be. Even so, this error is normally within the tolerable magnitude that will not affect the end results too significantly. To larger extents the latter is even useful because statistical measure of standard deviation is actually derived from such error. In so doing, we will have a feeling how precise our calculation is. Of highest importance is the transparency of the process whereby all ummahs will be able to double check the whole calculation process.

Ramadan during the period of Rasulullah

Astronomical and mathematical calculation can not only be used to precisely calculate the beginning of Muslim lunar month but also a more complex astronomical calculation such as solar or lunar eclipse that is going to happen in a hundred of years to come, for example. The calculation is so accurate in such a way that people are even able to tell when it will happen, the duration of astronomical event, and the size of umbra and penumbra, very accurately. Alternatively, the astronomical calculation is also able to accurately calculate the beginning of Muslim lunar month 1,400 years back in order to analyze the Ramadan during the period of Rasulullah SAW as shown in Table-3.

The table shows accurately the astronomical characteristics of crescent that had happened 1.400 years back. At the same time, it also reveals scientific facts that what we are practicing today is, very often, not in agreement with what Rasulullah had precisely practiced in the past. Some examples are given here: In general, the proponents of moon sighting put a

[11] See reference 6.

minimum altitude of the crescent in the event of moon sighting process to be higher than 4° as conditional requisites in order to avoid the brightness of the sun's twilight attenuate the process of sighting. If this condition is not fulfilled, these Muslim scholars normally perform isti'mal or a consensus to complete the fasting month to thirty days regardless of the fact that the astronomical calculation confirms the existence of crescent in the western horizon. A closer look at astronomical characteristics of Ramadan during Rasulullah era as shown in Table-3 reveals the following facts:

1. Rasulullah performed saum during Ramadan only nine years from 2H (624AD) until 10H (631AD, inclusive);
2. There were six times that the Ramadan had 29 days, whilst only three times it had 30 days. Some hadiths says that Rasulullah performed a 30-day-Ramadan only 2-3 times, the rests were only 29 days. The astronomical calculation therefore strongly confirms the quoted hadiths;
3. Out of nine Ramadan in the era of Rasulullah SAW, six of them were when the crescent altitude was far below the minimum altitude of 4°. Four of them were in the order of 1.7°-2.7° and this occurred even in the event when Ramadan was only 29 days (see highlighted part of the table). These facts simply indicate that Rasulullah and shahabats (i.e. immediate followers) undertook the moon sighting far more seriously than what we are doing now. Above all, isti'mal was not actually practiced although Rasulullah gives a way out in his hadiths. It is believed that this is just an escape path in the event that the beginning of the Syawal is not possibly determined for any possible reason in the future.

Year		Ramadan/Syawal				Time	Number	Crescent Alt	Time Lag	Crescent	Illuminastion
Hijri	Gregorian	Hijri	Gregorian			(h:m:s)	of days	(h:m:s)	MS-SS	Width	(%)
			dd	mm	yyy				(h:m:s)	(degrees)	
2	624	1 Ramadan	24	02	624	18:27:57		3,0°	0:13:34	4	0,23%
		End of Ramadan	25	03	624	18:36:49	30	9,0°	0:39:20	14	0,76%
3	625	1 Ramadan	13	02	625	18:23:45		9,4°	0:42:44	17	0,85%
		End of Ramadan	14	03	625	18:33:54	29	3,9°	0:17:11	5	0,28%
4	626	1 Ramadan	03	02	626	18:18:39		14,2°	1:05:07	35	1,71%
		End of Ramadan	04	03	626	18:30:54	29	9,1°	0:40:30	15	0,74%
5	627	1 Ramadan	23	01	627	18:12:05		4,7°	0:22:26	8	0,41%
		End of Ramadan	22	02	627	18:27:01	30	13,4°	0:59:50	29	1,41%
6	628	1 Ramadan	13	01	628	18:05:27		11,8°	0:56:39	26	1,40%
		End of Ramadan	11	02	628	18:22:29	29	5,7°	0:25:38	7	0,35%
7	629	1 Ramadan	01	01	629	17:58:00		9,9°	0:48:22	21	1,15%
		End of Ramadan	30	01	629	18:16:35	29	2,7°	0:12:36	3	0,16%
8	629	1 Ramadan	21	12	629	17:51:14		9,8°	0:48:15	22	1,22%
		End of Ramadan	19	01	630	18:09:44	29	2,7°	0:12:34	3	0,14%
9	630	1 Ramadan	10	12	630	17:45:58		7,7°	0:38:21	18	0,96%
		End of Ramadan	08	01	631	18:02:19	29	1,8°	0:08:25	2	0,09%
10	631	1 Ramadan	29	11	631	17:43:00		1,7°	0:08:07	6	0,30%
		End of Ramadan	29	12	631	17:55:39	30	10,3°	0:49:36	18	0,91%

MS: moon set time; SS: sun set time

Table 3: Characteristics of crescent during the month of Ramadan in the era of Rasulullah SAW

Accuracy of Astronomical Calculation

The main reason that astronomical calculation is able to foresee the eclipse that is going to happend in the next hundred of years, or to calculate the characteristics of Ramadan that occured 1.400 years back as shown in Table-3 is because modern man is actually capable of calculating the behavior of almost all celestial bodies very accurately. Back in 1990s, an astronomical navigation system was able to determine a position on the surface of the earth to the accuracy of 3 cm. Nowadays, the accuracy of better than 1 mm can even be obtained

with the advent of modern navigation system like the *Global Positioning System* (GPS). Astronomers are actually using a similar method in calculating the eclipse forecast and to calculate the Ramadan in the era of Rasulullah SAW as shown in the abovementioned table.

As part of an effort to show the accuracy potential of astronomical calculation to prepare an international Muslim calendar, this paper also shows the most important part of a Muslim calendar for the period of five years to come (1428H – 1432H) as shown in Table-4.

Hijri Year	Islamic Event	Gregorian Date	Time Lag MS-SS (hmns)	Crescent Alt (degree arc)	Mark
1428	End of Sya'ban	12-Sep-07	0:34:42	8,5	B
	1-Ramadan	13-Sep-07			
	End of Ramadan	11-Okt-07	0:02:35	0,6	D
	Eid-ul Fitri	12-Okt-07	0:46:47	11,2	A
	End of Dzulqaidah	10-Des-07	0:34:02	7,5	B
	1-Dzulhijjah	11-Des-07			
	Eid-ul Adha	20-Des-07			
1429	End of Sya'ban	31-Agust-08	0:24:30	6	C
	1-Ramadan	01-Sep-08	1:12:13	17,6	A++
	End of Ramadan	30-Sep-08	0:43:15	10,4	A
	Eid-ul Fitri	01-Okt-08			
	End of Dzulqaidah	28-Nop-08	0:32:43	7,3	B
	1-Dzulhijjah	29-Nop-08			
	Eid-ul Adha	08-Des-08			
1430	End of Sya'ban	21-Agust-09	0:50:17	12,1	A+
	1-Ramadan	22-Agust-09			
	End of Ramadan	19-Sep-09	0:25:47	6,3	B
	Eid-ul Fitri	20-Sep-09			
	End of Dzulqaidah	17-Nop-09	0:28:25	6,4	B
	1-Dzulhijjah	18-Nop-09			
	Eid-ul Adha	27-Nop-09			
1431	End of Sya'ban	10-Agust-10	0:12:03	2,8	D
	1-Ramadan	11-Agust-10	1:09:12	16,5	A++
	End of Ramadan	09-Sep-10	0:47:38	11,5	A
	Eid-ul Fitri	10-Sep-10			
	End of Dzulqaidah	06-Nop-10	0:07:01	1,6	D
	1-Dzulhijjah	07-Nop-10	1:06:35	15,2	A++
	Eid-ul Adha	16-Nop-10			
1432	End of Sya'ban	31-Jul-11	0:31:00	7,3	B
	1-Ramadan	01-Agust-11			
	End of Ramadan	29-Agust-11	0:08:34	2,1	D
	Eid-ul Fitri	30-Agust-11	1:04:20	15,6	A++
	End of Dzulqaidah	27-Okt-11	0:30:29	7,1	B
	1-Dzulhijjah	28-Okt-11			
	Eid-ul Adha	06-Nop-11			

MS : moon set time; SS : sun set time

D : Crescent altitude of 1°-3° (high possibility moon sighting different from astronomical calculation);

C : Crescent altitude of 3.1°-6° (moderate possibility moon sighting different from astronomical calculation);

B : Crescent altitude of 6.1°-9° (unlikely moon sighting different from astronomical calculation);

A : Crescent altitude of 9.1°-12° (very unlikely moon sighting different from astronomical calculation);

Table 4: Crescent characteristics in the next five years

All astronomical calculation in this paper is performed to the accuracy level that is described by the statsitical standard deviation of 3,6 seconds. Of primary importance in the table are data for:

- End of Sya'ban;
- First day of Ramadan;
- End of Ramadan
- Eid-ul Fitri;
- End of Dzulqaidah
- First day of Dzulhijjah;
- Eid-ul Adha

In addition to those, the table also gives important information such as, the corrsponding Gregorian date, time lag between the instance of moonset and sunset, crescent altitude, and additional information to mark the quality of the crescent in order to accommodate the interets of our brothers and sisters, the proponents of moon sighting method.

From the table we are able to foresee some possibility that may occur in the next few months when it is related to Muslim sacred months. Insya Allah, end of Sya'ban 1428H will coincide with the instance when sun sets on September 12, 2007. At that time, the crescent's altitude will be 8.5^o whilst the moon will set 34 minut and 42 seconds after the sun sets (marked "A" in the above table). With such a high crescent's altitude, insya Allah, there will be no difference in the interpretation of the beginning of Ramadan 1428H between moon sighting (ru'yat) and astronomical calculation (hisab) proponents. A potential difference will however occur in deciding the end of Ramadan which astronomically will coincide with the timing when sun sets on October 11, 2007. The crescent's altitude at that time will be as low as 0.6^o, far below 4^o the minimum criterium to perform moon sigting. At this point, the moon will set only 2 minut and 35 seconds after sun sets, far too short for a crescent observer even to prepare all his instrment and paper to record his observation. As such, the proponent of moon sighting wll most likely to draw a traditional consensus of isti'mal to complete the 30th day of fasting on October 12, 2007. In the mean time, the proponent of astronomical calculation will break the fast and perform Eid-ul Fitr on the October 12. Furthermore, astronomical calculation concludes that the end of Dzulqaidah will be coincident with the sunset of December 10, 2007 with the crescent's altitude of 7.5^o. This means, the moon will set 34 minutes and 2 seconds after sun sets which will give sufficient time for crescent observer to complete and conclude his observation. In this way, 1st of Dzulhijjah will be coincident with December 11, and Eid-ul Adha will be on December 20, 2007 (see Table-4). Wallahu 'alam, Allah knows best.

Finally, a comprehensive Muslim calendar must also accommodate the interests of brother Muslims who stick with their decision that seeing hilal in the event of determining the beginning of Muslim lunar month must be a visual seeing. This paper therefore propose that the Muslim calendar must also include all information needed by these Muslim brothers and sisters. The attached figure in the Appendix shows a mock up sample of such calendar which is the extension of all information contained in Table-4.

Allah's verdict will be thorough, accurate and transparent

Astronomical and mathematical calculations teach us a very important lesson that all decision related with the Islamic laws (sharia) must be carried out thoroughly, accurately and transparently. Binary type of decision: right or wrong, black or white, visible or invisible, especially if it relies only on a few people without check and rechecks mechanism is simply error prone and to a lesser extent is dangerous, and therefore must be avoided. Even in the hereafter, Allah the Highest and Omnipotent Judge will not try us with binary type of judgment (right or wrong). Instead, He will deliver His verdict very accurately and transparently based on all information that has been collected during our lives as demonstrated in these verses:

وَوُضِعَ الْكِتَابُ فَتَرَى الْمُجْرِمِينَ مُشْفِقِينَ مِمَّا فِيهِ وَيَقُولُونَ يَا وَيْلَتَنَا مَالِ هَذَا الْكِتَابِ لَا يُغَادِرُ صَغِيرَةً وَلَا كَبِيرَةً إِلَّا أَحْصَاهَا وَوَجَدُوا مَا عَمِلُوا حَاضِراً وَلَا يَظْلِمُ رَبُّكَ أَحَداً

And the Book (one's Record) will be placed (in the right hand for a believer in the Oneness of Allah, and in the left hand for a disbeliever in the Oneness of Allah), and you will see the Mujrimoon (criminals, polytheists, sinners, etc.), fearful of that which is (recorded) therein. They will say: "Woe to us! What sort of Book is this that leaves neither a small thing nor a big thing, but has recorded it with numbers?" And they will find all that they did, placed before them, and your Lord treats no one with injustice. (HQ, Al-Kahf: 49)

الْيَوْمَ نَخْتِمُ عَلَى أَفْوَاهِهِمْ وَتُكَلِّمُنَا أَيْدِيهِمْ وَتَشْهَدُ أَرْجُلُهُمْ بِمَا كَانُوا يَكْسِبُونَ

This Day, We shall seal up their mouths, and their hands will speak to Us, and their legs will bear witness to what they used to earn. (HQ. Ya Seen: 65).

وَمَا كُنتُمْ تَسْتَتِرُونَ أَنْ يَشْهَدَ عَلَيْكُمْ سَمْعُكُمْ وَلَا أَبْصَارُكُمْ وَلَا جُلُودُكُمْ وَلَكِن ظَنَنتُمْ أَنَّ اللَّهَ لَا يَعْلَمُ كَثِيراً مِّمَّا تَعْمَلُونَ

And you have not been hiding against yourselves, lest your ears, and your eyes, and your skins testify against you, but you thought that Allah knew not much of what you were doing. (HQ, Fussilat: 22).

Who will contest the Most Powerful Allah SWT in the hereafter should He deliver His final verdict without revealing detailed testimonies of our deeds (the good and the bad)? And yet, Allah will not do this because Allah wants to show that His decision will be thorough, transparent, precise, complete, and just. It is therefore obvious that Allah also wants us to use all detailed information when we decide to start or to end the month of Ramadan and Dhulhijjah. In so doing we then have to make use of our utmost intellectual capacity as human beings.

Muslims must be advanced in science and technology

Finally, let us quote a very good challenge revealed by the Omnipotent Allah SWT in Ar-Rahman: 33:

يَا مَعْشَرَ الْجِنِّ وَالْإِنسِ إِنِ اسْتَطَعْتُمْ أَن تَنفُذُوا مِنْ أَقْطَارِ السَّمَاوَاتِ وَالْأَرْضِ فَانفُذُوا لَا تَنفُذُونَ إِلَّا بِسُلْطَانٍ

O assembly of jinn and men! If you have power to penetrate beyond the zones of the heavens and the earth, then pass through. But you will never be able to pass them, except with authority (from Allah)!

This verse started with Allah's call to all genies as well as humankind irrespective whether or not they are Muslim. This call even applies to those who are disbelievers and transgressors, free from primordialistic barrier (religion, ethnicity, or nation). Allah gives a total freedom to all of them (and us) to penetrate beyond the zones of the heavens and the earth, and this is what has been better used by westerners (although they do not have to be aware of such opportunity) who work and think harder in their effort to scrutinizing the wonder of the universe Allah has created for us. In return, generally they are all better off than we are as Muslims, scientifically, technologically, socially, militarily, as well as culturally. In the mean time, we seemed to be too allergic in adopting any technology in such a way that we are now far behind in all aspects of worldly lives. We may argue that the life in the hereafter is far better than what we have in the world now, and this is what we are aiming. Then, why should we are using mobile phones, internet and so forth to communicate after all, if we really do not need the glory in the worldly life as well as in the hereafter. If Islam was so advanced culturally, scientifically and technologically during the 8th - 15th centuries, why should not we be now if we work and think harder?

Finally, the following hadith demonstrates the importance of knowledge for Islam and its development[12]: Mu'adh ibn Jabal (ra) said that the Messenger of Allah (pbuh) said:

Learn Al-Ilm (knowledge), for learning it is a type of Khashyah (Fear) of Allah, seeking it is an act of worship, studying it is a type of Tasbih (glorifying of Allah) searching for it is a Jihad, teaching it to those who do not know it is a charity and delivering it to those who worthy of it is an act of drawing closer (to Allah). Knowledge is the reference guide to the allowed and the disallowed, a light on the path for the people of Paradise, the companion during the loneliness, the friend during estrangement, the converser during seclusion, the guide in times of ease and times of difficulty, a weapon to use against the enemies and the quality that is valued by friends. Allah elevates some people by knowledge to the rank of leaders in righteousness who are followed, their actions imitated and their opinions referred to. The angels long to attend their gatherings (of learning knowledge) and shade them with their wings. Everything wet or dry, the fish in the sea and its creatures, beasts of pray and cattle that live on land invoke Allah to forgive them (people of knowledge). Verily, this is because the life of the heart against ignorance and the lamps of the eyes against darkness. With knowledge, the slave reaches the rank of righteous and the elevated grades in this life and hereafter. Thinking about knowledge is equivalent to Siyam (Fasting), and studying it is equivalent to Qiyam (praying at night voluntarily). With knowledge, ties of kinship are kept and the allowed and prohibited become distinguished. It is the Imam (Leader) of all actions and all actions follow its lead. Only the happy ones are endowed with knowledge while the miserable ones are deprived of it.

Conclusion

Allah's message revealed through the proportion of the meaning of the keyword *ro'a* contained in Table-1 and Table-2 is very obvious. It simply means that Allah wants us to make use of our utmost intellectual capacity in determining the beginning of a month in a Muslim calendar. The decision over it must be based on thorough, accurate and transparent work as Allah also will deliver His final verdict in the day of resurrection

[12] Reference 2, p. 28-29.

transparently, accurately, thoroughly and justly. Therefore, it is sufficient to conclude that the beginning of the holy month of Ramadan, Shawal, Dhulhijjah and other months must be determined by means of science and technology. As astronomical calculation is currently the most advanced technology available, the Muslim calendar must then be calculated based on such calculation. If in the future, moon sighting technique is technologically more reliable and gives more accurate results, then all Muslims should replace the technique accordingly.

It is now the right time for Muslims all over the world to have its proleptic calendar that can be prepared well in advance based on astronomical calculation. There are computer programs that are available in public domain that are very useful for such tasks. We will not be able to create such calendar when we stick to the visibility of hilal to mark the beginning of a Muslim month due to uncertainties with the moon sighting technique. Furthermore, all Muslims should work hand in hand in promoting the use of Muslim Calendar to gradually replace the solar (i.e. Gregorian) calendar for our daily lives. Allah has commanded the Messenger (pbuh) to delete the 13th month of the early pagan Arab luni-solar calendar that linked the calendar with seasonal ceremonies that involved idols (contestants) of Allah. This is the ultimate essence of using a pure lunar calendar for Muslims.

Acknowledgement

The author gratefully acknowledges the use of two computer programs developed by two Muslim scientists. They are *Accurate Times* developed by *Mohammad Odeh* and *MoonCalc* developed by *Dr. Monzur Ahmed*. These two computer programs are available in public domain and have been extensively used for the research. The research also concludes that these two programs are very accurate with achieved a-posteriori standard deviation as small as 3.6 seconds. May Allah bless these two Muslim brothers who have generously distributed these two programs for the development of Islam for free in the public domain. The author also acknowledges the help of al-ustadz Muhammad Mourist and Tarmidzi Firdaus who have checked the syaria aspect of the original research work. Special thanks are also for Muslim brothers and sisters at Masjid Baabut Taubah, Kemang Pratama, Bekasi and colleagues at the Central for Islamic Studies for their active role in the discussion.

References

1. Aejaz, H.A.R., *Axing of Methodology*, 9 p.
2. Darussalam, 2000. *Selected Friday Sermons.* Darussalam Publishers and Distributors, Riyadh, 388 p.
3. Dremali, I. *Calculation or Eye Sighting*, 4 p.
4. Hilal Sighting Committee of North America, 2006. *A Refutation to ISNA/Fiqh Council's Decision,* 10 p.
5. Memon, M.I., *Moon Sighting for the Month of Ramadan*, 3 p.
6. Ruskanda, F., 1996. *100 Masalah Hisab & Rukyat.* Gema Insani Press, 98 p.;

7. Rydan, A.S. *Moon Sighting: Hand in Hand with Calculations*. World Federation of Khoja Shia Ithna-Asheri Muslim Communities.
8. Saksono, T, 2007. *Why not Consider Ru'yatul 'Ilm: A Report from the Center for Islamic Studies, Indonesia*. Article #902, www.irfi.org.
9. Saksono, T, 2007. *Mengkompromikan Rukyat dan Hisab* (in print). Amythas Publicita, Jakarta, 300 p.
10. Yusuf, H. 2006. *Cesarean Moon Births, Part I*, 22 p.
11. Yusuf, H. 2006. *Cesarean Moon Births, Part II*, 17 p.

Appendix

Typical Muslim calendar that accommodates information for moon sighting process

Muharram 1429
Januari/Februari 2008

Ahad	Senin	Selasa	Rabu	Kamis	Jum'at	Sabtu
				1	2	3
				10	11	12
4	5	6	7	8	9	10
13	14	15	16	17	18	19
11	12	13	14	15	16	17
20	21	22	23	24	25	26
18	19	20	21	22	23	24
27	28	29	30	31	1	2
25	26	27	28	29		
3	4	5	6	7		

CENTER FOR ISLAMIC STUDIES
Safeguarding the true teachings, towards excellence

• Jl. Bintara Raya 62-B, Bekasi 17136, Indonesia
Phone/Fax: +62-21-865-6451
• Jl. Citra Niaga II/A3-6
Kemang Pratama, Bekasi 17116, Indonesia
Phone/Fax: +62-21-821-1327
E-mail: baksono@gmail.com

Sifat hilal pada maghrib 30-Dzulhijjah-1428:

MT-BT:	48m 14d
Ketinggian hilal, horizon lokal:	10,9 derajat
Azimut hilal:	+248°.10'.11"
Iluminasi:	0,89%
Lebar hilal:	17"
Nilai:	A

Keterangan:
MT= saat Matahari tenggelam; BT= saat Bulan tenggelam;

Nilai: Potensi perbedaan dengan *rukyat bil fi'li.*
1) 1° - 3° (D: potensi besar terjadi perbedaan);
2) 3,1° - 6° (C: potensi terjadi perbedaan);
3) 6,1° - 9° (B: potensi kecil terjadi perbedaan);
4) 9,1° - 12° (A: tidak berpotensi terjadi perbedaan);
5) 12,1° - 15° (A+: potensi besar tidak terjadi perbedaan);
6) 15,1° - 18° (A++: potensi sangat besar tidak terjadi perbedaan).